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Effect of Seasonal Variation on Quality of Domestic Water Sources in Central Gonja District

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ABSTRACT

The quality of water sources in the Central Gonja District in the Northern Region of Ghana has been questioned due to activities that pollute water in the area. This research analysed the quality of domestic water sources in the Central Gonja District in terms of pH, EC, Turbidity, Total hardness, Nitrate and Faecal coliform. One hundred and eight (108) water samples were collected from boreholes, rivers, rainwater and dam in the wet and dry seasons within six months. The samples were analysed in the laboratory according to the procedures and protocols outlined in the Standard Methods for the Examination of Water and Wastewater for pH, turbidity, total hardness, nitrate and faecal coliform. Analysis of the water sources showed that the parameters of boreholes measured were seasonally affected except for conductivity which was high in the dry season. All the parameters for river and dam water varied with the seasons. In relation to faecal contamination, the borehole, river water and dam were seasonally affected, and unsuitable for drinking without treatment. Based on the WHO guidelines, rainwater in the area can be regarded as potable owing to its higher quality over the other water sources in the study area. Generally, rainwater can be recommended for drinking, cooking, bathing and washing for the people of Central Gonja District.

Keywords: *Dam; River; Borehole; Rainwater; Season.*

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I. Introduction

Water supply which is easily available, potable and affordable is a prerequisite for good hygiene, sanitation and is central to the general welfare of all living things. The World Health Organisation (WHO) estimated 1.8 million deaths each year due to lack of access to safe water, sanitation and hygiene. However, about 784 million people worldwide still need to gain access to safe drinking water (UN, 2008). The United Nations Environmental Programme (UNEP) estimates show that 250 million people in Africa will be at risk of water stress, less than 1700 m^3 of water available per person per year by 2020 and up to 500 million by 2050 (Falkenmark *etal*., 1989). Sub-Saharan Africa is making the slowest progress in meeting the MDGs target with one-third of the population still need safe drinking water (UN, 2008).

Ghanaians still suffer from water shortages, 50 % of the population uses unimproved sources of drinking water. This figure is 10 % higher than the average for the African continent, where 40 % lack access to improved drinking water supply (Murcott *etal.*, 2008). In the Northern Region of Ghana, 56 % of the population uses unimproved water supplies for drinking. This problem is exacerbated by lack of improved sanitation in the region where 92 % lack access to good sanitation (vanCalcar, 2006).

The water supply situation in the Central Gonja District is grim and water scarcity is regarded as one of the root causes of water related diseases and poverty in the area. Residents of the district rely on boreholes, rainwater, dams, rivers, and dug-outs for their domestic water needs. Some of these water sources serve as drinking places for animals as well, and the health risks posed by this situation are endless and far reaching. This paper assessed the quality of domestic water sources in the Central Gonja District.

II. Methodology

2.1 Water sampling and preservation

First, 52 plastic bottles were soaked in nitric acid (NHO_3) overnight, washed with distilled water, rinsed with deionised water and dried in a drying cabinet. Some of the dry containers were selected, filled with distilled water and the *p*H tested, when it is 7.0 then it is ready for use, otherwise the container was washed and the *p*H tested again. This was done to minimise or eliminate potential contamination of the samples. Water samples were collected from each sampling site between the months of August 2010 and April 2011 that is from August

2010 to November 2010 (wet season) and from January 2011 to April 2011 (dry season). This was done to account for any seasonal variation in the quality of the water sources. In the wet season, fresh rainwater samples were collected directly from the sky using the plastic bottles at Buipe, Yapei and Mpaha towns (12 samples) which served as control. The plastic bottles were raised from the ground by placing them on top of 1 m blocks in order to avoid sand and rain splash and other ground based pollution. Three (3) boreholes were also sampled at Buipe, Yapei and Mpaha towns (36 samples). In addition, the Black and White Volta Rivers were sampled in Buipe and Yapei towns respectively, whilst the Mpaha dam was sampled in Mpaha town (16 samples). The boreholes, rivers and the dam (8 samples) were sampled every month for the wet season. Boreholes were pumped for five minutes prior to sampling to ensure collection of a representative sample. In the dry season, sampling was similarly repeated. The sample containers were clearly labelled with the site, date and time of sampling on the bottles.

2.2 Analysis of Water Samples

The key physico-chemical and biological parameters were determined according to procedures and protocols outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1992).

