Hydrogeochemical Classification and Groundwater Quality Status of Paiko Sheet 185, North-Central, Nigeria.

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Abstract

Paiko Sheet is witnessing increasing population due to its proximity to Federal Capital Territory, Abuja, presence of economic minerals and fertile land for agriculture. Increase in human activities increases waste generation that could affect the quality of groundwater if not properly disposed. Hydrogeochemical studies was carried out to classify and determine the quality status of groundwater of the area. Groundwater physical parameters were analyzed in the field while the chemical parameters were analyzed in the laboratory. Cations were analyzed with Micro-Plasma Atomic Emission Spectroscopy while anions were analyzed with Ion Chromatography. Ca^{2+} and SO_4^{2-} were the most abundant of the cations and anion respectively. The groundwater of the area was classified as fresh with TDS values. The dominant water type was Ca^{2+}- Mg^{2+} and Cl^-- SO_4^{2-}-HCO_3^-; and four groundwater sources that could have resulted from four hydrochemical processes of which simple dissolution or mixing is dominant were observed in the area. The pollution index shows that groundwater within the studied area was polluted by Fe^{2+}, Ni^{2+}, K^+, Mg^{2+}, Al^{3+}, Cd^{2+}, As^+, Hg^{2+} and Pb^{2+}. This implies that the groundwater should not be consumed without treatment. Treatment with some local materials have been suggested.

Keywords: *Hydrogeochemistry, water quality, Hydrogeochemical classification, pollution index, Paiko Sheet*

Introduction

Fresh water account for approximately three percent of the world water resources with two-third of this existing as ice that cannot be accessed easily (Olugboye, 2008). Groundwater however constitute about 60% of what is left of the one-third. Groundwater, apart from its abundance quantity, the quality is often good, the cost of development is low compared with surface water development, it is available in most area, and the resource is often renewable (Nwankwoala, 2015). Hence, its importance for domestic, agricultural and industrial purposes cannot be over emphasized. Groundwater is faced with threat of some natural processes (such as oxidation and reduction reaction, dissolution of minerals in the aquifer and the media through which it moves) and anthropogenic activities (pollutants from human activities such as agriculture, domestic, industries etc.) which could have negative effects on the quality and therefore reduce its usage. Improper waste management increases pollution load in groundwater (Iqbal and Gupta, 2009). Agricultural activities could also result to the degradation of groundwater resources with organic and inorganic pollutants (FAO, 1992). Nitrate and phosphate are common pollutant from agricultural activities (Galadima *et al.* 2011; and Sunitha, et al, 2012). Solid waste and effluent when indiscriminately dump into the environment could pollute the groundwater through infiltration or leaching of pollutants and these activities are considered the worst threat to groundwater quality (Bilal *et al.* 2014; and Iqbal, 2016). Mining is a major source of introduction of metals into the environment resulting in the pollution of air, soil, vegetation, surface and groundwater causing various health problems for plants and animals including human beings (Ezeh and Chukwu, 2012; Aremua *et al.* 2010; Prathumratana, L., Kim and Kim, 2008; Arogunjo, 2007; Bridge, 2004; Jarup, 2003; United Nations Environment Program, 2000; Garba, 2003; Duruibe *et al.* 2007; Jian-Min *et al.* 2007; Cai *et al.* 2009; Ameh and Akpah, 2011; Lucky and Temitayo, 2017; Baba, A. I., Imaji and Ocheni, 2018).

Paiko Sheet can be described as boundary Sheet since it cut across Niger States and the

Federal Capital Territory of Nigeria (Abuja). This area is experiencing surge in population because it provides cheaper alternative inhabitation for those working within the cities of Abuja. Another reason for increase of population in the area is the presence of some economic minerals within some localities. The area also has fertile land for agriculture. Increasing in human activities arising from the increasing in population will result in increase in waste generation that could contaminate both surface and groundwater. Domestic, agricultural, mining and other industrial waste could negatively affect the physical and chemical characteristics of groundwater. In Paiko Sheet, abnormal values of lead, potassium and magnesium have been reported from a surface water around marble mining site around Kwakuti (Ako, 2015). pH, conductivity, iron, zinc and copper have been found in elevated quantity in groundwater from hand-dug wells within Lapai in the southwestern part of the area (Oladipo *et al.* 2011; and Amadi *et al.* 2017).

