Physicochemical Evaluation of The Water from Boreholes Selected from The EJ and BAK Districts of the Ashanti Region of Ghana

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Abstract

The circumstances of available water to many Districts in Ghana reflect the global situation where water supplies needed for development are scarce and often polluted. This has prompted the digging of numerous boreholes in many rural communities in Ghana. Though the numbers of boreholes are impressive, there is the need to determine and monitor the quality of water that is being drawn for human activity.

This work determined physicochemical parameters of water from 21 boreholes from 13 communities in the Ejisu-Juaben (EJ) and 17 boreholes in 11 communities in the Bosomtwi-Atwima-Kwanwoma (BAK) districts of the Ashanti Region of Ghana (West Africa) within the period of November 2004 to June 2005 with the aim of accessing the quality.

Water samples were analysed for pH, Electrical Conductivity (EC), Turbidity, Colour, Total Hardness, Total Alkalinity TDS, SO_4^{2-}, Cl^-, PO_4^{3-}, NO_2^- , Fe, Mn, Cu, Zn, Cd, Na, K and Pb.

The UV-Visible Spectrophotometer was used to determine SO_4^{2-}, PO_4^{3-} and NO_2^- concentration. An atomic Absorption Spectrophotometer was used to determine Fe, Mn, Cu, Zn, Cd, 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 4.0-8.0, Electrical Conductivity (EC) 44 - 1114 μScm^{-1}, Turbidity 0.11 - 45 NTU, Colour <5-60 HU, TDS 31 -779 mgl^{-1}, hardness 3-402 mgl^{-1}, alkalinity 10-365 mgl^{-1} ,Cl^- 5.0 - 92 mgl^{-1}, SO_4^{2-} 0.25-17.0 mgl^{-1}, PO_4^{3-} 0-2.4 mgl^{-1} and NO_2^- 0-0.08 mgl^{-1}.

The rest were Fe 0.01-3.4 mgl^{-1}, Mn 0-1.65 mgl^{-1}, Cu 0.01 -1.3 mgl^{-1}, Zn 0-3.3 mgl^{-1}, Cd 0 - 0.059 mgl^{-1}, Pb 0-0.038 mgl^{-1}, Na 4-87.0 mgl^{-1} and K 0.2-68 mgl^{-1}.

With the exception of isolated cases of trace metal contamination and turbidity, the general results showed that water from the boreholes in the two districts had acceptable chemical quality for household activities

Keywords: trace metals, water, contamination, quality

1. Introduction

According to O.A. A. Eletta, water and land are being increasingly stressed through the action or inaction of man, leading to environmental pollution. And such water may be temporarily or permanently impaired in quality as a result of these actions [1].

Some of the important components of the environment are metals and metallic compounds. Some are toxic while others are essential. The transport of various toxic metals in our environment, however, can cause excessive exposures which may be hazardous to human health [2].

"Heavy metals are natural components of the earths crust, and they can enter the water and food cycles through a variety of chemical and geological processes" [3].

Industrial development and urban expansion frequently cause a rise in heavy metal levels in the environment [4].

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. 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. 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[5].

The majority of the rural and peri-urban population of Ghana perceive underground water as a safe remedy to their ever increasing water needs.

E-J and BAK are among the 21 administrative districts in the Ashanti Region of Ghana [Fig.1]. "The two districts are in close proximity. E-J stretches over an area of 637.2 Km^2 while BAK has an area of 681.799 Km^2. E-J has a population of 124,176 and BAK has 145,524 inhabitants according to the 2000 Population and Housing Census" [6].

The two fast growing districts under study are very close to Kumasi, the Capital City of the Region and are at the receiving end of urbanization, industrialization and its resultant pollution in the Region.

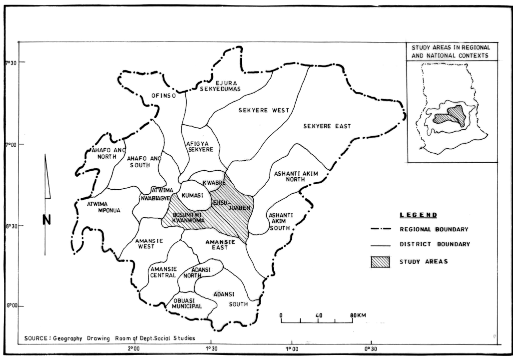

Figure 1: The Ashanti Region of Ghana showing administrative districts

Reliance on rain water is almost impossible and most surface water sources in these districts are either polluted or dried up. Government and individuals have resorted to groundwater to satisfy major water needs.

It is therefore crucial that periodic checks are performed on groundwater from these two to establish its security for consumption since most of the inhabitants depend on borehole water for their water requirements.

