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Trace metals investigation in groundwater of the Ayensu Basin in Central Region of Ghana

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ABSTRACT

Groundwater samples from the Ayensu Basin in the Central Region were investigated to ascertain the concentration of trace metals. Twelve (12) trace metals were analysed in twenty nine (29) groundwater samples from the study area. Fe, Zn, Cd, Ni, Pb, Cr, Hg, and Ag were analysed using Atomic Absorption Spectrometer (AAS) whiles Cu, Al, Mn and As were determined by Instrumental Neutron Activation analysis (INAA). Cd, Ni, Pb, Cr, Hg, and Ag were found below detection limits of <0.002, <0.010, <0.010, <0.006, <0.001 and <0.002 respectively. The detectable trace metals measured mean concentrations in the order; Fe (1.136±0.336 mg/L) > Al (0.856±0.459 mg/L) > Cu (0.382±0.379 mg/L) > As (0.287±0.232 mg/L) > Mn (0.269±0.212 mg/L) > Zn(0.090±0.080 mg/L). Mean concentrations of Al, As and Fe exceeded the WHO limits of 0.2 mg/l, 0.01 mg/l and 0.3 mg/l for drinking water. The trace metals concentrations were found to be generally low and therefore the groundwater from the localities are suitable for domestic use.

Introduction

Groundwater and surface waters are the main sources of water available to rural as well as some urban dwellers in Ghana (Tay C., 2007)

Some metal contamination of groundwater arises from natural geological and environmental conditions (Rao and Mamatha, 2004).

The occurrence of trace metals in groundwater and surface water can be due to natural sources such as dissolution of naturally occurring minerals containing trace elements in the soil zone or the aquifer material or to human activities such as mining, fuels, smelting of ores and improper disposal of industrial wastes. Trace elements are generally present in small concentration in natural water system (Jinwal et al., 2009).

Many trace elements are essential nutrients, however certain trace elements such as As, Cd, and Hg are known to be persistent environmental contaminants and toxic to most forms of life (Jinwal et al., 2009). Even essential trace metals can pose serious health effects at elevated levels.

The Ayensu Basin is an area extending from latitude 5º 20' to 6º 10' in the northern hemisphere and from meridian 0º 30' to 0º 50' on the western half of the globe.

It occupies an area of about 1,700 km² (WARM, 1998). The Ayensu River, which is about 103 km in length drains southerly into the Atlantic Ocean at the Gulf of Guinea near Winneba about 56 km west from the national capital - Accra. The part of the basin under study comprises three districts; the Agona, Gomoa and Awutu Efutu Senya districts.

Agriculture (small-scale) is the main source of livelihood in the rural communities of the Central Region (CCMA, 2006). The people grow cocoa, citrus, oil palm, and food crops like plantain, cassava, Cocoyam, yam etc. and vegetables. Animal rearing is also done to support the food crop farming. Ground, and surface water are therefore subjected to many potential sources of contamination.

This study seeks to assess the drinking water potability with regard to concentrations of trace metals in the groundwater of the study area.

Physical settings of the study area

The Ayensu basin is underlain by rocks of the middle Precambrian age; that is the Cape Coast granitoids and the Birimian System.

The Cape Coast Granitoids occupies about 1,528 km² of the basin while the Birimian System occupies about 136 km² of the basin (WARM, 1998).

The basin is located in two climatic regions: the wet Semi-Equatorial in the northern part and the dry Equatorial in the south. The two climatic regions have two rainfall maxima.

However, the dry Equatorial has mean annual rainfall less than 900 mm while the wet Equatorial has mean annual rainfall between 1200mm and 2000mm (WARM, 1998).

The area experiences high temperatures during the major part of the year. The hottest months are January to May, just before the main rainy season (BASH, 2008). The Landscape of the study area is generally undulating with hills of variable slopes.

