Physicochemical Studies of Water from Selected Boreholes in the Bosomtwi-Atwima-Kwanwoma District of Ghana.

Marian Asantewah Nkansah[1*] and J.H. Ephraim, Ph.D. [2]

[1]Department of Chemistry, KNUST, Kumasi-Ghana.
[2]Catholic University of Ghana, Fiapre, Ghana.

*E-mail: maan4gr@yahoo.co.uk
egyamkow@yahoo.com

*Telephone: 0233244977254
0233208716156

ABSTRACT

The physicochemical parameters of water from 17 boreholes from 11 communities in the Bosomtwi-Atwima-Kwanwoma (BAK) District of the Ashanti Region of Ghana (West Africa) were determined within the period June 2006 to investigate their quality. Analyses were done on water samples for pH, Electrical conductivity (EC), Total dissolved solids (TDS), total hardness, colour, turbidity, SO_4^{2-}, Cl^-, PO_4^{3-}, NO_2^-, Fe, Mn, Cu, Zn, Cd, Na, K, Pb and humic acid.

The UV-Visible Spectrophotometer was used to determine SO_4^{2-}, PO_4^{3-} , NO_2^- and humic acid concentration. An Atomic Absorption Spectrophotometer was used to determine Fe, Mn, Cu, Zn, Cd, and Pb. A flame photometer was used for the determination of Na and K, and titrimetry was employed to measure alkalinity, hardness, and chloride content.

The data showed the variation of the investigated parameters in samples as follows: pH 5.1-6.8, Electrical Conductivity (EC) 101-1114 μscm^{-1}, Turbidity 02-45.0 NTU, color <5-60 HU, TDS 36-779 mgL^{-1}, hardness 3-294 mgL^{-1}, alkalinity 20-365 mgL^{-1}, Cl^- 9-60 mgL^{-1}, SO_4^{2-} 0.5-17 mgL^{-1}, PO_4^{3-} 0.1- 2.4 mgL^{-1}, and NO_2^- 0-0.03 mgL^{-1}.

The rest were Fe 0.1 - 3.4 mgL^{-1}, Mn 0.0 - 0.8 mgL^{-1}, Cu 0.01 - 0.3 mgL^{-1}, Zn 0.0 - 3.3 mgL^{-1}, Cd 0.000 - 0.003 mgL^{-1}, Pb 0.000 - 0.038 mgL^{-1}, Na 6 - 87 mgL^{-1}, and K 0.2 - 8.0 mgL^{-1}. The range for humic acid was also 0.8-35.9 x10^{-6} (M).

Apart from some remote cases of trace metal contamination and turbidity the general results showed that water from the boreholes in the Bosomtwi-Atwima-Kwanwoma district had acceptable quality for household utilization.

(Keywords: trace metals, water contamination, water quality, humic acid)

INTRODUCTION

Water pollution arising from the presence of foreign substances (organic, inorganic, bacteriological, or radiological) which tends to degrade the quality of water has become a serious concern today [1]. Trace metals are natural components of the hydrosphere and many are necessary, in minute quantities, for the metabolism of organisms (e.g. arsenic, copper, iron, molybdenum, tin, etc.) [2] The presence of toxic metals such as Pb and Cd in the environment has been a source of worry to environmentalists, government agencies, and health practitioners. This is mainly due to their health implications since they are non-essential metals of no benefit to humans [3].

Trace metals have been referred to as common pollutants, which are widely distributed in the environment with sources mainly from the weathering of minerals and soils [4]. However, the level of these metals in the environment has increased tremendously in the past decades as a result of human inputs and activities [5]. Aside from anthropogenic sources, contamination of water ways can also be from natural sources. Metal pollution comes from both natural and anthropogenic sources [6].

Ghana's total actual renewable water resources are estimated to be 53.2 cubic kilometers per year (km^3/yr), of which 30.3 km^3/yr are internally produced (Table 3). Internally produced surface water amounts to 29 km^3/yr, while groundwater is estimated at 26.3 km^3/yr. The overlap between surface water and groundwater is estimated at 25 km^3/yr [7].

