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# An Investigation of Bacteriological, Physicochemical and Heavy Metal Quality of Treated Water Supplied from the Barekese Dam to the Kumasi Metropolis, Ghana

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***Abstract***

*Bacteriological, physicochemical and heavy metal analyses of treated water supply to the Kumasi Metropolis from the Barekese Headwork was carried out. Samples from $BK_4$ and $BK_6$ have their turbidity higher than the WHO acceptable limits for drinking water but the pH recorded were all within the limits of 6.5 to 8.5. Conductivity varied from 250.20 µS/cm at Asuofua ($BK_1$) to 368.11 µS/cm at KNUST Campus ($BK_7$). The TDS of both headwork and households were all below the standard of 1000mg/l. Calcium hardness was from 44.80 mg/L at site $BK_1$ to 72.10 mg/L at $BK_6$ whilst Magnesium hardness recorded 18.90 mg/L at $BK_5$ to 30.20 mg/L also at the headwork. There was no statistical difference between the samples collected from the headwork and the other sampling sites in its total hardness ($p > 0.05$). Samples from $BK_2$, $BK_4$ and $BK_6$ recorded Pb concentrations above the recommended limit. Ca, Mn, Fe and Mg on the hand, were all present but within the acceptable limit. The results indicated that water supplied to households in the Metropolis was potable in its physicochemical and trace metal quality except samples from $BK_4$ and $BK_6$ which recorded both total and faecal coliforms with the highest count being 41.20 cfu/100ml at $BK_4$.*

***Keywords**: Samples, Headworks, household, Coliforms, Heavy metals*

## 1. Introduction

Water-quality index is one of the most effective tools used in passing information on the quality of water to the concerned citizens and policy makers (Atulegwu and Njoku 2004). Potable water supplied to consumers therefore must be of highest quality and its biological and chemical contaminants should be reduced or totally eliminated (Cobbina, 2009). Water supplies are one of the fundamental requirements for human life and lack of access to adequate water supply leads to the spread of diseases. According to Froukh (2001), the term 'domestic water demand' is the amount of water required for domestic uses. Inability to have access to potable water may hinder sanitation and smooth livelihood in homes. Water source protection is therefore an essential part of interventions to improve community health.

The urban groundwater (Kulkarni et al., 2015) and processed groundwater from water headwork have emerged as one of the world's most challenging issues due to large users and contamination with chemicals of geogenic and anthropogenic origins. Even though sustainable access to improved drinking water has become the proxy criterion for the original UN Millennium Development Goals (MDGs) Target 7(c) guideline and seeks to halve the proportion of people without access to safe drinking water and sanitation by 2015 (UNDP, 2005), report by Sutton (2008) shows that Sub-Saharan Africa will only reach the MDGs water target by 2040. Again, even though the WHO proclaimed that the goal had been achieved in March 2012, that does not mean that the water is free of bacterial contaminants or meets WHO drinking water guidelines for *E. coli* (WHO/UNICEF (2012) ; UN News Center (2012); WHO (2013).

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Studies have shown that providing microbiologically and physicochemical safe drinking water at water headwork does not necessarily guarantee safe water at the point of consumption. This is because storage and handling methods can negate this gain by recontamination (Clasen et al. (2008); Rosa et al. (2010). Oswald et el., (2007) reports that there can be recontamination from the distribution pipelines and even from source water collection to time of consumption in a peri-urban areas. WHO (2004) also reports that water may be contaminated with pathogens at the source but contamination may also occur during distribution, transportation, or handling in households or other working places. Good quality of water resources therefore depends on a large number of physico-chemical and biological characteristics (Medudhula, 2012).

