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Evaluation of Groundwater Quality in Shakwatu Community, Part of Sheet 164 SW, Central Nigeria

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Abstract
Geology, mineralogical composition of rocks and geotechnical properties (grain size and permeability) of the soil within the river in Shakwatu and environs part of Sheet 164 SW were studied. Physico-chemical characteristics of groundwater collected from boreholes, hand dug wells and river were also determined. Statistical techniques where applied to the groundwater samples to determine hydro-geochemical parameters in order to establish the relationship among the measured parameters and their sources. Results show that the area is part of the Kushaka schist belt that have been intruded by faulted gneiss, granites and quartzite. The mineralogical composition of the rocks includes biotite, feldspar and quartz. The soils falls under A – C group that consist of poorly sorted sand with low fines and are of medium to high hydraulic conductivity (2.434×10^{-02}). The conductivity of the soil could aid in the infiltration of harmful wastes from the illegal mining activities that is prevalent in the area. The cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (Cl^{-}, HCO_3^{-}, CO_3^{2-}, SO_4^{2-}, F^{-}, NO_3^{-}) fell within WHO and NSDWQ recommended standards. Concentration of nitrite, chromium, iron, TDS, and turbidity are beyond the permissible limit of NSDWQ and WHO. The dominant water type is $CaHCO_3$ followed by $CaNaHCO_3$ water type. Rock weathering and cation exchange are the major geochemical processes responsible for the water chemistry in the study area.

Keywords*: Geology, groundwater, permeability, Nigeria standard of drinking water quality*

Introduction

The water on earth is extremely unevenly distributed, oceans hold about 96.5% of the Earth's water (USGS, 2016). Only a meager 3% of the water is freshwater and available for human use. 69% of the freshwater is located in glaciers and icecaps and 30 % is resident underground as groundwater, 1% of freshwater can be found in lakes, streams, rivers.

Safe drinking water, as defined by the World Health Organisation, (2017), as water which does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Water is a major source for irrigation which is a vital component of agriculture, in other words, agriculture is the largest user of water in all regions of the world except Europe and North America (FAO, 2002b).

Water is an essential requirement of human and industrial development and the most delicate part of the environment (Amadi *et al.*, 2017). In Nigeria, an estimated 65 million people don't have accessed to safe water (Majuru *et al.*, 2011) and the demand is on a daily increase. Most regions in the world are experiencing acute water shortage or scarcity due to high unmet water demand from most water-using sectors, climate change, rapid industrialization, and failure of the government to keep up with the constant supply of pipe borne water.

Groundwater can be defined as water found in the saturated zone underneath the earth. It is a vital hidden natural resource (Tularam and Krishna, 2009; Lashkaripour and Ghafoori, 2011), and a major source of water of millions of people in sub- Saharan Africa, where modern water supply scheme is almost absent. The estimated amount of groundwater in Nigeria is 6 x 10^{18} m^3 (Rijswijk, 1981) Its quality is intrinsically linked to the chemical properties of the aquifer's geology (Aston, 2000). The impact of anthropogenic activities such as artisanal mining activities on groundwater cannot be ignored. Groundwater, the preferred source of potable water is under a serious threat due to unregulated activities of artisanal mining.

One of the thriving businesses in Shakwata village, a suburb of Minna, Niger State is artisanal mining. Artisanal mining can be defined as an informal, low capital, high-labour intensive, unskilled method to extract valuable minerals. Many youth, women and children in Shakwata have actively embraced artisanal mining as a source of livelihood (plate 1 and 2). Despite the economic gains of artisanal mining, it could have a negative impact on the environment. In gold mining operation, water and soil are the recipients of indiscriminate disposal of toxic waste and gangue of gold ores. The use of gravity concentration method such as panning and sluicing during processing poses health challenges. (Amadi, 2016), as in the case of 2010 Zamfara Lead Poisoning epidemic, which claimed the life of 163 people, out of which 111 children were casualties. Drinking water must especially be low in metals, fluorides, nitrates and nitrites (WHO, 2017); therefore, the assessment of water quality is of high importance because human health requires water that is both safe to drink and palatable. (DWAF, 2006).

