HYDROGEOCHEMICAL AND QUALITY ASSESSMENT OF GROUNDWATER IN ABA CITY, SOUTHEASTERN NIGERIA

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Abstract
Hydrogeochemical analysis of groundwater samples from Aba metropolis was carried out with the aim of assessing their geochemical characteristics and their suitability. Thirty two (32) water samples were collected randomly from boreholes within Aba metropolis. Two sets of samples from each sampling borehole, a set was of the water samples were acidified immediately with HNO_3, while the other set was not acidified. Physical parameters such as temperature, pH, TDS and EC of the sampled groundwater were determined in-situ using HANAH Portable Multimedia. The acidified samples were analyzed for their major cations and trace elements using AAS while the anions were analyzed using titration method. The results of the physical parameters, pH ranged from (4.50-5.50), EC (0.00-1.64) and TDS (0.00-1202.0); the cation in mg/l showed that; Ca ranged from (1.00-57.60), Mg (3.60-8.12), Fe (0.17-2.01), Zn (0.28-1.30), Mn (0.01-1.90) and Pb (0.00-0.44) while the anions result in mg/l showed that HCO_3 ranged from (0.00-95.99), Cl (1.99-67.50), NO_3 (0.00-0.25) and SO_4 (4.10-461.54). This revealed that all the physical parameters and the anions as well as Mn were within the WHO standards for drinking water while other cations such as Mg, Ca, Fe, Zn, Cu, Cd, Cr and Pb were above recommended permissible limits. The high concentrations of the heavy metals like Zn, Pb, Cu, Cd and Cr can cause severe health implications; hence the water is not suitable for drinking but can be used for other domestic purposes.

Keywords: Hydrogeochemical, Sampling, quality, assessment, groundwater

INTRODUCTION

Water is one of the most vital natural resources necessary for the existence of life. In most urbanized cities in Nigeria, it is expected of the government to provide portable water as part of social amenities. Most often this responsibility is not adequately discharged causing the inhabitants to look elsewhere to meet their water demand which may be unwholesome. In Aba, the inability of the government to provide sufficient portable water has led private individuals to sink boreholes. Water from these boreholes is pumped out 'raw' and sold to the public without any form of treatment and is used for drinking and other domestic activities. As a result of the lucrative nature of this business, a lot of boreholes have sprung up in this city. Groundwater, if abstracted from an adequately protected source has undoubtedly bacteriological and physical qualities comparable to those of treated water (Okoye and Adeleke, 1991). The slow percolation and horizontal flow through the ground is superb filtration, removing pathogens including viruses and bacteria (Pelig-Ba, 1996). The quality limitations result from mineralization by the dissolved carbon dioxide as the water passes over rocks and from pollutants leached down from the earth surface. These processes could raise the concentrations of ions such as Ca^2, Mg^2,

K^+, Cl^- and PO_4^{3-} above acceptable levels.

Moreover, poor sanitation practices, improper municipal and industrial waste disposal systems could lead to groundwater contamination. For instance, influent seepage of urine and leachate from polluted surroundings, a pit latrine or soak away, sited upstream and near a borehole, could lead to accumulation of phosphate and nitrate in groundwater (Okoye and Adeleke, 1991). Improper disposal of byproducts of beer brewing, soap making and textile industries could lead to liberation of high levels of Ca^{2+}, Mg^{2+}, K^+, Cl^-, PO_4^{3-} and SO_4^{2-} into the environment which could be leached into surrounding groundwater. The World Health Organization (WHO) has fixed certain limits as maximum and minimum permissible levels for certain ions for drinking water. This is because of the fact that the presence of high amount of ions in groundwater has serious health implications.

In the eastern part of Nigeria, the population density of most eastern cities is so high thereby making the inhabitants to maximize the available land. This has led to indiscriminate siting of boreholes, sometimes boreholes are located too close or downstream of latrines or soak away pits belonging to adjoining buildings or very close to municipal and industrial waste dump sites. The quality of water from these boreholes cannot be guaranteed. Presently there is limited information on groundwater quality in Aba metropolis. Therefore, in this study, the groundwater quality of Aba city was evaluated from various boreholes to understand the hydro-geochemistry of the aquifers with special attention to the physico-chemical parameters. Similarly, its suitability for domestic purposes was also evaluated.

The Study Location

Aba city is one of the major cities in southern eastern Nigeria. It is located between Latitudes 05° 2' 30” N to 5° 08' 00” N and Longitudes 07° 20' 00” E to 07°26' 00” E. The city lies within the tropical rain forest zone of West Africa. The climate is humid and semi-hot equatorial type. The city experiences heavy rainfall, with an average annual rainfall of 2000-2400 mm/yr particularly during the rainy seasons (April – October), the superficial rainfall distribution is bimodal, with peaks in July and September and a two weeks break in August. The rainy season begins in March and lasts till October or early November. The higher annual rainfall depths and rainfall days encourages large volumes of runoff. However, variations occur in amount rainfall from year to year, usually between 1,990 mm and 2,200 mm (NIMET, 2012). Relative humidity alternates between 75% and 90% during the dry and rainy seasons. Aba is underlain majorly by the sedimentary sequences of the Benin (Miocene to Recent) and the Bende-Ameki Formations (Eocene). The Benin Formation is made up of friable sands with minor intercalations of clay. The sand units are mostly coarse –grained, pebbly, poorly sorted, and contain lenses of fine grained sands. In some parts of the city, impermeable layers of clay occur near the surface, while in other areas, the soil consists of lateritic material under a superficial layer of fine grained sand. The thickness of the Benin Formation in this area is about 800m (Onwueme and Asiabaka, 1992).

