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# COMPARATIVE ASSESSMENT OF THE METAL CONTENTS OF RAINWATER SAMPLES FROM DIFFERENT ROOFING MATERIALS IN IKOT AKPADEN MKPAT ENIN L.G.A AKWA IBOM STATE, NIGERIA.

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**ABSTRACT:**

This study was carried out to determine the metal contents of rainwater samples from different roofing materials in Ikot Akpaden, Mkpat Enin L.G.A, Akwa Ibom State, Nigeria and hence their health implications. The samples were collected randomly in the study area from the runoff of three (3) commonly used different rooftop materials such as, aluminium long span, asbestos and corrugated iron-zinc. The physical parameters that were assessed include pH, temperature, colour, odour, taste, electrical conductivity while the chemical parameters include total dissolved solid, total hardness, dissolved oxygen, heavy metals like iron (Fe), zinc (Zn), lead (Pb), copper (Cu), Nickel (Ni), Cobalt (Co), Chromium (Cr) and aluminium (Al). Anions include chloride ($Cl^-$) and sulphite ($SO_3^{2-}$). The purpose of this work is to study the effect of rooftop materials on the quality of rainwater that run through them. The physio-chemical analyses carried out were within the WHO and other regulatory specifications.

Results obtained were compared with reference standards contrasted and compared with other works and found that aluminium roofing sheet gave the least contaminant level in every parameter assessed. A level of chemical treatment is recommended for rainwater runoff from aluminium roof and all the roof materials in the study area.

**Key words:** Rainwater, rooftop materials, physio-chemical analyses. AAS

## 1 Introduction

Water is a universal solvent and one the most common substance fundamental to all forms of life on earth. Pure water does not exist in nature; even rain water dissolves the substances in the atmosphere.

Environmental pollution of natural water system by heavy metals such as chromium, zinc, copper, cobalt etc can now be associated with technological advancement and population growth which directly led to high level of industrialization and urbanization (korai et.al, 2008; Assubaie, 2011).

In many area 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). While roofing seems like an obvious choice for rainwater harvesting, there are some drawbacks in using this resource. Laboratory studies of roofing materials demonstrated the potential for pollutant leaching into the environment. A large reservoir of nutrients and metals existed in these materials, and if the environmental conditions were favourable some of this reservoir potentially could be released into the runoff.

Due to fast growing population in Mkpat Enin L.G.A especially Ikot Akpaden because of the establishment of Akwa Ibom State University (AKSU), dualization of Eket-Ikot Abasi road and the industrialization of the neighboring L.G.A (Exxon Mobil Eket and Aluminium Smelter Company of Nigeria(ALSCON) Ikot Abasi. It is of good objective to analyze and ascertain the quality of rainwater from roof run off in the area in order to ensure the safety of its utilization by man, animals and plants.

Several studies pointed at the effect of roofing material on harvested rainwater quality but common roofing materials and coatings will vary across the country and the world. Contamination in harvested rainwater is affected by roof type, including roofing materials, slope, and length (Kingett Mitchell, 2003; Yaziz et al., 1989). Due to the acidic nature of ambient rainwater, chemical compounds from roofing materials may leach into the harvested rainwater (King and Bedient, 1982). 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. (2010) made a comparative analysis of rainwater quality among six roof types: galvanized metal, cedar shake, asphalt shingle, two types of treated wood and green 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 mg/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 conditions.

Despins et al. (2009) found that harvested rainwater quality from steel roofs, particularly with respect to turbidity, total organic carbon, and colour. 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.

In the past, it has been assumed that as roofing materials age, their ability to release pollutants decreases to a low level, steady-state value. However, aging due to fluctuating temperature and ultra-violet light exposure and the ongoing interactions between the roof surface and the chemicals in the rain can result in newly exposed sub surfaces. These sub-surfaces may not have been sealed to prevent degradation, because they were not expected to be exposed to outdoor environment. Testing at PSH on two old(60+ years) painted and galvanized metal roof panels showed that pollutant release could continue for at least 60 years(Clark et al.2008b).

Studies have detected a range of organic compounds in ambient rainwater samples, including polycyclic aromatic hydrocarbons (PAHs) and pesticides, with concentrations exceeding the United States Environmental Protection Agency (USEPA) drinking water standards (Basheer et al., 2003; Polkowska et al., 2000). Ambient rainwater also is susceptible to contamination by microbial aerosols; urban aerosols have recently been shown to contain up to 1,800 different types of bacteria, which is comparable to the diversity of bacteria found in soils (Brodie et al., 2006). Deposition of fecal microorganisms on rooftops from animals such as birds, lizards, and squirrels is problematic as well (Ahmed et al., 2008; Crabtree et al., 1996).

