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RESEARCH ARTICLE

POLLUTION LEVEL ASSESSMENT OF DAM WATER USED FOR DOMESTIC ACTIVITIES, IN BUILPELA OF THE TAMALE METROPOLIS, GHANA

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ABSTRACT

In the Northern parts of Ghana, highly turbid rainwater runoff and intermittent streams are collected in earthen dams. These dams serve as main source of drinking and domestic water for many communities despite their physical and microbial contamination. This study was conducted at Builpela in the Tamale Metropolis of Ghana to analyse the levels of chemical properties in the dam water used by the people in the area. Eight water samples were collected in May 2012 for the analysis. Atomic Absorption Spectrophotometer (AAS,) Flame photometer, Turbidimeter amongst others were used for laboratory analyses. The mean concentration of the parameters analysed were; 624.1 µS/cm for Electrical Conductivity (EC), 8.72 for pH, 57.3 mg/l for Chloride (Cl^-) 50.1 mg/l for Potassium (K^+), 260.2 for Bicarbonate (CHO_3^-),16 mg/l for Magnesium (Mg^+), and 75 mg/l for Sulphide (SO_4^-). Apart from the mean Arsenic (As) concentration level of 0.0152 mg/l, all the heavy metals (Lead, Cadmium, Mercury) analysed were found to be absent in the dam water. Comparatively, most of the parameters were found to be within the WHO and Ghana EPA limits. pH, CHO_3, K^+ and As were however high in concentration. ANOVA on the concentration of these chemicals at the various banks of the dam realised significant difference for EC, pH and CHO_3^- with F probability ($Fpr < 0.05$) of 0.005, 0.008 and 0.012 respectively. Even though pollution of the water was observed, concentrations were not alarming. The protection of the catchment and upstream activities which result in pollution of the reservoir should be controlled.

INTRODUCTION

Water quality is determined by the physical and chemical limnology of a reservoir (Sidnei *et al.*, 1992) and includes all physical, chemical and biological factors of water that influence the beneficial use of the water. Water quality is important in domestic drinking water supply, irrigation, fish production, recreation and other purposes to which the water must have been impounded. Water quality deterioration in reservoirs usually comes from excessive nutrient inputs, eutrophication, acidification, heavy metal contamination, organic pollution and obnoxious fishing practices. The effects of these "imports" into the reservoir do not only affect the socio-economic functions of the reservoir negatively, but also bring loss of structural biodiversity of the reservoir. Water quality is a growing concern throughout the developing world. Deteriorating water quality threatens the MDG water target of halving the proportion of people without sustainable access to safe water. The chemical contamination of water supplies – both naturally occurring and from pollution – is a very serious problem. As populations, pollution and environmental degradation increase, so will the chemical and microbiological contamination of water supplies (UNICEF, 2008).

Ford (1999), also stated that globally, morbidity is estimated at 4 billion episodes per year, of which 30% (1.2 billion episodes / year) are related to contaminated water. In 2000, the lack of access to safe water remained a problem for over a billion people worldwide, and inadequate sanitation services affected at least 2.4 billion people (WHO and UNICEF, 2000; Mintz and Neufelt, 2001). Cities in developing countries, including Ghana, are experiencing unparalleled population growth coupled with increasing water supply and sanitation coverage which tends to generates large volumes of wastewater and often released untreated into the environment (GSS, 2002). The situation in northern Ghana, is not different thus, poses serious threat to the limited water resources and the environment as a whole. This study seeks to analyze the levels of chemical pollution properties in dam water used for domestic activities by the people of Builpela community in the Tamale Metropolis.

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MATERIALS AND METHODS

Study Area

The study area is Builpela Community in the Tamale Metropolis of Northern Ghana, about 2 km from the Tamale City Center. The dam was built in the year 1960 when the population and population density of Tamale was very low. It was to supply water for domestic use, livestock and vegetable cultivation. Currently due to the high rate of population growth, the Buipela dam is now found in the City and activities of inhabitants in the city highly affect the quality of the water.

