A Physico-Chemical and Bacteriological Analysis of Borehole Water Samples from the Wa Municipality of the Upper West Region, Ghana

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***Abstract*— Twelve samples of water from twelve boreholes at six locations in the Wa Municipality were analyzed to determine its quality. The physico-chemical properties of all the twelve samples were evaluated. The parameters analyzed include pH, residual chlorine, electrical conductivity, turbidity, total dissolved solids, true Colour, chloride, nitrate, nitrite, total hardness, alkalinity, calcium, magnesium total iron and total coliform. The results obtained were compared with recommended WHO guidelines for potable water. None of the samples analyzed was found to contain any residual chlorine. Most of the samples were found to contain coliforms while some samples recorded lower pH values than recommended.**

***Keywords—Physico-chemicals, Water quality, WHO drinking water guidelines, Underground water, Boreholes, Contamination*.**

I. INTRODUCTION

The quality of drinking water is a powerful environmental determining factor of health, survival, growth and development. Approximately 30 percent of the world's freshwater stocks are found underground, supplying drinking water for an estimated two billion people and irrigation for an estimated 40 percent of the world's food and has proved to be the most reliable resources for meeting rural water demand in sub-Saharan Africa [1], [2], [3], [4].

The majority of people in Upper West Region of Ghana drink untreated groundwater and they are mainly from boreholes [5]. Ground water contamination has become one of the main environmental issues today due to contamination by sewage, industrial wastes, chemicals and the activities of small scale miners, farmers and artisans [6], [7], [8]. To know whether the groundwater is contaminated or not, it is necessary that the quality of drinking water should be monitored at regular time intervals, because contaminated drinking water can cause various forms of water borne diseases [9].

Contamination of groundwater may stem from different sources. These include insanitary conditions during borehole construction, splashing of runoff into wells if left uncovered; flooding at borehole site, leachate from old buried waste pit or latrine into the hole through cracks in the aquifer and annular of the hole. The closeness of boreholes to septic tanks especially where space is a constraint and as such boreholes being drilled at old garbage landfill sites may also contribute to contamination [11], [12]. Sanitation at the surface around the well also affects the quality of the water as seepage through the soil surrounding the casing may also impart pollutant on the water quality [13], [14].

The use of water increases with growing population, putting increasing strain on these water resources [15]. An adequate supply of clean, safe and quality drinking water is one of the major problems in developing countries [16], [17], [18], [19].

The Wa Municipality in the Upper West Region of Ghana relies mainly on the Ghana Water Company for its urban water supply. The Company unlike those in other urban centres, depends on underground water as its source of intake. Due to inability of Governments to meet the ever-increasing water demand, most people in the Wa Municipality resort privately to groundwater sources such as shallow wells and boreholes as alternative water resources [20], [21].

The Ghana Water Company Limited (GWCL) has been unable to supply enough water to meet both household and commercial consumption demands in the Wa Municipality. For example, only 23% of the population is served with pipe-borne water from the Ghana Water Company and the rest of the population depend on privately owned boreholes [22].

The purpose of this study is to determine, assess and evaluate the physico-chemical and bacteriological quality of borehole water utilized in the Wa Municipality and to propose measures to prevent contamination of borehole water in future.

II. METHODOLOGY

A. Location and size of study area

The Wa Municipality is one of the eleven District Assemblies that make up the Upper West Region of Ghana. It shares administrative boundaries with the Nadowli District Assembly to the North, the Wa East District Assembly to the East and the Wa West District Assembly to the West and South. It lies within latitudes 1º40‟N to 2º45‟N and longitudes 9º32‟ to 10º20‟W with total land area of 234.74 sq. km (Fig.1.). Currently the total population of the municipality stands at 127,284 (male: 61,826/female: 65, 458) [22].

Sample points A, B, C, D, E and F on the Map are Wa-Sombo, Kumbiahi, Kpaguri, Kpongu, Bamahu, and Tampalipani respectively. As shown in Fig.1. two boreholes of some distance apart were selected as sample points in every locations of Wa circled in the map.

