Potable Quality Determination of Groundwater from Point Collection Sources in the Asante Mampong Municipality of Ashanti Region in Ghana

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Abstract

A study was conducted to determine the potable quality of groundwater from point collection sources in the Asante Mampong Muicipality of Ghana in 2011. Groundwater was collected from 4 actively used hand pump boreholes and dugout wells for analyses using various standard laboratory methods (APHA, AWWA, WEF, 1998) to determine some physical, chemical and biological quality effects of the groundwater. The study recorded average values of 5.95, 355.55 (µS/cm), 3.225 (NTU) and (7.565 and 0.0225)mg/L for pH, conductivity, turbidity, DO, TSS in the groundwater. The differences in levels of BOD_5, TDS, NO_3-N, Chloride and NO_2-N were highly significant ($P<0.000$) even though Fe and ammonia did not show significant differences. Detection of these chemicals in drinking water has several implications, particularly in evaluating potential human health effects or ecological outcome; though the levels detected in this present study were within the permissible limits proposed in the 2006 WHO Guidelines for Drinking Water Quality. Significant differences in total coliforms and Salmonella contamination were observed to have negative health implications. Stake holder discussion is mandatory to partnering appropriate solutions to the groundwater quality problems.

Key words: Well, borehole, physical, chemical, biological, health effect, water quality.

1. Introduction of Background

Water (H_2O), is common name applied to the liquid state of the hydrogen-oxygen compound. Pure water is an odourless, tasteless liquid. It has a bluish tint, which may be detected, however, only in layers of considerable depth. Under standard atmospheric pressure (760 mm of mercury, or 760 torr); the freezing point of water is 0° C (32° F) and its boiling point is 100° C (212° F). Its physical properties are used as standards to define the calorie and specific and latent heat and in the metric system for the original definition of the unit of mass, the gram (USGS, 1999). Water is one of the best-known ionizing agents. Because most substances are somewhat soluble in water, it is frequently called the universal solvent. Water combines with certain salts to form hydrates. It reacts with metal oxides to form acids. It acts as a catalyst in many important chemical reactions (USGS, 1999).

Water is important to life, without it life cannot go on. Human life as with animals and plant life on the planet is dependent on water. Groundwater is the only reliable water resource for human consumption, as well as for agriculture and industrial uses for many countries like Ghana. For evaluating the suitability of groundwater for different purposes, understanding the chemical composition of groundwater is necessary.

Further, it is possible to understand the change in quality due to rock - water interaction (weathering) or any type of anthropogenic influence (Howel *et al.*, 1995). Groundwater in non saline geological locations at reasonable depths is particularly good for its cooler temperatures; ability to get tapped at common depths in larger quantities and provision of unique natural filtration mechanisms for larger bacteria and protozoan (Howel *et al.*, 1995). Such improved knowledge can contribute to effective management and utilization of this vital resource. In this view, monitoring the quality of groundwater (chemical, physical, and biological constituents) is as important as assessing it's quantity.

The definition of water quality is very much dependent on the desired use of water. Therefore, different uses require different criteria of water quality as well as standard methods for reporting and comparing results of water analysis (Obiri-Danso & Jones, 2000). Major chemical elements including Total Dissolves Solids (TDS), Biological Oxygen Demand (BOD_5), Iron, Nitrate ($NO_3^{-)}$ Nitrite (NO_2^-) and Chloride (Cl^-) play significant roles in classifying and assessing groundwater quality.

1.2 Problem Statement

The most common source of groundwater pollution is from substances used in forestry, waste and agriculture such as insecticide, herbicide and fungicide. The constituents of many of the pesticides are highly toxic, even in minute amounts (Fetter, 1994). Nitrogen-based fertilizers are the most commonly identifiable pollutants in groundwater in rural areas. Nitrogen in the form of dissolved nitrate is the major nutrient for vegetative growth, when applied some nitrate is retained by plants and soil particles. However, if applied in excessive amounts, the excess nitrate not consumed by plants can be flushed down to groundwater. Although nitrate is relatively non-toxic it can cause certain conditions such as oxygen deficiency which reduces haemoglobin in the blood cells. This can lead to suffocation (Offodile, 2002).

