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Determination of Trace Metals Quality of Sources of Drinking Water in Some Selected Communities in the Akuapem South District of the Eastern Region, Ghana

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Abstract
The study was undertaken in three communities namely Adamrobe, Aburi and Pokrom-Nsaba, all located in the Akuapim South District of the Eastern Region. These communities depend on streams, wells, and springs for their drinking water requirements. The objective of the study was to assess the trace metals quality of the drinking water sources used by the communities. Water samples from these sources (streams, wells, and springs) were analyzed over a period of twelve months for various water quality parameters including the following trace metals: lead (Pb), cadmium (Cd), zinc (Zn), & arsenic (As), following standard methods designed in APHA, AWWA, and WEF. The results of the study revealed that, most of the mean levels of trace metals registered from the water samples were below the World Health Organization (WHO) and Ghana Water Company Limited (GWCL) recommended critical limits for drinking water standards. The low level of trace metals recorded in the water samples was due to the absence of industrial and mining activities in these communities and their environs. The high level of lead registered in ABSP was as a result of the low pH discovered in the water sample for that station. It is therefore recommended that further study be conducted to track the long term health effects of the trace metals in the drinking water sources used by the study communities.
Keywords: Trace Metals Quality, Sources of Drinking Water, Selected Communities, Akuapem South District, Eastern Region, Ghana.

1. Introduction

Water is the second most important natural resource of life after air (Aforo, 2006). As a result, there is increasing demand for water in various aspects of human life including industries, mining, hydropower generation, agriculture, recreation, environmental enhancement and particularly domestic consumption. The rapid increase of population and urbanization in the major urban and peri-urban areas in Ghana in the last few decades has increased the demand for water and has added a new dimension to the already precarious water pollution problems in most communities. The issue of clean water becoming a 'scarce commodity' is becoming more and more alarming due to the heavy anthropogenic effects that contaminate our water bodies each passing day. The situation becomes more alarming when the source of water serves as the main drinking water for a large population (Buah, 2003). Water pollution problems resulting from human activities such as mining, agriculture, improper waste disposal, and sanitary landfills are on the increase. Despite improved methods for sewage treatment, lakes, rivers, and underground waters throughout the world are becoming increasingly polluted (George, 1997). Water pollution has become very serious these days and flushing it down the sink' does not work in today's crowded world. The major chemical components of polluted water include trace metals such as lead, mercury, arsenic and cadmium. Trace metals when taken in by humans in water can react with proteins, DNA and RNA and affect metabolic processes causing undesirable physiological changes. Some of these metals are carcinogenic (WHO, 1987) and they can also cause enzyme inhibition by competing for the active sites on substances and thus affect the rate of catalytic decomposition of metabolites (FAO, 1991).

Pollution problems are far more serious when toxic chemicals or their by-products are present, particularly when long-term health effects are unknown (US **Environmental Protection Agency, 1999). The main sources of drinking water to the** study communities-Adamrobe, Aburi and Pokrom-Nsaba include streams, springs, boreholes and wells. The quality of these water sources continues to suffer from increased human activities including disposal of domestic wastes, sewage, and agro-chemicals directly or indirectly into these water sources. The existing drinking water sources in the study communities are still unsafe. Yet, these communities continue to rely on them and the ultimate result of this is the persistent higher mortality and morbidity rates in these communities. The need to identify the major human activities that are contributing to the poor water quality in these communities and suggest possible intervention measures to protect both life and the water resources cannot, therefore, be overemphasized. It is against this background that this study was conducted to assess the trace metal status of the drinking water sources used by the study communities.

