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Quality Determination of Groundwater for Drinking at Nkawkaw in the Eastern Region of Ghana

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Abstract

The physical, trace element and microbiology of groundwater randomly collected from four boreholes namely (BH3, BH5, BH103 and BH105) at Nkawkaw in the Eastern Region of Ghana were examined by comparing it to the Ghana standards for drinking water using various standard methods of analysis and the results were compared to the Ghana standards in 2011. The microbiological data indicated that the water from all the boreholes surveyed was safe for drinking since no thermotolerant colifom bacteria were detected in them. Although the results revealed evidence of minimum physical variations in terms of colour (0.67 Pt. Co - 61.0 Pt. Co), conductivity (819µs/cm - 1052µs/cm) and turbidity (0.59 NTU - 23.5 NTU), as well as relatively higher manganese (0.038mg/L - 0.638mg/L) and aluminum (0.064 - 0.479mg/L) concentrations in some boreholes, the values obtained were generally acceptable when compared to the Ghana water Company's Standards and WHO Guideline values. The boreholes with high levels of manganese were all located in the same area which signified a possible rock mineral and groundwater interaction. Additionally, nitrogen concentration was found to be within the acceptable limits according to Ghana Water Company's Standard even though at $p<0.05$, both forms of nitrogen (ammonium and nitrate), showed significant difference ($p<0.00094$) among their corresponding means (0.058, 0.054, 0.072 and 0.060) mg/L in BH3, BH5, BH103 and BH105 respectively. Frequent monitoring programmes and education are recommended to ensure implementation of safe water plans for the Nkawkaw area where tapping of groundwater from richer aquifer reserves appears unavoidable.

Keywords: Groundwater, Nkawkaw, Borehole, Ghana Water Company, Bacteria, Physico-chemical, Traced Metal.

1. Introduction

Water is a key component in determining the quality of our lives. Although water covers about 70 percent of the earth's total surface, only 0.3 % of it can be used by human beings. Notwithstanding the small quantity of water available as a usable source, the society continues to contaminate this precious resource. According to Abbey et al., (2008), water is the commonest solvent that exists in the largest amount and also the only solvent that dissolves most substances and is one of nature's most important gifts to mankind and it is very essential to life (Mwangi, et al., 1974). Without water, the body cannot function just as a car cannot run without fuel. In the past, most people especially the rural folks depended mostly on surface water as their drinking source. In recent years however, groundwater sources such as boreholes are being given preference. This is as a result of the increasing rate of surface water contamination (Dauda, 1993). The fresh groundwater source constitutes only 0.8 % of the earth's total water (USGS, 1999). The development of groundwater must therefore be of paramount concern to policy makers and implementers. No matter the quantity of water available at a given place within a given period of time, measures must be put in place to avoid a situation whereby water quality is compromised.

In an attempt to tackle this crucial menace, enormous effort is being made by Non-Governmental Organization, Stakeholders, and other philanthropic institutions in collaboration with government to ensure that quality water is obtained from these underground sources. For instance, government is currently working hard to solve a problem on fifty (50) groundwater sources in the Upper-East Region of Ghana. The fluoride level of these groundwater sources is said to be above the acceptable limits (Ghana Tele Vision News, 2010, Community Water and Sanitation Agency, 2010). This can be considered as a step in the right direction, since access to quality drinking water will consequently promote good health and national development.

Groundwater contamination can be very hazardous (Parker, 1984) and awareness of the dangers associated with the consumption of water from contaminated sources has served as an eye-opener to many people (Shaw, 1994). Consumers have therefore become critical about the quality status of water they consume. Access to quality drinking water is a powerful determinant of health to about half of the population of the developing world exposed to polluted sources of water that increase disease incidence (WHO, 1993). The need to provide quality drinking water to the inhabitants of a given area must therefore, be considered a necessity and must be met at all cost. In view of this, it is justifiable to monitor the quality of groundwater, which has become the major supplies of consumable water to many people, a necessity rather than a mere luxury. To further prevent disease incidence and other negative effect of consuming substandard water, it is imperative to systematically and regularly monitor quality of the groundwater consumed by people. This may help in adopting recommended safe use strategies when necessary.

Nkawkaw is the Municipal Capital of the Kwahu West Municipality of the Eastern Region. Due to its commercial activities, it is one of the heavily populated towns in the Kwahu Traditional area in Ghana. The high human population density has made most of the social amenities, especially the water supply system to be over-burdened. The entire area has only one industrial water treatment plant. This was constructed in the mid-1960s to supply water for a population which was 1/5 of the current population of the area. Moreover, the regularity of water supply by this network is graded below average (WRRI, 1992).

1.1 Basis and Justification for the Study

Majority of the people in Nkawkaw urban area depend on groundwater in the form of boreholes as their main drinking water source. In this regard, groundwater can be considered or treated crucial commodity in the area. However, much has not been done over the years to assess the extent of the quality of this vital resource. When the consequences of the consumption of sub-standard water are analyzed, then one would prefer to prevent them from occurring. The assurance of drinking –water safety serves as a foundation for the prevention and control of water borne diseases (WHO, 1993). It is therefore, reasonable to consider a systematic and regular assessment of groundwater quality since it will help reduce or prevent health problems that could be attributed to the consumption of water from contaminated sources in the Nkawkaw area. This research unveiled vital information about the quality status of groundwater consumed by the people of Nkawkaw. The findings further serve as a reference point for health authorities, the Environmental Protection Agency (EPA), Non- Governmental Organizations and community development advocates who are responsible for making policies and programmes on water and sanitation development in addition to the fact that recommendations and findings of the study provide the basis for further research work.

