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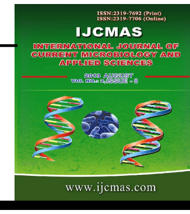

Original Research Article

Bacteriological profile and physico-chemical quality of ground water: a case study of bore hole water sources in a rural Ghanaian community

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A B S T R A C T

Water is a natural resource and is essential to sustain life. Its importance can therefore not be overemphasized. Poor drinking water quality has been linked to several diseases of man including diarrhea particularly in developing countries where availability of portable water is a big challenge. The aim of this paper was to investigate the bacteriological and physicochemical quality of borehole water in Dangme west district of Ghana, with the view to assist policy planners in setting standards to prevent ground water contamination. A total of one hundred and twenty two (122) water samples were obtained from eight hand-dug wells for assessment between June, 2011 and May, 2012. The samples were analyzed for physical, chemical and bacteriological quality following standard procedures. The results were then compared with World Health Organization (WHO) standards for drinking water. Results observed indicates that except for turbidity, total suspended solids, true and apparent colours which were higher than the WHO standards, all other physical properties of the borehole water were found to be within the WHO standards for drinking water. Chemical characteristics of the water show that, with the exception of potassium and the following heavy metals: Lead, nickel, cadmium, and chromium, all the other chemical properties of the water were within the WHO recommended values. Results obtained showed that the bacteriological quality of borehole water was unacceptable. Most Probable Number (MPN) of total coliforms in 100mls of water samples ranged between 0-33MPN/100ml for both total and faecal counts. Three of the samples had total count values of 0MPN/100ml values, which conform to the WHO standard for all drinking water. Additionally, *E. coli* was isolated from all 8 boreholes (20%), followed by *Klebsiella* sp. (19 %). Generally, more (67%) microbes were isolated in the dry season as compared to 33% during the rainy season.

Keywords

Borehole; Bacteriological profile; Ground water; Physico-chemical; Most Probable Number (MPN); Coliforms; Ghana.

Introduction

Water is life! Out of the total amount of global water, only 2.4% is distributed on the main land, of which only a small portion can be utilized as fresh water. The available fresh water to man is hardly 0.3-0.5% of the total water available on the earth (Ganesh and Kale, 1995),

Water has become a limited and scarce resource (Bouwer, 2000). This is due to over exploitation coupled with the growing population (Todd, 1995, and Indra Raj, 2000). Today, about 1 billion people in developing countries lack access to safe drinking water (WHO, 2000). This growing deficit of good quality water in developing countries has spurred the need to utilize other sources of water other than conventional treated waters at maximal risk of microbiological and chemical pollution. As a result, developing countries in particular, are plagued with water related diseases such as diarrheal diseases (Aderigbe *et al.*,2008; Park, 2002) which account for 10% of the disease burden in developing countries (Park, 2002). Furthermore, concentration of pollutants more than their permissible limits in drinking water leads to health problems, such as water borne diseases, like fluorosis, typhoid, jaundice, cholera, premature baby and other problems, especially in infants (Spalding and Exner, 1993).

In Ghana, about 70% of total populations rely heavily on groundwater for drinking purposes (Kortatsi et al, 2008). Groundwater quality reflects inputs from the atmosphere, soil and water rock reactions as well as pollutant sources such as mining, land clearance, agriculture, acid precipitation, and domestic and industrial wastes (Appelo and Postma, 1993; Zhang *et al.*,2011). However the quality of groundwater is deteriorating at a faster pace due to pollution ranging from septic tanks (Olaniya and Saxena, 1977; Gillison and Patmont, 1983), land fill leachates, domestic sewage (Eison and Anderson, 1980; Sharma and Kaur, 1995; Subba and shuba,1995), agricultural runoff/ agricultural fields (Banerji, 1983; Handa; 1986, Ramachandra *et al.*,1991; Datta and Sen Gupta, 1996, Somashekar *et al.*,2000) and industrial wastes (Sharma and Kaur, 1995; Todd, 1995 and Rengaraj *et al.*,1996; Indra Raj, 2000). It is also important to note that groundwater quality is one of the most important aspects in water resource studies (Ackah *et al.*, 2011; Sayyed and Wagh, 2011). It is largely controlled by discharge recharge pattern, nature of the host and associated rocks as well as contaminated activities (Raghunath, 1907; Sayyed and Sayadi, 2011; Zhang *et al.*,2011).

Suitability of water for various uses depends on type and concentration of dissolved minerals and groundwater has more mineral composition than surface water (Mirribasi *et al.*, 2008). The quality of groundwater is constantly changing in response to daily, seasonal and climatic factors. Continuous monitoring of water quality parameters is highly crucial because changes in the quality of water have far reaching consequences in terms of its effects on man and biota. Contamination of groundwater also depends on the geology of the area and it is rapid in hard rock areas especially in lime stone regions where extensive cavern systems are below the water table (Singh, 1982).

The changes in quality of groundwater response to variation in physical, chemical and biological environments through which it pass (Singh *et al.*, 2003). The aim of this study was to assess the microbial and chemical quality of groundwater with the view to assist policy planners in setting standards to prevent ground water contamination.