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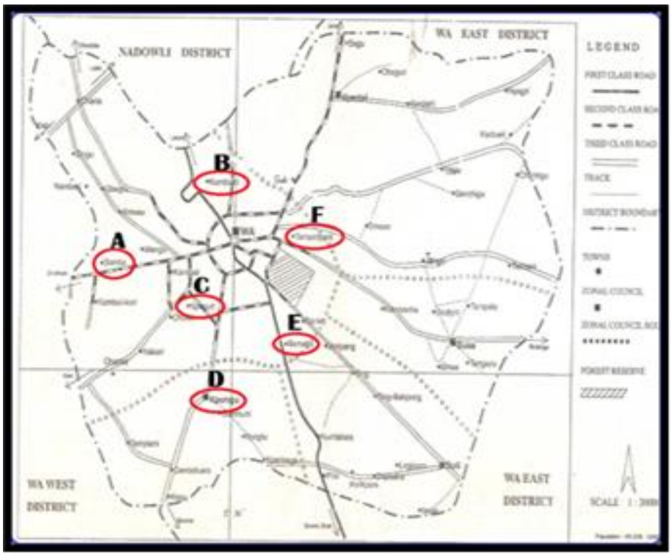

Fig.1. A Map of Wa Municipality showing sample locations

The samples collected from the various sites were labelled as shown in Table 1.

Table 1. Sample sites and labels.

Suburb	*First Sample*	*Second Sample*
Wa-Sombo	*A1*	*A2*
Kumbiahi	*B1*	*B2*
Kpaguri	*C1*	*C2*
Kpongu	*D1*	*D2*
Bamahu	*E1*	*E2*
Tampalipaani	*F1*	*F2*

B. Data collection and analysis

The water temperature, pH, conductivity, total dissolved solids and the turbidity were measured at the point of sampling.

Temperature

Temperatures of the samples were taken using a portable Celsius thermometer (470 Jenway). This was done by immersing the probe below the water surface (the sample) to a depth of about four inches for one minute. The value displayed on the meter was then recorded.

pH

The pH of each sample was determined using portable pH meter (370 Jenway). Measurement was carried out by immersing the cell in the sample. The readings were then allowed to stabilize and results recorded. The cell was rinsed in deionized water, shaken to remove internal droplets, and the outside wiped prior to immersion in the next sample to avoid possible contamination by the previous sample.

Conductivity and total dissolved solids

A general purpose hand held conductivity meter (470 Jenway) was used to measure the conductivity and the total dissolved solids of the samples. Measurement was carried out by immersing the probe into the sample. The readings were then allowed to stabilize and results recorded.

Turbidity

The turbidity of each sample was measured using a turbidity meter (HI 93703 Hanna). The turbidity meter was powered on after which the 10 FTU (Nephelometric Turbidity Unit) cell was filled with the water sample. The cell was then cleaned with a tissue. The sample cell holder was then inserted and covered with the lid and the readings read.

Some of the collected samples were preserved in sterile containers and transferred to the laboratory where parameters such as the total coliform, water hardness, residual chlorine, total iron, nitrate and nitrite, total alkalinity, true colour, magnesium ions, calcium ions and chloride ions were determined.

Total coliform (Most Probable Number index)

Double strength and single strength MacConkey broth was prepared and dispensed into five (5) and three (3) test tubes containing inverted Durham tubes respectively.

Each double strength tube was aseptically inoculated with 10ml of the water sample and 1ml of the same water sample was used to inoculate each single strength broth. This procedure was repeated for each water sample. The tubes were labeled and incubated for 24 hours at 37^{o}C.

Residual Chlorine

Residual Chlorine in the samples was calculated using HANNA Instrument (C108 USA). A pipette was used to fill each glass vial with 5 mL of sample. Deionized water was then added to another vial up to the 10 ml mark. The cap was then placed back and shaken to mix , after that 1 packet of HI 93701-0 reagent was added to both vials. This was also shaken vigorously to mix the reacted sample. One of the vials was then inserted into the left opening while the other sample was inserted into the right opening of the checker disc. The checker disc was then held for light to illuminate the samples from the back of the window. The checker disc was kept at a distance of 30-40 cm from the eyes to match the color. The disc was then rotated whiles looking at the color test windows and stopped when the color match was found. Readings and recordings were then undertaken.

