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The Quality of Water Sources from High Schools in the Accra Metropolis

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Abstract

Physico-chemical quality of borehole water and pipe-borne water from selected second cycle institutions in the Accra metropolitan area in the Greater Accra region of Ghana was evaluated. A total of Seventeen (17) samples were collected from eight (8) boreholes and nine (9) pipe-borne water sources respectively. The parameters determined were; physico-chemical (pH, Temperature, Conductivity, Total Dissolved Solids, Total Suspended Solids, Salinity, Turbidity, Colour, Alkalinity and Total Hardness), anions (Chloride, Fluoride, Sulphate, Phosphate and Nitrate), some trace metals and essential metals (Iron (Fe), Zinc (Zn), Lead (Pb), Sodium (Na), Potassium (K), Magnesium (Mg) and Calcium (Ca)). Standard methods were employed for the determination of all the parameters. From the results, pH of both the borehole and pipe-borne water samples were acidic to neutral (range: 4.78-7.38). Both water sources were moderately soft to slightly hard (range: 14.67-444.33 mg/l). The anions observed in the water sources were within the WHO guidelines except chloride concentrations in the borehole water which were above 250 mg/l. Magnesium, Zinc and Iron concentrations were below the WHO limits of 330 mg/l, 3.0 mg/l and 1.0 mg/l respectively. While Cadmium concentrations in both water sources were below detection, lead concentrations exceeded the WHO limit of 0.01mg/l. The results suggest that most of the borehole and pipe-borne water sources in the second cycle institutions are acceptable for household utilization except for the isolated cases of lead contamination.

Keywords: Physico-chemical; Boreholes; Pipe-borne; Water; Accra; Schools

Introduction

Water is one of the earth's precious resources. Although water is vital for human survival, many are denied access to potable drinking water supply and enough water to satisfy their needs [1]. Potable water from boreholes and pipes provides an estimated 1.5 billion people worldwide daily. Most people resort to boreholes as an alternative water resource due to its availability and the most important source for domestic, industrial and agricultural use in the world [2]. Human activities can alter the quality and quantity of water available through the disposal of chemicals and wastes on the surface or through soils. In addition, naturally occurring contaminants present in the rocks and sediments also have impact on the quality of borehole water [3]. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources. Pesticides and fertilizers applied to lawns and crops can accumulate and migrate to the water tables thus affecting both the physical, chemical and microbial quality of water [4]. Trace metals have been referred to as common pollutants, which are widely distributed in the environment with sources mainly from weathering of minerals and soils as well as industrial activities [5]. Foreign substances such as organic, inorganic, bacteriological or radiological present in water bodies leads to water pollution. These substances tend to degrade the quality of water in this present time. Good quality water is described by its physical, chemical and biological characteristics [6]. The chemistry of water from boreholes will mainly be influenced by inorganic chemicals and suspended solids as a result of urban run-offs [7]. However, when chemical pollutants exceed maximum or minimum allowable concentrations in water bodies, it would no longer be able to support the daily activities of man.

Drinking, cooking, bathing and cleaning are all domestic use of water, however, access to safe drinking water is critical for good health. The quality of water may be described according to their physico-chemical and micro-biological characteristics. Both borehole and pipe-borne water quality monitoring and testing are of paramount importance both in the developed and developing world

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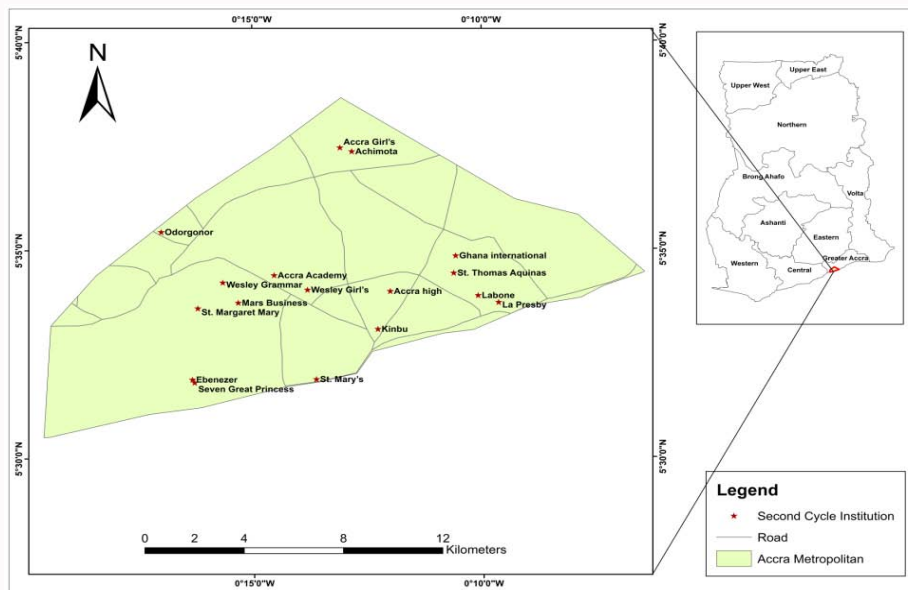


Figure 1: Customized map of the Accra Metropolis indicating sampling points.