The emergence of water borne diseases make the quality of groundwater a source of concern. Consuming contaminated water could results in irreversible damage. Some years back Nigeria have experienced various degree of casualty arising from water related diseases. The most notable was the lead poisoning within some villages in Zamfara and Rafi in Niger state, Nigeria where over 400 deaths were recorded in the former in the year 2010 while over 20 deaths were recorded in the later in the year 2015 (https://medicalxpress.com/news/2015-05-poisoning-children-central-nigeria-govt.html.). These incidences were due to improper gang disposer leading to the pollution of soil and water resources of the areas. Activities (e.g. gold mining) such as those that have led to the casualty reported above are common in Paiko Sheet. Baban Tsauni, Dadabiri, Ebbah, Pago, Butu, Saminaka are some examples where gold mining is active. Lead-zinc mining is also active in Baban Tsauni and Mining of Marble is going on around Kwakuti. These miners dump their gang into the environment indiscriminately with little to no care for safe environmental practice. These wastes could either be eroded into surface water which could also contaminate groundwater if it is an influent stream or leached into groundwater directly. In fact, some gold miners process their run off mines in streams and rivers leaving behind gang. Sheet wide hydrogeochemical classification and assessment of quality status of groundwater within Paiko Sheet has not been carried out. Nigeria Industrial Standard (2007) recommended that quality status of groundwater should be reviewed at least once in every three years. It is for these reasons that the hydrogeochemical classification and quality status of groundwater for drinking purpose within Paiko Sheet was undertaken to serve as base for future researches. This could aid in the proper management and protection of groundwater resources.

The study area

The area is located on latitude 9°00' to 9°30' and longitude 6°30' to 7°00'. It is bounded to the north and south by Minna and Gulu Sheets respectively; and to the east and west by Abuja and Bida Sheets respectively covering a total area of about 3080.25 km^2. It can be Access by main roads, secondary roads, main paths and minor paths. The relief of the area has a minimum of 130 meters above sea level and a maximum of 600 meters above sea level. The area has mainly dendritic type of drainage pattern with streams and rivers that are either indirect or direct tributaries of River Niger. River Gurara which empties its content into River Niger directly is the largest drainage within the area. It has a guinea savannah type of vegetation and is characterized by two distinct climatic condition of wet season and dry season. The duration of wet season is usually between the months of May and October while that of the dry season is usually between the month of November and April. The average annual rainfall is 1270mm with a maximum temperature of 35°C and a minimum temperature of 24°C (Njeze, 2011).

The area is underlain by basement complex rocks amounting to about 85% and sedimentary rocks of approximately 15% (Ejepu and Omar, 2015). Lithologically, the area comprises of Alluvium, laterite capped sandstone, Coarse grained porphyritic granite, Medium-coarse grained tonalite and amphibolite, Migmatitic gneiss and foliated granite, marble, phyllite, mica schist interlayered with amphibolite, talc-tremolite-actinolite schist and migmatite and Lateritic capped Sandstone Formation (Ejepu and Omar, 2015). Hydrogeological studies show that the fracture pattern within part of Paiko Town was discrete, localized and discontinuous (Amadi *et al.* 2013) and the average depth to aquifer in part of Lapai was 36.75 (Tsepav *et al.* 2014). The yield of shallow sedimentary aquifers was between 1.4 to 2.8 lt/s while those within granite/gneiss/migmatite ranges between 0.8 to 1.8 lt/s (Idris-Nda et al, 2015). The accumulation and flow of groundwater within Paiko sheet is largely controlled by rock types, fractures and slope (Ejepu *et al.* 2017).

Methodology

The methods adopted for this research included field work and laboratory analysis. The fieldwork comprises of water sampling for the purposes of evaluation of physical characteristics and chemical characteristics. Random sampling technique was used and a total of 66 and 59 water samples were collected for dry and wet seasons respectively. Sampling was done in accordance with groundwater sampling operating procedures by (Jonathan, 2013) developed for United State Environmental Protection Agency. The dry season sampling was done between the months of march and April of 2021 while that of the wet season was done in the month of October of 2021. Physical characteristics of groundwater was determined in the field. These physical characteristics include Water pH, total dissolve solid (TDS), Electrical conductivity (EC) and temperature (T) with a hatch kit containing necessary tools for the measurement. Samples were stored, transported and analyzed in accordance with (Jonathan, 2013). Water chemistry was analyzed with Micro-Plasma Atomic Emission Spectroscopy (for cations) and Ion Chromatography (for anions).