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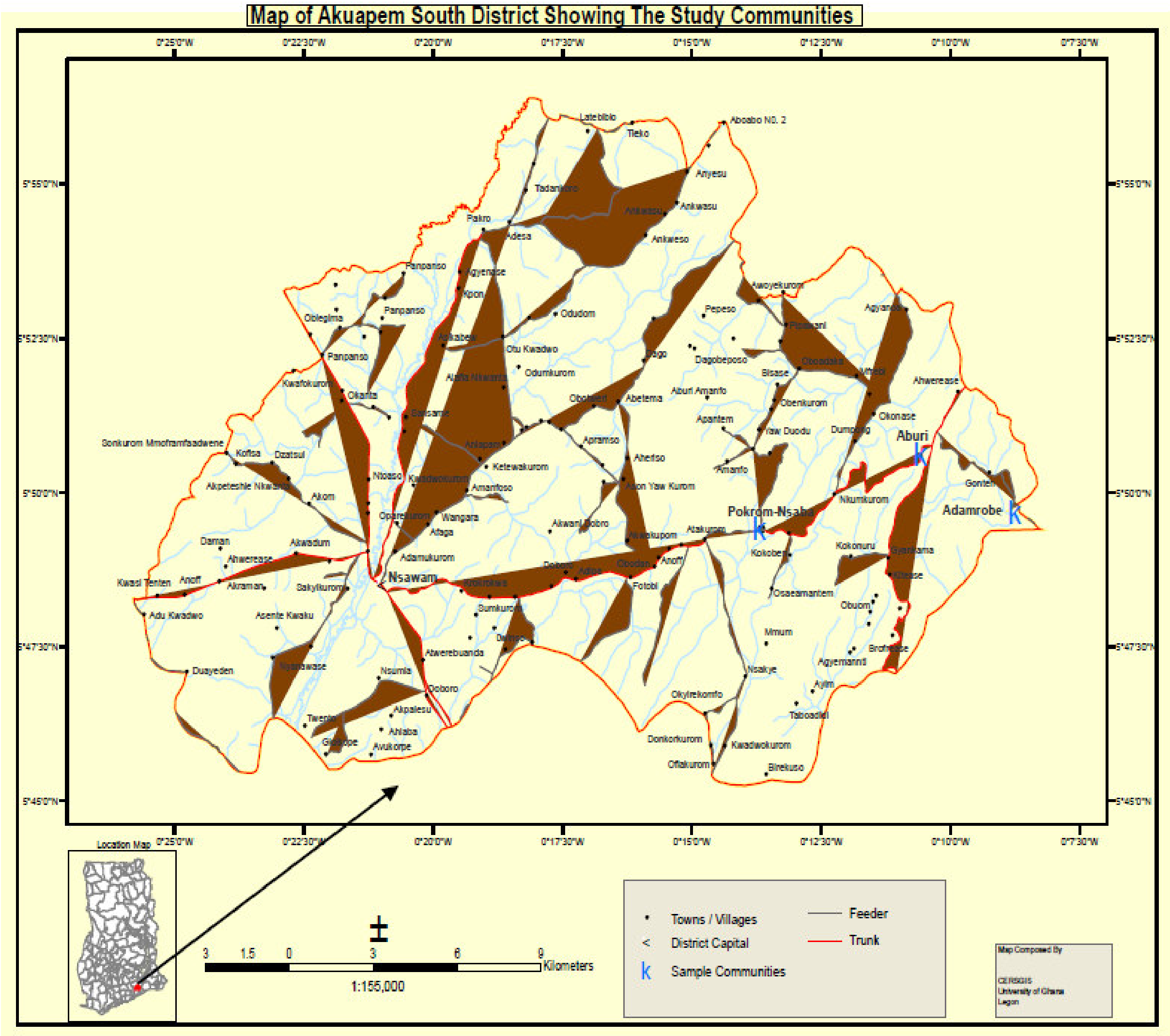
2. Methodology

2.1 Study Area

Figure 1 shows the Akuapim South District of the Eastern Region and the Study communities.



