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ASSESSMENT OF SOME QUALITY PARAMETERS OF HARVESTED RAINWATER - CASE STUDY AT DONASO A FARMING COMMUNITY IN EJISU MUNICIPAL, ASHANTI GHANA

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Abstract: Rainwater harvesting for domestic use is becoming increasingly popular as the availability of good quality water is declining. Harvested rainwater has been considered an effective alternative water source for drinking and various non-potable uses in a number of countries throughout the world, the most significant issue in relation to using untreated harvested rainwater for drinking or other potable uses, however, is the potential public health risks associated with microbial pathogens. The study was conducted to ascertain the physicochemical quality and heavy metal concentrations of harvested rainwater from different households at Donaso Township, small community in Ejisu Municipal. Samples were taken from ten households after harvested from roof tops and analyzed for the following parameters; pH, Total dissolved solids (TDS), Conductivity, Temperature, Turbidity, Alkalinity, Total hardness, lead (Pb^{2+}) and Zinc (Zn^{2+}). The pH meter, turbid meter, conductivity meter, TDS meter, titration method for physicochemical parameters. Atomic Absorption spectroscopy was used for the metals analysis. The mean levels of the parameters in samples well as follows: pH 4.948, temperature 24.14 ºC, conductivity 8.468 µs/cm, TDS 2.711 mg/L, total hardness 2.764 mg/L, alkalinity 15.757 mg/L, turbidity 1.927NTU, Zn 0.0958 mg/L, Fe 0.0233 mg/L and Pb 0.0017 mg/L. The range were to be; pH 4.53-5.48, temperature (23.8-24.4) ^{0} C, conductivity (EC) 7.78- 9.21µs/cm, turbidity 1.26-2.79 NTU, TDS 2.24-3.21 mg/L, alkalinity 14.2-16.9 mg/L, total hardness 2.42-3.30 mg/L, Zn 0.0256-0.2505 mg/L, lead 0.00086-0.00251mg/L. The standard deviation were reported as follows; conductivity 0.5341, TDS 0.302, alkalinity 0.9975, total hardness 0.2988, pH 0.2895, temperature 0.3400, turbidity 0.5361, Zn 0.3407, Fe 0.00082 and Pb 0.000066. The mean concentrations of all the parameters as wall as as heavy metal levels were all within the permissible limits recommended by World Health Organization for good drinking water with exception of pH which values fell outside the WHO recommended range.

Key words: Anthropogenic, physicochemical, quality, rainwater

1.0 INTRODUCTION

Rainwater harvesting is a method for collecting, storing and conserving rainwater from rooftops, land surface or rock catchments [1]. It is an ancient technology enjoying revival in popularity due to the inherent quality of rainwater and interest in reducing consumption of treated water [2]. In Ghana, rainwater harvesting began at household levels whereby small water storage containers such as barrels, plastic containers and pots are used to collect and store rainwater during downpours. However, at the moment, the technology has been developed to include construction of underground check dams and large concrete reservoirs for schools, churches and health facilities.

Rainwater may be collected from any kind of roof. Tiled or metal roofs are easiest to use, and may give the cleanest water, but it is perfectly feasible to use roofs made of palm thatch. The only common type of roof which is definitely unsuitable, especially to collect water for drinking is a roof made with lead flashing or painted with lead-based paint [3]. The quality of rainwater is quite high and it compares favourably with river waters [4]. For many areas of the world today, rainwater can either be the only source of water for the household, or more commonly a supplementary supply to ease the burden of water collection from other sources [5]. Rainwater harvesting for domestic use is becoming increasingly popular as the availability of good quality water is declining [6].

Harvested rainwater has been considered an effective alternative water source for drinking and various non-potable uses in a number of countries throughout the world, the most significant issue in relation to using untreated harvested rainwater for drinking or other potable uses, however, is the potential public health risks associated with microbial pathogens [7]. This has increased by the advert effect of climate change on water supply sources. As a result, water authorities around the world are keen to explore alternative water sources to meet ever-increasing demands for potable drinking water [8].

