Assessment of the Quality of Water from Rooftops (A Case Study of "Nkamponasi" in Tarkwa, Ghana)

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Abstract - Water scarcity has become a problem for many rural and urban communities in Ghana due to evolvement of small scale mining and heavy industries polluting most of the surface water. Rainwater harvesting has become a major source of water for the inhabitants of Nkamponasi, a community in Tarkwa. The aim of this study was to assess the quality of rainwater from rooftops (non-rusty and rusty) in Nkamponasi in Tarkwa. Rainwater samples were collected from non-rusty, rusty and no roof (rainwater without contact with roof surface). Six samples were collected from three rainfall events and analysed for physico-chemical parameters and metals concentration. Each parameter and metal was compared with the World Health Organization (WHO) Guidelines for drinking water quality. The results of the physico-chemical analysis indicated that pH, turbidity and colour were above WHO standard in all water samples collected from the three rainfall events. High lead and chromium concentrations were recorded from the rusty and non-rusty roofs. The study reveals that roofing sheets have an impact on the quality of harvested rainwater.

Index Terms – Rooftops, Water Quality, Nkamponasi, Rainwater

I. INTRODUCTION

The water cycle is the movement of water from the earth's surface into the atmosphere in a cyclic manner and it is powered by the sun (Kuchment, 2004). As the sun shines on the surface of the earth, evaporation takes place on water bodies, snow cover and from the soil. Also plants lose water through transpiration. As the water now in a form of a gas rises higher into the atmosphere, it cools and condenses to form clouds. When the cloud becomes heavy, it falls back on the surface as rain. The rain serves as a recharge for ground water and surface water (Kuchment, 2004).

In Ghana, the inhabitants of most communities rely on rainwater since they lack access to potable water. The evolvement of mining and small scale mining in the Tarkwa Nsuaem Municipality for instance, has rendered most of the available water bodies unclean for consumption. People harvest rain water for irrigation purposes, drinking and bathing.

Rainwater harvesting is a system of collecting and storing rainwater for later use (Daily and Wilkins, 2012). Rainwater is considered as a safe source of drinking water. This is mainly to the belief that the collection surfaces (mainly rooftops) are isolated from the major sources of contamination. This is however, not always the case. Pollutants such as dust, smoke and soot from air due to commercial and human activities can be dissolved in rainwater before it lands on a roof. Furthermore, birds and other climbing animals may defecate on rooftops contaminating them. The type and quality of roofing materials used for houses have different properties and effects. Rusty roofs may leach heavy metals which when harvested and used without treatment can adversely affect human lives and the environment. Hence, with all potential effects and threats, studies on the quality of rainwater from rooftops in the study area was not given an attentive concerns. This project therefore seeks to study the quality of rainwater from different rooftops (rusty versus non-rusty) in "Nkamponasi" a small community in Tarkwa.

II. MATERIALS AND METHODS

A. *Study Area*

Nkamponasi is located in the mining town of Tarkwa in the Western Region of Ghana. Tarkwa is the Administrative capital of the Wassa West District located in the southwest of Ghana (approximately on longitude 20º 59' 45" W and latitude 50º 17' 42" N) and is 160 m above mean sea level (Seidu, 2004). Figure 2.1 is a Map of Ghana showing the location of Tarkwa. The town is about 85 km from Takoradi, which is the regional capital, 233 km from Kumasi and about 317 km from Accra (Kesse, 1985)

