An Assessment of Water Quality of Angaw River in South-eastern Coastal Plains of Ghana

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Abstract

Physico-chemical and bacteriological water quality of the Angaw river were investigated at three different locations on the river. A range of water quality variables were measured in the river over a period of 12 months. The river was characterized by high ionic content. Relatively higher levels of ionic constituents occurred at the upstream while lower concentrations were observed downstream due to the influence of River Volta, which has lower ionic content. There was a dominance of Na and Cl over the cationic and anionic components, respectively, due to the effect of atmospheric deposition of sea salt. Calcium and magnesium showed a strong linear correlation $r = 0.993$ significant at $p < 0.05$, indicating biogeochemical mineral weathering. The water was moderately hard (mean range of 89-133 mgl^{-1} $CaCO_3$), salty and neutral with mean *p*H of 7.3±0.13. Conductivity, TDS and the major ions varied seasonally with elevated levels in the rainy season. However, nutrients levels were low during the study period and did not give any clear seasonal variation. The bacteriological quality of the water was poor, rendering it unsafe for domestic purposes without treatment. However, the water was suitable for primary and secondary contacts such as swimming and fishing. The poor bacteriological quality was due to direct contamination by animal and human wastes.

Introduction

Rivers are the most important freshwater resource for man. Social, economic and political development has been largely related to the availability and distribution of freshwaters contained in riverine systems. Water quality problems have intensified through the ages in response to the increased growth and concentration of populations and industrial centres. Polluted water is an important vehicle for the spread of diseases. In developing countries 1.8 million people, mostly children, die every year as a result of water-related diseases (WHO, 2004).

Ghana's water resources have been under increasing threat of pollution in recent years due to rapid demographic changes, which have coincided with the establishment of human settlements lacking appropriate sanitary infrastructure. This applies especially to peri-urban areas, which surround the larger metropolitan towns in the country. Many such settlements have developed with no proper water supply and sanitation services. People living in these areas, as well as downstream users, often utilise the contaminated surface water for drinking, recreation and irrigation, which creates a situation that poses a serious health risk to the people (Verma & Srivastava, 1990).

The River Angaw runs through farmlands and rural communities before its confluence with River Volta. Not much studies have, however, been done on the water quality of the river. This would be of importance since water supply treatment was being planned to supply water to the entire community at the time of the study.

A number of factors influence water chemistry. Gibbs (1970) proposed that rock weathering, atmospheric precipitation, evaporation and crystallisation control the chemistry of surface water. The influence of geology on chemical water quality is widely recognised (Gibbs, 1970; Langmuir, 1997; Lester & Birkett, 1999). The influence of soils on water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water (Hesterberg, 1998). Apart from natural factors influencing water quality, human activities such as domestic and agricultural practices impact negatively on river water quality. It is, therefore, important to carry out water quality assessments for sustainable management of water bodies.

The study serves to determine the water quality of River Angaw. It provides the physico-chemical and bacteriological characteristics of the water and, finally, contributes towards the limnological knowledge of the river.

Materials and methods

Study area

River Angaw is situated few kilometers from Ada Foah, a town noted for its beautiful beach and holiday resort (Fig. 1). The river is located between latitude 5° 45'–5° 50' N and longitude 0° 34'–0° 38' E. River Angaw follows a course of about 19.48 km to join the Volta Lake. There is virtually no industrial development in the area. Pollution within the area may come from human waste. The use of agro-chemicals is a potential problem, though the amounts in use are currently limited by high cost. The main economic activities in the catchment area are fishing, basket weaving and crop farming along the banks of the river. Major crops include vegetables, maize and cassava.

