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Investigating the potability of water from dug wells: A case study of the Bolgatanga Township, Ghana

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The aim of this study was to assess the levels of some physico-chemical and microbial water quality parameters in fifteen hand-dug wells in Bolgatanga of the Upper East region of Ghana. The effects of seasonal variation and proximity to pollution sources on the concentrations of some parameters of the well water samples were analysed. The results revealed that, total and faecal coliforms in all fifteen samples exceeded the World Health Organization (WHO) recommended thresholds for potable water in the dry season. Total coliform, faecal coliform, pH, conductivity, and turbidity, total dissolved solid and total hardness increased in concentration during the rainy season, pointing to infiltrations from storm water. Effect of distance from pollution sources was also pronounced on faecal and total coliform counts, which decreased with increasing distance from pollution sources. It is recommended that these wells be disinfected before use.

Key words: Bacteriological, drinking water, potable, water supply, water quality.

INTRODUCTION

Water is one of earth's most precious resources that is indispensably and intricately connected to life. Good drinking water is not a luxury; it is one of the most essential amenities of life. Safe drinking water is a priority for all. This is the reason for which water must be given the necessary attention at all times. Although water is essential for human survival, many do not have sufficient potable drinking water supply and sufficient water to maintain basic hygiene. Globally, 748 million people lack access to improved drinking water and it is estimated that 1.8 billion people use a source of drinking water that is faecally contaminated (WHO/UNICEF, 2004). The majority of these are in Asia (20%) and Sub-Saharan Africa (42%) (WHO, 2000). The need for water treatment before consumption cannot be over emphasized, but irregularity of potable water supply to the population has led to people drinking water from hand-dug wells and other sources including streams (Mustapha and Yusuf, 1999).

The quality of water from dug wells is largely dependent on the concentration of biological, chemical and physical contaminants (Musa et al., 1999). Water is a

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medium for thousands of microorganisms some of which are disease causing. Diseases in human can be causedby the presence of certain pathogenic bacteria and other organisms such as virus, protozoa, and worms. Pathogens causing diarrhoea-related illness such as cholera and dysentery, among many other water-borne diseases are normally derived from human wastes and other contaminated sources of water for consumption (Davis, 2005). According to the World Health Organization (WHO), there were four billion estimated cases of diarrhoea and 2.2 million cases of death annually, and consumption of unsafe drinking water has been implicated as the major cause of this occurrence (WHO, 2000). Well water close to refuse dump sites and septic systems contained more microbial counts of 1600 to 1800 MPN/100 ml than those wells away from septic and refuse sites (Shittu et al., 2008).

Water related diseases are responsible for 80% of all illness or death in the developing countries and kill more than 5 million people every year (UNESCO, 2007). The main drinking water sources, most especially in African countries are from boreholes, pipe borne, deep and shallow wells, dug outs, streams and rivers which are mostly of poor quality. Water quality is a growing concern throughout the developing world (UNICEF, 2013) and sources of drinking water are constantly under threat from contamination. This has both public health consequences as well as socio-economic implications (UNICEF, 2013). Faecal contamination of drinking water is a major contributor to diarrhoea and other water borne diseases, and is responsible for the death of millions of children every year (UNICEF, 2013).

In Ghana, 62 to 67% of the people depend on groundwater (GEMS/Water Project, 1997) and many cities and towns have problems with the quality of water used in homes and work places (Nkansah et al., 2010; Obiri-Danso et al., 2009). It is only about 52% of the population that have access to safe drinking water (GPRS II, 2005). Rural communities in Ghana, which forms about 56.0% of the total population, rely mostly on groundwater as the main source of drinking water (Ghana Statistical Service, 2002). Contrary to widely held theoretical view of groundwater being the “safest” water, wells are found to be polluted in terms of temperature, mineral contents, particles solute, organic matter and bacterial concentration. The quality of groundwater is determined by testing various parameters of interest on which results is compared with the standard qualities required for water intended for human consumption and use (Appelo and Postma, 2005).