[8]. The key to sustainable water resources is to ensure that the quality of water resources are suitable for their intended uses.

Majority of the populace in Ghanaian cities rely on pipe-borne water for their water needs. Pipe-borne water is mostly sourced from surface water sources. This has resorted to perennial water shortage due to the drying of surface waters as a result of the dry season where there is no rain. Due to the increasing number of students in second cycle institutions in the Accra Metropolis and the associated periodic climate induced water shortage, it has become imperative for schools to resort to other sources of water example borehole. It is therefore important to investigate the quality of these water sources in order to ascertain the safety of consumers.

Materials and Methods

Description of study area

The study was conducted in Accra which is 1.4 percent of the total land area of Ghana. It is bordered on the north by the Eastern Region, on the east by the Volta Region, on the south by the Gulf of Guinea, and on the west by the Central Region. Accra is located in longitude coordinates are $5^{\circ}45'0''N$ and $0^{\circ}0'0''E$ in DMS (Degrees Minutes Seconds) or 5.75 and 0 (in decimal degrees). It is located at an elevation of 81 meters above sea level with a population of 3,460,792 [9].

Sampling

A total of eight (8) boreholes and nine (9) pipe-borne water were sampled at various locations for the study. Borehole water was fetched from polytanks since the boreholes were mechanized while pipe-borne water was fetched direct from the tap. The samples were soaked in dilute nitric acid overnight before use. At the point of sampling, containers were rinsed with some of the water and then filled leaving no air space and immediately covered. Three bottles were fetched from each site. The environmental sanitation conditions around the borehole and the tap were taken into consideration.

Experimental methods

Determination of physicochemical parameters: pH: A WTW

pH meter with a temperature sensor was used to determine the pH and the temperature of the water samples carried out at $25^{\circ}C$ after calibrations using standard buffer solutions of pH 4.01, 7.00 and 9.20. In order to get a high precision, pH meter was warmed up for some time before use. The pH probe was placed in an aliquot of 50ml of each water sample for the determinations.

Conductivity, total dissolved solids (TDS), total suspended solids (TSS) and salinity: These were determined using Multifunctional conductivity meter (HACH Series 5). The multifunctional conductivity meter was calibrated before each measurement with KCl solutions of concentrations 84, 1413 and 5000 $\mu S/cm$.

The conductivity in $\mu S/cm$, TDS and TSS in mg/l and salinity in ‰ of the sample were recorded. The probe of the meter was rinsed with distilled water after each sample reading.

Total hardness: A volume of 2.5 ml ammonia buffer of pH 10 was added to 50 ml of the water sample in a fume hood and 3 drops of the Erichrome Black T indicator was added to the mixture. The mixture in the conical flask was titrated with 50 ml EDTA solution from the burette until the colour changed to blue at the end point of the titration. The value of the titrant was read and recorded.

Alkalinity: A burette was filled with 0.1 M HCl and 50ml portion of the water sample was measured and transferred quantitatively into a clean conical flask. With the help of a stopper, 3 drops of methyl orange indicator were added to the sample. This was titrated with 0.1 M HCl to the end point.

Measurement of colour and turbidity: These were determined using HACH DR/890 colorimeter. A 10 ml aliquot of each sample was measured into the sample cell of HACH DR/890 colorimeter. Turbidity readings were recorded in NTU and for colour, a 25 ml aliquot of each sample was measured into the sample cell of HACH DR/890 colorimeter and colour readings recorded in HU.

