

Geological and Geochemical Controls on the Composition of Natural Drainages in Homase Mineral Deposit Environment

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Abstract: This study investigated the geochemical and geological characteristics of the Homase mineral deposit(s) environment in Ghana. The aim of the study was to identify and characterize, the signatures influencing the composition of natural drainages in the area. Streams, hand-dugout wells and a borehole samples in the catchment area were analysed for water quality parameters including metals, major and minor elements. Mineralogical composition of mineralized and un-mineralized rocks carried out by other workers in the area was used to ascertain the possible sources of the metals etc. Local geology and sulphide mineralisation with arsenopyrite and pyrite being the dominant sulphide minerals influence water variation. Analytical results using standard methods study, shows that streams are being impacted by iron and arsenic in the ranges 0.02 to 3.56 mg/L and 0.02 to 1.30 mg/L, respectively. Also ranges for the above metals in hand-dugout wells are 0.03 to 0.48 mg/L and 0.24 to 1.32 mg/L, respectively. This geochemical information suggests the mineral deposit(s) is relatively benign to the Homase environment.

Key words: Environmental geochemical hazards, granitoids, hydrogeochemical media, pyrite, sulphide mineralization, weathered rocks

INTRODUCTION

Environmental issues are an integral part of mineral resource development by both concern and law (Closs, 1997) as geologic characteristics of mineral deposits have significant influence on both natural and post mining/processing environmental signatures of mineralized environs if appropriate prevention and mitigation practices are not followed (Plumlee, 1999). Concentrations of chemical, mineralogical, or biological forms of metals and other constituents form a mineral deposit prior to mining in waters, soils, sediments, plants, and organisms which define natural environmental signatures. Similarly, mining and milling wastes, mine waters, mineral processing solutions and by-products issues of metals and chemicals prior to mitigation or remediation define mining-related environmental signatures. Mineral deposits are concentration of elements (metals) or minerals in the earth's crust above normal crustal abundances, resulting from variety of complex geologic processes. Geologic processes of formation, environments of occurrence and similar geologic characteristics (Guilbert and Park, 1986; Cox and Singer, 1986; Bliss, 1992) had led to different types of mineral deposits, including magmatic, hydrothermal, supergene, residual and placer deposits. Weathering and erosion

disperses constituent elements of mineral deposits into waters, soils, sediments in the environs of the deposit. This implies geochemical and geological characteristics of mineral deposits have exploration and environmental implications (Plumlee and Logsdon, 1997). Surface water drainage contributes effectively to exploration (reconnaissance and detail) in detecting anomalies related to mineralization in mineral deposits. Geochemical studies of mineral deposits (Webb *et al.*, 1978; Bølviken *et al.*, 1986; Darnley, 1995) provide an understanding of the sources and fates of their constituent chemical elements in natural environments. This helps to compare and explain parameters affecting natural systems (e.g., water) with those affected by human activities like mining. Exploitation of mineral deposits can cause imbalance of other natural systems; soil fertility, land use and especially water in the environments where such mineral deposits occur.

The development of extensive mining operations in Obuasi and its environs, an ecologically sensitive zones with well-developed drainage system likely to give rise to environmental problems (Akabzaa *et al.*, 2007) have not been intensively monitored like that of processing facilities and ore, respectively (Amonoo-Neizer and Busari, 1980; Jetuah, 1997; Carboo and Sarfor-Armah, 1997; Clement *et al.*, 1997). Both ground and surface

waters have not been characterized based on specific geochemical studies of the numerous mineral deposits that the water bodies interact with in the Obuasi environs, though studies of characterization of waters based on the general geology of the environs are abound. The objective of this study is to investigate the geological and geochemical controls of the Homase mineral deposit on waters in its environs, to identify if any, the potential environmental geochemical hazards, by concentrating mainly on the hydrogeochemical media, the principal avenue for movement of metals from rocks and sediments into the aquatic biota.

Geological setting-Homase: Homase concession can be located 20 km NNE of Angologold Ashanti, Obuasi mine in Ghana. The concession area covers approximately 116 km² (longitudes 1°30' and 1°40' W and latitudes 6°20' and 6°25' N) is the study area (Fig. 1) and under the mining lease of AngloGold Ashanti Obuasi Mine. Topographically, the concession is moderately undulating with hills rising from 150 to 300 m above sea level. The hills mostly on the eastern side of the concession serve as watershed for many streams. Generally, the drainage pattern is dendritic with many of the streams being seasonal. Semi-equatorial climatic conditions with double maxima rainfall regime prevail within the area. Human activities (farming and logging) has transformed the original Semi Deciduous Forest to that of tall grasses in which fire tolerant trees and shrubs are scattered.