2. Materials and Methods

A total of 21 boreholes from 13 communities in the Ejisu-Juaben and 17 boreholes from 11 communities of the Bosomtwi-Atwima-Kwanwoma Districts of the Ashanti Region of Ghana were sampled for analysis within the period of November 2004 to June 2005.

Prior to sample collection, all bottles were washed with dilute acid followed by distilled water and were dried in an oven. At each sampling location, water samples were collected in one glass and two poly-propylene bottles. Before taking final water samples, the bottles were rinsed three times with the water to be collected. The sample bottles were labeled with date and sampling source [7].

Titrimetry was used to determine alkalinity, hardness and Chloride content.

Atomic Absorption Spectrophotometer 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-} and NO_2^-) present. The usual standard methods were employed for pH, conductivity, colour, turbidity and TDS.

3. Results

Physicochemical analysis was performed on 38 water samples. The results are shown in Tables 1, 2, 3, 4 and 5. Concentrations of anions (chloride, phosphate, nitrate and sulphate), trace metals, (Pb, Zn, Cd, Cu, Mn, Fe, Na and K) were determined.

Table 1: Physicochemical Parameters of samples from the E-J District

SAMPLE	pH	EC, µS/cm	TDS mg l^{-1}	Colour HU	Turbidity NTU	Hardness mg l^{-}	Alkalinity mg l^{-1}
AJI	6.4	108	47	<5	0.23	42	50
AJ2	6.2	201	86	<5	0.27	53	45
AC1	4.3	573	246	<5	0.19	88	10
AC2	4.3	376	162	<5	0.17	62	20
AC3	4.0	521	225	<5	0.11	91	20
AC4	5.2	103	44	<5	0.21	56	30
PA1	8.0	848	593	<5	1.66	231	320
AD1	6.7	482	208	<5	0.21	163	100
AD2	6.1	448	193	<5	0.22	120	45
AD3	6.9	105	46	<5	0.20	104	100
KA1	6.9	141	61	<5	0.62	72	110
KA2	6.6	251	108	<5	0.35	62	100
KA3	5.7	191	134	<5	0.56	30	120
OA1	6.3	622	435	<5	0.40	176	110
BBM	6.1	224	157	<5	0.81	77	220
OF	6.8	315	221	<5	1.60	81	360
BM	5.5	140	98	<5	0.36	40	180
KF	6.3	249	174	<5	0.88	94	310
EJ1	5.1	153	107	<5	0.24	37	100
PS	4.6	44	31	<5	0.22	10	45
AM	5.3	57	40	<5	0.28	13	55

Table 2: Concentration of Anions and Trace metals (mg l^{-1}) in water from Ejisu-Juaben district

SAMPLE	Cl^-	SO_4^{2-}	PO_4^{3-}	NO_2^-	Fe	Mn	Cu	Zn	Cd	Pb	Na	K
AJI	5	3.3	0.14	0.05	0.3	0.01	0.5	0.04	0.002	b/d	10	4
AJ2	44	1.5	0.87	0.01	0.3	0.04	0.2	0.1	0.002	b/d	21	9
AC1	43	1.2	0.21	0.01	0.4	1.65	0.3	0.2	0.002	b/d	30	68
AC2	24	1.4	0.01	0.01	0.2	0.35	0.1	b/d	0.002	b/d	8	6
AC3	67	3.7	0.01	0.01	0.2	0.50	0.7	0.1	0.001	b/d	37	15
AC4	31	1.0	0.15	0.03	0.1	0.30	0.6	b/d	0.001	b/d	21	5
PA1	38	0.7	1.12	b/d	0.7	0.09	b/d	b/d	0.002	b/d	76	3
AD1	31	3.0	0.07	0.01	0.1	0.43	0.2	0.1	0.002	0.029	33	14
AD2	12	0.5	0.05	0.02	0.4	0.09	0.1	0.3	0.003	b/d	36	1
AD3	15	3.3	0.19	0.08	0.2	0.13	0.1	0.1	0.059	b/d	19	1
KA1	15	2.6	0.10	0.01	2.1	0.10	1.3	0.3	0.003	0.005	27	3
KA2	9	0.6	0.06	0.01	0.3	0.04	0.1	0.1	0.001	b/d	28	2
KA3	27	1.4	0.22	0.01	0.2	0.01	0.2	b/d	0.001	b/d	13	1
OA1	92	2.5	0.11	0.02	0.6	0.04	0.2	b/d	0.001	b/d	49	14
BBM	14	1.2	b/d	0.01	0.2	0.03	0.1	0.2	0.006	b/d	7	3
OF	14	2.2	0.01	0.01	0.2	b/d	b/d	b/d	b/d	b/d	5	3
BM	19	2.1	0.39	b/d	0.2	0.26	0.1	b/d	0.006	0.022	22	4
KF	9	1.0	0.40	b/d	0.2	0.01	0.1	b/d	b/d	b/d	8	1
EJ1	14	5.9	0.47	0.01	0.6	0.26	0.3	0.4	b/d	b/d	4	1
PS	42	0.7	0.51	0.01	0.1	0.03	b/d	b/d	0.003	b/d	5	2
AM	18	0.25	0.90	0.01	0.4	0.06	b/d	b/d	b/d	b/d	8	1