Nitrite and Nitrate

The tests were done using the AQUACHEK® NITRATE/NITRITE (HACH USA) test kit. A strip was dipped into water for at least one second and removed without shaking off excess water from the test strip. The strip was then held horizontally, with the pad side up for about 30 seconds. The Nitrite test pad (bottom pad) was then compared to the color chart. Afterwards, the Nitrate test pad was also dipped into the water and the pad side held up for 60 seconds after

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which the test pad (top pad) was also compared to the color chart. The results were then recorded.

Colour

The colours of the samples were tested using a Comparator (Lovibond Nessleriser 2150). One Nessler cylinder was filled up to the 50 ml mark with the sample and the antimeniscus plunger fitted. The cylinder was then placed in the right compartment of the Nesleriser. Another Nessler cylinder was filled in the same way with deionized water and place in the left compartment. The disc was then inserted into the lid and Nesleriser fitted to the Daylight 2000 unit. The disc was then rotated until the closest colour match was obtained. Displayed values were then recorded.

Total Iron

The total iron of each sample was determined using AQUACHEK® IRON (HACH USA) test strip. A sample vial was half filled with the water sample. One foil packet of iron reducing reagent was opened and added to the vial. The vial was capped and shaken rapidly for 5 seconds. A test strip was then dipped into the sample and moved rapidly back and forth for 15 seconds. The test strip was removed and shaken to get rid of excess water and immediately compared to the colour chart and results recorded.

Total hardness

The total hardness of the samples was determined using AQUACHEK® TOTAL HARDNESS (HACH USA) test strips. The strip was dipped into the water for 1 second and removed. The strip was held horizontally with the pad side upward, for 15 seconds. Finally, a comparison of the end pad was compared to the low range color chart.

Alkalinity

50ml of the sample was measured into Erlenmeyer flask and two drops of phenolphthalein added. 0.02M $H_2SO_4$was titrated against the sample until colour change was observed.

Calcium/Magnesium Hardness

1ml of 1M NaOH was added to 50ml of the sample. It was then titrated against 0.01 M EDTA solutions using powdered Ammonium Murixide as an indicator. The Magnesium hardness was determined using the standard methods formula:

Magnesium Hardness = Total Hardness – Calcium Hardness

Chloride Ion

50ml of the sample was titrated against 0.014M of silver nitrate using 1ml 5% of Potassium chromate as an indicator until a colour change was observed.

III. RESULTS AND DISCUSSION

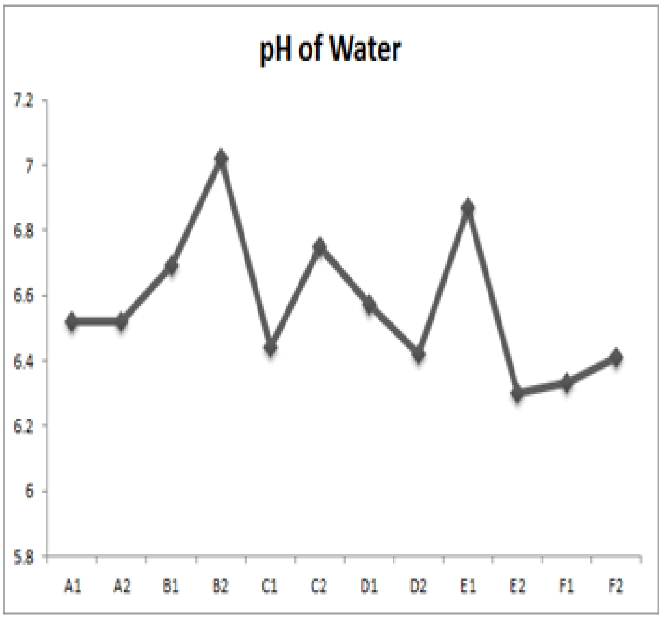

Fig.2. Graph of pH of various samples from the boreholes.