2.2 Sampling Sites and Sampling Period

Two sampling sites were identified in each community depending on frequency of usage of the water sources by each community. At Aburi, the sampling sites were well and spring; at Pokrom/Nsaba, the sampling sites included stream and spring; and at Adamrobe, the sampling site was stream (both upstream and downstream). The sites were chosen due to their ease of accessibility and also reflected different activities in the area, which affected the quality of the water. Table 1 shows the study communities, types of water sampled and number of sampling sites.

Table 1: Study Communities, Types of Water Resource and Number of sites.

	Community	Sampling Sites Types of Water Resource	Number of Sampling Sites
1.	Adamrobe	Stream (Upstream & Downstream)	2
2.	Aburi	Well & Spring	2
3.	Pokrom-Nsaba	Stream & Spring	2

The following abbreviations were used to distinguish one sampling site from the other. Adamrobe upstream (AUST), Adamrobe downstream (ADST); Aburi well (ABW); Aburi spring (ABSP); Pokrom stream (POST) and Pokrom spring (POSP). Water Sampling was carried out for twelve months beginning from September 2006 to August 2007, covering both dry and wet seasons. November–April and May–October constituted the dry and wet seasons respectively. Four water samples were collected from each sampling site each month. The mean monthly trace metals were determined for both dry and wet seasons using Unicam Solar 32 Atomic Absorption Spectrometry (AAS) with 50mm burner software (APHA, AWWA, WEF, 1995). The concentrations of trace metals in the water samples were determined using Unicam Solar 32 Atomic Absorption Spectrometry (AAS) with 50mm burner software (APHA, AWWA, WEF, 1995).

3. Results and Discussion

3.1 Zinc (Zn)

The mean Zn levels registered for the wet and dry seasons fluctuated between a minimum of 0.03 mg/l at ADST in the dry season to a maximum of 0.10 mg/l at ABSP in the wet season indicating that the highest mean value was recorded in the wet season (Figure 2). Variance analysis of mean Zn values obtained from the water collected from the various sampling sites indicated no spatial and temporal variations between the wet and dry seasons (temporal variation: p=0.967; spatial variation=0.082).

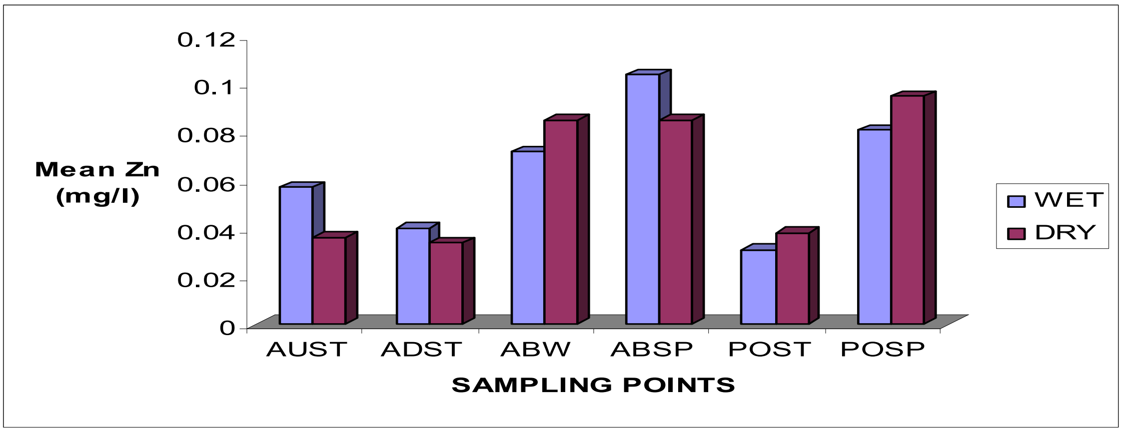


Figure 2: Wet and Dry Seasons Mean Zinc level of the Water Used by the Study Communities between September 2006 and August 2007