The two principal geological formations underlying Aba metropolis have a comparative groundwater regime. They both have reliable groundwater that can sustain regional borehole production. The Bende-Ameki Formation has less groundwater when compared to the Benin Formation. The numerous lenticular sand bodies within the Bende- Ameki Formation are not extensive and constitute minor aquifer with narrow zones of sub-artesian condition. Specific capacities are in the range of 3 - 6 m^3 per meter per hour, (Igboekwe, 2005). On the other hand, the high permeability of Benin Formation, the overlying lateritic earth, and the weathered top of this formation as well as the underlying clay shale member of Bende-Ameki series provide the hydrogeological condition favouring the aquifer formation in the area. The main source of groundwater for domestic, agricultural and industrial supply in the study area is boreholes which as well form parts of the municipal water supply in some parts of the city.

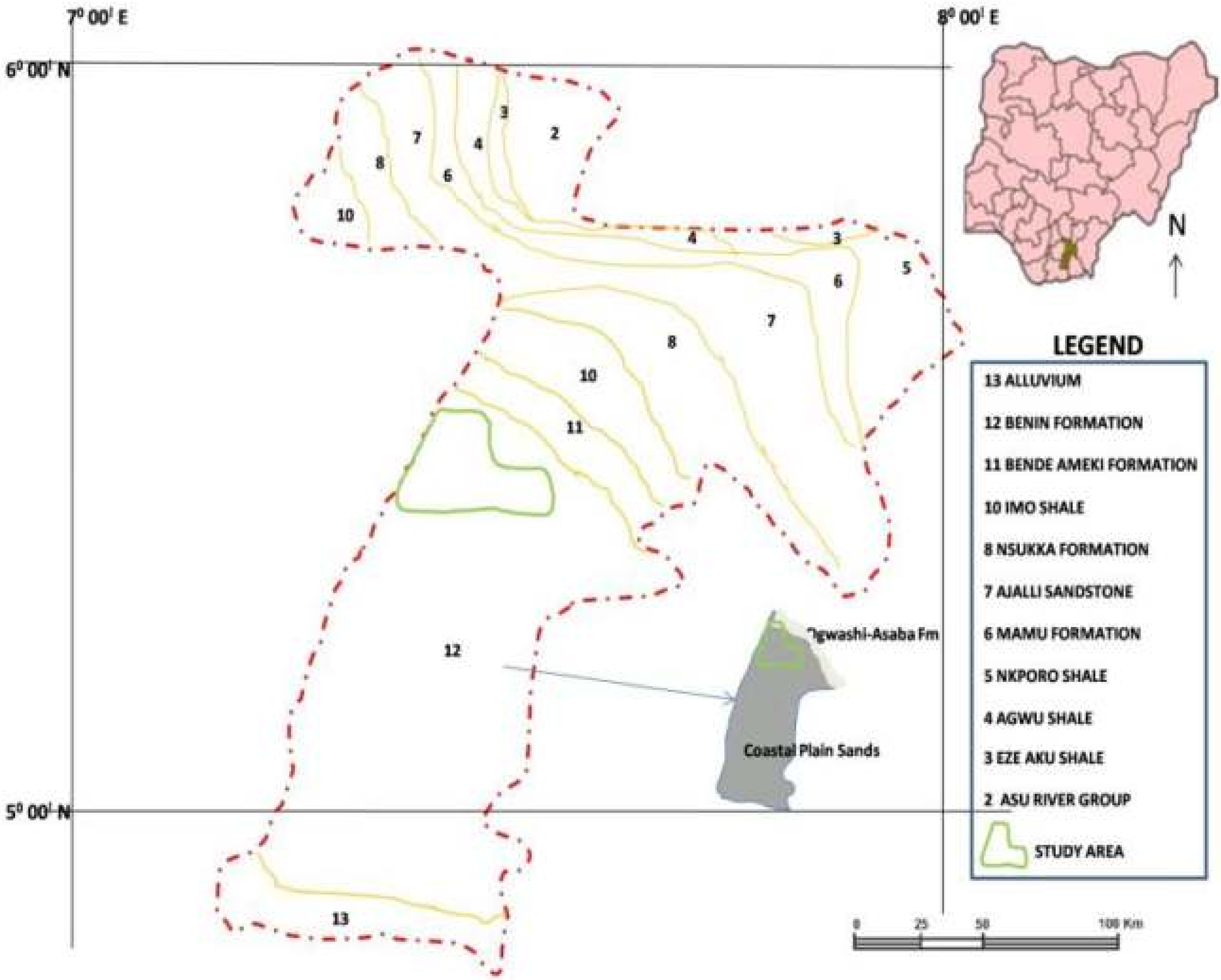

Figure 2: Geological Map of Abia State showing the study area

MATERIALS AND METHODS

In order to understand the hydro-geochemical variations in groundwater quality in Aba city, a reconnaissance visit was conducted a month earlier (December, 2017) prior to sampling and representative boreholes were identified. A total of thirty two (32) water samples were collected randomly from thirty two representative commercial boreholes within Aba metropolis. The groundwater samples collection took place January, 2018. At every sampling site, boreholes were allowed to pump for about 5 minutes before sampling in order to remove the interference of standing water in the metal casing and to stabilize the electrical conductivity. Water samples were collected in a clean 500ml capacity plastic bottle, prior to sampling; the plastic bottles were thoroughly rinsed with the water samples to prevent contamination. A separate sub-sample was collected and acidified with two drops of nitric acid (HNO_3) for the analysis of dissolved metals such as Ca^{2+}, Na^+, K^+, Mg^{2+}, Fe^{2+}, Pb^{2+}, Zn^{2+}, Mn^{2+}, Cd^{2+}, Cu^{2+}, Ni^{2+}, Se^{2+} and Cr^{3+}. The groundwater samples were kept in cooler and transported immediately to laboratory for chemical analyses.

