Water Quality Assessment in some selected communities along the Volta River

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ABSTRACT

Surface water samples and sediments from seven contact sites at the Volta River where small, large and domestic activities discharge their wastes were sampled. Levels of heavy metals in the samples were determined using flame atomic absorption spectrometry (FAAS). The sediments samples in the study area were moderately enriched with manganese while exhibiting minor enrichment with copper, zinc, nickel and arsenic. The geo-accumulation index showed that the study sites were currently practically unpolluted. In the long term, the situation might change.

Keywords: Heavy metals, Volta River, FAAS, Ghana, water

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1.0 INTRODUCTION

Pollution generally associated with heavy industrialization and dense population is a major menace of concern to the ecology of the Volta river basin. Aquatic environmental pollution comes from both natural and anthropogenic sources and can affect both water and biota. Some of the aquatic pollutants are sewage, inorganic plant nutrients, organic compounds, inorganic chemicals and radioactive substances.

Industries and human activities along the Volta River basin include the Banana Farm at Senchi. Inorganic plant nutrient used by the farmers is eventually washed by runoff into the Volta River as it rain. 81% of respondent admitted that they could not drink or use the Volta River for any domestic activities in such times. They added that during such period they observed oily substance covering the surface of the River and dead fishes floating. Domestic wastes from the Akosombo Continental Hotel as well as waste from the Atimpoku Abatoire (Slaughter house) are discharged into the Volta River. Effluent from the Toilet roll factory at Afabeng, a sub village of Atimpoku is discharge into the River.

Heavy metals and agrochemicals are among the most common environmental pollutants identified in water and biota. The health effect of these pollutants to humans at the top of the food chain therefore offers a justifiable ground to continually investigate these constituents and their occurrence in water and biota to indicate the presence of natural or anthropogenic sources. The existence of heavy metals in aquatic environment has led to serious concern about their influences on aquatic life. Long term effects of heavy metal pollution on the river water quality at the Volta River are poorly known.

According to a release by the Environmental Protection Agency (EPA) of Ghana, it was reported on August 19, 2002 that sections of the Volta River (Akosombo, Juapong and Kpong) are being polluted from unknown sources. This is evidenced in dead fishes that were floating on the water which were collected and sold to the unsuspecting public.

