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Environmental Stable Isotope Studies of Groundwater in the Accra Plains

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ABSTRACT

The environmental stable isotopic (oxygen-18 and hydrogen-2) composition of groundwater in the crystalline geological formation underlying the Accra Plains of South-east Ghana were studied to obtain information on the recharge process. The groundwater had an average isotopic value of –3.19‰ $\delta^{18}O$ and –14.36‰ $\delta^{2}H$. The groundwater recharge takes place in fractures with the occurrence of minor evaporation. The groundwater was also affected by the mixing of various rainfall events and or surface runoff. The groundwaters at Valley View University were more depleted than the other groundwaters in the Plains indicating that the groundwater was recharge at the Akwapim Togo Mountains through preferential channels.

Introduction

The geological formation surrounding a radioactive waste repository is intended to act as a natural barrier to retard the migration of radionuclides away from the repository. The geochemical suitability of the geological formation as a host rock is determined by the composition of the geomatrix and groundwater. Groundwater is the critical dissolving, mobilizing and transport medium of radionuclides contained in the disposed waste to the biosphere by natural processes (fig.1). The groundwater composition will affect the stability of the disposal system, degradation of the engineered barriers and control the solubility of the waste form. The groundwater flow will transport reactive groundwater components into the repository. The groundwater flow will also govern the release and transport of radionuclides from the near field of the repository. The flow of groundwater occurs along discrete fractures. Not only are the integrated flows at different depths important, but also the flow paths, the dispersion of flow, and the existence of an accessible system of microfractures. Assessment of the hydrogeochemical conditions requires information about the composition, origin and age of the groundwater within the geological formation.

The groundwaters may have various origins. They can be inherited from ancient marine transgressions, produced by sediment compaction or pressure dehydration of hydrated salts, or can be old waters of meteoric origin corresponding to conditions of recharge and circulation which are no longer prevailing. The limitations in the use of classical and conventional tools for actual field studies of low permeability rocks represent the basic reason for extensive use of environmental isotopes hydrogeochemical investigations.

The usefulness of environmental isotopes as isotopic tools relies on the fact that mass (energy) differences cause slight variations in the geochemical and physical behavior. Reaction rates and equilibrium constants differ for isotopic compounds which result in isotope fractionation effects. The environmental isotopes of hydrogen and oxygen are very suitable tools for hydrogeological investigations because

- They are part of the water molecules and follow their behavior through hydrological cycles and
- They are conservative (except for radioactive decay of ^{3}H) in low-temperature and low-circulation systems, as long as the relative amount of water involved in chemical reactions remains limited.

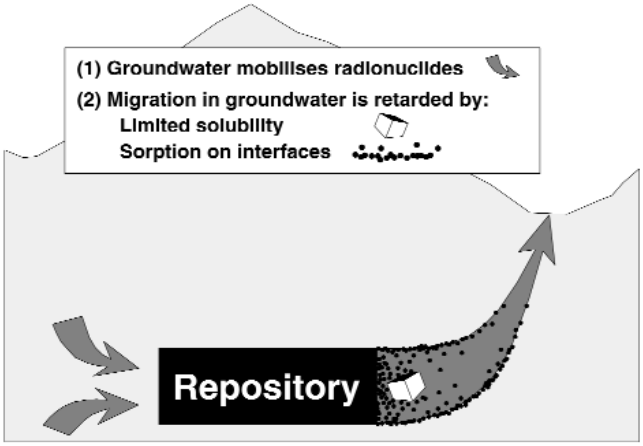

Fig. 1 Geological repository showing the main geochemical processes concerning radionuclide mobilization and retardation (Hummel, W, 2005)

The stable isotopes (deuterium and oxygen-18) thus play an important role in the study of groundwater. They can be used to trace the origin of water, the mode of recharge, determination of relative age (as old waters can be distinguished from present day recharged waters) and therefore recharge in a qualitative sense. This is essential information for the definition of hydrogeological systems. Therefore, stable isotope analyses are an integral part of all hydrogeological studies in the siting of a radioactive waste repository.

