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Groundwater Quality in the Sahelian Region of Northern Ghana, West Africa

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Abstract: In many arid ecological zones of the world, the utilization of groundwater for various purposes is common due to the scarcity of surface water. In the sahelian regions of northern Ghana, groundwater serves as a major source of freshwater for domestic and agricultural purposes. This study investigated the quality of groundwater from 129 boreholes in the Sawla-Tuna-Kalba district in the Sahelian region of northern Ghana, to promote and enhance the proper utilization of the resource. Samples were collected and analyzed for various water quality parameters to evaluate its usefulness for domestic and agricultural use. Results indicates that groundwater in the study is generally fresh and hard. It was found that majority of samples belong to the Ca-Mg-HCO_3 hydrochemical facies. Sodium Adsorption Ratio (SAR) for all groundwater samples in the district ranged from 0.18-3.61 (mean 1.00), implying that all the boreholes samples had excellent water that could be used for irrigation. This was confirmed by analytical data plot on the US salinity diagram which illustrates that majority of groundwater samples fall in the field of C2S1; indicating medium salinity and low sodium water. Though many of the analysed parameters fall within acceptable range and thus most of the boreholes had water which were chemically suitable for drinking, a few recorded total iron, manganese, lead, arsenic and fluoride concentrations above permissible WHO levels, suggesting some concern in terms of potability, especially since such water sources are extensively patronised by inhabitants for drinking and agricultural purposes.

Key words: Groundwater, hydrochemical facies, Northern Ghana, sahelian, Sawla-Tuna-Kalba, water quality

INTRODUCTION

In the savannah regions of northern Ghana, groundwater is generally the major source of freshwater for domestic, agricultural and small-scale industrial use and livestock watering (Kortatsi, 1994). Because groundwater usually occurs below the surface and not typically in contact with the atmosphere, it is often assumed to be fairly safe for consumption, compared to surface water (Quist *et al*., 1998). This assertion, however, is not always the case due to the fact that groundwater is sometimes affected by dissolved minerals from geological formation which may impact negatively on the water quality and thus affect human health (Aghazadeh and Mogaddam, 2010; Kortatsi, 2007; Domenico and Schwartz, 1990; Freeze and Cherry, 1979). Groundwater quality may also be compromised as a result of anthropogenic activities close to boreholes and shallow hand dug wells. Poor sanitation, improper waste disposal, seepage of agrochemicals and mining has been observed to affect the quality of groundwater (Fianko *et al*., 2010; Jain *et al*., 2009; Carpenter *et al*., 1998).

Due to the relatively long dry seasons experienced in the northern sahelian regions of Ghana, the government and its development partners continue to provide boreholes and dug wells to help alleviate water scarcity. There are, at present, over 10,000 boreholes that have been drilled by various organizations across northern Ghana (International Water Management Institute, 2010; Gyau-Boakye, 2001). Given that groundwater in some parts of this vastly sahelian and water stressed region is reported to be contaminated with high levels of fluoride and other heavy metals (Ofosu-Addo *et al*., 2008; Apambire *et al*., 1997) presumably due to the mineralogy of the aquifers, issues relating to borehole water quality become not only essential but also problematic. In addition, extensive use of pesticides and fertilizers for agriculture likely serve as human-induced sources of groundwater contamination, which, in addition to industrial or urban development, could persists for hundreds of years (Ravikumar *et al*., 2009).

The northern part of Ghana is an agricultural zone where majority of foodstuffs are cultivated annually for the sustenance of the indigenes and the country as a whole. Agriculture in this part of Ghana is mainly rain-fed, with a uni-modal rainfall regime lasting between 5-6 months and a long period of drought lasting 6-7 months in a year (Environmental Protection Agency, 2003; Gyau-Boakye and Dapaah-Siakwan, 1999). It has however, been estimated that about 5.8 Mha of land in Ghana has the potential for groundwater irrigation (International Water Management Institute, 2010). To increase crop

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production in the region various agrochemicals are used in farming and these serve as a ready source of toxic chemicals which could easily be washed into aquifers in the area. Other potential sources of pollution to groundwater in the area are the dumping of domestic waste from households and indiscriminate disposal of sewage. The main aim of this study was to assess the quality of groundwater in the Sawla-Tuna-Kalba district to contribute to the sustainable utilization of the resource. Specifically, the study sought to assess the physico-chemical quality of groundwater to ascertain its wholesomeness for domestic use. Additionally, the suitability of groundwater for agricultural purposes was assessed to inform policy makers of its potential to enhance and promote all year round farming. Groundwater samples were collected from 129 boreholes and analysed using standard methods. The suitability of groundwater for agriculture was determined by calculating the sodium adsorption ratio of water in each sampled borehole.