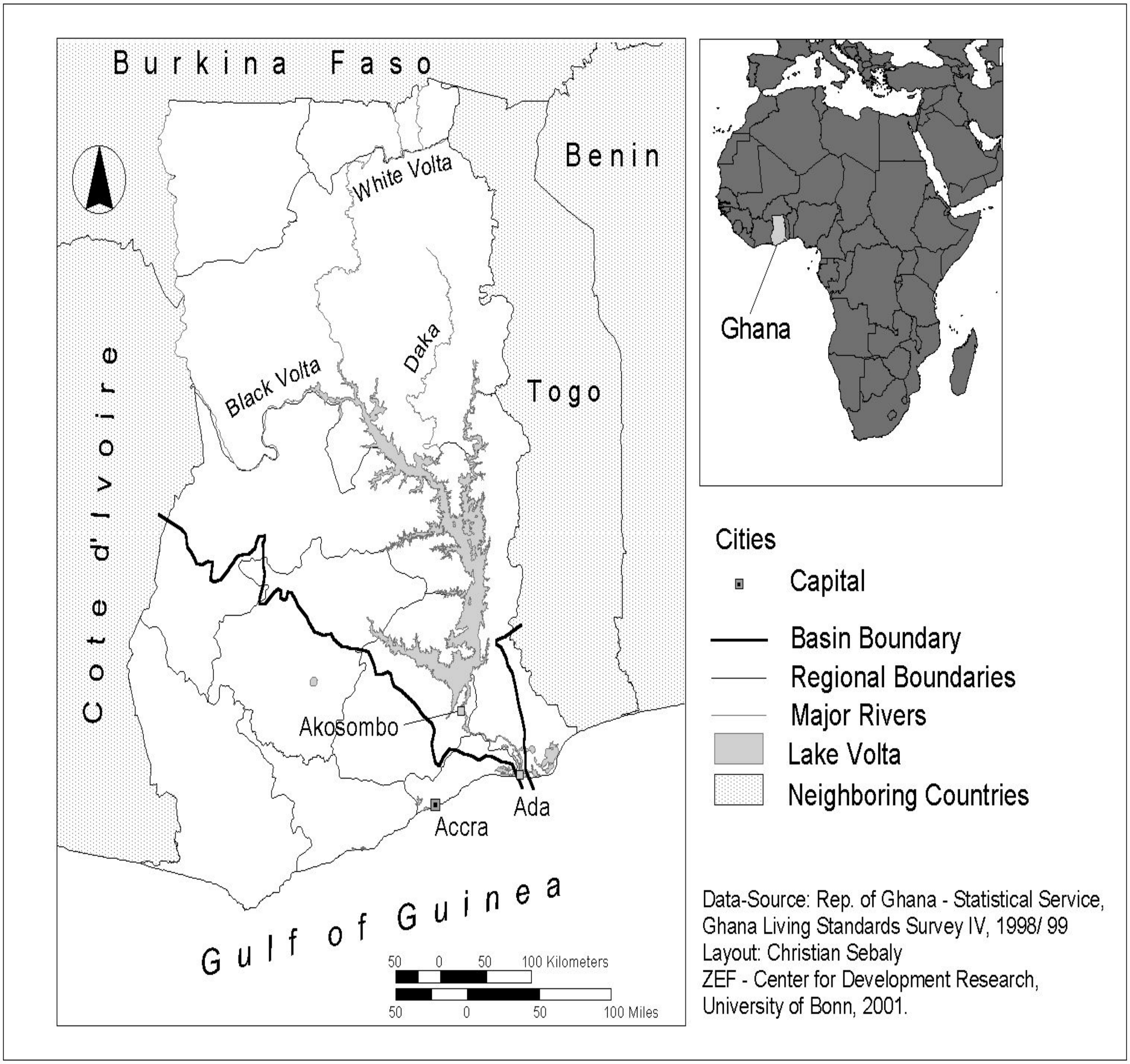
The main objective of this research work is to characterize and evaluate the major pollutants of the Volta River and assess any human health effects to dwellers from selected communities along the Volta River. This shall be achieved through measuring the physico-chemical parameters of water samples as well as determining the distribution of heavy metals and agrochemicals in water and biota samples. This study is to detect the principal pollutants produced by six chemical industries that discharge their effluent into the Volta River as well as activities of inhabitants along the River and assess the effect of these point source pollutants on aquatic life and consequently on humans.

2. METHODOLOGY

2.1 study area

The Study was conducted in towns and villages along the Volta River at the lower Volta basin in the south western part of Ghana. Majority of people living along the banks are mainly fisher folks while other economic activities in the catchment area include crop farming and basket weaving. There is a concentration of industries such as hotels and restaurants; textiles and also commercial plantations that make use of agrochemicals. The River serves as important resources for domestic and industrial water supply, occupation, transport and recreation. The study area has two yearly rainfall patterns. Major rains occur between April and June with a break in July while the minor rains occur between August and October. A major feature of the Volta River Basin is the high rainfall variability in the upland areas with frequent droughts and seasonal water shortages and problems of water security (IFPRI, 2005)

Fig. 1 Study Area



Data-Source: Rep. of Ghana - Statistical Service,
Ghana Living Standards Survey IV, 1998/ 99
Layout: Christian Sebaly
ZEF - Center for Development Research,
University of Bonn, 2001.

(Source: Asante et al., 2002)

2.2 Collection of water and sediment samples

Water samples were collected from six contact points namely ACH, AF, AKS, KP, AT, ATL and SS. Detailed descriptions of the sampling locations are presented in Table 1.

Sampling points	Location of sampling point
ACH	Akosombo Continental Hotel at Atimpoku near Adomi Bridge
AF	Toilet Roll Factory at Afabeng a sub village of Atimpoku
AKS	Akosombo waste treatment discharge point
KP	Kpone Head Pond at Ayikpala
AT	Atimpoku Abattoir (Slaughter House)
SS	Banana Farm at Senchi
ATL	Akosombo Textile Limited

Table 1 Description of sampling locations

Sampling of water was done using the “clean hand, dirty hands” techniques according to the method recommended by the USEPA method 1669 (Sampling ambient water for determination of metals at EPA water quality criteria levels). Four samples were picked from each sampling point.