Seasonal variations within sampling stations indicated no appreciable difference. The low mean Zn values obtained during the wet season may be attributed to stream dilution effect. Increase in volume of water tends to reduce concentration of dissolved substances. Drinking water with Zn concentration > 3.0mg/L has adverse effect on users (WHO, 1996). These effects include gastro-intestinal distress, diarrhoea, pancreatic damage and anaemia (USPHS, 1997); severe gastro-enteritis, irritability, muscular stiffness and pains, loss of appetite and nausea (UNEP, 1993). The mean values of Zn obtained from this study were all below the WHO (1996) recommended critical value for drinking water. In terms of zinc concentrations, these waters used by the study communities posed no health effects within the period of the study.

3.2 Lead (Pb)

The mean values of Pb ranged from a minimum of 0.005 mg/l to a maximum of 0.01 mg/l (Figure 3).

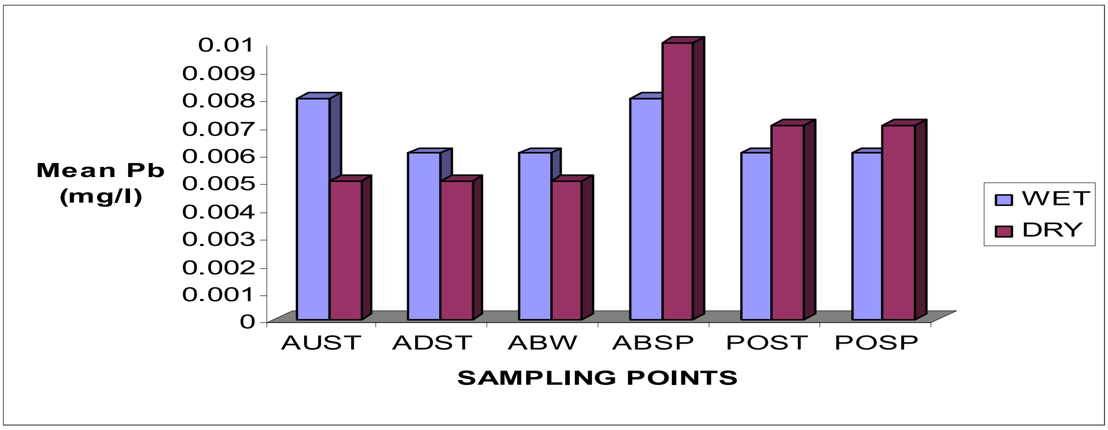


Figure 3: Wet and Dry Seasons Mean Lead (Pb) of the Water Used by the Study Communities between September 2006 and August 2007

The dry season registered the highest lead concentration (0.01mg/l). Analysis of variance showed no significant difference between the mean Pb concentration of the water samples for the wet and dry seasons (p=0.396). No spatial variations between sampling points for the wet and dry seasons was also observed (p=0.904). By comparison, the high mean values of Pb concentration levels observed in the water samples collected at ABSP for dry seasons may be attributed to both natural and anthropogenic sources. According to Ansa-Asare (2000) the pH of water is influenced by the substances over which it flows. The low pH recorded in ABSP might have accounted for the increased Pb concentration in the water. At low pH heavy metals leak from the soil into the water bodies and pollute them. The increased water withdrawal during the dry season by the community members also contributed to the high Pb concentration in ABSP. This is because for underground water supply sources, excessive withdrawals increases metals concentrations and have adverse effect on the chemical quality of the supply (AWW A, 1999). Drinking water with lead concentration level > 0.01mg/L has adverse effect on the users (WHO, 1996). Increased lead intake in adults have been associated with nervous system disorders, anaemia and decreased haemoglobin synthesis, cardiovascular diseases, disorders in bone metabolism, renal functioning and reproduction. In children it promotes low cognitive and behavioural development (Goyer, 1993; USPHS, 1997; Nriagu 1998; Pirkle *et al.*, 1998 ;) and brain retardation in children (Sadiq, 1992). Long-term exposure effects include stroke, kidney disease, and cancer (US Journal of Medicine, 1987). Though these effects were not readily on the clinical records of the study communities, increased accumulation of Pb concentration may have these adverse effects surfaced. There is therefore the need to check the concentration in further research to observe the future trends and take the necessary action.

