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Quality of Rainwater from Different Roof Material

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ABSTRACT

Roof material is an important consideration when designing a rainwater catchment system .This is because it affects the quality of the harvested rainwater which invariably affects the usage as potable or non potable.
This study was carried out to determine the quality of rainwater from four different roofing materials (asbestos, aluminium, concrete and corrugated plastic) within Ogbomosho North Local Government Area of Oyo State, Nigeria, between the months of July to October, 2011. The rainwater samples were taken to the laboratory and analyzed as recommended by Nigerian standard for Drinking Water Quality (NSDQW) and World Health Organization (WHO).

All the Physical and most of the chemical parameters analyzed conformed to the recommended standard value apart from chloride and total hardness value. Of interest is the rainwater sample from asbestos roofing sheet which had the highest mean value for pH (6.75), total hardness (84 – 86mg/l), aluminium concentration (3 – 9 mg/l), copper (0.03 – 0.04 mg/l), nitrate (31.9 – 39mg/l), and sulphate value between 11- 14mg/l, although, all these parameters fell within the standard values. However, Coliform as bacterial indicator was present in samples from asbestos, concrete and corrugated plastic roof, only the aluminium roof was free from pathogenic contamination. To ensure that the rainwater harvested satisfies health requirement for consumption as specified, all the harvested rainwater should be given some level of treatment in terms of pH, total hardness, chloride concentration and bacterial contamination. It was recommended that the rainwater from all the roofs in this case study area, be carefully examined. Consequently, if the harvested rainwater is being considered for domestic use, the gutters and the catchment areas should be regularly cleaned to remove animal droppings and leaves from over hanging trees as well as boiled to adequate temperature.

Keywords: *Rainwater,Contamination, Roof material, water quality, Asbestos*

1. INTRODUCTION

The issue of rainwater harvesting is now a widely used technique for the provision and supply of both potable and non potable supply of water specially in developing worlds were the mains water are insufficient to meet the growing needs of the society due to rapid industrialization and development as well as population growth. Rainwater can be a valuable resource and can be quite safe to drink when harvested and stored in a properly installed and maintained water catchment system (http://www.public.health.wa.gov.au). In many areas of the world today, it 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 (Peter, 2007 and Vikaskumar *et al*, 2007).

Among the various catchments for the harvesting of rainwater, roof catchment seems to be the most common. This is because the inhabitants use existing roofs of their houses thereby no additional costs are incurred and the amount and quality of rainwater collected depends on the area and type of roofing material. Roofs provide an ideal catchment surface for harvesting rainwater, provided they are clean. But Chang et al (2004) reported that roofs can be a serious source of non point source pollution as well. Examples of roofing materials are Galvanized, corrugated iron sheets, corrugated plastic, asbestos-cement sheets, concrete, thatch, tile or clay.

The quality of drinking-water is a powerful environmental determinant of health. Drinking-water quality management has been a key pillar of primary prevention of diseases for over one-and-a-half centuries and it continues to be the foundation for the prevention and control of waterborne diseases. Water is essential for life, but it can and does transmit disease – from the poorest to the wealthiest primarily from the catchment area. Table 1 shows the different pathogenic micro-organisms that can be found in water (Otto, 1995). The most predominant waterborne disease, diarrhoea/ dysentery, has an estimated annual incidence of 4.6 billion episodes and causes 2.2 million deaths every year (WHO, 2010).The quality of rainwater, which has been properly collected and stored, is expected to be substantially free from minerals and most of the common pollutants that are present in surface and groundwater sources.

Table 1: Pathogenic Micro-organisms in Water

Bacteria	Disease
Salmonella typhi	Typhoid fever
Salmonella enteritidis	Gastroenteritis
Shigella dysenteriae	Dysentery
Vibrio cholera	Cholera
Escherichia coli	Gastroenteritis
Leptospira icterohaemorrhzgicae	Leptospirosis (Weil's disease)
Mycobacterium tuberculosis	Tuberculosis
Legionella pneumophila	Legionellosis (Legionnaives disease
Viruses	
Hepatitis A virus	Infectious hepatitis
Polio virus	Infantile paralysis, poliomyelitis
Enteroviruses	Gastroenteritis
Protozoa	
Giarodia lamblia	Giardiosis
Entamoeba histolytica	Amoebioses

