

# Assessment of Physico-chemical Quality of Groundwater Sources in Ga East Municipality of Ghana

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## Abstract

Safe drinking water is essential to the protection of public health and well being of citizenry. The study investigated physico-chemical water quality parameters that could contribute to consumers' complain from communities benefiting from small town water supply schemes in Ga East Municipality of Ghana. Three samples were collected from each borehole, duplicate physico-chemical analysis was conducted and the result was compared to World Health Organisation guidelines for drinking water. The parameters analysed were based on their ability to impart colour to groundwater, change taste and form scales on storage and pipe fittings. The result showed that, the pH ( $5.2 \pm 0.5$ ,  $5.3 \pm 0.4$  and  $5.1 \pm 0.2$ ) of the three boreholes were below WHO recommended levels which made the water acidic and aggressive. The study reviewed that the borehole water were moderately hard ( $66.0 \pm 3.6$ ,  $91.3 \pm 5.1$  and  $73.7 \pm 3.5$  mg  $\text{CaCO}_3/\text{L}$ ). These two parameters can cause rusting and scale formation in pipe fittings which could lead to consumer complains. Other parameters such as ( $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Cl}^-$ , and  $\text{SO}_4^{2-}$  mg/l) were within acceptable limits. Colour imparting ions like iron ( $0.1 \pm 0.0$ ,  $0.1 \pm 0.0$  and  $0.1 \pm 0.0$  mg/l) and manganese ( $0.02$ - $0.03$  mg/l) were within WHO guidelines, were considered safe and had no major health implications on consumers. It was therefore recommended that liming should be considered to bring the pH level to an acceptable limit.

**Keywords:** groundwater quality, physicochemical, water scheme, consumers

## 1. Introduction

Ghana is not exempted from the world water crisis which is affecting other countries in many parts of the world. The assessment of groundwater quality status is important for socio-economic growth and development (Ishaku, 2011). Water is essential to life and safe drinking water reduces the burden of infection and increases life expectancy (American Water Works Association, 1953). Groundwater is the foremost source of drinking water in many rural areas in Africa for many decades and in Ghana, it plays an important role in the socioeconomic development of the country (Yankey et al., 2011).

Lack of safe drinking water and improved sanitation has been attributed to the occurrence of about 80% of all reported cases of diseases in developing world (UNESCO, 2006). Government of Ghana is currently developing groundwater resources for water supply to rural communities due to high pollution of surface water sources, lack of requisite human resource capacity and high cost of operating surface water treatment plants in the rural areas (Kortatsi, 2007). Exploration report by the Water Research Institute in Ghana (WRI, 1993), indicated that 90% and 25% of the rural and urban communities uses groundwater sources for their domestic use respectively. Chemical composition of water may be rendered unfit for human consumption, and thus may lead to health problems. The importance of groundwater quality in human health has recently attracted a great deal of interest (Vasanthavisar, Srinivasamoorthy, Rajiv Gantha, Vijayaraghavan, & Sarma, 2010).

Research has shown a major link between water supply infrastructure, treatment operations, water quality, waterborne diseases and population health (Hrudey & Hrudey, 2004; Craun & Calderon, 2001). It has been indicated that a lot of waterborne disease epidemics have been preceded by customer complaints about aesthetic

water quality problems (Hrudey & Hrudey, 2007). Water quality complaints have been used to monitor treatment operations and quantify the extent of distribution and water quality problems (Dietrich, 2006; McGuire, Hund, Burlingame, Graziano, & Sullivan, 2005; Khiari et al., 2002; Burlingame & Anselme, 1995). Research has shown that rural water wells are not tested as suggested by professionals, and are contaminated with pathogens and chemical from various sources (Charrois, 2010). Others have shown that, 33% documented outbreaks of water-related infections could be attributed to groundwater systems (Reynolds, Mena, & Gerba, 2008).

The geology of Ghana is predominantly crystalline silicate rocks and weathered derivatives and these have contributed to groundwater with low salinity, more acidic and low values of total hardness (Pelig-Ba, 1999). Most studies linked the physico-chemical quality of groundwater to health. However, there seems to be a gap between groundwater quality and its effect on distribution systems and consumer complaints. Reports suggest that water quality tests are either not regularly done or not done at all for rural water supply systems, wells and boreholes as suggested by experts in the field. Therefore, this study investigated physico-chemical water quality parameters in relation to small town water distribution systems and possible parameters that could contribute to consumer complaints from the beneficiary communities in Ga East Municipality of Ghana.

## 2. Description of Research Area

Ga East Municipal Assembly is located at the northern part of Greater Accra Region. The municipality covers a total area of 166 sq km. It is bordered to the west by the Ga West Municipal Assembly (GWMA), to the east by the Adenta Municipal Assembly (AdMA), to the south by Accra Metropolitan Assembly (AMA) and to the north by the Akwapim South District Assembly.