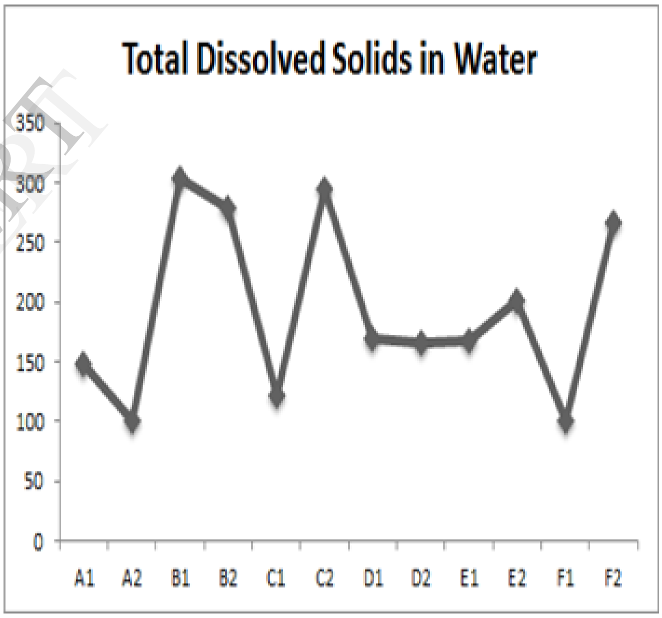

Fig.3. Graph of Total Dissolve Solid (mg/L) of various samples from the boreholes.

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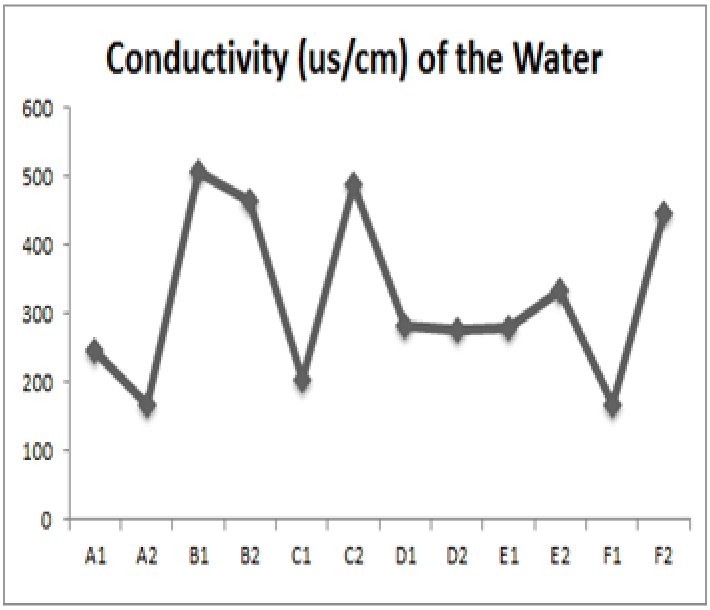

Fig.4. Graph of Conductivities (uS/cm) of various samples from the bore-holes.

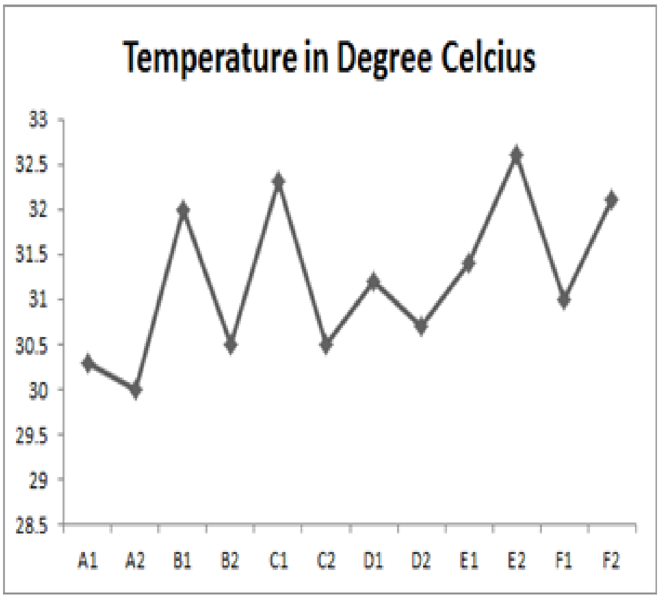

Fig.6. Graph of temperatures in Degree Celcius of various samples from the boreholes.