Methodology

Sampling

A total of twenty five boreholes samples and four river points were taken at various locations in the study area. All the water samples were collected in 500mL preconditioned high density polyethylene bottles.

The bottles were conditioned by washing with five (5%) percent nitric acid, and then rinsed several times with distilled water. This was carried out to ensure that the sampling bottles were free from contaminants. After filling the bottles, samples were preserved with few drops of nitric acid.

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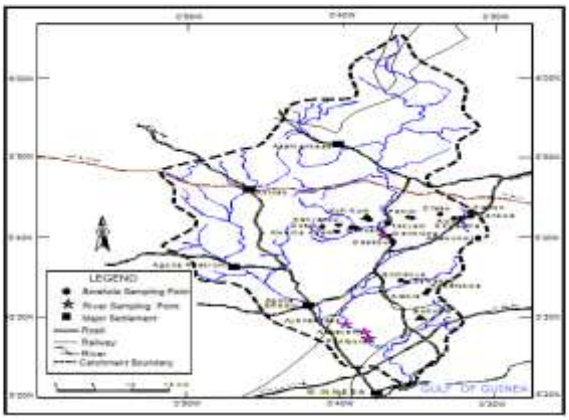

Fig.1 Map of the Ayensu Basin showing the Sampling points

Atomic absorption spectrometry (AAS)

Samples were acid digested using H_2SO_4, HNO_3 and H_2O_2. The digested samples, calibration standards and blanks were analysed using atomic absorption spectrometry, (Varian AA240FS) in an acetylene-air flame.

Instrumental neutron activation analysis (INAA)

Instrumental neutron activation analysis was used to determine Cu, Al, Mn and As. A 0.50 g of each water sample was pipetted using calibrated Eppendorf tip ejector pipette into clean pre-weighed 1.5mL polyethylene vials, and fitted with polyethylene snap caps and heat-sealed. Two replicates were prepared for each sample. The samples were then placed in 7.0mL vials and irradiated. Reference standards and blanks were prepared and analysed in a similar manner. Irradiation of the samples was done using the Ghana Research Reactor-1 (GHARR-1) facility operating at half full power of 15 kW and at a neutron flux of 5.0×10^{11} neutrons/cm^2s^1. The scheme for irradiation was chosen according to the half-lives of the elements of interest, sample matrix and the major elements present. The samples were sent into the reactor by means of a pneumatic transfer system operating at a pressure of 1,292.88 mmHg. At the end of the irradiation, the capsules were returned from the reactor and assayed according to the scheme adopted. The samples were then placed on top of the detector and the counts were accumulated for a pre-selected time to obtain the spectra intensities. A PC-based gamma ray spectrometry system was used for the measurement. The spectra intensities for the samples were obtained by means of an Ortec multi-channel buffer (MCB) emulation software card. The accumulated spectra intensities were analysed both qualitatively and quantitatively.

Result and Discussion

Trace elements are generally present in small concentration in natural water system. Their occurrence in groundwater and surface water can be due to natural sources such as dissolution of naturally occurring minerals containing trace elements in the soil zone or the aquifer material. It could also be due to anthropogenic activities such as mining and industrial waste or agrochemicals from agricultural farms.

Concentration of the trace metals; Cd, Ni, Pb, Cr, Hg, and Ag were found below their respective detection limits in all the samples analysed by AAS. Table 2 shows the concentrations of trace metals from the AAS analysis whilst the concentration of trace metals analysed by INAA are shown on Table 3 below.

Trace metals in Groundwater

The concentrations of trace metals in the samples were generally low. However, mean concentrations of Al, As and Fe significantly exceeded their respective WHO limits. The concentrations of Fe in the samples ranged between 0.652-1.888 mg/l. The maximum permissible concentration for iron in drinking water is 0.3 mg/l (WHO, 1993) and it is primarily for reasons of taste and avoidance of staining of sinks and laundered textiles. However, an upper limit of 1.0 mg/l suffices for most purposes (WHO, 1993). The relatively high levels of Fe may be due to its occurrence as a mineral from sediment and rocks or from mining and corroding metals. High concentrations of Fe in water, imparts a bitter taste to water and a brownish colour to laundered clothing. About 65.52% of the groundwater samples were above the WHO maximum permissible limit.