Collection of Sediment was done with a pre-cleaned polyethylene shovel (Donkor et al., 2006). Two sediment samples were picked from each station; however no sediment sample was picked at the sampling point ACH. Samples were immediately transferred into in tightly covered plastic bottles. No preservatives were added to the samples (Serfor-Armah et al., 2006). The bottles containing the water and sediment samples were then placed in hermitically closed polyethylene bags; the bags containing the samples were stored in thermo-insulated boxes with ice packs and transported to the laboratory at the Nuclear Chemistry and Environmental Research Centre of the Ghana Atomic Energy Commission, for analysis.

2.3 Samples preparation and analysis

At the laboratory, the water samples were filtered by suction through a Whatman membrane filter of pore size 0.45 µm. The samples were then stored in a refrigerator at 4 ^{o}C until analysis.

Sediment samples were air-dried, and micro-organisms, organic debris, stones and Shelly fragments were gloved hand picked from the sediment. The air-dried sediment samples were ground in a mortar to obtain homogenates and then passed through a 180 µm sieve to remove coarse particles. The samples were stored at 4 ^{o}C in acid-washed plastic bottles with screw caps (Adotey et al., 2011).

6 mL of HNO_3 (65%), 3 mL of HCl (37%) and 0.25 mL of H_2O_2 (30%) were added to 5 mL of water sample in Teflon digestion tubes, the tubes were covered tightly and

placed in the ETHOS 900 microwave digester. The water samples were digested for 21minutes at a temperature of 400-500 ^{0}C. At the end of the digetion, the digest was cooled, transferred into clean 25 mL volumetric flask and diluted to 20 mL with double-distilled water. Digestion of water samples was done according to the procedure described by Hoenig et al., (1998). The digests were used for the measurement of iron (Fe), manganese (Mn), copper (Cu), chromium (Cr), cadmium (Cd), nickel (Ni), lead (Pb), zinc (Zn), magnesium (Mg), cobalt (Co), arsenic (As) and mercury (Hg) using the Varian AA240 FS atomic absorption spectrometer. Acetylene gas and air were used as fuel and oxidant, respectively. The flow rates for acetylene and air 2 and 13.5 L/min, respectively, were kept constant for the analysis of the metals. The analysis of Mg by atomic absorption spectrometer was achieved by diluting 1 ml of the water sample to 10 ml with lanthanum solution prior to analysis.

The powdered sediment samples were digested by adding 6ml (65% HNO3) and 3ml (HCl) to 0.25 g of the powdered samples in a Teflon beaker and digested per the digestion code 308 (Milestone acid digestion cookbook 1996). The digests were diluted and analyzed for Fe, Mn, Cu, Cr, Cd, Ni, Pb, Zn, Mg, Co, As, and Hg similarly as described above for the water samples.

2.4 Sample analysis

Analytical instruments were precalibrated appropriately prior to measurements. Replicate analyses were carried out for each determination to ascertain the reproducibility and quality assurance. Electrical Conductivity, total dissolved solids, salinity, and temperature were measured in situ using sensION5 (HACH) and pH using Sartorius pH meter. Alkalinity was also determined onsite using the HACH alkalinity test kit. Water samples were analyzed for Ca, F, $SO_4{}^{2-}$, $NO_3{}^{-}$, and $PO_4{}^{3-}$ by classical methods as appropriated in the standard methods for the analysis of water and wastewaters (APHA 1992). Sodium and Potassium were measured by flame photometry. Fluoride was measured using DR/890 HACH colorimeter. SO_4^{2-}, NO_3^{-}, and $PO_4{}^{3-}$ were measured using Shimadzu UV-1201 spectrometer at the wavelengths of 420 nm (SO_4^{2-}), 410 nm (NO_3^{-}), and 880 nm ($PO_4{}^{3-}$). The absorbances obtained were converted to concentrations using standard calibration curves.

