# Heavy metal and drinking water quality on a river system at the Lower Manya Krobo and South Tongu districts, Ghana

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## Abstract

The water quality examination at the Lower Manya Krobo and South Tongu districts of Ghana was conducted by determining the physico-chemical parameters at 38 sampling sites. The ranges of physico-chemical parameters analysed were 6.45 to 7.26 for pH, -053 to -010 mV for Eh, 26.5 to 30.9$^{o}$C for temperature, 61.7 to 83.6 µS/cm for EC, 0 ‰ for salinity, 29.7 to 39.4 mg/L for TDS, 0.63 to 2.28 mg/L for DO, 0 to 4 NTU for turbidity, 0 to 8 mg/L for TSS, 36 to 108 mg/L for total hardness, 0.8 to 5 mg/L for BOD, 23.16 to 46.33 mg/L for $HCO_3^-$, 2.92 to 23.33 mg/L for $Mg^{2+}$, 7.8 to 11.0 mg/L for $Na^+$, 4.0 to 5.9 mg/L for $K^+$, 1.99 to 13.99 mg/L for $Cl^-$, 3.2 to 14.4 mg/L for $Ca^{2+}$, 1.0 to 24.88 mg/L for $NO_3^-$, 6.55 to 28.11 mg/L for $SO_4^{2-}$ and 1.33 to 11.66 mg/L for $PO_4^{3-}$. While the results for dissolved metals (µg/L ) were 32 to 348 for Fe, 12 to 278 for Mn, 16 to 84 for Cu, 4 to 38 for Pb, 20 to 162 for Ni, 12 to 32 for Cd and 12 to 98 for Cr. Hg, Se, V and Zn were below detection limit. Except Cu which was low, about 37%, 87%, 29%, 33%, 8% and 29% of the sampling sites had Pb, Ni, Cd, Cr, Fe and Mn values, respectively, above the WHO (2004) standard for drinking water. Therefore, effective water quality management is strongly needed.

**Keywords**: Lower Manya Krobo, South Tongu, Lower Volta River, physico-chemical parameters, trace elements

## 1.0 Introduction

Water is a universal solvent essential to man for various activities such as drinking, cooking, industrial and agricultural processes, waste disposal and human recreation. In view of its occurrence and distribution pattern, water is not easily available to man in the desirable amount and quality. This is a problem experienced in most cities and towns in the developing nations not to mention their rural settings. These factors have lead to the growing rate of water borne diseases like typhoid, guinea worm, onchocerciasis and schistomiasis experienced in this part of the world (Edwards, 1993). Even in the developed nations like the United States of America, cases of outbreaks of diseases associated with contaminated portable water were reported (Moore et al., 1993). Water quality is an index of health and well being of a society. Pollution of water bodies is one of the areas of major concern to environmentalists. Industrialization, urbanization and modern agriculture practices have direct impact on the water resources. These factors influence the water resources quantitatively as well as qualitatively. Various factors are responsible for water pollution, which makes it quite undesirable for portability. Such factors include: domestic waste, which contributes to oxygen demand and nutrient loading to a destabilized aquatic ecosystem (DWAF and WRC, 1995; WRC, 2000), agricultural practices and industrialization. Pollution easily arises when population growth outmatches availability of potable water due to inadequate urban planning process coupled. Among environmental pollutants, metals are of particular concern, due to their potential toxic effect and ability to bioaccumulation in aquatic ecosystems (Miller et al., 1993; Censi et al., 2006). Hence, it has public interest (Gibbs, 1972; Niemi et al., 1990). These serious environmental problems have been faced in developing as well as developed countries (Listori et al., 1990). Contamination of aquatic ecosystems with heavy metals is a serious problem, all over the world (Solak et al., 1995; Wagner et al 2003) and needed to be addressed.

The study area spans from the Akuse part of the Volta River which is in the Lower Manya Krobo district and is between latitude 6°05'S, 6°30'N and longitude 0°08'E, 0°20'W to Sogakope which lies in the South Tongu district and is between latitudes 6°10'N, 5°45'N and longitudes 30°30'W, 0°45'W (Figure 1). An investigation through major towns in the study area revealed that the major water sources for most activities is the untreated water from the Volta River, accounting for about 37% of the entire water sources used (Amoah and Koranteng, 2006). This water source is the alternative to the inconsistent flow of pipe borne water supply, which would have been more reliable source of safe water for the growing population. Therefore, constant monitoring of river water quality in the area is needed so as to record any alteration in the quality, which may lead to outbreak of health disorder or serious health effect.