In 2002, 79% of the total population had access to improved drinking water sources; this coverage was 93% in urban areas and 68% in rural areas. A majority of the rural and peri-urban population of Ghana perceive underground water as a safe remedy to their ever increasing water needs. It is therefore crucial that periodic checks are performed on groundwater from Bosomtwi-Atwima-Kwanwoma district to establish its security for consumption since most of the inhabitants depend on borehole water for their water requirements.

MATERIALS AND METHODS

Water was sampled from 17 boreholes from 11 communities in the Bosomtwi-Atwima-Kwanwoma District of the Ashanti Region of Ghana for analysis within the period of June 2006. Alkalinity, hardness, and chloride content were determined by titrimetric methods.

Atomic Absorption Spectrophotometer (AAS) was used for the determination of trace metals namely Fe, Mn, Cu, Zn, Cd, and Pb.

Flame Photometer was used for Sodium and Potassium concentration determinations.

UV-Visible Spectrophotometer was used to determine the cations (SO_4^{2-}, PO_4^{3-} , NO_2^- and humic acid) concentrations.

RESULTS

The results of the physicochemical analysis performed have been recorded in Tables 1, 2, 3, and 4. Concentrations of anions (chloride, phosphate, nitrate and sulphate) trace metals, (Pb, Zn, Cd, Cu, Mn, Fe, Na and K) and humic acid concentration were also determined.

Table 1: Physicochemical Parameters of Samples from the BAK District.

SAMPLE	pH	EC µs/cm	TDS mg/L	Color HU	Turbidity NTU	Hardness mg /L	Alkalinity mg / L
A1	5.6	157	60	<5	0.4	43	140
TA1	6.1	343	138	<5	7.5	103	135
TA2	6.1	333	132	<5	0.2	36	30
OD1	6.0	464	186	60	20.2	9	195
OD2	5.9	405	126	40	12.7	118	145
NKK1	5.3	192	72	<5	0.2	25	55
OKK1	6.1	297	114	15	5.1	106	130
OKK2	6.0	427	168	<5	0.4	143	140
AT1	6.0	188	72	<5	0.4	42	35
AT2	6.1	225	90	<5	0.2	45	30
AB1	5.5	101	36	<5	2.4	23	35
AB2	5.1	140	54	<5	0.7	33	20
KKM	6.7	671	469	<5	1.3	294	210
BKA1	6.8	551	386	<5	0.2	283	175
BKA2	6.8	443	310	<5	0.2	262	170
NN1	6.7	843	590	<5	0.2	3	365
ASS1	6.8	1114	779	40	45.0	402	170

Table 2: Concentration (mg/L) of Anions and Trace Metals in Water from BAK District.

SAMPLE	Cl^-	SO_4^{2-}	PO_4^{3-}	NO_2^-	Fe	Mn	Cu	Zn	Cd	Pb	Na	K
A1	9	1.5	0.6	0.01	0.1	0.01	0.01	b/d	b/d	b/d	25	0.2
TA1	15	2.0	1.3	b/d	1.3	0.31	0.01	0.1	b/d	b/d	27	2.0
TA2	17	1.2	1.2	b/d	0.8	0.30	0.10	0.1	0.001	0.038	17	2.0
OD1	24	1.1	2.0	b/d	0.3	0.80	0.02	b/d	b/d	b/d	27	1.0
OD2	20	2.6	1.7	b/d	0.5	0.40	0.10	b/d	b/d	b/d	33	1.0
NKK1	18	2.1	1.1	b/d	0.3	0.10	0.10	0.1	b/d	b/d	6	3.0
OKK1	9	0.5	2.4	0.01	0.5	0.10	0.10	b/d	b/d	b/d	9	3.0
OKK2	18	1.1	0.9	0.01	0.3	0.10	0.10	b/d	b/d	b/d	19	3.0
AT1	12	1.7	0.6	0.01	0.1	b/d	0.10	b/d	b/d	b/d	9	7.0
AT2	15	2.4	1.3	0.03	0.2	b/d	0.10	b/d	b/d	b/d	10	7.0
AB1	26	1.5	1.6	0.01	0.2	0.02	0.10	b/d	b/d	b/d	6	3.0
AB2	34	2.4	0.3	0.01	0.3	b/d	0.03	b/d	b/d	b/d	21	2.0
KKM	59	17.0	0.1	0.01	1.4	0.30	0.20	3.3	0.003	b/d	45	8.0
BKA1	40	11.2	0.1	0.01	0.5	0.14	0.30	0.2	0.001	b/d	55	1.0
BKA2	28	10.0	0.1	0.03	1.0	0.03	0.20	b/d	b/d	b/d	52	1.0
NN1	53	16.8	0.4	0.01	1.8	0.07	1.00	0.5	0.001	b/d	87	2.1
ASS1	60	9.5	0.1	0.01	3.4	0.02	0.10	b/d	0.001	b/d	59	5.0