2.2.1 Water pH

The pH of water samples was determined immediately after sampling using Fisher brand Hydrus 100 pH Meter. Before the measurement was taken, a manual three buffer solutions of pH 4.01, 7.0, and 9.2 were used to calibrate the pH meter. The CALCULATE key was pressed to calibrate and the automatic calibration procedure was followed. The pHs of the samples were measured by reading the values displayed on the screen after the READY signal had disappeared.

2.2.2 Electrical Conductivity

The Hi 9032 Microprocessor Bench Conductivity Meter was calibrated by pressing the TDS key to display ‘TDS’ to confirm the measurement mode. Once the measurement reading stabilizes, the conductivity button on the instrument was pressed to display its value which was recorded on a data sheet.

2.2.3 Turbidity

The Turbidity meter was first calibrated using Formazin polymer. The water samples were allowed to come to room temperature and thoroughly mixed to disperse the solids. After the air bubbles have disappeared, the samples were poured into the turbid meter tube and the turbidity value was read directly from the scale in Nephelometric Turbidity Units (NTU).

2.2.4 Total hardness

25 ml of the well-mixed water sample was measured into a conical flask. 2.0 ml of buffer solution and a pinch of Eriochrome black were added. If the sample turned into wine red in colour, magnesium and calcium was present. The solution was titrated against 0.01 M EDTA until the wine red colour turned to blue. A blank titration was also carried out using distilled water.

Calculation:

$$TH = \frac{(A-B)}{C} \times 1000 \qquad [1]$$

Where; TH: Total Hardness (mg/l), A: Volume of EDTA for sample (ml), B: Volume of EDTA for blank (ml) and C: Volume of water sample (ml).

2.2.5 Nitrate

An aliquot of 2 ml of 0.1 M NaOH solution and 1.0 ml of naphthyl-1, 1-amide was added to the sample. The mixture was allowed to stand for 20 minutes. The nitrate concentration was determined at wavelength 543 nm wavelength of absorbance using a 5500 photometer. A blank analysis was performed with all the reagents without sample for all the analysis.

2.2.6 Faecal Coliform

The Coliscan medium was poured into a sterilized Petri-dish, which was labelled with the code of sampling site and the quantity of sample water used from each site. 250 ml of the sample was measured into the Petri-dish using a sterilized pipette. The water sample was swirled around the Petri-dish to ensure even distribution. The Petri-dish was covered with a lid and set aside at room temperature until the solution solidified. The procedure was repeated for all the samples and the Petri-dishes were incubated at 44 °C for 24 hours. The Petri-dishes were then taken out from the incubator, and all developed dark-blue and pink colonies were counted separately.

Calculation:

$$FC = \frac{C_C}{V_f} \times 100 \qquad [2]$$

Where; FC: Faecal coliform units (cfu/100 ml), CFU: Coliform Faecal Unit per 100 ml, C_C: Colonies counted and V_f: Volume of sample filtered (litres).

2.3 Data Analysis

The mean values of parameters were computed using Microsoft Excel software. Two replicates were made and statistical test (t-test at 5 %) was used to separate the mean values of the parameters measured. Descriptive statistics were also presented using charts and comparing the mean values with WHO Drinking Water Guidelines.

III. Results

3.1 Water pH

The mean pH of borehole water from Buipe town were 8.65 and 7.65 for the wet and dry seasons respectively with significant difference (5.41, $P<0.05$) between the seasons. At Yapei town, the mean pH of borehole water in the wet season was 9.95 whilst the dry season had a value of 8.9 with significant difference (4.51, $P<0.05$) between the seasons. Borehole water from Mpaha town had mean pH of 9.74 for the wet season and 8.85 for the dry season with significant difference (4.51, $P<0.05$) between the seasons.

River water from Buipe had mean pH of 8.9 and 7.70 in the wet and dry seasons respectively. There was significant difference (3.70, $P<0.05$) of pH between the seasons. At Yapei town, the wet season had a mean pH of 9.25 and that for the dry season was 7.85 with significant difference (5.33, $P<0.05$) between the seasons.
The mean pH of the dam at Mpaha town was 8.25 in the wet season and 7.11 was recorded in the dry season. There was significant difference (5.29, $P<0.05$) of pH between the seasons. The mean pH of rainwater from Buipe, Yapei and Mpaha towns were 6.26, 6.37 and 6.82 respectively. There was no significant difference between rainwater from Buipe and Yapei towns (0.34, $P<0.05$). However, significant difference of pH was recorded between rainwater from Buipe and Mpaha (1.84): Yapei and Mpaha towns (1.92) at 0.05 significant levels.