Determination of cations and anions: Fluoride: The HACH DR/890 colorimeter was zeroed by pipetting 2 ml of SPADNS reagent

Table 1: Physicochemical parameters of water samples.

| | pH | Temperature °C | Conductivity - $\mu\text{S/cm}$ | TDS mg/L | TSS - mg/L | Turbidity NTU | Salinity ‰ | Colour HU | Alkalinity - mg/L | Total hardness - mg/L |
|---------|-------------|----------------|---------------------------------|-----------|------------|---------------|------------|-----------|-------------------|-----------------------|
| Schools | WHO=6.5-8.5 | WHO= - | WHO= 1500 | WHO= 1000 | WHO= 5 | WHO= 5 | WHO= - | WHO= 15 | WHO= 200 | WHO= 500 |
| AAC | 4.78 – 4.79 | 25.1 | 10293.33 | 5526.67 | 2 | b/d | 4.97 | 1 | 10 | 441.33 |
| WGR | 6.13 – 6.16 | 25.1 | 8993.33 | 4906.67 | b/d | b/d | 5.07 | b/d | 94 | 97.33 |
| LAP | 7.29 – 7.31 | 25.1 | 8943.33 | 4913.33 | b/d | b/d | 4.97 | b/d | 229.33 | 92 |
| SMR | 6.11 – 6.14 | 25.1 | 28100 | 15700 | b/d | b/d | 17.57 | b/d | 58 | 350.67 |
| ACH | 6.98 – 7.11 | 25.1 | 420 | 210 | 1 | b/d | 0.2 | b/d | 40 | 14.67 |
| LBN | 6.70 – 6.75 | 25 | 6840 | 3733.33 | b/d | b/d | 3.77 | b/d | 310 | 52 |
| AGS | 6.61 – 6.64 | 25 | 7783.33 | 4353.33 | b/d | b/d | 4.37 | b/d | 150.67 | 80 |
| SMG | 7.24 – 7.32 | 25.2 | 9830 | 5823.33 | b/d | b/d | 5.43 | b/d | 296.67 | 124 |
| ODG | 6.28 – 6.32 | 24.9 | 2026.67 | 1073.33 | b/d | b/d | 1.07 | b/d | 70.67 | 86.67 |
| KBU | 6.42 – 6.48 | 25.2 | 534 | 460 | b/d | 1 | 0.3 | b/d | 59.33 | 34.67 |
| MRS | 6.71 – 6.76 | 25 | 2036.67 | 1490 | b/d | b/d | 1 | b/d | 90.67 | 86.67 |
| STA | 6.57 – 6.62 | 25.1 | 350.67 | 8220 | b/d | b/d | 0.2 | b/d | 51.33 | 28 |
| WGS | 6.70 – 6.78 | 25.1 | 2040 | 1550 | 1 | b/d | 1.03 | b/d | 91.33 | 105.33 |
| EBN | 6.71 – 6.77 | 25.1 | 2036.67 | 1250 | b/d | 2 | 1.03 | b/d | 96 | 96 |
| AHS | 7.35 – 7.38 | 25.1 | 540 | 300 | b/d | b/d | 0.27 | b/d | 52.67 | 32 |
| GIS | 7.19 – 7.24 | 25 | 357.33 | 353.33 | b/d | b/d | 0.23 | b/d | 60 | 32 |
| SGP | 6.70 – 6.92 | 25.3 | 2150 | 1266.67 | b/d | 1 | 1.1 | b/d | 90 | 86.67 |

b/d= below detection

into the sample cell containing 10 ml of distilled water swirled to mix thoroughly and it was allowed to react for 1 minute after which the blank was zeroed. A 10 ml aliquot of sample was measured and 2 ml of SPADNS reagent was added and treated as the blank. Fluoride readings were recorded.

Chloride: Mohr's Argentometric Method was used to determine the content of chloride. An aliquot of 25 ml of water sample was measured and transferred into a clean conical flask. Using Potassium chromate ($\text{K}_2\text{Cr}_2\text{O}_4$) as the indicator, 3 drops were added to the sample which gave a greenish colour. Silver nitrate solution (0.141 M) in the burette was used to titrate the content of the conical flask until a reddish brown end point was obtained. The end point value was read and recorded. The blank was determined by using distilled water.

Calcium: Calcium content was determined by EDTA titrimetric method. A burette was filled with 0.01 M EDTA and 25 ml portion of the water sample was measured and transferred into a clean conical flask. A volume of 2.0 ml of 1 M NaOH buffer was added and a few grains of murexide indicator was added to the sample mixture in the conical flask which gave a pink colour initially and titrated against 0.01 M EDTA which gave the end point colour as purple. The blank was determined by using distilled water.