3.0 RESULTS AND DISCUSSION

Sampling Site	Season	pH	Cond (µS/cm)	Temp (ºC)	Salinity	Alkalinity	True Colour	Apperent Colour	Turbidity	TDS	TSS

ACH	Dry	6.47	83.6	24.6	0	33.75	1	19	6.5	42.3	5
	Wet	6.54	65.18	25.6	0	34.52	0	8	0	32.58	0
AF	Dry	6.6	735.33	26.4	0.1	30.5	0	68.3	11	367	49
	Wet	6.42	803	25.6	0	30.2	0	4	2	400	4
AKS	Dry	6.6	110.25	26.1	0.1	37.57	0	4	5	56.1	9
	Wet	6.71	93.41	25.6	0	37.12	0	6	5.7	46.59	3
ATL	Dry	8.7	279.3	26.5	0.6	222	15	35	38.5	138.2	12
	Wet	7.47	62.88	25.6	0.4	212	3	46	9	31.58	1
AT	Dry	6.48	94.23	26.6	0	54	2	141.3	6	47.28	9
	Wet	6.47	134.6	25.6	0.1	53.73	0	100	1.8	67.25	2
KP	Dry	6.48	87.13	26.1	0	41	6	2	5.8	44.75	6
	Wet	6.47	104.23	25.7	0	42	2	10	3.3	52.23	1
SS	Dry	6.35	84.18	26.1	0	37	1	2.3	3	41.1	12
	Wet	6.64	60.9	25.6	0	39	0	14	1.3	31.8	0

Table 2 Physicochemical Parameters

The physicochemical parameters in the water samples are shown in table 2. The pH of the water samples ranged from 6.35-8.70, which is indicative of the pH of natural waters, which range from 4.5-9.0. The pH values were also slightly alkaline with little variations among the study stations. The highest pH value of 8.70 recorded at ATL is probably due to the direct discharge of effluent into the Volta River. Temperature of water affects the concentration of biological, physical and chemical constituents of water (Nartey et al., 2012). There were minor variations in the temperature readings for the various samples. The ranges of temperatures of water recorded were between 24.6-26.6°C. The electrical conductivity of the water samples ranged from 60.90-803 µS/cm. The highest electrical conductivity value of 803 µS/cm was recorded at the Afabeng T roll factory waste discharge point. The total dissolved solids (TDS) ranged from 31.13-400 mg/L. The TDS mostly fell within the TDS of freshwater and also within the WHO prescribed limit of 1000mg/L for domestic uses. Turbidity in water is usually caused by the presence of suspended or colloidal matter in the form of clay, silt, plankton, etc. In this study, the turbidity ranged from 0.0-38.5.0NTU. Average number of the samples fell within the WHO prescribed limit of 5.0NTU for domestic waters and this was mostly recorded in the wet season. The samples with high turbidity values were mostly recorded in the dry season. The highest turbidity level of 38.5NTU was recorded at the Akosombo Textile Limited waste discharge point. This high turbidity level is as a result of dyes used in textile manufacturing. The next highest turbidity level of 11NTU was recorded in Afaabeng Toilet roll factory Effluent waste discharge point into the Volta River. Turbid waters may lead to higher costs of treating waters and may also increase microbial contamination of water (DWAF, 1998). The Total Suspended Solids (TSS) were generally very low, ranging from 0-49 mg/L. High suspended solids, according to Nartey et al, (2012) may influence photosynthesis by reducing the amount of light that penetrate through to the riverbed. This may in turn affect the growth of fauna and flora and affects breeding of fishes.

Sampling Site	Season	OH^-	HCO_3^-	Total Hardness	Calcium	Chlorine	Fluorine	SO_4^{2-}	NO_3^{2-}	PO_4^{2-}	Na	K
ACH	Dry	45	54.26	56	16	6	0.09	0.62	0.08	0.01	10.2	3.8
	Wet	1.7	41.15	84	14.4	7	0.17	7.28	0.14	0.08	14.08	6.3
AF	Dry	105	127.4	114	28	16	0.11	3.97	0.29	0.02	32.1	5.7

	Wet	1.5	37.18	50	12	6	0.29	6.72	0.04	0.06	13.98	5.45
AKS	Dry	59	71.9	59	17.6	12	0.07	2.8	0.19	0.02	17.1	5.8
	Wet	1.9	45.81	80	14.2	12	0.23	10.68	0.1	0.08	22.83	7.34
ATL	Dry	297	361.5	47	14.4	19	0.1	33.5	0.48	0.07	270.2	13.3
	Wet	11.1	270.6	260	28.6	130	0.36	14.46	0.07	0.16	268.5	27.15
AT	Dry	41	50	37	32	10	0.07	4.65	0.17	0.06	13.9	5.28
	Wet	2.7	65.84	94	15.2	12	0.17	9.96	0.17	0.16	31.18	13.32
KP	Dry	49	50.74	50	26.4	12	0.07	3.45	0.27	0.03	11.8	4.13
	Wet	2.1	49.98	92	8.8	11	0.17	7.96	0.19	0.14	25.7	9.75
SS	Dry	57	68.89	43	15.2	8	0.07	3.19	0.21	0.01	10.4	3.7
	Wet	1.9	45.51	77	9.6	5.3	0.06	2.8	0.1	0.06	16.47	5.8