However, in Abeokuta Ogun State of Nigeria, Aladenola and Adeboye (2009) addressed the potential of rainwater from roof catchments and concluded that the need to assess the quality of rainwater from different roof material within the case study area/ location is therefore vital. Pure rainfall is considered not to be significantly polluted, although this usually depends on the location, season, traffic intensity etc. Runoff can be influenced by the materials used for the roof, its slope, exposure, the rain event, meteorological factors etc. The acidic nature of rainwater makes it react with compounds retained in or by the roof and cause many elements in roof runoff to leach out. It is noted that roof interception causes enrichment (compared to free fall rainwater) in virtually all the water quality parameters being studied ( Adeniyi and Olabanji, 2005; Llopart-Mascaro et al., 2010).

Rain acts as the powerful mechanism to remove pollutants from the atmosphere. Precipitation chemistry is the result of a series of in-cloud and below-cloud atmospheric chemical reactions and a complex interaction between microphysical processes and cloud dynamics (Chunghtai et al, 2014).

Rainwater composition is important in evaluating the role of transport of soluble materials and the contribution of different sources of atmospheric pollutants.

Every day, large quantities of anthropogenic and natural materials are dumped into the atmosphere, majority of this materials return to the ground. Man is primarily responsible for the enrichment of many trace elements in the atmosphere caused by the combustion of fossil fuels including such addictives as lead in gasoline, processing of crystal materials for manufacturing cements, roasting of ores for refining metals and burning of waste materials. Composition of rainwater varies from site to site and is difficult to control as it is influenced by both natural and anthropogenic activities (Gaddamwar and Rajput, 2012; Obia et al. 2011). Environmental adverse effect of acid rain include change in leaching rate of nutrients from plants foliage and soil nutrient acidification of lakes and rivers, effect of metabolism in organism and corrosion of structures(Ajugwo, 2013). The objective of this study is to investigate the metal content on common roof materials used for rainwater harvesting in the study area. The research work also provides guidelines for the selection of roofing materials that will aid in the harvesting of water of improved quality

## 2 Materials and Methods

### 2.1 Apparatus/Equipment

Burette, pipette**,** Dissolved oxygen meter(DO analyzer JPS-605)**,** Conductivity meter(DDSJ-308A)**,** Hach DR 3800 model**,** Conical flasks, beakers**,** Polyethylene bottles**,** $P_H$ meters**,** Atomic Absorption Spectrophotometer (AAS)

### 2.2 Reagents

Distilled water, concentrated trioxonitrate(v) acid (2M), buffer solution(4,7,10), EDTA (0.01N), Ammonium chloride, Eriochrome Black T indicator.

2.3 Location of the study area.

This study was conducted in Mkpat Enin Local Government area of Akwa Ibom State within the industrial belt extending from Eastern Obolo, Etinan, Oruk Anam, and Onna to Ikot Abasi. Mkpat Enin one of the 31 Local Government Areas of Akwa ibom State. . It is located in the South- South of Nigeria; with coordinates: 4°44'1''N 7°44'55''E/ 4.73361°N 7.74861°E. The climate of the area is that of humid tropic. Temperatures are high, lying between 26°C and ,28°Crainfall is heavy and the mean annual rainfall lies between 2,000-4,000 mm.

2.4 Sample Collection and Preservation

The surveillance trip was to identify the roof materials that are commonly used for rainwater harvesting in Mkpat-Enin Local Government Area in general and Ikot Akpaden in particular. Households were randomly picked and interviewed on the major water sources, availability, and daily quantity of water including the uses of rain water. A random sampling technique was employed in selecting the sampled household. Three major roof types were identified, namely - asbestos, aluminum and the Corrugated iron-zinc roofs. Traditional thatch roofs have virtually disappeared except in the most remote hamlets. Rainwater samples were collected during the month of October 2015. Care was taken to ensure that samples were representative of water to be examined and that no accidental contaminations occur during sampling. A Two liters polyethylene Sample container were rinsed with sterile water and drained before they were used to collect the rainwater sample from the different roof types, it was placed about 100 meters above the ground to ensure no contamination occur. Concentrated trioxonitrate(V) acid ($HNO_3$) was added to the samples and was preserved in an ice packed cooler in the dark before transported to the laboratory. The samples were analyzed for physical, chemical content using standard methods for water examination (APHA, 1998 and ASTM, 1999) at Akwa Ibom state university Laboratories.