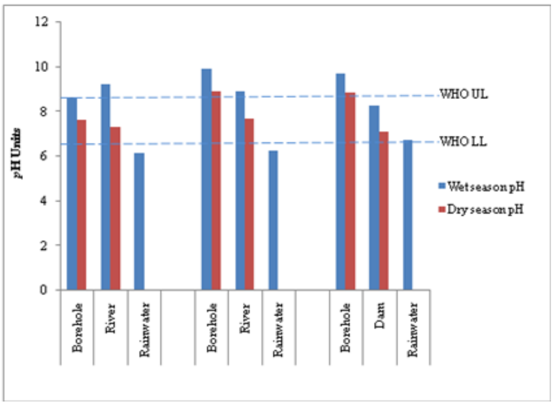

Fig. 1.0: Comparison of water sources in terns of pH

3.2 Electrical conductivity

The mean turbidity of the borehole samples from Buipe town was 2.85 NTU in the wet season and 1.21 NTU in the dry season. The borehole samples from Buipe were not significantly affected (1.05, $P< 0.05$) by seasonal variation in terms of turbidity. The mean turbidity of the borehole samples from Yapei town had 2.51 NTU in the wet season and 1.62 NTU IN the dry season. There was no significant difference (1.57, $P<0.05$) of turbidity between the seasons of the borehole samples from Buipe. The mean turbidity of the borehole samples from Mpaha town was 2.78 NTU and 1.46 in the wet and dry seasons respectively. There was no significant difference (1.63, $P<0.05$) of turbidity occurred between the seasons for the borehole samples from Mpaha town.
The river samples from Buipe town had mean turbidity of 22.8 NTU in the wet season whilst the dry season had a value of 13.10 NTU. There was significant difference (5.09, $P< 0.05$) of turbidity between the seasons for the river samples from Buipe town. In the wet season, the rivers had mean turbidity of 24.95 NTU and 15.25 NTU for the dry season. Significant difference (4.98, $P<0.05$) of turbidity occurred between the seasons. Rainwater samples from Buipe and Yapei towns had mean turbidity of 4.55 NTU, 4.42 NTU and 4.30 NTU respectively.

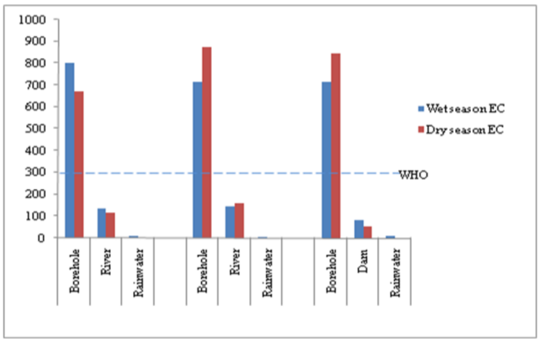

Fig. 1.0: Comparison of water sources in terns of EC

3.3 Turbidity

The mean turbidity of the borehole samples from Buipe town was 2.85 NTU in the wet season and 1.21 NTU in the dry season. The borehole samples from Buipe were not significantly affected (1.05, P<0.05) by seasonal variation in terms of turbidity. The mean turbidity of the borehole samples from Yapei had 2.51 NTU in the wet season and 1.62 NTU IN the dry season. There was no significant difference (1.57, P<0.05) of turbidity between the seasons of the borehole samples from Buipe. The mean turbidity of the borehole samples from Mpaha was 2.78 NTU and 1.46 in the wet and dry seasons respectively. There was no significant difference (1.63, P<0.05) of turbidity occurred between the seasons for the borehole samples from Mpaha town.

The river samples from Buipe had mean turbidity of 22.8 NTU in the wet season whilst the dry season had a value of 13.10 NTU. There was significant difference (5.09, P< 0.05) of turbidity between the seasons for the river samples from Buipe. In the wet season, the river samples from Yapei had mean turbidity of 24.95 NTU and 15.25 NTU for the dry season. Significant difference (4.98, P<0.05) of turbidity occurred between the seasons. The wet and dry seasons had mean turbidity of 31.25 NTU and 23.12 NTU respectively for the dam in Mpaha. However, there was significant difference (2.48, P< 0.05) of turbidity between the seasons. Rainwater samples from Buipe and Yapei had mean turbidity of 4.55 NTU, 4.42 NTU and 4.30 NTU respectively.