Demarcation of the study area

The Dangme West District is situated in the Southeastern part of Ghana, lying between latitude 5° 45' south and 6° 05' North and Longitude 0° 05' East and 0° 20' West. The District has a total land area of 1,442 square kilometers, making it the largest in the Greater Accra Region. The land size represents 41.5% of the regional land area. The Dangme West district was selected because of its unique location and characteristics, which is representative of most rural communities in Ghana.

Topography and Drainage

The district forms the central portions of the Accra plains. The relief is generally gentle and undulating, a low plain with heights not exceeding 70 metres. The plains are punctuated in isolated areas by a few prominent inselbergs (isolated rocky hills), outliers and knolls scattered erratically over the area.

Prominent relief features include the Yongua inselberg (427 metres) which appears conical in the air with a number of outliers close to the north of the district around Asutsuare and Osuwem areas; the Krabote inselberg also to the North and the Shai Hills (289 metres) found towards the western portions of the district.

Large rock outcrops and boulders a conspicuously stand in the vicinity of the hills in certain places. The rocky hills together with the large boulders provide immense potentials for stone quarrying, which is already a major pre-occupation in the district.

The general pattern of drainage in the Dangme West District is dendritic with most of the streams taking their source from the Akwapim range which is also serving as a watershed and then flow in a northwest to southwest direction into lagoons on the coast.

Flowing over a fairly low terrain, most of the streams have carved wide valleys for themselves, which are left dry for most parts of the year. The very seasonal nature of most of the streams caused by high temperatures and equally high insulation levels have encouraged the creation of a number of artificial dams and ponds of varying size, used for irrigation and for the watering of livestock.

Geology and Soil

Ancient igneous rocks underlie the major part of the district. Strongly metamorphosed ancient sediments occur along the western boundary. There are also important areas of relatively young unconsolidated sediments in the south and southeast. Dahomeyan gneiss and schists occupy most of the plains proper. Basic gneiss forms a number of large inselbergs in the north and center of the belt. Small rock outcrops are also common in the north close to the inselbergs but are rare in south and southeast. The eastern belt of acidic gneiss consists mainly of the grained metamorphosed rocks rather richer in minerals than the rocks in the western belt.

The predominant soil types in the district are the black clays classified as Akuse series and occupies the central to eastern parts of the district. The soils are highly elastic when wet but become hard and compact when dry and then crack vertically from the surface. This renders the soil unsuitable for land cultivation.

The soil here consists of gray-brown soils loamy for about 15-30 centimeter the surface than abruptly changing to impervious clay which contains lime concretion below a depth of 60 centimeters. The topsoil rapidly becomes draughty during the dry seasons. This type of soil fairly supports any level of crop production. Most parts of the area are however, left for grazing purposes.

Materials and Methods

Water sample collection

All water sampling and preservation procedures were performed according to Standard Methods for the examination of water and wastewater (APHA, 1998; APHA, 1995), and WHO guidelines for drinking water (WHO, 1996, 1982). Sampling for bacteriological analysis was done aseptically with care, ensuring no external contamination of samples. Water samples were taken from boreholes fitted with hand pumps. Before samples were taken, the pumps were continuously operated for about 5 minutes, after which the mouth of the borehole was cleaned with cotton wool soaked in 70% concentrated alcohol and then flamed for about 5 minutes.

Water was again pumped out for a further 3 minutes to allow the metal to cool. Water samples were then collected by direct flow into sterilized bottles and carefully sealed. Immediately after collection, samples were placed in an insulated box (an ice chest) filled with ice cubes to keep the temperature below 4-8C^o. Water samples were collected from wells using containers used by the communities and then transferred into sterile glass bottles for onward transportation to the laboratory. Samples were transported to the laboratory on ice and analyzed immediately in the laboratory or stored in the dark at 4-8^{0}C until they were analyzed.

Physico-chemical and biochemical analyses of the water samples

All procedures carried-out to examine the water samples were performed according to Standard Methods for the examination of water and wastewater (APHA, 1998, 1995), and examination of water for pollution control (WHO) and guidelines for drinking water (WHO, 1996, 1982). Chemical analyses of the water samples were done using the Atomic Absorption Spectrophotometer (AAS) method.

Microbiological analysis

Sub-samples were taken from the samples and analyzed for Total and Faecal Coliform counts (Most Probable Number (MPN) technique) following methods described by the APHA (1998). MacConkey broth Oxoid was used for total coliform and brilliant green bile broth for faecal coliform. Incubation of the total coliform test was done at 37^{0}C whiles faecal coliforms were incubated at 44^{0}C and used as a confirmation of the total coliform test. All bacteria in water samples were also identified by conventional methods and confirmed with an API 20E kit (Bio Merieux, SA France).