In-situ tests of physical parameters were carried out at every sampled point using HANA model HI 83200 multi-parameter ion specific meters. These measurements include temperature, pH, electrical conductivities and total dissolved solids (TDS) while the hardness of the groundwater was calculated. The samples were then transported to the laboratory and refrigerated prior before analysis. The samples were analyzed for bicarbonate, chloride, sulphate, nitrate, calcium, magnesium, sodium, potassium, iron, lead, zinc, nickel, chromium, cadmium, cobalt, selenium and manganese using standard procedures recommended by APHA, 1998 and suggested precautions were taken to avoid contaminations. Metal analyses such as Ca^{2+}, Mg^{2+}, Fe^{2+}, Pb^{2+}, Zn^{2+}, Mn^{2+}, Cd^{2+}, Cu^{2+}, Ni^{2+}, Se^{2+} and Cr^{3+} were carried out using Atomic Absorption Spectrometric method while Na^+ and K^+ concentrations were determined using Flame Spectrophotometry at the Central Research Laboratory, College of Sciences, Afe Babalola University, Ado-Ekiti. HCO_3^-, NO_3^- and Cl^- concentrations were determined by titrimetric method while SO_4^{2-} was measured using spectrophotometer (with values recorded in mg/l) at the National Geo-Hazard Research Laboratory, University of Ibadan. Application of various multivariate tools and diagrams were used to understand the interdependency of groundwater physico-chemical parameters.

Data Treatment and Analysis

Descriptive statistics of water quality data generated was carried out using SPSS 22.0. Correlations efficiency was performed using Pearson correlation procedure. Principle component analysis (PCA) was carried out using SPSS 22.0. Some chemical quality indices such as sodium absorption ratio (SAR) were further used to evaluate the dataset. These indices include permeability index (PI).

i. Sodium adsorption ratio (SAR):

SAR = Na / [(Ca+ Mg) / 2]1/2
(Subramani, 2005)

where, all ionic concentrations are expressed in meq/l.

Results and Discussion

Physical Parameters

pH is a measure of hydrogen ion concentration which determines the acidity and alkalinity of water. The relative mobility of most ions in groundwater is a function of the pH value. Only ions such as Na, K, NO_3 and Cl remain in solution through the entire range of pH found in normal groundwater (Offodile, 2002). Hence, water with low pH tends to carry elevated concentrations of dissolved ions. The pH values of the water samples were relatively homogeneous within the study area ranging from 4.5-6.5, indicating that all the water samples in Aba metropolis were acidic. About 95 % of the water samples have pH values below the permissible limits. pH much lower than 7.0 can cause water to have a sharp taste and even corrosion of plumbing in pipe borne water. According to WHO, (2011) standards, pH less than 6.5 or greater than 8.5 is consider harmful. Total dissolved solid is a measure of total inorganic loads. It ranged from 100–1202 mg/l with the average of 321.11 ± 345.0mg/l. Most of the samples collected from central part of Aba metropolis had elevated values and this can be attributed to the level of industrialization and population density of this part of Aba metropolis. Comparing the mean of values with the WHO, (2011) of 500 mg/l revealed that about 30 % of the sampled boreholes have values greater than the permissible limit. Classification of water based on TDS showed that the groundwater in Aba falls within the fresh and slightly saline water types. According to Mor *et al.,* (2009) high level of TDS is an indication of leaching of natural salts into the groundwater and this may pose a risk of salinization in Aba metropolis.

The Electrical conductivity of groundwater has a wide range depending on rock types and length of reaction time. The EC ranged from 500-1640 µS/m, with an average of 460 ± 470 µS/m. less than 20 % of the boreholes sampled had TDS greater than the WHO, (2011) permissible level.