Source: Otto , 1995

Several studies have looked at the effect of roofing material on harvested rainwater quality but common roofing materials and coatings will vary across the country and the world. Chang (2004) and Mendez (2010) carried out a research in Texas and revealed that residential roofing materials can negatively impact the rainwater quality and that the quality of harvested rainwater improved with roof flushing. Nicholson et al. (2009) compared harvested rainwater quality among six roof types: galvanized metal, cedar shake, asphalt shingle, two types of treated wood, and green (i.e., vegetated) and concluded that the galvanized metal, asphalt shingle, and green roofs neutralized the acidic rainwater to a greater extent than did the other roof materials. The treated woods yielded the highest copper concentrations (mg/L range), and the galvanized metal yielded the highest zinc concentrations (mg/L range), as compared to the m g/L concentrations of these metals from the other roof materials. Van Metre and Mahler (2003) found galvanized metal roofs to be a source of particulate zinc and cadmium and asphalt shingle roofs to be a source of particulate lead and potentially mercury. Kingett (2003) found higher zinc concentrations in rainwater harvested from painted galvanized iron roofs that showed evidence of weathering as compared to those in excellent condition. Despins et al. (2009) found that harvested rainwater quality from steel roofs was superior to that from asphalt shingle roofs, particularly with respect to turbidity, total organic carbon, and color. Efe (2006) assessed the level of portability of rainwater samples collected from thatch, aluminium, asbestos, corrugated iron roofing sheets, and open surfaces from catchment's roofs in 6 rural communities of Delta State, Nigeria. The result revealed that most of physiochemical and biological characteristics of rainwater samples were generally below the WHO threshold, as such the rainwater characteristics showed satisfactory concentration in these rural communities. Thus, the rainwater from these rural communities should be harvested, stored for human consumption and for other uses by the inhabitants.

However, In Abeokuta Ogun State of Nigeria, Aladenola and Adeboye (2009) addressed the potential of rainwater from roof catchments and concluded that Rainwater collection systems can provide water for purposes not requiring drinking water quality. The need to assess the quality of rainwater from different roof material within the case study area/ location is therefore vital. The objective of the current study is to thoroughly investigate the various common roof materials use for rainwater harvesting in the study area.

2. MATERIALS AND METHODOLOGY

2.1 Description of Study Site

This study was conducted in Ogbomoso, Ogbomoso North Local Government area of Oyo State. The study area falls within the humid forest zone of Nigeria with great potential of rain. The rainy period is usually between April and October and the average annual rainfall is between 1100 - 1400mm spreading over an average of between 90-120 days annually. The relative humidity varies between 60 and 80 percent. The study area was chosen because of non-availability of public or private water mains in the area, the major source of water for domestic use are from rain, hand dug well and borehole. Unfortunately, the majority of the wells dry up during the dry season when the rain ceases while the borehole water is sold. The community relies extensively on the available rainwater because it is cheap, accessible in the raining season and it was believed to be safe for drinking.

Geographical coordinates of Ogbomoso in decimal degrees (WGS84)
Latitude : 8.133
Longitude : 4.267
Geographical coordinates of Ogbomoso in degrees minutes seconds (WGS84)
Latitude : 8 08' 00"
Longitude : 4 16' 00"

2.2 Source of Data

The first field work was to identify roof materials that are commonly used in Ogbomoso North in general and roofing materials that are commonly used in Ogbomoso for rainwater harvesting. Households were randomly picked where roof water harvesting system was already in existence.
The data used for this study were collected from July to October, 2011 from a field survey in the study area. Information on major water sources, availability, daily quantity of water used and uses of rain water were collected.

2.3 Method of sampling and Collection of Rain Water Samples

A random sampling technique was employed in selecting the sampled household. Four roof types were identified, namely - asbestos, aluminum, concrete flat roof and the Corrugated Plastic roof. Four homes each with the above roof types were selected randomly and rainwater samples were collected at the beginning of each month. Care was taken to ensure that samples were representative of water to be examined and that no accidental contaminations occur during sampling. Sample containers were rinsed with sterile water and drained before they were used to collect the rainwater sample from the different roof types. The temperature and pH of the rainwater sample were measured immediately after collection with a mercury thermometer and pH meter respectively. Samples for microbial analysis were kept with a sterilized capped bottle to arrest the further growth of bacterial prior to analysis. They were then taking to the laboratory for microbial and physiochemical analysis.