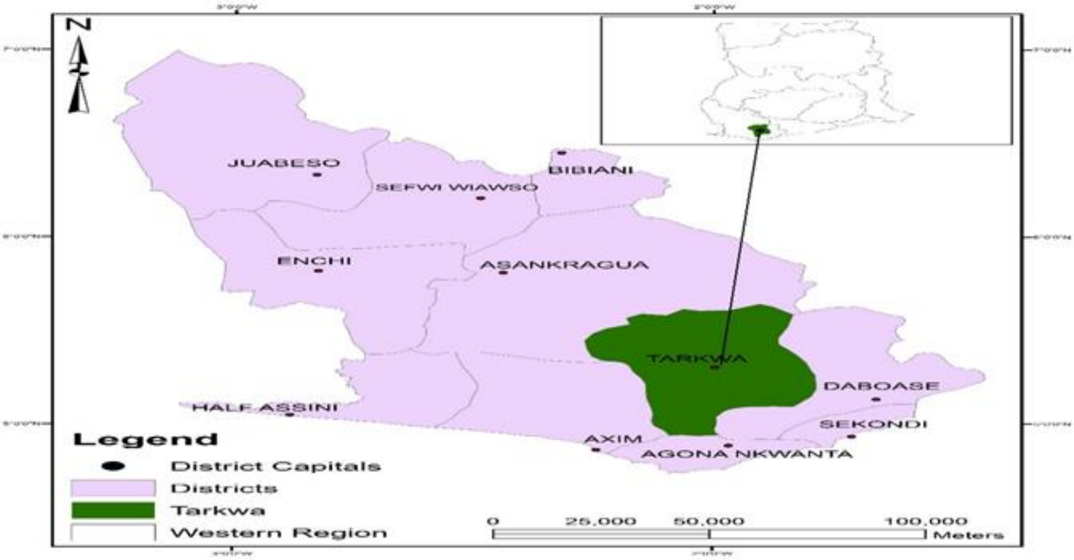

Figure 2.1: A map of Ghana showing the location of Tarkwa

B. *Climate*

Tarkwa experiences one of the highest rainfall patterns in Ghana (Anon., 2015). Nkamponasi, Tarkwa area has a South-Western Equatorial Climate with seasons influenced by the moist South-West Monsoon Winds from the South, Atlantic Ocean and the North-East Trade Winds. The mean rainfall is approximately 1500 mm with peaks of more than 1700 mm^3 in June and October. Between November and February, the rainfall pattern decreases to between 20 mm^3 and 90 mm^3. The mean annual temperature is approximately 25 ºC with small daily temperature variations.

Relative humidity varies from 61 % in January to a maximum of 80 % in August and September (Forson, 2006). The high precipitation experienced in Tarkwa supports plant growth without irrigation. Rain water becomes the main water source for agricultural activities which continues all throughout the year (Anon., 2015). The municipality has a peculiar rainfall pattern, in that during the raining season, it usually rains around 2 p.m. thus, the nickname of the municipality is "Tarkwa at 2" (Anon, 2014)

C. *Sampling and Analysis*

- ***Sampling of rainwater***

The first field work was to identify common roofing materials used in Nkamponasi. Two houses were selected for using a rusty and non-rusty roof. Figure 2.1 shows the non-rusty and rusty roofs sampled. There was no evident sources of pollution (trees) around the sampling points. Clean, plastic buckets were used in collecting rainwater samples from the rooftops before transferring them into sampling bottles which were closed tightly. To test composition of rainwater itself without the influence of rooftops, a bucket was placed in an open area to collect rainwater. After sampling, samples were immediately stored in a working refrigerator to ensure that water samples did not lose their integrity. Gloves were also worn to avoid contamination of the samples. All analysis were done in the laboratory. Six samples were collected from three different rainfall events. Care was taken to ensure that samples were representative of water to be examined and that no accidental contaminations occurred during sampling.

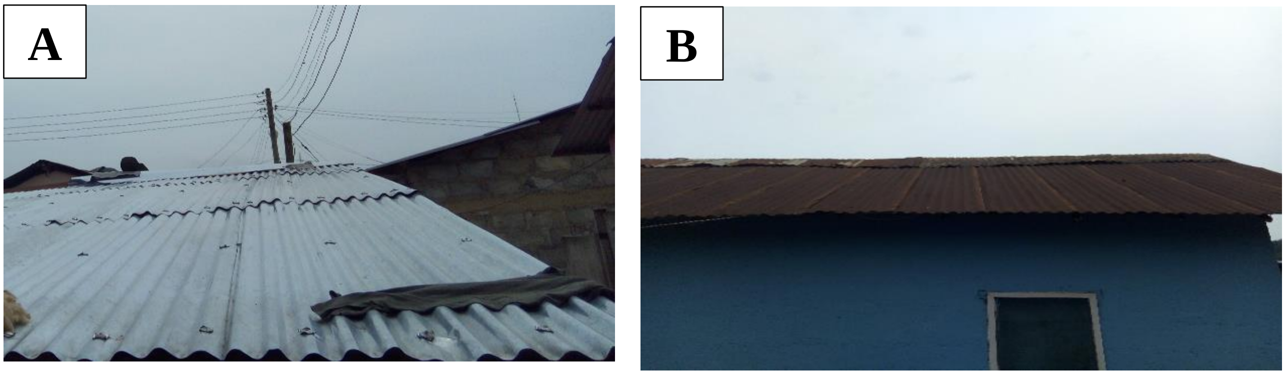

Figure 2.2: Non-rusty roof (A) and Rusty roof (B)

- ***Monitoring of rainfall events***

Monitoring of rainfall started in the early parts of the year 2017, where there is less rainfall in Tarkwa. Samples were collected from three different rainfall events. Rainfall data was collected from UMaT Meteorological office. Details of the rainfall events are presented in the Table 2.1.