3.3 Cadmium (Cd)

The adverse health effects of chronic exposure to Cd include kidney damage (Herber *et al*., 1988) and aches and pains in bones (Itai-itai disease) (Tsuchiya, 1978; Kjellstroem, 1986). Studies have also shown that the offspring of animals exposed to Cd during pregnancy experienced behavioural changes and learning disabilities (ATSDR, 1999; NJDHSS, 1999). The Cd levels recorded from the various sampling points ranged between <0.002mg/l and 0.004 mg/l. The mean values fluctuated between a minimum of 0.002 mg/l at ADST, ABW, and POST to a maximum of 0.004 mg/l at AUST and POSP (Figure 4). Analysis of variance indicated significant difference between the mean values of the wet and dry seasons (p=0.002). No spatial variations was observed between sampling points for the wet and dry seasons (p=0.212).

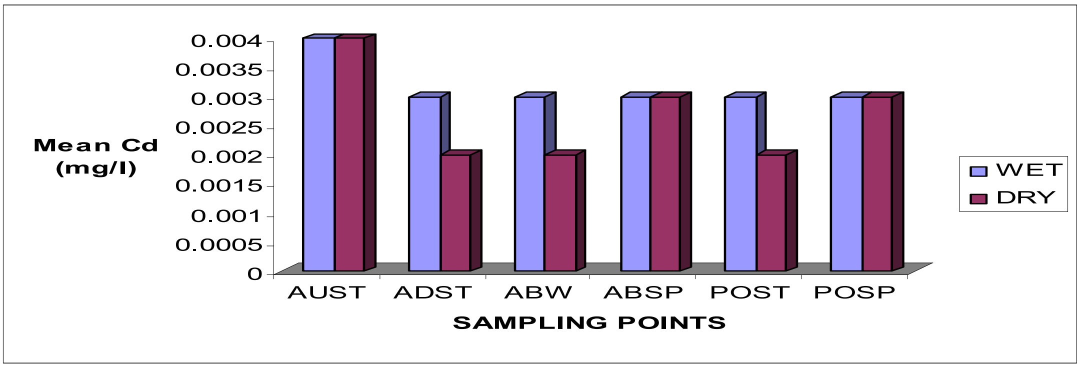


Figure 4: Wet and Dry Seasons Mean Cadmium (Cd) of the Water Used by the Study Communities between September 2006 and August 2007

Comparatively, AUST registered the highest mean Cd concentration levels for the wet and dry seasons. This was attributed to runoffs from the quarrying sites located close to the banks of the stream. According to Marian (1991) cadmium is a common environmental pollutant, which is widely distributed in the aquatic environment and its sources are mainly from weathering of minerals and soils; domestic effluents (Preuss and Kollman, 1974); storm-water runoff (Field and Lager, 1975).

The mean Cd concentration obtained from this study were within the WHO (1996) recommended critical limits of 0.003mg/L in waters for domestic use. These levels of Cd in the community water resource may not, however, have any short term adverse effect on the users of water from these sources for domestic purposes. This is because the reference dose for Cd in drinking water is 0.0005 mg/kg.d USEPA (1989), (IRIS, 2003). In other words, a 70 kg person can safely consume 0.035 mg of Cd per day without any adverse effects expected, whereas the estimated lethal oral dose for humans is 350 to 3500 mg of Cd dose (WHO, 1996), i.e. 10 000 times the reference dose. Zn intake by humans also tends to provide partial protection against toxic effects of cadmium (DWAF, 1996). However, concentrations as high as up to 0.01mg/l could be found in waters where there is contamination. Sources of this contamination may include household chemicals concentrated in groundwater supplies beneath dumps (Plummer *et al*, 1999).