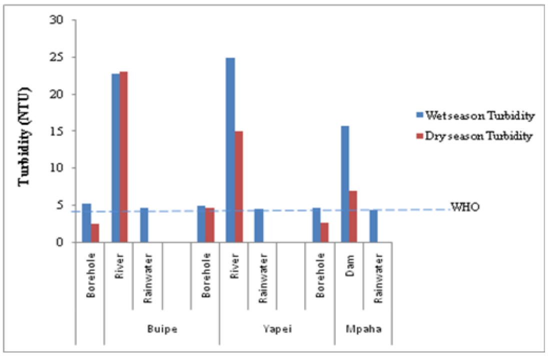

Fig. 1.0: Comparison of water sources in terns of Turbidity

3.4 Nitrate

The borehole samples from Buipe town had mean nitrate concentration of 4.5 mg/l and3.30 mg/l in the wet and dry seasons respectively. There was significant difference (2.52, P<0.05) of nitrate concentration between the seasons borehole samples from Buipe. In Yapei, the mean nitrate concentration was 4.33 in the wet season and 3.30 in the dry season. There was significant variation (2.41, P<0.05) of nitrate concentration between the season for borehole samples from Yapei. The mean nitrate concentration of the borehole samples from Mpaha town in the wet season was 4.25 mg/l and 3.20 mg/l in the wet season. At Buipe, the river samples had mean nitrate concentration of 9.93 mg/l in the wet season whilst the dry season had a value of 5.2 mg/l with significant difference (5.09, P<0.05) between the seasons. The river samples from Yapei town had mean nitrate concentration of 9.59 mg/l and 4.75 mg/l for the wet and dry seasons respectively. Mean concentration of nitrate for the dam in Mpaha was 24.10 mg/l and 20.87 mg/l in the wet and dry seasons respectively. There was significant difference (1.36, P<0.05) between the seasons in terms of nitrite concentration. Rainwater samples from Buipe, Yapei and Mpaha towns had mean nitrate concentration of 2.19 mg/l, 2.15 mg/l and 2.17 mg/l in the wet season.

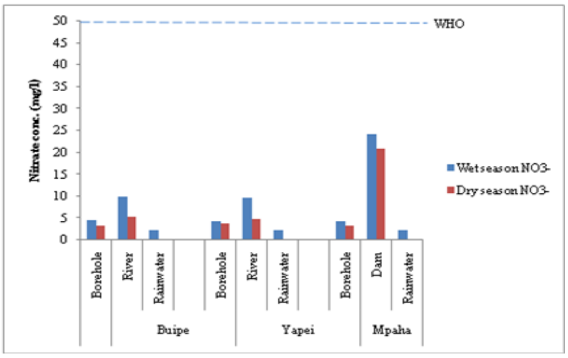

Fig. 2: Comparison of water sources in terms of Nitrate

3.5 Total hardness

The borehole samples from Buipe had mean total hardness of 226.67 mg/l in the wet season whilst the dry season had 170.83 mg/l with significant difference (3.83, $P<0.05$) between the season. The boreholes samples from Yapei had mean total hardness of 163.50 mg/l and 135.41 mg/l for the wet and dry seasons. The borehole samples from Yapei were also significantly affected (1.45, $P<0.05$) by seasonal variation. In Mpaha, the borehole samples had mean total hardness of 125.41 mg/l and 90.83 mg/l for the wet and dry seasons respectively. There was significant variation (1.48, $P<0.05$) of total hardness between the season for the borehole samples from Mpaha. Mean total hardness measured for the river samples from Buipe was 32.67 mg/l in the wet season and 20.35 mg/l for the dry season. The river samples from Buipe were significantly affected (3.32, $P<0.05$) by seasonal variation in terms of total hardness. In Yapei, the borehole samples had mean total hardness of 29.05 mg/l and 21.55 mg/l for the wet and dry seasons respectively. Also, significant difference (1.07, $P<0.05$) of total hardness occurred between the seasons of the Yapei river samples.