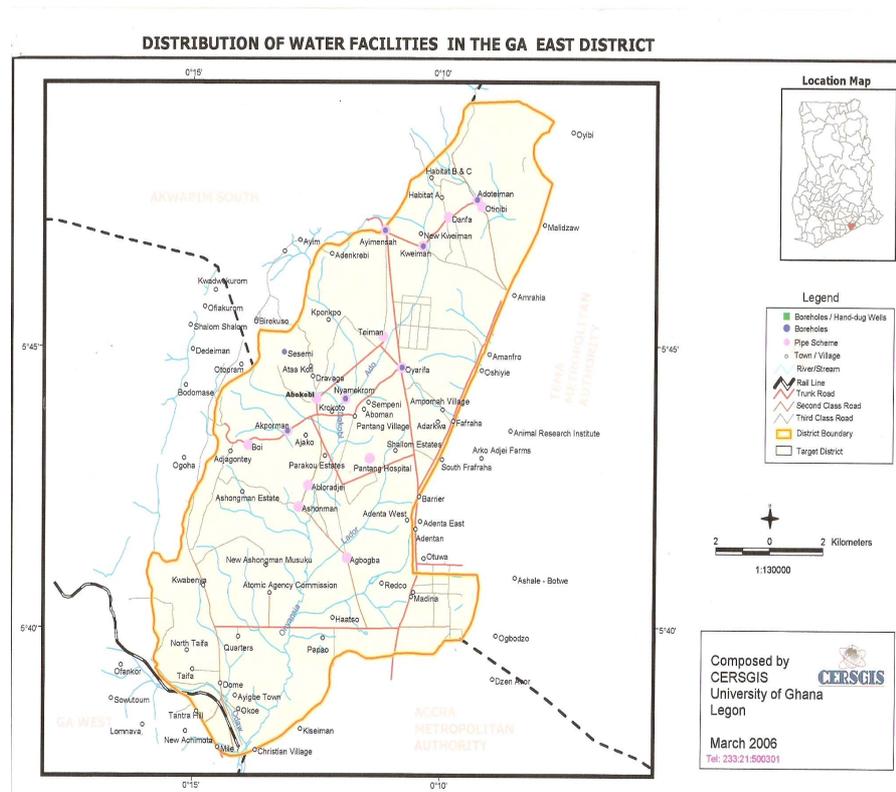


Figure 1. Water distribution network in Ga East Municipality adopted from CERSGIS

The projected population for the Municipality is estimated at 247,313 at a growth rate of 2.3% which is highly due to migration influx (Census, 2000). The average household size for the municipality is 4.6. The population of the municipality is characterised by more male (51%) than female (49%).

Rainfall pattern is bi-modal with the average annual temperature ranging between 25.1°C in August and 28.4°C in February and March, being the hottest months. Potable water supply in the municipality is done by Ghana

Urban Water Limited (GUWL) and the Municipal Assembly from Community Water and Sanitation Agency (CWSA) program. The urban areas are served by GUWL while the rural areas and small towns are served by the Municipal Assembly through Water and Sanitation Development Boards (WSDB) in the beneficiary communities. There are three small town water supply schemes in the municipality which serves semi-rural areas, including Abokobi-Oyarifa, Pantang Area and Kweiman-Danfa water schemes. The Abokobi-Oyarifa-Teiman water scheme serves about 10,750 people, Pantang area water scheme serves about 12,401 people and Kweiman-Danfa water scheme serves 5,400 people. The three schemes cover twenty-three communities within the Municipality. The three boreholes serving as the sources of supply are located in the valley of the Akuapem Ridge which falls within the Togo rock formation.

### 3. Materials and Methods

In this study the Flame atomic absorption Spectrometry method was used to determine the trace metals in underground water. In all, three (3) samples each were collected from the three small town water supply systems within the Ga East Municipal Assembly. The following equipment and glassware: Hach DR/2000, Spectrophotometer, Horiba Compact B-212 pH Meter, analytical balance, 250-ml conical flask, beaker, burette, pipette, dropper, wash bottle, measuring cylinder, magnetic stirrer, sterile sample bottles, were used in the water quality analysis. The Physico-chemical analysis of groundwater samples were carried by instrument and non-instrumental method. Temperature, pH, conductivity, TDS were determined by using in-situ water analysis Kit. The water quality parameters were analyzed using the standard procedure mentioned in APHA (1995). All the elemental analysis was conducted using digital Flame Photometer. All the reagents used for the analysis were AR grade and double distilled water used for preparation of solutions. Samples of water for analysis were prepared depending on the parameter to be tested. Two sample cells were used for each analysis. One sample cell was filled with measured quantity of prepared sample and the other cell was filled with deionised water to serve as blank. The sample cells with its contents were placed in the Hach DR/2000 Spectrophotometer and analysed. The results obtained were displayed and the values recorded. The test was repeated for the duplicate samples of each borehole. The samples were analysed for parameters such as colour, turbidity, TDS, alkalinity, pH, iron, hardness, calcium, magnesium, manganese, sulphate and chloride.