Rockwork 15 was used to plot Piper Diagram, Durov diagram and Stiff Pattern while IBM SPSS Statistics 21 was used to plot Schoeller diagram. Piper diagram was used to classify groundwater into hydrochemical facies according to Piper (1953) and Back (1966). classification with Durov was done in accordance with Lloyd and Heathcote (1985). Schoeller's diagram was used to compare the hydrochemical characteristics of groundwater samples using Schoeller (1959). Stiff diagram was used to show the proportion of ionic concentration in samples using interpretation of chemical water analysis by (Stiff, 1951). Results were compared with known standard for drinking water quality (Nigeria Industrial Standard, NIS (2007); USEPA. (2015); and World Health Organization, WHO (2021). Pollution Index (PI) was determined using the following formula.

$$PI = \frac{\sqrt{\left(C_i \div S_i\right)^2_{\max} - \left(C_i \div S_i\right)^2_{\min}}}{2}$$

Results and Discussion

Hydrogeochemical Classification

The results of physical parameters and that of chemical parameters of groundwater samples from Paiko Sheet for both seasons is summarized in Table 1. The result shows that the mean order of abundance of cations is $Ca^{2+} > Na^{+} > K^{+} > Mg^{2+} > As^{+} > Al^{3+} > Cd^{2+} > Fe^{2+} > Hg^{2+} > Zn^{2+} > V^{3+} > Ni^{2+} > Mn^{2+} > Co^{2+} > Cu^{2+} > Pb^{2+} > Cr^{2+}$ while that of the anions is $SO_4^{2-} > HCO_3^{-} > Cl^{-} > NO_3^{2-} > CO_3^{2-} > F^{-} > NO_2$. All anions were within the standards of NIS (2007), USEPA (2015) and WHO (2021) except SO_4 that exceeded NIS (2007) and (WHO (2021)) in just one location (Lambata 2). Cations such as Mg^{2+}, Al^{3+}, As^{+} and Hg^{2+} were higher than NIS (2007), (USEPA. 2015) and (World Health Organization, 2021) in all samples. Others such as Fe^{2+}, Pb^{2+}, Mn^{2+}, Ni^{2+} and Ca^{2+} were higher than NIS (2007), (USEPA. 2015) and (World Health Organization, 2021) by 19%, 71%, 15%, 41% (only in dry season) and 6% (only in dry season) respectively in some samples. The remaining cations such as Na^{+} and Zn^{2+} were within NIS (2007), (USEPA. 2015) and (World Health Organization, 2021). Cations such as Co^{2+}, V^{3+} and K^{+} had no bases for comparison by NIS (2007), (USEPA. 2015) and (World Health Organization, 2021). The mean values of pH fall within the range of NIS (2007) and (USEPA. 2015) for dry season samples while it falls outside the range for wet season samples. The southern half of the sheet had

Table 1: Summary of results of chemical and physical parameters of groundwater samples from Paiko Sheet for dry and wet seasons.

	Dry Season		Wet Season		Mean		Standards (S)		
Parameters	% of samples within S	% of samples outside S	% of samples within S	% of samples outside S	% of dry and wet season within S	% of dry and wet season outside S	NSDWQ (2007), mg/L	USEPA (2015), mg/L	WHO (2012), mg/L
Cl	100	0	100	0	100	0	250	250	250
CO_3	100	0	100	0	100	0	100	250	450
SO_4	98	2	98	2	98	2	-	-	150
HCO_3	100	0	100	0	100	0	-	-	150
F	100	0	100	0	100	0	1.5	0.5	2
NO_2	100	0	100	0	100	0	0.2	1	0.2
NO_3	100	0	100	0	100	0	50	10	50
Na	100	0	100	0	100	0	200	-	200
K	NA	NA	NA	NA	NA	NA	-	-	200
Ca	100	0	100	0	100	0	-	-	75-200
Mg	0	100	97	3	49	51	0.2	-	100
Al	0	100	0	100	0	100	0.2	0.05-0.2	0.2
Zn	100	0	100	0	100	0	5	5	3
Cd	0	100	100	0	50	50	0.003	0.005	0.003
V	NA	NA	NA	NA	NA	NA	-	-	-
Fe	81	19	82	18	81	19	0.3	0.3	0.3
Cu	100	0	100	0	100	0	1	1	1.5
Ni	100	0	100	0	100	0	0.02	-	0.02
As	0	100	0	100	0	100	0.01	0.05	0.05
Co	NA	NA	NA	NA	NA	NA	-	-	-
Hg	0	100	0	100	0	100	0.001	0.002	0.001
Pb	49	51	92	8	75	25	0.01	0.15	0.01
Cr	100	0	100	0	100	0	0.05	0.1	0.05
Mn	86	14	93	7	89	11	0.2	0.05	0.1
EC	88	12	90	10	89	11	1000	-	-
pH	61	39	73	27			6.5-8.5	6.5-8.5	-
TDS	89	11	92	8			500	500	-

higher pH values than the northern half. TDS and EC had values that within NIS, (2007).

