International Journal of Development and Sustainability
Online ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 1 Number 3 (2012): Pages 939-956
ISDS Article ID: IJDS12103102

Special Issue: Development and Sustainability in Africa – Part 1

Groundwater quality at Achiase and Wabiri in the Ejisu Juaben municipality of the Ashanti region in Ghana

B.M. Tiimub [1*], S. Frimpong [1], R.A. Kuffour [1], A.B. Dwumfour [1], I. Monney [1], K. Obiri-Danso [2]

[1] *University of Education, Winneba, College of Agriculture Education, Faculty of Science and Environment Education, Department of Environmental Health and Sanitation Education, P. O. Box 40 Asante Mampong, Ghana*

[2] *Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology- Kumasi, Ghana*

Abstract

Groundwater from one well and one borehole from Wabiri and Achiase in the Ejisu-Juaben community in Ashanti Region of Ghana was analyzed from January to December, 2011for its physical, chemical and biological quality characteristics using various standard methods. Bacterial in wells ranged between 1.0×10^2 - 2.42×10^2, 1.0×10^1 – 2.0×10^0 and 4.6×10^1 - 8.4×10^1 for total coliforms, *E. coli* and *salmonella*, but was absent from borehole waters. There were highly significant differences ($P < 0.000$ and $P < 0.000$) between the entire well and borehole waters. BOD_5 levels of the wells ranged from 1.05 ± 0.00mg/L - 1.35 ± 2.75mg/L while it was 0.9 ± 0.00mg/L in the boreholes throughout the study. Traces of chemicals were found in the well and borehole waters, but their concentrations:- iron (0.036 ± 0.01mg/L - 0.07 ± 0.57mg/L and 0.01 ± 0.00); nitrate (0.11± 0.0001mg/L - 0.17 ± 0.001mg/L and 0.03 ± 0.0005 - 0.05 ± 0.001); nitrite (0.005 ± 0.001mg/L - 0.008 ± 0.001mg/L and 0.001 ± 0.00mg/L - 0.013 ± 0.001mg/L, and chloride (15.6 ± 1.16mg/L - 18.33 ± 0.58mg/L and 27.65 ± 1.16mg/L – 38.33 ± 0.56mg/L) were within the WHO Guidelines. Water from the borehole was generally of higher quality than the well and so the latter water must be subjected to treatment such as filtration, chlorination and boiling before drinking.

Keywords: Wabiri, Achiase, Total coliform, E. coli, Salmonella, Contamination, Well, Borehole

Cite this paper as: Tiimub, B.M., Frimpong, S., Kuffour, R.A., Dwumfour, A.B., Monney, I. and Obiri-Danso, K. (2012), "Groundwater quality at Achiase and Wabiri in the Ejisu Juaben municipality of the Ashanti region in Ghana", *International Journal of Development and Sustainability,* Vol. 1 No. 3, pp. 939-956.

* Corresponding author. *E-mail address:* benmakimit@yahoo.com

1. Introduction

Water is important to life as life depends on it. Earlier on in 1972, Domenico stated that human life as with animals and plants on the planet is dependent on water. Human cultures and societies have rallied around water resources for tens and thousands of years for drinking, food production, transportation, and for recreation as well as for inspiration. Arising from the intimate relationship between water and life, water could be said to be woven into fabric in myriad ways. Water on earth can be said to be enormous in quantity when it is considered that more than two-thirds of the earth surface is covered by water (Barrett and Howard, 2002).

According to Fetter (1988), approximately 3% of the total water on earth is fresh and of this, groundwater comprises 95%, surface water 3.5% and soil moisture 1.5%. Out of all the freshwater on earth, only 0.36% is readily available for use. There is a finite supply of water on the earth but it is continually recycled naturally. Worldwide, more than a third of all water used by humans comes from the ground. It has been argued by the United Nations Environment Program and the World Health Organization (1996) that it is not sufficient merely to have access to water, but in adequate quality to maintain health and it must be free from harmful biological and chemical contamination. It was observed by Dauda (1993) that as surface water becomes increasingly polluted, people turn to groundwater for alternative supplies.

In Ghana, the rural dependency on groundwater is enormous. Groundwater accounts for over 60% of the domestic supply in the Ejisu-Juaben Municipality of the Ashanti Region of Ghana. Governments over the years have made frantic efforts to provide potable water for its citizens. This notwithstanding, most Ghanaians are still faced with water – borne and water related diseases such as bilharzias, diarrhoea, typhoid, etc. due to the usage of unsafe water (Ghana Health Service Report 2005).

The most common source of groundwater pollutions are from substances used in forestry, waste and agriculture such as insecticides, herbicides and fungicides. The constituents in these chemicals are highly toxic even in minute amounts (Fetter, 1994). The most commonly identifiable pollutant in groundwater in rural areas of the Ejisu Juaben Municipality is from the Nitrogen – based fertilizers. Excess applications of nitrogen in the form of dissolved nitrates are not consumed by plants and can be flushed down to groundwater. Although nitrate is considered as non-toxic, it can cause conditions such as serious blood disorder or methaemoglobinaemia in infants (Offodile, 2002). Additionally, Offodile in 2002 observed that, in Nigeria and other African Countries improper disposal of human or animal wastes pollute groundwater which may lead to ingestion of dangerous pathogens when it is used as drinking water while sanitation units such as latrines and septic systems discharge domestic waste water into the sub-surface and the increase in human activities has produced large volumes of domestic, commercial and industrial wastes than what the environment can absorb.

Comparatively, landfills in Ejusu Juaben Municipality are mostly in the form of uncontrolled dumps, where refuse is filled up with little or no regard to the environment. Solid wastes deposited in landfills decompose and could pollute underlying groundwater through the infiltration of leachates. Thus, groundwater quality assessment bears important social and health implications not only for the development of the Ejisu Juaben

Municipality but for the development of the economic welfare of the nation. The study was further necessary to conduct as it would enable individuals, especially the inhabitants of the area, know the effect of their activities on drinking water sources, the environment and human health.

2. Justification for the study

The inadequate availability of potable water has been a major problem facing majority of Ghanaian citizens due to the acute shortages during the dry seasons and many Ghanaians in peri-urban communities in northern region have turned to rely on groundwater abstracted from wells, springs and boreholes as the major source of supply for most of their daily activities (Tiimub *et al;* 2008). However, the safety aspect of the water from such sources for human consumption is questionably unless it is augmented with scientific research through standard water quality analyses.