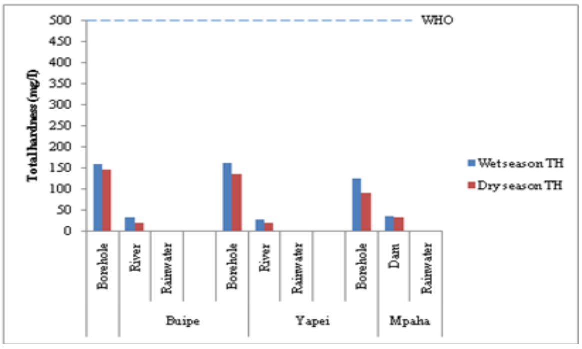

Fig. 3: Comparison of water sources in terns of TH

3.6 Faecal coliform

The mean faecal coliform of borehole samples from Buipe was 25.16 CFU/100 ml in the wet season and 3.33 CFU/100 ml in the dry season. There was significant difference (3.422, $P<0.05$) of faecal coliform between the seasons for the borehole samples from Buipe. In Yapei, the mean faecal coliform recorded for the borehole samples was 43.91 CFU/100 ml and 2.41 CFU/100 ml for the wet and dry seasons respectively. Significant difference (5.37, $P<0.05$) of faecal coliform was found between the seasons for the borehole samples from Yapei. The borehole samples from Mpaha had mean faecal coliform of 16.84 CFU/100 ml in the wet season whilst the dry season had a value of 2.16 CFU/100 ml. The borehole samples were also significantly affected (2.84, $P<0.05$) by seasonal variation in terms of faecal coliform.

The river samples from Buipe had mean faecal coliform of 1720.25 CFU/100 ml in the wet season and 627.5 CFU/100 ml in the dry season. There was significant difference (5.75, $P<0.05$) of faecal coliform between the seasons for the borehole samples from Buipe. In Yapei, the mean faecal coliform for the river samples was 1685 CFU/100 ml and 526.50 CFU/100 ml for the wet and dry seasons respectively. Significant difference (6.23, $P<0.05$) of faecal coliform occurred between the seasons for the river samples from Yapei.

The mean faecal coliform for the dam in the wet season was 904.25 CFU/100 ml and 403.75 CFU/100 ml in the dry season. There was significant difference (6.23, $P<0.05$) of faecal coliform between the wet and dry seasons Faecal coliform was not detected in the rainwater samples from Buipe, Yapei and Mpaha, suggesting that it is devoid of pathogens.

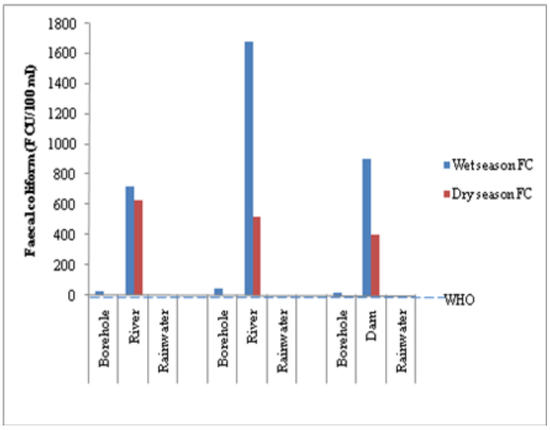

Fig. 3 Comparison of water sources in terns of FC

IV. Discussions

4.1 Borehole Water

The results indicated that borehole water from Yapei and Mpaha towns were alkaline throughout the year. However, the high mean pH in the wet season may be due to the presence of limestone in the aquifer formation that dissolved to release $CaCO_3$ into the water (Freeze and Cherry, 1979). The low mean pH in the dry season may have been caused by high temperatures that increased the concentration of H^+ ions, hence decreasing the pH of the borehole water. There was no significant difference of pH between the borehole water from Buipe and Yapei (1.33): Buipe and Mpaha (1.4): Yapei and Mpaha (0.82) at 0.05 significant level in the wet season. In the dry season, no significant difference of pH was recorded between borehole water from Buipe and Yapei (1.24): Buipe and Mpaha (1.45): Yapei and Mpaha (0.82) at 0.05 significance level. This may be attributed to the almost homogeneous geological materials, mainly sedimentary rocks that underlie the study area (Dickson and Benneh, 2004). The sedimentary rocks are sources of Calcium ions which might have increased the pH of borehole water from the studied towns.