The increase in human activities has produced huge quantities of waste greater than the environment can absorb. Community-based interactive, and systematic academic semester observational surveys conducted by Lecturers and students of the Department of Environmental Health and Sanitation Education at Asante Mampong Campus of the University of Education, Winneba revealed their frequent encounter of large volumes of domestic, commercial and industrial wastes accumulation in and around the Asante Mampong Municipal area. Current water supply reconstruction project in the area which leads to intermittent water shortages from household running taps has been a major source of worry to inhabitants who run short of water supply and usually bear additional cost of buying from some unreliable truck water suppliers with questionable state of water quality services. This phenomenon poses real challenge and compels the inhabitants to opt for groundwater extraction mechanisms from well and hand pumped boreholes sources, once groundwater resources constitute the preferred domestic water supply (USGS, 1999).

Consequently, we have to act fast and decisively on the quality assurance aspects of promoting groundwater resources development, particularly in the Sekyere West Municipality where there is limited and scarce drinking water supply to meet the divergent needs of growing populations.

1.3 Rationale of the Study

Generally, there is the residual effect from the excessive use of agrochemicals used for commercial vegetable farming, and from the landfills in Sekyere West (Mampong) Municipality. This occurs mostly in the form of uncontrolled dumping, where refuse is piled up with little or no regard to the safety of the environment. Solid waste deposited in landfills decomposes and pollute groundwater. Within this framework, groundwater quality assessment has important social and health implications not only for the development of the Mampong Municipality, but for the economic welfare of the entire nation, since about 85% of the population in the Mampong area are farmers and their major contributions to the national development are cereal and vegetable production. Therefore, groundwater resource assessment becomes an important issue of research interest in order to help the inhabitants of the area know the effect of their activities on the quality of groundwater and environmental health.

Presently, it has remained difficult and very expensive for Local Assemblies under Government of Ghana to administer policy strategies to manage the quality of their groundwater resources alone without the partnership of Donor Agencies, NGOs and Civil Society Organizations in Ghana (Reports of the Third Ghana Water Forum, 2011).

Whereas systems for the management of surface water quality are well established, there is still lack of scientific knowledge about groundwater management, not only about exactly where it occurs, but also about how to manage it so that its quality does not deteriorate to unacceptable levels.

2. Main Objective

The main objective of this study was to assess the quality of groundwater from two wells and two boreholes in active use by the majority of inhabitants in purposely selected areas within the Asante Mampong Municipality.

2.1 Specific Objectives were to examine**:**

1. groundwater samples for bacteria – total and faecal coliform pollution, *E. coli*, and *Salmonella* contamination.
2. the physico-chemical state of groundwater for Total Suspended Solids (TSS), Turbidity, Temperature, pH, Conductivity, Dissolved Oxygen, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Iron, NO_3^--N, NO_2^--N, NH_3-N and Chloride ion.
3. the factors affecting the quality of groundwater through physical observation of site conditions and community-based response survey.

3.0 Materials and Methods

3.1 Profile of the study area *(Source: Sekyere West Municipal Statistical Service, 2006).*

The research was carried out in the Mampong Municipality, which is one of the Administrative Municipalities in the Ashanti Region of Ghana. It is located on the northern part of the Ashanti region, and shares boundaries with Atebubu District, Sekyere East, Afigya-Sekyere, and Ejura-Sekyeredumasi to the north, east, south, and west parts respectively. The Municipality has two main seasons and average annual rainfall of 1270mm. The average temperature in the Municipality is about 27 ^{0}C with variations in mean monthly temperatures ranging between 22^{0}C and 30 ^{0}C throughout the year. The Sekyere West Municipality lies within the wet semi-equatorial forest zone. It is generally low lying and gradually rising through rolling hills stretching southwards towards Mampong.

The population of the Municipality is currently 155,755 (2006 projection), as against 143,206 of the 2000 Population and Housing Census figure. According to the 2000 Population and Housing Census, females out-number the males in the Municipality. From the census, the females form 51.3% of the total population whilst males constitute 48.7% with age-dependency ratio of 1:0:7.

The Municipality has a number of health facilities including 1 Hospital, 7 Health Centres, 3 Maternity Homes, 6 Private Clinics and 1 Midwifery Training Institution. There are 111 Primary Schools, 60, Junior High Schools, 4 Senior High Schools, and 1 Vocational School, 2 Teacher-Training Colleges and 1 University Campus. Over 80% of the post Junior High Schools are all located in Mampong; however, the standard of education in the Municipality is relatively not encouraging.