The four types of existing roof materials used as catchment were designated as follows:

i. A for asbestos cement roof material: sample were taken from four sources, designated as A1, A2, A3 and A4
ii. AL for aluminium roof material: samples were taken from four sources, designated as AL1, AL2, AL3 and AL4
iii. C for concrete flat roof: Rainwater were collected from four sources designated as C1 ,C2 ,C3 and C4
iv. PC for Corrugated Plastic roof: rainwater were collected from four sources, designated as PC1, PC2, PC3 and PC4

3. RESULT AND DISCUSSION

3.1 Results from Physical Analysis

The average temperature of all the samples collected from these roofs conforms to world Health organization standard. Temperature of Rainwater from Asbestos roofs was between 26.3 -26.4^0 C , from aluminium roof between 26.6- 26.8^0 C, from concrete flat roofs 26.5 -26.6^0 C and from corrugated plastic roof 26.5 – 26.6 ^{0} C, all within the specification of 20 - 32^0 C . All the samples were colourless and odourless. Turbidity as the measure of the cloudiness of water indicates the level of contamination as a result of the presence of any disease causing organism, dissolved chemicals or particles in the harvested rainwater was measured with the turbidity meter. The average turbidity in Nephelometric Turbidity Units (NTU) from asbestos roofs lies between 0.4 -0.8, from aluminium 0.0-0.2, concrete roof 0.2 -0.8 and 0.2 from corrugated plastic roof. That is, having mean values of 0.58, 0.1, 0.45 and 0.2 respectively for the different roofs. The values for the physical parameters are shown in tables 2a -2d while Fig.1 shows the variation of the different roofs with respect to average temperature and turbidity.

Table 2a: Physical test (Average Result from Asbestos Roofs)

Sample	Tempt. (0^C)	Odour	Colour	Taste	Turbidity (NTU)
A1	26.3	Odourless	Colourless	Tasteless	0.8
A2	26.4	Odourless	Colourless	Tasteless	0.4
A3	26.6	Odourless	Colourless	Tasteless	0.6
A4	26.4	Odourless	Colourless	Tasteless	0.5

WHO Standard	20-32	Unobjectionable	15TCU	Unobjectionable	5.0

*True Colour Units (TCU) *Nephelometric Turbidity Units (NTU).

Table 2b: Physical Test (Average Result from Aluminium Roofs)

Sample	Tempt.(0^C)	Odour	Colour	Taste	Turbidity(NTU)
AL1	26.8	Odourless	Colourless	Tasteless	0.0
AL2	26.7	Odourless	Colourless	Tasteless	0.1
AL3	26.6	Odourless	Colourless	Tasteless	0.1
AL4	26.6	Odourless	Colourless	Tasteless	0.2
WHO Standard	20-32	Unobjectionable	15TCU	Unobjectionable	5.0

*True Colour Units (TCU) *Nephelometric Turbidity Units (NTU).

Table 2c: Physical Test (Average Result from Concrete Flat Roofs)

Sample	Tempt.(0^C)	Odour	Colour	Taste	Turbidity(NTU)
C1	26.5	Odourless	Colourless	Tasteless	0.5
C2	26.6	Odourless	Colourless	Tasteless	0.6
C3	26.6	Odourless	Colourless	Tasteless	0.5
C4	26.6	Odourless	Colourless	Tasteless	0.2
WHO Standard	20-32	Unobjectionable	15TCU	Unobjectionable	5.0

*True Colour Units (TCU) *Nephelometric Turbidity Units (NTU).

Table 2d: Physical Test (Average Result from corrugated Plastic Roofs)

Sample	Tempt.(0^C)	Odour	Colour	Taste	Turbidity(NTU)
PC1	26.5	Odourless	Colourless	Tasteless	0.2
PC2	26.5	Odourless	Colourless	Tasteless	0.2
PC3	26.5	Odourless	Colourless	Tasteless	0.2
PC4	26.6	Odourless	Colourless	Tasteless	0.2
WHO Standard	20-32	Unobjectionable	15TCU	Unobjectionable	5.0