## 2.0 Materials and methods

Thirty eight surface water were sampled at sites as shown in (Figure 1) using pre-washed polythene containers. The sampling was done in July, 2011in the rainy season and February, 2012 in the dry season. pH, redox potential (Eh), temperature, electrical conductivity (EC), salinity, total dissolved solute (TDS), total suspended solids (TSS), turbidity, bicarbonate ion ($HCO_3^-$) and dissolved oxygen (DO) were determined in the field. The pH, Eh and temperature were determined using a (Ecoscan Ion 5) pH meter. Electrical conductivity (EC), salinity, and total dissolved solutes (TDS) were determined using a Specific conductance meter (HACH SensIon5). The dissolved oxygen (DO) was determined by using the Winkler's Method (APHA, 1998) and bicarbonate ion ($HCO_3^-$) was determined using HACH – Loveland Co. USA digital titrator. The chloride was determined by argentiometric method, phosphate by Vanadate-molybdate method, sulphate by turbidimetry method and nitrate by UV spectrophotometeric method (APHA, 1998). Total hardness (TH) was estimated by the complexometric titration with standard EDTA solution using Eriochrome BlackT as indicator. A DR/890 Calorimeter was used for the determination of total suspended solids and turbidity by the probe method. Samples for biological oxygen demand (BOD) were incubated in the laboratory for five days at $20^0$C and determined by the Winkler's Method (APHA, 1998). Sodium and potassium ions were determined by flame photometry (AWWA, 1998).

In the laboratory the dissolved trace metal concentrations in the water samples were determined for Fe, Mn, Cu, Pb, Ni, Cd, Cr and Zn by direct flame Atomic Absorption Spectrometry (AAS). A 6ml of 65% $HNO_3$, 3ml of 35% HCl, and 0.25ml of $H_2O_2$ were added to 5ml of water samples in teflon beaker. The resulting solutions were put into Ethos 900 Microwave for 30 minutes at 250 watts power for digestion. The digested solutions were topped to 20ml by adding de-ionized distilled water. The solutions were thoroughly mixed and aspirated into the spectrometer (Varian AA240 Fast Sequential Atomic Absorption Spectrometer) following specifications outlined for each element in the cook book of AAS. Hg and Se were determined using the hydride generation method (HGAAS) (APHA, 1998).

Mg, Ca, Cu and V were determined by Instrumental Neutron Activation Analysis (INAA). A 0.5ml volume of sample was transferred with calibrated Eppendorf tip ejector pipette (Brinkmann Instruments, Inc. Westbury New York) into pre-weighed 1.5 ml polyethylene vials with a piece of cotton, capped and heat sealed to obtain a mass of 500mg. The cotton wool was added as a safety measure to avoid the sample spilling and spreading radioactivity in case the vial opens in the reactor or whilst coming out of the reactor. Irradiations were performed using the Ghana Research Reactor-1 (GHARR-1) facility at Ghana Atomic Energy Commission, Kwabenya.

The results of the AAS, INAA and UV visible spectrophotometry analyses of standard reference materials of reported values of the ionic and elemental compositions were compared with those of the local laboratory. The precision of the parameters analyzed were calculated as percentage relative standard deviation (%RSD) of six replicate measurements and were found to be within 10%.