Result and Discussion

In the present study table.1 showed the results for the physical properties of water samples taken from borehole during the dry season. The pHs for all the eight (8)-borehole water samples fell between/below the WHO standards of 6.5-8.5. The same trend is observed with electrical conductivity (EC), Total hardness (TH), Alkalinity (OH) and Total dissolved solids (TDS) values. All the 8 samples fell within WHO's acceptable maximum values. However Seven (7) samples representing 88% recorded values above the WHO recommendations for both Total suspended solid (TSS) and Turbidity (TUR). The values obtained for true colour (TC) revealed that 7 (88%) of the samples were above the WHO standards of 5ptcou whiles 1 representing 12% is below the standards. Measurements for apparent colour (AC) also showed the same pattern of results as in measurement of true colour: seven (7) samples representing 78% were above the WHO standards whiles 1(12%) of the samples met the WHO standards of 25ptcou. Currently there are no WHO standards for temperature (TEM), Salinity (SAL), Dissolved Oxygen (DO) and biological oxygen demand (BODs). However it is observed from the table 4.1.8 that, dissolved Oxygen (DO) did not vary much. The highest value was obtained from sample B7 (4.05 mg/L) and the lowest was 1.15mg/L from samples B3 and B6. Biological Oxygen Demand (BOD) ranged from 1.05 mg/L (B3,B4) to 3.15mg/L (B1). Salinity also ranges between 0.10 – 0.20ppt. This value is below 4ppt at which level water is considered salty.

Table.2 presents the results for the physical properties of samples taken from boreholes during the rainy season. The pHs for all the eight (8) borehole water samples fell between/below the WHO standards of 6.5-8.5. The same trend is observed with electrical conductivity (EC), Total hardness (TH), Alkalinity (OH) and Total dissolved solids (TDS) values. All the 8 samples fell within WHO's acceptable maximum values. However five (5) samples representing 63% recorded values above the WHO recommendations for Total suspended solids (TSS). Six (6) samples representing 75% were above the WHO guidelines of 5 FAU for Turbidity (TUR). The values obtained for true colour (TC) reveal that 7(88%) of the samples were within the WHO standards whiles 1 representing 12% was above the standards. Measurements for apparent colour (AC) also showed the same pattern of results. Currently there are no WHO standards for temperature (TEM), Salinity (SAL), Dissolved Oxygen (DO) and biological oxygen demand (BODs). However it is observed from the table 4.1.9 that dissolved Oxygen (DO) recorded the highest value of 4.05mg/L from sample B7 and the lowest, 2.05 mg/L from samples B3 and B5. Biological Oxygen Demand (BOD) ranged from 1.00 mg/L (B4) to 3.13mg/L (B1). Salinity was 0.10 ppt. for all samples.

Table.3 shows the results for Chemical properties of water samples from boreholes during the dry season. As shown in the table all the eight samples fell within the WHO recommended guidelines/standard for: chloride (Cl^-), magnesium (Mg^{2+}), calcium (Ca^{2+}), sodium (Na^+) sulphates ($SO4^{2-}$) and nitrates ($NO3^-$) and fluoride (F-). However one of the samples (B3) had recorded value of 34.30mg/L for potassium (K^+). This was above the WHO recommended value of 30mg/L. There are no WHO standards / guidelines for $PO4^{3-}$ and $HCO3^-$. However it is worth noting that values recorded from all the samples were less than 1mg/L for Phosphates ($PO4^{3-}$). Whiles the highest and lowest values recorded for $HCO3^-$ were 70.71mg/L and 43.89mg/L respectively

Table.4 shows the results for Chemical properties of water samples from boreholes during the rainy season. The trends are similar to observations made in the dry season.

Table.1 Physical properties of water samples from boreholes during the dry rainy season

Sample No.	PH	EC (μS/cm)	TSS (mg/L)	TEM. (°C)	TUR (FAU)	SAL (ppt)	TC (ptcou)	AC (ptcou)	DO (mg/L)	BOD5 (mg/L)	TH (mg/L)	OH (mg/L)	TDS (mg/L)
B1	6.48	160.00	6.00	24.90	16.00	0.20	5.00	15.00	3.80	3.15	48.00	39.00	164.20
B2	7.18	158.20	14.00	25.70	24.00	0.20	0.00	0.00	2.35	1.65	44.00	56.00	76.90
B3	6.65	217.00	19.00	25.30	6.00	0.10	0.00	10.00	2.15	1.05	48.00	56.00	75.30
B4	5.87	152.50	6.00	24.90	3.00	0.10	5.00	15.00	3.80	1.05	30.00	54.00	76.90
B5	5.58	181.90	4.00	25.70	11.00	0.10	0.00	0.00	2.35	1.95	48.00	52.00	75.30
B6	5.53	289.00	9.00	25.30	7.00	0.10	0.00	0.00	2.15	2.00	44.00	40.00	56.50
B7	5.46	25.60	7.00	25.40	12.00	0.10	0.00	0.00	4.05	2.15	50.00	46.00	104.80
B8	5.47	25.50	11.00	25.50	18.00	0.10	28.00	89.00	3.35	2.05	50.00	36.00	87.90
WHO standards	6.5-8.5	300	5	NA	5	NA	5	25	NA	NA	500	200	1000
SAS	0 (0%)	0 (100%)	7 (88%)		7 (88%)		1 (12%)	1 (12%)			0 (0%)	0 (0%)	0 (0%)
SWS	8 (100%)	8 (100%)	1 (12%)		1 (12%)		7 (88%)	7 (88%)			8 (100%)	8 (100%)	8 (100%)