METHODOLOGY

Study area: The Sawla-Tuna-Kalba district is located in the sahelian region of northern Ghana between latitudes 9º15′ N and 9º52′ N and longitudes 1º46′ W and 2º47′ W. The topography of the area is generally undulating with elevations ranging between 245-350 m above mean sea level. The Black Volta River drains the area through several tributaries such as the Gbongbon, Mole, Dagbu and Kongpe streams. The area falls within the Tropical Continental or Interior Savannah climatic zone (Dickson and Benneh, 2004). It experiences a single rainfall season from May to October, with the highest rains occurring in August. Annual rainfall ranges between 1005-1150 mm. The average daily temperature exceeds 35ºC. Relative humidity is high during the rainy season (65-85%) but may fall to as low as 20% during the dry season.

The district is underlain primarily by granitic rocks, which constitute over 80% of the basement rocks (Fig. 1). Lower Birrimian rocks made up of phyllite, schist, tuff

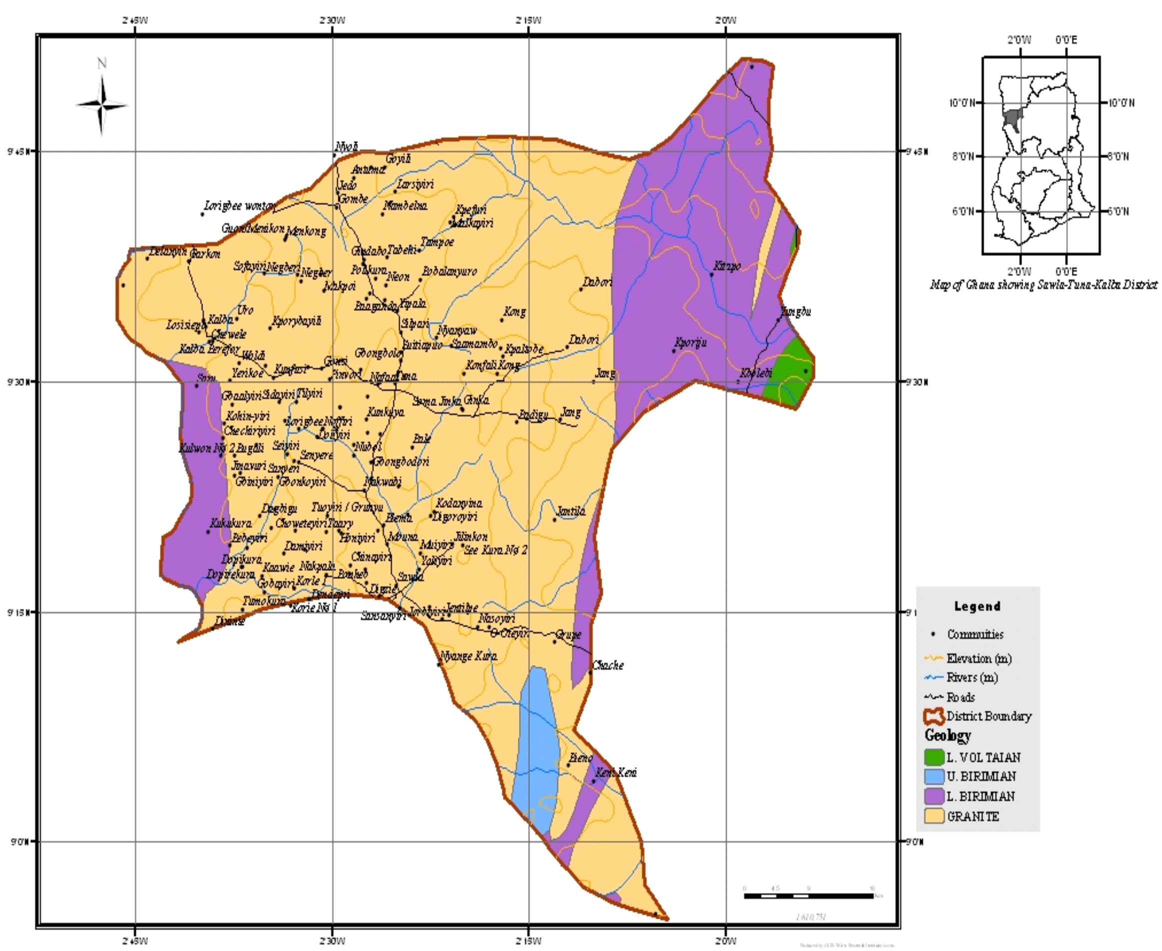

Fig. 1: Borehole location with respect to geology of the Sawla-Tuna-Kalba district