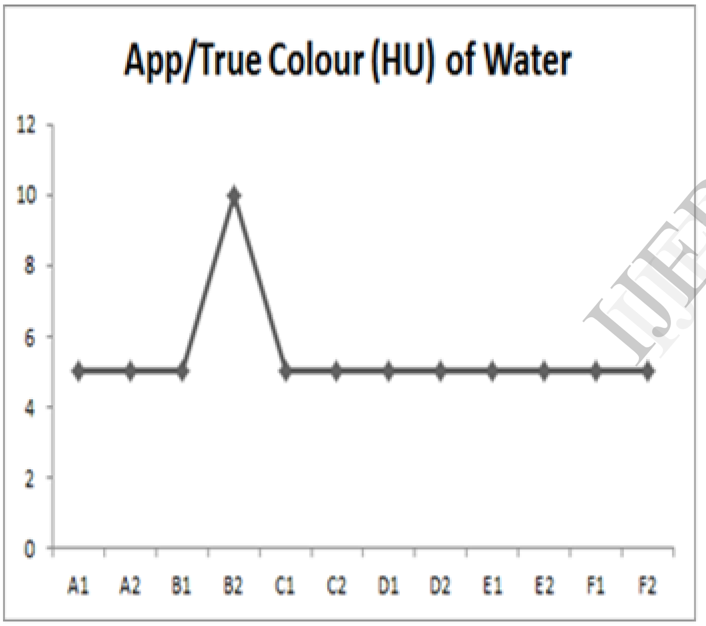

Fig.5. Graph of App/True Colour (HU) of various samples from Boreholes.

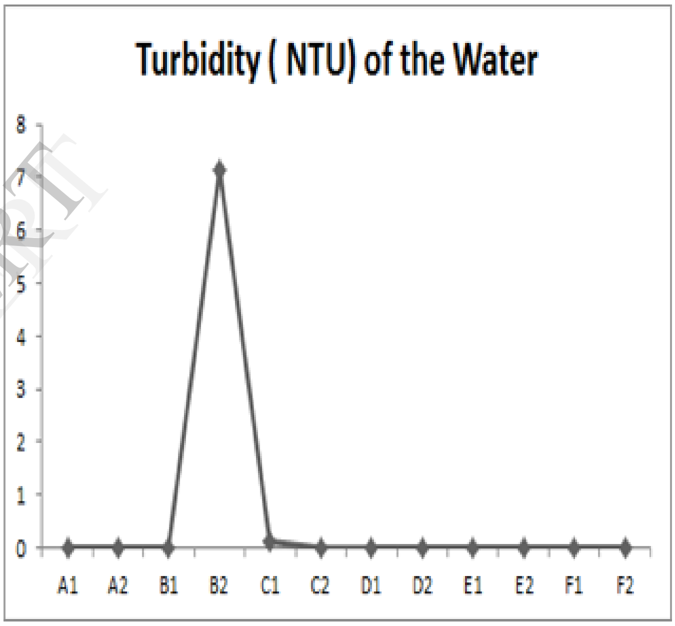

Fig.7. Graph of Turbidity (NTU) of various samples from the boreholes.

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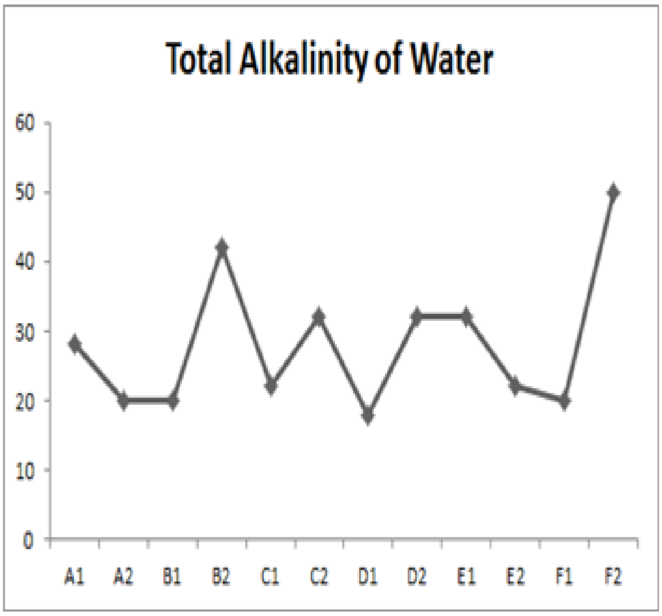

Fig.8. Graph of Total Alkalinity (mg/L) of various samples from the boreholes.