Table 1: Summary of the Physico-chemical Parameters of Groundwater Samples

Parameters	Minimum	Maximum	Mean ± Std. Dev.	W.H.O. 2011	Nig. Standard (2005)
Ph	4.5	6.5	5.10 ± 0.36	6.5 - 8.5	6.5 - 8.5
TDS	500	1640	460 ± 470	1000	500
EC	100	1202	330.24 ± 345.00	1400	1000
Tempt.	26.8	34	29.35 ± 2.18	27	Ambient
Na^{+}	0.5	13.5	3.98 ± 3.38	200	200
K^{+}	0.5	14	4.26 ± 3.31	10	10
Ca^{2+}	1	57.6	8.36 ± 11.24	75	NA
Mg^{2+}	3.6	8.12	5.81 ± 1.05	50	0.2
Fe^{2+}	0.17	2.01	0.66 ± 0.51	0.03	0.3
Mn^{2+}	0.01	1.09	0.42 ± 0.35	0.3	NA
Zn^{2+}	0.21	1.3	0.57 ± 0.22	3.0	3.0
Cu^{2+}	0.12	0.56	0.26 ± 0.10	2.0	1.0
Cd^{2+}	0	0.02	0.01 ± 0.01	0.003	NA
Ni^{2+}	0	0.09	0.02 ± 0.02	1.5	1.5
Pb^{2+}	0	0.44	0.10 ± 0.12	0.01	0.01
Cr^{3+}	0	0.89	0.33 ± 0.32	0.01	0.05
Se^{3+}	0.01	0.17	0.08 ± 0.04	0.01	0.01
As^{2+}	0	0.070	0.010 ± 0.013	0.01	0.01
Cl^{-}	1.99	67.5	22.4 ± 18.2	250	250
SO_4^{-2}	4.1	461.54	206.5 ± 214.2	400	100
HCO_3^{-}	0	95.99	19.6 ± 25.0	100	NA
NO_3^{-}	0	0.25	0.06 ± 0.06	50	50

All units except pH, Temperature (°C) and Electrical conductivity (µS/m) are in mg/l, SD = Standard Deviation, Min. = Minimum, Max. = Maximum, Mn = Mean

Hydrogeochemical Profiles

The chemical compositions of ground water depends greatly on the general geology, degree of chemical weathering of various rock types, quality of recharge water and inputs resulting from human activities. Also the relatively slow movement of water percolating through the ground causes long contact of the water with the geologic environment and these results in the dissolution of soluble minerals as it moves along until a point of equilibrium is reached. It is therefore important to understand the groundwater chemistry as it is a main factor in determining its suitability for drinking, domestic, agricultural and industrial purposes (Subramani *et al.*, 2005).

The concentrations of the major cations such Na^{+}, K^{+}, Fe^{2+}, Ca^{2+} and Mg^{2+} in the water samples varied significantly from borehole to borehole in Aba city. Ca^{2+} and Mg^{2+} are the most abundant cations in groundwater. Ca^{2+} can be derived from carbonate rocks or leached into groundwater from soils but the dissolved Mg^{2+} is generally lower than Ca^{2+} in groundwater. The concentrations of Ca^{2+} and Mg^{2+} ranged from 1.00–57.6 mg/l and 3.60–8.12 mg/l with mean of 8.36 ± 11.24 mg/l and 5.84 ± 1.05mg/l respectively (Table1).

Na^{+} and K^{+} ions naturally occur in groundwater however, their concentrations can be enhanced by addition of industrial and domestic waste into groundwater thereby making it unsuitable for domestic purposes. Na^{+} and K^{+} contents in groundwater from Aba city ranged from 0.5–13.5 mg/l and 0.5 – 14.0 mg/l with the average values of 3.98 ± 3.38 mg/l and 4.26 ± 3.31 mg/l respectively. High concentrations of Na^{+} in drinking water can cause heart related problems in human as well as salinity problems thereby rendering irrigated soil barren (Mor *et al.,* 2009). K^{+} ion plays a vital role in intermediate metabolism and in exchange of Na^{+}- K^{+}ions in groundwater.

In general, the concentrations of the major cations increase in the following order Mg<Na<K<Ca (Table 1). The average values of Ca^{2+}, Na^{+}, K^{+}, Fe^{3+} and Mg^{2+} in the water samples were below or less than the recommended permissible limits with the exception of Fe^{2+} although calcium has range of values that were higher than WHO standard. Despite the fact that the average values of these ions were below the permissible standards, elevated concentrations of Na, K, Fe, Ca, and Mg were recorded in samples collected along market road, St Michael Road, School Road and Umuogba Road all within the central district of Aba metropolis characterized by high population density, heavy industrial and commercial activities.

The alkalinity of water is a function of CO_3^{2-} and HCO_3^{-} and it is a measure of the ability of water to neutralize acids. HCO_3^{-} ranged from <0.01-95.99 mg/l with an average value of 19.66 ± 24.88 mg/l. It has be observed that high alkalinity in water does not pose health risk but rather a big challenge in the industries if alkaline water is used in a boiler for steam generation (Mor *et al.,* 2009). It leads to the formation of scale and thereby lowers the efficiency of the electric water heater. SO_4^{2-} is a major contributor to total hardness and occurs naturally in all types of water bodies, its concentrations in water samples from Aba city ranged from 4.10-461.54 mg/l with a mean of 109.26 ± 114.2 mg/l.

Cl^{-} in the water samples ranged from 1.99-67.50 mg/l with average values of 22.83 ± 18.2 mg/l. Chloride concentration of 40 mg/l is an indication of salt-water intrusion while >100 mg/l indicates zone of diffusion. The result showed that about 16 % of the boreholes sampled are prone to salt-water intrusion. Chloride occurs naturally in some sedimentary formations such as shale. It is soluble and move freely in groundwater. It has more residence time than nitrate in water due to its not readily biodegradation nature in water. Elevated concentration of Cl^- can add salty taste to groundwater and cause laxative effect. It can also causes corrosion of pipes, pumps and plumbing fixtures. NO_3^- ranged from <0.01 to 0.25 mg/l with mean of 0.06 ± 0.06 mg/l. The health effect of excess nitrate includes death of children under age 5 (due to high level of reduction of nitrate to nitrite by gastric bacteria), while shortness of breath in adult and methaemoglobinaemia otherwise known as "blue baby syndrome" have been linked to elevated nitrate concentration (Oketola *et al.,* 2013). Its sources in groundwater include domestic sewage, run off from urban and agricultural field and leachate from landfill site (Saroj *et al.,* 2010). Elevated nitrate concentrations were observed in samples with close proximity to the dumpsite in Obingwa area of the city. Hence, this can be attributed to the leachate from the dumpsite.

