

Assessment of Arsenic Level in Boreholes from the Wassa West District using Instrumental Neutron Activation Analysis

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Abstract: Surveillance of drinking water is a necessary action intended to prevent the general public from contaminating water borne diseases. In this study, arsenic concentrations in 22 borehole water samples from various locations in the Wassa West district have been studied using Instrumental Neutron Activation Analysis. The samples were irradiated using a 30 kW tank-in-pool Ghana Research Reactor-1 operating at a thermal neutron flux of $5 \times 10 \text{ n/s.cm}^2$. Elevated levels of arsenic were found in virtually all the 22 samples. Arsenic concentration in the samples ranged from 0.06 ppm to 9.43 ppm. (Mean-2.23, Standard Error of Mean-0.57) with minimum concentration of 0.06 ppm occurring at Ayensukrom No.1 and the maximum occurring at Tamsu-9.43 ppm. These values far exceed the World Health Organization's recommended value of 0.01 ppm for arsenic in drinking water. The occurrence of arsenic in the area is traced to the existence of sulphide minerals such as arsenopyrites (FeAsS_2) present in the underlying Birimian Basement rocks in the area.

Key words: Arsenic, boreholes, instrumental neutron activation analysis, wassa west district

INTRODUCTION

Wassa West district is a land locked area in the western region of Ghana that has a long standing history of mining activities. This district has the largest concentration of mines in a single district on the continent (Akabzaa, 2000). Rivers and streams used to be the main source of drinking water in the district. However, recent studies have shown that most of the surface waters are polluted and unsafe for drinking purposes as a result of the intense mining activities. For instance, River Ankobra which is the only major river in the area is regarded "dead" due to its high level of pollution (WRRI, 1996). Increasingly realizing that the surface waters are somewhat polluted, the Government of Ghana and some major mining companies operating in the district provide boreholes that draw groundwater from water-bearing rocks called aquifers as alternative source of drinking water. The number of boreholes has increased to the extent that borehole water has now become the principal and sometimes the only source of drinking water for most communities in the Wassa West district.

Arsenic in drinking water is considered one of the prominent environmental causes of cancer mortality in the world (Smith *et al.*, 1992). Toxic exposure to arsenic and its compounds may occur through air, water, sea food, tobacco smoking and industrial chemicals. Worldwide,

the main reason for a chronic human intoxication with arsenic is the intake of contaminated drinking water (Gebel, 2000).

Symptoms of exposure to high levels of arsenic may include stomach pain, vomiting, diarrhea etc. Arsenic can also produce a pattern of changes on your skin which includes darkening of wart-like growths mostly found on the palms and soles. Long term exposure to even relatively low concentrations of arsenic in drinking water can increase your risk of developing certain cancers including skin, lung, kidney, and bladder cancer (IRC, 2007).

Arsenic may pose a potential problem in the district because of the abundance of arsenic-bearing minerals, particularly arsenopyrite, which occurs in close association with gold in sulphide-mineralized veins (Kesse, 1985; Asomaning, 1993). In the extraction of gold, the ore concentrate, mainly of pyrites and arsenopyrites are roasted to get rid of the sulphur and arsenic, which prevent the final extraction of gold with Potassium Cyanide. The net result is the emission of considerable quantities of arsenic into the atmosphere.

Several methods have been used to determine Arsenic in environmental matrices. In earlier studies, chemical methods like gravimetric, volumetric and colorimetric techniques were employed. Other researchers employed nuclear related techniques. These include