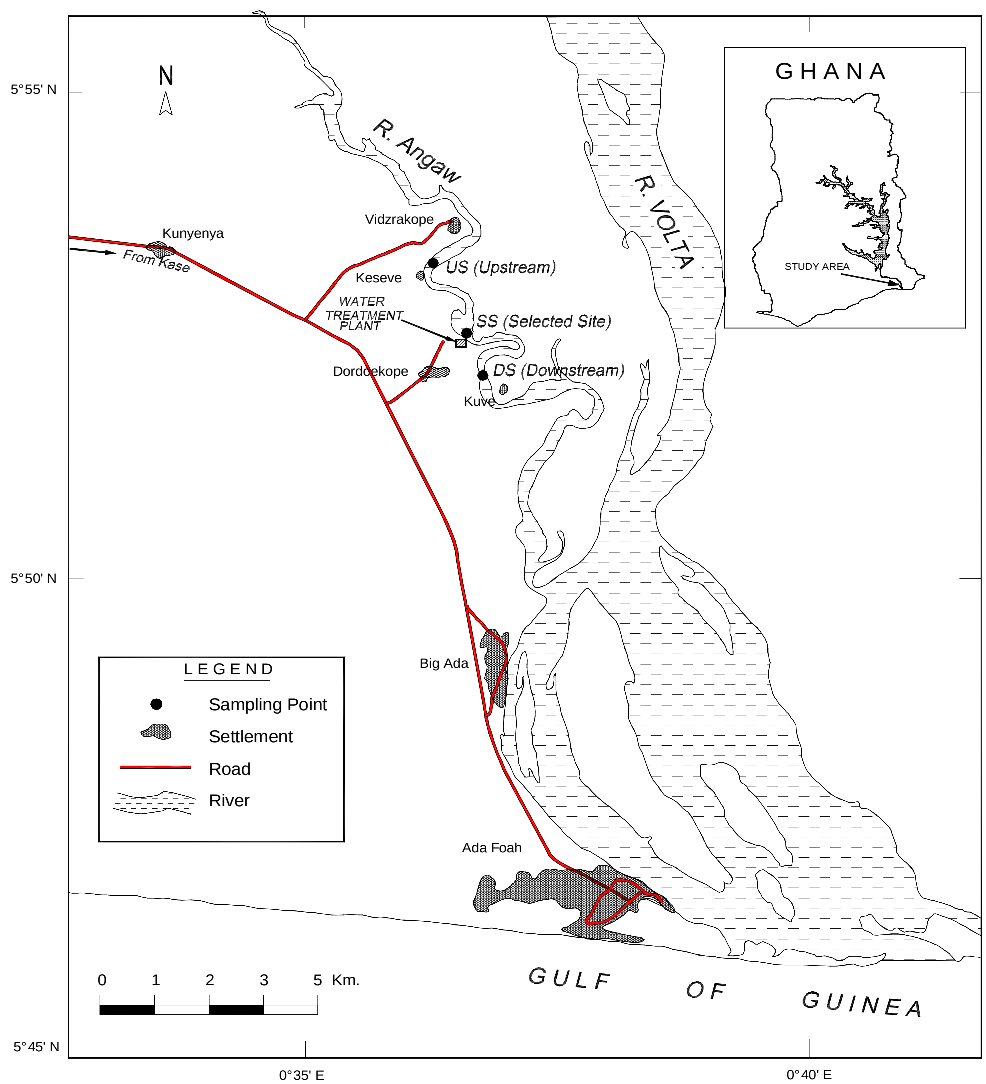

Fig. 1: Map showing the sampling points in the study area

The study area experiences two seasons; a dry season from November to March and a two maxima rainfall. According to data from the Ghana Meteorological Agency at the Ada synoptic station, the major rains occur between April and June with a break in July while the minor rains occur between August and October. Meteorological data (1994–2004) at the Ada synoptic station revealed that the annual rainfall for the study area was 796.3 mm with mean daily temperatures ranging between 25.9 in August and 30.0 in March.

Sampling

Three sites on River Angaw were selected and monitored once a month over a period of one year, from September 1997 to August 1998. The first site was located near the proposed water treatment plant known as selected site (SS) at Keseve. The other two sampling sites were located about 2 km upstream (US) and downstream (DS) of the proposed water supply treatment plant. Surface water samples for physico-chemical analyses were collected mid-stream at depth 20-30 cm directly into clean 1-litre plastic bottles. Temperature and *p*H were measured *in situ*, using a temperature probe and portable *p*H meter, respectively. For dissolved oxygen (DO) determinations, samples were collected into 300-ml plain glass bottles and the DO fixed using the azide modification of the Winkler's method. Samples for bacteriological analyses were collected into sterilized plain glass bottles. All samples were stored in an icebox and transported to the CSIR-Water Research Institute's Laboratory in Accra for analyses.