In effect, Achiase and Wabiri communities situated in the Ejisu Juaben Municipality of the Ashanti Region of Ghana where its inhabitants rely mostly on groundwater for their daily activities are no exception of the situation. These areas are among the areas where local mining (Galamsay) has been on rampant increase in recent times. Consequently, there is a high possibility of having heavy metal residuals in the groundwater in those areas. Additionally, the Ejisu Juaben Municipality is a farming community and its inhabitants tend to use a lot of herbicides, fungicides and pesticides which eventually serve as pollutants to the drinking water sources. Stemming from the accelerated growth and development in the Achiase and Wabiri communities, this phenomenon has resulted in increased waste accumulation from domestic chores that include refuse dumping and the discharge unsewered liquid wastes in the form of grey water which are potential pollutants to the groundwater in these communities.

Additionally, the Ghana Health Service report from the Achiase community health centre from 2005-2010 showed that most of the sicknesses reported by the inhabitants from the community were water borne and critical view of these problems necessitated to a pragmatic assessment of the groundwater quality in Achiase and Wabiri communities to identify the specific pollutants that contaminate the groundwater so as to enable water quality assurance agencies adopt interventions for treatment of groundwater for safe uses such as drinking, washing, cooking and boost the potential to support commercial activities.

This scientific paper summarizes the findings of the study on the quality of groundwater in Achiase and Wabiri in the Ejisu Juaben Municipality of the Ashanti Region of Ghana with recommended strategies for improvement. The specific objectives the study addressed were:

i. an examination of the level of contamination of the groundwater at Achiase and Wabiri Municpality by total and faecal coliforms, *E. coli* and Salmonella bacteria strains.

ii. analyses for temperature, pH, BOD, COD, dissolved oxygen, nitrate, nitrate, and phosphate concentrations in the water for its portable acceptance.

The study was relevant to the inhabitants in that it could create awareness of their activities that contaminate the groundwater in the area so as to prompt them adopt appropriate control measures against water pollution in the Ejisu-Juaben Municipal Assembly following discussion of the results achieved with the opinion . The Municipal Assembly could then come out with measures for groundwater quality monitoring to prevent water-borne and water related diseases in other villages where similar problems are encountered with their groundwater resources. The results could further inform community development partners once it might be used in formulation of national policies on water quality assurance safety and standards of drinking water from ground sources so to make it safe, and availability in requisite quantities in the study area as compared to other communities in Ghana.

3. Profile of the study area

The selected drinking water wells and boreholes were from two communities namely Wabiri and Achiase in the Ejisu Juaben Municipality of the Ashanti Region of Ghana. The Ejisu Juaben Municipality shares boundaries with Kumasi Metropolis, the Ashanti Akim North Municipality, Bosom-Freho and Bosomtwe Districts. Due to its nearness to the Ashanti Regional Capital City (Kumasi), it has experienced rampant growth and its population has also increased tremendously. The population of humans in Ejisu-Juaben Municipality is estimated to be around 200,000 people according to the December 2010 population and housing census. Due to its high population density, resources such as water has become one of the major problems confronting the inhabitants often compelling most of them to rely on the use of groundwater as an alternative source for drinking.

Mining activities have been on the increase in the Ejisu-Juaben Municipality especially, where it shares boundaries with the Bosome-Freho District. Farming and surface mining which are often the predominant occupations of the people could lead to the contamination of groundwater supply sources by some minerals and other poisonous industrial chemicals such as fertilizers and agrochemicals. These observations prompted the researchers to examine the groundwater sampled from selected wells and boreholes from the Wabiri and Achiase communities to determine its quality for drinking purposes and other household chores.

4. Methodology

Drinking water samples were randomly collected from one well and one borehole each from Wabiri and Achiase communities and evacuated to the Department of Civil Engineering Water Quality Assurance laboratory at the Kwame Nkrumah University of Science and Technology (KNUST) for the analysis of pH, Total Dissolved Solids, (TDS), Total Suspended Solids (T.S.S), Turbidity, Temperature, Conductivity, Dissolved oxygen, Ammonia, Chloride, BOD, Total coliform, *E. coli and Salmonella.* Intelligent physical observations and interaction were made with the people living around the sampling sites and using the water whilst pictures of the sampling sites were taken.

4.1. Physical Parameters

A PC 300 Waterproof Handheld pH/Conductivity/TDS/Temperature meters were the apparatus for temperature, pH, TDS and EC analyses. A digital reading appeared upon inserting the probes into the water samples indicating first the values of pH and temperature. The sample was stirred and the digital reading allowed stabilizing before it was recorded. The "MODE" button which allows switching to other parameters was then used to read the values of TDS and EC. For Dissolved Oxygen analysis**,** a WTW Oxi 340 oximeter was used. The meter probe was inserted into the water sample collected into an air tight BOD_5 bottle and the digital reading was recorded after it has stabilized. Total Suspended Solids (TSS) was analyzed by filtering a100mL volume of a well-mixed water sample through a weighed standard glass-fiber filter. The residue retained on the filter was then dried in an oven at 103°C to 105°C for 1 hour. It was then cooled in desiccators and weighed. The increase in weight of the filter represented the total suspended solids based on the conventional calculation using the formula below:

$$\text{Mg TSS} = \frac{(A - B) \times 1000}{\text{sample volume, mL}}$$

where, A = weight of filter + dried residue in mg, and B = weight of filter in mg.

A five day Biochemical Oxygen Demand (BOD_5) of the groundwater samples was determined using the Dilution method as an empirical test in which standardized laboratory procedures were used to determine the relative oxygen requirements of effluents and polluted waters. It was computed from the initial and final DO of a sample after incubating at 20°C for five days. Systematically**,** a known volume of the sample was poured into a 300ml BOD bottle and mixed with dilution water until it overflowed and then stoppered. Another standard 300mL BOD bottle was filled with dilution water to represent the blank. The initial dissolved oxygen concentrations of the blank and diluted water samples were determined using a DO meter. Both bottles were stored at 20°C in the incubator for five days. After 5 days the amount of dissolved oxygen remaining in the samples were measured with a DO meter based on a conventional calculation using the formula below:

$$BOD_5\text{, mg/L} = \frac{D_1 - D_2}{P}$$

where D_1 = DO of diluted sample immediately after preparation, mg/L, D_2 = DO of diluted sample after 5 days incubation at 20°C, mg/L, and P = decimal volumetric fraction of the sample used.