Materials and Data Collection

500 ml bottles were used for collecting water samples for laboratory analyses. Ice chest was used to keep the collected water sample during the transport process to the laboratory.

Laboratory Materials

- 4520 conductivity meter
- 3510 pH meter
- Flame photometer
- Turbidimeter
- Atomic Absorption Spectrophotometer (AAS)

Data Collection

Water samples were collected once on 31st May 2012. It was taken direct from the water source to the laboratory for analysis. The reservoir was divided into four banks (A, B, C and D). A total of eight water samples two (2) each from the four banks were collected. The samples were collected in 500 ml bottles which were thoroughly washed with 1:1 nitric acid and distilled water. The samples were stored in ice-chest at a temperature below 4°C and transported to the Water Research Institute's Tamale, Ghana laboratory for analysis.

METHODS

The following standard methods were used for the determination of the levels of the various parameters;

- Electrical Conductivity (4520 Conductivity Meter Method)
- Chloride (Argentimetric Titration Method)
- Bicarbonate (Strong Acid Titration Method)
- pH (3510 pH Meter Method)
- Magnesium (Ethylenediaminetetraacetic acid Titration)
- Arsenic (Atomic Absorption Spectrophotometer Method using Shimadzu model AA 6300)
- Lead (Atomic Absorption Spectrophotometer Method using Shimadzu model AA 6300)
- Cadmium (Atomic Absorption Spectrophotometer Method using Shimadzu model AA 6300)
- Mercury (Atomic Absorption Spectrophotometer Method using Shimadzu model AA 6300)
- Potassium (Flame photometer Method)
- Sulphur (Terbidemetric Method)
- Water samples were prepared using standard methods and procedure for the preparation and analysis process.

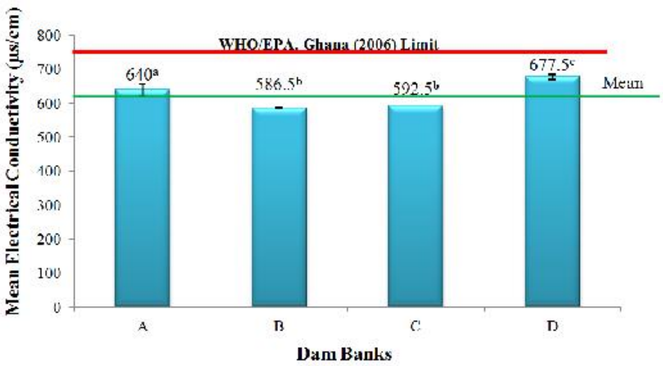
RESULTS AND DISCUSSIONS

General Overview

Varying concentration levels of EC, pH, Cl^-, K^+, CHO_3^-, Mg^+ and SO_4^- were detected in the dam water analysed. Apart from Arsenic (As) the other the heavy metals analysed; Lead, Cd, and Hg were realized to be absent in the dam water. Analyses of variants (ANOVA), at 5% level of significance was performed for the parameters to determine the degree of variation among the four banks (A, B, C, and D) identified for the study. World Health Organization (WHO) (2006) and the Environmental Protection Agency Ghana (EPA) (2006) recommended guidelines limits were adapted to comparatively assess the situation of risk associated with chemical pollution level of the dam water.

Level of Electrical Conductivity (EC)

Generally, conductivity of water is determined to obtain the ability of the water to conduct electrical current. Electrical conductivity is widely used to indicate the total ionized constituents of water. Electrical conductivity is a rapid and reasonably precise determination and values are always expressed at a standard temperature of 25°C to enable comparison of readings taken under varying climatic conditions. It should be noted that the electrical conductivity of solutions increases approximately 2 percent per °C increase in temperature (FAO 1992). Conductivity tests are often used to assess water suitability for irrigation, for which the units used are usually decisiemens per metre. Figure 1 indicates the concentration of EC with respect to the WHO (2006) and EPA, Ghana (2006) recommended limits.