NA = Not Applicable; SAS – Above WHO Standards/Guidelines; SWS - Within/below WHO Standards/Guidelines

Table.2 Physical properties of water sample from bore holes during the rainy season

Sample No.	PH	EC (μS/cm)	TSS (mg/L)	TEM. (°C)	TUR (FAU)	SAL. (ppt)	TC (ptcou)	AC (ptcou)	DO (mg/L)	BOD5 (mg/L)	TH (mg/L)	OH (mg/L)	TDS (mg/L)
B1	5.48	160.00	4.00	22.90	14.00	0.10	4.00	15.00	3.50	3.13	40.00	33.00	160.20
B2	6.18	148.20	12.00	24.70	20.00	0.10	0.00	0.00	2.12	1.45	42.00	53.00	74.90
B3	6.65	210.00	14.00	23.30	4.00	0.10	0.00	10.00	2.05	1.05	42.00	54.00	73.30
B4	5.87	150.50	3.00	22.90	2.00	0.10	4.00	15.00	3.50	1.00	27.00	50.00	72.90
B5	5.58	180.00	3.00	21.70	9.00	0.10	0.00	0.00	2.05	1.65	46.00	50.00	73.30
B6	5.53	279.00	7.00	23.30	6.00	0.10	0.00	0.00	2.25	2.00	43.00	36.00	54.50
B7	5.46	24.60	6.00	23.40	10.00	0.10	0.00	0.00	4.05	2.05	40.00	43.00	99.80
B8	5.47	24.50	8.00	24.50	16.00	0.10	25.00	87.00	3.05	2.05	40.00	33.00	84.90
WHO standards	6.5-8.5	300	5	NA	5	NA	5	25	NA	NA	500	200	1000
SAS	0 (0%)	0 (100%)	5(63%)		6(75%)		1(12%)	1(12%)			0(0%)	0 (0%)	0 (0%)
SWS	8 (100%)	8 (100%)	3(37%)		2(25%)		7(88%)	7(88%)			8(100%)	8 (100%)	8 (100%)

NA - Not Applicable; SAS – Above WHO Standards/Guidelines; SWS - Within/below WHO Standards/Guidelines

Table.3 Chemical properties of water sample from boreholes during the dry season

Sample No.	CI^- (mg/L)	Mg^{2+} (mg/L)	Ca^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	$SO4^{2-}$ (mg/L)	$PO4^{3-}$ (mg/L)	$NO3^-$ (mg/L)	$HCO3^-$ (mg/L)	F^- (mg/L)
B1	35.99	10.05	11.75	11.80	26.10	31.94	0.02	0.38	68.27	0.00
B2	43.99	8.86	21.05	11.10	27.00	37.10	0.05	0.34	65.84	0.00
B3	33.99	10.95	16.11	16.70	34.30	34.68	0.09	1.06	63.40	0.00
B4	55.98	9.66	14.13	11.60	18.10	13.71	0.09	0.25	48.77	0.10
B5	35.99	9.31	13.85	13.50	28.50	23.39	0.08	0.70	56.08	0.00
B6	45.98	8.25	12.35	11.50	19.50	23.87	0.05	0.29	43.89	0.05
B7	24.99	8.49	9.67	50.70	28.30	140.97	0.04	0.32	70.71	0.00
B8	67.98	11.01	9.25	48.10	27.70	249.81	0.09	0.27	68.27	0.00
WHO Std	250	150	200	200	30	250-500	NA	10-45	NA	1.5
SAS	0(0%)	0(0%)	0(0%)	0(0%)	1(12%)	0(0%)		0(0%)		0(0%)
SWS	8(100%)	8(100%)	8(100%)	8(100%)	7(88%)	8(100%)		8(100%)		8(100%)

NA = Not Applicable; SAS – Above WHO Standards/Guidelines; SWS Within/below WHO Standards/Guidelines

As shown in table 4. 1.11, all the eight samples fell within the WHO recommended guidelines/standard for chloride (Cl^-), magnesium (Mg^{2+}), calcium (Ca^{2+}), sodium (Na^+) sulphates ($SO4^{2-}$) and nitrates ($NO3^-$) and fluoride (F^-). However one (1) sample (B3) had measurements (32.30mg/L) above the WHO guidelines/standard of 30mg/L for potassium (K^+). It is worth noting that values recorded from all the samples were less than 1mg/L for Phosphates ($PO4\ ^{3-}$). Whiles the highest and lowest values recoded for $HCO3^-$ were68.71mg/L (B7) and 41.89mg/L (B6) respectively.