Table 3 Chemical Parameters

Nitrogen, which exists in water bodies as nitrates, is a key ingredient in fertilizers (Nartey et al, 2012). The concentration of nitrates measured at the sampling stations ranged from 0.04 to 0.48 mg/L. Nitrogen in natural waters are incorporated into cells and chemically reduced by microbes and converted to atmospheric nitrogen. Thus low concentrations levels of nitrate measured in the sampling stations could be attributed to this phenomenon (Chapman, 1996)

Excess amounts of phosphates in aquatic environments such as freshwater lakes, reservoirs and ponds may lead to the growth and proliferation of aquatic microscopic algae referred to as phytoplankton. Phosphate is a component of most fertilizers and may be eroded into natural waters from nearby agricultural industries or farms. The concentration recorded in this study ranged from 0.01 to 0.16 mg/L. These values were well below the WHO limit of 0.3 mg/L for natural waters.

Sulphates are discharged into aquatic environments in wastes from industries that use sulphates and sulphuric acid such as Kraft pulp and paper mills, textiles mills and tanneries (Delisle and Schmidt, 1977; Mckee and Wolf (1963). The sulphates concentrations in the study area ranged from 0.62 to 33.5 mg/L. The highest concentration of sulphate (i.e 33.5mg/L) was recorded at Akosombo Textile Limited.

3.5 Geo-accumulation Index and Enrichment Factor as Indices of heavy metal pollution in sediments

Sample Sites	Fe	Mn	Cu	Zn	Pb	Cd	Hg	Ni	As	Mg
KP 1a	12.51	209.98	128.19	8.18	6.36	7.41	0.08	0.04	4.16	1.31
KP 1b	12.75	206.51	127.77	6.37	5.44	7.30	0.09	0.03	2.80	1.35
SS 1a(BF)	6.76	178.17	73.13	0.71	0.29	<0.001	<0.002	0.01	1.44	1.15
SS 1b (BF)	5.49	180.38	60.32	0.44	0.24	<0.001	0.09	0.01	1.92	0.97
AT 1 (S)	11.35	217.34	74.27	35.11	12.07	<0.001	0.40	0.03	4.88	1.64
AT 2 (S)	7.73	196.94	40.83	1.40	5.84	5.48	0.04	0.01	0.65	0.13
AKS 1	5.96	194.29	24.10	1.33	1.17	<0.001	<0.002	0.01	0.83	0.96
AKS 2	7.30	195.16	28.83	0.99	0.97	<0.001	<0.002	0.01	1.59	0.95
AF 1 (T-Roll)	7.45	195.05	46.60	1.33	0.52	<0.001	<0.002	0.01	1.41	0.81
AF 2 (T-Roll)	5.85	189.71	50.96	1.07	0.41	<0.001	<0.002	0.01	1.00	0.45
Min	5.49	178.17	24.10	0.44	0.24	5.48	0.04	0.01	0.65	0.13
Max	12.75	217.34	128.19	35.11	12.07	7.41	0.40	0.04	4.88	1.64
Mean	8.31	196.35	65.50	5.69	3.33	6.73	0.14	0.02	2.07	0.97

Table 4 Summary of heavy metal content in Sediments at the sampling stations

A summary of the results is presented in Table 4 and Table 5. The concentrations of heavy metals in sediments measured showed the following ranges; Fe (5.49-12.75 mg/L), Mn (178.17-217.34 mg/L), Cu (24.10-128.19 mg/L), Zn(0.44-35.11 mg/L), Pb (0.24-12.07 mg/L), Cd (5.48-7.41 mg/L), Hg(0.04-0.4 mg/L), Ni(0.01-0.04 mg/L), As(0.65-4.88 mg/L). This is shown in Table 4. Copper and Zinc levels measured in the water samples were below the limits of detection. In order to quantify the extent of pollution of sediments by heavy metals, two indices were used namely the geo-accumulation index and the enrichment factor. The Geo-accumulation Index is given by

$$Igeo = \log_2 \left[\frac{Cn}{1.5Bn}\right]$$

Where Cn represents the measured concentration of the element of interest ‘n’

Bn refers to the background content of element ‘n’ in abundance of chemical elements in the continental crust.