Rocks of the Lower Birimian System (Fig. 2) with varied degree of textural and mineralogical changes, caused mainly by contact metamorphism near intrusive granitoids occur in the concession (Murray, 1966). The rocks are predominantly grey and black phyllites (spotted), silicified phyllites, greywacke and schists. The granitoids include muscovite-biotite granite, hornblende-biotite granodiorite which are deeply weathered such that outcrops of fresh rocks are rarely seen. Sheared zones strike NNE with near vertical dips to the NW and are marked by graphitic or silicified dark grey phyllites just at contacts between the metasediments and the granitoid intrusions. Ntiamoah-Agyakwa (1979) and Dzigbodi-Adjimah (1991) studying Birimian gold mineralisation in Ghana, noted that gold occurs in quartz veins as lenticular reefs and in some tuffaceous argillaceous rocks, gold mineralization occurs with sulphides with chalcopyrite, bornite, galena, and sphalerite.

Mineralogical studies by Mücke and Dzigbodi-Adjimah (1994) in the Obuasi environs revealed gold mineralization was not limited to only the auriferous quartz ore bodies but that sulphide mineralizations also occur in sheared schistose and fractured rocks of the wall rocks. Granitoids in close proximity to the reef are metasomatically altered and carry some gold suggesting the auriferous solutions were introduced after the

granitoids intrusion. Also, wallrock alteration is characterized by sulphidation, sericitization and carbonatization (Bowell *et al.*, 1990) Gold-bearing sulphide mineralization in the concession is associated with thin, pale green, silicified quartz-chlorite rocks sometimes carbonated in sheared zones. Mineral associations include pyrite, arsenopyrite, rutile, tourmaline, galena and carbonate. Pyrite occurs in various grain sizes and characterized by absence of pyrrhotite and/or chalcopyrite inclusions.

Disseminated sulphide mineralization does not appear to be restricted to a particular rock type but rather associated with shearing, fracturing and other foliation in all lithological units close to ore channels (Dzigbodi-Adjimah, 1991).

MATERIALS AND METHODS

Direct water collection method was used to sample streams draining the mineralized areas (mining pits), waste and ore dumps as well as un-mineralized areas, hand-dug wells and a borehole (Fig. 2) within the Homase gold mining concession, NNE of Angologold Ashanti, Obuasi mine. The sampling was done in June-July (Wet season) and September - October (Dry season) 2010, and according to outlined standard procedures for water quality analysis (APHA, 1992; Smith *et al.*, 2000). The sampling covered both wet and dry seasons to capture possible seasonal effects. Control surface water samples were taken from two streams which are outside the study area and far from any influence of the mining activities. Sterilized polyethylene bottles used to collect the samples were carefully rinsed three times with the water to be sampled at each station before being filled with the unfiltered water. No preservatives were added to the unfiltered samples taken. Sample locations were chosen to cover areas before mining pits (upstream), within pits and areas after the pits (downstream) (Fig. 2).

Seventy-nine (79) samples representing thirty one (31) wet season samples and forty eight (48) dry season samples, comprising twenty-two (22) samples from hand-dug wells and a borehole and fifty-seven (57) streams samples were analyzed for metals and other water quality parameters.

There were some limitations during field sampling exercise. Swift flow of some flooded streams in the wet season created dangerous situations such that two streams were not sampled. Some unprotected hand-dug wells that had surface runoff water draining into them and therefore were not sampled in the wet season. The Brapong, Nyamewaa and Ago streams and one well (WS 9) in Homase village were dried up in the dry season, hence they were not sampled. During the dry season sampling session, rain fell twice, a situation that most likely affected water pH, which in turn, affected the solubility of some elements in solution.