Table 2.1: Details of rainfall events

Rainfall Event	*Date*	*Sampling Time*	*Number of Samples*	*Rainfall Volume(mm^3)*	*Wind Speed*	*Wind Direction*
A	3/3/2017	6:20 pm-7:14 pm	2	10.8	40.27	SW
B	8/3/2017	3:02 pm- 3:58 pm	2	11.0	25.44	NW
C	9/3/2017	2:02 pm -3:12 pm	2	8.4	22.33	SW

- ***Sample Labelling***

Clean 500 ml bottles were used for the rainwater collection. The sample bottles were labelled using a permanent marker to prevent water from cleaning the labels. The labels were RW (rainwater without contact with roof surface), NR (rainwater from non-rusty roof) and R (rainwater from rusty roof) for each rainfall event.

D. Laboratory analysis

In the laboratory, the samples were analyzed for physico-chemical parameters as well as for metal concentration.

- ***Analysis of Physico-chemical parameters***

The physico-chemical parameters were analysed using various instruments in the laboratory. The instruments used and the parameters they measure are outlined in Table 2.2.

Table 2.2: Instruments used in measuring physico-chemical parameters

Instrument	**Parameter(s)**
LaMotte SMART 3 Colorimeter	Colour
OARTON PC 300 Cond./ TDS	Conductivity and TDS
Extech pH multimeter	pH
Hanna H1 9146 DO	Dissolved Oxygen

- ***Metal concentration analysis***

Prior to the metal ion content determination, samples were filtered using 0.45 µm Whatman Filter paper to remove suspended matter. 1 ppm of concentrated HNO_3 was added to the filtered samples to make the metals mobile in solution. Eight metals (Fe, Zn, Cd, Cr, Pb, Mn, Ni, Co) were analysed using the Varian AA240FS Atomic Adsorption Spectrometer (AAS). The AAS works on the principle of Beer Lamberts law which describes the relationship between absorbance and concentration. Deionized water was used in preparing blank samples. The blank solution was used together with each standard for a particular metal analysis during calibration. Samples were presented after calibration to the AAS for metal concentration reading.

III. RESULTS AND DISCUSSION

- **Physico-chemical analysis of water samples**

Table 3.1 shows the average results of the physico-chemical analysis carried out on the water samples from rusty, non-rusty and no roof with the exception of pH which is in ranges. The results obtained were compared with the WHO standard for drinking water quality. Conductivity, TDS and DO were all below the WHO standards. pH, turbidity and colour exceeded the WHO standard and are discussed below.

Table 3.1: Results of physico-chemical parameters

Parameter / Roof	pH	CON $\mu s/cm$	TDS (mg/L)	DO (mg/L)	TURB (NTU)	COL. (TCU) TRUE	APP.
No roof	4.63 - 6.31	25	16	7.29	20	243	105
Non-rusty	4.86 - 6.26	39	25	6.94	24	285	133
Rusty roof	5.30 -7.20	40	26	6.76	43	455	167
WHO STD	6.50-8.50	1500	1000	-	5	15	15

A. pH

From Table 3.1, the pH of the water samples collected were within the ranges of 4.63-6.31, 4.86-6.26 and 5.30-7.20 for no roof, non-rusty and rusty roofs, respectively. The pH of all the water samples analyzed were below the range of the WHO standard value for drinking water (6.50-8.50). Low pH was recorded in the no roof and it may be from emission of gases (Nitrogen oxides and Sulphur oxide) from vehicles and heavy industries. These gases are released from heavy industries and vehicles and find themselves in the atmosphere causing acid rain. The pH from the rusty and non-rusty roof samples may also be from anthropogenic and wind-blown particulates. According to Winters and Graunke (2014), pH of rain plays a more prominent role in metal roofs or roofs containing metals in their matrix. Low pH of rainwater has the ability to cause corrosion to metal roof surfaces and other metal fittings used in the construction of the roofs. It can also lead to a metallic and bitter taste of the water. Concerns regarding rainwater acidity do not relate to any direct threat posed by low pH value, but are due to indirect effects of this more 'aggressive water' in leaching out metals (Gould, 1999).