The constant of 1.5 is used to account for the effects of possible variations in the background values, which may be attributed to lithologic variations in the sediments. Igeo<0 means the site is practically unpolluted, 0-1 Igeo. means the site is unpolluted to moderately polluted, Igeo of 1-2 means the site is moderately polluted, whereas Igeo. of 3-4 means the site is strongly polluted, Igeo of 4-5 means the site is strongly to extremely polluted, while the geo-accumulation index of >5 means the site is extremely polluted. The geo-accumulation index data for the various sampling stations is described in Table 5. Iron (Fe) concentration in measured samples was used as the background content of element in abundance.

Samples	Igeo(Fe)	Igeo(Cu)	Igeo(Zn)	Igeo(Ni)	Igeo(As)	Igeo(Hg)
KP 1a	-8.6517	-3.0439	-4.48615	-4.6162	-3.89987	-1.58532
KP 1b	-8.67574	-3.40513	-4.71157	-5.18736	-3.85637	-2.17029
SS 1a(BF)	-8.88868	-6.57807	-8.92457	-6.14672	-4.08832	-3.17029
SS 1b (BF)	-8.87088	-7.2616	-9.21407	-5.73168	-4.32476	-3.17029
AT 1 (S)	-8.60199	-0.94296	-3.5619	-4.3859	-3.57207	-2.17029
AT 2 (S)	-8.74422	-5.59175	-4.60921	-7.28689	-7.19265	-3.17029
AKS 1	-8.76377	-5.66214	-6.92457	-6.94741	-4.34466	-3.17029
AKS 2	-8.75727	-6.09654	-7.19417	-6.00679	-4.36483	-3.17029
AF 1 (T-Roll)	-8.75812	-5.66214	-8.0986	-6.17368	-4.58384	-3.17029
AF 2 (T-Roll)	-8.79816	-5.98407	-8.4298	-6.67279	-5.42712	-3.17029

Table 5 Geo-accumulation index for various metals

From Table 5, the Igeo values show that the sediments are largely not polluted with the above heavy metals.

The Enrichment factor (EF) is based on the standardization of a measured element against a reference element (Ahiamadjie et al., 2011). The Equation is given as:

$$EF = \frac{Cx/(ref)sample}{Cx/C(ref)background}$$

Where Cx is the concentration of the element of interest, Cref is the concentration of reference element for normalization. According to Sezgin et al, 2003, EF values less than 5 are not considered significant because such small enrichments may be attributed to differences in the composition of local soil material and reference soil used in Enrichment Factor calculations. An enrichment factor of <2 indicates deficiency to minimal enrichment, while enrichment factors of 2-5 indicates moderate enrichment, enrichment factors of 5-20 indicates significant enrichment, enrichment factor of 20-40 indicates very high enrichment, whereas enrichment factor of >40 indicates extremely high enrichment (Duzgoren-Aydin et al., 2006; Sezgin et al., 2003). The data of the enrichment factors for the various metals is showed in Table 6. Iron was used as the background reference metal. From Table 6, the enrichment factors for copper, zinc, nickel and arsenic were all less than 1, indicating minor enrichment, whereas the ranges of enrichment factors of manganese indicated moderate enrichment of the study sites with manganese.

Samples	EF(Mn)	EF(Cu)	EF(Zn)	EF(Ni)	EF(As)
KP 1a	4.05	0.21	0.45	0.32	0.06
KP 1b	4.12	0.22	0.46	0.33	0.06
SS 1a(BF)	4.77	0.25	0.53	0.38	0.07
SS 1b (BF)	4.71	0.25	0.53	0.38	0.07
AT 1 (S)	3.91	0.21	0.44	0.31	0.06
AT 2 (S)	4.32	0.23	0.48	0.35	0.07
AKS 1	4.37	0.23	0.49	0.35	0.07
AKS 2	4.36	0.23	0.49	0.35	0.07
AF 1 (T-Roll)	4.36	0.23	0.49	0.35	0.07
AF 2 (T-Roll)	4.48	0.24	0.50	0.36	0.07