Harvested rainwater is essential and valuable sources of water for domestic purposes. Roofs are the first candidates for rainwater harvesting systems because their runoff is often regarded to be or, at least, it presents relatively good quality standards compared to the rainwater from surface catchment areas [9]. Harvested rainwater from roofs can be used for flushing toilets, washing cloths and watering plants without special treatment [10]. However, water intended for consumption and domestic use must be free from significant concentration of pollutants [3]. The major constituents of the raw harvested rainwater are biodegradable organics. The biodegradable organics can lead to the depletion of natural oxygen resources and are potential sources for water-borne disease vectors [11]. When rainwater comes in contact with a catchment surface, it can wash bacteria, molds, algae, faecal matter and dust into the storage tanks. The longer the span of continuous number of dry days, the more catchment debris is washed off the roof by a rainfall event 12]. Some bacteria, although naturally occurring are known to cause disease in humans, especially those with compromised immunity [13]. Several types of disease-causing viruses, protozoa and bacteria are known to occur in sewage, human faeces, and faecally contaminated waters. Many of these pathogens originate directly from human and other warm-blooded animal sources, and are the causative agents of some of the most waterborne diseases in the world, especially in the developing nations where sanitation is generally poor and access to potable water is limited [14]. Water is one of the essential things needed for the wellbeing of individuals. The quality of sources of drinking water cannot therefore, be left out. To ensure good quality of drinking water, its microbiological and physicochemical analysis should be done. This analysis will help to identify micro-organisms that results in water- borne diseases and its subsequent effects on the health of people especially the rural folks. Quality drinking water is essential for life. Unfortunately, in many countries around the world, including Ghana, water has become a scarce commodity as only a small proportion of the populace has access to treated water. Alternative sources of water such as rainwater and ground water have become major sources of drinking water for people living in new settlements and some residents who do not have access to treated water in Ghana. The need to assess the quality of water from some of these alternative sources has become imperative because they have a direct effect on the health of individuals. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources. Even if no sources of anthropogenic contamination exist there is potential for natural levels of metals and other chemicals to be harmful to human health.

Of all the issues related to water management, governance is considered the most important. Water tariffs are among the lowest in the world, and not most of the resident get the water supply. However, population growth cannot be avoided. In Ghana, population growth keeps on increasing. As the population increases, the demand towards clean water will increases as well. As the demand keep increasing, with the limited water resources, eventually the demand will exceed the supply and this will create problems to the country. Thus, the water that is used can be substituted by using alternative water sources such as precipitation. As an alternative to solve the water crisis in the future, a rainwater harvesting system and its implementation has been proposed as part of the settlement by the government. Ghana is blessed with adequate water supply because of good rainfall pattern in some part of the country. Typically, the average rainfall is around 2000 mm in the northern part of Ghana, 3830 mm in the western part of Ghana and 2400 mm in Eastern part of Ghana throughout the year. Rain water is selected as an alternative to reduce the dependent towards the existing water resources because it is natural water that falls from the sky which is precipitate throughout the year especially for country tropical rainforest climate country like Ghana. Since clean water is important, it is seen as a waste for it to be used for outdoor use, agriculture, gardening, washing the car, and for flushing of toilets. By using rainwater as an alternative, clean water can be saved and be used for other purposes and simultaneously decrease the demand of clean water which will resulted in lower cost of water bill and cost of operation in the water plants.

2.0 MATERIALS AND METHODOLOGY

2.1. Study Area

The study was carried out at Donase a farming community at Ejisu Municipal in Ashanti region which is about 10 minutes drive from Ejisu township off Abenas road. The town has no pipe-borne water. The main source of water in this community is hand-dug wells which had been dug by individuals in the community. The inhabitants depend largely on this source of water during both wet season and dry seasons. The families are generally large at Donaso and span from 12 to 28 members. The main form of employment is petty trading and farming. Asa a result of lack of piped water in the community, the people therefore depend heavily on rainwater as alternative source of water to the hand-wells for their house chores. Many of the roofs used to harvest rainwater are made of 80% aluminium and 20% corrugated iron sheet. The roof catchment system is most common method of harvesting the rainwater because the inhabitants are not worthy enough to practice complex technology like the underground check dams. The collection of the rainwater is done by metal gutters. The water is directed into the various collection containers by means of bamboo sticks. Some also collect it directly from the eave of the roofs. The types of containers that mainly are used to harvest the rainwater vary from house to house. Some use plastic containers, aluminium pots, but others use barrels. The rainwater is used directly for washing, cooking and drinking. They also see the rainwater as quality was as compared with the other sources of water.