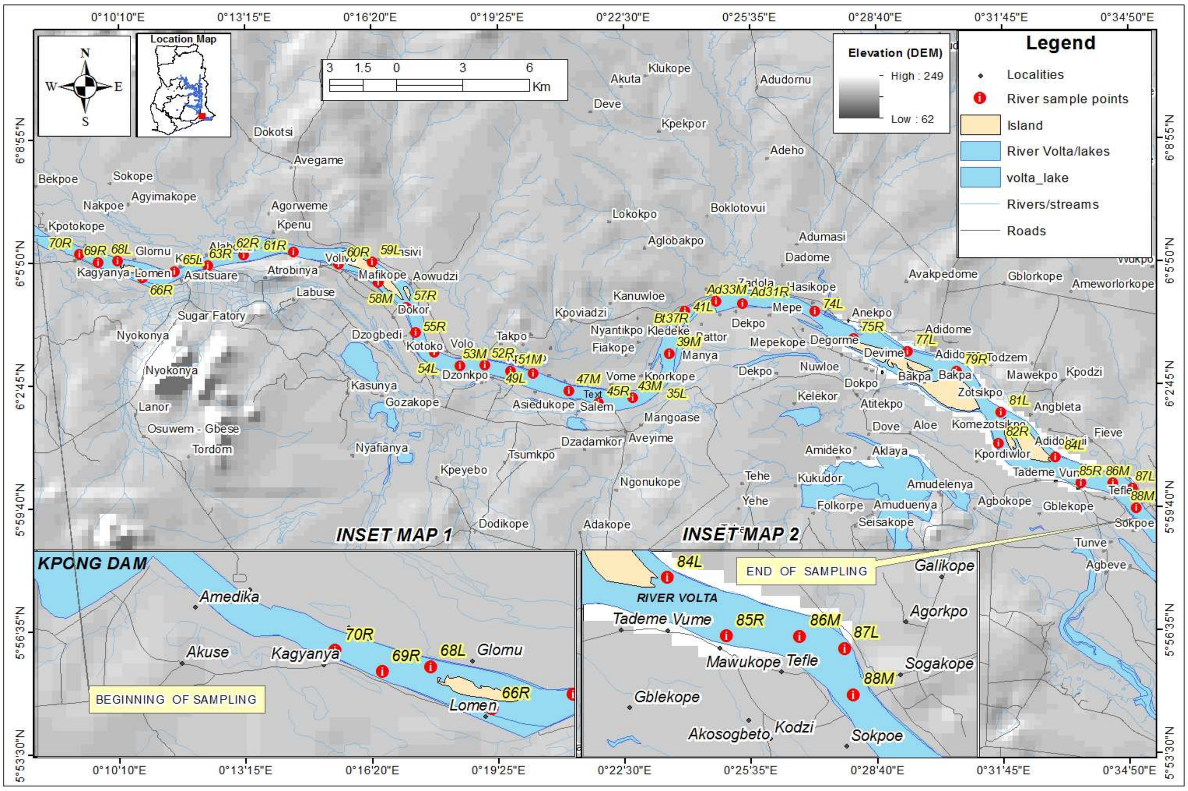

Figure.1. Location map showing the river water samples collecting sites.

## 3.0 Results and discussion

The water quality parameters at the 38 sampling sites are summarized in Table 1.

### pH, Redox potential (Eh) and Temperature

The pH values which measure how acidic or basic water is, ranged from 6.45 to 7.26 for all sampling sites with a mean value of 6.9 (Table 1) falling within the World Health Organization Standards (WHO 2004) for drinking water indicating neither a threat to biological life nor causing skin-eye irritation problems during contact due to water sports. These could be described as moderately acidic to neutral waters. The redox potential (Eh) also ranged from -053 to -010 mV with a mean value of -032 mV. All the sampling sites had negative Eh potentials indicating reducing environment in the surface water. Water temperature ranged from 26.5°C to 30.9°C with a mean value of 28.8 °C.

### Electrical conductivity (EC), Salinity and Total dissolved solutes (TDS)

The electrical conductivity (EC) of the water samples ranged between 61.7 to 83.6 µS/cm with a mean value of 70.4 µS/cm. The salinity of all the water samples was recorded to be 0 ‰. The EC values observed at all the sampling sites were less than 1400 µS/cm set by the WHO (2004) standard for drinking water. Total dissolved solutes (TDS) were found ranging from 29.7 to 39.4 mg/L with a mean value of 33.6 mg/L. The primary sources for TDS in the study area could be attributed to agricultural runoff and leaching of soil contaminant. Thus, according to the Ghana Environmental Protection Agency (GEPA) and WHO (2004) standards, which gave the TDS recommended limit as 1000 mg/L, the water could be safe enough for use.

### Dissolved oxygen (DO) and Biological oxygen demand (BOD)

Dissolved oxygen (DO) ranged from 0.63 to 2.28 mg/L with a mean value of 1.07 mg/L. The DO refers to the amount of oxygen dissolved in the water and it is particularly important in limnology (aquatic ecology) (Weiss 1970). The value of DO is of critical importance because low DO causes reduction in specific fish and loss of aquatic ecosystem. The major factors controlling dissolved oxygen concentration are photosynthesis producing oxygen while respiration and nitrification consume oxygen (Best et al., 2007). The study area is farming and a fishing community hence fertilizers and pesticides which get into the water could affect the growth of aquatic plants, thus affecting the photosynthetic rate resulting in low DO. The water lacked aquatic plants which produced oxygen through respiration (Best et al. 2007), thus resulting in low DO. BOD concentration ranged from 0.04 to 0.47 mg/L with a mean concentration of 0.21 mg/L. Since all the values were within the WHO (2004) standards for drinking water which is 0.8 to 5 mg/L, it could mean that the water from the whole area is less polluted by organic matter and could therefore support aquatic life.