B. Turbidity

From Figure 3.1, the average turbidity values of all the water samples were above the WHO standard value of 5 NTU. The turbidity of water from the rusty roof was highest with a value of 43 NTU but was comparatively lower in the non-rusty roof. This may be attributed to the composition and age of the roofing materials. The high turbidity recorded for all water samples may be as a result of dry deposition such as dust and soot on both roof surfaces and in the direct rainwater (no roof). The dry deposition acts as a condensation nuclei for cloud particles before it falls to the surface as rain. It may also attach itself to the rain particles before it gets to the surface.

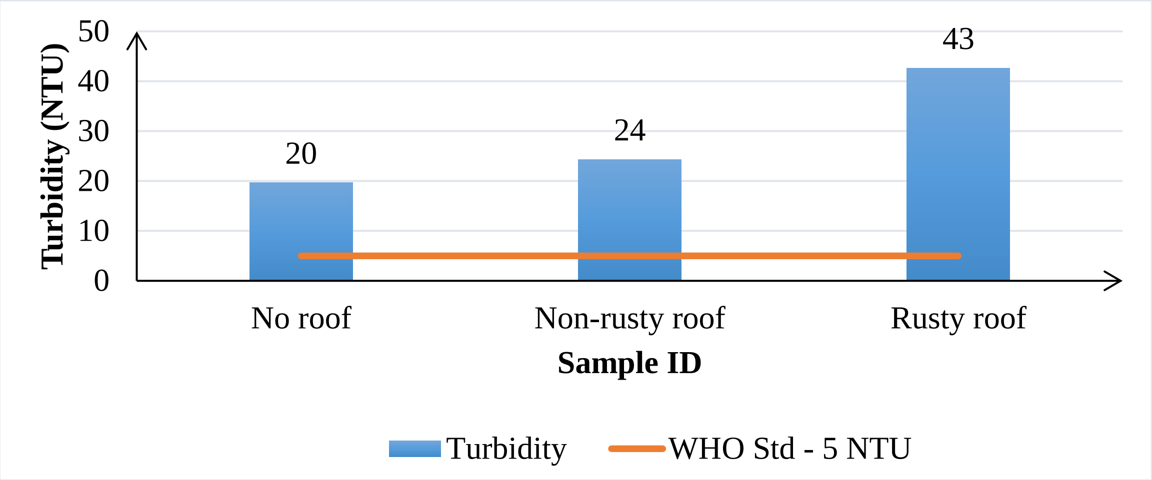

Figure 3.1: Average turbidity for rainfall events

C. Colour

The average colour of the samples were 243, 285 and 455 TCU for no roof, non-rusty and rusty roof, respectively from Fig 5.2. They all exceeded WHO standard value of 15 TCU. The colour was high in the rusty roof with a value of 455 TCU than all the samples. The colour in Figure 3.2 can be linked with the turbidity in Figure 3.1. This means the more turbid the water from the rusty roof is, the higher the colour and vice versa. The presence of colour in the no roof sample may be as a result of dry deposits such as dirt which attaches itself to the rain before it lands on the roofing material. The high colour from the roofs which was significantly higher in the rusty roof may be attributed to the composition and the age of roofing material and from dry deposits such as soot, dirt from anthropogenic activities.