The supply of public water in Bolgatanga (study area) is insufficient, as a result many rely on the use of hand-dug wells for their domestic purposes, and also it is quite common to see wells sited close to pollution sources. The exposure of the wells to such sources can cause health problems such as water borne diseases which includes cholera, typhoid, viral infections, intestinal diseases etc. Water and sanitation related diseases accounted for about 60% of out-patient department attendance at health institutions in the study area. Unsafe drinking water has contributed to numerous health problems in developing countries such as the one billion or more incidents of diarrhoea that occur annually (Gleick, 2002). Long exposure of the wells close to such pollution sources can contaminate the wells thereby changing the quality of the well water and posing a significant health threat to humans if consumed. Globally, it is estimated, that more than 3.4 million people die each year from water, sanitation, and hygiene related diseases such as cholera, diarrhoea, etc. (Mathers et al., 2001). Provision of safe and adequate water contributes to better health and increase individual productivity. In addition, improved water quality reduces the incidence of water related diseases such as diarrhoea, cholera, typhoid etc. In view of this, it is necessary to conduct the assessment on the quality of water from hand-dug wells. The objective of the study was to provide an overview of the quality of water from hand-dug wells in the Bolgatanga Township. Specifically, the study sought to determine some physico-chemical and microbial parameters of water from hand-dug wells within the study area.

Study area

Bolgatanga is located in the Bolgatanga Municipality (Figure 1) of the Upper East region of Ghana. It has a land mass of 729 km^2 and lies between latitude 10˚30` and 1˚55 North and longitude 0˚33` and 1˚00` West. It is bordered to the north by Bongo district, south and east by Talensi and Nabdam districts respectively, and Kassena-Nankana West district to the west.

Bolgatanga has a total population of 131,550, with a male population of 62,783 and a female population of 68.767 (Population and Housing Census, 2010). The climate is classified as tropical and has two distinct seasons; a wet season which runs from May to October and a long dry season which stretches from October to April with hardly any rains. Mean annual rainfall is 950 mm while maximum temperature is 45°C in March and April with minimum of 12°C in December (Bolgatanga Municipal Assembly, 2010).

MATERIALS AND METHODS

Through desk study and reconnaissance survey, the study area was categorized into three clusters, based on the residential types. Five wells were selected randomly from each cluster for sampling, giving a total of fifteen hand-dug wells (W1-W15). The clusters were then labelled as A, B, and C with the corresponding wells in each cluster been labelled as well. A 12-Channel Garmin GPS (Global Positioning System) was used in picking the geographic locations and altitudes of each of the sampling points in all the sections in the study area. The geographic locations of the dug wells were plotted using ArcGIS 9.1 to generate a map of sampling points.