Classification of Groundwater Water With TDS

The classification of groundwater with TDS values was in accordance with (Gorrell, 1958). The result shows that groundwater within the area can be classified as freshwater because all TDS values were less than 1000 mg/l for both seasons as shown by Table 2.

Classification of Groundwater with Piper Diagram

The results of both seasons indicated that water from the studied area plotted within the region that has no dominant cations and anions water type in both triangles below the central diamond-shaped diagram (Figures 1) of the Piper diagram. Ca^{2+} and SO_4^{2-} however occur in significant amount when compared with other individual ions. Most of the water samples plotted within the region where strong acid exceeded weak acid in the central diamond-shaped diagram. Approximately 92% and 96% of the water samples plotted within the region of Ca^{2+}–Mg^{2+} and Cl^-–SO_4^{2-}-HCO_3^- in the hydrochemical facies diagram for dry and wet seasons respectively implying that both seasons average of 94% of water within the area belong to Ca^{2+}–Mg^{2+} and Cl^-–SO_4^{2-}-HCO_3^- water types. The remaining water samples plotted within the region of Ca^{2+}–Mg^{2+}, Na^+-K and CO_3^{2-}-Cl^-–SO_4^{2-} signifying that the remaining water samples were mixtures of Ca^{2+}–Mg^{2+}, Na^+-K and CO_3^{2-}-Cl^-–SO_4^{2-}.

Table 2: Classification of Formation Waters Based on TDS (Gorrell, 1958)

Freshwater	0 to 1,000 mg/l TDS
Brackish water	1,000 to 10,000 mg/l TDS
Salty water	10,000 to 100,000 mg/l TDS
Brine water	>100,000 mg/l TDS

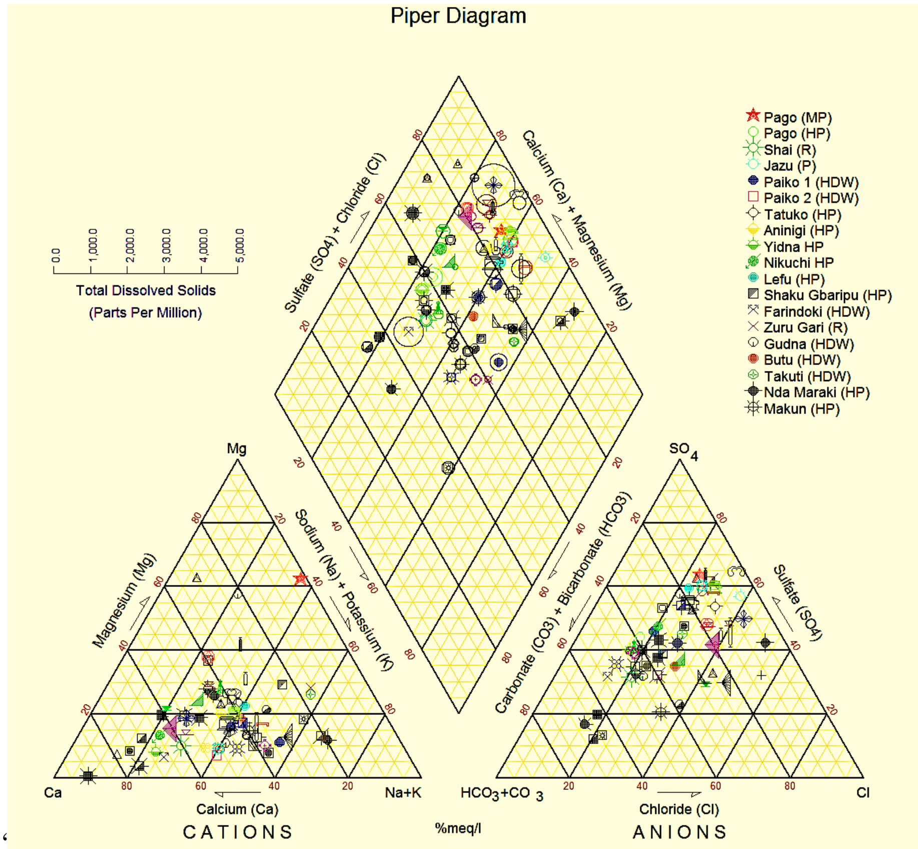

Figure 1: Piper diagram displaying water types for the dry season water samples from Paiko Sheet

