Full Length Research Paper

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

Samuel Kojo Abanyie*, Ampadu Boateng and Steve Ampofo

Department of Earth and Environmental Sciences, University for Development Studies (UDS), P. O. Box 24, Navrongo, Upper East Region, Ghana.

Received 21 April, 2016; Accepted 12 August, 2016

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 indispensable 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
medium for thousands of microorganisms some of which are disease causing. Diseases in human can be caused by 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 km² 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 repeats. 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.
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.

Chemical analysis

A photometric method was used for the determination of NO₃⁻, NO₂⁻ and SO₄²⁻ 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 NO₃⁻, NO₂⁻ and SO₄²⁻ 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
season (Figure 2). In the dry season, it ranged from 2.6 to 5.6 MPN/100 ml with mean value of 4.11 MPN/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 372 mg/l and 249 to 657 μS/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...
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 (CaCO₃) and magnesium carbonate (MgCO₃) 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 | Turbidity | Color | TDS | TH | F⁻ | SO₄²⁻ | NO₂⁻ | NO₃⁻ |
| 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    | 0.21  | 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 | Turbidity | Color | TDS | TH | F⁻ | SO₄²⁻ | NO₂⁻ | NO₃⁻ |
| 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.

| Well | Well ID | Latitude | Longitude | Total Coliform | Faecal Coliform | THM | TDS | Conductivity | Turbidity | pH | Nitrate | Nitrite | Fluoride | Sulphate | Chloride |
|------|---------|----------|-----------|---------------|----------------|-----|-----|--------------|-----------|-----|---------|--------|----------|---------|---------|
| W 11 | 0735304 | 1194187  | 6.3       | 535           | 1.00           | 7   | 287 | 0.22         | 115       | 0.018 | 2.72    | 313     | 2.6      | 0.003   | 106     |
| W 12 | 0735369 | 1194083  | 5.8       | 481           | 2.01           | 8   | 340 | 0.82         | 99        | 0.017 | 4.46    | 295     | 3.8      | 0.001   | 73      |
| W 13 | 0735090 | 1192101  | 6.7       | 401           | 1.06           | 6   | 377 | 0.00         | 65        | 0.041 | 2.82    | 115     | 0.05     | 4.0     | 290     |
| W 14 | 0734345 | 1193220  | 6.1       | 622           | 1.64           | 9   | 498 | 0.09         | 79        | 0.009 | 2.23    | 136     | 0.15     | 4.2     | 62      |
| W 15 | 0735430 | 1193963  | 7.5       | 369           | 3.31           | 10  | 381 | 0.14         | 100       | 1.15  | 3.16    | 143     | 2.6      | 5.2     | 205     |

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     | 393.7 | 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           |
| Nitrate     | mg/l        | 0.002   | 1.00    | 0.213 | 0.3-3.0       |
| Nitrite     | 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 methaemoglobinemia, 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\textsuperscript{2-} and NO\textsuperscript{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           |
| Nitrate            | 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 | Total coliform MPN/100 | Pollution source | Distance from pollution source/metres |
|----------|------------------------|------------------------|------------------|---------------------------------------|
|          | dry season              | wet season              |                  |                                       |
| 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.

ACKNOWLEDGEMENTS

The authors would like to thank Bismark Akuruugu and Sanusi Abdul-Malik, both past students of the University for Development Studies, Navrongo for their input in this study.

REFERENCES

Adekunle IM, Adetunji MT, Gbadebo AM, Banjoko OB (2007). Assessment of Groundwater Quality in a Typical Rural Settlement in Southwest Nigeria. Int. J. Environ. Res. Public Health 4(4):307-318. American Public Health Association (APHA), (1995). Standard methods for the examination of water and wastewater, 19th ed. American Public Health Association, Washington, D.C. Ameyibor K, Wiruedu MB (1991). Chemistry Senior Secondary Schools. Macmillan Education Ltd., London. Anim-Gyampo M, Zango MS, Ampadu B (2014). Assessment of Drinking Water Quality of Groundwaters in Bunpikuru-Yunyo District of Ghana. J. Environ. Pollut. 3:3. Appelco CAJ, Postma D (2005). Geochemistry, groundwater and pollution (2nd ed.): Leiden, The Netherlands, A.A. Balkema, 649 p. Bolgatanga Municipal Assembly (BMA) (2010). Municipal Medium Term Development Plan (2010-2015) Bolgatanga, Ghana: Bolgatanga Municipal Assembly. Brenner KP, Rankin CC, Roybal YR (1993). New medium for the simultaneous detection of total coliforms and Escherichia coli. Appl. Environ. Microbiol. 59:3534-3544.