3.2 Sampling methods

Water samples were collected in clean 1500ml bottles from the 4 sites (plate 3.1), namely:

1. Tadeem source
2. Abendale source
3. Doti source
4. Station source (close to old Atak's store).

The portion around the tip of the boreholes where the water was directly drawn was disinfected using flames of candle burner. The sampling containers were autoclaved before filling with the water samples. Sterilized forceps were used in holding and lifting the sampling containers before and after fetching the water. These samples were gently transferred into an ice chest containing ice blocks to suspend bacteria growth in the process of transportation to the laboratory for analysis. The containers were cap closed tightly with decontaminated hands which had been masked by sterilized rubber hand gloves.

The samples were taken in the evenings between 16:00 GMT and 19:00 GMT in the order of the sites shown above. The collected samples were stored in a refrigerator and analyzed as quickly as possible within twenty four hours. Odour and colour were examined direct in the field. All other parameters were assessed later in the laboratory according to the (WHO, 2006) Guidelines for drinking water quality examination.

The analysis of water samples was done at the Civil Engineering Department Laboratory at Kwame Nkrumah University of Science and Technology, Kumasi-Ghana using various standard protocols (APHA, AWWA, WEF, 1998).

3.3 Physical Parameters

3.3.1 Total Suspended Solids (TSS)

The suspended solid of a water sample is determined by filtering the sample, drying the residue and determining the weight difference. In this analytical procedure, the same Petri dishes each containing a filter pad were kept overnight in the drying oven. The crucibles were removed and put in a dessicator for drying and then weighing. Each of the filters was then put on the Hartley funnel or filter flask and the flask connected to a vacuum pump. About 100ml of the samples was filtered with the aid of the pump. The Petri dish and the filter were then placed in an oven and dried at 104^0C for 45 minutes. The crucibles was then cooled again in a dessicator and re-weighed.

3.4.1 Dissolved Oxygen (DO_5) - Winkler Method.

The principle underlying this method is that, in the presence of oxygen, manganese hydroxide is oxidised to higher oxides of manganese. After acidification, and in the presence of iodide, this is reduced back into manganese ions liberating iodide in equivalent amount to the oxygen originally dissolved in the sample.

Following the analytical procedure, The BOD bottles were carefully filled with the sample to avoid alteration of the dissolved oxygen concentration. About 2ml each of manganese sulphate followed by alkaline iodide oxide reagent was added to the sample. The bottles were stoppered without trapping any air bubbles and mixed up by inverting the bottles several times. The precipitate was allowed to settle to at least the lower half of the bottle leaving a clear supernatant above. The stoppers were carefully removed. About 1ml of concentrated H_2SO_4 was added allowing the acid to run down the neck of the bottle. The bottles were again stoppered and mixed up by inverting the bottles several times until there was a uniform yellow colour in the bottle. About 200ml of the mixture was then titrated with the sodium thio-sulphate adding 1-2ml of freshly prepared starch as an indicator.

3.4.2 Turbidity

Turbidity is the light-scattering properties of a sample containing suspended particles. The amount and distribution of scattered light is dependent on the concentration of suspended particles, size, shape, and the refractive index.

In this analytical process, the sample was poured into a clean sample cell until it was full. The surface of the sample cell was thoroughly cleaned with tissue paper and then placed in the instrument's light cabinet. The reading as it appeared on the instrument was taken. The sample cell was removed and cleaned after every reading.

3.4.3 Instrument Measurement for conductivity, temperature and pH.

Conductivity, temperature, and pH were measured in the laboratory using appropriate instruments below:

- Conductivity : LF 323 – B/Set conductivity meter
- Temperature : Mercury-in-glass thermometer
- pH : Digital pH meter(323-B/set-2)
- Turbidity : Turbidimeter (Hach, 2100A)

Following a careful analytical procedure, about 200ml of the sample was poured into a beaker and the electrodes of the various instruments dipped into the sample. The readings as they appeared on the screens of the instruments were taken after they have stabilized. Same amount of distilled water was used for the rising of the electrodes after each test.