and greywacke occur in the southwest and the northeast whilst Upper Birimian rocks comprising metamorphosed lavas and pyroclastic rocks underlie the south-eastern portion of the area. Basal sandstone of the Lower Voltaian System also underlies the extreme northeast section of the district. The basement rocks have very little intergranular pore space and are thus characterised by negligible primary porosity and permeability. Where the rocks occur near the surface, they are usually fractured and weathered and acquire considerable secondary porosity within the regolith. They may also contain openings along joints and fissures, bedding and cleavage planes. When these openings are extensive, continues and/or interconnected, and are not filled with impervious material, percolation of considerable water might occur to form groundwater reservoirs (Darko *et al*., 2006). Figure 1 shows the locations of boreholes in the respective geological units which were sampled for the study.

Borehole depth and groundwater occurrence: The depth of boreholes in the district ranges from 24.0-81.0 m with an average depth of 43.8 m. The borehole yield ranged from 4.0 to 600 L/min (Darko *et al*., 2006). The main sources of groundwater to the granitic and metamorphosed rocks are the weathered layer or regolith developed on the rocks and fractures within the bedrock (Gill, 1969). Groundwater is abstracted through shallow wells located in the fractures or fracture zones with saturated regolith rather than from extensive aquifers.

Water sampling and analysis: Most of the sampled boreholes are located in the predominantly granitic formation in the district. Water samples were collected for the analysis of major ions and trace metals and spatially mapped so as to determine boreholes with elevated concentrations. The sampling and analytical procedures followed the Standard Methods for the Examination of Water and Wastewater (American Public Health Authority, 1998) and the Global Environmental Monitoring Systems/Water Operational Guide (WHO/UNEP/UNESCO/WMO, 1998). Samples for major ions were collected into clean 1 L polyethylene bottles and that for trace metal analyses, into 12 mL polyethylene bottles. Samples for trace metal analysis were acidified (pH<2) with 0.5 mL concentrated nitric acid. *In situ* measurements of pH and conductivity were done using an Eijkelkamp water quality field kit. Samples were stored in ice-chests and transported to the CSIR-Water Research Institute laboratory in Tamale for analysis. Those for trace metal analysis were sent to the CSIR Water Research Laboratory in Accra for analysis. Visual comparison and turbidimeter were used to determine colour and turbidity respectively. Silica, fluoride, orthophosphate, nitrate-nitrogen and sulphate contents were analysed using the molybdosilicate, SPADNS, stannous chloride, hydrazine reduction and turbidimetric methods, respectively. A flame photometer (Jenway model PFP 7) was used to determine sodium and potassium while EDTA titration was used for calcium and total hardness. Chloride contents were determined by argentometric titration and total alkalinity by strong acid titration. Calcium and magnesium hardness, on the other hand, were determined by calculation. The trace metals Fe, Mn, and Pb were determined using a Unicam 696 Atomic Absorption Spectrophotometer (AAS); arsenic was however determined using an arsenator.

The ionic dominance was calculated by converting the concentrations (mg/L) of the major ions in meq/L by the equation:

$$\text{meq/L} = \text{(Concentration in mg/L)/ (Atomic weight of ionic species)/ (number of charges)} \quad (1)$$

Percent sodium was calculated with the formula:

$$\%\,Na = [(Na^{+}\times 100)/(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})] \times 100 \quad (2)$$

where the quantities of Ca^{2+}, Mg^{2+}, Na^{+} and Mg^{+} all expressed in meq/L.

The Sodium Adsorption Ratio (SAR) of groundwater in the study area was calculated using the equation:

$$\text{SAR} = \left[Na^{+}\right] / \sqrt{\frac{1}{2}\left(\left[ca^{2+}\right] + \left[Mg^{2+}\right]\right)} \quad (3)$$

where concentrations of Na^{+}, Ca^{2+} & Mg^{+} are all in meq/L.

Statistical analysis was performed using SPSS 10.1 software. One half of the values of the detection limit of the various parameters was substituted for values below the limit of detection and used in the statistical analysis. Water quality data from laboratory analysis were subjected to normality tests by fitting them with Normal and Lognormal distributions, on the premise that the observations were independent and identically distributed over the area and sampling period. Quality assurance was applied to analytical results by applying anion-cation balance. The Spearman's rank correlation was used to examine correlation between selected parameters; all tests were two-tailed.

RESULTS AND DISCUSSION

The physico-chemical characteristics of groundwater from 129 boreholes in the Sawla-Tuna-Kalba district (STK) are presented in Table 1-6. The physical observations of the samples indicated that they are

Table 1: Physico-chemical characteristics of groundwater in the STK district (mg/L).