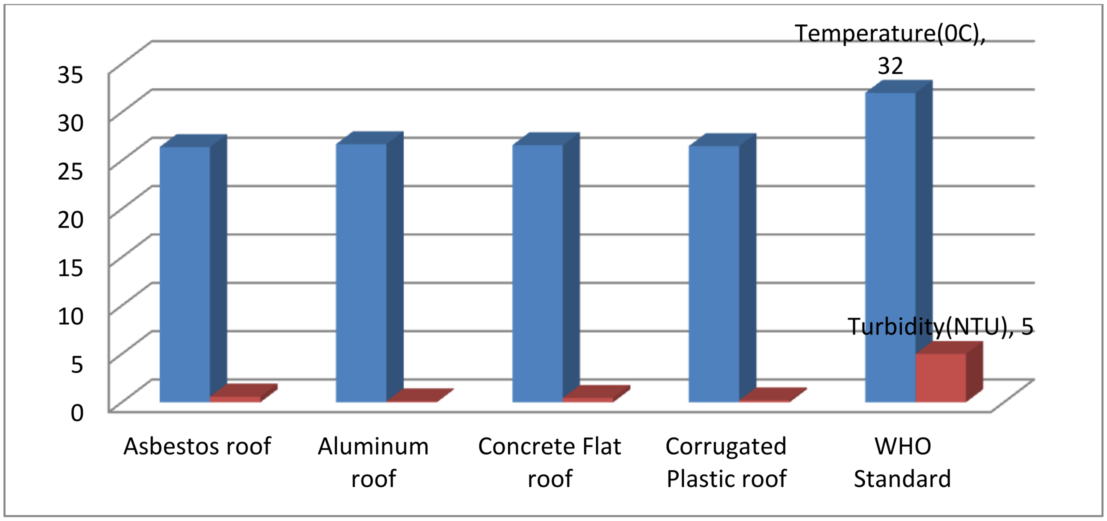

Fig.1: Average temperature and turbidity from samples for the different roofs with respect to WHO standard

3.2 Results from Chemical Analysis pH Value

The average pH of rainfall samples collected from the different roof types varied from 6.58 -6.94, 6.13 -6.3, 5.81 – 5.95 and 6.14 -6.45 for asbestos, aluminium, concrete and corrugated plastic roofs respectively. All the samples analyzed from concrete flat roofs were more acidic with average pH of 5.85 than that from aluminium and corrugated plastic roof. The pH value of most samples analyzed (as shown in Figure 2) fell below the NSDQW and WHO maximum allowable limit for potable water of 6.5 -8.5 except for asbestos roof with average pH range between 6.58 -6.94.

Total Hardness

The average hardness of rainwater samples from the different roof type was between 84 -86 mg/l for asbestos, 31-39 mg/l for aluminium, 29-31 mg/l for the concrete roof and 40-50 mg/l for the corrugated plastic roof. This fell below the W.H.O standard which ranges between (100-300 mg/l) .Fig.3 show the variation in the hardness value against the WHO recommended standard value for the different roof types.

Chloride

All the rainwater samples from the four roof types fell below the limit. Fig.3 shows the mean chloride values for the selected roof types. Average chloride values derived were 90, 80, 90 and 90 mg/l respectively which does not conformed to the recommended value between 200-300 mg/l.

Total Alkalinity

The alkalinity of water as a measure of its capacity to neutralized acids. In natural waters, the alkalinity is related to the bi-carbonates HCO3, carbonate CO and hydroxide OH concentration. The average value for alkalinity of the samples from asbestos was between 3-9 mg/l, 6 mg/l from aluminium roof, 0.6 mg/l from concrete roof and 0.9-1.2 mg/l from the corrugated plastic roof. All the values conform to the recommended standard value.

Copper and Iron

The mean values for copper was 0.03, 0.0, 0.01 and 0.02 mg/l for asbestos, aluminium, concrete and corrugated plastic roof respectively. This fell within the standard value of 1 or 2 mg/l recommended. Iron content in the rainwater samples was 0. It also conforms to the required standard of 0.3mg/l. Fig.4 shows the concentration of copper and iron in the water samples from the various roof types identified.