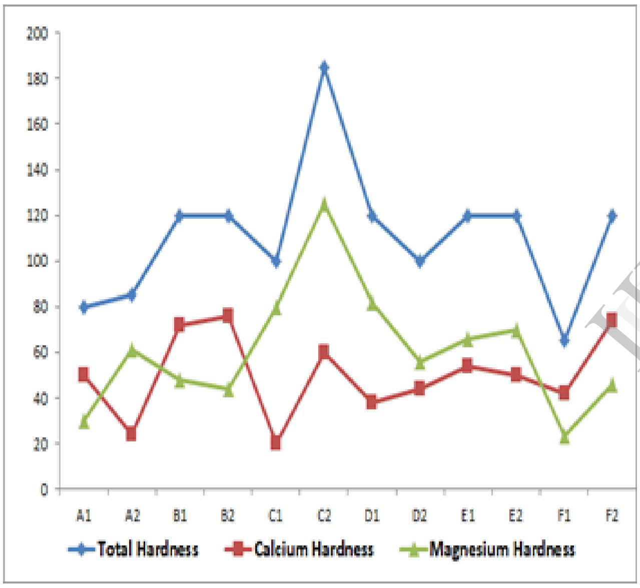

Fig.9. Graph of Total hardness, Calcium and Magnesium Hardness of various samples from the boreholes.

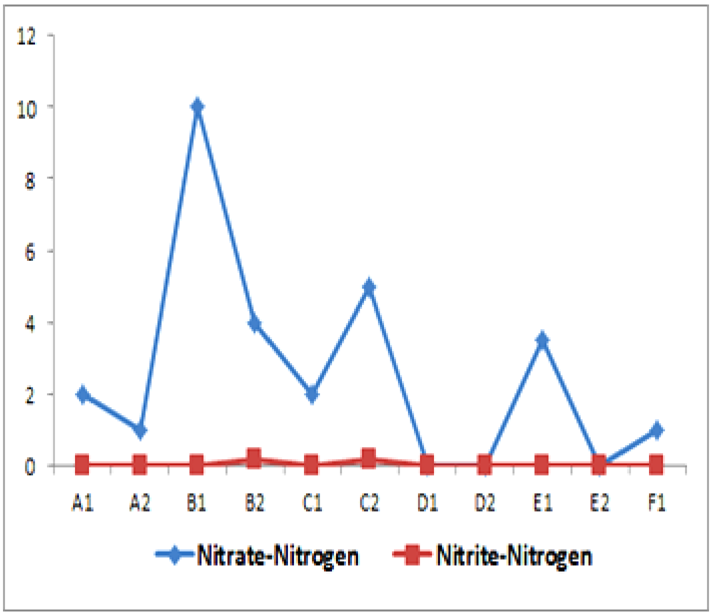

Fig.10. Graph of Nitrate and Nitrite Nitrogen of various samples from the boreholes.

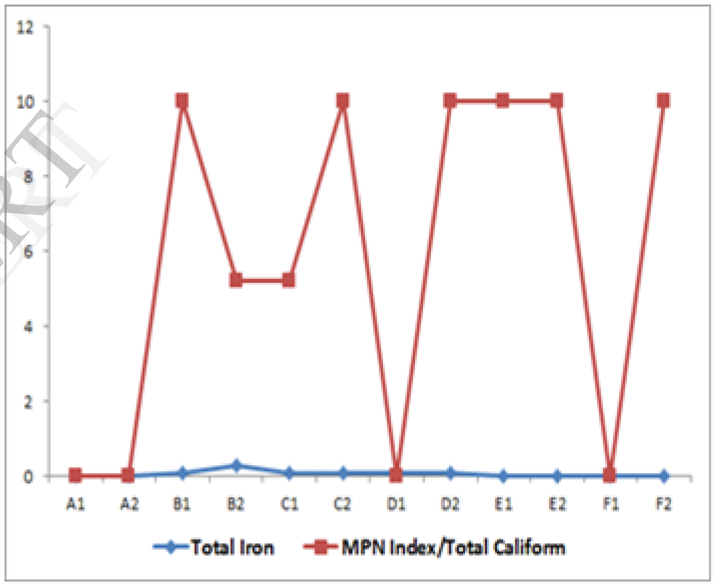

Fig.11. Graph of Total Iron and Caliform of various samples from the boreholes.