The result generally revealed low abundance concentrations of chloride, nitrate, bicarbonate and sulphate pointing at potability of the groundwater in the city. Despite this low abundance of anions, Most of the water samples collected from Cameroon and Okigwe Roads recorded elevated concentrations of $HCO^-_{3,}$ Cl^- and SO_4^{-2}. Comparing the concentrations ranges of Cl^-, NO^-_3, SO_4^{2-} and HCO^-_3 in the water samples with the permissible limits, showed that these values were within the permissible limits with the exception of SO_4^{2-} where about 60 % of the water samples were higher than the permissible limit.

Heavy Metals Distributions in groundwater Samples

The heavy metals in the water sample analysed in Aba include Ni, Fe^{2+}, Mn^{2+}, Zn^{2+}, Cu^{2+}, Pb^{2+}, Cr^{3+}, As^{2+} and Cd^{2+} having concentration ranges of 0.01 to 0.09 mg/l, 0.17 - 2.01 mg/l, 0.01-1.09 mg/l, 0.28-1.30 mg/l, 0.12-0.56 mg/l, 0.00-0.44 mg/l, 0.00-0.89 mg/l, 0.00-0.07 mg/l and 0.00-0.02 mg/l and average concentration of 0.02 ± 0.02 mg/l, 0.68 ± 0 51 mg/l, 0.43 mg/l, 0.59 mg/l, 0.26 mg/l, 0.09 mg/l, 0.34 mg/l, 0.01 mg/l and 0.01 mg/l respectively. The concentration of these trace elements are in the order Fe > Zn > Mn > Cr > Cu > Pb > As > Cd. The higher and elevated concentrations of most of the potentially toxic metals (PTMs) such as Mn, Zn, Pb and Cd were recorded in water samples collected from Market, Azikiwe and Jubili Roads while samples collected from Ukaegba, Obingwa and Federal Housing Estate have low concentrations of PTMs. The average concentration of Fe, Pb, Mn, Se, Cd and Cr were significantly higher than the WHO permissible limits for drinking water whereas Cu, Zn, Ni and As were within or slightly below the WHO (2011) permissible limits for drinking water.

The exceeded levels of some of the water quality parameters were calculated as ratio of mean concentration of each water quality variable to respective guideline values and it is expressed with no unit. The exceeded levels of variables such as sulphate, nitrate, lead, iron, nickel, cadmium, chromium, arsenic and manganese are presented in Table 2. This approach according to Saroj *et al.,* (2010) is effective in visualizing the levels of pollution. The order of levels of different parameters in relation to the non-uniform increase in exceedance value in groundwater samples from Aba metropolis was in the following order Pb > Fe > Cr > Cd.> Se > Mn >As > SO_4.

Table 2. Exceedance level of groundwater parameters with respect to WHO (2017) in Aba

Parameters	Fe	Mn	Zn	Cu	Cd	Ni	Pb	Cr	Se	As	SO_4
Aba Groundwater	22.00	1.40	0.19	0.13	3.33	0.01	33.33	6.60	1.60	1.00	0.52

Characterization of Aquifer/Groundwater in Aba City

The data derived from the groundwater under investigation were used in plotting trilinear diagram suggested by Piper (1944) for groundwater characterization. All the data plotted in type I groundwater type where alkaline earths metals exceed alkaline metals and strong and strong acidic anions exceed weak acidic anions. The position of the data points represents Ca-Mg-SO_4 and/or Ca-Mg-Cl water type. This is also supported by Gibb's plot which showed that the majority of the groundwater data fell in the rock dominance and resulted from the weathering of calcite, dolomite or silica rich rocks. The groundwater chemistry is largely controlled by alkaline earth metals (Ca^{2+} and Mg^{2+}) rather than alkaline metals. The hydrogeochemistry of the aquifers of Aba city revealed the dominance of alkaline earths metals over the alkaline metals and strong acidic anions over weak acidic anions.