The study purposively assessed the quality of groundwater for drinking at Nkawkaw in the Eastern Region of Ghana by examining the potential physical, chemical, trace element or biological pollutants influencing the quality selected boreholes waters for potable reasons by comparing it with the Ghana Water Company Standards.

2. Methodology

2.1.1 The Study Area

The study was conducted at Nkawkaw in the Kwahu traditional area in the Eastern Region of Ghana in West Africa in 2011. The Nkawkaw area lies on latitude 6°33'0'N and longitude 0° 46'0'W (Google earth map, 2010). The largest part of the Kwahu traditional area is mountainous in nature, but Nkawkaw, which is the study area, lies at the foot of the Kwahu Mountain. The area forms part of the Kwahu – Wenchi plateau. Nkawkaw is located about 214kilometers North – West of Accra. It lies within the wet – semi equatorial region. As such, it experiences a double maximal rainfall pattern with average monthly relative humidity ranging between 75% and 80% during the two rainy seasons. Mean monthly temperature of about 30°C is often recorded between the months of March and April but declines to about 26°C in August. During the rainy season, there are volumes of fresh water in the form of spring from the mountains. Most of the low land areas also get flooded to recharge the groundwater. The study area being the Municipal Capital is one of the most densely populated with about 47, 162 persons (Geo. Names Geographical Database, 2010). Out of this population, about 85% depend on groundwater sources. Apart from the public and civil workers, majority of the people are engaged in farming and merchandizing activities. This has made Nkawkaw the busiest of all the Kwahu Towns.

2.1.2 Sampling Strategy, Materials and Equipment

The entire catchment area of Nkawkaw has eight (8) boreholes. These boreholes collectively supply water into one big reservoir which is later on distributed to the community. Out of the eight boreholes, four of them, constituting 50% were selected for the study. This was to ensure a true representation sample that reflected one or more characteristics of the population sampled and as defined by the study objectives. The strategy used for the sampling was simple random strategy. This was deemed applicable because; the sites were not located too close to one another, there was no background information available and there was no visible sign of contamination. Materials/equipment used for the sample collection includes: sterile bottles, an ice chest containing ice cubes sterile forceps, cotton wool and methylated spirit.

2.1.3 Sampling Procedure

Groundwater sampling procedure involves three basic things; this includes information on the physical, chemical and biological properties. Based on WHO guidelines (1996), the physical properties investigated include pH, electrical conductivity, temperature, total dissolved solids and total suspended solids. Chemical and trace element properties were iron, manganese, chloride, alkalinity, total hardness, phosphate, cyanide, lead, copper, aluminum, nitrates, zinc, potassium and ammonium. The biological properties were total coliform, faecal coliform and *Escherichia coli*.

It is very important to ensure that water sample collection; handling and storage processes do not alter the true state of the water under investigation. Standard precautionary measures were adopted to minimize or avoid the introduction of alteration into the sample. Firstly, taps fixed on the boreholes were disinfected through a process known as flaming. This was done by lighting cotton soaked in methylated spirit. With disinfected hands, selected boreholes were flushed for a while to ensure that sample collected came directly from it. Secondly, well labeled sterile bottles were used to collect the water sample, and tightly closed immediately. Next, the samples were put into an ice chest containing ice cubes. This was to keep the temperature of the sample at 4°C where microbial activity is impossible. Finally, the samples were then transported to the Eastern Regional Water Company laboratory in Koforidua for analysis.

2.1.4 Physical Aspects of Water Quality Analysis

The physical parameters analysed are those involved in the aesthetic properties of water. Among the parameters that were analysed were, colour, turbidity total suspended solids, total dissolved solids, odour, conductivity and temperature. Colour was measured in pt.co using the Hach DR200 spectrophotometer. The turbidity meter was used to measure the turbidity in Nephelometric Turbidity Unit (NTU). Conductivity was measured in microsiemens percent metre (µs/cm), using the conductivity metre. Total dissolved solids were obtained by evaporating measured volumes of samples to dryness at 180°C after which the residue was weighed on a scale.

Figure 1 Samples of the borehole water being analyzed at the Eastern Regional Laboratory of the Ghana Water Company Limited.

2.1.5 Chemical and Traced Metal Analysis

The comparator method was used for determination of pH of water samples. This dealt with specific reagents with their corresponding pH range. The sample tested was compared to these standard reagents and their corresponding range to determine the pH value.

Total alkalinity was determined by titration method - whereby about 50ml of sample was measured into a clean Erlenmeyer flask and 2 drops of phenolphthalein indicator were added. The samples remained colourless indicating the absence of phenolphthalein alkalinity. Two drops of methyl orange indicator were added to the colourless sample. The sample which turned yellow was titrated with 0.02N H_2SO_4 and swirled gently until the colour changed from yellow to orange. The titer value (Tv) was recorded and was the end point of total alkalinity of titration. Calculation was based on the formula:

$$\text{Total alkalinity as mg/L } CaCO_3 = \frac{A \times t \times 1000}{\text{Sample Volume}}$$

Where A = ml standard acid used, and t= titre of standard acid mg $CaCO_3$

The Ethylene Diamine Acetic Acid (EDTA) titration method was used in determination of Total Hardness whereby- about 50ml of the water sample was measured. Then 1ml of a buffer made from 16.9g ammonium chloride (NH_4Cl) was dissolved in 143ml of concentrated ammonium hydroxide (NH_4OH) with 1.25g of magnesium salt of ETDA and dilute to 250ml with distilled water. A few grams Eriochrome Black T indicator was added. The sample was then titrated against 0.01N until it changed from red to blue. The titer value (Tv) was recorded and the level of hardness of the water was calculated using the formula:

$$\text{Total hardness as mg/L } CaCO_3 = \frac{A \times B \times 1000}{\text{Sample}}$$

Where: A =Titre value for sample and B = mg $CaCO_3$ equivalent of EDTA (Standard methods).