Table 1: Water quality parameters status for hand-dug wells and a borehole in (mg/L) except

Parameters	Min.	Max.	Mean	Median	SD	WHO standard
pH	6.20	8.20	7.10	7.10	0.58	6.5 - 8.5
Cond. (µS/cm)	63.30	170.00	96.64	93.70	24.33	-
Turbidity (NTU)	0.50	63.00	8.41	3.601	5.11	5.0
TSS	1.00	198.00	63.63	26.50	71.56	-
TDS	21.00	102.40	57.95	61.90	27.44	1000
Total hardness	20.00	140.00	53.88	51.00	30.57	-
Fe	0.03	0.48	0.17	0.08	0.17	0.3
Zn	0.03	0.07	0.05	0.05	0.03	2.0
As	0.24	1.32	0.57	0.26	0.48	0.01
Mg	0.09	0.09	0.09	0.09		
Na	0.00	7.00	1.46	0.80	2.48	150
Ca	3.80	22.40	9.00	4.90	6.78	200
K	0.33	17.90	6.20	5.17	4.57	200
SO ₄	1.00	7.30	2.69	1.80	2.14	30
Cl	0.00	29.30	3.47	1.20	6.89	400
Li	0.43	35.44	10.20	5.50	10.34	250
F	0.00	1.00	0.04	0.00	0.05	-
NO ₃	0.00	0.30	0.14	0.13	0.08	1.5
NO ₂	0.04	24.90	5.24	1.58	7.61	10
PO ₄	0.00	0.20	0.13	0.20	0.10	-
Alkalinity	10.00	98.00	41.53	26.00	28.57	-

Table 2: Water quality parameters status for stream water in (mg/L) except otherwise stated

Parameters	Min.	Max.	Mean	Median	SD	WHO standard
pH	6.40	8.50	7.25	7.10	0.49	6.5-8.5
Cond. (µS/cm)	29.90	148.00	106.74	103.33	24.00	-
Turbidity (NTU)	5.80	670.00	103.73	41.50	161.55	5.0
TSS	1.00	700	120.93	99.00	129.23	-
TDS	12.90	91.00	42.88	39.10	16.84	1000
Total hardness	12.00	76.00	40.14	40.00	11.86	-
Fe	0.02	3.56	1.27	1.24	0.98	0.3
Zn	0.02	0.03	0.02	0.02	0.01	3.0
As	0.12	1.30	0.41	0.26	0.39	0.01
Mg	0.00	11.60	3.90	2.60	3.53	150
Na	3.60	17.30	11.33	13.30	4.86	200
Ca	0.02	8.70	3.61	4.20	2.96	200
K	0.80	6.10	2.47	2.70	1.38	30
SO ₄	0.03	12.50	1.81	1.00	2.34	400
Cl	0.63	11.30	5.32	5.40	1.61	250
Li	0.00	0.10	0.07	0.10	0.05	-
F	0.03	0.40	0.14	0.12	0.08	1.5
NO ₃	0.00	21.50	1.08	0.26	3.30	10
NO ₂	0.00	3.20	0.52	0.20	0.91	-
PO ₄	0.00	2.60	0.43	0.10	0.65	-
Alkalinity	8.00	88.00	36.76	25.00	26.71	-

The samples were analyzed in Anglogold Ashanti Obuasi Mine Environmental laboratory and followed standard methods as described in APHA (1992). The carbonate and bicarbonate concentrations were determined by titrations.

RESULTS

Statistical summaries of analytical results for water quality parameters of stream and wells are presented in Table 1 and 2. Though concentrations of parameters at a number of sampling points were below detection limits, the results demonstrate significant concentrations of some determined metals at some sampling points.

The concentrations of Fe and As are higher with higher variances in streams than they are in wells. Iron (Fe) concentrations range between 0.02 and 3.56 mg/L with a mean of 1.27 mg/L in streams, whereas the

corresponding well water values are between 0.03 and 0.48 mg/L with a mean of 0.17 mg/L. The only lead (Pb) value of 0.09 mg/L recorded in the course of this investigation as all other samples values were below detection limit, occurred in the only borehole in the study area at the mine workshop for servicing mining equipments.