- **b/d: below detection**

Table 3: Physicochemical Parameters of samples from the BAK-J District

SAMPLE	pH	EC, μS/cm	TDS mg l^{-1}	Colour HU	Turbidity NTU	Hardness mg l^-	Alkalinity mg l^{-1}
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

Table 3: Physicochemical Parameters of samples from the BAK-J District (Continued)

SAMPLE	pH	EC, μS/cm	TDS mg l^{-1}	Colour HU	Turbidity NTU	Hardness mg l^{-}	Alkalinity mg l^{-1}
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 4: Concentration of Anions and Trace metals (mg l^{-1}) 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

Table 4: Concentration of Anions and Trace metals (mg l^{-1}) in water from BAK district (Continued)

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 5 Analyte, % Recovery and Standard Deviation

Analyte	**% Rec.**	**Standard Deviation n=3**
Sulphate	99.7	0.66
Phosphate	99.6	0.12
Nitrite	99.7	1.10
Iron	96.0	0.71
Manganese	97.7	0.50
Copper	99.8	0.38
Zinc	99.5	0.31
Cadmium	99.2	0.64
Lead	99.3	0.50
Sodium	96.3	1.10

4. Discussion

pH

The pH of water samples of the two districts under the study was of the range 4.0 - 8.0 for 21 samples and 5.1 - 6.8 for 17 samples from the Ejisu Juaben (EJ) and Bosomtwi- Atwima-Kwanwoma (BAK) districts respectively [Tables 1 and 3].

Most of these samples fell within the WHO standard of 6.5 - 8.5 [8] for drinking water with the exception of few which were within the acidic range of 4.0 - 5.0 .

It can however be said that the general levels of pH in the BAK were better than EJ.

Conductivity (EC) and Total Dissolved Solids (TDS)

These parameters were all below the acceptable limits of 1500 μS/cm for conductivity and 1000 mg l^{-1} for TDS for both districts. EJ gave a range of 44 - 848 μS/cm for conductivity and 31- 593 mg l^{-1} for TDS while BAK gave 101 μS/cm-1114 μS/cm for conductivity and 36 - 779 mgl^{-1} TDS.

It was observed that the samples from BAK had relatively high values of TDS and conductivity as compared to that of EJ.

It was also realised that most of the TDS values recorded were approximately equal to the product of the conductivity values and a factor within 0.55 - 0.9 .

This is an indication that the analysis was well performed since the expected factor is 0.55-0.9 [9].

Colour and Turbidity

Colour and turbidity are closely related and these parameters usually have a direct correlation. The experimental results in this work did not differ in any way from this assertion. Samples from the EJ district all had colour values less than 15 HU, the acceptable limits for drinking water. It was therefore not surprising that turbidity in the same district, gave a range of 0.11 - 1.66 NTU, also below the limit of 5

NTU. With reference to the BAK district the general trends of colour and turbidity were acceptable with few areas of concern giving rise to a range of <5 HU - 60 HU for colour and 0.2

NTU - 44.95 NTU for turbidity [Tables 1and 3].

Hardness and Alkalinity

Analysis of water samples for hardness and alkalinity proved very acceptable with hardness of water from EJ occurring in the range of 10 - 231 mg l^{-1} as $CaCO_3$ and alkalinity of 10-360 mgl^{-1} as $CaCO_3$. In the case of BAK an equally satisfactory results were recorded with hardness in the range of 3 - 402 mg l^{-1} as $CaCO_3$ and alkalinity of 20-365 mg l^{-1} as $CaCO_3$ [Tables 1and 3].

Hardness values all fell below the WHO guideline value of 500 mg/l. The WHO value for alkalinity however is 200 mg/l as $CaCO_3$ and both districts recorded values that happened to be higher than this value. These however do not pose any health threat to consumers since $CaCO_3$ up to 500 mg l^{-1} is permissible [10].

