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Physico-Chemical Analysis of Streams on the Akwapim Ridge of Ghana

V. K. Nartey,[1] J. R. Fianko,[1] A. Donkor[2]

[1] Department of Chemistry, University of Ghana, Legon, Accra, Ghana

[2] Department of Environmental Engineering Sciences, University of Florida, Gainesville, FL, USA

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Ghana is endowed with several freshwater bodies – lakes, rivers, streams, etc. Many of these are utilized for drinking and domestic purposes. Others serve as a means of transportation of goods and people, for example, the lake Volta. Above all, the different species of aquatic organisms serve as a source of food for many living around these freshwaters. Unfortunately, the banks of these freshwaters are the farming grounds of the rural dwellers practicing modern agricultural methods such as the use of fertilizers and other pesticides, now prevalent in Africa. These chemicals discharged into the environment could reach the perimeters of these surface waters, endangering both human and aquatic lives. Consequently, several studies as regards pollution of water systems have been carried out in many parts of Africa. For instance, Chale (2002) studied trace metal concentrations in Lake Tanganyika in East Africa. Ishmail and Ramadan(1995) have discussed the characteristics of the Nile and drinking water quality in some cities in Egypt. Further, in 1998, Offiong and Edet reported baseline evaluation studies of potable water in Cross River state in Nigeria, and in addition, surface water quality studies in Cote d'Ivoire have been assessed (Wandan and Zabik 1996). On the other hand, in Ghana, a number of studies as regards water quality have been conducted (e.g. Asante 2001; McGregor et al. 2000). Nevertheless, physico-chemical studies with regard to the streams/rivers draining the Akwapim ridge is lacking.

In Ghana, only 30% of the population has access to safe drinking water and over 50% also use natural "unprotected" sources of water (Ministry of Health 1999). The Akwapim Ridge which is in the Eastern part of Ghana is 1000ft above sea level and is no exception. The nature of the area makes it such that the indigenous population in this part of Ghana depends on the waters on the ridge for their living, and as well as the only source of potable water. The qualities of these waters vary naturally and widely depending on climate, season, and the geology of the local bedrock, which may have a negative impact on the suitability of water for human use, besides the contributions emanating from human activities like agricultural practices characteristic of the ridge. Hence, these surface waters are very prone to pollution, and this coupled with water needs and anticipated future development of the area make it imperative to monitor and carry out an extensive baseline water quality, uses and management evaluation study of the Akwapim Ridge. This is essential, since the effective water monitoring network requires an accurate characterization of background quality.

Correspondence to: V. K. Nartey

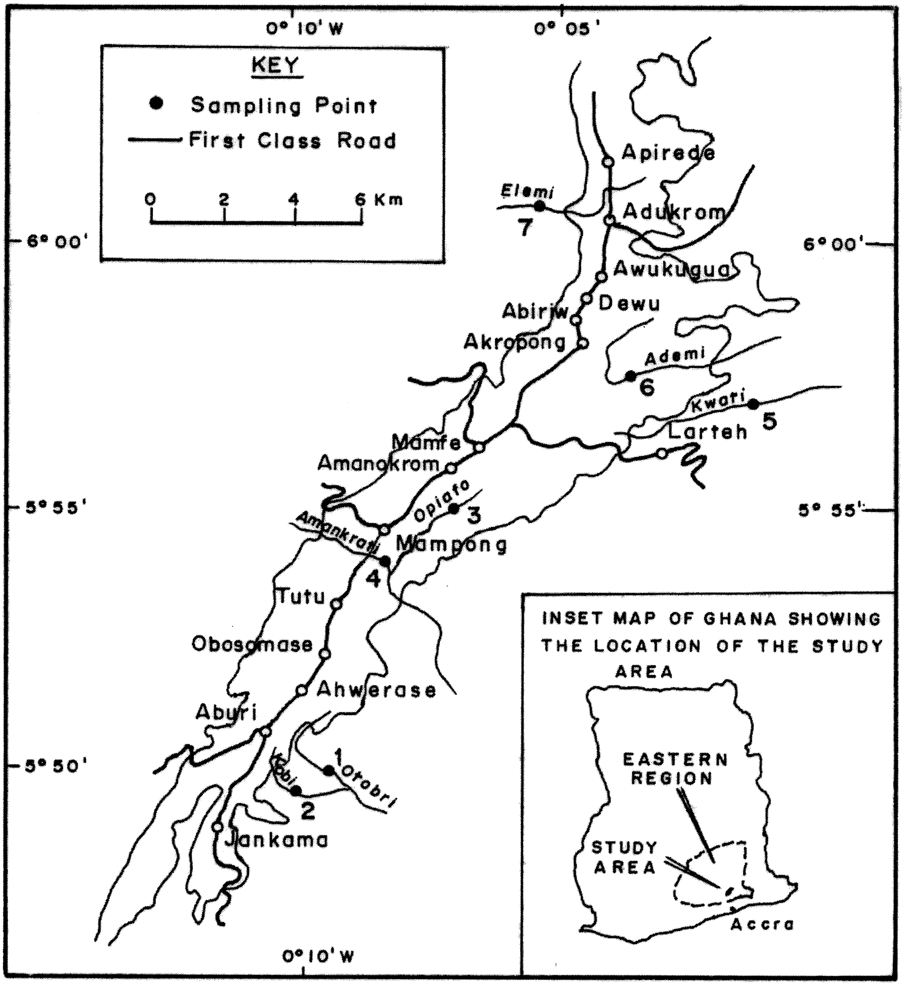
This present study, the first in a series, focuses on the water quality of the springs/streams on the Akwapim Ridge to evaluate their suitability for domestic purposes. It also aimed at identifying potential sources of pollution into the springs/streams.