Municipalities are required to test their drinking water quality, according to the schedule outlined in their water treatment plant operating permit. Ghana Water Company limited (GWCL) is responsible for the provision and distribution of urban water supply in Ghana. The Barekese headwork in the Ashanti region is under the GWCL and treats water from the Offin river for distribution in the Kumasi Metropolis. But in recent times, some residents and consumers in the Metropolis have been expressing concern about the quality of water supplied by the water headwork. Unfortunately, no analysis of the treated water from source to the households has been done on the bacteriological, physicochemical and trace metals quality of water to the households. This has compelled most residents and consumers especially the University students at the Kwame Nkrumah University of Science and Technology (KNUST) to resort to drinking sachet or packaged water instead of the pipe borne water and thereby increasing the economic hardship on residents. According to Hunter (1994), the increase in the consumption of packaged water is mainly due to the lack of reliable, safe and quality drinking water in the urban areas. This study therefore seeks to assess and evaluate the bacteriological, physicochemical qualities and trace metal content of treated water at the Headwork and compare to samples from seven (7) other booster stations namely; Asuofua, Abrepo, Kejetia, Anloga, Amakom, Aboabo and KNUST Campus to help address the concern of consumers.

## 2. Materials and Methods

### 2.1 Study Area, Survey and Sample Collection

The study was carried out at Kumasi, Ghana (between 6.35-6.40$^{O}$ and longitude 1.30-1.35$^{O}$). Kumasi has a population of 4,780,380 (GSS, 2014) and it is the second largest city in Ghana. The centrality of the city as a traversing point from all parts of the country makes it a special place for many migrants, especially students due to the increased student population. Sampling was conducted during the months of November and December, 2015 through to January, February, March and April 2015 from eight different sampling locations around the Kumasi Metropolis, Ghana and listed in Table 1.

 

**Table 1. Sample Sites (Booster Stations) around the Kumasi Metropolis, Ghana, where Sampling Water was Used for the Study**

| Site Code | Name of Sampling Location |
|---|---|
| $BK_1$ | Asuofua |
| $BK_2$ | Abrepo |
| $BK_3$ | Kejetia |
| $BK_4$ | Anloga |
| $BK_5$ | Amakom |
| $BK_6$ | Aboabo |
| $BK_7$ | KNUST Campus |
| Hw | Headwork |

All the chemicals and reagents used were of analytical grade BDH chemicals Limited, United Kingdom. Water samples were taken from booster stations which supply water to the residents (Table 1). Samples were collected in 250 ml sterile polyethylene bottles that were fitted with screw caps. Sterilisation of the bottles was performed by autoclaving at 121°C for 15 min prior to sampling. Samples were transported to the Microbiology laboratory, Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and analysed for bacteriological presence, physicochemical properties as well as some trace metals. Each sample bottle was clearly labeled and relevant details recorded. Water samples collected for metal analysis were preserved with 50% $HNO_3$ to attain a pH of 2 in order to keep the metal ions in the dissolved state and also to prevent microbial influence (APHA *et al.*, 2005).

### 2.2 Water Sampling and Analysis

All the samples were analysed in triplicates in the laboratory employing standard methods for physicochemical parameters (turbidity, colour, pH, electrical conductivity, total dissolved solids, total suspended solids and colour), microbial properties (Total coliforms, Faecal coliforms and *Escherichia coli*) and some trace metals (Fe, Mn, Mg, Ca, Cu and Pb). The average concentration of the metal present being displayed in mg/L by the instrument after extrapolation from the standard curve. Electrical Conductivity, TDS (Total Dissolved Solids), and pH were measured using potable Orion 5 star sensor multiparameter analyzer from Orion instruments (Model No. Orin 5 Star, S/N: A03158). The physical and chemical analysis of water samples were based on APHA *et al., (*2005).
Faecal and total coliform counts were performed using the standard membrane filtration technique. Samples for microbial determination were analysed within 18.0 hours after sampling, while samples for physicochemical parameters were analysed within a week (Cobbina, 2009). The 100 ml water sample was filtered using 0.45 mm pore size, 47 mm diameter filter membrane as described by APHA (1998). Multiple tube technique was used for the enumeration of Most Probable Number of coliform bacteria. Nutrient agar (NA) as a basal medium, MacConkey agar as a differential medium and Blood agar as a special medium were used to determine enteric bacteria. *Escherichia coli* were isolated by inoculating the sample in Bismuth green bile broth. Enteric bacteria isolated on respective selective or differential media were identified on the basis of their colonial, morphological and biochemical properties using Bergey's Manual of Determinative Bacteriology, 1994. Heavy metals were analysed using the Perkin Elmer Optima 5300 DV for Inductively Coupled Plasma-Atomic Emission Spectrometry analysis.