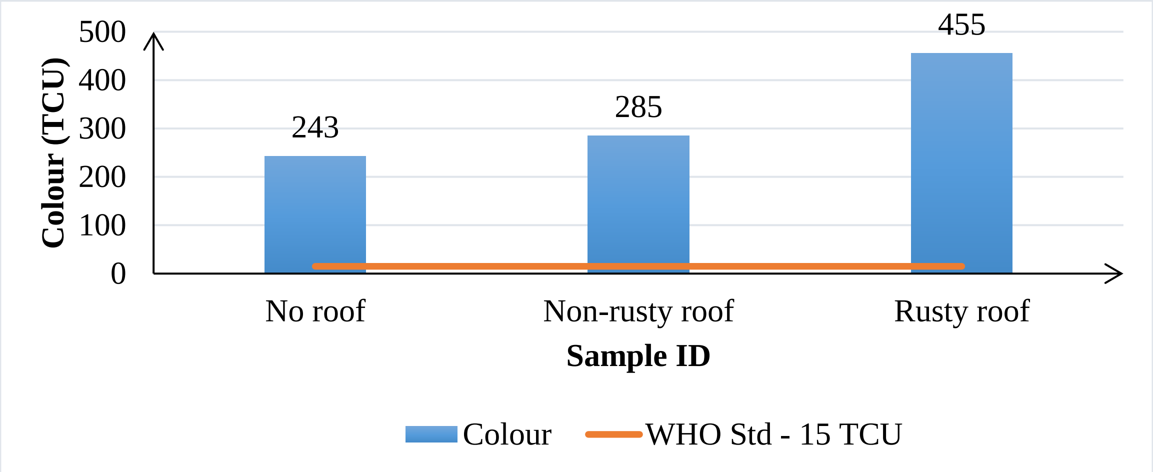

Figure 3.2: Average colour for rainfall events

- ***Concentration of metal ions***

Table 3.2 summarizes the average results of metal concentration analysis carried out on the water samples. The results obtained were compared with the WHO standard for drinking water quality. Zn, Cu, Mn, Cd, Co, Ni and Fe were below the WHO standards. Cr and Pb exceeded the WHO standard and are discussed below.

Table 3.2: Average results of metal concentration analysis

Parameter / *Roof*	*Cu* *mg/L*	*Cd* *mg/L*	*Pb* *mg/L*	*Mn* *mg/L*	*Ni* *mg/L*	*Zn* *mg/L*	*Co* *mg/L*	*Fe* *mg/L*	*Cr* *mg/L*
No roof	0.010	0.000	0.024	0.113	<0.002	0.064	0.000	0.181	0.086
Non-rusty	0.011	0.000	0.015	0.170	<0.002	0.046	0.021	0.261	0.171
Rusty	0.033	0.001	0.097	0.224	<0.002	0.515	0.016	0.263	0.100
WHO STD	2.000	0.050	0.010	0.500	<0.002	5.00	-	0.300	0.050

A. Lead Concentration

All the water samples had their Pb concentration exceeding the WHO value which can have adverse effect on humans, plants, animals and surface water (Figure 3.3). Average Pb concentration was higher in no roof as compared to the non-rusty roof. The presence of Pb in the water sample may be as a result of anthropogenic activities and wind-blown particles containing lead. The concentration of Pb from the rusty roof sample was the highest concentration of 0.097 mg/L which exceeded the WHO standard value of 0.01mg/L. According to Waller and Inman (1982), high Pb concentrations was recorded in old roofs (rusty roofs) water samples in Halifax, Nova Scotia. The presence of Pb from samples collected from roofs may likely to be from materials such as lead headed nails, primers for roof construction and deposition of Pb particles on the roof surface in areas subject to heavy industrial activities and traffic pollution (Gould, 1999). Lead toxicity is a particularly insidious hazard with the potential to cause irreversible health effects (Anon., 2007).