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The mean, maximum, minimum and standard deviation of the physical, chemical and biological characteristics of water samples from various boreholes in the Wa Municipality are shown in Table 2.

Table 2. Shows Mean, Minimum and Maximum, Standard deviation of the Parameters and WHO guidelines for drinking water.

Parameter	Mean	Min	Max	Standard deviation	WHO Guidelines
pH	6.57	6.30	7.02	0.22	6.5-8.5
Conductivity (us/cm)	321.78	166.9	507	124.84	-
Total dissolved solids	193.08	100.1	304	74.88	1000
Temperature	31.2	30.0	32.6	0.86	30.5
App true colour	5.42	5.0	10.0	1.44	5-15
Turbidity (NTU)	0.66	0.0	7.13	2.06	5
Total alkalinity	28.17	18.0	50.0	9.96	-
Total hardness	111.25	65.0	185.0	30.09	500
Calcium hardness	50.33	24.0	76.0	18.27	-
Magnesium hardness	60.92	23.0	125.0	27.16	-
Calcium	20.10	8.0	30.4	7.32	100
Magnesium	14.80	5.59	30.4	6.60	50
Chloride	26.50	10.0	52.0	13.28	250
Nitrate	2.38	0.0	10.0	2.95	0-10
Nitrite	0.03	0.0	0.15	0.06	0.0-0.03
Total iron	0.07	0.0	0.1	0.09	0.0-0.3
MPN Index/Total coliform	5.87	0.0	10.0	4.68	0

pH. At the time of sampling, it was realized that pH varied from 6.30 to 7.02. The mean pH for all the samples was 6.57. Five of the pH values obtained from C1,D2,E2,F1 and F2 were not within the permissible ranges of WHO guideline for potable water as shown in fig.2.

Water with low pH is likely to be corrosive. This could cause the corrosion of water mains and pipes in household water systems. If not controlled, it could lead to the contamination of drinking water and have adverse effects on its taste and appearance [23]. Low pH values could be adjusted to normal levels using Sodium Sulphate or calcium carbonate.

Electrical Conductivity (EC): The electrical conductivity of water at an average temperature of 32.6°C is due to the ionic content of the sample which in turn a function of the dissolved salts [24]. The EC increases with temperature. The EC values for the samples vary from 166.7 to 507 µS/cm with a mean value of 321.78 µS/cm at a mean temperature of 32.6°C. The maximum limit of EC value in drinking water per WHO guidelines is much higher than the mean value of EC obtained at 32.6°C for the samples. This shows that EC value obtained lies within the maximum permissible limits for drinking water.

Total Dissolved Solid: The TDS values obtained from our study was considered satisfactory, because it ranges from 100.1 to 304mg/L with the mean value of 193.08mg/L. The TDS values obtained are below 1000 mg/L in all sampling locations hence the water is considered suitable for drinking.

Temperature: Generally the temperature of the water at any location is determined by the seasonal climatic conditions. The temperature at the time of sampling ranged from 30.0°C to 32.6°C with the mean value of 31.22°C. Temperature may affect the taste, odour, colour and corrosiveness of water. High water temperature may also enhance the growth of microorganisms [23].

True Colour (HU): At the time of sampling, it was realized that true colour of the samples varied from 5.0HU to 10.0HU with the mean value of 5.42HU. Thus the true colour values obtained at the sampling locations were within the permissible ranges of 5.0HU to 15HU of WHO guideline for potable water.

Turbidity (NTU): It ranges between 0.0 NTU to 7.13 NTU, with the mean value of 0.6 NTU for the borehole water in the municipality. The value for one of the boreholes, B2 was 7.13 NTU as shown in fig.7. This was considered unsatisfactory, because it was beyond the recommended maximum value of 5.0 NTU by WHO. This could partly be due to high alkalinity, hardness and colour as shown in fig. 5, fig. 9 and fig. 10 respectively.

Total Alkalinity: Alkalinity is the buffering capacity of water. It is basically made up of carbonates and bicarbonates of Calcium, Magnesium, Potassium and Sodium, which appear in the water in the form of natural salts. The alkalinity for the boreholes in the Wa Municipality varies from 18.0mg/L to 50.0mg/L with the mean value of 28.17mg/L.