Plate I: An artisanal miner sluicing 09°41'58"06°31'59"

Plate II: Mine tailings from a mining pit 09°39'23" 06°37'13"

Location of the study area

The study was carried out in shakwata village and its environs, bosso local government. The area lies between latitudes 09° 38′ 30″ and 09° 40′ 0″ n, longitudes 06° 36′ 0″ and 07° 38′ 30′′ e it is about 10km from minna metropolis. The area is located within the kushaka schist belt which had been intruded by faulted granite, gneiss and quartzite.

Guinea Savannah is the vegetation host to the study area, which is characterized by different species of shrubs and also forest like vegetation along the stream channels (Kogbe, 1989; Ajibade, 1982).

The study area lies in a tropical climatic region; this is characterized by an annual temperature of 27°C and annual precipitation of 1246mm which start by March and ends by November (climate-data.org, 2019). Two seasons are prevalent in the study area, namely wet season (March to November) and dry season (December to February). The dry season is accompanied by the North-East trade wind (Harmattan wind) which originates from the Sahara desert. The driest month January witnesses precipitation of 1mm (climate-data.org, 2019), whereas September is the wettest month, usually witness precipitation of 263mm (climate-data.org, 2019).

Geology of the area

The study area lies within the Kushaka Schist Belt aged Kibaran 1159± 70ma. The schist belt with biotite-muscovite.

The rock types mapped included fine to medium grained biotite granite, gneiss and amphibolites schist, The granite has been affected by the Pan African Orogeny with late tectonic emplacement of granites and granodiorites. The end of the orogeny was marked by faulting and fracturing· according to Abaa, (1983; Ganduet al., 1986; Olayinka, 1992; Obaje, 2009; Waziri, 2015). The granites are thus fractured, jointed and deeply weathered in some places.

Materials and Methods

Geological mapping of the was carried with aid of compass/clinometers, hand lens and GPS. Thin section was done at the Nigerian Feological Survey Agency (NGSA) Kaduna while the petrograpgic studied was at the Geology department of the Federal University of Technology (FUT) Minna. Twelve (12) representative water samples were taken in transparent labeled plastic bottles, (2 hand dug wells, 4 stream channels, mining pit, 5 boreholes) to the laboratory for physicochemical analysis. The physicochemical analysis was carried out at the National Regional Water Quality Laboratory, Minna. The physicochemical parameters were analysed and compared with the WHO, NSDWQ recommended standard. Grain size distribution was done on soils taken from the river channel at the Engineering geology lab, FUT, Minna. Hydraulic conductivity was calculated from the grain size distribution curves

Results and Discussion

The rock types revealed from the geological mapping include granites, gneiss and schist with quartzite intrusions. The rocks have been intruded by quartz veins, foliated and faulted (plate 3 and 4). Minerals observed from the petrographic studied include biotite, muscovite, hornblende, quartz, orthoclase amphibole and opaque minerals. Since the rocks are faulted and fractured, water can easily penetrate through the rock and cause chemical break down of the minerals that could eventually leach in to the groundwater.

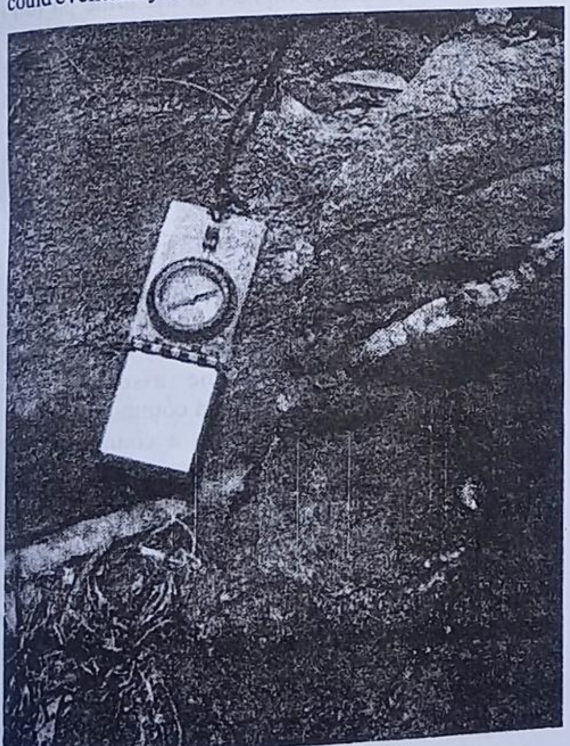

Plate III: A sinistral fault 09 °38' 37", 06° 37' 0"

Table one is the result of hydraulic conductivity as calculated from the grain size distribution curves. Table