2.5 Recommended Storage

Several international standards (ISO) have been defined for water quality sampling. These cover, among other topics, guidance on the design of sampling programs, sampling techniques, preservation and handling of water samples. An alternative source of advice is a compilation of the US Environmental Protection Agency's (USEPA) recommended sampling and analysis methods, which also covers sample preservation, sample preparation, quality control and analytical instrumentation. Even if the above mentioned conservation methods are used, the storage period for water samples is limited.

Table 1 gives an overview of recommended sampling and storage bottles as well as conservation methods and maximum storage periods for different determinants in the sample derived from 2003 edition of international ISO standard,

**Table 1**

| Analyte | Container (capacity, ml) | Preservation | Maximum time recommended |
|---|---|---|---|
| Aluminum | PA or G or BGA 100 | $HNO_3$ | 1 month |
| Calcium and hardness | P or G 100 | $HNO_3$ | 1 month |
| Chlorine | P or G 500 | C exclude light | 1 month |
| Chromium | PA or GA 100 | $HNO_3$ | 1 month |
| Cobalt | PA or BGA 100 | $HNO_3$ | 1 month |
| Colour | P or G 500 | C exclude light | 5 days |
| conductivity | P or BG 100 | C exclude light | 24 hours |
| Copper | PA or GA 100 | $HNO_3$ | 1 month |
| Iron | PA or BGA 100 | $HNO_3$ | 1 month |
| Odour | G 500 | C | 6 hours |
| Ph | P or G 100 | C and no air | 6 hours |
| Zinc | PA or BGA 100 | $HNO_3$ | 1 month |
| Dissolved oxygen | P or G 300 | C, no air and exclude light | 4days |

P-Plastic, PA-Plastic (acid-washed), G-Glass, GA-Glass (acid-washed), BGA –Borate glass (acid washed), BG- borate glass, C- cool to 1°C to 5°C, $HNO_3$- Acidify with nitric acid to pH 1-2.

## 3.0 METHODS OF ANALYSES

### 3.1 Determination of Temperature, total dissolved solid (TDS) and total dissolved salt.

Temperature and total dissolved solid (TDS) of the samples were measured at site using conductivity meter (DDSJ-308A).

**3. 2 Determination of $_P$H.** pH meter phs-3C was used for this determination.

### 3. 5 Determination of dissolved oxygen (DO)

Determination of total dissolved oxygen was carried out using DO analyzer JPS-605. The electrode was immersed in 200ml beaker filled with the sample after rinsing with distilled water and the reading was recorded at steady value.

**3. 6 Determination of colour/** Lovibond colour disc (comparator) was used for this determination.

**3. 7 Determination of electrical conductivity**. Electrical conductivity was measured using conductivity meter (DDSJ-308A) after calibration.

**3. 8 Determination of total hardness as $CaCO_3$.** Parameter was determined by titrimetric method. 50ml of the sample was measured and poured into a conical flask 2 drops of $NH_4Cl$ was added which acted like a buffer followed by Eriochrome black T as an indicator and was titrating against 0.01N EDTA until the endpoint, which was observed by a change in colour from wine red to blue.

Calculation:

$$\text{Mg/l } CaCO_3 = \frac{V_2 \times E \times N \times 1000}{\text{Volume of sample used}}$$

$V_2$ = Volume of EDTA

E =Equivalent Weight of $CaCO_3$

N =Normality of EDTA

**3.4.9 Determination of heavy metals (lead, iron, copper, nickel, zinc, cobalt, chromium) and some ions (chloride, sulphates, aluminium).**

The concentration of these ions and heavy metals in the sample were determined using atomic absorption spectrophotometer (Harch DR 2010PDLS) model.