Laboratory analyses

The methods outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998) were followed for the analyses of all the physico-chemical parameters. Conductivity was measured with Jenway model 4020 conductivity meter, and turbidity with a Partech model DRT 100B Turbidimeter. Sodium and potassium were measured by flame emission photometry; calcium and magnesium by EDTA titration; sulphate by the turbidimetric method; colour by colour comparator and chloride by argentometric titration. Other analyses included alkalinity by strong acid titration method.

Nitrate-nitrogen was analysed by hydrazine reduction and spectrometric determination at 520 nm, nitrite-nitrogen by diazotization and spectrophotometric determination at 540 nm, phosphate by reaction with ammonium molybdate and ascorbic acid, and measured at 880 nm, and ammonium by direct nesslerisation and spectrophotometric determination at 410 nm. Fluoride by SPADNS method and total dissolved solids, and suspended solids were measured gravimetrically after drying in an oven to a constant weight at 105 ^{o}C. Total and faecal coliforms were determined by membrane filtration method using M-Endo-Agar Les (Difco) at 37 ^{o}C and on MFC Agar at 44 ^{o}C, respectively.

Statistical analysis

Pearson's rank correlation was used to establish relations between parameters. All tests were two-tailed. The analyses were executed by SPSS (version 12 for Windows, year 2003).

Results and discussion

The physico-chemical and bacteriological characteristics of River Angaw are presented in Tables 1and 2, and Fig. 2-4.

TABLE 1

Physical characteristics of Angaw river.

Parameter	*Upstream (US)*		*Selected site (SS)*		*Downstream (DS)*	
	Mean±SD	*Range*	*Mean±SD*	*Ran ge*	*Mean±SD*	*Range*
Temperature (°C)	29.5±1.8	26.0–33.5	29.1±1.7	26.8–32.6	29.4±2.0	26.4–33.8
*p*H	7.2±0.13	7.0–7.4	7.3±0.09	7.1–7.4	7.3±0.11	7.1–7.5
Turbidity (NTU)	2.96±1.3	0.90–5.10	2.28±1.2	0.60–4.60	1.75±0.87	0.70–3.40
Conductivity (µS/cm)	947±194	698–1222	742±321	412–1400	608±394	243–1306
TDS (mgl^{-1})	603±155	436–960	474±173	290–772	376±210	186–724
SS (mgl^{-1})	8.56±4.3	3.00–18.0	7.11±3.2	2.00–10.0	5.50±3.4	1.00–9.00
Total hardness(mgl^{-1})	133±20.6	96.2–159	107±28.0	70.2–145	89.0±40.2	46.0–15
Alkalinity (mgl^{-1})	43.1±3.1	38.0–48.0	40.6±2.7	37.0–44.0	35.8±4.7	26.0–42.0
DO (mgl^{-1})	6.15±0.96	5.00–7.80	6.51±0.86	5.30–8.70	6.87±0.79	6.00–8.50

TABLE 2

Nutrient concentrations of Angaw River in mgl^{-1}

Parameter	*Upstream (US)*		*Selected site (SS)*		*Downstream (DS)*	
	Mean±SD	*Range*	*Mean±SD*	*Range*	*Mean±SD*	*Range*
Nitrate-N	0.88±1.7	0.14–6.1	0.321±0.42	0.005–1.5	0.304±0.47	0.005–1.7
Phosphate-P	0.030±0.05	0.002–0.14	0.05±0.12	0.002–0.40	0.030±0.05	0.002–0.15
Ammonia-N	0.191±0.22	0.005–0.55	0.144±0.11	0.005–0.28	0.113±0.17	0.005–0.50
Silica	14.2±3.2	7.75–18.6	11.0±3.1	5.64–14.3	11.2±3.4	4.50–14.6

