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Investigating the quality of drinking water from selected boreholes in the Akuapem North District in the Eastern Region of Ghana

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ABSTRACT

The object of this work was to study the quality of drinking water from boreholes in selected towns in the Akuapem North District of the Eastern Region of Ghana. In all nineteen (19) boreholes were sampled for trace metals physico-chemical and nutrient analysis. A combination of pH and conductivity meter, potentiometric titration, neutron activation, atomic absorption spectroscopic and ultra violet spectrophotometric techniques were used for the analysis of the water samples. It was observed that about 90% of the samples had pH values below the recommended World Health Organisation (WHO) threshold for drinking water. Analysis of the trace elements revealed that the sampled boreholes have concentration of iron (Fe) in the range (0.09- 3.99mg/l) some of which are above the recommended levels of iron in drinking water. The concentrations of manganese (Mn), aluminium (Al) and Iron are in the range 0.02-1.20mg/l, 10.65-23.12mg/l and 0.09-3.99mg/l respectively.

Introduction

Water is a fundamental resource, integral to all environmental and social processes. Access to adequate safe drinking water is of prime importance to many governments and international organizations because it is a core component of primary health care (Quagraine and Adokoh 2010). It is the basic component of human development as well as a precondition for man's ability to deal with hunger, poverty, disease and death. Regrettably, water has become a scarce commodity as only a small proportion of the world population have access to quality drinking water (IDLO, 2006). Rain and ground water have become major alternative sources of drinking water for many people in Ghana.

All natural waters contain many dissolved substances. Contaminants such as bacteria, viruses, heavy metals, nitrates and salts have polluted water supplies as results of uncontrolled human activities and untreated industrial waste discharges (Singh and Moseley, 2003). Even if no anthropogenic sources of contamination exist there is the potential of natural levels of metals and other chemicals to be harmful to human health (Akpoveta *et al.*, 2011). Site-specific characteristics such as soil type, depth of the aquifer, weather, season and the recharge rate can influence the probability and severity of contamination of groundwater. Any contamination that can percolate the soil and rocks has the potential to reach the groundwater beneath. Generally, areas that are replenished at a higher rate are generally more vulnerable to contamination than those replenished at a lower rate. Large fractures in bedrock also contribute to contamination by providing a pathway for the contaminants (Palaniappan *et al.*, 2010). In Bangladesh for example, high levels of natural Arsenic (As) which is having adverse human health impacts have been reported (Anawara *et al.*, 2002). Monitoring the quality of drinking groundwater is essential for environmental safety and as such analysing physico-chemical properties including trace element content are crucial for public health (Kot *et al.*, 2000).

The Akuapem North District is located in the south-eastern part of the Eastern Region and is about 58km from Accra, the capital city of Ghana. The district shares boundaries to the northeast with Yilo Krobo, north with New Juaben Municipal Assembly, southeast with Dangme West, southwest with Akuapem South Municipal Assembly, and in the west with the Suhum-Kraboa-Coaltar District. The District covers a land area of about 450 sq. km representing 2.3% of the total area of the Eastern Region. The boundary stretches from Obosomase in the South, to Abonse in the east to Okrakwadwo and Asamang in the North to Okorase and Mangoase in the West. The Akuapem North District has about 230 settlements with Akropong as its capital. According to the Population Census publications of Ghana, it is estimated that the total population as at 2000 was 104,753. The District is mountainous, with hills ranging between 381 metres and 488 metres in height, although the highest peak reaches 500 metres above sea level. The district vegetation is made up of broken forest, secondary forest, shrub and bush. Rainfall averages 1270mm, and the weather reflects the invigorating and healthy, mild cold mountainous climate. Geologically, the district is dominated by rocks of Precambrian age, the Togo series and the Birimian series (Asomaning 1993; www.ghanadistricts.com/akuapemnorth).