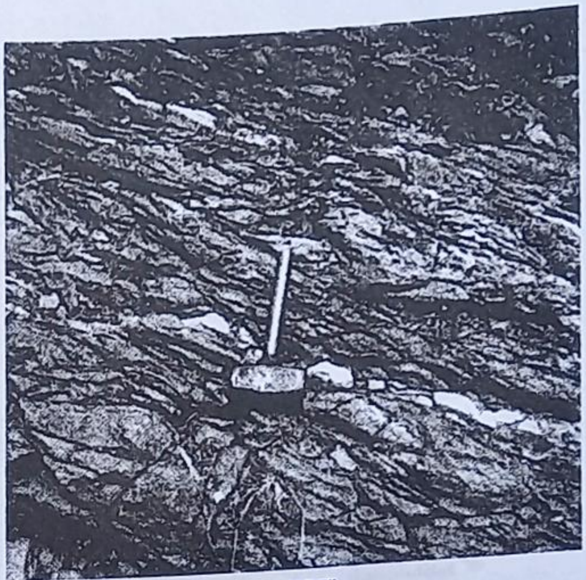

Plate IV: Foliated schist 9°38'4 "6°37'5"

1 shows that the hydraulic conductivity of the studied soils vary from 4.43 x 10^{-2} cm/s to 3.00 x 10^{-1}cm/s. Conductivity values of this range according to Macauley (2008) are high. This means that the soils in the river channel are permeable and could aid in the downward movement of the materials discharged from the mines (figure 2).

Table 1: Hydraulic conductivity (k) of soils from a river channel in the study area

SOIL PROFILE A1	4.43 x 10^{-2} cm/s
SOIL 3. HORIZON A	3.42 x 10^{-2} cm/s
SOIL HORIZON B	8.86 x 10^{-2}cm/s
SOIL PROFILE C	3.00 x 10^{-1}cm/s

The physical parameters compared with the NSDQW, WHO standards are presented on table 2.

From table 2, the pH ranges between a value of 6.16 and of 7.47, indicating a slightly acidic to mildly alkaline nature of the water in the study area. pH plays an important role in chemical reactions, solubility and toxicity of metal. Table 2 also reveal a turbidity range between 0 and 8,300 NTU, conductivity between 64 and 1,700 µ/cm and a TDS range between 42 and 1,105mg/l. The lowest pH value observed at borehole location 4 (BH4) can be as a result of mine water drainage which could have infiltrated through the soil into the groundwater. Turbidity ranges from 0 NTU to 8,300 NTU. The cause of the high turbidity observed at stream channel 1 (SC1) could be as a result of run off of mine water from the mining site due to its proximity to the site, and presence of silty clay, colloidal inorganic

Table 2: Physical parameters compared with the NSDQW, WHO standards

PHYSICAL PARAMETERS	W1	W2	SC1	SC2	SC3	SC4	MP	BH1	BH2	BH3	BH4	BH	NSDWQ(2015)	WHO(2017)
pH	6.56	6.5	7.03	6.69	6.72	6.83	7.47	6.65	6.6	6.6	6.16	6.43	6.5-8.5	6.5-8.5
Turbidity(NTU)	4	0	8300	18	16	22	5570	9	11	6	8	7	5	5
EC(μ/cm)	482	1700	138	486	474	242	64	814	546	496	448	510	1000	NS
TDS(mg/l)	313	1105	90	316	308	157	42	529	355	322	291	332	500	600-1000

Table 3: Chemical parameters is compared with NSDWQ and WHO

Heavy metals	W1	W2	SC1	SC2	SC3	SC4	MP	BH1	BH2	BH3	BH4	BH6	NSDWQ (2015)	WHO(2017)
Iron(mg/l)	0.89	0.64	10.1	4.68	3.72	2.29	29.2	1.27	2.09	0.52	0.37	0.18	0.3	NS
Cadmium(mg/l)	0.001	0.001	BDL	BDL	BDL	BDL	0	0	BDL	0	0	0.001	0.003	0.003
Lead(mg/l)	0.002	0.001	0.001	0.001	0	0	0.002	0	0	0	0.002	0.004	0.01	0.01
Manganese(mg/l)	BDL	BDL	BDL	BDL	BDL	BDL	0.08	0.04	0.002	0	0.002	0.001	0.2	NS
Zinc (mg/l)	0.002	0.003	BDL	BDL	BDL	BDL	0.015	0.009	0.013	0.028	0.064	0.029	3	4
Chromium(mg/l)	0.03	0.01	4	0.04	0.03	10	0.01	0.02	0.01	0	0	0	0.05	20
Arsenic(mg/l)	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01
Copper(mg/l)	BDL	BDL	0.005	BDL	0	0	0.004	0	0	0.001	0.006	0.005	1	2