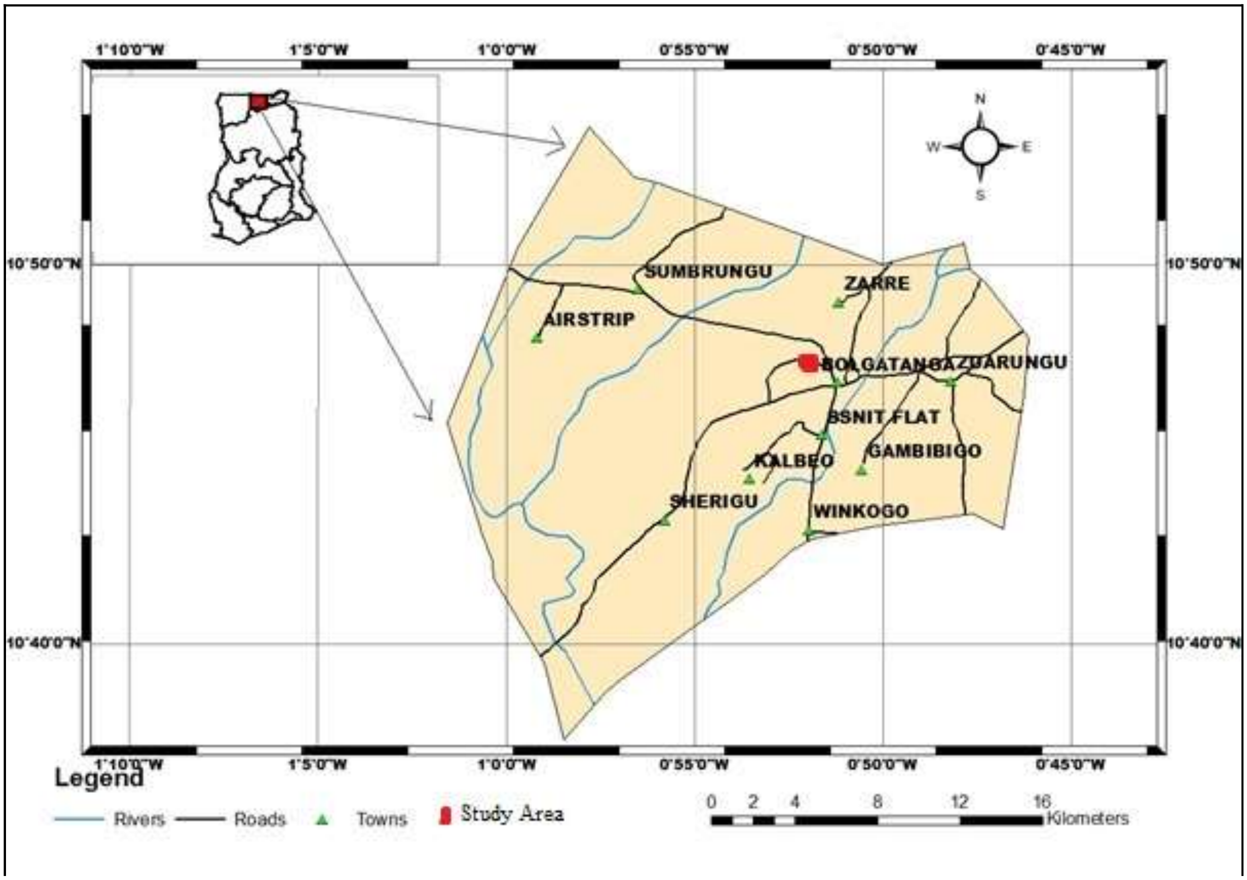

Figure 1. Map of Ghana and Bolgatanga municipality showing the location of the study area.

Sample collection

Seasonal variation from dry to rainy periods increased the concentrations of faecal coliform, total coliform, BOD, COD, electrical conductivity, total dissolved solids among others, in most cases (Adekunle et al., 2007); hence samples were collected as such; dry season and wet season. Samples were collected in the dry season (October to April) and wet season (May to October) 2014, from each of the three clusters within the early period of the day. The water samples were collected using sterile plastic bottles, following the appropriate procedures. Parameters such as total coliform, faecal coliform, pH, conductivity, turbidity, TDS, total hardness, fluoride, sulphate, nitrite and nitrate were analysed from the samples using standard methods referred to previously and the spectrophotometer. Sensitive parameters such as temperature and pH were measured immediately after collection of the well water samples. The Crison Basic 20 pH meter and a mercury thermometer was used for pH and temperature measurements, respectively.

Microbial analysis

Samples for bacteriological analyses were kept in screw-capped bottles that have been sterilized in an autoclave for 15 min at 121°C. Samples were then transferred to the laboratory where they were stored in the refrigerator for microbial analyses. Standard methods for the determination of total and faecal coliforms (Brenner et al., 1993; APHA, 1995) were employed.

Chemical analysis

A photometric method was used for the determination of NO^{3-}, NO^{2-} and SO_4^{2-}as these are nutrients related to pollutants. Analytical water test tablets prescribed for Palintest Photometer 5000 (Wagtech, Thatcham, Berkshire, UK) series were used. Each sample was analysed for NO_3^-, NO_{2-} and SO_4^{2-} using procedures outlined in the Palintest Photometer Method (Palintest, US) for the examination of drinking water and wastewater. Other analyses such as the determination of total hardness and F^- were done by complexometric titration using ethylenediaminetetraacetic acid (EDTA). The determination of concentrations was completed using argentometric titration. Total dissolved solids and electrical conductivity were determined by a means of a multifunctional WTW cond. 730 series, conductivity meter.

RESULTS AND DISCUSSION

The mean values and seasonal variations of the bacteriological and physico-chemical parameters of hand-dug well water samples in Bolgatanga of the Upper East Region of Ghana for dry and wet seasons are presented in Tables 3 and 4.