Table.5 shows the results for metallic properties of water samples from boreholes during the dry season. Generally all the samples fell within the WHO standards for Iron (Fe), Manganese (Mn,), Copper (Cu), Zinc (Zn), Arsenic (As) and Mercury (Hg). Two samples representing 25% were above the WHO recommended limits for Lead (Pb) whereas three (3) of the samples were above the WHO limits for the following parameter Nickel (Ni), cadmium (Cd and Chromium (Cr). However it is worth noting that some of the metals, for example Mercury (Hg), were below the detection limits in all the water samples analysed. Table 6 shows the results for metallic properties of water samples from boreholes during the rainy season. Generally all the samples fell within the WHO standards for Iron (Fe), Manganese (Mn,), Copper (Cu), Zinc (Zn), Arsenic (As) Mercury (Hg) and Chromium (Cr). Lead (Pb), Nickel (Ni) and cadmium (Cd). Each recorded two (2) samples above the WHO recommended limits. However it is worth noting that some of the metals, for example, Mercury (Hg), were below the detection limits in all the water samples analyzed. Total and faecal coliform count for samples from borehole water sources is presented in table 7. A total of eight (8) different borehole samples were analyzed. The total count for the rainy season ranges from 0 MPN/100ml to 17 MPN/100ml. Samples labeled B6 and B17 had the highest record count of 17 MPN/100ml. Samples labeled B1and B2 recorded the counts of 0MPN/100ml. The faecal count for the rainy season ranges from 0/100ml to 7 MPN/100ml. Samples B5, had the highest record of count of 7MPN/100ml. Sample numbers B1 and B7 had 0 MPN/100ml, counts. The total count for the dry season ranges from 0MPN/100ml to 17 MPN/100ml. Sample labeled B5, had the highest record count of 33 MPN/100ml. Sample labeled B7, recorded count of 0 MPN/100ml.The faecal count for the dry season ranges from 0MPN/100ml to 12 MPN/100ml. Sample B5, had the highest record of faecal count of 22 MPN/100ml. This was followed by sample B3, faecal count of 7 MPN/100ml. Sample numbers B4 and B7, faecal count of 0/100m followed by samples B1 and B2 with a faecal count of 2 MPN/100ml each. Results from Table.8 show that a total of fifty four bacterial isolates (54) was obtained during the period of study. Most of the isolates (36) representing 67% of the total were obtained during the dry season, as against (18) representing 33% in the rainy season. The most commonly occurring organism in the water samples was *E. coli* (11). The second most occurring bacteria were *Klebsiella* sp. (10) representing 19% of the total isolates. This was followed by *Enterobacter* sp. (8) and *Pseudomonas auriginosa* (8) Representing 15% each of the total number of isolates obtained. This was followed by: *Proteus vulgaris* (13%), *Enterococcus faecalis* (9%), *Salmonella S. typhi* (71%), *Vibrio cholerae* (1.%). *Shigella* and *Staphylococcus* were not detected.

Table.4 Chemical properties of water sample from bore holes during the rainy seas

Sample No.	Cl^- (mg/L)	Mg^{2+} (mg/L)	Ca^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	$SO4^{2-}$ (mg/L)	$PO4^{3-}$ (mg/L)	$NO3^-$ (mg/L)	$HCO3^-$ (mg/L)	F^- (mg/L)
B1	30.50	8.05	10.75	10.80	24.10	30.94	0.01	0.31	64.27	0.00
B2	40.99	6.86	19.05	10.10	24.00	36.01	0.03	0.14	62.84	0.00
B3	30.99	8.95	13.11	14.70	32.30	32.68	0.07	1.03	61.40	0.00
B4	51.98	8.60	13.13	10.60	14.10	12.71	0.08	0.15	43.77	0.01
B5	32.99	7.31	12.85	12.50	26.50	21.39	0.07	0.60	53.08	0.00
B6	43.98	6.20	10.35	10.50	15.50	20.87	0.05	0.19	41.89	0.01
B7	22.99	7.09	7.67	47.70	24.30	132.97	0.03	0.22	68.71	0.00
B8	63.98	9.01	6.25	47.10	25.70	240.81	0.07	0.17	66.27	0.00
WHO	250	150	200	200	30	250-500	NA	10-45	NA	1.5
SAS	0(0%)	0(0%)	0(0%)	0(0%)	1(12%)	0(0%)		0(0%)		0(0%)
SWS	8(100%)	8(100%)	8(100%)	8(100%)	7(88%)	8(100%)		8(100%)		8(100%)

NA - Not Applicable; SAS – Above WHO Standards/Guidelines.; SWS - Within/below WHO Standards/Guidelines

Table.5 Metallic properties water of sample from bore holes dry raining season

Sample No.	Trace metals					Heavy metals				
	Fe (mg/L)	Mn (mg/L)	Cu (mg/L)	Zn (mg/L)	As (mg/L)	Pb (mg/L)	Ni (mg/L)	Cd (mg/L)	Cr (mg/L)	Hg (mg/L)
B1	0.120	0.028	0.052	0.004	<0.001	<0.001	0.008	<0.002	0.056	<0.001
B2	0.024	0.008	0.012	0.004	<0.001	0.004	0.015	0.008	0.060	<0.001
B3	0.044	0.104	0.024	8.028	<0.001	<0.001	0.008	<0.002	0.032	<0.001
B4	0.040	0.00	0.012	0.004	<0.001	<0.001	0.084	<0.002	0.004	<0.001
B5	0.160	0.104	0.016	0.004	<0.001	<0.001	0.008	0.008	0.036	<0.001
B6	0.032	0.028	0.024	0.004	<0.001	0.004	0.048	<0.002	0.080	<0.001
B7	0.024	0.052	0.012	0.004	<0.001	<0.001	0.060	<0.002	0.032	<0.001
B8	0.032	0.028	0.012	0.004	<0.001	<0.001	0.088	0.008	0.032	<0.001
WHO	1.0	0.005-0.5	2.0	3.0	0.01-0.05	0.001	0.02	0.003	0.05	0.001
SAS	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (25%)	3 (37%)	3 (37%)	3 (37%)	0 (0%)
SWS	8 (100%)	8 (100%)	8 (100%)	8 (100%)	8 (100%)	6 (75%)	5 (63%)	5 (63%)	5 (63%)	8 (100%)