Table 4: concentration,of other parameters compared with NSDWQ and WHO

CHEMICAL PARAMETERS	W1	W2	SC1	SC2	SC3	SC4	MP	BH1	BH2	BH3	BH4	BH6	NSDWQ(2015)	WHO (2017)
Chloride(mg/l)	7.99	8.19	49.9	18.9	6.99	8.99	49.99	9.99	15.9	19.9	12.9	26.9	250	250
Nitrite(mg/l)	0.009	0.096	0.018	0.061	0.085	0.01	0.505	0.02	0.191	0.024	0.027	0.017	0.2	1
Bicarbonate(mg/l)	119	216	300	158	127	72	390	246	155	88	126	82	NS	NS
Sodium(mg/l)	11	85	15	28	25	10	15	21	26	34	19	35	200	200
Magnesium(mg/l)	5.37	39.5	9.76	1.46	2.44	1.95	9.76	27.8	12.7	7.81	7.81	1.46	20	NS
Sulphate(mg/l)	4	27	200	9	7	3	220	1	3	3	3	3	100	NS
Potassium(mg/l)	3	66	6	5	4	1	4	2	1	2	1	1	NS	NS
Carbonate (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0	NS	NS
Calcium(mg/l)	31.2	17.6	24.1	24.5	29.7	12.8	40.1	22.5	20.9	18.5	22.5	22.5	NS	NS

particles (Omonona *et al.*, 2019) Turbidity is an essential physicochemical marker of the presence of the possible presence of pollutant that are of concern to human health (Omonona *et al.*, 2019). The high value of electric conductivity (1,700μ/cm) which is above the permissible limit of NSDWQ at hand dug well W1 could be attributed to the presence of some elements in the water body. All water samples are within the permissible limit by WHO as it is not stated. The impact of high TDS in hand dug well (W2) could impact unpleasant taste on the water.

Result of the chemical parameters is compared with NSDWQ and WHO and shown on table 3

Table 3 shows that the concentration of manganese ranges from 0.00mg/l to 0.08 mg/l which is within the permissible limit of NSDWQ and WHO. Concentration of zinc, sodium, arsenic, copper, lead, potassium, cadmium are all within the permissible limit of NSDWQ, WHO.

Table 3 further show that the concentration of chromium varies from 0.001 mg/l to 10mg/l and is highest in the mine pit (MP). This is above the permissible limit of NSDWQ. This is worrisome because Chromium is toxic and carcinogenic. It exists in several forms (Cr III and Cr VI). Hexavalent Chromium (Cr VI) is the most toxic form of chromium as it damages DNA. It is highly soluble and usually occur in site that are contaminated. Another heavy metal that exceeded the permissible limit of NSDWQ and WHO is Iron (table 3). The concentration of iron is highest at the mine pit (MP) having a value of 29.2 mg/l. Concentration of ion of such magnitude can cause brown coloration in water and textiles (Adeniyi and Waziri, 2017). The excess magnesium concentration recorded at W2, BH1 signifies that the water is hard and can contribute in making the water in Shakwatu and environs hard. This can make the inhabitants of the area to spend more money on detergent.

Nitrite has concentration values within 0.001 and 0.505 mg/l (table 4) with the highest concentration at the mine pit (MP). The high concentration at the mine pit above the permissible limit can be associated with denitrification process by bacteria commonly found in stagnant water. Denitrification is a common feature associated with mining pits because indiscriminate use of explosives for blasting of rock, in other words, common explosives used at mine sites contains large percentage of nitrogen compounds (Morin and Hutt,2008), this compounds' are released into the groundwater bodies during mining operations. All other elements are within the permissible limit by NSDWQ, WHO.

Hydrochemical Facies

The water from Shakwata and environs was classified based on Piper (1944) and presented in figure 1.