Table 1: Statistical summary of physico-chemical parameters determined at 38 sampling sites (N=38) in the study area.

| Parameter | Unit | N | Min. | Max. | Mean | Median | Std.Dev. | WHO (2004) limit | GEPA Std |
|---|---|---|---|---|---|---|---|---|---|
| pH | | 38 | 6 .45 | 7.26 | 6.9 | 6.86 | 0.19 | 6.5-8.5 | 6.5-8.5 |
| Eh | mV | 38 | -053 | -010 | -032 | -032 | 9.31 | - | - |
| Temp | °C | 38 | 26.5 | 30.9 | 28.8 | 28.8 | 1.19 | - | - |
| EC | μS/cm | 38 | 61.7 | 83.6 | 70.4 | 69.1 | 5.4 | 1400 | - |
| TDS | mg/L | 38 | 29.7 | 39.4 | 33.6 | 33.2 | 2.38 | 500 | 1000 |
| Salinity | ‰ | 38 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | - |
| DO | mg/L | 38 | 0.63 | 2.29 | 1.09 | 0.93 | 0.43 | - | - |
| TURB | NTU | 38 | 0 | 4 | 0.72 | 2 | 1.04 | 5 | 5 |
| TH | mg/L | 38 | 36 | 108 | 55.63 | 52 | 13.41 | 130 | |
| TSS | mg/L | 38 | 0 | 8 | 1.85 | 1 | 1.82 | - | - |
| BOD | mg/L | 38 | 0.04 | 0.47 | 0.21 | 0.2 | 0.074 | 0.8-5.0 | |
| $HCO_3^-$ | mg/L | 38 | 23.16 | 46.33 | 35.28 | 35.24 | 3.63 | - | - |
| $Mg^{2+}$ | mg/L | 38 | 2.92 | 23.33 | 10.00 | 9.72 | 3.47 | 50 | |
| $Na^+$ | mg/L | 38 | 7.8 | 11.0 | 8.65 | 8.6 | 0.69 | 200 | |
| $K^+$ | mg/L | 38 | 4.0 | 5.9 | 5.19 | 5.2 | 0.34 | 12 | |
| $Cl^-$ | mg/L | 38 | 1.99 | 13.99 | 4.44 | 3.99 | 2.74 | 250 | |
| $Ca^{2+}$ | mg/L | 38 | 3.2 | 14.4 | 5.98 | 5.60 | 2.37 | 100 | |
| $NO_3^-$ | mg/L | 38 | 1.00 | 24.88 | 11.74 | 9.94 | 9.32 | 50 | |
| $SO_4^{2-}$ | mg/L | 38 | 6.55 | 28.11 | 17.48 | 18.33 | 6.3 | 250 | |
| $PO_4^{3-}$ | mg/L | 38 | 1.33 | 11.66 | 4.98 | 4.667 | 3.07 | - | - |
| Fe | μg/L | 38 | 32 | 348 | 92.82 | 44 | 109.30 | 300 | - |
| Mn | μg/L | 38 | 12 | 278 | 80.53 | 60 | 71.33 | 100 | - |
| Cu | μg/L | 38 | 16 | 84 | 24.84 | 24 | 21.89 | 2000 | - |
| Hg | μg/L | 38 | <1 | <1 | <1 | <1 | <1 | 0.01 | 0.2 |
| Pb | μg/L | 38 | 4 | 38 | 20 | 19 | 10.19 | 10 | |
| Ni | μg/L | 38 | 20 | 162 | 79.92 | 72 | 45.03 | 20 | |
| Cd | μg/L | 38 | 12 | 32 | 5.39 | 20 | 8.89 | 3 | - |
| Cr | μg/L | 38 | 12 | 98 | 42.27 | 36 | 28.02 | 50 | |
| Zn | μg/L | 38 | <1 | <1 | <1 | <1 | <1 | 3000 | 10000 |
| Se | μg/L | 38 | <1 | <1 | <1 | <1 | <1 | - | - |
| V | μg/L | 38 | <2 | <2 | <2 | <2 | <2 | - | - |