Turbidity is defined as the light scattering and absorbing property that prevents light from being transmitted in straight lines through the water sample. Whereas most suspended matter scatter light waves, optically black particles such as activated carbon adsorb light and increase turbidity readings. In determining the turbidity, about 10ml of the raw water sample was measured using measuring cylinder and poured into the sample cell. The surface of the sample cell was carefully cleaned with tissue paper. The sample cell was placed into the instrument light cabinet and covered with the light shield. The turbidity of water was then read. In instances that the reading was beyond range, the procedure was repeated using different ranges and different standards). The reading was obtained for the turbidity of the sample in NTU. The light shield and sample cell were then removed and the cell was cleaned after emptying the sample.

4.2. Bacteriological Analyses (Total coliforms, *E. coli* and Salmonella)

Bacteriological analyses of the groundwater samples were achieved by Membrane filter technique using Chromocult Coliform Agar. In Principle, the Chromocult Coliform Agar determines the presence or absence of coliform bacteria and *E. coli, and salmonella* in water. A water sample was passed through the membrane that retains the bacteria. Following filtration, the membrane containing bacterial cells was then placed on the media and incubated at 36 ± 1°C and 24 ± 1°C for 1 hour. Salmon to red colonies were recorded as coliforms. In contrast, dark-blue to violet colonies were recorded as *E. coli* and green to turquoise colonies were counted as salmonella. Salmon to red, dark-blue to violet and turquoise colonies were recorded as total coliforms. Generally, in this method, an appropriate volume (1mL) of the groundwater sample was added to a known volume of dilution water (99mL). Three serial dilutions with 99mL dilution of water and 1mL of the resulting solutions were performed and the final solution was filtered through a sterile micropore filter by suction, thereby capturing any coliforms. With the aid of sterile forceps, the filter membrane was placed aseptically and rolled onto the Chromocult Coliform Agar in a Petri dish. The dish was inverted, closed and incubated at 35°C. After 24 hours of incubation, the number of Salmon to red colonies was recorded as coliforms by visual examination whiles dark-blue to violet colonies were recorded as *E. coli*. The sum of these two colonies was recorded as total coliforms.

4.3. Chloride Analysis

The presence of chloride was determined by the Argentometric method. The procedure involved the addition of 1.0mL K_2CrO_4 indicator solution to a known sample volume (50mL) of the groundwater samples. The solution was titrated with standard $AgNO_3$ titrant to a pinkish yellow end point. The procedure was repeated for an equal volume of distilled water, representing the blank. The concentration of chloride was computed using the equation below:

$$\text{mg Cl}^-/\text{L} = \frac{(A - B) \times N \times 35450}{\text{mL sample}}$$

where: A = mL titration for sample, B = mL titration for blank, and N = normality of $AgNO_3$ (0.0141M)

4.4. Spectrophotometer Analysis for (Iron, Nitrate–nitrogen and Nitrogen–ammonia) in Groundwater

A DR/2400 Spectrophotometer (shown in Plate 1) was used in determining the concentration of iron, phosphates, sulphates, nitrates–nitrogen and nitrogen–ammonia. The procedures involved are described below

Plate 1. DR/2400 Spectrophotometer

4.5. Iron

Iron level of the water was analyzed using the FerroVer Method. In principle, the FerroVer Iron Reagent converts all soluble iron and most insoluble forms of iron in the sample to soluble ferrous iron. The ferrous iron reacts with the 1.10 phenanthroline indicator in the reagent to form an orange colour in proportion to the iron concentration. The initial concentration of iron was determined by selecting Program 265 Iron, FerroVer from the Hach Programs. A clean, round sample cell was filled with a known volume of the water sample diluted to 10mL and the content of one FerroVer Iron Reagent Powder Pillow was then added to it. The sample cell was swirled to mix the contents and the timer icon pressed to begin a three-minute reaction period. Another sample cell was filled with 10mL distilled water (the blank) and placed in the cell holder of the spectrophotometer after thoroughly wiping it. The 'Zero' button was pressed and a 0.00 mg/L Fe concentration was displayed. After the three-minute reaction period, the prepared sample was also placed in the cell holder and 'Read' button pressed. The concentration of iron was displayed in mg/L Fe.

4.6. Nitrate-nitrogen

Nitrate-nitrogen level of the water was analyzed using the Cadmium Reduction Method. Nitrate-nitrogen was determined by selecting Program 353 N, Nitrate MR from the Hach Programs. A clean, round sample cell was filled with a known water sample volume to 10mL and the content of one NitraVer 5 Nitrate Reagent Powder Pillow was added to it. The sample cell was shaken vigorously to mix the contents and the timer icon pressed to begin a one-minute reaction period. The timer icon was pressed again after the one-minute reaction for a five-minute reaction period to begin. Another sample cell was filled with 10mL distilled water (the blank) and placed in the cell holder of the spectrophotometer after thoroughly wiping it. The 'Zero' button was pressed and a 0.00 mg/L NO_3^--N concentration was displayed. After the five-minute reaction period, the prepared sample was also placed in the cell holder after wiping the sample cell and the 'Read' button was pressed. The concentration of Nitrate-nitrogen in the water was displayed in mg/L NO_3^-N.

4.7. Nitrogen-ammonia

Nitrogen-ammonia level of the water was analyzed using the Salicylate Method from the Hach Programs. The 5-aminosalicylate was oxidized in the presence of a sodium nitroprusside catalyst to form a blue colored compound. The blue color is masked by the yellow colour from the excess reagent present to give a green-colored solution. Nitrogen-ammonia was determined by selecting Program 385 N, Ammonia and Silicylate. A clean, round sample cell was filled with the water sample to the 10mL volume and another sample cell was filled with 10mL deionised water (the blank). To each of these cells, the content of one Ammonia Salicylate Powder Pillow was added. The cells were stoppered and shaken to mix the contents and the timer icon pressed to begin a three-minute reaction period. After this period, the contents of one Ammonia Cyanurate Powder Pillow were again added to each cell that was stoppered and shaken to dissolve the reagent. The timer icon was pressed to begin a 15-minute reaction period. The blank was first placed into the cell holder after the reaction period and the 'Zero' button pressed. A 0.00 mg/L NH_3-N concentration was displayed. Subsequently, the prepared sample was also placed in the cell holder after wiping the sample cell and the 'Read' button was pressed. The concentration of Nitrogen-ammonia was then displayed in mg/L NH_3-N.