Concentrations of Fe, As and Pb exceeded WHO (2005) acceptable limits for potable drinking water. Concentrations of all other metals are within permissible limits (Table 1 and 2). Zinc (Zn) and phosphate (PO₄) in the well water samples were below detection limit throughout the study area. The observed stream water major cationic concentration pattern is Na>Ca>Mg>K. The pattern of distribution of the major anions in stream water is SO₄>Cl>NO₃, with F, PO₄ and NO₂ occurring in minor concentrations. The major cation distribution

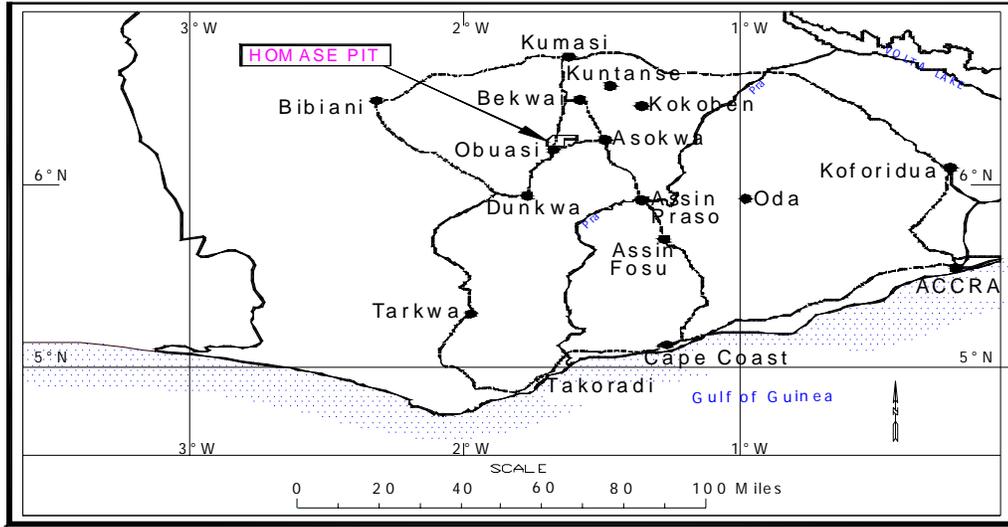


Fig. 1: Map of southern Ghana showing the location of the study area

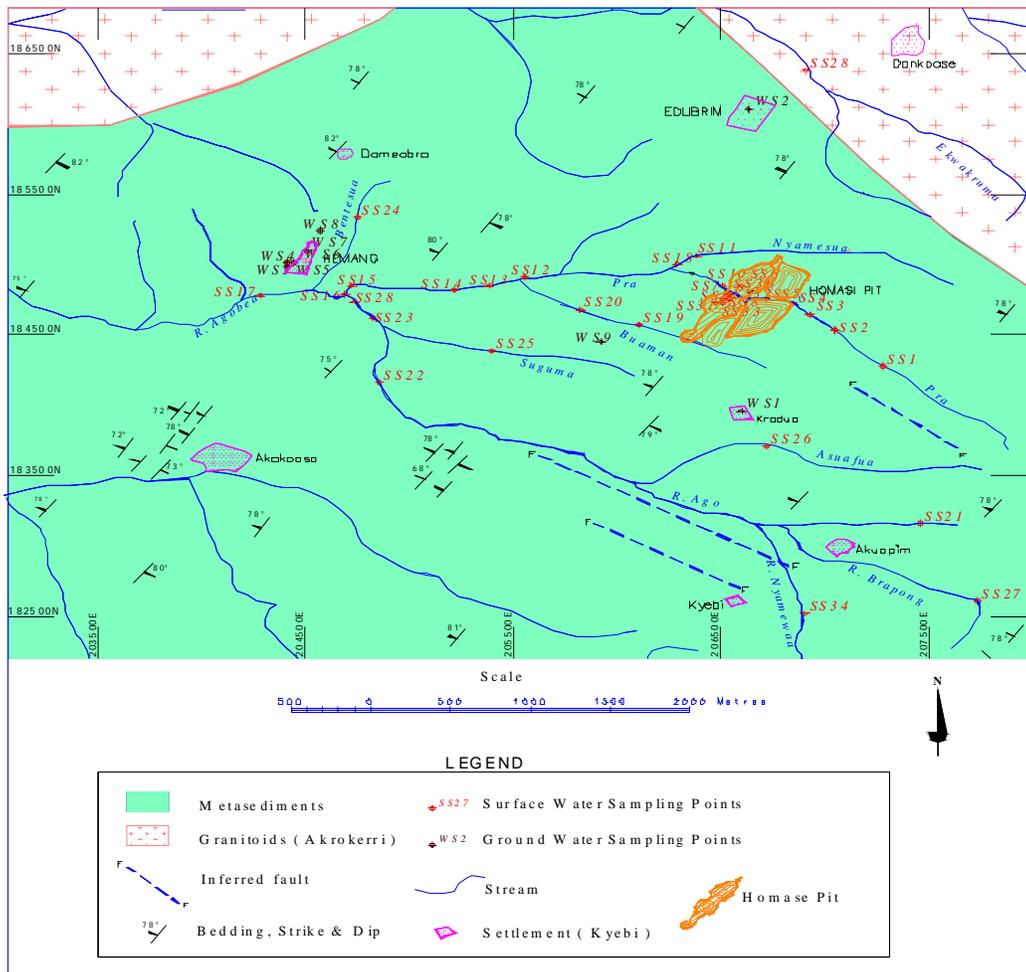


Fig. 2: Geological map of study area showing sampling points

pattern in well water was observed to follow the pattern Na>Ca>K>Mg. The major anions follow the pattern $O_3>Cl>SO_4$. The minor anions distribution takes a trend similar to that observed in stream water. Cation concentrations in stream water are low in the watershed regions.

DISCUSSION

The pH of water (both stream and hand-dug well) irrespective of the season, in the Homase environs is near neutral (Table 1 and 2). However, moderately low pH values were recorded at some sampling stations in the vicinities of watershed where hilltops have thick lateritic covers. A mean pH of 7.2 is suggestive that water is either interacting with low/non-acid generating weathered rocks as well as lateritic caps of hills or it reflects equilibrium interaction between carbonate ions (CO_3^{2-}) and weak acid H_2CO_3 , regardless of their original sulphide content (Plumlee *et al.*, 1995). This is so because in the mineral deposit acid generating sulphide minerals either intergrow with or occur in close proximity to various carbonate and aluminosilicate minerals (Plumlee, 1999) as well as some metal carbonates in the weathered zones react and consume acid generated during sulphide oxidation. But the occasional moderately low pH recorded at some sampling points may be due to pockets of acid generating iron minerals (Eppinger *et al.