Manganese also occurs naturally as a mineral from sediment and rocks or from mining and industrial waste. Concentrations measured for manganese in the groundwater samples ranged between 0 .035- 0.959 mg/l.

WHO (1993) has given guideline limit for water potability with respect to manganese as 0.5 mg/l. Apart from three groundwater samples; ADT (0.685 mg/l), AKK2 (0.710 mg/l) and A3 (0.959 mg/l) all of the water samples analysed had concentrations less than 0.5 mg/l. Manganese, similarly as Fe, also causes aesthetic and economic damage; causing dark brown or black stains on plumbing and fixtures. It is however, relatively non-toxic to animals but toxic to plants at high levels.

Zinc occurs as a natural mineral in drinking water (Vallee, 1957). Excess zinc produces aesthetic effect and metallic taste on the water. The WHO (1993) recommends a limit of 3.0 mg/l for potable water. Zinc concentration in the groundwater samples in the study area range from 0.032 to 0.380 mg/l. Thus, zinc concentrations in all the samples analysed does not pose quality problem for groundwater supply and development in the area.

Aluminium forms during mineral weathering of feldspars, such as orthoclase, anorthite, albite, micas and bauxite, and subsequently ends up in clay minerals. Aluminium also occurs as an aerosol in oceanic surface layers and in waters. This is because aluminium dust ends up in water bodies through surface run-off or atmospheric transport (LWT, 2009). Aluminium concentration in the groundwater samples ranged from 0.411 to 2.400 mg/l which is higher than the World Health Organization (WHO) legal limit of 0.2ppm for drinking water. The concentration of Aluminium in the study area is therefore of great concern. Aluminium can precipitate out of water, causing increased turbidity or discoloured water. Concentration of Al could therefore pose quality problem for groundwater supply and development in the area.

The provisional WHO recommended limit of Cu is 2.0 mg/l for water potability. The concentrations of Cu in the samples ranged from 0.022 to 1.700 mg/l. Cu is an essential trace metal but toxic to plants and algae at moderate levels. Copper finds its way into water bodies through industrial and domestic waste, mining and mineral leaching. At high levels, Cu can cause gastrointestinal distress in humans and also capable of imparting an adverse taste and significant staining to clothes. Copper concentration, therefore does not pose quality problem for groundwater supply in the area.

Apart from DAN (0.451 mg/l) and PEN2 (0.123 mg/l) all the samples analysed for Arsenic were >0.001, the detection limit. Arsenic is introduced into groundwater through erosion of natural deposits. Other anthropogenic sources may be from the mining industries. Thus two of the samples exceeded the WHO limit of 0.01 mg/l for Arsenic. Arsenic in water can cause skin damage or problems with circulatory systems, and may have increased risk getting cancers. Fig. 1 below shows an area plot of the mean concentrations of trace metals vis-a-vis WHO limits.

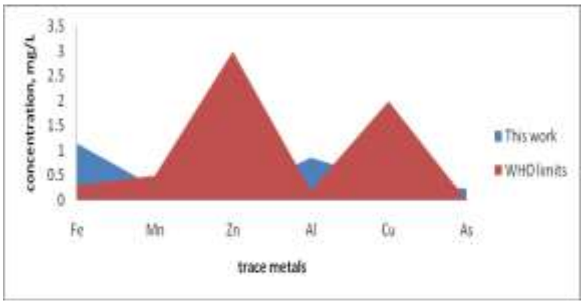

Fig.2 A comparison of WHO limits with trace metals concentrations in this work

Even though most of the samples in the various localities measured concentrations of trace metals below the WHO limit, the mean concentrations of Fe, Al and As were in excess. The mean concentrations of Fe (1.136 ±0.336 mg/l), Al (0.856 ±0.459 mg/l) and As (0.287 ±0.232 mg/l) were above the WHO limits of 0.3 mg/l, 0.2 mg/l and 0.01 mg/l respectively.