Sulphate: An aliquot of 10 ml water sample was measured into a clean labeled test tube, and 1 ml of acid salt solution which was prepared by dissolving 60g of NaCl in 100 ml distilled water containing 5 ml concentrated HCl was added to the samples. A volume of 0.5ml glycerol was then added to it, followed by 0.05 g of BaCl_2 and the content was covered cling wrap and shaken for 30 seconds and then reaction was allowed to take place for 5-10 minutes. After this the absorbance of the sample was recorded on the UV-1600 PC Spectrophotometer at a wavelength of 420 nm. The same procedure was used for the blank and standards preparations. Sulphate readings were recorded.

Nitrate: An aliquot of 5 ml water sample was measured and transferred into a clean labeled test tube. A 1ml portion of 30% sodium chloride (NaCl) was added to the sample followed by 5 ml of conc. H_2SO_4 . A 0.25 ml portion of brucine reagent was then added while the test tube was covered with cling wrap and placed inside a water bath at a temperature of 95°C per 25 minutes. The sample mixture was removed from the water bath and allowed to cool for colour formation and finally read on the UV-1600 PC Spectrophotometer at a wavelength of 410 nm. The same treatment was performed on the blank and standards (0.2, 0.4, 0.6, 0.8, and 1.0) mg/l except that the brucine reagent was not added to the blank.

Phosphate: An aliquot of 10 ml water sample was measured in a clean labeled test tube and 2 ml of the combined reagent (Antimonyl-Tartrate reagent) was added and allowed to stand for 5 minutes. After the 5 minutes the sample was read using UV-1600 PC Spectrophotometer at 880nm wavelength. The same procedure was done for the blank and the standards.

Determination of heavy/trace metals: Flame photometric determinations: Sodium and Potassium concentrations were determined by Flame Photometer. Calibration of the standard was done. This type of flame photometer takes only a single calibration. After the calibration, the various water samples were analyze using the flame photometer for Na^+ and K^+ values in mg/l. A volume of 5ml of sample was measured, followed by the addition of 2ml lithium standard and the mixture was aspirated. The concentrations of sodium and potassium were read on the photometer.

Determination of Mg, Pb, Fe, Cd and Zn using atomic absorption spectrophotometer (AAS): Digestion of samples: Samples were digested using a mixture of concentrated hydrochloric acid and concentrated nitric acid (aqua regia - 4.5 ml of HCl and 0.5 ml of HNO_3). An aliquot of 4.5 ml of HCl and 0.5 ml of HNO_3 was mixed together to generate an orange colour. An aliquot of 40 ml of

Table 2: Concentration of trace metals and some other essential metals.

| Sample ID | Sodium - mg/L | Potassium - mg/L | Magnesium - mg/L | Zinc - mg/L | Lead - mg/L | Cadmium -mg/L | Iron - mg/L | Calcium - mg/L |
|------------|---------------|------------------|------------------|-------------|-------------|---------------|-------------|----------------|
| WHO limits | WHO = 200 | WHO = - | WHO = 30 | WHO = 3 | WHO = 0.01 | WHO = 0.03 | WHO = 0.3 | WHO = 75 |
| AAC | 118.87 | 10.90 | 19.34 | 1.1 | 0.03 | <0.002 | 0.08 | 92.27 |
| WGR | 96.23 | 3.70 | 19.01 | 0.5 | 0.04 | <0.002 | 0.03 | 101.87 |
| LAP | 103.87 | 4.33 | 17.17 | 0.12 | 0.04 | <0.002 | 0.02 | 77.87 |
| SMR | 1208.00 | 14.60 | 24.20 | 0.09 | 0.03 | <0.002 | 0.08 | 54.40 |
| ACH | 2.10 | 0.60 | 0.77 | 0.11 | 0.04 | <0.002 | 0.01 | 12.27 |
| LBN | 97.93 | 3.13 | 11.39 | 0.69 | 0.05 | <0.002 | 0.02 | 30.93 |
| AGS | 84.97 | 4.20 | 13.77 | 0.13 | 0.03 | <0.002 | <0.006 | 75.20 |
| SMG | 84.13 | 2.30 | 21.41 | 0.09 | 0.08 | <0.002 | <0.006 | 92.27 |
| ODG | 2.40 | 0.80 | 3.87 | 0.09 | 0.05 | <0.002 | 0.01 | 30.40 |
| KBU | 3.97 | 0.80 | 1.22 | 0.05 | ND | <0.002 | 0.03 | 9.07 |
| MRS | 18.30 | 2.37 | 3.63 | 0.04 | 0.04 | <0.002 | 0.01 | 17.07 |
| STA | 2.00 | 0.57 | 0.82 | 0.04 | 0.03 | <0.002 | 0.03 | 9.07 |
| WGS | 18.73 | 2.50 | 3.81 | 0.09 | 0.04 | <0.002 | <0.006 | 30.40 |
| EBN | 18.60 | 2.37 | 3.86 | 0.11 | 0.05 | <0.002 | 0.01 | 21.87 |
| AHS | 2.03 | 0.50 | 0.88 | 0.11 | 0.07 | <0.002 | <0.006 | 5.87 |
| GIS | 2.00 | 0.63 | 1.13 | 0.11 | 0.05 | <0.002 | <0.006 | 15.47 |
| SGP | 19.70 | 2.40 | 3.94 | 0.07 | 0.04 | <0.002 | 0.01 | 24.53 |