As water moves into the ground it begins to record information on the history of its recharge source and properties, mainly from rainfall solutes as well as isotopic ratios in the water molecule. For most groundwater in the "normal" temperature range, there are no modifications of their ^{2}H and ^{18}O content due to interactions between the aqueous phase and solid minerals (geochemical behaviour), unless isotopic exchange with different oxygen and hydrogen bearing minerals or

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compounds in the subsurface modifies their concentrations either during very long residence times or by geochemical reactions at elevated temperatures (Fontes, 1980; Gat, 1981, IAEA, 1981). These changes result in isotopic fractionation to give isotopic fingerprints due to different physicochemical, biochemical kinetic and thermodynamic effects and can be used to estimate recharge areas and mixing fractions between aquifers and between surface water and groundwater, as well as to provide a window into past changes in recharge or climatic condition during the recharge processes (Tyler et al. 2000).

Worldwide analyses of precipitation have established that a relation exists between δD and δ ^{18}O, known as the global meteoric water line (GMWL),) defined by the relationship δD = 8 δ^{18}O + 10 ‰ (Craig, 1961).

A crucial parameter for the discussion of the origin of a given water is the deuterium excess (Dansgaard, 1964), which is defined as d (per mil) = δ^2H - 8 δ^{18}O. The d-value is a reflection of the origin and history of a vapour mass. Values of d are generally close to 10 °/oo in present day oceanic precipitation (Craig, 1961; Yurtsever and Gat, 1981) and, depending on the slope, are obviously much lower for evaporated waters. Since in any given area meteorological regimes are not subject to major ultra-annual fluctuations, this value remains rather constant in the average annual precipitations at a given location. These are essential information for the definition of hydrogeological system in the characterization of a site for repository development.

Crystalline rocks such as granites and gneiss have been considered as suitable host rocks of radioactive waste repository. As a result, many of hydrogeochemical investigations in crystalline rocks are been carried out to determine their suitability as host rocks for repositories.

In this study, environmental stable isotopes (oxygen-18 and hydrogen-2) were used to evaluate the hydrogeological characteristics of the aquifer systems of the crystalline basement rocks setting of the Accra Plains.

Study Area

The Accra Plains is located in the south eastern part of Ghana between latitude 5^o 30’ and 6^o 15’ North of the equator and longitude 0^o 20’ west and 0^o 40’ east of the Greenwich meridian (Fig.2). It covers approximately 7000 km^2. The area is bounded on the west and the northwest by the Akwapim Mountains and in the north to the east by the Volta River. It is bounded on the south by the Gulf of Guinea.

The Plains falls in the rainfall shadows of the Akwapim mountains and has equatorial climate characterised by two rainfall seasons of unequal intensities. The period May to July represents the main rainy season with torrential rainfall which attains a mean monthly rainfall of over 200 mm with the peak occurring in June. September and October has minor rains with a mean montly rainfall of about 66 mm with the peak in October. A dry season from November to April during which period the mean monthly rainfall is about 30 mm per month. The mean annual rainfall is 800 mm (Akiti, 1981).

The mean annual temperature is about 26 ^{o}C . The higest mean monthly temperature of about 32 ^{o}C occurs between March and April and the lowest of about 23^{o}C in August (Darko et al 1995).

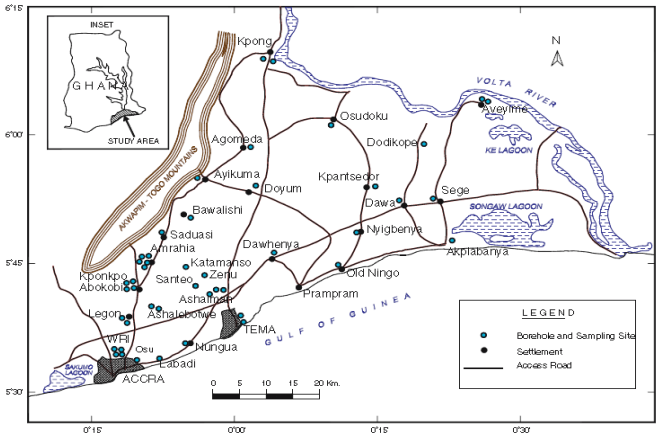

Fig. 2: Location map of the Accra Plains

Crystalline basement rocks dominate the hydrogeological setting of the Accra Plains. These rocks are considered to be very old crystalline metamorphic and intrusive rocks and considered to be Archean in age (Hirdes and Davis, 2002). They are separated into four alternate belts of mafic and felsic components and consists of ortho- and para gneisses, schists and migmatities many of which are rich in garnet, hornblende and biotites (Akiti, 1986). All the four belts trend in a south-southwest to north-northeast direction from the coastal plains and enter the Republic of Togo (fig. 3)