NA - Not Applicable; SAS – Above WHO Standards/Guidelines; SWS - Within/below WHO Standards/Guidelines

Table.6 Metallic properties water of sample from boreholes during rainy season

Sample No.	Trace metals					Heavy metals				
	Fe (mg/L)	Mn (mg/L)	Cu (mg/L)	Zn (mg/L)	As (mg/L)	Pb (mg/L)	Ni (mg/L)	Cd (mg/L)	Cr (mg/L)	Hg (mg/L)
B1	0.120	0.028	0.052	0.004	<0.001	<0.001	0.008	<0.002	0.004	<0.001
B2	0.024	0.008	0.012	0.004	<0.001	<0.001	0.015	0.008	0.036	<0.001
B3	0.044	0.104	0.024	8.028	<0.001	<0.001	0.008	<0.002	0.032	<0.001
B4	0.040	0.00	0.012	0.004	<0.001	<0.001	0.084	<0.002	0.004	<0.001
B5	0.160	0.104	0.016	0.004	<0.001	<0.001	0.008	<0.002	0.036	<0.001
B6	0.032	0.028	0.024	0.004	<0.001	<0.001	0.015	<0.002	0.036	<0.001
B7	0.024	0.052	0.012	0.004	<0.001	<0.001	0.060	<0.002	0.032	<0.001
B8	0.032	0.028	0.012	0.004	<0.001	<0.001	0.008	0.008	0.032	<0.001
WHO standards	1.0	0.005-0.5	2.0	3.0	0.01-0.05	0.001	0.02	0.003	0.05	0.001
SAS	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	2(25%)	2(25%)	2(25%)	0(0%)	0(0%)
SWS	8(100%)	8(100%)	8(100%)	8(100%)	8(100%)	6(75%)	6(75%)	6(75%)	8(100%)	8(100%)

NA - Not Applicable; SAS – Above WHO Standards/Guidelines. SWS - Within/below WHO Standards/Guidelines

Table.7 Total and fecal coliform count (MPN/100ml) of water samples from bore holes

Sample number	Rainy season		Dry season	
	Total count	Faecal count	Total count	Faecal count
B1	0	0	4	2
B 2	12	2	17	2
B 3	11	5	26	7
B 4	0	0	2	0
B 5	12	7	33	12
B 6	17	5	22	5
B 7	0	0	0	0
B 8	17	6	21	6
WHO standards	0	0	0	0

Source: Fieldwork

The quality of water is central to all of the roles that water plays in our lives. From the beauty of natural waterways teeming with wildlife, to the vital livelihoods that clean rivers and streams support, to the essential role that safe water plays in drinking water and health – good water quality is fundamental to the network of life and livelihood that water supports. Water is an important source of life on earth, and human civilizations blossomed where there was reliable and clean freshwater. Use of water by humans – for drinking, washing, and recreation – requires water free from biological, chemical, and physical contaminations.

Physical Aspects of water quality

The potability of drinking water from domestic well samples is mainly based on recommended permissible limits for certain parameters described by WHO, (1996). The pH is the/a measure of the intensity of acidity or alkalinity and the concentration of hydrogen ions. Apart from acidosis (Ackah et al, 2011), pH has no direct adverse effects on health; however, higher values of pH hasten the scale formation in water heating apparatus and also reduce germicidal potential of chloride. High pH induces the formation of tri halo methane, which is toxic. Below pH 6.5, corrosion in pipes starts, thereby releasing toxic metals such as Zn, Pb, Cd and Cu etc. (Trivedy and Goel, 1986). The pH values of water samples of present study ranged from 5.48 to 7.18 for all the water samples. However the majority of samples (95%) are within the prescribed limit of standards (WHO 2001; 2002).

There was variation in the Electrical conductivity values of the water samples. Generally all the water samples were within the WHO standards of 300 μS/cm. Total suspended solids (TSS) are found mostly in natural surface water. The WHO guideline for Total suspended solids is 5mg/L. The highest values of total suspended solids was recorded in sample numberB3 which had a value of 19mg/L in the dry season and the least from sample5 and B4 both of which recorded 3.0 mg/L.

It can be observed generally that the highest values for TSS were obtained during the dry season, whiles the least values were obtained in the rainy season.