### 4. Results and Discussion

Table 1. Physical and chemical characteristics of boreholes in the selected communities in Ga East Municipality

| Parameter                            | Mean $\pm$ S.D  |                 |                 | WHO*      |
|--------------------------------------|-----------------|-----------------|-----------------|-----------|
|                                      | Abokobi-Oyarifa | Pantang Area    | Kweiman-Danfa   |           |
| pH                                   | 5.2 $\pm$ 0.5   | 5.3 $\pm$ 0.4   | 5.1 $\pm$ 0.2   | 6.5 – 8.5 |
| True colour (PtCo)                   | 5.0 $\pm$ 0.0   | 5.0 $\pm$ 0.0   | 5.0 $\pm$ 0.0   | 15        |
| Turbidity (NTU)                      | 0.2 $\pm$ 0.0   | 0.2 $\pm$ 0.0   | 0.2 $\pm$ 0.0   | 5         |
| Total Dissolved Solids (mg/l)        | 375.0 $\pm$ 5.6 | 323.3 $\pm$ 9.7 | 217.3 $\pm$ 8.7 | 1000      |
| Total Suspended Solids (mg/l)        | 1.0 $\pm$ 0.0   | 1.0 $\pm$ 0.0   | 1.0 $\pm$ 0.0   | -         |
| Total hardness (mg/l)                | 66.0 $\pm$ 3.6  | 91.3 $\pm$ 5.1  | 73.7 $\pm$ 3.5  | 500       |
| Alkalinity (mg/l)                    | 30.7 $\pm$ 3.1  | 25.7 $\pm$ 2.5  | 26.7 $\pm$ 5.1  |           |
| Ca <sup>2+</sup> (mg/l)              | 11.2 $\pm$ 0.5  | 17.3 $\pm$ 1.4  | 5.1 $\pm$ 1.0   |           |
| Mg <sup>2+</sup> (mg/l)              | 9.8 $\pm$ 0.6   | 12.9 $\pm$ 0.7  | 3.5 $\pm$ 0.5   |           |
| Na <sup>+</sup> (mg/l)               | 56.3 $\pm$ 4.0  | 53.2 $\pm$ 3.7  | 48.4 $\pm$ 2.9  | 200       |
| Cl <sup>-</sup> (mg/l)               | 140.4 $\pm$ 5.9 | 128.7 $\pm$ 1.2 | 107.7 $\pm$ 4.5 | 250       |
| Fe <sup>2+</sup> (mg/l)              | 0.1 $\pm$ 0.0   | 0.1 $\pm$ 0.0   | 0.1 $\pm$ 0.0   | 0.3       |
| Mn <sup>2+</sup> (mg/l)              | 0.0 $\pm$ 0.0   | 0.0 $\pm$ 0.0   | 0.0 $\pm$ 0.0   | 0.5       |
| SO <sub>4</sub> <sup>2-</sup> (mg/l) | 33.3 $\pm$ 4.0  | 38.7 $\pm$ 2.1  | 6.7 $\pm$ 5.0   | 250       |

\*WHO drinking water quality, 1993 and 2011.

As shown in Table 1, the pH levels from the three boreholes were below the WHO guideline permissible limit for drinking water. The pH level of 5.1-5.3 revealed that the water from the boreholes was mildly acidic. The acidity may be from carbonic acid due to the presence of CO<sub>2</sub> within the soil zone and other natural biogeochemical processes (Yankey et al., 2011; Hounslow, 1995; Langmuir, 1997). Acidity increases the capacity of the water to attack geological materials and leach toxic trace metals into the water making it potentially harmful for human consumption. There were some distribution lines, fixtures that were corroding, and some development of stains in household sinks. This confirms the findings EPA-US, that acidic pH and the presence of CO<sub>2</sub> make the water aggressive and attack pipe fittings and distribution lines and cause aesthetic problems, such as a metallic or sour taste, laundry staining or blue-green stains in sinks and drains (EPA-US, 2007; WHO, 1993). Acidic water, however, can be conditioned with lime to give product water with increased pH (McGuire, 2007). The true colour measured for the water samples from the boreholes were below the WHO guidelines of 15 PtCo. This implies that the colour of the water is very good and does not pose any aesthetic problems to the users and therefore can be considered safe for domestic use. The turbidity values for the three borehole water samples (0.2NTU) were below the recommended value of 5 NTU by WHO. This is expected of groundwater and it is therefore safe for domestic use and does not pose any health problems to the consumers. The total dissolved solids (TDS) ranged between 217.3-375.6 mg/l, which are below the recommended level by the WHO (1000mg/l). Even though no direct health effects is known for TDS, certain components of TDS, such as chlorides, sulphates, magnesium, calcium, and carbonates, affect corrosion or encrustation in water-distribution systems. Since the TDS was not too high it does not excessively contribute to scaling as suggested by WHO (1996) that high TDS levels (>500 mg/litre) result in excessive scaling in water pipes which can decrease the life of service appurtenance, water heaters, boilers, and household appliances such as kettles and steam irons.