The mafic Dahomeyan gneisses are also subdivided into two groups- the metabasics and the basic intrusive. The Plain is remarkably flat, forming a low-lying area broken by isolated inselbergs, Shai, Osudoku and Krobo Hills which rise 100 m above mean sea level. Other geological units in the Plain include the Togo series, the Accraian series, the Tertiary and Recent sediments. The Togo series occurs mainly to the north western part of the Plain and consist mainly of quartzites and phyllites. Sandstones, shales, schists and silicified limestones are other rock types of the Togo series and as outliers in the Plain. The Accraian series consisting of sandstones, grits and shales are found near Accra. The Tertiary and recent sediment occur in the south eastern part of the Plain near the estuary of the Volta River.

The rocks are inherently impermeable and groundwater occurrence in the geologic formation is controlled mainly by the development of secondary porosity e.g. fractures, faults, joints and the associated weathered zone (Akiti, 1986).

The Plain has no perennial river with the exception of the Volta River which forms the northern and eastern borders of the Plain. A distinct hydrologic feature of the Plain is the east-west watershed which divides the Plain into north and south drainage systems. Streams in the north sub basin (Okwe and Danwhe) have their source from the Akwapim Mountain, flow north eastwards and drain into the Volta River. Streams in the south (Mamahuma, Dechidaw and Onyasia) have their sources from the Akwapim Mountains. They drain southwards into the sea.

Within the plains, groundwater potential is relatively high at the foothills of the Akwapim Mountains. Recharge to the aquifer is by direct percolation of rainfall along the Akwapim Mountains (Akiti 1986). Minor or indirect recharge also occurs mainly in the rainy season when fractures or mega joints intercept the ephemeral stream courses (Kortatsi, 2006). These channels act as conduits that allow water to recharge the aquifer. Recharge of the groundwater system is estimated as 15% of the annual precipitation. Boreholes drilled in the Plains at average depth of 55 m have a mean yield value of 2.7m^3/h.

Transmissivity values are generally low due to the clayey content of the regolith (Kortatsi, 2006). They vary from 0.2m^2/h in the clayey regolith to 4.5 m^2/d in the (Darko, 2001).

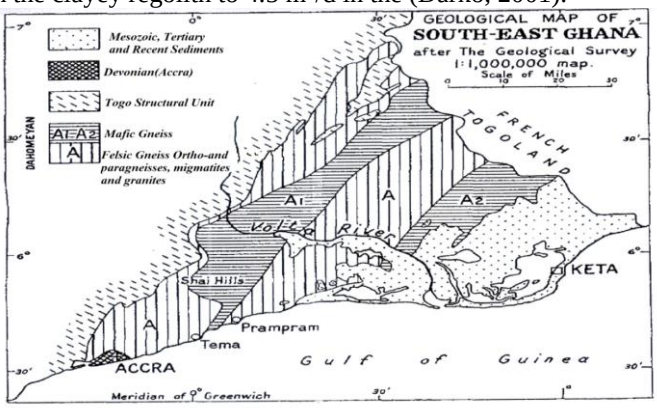

Fig.3 Geological map of the Accra Plains

Sampling and Analysis

A total of fifty-seven (57) groundwater samples were collected from various boreholes. The depths of the boreholes vary from 40-80m deep. The groundwater samples were collected in 100 ml pre conditioned high density polyethylene bottles. They were conditioned by washing initially with nitric acid and then rinsed several times with distilled water. It was to ensure that the bottles were free of contamination. Unfiltered groundwater samples were collected after about fifteen (15) minutes of pumping. This was to purge the borehole of stagnant waters. Electrical conductivity (EC), total dissolved solids (TDS) and pH measurements were carried out *in situ* using a Hach potable EC and pH meters. The samples were transported to the laboratory in an ice chest maintained at 4 ^oC with ice cubes. In the laboratory 50 ml of the groundwater samples were transferred into clean dry 50 ml glass vials and sealed with bromobutyl synthetic rubber stopper further protected by aluminum cap using hand held crimping tool to prevent evaporation that can alter $^{18}O/^{16}O$ and $^2H/^1H$ ratios. The samples were analyzed for stable isotopes concentrations (^{18}O, ^2H) at the Isotope Geochemical laboratory of the Institute of Environmental Geology and Geoengineering (IGAG), Rome. The chloride concentrations were determined using ion chromatography.