MATERIALS AND METHODS

The Akwapim Ridge (Fig. 1), located in the Eastern Region of Ghana consists of seventeen (17) major towns and numerous surrounding villages. Surface water samples were collected from seven streams/springs on the ridge during the wet and dry seasons in 2001 (Fig. 1). For the purpose of this write up the different sampling points are given designations as presented in Table 1. Water samples were collected mid-stream at depths 20-30 cm. Four samples (two for each season) of 1-litre volume each were collected from each sampling point for the determination of various physico-chemical parameters. A total of 112 samples were collected during the entire sampling period, 56 samples each for both the dry and wet seasons. Twenty parameters have been evaluated in each sample. The pH and water temperature were measured in the field using portable pH meter and Mercury – in – glass thermometer respectively. All 1-liter polyethylene bottles used were cleaned with detergent, thoroughly rinsed, soaked in 10% HNO_3 solution overnight and finally rinsed with doubly de-ionized water. Bottles were also rinsed three times with stream water before being filled. The water samples for analysis of trace metals were immediately acidified (1% nitric acid). After sample collection, and during transportation to the laboratory, samples were stored on ice pack in coolers. All samples were filtered through a pre-cleaned glass filter. Analytical procedures used were those currently suggested in manuals, (APHA, AWWA and WEF 1998). Trace metals as well as the major cations (Na^+, K^+, Ca^{2+}, Mn^{2+}) were analyzed by flame atomic absorption spectrometer (Perkin 3110). The dichromate closed tube and Winkler's azide modification methods (APHA 1998) were used to determine both chemical oxygen demand (COD) and dissolved oxygen (DO) respectively. Samples for biochemical oxygen demand (BOD) were collected into dark brown bottles and incubated at 20°C for five days before analysis by Winkler's azide modification method. The nutrients (phosphate, nitrate, and sulphate) were measured by 6100 visible range spectrometer.

All reagents used were of analytical grade and instruments pre-calibrated prior to measurement. Replicate analyses were carried out for each determination to ascertain reproducibility and quality assurance. The detection limits for the trace elements Zn, Cu, Fe, Mn, and Pb were 0.01, 0.01, 0.003, 0.001, 0.05 mg/l respectively. For these elements, standard stock solutions were prepared in each case. Internal calibration standards of 0.01 and 50.00mg/l were prepared from the stock solutions and used to calibrate the AAS.

The different stock solutions were prepared as outlined. Cu standard was prepared by dissolving 0.1g of copper metal in a (2:1) mixture of conc. HNO_3 and conc. HCl



SOURCE: SURVEY DEPT. OF GHANA, ACCRA.

Figure 1. Akwapim Ridge showing the study area and sampling sites

Likewise, Fe and Mn standards were prepared by dissolving 0.1g each of the metal in a (1:3) and (10:1) mixture of conc. HCl and conc. HNO_3 respectively On the other hand, Zn standard solution was prepared by dissolving 0.1g zinc metal in 20 ml of 0.25MHCl, whereas Pb standard was obtained by dissolving 0.1598g of $Pb(NO_3)_2$ in 10ml of 0.20M HNO_3 solution. All the standard mixtures were then made up to 1 litre with doubly de-ionized water to yield a concentration of 100mg/l per an element.