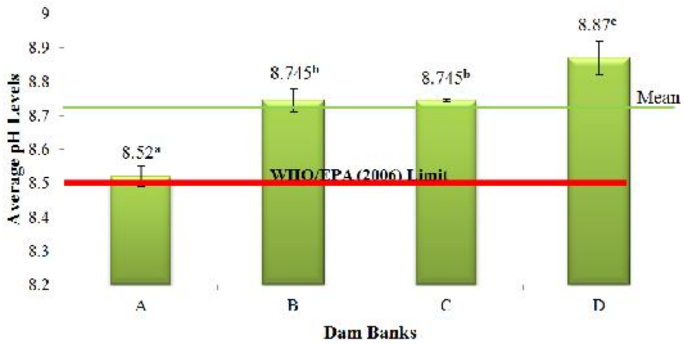
Data labels with different superscripts a, b or c imply significant difference among banks, whiles common superscripts have no significant difference

Figure 1: Electrical Conductivity Levels at Various Banks

It can be noted from Figure 1 that the level of EC recorded in the four banks (A, B, C and D) of the dam ranged, from 586.5 µS/cm to 677.5 µS/cm with bank D recording the highest EC whilst bank B the lowest. Analyses of variance performed at 5% level of significant among the various banks indicated a high level of significant difference with F probability (Fpr <0.05) value of 0.005 and coefficient of variation (CV) of 2%. High level of EC at bank D may be attributed to the large quantity of dissolved mineral salt washed from nearby gardens which are first deposited at bank D, being the mouth of the dam, before dissolving into the entire dam. The overall behaviour may be attributed to low concentration of dissolved ions present in the dam. According to Ansah (2008), anions such as chloride, nitrate, phosphate and sulphate as well as cations such as sodium, calcium, magnesium and iron contribute to the overall conductivity. On average the total EC in the dam is 624.1 µS/cm which falls below WHO and Environmental Protection Agency Ghana (EPA) (2006) guideline limit of 750 µS/cm.

Level of pH

pH is one of the parameters that affects the aesthetic quality of drinking water. The lower values of pH may cause tuberculation and corrosion while the higher values may produce incrustation, sediment deposition and difficulties in chlorination for disinfections of water (Priyanka *et al*., 2009).



Data labels with different superscripts a, b or c imply significant difference among banks, whiles common superscripts have no significant difference

Figure 2. Levels of pH at Various Banks of the Dam

Figure 2 shows that the levels of pH recorded in the four banks (A, B, C and D) of the dam ranged from 8.52 to 8.87 with bank D recording the highest and A the lowest. Variation of levels among the banks was realized to be statistically significant with F probability (Fpr <0.05) of 0.008 and a coefficient of variation of 0.6 %. Average level of pH recorded in the dam is 8.72 which exceeds the WHO and EPA, Ghana guideline limit of 6.5-8.5. This may be attributed to the high metabolic activities of microorganism in the dam. According to Prescott *et al*. (1999), microorganisms change the pH of their own habitat by producing acidic or basic metabolic waste products. The high level of pH in the water may not have direct adverse effects on crops, but can limit the performance of other nutrients (www.aquapurefilters.com/contaminants/111/ bicarbonate, 2012). Fitzpatrick (1996) also stated that high acidity in water and in the soil causes low availability of potash (PO_4), reduce root activity and low form of nitrate, and thus may be a hindrance to improving agricultural productivity. The average concentration of the pH is therefore above the acceptable limit for drinking purposes.

Concentration of Chloride (Cl^-)

Chlorides are usually related to the “salt” content of the water. Water with a high chloride concentration may have a salty taste and will increase the corrosion of plumbing and home appliances. The presence of chlorides in drinking water is generally not considered to be harmful to humans or animals. If a water softener is being used, the taste will be even more pronounced (www.scdhec.gov/environment/water/, 2012).