3.5.0 Chemical Parameters

3.5.1 Biochemical Oxygen Demand (BOD_5)

Microorganisms utilize dissolved oxygen in water to oxidise polluting organic substances. By way of measuring the initial concentration of oxygen of a sample and that after 5 days of incubation at 20^0C, the BOD_5 can be determined.

A known volume of the water sample was poured into a 300ml BOD bottle and mixed with dilution water until it overflowed and was 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 sample were determined using a DO meter. Both bottles were stored at 20°C in the incubator for five days. After 5 days, the amounts of dissolved oxygen remaining in the samples were measured with a DO meter.

Calculation

The 5-day BOD was computed using the equation below:

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

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

3.5.1 Iron (FerroVer Method)

Principle

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.

In this method, the concentration of iron was determined by initially selecting Program 265 Iron, FerroVer from the Hach Programs. A clean, round sample cell was filled with a known sample volume diluted to 10mL and the contents of one FerroVer Iron Reagent Powder Pillow 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.

3.5.2 Total Dissolved Solids (TDS)

An inorganic substance which may dissolve in water includes minerals, metal, and gases. Water may come into contact with these substances in the atmosphere, on surfaces and within the soil. Materials from decayed products of vegetation, organic chemicals and organic gases are common organic dissolved constituents of water.

In this analytical procedure some dry porcelain crucibles were weighed and 100ml of the filtered samples poured on them. The crucibles were placed on a water bath for the samples to evaporate to dryness. The crucibles were put in a dissector and allowed to cool. The crucibles were then weighted and the extra weight recorded portrayed the total amount dissolved solids.

3.5.3 Nitrate-Nitrogen (NO_3-N)

This is a common form of inorganic compound found in water solution. In agricultural regions, heavy fertilizer application results in unused nitrate migrating into water bodies. Surface waters can be contaminated by this compound due to the discharge of municipal waste water and drainage from agricultural lands.

In principle, Cadmium metal reduces nitrates in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt. The salt couples with gentisic acid to form an amber coloured solution.

Using the Cadmium Reduction Method of analysis the concentration of 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 sample volume to 10mL and the contents of one NitraVer 5 Nitrate Reagent Powder Pillow 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 was displayed in mg/L NO_3^-N.

3.5.4 Nitrite Nitrogen (NO_2-N)

Total oxidized nitrogen exists in two forms, namely: Nitrite and Nitrate. The oxidation of ammonia to nitrite by the *Nitro somonas* bacteria is the rate limiting the two distinct steps in the bacteriological oxidation of ammonia and therefore it is not usual to find nitrite in any appreciable concentration in water. Even though nitrite is preferred in surface waters to ammonia, there is the tendency of water containing only relatively low concentration of nitrate, together with phosphate to develop algal blooms.

Following the analytical steps about 50ml each of the water samples were measured and poured in Nessler glasses. Then, 2ml of sulphonic acid followed by the same amount of Naphthyamine Sulphonic were added to the samples. A blank sample was prepared using the same reagents. All the samples were left for 35 minutes. The blank sample was then placed in the left compartment of the Nesslerisser on the right compartment in turns. The disc of the instrument was moved until both colours of the blank and sample match and the reading was then taken.

3.5.5 Ammonia Nitrogen (NH_3-N)

The presence of ammonia nitrogen in water is usually the results of the biological decomposition and stabilization of organic nitrogen. It is therefore the end-product of metabolic activity of heterotrophic micro-organisms. This compound is unwanted in surface water even if in very low concentrations because it is toxic and can as well exert a significant oxygen demand.

In principle ammonia compounds combine with chlorine to form monochloramine. Monochloramine reacts with salicylate to form 5-aminosalicylate. The 5-aminosalicylate is oxidized in the presence of a sodium nitroprusside catalyst to form a blue coloured compound. The blue colour is masked by the yellow colour from the excess reagent present to give a green-coloured solution.

Using the Salicylate Method**,** ammonia-Nitrogen was determined by selecting Program 385 N, Ammonia, Salicylate from the Hach Programs. A clean, round sample cell was filled with the water sample to the 10mL volume and another sample cell filled with 10mL deionised water (the blank). To each of these cells, the contents of one Ammonia Salicylate Powder Pillow were 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, 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 displayed in mg/L NH_3-N.