Nitrate and Magnesium (Mg^+)

Nitrate as NO value was also within the standard (50mg/l),ranging from 31.9 –39 mg/l for asbestos, 5.3-11 mg/l for aluminium, 3.54 -12.4 mg/l for concrete roof and 15.8-17.3 mg/l for corrugated plastic roofs .The magnesium value was also within the recommended range, they fell within the limiting value of 50mg/l. For, magnesium values were 30.8-38.6 mg/l , 20.7- 24.8 mg/l, 36-38.6 mg/l and 24.9-32.3 mg/l for asbestos, aluminium ,concrete and corrugated plastic roofs respectively. Fig.5 shows the real concentration value in the water samples analyzed.

Zinc and Sulphate Value

The NSDQW and WHO values for Zinc and sulphate are 3 mg/l, 100 mg/l and 5 mg/l , 200mg/l respectively. The entire sample fell within the recommended specification. The rainwater samples are adequate in Zinc and sulphate concentration.

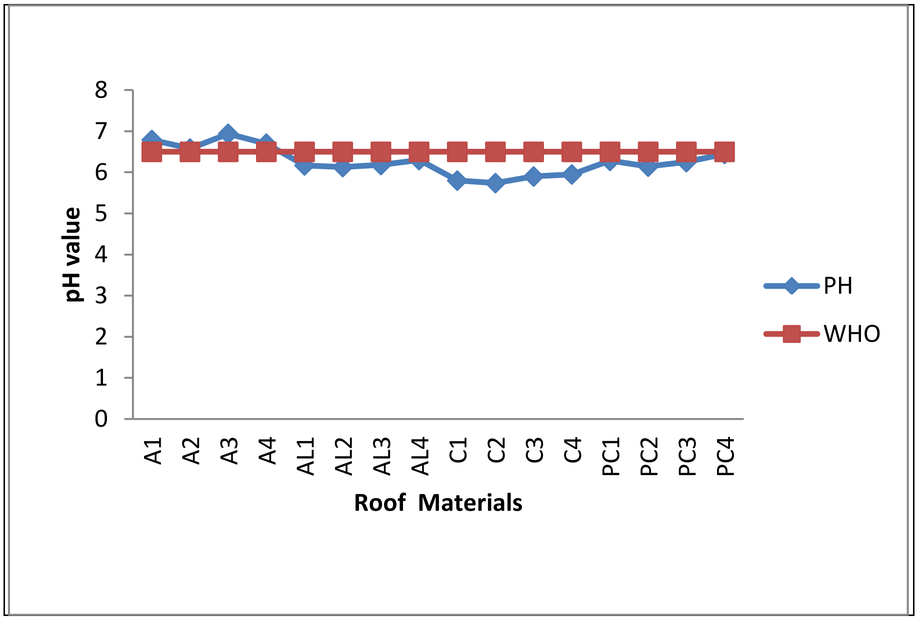

Fig.2: Average pH value for the different roof types

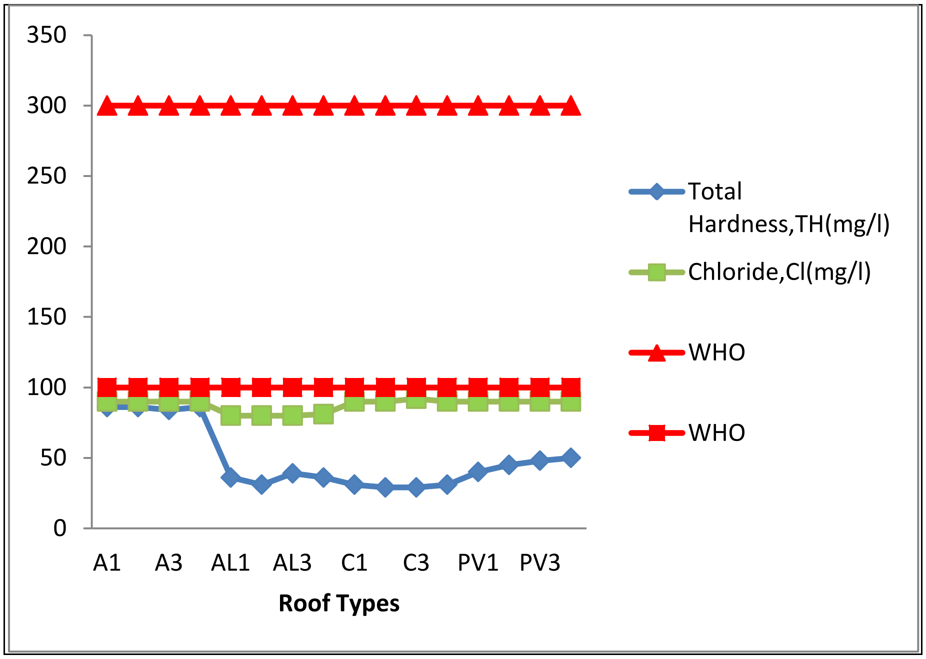

Fig.3: Average TH and Cl value for the different roofs

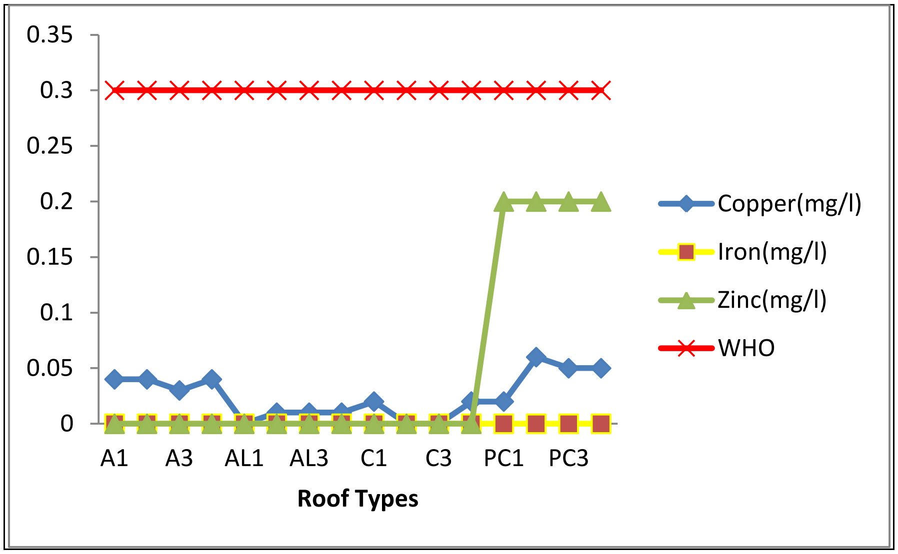

Fig.4: Average value for Copper, Iron and Zinc for the different roofs

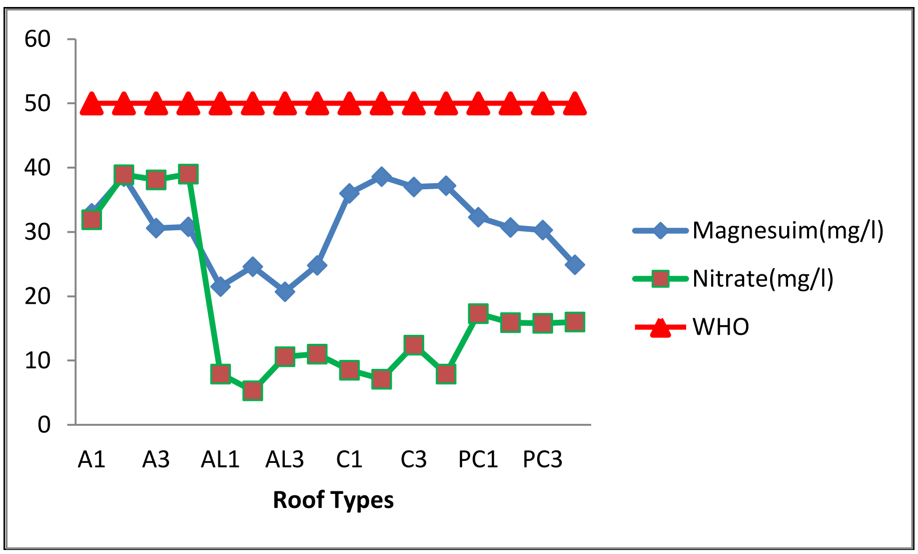

Fig.5: Average value for Nitrate and Magnesium for the different roofs

3.2 Results from Bacteriological Analysis

The WHO specifies that any disease causing organism must not be detectable in any 100ml of water sample and must not be present in 95% of sample taken throughout any 12 months period. Fig.6 show the approximate coliform count in a 100ml of rainwater sample from the different roof investigated in the study area.