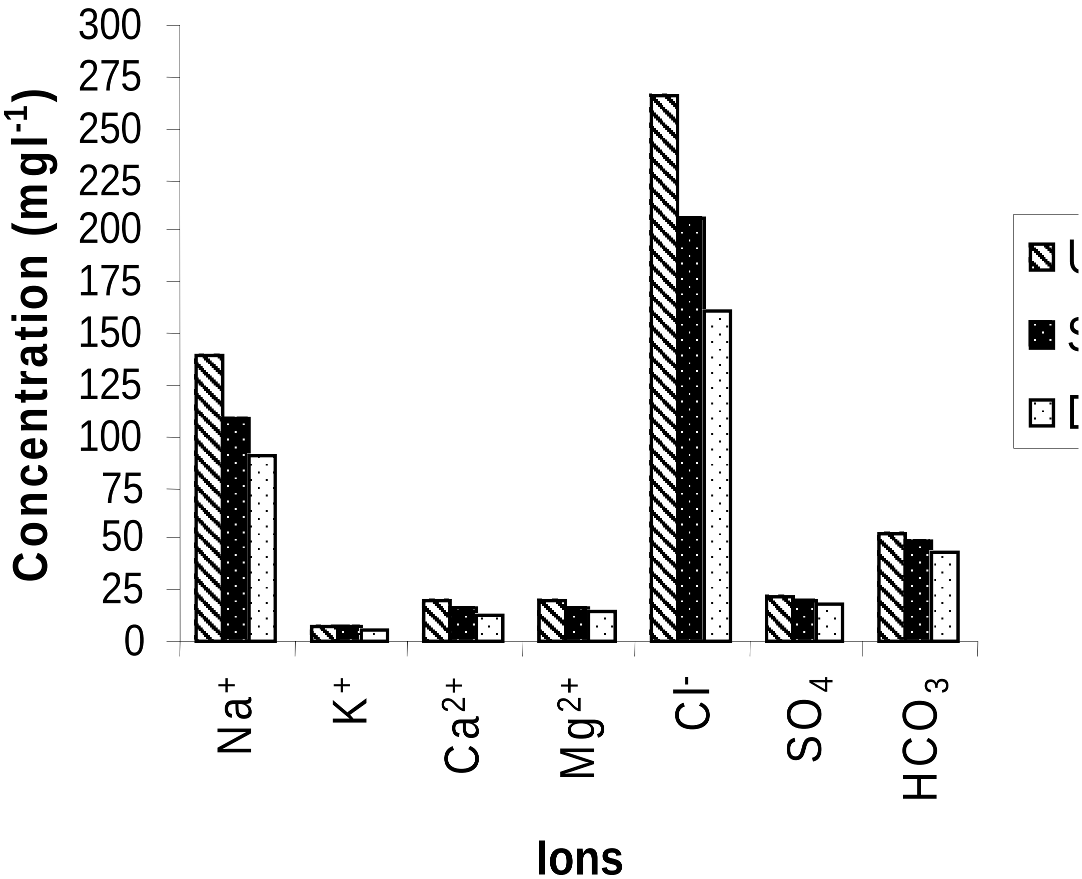

Fig. 2. Mean ionic concentrations of Angaw river

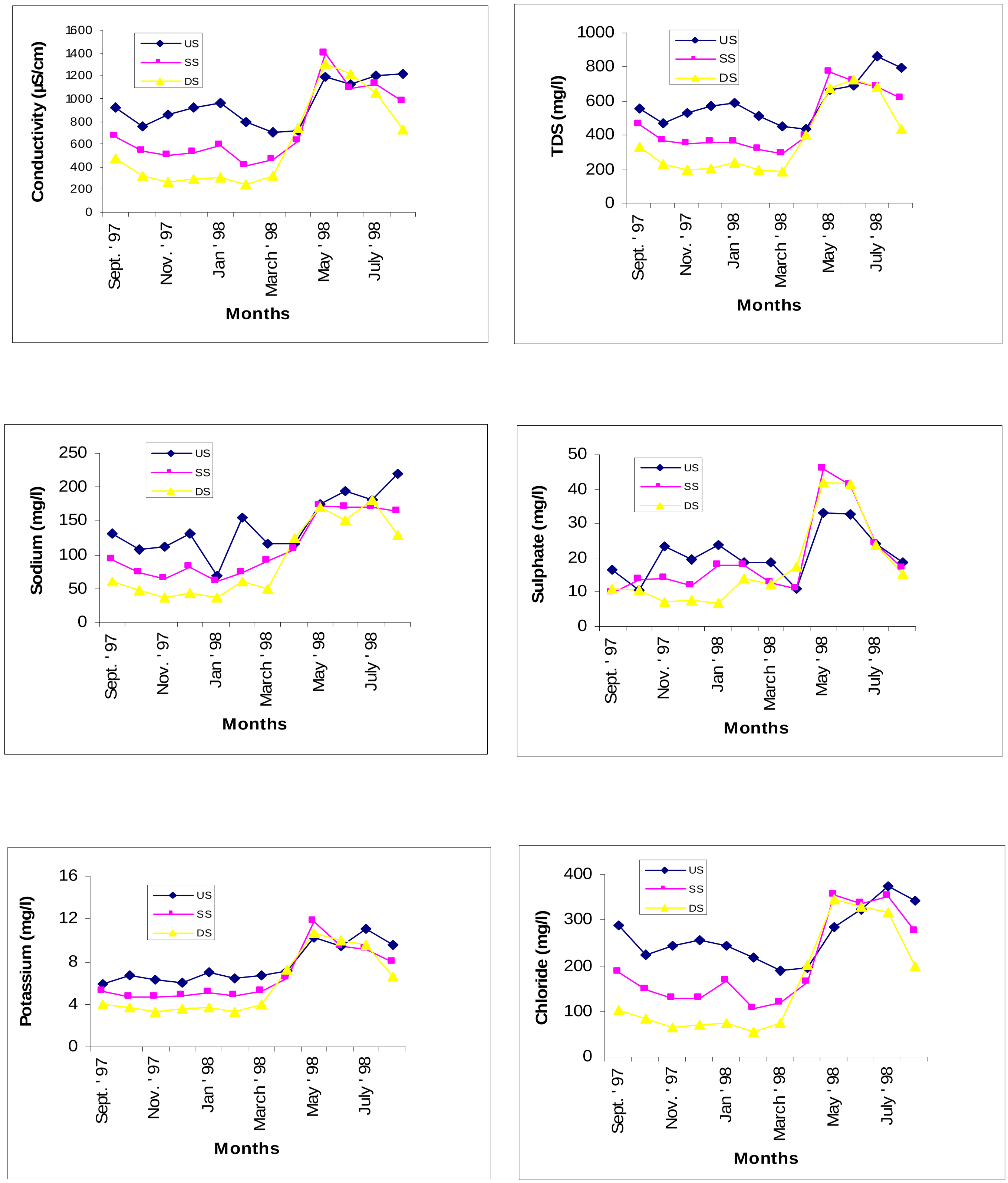

Fig. 3. Seasonal variation of conductivity, TDS, sodium, sulphate, potassium and chloride in Angaw river