3.5.7 Chloride

The presence of chloride was determined by the Argentometric method. The method involved the addition of 1.0mL K_2CrO_4 indicator solution to a known sample volume (50mL) of the portable water. 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)

3.6. Bacteriological Parameters

3.6.1 Total Coliform, *E. coli*, and *Salmonella*

The method for Thermotolerant bacterial analysis in water samples was the Membrane filter technique using Chromocult Coliform Agar.

In principle, Chromocult Coliform Agar determines the presence or absence of Coliform bacteria and *E. coli, and Salmonella* in drinking water. A water sample was passed through the membrane that retains the bacteria. Following filtration, the membrane containing bacterial cells was placed on the media and incubated at 36 ± 1°C for 24 ± 1 h. Salmon to red colonies were recorded as presumptive 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.

Statistical data analysis of the results was conducted using Version 16.0 of 1998 3rd Edition of Statistical Package for Social Scientists (Anon, 1988).

4. Results

4.1 Physical quality of the water

The physical parameters assessed showed some extent of variations in the quality of water from the different sources (Table 4.1). The mean temperature from the two well waters did not vary and was 27.89 $\pm0.31^0$C over the three months period of study. Temperatures of the two borehole water samples varied from 27.84$\pm0.11^0$C to 28.11$\pm0.11^0$C, the lowest value was recorded at Tadeem borehole whilst the highest value at Mampong Station borehole. There was no significant difference between the well and borehole water temperatures ($p<0.876$). The mean pH levels in the two wells ranged between 5.47±0.03 to 6.14±0.02, the lowest value was detected at Abendale whilst the highest in Doti well. Similarly, it further ranged between 5.46±0.01 and 6.67±0.01 in Tadeem and Mampong Station boreholes respectively. However, there was significant difference between the well and borehole water pH ($P<0.00$).

The mean well water conductivity ranged from 52.47±1.37µS/cm - 681.00±2.60 µS/cm at Abendale and Doti respectively. In the boreholes, conductivity ranged from 174.44±1.04 µS/cm - 512.5±2.19 µS/cm at Tadeem and Mampong station respectively. There was significant differences in water conductivity between the wells and boreholes ($p<0.000$).

Turbidity in the well water ranged from 2.86±0.06NTU - 4.24±0.13 NTU at Abendale and Doti respectively. In the boreholes, it ranged from 2.85±0.07 NTU - 2.95±0.09 NTU at Tadeem and Mampong Station. Similarly there was significant differences between the well and borehole turbidities ($P<0.00$).

Dissolved oxygen (DO) in the wells ranged from 7.13±0.05mg/L - 6.11±0.03 mg/L at Abendale and Doti respectively. In the boreholes it ranged from 9.91±0.03 mg/L - 7.11±0.06 mg/L at Tadeem and Mampong station. There was significant differences in DO between the well and borehole ($P<0.00$). The total suspended solids (TSS) in the wells ranged from 0.03±0.01 mg/L - 0.02±0.01 mg/L at Abendale and Doti. In the borehole waters it ranged from 0.02±0.01 mg/L - 0.02±0.00 mg/L at Tadeem and Mampong station. There was statistically significant difference between the well and borehole dissolved oxygen levels ($P<0.00$).

4.2 Chemical quality of the water

The concentrations of chemical parameters from the water samples examined varied among the different sources of the waters sampled for the study (Table 4.2).

It was observed that parameter such as BOD_5, TDS, NO_3-N, and Chloride NO_2-N showed variations which were highly statistically significant (*P*=0.000) among the means of the various chemical water quality parameters at 0.05 level of probability. Additionally, Iron and Ammonia showed a slight variation in their levels in the various waters examined for its quality. However, no significant difference was observed among their mean values (*P* >0.345 and P>0.228) at 0.05 level of probability.

4.3 Microbial quality of the waters

The study revealed the absence of *E. coli* bacteria in all the water samples examined for its quality. The presence of total coliforms and *Salmonella* were detected in the water samples (Figure 4.1). There was much significant difference between the various means of the waters in terms of the entire biological water quality parameters examined (*P* = 0.000 throughout) at 0.05 level of probability.

5.0 Discussion

5.1 Physical effects of the groundwater quality

The physical property of the drinking water was judged by parameters such as temperature, pH, conductivity, turbidity, DO and TSS. The physical parameters examined from the groundwater showed slight variations in terms of its quality from the different sources.