5. Results

5.1. Physical Quality of the Groundwater

The mean temperature in the water wells as well as the boreholes over the study period did not critically vary. It ranged from 28.0±0.01 - 28.0±0.02°C at Wabiri and Achiase respectively (Table 1). However, the pattern of similarity in means temperature of the well and borehole waters were not correlated with the geology of the area.

Table 1. Mean Concentrations of Physical Parameters in the Water Samples

Parameters	Community and Water Sources			
	Wabiri		Achiase	
	Borehole	Well	Borehole	Well
Temperature (°C)	28.0 (±0.02)	28.0 (±0.01)	28.0 (±0.02)	28.0 (±0.02)
pH	5.62 (±0.02)	4.61 (±0.04)	4.93 (±0.02)	6.28 (±0.03)
Conductivity (µS/cm)	262.67(±4.16)	112.37 (±0.04)	224.33 (±6.43)	77.23(±0.06)
Turbidity (NTU)	2.40 (±0.35)	17.80 (±0.61)	1.83(±0.32)	30.0 (±1.00)
TDS (mg/L)	130 (±2.35)	56.17 (±0.32)	112.33 (±3.06)	38.57(±0.06)

The mean pH in water wells ranged from 4.61±0.04 - 6.28±0.03. In the borehole waters, it ranged from 5.62 ± 0.02 - 6.28 ± 0.03 (Table 1). A site by site comparison of the mean water temperatures between the boreholes and the wells at Wabiri and Achiase revealed a statistically significant difference (P<0.000 and P<0.000) respectively at p< 0.05 level of probability.

The mean conductivity of wells in Achiase and Wabiri ranged from 77.23±0.06 µS/cm - 112.37 ± 0.04µS/cm. In the boreholes it ranged from 224.33 ± 6.43µS/cm, - 262.67 ± 4.16µS/cm respectively (Table 1). A site by site comparison of the water conductivity means showed a statistically significant difference of P<0.000 and P<0.000 between the boreholes and the wells in the two communities. Similarly, there was also statistically significant differences of P<0.001 between only boreholes in the two communities and P<0.000 between only wells in the two communities at p< 0.05 level of probability.

The mean turbidity of wells at Wabiri and Achiase ranged from 17.80 ± 0.61 NTU - 30.0 ± 1.00 NTU (Table 1). However in the boreholes, the mean turbidity levels ranged from 1.83 ± 0.32NTU - 2.40 ± 0.35NTU. A site by site comparison of the means turbidity limits revealed statistically significant differences of P<0.000 between the boreholes and P<0.000 between the wells in Wabiri and Achiase. In addition, a well to well water turbidity comparison, showed statistically significant difference of P<0.000 between the two communities (Appendix 4). However, comparing the turbidity limits of the borehole waters in Wabiri and Achiase the differences were insignificant (P<0.106) at P<0.05 level of probability. However, the Total Suspended Solids (TSS) concentration of groundwater from Wabiri and Achiase was non detective (it was 0.00) in all the wells and boreholes.

The Total Dissolved Solid (TDS) level in the well waters ranged from 38.78±0.06mg/L -56.17± 0.32mg/L at Achiase and Wabiri respectively. However, it ranged from 112.33 ± 3.06mg/L - 130.00 ± 2.35mg/L in the boreholes from both communities (Table 1). A site by site TDS comparison between the boreholes was statistically significant (P<0.000) and between the wells, it was further significant (P<0.000). Generally there was a statistically significant difference of P<0.001 in TDS levels between the boreholes and P<0.000 between the wells in both communities at P<0.05 level of probability (Appendixes 1, 2, 3 and 4).

5.2. Dissolved oxygen content of the well and borehole waters

The mean dissolved oxygen content in the well waters from Achiase and Wabiri ranged from 6.35 ± 0.06mg/L - 6.37 ± 0.12mg/L whilst in the borehole waters, it ranged from 5.57 ± 0.12mg/L - 6.27± 0.12mg/L from both communities (Figure1). However, a comparison of site-by-site data, revealed statistically insignificant differences between the borehole and the well waters (P< 0.288) from Wabiri and between the well in Wabiri and Achiase (P<0.374) respectively. Contrarily, the differences in dissolved oxygen concentrations between the borehole and the well in Achiase and between the two boreholes in Wabiri and Achiase waters were statistically significant (P<0.001 and P<0.002) at P<0.05 level of probability.

5.3. Biochemical Oxygen Demand (BOD_5 (mg/L)) of the Water

The mean BOD_5 levels of the groundwater ranged from 1.05 ± 0.00mg/L - 1.35 ± 2.75mg/L in the Wabiri and Achiase wells (Figure 2). The mean BOD_5 levels in the boreholes from the two communities were the same throughout the study period. It recorded a value of 0.9 ± 0.00mg/L.