Classification of Groundwater with Durov Diagram

Durov diagram (Figure 2) shows that approximately 80% and 88% (field 5) of water samples of dry and wet seasons respectively had no dominant anions and cations signifying that simple dissolution or mixing (a hydrochemical process) must have taken place. 7% and 10% (field 6) of water samples had SO_4^{2-} and Na^+ which is a rare water type that may have occurred as a result of mixing influence for only dry and wet seasons respectively. 6% (field 4) each of water samples of respective dry and wet seasons had Ca^{2+} and SO_4^{2-} as the dominant ions indicating either recharge water in lava, or mixed water or simple mixing. 3% and 2% (field 9) of samples had Cl^- and Na^+ dominant frequently indicate end point waters for dry and wet seasons respectively and also 3% (field 8) had chloride and sodium ions dominance indicating that reverse ion exchange must have taken place for only dry season. 1% (field 2) of the dry season samples had calcium and bicarbonate as the dominant ions signifying ion exchange may have taken place and another 1% (field 1) had HCO^{3-} and Ca^{+2} as dominant, frequently indicates recharging water in limestone, sandstones and other aquifers for only dry season.

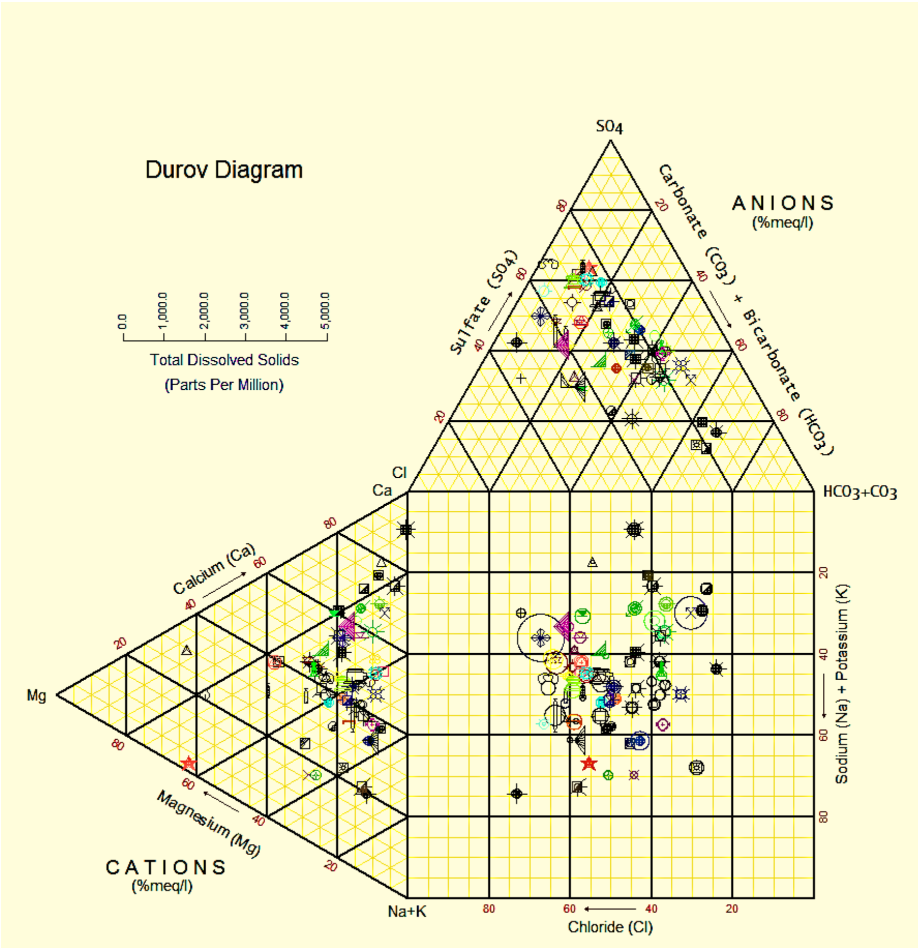

Figure 2: Durov diagram displaying water types and hydrochemical processes for the dry season water samples from Paiko Sheet.

Classification of Groundwater with Stiff Plots

Stiff plots show that there are four sources for groundwater within the area as shown by four different types of polygonal shapes with each shape type varying in size as a result of variation in the concentration of the ions. The shapes with larger surface areas show higher ionic concentration than those with lower surface areas. About 60%, 21%, 12% and 7% of water samples had similar shapes respectively for dry season while about 44%, 37%, 14% and 5% of water samples had similar shapes respectively for wet season. Figure 3 shows Stiff plots of some wet season samples of some locations. These water sources include water resulting from simple dissolution or mixing; recharging water in limestone, sandstones and other aquifers; reverse ion exchange and mixed water.