2.2. Sampling Technique

Samples were collected in labelled 1.5 L plastic containers initially pre-treated by washing with nitric acid and rinsed with distilled water. The containers were later sun dried. At the sampling collection point, the containers were shaken to ensure homogeneity in its composition. For each collection, the sample containers were rinsed twice with the relevant sample and 1.5 L of the sample collected. Samples were then taken to the laboratory for analysis. The harvested rainwater samples for the study was collected from ten (10) randomly selected harvested rainwater containers in ten (10) different houses from February to April. Temperature and pH were determined at the sample collection point or at the point source. Sample bottles were not filled completely, at least 2.5 cm air space was allowed for mixing the sample prior to analysis. They were transported to Kwame Nkrumah University of Science and Technology within 24 hours after collection for analyses.

2.3. Methodology

The physico-chemical parameters of all the samples were determined at chemistry laboratory department of Agroforestry at Kwame Nkrumah University of Science and Technology using the appropriate instrument. The heavy metals concentrations of all the samples were also analyzed at soil science department at Kwame Nkrumah University of Science and Technology with the help of atomic absorption spectrophotometer.

3.0 RESULTS

Table 1: Mean Chemical parameters results for the harvested rainwater based on months sample taken between February, 2019 and 2019 for each household at **Donaso**

Household	Cond µs/cm	TDS mg/L	Alkalinity mg/L	TH mg/L
DS1	9.02	2.96	16.30	2.45
DS2	7.82	2.42	14.49	3.02
DS3	9.21	3.21	16.10	2.58
DS4	8.44	2.66	14.20	2.73
DS5	9.05	3.02	15.56	3.10
DS6	8.60	2.86	16.28	2.42
DS7	7.78	2.24	17.20	2.68
DS8	8.20	2.58	14.86	2.50
DS9	7.88	3.02	15.68	3.30
DS10	8.68	2.71	16.90	2.86
WHO	**2500**	**1000**	**200**	**180**

DS1 = Household 1, DS2 = Household 2, DS3 = Household 3, DS4 = Household 4, DS5 = Household 5, DS6 = Household 6, DS7 = Household 7, DS8 = Household 8, DS9 = Household 9, DS10 = Household 10

Cond. = conductivity, TDS = Total dissolved solid, TH = Total Hardness

Table 2: Mean Physico.chemicalcal parameters results for the harvested rainwater based on months sample taken between February, 2019 and 2019 for each household at **Donaso**

Household	pH	Temperature °C	Turbidity NTU
DS1	4.86	24.3	2.02
DS2	5.17	23.9	1.26
DS3	5.05	24.4	2.79
DS4	4.91	24.1	1.68
DS5	4.88	24.4	2.68
DS6	4.60	24.2	2.01
DS7	5.48	23.8	1.29
DS8	4.78	24.1	1.67
DS9	4.53	24.0	1.56
DS10	5.22	24.2	1.67
WHO	**6.5-8.5**		**5.00**

Table 3: Mean heavy metal concentrations results for the harvested rainwater based on months samples were taken between February, 2019 and 2019 for each household at **Donaso**

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Household	No.	Zinc mg/L	Lead mg/L	Iron mg/L
DS1	3	0.1218	0.0025	0.0167
DS2	3	0.1217	0.0019	0.0162
DS3	3	0.0550	0.0013	0.0300
DS4	3	0.0599	0.0025	0.0267
DS5	3	0.0579	0.0011	0.0200
DS6	3	0.1637	0.0009	0.0433
DS7	3	0.0210	0.0013	0.0200
DS8	3	0.0812	0.0025	0.0233
DS9	3	0.2505	0.0009	0.0231
DS10	3	0.0256	0.0017	0.0133
WHO Standard		**3.000**	**0.01000**	**0.0000**

Table 4: Statistical Data for all the parameters for the harvested rainwater based on months samples were taken between February, 2019 and April, 2019 for each household at **Donaso**

Parameter	Range	Mean	Min
Cond	7.78-9.21	8.468	7.78
TDS	2.24-3.21	2.711	2.24
Alk.	14.20-16.90	15.757	14.20
TH	2.42-3.30	2.764	2.42
pH	4.53-5.48	4.948	4.53
Temp.	23.8-24.4	24.14	23.8
Turb.	1.26-2.79	1.927	1.26
Zn	0.0120-0.1637	0.0958	0.021
Fe	0.0133-0.0433	0.0233	0.0133
Pb	0.0009-0.0025	0.0017	0.0009