The recommended bacterial indicator is coliform group of organisms. Coliform group of organisms are not pathogenic, they are aerobic, facultative anaerobic, gram negative, nonsporulating, rod shaped bacteria, that ferment lactose with gas formation and aldehyde/acid within 48 hours at 35^0C incubation. Rainwater samples from two asbestos roofs A3 and A4 were contaminated, all samples from aluminium roofing material were free of pollution because there was no bacterial detection in any of the sample. Concrete and corrugated plastic roof were not completely free of bacterial contamination as few samples had bacterial contamination detected in them.

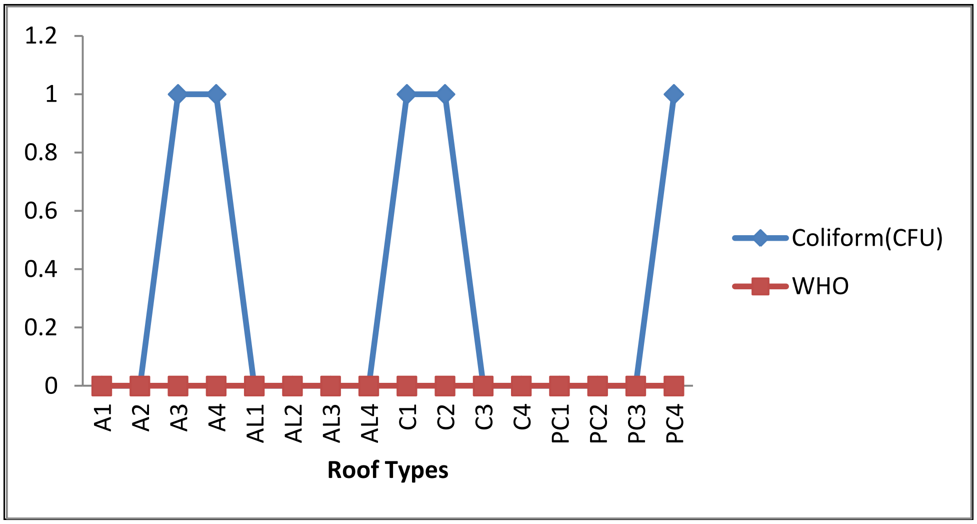

Fig.6: Approximate Coliform count for the different roofs

4. CONCLUSION & RECOMMENDATIONS

All the Physical characteristics (temperature, odour , colour , taste and turbidity) of all the rainwater samples analyzed conformed with the recommended WHO standard even though rainwater from asbestos roofs has the highest turbidity value ,it was within the recommended NSDQW and WHO standards. For the chemical analysis, rainwater from asbestos roofing sheet has the highest mean value for pH (6.75), total hardness (84 – 86mg/l), aluminium concentration (3 – 9 mg/l), copper (0.03 – 0.04 mg/l), nitrate (31.9 – 39mg/l), and sulphate value between 11- 14mg/l level of contamination ,although, all these parameters fell within the standard values, all the rainwater samples require some level of treatment before it can be fit for drinking . Rainwater samples from aluminium roofs had the highest level of magnesium (36 -38.6mg/l) ,though within the standard value. Concrete and corrugated plastic roofs also had some level of contamination but also fell within the limits of WHO recommendations. Coliform as bacterial indicator was absence from all the samples collected from aluminium roofs. However, asbestos, concrete and corrugated plastic roofs were not completely free from bacterial contamination. Proper attention should be given to roofs A3, A4, C1, C2 and PC4to prevent further or continuous contamination. Rainwater from Aluminium roofing sheet proved to be most suitable. None the less, to ensure that the rainwater satisfies health requirement for consumption all the harvested rainwater should be given some level of treatment in terms of pH, total hardness, chloride concentration and bacterial contamination. From the health point of view it is also important to clean the gutter from time to time and ensure that water does not stagnate inside the gutter pipes which can lead to mosquito breeding. Trees hanging in the vicinity definitely enhance the possibility of contamination due to increased access of the roof to birds and animals. Leaves and animal droppings contribute to organic loading of the rainwater samples, which in turn act as nutrient for bacterial growth. It is also recommended that the rainwater from this case study area be carefully examined if the harvested rainwater is being considered for domestic use especially if it is to be consumed, it should be boiled at least 100^0C before consumption and Chlorine tablets (dosage to be determined by a water quality specialist) can be used for disinfection.

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