 

### 2.3 Statistical Analysis

The water samples chemical analysis together with the statistical analyses were carried out using AqQA (version 1.1.1) water-quality software and SAS (version 9.2), MINITAB (version 14) and Rockworks (version 15) respectively.

## 3. Results and Discussion

### 3.1 Physicochemical Characteristics

According to WHO guidelines, turbidity of drinking water should not be more than 5 NTU (Cech, 2009). In the present study, two of the sampling sites $BK_4$ and $BK_6$ have their turbidity values higher than the WHO (2011) acceptable limits for drinking water (Table 2). Gyamfi et al., (2012) reported that water samples with high turbidity presents colloidal materials which provides adsorption sites for chemicals that may be harmful or cause undesirable tastes and odors. Turbidity may indicate the presence of disease causing organisms. All the water samples measured have pH values within the WHO (2011) limit of 6.5-8.5. The colour varied from 7.1 Hz ($BK_2$) to 28.70 Hz ($BK_6$). Two samples ($BK_4$ and $BK_6$) out of the eight recorded values above the WHO (2011) standard of 15.0Hz (Table 2).

**Table 2. Physicochemical Parameters of Treated Domestic Water Supplied to Residents in the Kumasi Metropolis from the Barekese dam**

| Sampling sites | Turbidity (NTU) | Colour Hz | pH | Conductivity µS/cm | TSS mg/L | TDS mg/L | TH mg/L | Ca/Mg Hardness/mg/L | |
|---|---|---|---|---|---|---|---|---|---|
| $BK_1$ | 3.51 | 13.68 | 6.54 | 250.20 | 1.80 | 194.20 | 44.80 | 35.20 | 20.12 |
| $BK_2$ | 3.30 | 7.81 | 6.24 | 302.22 | 1.21 | 210.10 | 66.10 | 38.40 | 22.41 |
| $BK_3$ | 3.56 | 9.22 | 7.81 | 341.00 | 0.82 | 248.10 | 64.10 | 38.10 | 24.86 |
| $BK_4$ | 5.20 | 25.91 | 6.15 | 254.12 | 5.22 | 238.00 | 58.10 | 26.40 | 22.20 |
| $BK_5$ | 3,88 | 19.30 | 7.48 | 297.90 | 3.10 | 252.00 | 56.70 | 44.80 | 18.90 |
| $BK_6$ | 6.18 | 28.70 | 6.14 | 260.00 | 2.41 | 236.00 | 72.10 | 29.30 | 23.20 |
| $BK_7$ | 4.33 | 13.71 | 7.47 | 368.11 | 3.60 | 267.20 | 55.10 | 41.20 | 24.30 |
| **$H_W$** | 3.82 | 14.11 | 7.15 | 281.40 | 10.80 | 175.8 | 61.80 | 60.20 | 30.20 |
| **SD** | **±1.31** | **±12.61** | **±0.74** | **±41.31** | **±1.76** | **±7.39** | **±6.96** | **±4.28** | **±3.68** |
| **WHO(2011)** | **5.0** | **15.0** | **6.5-8.5** | **1500** | **-** | **1000.0** | **500** | **500** | **500** |

This may provide evidence of possible contamination since waste water disposal facilities were non-existent for most households in these areas and therefore waste water can find its way into treated water through distribution leakage pipes. There was however, a strong correlation between the Hw and the households with a correlation from 1 to 0.99. This may be due to the natural colour from the presence of colloidal iron and manganese in the water. The high colour measured in some samples may be due to dissolved components such as iron and manganese, humus, plankton, weeds and or industrial wastes which find their way into leaking distributing pipes.