Burkart MR, Kolpin DW (1993). Hydrologic and land – use factors associated with herbicides and nitrate in near surface aquifers. J. Environ. Qual. 22:646-656. Davis EL (2005). Marion Medical Mission Shallow Well Program Health Impact Assessment Report. Malawi, Africa. Efe SI, Ogban FE, Horsfall M, Akporhonor EE (2005). Seasonal variations of physico-chemical characteristics in water resources quality in western Niger Delta region, Nigeria. J. Applied Sci. Environ. Manag. 9(1):191-195. Fediham R, Mcgarry M, Mara D (1986). Water, Wastes and Health in Hot Climates, Wiley and Sons. New York, P 82. GEMS/Water Project (1997). Water Quality Data for selected stations 1991-1995. Ghana National Committee for International Hydrology and Water Resources Programmes. Water Research Institute (WRICSIR) Accra, Ghana. Ghana Statistical Service (GSS) (2002). 2000 Population and Housing Census, summary report of final results. Accra, Ghana: Ghana Statistical Service. Gleick HP (2002). Dirty Water: Estimated Deaths from Water-Related Diseases 2000-2020. Pacific Institute Research Report. Groen J, Schumann JB, Gernaer TW (1988). The occurrence of high nitrate concentration in groundwater in villages in North-western Burkina Faso. J. Afr. Earth Sci. 7(7/8):999-1009. Growth and Poverty Reduction Strategy (GPRS II) (2005). National Development Planning Commission, Republic of Ghana. Kempest PL, Van-Vliet HR, Kuhn A (1997). The Need for Guideline to Bridge the Gap between Ideal Drinking Water Quality and Quality which is ractically Available and Acceptable. Water SA. 23:163-167. Matthers CD, Vos T, Lopez AD, Ezzati M (2001). National burden of disease studies: a practical guide. Edition 2.0 Geneva, World Health Organization, Global Programme on Evidence for Health Policy. Musa HA, Shears P, Kofi S, Elsabag SK (1999). Water quality and public health in northern Sudan: A study of rural and peri-urban communities. J. Appl. Microbiol. 87:676-682. Mustapha S, Yusuf MI (1999). A textbook on Hydrology and Water Resources. Jenas Prints and Publications Company, Abuja, Nigeria. Nkarah MA, Owusu Boadi N, Badu M (2010). Assessment of the quality of water from hand-dug wells in Ghana. Environ. Health Insight 4:1-12. Obiri-Danso K, Adjei B, Stanley KN, Jones K (2009). Microbiological quality and metals in wells and boreholes water in some peri-urban communities in Kumasi, Ghana. Afr. J. Environ. Sci. Technol. 3(1):055-066. Population and Housing Census (2010). Regional and District reports: Ghana Statistical Service. Root J, Graveland A, Schultink LJ (1982). Consideration of organic matter in drinking water treatment. Water Res. 16(1):113-122. Shittu OB, Olaiton JO, Amusa TS (2008). Physico-chemical and bacteriological analysis of water used for drinking and swimming purposes in Abeokuta, Nigeria. Afr. J. Biomed. Res. 11:285-290. United Nations Educational Scientific and Cultural Organization (2007). UNESCO Water Portal Newsletter no. 161. United Nations International Children’s Emergency Fund (UNICEF) (2013). Annual Report 2012. UNICEF. ISBN: 978-92-806-4693-1 World Health Organisation (WHO) (2004). Guidelines for Drinking-water Quality. Volume 1 Geneva. World Health Organisation, (2000). The World Health Report: Making a difference. Geneva World Health Organization (1998),Guidelines for drinking water quality. Health criteria and other supporting information, Geneva. WHO/OECD. 2:11