Table 5: Physicochemical parameters results for the harvested rainwater based on months samples were taken between February, 2019 and April, 2019 for each household at **Donaso**

Parameter	Max.	SD	Mean
Cond.	9.21	0.5341	8.52
TDS	3.21	0.3025	2.685
Alk.	17.20	0.9975	15.890
TH	3.30	0.2988	2.705
pH	5.48	0.2895	4.895
Temp.	24.4	0.3400	24.15
Turb	2.79	0.5361	1.845
Zn	0.2505	0.3407	0.0706
Fe	0.0433	0.000082	0.0255
Pb	0.0025	0.000066	0.00015

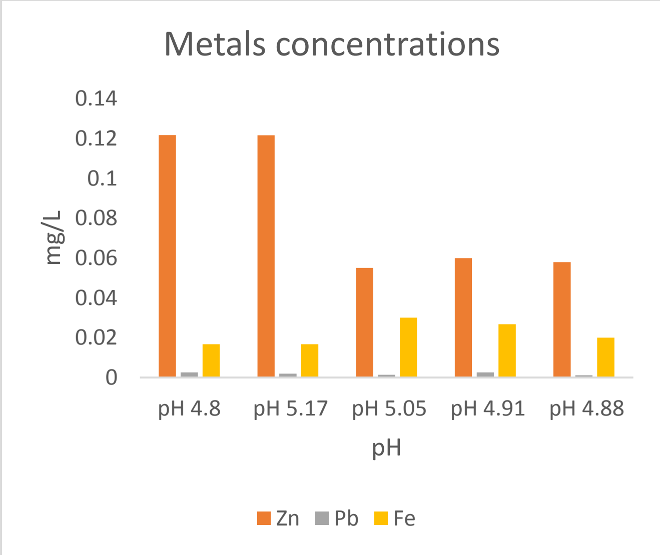

Figure 1: Average pH against average metal concentrations for each household

The above figure gives the levels of the heavy metals in the harvester rainwater as the pH varies.

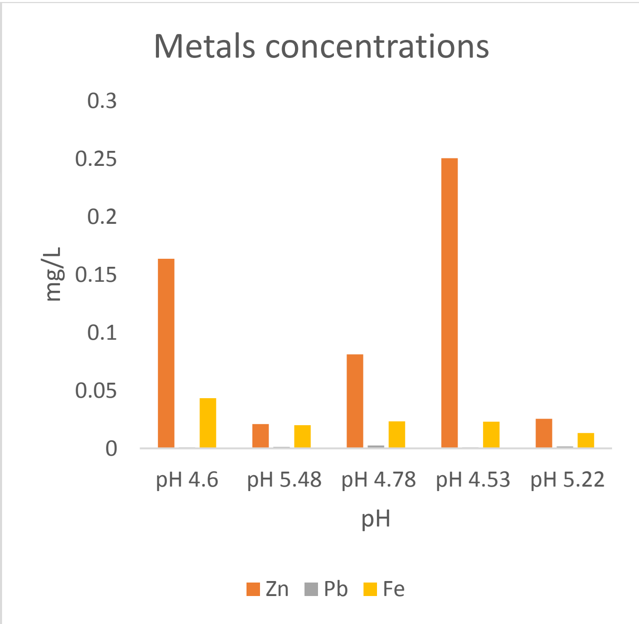

Figure 2: Average pH against average metal concentrations for each household.