 

The electrical conductivity (EC) of water relates to the total concentration of dissolved ions in water and the temperature at which the measurement is taken (Gyamfi et al., 2012). The study showed that conductivity varied from 250.20 µS/cm at Asuofua ($BK_1$) to 368.11 µS/cm at KNUST Campus ($BK_7$). There was no significant difference between the household and the Headwork samples as $p > 0.05$. Our work supports that of Meybeck (1997) who also reported that conductivity is directly proportional to the Total Dissolved Solids (TDS) for all the samples analysed (Figure 1 and Table 2). An increased TDS concentration results in an undesirable taste, which can be salty or bitter, and it can cause excessive scaling in distribution pipes, heaters, and boilers (Gray, 2008). The TDS of both headworks and households were all below the WHO (2011) standard of 1000mg/l.

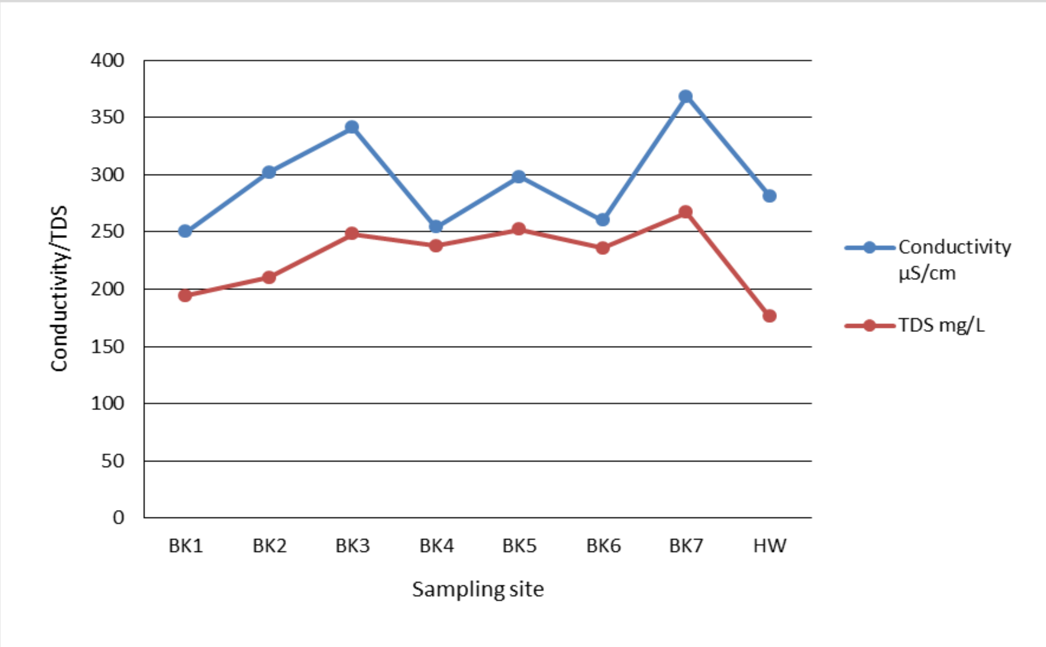


**Figure 1. Variation between Conductivity (µS/cm) and TDS (mg/l) of the Samples from the Eight Sites**

Hardness of water is caused by the presence of multivalent metallic cations and is largely due to calcium, $Ca^{++}$, and magnesium, $Mg^{++}$ ions. The total hardness measured in this study ranged from 44.80 mg/L at site $BK_1$ to 72.10 mg/L at $BK_6$. All samples were below the WHO (2011) limit of 500 mg/l. Cobbina et al., (2009) reported that the total hardness of water obtained for household piped water analysis in Western Accra, Ghana, ranged from a minimum of 86 mg/L to a maximum of 125 mg/L. In terms of calcium hardness, the range was 26.40 mg/L at site $BK_4$ to 60.20 mg/L at Hw whilst Magnesium hardness was 18.90 mg/L at $BK_5$ to 30.20 mg/L also at Hw. There was no statistical difference between the water samples collected from the Hw and the other sampling sites in its total hardness ($p > 0.05$). Even though no adverse health effects have specifically been attributed to calcium and magnesium in drinking water, Tay (2004) reports that the presence of calcium and magnesium in drinking water may result from their ability to render water hard.

### 3.2 Heavy Metal Concentration

Heavy metal contamination of ground, stream and river water ecosystem is a worldwide environmental problem (Sekabira et al., 2010) and among the contaminants affecting water resources, heavy metals receive particular concern considering their strong toxicity even at low concentrations (Marcovecchio et al., 2007). Water assessment and chemical analysis for heavy metals is therefore very important as they are harmful and insidious pollutants due to their non-biodegradable nature and their potential to cause adverse effects in humans (Akoto, 2007; Momudo et al., 2010; David et al., 2011). The heavy metal concentrations in water samples from the eight sampling sites are summarized in Table 3.