Oxygen isotopic ratios were determined using a modified version of Epstein and Mayeda (1953) technique (Krishnamurthy, 1984). Water sample (2 ml) was equilibrated with a fixed amount (28 ml at 86 mm Hg) of purified tank CO_2 in a glass bottle (8 ml) at 25 ^oC ± 1 ^oC in a shaking equilibration bath for a period of 24 h. The CO_2 gas were then extracted and cryogenically purified in a vacuum line. The isotopic ratios were determined using a mass-spectrometer with analytical reproducibility (determined by repeated analyses of the laboratory standard) of 0.2‰.

δD (deuterium or δ^2H) was determined by quantitatively converting the water to hydrogen gas by reaction with zinc at 500 ^oC in individual reaction tubes (Coleman et al., 1982), and the hydrogen was then isotopically analysed using a mass spectrometer. The analytical reproducibility of isotopic measurements was ± 0.1‰.

Both $\delta^{18}O$ and δ^2H values were determined relative to internal standards that were calibrated using Vienna-Standard Mean Ocean Water (V-SMOW).

$\delta(‰) = (R_{sample} - RV_{SMOW})/RV_{SMOW}$ x1000

where R_{sample} is the mass ratio of the stable isotope and R_{VSMOW} is the value for the Vienna Standard Mean Ocean Water.

Results and Discussion

The $\delta^{18}O$ and δ^2H values of the groundwater samples from summarized in Table 1. The $\delta^{18}O$ isotope composition of the groundwater range from -4.53‰ vs V-SMOW at Valley View University (VV1) located at Oyibi to -1.72‰ vs V-SMOW at Bawaleshie. The mean $\delta^{18}O$ isotopic groundwater composition is -3.19‰ vs V-SMOW. The δ^2H isotope composition of the groundwater range from -23.5‰ vs V-SMOW at Valley View University (VV3) located at Oyibi to -7.5 ‰ vs V-SMOW at Oyarifa. The mean δ^2H isotopic groundwater composition is -14.36‰ vs V-SMOW. The groundwater samples collected along the foothill of the Akwapim Togo Mountain were relatively more negative than those from the central and coastal parts of the Accra Plains. It may be due to the higher rain value observed along the foothill of the Akwapim Togo Mountain where the elevation is higher. Mountains are characterized by isotopically more depleted precipitation with increasing elevation due to the cooling of the air mass when it is forced to ascend (''altitude effect''). Sites that are more distant from the coast also exhibit more depleted precipitation due to increasing degree of rainout (the ''continental effect'').

Precipitation is the main source of groundwater recharge on the Plain. In order to understand the groundwater system in the Plain, use can be made of the local meteoric water line (LMWL) that was established by Akiti (1980). He defined the ^2H and ^{18}O composition of the rainwater in Accra (altitude 35m) by the equation, $\delta\ ^2H‰ = 7.86\ \delta^{18}O + 13.6$. This LMWL is similar to the GMWL except the deuterium excess. The GMWL is actually an average of many LMWL controlled by local climatic parameters inkling origin of the vapour mass, re-evaporation during rainfall and the seasonality of precipitation (Clark and Fritz, 1997).

The LMWL is a foci of all the points that fall in a $\delta D - \delta^{18}O$ plot with the slope reflecting, approximately, the equilibrium fractionation associated with hydrogen and oxygen, and the intercept reflecting the kinetic fractionation within the Plain. Deviation of slope and intercept gives useful information regarding secondary processes related to surface water-groundwater interaction.

The LMWL for the Plains attributed to Akiti(1980) is the same as the LMWL obtained at Dodoma, Tanzania and defined by the equation $\delta\ ^2H‰ = 7.9\ \delta^{18}O + 13.83$, (Nkotagu,1996). The deuterium excess intercept in the equation is higher than 10‰ and suggests a low relative humidity prevails in the air masses directly above the ocean surface in comparison with the average relative humidity over the ocean surface at the time the vapours forming the analysed precipitations were formed (Nkotagu, 1996). A slope of almost the same as that of the world meteoric line is obtained. However the ^2H and ^{18}O content of precipitation is more dependent on the rainfall intensity than the absolute amount of rainfall.