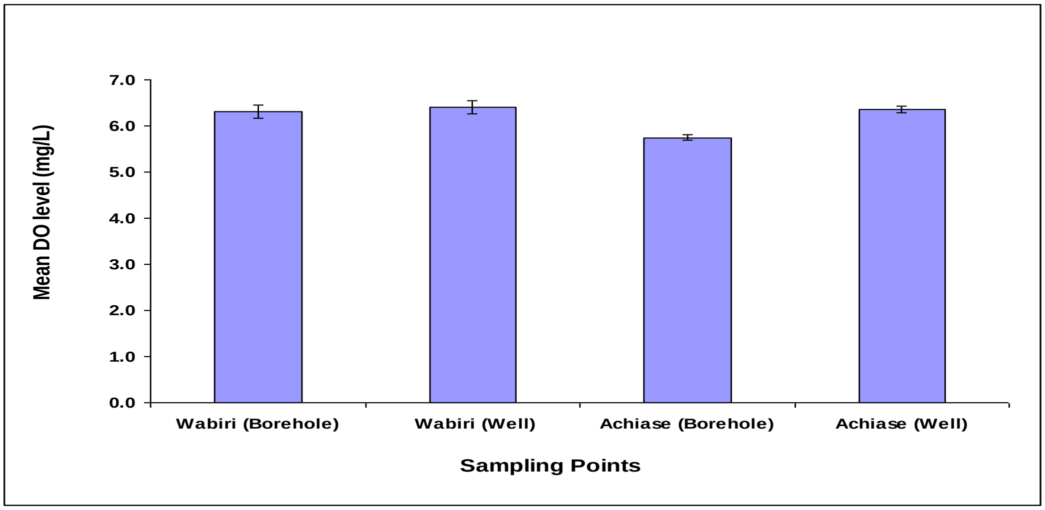

Figure 1. Dissolved oxygen content of the well and borehole waters

5.4. Microbial Quality of the Groundwater

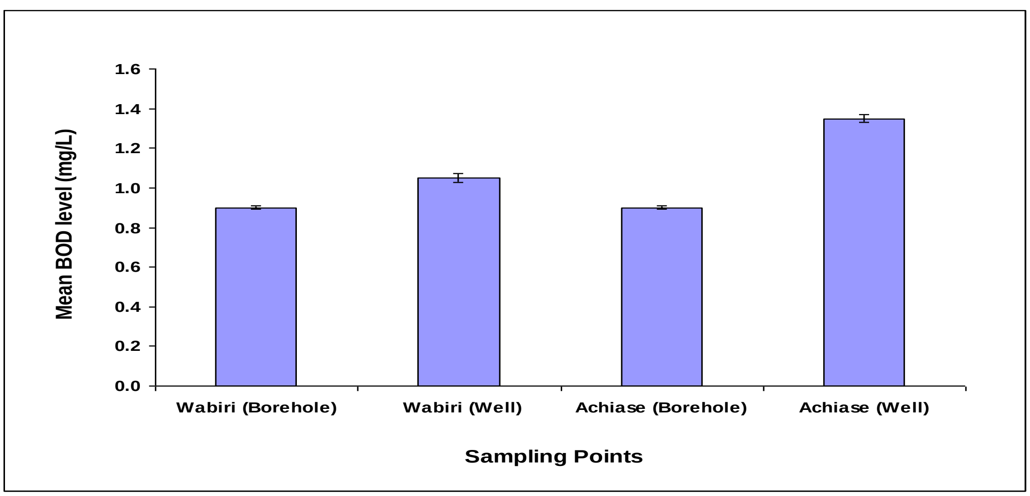

Figure 2. BOD_5 content of the well and borehole waters

Table 2. Microbial quality of the water samples (N/100ml i.e. Estimated bacterial numbers per hundred milliliters of water sample) from wells and boreholes at Wabiri and Achiase.

Parameters	Community and water sources			
	Wabiri		Achiase	
	Borehole	Well	Borehole	Well
Total Coliform (N/100ml)	0	2.42×10^2	0	1.09×10^2
E.coli (N/100ml)	0	2.00×10^0	0	1.0×10^1
Salmonella (N/100ml)	0	4.6×10^1	0	8.4×10^1

The total coliform bacteria in the well waters ranged from 1.09×10^2N/100ml - 2.42×10^2N/100ml in the two communities. However, total coliform bacteria were absent in all the boreholes (Table 2). The mean *E. coli* counts in the water wells ranged from 1.0×10^1N/100ml - 2.00×10^0N/100ml in Achiase and Wabiri. However, *E. coli* was absent in all the borehole water samples analyzed.

The mean salmonella numbers in the well waters sampled ranged from 4.6×10^1N/100ml - 8.4×10^1 N/100ml at Wabiri and Achiase (Table 2). However, no *Salmonella* bacteria was detected in water samples analyzed from the boreholes in the two communities. A site-by-site comparison of salmonella bacteria counts between the boreholes and the wells revealed a statistically significant difference of $P<0.000$ in Achiase (Appendix 2) whilst an insignificant difference of $P<0.374$ was noted between the wells in Achiase and Wibiri at $P<0.05$ probability level (Appendix 4).

5.5. Chemical Quality of the Well and Borehole Waters

5.5.1. Ammonia content of the waters

Ammonia was not detected from any of the samples taken from the various groundwater sources at Wabiri and Achiase.

5.5.2. Nitrite and Nitrate levels in the Well and Borehole Waters

The mean nitrite levels in the well waters in Achiase and Wabiri ranged from 0.005 ± 0.001mg/L - 0.008 ± 0.001mg/L. It however ranged from 0.001 ± 0.00mg/L - 0.013 ± 0.001mg/L in the borehole waters from Achiase and Wabiri (Figure 3). The site-by-site comparison of mean concentrations for nitrite revealed statistically significant difference ($P<0.002$) between the boreholes and the wells in each of community. Comparison of mean nitrite concentrations between the well and borehole waters further revealed statistically significant differences ($P<0.000$ and $P<0.021$) them at $P<0.05$ probability level.