b/d= below detection

water samples were measured into a clean labeled 100 ml beaker. To each sample, 5 ml of aqua regia is added and covered with a watch glass and heated on a Stuart, SB500, and hot plate to boil for 3 hours in fume hood. After the 3 hours, 30 ml of distilled water is measured and used to rinse the watch glass into the beaker. The digests were poured into clean labeled test tubes. The blank solution was similarly prepared. The samples were kept in a rack covered with cling wrap, ready for analysis.

Analysis of the metals: The concentrations in mg/l of five metals were determined in all the samples namely, Mg, Zn, Cd, Pb and Fe with the Varian Fast Sequential Atomic Absorption Spectrophotometer (model AA 240FS). The AAS was calibrated and was set to give the mean of different concentrations of each metal. Standard solutions ranging from 0.1 to 10 mg/l were prepared. Background correction was ensured. The instrument detection limit was noted. The readings of the standards were taken to plot calibration curves for the various metals. A blank analysis was performed with distilled water. The flame used for the analysis was air-acetylene mixture. The metal concentrations were determined one after the other using their respective hollow cathode lamps. The working conditions for the atomic absorption spectrophotometer were acetylene and air as fuel and support. Also wavelengths for Zn, Pb, Mg, Fe and Cd were 213.9, 217.0, 285.2, 248.7 and 228.8 nm respectively. Slit width of 1.0 nm for Zn and Pb, 0.5 nm for Mg and Cd and 0.2 nm for Fe.

Results and Discussion

Physico-chemical determinations

Temperature measurements: In this study, the temperature ranged from 24.9 to 25.3°C. However, the quality of water with respect to temperature is usually left to the individual taste and preference and there are no set guidelines for drinking water temperature. The values are below body temperature of 37°C and therefore do not pose any health risk. It can be asserted that the findings of this work

correspond to [10] with similar temperature range between 25.2°C - 26.2°C.

pH measurements: The pH of the borehole samples collected from eight schools ranged from 4.8 to 7.32 (Table 1). The least recorded pH was 4.8 for sample AAC and the highest was 7.32 from SMG. The pH values were low compared to the WHO standard for drinking water (6.5 to 8.5). pH values below 6.5 are considered slightly acidic for human consumption [11]. Acidic water can cause health problems such as acidosis. Sample AAC is considered very acidic. The acidity may be due to the presence of carbon dioxide (CO₂) within the soil zone and other natural biogeochemical processes [12]. Similar pH results were recorded in [13], with the ranges from 5.53-7.21 pH units respectively.

Conductivity measurements: The WHO permissible limit for conductivity of water is 1500 µS/cm [14]. Conductivity levels ranged from 420.00 to 28100.00 µS/cm and 350.67 to 2150.00 µS/cm in borehole and pipe-borne samples respectively. Generally, the conductivity levels in the borehole samples were very high. This indicates the presence of inorganic dissolved salts in the water may cause the water to taste salty [15].

Total dissolved solids and total suspended solids measurements: Total Dissolved Solids (TDS) in the water samples in thirteen schools were high based on the WHO limit of 1000 mg/l. The levels of total dissolved solids in borehole samples ranged from 210.00 to 15700 mg/l and 300.00 to 8220.00 mg/l in pipe borne samples.

Total suspended solids ranged from 0 to 2 mg/l (Table 1). The highest value of 2 mg/l was measured in AAC. Most of the water samples were all below the WHO (2004) limit of 1000 mg/l.

Turbidity and colour measurements: Increasing turbidity values influences the colour of water. All the samples analyzed were clear with turbidity values below the WHO (2004) limit of 5.0 NTU.