3.4 Arsenic (As)

The mean values from the sampling points ranged between a minimum of 0.001mg/l to a maximum of 0.004 mg/l (Figure 5). The highest mean values for the wet and dry seasons were therefore recorded at ADST. Analysis of variance showed no significant difference between the sampling sites for the wet and dry seasons (p=0.758). This may be attributed to the pesticides use to control pests in the high-scale pineapple production carried out close to the water source. Pesticides, according to MEHD, (1993) get into water bodies via its use in agricultural activities.

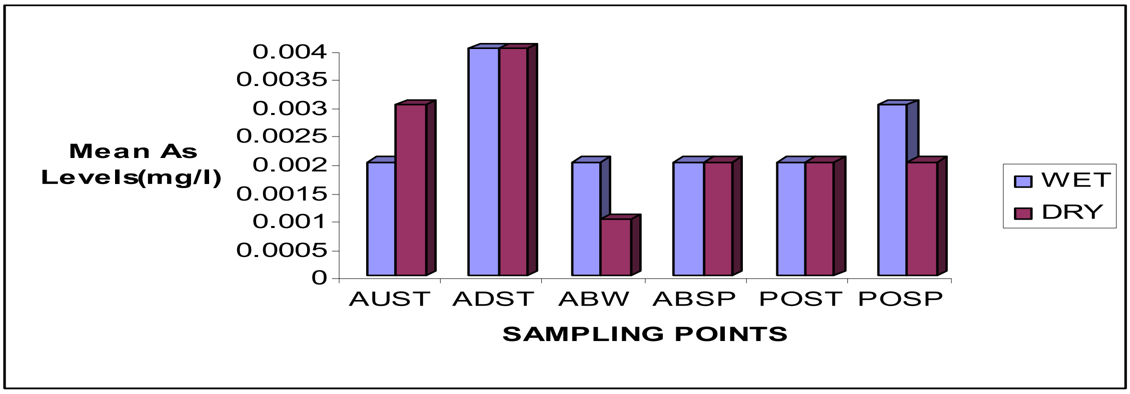


Figure 5: Wet and Dry Seasons Mean Arsenic (As) of the Water Used by the Study Communities between September 2006 and August 2007

Comparison of the mean As levels registered from all the sampling points shows that AUST and ADST contained more Arsenic than POST. Both natural and anthropogenic factors may be responsible for the observed elevation in the wet season As levels compared to the dry season. As natural components of underground rocks and soils, arsenic works its way into the underground water sources. Anthropogenically, arsenic gets into water bodies from sources such as mining, manufacturing and use of or disposal of pesticides into the environment. The low concentration of As recorded in the water samples in this study agreed with the work done by Nartey *et al* (2001) on water quality of the Akwapim Ridge. They concluded that the concentrations of heavy metals in the streams on the Akwapim Ridge were below the WHO critical limit for drinking water. They attributed this to low level of industrial and mining activities in the Akwapim Ridge. Exposure to arsenic in drinking water has been reported to increase the risk of skin, liver, bladder, and kidney cancer. (USEPA, 2000). Studies suggest that these cancer effects may occur following long-term exposure. Lifetime exposure of arsenic at 0.019mg/l in water would pose a cancer risk of less than one-in-three-thousand (USEPA, 2000). The amount of As in freshwater that has no health implication was 0.01mg/l (WHO, 1996). Concentrations as high as up to 0.1 mg/l may be found where there are contamination. Based on the As level obtained from this study, water from these sources posed no health hazards to its users.