Conclusion

Most of the trace metals analysed in the groundwater samples recorded either low values or were below the detection limit (metals that were below detection include; Cd, Ni, Pb, Cr, Hg, and Ag) of the instruments. This could imply the absence of these metals in the waters or if they are present they might have been adsorbed onto clay surfaces. In soils, some metal ions can be adsorbed on clays, forming moderately strong chelates (Celis et al., 2000).

Even though the trace metal concentrations in the groundwater samples were generally low, extremely high concentrations measured for Mn in samples from Duato (ADT), Kukuadu (AKK2) and Ayensuadze (A3) are alarming. Activities in these localities therefore need to be fully studied in future to ascertain the sources of Mn. It is interesting that all the samples measured concentrations of As below 0.001 except samples from Dankwa (DAN) and Penim (PEN 2) which exceeded the WHO limit of 0.01 mg/l. The very high concentrations of As in DAN and PEN 2 of 0.451 mg/l and 0.123 mg/l therefore requires urgent attention in those localities. Further investigations should be carried out to monitor the activities in those localities regarding As contamination of groundwater. Concentrations of Al and Fe exceeded the WHO limits in all the samples analysed. In general quality of the groundwater in the study area is good for domestic purposes.

References

Tay, C (2007). Chemical Characteristics of Groundwater in the Akatsi and Ketu Districts of the Volta Region, Ghana. West African Journal of Applied Ecology.Vol.11: 1-23.

BASH (Baseline Study of Hydrogeology and Water Resources in Central Region), (2008). Vol 1. Technical Reports, for Gomoa, Agona and Awutu Efutu Senya.

Jinwal, A., Dixit, S., Malik, S. (2009). Some Trace Elements Investigation in Ground Water of Bhopal & Sehore District in Madhya Pradesh: India, J. Appl. Sci. Environ. Manage. December, 2009 Vol. 13(4) 47 - 50)

Rao, M.S and Mamatha, P. (2004) Water quality in sustainable water management, Current Science, Vol. 87, No. 7, 10 October 2004

World Health Organisation (WHO) (1993). Guidelines for drinking water quality. Revision of the 1984 guidelines. Final task group meeting. Geneva 21–25 September 1992

LWT, (Lenntech Water Treatment and Purification), 2009. Retrieved 22-03-2010 from the World Wide Web: http://www.lenntech.com/periodic/water/water-glossary.htm

Vallee B. L. (1957). Zinc and its biological significance. Arch. Industrial. Health 16: 147.

CCMA, (Cape Coast Municipal Assembly, about Cape Coast Metropolitan), 2006. Retrieved 22-07-2011 from the World Wide Web: http://www.ghanadistricts.com/districts1on1/capecoast/?arrow=atd&_=50&sa=1915

Table 1.0 Nuclear data of elements determined using INAA

Element	Target Isotope	Formed Isotope	Half - life	Gamma ray Energy Kev
Cu	^{65}Cu	^{66}Cu	5.10min	1039.2
Al	^{27}Al	^{28}Al	2.24min	1778.9
Mn	^{55}Mn	^{56}Mn	2.58h	2113
As	^{75}As	^{76}As	26.32h	559.1