The Argentometric titration method was used for chloride analysis whereby about 50% volume of the water sample was measured into a clean Erlenmeyer flask. Then 1ml of 5% potassium chromate (K_2CrO_4) indicator was added. The sample then was titrated with 0.0141N Ag NO_3 solution and swirled gently until the colour of water changed from yellow to brick red. The titer value was recorded and the chloride concentration was calculated using the formula:

$$\text{Mg Cl/L} = \frac{(A - 0.2) \times N \times 35450}{\text{Sample Volume}}$$

Where: A = titre value and N = normality of Silver Nitrate ($AgNO_3$).

Fluoride analysis was conducted spectrophotometrically by the Spadns method at a particular wavelength. The Per sulphate method was used to analyze for Manganese. The chloride content of 50 ml of the sample was determined and volume of silver nitrate used in the titration was recorded. Another 50ml of sample was measured and acidified with 1:2 HNO_3 acids. Same amount of silver nitrate was added to the acidified sample and swirled gently. The sample was boiled on a hot plate to precipitate the chloride ion in the sample. The precipitate was filtered off and the filtrate heated to boiling point. About 2g of ammonium sulphate was added to the boiling sample. Presence of manganese caused colour change of the sample to purple. The sample colour was compared to the standard and the matching colour (Xm) was used for the calculation based on the formula:

$$Mn\ (mg/L) = \frac{Xm \times 0.1 \times 1000}{\text{Sample Volume}}$$

1ml standard = 0.1Mn (Standard method, 19th edition). The field method was used for total iron analysis whereby, about 50ml of the water sample was measured. The sample was acidified with 1ml of 1:HNO_3 acid. About 1ml of 0.2N $KMnSO_4$ solution was added in drop wise until a permanent pink colour was obtained. Half of the volume of sample was evaporated in a hot plate. The sample was allowed to cool to ambience and 2ml of 10% ammonium thiocyanate solution was then added. (Notably, colour of the water sample changed from pink to brown indicating presence of iron while three of the samples did not change). A sample that tested positive was topped up with distilled water up to the 50ml mark. A blank was prepared using distilled water and following the same procedure above. The blank was titrated against the standard iron solution by comparing the colours until a matching colour to that of the sample was obtained. The titre value which gave the matching colour was then recorded and the concentration of the total iron was calculated based on the formula:

$$\text{Total iron mg/L} = \frac{Tv \times 0.05mgFe \times 100}{\text{Sample Volume}}$$

Where: Tv = titre value and 0.05mgFe = 1ml Standard iron solution.

Sulphate analysis was by the Gravimetric method whereby, about 100 ml of water samples were measured into 250ml beaker and filtered. About 2ml+1ml HCL was then added to the solution. A hot plate was used to evaporate it to half the initial volume and 5ml of boiling $BaCl_2$ solution was added and digested on the water bath until the precipitate settled. The chlorine was filtered off through an ash less filter paper and washed with hot distilled water. The filtrate was tested with silver nitrate solution. The filter paper was dried and an empty crucible weighed. The dried filter paper was folded into the crucible and was blasted for 1hr at 800°C. The crucible was then removed and put into a dessicator for 30 minutes and weighed. Initial weight was subtracted from the final to calculate the sulphate concentration based on the formulae:

$$CaSO_4 + BaCl_2 = BaSO_4 + CaCl_2$$

$$Mg\ SO_4^{-2}/\ L = \frac{A \times 411.6}{\text{Sample Volume}}$$

Where: A= mg $BaSO_4$

The Phenoldisulfonic Acid method was used to analyze for nitrate whereby about 50ml of the water sample was taken into a beaker and about 2ml acetic acid was added. The chloride in the sample was precipitated with $AgSO_3$ solution. The Cl was filtered off into an evaporating dish and evaporated to dryness. The sample was cooled, and dissolved with 1ml phenoldisulfornic acid. About 25ml each of NaOH solution and distilled water were added. The colour developed was matched with a standard colour comparator.

Calculation: mg/L Nitrogen Nitrate as N = $\frac{A \times 10}{\text{Sample volume}}$

Where A = ml of Standard nitrate and mg/L = $N0_3$mg/L Nitrate as N x 4.427

Nitrite was determined by the Colorimetric method. About 50ml of the water sample was measured into a clean Erlenmeyer flask. Then 2ml of Griess – Ilosvay's solution number 2 was added to swirl gently and the mixture was allowed to stand for 15 minutes. The sample was transferred in a Nesseler's tube and the value of the matching colour was read using the nitrate disc comparator. The marking on the disc represented the actual amount of Nitrogen present in nitrite.

Calculation: N (mg/L) = $\frac{\text{Disc reading x 0.5}}{\text{Sample volume}}$

$N0_2$ (mg/L) = N (mg/L) x 3.284

The flame emission photometry method was used for analysis of Potassium. This was done by determining trace amount of potassium in a direct reading type of flame photometer at a wavelength of 766.5mm and a slit width of 2mm. Minimum detectable concentration was approximately 0.1mg/L.

Cyanide concentration was determined using the pyridine - pyrazalone method whilst Arsenic concentration was determined using silver Diethylthio - carbonate method.