The main sources of drinking water is pipe borne treated water especially for bigger towns within the District, boreholes and hand dug wells, surface running water and rain water harvesting. Owing to erratic nature of treated pipe borne water supply, most households rely on untreated water from boreholes and hand dug wells for their domestic needs. It has therefore become imperative to investigate the quality of the underground

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drinking water from selected boreholes in some of the towns within the Akuapem North District with the view to informing and educating people on the use of untreated water for domestic purposes.

Materials and Methods

Sample Collection

In all about nineteen borehole water samples were taken from Akropong (9), Mamfe (2), Amanokrom (1), Mampong (2), Abiriw (1), Awukugua (2), Adukrom (1) and Apiredi (1). Water samples were collected individually from a combination of private and public boreholes into acid cleaned high-density 1-L linear polyethylene sampling bottles with strict adherence to the sampling protocol as described by Fianko *et al* (2009) and analyzed independently. Water samples from boreholes were pumped out using the existing infrastructure for over 5 min before samples were taken. Samples were filtered using Sartorius polycarbonate filtering apparatus and a 0.45-μm cellulose acetate filter membrane. At each point, two samples were collected for major ions and trace metal analyses. Samples for trace metal analyses were acidified to pH < 2 after filtration with 10% analytical-grade HNO_3. On-site measurement of temperature, electrical conductivity, total dissolved solids (TDS) and pH were conducted using portable HACH conductivity meter and Metrolin model 691-pH meter, respectively. Before taking readings, all equipments were adequately calibrated. Water samples were transported over ice to the laboratory and stored in a fridge at 4°C prior to analyses.

Sample Preparation and Analysis

About 0.5ml of each sample was pippetted using calibrated Eppendorf tip eject or pipette into a clean pre-weighed 1.5 ml polyethylene vials, weighed and heat sealed. This was done for samples intended for elements with short and medium half lives. For short half life, each sample was placed in a bigger capsule (7.0 ml) with the empty space was filled with cotton wool and heat sealed carefully. For samples intended for medium half life, three of the small vials were put into a bigger capsule and also heat sealed. Standard solutions of the elements of interest were also prepared the same way as samples for irradiation. The samples and standards were irradiated using the Ghana Research Reactor-1 (GHARR-1) facility at the Ghana Atomic Energy Commission (GAEC), Accra. This miniature neutron source research reactor operated at 15 KW with a thermal neutron flux of $5.0x10^{11}n\ cm^{-2}\ s^{-1.}$ The samples were transferred into the inner irradiation sites by means of pneumatic transfer systems at a pressure of 1.723 bars. Samples meant for short-lived elements were irradiated for two minutes and counted for ten minutes while those for medium-lived elements were irradiated for one hour, allowed a decay time of twenty four hours and counted for ten minutes. Counting of samples and standards was done on a PC-based gamma ray spectroscopy system using an N-type high purity germanium detector (HPGe) (Model GR 2518). Taking into consideration the delay time, the dead time and other factors, the concentrations of the samples were computed using the comparator method (Chatt *et al.,* 1981). The iron (Fe) and lead (Pb) were determined by atomic absorption spectrometric methods preceded by acid digestion. The ionic balance for the analyses was within. Analytical grade reagents were used and instruments were pre-calibrated prior to analysis. Replicate samples were analysed to determine the reproducibility of the results.

Water samples collected were analyzed following methods prescribed by the standard methods for the analyses of water and wastewater and EPA (Standard Methods, 1998). The concentrations of the major ions sulphate (SO_4^{2-}), phosphate (PO_4^{3-}) and nitrate (NO_3^-) were determined UV spectrophotometer while that of total hardness and alkalinity were determined by titration in the laboratory.