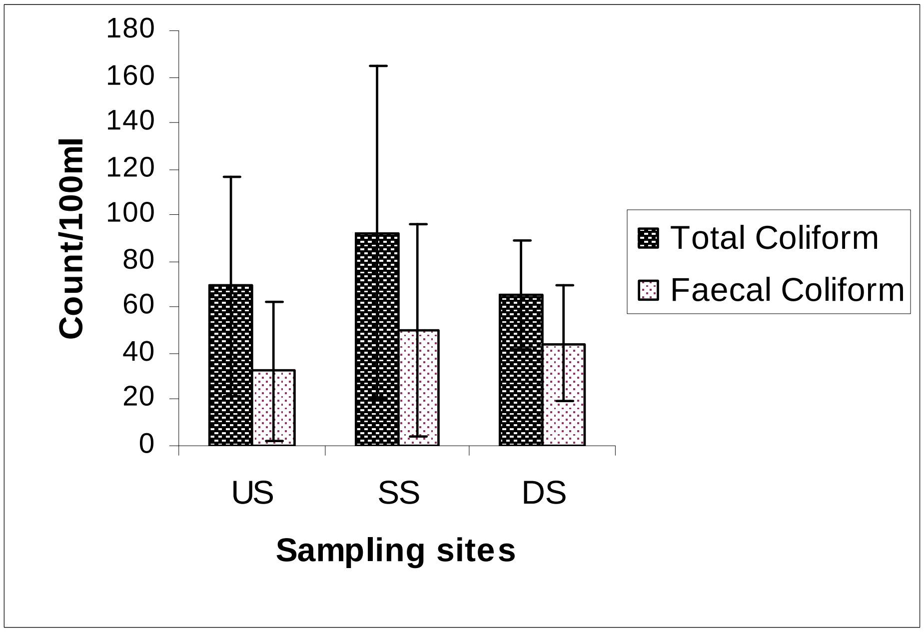

Fig. 4. Mean ±SD total and faecal coliforms of upstream (US), selected site (SS) and downstream (DS) of Angaw River

Physical characteristics

The mean *p*H of the river water was neutral at all stations for the study period with a range of 7.2–7.3. The *p*H fell within the range associated with most natural waters which is between 6.0 and 8.5 (Chapman, 1992), stipulated for drinking and domestic purposes. The mean conductivity of the river ranged between 608 and 947 µS/cm in this order of increasing magnitude: downstream < selected site < upstream. This order prevailed most of the time throughout the study period. The downstream recorded relatively low conductivity throughout the monitoring, due to dilution from River Volta which has much lower conductivity (62–77.5 µS/cm) (Antwi & Ofori-Danson, 1993). The upstream level was always high probably due to the nature of the soil at the water source.

Mean values of turbidity were 2.96 NTU, 2.28 NTU and 1.75 NTU for the upstream, selected site and downstream, respectively. The levels of turbidity recorded in this study were comparable to those reported for River Volta at Akuse (mean range 2.8–3.2 NTU) by Water Research Institute (1999). However, average turbidity recorded in Birim basin (37.5 NTU) by Ansa-Asare & Asante (2000) were much higher than those observed in the study. The low turbidity throughout the sampling period suggests that discharges from domestic effluents and run-offs from agricultural activities that reach the river may be minimal or large particulates that readily settled to the bottom. The low turbidity of the river will facilitate water purification processes such as flocculation and filtration, which could reduce treatment cost.

The hardness of the river reduced from upstream to the downstream. The US, SS and DS recorded average hardness levels of 133, 107 and 89 mgl^{-1} $CaCO_3$, respectively. The relatively lower levels downstream may be attributed to the influence of River Volta which has very low levels of hardness (19–38 mgl^{-1} $CaCO_3$) (Antwi & Ofori-Danson, 1993). Alkalinity followed a similar trend as hardness.

Dissolved oxygen (DO) mean levels varied between 6.15 and 6.87 mgl^{-1}. The downstream had relatively higher oxygen throughout the study. This might be due to the windy nature of the area and the regular mixing of the water with the Volta Lake which has higher DO content. Pristine surface waters are normally saturated with DO, but such DO can be rapidly removed by oxygen demand of organic wastes. The measurement of DO provides a broad indicator of water quality (DFID, 1999). DO concentra-tions in unpolluted water are normally about 8.0–10 mg/l (at 25 ^{o}C) (DFID, 1999). Concentrations below 5.0 mgl-^{1} adversely affect aquatic life. The concentration of DO in the Angaw river were above 5.0 mgl-^{1} and, therefore, the river water would be suitable for use of the aquatic ecosystem.

Nutrients

NH_4-N, NO_3-N and NO_2-N are considered to be non-cumulative toxins (Dallas & Day, 1993). High concentra-tions of NO_3-N and NO_2-N may give rise to potential health risks particularly in pregnant women and bottle-fed infants (Kempster *et al*., 1997; Kelter *et al*., 1997). NO_3-N at elevated concentra-tions is known to result in cyanosis in infants. Ammonia is naturally present in surface water and groundwater and can be produced by the deamination of organic nitrogen containing compounds and by the hydrolysis of urea. The problem of taste and odour may, however, arise when the NH_4-N level is greater than 2 mgl-^{1}. Above 10 mgl^{-1}, appreciable amounts of NO_3-N may be produced from NH_4-N under suitable anaerobic conditions (WHO, 1993; Kempster *et al*., 1997).