Table 2.0 Concentration (mg/L) of trace metals analysed using AAS

ID	Town	Fe	Zn	Cd	Ni	Pb	Cr	Hg	Ag
ADT	Duato	0.652	0.036	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
AOS	Oseedu	0.672	0.046	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
ADW	Adawukwa	0.680	0.060	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
AKK	Kukuadu	0.768	0.068	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
AKK2	Kukuadu	0.668	0.044	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
AKM	Kwame Abam	0.932	0.052	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
AKN	Kanyanko	1.024	0.380	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
AMA	Mankrong	0.860	0.100	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
A1	Pamfokrom(R)	1.492	0.120	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
A2	Nsuayem(R)	1.196	0.068	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
A3	Ayensuadze(R)	1.048	0.044	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
A4	Mankrong(R)	0.864	0.054	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
GBD1	Buduata	0.960	0.056	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
GBD2	Buduata	0.952	0.072	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
BEW	Bewadze	1.888	0.136	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
SOM	Somanya	1.836	0.136	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
AOK1	Awutu Okwabina	1.368	0.056	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
AOK2	Awutu Okwabina	1.284	0.036	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
OFA	Ofaso	1.572	0.056	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
DAN	Dankwa	1.040	0.072	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
TEK	Tekyem	1.104	0.036	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
PEN1	Penim	1.096	0.084	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
PEN2	Penim	1.104	0.036	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
FIA	Fianko	1.288	0.032	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
KOK1	Kofi Kum	1.144	0.152	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
KOK2	Kofi Kum	1.100	0.036	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
KOK3	Kofi Kum	1.636	0.308	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
ADU	Aduafokwa	1.476	0.164	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
ALA	Alabra	1.232	0.076	<0.002	<0.010	<0.010	<0.006	<0.001	<0.002
Min		0.652	0.032						
max		1.888	0.380						
Mean		1.136	0.090						
Stdev		0.336	0.080						

Table 3.0 Concentration (mg/L) of trace metals analysed using INAA

ID	Town	Cu	Al	Mn	As
ADT	Duato	0.243	0.821	0.685	<0.001
AOS	Oseedu	0.071	1.694	0.437	<0.001
ADW	Adawukwa	0.544	0.831	0.276	<0.001
AKK	Kukuadu	0.030	0.650	0.386	<0.001
AKK2	Kukuadu	0.476	1.051	0.710	<0.001
AKM	Kwame Abam	0.223	0.563	0.182	<0.001
AKN	Kanyanko	0.586	0.971	0.205	<0.001
AMA	Mankrong	0.179	0.666	0.235	<0.001
A1	Pamfokrom(R)	0.077	0.645	0.310	<0.001
A2	Nsuayem(R)	0.855	0.611	0.487	<0.001
A3	Ayensuadze(R)	0.369	0.913	0.959	<0.001
A4	Mankrong(R)	0.048	0.997	0.241	<0.001
GBD1	Buduata	0.140	0.672	0.065	<0.001
GBD2	Buduata	0.087	0.590	0.153	<0.001
BEW	Bewadze	0.403	0.664	0.124	<0.001
SOM	Somanya	0.022	2.400	0.118	<0.001
AOK1	Awutu Okwabina	0.570	0.472	0.265	<0.001
AOK2	Awutu Okwabina	0.326	0.487	0.230	<0.001
OFA	Ofaso	0.263	0.700	0.176	<0.001
DAN	Dankwa	1.354	0.878	0.188	0.451
TEK	Tekyem	0.476	0.411	0.035	<0.001
PEN1	Penim	0.187	0.543	0.082	<0.001
PEN2	Penim	0.245	0.709	0.241	0.123
FIA	Fianko	0.487	0.592	0.141	<0.001
KOK1	Kofi Kum	0.298	0.574	0.041	<0.001
KOK2	Kofi Kum	0.496	0.855	0.287	<0.001
KOK3	Kofi Kum	0.152	2.108	0.274	<0.001
ADU	Aduafokwa	0.159	0.933	0.135	<0.001
ALA	Alabra	1.700	0.828	0.153	<0.001
Min		0.022	0.411	0.035	<0.001
Max		1.700	2.400	0.959	0.451
Mean		0.382	0.856	0.269	0.287
Stdev		0.379	0.459	0.212	0.232