Water temperature has profound effects on the rates of biological and chemical processes of man. An overall average temperature of the groundwater (27.93^{o}C) observed was probability an indication of its consistent cool nature at lower depths. This could be attributed to stable climatic and environmental conditions of the aquifer regimes in the study area. At such relatively lower water temperature, it is usually, widely acceptable for drinking based on the recommendation of Howell *et al.*, (1996) in the United States of America. The effects associated with usage of water with extreme temperature such as reduction in chemical and biological processes and efficacy indexes in the body could therefore, be prevented to some extent (WHO, 2006).

The study recorded average values of 5.95 for pH, 355.55 (µS/cm) for conductivity, 3.225 (NTU) for turbidity, 7.565 (mg/L) for DO and 0.0225 (mg/L) for TSS. Each of these parameters operate in its own dimension but contribute in aggregate to influence the suitability of drinking water. With reference to the 2006 WHO Guidelines for drinking water, pH of < 6.5 or > 9.2 would markedly impair the portability of the water. This subjects the mean pH values of the groundwater recorded unacceptable, because it could produce negative health outcome upon consumption.

Conductivity, turbidity and total suspended solids level in groundwater are a measure of direct or indirect concentration of dissolved ions and impurities or sediments in the major drinking sources in the study area. These effects may be attributed to farming around water sources using agrochemicals coupled with unhygienic anthropogenic practices. This could result in degradation of both organic and inorganic compounds releasing ions and sediments into water bodies when it rains, thus increasing the turbidity and TSS levels of water and consequently rendering it unsafe for human use as well as other biological entities and correlate positively with gastrointestinal disorders such as hyperacidity, diarrhoea, typhoid and cholera (Abdulaziz, 2003).

5.2 Chemical effects of the groundwater quality

Fe levels detected in all the water wells and hand pump boreholes were not consistent with the trends reported by Tiimub *et al.*, (2008) in their study on groundwater quality, sanitation and vulnerable groups in peri urban communities of the Bawku East District in Ghana whereby it was detected that no Fe was found in all the groundwaters sampled from selected UNICEF hand-pump boreholes and wells in 2006. In effect, the mean Fe concentrations in all the boreholes 0.01(±0.00) mg/L and all the wells (0.02 (±0.00) mg/L generally conformed to the 0.3 mg/L WHO Guideline value. This level of Fe in water could be tolerated since it could not pose significant health hazards (WHO, 2003). Among the chemical parameters measured, the differences in levels of BOD_5, TDS, NO_3-N, Chloride and NO_2-N were highly statistically significant (*P*<0.000) even though Fe and ammonia did not show significant differences (*P*<0.345 and P<0.228). Detection of these chemicals in drinking water has several implications, particularly in evaluating potential human health effects or ecological outcome; though the levels detected in this present study were within the permissible limits proposed by the International Standards for Drinking-water (WHO, 2006).

It has been observed that the traces of chemicals such as ammonia nitrogen in drinking water supplies may be traced to proliferation of farming along water sources using various pesticides and agrochemicals such as organo-chlorine and organo-phosphate fertilizers to boost crop yields in adjacent valleys and plains in the Mampong Municipality.

Similar trends of groundwater pollution have been observed in peri-urban areas in developing counties whereby rising nitrate and chlorine levels have been documented and fertilizer use is on the rise (Jacks *et al*., 1999). Indeed, in the USA alone where there is even food security, about 25% of pesticides is of urban, agricultural/industry origin and its presence is wide spread in well waters (USEPA 1990). This gives an indication of the possibility of high groundwater pollution by fertilizers in developing parts of Africa where poverty is high and poor farming practices cannot be overlooked as significant dangers due to food insecurity (UNEP 1996). Concentration of chemical entitles particularly ammonia in drinking water is an indication of possible bacterial, sewage and animal waste pollution which typifies the poor sanitation condition around the major sources of drinking waters in the study area. The effect of high chemical concentration of drinking water on health outcome in relation to an exposure beyond tolerable limit by users could therefore predispose the affected communities to incidence of osteoporosis, cancers, impaired liver, kidney and cardiopulmonary functions (UNEP 1996).

5.3 Biological effects of the groundwater quality

The study detected presence of microbial entities at varying levels in all the water examined even though *E. coli* was absent. However, significant levels of differences in total coliforms and *Salmonella* at (P<0.000) were observed on the biological water quality. The total coliforms counts in all the samples far exceeded that of Salmonella. The presence of bacteria strains at minimal level is capable of inducing negative health outcomes.