Results

The results show that the groundwaters in the Akuapem North District are generally within the pH range 5.1–6.5 indicating that the groundwaters are mildly acidic. The guidance value for drinking water in Ghana is in the range of 6.5–8.5 (WHO, 2006). As can be seen from Table 1, the pH values for all the sites except OK2 and AD fell outside this range. Acidity increases the capacity of the water to attack geological materials and leach toxic trace metals into the water making it potentially harmful for human consumption. The moderate acidity of the groundwaters suggests that the waters are susceptible to trace metal pollution if these metals are present in the rock matrix through which the water passes and gives the water sour taste. Electrical conductivity values are in the range of 152.2–777 μS /cm and TDS values also in the range of 68-410mg/l. The guidance values for electrical conductivity and TDS are 1000 μS/cm and 1000mg/l respectively, signifying that the groundwaters are generally fresh. Fianko *et al* (2009) regard groundwater as fresh water if the TDS value is less than 1000 mg/l. Water with hardness in the range 0–60 mg/l, 61–120 mg/l, 121–180 mg/l and > 180 mg/l are regarded as soft, moderately hard, hard and very hard, respectively (Kortatsi, 2007). Groundwaters from the samples varied largely in total hardness from 31-66mg/l. Generally, the waters are soft to moderately hard. The hardness of the groundwaters is derived mainly from carbonate sources.

The results in Table 1 further indicate that about 37% of the samples have nitrate concentration exceeding the maximum threshold levels of 10mg/l. High levels of nutrients, such as nitrate, in water in water can have a negative impact on the groundwater potability (Emmanuel *et al*,. 2009). It is also known that high nutrient concentration can lead to eutrophication which will eventually encourage the growth micro-organisms in the water (Akoto and Adiyia, 2007). The results further revealed that the highest concentration of nitrate (11.6mg/l) was recorded at PJ. The concentration of SO_4^{2-} are generally low and well below the drinking water standard for water potability in Ghana. Generally a low concentration of PO_4^{3-} was observed from all samples. This is important to check the growth of microbiological organisms such as bacteria and algi which can have adverse health on the users of well water (Singh *et al.*, 2006)

The results of the trace metal analysis (Table 2 and Fig.1) revealed that iron (Fe) is one of the most problematic elements associated with the groundwaters in the sampling area. Results from 42% of the samples showed exceedingly high concentrations which are way beyond the threshold values for drinking water (WHO, 2006). The case of SN, PT and OK2 are alarming since these are schools where students depend on well water for their daily activities. At AP and OK2 for instance, brownish colorations were observed around the reservoir at the time of sampling indicating the oxidation of Fe^{2+} to Fe^{3+} at the site. The incidence of high iron concentration in boreholes has resulted in complain from people using the water thereby resulting in low patronage or total rejection of water sourced from these boreholes. Thus, if boreholes are to be relied on for potable water supply as currently practiced, then there is the need to build simple iron removal plant.

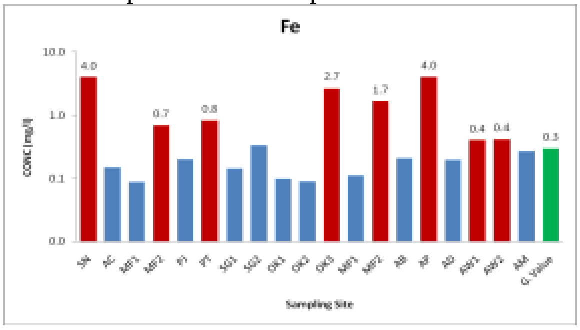

Figure 1: Concentration of Iron (Fe) in samples from all sampling sites

The concentration of aluminium (Al) in the groundwaters is in the range 10.65-23.12 mg/l these values are far in excess of threshold values (WHO 2006) values for drinking as shown in Table 2. The aluminium concentration in the groundwaters within the sampling areas appears to pose quality problem to borehole water supply since all the boreholes exceed the permissible limit for water potability.