Total coliform counts in the wet season were mostly higher than that of the dry season and showed a declining trend in the dry season and increased in the wet

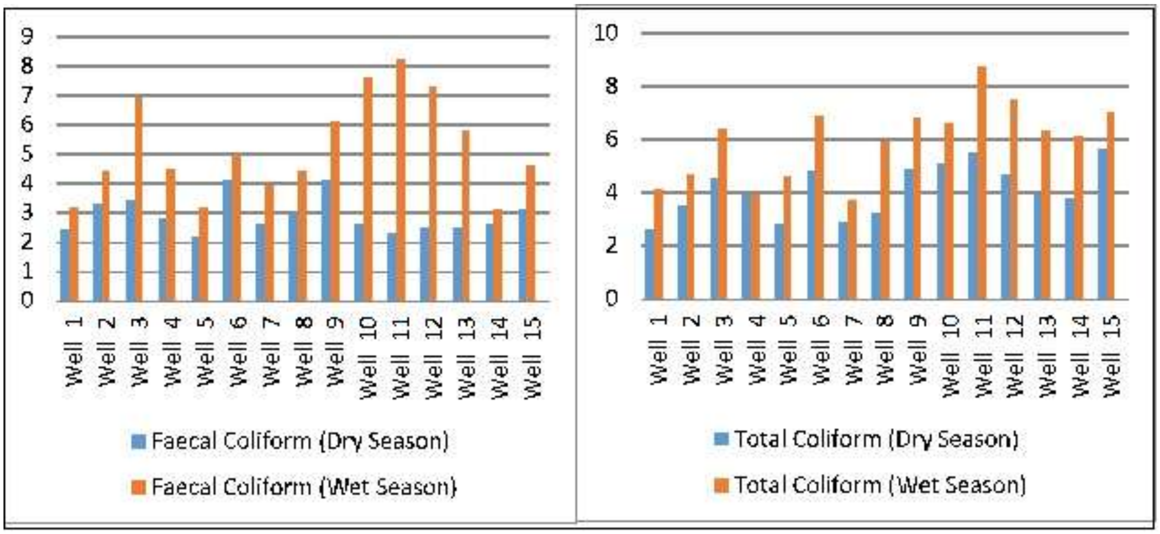

Figure 2. Faecal and total coliform content of water from sampled wells (dry and wet seasons).

season (Figure 2). In the dry season, it ranged from 2.6 to 5.6MPN/100 ml with mean value of 4.11MPN/100 ml (Table 3). However, in the wet season a range of 4.1 to 8.7 MPN/100 ml of total coliform in the wells were recorded with a mean value of 5.94 MPN/100 ml (Table 4). This finding confirms that of Anim-Gyampo et al. (2014) who recorded higher coliform in the wet season than in the dry season. Levels of total coliform recorded in this study exceeded WHO guideline value in drinking water which is nil. However, faecal coliform count in the wells showed a decreasing trend in the dry season and an increasing trend in the wet season as shown in Figure 2. This may be due to runoff from polluted sources such as septic tanks located nearby or from waste dumps. In the dry season it ranged from 2.4 to 4.1 MPN/100 ml with a mean value of 3.07 (Figure 2). Faecal coliform count in the wet season had a range of 3.1 to 8.2 MPN/ml with a mean value of 5.21 MPN/100 ml (Table 4). The higher level of faecal coliform present in Well 6 was due to open vegetation around the well which animals usually feed on and defecate around. This confirms the assertion made by Adekunle et al. (2007), that the high coliform populations in all the water samples are an indication of poor sanitary conditions in the community. Inadequate and unhygienic handling of solid wastes in the area could have generated high concentration of microbial organisms.

The pH values ranged from 5.4 to 6.4 in the dry season and 5.5 to 7.6 in the wet season with mean values of 5.84 and 6.4 for dry and wet seasons respectively (Tables 1 and 2). The average pH values were below the WHO limit of 6.5 to 8.5. The pH values lower than 6.5 are considered too acidic for human consumption and can cause health problems such as acidosis which could have adverse effects on the digestive and lymphatic systems of humans (Nkansah et al., 2010). In all except one instance (W9), pH values for the wet season exceeded that of the dry season.

The reduced pH of water samples from wells located close to the defecation and dump sites was attributed to sulphur and amino acid compounds from human and animal excreta. In addition, the organic matter could have depleted oxygen resulting in a negative redox potential (Efe et al., 2005, Root et al., 1982).

Total Dissolved Solids (TDS) and conductivity of the water in the sampled wells were relatively higher in the wet season than in the dry season (Figure 3). In dry season, the range of TDS and conductivity were respectively 106 to 372mg/l and 249 to 657µS/cm with mean values of 224 mg/l and 393.73 µS/cm (Table 3).