The presence of these micro organisms and coliform bacteria in drinking water is probably the result of poor environmental hygienic habits of the people, particularly in areas where wells have been exposed to sub-surface migration of contaminants as a result of leachates infiltration from the unprotected conditions prevailing around these major sources of drinking water. This situation is comparable to the incidence of poor drinking water quality arising from poor sanitation habits among the vulnerable groups in Ghanaian communities particularly observed in recent studies conducted in areas of the Bawku East District of the Upper East Region, where, indiscriminate sitting of on-site sanitation facilities and improper liquid waste disposal methods contributed significant pollution trends to peri urban groundwater supplies and population growth was on the ascendancy and the people lacked public health education (Tiimub *et al.,* 2008).

The indications are that, there would be likelihood outbreak of diarrhoeal and other water borne infections in the study area if, cleansing or adequate water improvement treatment measures are not put in place to address shortfalls with the biological aspects of the drinking wells and boreholes that the communities patronize on daily basis. In line with these observations is the recommendation of the WHO technical concept on drinking water pointing out clearly that in order for a water sample to be adequately safe for drinking purposes, it should be free from chemical and microbial contaminants and traces of metallic parameters. For acceptance of good standards, the microbial levels detected should not exceed the WHO Guideline values (WHO, 2006). The Centre for Disease Control (1991) further specified that potable water should remain physically free from total suspended solids, larger protozoans and bacteria and be of good taste at neutral pH in order to avoid diarrhoeal, dysentery and other water related diseases outbreaks.

5.4 Conclusion

The data collected have provided some useful information regarding the water quality of the Sekyere West Municipality of Ghana. The results clearly reveal that the wells and boreholes waters monitored for its quality are of immense value for present and future generations; but it is being degraded gradually as a result of a wide range of preventable impacts; agricultural activities, unprotected sitting and encroachment due to uncontrolled land developments are the major causes. Anthropogenic influences are important contributors to pollution of the wells and boreholes. In view of this, there is urgent need to control the treatment and disposal of domestic solid, liquid and farm wastes in the vicinities of water sources. Again, the synergistic impacts of the groundwater pollution on the health of humans need to be carefully assessed and realistic control strategies adopted to minimise the dangers it poses.

5.5 Recommendation

The Community water and Sanitation Agency and the Environmental Health and Sanitation Unit of the Mampong Municipality should partner at stakeholder discussions and regulate safety measures to ensure that, dumping and burning of refuse along point well and borehole water sources should be discouraged. Refuse traps should be provided in the four study sites for safe collection of wastes. Farming activities close to these water sources should be discouraged. The Environmental health division should adopt legislation to control sullage discharge which flow along the direction of the water bodies with the likelihood of causing sub-surface contamination of the groundwater. The Department of Environmental Health and Sanitation at the University of Education, Winneba should mount be environmental education programmes to sensitise people on the need to conserve and monitor water resources in the Mampong Municipality. There is the need for the Environmental Health Division to conduct environmental impact assessment on any project that may have adverse effect on the water bodies and those who pollute the water should be prosecuted and made to pay.

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Plate 1 water samples collected for laboratory analysis

Plate 2 Tadeem source (TD)

Plate 3 Doti source (DT)

Plate 4 Abendale source (AB)

Plate 5 Station source (SS)

Plates (2-5) Pictorial view of water sample collection from boreholes and wells from four communities in Asante Mampong Municipality.

Table 4.1: Physical quality of groundwater from four communities in Asante Mampong Municipality from January – March, 2011

Parameters (Mean value /unit)	**Sources of samples**			
	Abendale	Doti	Tadeem	Station
	GM / SE	GM / SE	GM / SE	GM / SE
Temperature (^{O}C)	27.89 (±0.31)	27.89 (±0.35)	27.84 (±0.11)	28.11 (±0.11)
pH	5.47 (±0.03)	6.14 (±0.02)	5.46 (±0.01)	6.67 (±0.01)
Conductivity (µS/cm	52.47 (±1.37)	681.00 (±2.60)	176.44 (±1.04)	512.30 (±2.19)
Turbidity (NTU)	2.86 (±0.06)	4.24 (±0.13)	2.85 (±0.07)	2.95 (±0.09)
DO (mg/L)	7.13 (±0.05)	6.11 (±0.03)	9.91 (±0.03)	7.11 (±0.06)
TSS (mg/L)	0.03 (±0.01)	0.02 (±0.01)	0.02 (±0.01)	0.02 (±0.00)

GM= Geometric mean, SE= Standard error

Table 4.2: Chemical quality of groundwater from four communities in Asante Mampong Municipality from January – March, 2011.