The deviation in the LMWL attributed to Akiti (1980) indicates that the rain particles have undergone partial evaporation in the atmosphere. However the fact that the gradient is close to 8 explains enrichment due to partial evaporation in the atmosphere. This may be due to the high relative humidity during the rainy season. An evaporation line determined by Akiti (1980) for the Accra Plains in the south-east of Ghana is $\delta^2H‰ = 5.0\ \delta^{18}O‰ - 0.56$.

Linear regression analysis for the ^2H and ^{18}O in the groundwater carried out in this study resulted in the equation: $\delta^2H = 4.39\ \delta^{18}O - 0.34$, with a correlation coefficient (r^2) of 0.62. The low slope could indicate that the rainfall forming the groundwater in the area has undergone significant evaporation

before infiltration. The Accra Plains which is located in a dry environment is characterized by evaporation therefore secondary evaporation during rainfall is expected. Friedman et al (1962) first showed that evaporation during rainfall would shift the water away from the GMWL. However the mean $\delta^{18}O$ value for the groundwater is similar to that of the rainfall value measured by Akit i(1980). This suggests that the local rainfall recharges the groundwater after minor evaporation, possibly during flash floods. Therefore, the slope of the equation might not indicate major evaporation effects prior to infiltration, but the mixing of various rainfall events and/or surface runoff with variable stable isotopic contents. This also implies that the groundwater recharge takes place predominantly through macropores where further minor evaporation could occur (Nkotagu, 1996).

The oxygen-18 isotope composition of rainwaters in Accra (altitude 35m) analysed by Akiti (1980) varied from +0.12 to -8.42‰ vs SMOW with a mean of -3.20‰ vs SMOW. The oxygen-18 isotope composition of rainwaters in Aburi (altitude 427m) varied from +0.84 to -9.78‰ vs SMOW with a mean of -3.46‰ vs SMOW.

Coplen et al (2000) and Scholl et al (1996) observed variations in rainwater isotopic signatures that may be due to rainout and altitudinal effects where an approximate shift of –0.2 ‰ per 100m were measured. The mean isotopic altitude recharge was found to be -0.13‰ vs SMOW per 100m (Akiti 1980).This value agrees with a value of -0.16 vs SMOW per 100 m obtained on the Cameroon Mountains (Gonfiantini et al 2001). The isotopic altitude of recharge is a variable quantity which depends on the nature of the rainfall and season (Fontes and Zuppi 1976).

When water evaporates from a surface water body, ^{2}H and ^{18}O are enriched in the residual liquid, with kinetic isotope fractionation resulting in a greater relative enrichment of ^{18}O than ^{2}H (Barnes and Allison 1983). The relationship between $\delta^{2}H$ and $\delta^{18}O$ in the residual liquid consequently changes, exhibiting a slope depending primarily upon relative humidity regardless of the original isotopic content (Payne, 1988). River water samples analysed by Akiti (1980) in the Plains deviate considerably from the meteoric water line and follow the equation $\delta^{2}H‰ = 5.14\ \delta^{18}O‰ – 0.56$. This shows the high evaporation that the surface waters are subjected to in the Plains. This variation will aid in distinguishing areas that are recharged by evaporated river or surface water.

Taking the enrichment of heavy isotopes in rain before infiltration studies carried out by Gat and Tzur (1967) together with the enrichment which can occur in shallow aquifers, it can be deduced that the aquifer in the Plains was recharged by vertical infiltration of meteoric waters. The isotopic values of shallow groundwater have a broader variation than deep groundwater and a narrower variation than precipitation. The broad variation of shallow groundwater indicates the presence of macropores and preferential flow. Macropores and preferential flow channels in the unsaturated zone permit the fast movement of mobile water to the water table with very limited mixing. In such cases, groundwater preserves an isotopic composition similar to that of precipitation.