Table 1 also showed that total hardness of the water samples from the boreholes ranged between 66.4-91.3mg/l and this was below the WHO guideline value of 500mg/l. This showed that the water from the boreholes were moderately hard. According to Langmuir (1997), water is considered to be soft, moderately hard, hard, and very hard when its hardness level is 0-60 mg/l, 61-120 mg/l, 121-180 mg/l, and >180 mg/l, respectively. Hardness of water is mainly due to the presence of salts of calcium and magnesium and this reduces lather formation and also increases the boiling point of the water (Murhekar, 2011). Hardness of water also leads to the formation of scales in sinks, pipe fittings and cooking utensils. The users of hard water tend to use a lot of soaps for washing.

## 5. Manganese and Iron

The concentration of Manganese ions [Mn<sup>2+</sup>] in the three sampled boreholes were below the recommended WHO guidelines. Manganese is an important micronutrient for both plants and animals, however if taken in large doses can cause some diseases and liver damage (Hem, 1970). The total iron concentration [Fe<sup>2+</sup>] in the water samples were below the WHO guideline value of 0.3mg/l (WHO, 2011). Iron is essential to the human body and its intake through drinking water is normally an insignificant portion of the body requirement (Freeze & Cherry, 1979; Kortatsi, 2007). The maximum permissible concentration of 0.3mg/l in drinking water is primarily for reasons of taste and avoidance of staining of sinks and laundered textiles (Woiff & Wasserman, 1972). Therefore this parameter is acceptable for the three boreholes analysed.

The concentration of calcium ions [Ca<sup>2+</sup>] in the water samples of the three communities' ranges between 4-20mg/l and these are below the Ghana Urban Water Limited (GUWL) standard of 200mg/l. The levels in the tested samples therefore indicate that the water is safe for consumers however it contributes to the hardness of the water especially in the samples from Pantang and Abokobi. The concentration of magnesium ions [Mg<sup>2+</sup>] was found to be below the GUWL standard of 200mg/l and WHO guidelines. It is known that Ca<sup>2+</sup> and Mg<sup>2+</sup> ions in water are essential for human health and metabolism (Kortatsi, 2007). Concentrations of other ions such as chloride (Cl<sup>-</sup>), sodium (Na<sup>+</sup>) and Sulphate (SO<sub>4</sub><sup>2-</sup>) were below the recommended standard by WHO as 250mg/l, 200mg/l and 250mg/l for Cl<sup>-</sup>, Na<sup>+</sup> and SO<sub>4</sub><sup>2-</sup> respectively. Intake by humans of water with concentrations of these ions above the recommended limits is generally not harmful (Kortatsi, 2007). When Na<sup>+</sup> exceeds the recommended limit of 200 mg/l, the water tastes salty. Similarly, maximum chloride concentration permissible in drinking water is 250 mg/l primarily because of taste. Likewise, sulphate concentration in drinking water must not exceed 250 mg/l otherwise the water will taste bitter. Higher SO<sub>4</sub><sup>2-</sup> concentrations can even produce laxative effect (Kortatsi, 2007). Therefore, they do not pose neither physiological nor aesthetic problems to groundwater usage for drinking or domestic purposes within the Ga East Municipal Assembly. They may however contribute to scale formation and water hardness.

## 6. Conclusions

The research conducted in the Ga East Municipality on the three small town water supply schemes indicated that the pH levels of the groundwater were acidic and may facilitate corrosion of the pipe fittings and contribute to scale formation. The waters supplied to the communities were moderately hard which suggest the formation of scales in utensils, pipe fittings and formation of whitish substances after heating the water. This may be so because the hardness is due to the salts of calcium and magnesium sulphate or carbonate present in the water. All the other physicochemical parameters determined in this research were within acceptable limits and poses no known health or aesthetic effects to the consumers. It is therefore suggested that liming should be done to raise the pH of the waters to an acceptable level and further studies to assess customer satisfaction of services and water quality should be considered.

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