DETERMINATION OF THE EFFECTS OF ROOFTOPS ON THE QUALITY OF RAINWATER COLLECTED IN UGHELLI, DELTA STATE, NIGERIA.

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ABSTRACT

This study was aimed at investigating the effects of roofing materials on water quality, in Ughelli. Random sampling technique was used to collect 42 rainwater samples from different roofing materials made from (asbestos, zinc, aluminium and thatch) including the control (rainwater collected directly from the sky) in Ughelli. The results obtained are as follows; pH ranged from 5.90 –7.00, EC from 63.5 – 9.0 μS/cm, TDS from 41.4–5.9 mg/L, turbidity from 2.84 – 0.21 NTU, total alkalinity from 32.00 – 8.00 mg/L, total hardness from 24.00 – 0.20 mg/L, Cl from 4.79 – 0.29 mg/L, NO_3 from 0.09 mg/L – ND, SO_4 from 0.4 mg/L - ND, BOD from 1.90 – 1.10 mg/L, COD from 4.32 – 2.62 mg/L, DO from 4.80 – 5.70 mg/L, Ca from 2.112 – 0.042 mg/L, Mg from 4.571 – 0.023 mg/L, Pb from 0.16 - <0.001 mg/L, Fe from 0.470 - 0.008 mg/L, and Cr from 0.047 - < 0.001 mg/L. The results revealed that most of physicochemical parameters of rainwater samples analyzed results were generally below the WHO threshold. Furthermore, the concentration of Pb, Fe and Cr, in the samples ranged from 0.15-0.02 mg/L, 0.218-0.117 mg/L, 0.008- <0.001 mg/L respectively. The study has revealed that the first flush from all the rooftops should not be used for human consumption. However, from the fifth flush and above could be used for domestic purpose but for oral consumption, appropriate water treatment protocol would be required.

Keywords: Rainwater, Roof-runoff, Water quality, Roofing material.

INTRODUCTION

Rainwater as it falls from the sky is relatively soft, and is among the cleanest of water sources (Obruche *et al.*, 2019). However, contamination may result from the environment, roof materials and containers which are used for rainwater collection and storage. The type of roofing materials could impact on the quality of the rain water harvested. Research has shown that the type of roof material (from which the water is collected) could determine the quality the water particularly for drinking. There are reports that metal roofs can react with rainwater to cause corrosion (Ray, 2007; Ibrahim, 2009). For instance, high concentrations of heavy metals could easily lead to corrosion of the roofing materials if they are left on it for a long time. The situation is worsened by wear and tear conditions of metal materials, which could release the heavy metals such as aluminum and zinc, which are toxic to human if their concentration exceeds certain concentrations into the harvested rainwater (Hermann and Hasse, 2007). The constructed materials used for rainwater harvesting can be source of contamination, either through leaching of the materials particles or as a result of anthropogenic inputs (deposits of plants in contact with roofing sheet) or geographical location (Efe, 2010; Sanches and Pacheco, 2015). The quality of rainwater collected from rooftops is a function of the type of roof materials, climatic conditions, and the environment. Several types of chemical contaminants have been found in harvested rainwater including (Obruche *et al*., 2019). Heavy metals (Aderogba,2005; Douglas *et al*., 2008). The World Health Organization (WHO) estimates 1.8 million deaths each year due to lack of access to safe water, sanitation and hygiene (WHO, 2010). Out of these deaths, 99.8 % occur in developing countries and out of which 90% are children (WHO, 2010). Microorganisms are also present in rooftops, faecal coliform indicator bacteria and potentially pathogenic. However, Obruche *et al*., (2019) reported that rooftopss can be a serious source of water pollution as well to human health. Contamination by chemical pollutants may arise from a variety of materials with which the rainwater comes in contact with; starting from the atmosphere (Ahmed *et al*., 2008). Rainwater could dissolve gases which might have accumulated on top of the roofing materials and also wash off chemicals from contacting dust particles and roof materials into harvested water which will be very dangerous to human health (Hoff et al., 2010; Musa *et al.*,2013). Pollutant level at early rainfall and subsequent rainfall do lead to pollutant load can be cause by non-metal oxides such as sulphur dioxide, SO_2, nitrogen dioxide, NO_2 and carbon dioxide, CO_2, from human activities, mostly from the combustion of fossil fuels (Helmreich and Horn, 2009). Acid rain contributes to the corrosion of surface materials exposed to air and is responsible for the deterioration of limestone, marble buildings and monuments (Gould *et al*., 1999). Rainwater Harvesting uses a wide range of techniques for concentrating, collecting and storing rainwater and surface runoff for different uses by linking a runoff producing area with a separate runoff-receiving area (Simmons *et al*., 2001). Several international studies have been performed to study the quality of harvested rainwater. Some studies done in Africa include; Rainwater harvesting (RWH) primarily consists of the collection, storage and subsequent use of captured rainwater, either as the principal or supplementary source of water. Water is in great demand opined by (Qingyun *et al*., (2008) as it represents a unique feature in every settlement: for drinking, sanitation, washing, fishing, recreation and industrial processes. In Nigeria, rainwater harvesting is practiced in the whole country during the raining season (Quek and Forster, 1993). This research is aimed at the study of the effects of roofing materials and settlement on rainwater quality, harvested in Ughelli, Nigeria. This study is limited to the analysis of quality parameter of rainwater harvested from the first to the fifth annual rainfall of the year, 2019.