Parameter	Range	Mean	SD	WHO limit (2004)
(n = 129)				
Conductivity (μS/cm)	84.8-1486	454	1.84	-
pH (pH unit)	6.09-9.81	7.23	0.69	6.5-8.5
Turbidity (NTU)	0.10-56.0	2.75	8.27	15
T/Alkalinity	50.0-422	197	76.7	-
Calcium	8.0-131	34.7	1.71	200
Magnesium	3.4-94.2	22.3	13.6	150
Sodium	6.3-93.1	30.1	18.3	200
Potassium	0.4-12.4	4.5	2.29	30
Bicarbonate	61.0-515	239	93.5	-
Sulphate	1.6-246	14.6	2.65	400
Chloride	3.0-131	18.2	2.21	250
Nitrate-N	0.01-7.01	0.95	1.57	10
Phosphate-P	<0.001-0.51	0 0.058	0.080	-
Fluoride	0.01-2.90	0.7	0.46	1.5
T/hardness	54.0-642	178	88.2	500
Total Dissolved Solids (TDS)	42.3-740	233	149	1000
Total iron	0.01-2.79	0.21	0.45	0.3
Manganese	0.01-1.05	0.13	0.17	0.5
Lead	0.01-0.05	0.009	0.008	0.01
Arsenic	<0.01-0.03	0.002	0.004	0.01
% Na	5.27-60.90	26.2	10.77	-
SAR	0.18-3.61	1.00	0.61	-

Units are in mg/L unless otherwise stated

odourless and colourless in nature. The pH of groundwater in the district varied from 6.1 to 9.8. pH was generally within WHO recommended limit of 6.5-8.5 for potable water (WHO, 2004). A few samples, however, recorded slightly acidic as well as alkaline conditions. Spatially, borehole water from Nyoli (6.10), Gombe (6.2), Nakpala (6.3), Nasoyiri (6.4) and Baaganda (6.48) were slightly acidic, whiles Daniwur BH2 (8.6), Soma Jink (8.8), Gbongbolo (9.1), Dopikura BH2 (9.1) and Kpongeri 2 (9.8) were slightly alkaline. Boreholes with low pH levels have a potential to enhance corrosion of pump parts but may not affect its use for domestic purposes. Slightly acidic groundwater may also enhance the dissolution of trace elements while high pH levels may facilitate the leaching of others such as Mo into the water (Brady, 1984). Low pH values may be as a result of the production of CO_2 from microbial respiration, which leads to the lowing of pH of the water (Pelig-Ba *et al*., 1991). Electrical conductivity ranged from 84.8 to 1486 μS/cm and Total Dissolved Solids (TDS) from 42.3 to 740 mg/L. The lowest conductivity was recorded at Nahar-Jissi (84.8 μS/cm) and the highest at Tuna (1486 μS/cm). Generally groundwater in the district have low conductivities implying low mineralization and may be termed as fresh since TDS concentrations were generally lower than 1000 mg/L (WHO, 2004; WHO, 1993; Freeze and Cherry, 1979). High TDS in water may produce bad taste, odour and colour and may also induce unfavourable physiological reactions in the consumer (Spellman and Drinan, 2000). Groundwater with low conductivities is suitable for irrigation.

Table 2: Classification of water based on total hardness

Total hardness as CaCO3, mg/L	Water class	Number of samples
0-75	Soft	9 (7%)
75-150	Moderately hard	37 (29%)
150-300	Hard	73 (57%)
>300	Very hard	10 (7%)

Table 3: Classification of water samples based on sodium percent

Sodium (%)	Water class	Number of samples	Remarks
<20 (5.27-19.70)	Excellent	37	Range
20-40 (20.13-39.77)	Good	78	Range
40-60 (40.14-53.80)	Permissible	14	Range
60-80	Doubtful	1	Value was 60.90
>80	Unsuitable	0	

Table 4: Classification of water samples based on USSL sodium hazard for irrigation purposes

Sodium hazard class	SAR in equivalent per mole	Water class	Number of samples
S1	<10	Excellent	129
S2	10-18	Good	0
S3	18-26	Doubtful	0
S4 & S6	>26	Unsuitable	0

Table 5: Classification of water samples based on salinity hazard

Sodium hazard class	EC in (μs/cm)	Water class	Number of samples
C1	<250	Excellent	29
C2	250-750	Good	91
C3	750-2250	Doubtful	9
C4 & C5	>2250	Unsuitable	0