*, 1999) within thick lateritic covers rich in limonite on hilltops. Unstable sulphide minerals on exposure to atmospheric oxygen and oxygenated water generate acid but the volume is dependent on complex function of the sulphide minerals present in the mineral deposit and their resistance to weathering. According to Price and Errington (1997), though acid-buffering effects of carbonate-rich host rocks and low acid generating potential of the oxide ores result in near neutral pH mine waters, un-oxidized pyrite and sulphide rich ores in zones of intense de-carbonatization may generate locally acidic water zones. The TDS concentrations are generally low. However, well water TDS values are slightly higher than that of stream water, though some streams have high TDS concentrations, probably due to evaporation. Possibly percolating water is moving more dissolved solutes downward. Short residence time of solutes or simple history of rainwater infiltration (Mazor *et al.*, 1974) might be responsible for the low TDS concentrations.

Despite the extremely low metal concentrations, Fe concentrations in streams at some sampling stations were quite high with a maximum of 3.56 mg/L. Arsenic concentrations also in streams reached a maximum of 1.3 mg/L. The relatively high Fe concentrations in the watershed regions (Fig. 2) could be due to leaching from limonites in the laterites and weathered rocks capping the tops of hills. The drop in Fe concentrations within the

mining pits may be due to either sorption of Fe ions onto particulate matters or dewatering activities as mining had gone below the water table. The mean pH within the pits is 7.6, a condition that favours Fe ions being attached onto surfaces of particulate matters that eventually settle to the pit floors (Smith *et al.*, 1992). The dewatering of the pits, especially in the raining season moved Fe laden waters out of the pits. These processes remove Fe from solution thereby lowering its concentration. Downstream mining pits (Fig. 2) spikes of Fe concentration occurred especially in streams flowing beyond the settling pond constructed for mining operations. Comparatively Fe concentrations downstream mining pits are higher than recorded concentrations within watershed vicinity. It implies that the mineral deposit is contributing to the natural metal concentration in the Homase environs.