N=Total number of data points
World Health Organization (WHO)
Ghana Environmental Protection Agency (GEPA)
Standard (std)

**Turbidity and Total suspended solids (TSS)**

Turbidity values ranged narrowly from 0 to 4 NTU in the study area with a mean value of 0.72 NTU. Total suspended solids (TSS) ranged from 0 to 8 mg/L with a mean value of 1.85 mg/L. The highest values for TSS were recorded at sampled sites 82R, 79R, 75R, and 70R with values ranging from 4 to 8 mg/L. Turbidity and TSS determine the amount of particulate matter that is suspended in water. TSS and turbidity are typically composed of clay, silt, organic and inorganic matter, plankton and microscopic organisms (Lawler, 2004). High turbidity and the associated suspended solid concentrations have important ecological impacts, because of light suppression effects. The high turbidity and TSS values measured at sampling sites AD31R, 52R, 60R, 82R, 79R, 75R and 70R may be the results of organic and inorganic wastes flowing into the river water from the residential areas, erosion, storm water runoff, and microorganisms. The WHO (2004) and Ghana Environmental protection Agency (GEPA) standard for drinking water for turbidity is 5 NTU and all of the values determined fell below this limits.

**Total hardness (TH)**

Total hardness ranged from 36 to 108 mg/L with a mean value of 55.63 mg/L. “Soft” and “Hard” water have been associated with total hardness over the years and this has been classified by Durfor and Becker (1964) as follows: Soft (0 to 60 mg/L), Moderately hard (61 to 120 mg/L), Hard (121 to 180 mg/L) and above 180 mg/L as

Very hard. About 76% of the sampled water felt within the soft category, hence the water in the study area could be said to be “Soft”.

**Bicarbonate ($HCO_3^-$), Magnesium ($Mg^{2+}$), Sodium ($Na^+$) Potassium ($K^+$) Chloride ($Cl^-$) and Calcium ($Ca^{2+}$)**

Bicarbonate ion ranged between 23.16 to 46.33 mg/L with mean value of 35.28 mg/L. $Mg^{2+}$ ranged from 2.92 to 23.33 mg/L with mean value of 10mg/L. $Na^+$ and $K^+$ values ranged from 8.53 mg/L to 8.78 mg/L and 4.0 to 5.9 mg/L, respectively. The mean for $Na^+$ was 8.65 mg/L and $K^+$ was 5.19 mg/L. $Ca^{2+}$ concentrations ranged from 3.2 to 14.4 mg/L with a mean value of 5.98 mg/L. $Mg^{2+}$, $Na^+$, $K^+$, $Cl^-$ and $Ca^{2+}$ ions in the river water could come from household wastewaters which contain high concentrations of these salts and soaps. These salts could also come from spillages of oil from outboard motors of canoes. The salts could also come from a tissue manufacturing factory located upstream which releases effluent containing bleaching powder into the Volta River. $Mg^{2+}$, $Na^+$, $K^+$, $Cl^-$ and $Ca^{2+}$ had their concentrations at all the sampling sites below the WHO (2004) standards for drinking water.

**Nitrate ($NO_3^-$)**

Nitrate concentration ranged from 1.0 to 24.88 mg/L whiles the mean was 11.74 mg/L. The lowest and highest concentrations were recorded at sampling sites 51M (1.0 mg/L) and 54L (24.88 mg/L), respectively. About 21% of the sampling sites had values that were below the detection limit (<0.001 mg/L). All the values were below the WHO (2004) standards for drinking water which is 50 mg/L. Sewages generated from domestic activities could be sources of $NO_3^-$ in the area. The $NO_3^-$ could also originate from ammonium and $NO_3^-$ fertilizers used in farmlands located along the banks of the river.

**Sulphate ($SO_4^{2-}$)**

Sulphate ion concentration ranged from 6.55 to 28.11 mg/L. The mean value was 17.48 mg/L. The sulphate could be released into the river water from agricultural activities and animal husbandry.