**Table 3. Heavy Metal Concentration in Treated Domestic Water Supplied to Residents in the Kumasi Metropolis**

| Sampling sites | Fe mg/L | Mn mg/L | Mg mg/L | Ca mg/L | Cu mg/L | Pb mg/L |
|---|---|---|---|---|---|---|
| **$BK_1$** | 0.18 | 0.03 | 7.12 | 15.03 | 0.11 | 0.08 |
| **$BK_2$** | 0.12 | 0.03 | 8.33 | 15.42 | 0.05 | 0.16 |
| **$BK_3$** | 0.16 | 0.03 | 5.35 | 15.84 | 0.84 | 0.02 |
| **$BK_4$** | 0.21 | 0.02 | 5.89 | 14.82 | 0.42 | 0.11 |
| **$BK_5$** | 0.25 | 0.03 | 5.84 | 14.73 | 0.75 | 0.09 |
| **$BK_6$** | 0.23 | 0.03 | 6.12 | 15.99 | 0.90 | 0.24 |
| **$BK_7$** | 0.31 | 0.02 | 8.10 | 19.85 | 0.30 | 0.07 |
| **$H_W$** | 0. 18 | 0.04 | 5.59 | 17.62 | 0.91 | 0.01 |
| **SD** | **±0.06** | **±0.01** | **±1.09** | **±1.98** | **±0.18** | **±0.04** |
| **WHO (2011)** | **0.3** | **0.40** | **150** | **200.0** | **1.50** | **0.10** |

In the analysis, the concentration of Fe in all the samples were below the WHO maximum contaminant level of (0.3 mg/L) except samples from $BK_7$ which was slightly above (0.31 mg/L) the recommended level. The results indicated that the levels of Fe in the water samples do not pose health threats to the consumers. Iron is an essential element in human nutrition but long time consumption of drinking water with a high concentration of iron can lead to liver diseases (hemosiderosis). Water with high concentration of the iron when used in preparation of tea and coffee, interacts with tanning giving a black inky appearance with a metallic taste.

Even though the WHO does not propose any health based guideline for magnesium, Kalagbor and Mgbodom-Okah (2013) reported that Mn is toxic when high concentrations are present in the human body leading to neurological, organ and cardiac problems. From Table 3, all the samples recorded Mn concentrations below the WHO (2011) limit. Drinking water containing very high level of magnesium can cause vomiting, diarrhoea, muscle weakness, and breathlessness. The lowest magnesium value was 5.35 mg/l and was recorded at $BK_3$ while the $BK_7$ recorded the highest magnesium value of 8.10 mg/l. The headwork recorded magnesium concentration of 5.59 mg/l. All the other samples recorded magnesium concentrations below the WHO (2011) maximum acceptable limit.The study also revealed that the calcium ions concentrations were all below and within the permitted limit of 200.0 mg/l set by the WHO (2011) for drinking water (Table 3).