The intercept of the evaporation line and the LMWL is the original isotopic composition of groundwater before evaporation. It is –3.85 and –16.35 ‰ for $\delta^{18}O$ and $\delta^{2}H$ respectively (fig.4). The displacement of the evaporation line from the meteoric line is a reflection of the evaporative loss and can be used to calculate an average evaporative loss. The few that deviate considerable from the GWML and plot close to the evaporation line indicate an evaporative enrichment of ^{18}O and ^{2}H in the surface water before recharge or the rain water mixed with previous rainwater before infiltration to the groundwater. Evaporation can take place in the upper vadose zone before infiltration through the soil thus enriching groundwater in heavy isotopes mainly in areas characterized by an arid or semi-arid climate (Shivanna et al 2004; Leontiadis et al., 1996)

The calculate deuterium excess (d) values (Table 1.) showed that all the groundwater samples that deviate from the GMWL had values less than 10‰ with Bawaleshie having a value of 1.66‰ suggesting evaporation from a source more humid than the global ocean average. The climate of the Accra Plains is influenced by the Atlantic Ocean where the relative humidity is higher and more uniform. The'd' values above 10‰ were obtained for the groundwaters that plot between the GMWL and the LMWL with a mean value of 12.7‰. The groundwater sample at Valley View University had a'd' value of 16.24‰. The groundwater samples from Abokobi also had'd' values of 14.48‰ and 15.76‰. Gonfiantini et al. (2001) reported increase in deuterium excess in mountain areas. These areas are located near the Akwapim Mountains. Dansgaard (1964) established that the mean'd' value in Africa and Near East is about 15‰ with a considerable spread with the highest deviation being due to evaporation of raindrops.

Groundwater in arid and semi-arid areas can exhibit a wide range of isotopic compositions because the factors that lead to recharge are usually governed by specific conditions being met at the time of recharge (Allison 1982). Such conditions could include flash floods, which may recharge through localized features (preferred pathways) in the vadose zone, as well as diffuse (matrix pathways) recharge. In spite of the evaporative enrichment, no relationship was observed between isotopic enrichment and increasing salinity in the chloride vs ^{18}O plot (fig.5). It has been demonstrated that rains on the Accra Plain contain high chloride contents and also that the soils of the Plains contain sodium chloride at depths (Akiti, 1980). These effects suggest that the high chloride contents of the groundwaters originate from the dissolution of evaporitic salts in the soils. These salts could have originated from marine aerosols which upon evaporation became solid.

The main causes of variations in the stable-isotope signature of groundwater are natural variations in the isotopic composition of rainfall, mixing with pre-existing waters and evaporation during percolation through soil and/or the unsaturated zone (Kendall and McDonnell, 1998). In view of the temperatures generally encountered in the subsurface, the stable isotopes of water can be considered as conservative and not affected by exchanges with soil or rock (Barth, 2000).

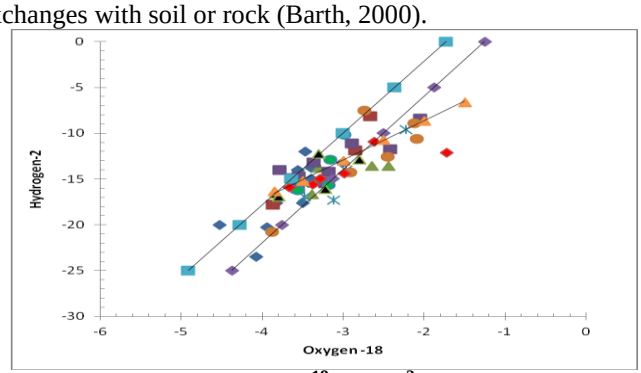

Fig 4: Relationship between ^{18}O and ^{2}H for groundwater in the Accra Plains

Table 1: Stable isotope analysis of groundwater samples from boreholes in the Accra Plains