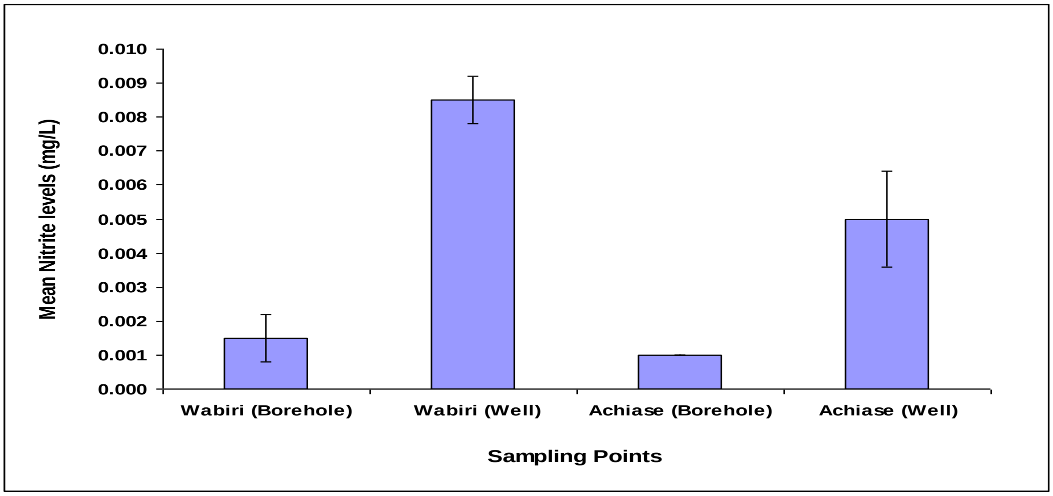

Figure 3. Nitrite levels of the well and borehole waters

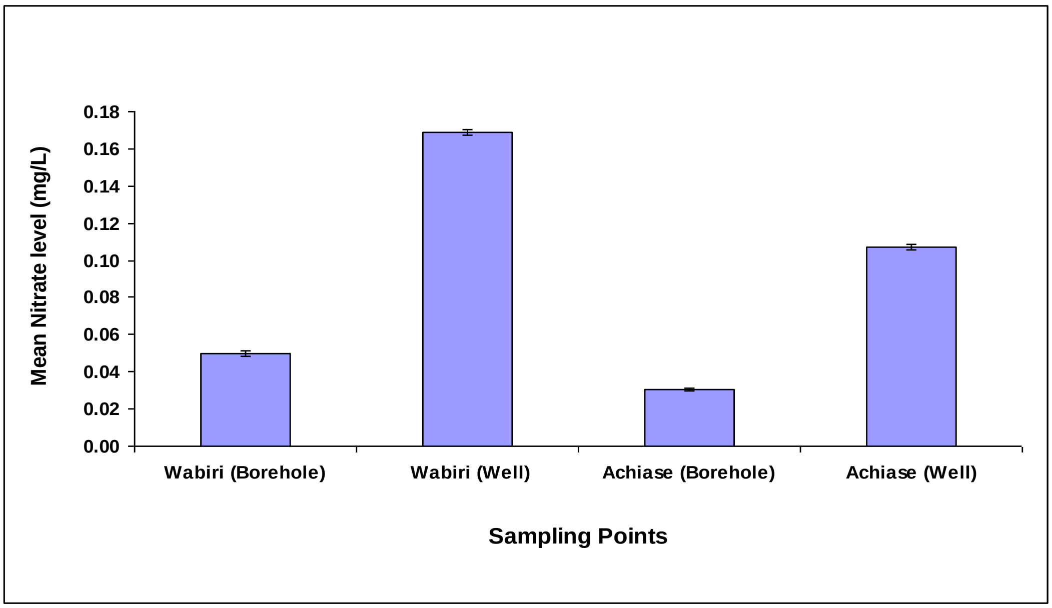

Figure 4. Nitrate levels of the well and borehole waters

The mean nitrate level of the groundwater ranged from 0.11± 0.0001mg/L - 0.17 ± 0.001 mg/L from Achiase and Wabiri wells. In the boreholes however, it ranged from 0.03 ± 0.0005mg/L - 0.05 ± 0.001mg/L (Figure 4). A site by site comparison revealed statistically significant difference of $P<0.000$ between the boreholes and $P<0.000$ between the wells in the two communities at $P<0.05$ probability level.

5.5.3. Chloride content in the Well and Borehole Waters

Chloride level in the well waters ranged from 15.6 ± 1.16mg/L - 18.33 ± 0.58 mg/L. It further ranged from 27.65 ± 1.16mg/L- 38.33 ± 0.56 mg/L in the borehole waters from the two communities (Figure 5). A site-by-site comparison of mean chloride concentrations revealed statistically significant difference of $P<0.000$ between the boreholes and $P<0.018$ between the wells from the communities at $P<0.05$ probability level.

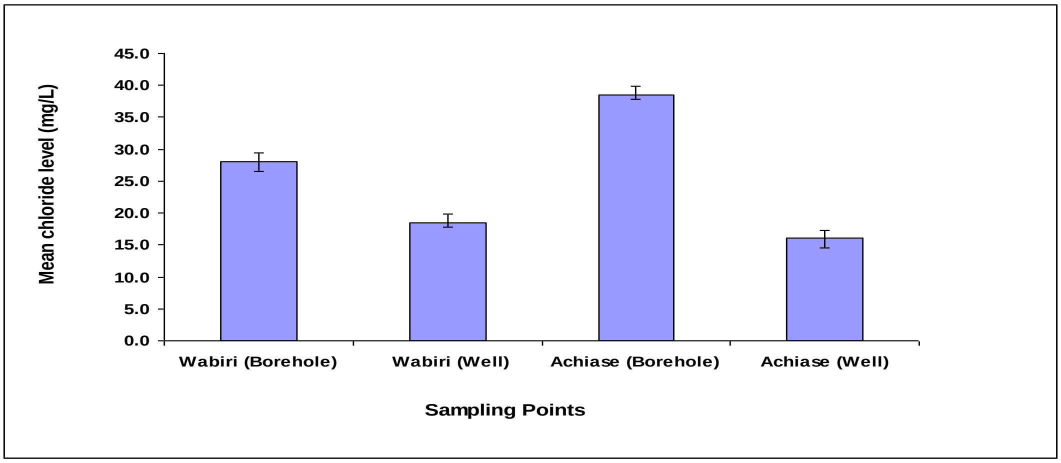

Figure 5. Chloride level in the waters

5.5.4. Iron levels in the waters sample

The iron level in the well waters from the two communities ranged from 0.036 ± 0.01mg/L - 0.07 ± 0.57mg/L. However, it was 0.01 ± 0.00 mg/L throughout the period of analyses from the boreholes in the two communities (Figure 6). A site-by-site comparison revealed statistically significant difference of $P<0.000$ between the boreholes and the wells in Wabiri and $P<0.007$ between the borehole and the well in Achiase at $P<0.05$ probability level. Similarly, there was statistically significant difference of $P<0.007$ between the wells in the two communities.

6. Discussion

The sanitary conditions around the wells and boreholes in Wabiri and Achiase were observed to be poor. For instance, the Achiase well was cited on the drainage path where when it rains, filth and other contaminants drain into it. The apron cover was very short and half way covered. The wells were located nearer to farms which constituted the potential source of nitrogen pollution of the groundwater through infiltration. Internal portions of these wells were neither cemented nor lined with geotextile membranes, thereby, allowing algae and other microbes to be growing inside them (plates 2 and 3).

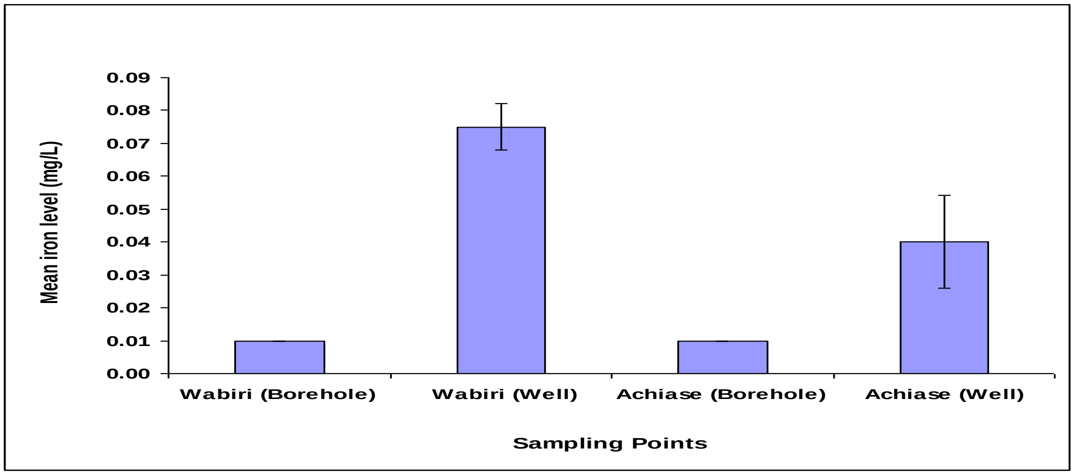

Figure 6. Iron levels in the well and borehole waters.