Water is termed to be soft, moderately hard, hard or very hard if total hardness ranges from 0-75, 75-150, 150-300 and >300 mg/L respectively (Lester and Birkett,

Table 6: Correlation coefficients for the analysed physico-chemical parameters

	Cond	pH	Ca	Mg	Na	Alk	HCO_3	SO4	Cl	NO_3-N	PO_4-P	F-	T/Iron	Mn	Pb	TDS	T/hard
Cond	1.000	0.481	0.706	0.544	0.677	0.824	0.826	0.448	0.488	0.030	-0.589	0.618	0.269	0.506	0.325	0.944	0.121
pH			0.241	0.265	0.569	0.586	0.567	0.001	-0.041	-0.199	-0.456	0.574	0.563	0.302	0.376	0.589	0.048
Ca				0.280	0.420	0.578	0.593	0.376	0.401	-0.067	-0.437	0.380	0.131	0.288	0.312	0.743	0.110
Mg					0.230	0.643	0.637	0.221	0.172	-0.049	-0.315	0.282	0.103	0.287	0.322	0.621	0.124
Na						0.703	0.700	0.233	0.265	-0.065	-0.495	0.689	0.474	0.361	0.283	0.606	0.043
Alk							0.997	0.176	0.195	-0.139	-0.578	0.599	0.332	0.393	0.483	0.810	0.047
HCO_3								0.182	0.208	-0.138	-0.585	0.598	0.326	0.392	0.483	0.810	0.047
SO_4									0.462	0.373	-0.083	0.312	-0.017	0.318	0.329	0.492	0.072
Cl										0.415	-0.236	0.126	0.015	0.275	-0.207	0.504	0.170
NO_3-N											0.270	-0.136	-0.120	0.101	-0.222	0.087	0.012
PO_4-P												-0.402	-0.284	-0.240	-0.186	-0.556	-0.161
F^-													0.342	0.408	0.308	0.616	0.038
T/Iron														0.208	0.100	0.313	0.201
Mn															0.347	0.594	0.013
Pb																0.325	0.325
TDS																	0.218
T/hard																	

BOLD: Correlation is significant at the 0.01 level

1999). Approximately 57% of borehole water analysed recorded total hardness levels between 151 to 300 mg/L (Table 2); groundwater in the Sawla-Tuna-Kalba district could thus be classified as hard. Excess hardness is undesirable for aesthetic and economic reasons (Raghunath, 1987). Mean total hardness and alkalinity concentrations were 178 and 197 mg/L, respectively. This suggests that hardness of water is derived mainly from carbonate sources since the mean total alkalinity was slightly higher than that of total hardness. Groundwater with alkalinities higher than total hardness is mainly derived from carbonate sources. According to WHO (2004), a number of ecological and epidemiological studies have shown a significant inverse relationship between hardness of drinking water and cardiovascular diseases.

Effects of major ions on health and agriculture: Major ions determined during the study are Mg^{2+}, Na^+, Ca^{2+}, K^+, HCO_3^-, Cl^- and SO_4^{2-}. From Table 1, the concentrations of major ions in borehole water were generally low and well below WHO recommended limit for potability, except HCO_3^- (whose guideline is not available). The presence of these ions in drinking water may not generally have harmful effects on humans; they may, however, present physiological or aesthetic problems to consumers. High Na^+ and Cl^- levels above WHO recommended guideline limits of 200 and 250 mg/L, respectively, would impart delectable taste to water (WHO, 2004) while high SO_4^{2-} contents above 400 mg/L could have laxative effects in some people. Acute ingestion of doses of K^+ greater than 2.0 meq/kg body weight by people with normal kidney function could also, overwhelm homeostatic mechanisms and possibly cause death (Buckley *et al*., 1995). The major ions therefore suggest that groundwater quality in the STK district is good and suitable for drinking and domestic purposes.

The suitability of groundwater for agricultural irrigation was assessed using the Sodium Adsorption Ratio (SAR). SAR is important to plant growth because its magnitude is an indication of the availability of soil pore water to plant roots (Weiner, 2000). The higher the SAR, the less suitable the water for irrigation. Irrigation water with excess sodium can affect soil structure, soil aeration, flow rate, permeability, infiltration etc. The SAR calculated for all groundwater samples in the district ranged from 0.18-3.61 with a mean of 1.00±0.61 (Table 1). According to Richards (1954) classification based on SAR values, all samples belong to the excellent category (Table 4) implying that groundwater in the district could be harnessed for irrigation. This is true provided essential nutrients like nitrogen and available phosphorus are not limiting in soils in the district. The analytical data plotted on the US salinity diagram (Richards, 1954) illustrates that majority of the groundwater samples fall in the field of C2S1, indicating medium salinity and low sodium water, which can be used for irrigation on all types of soils without danger of exchangeable sodium (Fig. 2). The Wilcox (1955) diagram relating sodium percent (Table 4) and electrical conductivity (Table 5) shows that about 93% of the groundwater samples fall in the field of excellent to good and 7% in the field of good to permissible for irrigation (Fig. 3).