The mean concentrations of nutrients are presented in Table 2. Nitrate levels averaged 0.880 mgl^{-1} as N at the upstream; 0.321 mgl^{-1} at the selected site and 0.304 mgl^{-1} at the downstream. The average NO_3-N concentration of Angaw river was much higher than the 0.1 mgl^{-1} for unpolluted world rivers (Webb & Walling, 1992). The WHO safe limit for nitrate for lifetime use is 10 mgl^{-1} as N (WHO, 1984). This limit was not exceeded in the river water; thus, nitrate is not considered to pose a problem for the domestic use of water from the river. However, nitrate could be a problem for other uses because of eutrophication (Rast & Thornton, 1996).

Mean levels of ammonia were 0.191 mgl^{-1}; 0.144 mgl^{-1} and 0.113 mgl^{-1} for upstream, selected site and downstream, respectively. Low ammonia concentrations were also observed in the Kpong Reservoir by Antwi & Ofori-Danson (1993) with a mean of 0.02 mgl^{-1} and a range of < 0.001–0.12 mgl^{-1}. At Akuse on the Volta river, Water Research Institute (1999) recorded a mean level of 0.21 mgl^{-1} ammonia and a range of 0.193–0.227 mgl^{-1}. Unpolluted waters contain small amounts of ammonia, usually less than 0.1 mgl^{-1} (Chapman, 1992). The concentrations of ammonia in the Angaw river for the duration of the study were not alarming due to low anthropogenic activities reaching the river.

Phosphurous is the limiting nutrient for algal growth and, therefore, controls the primary productivity of a water body. In most natural surface waters, phosphorous ranges from 0.005 to 0.020 mgl-^{1} PO_4-P (Chapman, 1992). In some pristine waters concentra-tions as low as 0.001 mgl-^{1} may be found. Mean levels of phosphates were 0.030 mgl-^{1} as P at the US; 0.050 mgl-^{1} at the SS; and 0.030 mgl-^{1} at the DS. High concen-trations of phosphate can indicate the presence of pollution and are largely responsible for eutrophic conditions. Eutrophication-related problems in warm-water systems begin at P concentrations of the order 0.34–0.70 mg P/l (Rast & Thornton, 1996). The associated N concentrations would be of the order 0.34–0.70 mg N/l.

It is accepted that these represent nutrient threshold levels, beyond which there will be a corresponding increase in the risk and intensity of plant-related water quality problems (OECD, 1982). River Angaw was not observed to be eutrophic, nevertheless, care must be taken so that eutrophication would not be a problem in the river. The river is being abstracted and treated to supply water to Ada Foah, Kasseh and its environs and eutrophication could increase its treatment cost through filter clogging in water treatment works (Murray *et al*., 2000).

Silica is an essential element for aquatic plants (e.g. diatom). It is taken up during cell growth and released during decomposi-tion and decay giving rise to fluctuations. The mean silica values (between 11 and 14.2 mgl^{-1}) observed in the river (Table 2) was higher than the world average of 9 mgl^{-1} in rivers (Horne & Goldman, 1995) but fell within 1-30 mgl^{-1} which is the range for most rivers and lakes (Chapman, 1992).

Major ions

The concentrations of the major cations in the river were generally in the order of Na > Mg > Ca > K. The major anion concentrations followed the order Cl > HCO_3 > SO_4. The cationic dominance pattern was similar to that of seawater but the anionic dominance pattern was a blend between those of the seawater and freshwater. A general downstream decrease in the river water concentrations was observed for the majority of determinands (Fig. 2). Correlation between mean values of selected determinands revealed expected process-based relationships, such as that between Ca^{2+} and Mg^{2+} (r = 0.993; p < 0.05) derived mainly from biogeochemical mineral weathering and that between Na^{2+} and Cl^- (r = 0.998; p < 0.05) derived mainly from atmospheric deposition. However, there were also many strong linear relationships between determinand species that are not normally expected to be linked in terms of processes. Examples of significant correla-tions between apparent unrelated species include those between Ca^{2+} and Cl^- (r = 0.999; p < 0.05), between Na^+ and NO_3^--N (r = 0.935) and between K^+ and SO_4^{2-} (r = 0.858).