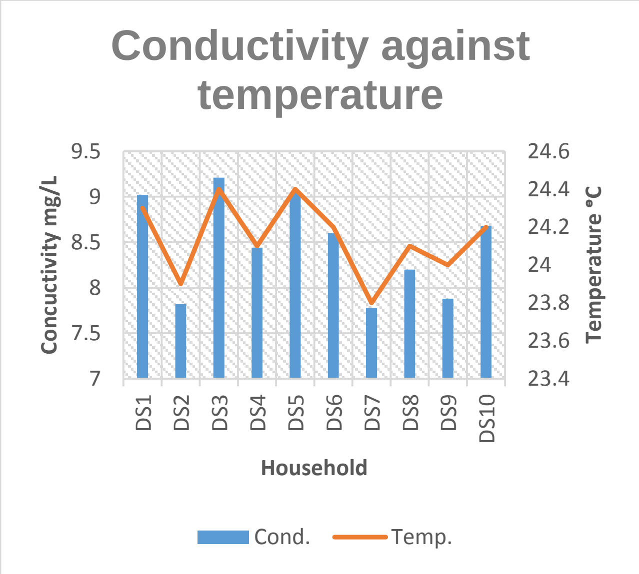

Figure 3: The effect of temperature change on conductivity

DISCUSSION

Ten rainwater samples were sampled from ten different households at Donaso for physicochemical analyses as well as some heavy metal concentrations determinations between the February and April. Table 2 indicates the mean physical parameters analyzed in the harvested rainwater at Danoso from the different households. The rainwater collected were all having some levels of physical and chemical containments. However the parameter found in these water samples were all within the permissible limits prescribe by WHO but quite below the upper limits. Exception is taken for pH which found to be outside the acceptable range of 6.5-8.5 set by WHO. Lowest average pH of 4.60 was recorded at DS9 and the highest of 5.48 was found in rainwater samples at DS1 (Table 2). The low pH figures recorded in all the samples at Donaso may due to the presence of nitrogen and Sulphur oxides which enter the atmosphere and converted to nitric acid and sulphuric acid respectively. These acids combined with hydrochloric acid arising from hydrogen chloride emissions, these acids cause acidic precipitation. Conductivity, TDS, and turbidity figures were very low compared to the international standards as shown in table 1 and 2. This may due to the fact that there were no major road or construction activities in the town and its environs during the time of research. This is in consonance with the assertion by WHO [15], that the primary sources for TDS in receiving waters include agricultural runoff, urban runoff, and industrial wastewater. Sewage, and natural sources such as leaves, silt, plankton, and rocks. The principal ions contributing to TDS are carbonates, chlorides, sulphates, nitrates, sodium, potassium, calcium, and magnesium. Total dissolved solids influence other qualities of drinking-water, such as taste, hardness, corrosion properties, and tendency to incrustation. It is a measure of the amount of material dissolved in water. Waters in areas of Palaeozoic and Mesozoic sedimentary rock have higher total dissolved solids (TDS) levels, ranging from as little as 195 to 1100 mg/litre [16]. According to Bruvold and Ongerth [17], palatability of drinking water has been related to its TDS. It is rated as excellent, less than 300 mg/L; good, between 300 and 600 mg/L; fair, between 600 and 900 mg/L; Poor, between 900 and 1200 mg/L; and unacceptable, greater than 1200 mg/L. Turbidity depends on the amount of particulate matter in the environment which may due natural or come from human activities. High turbidity may impact significantly on the number of ions in the harvested rainwater which eventually affects the conductivity of the water sample. Increase in solution temperature will cause a decrease in its viscosity and an increase in the mobility of the ions in solution. An increase in temperature may also cause an increase in the number of ions in solution due to dissociation of molecules. As conductivity of a solution depends on these factors then an increase in the solution's temperature will lead to an increase in its conductivity as shown in figure 3. The highest conductivity was found to be 9.21 µ/Sc with corresponding highest temperature of 24.4 which were recorded at DS3 as seen in figure 3. The trend ran through (figure 3). From table 2 the highest turbidity of 2.79 NTU was recorded at DS3 which invariably recorded the highest conductivity figure of 9.21 µs/cm and highest TDS of 3.21 mg/L. According to American Public Health Association [18], turbidity in water is caused by suspended matter such as clay, silt and organic matter as well as by plankton and other microscopic organism. This shows a linear correlation between conductivity and turbidity. This high turbidity levels in the harvested rainwater samples may be as a result of accumulation of dust on the roofing during the period of sample collection. In general, as the turbidity increases, the conductivity also goes up. The lowest turbidity of 1.26 NTU was recorded at DS2 with corresponding conductivity of 7.82 and TDS of 2.42 mg/L. The main source of natural alkalinity are rocks which contain CO_3^{2-}, HCO_3^- and OH^- compounds. As shown in table 1, the average conductivity figure per household was quite low in relation to the standard limit by WHO, 200 mg/L. The mean range during the period was 7.78-9.21µ/Sc. The minimum occurred at DS7 but the maximum occurred at DS3. The highest mean alkalinity of 17.20 mg/L was recorded at DS7 and the lowest was found at DS4, 14.20 mg/L. the rainwater samples were harvested from roof in plastic containers which have no contact with rocks that may impart ions in the rainwater. This explains why the mean alkalinity values were very low in all the water samples. Also it accounted for the low pH values. Because alkalinity is the ability or the capacity of water to resist changes in pH or to neutralize acid. Since the alkalinity was low in all the samples, it gave reason to understand that the ability of the harvested rain water which to neutralize the H^+ ions already in the rainwater is minimal. The relatively low alkalinity values mean that the water may have a low capacity to neutralize or "buffer" incoming acids and, therefore could be susceptible to acidic pollution since alkalinity is a measure of all the substances in water that can resist a change in pH when acid is added to the water. This reflects the very low pH values recorded in this study. The highest mean alkalinity of 17.20 mg/L with corresponding pH of 5.48 and the lowest was recorded as 14.20 mg/L and the corresponding pH 4.86 (table 1). The average concentration range over the entire period was 14.20 – 17.20 mg/L (See Table 4). The high average alkalinity value for DS7 is due is to its high total hardness and high pH values (See Tables 1 and 2). The total hardness of rainwater is due to the presence of ions such as carbonates, magnesium, bicarbonate and iron ions which cause both the temporarily and permanent hardness of water. It is most commonly expressed as milligrams of calcium carbonate equivalent per litre. Water containing calcium carbonate concentrations below 60 mg/L is generally considered as soft; 60-120 mg/L, moderately hard; and more than 180 mg/L, very hard. Hence all the harvested rainwater samples taken from the community can confidently be described as soft water. Generally the total hardness for all the samples was very low compared to the threshold limit recommended by the international bodies of 180 mg/L. The relatively low total hardness all the rainwater samples supports the existing notion that rainwater is soft and therefore, it does not contain high concentration of the ions which are responsible for permanent and temporarily hardness of water. From table 1 the maximum mean concentration of total hardness was 3.30 mg/L and the minimum was 2.42 mg/L. These low values may attribute to the fact that rainwater was harvested directly from roof tops into containers which have no sedimentary rocks that may impact calcium and magnesium ions in the rainwater. Essentially the principal source of hardness of water was completely absent. According to Exploring the Water Environment, a stream's hardness reflects the geology of the catchments area and sometimes provides a measure of the influence of human activity in watershed. Significant concentrations of all the three metals; zinc, iron and lead were found in all the water samples analyzed (table 3). This might have resulted from the dissolution of carbon dioxide, sulphur dioxide and nitrogen dioxide in the rainwater samples from that community. This led to the relatively high concentration of the metals analysed in the rainwater samples from the area as a results of the corrosion the roofing materials and rainwater collection tanks. Low pH values will lead to erosion of the aged metal roofing sheets into the water samples. The research showed considerable relationship between pH and metals concentrations.