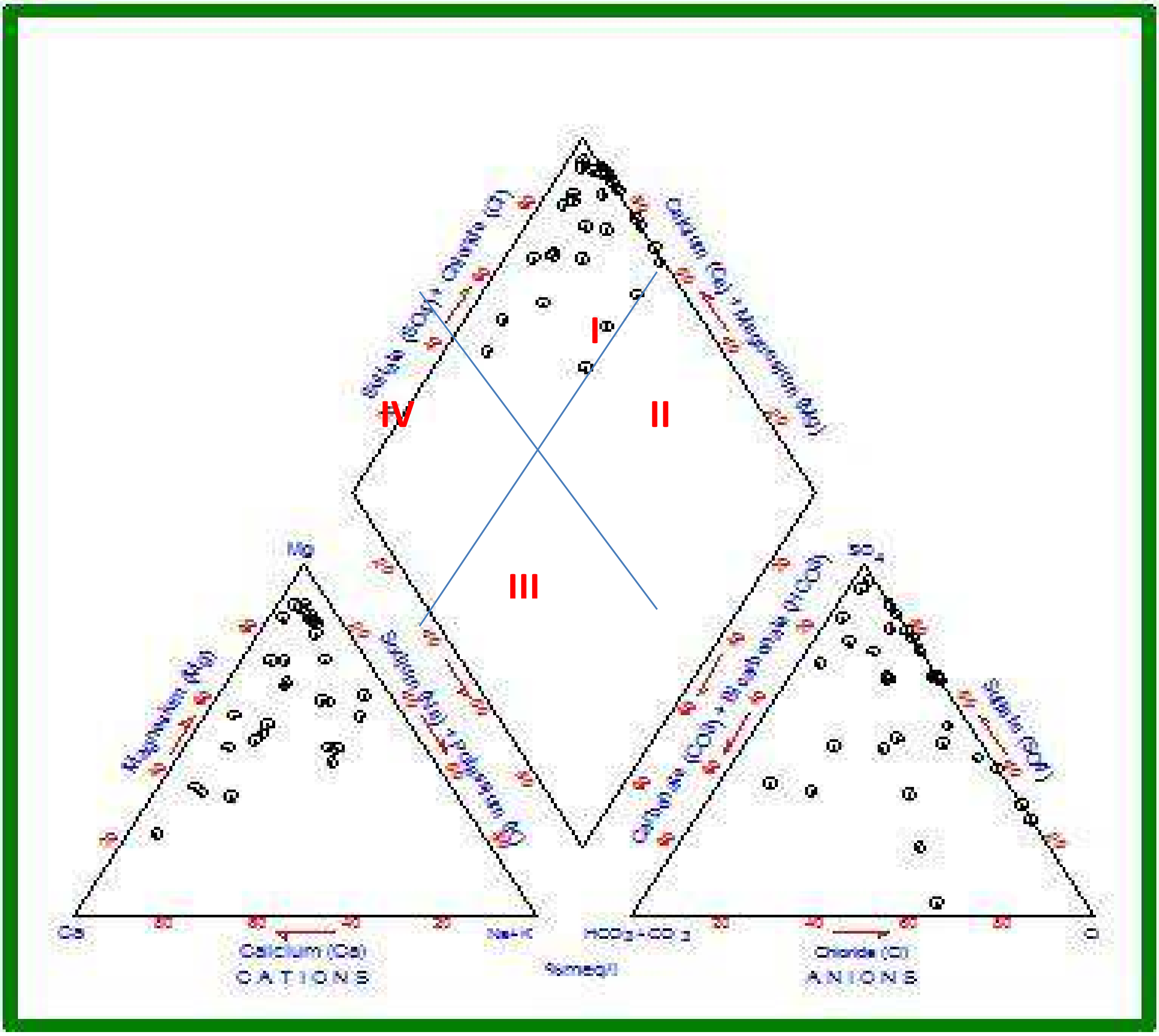

Figure 3: Piper Trilinear plot of hydrochemical data in Aba groundwater

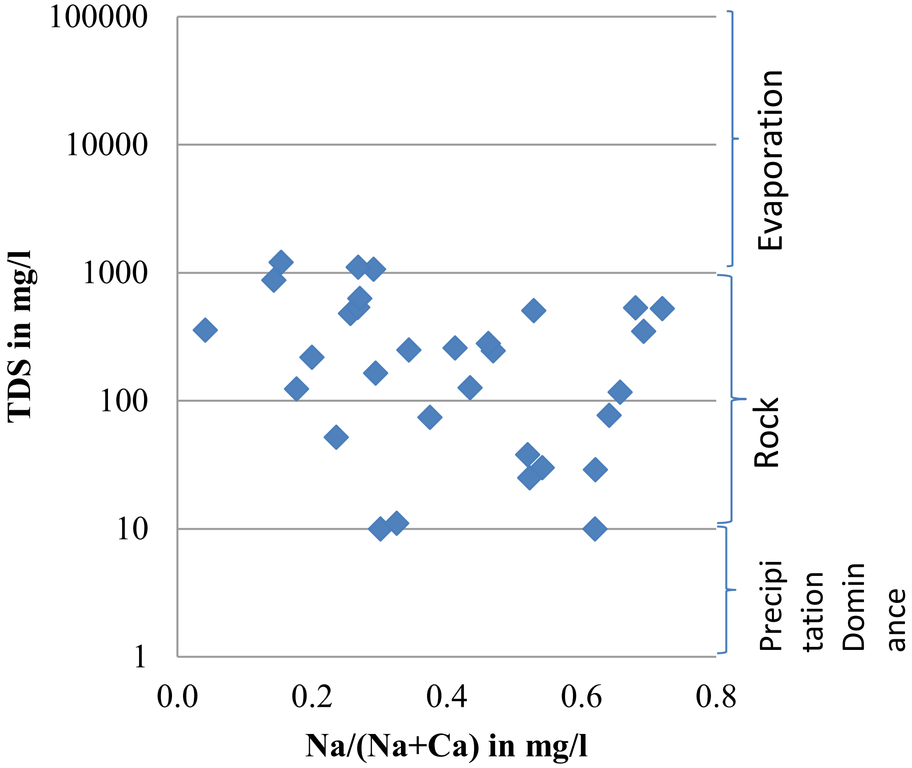

Figure 4: Gibbs plot showing hydrogeochemical processes in groundwater from Aba city