b/d: below detection

Table 3: Organic Acid Concentration of Water and Depth of Boreholes.

SAMPLE	DEPTH OF BOREHOLE (m)	Organic Acid Conc. x10^{-6} (M)
A1	46	1.3
TA1	71	19.9
TA2	70	26.2
OD1	73	35.9
OD2	63	34.6
NKK1	61	11.8
OKK1	64	13.5
OKK2	55	14.0
AT1	57	2.1
AT2	61	1.3
AB1	60	4.2
AB2	63	8.4
KKM	49	6.8
BKA1	59	3.6
BKA2	40	0.8
NN1	74	3.8
ASS1	82	67.6

Table 4: Analyte, %Recovery and Standard Deviation.

PARAMETER	Mean % Recovery	Standard Deviation (n = 3)
SO_4^{2}	99.7	0.66
PO_4^{3-}	99.6	0.12
NO_2^-	99.7	1.10
Fe	96.0	0.71
Mn	97.7	0.50
Cu	99.8	0.38
Zn	99.5	0.31
Cd	99.2	0.64
Pb	99.3	0.50
Na	96.3	1.10
K	98.8	0.31
Organic Acid	95.4	1.50

DISCUSSION

The water samples had acceptable levels pH in the range of 5.1- 6.8. Even though the WHO limit is 6.5-8.5, values of 5.0 are still permissible according to the Ghana Water Company standards.

Levels of EC and TDS were all below the WHO limits of 1500µs/cm and 1000mg/L respectively. It was observed that the EC of samples increased with increasing TDS results [Table 1].

The acceptable limit of color for drinking water is 15HU. Samples OD1, OD2 and ASS1 had color of 60, 40 and 40 respectively. These values all exceed the WHO limit. The rest of the samples gave acceptable color readings [8].

In the case of turbidity, the limit is 5NTU. Five of the analyzed sample had levels above the limit of

5NTU while the rest were below the limit [Table 1].

Hardness and alkalinity of drinking water are said to be acceptable at 500mg/L and 200mg/L respective according to the WHO. Alkalinity of 500mg/L is however also acceptable by the Ghana Water Company and USEPA standards [Table 1]. Based on these standards, the levels of alkalinity and Total Hardness recorded for all the samples can be said to be within safe limits.

Evidence relating chronic human health effects to specific drinking water contaminants is very limited. In the absence of exact scientific information, scientists predict the likely adverse effects of chemicals in drinking water using laboratory animal studies and, when available, human data from clinical reports and epidemiological studies. The standard development process uses assumptions that are protective of public health in that they tend to err on the side of caution in assessing potential health risks [9].

From Table 2, it is realized that levels of Chloride, Sulphate, Phosphate and Nitrite are all below the acceptable limits.

Even though the Who limit of iron in water is 1 mg/L, samples TA1, KKM, NN1 and ASS1 which gave concentrations more that 1 mg/L do not pose any health hazards.

Iron is not hazardous to health, but it is considered a secondary or aesthetic contaminant. Essential for good health, iron helps transport oxygen in the blood. Most tap water in the United States supplies approximately 5 percent of the dietary requirement for iron [10].