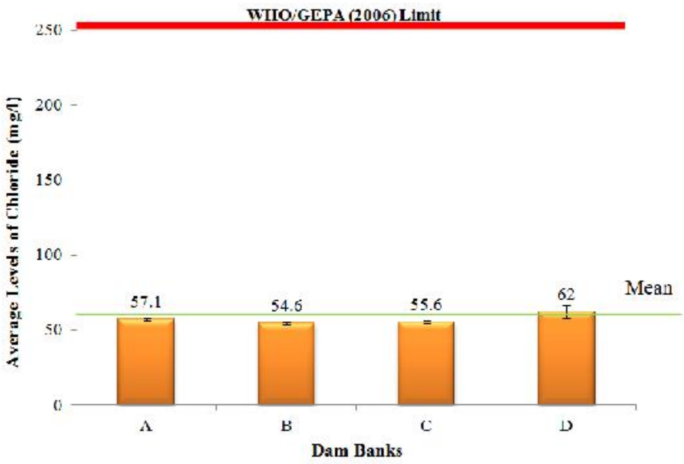


Figure 3. Concentrations of Chloride Ions at Various Banks

It can be observed from Figure 3 that very little Cl^- concentration variation exist among the various banks (A, B, C and D). The ANOVA results indicated that there were no statistical difference between the various banks in relation to Cl^- concentration. A coefficient of variation of 5.8% was however recorded. The overall concentration of Cl^- in the dam was 57.3 mg/l and falls below WHO and EPA, Ghana guideline limits of 250 mg/l. According to Dean (2001), high concentrations of chloride ions may result in an objectionable salty taste to water. High chloride waters may also produce a laxative effect. Higher concentrations do not appear to cause adverse health effects. An increase in the normal chloride content of water may indicate possible pollution from human sewage, animal manure or industrial wastes.

Concentration of Potassium (K^+)

Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. It occurs widely in the environment, including all natural waters. It can also occur in drinking water as a consequence of the use of potassium permanganate as an oxidant in water treatment (WHO, 2009).

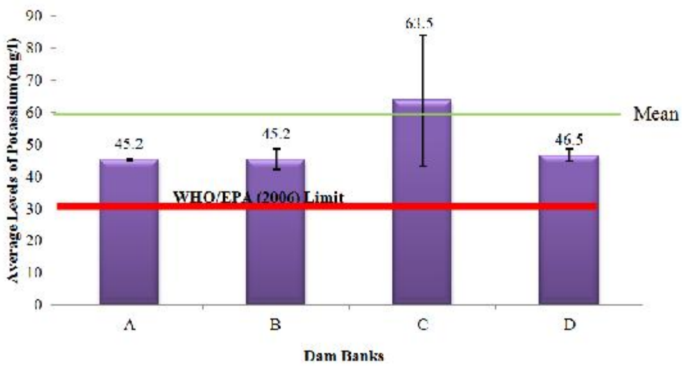


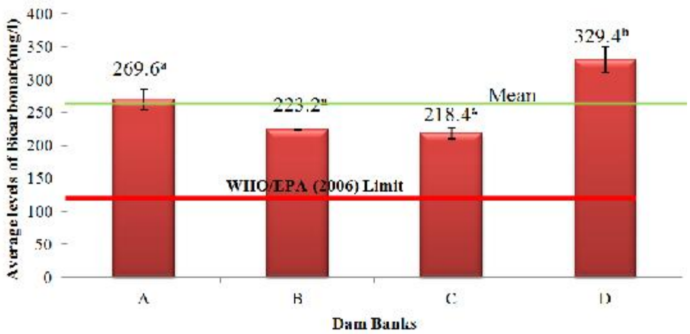
Figure 4. Levels of Potassium at Various Banks

Apart from Bank C little concentration variation exists among banks A, B and D as indicated by figure 4. Statistically insignificant difference was released among the various banks by analyses of variance with F probability (Fpr <0.05) value of 0.584 and a coefficient of variation (CV) of 29.4%. The mean concentration of K^+ in the dam water was 50.1 mg/l which exceeds the (WHO, 2006) and (EPA, 2006) guideline limit of

30 mg/l. The situation of high concentration level of potassium in the water may be attributed to the burning of tires used to process slaughter animals and the application of fertilizers (organic and inorganic) on vegetable crop farms in the catchment area of the dam. According to Gosselin *et al.* (1984), adverse health effects due to potassium consumption from drinking-water are unlikely to occur in healthy individuals. Potassium intoxication by ingestion is rare, because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting.