**Phosphate ($PO_4^{3-}$)**

Phosphate concentration ranged from 1.33 to 11.66 mg/L with a mean concentration of 4.98 mg/L. About 8% of the sampling sites (75R, 51M and 59L) had values below the detection limit (<0.001 mg/L). Non-point sources of phosphates may include: natural decomposition of rocks, agricultural runoff, atmospheric deposition and direct input by animals/wildlife; whereas point sources may include: aquaculture activities and industrial discharges upstream. Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate (Morrison et al., 2001). About 37% of the sampling site exceeded the 5 mg/L set as standard in South Africa (Morrison et al., 2001). High concentration of phosphate at this level may lead to eutrophication of the water body, which can reduce their recreational use and also endanger aquatic life.

## 4.0 Dissolved trace metal concentrations

The dissolved metal concentrations in the water samples are also presented in Table 1. The wide range of concentrations of trace metals found in all the sampling sites showed signs of trace metal pollution.

**Iron (Fe)**

The concentration of Fe ranged from 32 to 348 µg/L with a mean concentration of 92.82 µg/L. About 37% of the sampling sites recorded values that were below the detection limit (<6 µg/L). When compared to the WHO (2004) standards for drinking water, the normal criterion for Fe is 300 µg/L. There were only a few places that exceeded this value and this included 87L, 84L and 69R. The sources of Fe could be due to runoff from domestic activities as well as waste water releases from Akosombo and Juapong Textile factories upstream. The iron content of river and lake waters also can be influenced by aquatic vegetation, both rooted and free-floating forms (Oborn and Hem, 1962).

**Manganese (Mn)**

Dissolved Mn ranged from 12 to 278 µg/L. The mean value was 80.53 µg/L. Water samples at sites 86M, 61R and 70R had values below the detection limit (<2 µg/L). About 71% of the water sampled had values that fell within the 100 µg/L set by WHO (2004) standard for drinking water whiles the rest had values above this limit. Also about 92% of the samples met the 180 µg/L levels for Mn in water meant for aquatic ecosystem use (Fatoki et al., 2002). The trace metal manganese could come from domestic waste and runoffs from small scale Agro processing and pottery industries located in the study area.

**Copper (Cu)**

Copper concentration ranged from 16 to 84 µg/L with a mean concentration of 24.84 µg/L. About 30% of the sampling sites had values below the detection limit (<3 µg/L). The lowest and highest values of Cu in the water samples were recorded at 41L (16 µg/L), 55R (16 µg/L) and 62R (84 µg/L), respectively. The sources of Cu in the study area may be due to corrosion of household plumbing systems and erosion of natural deposits which get into the river. The concentration of Cu was below 2000 µg/L set as the maximum that is allowable for drinking water (WHO, 2004), and this could pose no danger to the community.

**Lead (Pb)**

Lead concentration ranged from 4 to 38 µg/L. The mean concentration was 20 µg/L. About 53% of the sampling sites recorded values below the detection limit (<1 µg/L). Also about 15% of the sampling sites had values within WHO (2004) standard for drinking water. The rest of the sites (about 32%) recorded values that were above the WHO (2004) standard of 10µg/L and maximum contaminant level (MCL) of 15 µg/L for drinking water (Nkono and Asubiojo, 1997). It is evident that Pb is used in paints (pigments), batteries, pesticides, herbicides which happens to be human activities that introduce Pb into the water body. Lead in drinking water can be toxic. According to U.S. Environmental Protection Agency (1999), the health effect of too much lead in human can cause serious damage to the brain, kidneys, nervous system, and red blood cells. High lead levels can also cause high blood pressure in adults and paralysis of the wrists and ankles. Therefore, the water samples at those sites need to be treated so that the lead level meets these standards before it could be safe for drinking and used for domestic activities.

**Nickel (Ni)**

Dissolved nickel values ranged from 20 to 162 µg/L with a mean concentration of 79.92 µg/L (Table 1). Sampling sites 86M, 84L and 53M recorded values that were below the detection limit (<1µg/L) representing 8% of sampling sites. About 89% of sampling sites had values above the WHO (2004) standard for drinking water which is 20 µg/L (Figure 2). Larger doses of nickel are carcinogenic and toxic affecting the skin, teeth, and bones of consumers. The sources of Ni in the water samples could come from the waste water releases from the Akosombo and Juapong Textile factories located upstream, since nickel is present in nickel acetate which is usually applied as a mordant in textile printing.