4. Conclusion and Recommendations

4.1 Conclusion

The mean concentrations of the trace metal (Zn, Pb, Cd, & As) analyzed in the water samples used by the three communities were all below the drinking water quality standard and therefore pose no immediate health hazard to the communities within the period of the study. However, concentrations of these trace metals could be found in waters where there is contamination. The high mean values of Pb concentration registered at ABSP for dry seasons may be due to both natural and anthropogenic effects, as well as the low pH of water samples. Though these effects were not readily on the clinical records of the study communities, increased accumulation of the Pb concentration may have some adverse health implications for the users since at low pH, the ionic state of trace metals become more prevalent and their toxicity increased. There is therefore the need to track the concentration in further research to observe the future trends and take the necessary action.

4.2 Recommendations

Based on the findings of the study, the following are recommendations to offset any future impacts of human activities on the drinking water resources used by the study communities:

- There is the need to increase the lateral separation between pollution sources in these communities and their sources of drinking water supply to reduce the risk of trace metal pollution. It is therefore necessary that town committees/opinion leaders should provide the longest distance possible between water sources and the major potential anthropogenic sources of contamination available in the communities.
- People should be educated on the need to avoid washing and bathing near the water sources. Getting to know the effect of these unhygienic practices on the quality of the water will make them refrain from these activities.
- Quarrying sites should not be sited near community water sources, especially where the water is used as drinking water. This is very crucial as there is the possibility of trace metals being carried into this water via

storm drains and runoffs. The quarry sites located closed to Adamrobe stream should be relocated.

- It was obvious that agriculture is the largest contributor to water pollution caused by runoff in the study communities. The Government in collaboration with the District Assembly should therefore provide clear guidelines and by-laws in the land use planning process for the protection of community drinking water sources so that land and water resource management are integrated at the local level to minimize pollution from agricultural activities.
- Geographic Information System (GIS) Department in conjunction with the Ghana Water Management Sector should identify all point and non-point sources of pollution in the study communities and develop strategies based on local initiatives to safeguard further pollution of community drinking water sources.
- Finally, there is the need to undertake further study to cross check the long term health effects of human activities on drinking water sources in three studied communities. This study will provide the baseline data for effective monitoring and sound environmental management practices.

Competing Interests

The authors declared that no competing interests exist.

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Appendix 1: Concentration of Trace Metals Obtained From the Water Sources

Appendix A: Absolute and Seasonal Mean Zn (mg/l)

		Sampling Sites					
SEASONS	MONTHS	AUST	ADST	ABW	ABSP	POST	POSP
	NOV	0.08	0.039	0.146	0.154	0.04	0.188
	DEC	0.012	0.028	0.034	0.138	0.033	0.194
DRY	JAN	0.077	*	0.055	0.133	0.028	0.08
SEASON	FEB	0.02	*	0.074	0.038	0.019	0.033
	MAR	0.022	*	0.162	0.039	0.062	0.037
	APRIL	0.005	*	0.038	0.01	0.046	0.037
SEASONAL MEAN		0.036	0.034	0.085	0.085	0.038	0.095
	MAY	0.005	*	0.023	0.016	0.037	0.005
	JUN	0.005	0.005	0.018	0.017	0.019	0.038
WET	JUL	0.012	0.016	0.017	0.028	0.038	0.035
SEASON	AUG	0.019	0.024	0.047	0.2	0.013	0.062
	SEPT	0.153	0.084	0.172	0.186	0.055	0.169
	OCT	0.146	0.073	0.157	0.177	0.025	0.174
SEASONAL MEAN		0.057	0.04	0.072	0.104	0.031	0.081

- Sampling Site Dried

Appendix B: Absolute and Seasonal Mean Lead (mg/l)