Classification of Groundwater with Schoeller diagrams

Schoeller diagrams (Figure 4) for dry season samples shows that majority of cations had

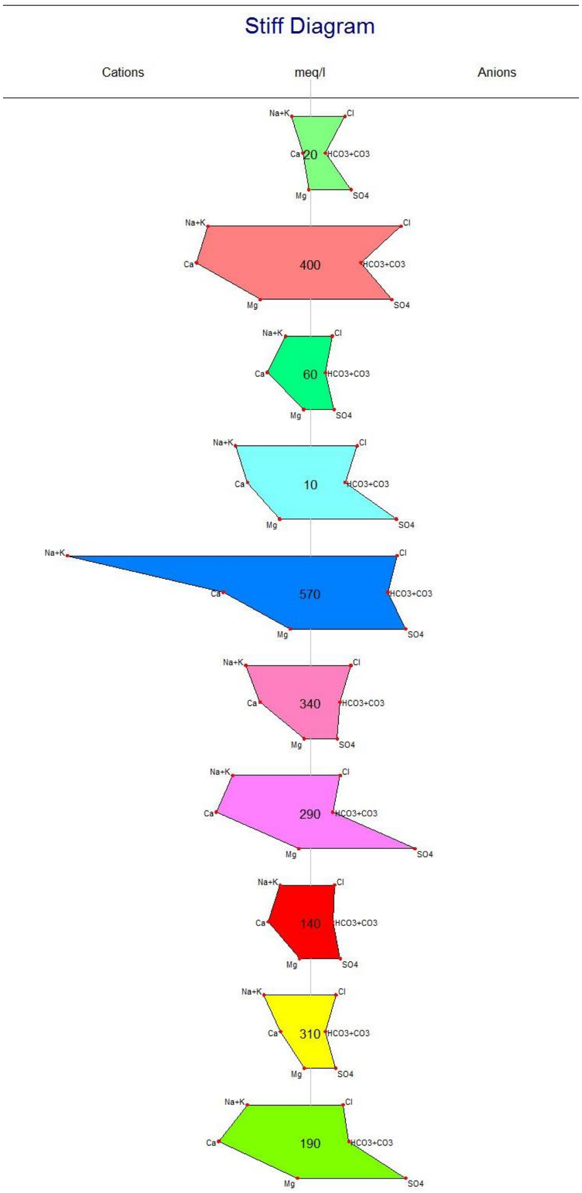

Figure 3: Stiff plots of wet season samples for Pago Mp, Pago HP, Shai, Jazu, Paiko 1 and Paiko 2

similar pattern of distribution. The plot shows a fall from Ca^{2+} ions to Mg^{2+} then rise to Na^{+} then fall to K^{+}. This occur in about 85% of the samples. 6% show a rise from Ca^{2+} to Mg^{2+} to Na^{+} and then fall to K^{+}. 2% show a fall from Ca^{2+} to Mg^{2+} and Na^{+} and then rise to K^{+} while the remaining 7% show a fall from Ca^{2+} to Mg^{2+} to Na^{+} to K^{+}. Wet season samples show a fall from Ca^{2+} to Mg^{2+} then rise to Na^{+} then fall to K^{+} in the majority of the samples. This occur in about 97% of the samples. 1.5% show a fall from Ca^{2+} to Mg^{2+} and Na^{+} and then rise to K^{+} while the remaining 1.5% show a fall from Ca^{2+} to Mg^{2+} to Na^{+} to K^{+}. 12% of dry season samples had anions with similar pattern of distribution where the concentration of Cl^{-} exceeded those of SO_4^{2-} and HCO_3^{-}, 12% had lower SO_4^{2-} concentration than the Cl^{-} and HCO_3^{-}, 28% had higher HCO_3^{-} than both SO_4^{2-} and Cl^{-} while 48% had higher SO_4^{2-} than both chloride ions and HCO_3^{-}. 32% of wet season samples show that anions had similar patterns with Cl^{-} concentration exceeding those of SO_4^{2-} and HCO_3^{-}, 10% had lower SO_4^{2-}concentration than both Cl^{-} and HCO_3^{-}, 2% had higher HCO_3^{-} than both SO_4^{2-} and Cl^{-} while 56% had higher SO_4^{2-} concentration than both Cl^{-} and HCO_3^{-}.