The dominant cation and anion in borehole water in the district were Mg^{2+} and HCO_3^- respectively. The ionic dominance for water bodies according to Stumm and Morgan (1981) is Ca>Mg>Na>K and HCO_3>SO_4>Cl for fresh waters. Generally, the ionic dominance pattern recorded for the Sawla-Tuna-Kalba district was Mg>Na>Ca>K: HCO_3>Cl>SO_4, which was close to that of fresh waters. Correlation between selected parameters revealed expected chemical relationships (Table 6), such as that between conductivity and TDS (r^2 = 0.944, $p<0.01$)alkalinity and HCO_3 (r^2 = 0.997, $p<0.01$), alkalinity and conductivity (r^2 = 0.824, $p<0.01$), conductivity and bicarbonate (r^2 = 0.826, $p<0.01$), TDS and Ca (r^2 = 0.743, $p<0.01$), Na and bicarbonate (r^2 = 0.700, $p<0.01$) and Mg and bicarbonate (r^2 = 0.637,

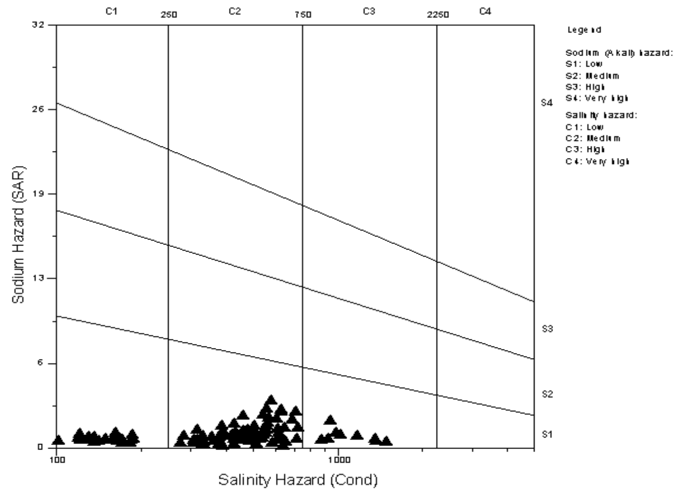

Fig. 2: US salinity diagram of groundwater in STK

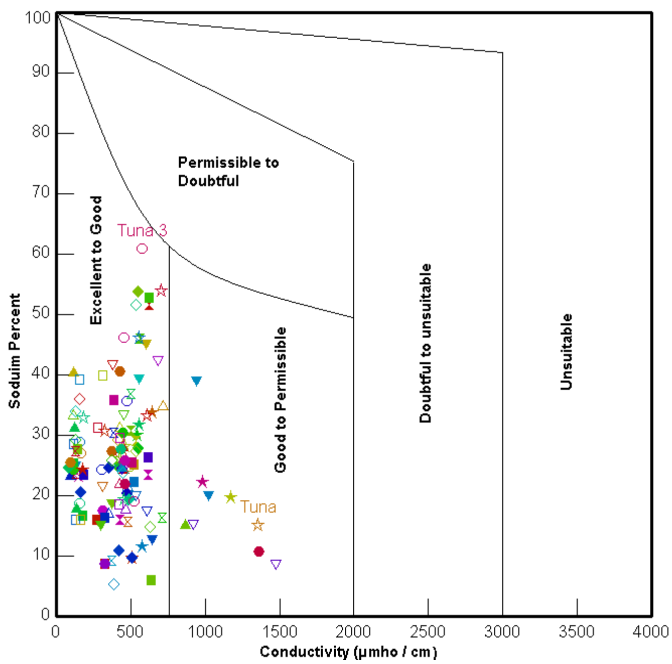

Fig. 3: The quality of water in relation to percent sodium and electrical conductivity (Wilcox diagram)

p<0.01). There was a moderately positive correlation between F^- and Na ($r^2 = 0.689$, $p<0.01$), implying that they were from the same source.

Data for major ions in borehole water in the STK district are plotted on a Piper trilinear (Piper, 1994) diagram (Fig. 4) which is used for the determination of the hydrochemical nature of groundwater based on the dissolved major ions. It is evident from the results that groundwater in the study area falls in the Ca-Mg-HCO_3 hydrochemical facies. This compares well with work done by Apambire *et al*. (1997) in other parts of northern Ghana.