For the wet season, the ranges of TDS and conductivity were respectively 287 to 559 mg/l and 303 to 761 µS/cm with mean values of 388.13 mg/l and 473.13 µS/cm (Figure 2). Previous studies (APHA/AWWA/WEF, 1995; Obiri-Danso et al., 2009) reveal that, conductivity is affected by the presence of dissolved inorganic solids. According to Adekunle (2007), conductivity increases as TDS increases. The higher levels of TDS during the wet season show the impact of rainfall on the soil strata which facilitates the dissolution of solids in the water. Generally, the TDS and conductivity of the water in the wells were below their respective guideline values for drinking water as recommended by W.H.O. (Tables 1 and 2).

Turbidity for the samples ranged from 0.09 to 2.40 NTU in the dry season and 0.19 to 3.31 NTU in the wet season with the mean values of 0.94 and 1.58 NTU respectively (Tables 3 and 4). In general, the turbidity of the wells was predominantly within the recommended guideline value of 5.0 NTU by W.H.O. Apart from rendering water aesthetically displeasing, turbidity-causing substances can also cause taste and odour problems in water. Moreover, bacteria, viruses and parasites such as giardia

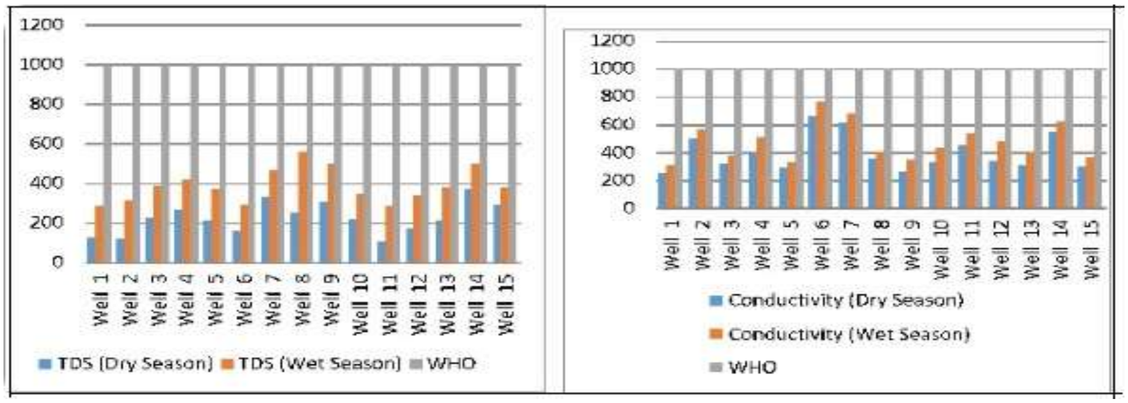

Figure 3. TDS and conductivity of water from sampled wells (dry and wet seasons).

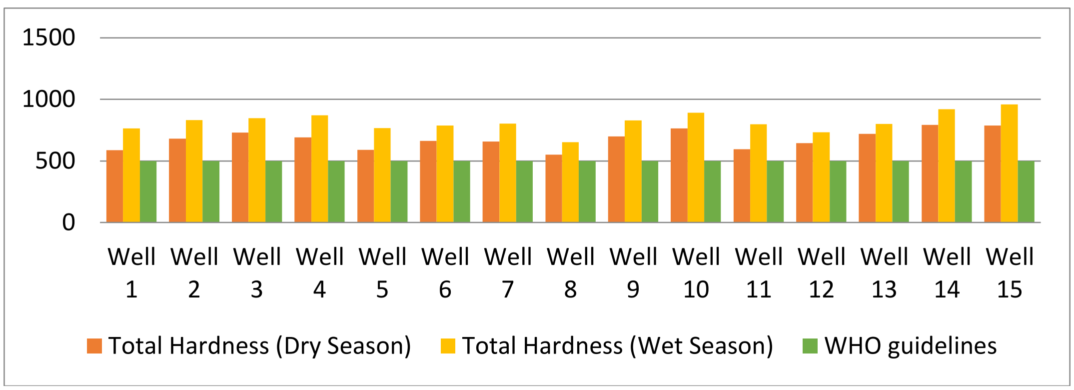

Figure 4. Total hardness of water from sampled wells (dry and wet seasons).

and cryptosporidium can attach themselves to the suspended particles in turbid water and thus interfere with disinfection by shielding contaminants from the disinfectants (Nkansah et al., 2010). The low levels of turbidity in this study could also be attributed to the fact that human activities including logging, agriculture, and road construction, which contributed to periodic pulse or chronic levels of suspended sediment in water, may not have affected the wells sampled. Turbidity was highly significant in the wet season than in the dry season.