 

From the result, the minimum concentration of copper detected in the water samples was 0.05 mg/L with the maximum concentration being 0.91 mg/L. None of the water samples con-tained copper above the acceptable concentration of 1.5mg/L even though copper was detected in all the water samples. Anyakora and Momodu (2010) reported that toxicity is associated with continuous low level exposure and can eventually lead to serious health effect.

Lead concentration from samples $BK_2$, $BK_4$ and $BK_6$ were all slightly above the maximum acceptable limit of 0.10 mg/L. This may be due to the possible high emission of lead into the environment as a result of siting of mechanic workshops around these areas which finds its way into distribution leaked pipes. It can also be due to the usual heavy traffic of motor vehicles on that route which might contribute to the deposition of lead which will find its way into the distribution system (Ehi-Eromosele and Okiei, 2012).

### 3.3 Bacteriological Analysis and Enumeration

In as much as the samples from the Hw showed no Total and faecal coliform contamination, there were however, the presence of possible contamination of samples from $BK_4$ and $BK_6$ (Table 4) emanating from the distribution system. It is important to note that coliform bacteria are widely found in nature and do not necessarily indicate faecal pollution (Binnie, 2002; Griffith et al., 2003). Semenza et al., (1998) in their study reported that the presence of bacteria in water pipes could be attributed to cross-contamination between the municipal water supply and sewer, due to leaky pipes and lack of water pressure.

Drinking water regulations require that potable water for human consumption be free from human disease-causing bacteria and specific indicator bacteria that are indicative of the presence of these pathogens (Lisle, 1993). Total coliform count of samples from $BK_4$ and $BK_6$ were 41.2 cfu/100ml and 21.4 cfu/100ml respectively. These two sites which lack access to toilet facilities also recorded faecal coliform counts of 12.8 cfu/100ml and 4.1 cfu/100ml respectively. This contamination may be due to the indiscriminate disposal of faeces in the Anloga and Aboabo communities which find its way into some leaking distributing systems. Occasional leakages in pipe-lines may be the cause of external waters infiltrating into the distribution systems. Cobbina et al., (2009) in their studies on pipe water quality supplied to households in Accra North West district reported similar results of total coliform bacteria count from 0 to 120 cfu/100ml with a mean of 10 cfu/100ml. The WHO guideline value for Total coliform is 0 cfu/100ml. Apart from these samples, none of the other samples showed possible contamination. There was however, no detection for *E. coli* in any of the samples from households and the headworks (Table 4).

**Table 4. Bacteriological Levels in Water Samples from the Eight Sampling Sites**

| | Sampling Sites | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Bacterial isolates (cfu/100ml)** | $BK_1$ | $BK_2$ | $BK_3$ | $BK_4$ | $BK_5$ | $BK_6$ | $BK_7$ | $H_W$ | SD | WHO (1996) |
| **Total coliform** | ND | ND | ND | 41.2 | ND | 21.4 | ND | ND | ±7.8 | 0 |
| **Faecal coliform** | ND | ND | ND | 12.8 | ND | 4.1 | ND | ND | ±1.7 | 0 |
| ***E. coli*** | ND | ND | ND | ND | ND | ND | ND | ND | - | 0 |

## 4. Conclusion

The present study indicates that treated water supplied to households in the Kumasi Metropolis generally was potable by WHO standards in its physicochemical and trace metal quality. However, the levels of coliform and faecal coliform recorded in the $BK_4$ and $BK_6$ samples suggest contamination from the distribution system. The number of coliforms were above the recommended international and national limits. This probably account for the consumers concern about the quality of treated water used in households and also has compelled most consumers especially the University students and in the Kumasi Municipality to resort to drinking sachet water instead of the pipe born water.

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