Concentration of Bicarbonate (HCO_3^-)

Bicarbonate (HCO_3) ion is the principal alkaline constituent in almost all water supplies. Bicarbonate alkalinity is introduced into the water by CO_2 dissolving carbonate-containing minerals (www.aquapurefilters.com/contaminants /111/ bicarbonate, 2012).



Data labels with different superscripts [a] or [b] imply significant difference among banks, whiles common superscripts have no significant difference

Figure 5. Levels of Bicarbonate at the Various Banks

Bicarbonate concentration was statistically significant among the various banks i.e. A, B, C, and D with F probability (Fpr <0.05) value of 0.012 and a coefficient of variation of 7.2% as indicated by Figure 5. The mean concentration of Bicarbonate in the dam water was 260.2 mg/l which exceeds both WHO and GEPA (2006) guideline limit of 120 mg/l by slightly over one fold. The high level HCO_3^- in the water may be attributed to the application of fertilizers (organic and inorganic) on vegetable crops in the catchment area of the dam and runoff from refuse dumps around the dam. Bicarbonate is considered hazardous when concentrations are excessive in some areas and not in others. Waters of high bicarbonate concentrations have been used for many years with no adverse effects in Alberta (AEP, 1997).

Concentration of Magnesium (Mg^+)

Water calcium and magnesium result from decomposition of calcium and magnesium aluminosilicates and, at higher concentrations, from dissolution of limestone, magnesium limestone, magnesite, gypsum and other minerals, (Pitter, 1999). Magnesium plays an important role as a cofactor and activator of more than 300 enzymatic reactions including glycolysis, ATP metabolism, transport of elements such as Na, K and Ca through membranes, synthesis of proteins and nucleic acids, neuromuscular excitability and muscle contraction. It acts as a natural antagonist of calcium. Magnesium deficiency increases risk to humans of developing various pathological conditions such as vasoconstrictions, hypertension, cardiac arrhythmia, atherosclerotic vascular disease, and acute myocardial infarction, eclampsia in pregnant women, possibly diabetes mellitus of type II and osteoporosis (Rude, 1998; Innerarity, 2000; Saris *et al.*, 2000).

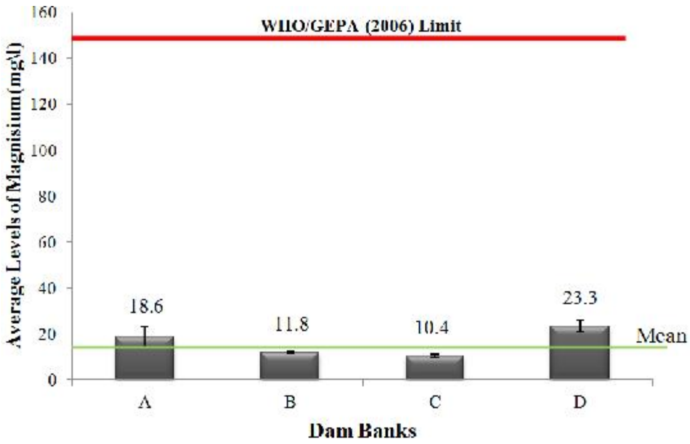


Figure 6. Concentration of Magnesium (Mg^+) at the various Banks

The concentration of Magnesium at the various banks (A, B, C and D) varied though not statistically significant by analysis of variance with F probability (Fp <0.05) of 0.073 and a coefficient of variation of (CV) 23.3%. The mean concentration for the dam water was 16 mg/l, which falls below both (WHO, 2006) and (EPA, 2006) guideline limits of 150 mg/l as shown in Figure 6. According to Cakmak and Ailla (2010), the low level of magnesium in the water will lead to hypercalcemia and depression anxiety in human if they use it as drinking water. When such water is used in crop production, it causes impairment in growth and yield, leaves yellowing in the form of interveinal chlorosis and cannot activate enzymes for photosynthesis and metabolism.