The relatively low conductivity in the wet season may be due to low temperatures that reduced the mobility of the inorganic particles such as carbonate and bicarbonate ions in the aquifer. The conductivity of the borehole samples was higher in the dry season. High temperatures might have enhanced the mobility of the inorganic particles in the aquifer. However, the presence of carbonates, for instance $NaHCO_3$ in the aquifer may give salty taste to the borehole water leading to its rejection. The alkali carbonate resulted from meteoric water dissolving Na^+ from sodium-bearing silicates (e.g. Albite) or reverse cation exchange where Ca^{2+} is taken up from the groundwater, in return for Na^+ helps to refresh the water quality and prevent it from having salty taste (Nii Consult, 1998).

The mean turbidity of borehole samples in the wet season was high. This could be the result of rainwater percolation in the soil that may have dissolved soil particles on its trip to recharge groundwater. The low recharge in the dry season may have resulted in lower turbidity of the borehole water. Generally, the low turbidity of the borehole samples from the communities may be due to the fact that groundwater is naturally filtered by the soil and extracted by filter-aided mechanical pumps.

The presence of nitrates in the boreholes suggests the leaching of dissolved nitrogen from fertiliser application from nearby farms facilitated by rainwater percolation into the groundwater. The low mean nitrate concentration in the borehole samples may be due to the reduction of nitrate to nitrogen gas and ammonia by microbes (e.g. nitrobacteria). A study on the modelling of groundwater flow and quality by Konikow and Glynn (2005) found that the presence of organic carbon (present in the soil) may cause the reduction of NO_3^- to NO_2 and sometimes to NH_4^+ ions in the phase of denitrifying microbes

The high mean total hardness of the borehole samples in the wet season may be due to dissolution of metallic ions such as Mg^{+2}, Ca^{+2} ions from limestone and sedimentary rocks by rainwater percolation in the soil. The ions may have originated from run-offs that infiltrated into the soil, causing leaching and weathering of limestone and feldspars in the soil. The result is the precipitation of Ca^{+2} and Mg^{+2} ions and other mineral constituents in the soil that can also increase the total hardness of groundwater. A study by Freeze and Cherry (1979) of groundwater established that Ca^{+2} and Mg^{+2} ions are usually released into groundwater by the dissolution of limestone, feldspars and micas which increases its hardness. The low total hardness in the dry season may be the result of low aquifer recharge, hence less dissolution of the mineral composition of the aquifer.

The high faecal coliform in the wet season can be associated with the insanitary habits of residents in the studied communities. For instance, the practice of *compound burial* by the inhabitants can be reflected in the presence of faecal coliform in the borehole samples from all the communities. In Buipe and Yapei, the boreholes are located within households and may have been the reason for the higher faecal loads in the borehole samples. However, the boreholes from Mpaha are located 2 km away from the households, and the possibility of faecal contamination may be low. The ingress of coliform bacteria into the groundwater might have been facilitated by rainwater which percolated into the borehole.

4.2 River Water

The high mean pH of river water in the wet season could be due to the release from farmlands of alkaline fertilizers such as ammonia and phosphates carried by run-offs into the rivers. These substances might have altered the acid-base equilibrium and resulted in a lower acid-neutralizing capacity, hence raising the pH of the rivers (Wetzel, 2001). However, the mean pH of the river samples decreased in the dry season. During the dry season, CO_2 is released when phytoplankton and other organic materials in the river decay (Wetzel, 2001). The CO_2 can combine with the water to form HCO_3^- that may have lowered the pH of the rivers in Buipe and Yapei. Significant difference (1.82, $P<0.05$) of pH was recorded between river water from Buipe and Yapei in the wet season. The relatively low pH of Black Volta at Buipe may be due to high concentration of dissolved organic loads (Rickey *etal.,* 1990). The low pH of Black Volta at Buipe might have been caused by high amounts of dissolved sediments.

The relatively high mean conductivity in the wet season can be adduced to run-offs that carried dissolved fertilizer, pesticides, herbicides and other particles from cultivated fields into the rivers. The relatively low mean conductivity may be due to the absence of run-offs in the dry season.

The high turbidity of the river samples from Buipe and Yapei may have been caused by higher flow rates during rainfalls that might have carried sediments and other materials into the rivers. The low mean turbidity of the river samples may be due to the absence of run-offs and the recession in flow level in the dry season.

The high mean nitrate concentration in the wet season can be attributed to run-offs from nearby farms which carried nitrogen fertilizers into the rivers. A study of trading on water by Greenhalgh and Faeth (2001) indicates that in the wet season, run-offs carry nutrients from farmlands and deposit it in the river body. In the presence of denitrifying bacteria, the nitrates may have been converted to NH_4^+ ions which lowered the nitrate concentration of the rivers as confirmed by Konikow and Glynn (2005). The high total hardness of the river samples in the wet season means run-off carried sediments containing Ca^{+2} and Mg^{+2} ions into the rivers.