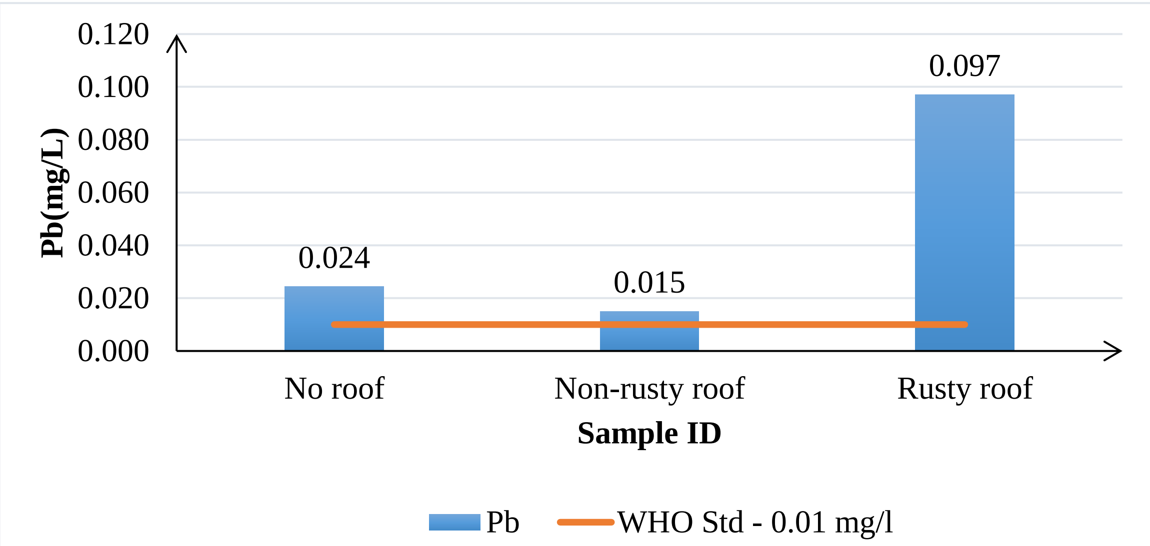

Figure 3.3: Average lead for rainfall events

B. Chromium concentration

From Figure 3.4, Cr concentration in all the water samples exceeded the WHO value of 0.05 mg/L. Cr concentration of 0.024 mg/L was detected in the no roof sample and it may be due to anthropogenic activities (burning of materials containing chromium) and wind-blown particulates containing chromium. Cr concentration was higher in non-rusty roof compared to with the rusty roof. The high concentration of chromium in the samples from the roofs may be from the composition of the roofing materials. Cr is used for electroplating metals to prevent it from corrosion e.g. chromated roofing sheets (Winters and Graunke, 2014). Due to atmospheric changes, chromium from roof surfaces begin to leach off from the surface. It may also be attributed to anthropogenic activities such as burning of materials containing chromium and from dry deposition of chromium particles on roof surfaces.

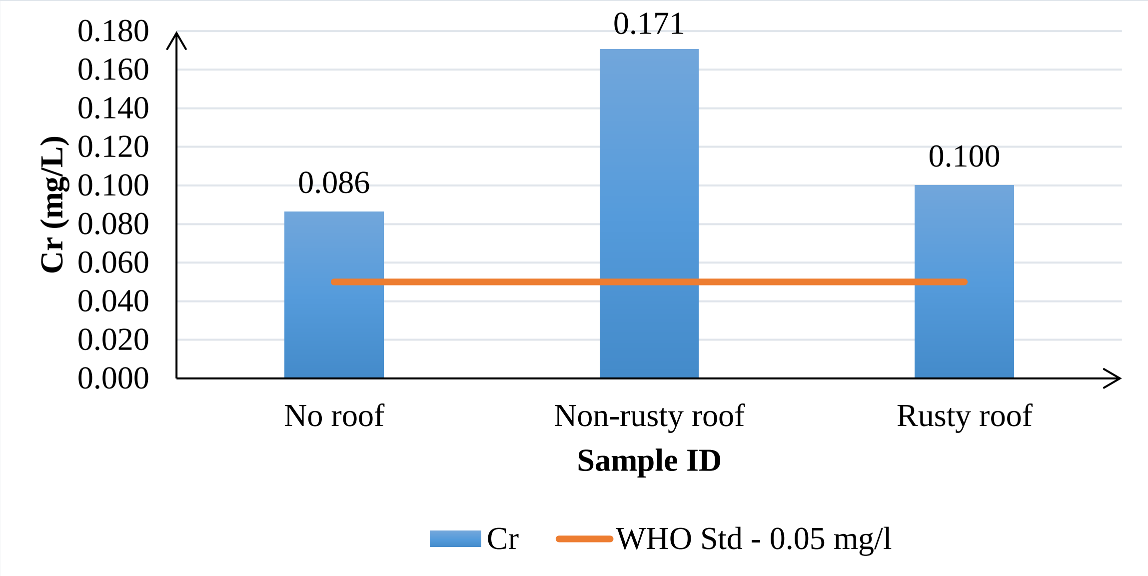

Figure 3.4: Average chromium concentration for rainfall events

IV. CONCLUSION

This study focused on the assessment of water quality from rooftops (rusty and non-rusty) in Nkamponasi, a community in Tarkwa. The physico-chemical parameters and metal concentrations from different (rusty and non-rusty) rooftops within the study area were analyzed. The study findings reveal that Physico-chemical parameters such as pH, turbidity and colour exceeded the WHO standard for safe drinking water in most of the water samples tested. The concentrations of lead and chromium detected in the water samples exceeded the WHO standard value for safe drinking water. All other metals were within the WHO limit. Environmental and anthropogenic activities (burning of materials containing metals) might have influenced the concentrations of metals in both direct rainwater and rainwater harvested from rooftops. It is therefore indicated that contamination of rainfall was dependent on the roofing material used and the age of roofing materials; the older the roofing sheet, the more contaminated rainwater was.

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