Particles of matter are naturally suspended in water. These particles can be clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Turbidity is a measurement of how light scatters when it is aimed at water and bounces off the suspended particles. It is not a measurement of the particles themselves. In general terms, the cloudier the water, the more the light scatters, and the higher the turbidity. The WHO standard for turbidity in drinking water is 5fau. However, there were variations in the values obtained from the water samples. The highest turbidity values was obtained from sample number B2 with a record of 24fau during the dry season, whiles the least value of 2fau was obtained from sample number B4 during the rainy season. The high level of turbidity could be as a result of anthropogenic activities that usually discharge suspended matter into the water and displace the settled matter (Abdul-Razak et al, 2009)

The WHO guideline/Standard for True colour (TC) and Apparent Colour (AC) are 25ptcou and 5ptcou respectively. The highest values for apparent colour were obtained from sample labeled number B8 which recorded 89ptcou during the dry season and the least value was 0.00. This was obtained from samples numbers B2,B3,B5,B6, in the dry season. The trend was similar for true colour. However it is worth noting that anthropogenic influences have an effect on the colour of water.

The WHO has no guideline for Dissolved oxygen (DO). However, according to the USDA (1992), the level of oxygen depletion depends primarily on the amount of waste added, the size, velocity, and the turbulence of the water body. The highest value of dissolved oxygen was obtained from sample number B7 in the dry season and the least 2.05 mg/L, was recoded from dam sample samples numbers B3 and B5 during the rainy season.

There were variations in results obtained for Biological oxygen demand (BOD). The least value for biological oxygen demand was obtained from dam sample labeled D10 and least from river sample labeled R1, which recorded values of 3.6mg/L and 0.40mg/L respectively. The high BOD values recorded from the river sources could be as a result of discharge of organic waste such as refuse, human and animal excreta, soap etc., into the river.

The WHO guideline/Standard for Total hardness (TH) is 500mg/L. Hardness is caused primarily by calcium and magnesium, but is expressed as mg/L equivalent of calcium carbonate. Hard water causes soap curd, which makes bathroom fixtures difficult to keep clean and cause greying of laundry. Hard water also tends to form scale in hot water tanks, kettles, piping systems, etc. It can foul some water treatment systems such as distillers and reversed osmosis units. Hard water also caused excessive soap consumption and scaling. The highest total hardness value (50mg/L) was obtained from dam sample numbers B7 and B8 during the dry season. The lowest values were obtained from sample number B4, which recorded a value of 27mg/L during the rainy season. Thus all the water samples collected fell within the prescribed limits. It is important to note that total hardness also causes excessive soap consumption and scaling.

The alkalinity (OH) of the water samples was also measured. It is worth noting that the alkalinity is not a specific substance but rather a combined effect of several substances. It is a measure of the resistance of water to a change in pH. The WHO guideline for alkalinity in drinking water is 200mg/L. Alkalinity is a factor in corrosion or scale deposition and may affect some livestock when over 1,000 mg/L. All the water samples were within the WHO standards. It is important to note that notwithstanding the WHO guidelines, it is well known that alkalinity of most prairie waters is in the range of 100 to 500 mg/L, which is considered acceptable.

Total Dissolved Solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulphates and, particularly in groundwater, nitrate (from agricultural sources). The WHO guideline/standard for total dissolved solids is set at 1000mg/L. The highest total dissolved solids value of 164.20mg/L was obtained from sample B1 during the dry season. However the least value recorded was 54mg/L and this was obtained from dam sample B6 during the rainy season. All the results from the various water samples were therefore within the WHO limits.

High levels Nitrate ($NO3^-$**)** **-** are often an indicator of contamination by human or livestock wastes, excessive fertilization, or seepage from dumpsites. The WHO maximum recommended value for nitrates in water is 45mg/L, however maximum acceptable concentration in drinking water should not be more than 10 mg/L. This figure is based on the potential of nitrate to poison infants. Adults can tolerate higher levels, but high nitrate levels may cause irritation of the stomach and bladder. Nitrite causes asphyxiation by entering the bloodstream and reacting with hemoglobin (the red, oxygen-carrying pigment of the blood) to form methemoglobin, which is not able to carry oxygen to the body's tissue. Nitrate in water is approximately 10 times more soluble than in feed. Caution is needed to differentiate between nitrate and nitrate-N or nitrate as N. Nitrate = Nitrate-N * 4.4. The results obtained from the water samples were all below 10mg/L. Thus the samples were safe for consumption by both adults and infants with respect to nitrates levels.

Exposure to high levels of fluoride (F^-), which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis. The WHO standard for fluoride is <1.5mg/L. Similarly, Fluoride - occurs naturally in most groundwater wells and can help prevent dental cavities. As fluoride levels increase above this amount, there is an increase in the tendency to cause tooth mottling. Fluoride levels less than 2mg/L are not considered a problem for livestock. The Fluoride level in samples from the following water sources were all within the WHO guideline/standards. However it is worth noting that fluoride, in varying concentrations, is freely available in nature

Trace metals are needed by the body to satisfy its nutritional requirements. However, only minute quantities are required as high doses lead to health hazards, which are sometimes lethal

(Ackah et all, 2011). Trace metals are widely distributed in the environment with sources mainly from weathering of minerals and soils (Merian, 1991; O'Neil, 1993). However, inputs from anthropogenic activities are known to have increased the levels in the environment tremendously (Prater, 1975; Sayyed and Sayadi, 2011). The WHO Guidelines for trace are metals in water are as follows: iron (Fe) 1.0mg/L, manganese (Mn) 0.5mg/L, Copper (Cu), 2.0mg/L and zinc (Zn) 3.0mg/L. All the samples analyzed fell within the WHO (1996) recommended limits of trace metals in drinking water. In some cases some of their values were even below detectable limits. All the drinking water samples are therefore safe for human consumption as per trace metals standards outline by the WHO.