Anions

The concentrations of chloride, sulphate, phosphate and Nitrite in the samples from EJ and BAK were all of acceptable levels for potable water [Tables 2 and 4].

The concentrations of Nitrite, chloride, sulphate and phosphate in the samples from EJ and BAK were all of acceptable levels for potable water [Tables 2 and 4]. "Nitrite is sometimes produced as a by-product, when chloramine is used as the essential residual disinfectant in public water supplies" [11].

Chloride is found in surface and groundwater from both natural and anthropogenic sources, such as run off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates and septic tanks. Chloride in water is mostly of the form of sodium chloride, potassium chloride and calcium chloride. Chloride concentrations in excess of about 250 mg l^{-1} can give rise to detectable taste in water, but the threshold depends upon the associated cations. Consumers can, however, become accustomed to concentrations in excess of 250 mg l^{-1}. No health-based guideline value is proposed for chloride in drinking-water [12]. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have found their way into water supplies as a result of inadequate treatment and disposal of waste (human and livestock), Industrial discharges, and over-use of limited water resources [13].

Trace metals

Levels of trace metals like copper, zinc, cadmium, sodium and potassium were all of acceptable levels in water from both the Ejisu Juaben and Bosomtwi-Atwima-Kwanwoma districts [Table 2 and 4]. The upper limit of zinc for BAK was 3.3 mg l^{-1} which is 0.3 mg l^{-1} above the WHO limit of 3.0 mg l^{-1}. It however will not pose any health risk to consumers since levels as high as high as 5.0 mg/l are permissible according to the USEPA [14] guideline.

"Zinc and lead concentrations have been related to increase in traffic densities" [15].

In the case of iron and manganese the two districts exhibited higher levels than the acceptable levels. The range for iron was 0.1 - 2.1 mg l^{-1} for EJ and 0.1 - 3.4 mg l^{-1} for BAK. Manganese concentration was in the range of 0 -1.65 for EJ and 0 - 0.8 mgl^{-1} for BAK.

"High levels of Iron and Manganese normally affect the aesthetic value of water. Whereas high iron causes colourisation of water, high manganese can impact taste and odour of water sources" [16].

'Manganese intake from drinking water is normally substantially lower than intake from food. At the median drinking-water level of 10 g/L determined in the National Inorganic and Radionuclide Survey (NIRS), the intake of manganese from drinking water would be 20 g/day for an adult, assuming a daily water intake of 2l. Exposure to manganese from air is generally several orders of magnitude less than that from the diet, typically around 0.04 ng /day on average" [17], although this can vary substantially depending on proximity to a manganese source.

At concentrations most commonly found in drinking water, the presence of iron is not considered a health problem. Iron in drinking water can even provide a health benefit. Small concentrations are essential to human health, because iron helps transport oxygen in the blood [18].

Out of the 21 samples from the EJ district, 2 samples contained lead; the rest had levels that were below detection. In the case of BAK, 1 out of 17 samples contained lead with the rest giving no signal for lead. Even though the ranges given in Table 3 are a bit scary, the reality is that 3 out of 38 samples contained lead.

"Sources of anthropogenic contamination for the aquatic environment include urban sewage (arsenic, chromium, copper, manganese, nickel), biomass combustion (arsenic, mercury, selenium), metal processing (cadmium, nickel, lead, selenium, chromium, molybdenum, antimony, zinc), and seepage from refuse deposits (arsenic, manganese, lead)" [19].

The results therefore do not spell the doom of consumers because 35 out of 38 of the samples are safe for drinking, while the rest can be used for household purposes.

Recovery analysis

A recovery analysis was performed with standard solutions of the analytes and phosphate which gave a mean recovery of 99.6 % and which a standard deviation of 0.12.

Sulphate also gave a mean recovery of 99.7 % and a standard deviation of 0.66. These values indicate high levels of accuracy.

The mean recovery of nitrite was 99.7 % and the standard deviation was 1.1 %.

Standard reference reagents were obtained from the Chemistry laboratory of the Environmental Protection Agency-Ghana (EPA-Ghana) for the recovery analysis of the trace metals.

Iron and Manganese had recoveries of 96 % and 97.7 %, respectively. Their corresponding standard deviations were 0.71 and 0.5, respectively.

The standard solutions of the other metals like lead, cadmium, zinc, copper, sodium and potassium all gave recoveries above 96 % and standard deviations not more than 1.1[Table 5]

5. Conclusion

Regardless of the worry associated with a few records of low pH, high colour and isolated cases of trace metal contamination, most of the borehole water from the EJ and BAK districts of Ghana, using physico-chemical parameters as indicators, can be said to be of acceptable quality for household utilisation.

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