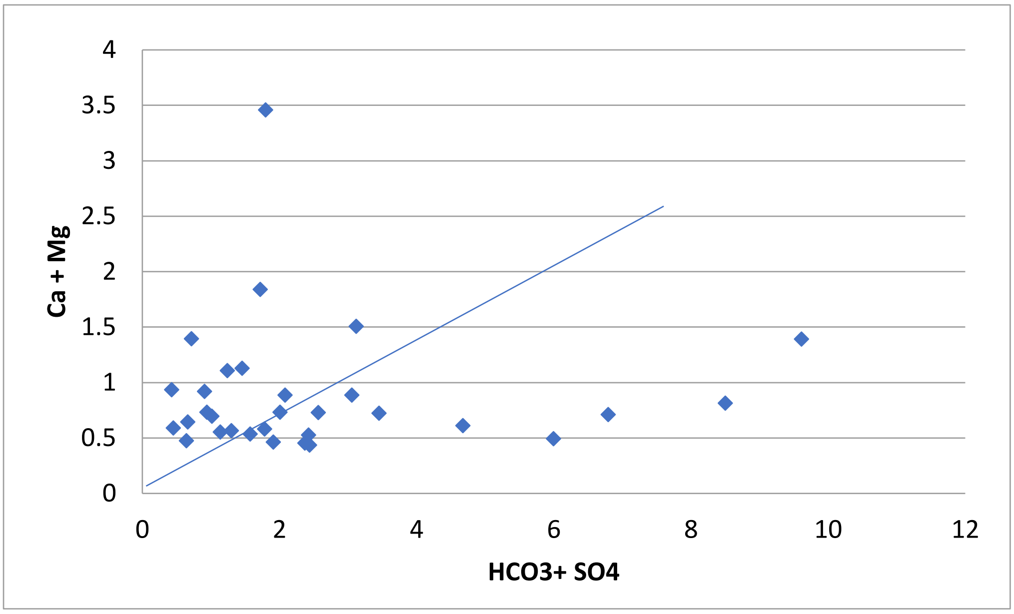

Figure 5. Graph of (Ca + Mg) versus acidic anions (HCO_3 + SO_4), the trend line represents an ideal situation where the charge balance is 100%

Correlation Matrix

Pearson correlation analysis of the results was undertaken using the Statistical Program for Social Science (SPSS). The correlation coefficients matrixes for physiochemical parameters are presented in Table 3; this correlation analysis was used to examine the interdependency of parameters in the groundwater samples.

The analysis revealed a wide range of variations in the correlation values as both positive and negative correlations were established between some of the variables.

From Table 3, almost 70 % of all the parameters analysed displayed moderate to very high correlation with respect to TDS with exception of some few ones such Na, K, Fe, Zn, HCO_3 and Ni. This is an indication that these ions are responsible for the dissolved solutes as well as conductivities in the water samples. The very strong positive associations observed between chloride and divalent cations such as Mg (0.93), Cd (0.94), Pb (0.93) and As (0.76) is an indication that similar geochemical processes are responsible for the co-precipitation of the chloride salts in the groundwater of Aba metropolis. Similarly, Ca, Zn, Cu, SO_4 and HCO_3 showed close relationship with the pH. This showed that these ions were largely responsible for the variations in groundwater pH of Aba metropolis. This is likely to be seepage from septic tanks or leachate from waste in industrialized areas.

Factor Analysis

In this study, all analysed physico-chemical parameters including the cations, anions, temp., EC, TDS and pH were considered for factor analysis in order to have better understanding of their interrelationships (Chen *et al.,* 2007). Table 4 shows the principal components, eigenvalues and associated variance explained in the data. Factors with initial eigenvalue greater than 1 were retained and therefore leading to 8 factors.

Factor 1 has an eigenvalue of 4.59 which accounts for 22.95 % of the total variance. This factor is strongly and positively loaded with EC, TDS, Ca, Mn, Cl Iron and Zinc. This factor shows that these parameters are responsible for the TDS in the groundwater. Factor 2 was found to associate with strong and positive loaded with Temp, K, Na, Cd, As and Nickel. Factor 3 is loaded with pH, Pb and Se. Factor 4 has an eigenvalue of 1.91 which accounts for 9.59 % of the total variance. This factor is moderately, positively and negatively loaded with the following parameters; HCO_3, Cr and As while the remaining factors were characterized by the dominancy of one or two variables with low loading of other variables. Table 3. Correlation coefficient matrix of physio-chemical parameters of groundwater samples of the Aba metropolis