Fluoride ions in groundwater are mainly from natural sources and sometimes from the use of phosphate fertilizers (which contain 4% fluorine) (WHO, 2004). During the study fluoride ion concentration ranged from 0.1 to 2.9 mg/L with a mean of 0.7 mg/L. Fluoride levels were generally low, with the exception of Kalba Berefor BH4 (2.9 mg/L), Kalba Berefor BH3 (2.3 mg/L), Goyili BH3 (2.2 mg/L), Yilenteyiri (1.9 mg/L) and Gbongbolo (1.6 mg/L), which were all above the recommended WHO guideline value of 1.5 mg/L. Fluoride in drinking water is important for health, in that it prevents tooth decay. However, high levels may lead to dental fluorosis. At

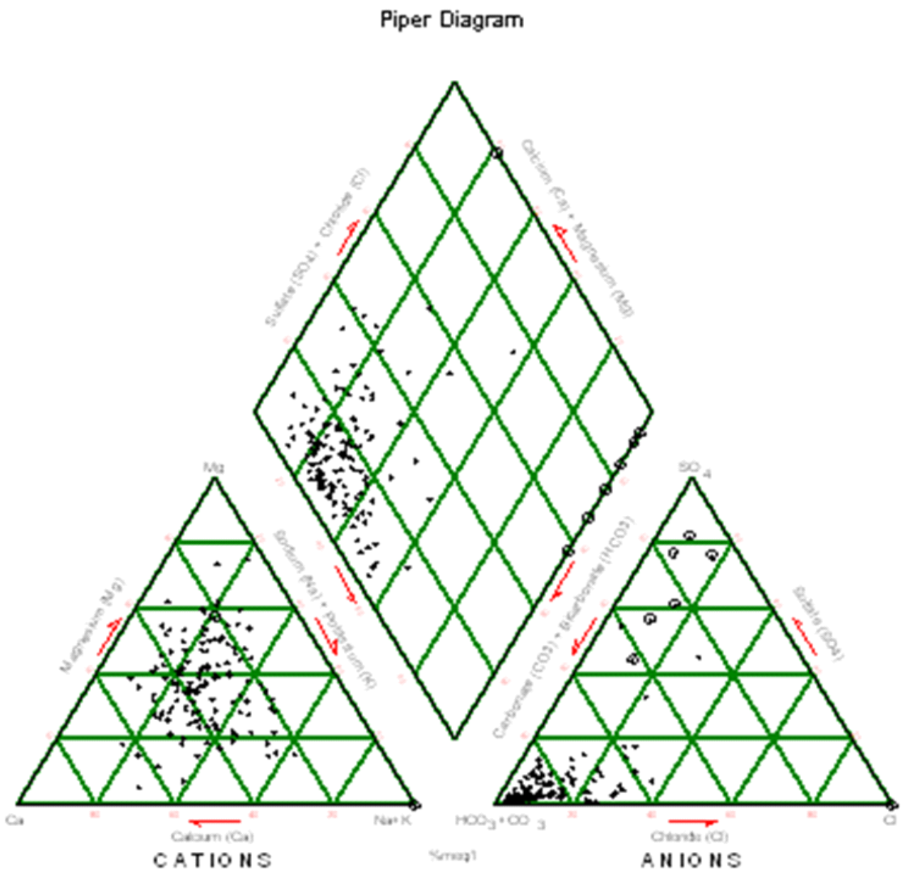

Fig. 4: Piper trilinear diagram showing chemical character of groundwater

elevated levels it may increase the rise of skeletal fluorosis. At higher concentrations fluoride is known to be poisonous and perhaps carcinogenic (Baird, 1999). The presence of fluoride in borehole water at these locations in the district give cause for concern, especially given that high fluoride have been recorded in groundwater from some other areas in the region in previous studies (Apambire *et al*., 1997; Dey *et al*., 2004). Even though fluoride may possibly be derived from weathering of fluorapatite [$Ca_5(PO_4)_3F$] in rock formations of the area, it is still not clear what mineral or substance do actually host fluoride in different geological rock units in northern Ghana.

Nutrients: High levels of nitrate in drinking water may cause methemoglobinemia in newborn infants under four years, as well as in adults with particular enzyme deficiency (Baird, 1999). Nitrate-N levels recorded in groundwater in the district ranged from 0.01 to 7.0 mg/L with a mean of 0.95 mg/L. All samples collected recorded nitrate-nitrogen levels below the WHO recommended limit of 10 mg/L. This suggests, no immediate threat to the health of infants in the community, from to nitrate-N pollution. Phosphate ion concentration also ranged from 0.001 to 0.510 mg/L with a mean of 0.010 mg/L. The source of anthropogenic phosphorus is sewage, detergents, agricultural effluents and fertilizers (Sinha *et al*., 2000).