For Phosphate analysis, the Stannous chloride method was used. About 0.05ml of phenolphthalein indicator was added to 100ml of sample that was free from colour and turbidity. An acid was added drop wise to neutralize the sample that turned pink. Then, 4.0ml of molybdate reagent 1 and 0.5ml stannous chloride reagent 1 were added with thorough mixing. About 10ml of the prepared sample was taken and the absorbance at wavelength 690mm was read after zeroing with distilled water. The corresponding phosphate concentration was taken on the calibrated curve and calculated using the formula:

Mg/L P = $\frac{\text{mg P in 100ml x 1000}}{\text{Sample Volume}}$

The Colorimetric method was used for the analysis of Aluminum concentration in the water samples. About 50ml of the water sample was placed into conical flask. Then 1ml of alizarin red end solution was added drop by drop until slight purple tinge was obtained. Exactly 0.5ml excess of the $NaHCO_3$ was added and the sample was boiled for 2 minutes, cooled and rinsed into Nessler tubes whilst making it up to 50ml with distilled water. About 1ml of acetic acid solution was then added and the content was allowed to stand for 1minute and compared to the colour with the standard. Alunimum calculation was based on the formula:

mg/L Al^{3+} = $\frac{\text{ml of standard alums x10}}{\text{ml of sample}}$

2.1.6 Bacteriological Analyses of the Groundwater

Bacteriological Analysis (Faecal coliform and *E.coli)* depended on the multiple tube technique whereby the fermentation tubes were arranged in rows and with sterilized pipette, each tube was inoculated with 10ml of the water sample. The tubes were incubated at 37^0 C. after 24hrs, tubes were inspected for growth, gas, and acids (they were shook for yellow colour) and in cases where no gas or acid reaction was evident, reincubation and re-examination was done at the end of 48hours. Production of acid and gas in the tubes constitute presumptive coliform bacteria reaction. Notably, the procedure did not continue because there was no production of acid or gas to signify a presumptive reaction, hence no faecal coliform or *E.coli* was present in the water samples. Thermo tolerant coliforms were estimated using a three-tube Most Probable Number (MPN) method according to standard procedures (Anon, 1992).

3. Results and Discussion

The results show the mean values in terms of concentrations of the physical, chemical, trace element and biological aspects of the borehole water quality measured based on the various parameters comparatively assessed in terms of the least significant differences (LSD) and co-efficient of variation (CV) between the different boreholes.

3.1.1 Physical Aspects of the Groundwater Quality from the Boreholes

The physical parameters investigated include; colour, electrical conductivity, temperature, total dissolved solids and turbidity. The data table 1 below illustrates the corresponding mean of each physical parameter as recorded per hand pump boreholes.

Table 1. Means of Physical parameters influencing groundwater quality of four boreholes from the Kwahu-West Municipality

Borehole description	Colour	Electrical conductivity	Temperature	Total dissolved solids	Turbidity
BH 3	4.00 C	819.0 C	28.70 B	4.0 D	23.500 A
BH 5	6.00 B	1052.0 A	28.60 B	517.0 A	0.640 BC
BH103	61.00A	957.0 B	28.30 C	466.0 B	0.590 C
BH105	0.67 D	776.0 D	29.00 A	379.0 C	0.730 B
LSD(0.05)	1.438	1.631	0.1631	1.331	0.0951
CV%	4.3	0.1	0.3	0.2	0.8

Means in columns with the same alphabets are not significantly different from each other at 0.05 probability level.

3.2.1 Colour and Odour

Physical examination of the appearance of the borehole water showed that it was very clear except borehole three (BH3) whose sample was quite opaque. No offensive odour problem was detected from the samples. Interactions with a section of the community residents actively patronizing the boreholes for drinking showed that its taste was acceptable. They disclosed that it constitutes their major source of drinking water for the area.

3.2.2 Temperature

Temperature is one of the physical aspects of groundwater quality (Price, 1985).Temperature of the borehole water samples varied from 28^0C to 29^0C. Comparison of the mean water temperatures between BH3 and BH5 did not show any significant difference at $p<0.05$. However, there was evidence of significant difference between all the other means at same probability level (table 1).

3.2.3 Colour

Colour of the borehole water samples ranged between 0.67 Pt. Co and 61.0 Pt. Co. This indicates that the colour levels were within the acceptable limits of 0 Pt. Co to 15 Pt. Co as prescribed by Ghana's Standard except in BH 103 which recorded the 61.0 Pt. Co value. The mean colour of water samples from the four boreholes showed that they were all significantly different from each other at $p<0.05$ (table 1).

3.2.4 Electrical Conductivity

Electrical conductivity is a determinant of the ionic concentration of water. It however, ranged between 819µs/cm and 1052µs/cm in all the four borehole waters. According to the Ghana's Standards for drinking water, it was realized that the conductivity values in three of the boreholes were within the acceptable limits of 1000µs/cm. But in this study, one of them (BH 5) recorded a value of 1052.0µs/cm which is beyond the acceptable standard by Ghana Water Company Limited. Conductivity depends on ionic concentrations and mobility among other factors (Quaittoo, 1996). At 25^0C, the values of calcium, magnesium, sulphate, zinc, copper, fluoride, phosphate, potassium and aluminium were all within the acceptable limits as prescribed by Ghana's standard. Although within the acceptable limits, borehole 5 (BH5) in all instances showed a comparatively high levels, if not highest of the above mentioned ions. This probably could be attributed to the evidence of high conductivity level of water produced in this borehole since ionic concentration and mobility account for conductivity (Quaittoo, 1996). The means of electrical conductivity of all the boreholes were significantly different from one another at $p<0.05$ (table 1). This was probably due to different levels of ionic concentration and mobility of samples among other factors.

3.2.5 Total Dissolved Solids

Total dissolved solids concentration of the four borehole waters ranged between 379mg/L and 517mg/L. This indicates that it was within the acceptable level since the required Ghana Water Company Standard is 1000mg/L. The mean TDS of all the water samples showed significant differences from one another at $p<0.05$ level of significance.

3.2.6 Turbidity

Turbidity, which indicates water clarity ranged from 0.59 NTU to 23.5 NTU (Fig. 1).