The presence of iron and zinc in the water samples may due to the leaching of these metals from the roof surfaces. This is likely so because most of the roofs were old and rusty, and as the pH decreases the metal got eroded and found their way in the rainwater harvested.

CONCLUSION

In general, the physico-chemical quality of rainwater samples analysed in terms of total dissolved solids (TDS), total hardness and temperature, alkalinity, turbidity, and conductivity, met prescribed standards by World Health Organisation and other international bodies. However, the rainwater was found to be acidic in nature (pH < 7).

The levels of metals such as Zn, Pb and Fe, were reported present in all the samples analysed. They were also found to be below the threshold values recommended by World Health Organisation. With lead, the concentration of the metal, in all the samples was far below the permissible limit and might have arisen from the suspension of lead in the atmosphere due to previous vehicular activities and atmospheric pollutants adsorbed on the dust since no lead fittings were found on the roof of the houses were the rainwater samples were collected.

The aged nature of most of the roofing sheets and the type of collection systems might have contributed to the high levels of the remaining two metals; iron and zinc. In addition, the acidic nature of the rainwater samples analysed contributed to the high levels of metals such as Zn and Fe. On the other hand, the main problem with the quality of harvested rainwater in the studied area lies acidity. All the samples analyzed had pH below the acceptable range for good drinking water prescribed by WHO.

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