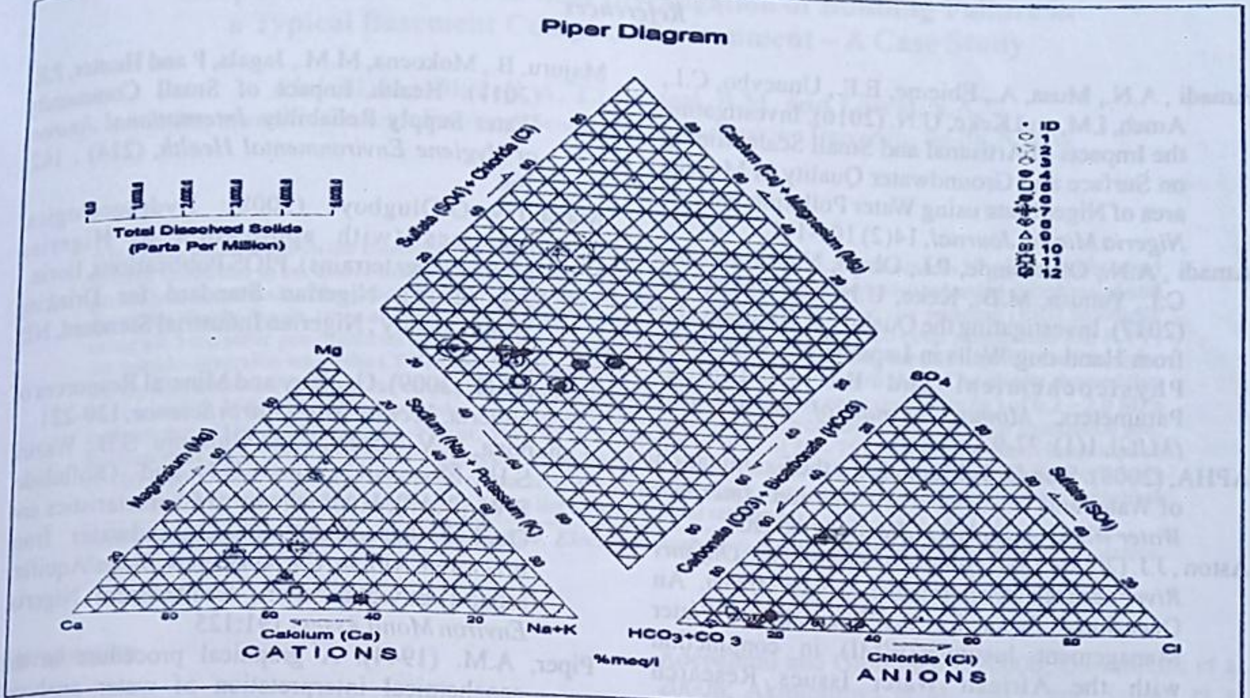

Fig. 1: Water types within Shakwatu and environs

Figure 1 shows that the dominant water type in Shakwatu and environs is Ca $-HCO_3$ followed by $NaHCO_3$ and $CaMgHCO_3$. This diagram implies that weak acids dominates strong acids, alkali earth ion dominates alkali ions.

Conclusion

The study area is made up of amphibolite schist,quartzite, granites and granitic gneiss. The mineralogical composition of these rocksinclude quartz,amphibole, biotite, plagioclase. High hydraulic conductivity derived from the grain size distribution (4.43×10^{-2} cm/s to 3.00×10^{-1}cm/s) , imply high permeability in the soil , and this could aid the downward transportation of mine tailings into the groundwater. Low pH recorded in most of the water bodies aids the solubility, increases the movement of ions and accounts for high turbidity . Electric Conductivity (EC) high value at hand dug well W1 could be as a result of metallic presence. Among all the heavy metals element, chromium concentration poses a threat to human life. The value in the study area is well above the permissible limit of NSDWQ ,2015, WHO, 2017. The dominant water facies is $CaHCO_3$, $CaNaHCO_3$, $CaMgHCO_3$, implying the dominance of alkali earth ion over alkali ion.

Among other chemical parameters, Nitrite is not within the permissible limit, and it can not be ignored because of its negative impact on DNA when ingested either by man or animals. Most of the parameters tested and compared with NSDWQ and WHO are all within the permissible limit. The high concentration of iron in the study area could lead to rusting of boreholes and borehole installation accessories, such as riser pipes, and coloration for cloths.

This menace can be regùlated if the government look into the issue of illegal mining activities, and curtail their nefarious activities.

It is recommeded that the activities of the artisanal mine must be bought under control and checked.

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