Table 3: Levels of anions in both borehole and pipe borne water samples.

| Sample ID | Fluoride - mg/L | Chloride - mg/L | Sulphate - mg/L | Phosphate - mg/L | Nitrate - mg/L |
|------------|-----------------|-----------------|-----------------|------------------|----------------|
| WHO limits | WHO = 1.5 | WHO = 250 | WHO = 250 | WHO = - | WHO = 5 |
| AAC | 0.32 | 662.79 | 71.34 | 0.004 | 0.85 |
| WGR | 0.52 | 602.81 | 75.48 | 0.061 | 0.44 |
| LAP | 0.57 | 482.85 | 20.33 | 0.001 | 0.65 |
| SMR | 0.68 | 4563.58 | 324.34 | <0.001 | 0.74 |
| ACH | 0.31 | 10.00 | 2.64 | 0.003 | 0.49 |
| LBN | 0.89 | 232.93 | 170.36 | 0.003 | 1.50 |
| AGS | 0.62 | 346.89 | 129.51 | 0.023 | 0.96 |
| SMG | 0.37 | 579.82 | 49.51 | 0.042 | 0.93 |
| ODG | 0.47 | 39.39 | 71.53 | 0.001 | 0.60 |
| KBU | 0.38 | 12.00 | 4.89 | 0.002 | 0.43 |
| MRS | 0.28 | 42.59 | 54.97 | 0.003 | 0.48 |
| STA | 0.36 | 8.00 | 2.64 | 0.002 | 0.67 |
| WGS | 0.24 | 39.39 | 63.06 | 0.001 | 0.56 |
| EBN | 0.39 | 44.59 | 54.59 | 0.001 | 0.45 |
| AHS | 0.28 | 10.00 | 2.26 | 0.001 | 0.46 |
| GIS | 0.26 | 8.60 | 3.95 | 0.003 | 0.56 |
| SGP | 0.43 | 43.99 | 63.25 | 0.001 | 0.36 |

Turbidity values ranged from 0 NTU to 2 NTU (Table 1). Even though all the samples were within acceptable limits, sample from EBN however showed significant turbidity value of 2 NTU.

The colour of the water samples from both the borehole and pipe-borne were all of acceptable values with respect to the WHO (2004) guideline value of 15HU (Table 1). Both the borehole and pipe-borne water samples were all aesthetically satisfactory as far as colour is concerned.

Salinity measurements: Salinity levels in the borehole and pipe-borne samples were generally high (Table 1). Sample SMR recorded the highest level of salinity with the value of 17.57‰. This could be attributed to higher concentrations of dissolved salts in the water particularly sodium and chloride ions and the fact that the study area is very close to the sea, especially (SMR). It could even be that the sea water also intrudes into the boreholes located in such places. Comparatively, from the results of Gyamfi et al. (2012), salinity of borehole samples was generally high.

Alkalinity and total hardness measurements: The levels of alkalinity in borehole samples ranged from 10.00 to 310.00 mg/l and pipe-borne samples ranged from 51.33 to 96.00 mg/l (Table 1). All the pipe-borne samples had alkalinity concentration below the WHO (2004) limit. With the boreholes, least alkalinity value recorded was 10.00 mg/l for AAC and the highest was 310.00 mg/l recorded from LBN. LAP, LBN and SMG were all above the WHO (2004) guideline of 200 mg/l. These samples with high alkalinity can dry out skin and cause scaling. However, there does not appear to be serious adverse health effects from drinking water with alkalinity above or below the suggested levels [16].

Total hardness levels in eight borehole samples ranged from 14.67 to 441.33 mg/l and nine pipe-borne samples ranged 28.00 to 105.33 mg/l (Table 1). The borehole and pipe-borne samples were all below the WHO (2004) limit of 500 mg/l. However, samples AAC and SMR showed significant values of 441.33 mg/l and 350.67 mg/l

respectively. These samples may be described as hard water and requires considerably more soap to produce lather. However, all the pipe-borne samples were below the permissible limit of WHO (2004).

Levels of metals measurements

The concentrations of trace metals sodium, potassium, magnesium, zinc, lead, cadmium, iron and calcium in the drinking water samples are presented in Table 2.

Sodium and potassium measurements: Sodium concentrations in all the samples were below the WHO permissible level of 200 mg/l (WHO, 2004) in drinking water except SMR which generated a result of 1208 mg/l.