The total hardness variations showed significant importance in the dry season and in the wet season (Figure 4). The values for dry and wet seasons were above the WHO standard of 500 mg/l. Levels of total hardness recorded in the dry season ranged from 84 to 740 mg/l with a mean value of 256.4 mg/l (Table 3), whiles in the wet season, it ranged from 105 to 532 mg/l with a mean value of 273 mg/l (Table 4). High levels of total hardness is as a result of the presence of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) which are washed from rocks and subsequently ends up in water as well as run- off from agricultural fields. High levels of hardness do not pose a health risk but with hard water, soap solution forms a white precipitate instead of producing lather. The effect arises because the dications destroy the surfactant properties of the soap by forming a solid precipitate (Ameyibor and Wiredu, 1991).

Levels of fluoride in the sampled wells also ranged from 0.00 to 0.8 mg/l and 0.00 to 0.82 mg/l in the dry and wet seasons respectively with the mean values of 0.174 and 0.212 mg/l (Tables 3 and 4). The values were all below the WHO standards of 1.5 mg/l. Fluoride levels were significantly higher in the wet season than in the dry season and indicate that infiltration of rainfall possibly increases the dissolution of fluoride in the sampled wells thereby increasing its content.

The nitrite and nitrate levels of the sampled wells were insignificant in the seasons as compared to the WHO standards (Figure 5). In the dry season, the levels ranged from 0.002 to 1.00 mg/l and 0.09 to 4.21 mg/l with the mean values of 0.213 and 2.149 mg/l, respectively (Table 3). For the wet season, the levels ranged from 0.018 to 1.15 mg/l and 1.9 to 5.33 mg/l with mean values of 0.493 and 3.355 mg/l, respectively. Levels of nitrite and nitrate in sampled wells were far below their respective WHO guideline values for drinking water of 3.0 and 10 mg/l.

Table 1. Analytical results of physico-chemical parameters of well water (dry season).

Sample I.D	Location		Tested parameter										
	UTM-E	UTM-N	pH	E.C µS/cm	Turbidity NTU	Color mg/l	TDS mg/l	TH mg/l	F^- mg/l	SO_4^2 mg/l	NO_2^- mg/l	NO_3^- mg/l
W 1	0735168	1191971	5.4	249	0.12	4	125	84	0.00	29	0.030	1.2
W 2	0735026	1191692	6.4	498	0.55	5	117	120	0.25	24	0.66	2.15
W 3	0735184	1192404	6.0	314	1.64	5	227	180	0.45	29	0.044	1.20
W 4	0735293	1192192	5.4	407	0.43	6	263	210	0.01	32	0.007	2.56
W 5	0734368	1192332	5.7	288	1.09	6	211	404	0.00	20	0.42	0.96
W 6	0734117	1192355	6.4	657	2.14	4	161	740	0.02	23	0.88	1.3
W 7	0733929	1192250	5.5	615	0.33	9	333	120	0.05	27	0.02	2.75
W 8	0734420	1193006	5.8	357	0.20	6	251	340	0.03	32	0.021	3.27
W 9	0734283	1193343	6.1	263	1.10	4	309	100	0.24	48	0.006	3.01
W10	0734320	1193312	6.0	323	0.63	7	221	170	0.8	31	0.005	1.38
W11	0735304	1194187	5.8	445	0.09	5	106	200	0.15	39	0.011	0.09
W12	0735369	1194083	5.6	339	1.36	7	172	145	0.40	36	0.002	2.13
W13	0735090	1192101	6.1	306	0.88	5	215	504	0.00	29	0.038	3.65
W14	0734345	1193220	5.5	548	1.21	5	372	212	0.09	37	0.05	2.82
W 15	0735430	1193963	5.9	297	2.40	8	290	317	0.12	44	1.00	4.21

Table 2. Analytical results of physico-chemical parameters of well water (wet season).