		Sampling Sites					
SEASONS	MONTHS	AUST	ADS T	ABW	ABSP	POST	POSP
	NOV	0.005	0.005	0.005	0.005	0.005	0.005
	DEC	0.005	0.005	0.005	0.005	0.005	0.005
DRY	JAN	0.005	*	0.005	0.005	0.005	0.005
SEASON	FEB	0.005	*	0.005	0.017	0.005	0.005
	MAR	0.005	*	0.005	0.015	0.005	0.015
	APRIL	0.005	*	0.005	0.014	0.015	0.005
SEASONAL MEAN		0.005	0.005	0.005	0.01017	0.0067	0.0067
	MAY	0.005	*	0.005	0.005	0.005	0.005
	JUN	0.005	0.005	0.005	0.005	0.005	0.005
WET	JUL	0.005	0.005	0.005	0.005	0.005	0.005
SEASON	AUG	0.01	0.005	0.005	0.017	0.005	0.005
	SEPT	0.011	0.01	0.011	0.01	0.005	0.009
	OCT	0.01	0.005	0.005	0.005	0.01	0.005
SEASONAL MEAN		0.008	0.006	0.006	0.008	0.006	0.006

* Sampling Site Drie

Appendix C: Absolute and Seasonal Mean Cadmium (mg/l)

		Sampling Sites					
SEASONS	MONTHS	AUST	ADST	ABW	ABSP	POST	POSP
DRY SEASON	NOV	0.003	0.002	0.002	0.002	0.002	0.002
	DEC	0.002	0.002	0.002	0.002	0.003	0.008
	JAN	0.002	*	0.003	0.004	0.002	0.002
	FEB	0.002	*	0.002	0.003	0.003	0.002
	MAR	0.003	*	0.002	0.002	0.002	0.002
	APRIL	0.009	*	0.002	0.002	0.002	0.003
SEASONAL MEAN		0.004	0.002	0.002	0.003	0.002	0.003
WET SEASON	MAY	0.002	*	0.002	0.004	0.005	0.002
	JUN	0.005	0.002	0.002	0.002	0.006	0.005
	JUL	0.007	0.007	0.005	0.002	0.002	0.003
	AUG	0.002	0.004	0.002	0.003	0.002	0.002
	SEPT	0.003	0.002	0.002	0.002	0.002	0.002
	OCT	0.002	0.002	0.003	0.002	0.002	0.002
SEASONAL MEAN		0.004	0.003	0.003	0.003	0.003	0.003

* Sampling Site Dried

Appendix D: Absolute and Seasonal Mean Arsenic (mg/l)

		Sampling Sites					
SEASONS	MONTHS	AUST	ADST	ABW	ABSP	POST	POSP
DRY SEASON	NOV	0.002	0.001	0.003	0.001	0.001	0.001
	DEC	0.005	0.006	0.001	0.001	0.001	0.001
	JAN	0.001	*	0.001	0.001	0.001	0.003
	FEB	0.004	*	0.001	0.003	0.001	0.001
	MAR	0.001	*	0.001	0.001	0.001	0.001
	APRIL	0.005	*	0.001	0.003	0.004	0.005
SEASONAL MEAN		0.003	0.004	0.001	0.002	0.002	0.002
WET SEASON	MAY	0.001		0.001	0.001	0.001	0.001
	JUN	0.001	0.013	0.001	0.002	0.002	0.003
	JUL	0.001	0.001	0.001	0.001	0.001	0.001
	AUG	0.001	0.001	0.001	0.001	0.001	0.001
	SEPT	0.005	0.002	0.004	O0.006	0.005	0.005
	OCT	0.001	0.003	0.001	0.006	0.003	0.005
SEASONAL MEAN		0.002	0.004	0.002	0.002	0.002	0.003

* Sampling Site Dried

Appendix 2: Water Sources Used By the Study Communities

Plate A: Water sources used by Aburi Community

Plate B: Stream used by Pokrom Community as Source of Drinking Water

Plate C: Spring used by Pokrom-Nsaba Community as Source of Drinking Water

Plate D: Stream used by Adamrobe Community as Source of Drinking Water

Plate E: Spring Water used by Aburi Community as Source of Drinking Water

Plate F: Well Water used by Aburi Community as Source of Drinking Water