Seasonal variation of chemical parameters

There were seasonal changes associated with the conductivity and the general tendency was high values during the rainy season (May, June and July) and relatively lower values in the dry season (Fig. 3). This observation reflected in high TDS, chloride, sodium, potassium, sulphate and magnesium in the river water during the rainy season. These parameters varied for all the sites with the seasons and were generally high during the rainy season (Fig. 3). However, nutrients such as orthophosphate, nitrate-nitrogen and ammonia-nitrogen did not show any clear seasonal variation.

Conductivity values have a direct relationship with the concentration of TDS and major ions in water (Chapman, 1992). The elevated levels of the conductivity, TDS, chloride, sodium, potassium, sulphate and magnesium during the rainy season could be attributed largely to soil salts that were flushed into the river by run-off. High sodium and electrical conductivity levels were observed in soils in the study area. These were attributed to enrichment from ingressed seawater and deposition by salty water particles carried by the wind (FAO, 1988) judging from the basin's proximity to the Atlantic Ocean. According to Asiamah (1995), there are four possible sources of salts in the soils, ocean drift, underground water, deposition by wind and mineral weathering in the till.

The maximum conductivity value of 1,400 µS/cm occurred in May at the selected site (SS). There is currently no official guideline as to what is considered a safe level for conductivity. However, according to Chapman (1992), conductivity of most freshwaters range from 10-1000 µS/cm but may exceed 1000 µS/cm especially in polluted waters, or those receiving large quantities of land run-off.

Bacteriological water quality

The results obtained for bacteriological analysis are shown in Fig. 4. The data collected indicated that the microbial water quality of the Angaw river was poor. Total and faecal pollution occurred at all sampling stations throughout the sampling period, rendering the water unsuitable for domestic use without treatment. However, the river is suitable for primary and secondary contacts such as swimming and fishing. The mean total coliform counts for the upstream, selected site and the downstream were 69.3 ±47.4 cfu/100 ml, 92.5 ±71.7 cfu/100 ml, and 65.3 ±23.7 cfu/100 ml, respectively. The mean faecal coliform counts were US (33.3 ±30.0 cfu/100 ml); SS

(50.5 ±46.1 cfu/100 ml) and DS (44.3 ±24.8 cfu/100 ml). These counts were far above 0 cfu/100 ml, which is the recommended limit for no risk (WHO, 1987). These results imply the water source poses a health risk to consumers. The presence of pathogenic organisms in the water could be attributed to human and animal wastes from the communities along the river.

Although the microbial pollution is high for River Angaw, thus rendering the water unfit for human consumption, it is low in comparison with those of the Kakum, Nakwa and Birim rivers as reported by Ampofo (1997). In the interpretation of microbial data, it is very important to note that microbial constituents have a strong non-conservative behaviour in water. The concentration of the amount entering the water could change independently through various processes such as growth, settling to the sediments, chemical reactions and decay (DWAF, 2000).

Conclusion

The results indicated that most of the physico-chemical quality parameters of River Angaw were within the WHO limits for drinking water and, therefore, may be suitable for domestic purposes. In contrast, however, the bacteriological quality of the water points, as suggested by the total and faecal coliform counts, exceeded the standard (0 cfu/ 100 ml) for potable water. In general, the bacteriological quality of the water was unacceptable, and would pose a serious risk to consumers without treatment. The poor bacteriological quality was due to direct contamination by animal and human wastes.

The striking characteristic of River Angaw is its high ionic content which is reflected in high conductivity, total dissolved solids and sodium levels. Relatively higher levels of most physico-chemical constituents occurred at the upstream while lower concentrations were observed downstream due to the influence of River Volta which has lower ionic content. Conductivity, TDS and most major ions varied seasonally with elevated levels in the rainy season. However, nutrient levels were low during the study period and did not give any clear seasonal variation. Even though the nutrient concen-trations were low, care must be taken by the inhabitants and the District Assembly to avoid eutrophication in the river since it is being abstracted and treated for water supply.

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