Sample I.D	Location		Tested parameter									
	UTM-E	UTM-W	pH	Conductivity µS/cm	Turbidity NTU	Color mg/l	TDS mg/l	TH mg/l	F^- mg/l	SO_4^2 mg/l	NO_2^- mg/l	NO_3^- mg/l
W 1	0735168	1191971	5.5	303	0.19	4	288	105	0.00	31	0.55	1.9
W 2	0735026	1191692	6.9	561	1.12	6	310	210	0.43	37	0.97	3.02
W 3	0735184	1192404	7.6	375	2.00	7	385	180	0.67	44	0.073	2.19
W 4	0735293	1192192	5.9	511	0.99	6	420	288	0.04	149	1.00	3.79
W 5	0734368	1192332	6.7	329	1.29	7	374	496	0.01	82	0.81	1.23
W 6	0734117	1192355	6.8	761	3.05	4	292	384	0.09	76	1.01	2.55
W 7	0733929	1192250	5.9	680	1.22	11	467	135	0.11	40	0.08	4.86
W 8	0734420	1193006	6.1	400	0.89	8	559	301	0.09	96	0.051	4.56
W 9	0734283	1193343	5.7	341	1.59	5	496	142	0.35	128	1.01	4.20
W 10	0734320	1193312	6.5	428	2.07	9	348	222	0.12	88	0.029	2.91

Table 2. Contd.

W 11	0735304	1194187	6.3	535	1.00	7	287	181	0.22	115	0.018	2.72
W 12	0735369	1194083	5.8	481	2.01	8	340	293	0.82	99	0.51	4.46
W 13	0735090	1192101	6.7	401	1.06	6	377	532	0.00	65	0.041	3.79
W 14	0734345	1193220	6.1	622	1.64	9	498	297	0.09	79	0.09	2.82
W 15	0735430	1193963	7.5	369	3.31	10	381	338	0.14	100	1.15	5.33

Table 3. Bacteriological and physico-chemical characteristics of well water samples (dry season).

Parameter	Units	Minimum	Maximum	Mean	WHO Guidelines
Total coliform	MPN/100 ml	2.6	5.6	4.11	0.0
Faecal coliform	MPN/100 ml	2.4	4.1	3.07	0.0
pH	-	5.4	6.4	5.84	6.5-8.5
Conductivity	µS/cm	249	657	393.73	1000
Turbidity	NTU	0.09	2.40	0.94	0-5
TDS	mg/l	106	372	224.87	1000
Total hardness	mg/l	84	740	256.4	500
Fluoride	mg/l	0.00	0.8	0.174	1.5
Sulphate	mg/l	23	48	32	400
Nitrite	mg/l	0.002	1.00	0.213	0-3.0
Nitrate	mg/l	0.09	4.21	2.149	0-10

The major health concern regarding high levels of nitrite and nitrate in drinking water according to W.H.O. (2004) and Kempster et al. (1997), is the formation of methaemoglobinaemia, also called "blue-baby" syndrome in infants in which blood loses its ability to carry sufficient oxygen (Fecham et al., 1986; Burkart and Kolpin, 1993; Groen et al., 1988). The low values of nitrite and nitrate could be attributed to the absence of manure spill, fertilizer application, animal feedlots, and sludge, which contributes to NO^{2-} and NO^{3-} concentration in water. However, the levels were higher in the wet season than in the dry season (Figure 5).

Relationship between bacteriological parameters and distance from pollution sources

Total coliform count in the wells did not any show any significance with distance from the pollution sources during the wet season with mean value of (5.9 MPN/100 ml) as compared to the dry season (4.11 MPN/100 ml). The results revealed that total coliforms in the wells did not necessarily increase with decreasing distance from the pollution sources (Table 5). However, Shittu et al. (2008), recorded more coliforms in wells close to septic tanks and latrines.

Conclusions

The study revealed that the qualities of the water samples were affected by the conditions of the immediate environment. All 15 hand-dug wells water samples in the vicinities contained faecal and total coliforms above the WHO stipulated limits for potable water. On the other hand, the physico-chemical parameters analysed were found to be acceptable and below WHO guideline values

Table 4. Bacteriological and physico-chemical characteristics of well water samples (wet season).