Plate 2. The inner portions of the Wabiri well

Plate 3. Inner portions of the Achiase well

Most of the water carrying receptacles were old and local containers (rubber buckets with metal handles) tied to nylon or jute robes, often left in the muddy surroundings of the well or coiled into containers when unused. The immediate surroundings of the boreholes were similarly not hygienic because it was often used as refuse dumps and humans and animals excreted around it. From the interactions made with the inhabitants, it revealed that, children play with the boreholes often putting their hands and filthy things inside it. This could be a direct cause of microbial contamination of the water (Howel et al., 1995).

High rate of unhygienic practices around the wells and boreholes could contaminate the groundwater with microbes as observed by Tiimub et al. (2008) in water wells of the Bawku East District in Ghana. The mean temperature of 28^{o}C recorded from all the water samples was found to be within average for drinking purposes since no guideline is set by the WHO in 2005 and USEPA in 1991 even though, extreme high temperatures in drinking waters could impair the health of users.

The WHO in 2005 suggested that the pH of drinking water should be within the range of 6.5 – 8.5. The same range had been specified by the USEPA in 1991. The mean pH of the water samples from the wells and boreholes which ranged from 4.61- 6.28 varied from the suggested range stated above with significant differences of $P<0.000$ observed between the entire well and borehole water sources. This might indicate a high acidic content in the waters which is likely to impair the health of those who drink from it.

The conductivity of the water from the wells was within the range specified in the 2004 WHO guidelines as 250µS/cm. The values recorded ranged from 77.33 ± 0.03 µS/cm - 112.37± 0.0 µS/cm. However, the electrical conductivity of the Wabiri borehole water was above the said guideline (250µS/cm) as it was detected to be 262.67 ± 4.16 µS/cm. The borehole from Achiase recorded a conductivity of 224.33 ± 6.43µS/cm which is within the 2005 WHO acceptable guideline value. There could be a negative health effect on the inhabitants as they continue to drink water from the Wabiri borehole with high conductivity due to the accumulation of cat ions and anions. The high level of conductivity in the Wabiri borehole could be attributed to the proliferation of local surface mining (galamsey) activities in the community (USGS, 1999).

The turbidity levels of both the well and borehole waters which ranged from 1.83 ± 0.32 NTU - 30.0 ± 1.00 NTU was slightly higher when compared to the 1991 USEPA standard range of 0.5 – 1.0 NTU and could influence its acceptability for drinking purposes.

No significant amount of Total Suspended Solids was found in all the water samples analyzed over the entire 12 months period of study. Total Dissolved Solids in all the samples which ranged from 38.57 ± 0.06mg/L - 130.0 ± 2.35 mg/L were within the 1991 USEPA standard value of 500mg/L.

The dissolved oxygen levels in the groundwater sources which ranged from 5.57 ± 0.12 mg/L, could be referred to be on the higher side since concentrations of less than 1.0mg/L is what has been considered as low based on International Standards (WHO, 2005). Low dissolved oxygen level in groundwater may be as a result of the presence of organic materials in the water, which allow microorganisms to grow and consume the oxygen. The BOD_5 (mg/L) levels of the well and borehole waters ranged from 0.9 ± 0.00 - 1.35± 2.72 and could be tolerated based on Ghana's Standards (Esi, 2012).

Nitrogen is a nutrient that occurs naturally in groundwater. However, elevated nutrient concentrations may result from human activities such as lawn fertilization and dispel of raw animal and human wastes (Esi, 2012). Nitrate concentrations in the groundwater samples ranged from 0.03 ± 0.005mg/L - 0.17 ± 0.001 mg/L. This could be acceptable in water for drinking purposes when compared to the 2005 WHO Guidelines and the 1991 USEPA standard of 50mg/L and 10mg/L respectively.

Nitrites concentration in the well and borehole waters ranged from 0.001 ± 0.00mg/L - 0.008±0.001mg/L. At this range, it could be tolerated when compared to the 2005 WHO guideline and 1991 USEPA Standard values of 3 mg/L and 1mg/L respectively. Although the nitrite levels could be tolerated at the time of this study, the inhabitants need be cautious about their activities such as the use of nitrogen based fertilizers for farming since enrichment of plant nutrients, most commonly phosphorus and nitrogen by the process known as eutrophication may lead to high levels of nitrates and nitrites in the wells and boreholes that are prone to contamination (Esi, 2012).

A major ion that may be associated with drinking water and waste water is chloride (Barrett and Howard, 2002). Chloride is present in all natural waters, usually in relatively small amounts; however, chloride can also be derived from human sources. Chloride is not effectively removed by the Septic systems, and therefore remains in their effluent. Chloride concentrations detected in the sampled groundwater from Wiper and Achiase communities did not exceed the 1991 USEPA standard and 2005 WHO guideline value of 250mg/L. This limit is similar to what has been recommended as acceptable by the Ground – Water – Quality – Assessment of selected Wells in the Fraser Watershed, Colorado (USA) in August, 1999 by the United States Geological Survey. However, the chloride levels of the groundwater samples were within the range of 15.64 ± 1.16mg/L - 38.33 ± 0.56 mg/L. By implication, the chloride concentrations detected cannot be related to ISDS's (Individual Sewage Disposal System) in the study areas.

The mean iron levels detected in the water samples ranged from 0.01 ± 0.00 to 0.07 ± 0.057 (mg/L). Unlike the levels detected in a research conducted by Tiimub, *et al;* in 2008 as part of the KNUST/UNICEF Joint Water Monitoring Program in the Bawku East District of Ghana where no iron was detected in any of the boreholes and the wells, traces of iron were detected in all the wells and boreholes in the Wabiri and Achiase communities. However, at such lower concentrations, it could be accepted since the USEPA 1991 standard and the 2008 Ghana Standards Specification for Drinking Water Quality for iron was set at 0.3mg/L. Definitely, the site-by-site comparison of the various sources of the waters sampled denotes that, care must be taken to avoid any increase in the iron level in the waters since it could impair the health of the users (Obiri-Danso et al*.,* 2002) because statistically significant mean differences of $P<0.000$, $P<0.007$ and $P<0.007$ in concentrations of Fe were revealed throughout the study.