BH ID	Location	Temp °C	pH	TDS	Ele. Con.	Cl	O^{18}	H^2	d
				(mg/l)	(µS/cm)	(mg/L)	‰	‰	‰
AB1	Abokobi	28.8	6.4	248	595	111.5	-3.56	-14	14.48
AB1Res	Abokobi	29.2	6.3	249	601	115.25	-3.5	-17.6	10.4
AB2S	Abokobi	29.9	6.5	276	670	147.9	-3.47	-12	15.76
AB 3R	Abokobi	29	6.4	241	564	144	-3.4	-15	12.2
AYM K	Ayimensa	29.8	6.4	338	528	147.8	-3.55	-15.3	13.1
AA	Madina	26	6.49	110.2	242	194.95	-3.01	-13.2	10.88
AHD 1	Adenta	25.5	6.98	235	350	271.89	-3.4	-13.8	13.4
VV1	Oyibi	30.5	6.5	242	600	99.64	-4.53	-20	16.24
VV2	Oyibi	31	6.2	243	601	119.63	-3.94	-20.3	11.22
VV3	Oyibi	29.7	5.6	226	550	121.96	-4.07	-23.5	9.06
SAD A	Saduase	26.8	7.1	552	680	116.43	-3.83	-17.6	13.04
BF2	GAEC	26	7.5	438	684	149.95	-2.85	-11.89	10.91
BF3	GAEC	26.6	7.7	379	592	139.98	-2.67	-8.14	13.22
KPE 66	Kpone	30	7.8	369	577	179.87	-3.87	-17.8	13.16
ASB 1	Ashale Botwe	26.5	7.42	233	488	143.99	-2.44	-13.6	5.92
AHD 2	Adenta	26.6	6.32	50	129	93.8	-2.65	-13.6	7.6
UG K	UG Legon	26.7	5.6	288	450	143.46	-3.39	-16.7	10.42
DA 2K	Danfa	28.1	6.3	195	250	44	-3.3	-13.8	12.6
AR1	Armahia	29.8	7.4	539	1318	272	-3.55	-14.7	13.7
AR2	Armahia	30.5	6.9	259	640	172	-3.63	-14.9	14.14
WRI 1	WRI/CSRI	29.8	6.8	639	1056	287.78	-2.89	-11.1	12.02
AGT 1	Afienya	29.2	7	696	1681	299.93	-2.05	-8.4	8
PWC 2	Abokobi	30.3	6.2	827	2020	436.65	-3.22	-15.5	10.26
PWC2R	Abokobi	29.9	6.1	830	2025	441.48	-3.79	-14	16.32
PWC F	Abokobi	29.5	6.8	1262	2650	458.45	-3.25	-15.3	10.7
PWC K	Abokobi	32.1	6.5	1510	2370	468.7	-3.36	-13.2	13.68
LQP	Madina	25.3	6	1102	2450	459.79	-3.56	-16.03	12.45
WAS	Madina	25.3	6.1	937	2090	481.9	-3.57	-15.58	12.98
DA 1K	Danfa	27.8	6.8	847	1320	337.7	-3.18	-14.2	11.24
ALA	Madina	25.6	6.72	1027	2300	397.38	-2.42	-11.76	7.6
KA 68	Katamanso	30.5	7.5	2970	4400	1448.21	-3.5	-15.5	12.5
BF 1	GAEC	26.8	7.7	1671	3760	746.08	-2.96	-14.01	9.67
TTL 0K	Tema	30	7.4	2550	3980	1302.39	-3.12	-17.3	7.66
TTL 5K	Tema	30.4	7.5	2210	3450	1080	-2.22	-9.6	8.16
MAA	Malejor	28.5	7.25	2895	4200	1269.29	-3.48	-16.9	10.94
OY1	Oyarifa	26.4	6.7	1517	2900	493.8	-2.74	-7.5	14.42
OY K	Oyarifa	28.4	6.8	1320	2060	517.98	-2.12	-8.9	8.06
FRA K	Fafraha	28.6	6.9	1753	2740	458.95	-3.88	-20.8	10.24
TE K	Tema	28.9	7	2141	3350	1020.72	-2.91	-14.3	8.98
VAL 4	Tema	30	7.4	2060	3220	1035	-2.45	-12.6	7
TE 4K	Tema	29.4	7.5	2890	4520	1463	-2.09	-10.6	6.12
ADH 3	Adenta	26.8	8.11	1470	2337	493.88	-3.18	-15.65	9.79
PRE 1	Legon	24	7.7	1489	3240	877.46	-2.98	-10.2	13.64
PRE 2	Legon	24.4	7.5	1204	2640	789.73	-3.16	-12.9	12.38
SHA	Shai Hills	29	7.45	1546	2590	755.45	-3.56	-16.2	12.28
KPG 54	Kpong	27	7.3	1400	2300	257.83	-2.98	-14.4	9.44
AYK A	Ayikumah	28	7.2	920	2400	284.1	-3.38	-15.6	11.44
BA 40	Bawaleshie	28.4	7.4	600	1445	263	-1.72	-12.1	1.66
BA 42	Bawaleshie	28.7	7.1	1420	2200	487.5	-2.61	-10.9	9.98
WRI 30	WRI/CSRI	29.8	7.55	1114	1460	351	-3.66	-15.9	13.38
AR A	Armahia	28.8	7.3	875	1260	178.93	-3.28	-15	11.24
TFS K	La	29	7.6	7516	11710	3876.14	-2.8	-12.9	9.5
ASH 44	Ashiaman	30.5	7.2	2780	4320		-3.83	-16.6	14.04
ASH 77	Ashiaman	29.6	7.2	3843	5800	1875	-3.8	-16.9	13.5
ASH K	Ashiaman	29.7	7.3	5980	9370	3048.21	-3.22	-16.1	9.66
VAL 5	Tema	30	7.4	4320	6760	2354	-3.3	-12.25	14.15