Levels of Manganese and copper measured were all below the Who standard of 0.5mg/L and 2.0mg/L.

The health effects from over-exposure of manganese are dependent on the route of exposure, the chemical form, the age at exposure, and an individual's nutritional status [11].

Copper is an essential mineral in the diet. Too much copper, however, can cause health problems. Major food sources of copper are shellfish, nuts, grains, leafy vegetables, and stone fruits. Typical sources of copper from food range from less than 2 milligrams (mg.) to 5 mg. per day [12].

Although Zinc has been found to have low toxicity to man, prolonged consumption of large doses can result in some health complications such as fatigue, dizziness and neutropenia [13]. The Zinc concentration of all the samples analyzed was below the limit of 3.0 mg/L set by WHO.

Out of the 17 samples analyzed, 5 contained trace and safe amounts of Cadmium while the remaining 12 samples had no delectable cadmium. Cadmium is one of the most toxic elements with reported carcinogenic effects in humans [14]. It accumulates mainly in the kidney and liver and high concentrations have been found to lead to chronic kidney dysfunction [15].

The United States Environmental Protection Agency has classified lead as being potentially hazardous and toxic to most forms of life [16].

Out of the 17 samples analyzed, 1 sample contained lead with concentration of 0.038mg/L (sample TA2). Water from this sample cannot be consumed since the form of the lead was not determined. The WHO however sets the limit for lead at 0.01mg/L which is far lower that the result obtained. The remaining 16 samples did not contain detectable levels of lead.

Sodium and potassium have no health implications and the levels obtained were of acceptable limits for drinking water. The sodium ion is ubiquitous in water. Most water supplies contain less than 20 mg of sodium per liter, but in some countries levels can exceed 250 mg/liter [17].

Potassium is an essential element in plant, animal and human nutrition [18]. In humans, potassium ions play a critical role in many vital cell functions, such as metabolism, growth, repair and volume regulation, as well as in the electric properties of the cell [19].

Potassium intoxication by ingestion is rare, because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting [20]. However, acute ingestion of doses greater than 2.0 meq/kg bw (>78 mg/kg bw or 5.5 g for a 70 kg adult) by individuals with normal kidney function can overwhelm homeostatic mechanisms and possibly cause death [21].
The USEPA has not been able to set a guideline for sodium in drinking water.

There was no correlation between the concentration of humic acid and the depth of boreholes. Even though humic acids can act as adsorbents for metals in solution, there was no such correlation between the concentrations of total metals and the humic acid concentrations in samples analyzed [Table 4].

CONCLUSION

The project exposed that majority of the water from boreholes analyzed from the Bosomtwi-Atwima-Kwanwoma district of the Ashanti Region of Ghana are harmless for household consumption even though there were isolated cases of high levels of turbidly, color, and trace metals. The methods of determinations gave acceptable recoveries making the results authentic.

ACKNOWLEDGEMENT

We are grateful to the Catholic Academic Exchange Service (KAAD) - Germany, the Government of Ghana, the Community Water and Sanitation Agency of Ghana, and the Department of Chemistry-KNUST, Ghana for their support and contributions to the success of this project

REFERENCES

1. Salami, A.W. 2003. "Assessment of the Level of Water Pollution along Asa River Channel, Ilorin, Kwara State, Nigeria". *Nig. J. Pure Appl. Sci.* 18: 1423–1429.

2. Ward, N.I. 1995. "Trace Elements". In: Fifield, F.W. and Haines, P.J. (eds.). *Environmental Analytical Chemistry*. Blackie Academic and Professional. Chapman and Hall: London, UK.

3. Tyler, T.G. 1981. "Heavy Metals in Soil Biology and Biochemistry". In: Paul, E.A. and Ladd, J.N. (eds.). *Soil Biochemistry*. Marcel Dekker: New York, NY. 33 pp - and - Borgmann, U. 1983. "Metal Speciation and Toxicity of Free Metal Ions to Aquatic Biota". In: Nriagu J.O. (ed.) *Aquatic Toxicity, Advances in Environmental Science and Technology*. Vol. 13. John Wiley & Sons: New York, NY. 47-73.