Total coliform, *E. coli* and *Salmonella* bacteria were absent in water samples from all the boreholes (Table 2). Although, the total coliforms, *E. coli* and *Salmonella* bacteria numbers detected in the well waters ranged from 1.09×10^2 N/100ml - 2.42×10^2 N/100ml, 1.0×10^1 N/100ml - 2.00×10^0 N/100ml and 4.6×10^1 N/100ml - 8.4×10^1 N/100ml at Wabiri and Achiase with no statistical significant difference between them ($P<0.005$), its presence in drinking water is not tolerated based on the 2005 WHO guidelines which states that, for drinking purpose, no bacterial contamination should be found in groundwater.

This phenomenon could be a major source of worry to the public health professional since various bacteria species have been found to cause diarrhoeal, typhoid fever and water related diseases which attract high treatment costs and could lead to debilitation and reduction of economic productivity of the individuals in affected communities (CDC, 1991).

The presence of bacteria strains in drinking water may be as a result of unhygienic practices in the surroundings of the wells. Conscious efforts must be taken to avoid accumulation of these microbial organisms which may have health defects such as outbreak of cholera, typhoid, dysentery etc. on those who patronize these groundwater sources for drinking in the near future. This requires the administration of current and comprehensive house-hold water use safety plans, policies and programmes by the Community Water and Sanitation Agency and District Water and Sanitation Teams in order to meet the WHO requirements for drinking water at Wabiri and Achiase.

7. Conclusion

The quality of the boreholes and the wells studied could be referred to be within the WHO and EPA accepted guidelines for most of the parameters analyzed and may be recommended for use as reliable drinking water sources; although care must be taken to ensure good hygienic practices around it. Statistically significant differences were generally revealed in terms of the site-by-site comparison of the various sources of the groundwater between the boreholes and wells for almost all the parameters analyzed and it was further revealed that the hygienic practices of the inhabitants around the water sources were poor. The borehole water was generally of higher quality than water from the wells and so the latter water must be subjected to treatments such as filtration, chlorination and boiling before drinking. Critical efforts should be made to improve the sanitation practices around the wells and the boreholes at Wabiri and Achiase.

8. Recommendations

The wells should be well constructed with apron caps to a reasonable height to avoid runoff water infiltration into them whenever it rains. Additionally, the inner surfaces of these wells should be properly lined to avoid growing of weeds and algae that may consume the oxygen and consequently reduce the oxygen content in the water. The wells and the boreholes should be protected from children and domestic animals by fencing to avoid contamination. The inhabitants should avoid farming close to the wells and boreholes since the use of nitrogen-based fertilizers my increase the nitrate and nitrite levels in the water through leaching and infiltration. Importantly, local mining (galamsay) operations should not be encouraged nearer to sites where drinking water is tapped in order to avoid accumulation of heavy metals in the groundwater sources. Receptacles that are used in fetching water from wells should be kept clean to avoid the introduction of microbes into the water. Generally, funds should be made available by the Ejisu Juabeng Municipality, Government of Ghana, the Non Governmental Organizations working on the water and sanitation development and other community Development Partners to support the researchers develop technical solutions on effective ways of promoting small scale safe drinking water supply projects for the two communities being closely monitored.

Acknowledgement

We, the authors are extremely grateful to our Mentor, Professor Richard Tuyee Awuah for his encouragement and guidance which helped us to produce this paper for publication.

References

Barrett, M.H. and Howard, A.G. (2002), "Urban groundwater and sanitation – developed and developing countries", In Howard, K. W. F, Israfiloy, R. G. (eds). *Current problems in hydrology in urban areas Kluwer, Dordrecht*, pp. 39-56.

Centre for Disease Control (CDC) (1991), "Waterborne diseases outbreaks", 1989 -1990. *MMWR* 40(SS3), pp. 112.

Dauda, A.M. (1993), "A Comprehensive approach in water resources management for the 21st century", *Environmental Bullets*, Vol. 12, Nigeria.

Domenico, P.A. (1972), "Concept and models in groundwater hydrology". *New York. McGraw hill*. PP 1-15

Esi, A. (2012), "Environmental and Sanitation Studies in the Tropics". *Department of CIVIL Engineering KNUST, Kumasi-Ghana*. Third Revised Edition, pp. 99-119.

Fetter, C.W. (1994), "Applied hydrology", University of Wisconsin, Third revised edition pp 18-45.

Ghana Health Service Report (2005), *Accra, Ghana*, December, 2005, pp. 1-28.

Ghana Standard Water Quality (2008), "Specification for drinking water"- *GS* 175-1:2008:1-22.

Ghana Statistical Service Report (2010), "Population and Housing Census". *Accra, Ghana* December, 2010.

Howell, J.M., Cayne, M.S and Cornelius, P.L. (1995), "Faecal bacteria in agricultural waters of the bluegrass region of Kentucky", *J. Environmental Quality*, Vol. 24, pp. 44-419.

Obiri-Danso K.S., Adjei, B., Stanley, K. and Keith J. (2002), "Microbiological quality and metal levels in wells and boreholes water in some pre-urban communities in Kumasi", *Department of Theoretical and Applied Biology KNUST Kumasi Ghana. Science and Technology,* Vol. 3 No. 1, pp. 059-066.

Offodile, M.E. (2002), "Groundwater study and development in Nigeria", University of Ibadan Press. Nigeria.

Tiimub, B.M. Forson, M.A. and Obiri-Danso, K.S. (2008), "Groundwater Quality, Sanitation and Vulnerable groups: case study of Bawku East District". Pub. in 33rd WEDC International conference, La Palm Royal Beach Hotel Accra Ghana. *Access to Sanitation and Safe Water: Global Partnerships and Local Actions.* 7th-11th April, 2008. pp108 -111.

United States Geological Survey (USGS 1999), "The quality of our nation's waters. Nutrients and pesticides". *United States Geological Survey* Cir. 1225.

USEPA (1991), "Water quality criteria summary poster of the office of science and Technology", *Washington*, May 1, 1991.

WHO (2005), "Water, Sanitation and Health". Electronic Library. *A compendium of information on water, sanitation and health*. May, 2006.

WHO (1996), "Guidelines for Drinking Water Quality", Geneva, Vol. II. pp 1- 8