The log of the only borehole in the Homase environs shows that the average depth of weathering is about 55 m with highly weathered materials occurring from 7 m to 15 m and two aquifers at approximately 44-53 m and 56-62 m. All the hand dug wells that supplied the sampled well water were not more than 23 m deep. It means that the wells are tapping mostly percolating surface water from highly weathered rocks consisting of insoluble minerals that are not likely to contain enough ions than water from fractured basement rocks. This probably explains why samples recorded low to below detection limits concentrations of ions. It implies, iron laden streams may be recharging wells. According to Plumlee *et al.* (1995) sulphide oxidation alone is not sufficient to explain rapid rise of metals and acid observed in waters. They surmised that water in unsaturated zone evaporates during low flow, leaving behind soluble acid-metal sulphates. Metals in groundwater do not usually move very far from their sources as the tendency is to attach to fine-grained sediments and settle out of water. However, in very acidic water, metals do not easily get adsorbed onto sediments but rather remain mobile. It therefore implies that with the near neutral pH condition of waters (stream and well) prevailing in the study area, metals in water would not migrate far. This is demonstrated in the spatial distribution of the significant Fe values recorded in the study area. These Fe values occur downstream proximal to the mineral deposit being mined in the pits and on hilltops with lateritic material covers serving as streams watersheds. Iron in water promotes proliferation of iron-oxidizing bacteria, which oxidize ferrous iron to ferric iron to coat stream channels and impact water quality (Kempster and Smith, 1985).

Stream and well water mean As concentrations 0.41 and 0.57 mg/L, respectively in the Homase environ, exceed WHO (2005) tolerable limits for drinking water. Though the near neutral pH of waters in the environment would not allow too much of arsenic to remain in solution for a long period of time or permanently, its precipitation

as sediment load is equally not safe. This is because it will get adsorb onto sediments surfaces and eventually go into solution with storm flow.

Sources of Metals and other elements in Water:The main sources of dissolved solids in the water are from the dissolution of minerals in rocks and soils, storm water and agricultural runoffs. The decomposition of plant materials may contribute some dissolved solids (Kramer, 1982; Mitchell and Stapp, 1997). Ions in sampled water are from soluble mineral assemblages in fresh to semi-fresh rocks, because in weathered rocks, the chemical break down of original minerals result in the formation of new clay minerals composed of residuum insoluble minerals after the dissolution of carbonates, as in the case of the study area, appears to be the most important. Leachates from weathered zones of mineral deposits (Plumlee *et al.*, 1999) lateritic hilltops covers may have contributed to the metal loads of water. The gold-bearing sulphide mineralization in the Homase mineral deposit has mineral associations which include pyrite (characterized by absence of pyrrhotite and/or chalcopyrite inclusions), arsenopyrite, rutile, tourmaline, galena, sphalerite in silicified quartz-chlorite rocks sometimes carbonated in sheared zones (Mücke and Dzigbodi-Adjimah, 1994). The disseminated sulphide mineralisation does not appear to be restricted to a particular rock type but rather associated with shearing, fracturing and other foliation in all lithological units close to ore channels. The weathering of these minerals has the potential of producing significant metal species to influence natural environmental signatures. The oxidation of these sulphide minerals introduced metals such as Fe, As and Cu, respectively, into the water through abiotic oxidation at near neutral pH conditions (Scharer *et al.*, 2000) although oxidation of sulphide minerals occur by both chemical and biological mechanisms in acidic conditions. Streams and ground water flowing through the sheared zones and fracture country rocks may have dissolved metals (Fe, As, Cu and possibly Pb) under favorable conditions since it is not limited to just the ore zones of the Birimian metasediments in the study area. Price and Errington (1997) indicated that increase arsenic concentration in waters from gold deposits reflects desorption of arsenate species from particulates at higher pH in oxidized pit waters. Even though pH is not high in the Homase environment, the near neutral pH might initiate the process coupled with long interaction time. Desorption processes are however considered to be slower than sorption processes (Stumm and Wieland, 1990) therefore may serve as a long-term source of arsenic contaminant to water in the Homase environment. It could also be that the value for Pb recorded in the only borehole in the study area might have come from galena. Though the source of Pb in the area could not be precisely determined, it is

suspected to be coming from anthropogenic activity in the workshop for servicing mining equipment, where all kinds of lubricants are being used. Further investigations are required to identify the main source of Pb in the study area since metabolically, lead interacts with iron to render water undrinkable and it interferes with haemoglobin synthesis. Given the elevated level recorded, Pb is a potential metal that can seriously impact water in the Homase environ.