## RESULTS AND DISCUSSIONS

**Table 2 Sampling Source and Alphabetical Representation is illustrated below:**

| Rainwater sampling location and source | Alphabetical Representation |
|---|---|
| | |
| Open Air(Control) | A1 |
| Aluminum Long Span | A2 |
| Asbestos | A3 |
| Corrugated Iron-Zinc | A4 |

**Table 3 Physical Test (Result from Control A1)**

| Parameter | Measured value | WHO standard |
|---|---|---|
| Temperature($0^c$) | 24.00 | 20-32 |
| Odour | Odourless | Unobjectionable |
| Colour(TCU) | 5.00 | 15.00 |
| Taste | Tasteless | Unobjectionable |
| pH | 8.36 | 6.5-8.5 |
| Conductivity µs/cm | 2.82 | 900 |

**Table 4 Physical Test (Result from Aluminium Long Span A2)**

| Parameter | Measured value | WHO standard |
|---|---|---|
| Temperature($0^c$) | 24.4 | 20-32 |
| Odour | Odourless | Unobjectionable |
| Colour(TCU) | 5.00 | 15 |
| Taste | Tasteless | Unobjectionable |
| pH | 5.65 | 6.5 -8.5 |
| Conductivity µs/cm | 4.40 | 900 |

**Table 5 Physical Test (Result from Asbestos A3)**

| Parameter | Measured value | WHO standard |
|---|---|---|
| Temperature($0^c$) | 25.00 | 20-32 |
| Odour | Odourless | Unobjectionable |
| Colour(TCU) | 5.00 | 15.00 |
| Taste | Tasteless | Unobjectionable |
| pH | 6.94 | 6.5 -8.5 |
| Conductivity µs/cm | 65.1 | 900 |

**Table 6 physical test (Result from corrugated iron-Zinc A4)**

| Parameter | Measured value | WHO standard |
|---|---|---|
| Temperature($0^c$) | 24.3 | 20-32 |
| Odour | Odourless | Unobjectionable |
| Colour(TCU) | 5 | 15 |
| Taste | Tasteless | Unobjectionable |
| pH | 5.77 | 6.5-85 |
| Conductivity µs/cm | 6.65 | 900 |

**Table 7 Result for Chemical Test (mg/l)**

| **Parameter** | **A1** | **A2** | **A3** | **A4** | **WHO standard** |
|---|---|---|---|---|---|
| Total hardness | 22.00 | 22.00 | 100 | 42.00 | 100-300 |
| Dissolved oxygen | 3.81 | 4.32 | 3.74 | 3.61 | NS |
| Dissolved solid | 3.40 | 2.17 | 32.6 | 3.98 | 500 |
| Cu D1688 | <0.0001 | <0.0001 | <0.0001 | 0.0553 | 1 |
| Zn D1691 | 0.0112 | 0.0172 | 0.0280 | 5.8145 | 5.00 |
| Pb D3539 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.01 |
| Fe D1068 | 0.0056 | 0.0065 | 0.0106 | 0.0079 | 1.00 |
| Ni D1886 | <0.0001 | 0.0362 | 0.0157 | 0.0084 | 0.07 |
| Co D3558 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | NS |
| Cr D1687 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.05 |
| Al HACH DR3800 | <0.0001 | 0.0181 | 0.0107 | <0.0001 | 0.10 |
| APHA $SO_4^{2-}$ | 0.00 | 0.00 | 0.14 | 0.02 | 200 |
| APHA $Cl^-$ | 0.04 | 0.08 | 0.06 | 0.12 | 200 |

NS = Not specified. Method Source "America Society for Testing and materials" (ASTM) 1999. "American Public Health Association (APHA) 20th Edition 1998.