Trace metals: Total iron concentration in the STK district ranged from 0.01 to 2.8 mg/L with a mean of 0.07 mg/L. The prevalence of iron levels above 0.3 mg/L was noticeable in few places within the district. About 11% of boreholes had iron levels above the WHO recommended guideline (0.3 mg/L). The presence of high iron levels in these boreholes could be as a result of chemical weathering of the host granitic and metamorphosed rocks, which could have resulted in the dissolution of iron that ultimately, percolate through the overburden to enrich the groundwater in storage (Darko *et al*., 2006). Rusty pump parts could also be a possible source of iron in borehole water. Turbidity, taste, discolouration, deposits and growth of iron-bacteria in pump parts could be widespread in boreholes with high iron concentration. Manganese concentration ranged from 0.01 to 1.05 mg/L. Generally, borehole water registered low Mn concentrations in the district, which confirms work done by Smedley *et al*. (1995) in parts of the country. However, Kunfusi (0.80 mg/L) and Jilinkon (1.05 mg/L) recorded high Mn concentrations above the provisional WHO guideline limit of 0.5 mg/L. Areas with high Mn might experience taste and discolouration problems and deposits in pumps and pipes. In large doses, Mn may cause headaches, apathy, irritability, insomnia and weakness of legs. Long term heavy exposure may result in a nervous system disorder. Boreholes with high Mn need to be investigated further.

Lead (Pb) is a cumulative poison, meaning that it remains in the body following exposure. Lead content ranged from <0.005 to 0.051 mg/L. Approximately 17.4% of boreholes in the district recorded slightly high lead concentrations above the WHO recommended guideline of 0.01 mg/L. These boreholes include Bebeyiri BH3 (0.015 mg/L), Dininie BH2 (0.020 mg/L) Gobayiri (0.026 mg/L) and Tachirikrom (0.051 mg/L). Thus there is the need for regular monitoring of these boreholes. Minor symptoms of lead poisoning include abdominal pains, decreased appetite, constipation, fatigue and decreased physical fitness. High concentrations in drinking water may lead to damage of the brain, red blood cells, nerves and kidneys. High Pb concentration may affect protein synthesis (Pelig-Ba *et al*., 2004).

Arsenic levels ranged from 0.001 to 0.033 mg/L with a mean of 0.001 mg/L. Only one borehole in Kunfunsi (0.033 mg/L) registered a value slightly above the WHO limit of 0.01 mg/L. In all, 87.7% of boreholes sampled registered as concentration below the detection limit (0.001 mg/L). About 7% of boreholes recorded as levels above the detection limit but lower than the WHO recommended guideline limit for drinking water. This compares well with work done by (Fianko *et al*., 2010; Kortatsi *et al*., 2008) in other parts of Ghana. Arsenic in groundwater may be mainly from mine pollution, application of fertilizers and pesticides and natural oxidation of sulphide minerals, predominantly arsenopyrite (FeAsS) (Smedley *et al*., 1996). Exposure to as in drinking water at high concentrations poses serious health effects as it is a known human carcinogen. Long term exposure is associated with increased risk of cancer in the skin, bladder and kidney. It also leads to skin related problems such as hyperkeratosis and changes in pigmentation (Serfor-Armah *et al*., 2006). It has also been reported to affect the vascular system in humans and has been associated with development of diabetes. The borehole which recorded high as has to be monitored regularly.

CONCLUSION

Interpretation of hydrochemical analysis reveals that groundwater in the study area is fresh and hard. Groundwater in the district was found to fall into the Ca-Mg-HCO_3 type of hydrochemical facies and was excellent for agricultural purposes due to low SAR values 0.18-3.61(1.00±0.61) recorded. Analytical data plot on the US salinity diagram also illustrated that majority of groundwater samples fall in the field of C2S1; indicating medium salinity and low sodium water. Though majority of the boreholes were chemically suitable for drinking, elevated concentrations of fluoride as well as lead in some was a major cause for concern. Since the population depends entirely on borehole water for most parts of the year, periodic monitoring of groundwater quality in order to isolate and possibly advise on discontinuation, or better still "capping" of boreholes with high levels of contaminant fluoride and lead may have to be urgently pursued in order not to compromise the socio-economic and health status of the many water users. Such groundwater quality monitoring could, in addition, provide invaluable data that could be used in water management strategies throughout the sahelian region.

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