Classification with Pollution Index

Some parameters (such as Cl^{-}, SO_4^{2-}, F^{-}, K^{+}, Ca^{2+}, Mg^{2+}, Zn^{2+}, Cd^{2+}, Cu^{2+}, Ni^{2+}, As^{+}, Mg^{2+}, Hg^{2+}, Pb^{2+}, Mn^{2+} and TDS) had higher pollution index values in dry season while others (such as NO_3^{2}, Na^{+}, Al^{3+}, Fe^{2+}, Cr^{2+} and pH) had higher values in wet season (Table 1). Table 3 shows that Cl^{-}, F^{-}, NO_2^{-}, NO_3^{2-}, Na^{+}, K^{+}, Ca^{2+}, Zn^{2+}, Cu^{2+}, Cr^{2+}, conductivity, pH and TDS in the dry season groundwater samples from area were classified as excellent. SO_4^{2-} and Mn^{2+} in groundwater within the area were classified as acceptable. There was pollution of groundwater by Fe^{2+} and Ni^{2+} while K^{+}, Mg^{2+}, Al^{3+}, Cd^{2+}, As^{+}, Hg^{2+} and Pb^{2+} heavily pollute the dry season groundwater samples. Table 3 also shows that parameters such as Cl^{-}, SO_4^{2}, F^{-}, NO_2^{-}, NO_3^{2-}, Na^{+}, K^{+}, Ca^{2+}, Zn^{2+}, Cu^{2+}, Cr^{2+}, conductivity, pH and TDS in wet season groundwater samples were classified as excellent. The groundwater within the area contain acceptable level of Cd^{2+}, Ni^{2+} and Mn^{2+} and polluted by Pb^{2+} and Fe^{2+} for wet season samples. There was heavy pollution by Mg^{2+}, Al^{3+}, Cd^{2+}, Ni^{2+}, As^{+}, $Hg^{2+}$and Pb^{2+} ions in wet season samples. These results imply that groundwater samples from Paiko Sheet is polluted with some heavy metals (Hg^{2+}, As^{+}, Pb^{2+}, and Fe^{2+}), Mg^{2+} and Al^{3+}.

Groundwater Drinking Water Quality

Table 1 shows that the groundwater of Paiko Sheet cannot be consumed directly without treatment as elevated amount of some parameters such as Mg^{2+}, Al^{3+}, As^{+} and Hg^{2+} were found in all the samples analyzed. Fe^{2+}, Pb^{2+}, Mn^{2+}, Ni^{2+}, Ca^{2+} and SO_4^{2-} were also found in elevated amount in some of the samples analyzed. In addition, pollution index

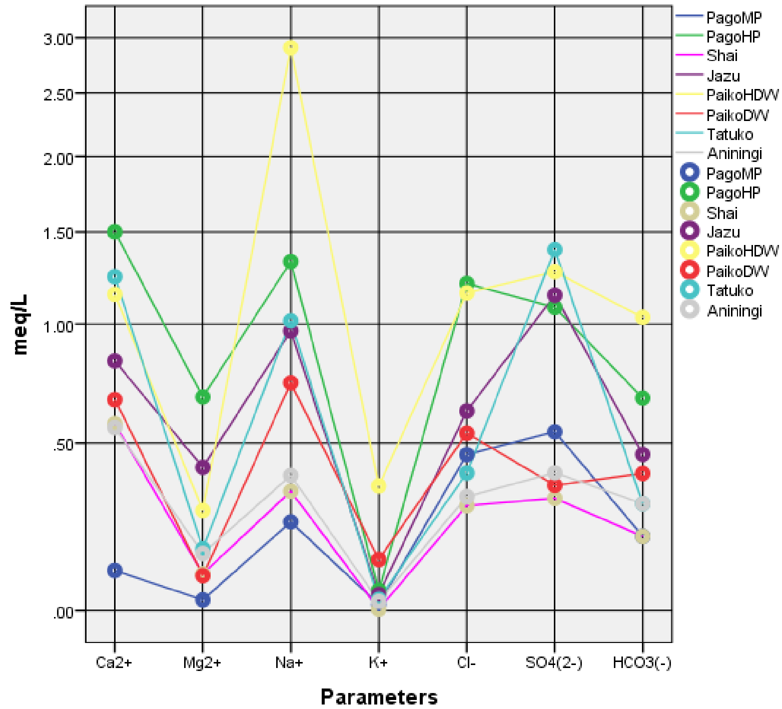

Figure 7: Schoeller diagram for Pago – Aninigi for dry season samples

values of K^+ show that it also heavily polluted groundwater within Paiko Sheet. These parameters could have negative health effects on the consumers. Presence of metals in groundwater could have been as a result of geogenic processes especially dissolution of

minerals rich in these metals (Singhal and Gupta, 2010). Anthropogenic activities must have also contributed reasonably as waste from mining, agricultural and domestic activities were discarded into the environment without standard practice.

The presence of sulphate in Lambata HP in elevated amount could be attributed to geogenic sources such as oxidation of Sulphur rich minerals. Mining of Sulphide rich minerals is going on within the neighborhood (BabanTsauni) of Lambata. The physical parameter results also show that about 39% of the samples analyzed were acidic. There are however inexpensive materials such as rice husk, maize cub, activated charcoal among other that can be used to reduce the metal loads in groundwater within Paiko Sheet.