Parameter	Units	Minimum	Maximum	Mean	WHO Guidelines
Total coliform	MPN/100 ml	4.1	8.7	5.9	0.0
Faecal coliform	MPN/100 ml	3.1	8.2	5.2	0.0
pH	-	5.5	7.6	6.4	6.5-8.5
Conductivity	µS/cm	303	761	473.13	1000
Turbidity	NTU	0.19	3.31	1.56	0-5
TDS	mg/l	287	559	388.13	1000
Total hardness	mg/l	105	532	273.6	500
Fluoride	mg/l	0.00	0.82	0.212	1.5
Sulphate	mg/l	31	149	81	400
Nitrite	mg/l	0.018	1.15	0.493	0-3.0
Nitrate	mg/l	1.9	5.33	3.355	0-10

Table 5. Pollution sources and distances from pollution sources of wells.

Well No.	Total coliform MPN/100 dry season	Total coliform MPN/100 wet season	Pollution source	Distance from pollution source/metres
W1	2.6	3.4	Septic tank	2.0
W2	3.5	4.7	-	-
W3	4.5	6.4	Refuse dump site	6.4
W4	3.9	4.6	-	-
W5	2.8	3.9	Pit latrine	7.0
W6	4.8	6.9	Animal pen	1.0
W7	2.9	3.7	Refuse dump site	0.57
W8	3.2	5.9	-	-
W9	4.9	6.8	Refuse dump site/animal pen	3.0/1.8
W10	5.1	6.6	Pit latrine	10.4
W11	5.5	8.7	Pit latrine	7.9
W12	4.7	7.5	Septic tank	5.0
W13	3.9	6.3	Refuse dump site	12.4
W14	3.8	6.1	-	-
W15	5.6	7.0	Pit latrine	3.2

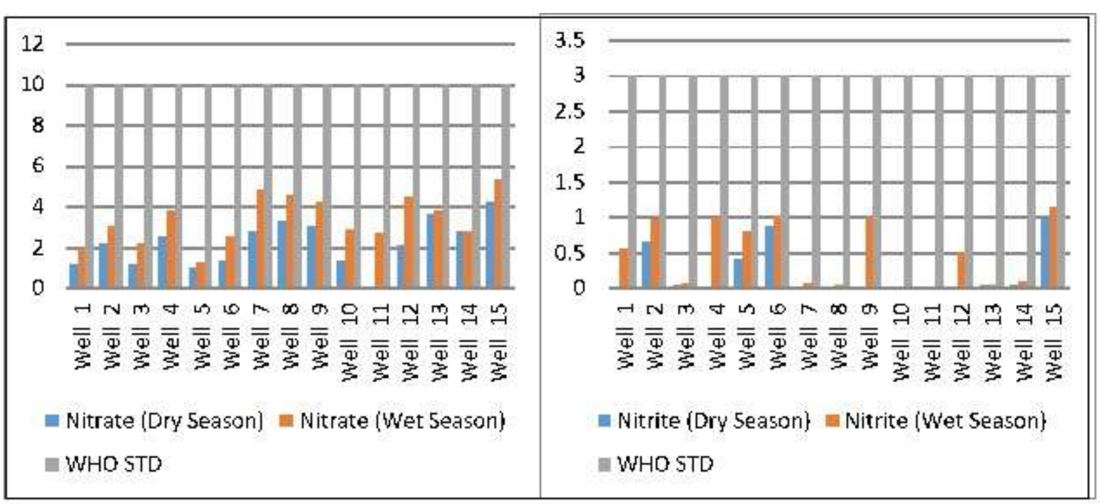

Figure 5. Nitrate and Nitrite levels in sampled wells (dry and wet seasons).

for potable water. It was also revealed that total coliform, faecal coliform, pH, turbidity and total hardness increased in the wet season and decreased in the dry season. The high coliform index, increased metal levels and organic loads of the water samples in the wet season were indices of pollution from leachates, seepages and runoffs of the polluted environment where these wells were located. Hence, the hand-dug wells without standard treatment are unfit for drinking water and domestic uses. It is recommended that these wells be disinfected before use. Also wells in the study area should be constructed high above ground (at least 1 m) and sited at least 30 m away from any source of pollution to prevent runoffs and other contaminants from contaminating the wells during wet periods. Intensification of education and implementation of regulations on safe drinking water by the Ghana Standards Authority, the Ghana EPA and district environmental units and other state enforcements agencies will go a long way to reduce incidences of water pollution and the associated diseases.

Conflict of Interests

The authors have not declared any conflict of interests.

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