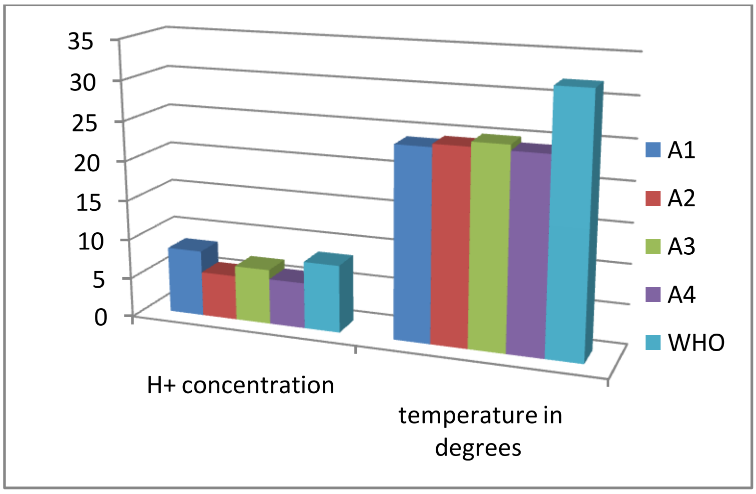



**Figure 1 Assessment of pH and temperature of rainwater from different roofing materials**

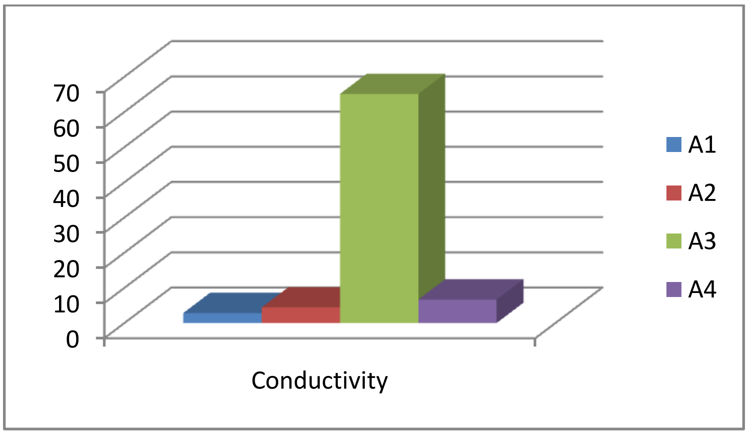



**Figure 2 Assessment of conductivity of rainwater from different roofing materials**

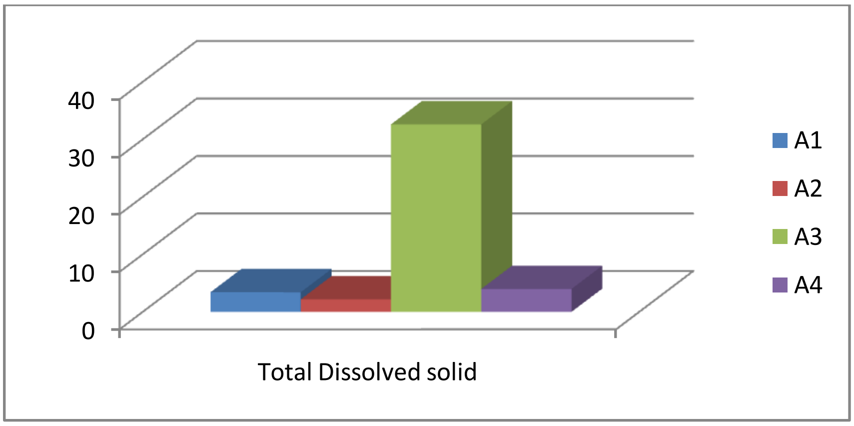



**Figure 3 Assessment of Total Dissolved Solid of rainwater from different roofing materials**

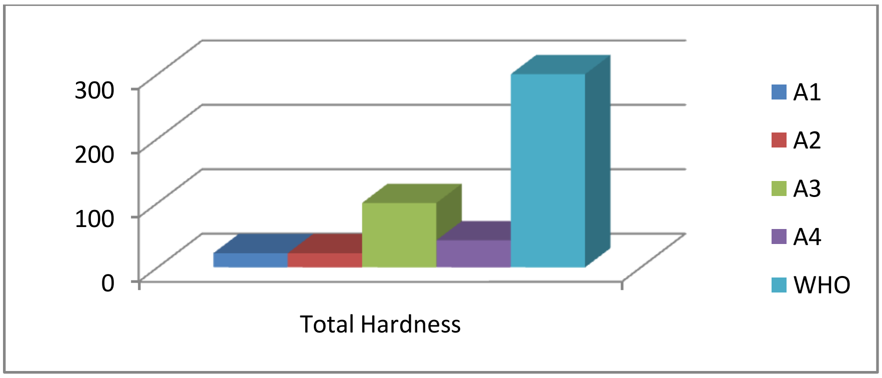



**Figure 4 Assessment of total hardness of rainwater from different roofing materials**

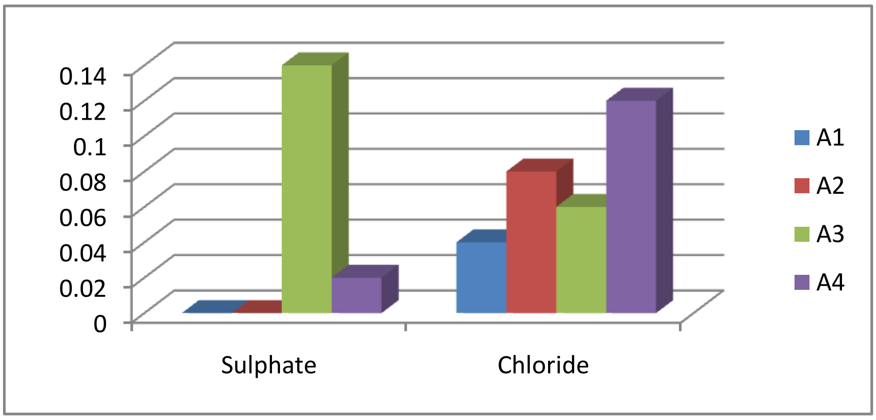



**Figure 5 Assessments of sulphate and chlorine of rainwater from different roofing materials**

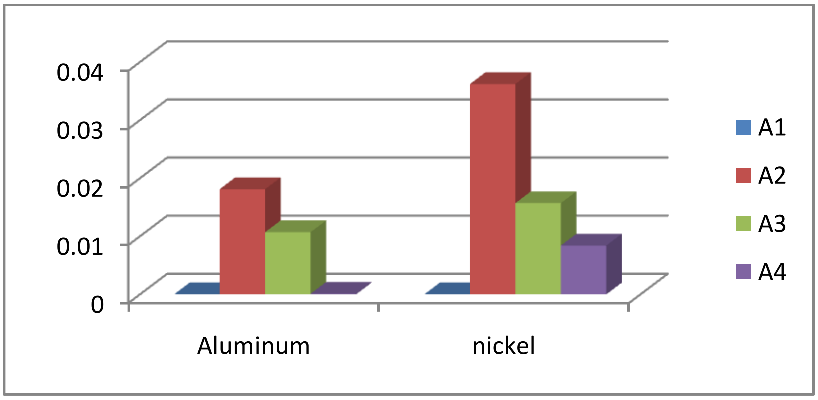