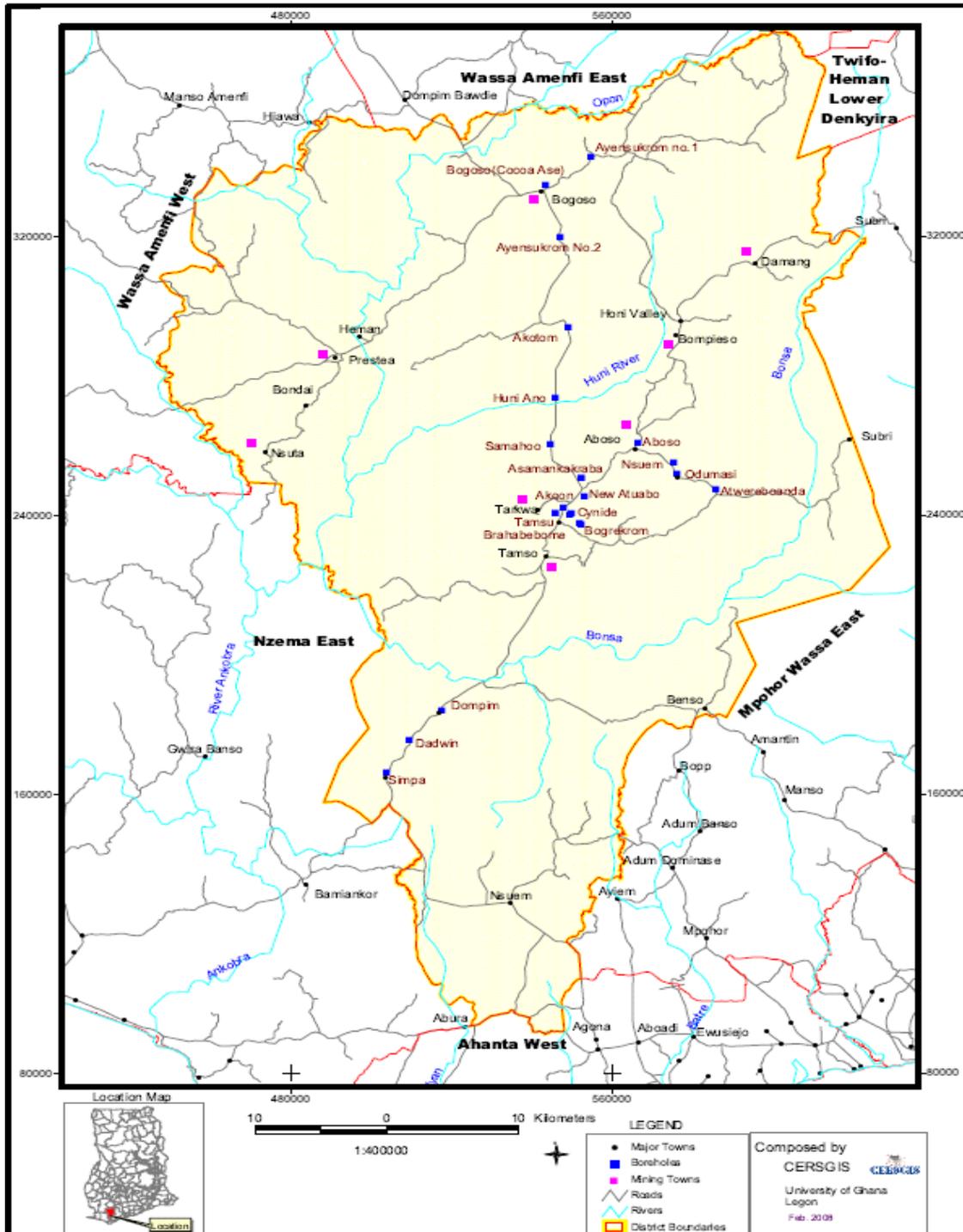


Fig. 1: Map of Wassawest district showing the location of sampled boreholes

Proton-induced X-ray Emission (PIXE), X-ray Fluorescence (XRF) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). In this work, the principle of Instrumental Neutron Activation Analysis (INAA) is used because of its high accuracy and precision in analyzing trace elements.

Due to the toxicological effect of arsenic on humans, studies into the various environmental impact assessment of arsenic at the mining areas is necessary in order to mitigate the problem. Not much research into arsenic has been done at the mining towns in the Wassa West district.

EXPERIMENTAL

Sampling and sample treatment: Water samples were collected from boreholes in the Wassa West district on the first week of February, 2008. In all, 22 borehole-water points were sampled. At each borehole, a sample was collected. Each sample was collected in a 60ml acid-washed high-density linear polyethylene bottle with strict adherence to the sampling protocol described by Claasen (1982). To remove particulate matter from samples, filtering was performed using a Sartorius polycarbonate filtering apparatus and a 0.45- μ m cellulose acetate filter membrane. The GPS coordinate of each borehole was taken and a map of Wassa West district was developed showing the exact locations of the sampled boreholes as shown in Fig. 1.