MATERIALS AND METHOD

Study area

This study was conducted in Ughelli North Local Government area of Delta State, Nigeria. The region lies within the . The high rainfall, humidity and river discharge during the rainy season combined with the low, flat terrain and poorly drained . The climate of Ughelli follows a tropical pattern with the rainy season lasting for between eight to ten months between early March to late November with an interruption in August (commonly known as August break) and the dry season running through

longitudes 3°E-9°E and latitudes 4° 30’N-5° 21’N of Niger Delta region (oil rich area) (Obruche *et al*., 2019). Delta area is known to be region of frequent precipitation with annual rainfall ranging from 3000 to 4500 mm (Obruche *et al.,* 2019) soils result in extensive flooding (Obruche *et al*.,2019)

late November till mid February. Ughelli being a great socio-economic city in the Delta area has drawn the attention of many researchers in recent decades for several reasons.

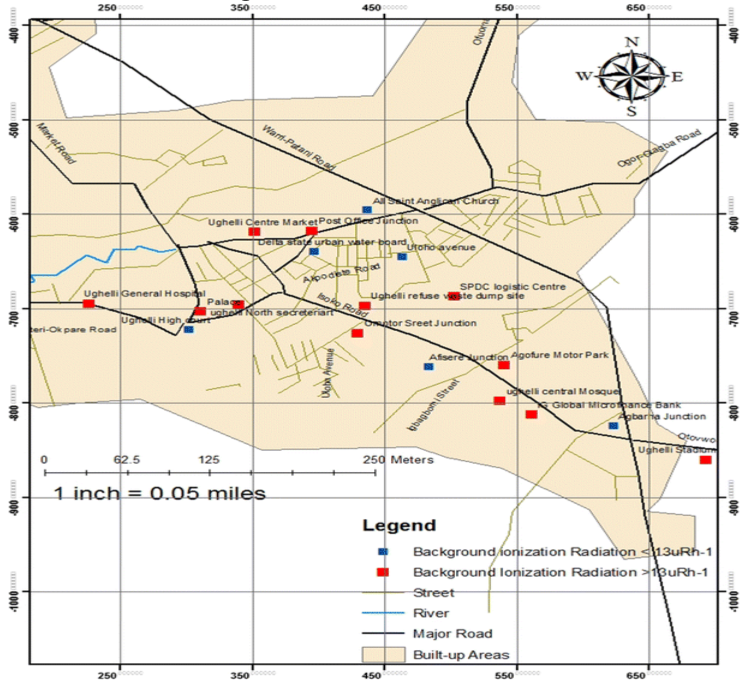

Figure 1. Map of Ughelli Metropolis Showing Sampling Locations

Source of Data

The first fieldwork was to identify the four roof materials (zinc, aluminium, asbestos and thatch roof), that are commonly used in Ughelli metropolis for rainwater harvesting. Households were randomly picked (APHA, 2005) where roof water harvesting system was already in existence. The data used for this study were collected from March to November 2019 from a field survey in the study area.

Pre-treatment of Sampling Container

To obtain accurate results, proper sample pre-treatment procedures were adopted to eliminate potential contamination of the harvested rainwater samples (USEPA, 2008). Sample containers were washed and rinsed with dilute nitric acid, HNO_3, and dried under the sun for 24 hours. Sample containers were clearly and properly labeled to enhance record keeping. Rainwater samples that were collected from Ughelli were labeled; UGH1, UGH2, UGH3, UGH4 and UGH5 for the first to fifth rain respectively. The control sample (rainwater samples that were collected directly from the sky), were labeled CRL.