	pH	EC	TDS	T	Na	K	Ca	Mg	Fe	Mn	Zn	Cu	Cd	Ni	Pb	Cr	Se	As	Cl	SO_4	HCO_3	NO_3
pH	1																					
EC	.23	1																				
TDS	.20	1	1																			
T	**.92**	**.52**	**.52**	1																		
Na	**.55**	.26	.27	-.32	1																	
K	**.78**	.20	.22	-.34	**.83****	1																
Ca	**.62****	**.45***	**.45***	-.20	**.68****	.47**	1															
Mg	**.80**	**.93**	**.93**	**.83**	.31	.52	.21	1														
Fe	.19	.38*	.39*	**.75**	**.58****	.35	**.65****	.20	1													
Mn	.41	**.53****	**.53****	-.43	.25	.22	.44*	.24	.22	1												
Zn	**.60**	.31	.32	-.32	**.57**	**.58**	.21	.90	.26	.35	1											
Cu	**.55**	**.42**	**.40**	**.75**	.23	**.87**	**.91**	**.70**	**.99**	**.67**	**.70**	1										
Cd	**.47**	**.96**	**.92**	**.54**	**.54**	.05	**.58**	.41	.28	**.81**	.22	**.59**	1									
Ni	-.17	-.19	-.18	**.72**	.23	.31	**.50**	.43	-.30	-.19	-.31	-.01	.41*	1								
Pb	.17	**.46**	**.48**	.33	.18	**.57**	.24	.18	.37*	**.89**	-.24	-.24	.52	.97	1							
Cr	-.18	**.70**	**.70**	.56	.69	.36	**.50**	.30	**.74**	**.61**	**.44**	**.58**	**.80**	.25	.53	1						
Se	.28	**.87**	**.85**	**.57****	-.24	**.55**	**.61**	**.89**	-.34	-.23	.44*	-.21	.13	.32	.38*	-.11	1					
As	**.69**	**.72**	**.71**	-.17	.92	.22	-.18	-.30	-.25	-.14	-.23	**.62**	.31	.34	.06	.17	.12	1				
Cl	**.53**	**.83****	**.83****	-.31	.30	.29	**.46****	**.97**	.35	**.70****	.33	**.59**	**.98**	-.19	**.93**	-.21	-.21	**.77**	1			
SO_4	**.81**	**.59**	**.52**	**.75**	**.42**	.18	**.71**	-.32	.16	.17	**.81**	.24	.20	**.82**	-.22	-.20	-.19	**.59**	.36*	1		
HCO_3	**.67**	-.24	-.24	-.25	**.92**	**.69**	**.57**	**.64**	-.22	-.23	-.32	**.55**	**.77**	.24	**.63**	.39	**.93**	**.46**	-.21	-.28	1	
NO_3	.25	**.44**	**.46**	**.78**	**.74**	**.44**	.33	**.83**	**.50**	.19	**.67**	**.66**	**.53**	**.83**	**.48**	-.25	**.66**	**.41**	**.76**	**.46**	**.75**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4: The Result of the Factor Analysis

	Component							
	1	2	3	4	5	6	7	Extraction
pH	.29	-.29	**.50**	.01	.28	-.19	.43	.74
EC	**.79**	-.10	.06	**.45**	-.13	.00	.06	.97
TDS	**.79**	-.09	.05	**.45**	-.13	.02	.05	.97
T	-.38	**-.44**	.39	.27	-.27	**.47**	-.16	.89
Na	**.63**	**.46**	.26	-.42	-.03	.25	.04	.93
K	**.51**	**.65**	.24	-.25	-.16	.02	-.08	.86
Ca	**.77**	-.08	.38	-.26	.14	-.02	.16	.89
Mg	.15	-.11	.29	-.47	.24	.02	**-.50**	.82
Fe	**.68**	-.16	.15	-.38	-.26	.26	.06	.81
Mn	**.71**	-.05	-.13	.11	.24	-.34	-.28	.79
Zn	**.47**	-.18	**-.53**	-.15	-.16	-.21	-.20	.67
Cu	.10	.07	-.21	.01	.23	**.74**	.20	.78
Cd	-.05	**.66**	.11	.31	.00	-.06	-.27	.66
Ni	-.24	**.67**	.37	.04	.20	.02	-.27	.78
Pb	.11	-.22	**.69**	-.07	-.37	-.03	-.02	.69
Cr	-.05	.10	-.18	-.24	**-.74**	-.21	.19	.73
Se	-.31	-.12	**.71**	**.44**	-.08	-.05	-.12	.84
As	-.10	**.59**	.10	.38	-.23	-.22	.33	.72
Cl	**.84**	.01	-.12	.39	.13	-.04	-.02	.90
SO4	.27	.22	-.27	.35	.18	.42	.03	.82
HCO3	-.29	.23	.11	-.25	.40	-.12	**.48**	.83
NO3	.01	-.25	.15	.05	**.53**	-.22	.00	.69
Eigen values	4.985	2.492	2.428	2.031	1.759	1.432	1.195	
% of Variance	22.66	11.34	11.04	9.23	8.0	6.51	5.43	

CONCLUSION

The study was born out of curiosity that groundwater in Aba region is susceptible to contamination due to the presence of several chemical and manufacturing industries characterizing the city. The concentration of the physio-chemical analyses was compared with the WHO (2011) permissible standards to determine the quality of the drinking water.

The comparative study carried out on the hydrochemical data derived of the groundwater revealed that the physical parameters were below the WHO (2011) standard. This indicates that the groundwater within Aba metropolis is slightly acidic. Similarly, the major cations such as Fe, Mg, Ca, Zn, Cu, Cd, Pb, and Cr with average concentration of 0.68 mg/l, 5.84 mg/l, 8.26 mg/l, 0.59 mg/l, 0.26 mg/l, 0.1 mg/l, 0.09 mg/l and 0.34 mg/l respectively, is observed to be higher than the WHO (2011) permissible standard for drinking water. As such the groundwater in Aba metropolis is fairly suitable for drinking. The hydrogeochemistry of the aquifers of Aba city revealed the dominance of alkaline earths metals over the alkaline metals and strong acidic anions over weak acidic anions.

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