Concentration of Sulphur (SO_4^-)

The source of sulphate according to Mckee and Wolf (1976) could probably be from the mineral rocks anthropogenically added and also enters with rain. Sulphur is utilized by all living organisms in the form of both mineral and organic sulphates. In general, the average daily intake of sulphate from drinking-water, air and food is approximately 500 mg, food being the major source. However, in areas with drinking-water supplies containing high levels of sulphate, drinking-water may constitute the principal source of intake (WHO 2003).

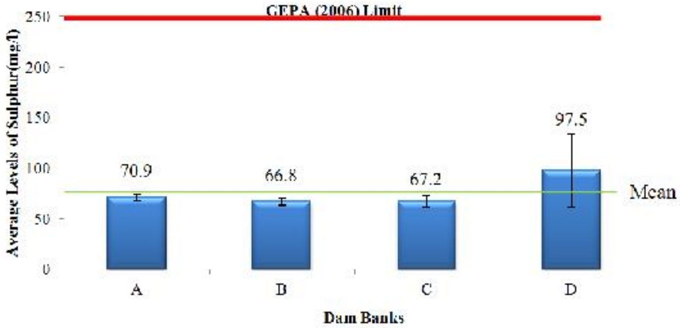


Figure 7. Concentration of Sulphur at the Various Banks

The behaviour of Sulphur also varied at different levels at the various banks (A, B, C, and D) but the variation was statistically insignificant with F probability of 0.631 and a coefficient of variation (CV) of 34.7%. The mean concentration of Sulphur contained in the dam water was 75.6 mg/l which was considerably far below both EPA (2006) and WHO (2006) guideline limit of 250 mg/l and 400 mg/l respectively. Concentration of SO_4^- in water bodies can be attributed to erosion of natural deposits, runoff from orchards and runoff from grasses and electronics production wastes which are transported and deposited in the water. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources (WHO 2003).

Heavy Metals Concentration

Concentration levels of lead, cadmium, mercury and arsenic in the banks where samples were taken have been presented in Table 1

Table 1. Concentration Levels of Heavy Metals in Buipela Dam

Dam Bank	Pb(mg/l)	Cd(mg/l)	Hg(mg/l)	As(mg/l)
A	0	0	0	0.0055
B	0	0	0	0.0055
C	0	0	0	0.005
D	0	0	0	0.045
Grand Mean	0	0	0	0.0152
F pr (< 0.05)	-	-	-	0.322
WHO (2006)	0.05	0.003	0.01	0.01
EPA Ghana (2006)	0.1	0.005	0.2	1.00

It can be observed from the results presented in Table 1 that the concentration levels of Pb, Cd and Hg were 0 mg/l in the water. This implies that activities upstream of the dam do not really affect the quality of the water in terms of pollution regarding these parameters. The results however showed varying levels of concentration of As in the water this was observed to range from 0.005 mg/l to 0.045 mg/l. The average concentration in the dam recorded during the study was 0.0152 mg/l which exceeds the WHO, (2006) guideline limit of 0.010 mg/l but falls below EPA (2006), Ghana limit of 1.0 mg/l. Concentration at the various banks were realised not to be statistically significant as in Table 1 with F probability ($Fpr<0.05$) of 0.322. The presence of As in the water may be attributed to the use of wood and car tyres for the processing meat at the slaughter house upstream. Sources of As exposure includes burning plywood treated with an arsenic wood preservative or dermal contact with wood treated with arsenic. Again runoff from electronics production waste is another source of arsenic exposure (ATSDR 1990).

Conclusions

Largely, physico-chemical parameters are very important in the quality assessment of water used for domestic activities. The usage of the dam water at Builpela can be described as being environmentally safe since most of the parameters were found to be within the WHO and EPA, Ghana guideline limits, with the exception of pH, Bicarbonate, potassium and Arsenic. Upstream activities which cause the pollution of water bodies regarding these pollutants therefore need to be assessed to avoid further or an increase in contamination. Education of inhabitants who use the water for many household activities is very important in an attempt to reduce human contamination and diseases.

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