**Cadmium (Cd)**

Dissolved Cd concentration ranged from 12 to 32 µg/L with a mean concentration of 5.39 µg/L. About 71% of the sampling sites recorded values below the detection limit (<2 µg/L). The rest of the sites (about 29%) had values above 3 µg/L set as the maximum that is allowable for drinking water (Figure 2). Factors such as the dumping of agricultural wastes, usage of pesticides and leaching of metals from wastes site to the water could be responsible for the observed high concentrations of Cd at those sites. Hence the water at those sampling areas may pose danger to the health of the community.

**Chromium (Cr)**

Dissolved Cr concentration ranged from 12 to 98 µg/L with a mean concentration of 40.27 µg/L. Sampling sites 84L, 39M, 53M and 57R recorded values below the detection limit (<1µg/L) representing about 11% of sampling sites. Also about 55% of the sampling sites had values below the 50 µg/L set by WHO (2004) standards for drinking water. The rest (about 34%) recorded values above the 50 µg/L set by WHO (2004) standard for drinking water (Figure 2). The observed high concentration of Cr at those sites could be due to wide use of Cr in metal plating, pigments for paints and industrial waste water releases upstream.

**Mercury (Hg), Selenium (Se), Zinc (Zn) and Vanadium (V)**

Hg, Se and Zn recorded values below the detection limit (<1 µg/L). Vanadium also recorded values below the detection limit (<2 µg/L). Hg content had been shown as an example of the evolution of toxic metals associated with mining contamination (Olias et al., 2006). This confirms the fact that there are no heavy metal activities in the study area.

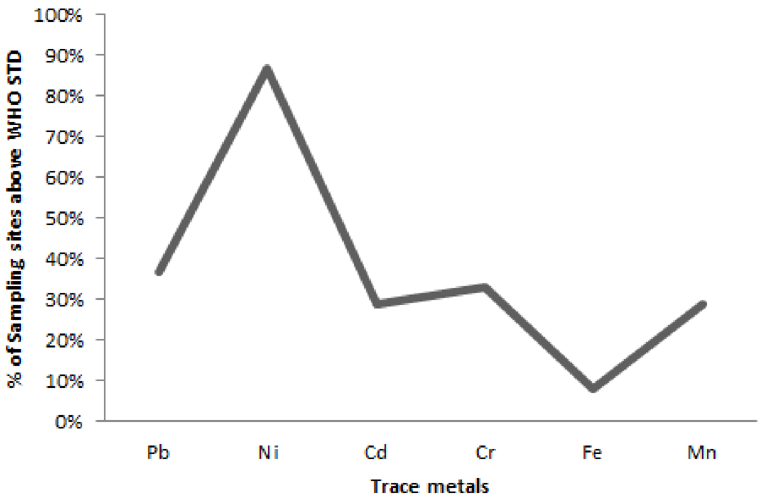

Figure 2: Bar chart showing the percentage (%) of sampling sites having trace metal levels above the WHO (2004) standards for drinking water in the study area. Standard (STD)

## 5.0 Conclusion

This study has shown that the pH, electrical conductivity (EC), total dissolved solutes (TDS), turbidity, total hardness (TH), biological oxygen demand (BOD), $Mg^{2+}$, $Na^{+}$, $K^{+}$, $Cl^{-}$, $Ca^{2+}$, $NO_3^{-}$ and $SO_4^{2-}$ content of the river water were found within the limits set by the WHO (2004) standards for drinking water and domestic use. Few exceptions were observed in the phosphate concentrations, as some of the sampling sites (about 37%) recorded values above the 5 mg/L set as standard in South Africa (Morrison et al., 2001). Similarly, apart from Cu, which recorded all its values within the stated limit, some of the trace elements (Pb, Ni, Cd, Cr, Fe and Mn) at some sites recorded values above the WHO (2004) standard for drinking water (Figure 2). At sites where Pb, Cd, Cr, Fe and Mn were within standards, Ni concentrations were observed to be above the WHO (2004) standard for drinking water. Industrial waste water releases upstream, runoffs from small scale brick and tile factories downstream, domestic waste and fishing activities were the major sources responsible for river water quality deterioration. Interventions should be made to reduce anthropogenic discharges in the river basin; otherwise, high levels of trace metal pollution will pose some danger to health and the society as a whole.

## 6.0 Acknowledgements

The authors are very grateful to the Ghana Atomic energy Commission and Graduate School of Nuclear and Allied Sciences, Kwabenya, Accra for equipment and expertise support.

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