The samples were transported to the Ghana Atomic Energy Commission for analysis. At the preparation room of the reactor center, 500 μ g/L of each sample was pipette into a small polyethylene capsule. The capsules were heat sealed with a soldering rod. These were then double encapsulated by placing them into a larger polyethylene capsule known as rabbit capsule. In order to ensure stability the samples were plucked with cotton wool before finally getting them seated for irradiation. The standard was also prepared in the same manner as the text samples.

Sample irradiation: Irradiation of the samples and standards was carried out in the Ghana Research Reactor-1 operating at 15 kW power level with neutron flux of 5×10^{-11} nc/ms. The irradiation time was chosen according to the half-life of the element of interest. Arsenic is medium-lived, with half-life of 23.3 h. The capsules were sent into irradiation sites by means of the pneumatic transfer systems at a pressure of 60 psi. The samples were irradiated for one hour. At the end of each irradiation, the capsule was returned from the reactor and allowed to decay until the level of activity was within the acceptable limit for handling.

Counting: The samples were then counted for 1000 seconds on a PC-based gamma-ray spectroscopy system, which uses an N-type high purity germanium (HPGe) detector. During the counting period the spectral

Table 1: Concentration of as standard (single element standard) used for validation

Element	No. of Measurements	Measured average value (ppm)	Reported value (ppm)	Units
As	6	19.6 \pm 0.03	20	mg/L

intensities of the sample was accumulated by means of a Silena EMCAPLUS Multichannel Analyzer (MCA) Emulation Software card and a 486 microcomputer for data evaluation and analysis. Identification of gamma rays of product radionuclides through their energies and quantitative analysis of their concentrations were achieved using the gamma ray spectrum analysis software, ORTEC MEASTRO-32. The major photopeak counting for arsenic occurs at 559.1 KeV. The relative efficiency of the detector used was 25% and its energy resolution of 1.8 KeV at gamma-ray energy of 1332 KeV belonging to Co. The results obtained from the analysis were validated using a single element (As) standard. Results for the validation of the analytical method are shown in Table 1.

RESULTS AND DISCUSSION

Results of the arsenic concentration in the various samples is shown in Table 2, whiles Fig. 2 shows graph of concentration against sampling points. In figure 2, the letters A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V represent Ayensukrom No 2, Nsueam, Samanhoo, Akoon, Simpa, Odumasi, Dompim Dadwin, Atwereboanda, Cyanide Park, Bogoso, Asamankakraba-2,

Table 2: Concentration of Arsenic in the 22 groundwater samples

Sample Code	Sample Location	Concentration (ppm)
BH1	Ayensukrom No.2	6.34 \pm 0.80
BH2	Nsueam	0.09 \pm 0.01
BH3	Samahoo	0.26 \pm 0.04
BH4	Akoon	2.09 \pm 0.38
BH5	Simpa	0.27 \pm 0.04
BH6	Odumasi	1.26 \pm 0.20
BH7	Dompim	2.16 \pm 0.32
BH8	Dadwin	6.4 \pm 0.01
BH9	Atwereboanda	1.50 \pm 0.22
BH10	Cynide Park	0.68 \pm 0.10
BH11	Bogoso	5.98 \pm 0.83
BH12	Asamankakraba -2	0.76 \pm 0.12
BH13	Huni Ano	0.84 \pm 0.12
BH14	Aboso	0.93 \pm 0.14
BH15	Akotom	0.14 \pm 0.02
BH16	Asamankakraba -1	0.76 \pm 0.11
BH17	Ayensukrom No 1	0.06 \pm 0.01
BH18	Bogrekrom-1	5.50 \pm 0.83
BH19	Bogrekrom-2	0.13 \pm 0.02
BH20	Tamsu	9.43 \pm 1.29
BH21	Brahabebome	1.87 \pm 0.28
BH22	New Atuabo	1.65 \pm 0.26

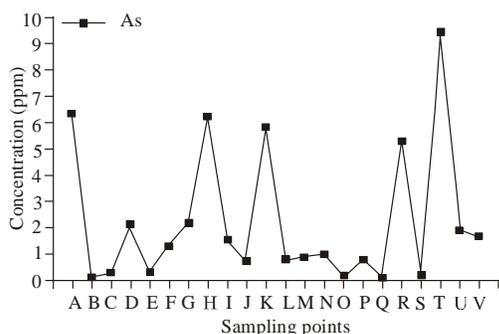


Fig. 2: A graph of concentration (ppm) against sampling points

Huni Ano, Aboso, Akotom, Asamankakraba-1, Ayensukrom No.1, Bogrekrom-1, Bogrekrom-2, Tamsu, Brahabebom, and New Atuabo respectively.