The presence of heavy metals in the water was also assessed. The Who standards/guidelines for heavy metals in drinking water is as follows: Arsenic (As) 0.05mg/L, lead (Pb) 0.00qmg/L, nickel (Ni) 0.02mg/L, cadmium (Cd) 0 0.003 mg/L, Chromium (Cr) 0.05 mg/L and mercury (Hg) 0.001mg/L. In general chemical characteristics of the water show that, with the exception of potassium and the following heavy metals: Lead, nickel, cadmium, and chromium, all the other chemical properties of the water were within the WHO recommended values.

Microbiological aspects of water quality

The quality of drinking water is a global issue due to the fact that it is an important environmental determinant of health, which is directly linked to the socio-economic development of nations. Unfortunately, about 1 billion people in developing countries lack access to safe drinking water (WHO, 2000). This growing deficit of good quality water in developing countries has spurred the need to utilize other sources of water rather than conventional treated waters at maximal risk of microbiological and chemical pollution. As a result, developing countries particularly, are plagued with water related diseases such as diarrheal diseases (Aderigbe *et al.*, 2008; Park, 2002), which account for 10% of the disease burden in developing countries (Park, 2002). Inhabitants in the study area did not have access to safe and/or quality water in terms of microbial contamination.

Most often, in the rainy season, the frequency and/or number of total and faecal coliform in water sources increases as faeces of human and/or animal are washed into creeks, rivers, streams, lakes or ground water. However, in the dry season, the number/frequency of *E. coli* is higher (Obi *et al.*,1998) due to concentration of the organism during the dry season. This phenomenon was confirmed by the results obtained for the total and faecal coliform counts. The highest total fecal count of 33MPN/100ml was recorded by sample B5 in the dry season.

The same trends are observed with the faecal coliform counts as well. However the WHO standards for drinking water is 0MPN/100ml for both total and fecal coliform counts. The results from table 7 show that only sample number B7 recoded 0MPN/100ml for total and faecal coliform count during both seasons. However two samples B1 and B4 also recoded 0MPN/100ml during the rainy season. Though, the analyses conducted proved microbial presence or contamination of the various samples collected, the degree to which each sampling site was contaminated really differed.

Detection of coliforms in borehole water, no matter how low the counts (in MPN/100 ml), without doubt introduces much concern regarding the bacteriological safety of the water. In some communities, significantly high coliform bacteria in borehole water appear to qualitatively correlate with levels of possible pollution in the immediate surroundings (Anima *et al.*, 2010).

Relying on water for domestic purposes and drinking is indispensable in every country including Ghana. However, data on bacteriological quality and profile of water sources in Ghana is lacking. In this study, the bacteriological quality as well as antibiotic susceptibility profiles of different water sources were examined in order to establish the biological safety of water sources and to provide updated data on resistance of enteric pathogens. Communities in Ghana are known to rely on different water sources, which are devoid of treatment for their domestic water needs as reported in Nigeria by Obi *et al*., (1998).

The higher distribution of bacteria isolates (table 8) in the various water samples implied the level of impurity and/or contamination of the water sources. Moreover, the higher percentage of *E. coli* recorded in all the water sources indicates the rate of faecal contamination from either human or animal source. This corroborates findings by Obi et al. (2002) which revealed that the majority of the water sources in rural communities in Nigeria harbored enteropathogens and were also reported to be of poor microbiological quality and unsafe for consumption. It is also worth noting that the presence of *E. coli* in the water has a potential health hazards effect. It may lead to diseases such as diarrheal, which account for a substantial degree of morbidity and mortality in adults and children (Black, 1993; Du Pont, 1995; Jousilahti *et al.*, 1997; Wasfy *et al.,*2000; El-Sheikh and El-Assouli, 2001).

There was high incidence of bacterial isolates in the rainy season than the dry season indicating that, more bacterial contaminants from incinerators, refuse dumps and human effluents are washed down into the various water sources making them potential sources of conveying microbial pathogens creating greater health complications in the Ghanaian community. According to Payment (1997) and Dufour *et al.*, (2003), the potential of drinking water to transport microbial pathogens to a great number of people, causing subsequent illness is well documented in developing and developed countries at all levels of economic development. Furthermore, the availability of safe drinking water is an indispensible feature for preventing epidemic disease and improving the quality of life (Borchard *et al.*, 2004).

In conclusion it is very important to take into consideration a complete profile of activities within a community when citing boreholes. Indeed, many hydro-geologists and geophysicists involved in the selection of water points actually give little or no consideration to environmental issues; their main objective for success being determined by the ability to "hit" water. Most often, rural folks locate water sources close to their residence for the purpose of convenience and/or proximity. However, the nearby surroundings are at the same time polluted by them making them environmentally unfriendly and highly susceptible to contamination with time.

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