The high faecal coliform in the wet season may be caused by the massive floods that hit the Central Gonja District between August and December yearly. The floods affected 112 communities with 15 boreholes and 3 public toilets submerged in the district (CGDHD, 2010). Also, the high microbial load in the rivers might be due to contamination caused by human activities and livestock in the area. It is a common practice for people living along the river catchment to discharge domestic and agricultural wastes as well as human excreta into rivers. In addition, children use the river for bathing, washing of clothes and for recreational purposes such as swimming. They also serve as sources of drinking water for livestock which can contaminate the water through direct defecation and urination.

4.3 Rainwater

Buipe and Yapei are situated along the Kumasi-Tamale trunk road, hence the lower mean pH values can be attributed to wet atmospheric deposition of CO_2, SO_2 and NO_2 produced by vehicular emissions including the slash and burn method of land preparation for farming in the study communities. Kohler *et al.* (1997) in their study of the contribution of aircraft emission to atmospheric nitrogen content indicates that rainwater acquires slight acidity as it dissolves CO_2 and NO_2 gases in the atmosphere. Rainwater from Buipe and Yapei may acquire slight acidity from vehicular emissions along the Kumasi-Tamale trunk road as confirmed by Kholer *etal.* (1997). Mpaha is located about 60 km away from the main road which might have accounted for relatively high pH values. Generally, the mean pH of the boreholes, rivers, dam and rainwater sources in Buipe, Yapei and Mpaha areas were within the "safe range" of drinking water. Therefore, no skin diseases are expected in the study area. This may be the reason for no major reported cases of skin diseases in the study area as indicated by 2009/2010 annual report of Central Gonja District Health Directorate.

The low conductivity of rainwater may be due to low levels of organic and inorganic ions in the atmosphere. Further, the low conductivity of fresh rainwater is validated by frequent rainfalls combined with low temperature during the sampling period (wet season). This is probably due to low levels of particulates such as smoke, dust, and soot suspended in the atmosphere which dissolved in the rain droplets as it falls from the sky. This may also be related to the presence of particles of clay, organic components and other microscopic substances (Ovrawah and Hymone, 2001). In addition, the low turbidity in the rainwater samples can be associated with frequent rainfalls during the sampling period. Appiah (2008) studied the physicochemical analysis of roof run-off established that turbidity is affected by dry spell, and the longer the span of continuous rainfalls, the lower is the turbidity.

The presence of nitrates in the rainwater samples may be due to direct dissolution and oxidation of NO_2 to NO_3^- particles caused by the use of nitrogen fertilizers for crop cultivation in the study area. This observation is buttressed by Thomas (1993) in his study of rainwater quality from different roof catchments that in agricultural areas, rainwater could have higher concentration of nitrate due to fertilizer residue in the atmosphere. Rainwater samples from Buipe, Yapei and Mpaha areas recorded 0.00 mg/l mean total hardness. The above is confirmed by Krishna (2003) that the zero hardness of rainwater helps prevent scale formation on appliances. However, there is some indication that very soft water may have adverse effect on mineral balance (Appiah, 2008).

Faecal coliform was not detected in the rainwater samples from Buipe, Yapei and Mpaha, suggesting that it is devoid of pathogens. The absence of coliforms can partly be explained by its mode of collection. Rainwater samples were collected directly into containers as it fell from the sky. However, contamination of rainwater may result from the environment, roof materials and containers which are used for rainwater storage (Polkowska *etal*., 2001). The unacceptable coliform counts in the boreholes, rivers and dam may be linked to the high rate of gastro-enteritis because many inhabitants rely on these water sources for domestic use. Currently, medical records from the District Health Directorate in the study area indicate that diarrhoeal diseases increased by 168 % in 2009 against 2010 318 %, and 321 % for Buipe, Yapei and Mpaha.

V. Conclusion

The results of the study showed that the parameters of boreholes measured were seasonally affected except for conductivity which was high in the dry season. All the parameters for the river and dam water varied with season. In relation to faecal contamination, the borehole, river water and dam were seasonally affected, and unsuitable for drinking without treatment. Based on the WHO guidelines, rainwater can be regarded as potable owing to its higher quality over the other water sources in the study area.

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