However, metals concentrations are likely to be affected by several factors including amount of sulphides and oxygen present, dilution, discharge of metals and acid from unsaturated zone, discharge of buffered water from non-mineralized host rock and geochemical reactions that precipitate metal hydroxides (Posey *et al.*, 2000). Thus rates of minerals weathering in the study area significantly influence acid production and consumption as well as metal liberation from the deposit into the environment. The low metal concentrations in waters in the study area may be due to acid-buffering effects of carbonate-rich host rocks (near neutral pH), low acid-generating potential of oxide ores of the mineral deposit (Price and Errington, 1997) and possibly dilution especially in the wet season. It is also likely that oxide minerals become insoluble in near neutral waters thereby reducing the release of metals into waters. Thus oxide ore deposits produce relatively non-acid drainage waters with minimal metal concentrations. Sometimes the coating of fresh remnant sulphides present in the deposit by impermeable oxidized minerals reduces rates of sulphide oxidation, acid and metal generation (Nordstrom and Alpers, 1999).

Major and trace elements investigations of mineralized and non-mineralized Birimian rocks by Oberthür *et al.* (1994) in Obuasi area which included Homase environs, revealed that percentage compositions of elements (Ca, Na, K, Mg, Fe, Mn etc.) in the rocks are minimal except arsenic (As) in mineralized rocks. This explains why arsenic concentrations are quite high in the study area. Therefore water moving through mineralized sheared zones hosting the mineral deposit(s) in Homase environs would probably leach out metals especially arsenic and other ions from certain minerals depending on physical and chemical equilibrium conditions prevailing at a time to impact water quality (Klusman and Edwards, 1977). At near neutral pH conditions water probably contributed to the low solutes solubilities (Mazor *et al.*, 1974) as observed in the Homase environs, ions (cations and anions) concentrations in hand-dug wells are relatively higher than corresponding concentrations in streams (Table 1 and 2). Though rocks in the Homase environs may not contain enough elements (Oberthür *et al.*, 1994) to release as ions into water, longer interaction time between well water and rocks might have resulted in the dissolution more solutes than in streams.

Lithological differences and structure of bedrocks in the study area might result in both vertical and lateral inhomogeneities to generate significant variations in the physical characteristics of the weathered zones that would possibly result in variable flows from different horizons on local scale. Sporadic elevated concentrations of some ions in streams at some sampling points may be due to dissolve solutes from debris and/or fertilizers or due to evaporation. Three wells recorded high Na concentrations with the highest being 22.4 mg/L in a well located proximal to the contact between metasediments and granitoid intrusion than the concentrations of Ca, K and Mg. Development of secondary fractures during tectonic movements along this structural contact might have enhanced porosity for ground water to recharge this well. The upward movement of water that had come in contact with fresh rocks most probably dissolved a lot more solutes or accelerated the weathering of some minerals to increase ions concentrations. Weathering of ubiquitous pyrite in the metasediments might have released SO_4^{2-} ions into groundwater (Eppinger *et al.*, 1999) in the neighborhood of the well to increase the concentration to 22.4 mg/L.

Nitrate sources in streams are runoffs from agricultural lands (Pionke and Urban, 1985) and probably other specialized synthetic organic agricultural chemicals (poultry feed) (Rothschils *et al.*, 1982). This is because prior to the commencement of mining activities in the Homase environment, subsistence agricultural activities were the only occupational venture undertaken. However, according to Baird (1999) it now appears that intensive cultivation of land, even without the application of fertilizer or manure, facilitates the oxidation of reduced nitrogen to nitrate in decomposed organic matter in the soil. Also the mishandling of poultry feed on poultry farm and some homes in the Homase township, contributed to nitrate in the environs.

The moderate alkalinity values reflect the carbonate type of waters in Homase environs. The metasediments forming the country rocks include carbonate (Murray, 1966; Dzigbodi-Adjimah, 1991) mineral associations alongside others like pyrite, arsenopyrite, rutile, tourmaline and galena. The minimal water-rock interaction time between streams and carbonate rocks due to swift flow (Bove *et al.*, 2000) probably resulted in little amount of carbonates/bicarbonates to be dissolved. Streams mean alkalinity is 36.76 mg/L, slightly lower than the mean alkalinity (41.53 mg/L) for well water. Water in wells might have had longer interaction time directly with carbonates/bicarbonates in rocks due to slow flow rates. Consequently water in wells dissolved larger volumes of soluble carbonates/bicarbonates to increase alkalinity.

CONCLUSION

The result shows that the deposit in the Homase environment is gradually impacting natural drainage with mainly iron and arsenic. Waters in the area are mostly sodium carbonate type with minor calcium-magnesium carbonate type. However undifferentiated types do occur at some locations. This is because at such locations concentrations of constituent cations are almost equal. Further investigations are required to identify the main source of Pb in the study area.

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