For the nutrients, PO_4^{3-}, NO_3^-, and SO_4^{2-} the detection limits were 0.005, 0.01 and 0.50 mg/l respectively. Total dissolved solids (TDS) were gravimetrically determined, whereas total hardness, alkalinity and chloride were by titrimetric method (APHA and AWWA 1998).

Table 1. Description of sampling stations.

S/N	Name of stream	Location	Code
1	Otobri	Aburi	AB1
2	Kobi (Jamaica)	Aburi	AB2
3	Opiafo	Mampong	MG1
4	Amankrate	Mampong	MG2
5	Kwati	Larteh	LT
6	Ademi	Akropong	AK
7	Elemi	Adukrom	AD

RESULTS AND DISCUSSION

The field and laboratory results of the streams on the Akwapim Ridge at different seasons are presented in Tables 2 through 5 alongside the natural background quality levels for tropical surface waters (Stumm and Morgan 1981) and WHO limits for drinking water (WHO 1984).

Table 2. Physico – chemical parameters of water samples collected in the dry season (Nov. – Feb. 2001).

Parameter	**AB I**	**AB 2**	**MG 1**	**MG 2**	**LT**	**AK**	**AD**
pH	6.59	6.69	7.20	6.66	7.02	6.10	6.17
Temp	25.00	26.50	27.00	27.00	27.00	25.00	27.00
TDS	430.00	440.00	640.00	610.00	650.00	770.00	-
Cond.	411.00	240.00	1167.00	294.00	951.00	1400.00	175.0
DO	4.27	2.84.	3.01	4.31	3.98	3.33	2.95
BOD	1.93	1.62	0.69	1.18	0.99	0.79	0.51
Hardness	50.00	55.00	101.00	61.00	74.00	74.00	26.00
Alkalinity	60.00	70.00	240.00	80.00	80.00	32.00	34.00

Temp. ^{0}C , TDS mg/l , cond. µS/cm , DO mg/l , BOD mg/l, COD mg/l , Hardness mg $CaCO_3$ /l , Alkalinity mg $CaCO_3$ /l

Table 3. Physico – chemical parameters of water samples collected in the rainy season (May – Sept. 2001).

Parameter	AB I	AB 2	MG 1	MG 2	LT	AK.	AD
pH	6.30	6.03	6.83	6.57	6.81	6.32	6.51
Temp	25.00	27.00	25.00	25.00	24.00	26.00	28.00
TDS	120.00	n.d	360.00	240.00	380.00	963.00	430.0
Cond.	210.00	520.00	650.00	470.00	889.00	1184.00	414.0
DO	5.59	3.05	4.06	3.35	3.25	6.20	3.25
BOD	2.34	0.21	1.32	0.61	0.30	3.36	0.91
COD	43.20	48.00	48.00	56.00	46.40	46.40	39.20
Hardness	40.00	72.00	140.00	84.00	140.00	56.00	50.00
Alkalinity	24.00	20.00	102.00	42.00	62.00	22.00	28.00

n.d. - not determined

Table 4. Major ions, Trace metals and Nutrient Levels (all in mg/l) in waters collected in the dry season (Nov. – Feb. 2001).

Parameter	AB1	AB2	MG1	MG2	LT	AK	AD
Cl^-	134.73	127.65	195.00	131.19	106.35	148.89	95.72
SO_4^{2-}	362.73	107.12	128.40	104.20	239.00	265.40	135.41
Na	9.60	20.70	5.70	2.20	nd	nd	nd
K	11.20	7.10	3.70	1.30	nd	nd	nd
$PO_4 - P$	0.01	0.02	0.02	0.01	0.037	0.004	0.049
$NO_3 - N$	0.110	0.113	0.104	0.096	0.371	0.605	0.021
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	0.10	0.10	< 0.01	< 0.01	1.20	< 0.01	0.20
Fe	0.12	0.16	0.88	0.79	0.32	0.07	2.00
Mn	0.20	0.20	1.50	0.10	0.30	0.30	0.80
Cu	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

BDL - Below Detection Limit n.d. - not determined.

Table 5. Major ions, Trace metals and Nutrient Levels (all in mg/l) in waters collected in the rainy season (May – Sept. 2001).