It is known that subsurface stratigraphy and structures give rise to variations in hydraulic conductivity. The differences in hydraulic conductivities can exist in an infinite variety and would have profound effect on groundwater flow. This is an important aspect to consider when characterizing a site for radioactive waste repository especially in the subsurface. A situation of this nature has been identified on the compound of the Valley View University on the Accra Plains.

Groundwater in the Accra Plains is known to flow through fractures and the weathered zones (Akiti, 1980). This means that there exist channels of preferential flow in the geology. Macropores and preferential flow channels permit fast movement of groundwater with limited mixing. In such cases the groundwater preserves the isotopic composition similar to that of precipitation.

From the results of this study, it was observed that the chemistry of the groundwater drilled on the compound of the Valley View University are different from those of the surrounding Plains. For example the total dissolved solids are rather low compared to those of the Plains. The water quality is generally good.

In order to find out the origin of this relatively fresh water in the Plains, stable isotopes analyses were done. From the stable isotope measurement, it was found out that the groundwater have oxygen-18 values ranging from -3.94 to -4.53 vs VSMOW. The deuterium values range from -20 to -23.5 vs VSMOW. These values plot around the LMWL.

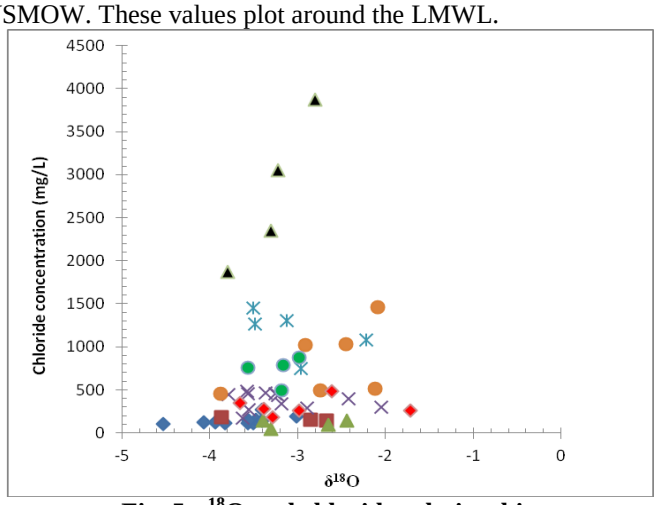

Fig. 5: ^{18}O and chloride relationship

These results are more depleted than those that are occurring in the surrounding groundwater. This suggests that these waters are recharged at a high elevation, hence the depleted values. The nearby Akwapim-Togo Mountains would be the source of these groundwaters. In terms of hydrogeology, this would imply that there are preferential channels or routes through which waters that are recharged on the Akwapim-Togo Mountains find their way to the Valley. This means that any waste disposed on the flow path of these groundwaters would find its way to the groundwater and thus to the surface water faster than can be expected.

Conclusion

The stable environmental isotopes of hydrogen and oxygen of the rainfall and groundwater in the Accra Plains indicate that the groundwater is being recharged by meteoric water. The recharge takes place in fractures in the geological formation with the occurrence of minor evaporation. The groundwater is also affected by the mixing of various rainfall events and or surface runoff.

There was no relationship between isotopic enrichment and increasing salinity. The salinity in the groundwater is due to the dissolution of soluble salts in the soil. These salts could have originated from marine aerosols which upon evaporation became solid.

The groundwaters at Valley View University located a Oyibi were more depleted than the other groundwaters in the Plain. Mountains are characterized by isotopically more depleted precipitation with increasing elevation due to the cooling of the air mass when it is forced to ascend (‘‘altitude effect’’). This implies that the groundwaters at Valley View University are being recharged by rain at the Akwapim Togo Mountains through preferential channels.

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