Conclusion

The order of abundance of cations is $Ca^{2+} > Na^+ > K^+ > Mg^{2+} > As^+ > Al^{3+} > Cd^{2+} > Fe^{2+} > Hg^{2+} > Zn^{2+} > V^{3+} > Ni^{2+} > Mn^{2+} > Co^{2+} > Cu^{2+} > Pb^{2+} > Cr^{2+}$ while that of the anions is $SO_4^{2-} > HCO_3^- > Cl^- > NO_3^{2-} > CO_3^{2-} > F^- > NO_2$. Some chemical parameters such as Mg, Al, As and Hg were higher than the acceptable limit in all samples while Fe, Lead, Mn, Ni, Ca and SO_4^{2-} were higher than the acceptable in some samples. Na^+, Zn^{2+}, HCO_3^-, Cl^-, NO_3^{2-}, CO_3^{2-}, F^- and NO_2 were within the acceptable limit. Co, V and K had no bases for comparison. About 39% of groundwater were acidic while 11% and 10% of EC and TDS were above the acceptable limits respectively. The groundwater was classified as fresh water with TDS values. Ca^{2+}-Mg^{2+} and Cl^-- SO_4^{2-}-HC O_3^- was the dominant water type while simple dissolution was the dominant hydrochemical process that have affected the quality of groundwater within studied area. There were four processes (simple dissolution or mixing; recharging water in limestone; sandstones and other aquifers; and reverse ion exchange and mixed water) that had taken place in groundwater system of Paiko Sheet. Majority of the cations had similar pattern of distribution while the anion had diverse pattern of distribution. The groundwater of the studied area was polluted

Table 3: Pollution Index values of Dry Season and Wet Season

Parameters	Si	PI (Dry Season)	PI (Wet Season)	PI (Dry and Wet Season Average)	Class index score	Class	Classification
Cl	250	0.27	0.17	0.2	0-1	C_1	Excellent
CO_3	100	1.09	0.17	0.6	1-2	C_2	Excellent
SO_4	1.5	0.32	0.26	0.3	0-1	C_1	Excellent
HCO_3	0.2	0	0	0.0	0-1	C_1	Excellent
F	50	0.006	0.89	0.4	0-1	C_1	Excellent
NO_2	200	0.17	0.26	0.2	0-1	C_1	Excellent
NO_3	150	0.14	0.066	0.1	0-1	C_1	Excellent
P	200	0.45	0.097	0.3	0-1	C_1	Excellent
Na	0.2	52.53	20.55	36.5	8-16	C_5	Heavily polluted
K	0.2	8.58	22.53	15.6	8-16	C_5	Heavily polluted
Ca	3	0.47	0.032	0.3	0-1	C_1	Excellent
Mg	0.003	235	1.67	118.3	8-16	C_5	Heavily polluted
Al	0.3	4.88	6.067	5.5	4-8	C_4	polluted
Zn	1	0.025	0.016	0.0	0-1	C_1	Excellent
Cd	0.02	7.25	1	4.1	4-8	C_4	polluted
V	0.01	131.21	67.12	99.2	8-16	C_5	Heavily polluted
Fe	0.001	260.05	195.02	227.5	8-16	C_5	Heavily polluted
Cu	0.01	36.5	4.36	20.4	8-16	C_5	Heavily polluted
Ni	0.05	0	0.14	0.1	0-1	C_1	Excellent
As	0.2	1.35	1.25	1.3	1-2	C_2	Acceptable
Hg	0.001	260.05	195.02	227.54	8-16	C_5	Heavily polluted
Pb	0.01	36.5	4.36	20.43	8-16	C_5	Heavily polluted
Cr	0.01	0	0.14	0.07	0-1	C_1	Excellent
Mn	0.05	1.35	1.25	0.8	0-1	C_1	Excellent
EC	1000	0.94	0.7	0.8	0-1	C_1	Excellent
pH	7.5	0.59	0.62	0.6	0-1	C_1	Excellent
TDS	500	0.94	0.61	0.8	0-1	C_1	Excellent

by Fe^{2+}, Ni^{2+}, K^{+}, Mg^{2+}, Al^{3+}, Cd^{2+}, As^{+}, Hg^{2+} and Pb^{2+} as shown by pollution index result. The groundwater from the studied area cannot be consumed without treatment. Purification with materials such as rice husk, activated charcoal and maize cubs can reduce the metal load of the groundwater. It is also recommended that the water be boiled before drinking.

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