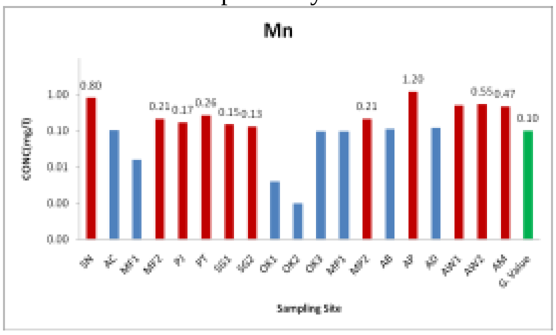

Figure 2: Concentration of manganese in samples from various locations

Manganese occurs in concentrations in the range 0.01 to 1.20mg/l. The highest recorded (1.20mg/l) value was at Apiredi which incidentally recorded high concentration of Fe. Sites like SN, MF2, PJ, PT, SG1, SG2, MP2, AP, AW1, AW2 and AM recorded concentrations that are greater than the standard for drinking water. Building iron removal plant to be attached to the boreholes may be a possible solution to the manganese problem, since most of the wells that have high iron content incidentally have high manganese content. The ferric hydroxide formed in the iron removal plant during aeration has the capacity to absorb manganous ions and hence, the dual removal of both iron and manganese (Jusoh *et al.*, 2005; Ellis *et al.*, 2000).

Conclusion

The study has shown that although most parameters measured were well below WHO drinking water guidance values, about 90% of the sampled boreholes had pH values above the recommended limits that the waters are mildly acidic. The trace metal analysis showed that about 42% of the sampled boreholes have concentration of iron (Fe) above the recommended concentration of iron in drinking water. Furthermore, about 68% of the boreholes had concentration of manganese (Mn) above the recommended levels and all samples had aluminium (Al) levels above the recommended values. It can therefore be concluded that these elements are the major contaminants of groundwater in the samples. It was also found that about 37% of the boreholes sampled had concentration of nitrate above the recommended values indicating that there is possibility of eutrophication occurring in the boreholes. It is therefore recommended that detailed hydrogeochmical analysis be carried out to ascertain the true hydrological conditions of ground water resources in Akuapem.

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Table 1: Physico-chemical characteristics of water samples in the study area

SITE	PH	TEMP	COND	SAL	TDS	ALK	HCO_3^-	NO_3^-	SO_4^{2-}	PO_4^{3-}
Akropong										
SN	5.1	28	152.2	0.1	168.3	40.0	42.0	9.1	89.7	0.035
AC	5.3	27.9	152.5	0.1	68.5	31.0	35.0	8.1	25.0	0.021
PJ	5.4	27.7	777	0.4	348	29.0	50.0	11.6	71.0	0.029
PT	6.3	27.8	393	0.2	176	33.0	55.0	10.9	60.0	0.002
SG1	6.3	27.6	377	0.2	168.6	34.0	49.0	10.1	49.1	0.037
SG2	6.4	27.7	343	0.2	153.2	31.0	48.0	10.0	45.0	0.037
OK1	6.3	25.6	541	0.2	270	30.0	39.0	1.3	90.0	0.034
OK2	6.5	25.6	725	0.2	362	32.0	45.0	1.1	15.0	0.033
OK3	6.2	25.6	381	0.2	181	25.0	35.0	7.2	12.0	0.04
Mamfe										
MF1	5.8	28	492	0.2	220	30.0	37.0	9.5	28.0	0.041
MF2	5.2	27.1	300	0.5	350	28.0	46.0	10.2	27.0	0.022
Mampong										
MP1	6.4	26	400	0.1	166	22.0	32.0	1.4	95.2	0.03
MP2	5.1	27	500	0.5	330	32.0	49.0	8.0	12.5	0.05
Awukugua										
AW1	6.1	26	620	0.5	364	40.0	50.0	10.2	81.5	1.1
AW2	5.91	26.3	661	0.5	370	36.0	51.0	10.3	80.1	1.31
Abiriw										
AB	6.4	26.5	430	0.1	212	31.0	40.0	3.1	86.0	0.034
Apiredi										
AP	5.1	26.1	730	0.8	410	28.0	66.0	9.3	22.0	0.049
Adukrom										
AD	6.5	25.8	333	0.1	321	35.0	31.0	1.2	10.5	0.01
Amanokrom										
AM	6.3	27	400	0.4	366	34.0	36.0	1.4	87.0	0.031
G.V	6.5- 8.5	NGV	1000	NGV	1000	NGV	500	10	200.0	NGV