Table 6 Enrichment Factors for various metals analyzed in this study

4.0 CONCLUSION

The study revealed the major pollutants of the Volta River. The major source of pollutant identified was sulphate which could be attributed to runoffs from the industries that use sulphate as raw materials, especially the textile industries. The Geo-accumulation indices and enrichment factors suggest that there is no major threat of pollution. Even though, the communities do not depend directly on the water for drinking, the spate of water shortages could turn the tide. Continuous monitoring of the Volta River is therefore suggested.

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References

1. Adotey D.K., Stibilj V., Serfor-Armah Y, Nyarko B.J.B, Jacimovic R. 2011 Dietary supply of selenium for adolescents in three residential care orphanages in southern Ghana. Science of the Total Environment 410-41, 72-79
2. Ahiamadjie H, Adukpo O. K., Tandoh J.B., Gyampo O, Nyarku M, Mumuni I. I., Agyemang O, Ackah M, Otoo F, Dampare S. B. 2011. Determination of the elemental contents in soils around Diamond cement factory, Aflao. Research Journal of Environmental and Earth Sciences (51) 46-50
3. Asante, F., Berger, T., Engel, S., and M. Iskandarani. 2002. Water security in the Ghanaian Volta Basin: Patterns, determinants, and consequences. In

Quarterly Journal of International Agriculture (Special Issue on Agricultural water management and land use in relation to future water supply) 41(1/2) 145-167.

4. Chapman D., 1996. Water Quality Assessment. A Guide to the use of biota, sediments and water in environmental monitoring. 2nd Edition, E&FN Spon. New York, 1996
5. Delisle, C.E. and Schmidt, J.W. 1977. The effects of sulphur on water and aquatic life in Canada. In: Sulphur and its inorganic derivatives in the Canadian environment. NRCC No. 15015, Associate Committee on Scientific Criteria for Environmental Quality, National Research Council of Canada, Ottawa
6. Donkor, A.K., Bonzongo, J.C., Nartey, V.K., Adotey, D.K., 2006. Mercury in different environmental compartments of the Pra River Bay, Ghana. The Science of theTotal Environment 368, 164-176
7. Duzgoren-Aydin, N.S, C.S.C Wong, A. Aydin, Z. Song, M. You and X. D. Li 2006. Heavy metal contamination and distribution in the urban environment of Guangzhou, S. E, China, Environ. Geochem. Health, 28:375-391
8. DWAF 1998. Quality of domestic water supplies. Assessment Guide 2nd Edition. Department of water affairs and Forestry, Department of health and water research commission, Pretoria, South Africa
9. IFPRI (International Food Policy Research Institute) 2005. Improved water supply in the Ghanaian Volta Basin: Who uses it and who participates in community decision making? EPT Discussion Paper 129. February
10. Serfor-Armah Y, Nyarko, B.J.B, Adotey D.K., Dampare S.B, Adomako D., 2006. Levels of arsenic and antimony in water and sediment from Prestea, a gold-mining town in Ghana and its environs. Water, Air and Soil Pollution, September, 2006 Vol. 175. Issue 1-4, pp. 181-192.
11. Hoenig M., Baeten H., Vanhentenrijk S., Vassileva E., Quevauviller Ph. 1998. Critical discussion on the need for an efficient mineralization procedure for the analysis of plant material by atomic spectrometric methods. Analytica Chimica Acta, 358: 85-94
12. McKee, J.E. and Wolf, H.W. 1963. Water quality criteria. 2nd edition. California State Water Quality Control Board, Sacramento, CA
13. Milestone Acid Digestion Cookbook 1996. Milestone Technical Papers. Microwave Laboratory Systems
14. Nartey Kodjo Vincent, Hayford Kofi Ebenezer, Ametsi Kwami Smile 2012. Assessment of the impact of solid waste dumpsites on some surface water systems in the Accra Metropolitan Area, Ghana. Journal of water resource and protection 2012, 4. 605-615

Sezgin N., Ozcan H. K., Demir G, Nemlioglu S. and Bayat C. 2003. Determination of heavy metal concentrations in street dusts in Istanbul E-5 highway. Environ. Int. 29:979-985