Total hardness: Hardness is the soap-destroying property of water which is largely produced as a result of prevalence of carbonate of Calcium and Magnesium. Total hardness of borehole water ranges between 65.0 mg/L to 185 mg/L with the mean value of 111.25mg/L. The Total hardness values obtained were all below 500 mg/L as recommended by WHO. Thus the values are considered satisfactory for potable water.

Calcium: Calcium, which is a major component of natural water, comes mainly from the rocks, seepage, drainage and wastewater. The Calcium content ranged from 8.0 to 30.4 mg/L with a mean value of 20.0mg/L. Calcium level of all the samples was below the permissible limit of 100mg/l as recommended by WHO.

Magnesium: Magnesium is an essential nutrient for plants and animals. A maximum concentration of 50 mg/L is recommended by WHO for drinking water. The concentration of magnesium ion varies from 5.59 mg/l to 30.0 mg/L with a mean value of 14.8mg/l. Thus the values of the Magnesium ions are below the maximum recommended value which is satisfactory.

Chloride: The chloride contents ranged from 10 mg/L to 52.0 mg/L with a mean value of 26.5mg/L. Chloride content was lower than the acceptable maximum limit of 250 mg/L recommended by WHO. Thus, the concentration of the chloride was considered satisfactory.

Nitrate: The concentration of nitrate in the samples varied between 0.0 mg/L to 10 mg/L with a mean value of 2.38mg/L. Samples from eight boreholes contained varying concentrations of nitrate. The concentrations of nitrate in the water samples were within the permissible range of 0.0-10.0mg/L as recommended by WHO for drinking water. Nitrate content is very low in natural surface waters, but it is very common in ground water. Fertilizers, industrial wastes and septic tanks are the common sources of Nitrates in ground water. [24].

Nitrite: The concentration of nitrite in different samples varied between 0.0 mg/L to 0.15 mg/L with a mean value of 0.03mg/L. The concentrations of the samples of water from the boreholes were within the permissible limits of 0.0-3.0mg/L in line with WHO standards for drinking water.

Total Iron: The total iron concentration ranges from 0.0mg/L to 0.1mg/L with a mean value of 0.07mg/L. The total concentration of iron was within the range of 0.0-0.3mg/L as per WHO standard. Thus, the water from all the samples is considered to be satisfactory for human consumption.

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Residual Chlorine: None of the water samples analyzed contain any residual chlorine. This could be due to non-chlorination of the borehole water.

Total Coliform (Most Probable Number Index): The values for total coliform of all the samples from the boreholes range from 0.0-10.0/100mL with the mean value of 5.87/100mL. The total concentrations of coliform for samples of water from eight boreholes B1, B2, C1, C2, D2, E1, E2 and F2 were more than the zero value recommended by WHO. The presence of coliforms in most of the samples studied could be attributed to the absence of residual chlorine, an indication that the borehole water had not been chlorinated. Low coliforms level (i.e. $\leq$ 16 per 100ml) may not be threatened to the health of potential consumers. However, levels greater than 16 per 100ml as observed in 6 out of the 8 infected boreholes renders the water unwholesome, unless it is chlorinated. This is because excess coliforms may lead to the spread of water-borne diseases such as Typhoid fever, Hepatitis, Gastroenteritis, Dysentery and Ear infection.

IV. CONCLUSION

Most (90%) of the parameters analyzed for water from the boreholes in the Wa Municipality were within the acceptable range as recommended by WHO for drinking water. None of the samples analyzed was found to contain any residual chlorine. A total of 75% of the samples were found to contain coliforms while some (41%) samples recorded lower pH values than recommended by WHO.

Overall, the water from boreholes in the Wa Municipality is suitable for drinking, bathing, recreation, irrigation and industrial uses. Thus, it can be concluded that borehole water is within the safe limits and fit for domestic consumption.

As much as possible all boreholes should be disinfected regularly through chlorination or other suitable methods to prevent microbial contamination and the spread of water-borne diseases. The Ghana Water Company Limited should monitor and ensure that this is achieved.

Through regular monitoring and testing, borehole water observed to have abnormal pH values should be adjusted to normal levels using appropriate chemical agents.

Hence subject to appropriate chlorination and adjustment of pH where necessary, water from boreholes in the Wa Municipality could be considered as safe for domestic use.

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