The potassium level in this study ranged from 0.60 to 14.60 mg/l for borehole samples and 0.50 to 2.40 mg/l in pipe-borne samples. There is no set guideline for potassium in drinking water WHO (2004). The levels of sodium and potassium observed in the borehole and pipe-borne samples (Table 2) under observation can therefore be said to be acceptable and poses no harm to consumers for whatever purpose except sample SMR. It can be asserted that the findings of this work correspond to Zakaria et al. (2012) with similar sodium and potassium concentrations in boreholes. Sodium is an essential element needed by normal body function including fluid regulation, nerve impulse transmission, muscle contraction and relaxation [17,18]. However, in higher concentrations, sodium increases individual risk of hypertension, heart disease and stroke [19]. Sodium and potassium have no health implications and the levels obtained in this study were of acceptable limits except sample SMR which had higher sodium concentration. Areas where water is hard, highly mineralized, sodium concentration is also high. The high sodium concentration in sample SMR could be attributed to the area.

Calcium and magnesium measurements: Calcium ion concentration in the borehole samples ranged from 12.27 to 101.87 mg/l and 5.87 to 30.40 mg/l in pipe-borne samples. For the pipe-borne samples, all the concentrations were below the permissible

limit of WHO (75 mg/l). The least concentration was recorded in sample AHS and the highest in samples WGS and ODG.

Magnesium levels in the borehole samples ranged from 0.77 to 24.20 mg/l. For the pipe-borne samples, all the concentrations were below the permissible limit of WHO. The least magnesium concentration was recorded in sample ACH and the highest in sample SMR. The salts of calcium and magnesium play a major role in bone structure, muscle contraction, blood clotting, cell signaling and impulse transmission [20]. Water is described as "hard" is high in dissolved minerals, specifically calcium and magnesium. Hard water is not a health risk, but a nuisance because of mineral buildup on fixtures and poor soap and/or detergent performance. The degree of hardness becomes greater as the calcium and magnesium content increases and is related to the concentration of multivalent cations dissolved in the water. Therefore samples AAC, WGR, LAP, AGS and SMG with higher calcium concentration could be said to be hard since the magnesium concentrations for those samples were also high as compared to the pipe-borne samples.

Zinc and iron measurements: All the zinc concentrations for the samples were all below the acceptable limit of WHO of 3 mg/l. Concentrations ranged from 0.5 to 1.10 mg/l in borehole and 0.04 to 0.11 mg/l for pipe-borne samples. Samples MRS and STA with zinc concentrations of 0.04 mg/l had the least value while AHS and GIS registered the highest value at 0.11 mg/l. Zinc commonly enters domestic supply from deterioration of galvanized iron and dezincification of brass [20].

Iron concentration in this investigation ranged from 0.01 to 0.08 mg/l (Table 2). The least concentration was recorded in sample ACH and the highest in sample AAC. Looking at the results for iron concentrations in the borehole samples, they were all below the WHO standard of 1.0 mg/l. The iron concentration for sample AGS and SMG were below detection.

For the pipe-borne samples, iron concentrations ranged from 0.01 to 0.03 mg/l (Table 2). Samples ODG, MRS, EBN and GIS registered the least iron concentration and the highest in samples KBU and STA. All the pipe-borne samples were below the WHO standard of 1.0 mg/l. Samples WGS, AHS and GIS had iron concentrations below detection. Iron concentrations at these levels, however, will not pose any health implications.

Lead and cadmium measurements: Lead was above the set standard for WHO of 0.01 mg/l except pipe-borne sample KBU. Lead could enter drinking water from plumbing works, brass and many other alloys that contain it. During high temperatures, Lead can leach into water bodies, therefore with the constant high temperatures in Accra, the leaching of this metal into the underground water table is a highly possibility. Also, with the pipe-borne samples, high lead concentrations could be attributed to plumbing works. High levels of lead have many adverse effects such as renal diseases on the health of consumers [21]. Therefore, all borehole and pipe-borne samples except sample KBU are not recommended for drinking due to high levels of lead concentrations.

Cadmium levels in borehole and pipe-borne samples were below detection. The WHO standard for cadmium in drinking water is however 0.003 mg/l. Cadmium concentrations were all below detection thereby causing no health implications. Cadmium poisoning has been associated with kidney disease, hypertension and possibly genetic mutation [22].

Levels of cations and anions

Levels of anions determined in the water samples are shown in Table 3.

Fluoride measurements: The fluoride level in the eight borehole samples ranged from 0.31 to 0.89 mg/l (Table 3). The least fluoride level was 0.31 mg/l for sample ACH and the highest level 0.89 mg/l was recorded from LBN. The nine pipe-borne samples had fluoride levels ranging from 0.26 to 0.43 mg/l. The least was recorded from sample GIS and the highest, SGP. The fluoride levels of all the borehole and pipe-borne samples were all below the permissible limit of 1.5 mg/l [15]. In general, the dominant controls on fluoride occurrence in groundwater are climate and geology. From these results, water sources in the area of study do not pose any risk of fluoride related disease.