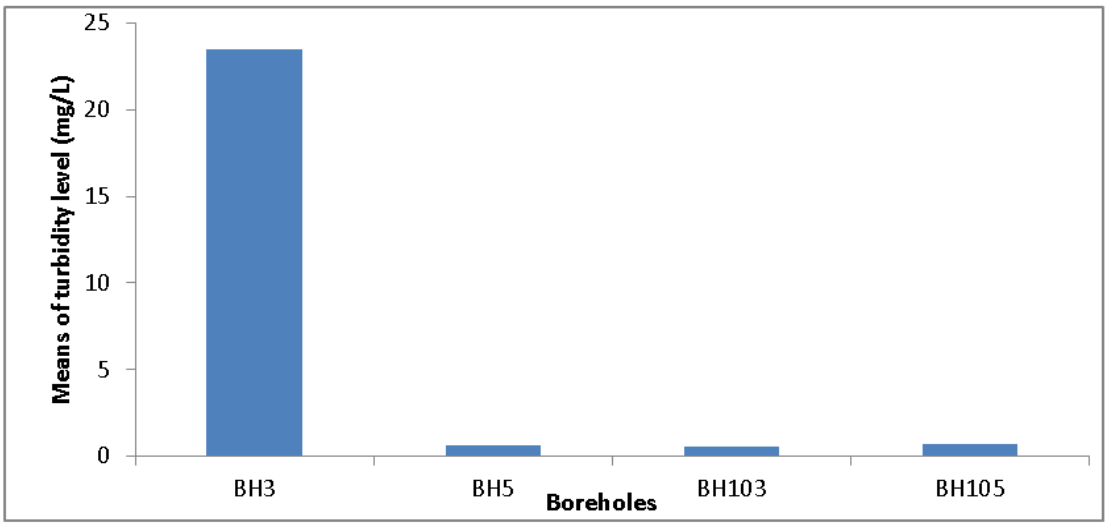

Figure 1: A bar chart illustrating the means turbidity level in the various boreholes.

The results revealed that BH3 which recorded turbidity of 23.5 NTU was far above the acceptable limit of 5 NTU as prescribed by the Ghana's Standard (Fig.1). This could be attributed to the fact that the borehole (BH3) is located closer to a water logged area where there is also a small – scale production of palm kernel oil. The high level of turbidity in this borehole therefore could be traced to the probable cross contamination of the borehole with waste water discharged from the palm kernel production. However, by comparison of the mean turbidity levels of the four boreholes, the results showed that the differences between BH5and BH103 were not significant at $p<0.05$, likewise between BH5 and BH105.

3.3 Chemical Aspects of Groundwater Quality from the Boreholes

3.3.1 Hydrogen Ion Concentration (pH)

The hydrogen iron concentration (pH) of the water ranged from 6.5 to 6.8. The value of each sample fell within the acceptable range of 6.5 to 8.5 when compared to the Ghana's Standard. The difference in mean pH of the boreholes (BH3, BH5 and BH103) showed no significant difference at $p<0.05$ probability level (table 2).

Table 2 Mean values of chemical parameters influencing groundwater quality of four boreholes from the Kwahu-West Municipality

Borehole Description	Ca	Mg	N0$_3$-N	P0$_4$	K	S0$_4$	CaCO$_3$	Ca+Mg	pH
B H 3	48.80 C	5.280A	0.058C	0.770B	0.08D	11.0C	220.0 A	144.0B	6.50B
B H 5	55. 57B	5.260A	0.054D	0.760C	8.40A	15.0A	220.0 A	161.0A	6.60B
B H 103	56.00A	2.027B	0.072A	0.760C	1.00B	15.0A	195.0 B	145.0B	6.60B
B H 105	47.20D	1.200B	0.060D	1.070A	0.40C	13.0B	195.0 B	132.0C	6.80A
L.S.D(0.05)	0.1719	1.091	0.00094	0.00941	0.1331	1.331	0.941	1.331	0.1331
C V %	0.2	16.8	0.8	0.6	2.9	5.2	0.2	0.5	1.1

Means in column with the same alphabets are not significantly different from each other at 0.05 probability level.

3.3.2 Total Hardness

Total hardness of groundwater depends on the presence of high levels of magnesium and calcium ions in it (Abby *et al*., 2009). But, from the results the levels ranged from 1.2mg/L to 5.28mg/L for magnesium and 47.2mg/L to 56 mg/L for calcium ions respectively. At these concentrations, it however, did not exceed their acceptable limits for the Ghana Standards; hence the water could be accepted for potable purposes.