From the results, it is observed that the concentration increases around areas of intense mining activities. The highest concentration is obtained from Tamsu with a value as high as 9.43 ppm. This value is woefully above the WHO's safe limit of 0.01 ppm of arsenic in drinking water. This borehole is situated on the premises Tamsu Primary / Junior High School. Arsenic getting into the food chain at Tamsu has already been established (Amin, 2006). This make the people of Tamsu who consume water from this borehole to be at the highest risk of arsenic related diseases.

The second, third, fourth, and fifth highest concentrations were observed at Dadwin, Ayensukrom No. 2, Bogoso and Bogrekrom, respectively. It is clearly observed that the concentration becomes relatively lower as one departs from Tarkwa through Samahoo with a concentration of 0.26 ppm; Huni Ano with a concentration of 0.84 ppm; and Akotom with a concentration of 0.14 ppm. After Akotom the concentration increases relatively with values of 6.34 ppm and 5.98 ppm observed at Ayensukrom No. 2 and Bogoso respectively. Bogoso is a heavy mining operation town. The minimum concentration was 0.06 ppm, and this was observed at Ayensukrom No. 1, which marks the departure from Bogoso, a heavy mining operation centre.

The moderate to strong acidity of the groundwater suggests that the waters are susceptible to trace metal pollution if these metals are present in the rock matrix through which the water percolates.

Arsenic in sediments or water can move in absorbed phase with iron. Pelig-Ba (1989) has reported elevated levels of iron in ground water samples of the Wassa West district. They are usually associated with acidic groundwater or anaerobic (oxygen free) groundwater. Concentrations as high as 57 mg/L have been found in some sources (Pelig-Ba, 1989). Similarly, a high iron concentration of 7.52 ppm in ground water sample from Odumasi in the Wassa West district has been reported (Obiri, 2007).

Tarkwa soil is known to be highly porous and high porosity of soil causes percolation of chemicals and

contamination of groundwater. Further, everyday dumping of thousands of tons of garbage containing hazardous chemicals in open landfills of Tarkwa may be adding arsenic to the groundwater.

Generally, arsenic level detected is in the range of 0.06 to 9.43 ppm (Mean- 2.23, Standard Deviation- 2.66, Std. error of Mean- 0.57). The minimum value was found in the groundwater sample of Ayensukrom No 1 (0.06 ppm) and maximum value in the groundwater sample of Tamsu (9.43 ppm).

RECOMMENDATIONS

If the following recommendations for research and development are successfully carried out, the remediation of arsenic contamination will be much easier.

- It is highly desirable to form a research group with geologists, hydrologists, geo-chemists, water supply and environmental engineers, and public health experts to conduct in-depth investigation on the sources and causes of arsenic contamination in groundwater.
- It is highly recommended that every donor projects in arsenic mitigation by law ensure community participation for smooth running in future.
- A national groundwater resources management policy be established by the Government in order to limit the indiscriminate abstraction of groundwater.
- A comprehensive water distribution system should be implemented and an efficient monitoring system should be established to provide potable water and to prevent future arsenic contamination in drinking water.
- The Wassa West district Assembly should establish an effective sewage disposal system to accompany any deployment of water distribution system.
- Guidelines on the disposal of arsenical wastes should be established by the Ministry of Agriculture to minimize the contamination in soil and water.
- Total As was determined in this study. In future, an attempt should be made to determine the different species of As in drinking water, human urine, and food items to evaluate the intake of inorganic As in the Wassa West district.
- Social conscience about health risks and consequences of environmental pollution has to be developed and the actual situation must be taken into account by authorities (Environmental Protection Agency, Minerals Commission, Ghana Chamber of Mines, etc.) to achieve a definite solution to the problem. For example, the powers of the district assemblies should be enhanced to monitor activities and enforce regulations on polluting discharges into the environment from mining companies and also check the illegal activities of small-scale miners.

CONCLUSION

In all the samples arsenic level in groundwater is more than the permissible limit of WHO (1993) and represents a serious public health threat. This condition may deteriorate further particularly in view of the present days continuous, uncontrolled and heavy extraction of groundwater and excessive use of chemicals along with discharge of hazardous waste in open landfills.

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