Parameter	AB1	AB2	MG1	MG2	LT	AK	AD
Cl^-	70.90	106.40	248.20	70.90	177.30	177.30	70.90
SO_4^{2-}	nd	99.80	319.60	124.60	203.60	226.60	109.80
Na	5.00	3.50	16.60	14.70	15.20	26.10	17.60
K	4.40	1.70	13.50	5.70	12.90	19.90	2.70
$PO_4 - P$	0.055	0.041	0.072	0.064	0.078	0.080	0.054
$NO_3 - N$	0.015	< 0.001	0.394	0.228	n.d.	n.d.	n.d.
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Fe	0.18	0.27	0.51	0.58	0.18	0.19	3.53
Mn	0.40	2.70	0.50	0.1	0	0.20	1.00
Cu	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

BDL - Below Detection Limit n.d. - not determined.

The water temperature varied from 24^0C in the wet season to 28^0C in the dry season with a mean temperature of 26.05^0C Tables 2 and 3. These values are within the natural background level of 22 – 29^0C for waters in the tropics (Stumm and Morgan 1981). The slight increase in temperature in the dry season is probably due to the low cloud cover and direct sun-rays during the dry season coupled with excessive evaporation from surface waters. The mean pH also varied
from 6.52, for example, in Aburi (AB2) wet season to 7.20 in the dry season for Mampong (MG1), which conform to values found in fresh waters Table 2 and 3 (Stumm and Morgan 1981). None of the TDS values recorded exceeded the WHO recommended limit of 1000mg/l for drinking water (WHO 1996) Tables 2, and 3.

The mean conductivity levels of the streams are within the limits of acceptable standards (700μS/cm) (WHO 1984) for domestic water but were above the background range of 50 - 300μS/cm (Stumm and Morgan 1981). Most of the sampling points however gave values above the WHO limits particularly all in the dry season (Table 2). The mean values for these streams over the entire sampling period were observed to be generally high. This is suggestive of heavy impact of, human activities on the streams, runoffs emerging from farming lands, drains from the communities into the catchment areas of the streams, and possibly rock weathering followed by dissolution.

Alkalinity, Total Hardness, Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) levels recorded were all within the WHO recommended levels for drinking water. The BOD values for all the streams sampled ranged between 0.21mg/l at AB2 (Aburi) and 3.36mg/l at AK in Akropong for the wet season, Table 3. This reveals low organic matter contamination of the waters sampled. The overall mean value of 1.2mg/l recorded fell within the WHO recommended value of < 3.0mg/l for drinking water (WHO 1996). In contrast, the amount of sulphate detected in the area, exceeded the WHO limit of 200mg/l for drinking water, with the highest in the dry season, Table 2. These high levels are the consequence of intense vegetable farming activities along the banks of these streams, due to the application of fertilizers and agro chemicals. MG1 and AK streams were characterized by high chloride concentration. Chloride levels were almost up to the WHO limits of 250mg/l for drinking water Tables 4 and 5. Values of 248mg/l and 177.30mg/l were found for MG1 and AK in the wet season respectively, which could be due to the numerous farming activities along the banks and sewage effluence from the upper parts of Mampong and Akropong townships. Comparatively, potassium and sodium levels recorded in streams on the Akwapim Ridge were insignificant and far below the WHO values of 30mg/l and 200mg/l respectively for drinking water. Additionally, concentrations of nitrate and phosphates found in all sites were far below WHO limits, which, demonstrate low biological productivity. Hence, less eutrophication of the aquatic ecosystem.

Trace metal concentrations in the streams were very low, indicative of lesser industrial activities on the Akwapim Ridge. The higher concentration of Fe and Mn in the water samples is a reflection of the geology of the mountains, Tables 4 and 5. The mean concentrations of both iron and manganese, were above the WHO limit of

0.30mg/l and 0.1mg/l respectively for drinking water. Though the presence of Fe and Mn in water are not hazardous to health, they are considered as aesthetic. However, high levels could result in reddish brown colouration of the water (WHO 1996).

The streams on the Akwapim Ridge showed seasonal variations of concentration in all water quality parameters examined. Thus the study revealed that most of the water quality defined parameters of the streams were below the WHO limits for drinking water and therefore may be suitable for domestic purposes. Although, the levels of sulphate recorded at MG1 (224mg/l), LT (221.30mg/l) and AK (246mg/l) in addition to conductivity at AK (1292μS/cm), LT (920μS/cm) and MG1 (908.50μS/cm) were above the WHO recommended values (WHO 1996). Moreover, the study indicated no danger of nitrite poisoning from the stream waters, as the concentration of nitrate $NO_3 - N$ was far below the critical value of 10mg/l. In addition, human activities along the banks of the streams and inflow of domestic sewage from communities in the catchment areas of the streams were found to have great impact on the quality of water from streams and need attention to avoid long term pollution and destruction of the ecosystem.

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