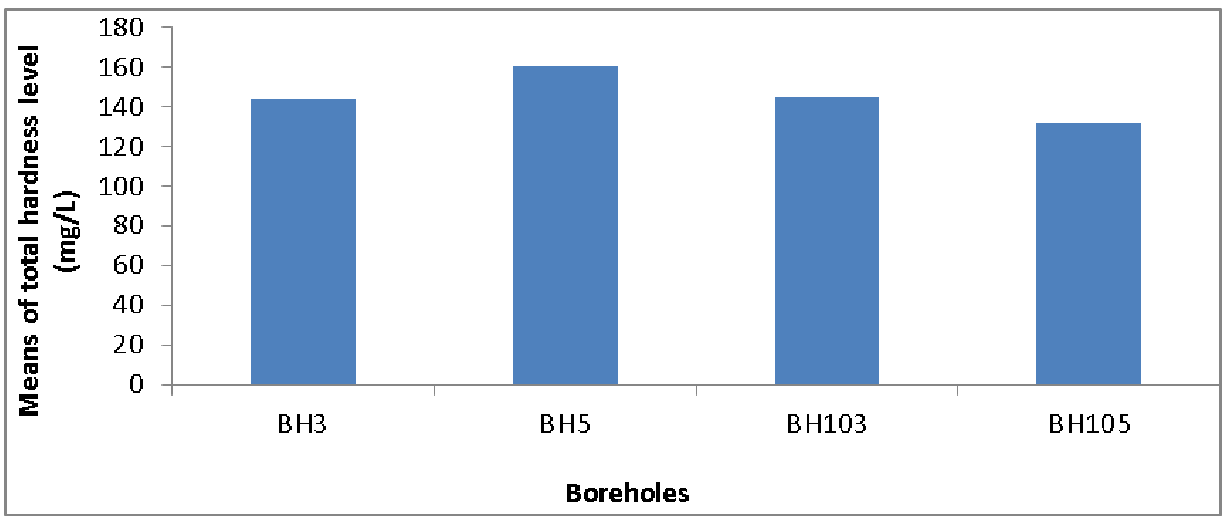

Figure 2. Means of total hardness of different borehole water samples at Nkawkaw.

The Total hardness levels recorded from all the groundwater samples analyzed were within the Ghana Standards Board limits. Since the percolation of groundwater through minerals containing magnesium and calcium could be attributed to the hardness of water, it could be referred that the groundwater at Nkawkaw probably percolates through minerals with quite a low concentration of magnesium and calcium ion. The actual range of total hardness (132mg/L to 161mg/L on Fig.4.2) recorded from the four boreholes confirmed that the water contains magnesium and calcium ions, but at an acceptable level when compared to the Ghana Water Company's Standard of 500mg/L. From the analysis, total hardness of the borehole water samples from BH3 and BH103 showed no significant difference in their mean concentrations at $p<0.05$ level probability. However, the remaining ones showed significant differences ($P<0.00$ and $P<0.000$) respectively at the same probability level of $p<0.05$ (table 2).

3.3.3 Sulphate

The sulphate concentration recorded very low values that ranged from 11mg/L to 15mg/L in all the borehole waters analyzed. This implies that the values were below the Ghana's Standard Boards' l200mg/L maximum acceptable standard. By comparing of mean sulphate concentration of the water samples from BH5 and BH103, it did not show any significant difference at $p<0.05$. However, between BH3 and BH105 there was significant difference ($P<0.000$) at the probability level of $p<0.05$ (table 2).

3.3.4 Ammonium (NO_3) and Nitrate Nitrogen (N)

Nitrogen in the form of ammonium and nitrate which ranged from 0.054 – 0.072mg/L was found to be within the acceptable limits according to the Ghana Standard of 50mg/L (table 2). At $p<0.05$ level of probability, both forms of nitrogen (ammonium and nitrate), showed significant differences in their corresponding means. Nitrate gives a state of pollution by organic waste with large quantities in nitrate form (Shaw, 1994). The low values of nitrogen recorded in all the forms could be attributed to the fact that the boreholes are not located in farming areas where there could be a possible seepage of animal waste and fertilizers containing nitrogen into groundwater.

3.4 Traced Elements influencing Groundwater Quality from the Boreholes

3.4.1 Cyanide

Cyanide is a poisonous substance that can infiltrate and pollute groundwater. It is mostly introduced into water bodies as a result of mining activities and improper waste disposal. Cyanide acts by blocking the cells of humans from effectively utilizing oxygen (Abbey *et al.*, 2008). Higher toxicity of cyanide may also cause brain, spleen and liver damage. Based on the standard set by Ghana on drinking water, the cyanide level must not exceed 0.1mg/L. However, the values recorded in this study ranged from 0.007mg/L to 0.023mg/L (table 3). It such relatively much lower concentrations compared with the required standard, it therefore implies that the levels could be tolerated.

Table 3 Means of trace elements influencing groundwater quality of four boreholes from the Kwahu-West Municipality

Borehole	Parameter								
	Al	Cr	Cu	CN	F	Mn	Fe	Zn	Cl
B H 3	0.112	0.03	0.18A	0.0080C	0.160D	0.160C	0.01	0.1400A	12.0 D
B H 5	0.064	0	0.11C	0.0070C	0.910B	0.630A	0	0.0400B	20.99B
B H 103	0.479	0	0.11C	0.0800A	1.280A	0.030D	0	0.0400B	14.50C
B H 105	0.087	0	0.14B	0.0230B	0.886C	0.190B	0	0.0300B	23.00A
L.S.D (0.05)	0.00	0	0.01331	0.00946	0.0196	0.00163	0	0.01331	0.946
C V %	0.0	0	5.2	17	1.3	0.3	0	11.3	2.9

Means in columns with the same alphabets are not significantly different from each other at 0.05 probability level.

3.4.2 Chloride

Total chloride indicates the level of salt in the water and occurs in the form of NaCl (Shaw, 1994). The chloride levels in the groundwater samples investigated ranged from 12mg/L to 23mg/L. This is said to be within acceptable limits since the maximum level prescribed by Ghana Water Company Standard is 250mg/L. Chloride plays vital role in water purification because it chlorine and its compounds are widely used in industry for the disinfection of drinking water and swimming pools, but can be hazardous when in excess (Shaw, 1994). According to Mason (1991), minerals which are essential to life can become harmful when it exist in excess. Chloride in water may cause skin irritation when in excess. This is why chlorination of household water is carried out by experts. Excess chlorine also damages water works equipment and water heaters. By comparison, the means of chloride at $p<0.05$ were significantly different in all instances observed from the four borehole water samples analyzed (table 4.3). This may be as a result of the difference in salt concentration of the individual boreholes.