SN-Mt Sinai SHS Campus, AC-Akropong Clinic, PJ-Ademi water project site, PT-PTC campus, SG-Okuas School gate borehole1&2, OK1, 2&3-Okuas Campus, MF1-Mamfe Apostolic Church, MF2-Mt Horeb Church, AW1&2-Awukugua, AB-Abiriw, AP-Apiredi, AD-Adukrom, AM-Amanokrom community centre, GV-Guidance value, NGV-No Guidance value

Table 2: Concentration of trace metals in water samples

SITE	Fe	Mn	Cu	Al	Na	As	K	Cl	I	Zn	Ca	Mg	Pb	Cd
Akropong														
SN	3.97	0.8	0.03	11.43	2.95	BDL	13.92	7.27	11.3	0.08	3.32	2.29	BDL	BDL
AC	0.15	0.1	0.01	13.33	5.21	BDL	19.34	6.39	10.78	0.06	3.19	1.44	BDL	BDL
PJ	0.2	0.17	0.15	21.3	8.43	BDL	12.05	16.57	20.83	0.08	4.82	2.36	BDL	BDL
PT	0.85	0.26	BDL	12.99	6.01	BDL	21.04	9.39	17.65	0.15	6.88	2.5	BDL	BDL
SG1	0.14	0.15	0.06	21.55	5.37	BDL	17.61	13.6	11.36	0.12	4.95	1.98	BDL	BDL
SG2	0.34	0.13	0.01	22.81	5.34	BDL	18.53	5.81	11.4	0.1	3.86	2.58	BDL	BDL
OK1	0.1	0.01	0.01	11.32	5.58	BDL	16.26	28	12.58	0.12	4.59	3.05	BDL	BDL
OK2	0.09	BDL	0.02	11.56	6.25	BDL	17.1	19.89	11.79	0.18	4.59	3.33	BDL	BDL
OK3	2.7	0.1	0.03	22.14	6.05	BDL	18.5	39	13.22	0.21	4.66	3.33	BDL	BDL
Mamfe														
MF1	0.09	0.02	0.05	16.12	3.81	BDL	17.51	21.12	10.56	0.09	4.51	3.17	BDL	BDL
MF2	0.7	0.21	0.12	16.25	4.89	BDL	13.26	20.34	10.22	0.22	5.68	3.57	BDL	BDL
Mampong														
MP1	0.11	0.1	0.23	10.65	2.88	BDL	10.69	7.5	10.15	0.08	4.78	3.11	BDL	BDL
MP2	1.7	0.21	0.26	22.15	8.11	BDL	20.01	35.11	10.99	0.32	5.63	2.87	BDL	BDL
Awukugua														
AW1	0.41	0.51	0.34	22.3	31.2	BDL	20.5	35.41	10.2	0.77	5.21	5.71	BDL	BDL
AW2	0.42	0.55	0.39	23	33	BDL	20.5	37	10.21	0.68	5.22	5.86	BDL	BDL
Abiriw														
AB	0.21	0.11	0.22	15	7.54	BDL	19.44	19.46	10.23	0.31	5.33	2.88	BDL	BDL
Apiredi														
AP	3.99	1.2	0.5	23.12	10.1	BDL	25.1	43.2	22.1	0.9	6.1	6.01	BDL	BDL
Adukrom														
AD	0.2	0.12	0.24	18.3	11.8	BDL	18.5	24.1	10.9	0.1	4.79	4.32	BDL	BDL
Amanokrom														
AM	0.27	0.47	0.27	16.12	27.2	BDL	21.2	32.2	10.3	0.15	6.01	4.22	BDL	BDL
G. V	0.3	0.1	1	0.2	200	0.01	30	250	NGV	3	200	150	0.01	0.003