4. Merian, E. (ed.) 1991. *Metals and their Compounds in the Environment*: *Occurrence, Analysis and Biological Relevance*. UCH Weinheim: New York, NY. -and- Basel-Cambridge, O'Neil P. 1993. *Environmental Chemistry*. Chapman and Hall: London. UK. 193.

5. Preuss, E. and Kollman, H. 1974. "Metallgehalte in Klarschlammen". *Naturwissenschafter*. 61: 270-274. -and- Prater, B.E. 1975. "The Metal Content and Characteristics of Steelwork Effluents Discharging to the Tees Estuary". *Water Pollution Control.* 74:63-78.

6. Moore, J.W. and Ramamoorthy, S. 1984. "Heavy Metal in Natural Waters". *Applied Monitoring and Impact Assessment*. Springer-Veriag: New York, NY. 59(4):493.

7. Food and Agriculture Organization (FAO). (Content source); Jim Kundell (Topic Editor). 2007. "Water Profile of Ghana." In: *Encyclopedia of Earth*. Cutler J. Cleveland (ed.). Environmental Information Coalition, National Council for Science and the Environment: Washington, DC. [First published in the Encyclopedia of Earth March 15, 2007; Last revised April 8, 2007; Retrieved November 6, 2007].

8. World Health Organization (WHO). 2004. "Guidelines for Drinking-Water Quality". 3(11)1: 45-196.

9. Rutgers Cooperative Research & Extension. 2005. *Interpreting Drinking Water Quality Analysis: What Do the Numbers Mean?* 6th edition. Princeton, NJ. p.4.

10. Illinois Department of Public Health. 1999. "Iron in Drinking Water. Division of Environmental Health: Springfield, IL. 217-782-5830.

11. United States Environmental Protection Agency (USEPA). 2004. *Drinking Water Health Advisory for Manganese*. Health and Ecological Criteria Division: Washington. DC.

12. Washington State Department of Health (WSDH). 2006. *Copper in Drinking Water*. Division of Environmental Health: Washington. DC.

13. Hess, R. and Schmidt, B. 2002. "Zinc Supplement Overdose Can Have Toxic Effects". *J. Paediatr. Haematol./Oncol*. 24:582-584.

14. Goering, P.L, Waalkes, M.P., and Klaassen, C.D. 1994. "Toxicology of Metals". In: Goyer R.A. and Cherian M.G. (eds.). *Handbook of Experimental Pharmacology*. Springer: New York, NY. 115:189.

15. Woodworth, J.C. and Pascoe, V. 1982. "Cadmium Toxicity to Rainbow Trout, *Salmon gairdneri* Richardson. A Study of Eggs and Alevins". *J. Fish. Biol.* 21:47-57.

16. United States Environmental Protection Agency (USEPA). 1986. *Quality Criteria for Water*. Office of Water Regulations and Standards: Washington DC.

17. World Health Organization (WHO). 2003. *Guidelines for Drinking-Water Quality*. 23(11):145-196.

18. Lewis, R.J. 1997. *Hawley's Condensed Chemical Dictionary. 13th edition*. Van Nostrand Reinhold: New York, NY.

19. Adriogué, H.J. and Wesson, D.E. 1994. *Blackwell's Basics of Medicine: Potassium*. Blackwell Scientific Publications: Boston, MA.

20. Gosselin, R.E., Smith, R.P., and Hodge, H.C. 1984. *Clinical Toxicology of Commercial Products. 5th edition.* Williams and Wilkins: Baltimore, MD.

21. Buckley, N.A., Dawson, A.H., and Reith, D.A. 1995. "Controlled Release Drugs in Overdose: Clinical Considerations". *Drug Saf.* 12(1): 73-84.

SUGGESTED CITATION

Nkansah, M.A. and J.J. Ephraim. 2009. "Physicochemical Studies of Water from Selected Boreholes in the Bosomtwi-Atwima-Kwanwoma District of Ghana". *Pacific Journal of Science and Technology.* 10(2):643-648.

Pacific Journal of Science and Technology