3.4.3 Fluoride

Fluoride occurs naturally or as an additive to municipal water supplies to promote dental health (Abbey et al., 2008). Fluoride in acceptable quantities reduces the incidence of tooth decay. This is scientifically proved by the evidence that fluoride forms an essential ingredient of every tooth paste. However, high levels of fluoride stains the teeth or causes mottle teeth as experienced by people in the Bongo District of the Upper East Region of Ghana (Young et al., 2004). Excess fluoride in drinking water may also cause calcification of bones and joints (Pelig-Ba et al., 1991). According to the analysis carried out, none of the boreholes recorded a fluoride value beyond the 1.5mg/L maximum acceptable level prescribed by the Ghana Water Company's Standards. The values recorded ranged from 0.16mg/L to 1.28mg/L. The statistical analysis showed that the means of all the samples were significantly different from one another at $p<0.05$ (table 3).

3.4.4 Total Iron

Iron in recommended amount is beneficial for blood building. The presence of iron in water is attributed to rock water interaction and effluents from industries like tanning and dyeing etc However, iron in water becomes a nuisance when it occurs in excess. For instance, excess iron produces a metallic taste and orange brown stains in water. No iron was detected in three of the boreholes. However, the borehole (BH 3) recorded 0.01mg/L which is far below the maximum value of 0.3mg/L prescribed by the Ghana Standard.

3.4.5 Arsenic, Zinc and Copper

Arsenic is a heavy metal. Heavy metals are elements with high atomic weights. Arsenic can cause skin lesion and circulatory problems (Brown et al., 1990). No arsenic was redetected from the entire boreholes waters. Zinc concentrations ranged from 0.03mg/L to 0.14mg/L whilst that for copper ranged from 0.11mg/L to 0.18mg/L respectively when compared to the Ghana standards of 3.0mg/L and 1.0mg/L respectively for zinc and copper. At these lower concentrations both trace elements could be tolerated in drinking water based on the Ghana's standard.

3.4.6 Manganese

Manganese is a mineral that naturally occurs in rocks and soil as a trace element.

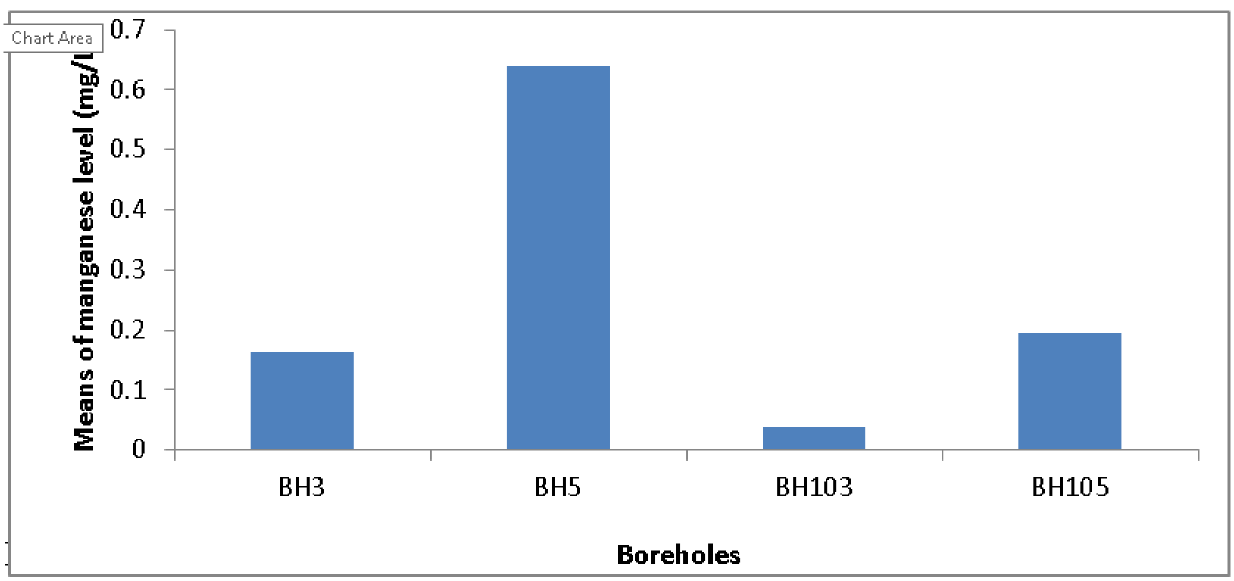

Figure 3 A bar chart showing means of manganese level in the various boreholes.

In three out of the four boreholes investigated, the manganese level exceeded the acceptable limit of 0.1mg/L as prescribed by Ghana's standard (Fig.3). The values recorded ranged from 0.038mg/L to 0.638mg/L. It was observed that the three boreholes which recorded high levels of manganese namely, BH3, BH5 and BH105 were located in the same area. The high levels of manganese recorded, could therefore be attributed to the probable interaction of groundwater and rock layers or soil minerals. Apart from the possible health effects, high levels of manganese in drinking water cause brownish coloration of water which also affects its taste (Hem, 1992). The comparison of means of manganese concentration in water samples from four of the boreholes revealed significant differences between them at $p<0.05$ (table 4.3)

3.4.7 Aluminium

Aluminium as a trace element must not exceed 0.2 mg/L in drinking water according to the Ghana Standards.