Chloride measurements: Chloride concentrations ranged from 10.00 to 4563.58 mg/l and 8.00 to 44.59 mg/l for borehole and pipe-borne samples (Table 3). The entire pipe-borne samples were within the WHO (2004) limit of 250 mg/l. This is because the pipe-borne water has been treated before distribution. Generally, the chloride concentration in the borehole samples were very high as compared to the permissible limit of WHO (2004) of 250 mg/l. It can be asserted that the findings of this work corresponds to Zakaria et al. (2012) with similar chloride concentrations in borehole ranging between 115.99-499.88 mg/l. Samples which were above the WHO limit were AAC, WGR, LAP, SMR, AGS and SMG. Only samples ACH and LBN were below the permissible limit of the WHO. These high concentrations could be attributed to the fact that water from the boreholes is not treated. The presence of chloride in drinking water has a disinfecting ability but too much of it can be organoleptically unacceptable [15].

Sulphate measurements: The sulphate levels in the eight borehole samples ranged from 2.64 to 324.34 mg/l (Table 3). The least level was recorded in sample ACH and the highest was also recorded in sample SMR. All the borehole samples had sulphate concentrations below the WHO standard of 250 mg/l except sample SMR. The presence of high levels of sulphate in water may contribute to corrosion of distribution system [15]. Aside the bad taste that sulphate gives, it can also act as purgative in humans. Sulphate concentration in pipe-borne samples ranged from 2.26 to 71.53 mg/l. In this investigation, sulphate concentrations in the pipe-borne samples were far below the WHO standard of 250 mg/l.

Phosphate measurements: The phosphate concentrations in the borehole samples ranged from <0.001 to 0.061 mg/l (Table 3). The least phosphate concentration was recorded in sample LAP and the highest WGR. Sample SMR had phosphate concentration below detection limit. From the study, phosphate concentrations correspond to the findings of Gyamfi et al. (2012).

For the pipe-borne samples, phosphate concentrations ranged from 0.001 to 0.003 mg/l. Generally, phosphate concentrations in both borehole and pipe-borne samples were very low. However, various forms of phosphorus as phosphates are applied to drinking water supply network as anti-corrosives to protect the pipes.

Nitrate measurements: Nitrate concentration in this study ranged from 0.44 to 1.50 mg/l for borehole samples (Table 3), with the least recorded in sample WGR and the highest LBN. The permissible limit is 50 mg/l. All the borehole samples were within the permissible limit of WHO (2004). It can be asserted that the findings of this work correspond to Zakaria et al. (2012) with similar nitrate concentration

ranging between 0.00-1.00 mg/l.

The nitrate concentrations recorded in the pipe-borne samples ranged from 0.36 to 0.67 mg/l. The least concentration was recorded in sample SGP and the highest, STA. However, all the pipe-borne samples were below the permissible limit of WHO (2004). Sources of nitrogen and nitrate may include runoff or seepage from fertilized agricultural lands, municipal and refuse dumps. Exposure to high levels of nitrates for a long time could lead to Methaemoglobinaemia [23].

Conclusion

This study was carried out to determine the quality of water sources; thus borehole and pipe-borne water of seventeen second cycle institutions in the Accra Metropolis.

The physico-chemical parameters of the water sources sampled as determined in this study were within the WHO limit except conductivity and total dissolved solids. Most of the water sources had very high conductivity and total dissolved solids levels which corresponding to high salinity levels. The water sources sampled were generally acidic to neutral in pH.

The anions (fluoride, chloride, sulphate, phosphate and nitrate) analyzed in this study were within the acceptable limits of WHO except chloride concentration in the borehole samples. Higher chloride concentration is aesthetically unacceptable and this could be attributed to seawater intrusion.

Trace amount of metals are ubiquitous in water. The essential metals (sodium, potassium, magnesium and calcium) analyzed in this study were below the permissible limit of WHO except concentrations of sodium and calcium. For the sodium concentration, only sample SMR exceeded the WHO limit. Also, all borehole samples had high calcium concentrations except sample ACH. The results showed that, all the water samples were rich in essential metals analyzed [21].

For the concentrations of trace metals, the results showed that Zinc and Iron were below the WHO limit. Cadmium concentrations in all the water samples were below detection therefore, posing no health implications. Again, higher lead concentrations were recorded in all the water samples except KBU. Lead in drinking water poses serious health implications. From the above findings, it can be concluded that water samples except KBU from the study area is unwholesome for drinking according to the WHO standards for drinking.

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