**Figure 6 Assessment of Aluminium and Nickel of rainwater from different roofing materials**

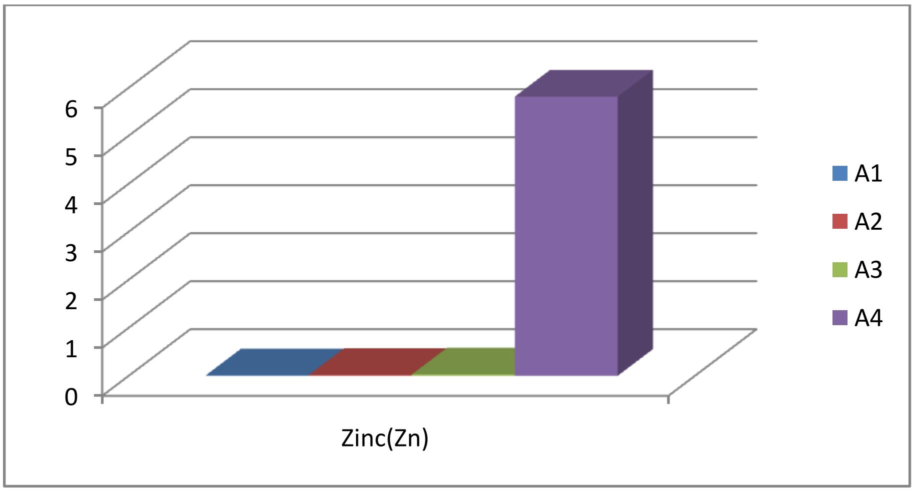



**Figure 8 Assessment of Zinc from rainwater on different roofing materials**

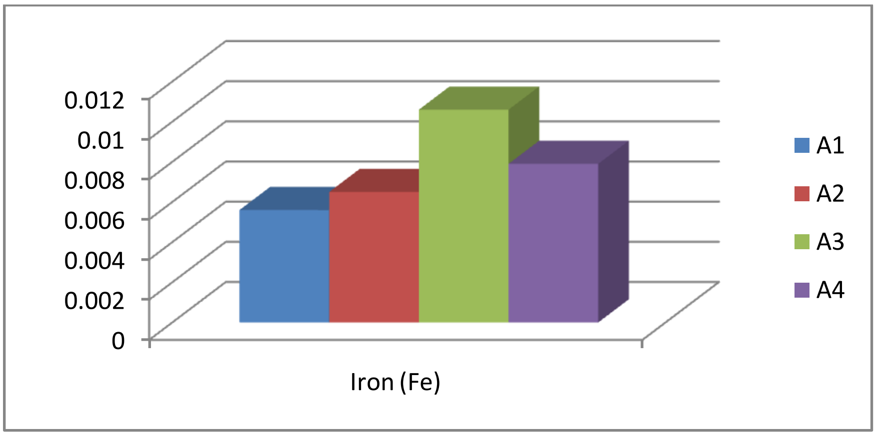



**Figure 9 Assessment of Iron from rainwater on different roofing materials**

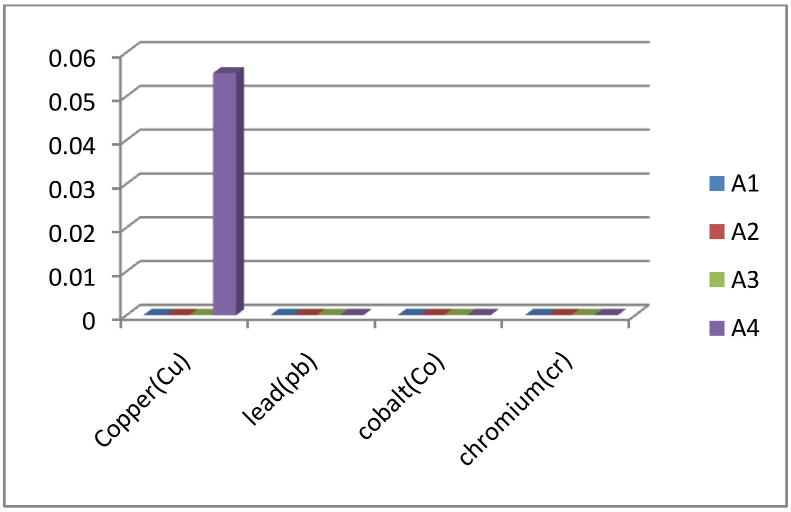
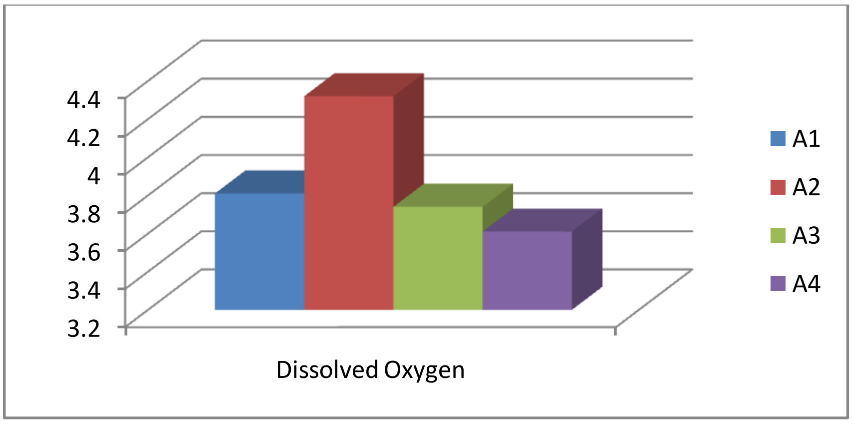



**Figure 10 Assessments of copper, lead and cobalt of rainwater from different roofing materials**




**N/B** the missing colours represents "Below Detectable Limit" (BDL).

**Figure 11 Assessment of Total Dissolved Oxygen of rainwater from different roofing materials**

## CONCLUSION AND RECOMMENDATION

From the analysis and data obtained from this work, all the physical and chemical characteristics such as: (conductivity, pH, temperature, colour, taste, total dissolved oxygen, total hardness, dissolved solid and heavy metals) were within World Health Organization (WHO) and National Standard Drinking Water Quality (NSDWQ) specification except for zinc on corrugated iron-zinc sheets. However rainwater obtained from asbestos roof sheets has the highest value of contaminants example water hardness 100mg/l, dissolved solid 32.6mg/l, iron (fe) 0.0106mg/l and sulphide 0.14mg/l followed by iron-corrugated zinc and the aluminum long span with the least contamination. Although, all these parameters fell within the standard values, all the rainwater samples required some level of treatment before it can be adequately fit for drinking.

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