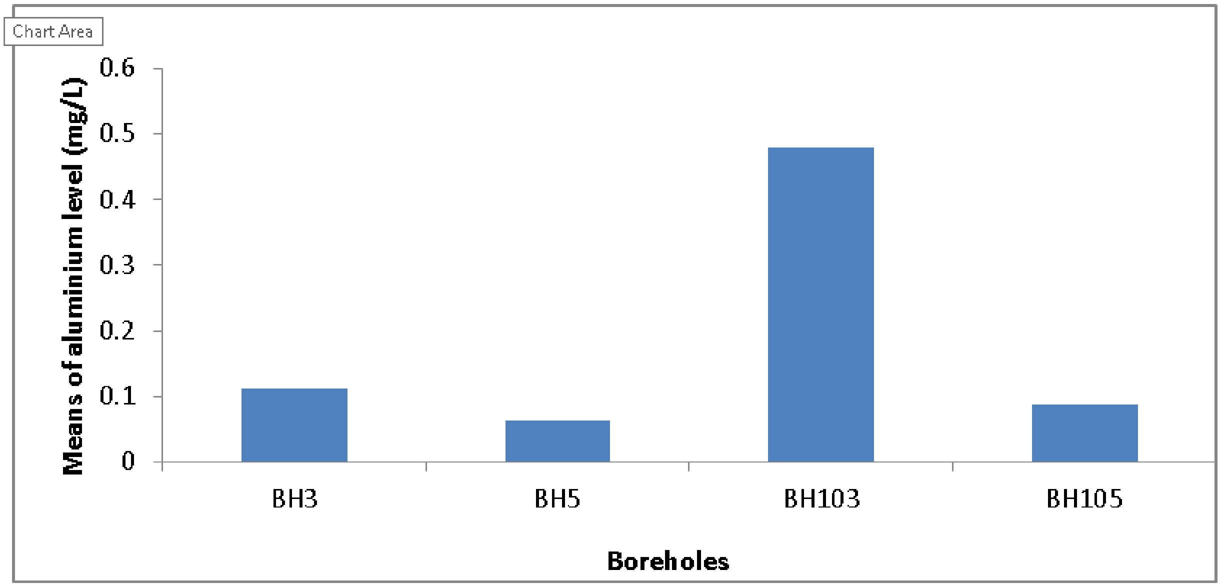

Figure 4: A bar chart illustrating the means of aluminium level in the various boreholes.

The mean concentration of aluminium in three of the boreholes was within the acceptance limits of 0.2mg/L as recommended in Ghana's Standards. However, one of the boreholes, namely BH103 recorded a higher value of 0.479mg/L which was more than twice the maximum acceptance limit. High levels of aluminium recorded from groundwater from BH 103 could be causing discolouration of the water (EPA, 2011). Apart from the discolouration, health problems such as osteomalacia, a bone wasting disease and Alzheimer's disease, premature senile dementia are the likely defects associated with higher concentrations of aluminium in drinking water supplies from groundwater sources (Mason, 1991).

3.5.0 Bacteriological Aspect of Groundwater Quality from the Boreholes

In a routine analysis of water, including drinking water, enteric pathogens are not enumerated; rather indicators of faecal pollution are determined. The commonly used indicator is the coliform group of bacteria. Coliforms are gram negative non spore forming bacteria. Total coliform include bacterial found in the soil, in water that has been influenced by surface water, and in human or animal wastes. *Escherichia coli (E. coli*) are the major species in faecal coliform. Out of about five bacteria groups that constitute total coliform, *E. coli* is the only group that does not grow and reproduce in the environment. Consequently, *E. coli* is regarded the best indicator of faecal pollution and the possible presence of pathogens (Parker, 1984). According to the WHO 1997acceptable standard for quality assurance of drinking water, the presence of such bacteria may result in intestinal diseases. Based on the borehole water analysis conducted at Nkawkaw, the presence of any of the coliform strains was not detected in them. This may be attributed to the fact that latrines or septic tanks which could discharge waste water into sub-surfaces of the groundwater sources were not situated closer to the boreholes.

4. Conclusion

Based on the findings, it has been ascertained that the active users of the groundwater resources at Nkawkaw are not likely to develop immediate adverse health problems as far as the results from this study is concerned. The parameters such as; pH, total dissolved solids, suspended solids, alkalinity, total hardness, chloride, fluoride, magnesium, calcium, iron, copper, zinc, chromium, cyanide, nitrate, nitrite, ammonium, sulphate, and phosphate were generally acceptable at their respective concentrations when compared with the Ghana's Standards. Inorganic chemicals such as lead and arsenic, as well as total coliform, faecal coliform, *Escherichia coli* and total heterotrophic bacteria were generally absent in the boreholes making its quality less questionable for drinking purposes. However, in some instances, there was evidence that the levels of conductivity, turbidity, manganese and aluminum exceeded the maximum allowable limit set by the Ghana's Standard. To this effect, possible defects due to the consumption of water containing high levels of these parameters may be encountered if it bio-accumulates beyond idiosyncratic concentrations in the body.

5. Recommendations

The Ghana water company authorities in the Nkawkaw area should intensify their routine water quality assessment in order to keep users of the boreholes informed of the groundwater quality status in the area. Since manganese in excess is likely to affect the aesthetic nature of water and also cause toxicity in both children and adults, the Ghana Water Company and related authorities or agencies should endeavour to provide the necessary treatment techniques to remediate the boreholes with excess manganese level before the situation gets out of hand. Conventional methods such as coagulation/flocculation and filtration could be adopted to remove excess manganese in the affected boreholes. Conversely, granular activated carbon could be useful in removing colour-causing contaminants like aluminium from the borehole water to make it safer for use. The Ghana Water Company authorities together with health care providers in the Nkawkaw area should continue to educate the people on the dangers of unsafe waste disposal and locating of latrines and septic tanks closer to water sources. This is to help maintain the bacteriological free nature of the groundwater in the area.

Additionally, zoning, a strategy in which a given area is divided into sub units for specific uses could be adopted to help check pollution that results from improper and inefficient land uses (Burchi, 1994). Additional studies should be carried out in the rest of the towns and villages of the entire Kwahu- West Municipality to investigate the safety of groundwater in the entire area for drinking.

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