Parameters (Mean value /unit)	Sources of samples			
	Abendale	Doti	Tadeem	Station
	GM / SE	GM / SE	GM / SE	GM / SE
BOD_5 (mg/L)	1.50 (±0.01)	2.38 (±0.04)	2.09 (±0.04)	1.27 (±0.04)
Iron (mg/L)	0.02 (±0.00)	0.02 (±0.00)	0.01 (±0.00)	0.01 (±0.00)
T.D.S. (mg/L)	25.18 (±0.25)	342.22 (±1.33)	88.53 (±0.50)	265.00 (±0.88)
NO_3^-N (mg/L)	0.05(±0.00)	0.73 (±0.01)	0.29 (±0.01)	0.22 (±0.00)
NO_2^-N (mg/L)	0.002(±0.00)	0.002 (±0.00)	0.003 (±0.01)	0.006 (±0.00)
Ammonia (mg/L)	0.015(±0.00)	0.015 (±0.00)	0.014 (±0.00)	0.010 (±0.00)
Chloride (mg/L)	6.50 (±0.00)	69.28 (±0.17)	21.54 (±0.16)	37.66 (±0.17)

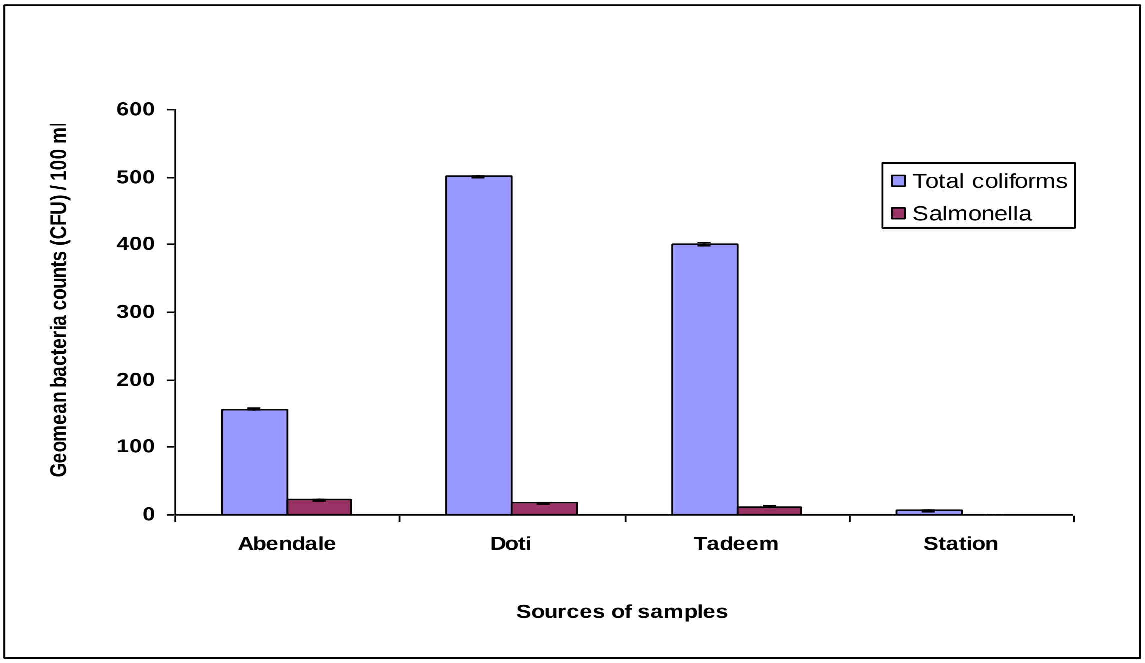

Figure: 4.1 Microbial quality of the portable groundwater from four communities in Asante Mampong Municipality from January to March, 2011.