Method of Sampling and Collection of Rain Water Samples

A random sampling technique was employed in selecting the sampled household. Harvested rainwater samples were collected via rooftop run off (USEPA, 2008). Four roof types were identified, namely - asbestos, aluminum, thatch and zinc roof. Four homes each with the above roof types were selected randomly and rainwater samples were collected at the month of March to November 2019. These were done to account for any annual rainfall variation in the harvested rainwater quality. The plastic containers were raised from the ground by placing them on top of tripod. Twenty one (21) samples were collected from different roofing materials (asbestos, zinc sheets, alumnium and thatch roof) in Ughelli. Rainwater samples collected for physical and chemical analyses were transported under controlled temperature in a cooler and refrigerated at 4^oC in the chemistry laboratory till all the parameters were analyzed (APHA, 2005).

Reagents

The chemicals/reagents used this research are : silver nitrate, $AgNO_3$ (Chem Light (India), Ammonium buffer (NH_4Cl), Eriochrome Black T indicator, by Griffin and George, England. Ethylene-diamine-tetraacetate acid (0.01M EDTA), dilute sulphuric acid, 0.01M H_2SO_4, mixed indicator. Potassium hydroxide, KOH, Concentrated sulphuric acid, H_2SO_4, Manganese (11) sulphate reagent (winkler A), Sodium Azide solution (winkler B), starch solution(as indicator), distilled water, concentrated Nitric acid, HNO_3, sodium thiosulphate,$Na_2S_2O_3$, potassium dihydrogen phosphate by Chem Light (India), KHP_2O_4 , and magnesium chloride solution by BDH England. All solutions were prepared using distilled water.

Analysis of Physical Characteristics

In order to assess the quality of harvested rainwater, physical parameters were determined according to procedures and protocols outlined in the Standard Methods for the Examination of Water and Wastewater (USEPA, 2008; WHO, 2010). The physical parameters determined include pH, electrical conductivity (μ/Scm), total dissolved solids (TDS) (mg/L) and turbidity (NTU). The pH, electrical conductivity, total dissolved solids was measured using a JENWAY 3540 Bench combined pH/conductivity/TDS meters (UK). Turbidity was measured using a potable turbidity meter WAG-WE30210 (UK).

Analysis of Chemical Characteristics

Chemical parameters considered include; total Hardness, total alkalinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolve oxygen (DO), chloride, Cl_2, Nitrate,NO_3, sulphate, SO_4 calcium, magnesium, iron, Fe, lead, Pb, chromium, Cr. Total alkalinity and chloride measured using titrimetric methods (Radaideh *et al*., 2009). BOD was carried out by Iodometric Method, COD was determined using the Open Reflux Method Dissolve oxygen was determined by winkler method (Ishaku *et al*., 2012). Total Hardness and calcium by EDTA Titrimetric Method , Magnesium analysis was carried out by Calculation Method. Magnesium was estimated as the difference between total hardness and calcium hardness. Sulphate was determined by turbidimetric method and Nitrate was determined by the Brucine method (Olobaniy, 2007; Islam *et al*., 2010). The determination of heavy metals was carried out using the flame atomic absorption spectrophotometer Perkin-Elmer A Analyst 200 (USA) described by APHA's Standard Methods for the Examination of Water and Wastewater.

RESULTS AND DISCUSSION

Table1. Physicochemical Results for First Harvested Rainwater

Parameter	UGH				WHO
	Al-s	Zn-s	Asbestos	Thatch	
pH	6.40	6.30	5.90	6.20	6.5-8.5
EC(μS/cm)	11.8	20.3	27.6	63.5	900
TDS (mg/L)	7.8	12.6	16.8	41.3	250
Turbidity (NTU)	0.72	0.59	2.16	2.84	5.00
Total/Alk. (mg/L)	10.00	8.00	2.00	6.00	120
T/Hardness(mg/L)	0.90	2.00	24.00	7.00	100-300
Cl (mg/L)	0.86	1.39	1.85	4.79	250
NO_3 (mg/L)	ND	ND	0.09	0.02	50
SO_4 (mg/L)	0.03	0.4	0.28	0.09	250
BOD (mg/L)	1.40	1.50	1.70	1.90	5.0
COD (mg/L)	3.41	3.49	4.15	4.32	10.0
DO (mg/L)	4.80	4.30	5.00	5.20	4.0
Ca (mg/L)	0.198	0.432	2.112	1.456	75
Mg (mg/L)	0.099	0.225	4.571	0.820	50
Pb (mg/L)	0.15	0.09	0.16	<0.01	0.01
Fe (mg/L)	0.218	0.066	0.039	0.470	0.3
Cr (mg/L)	0.008	0.047	<0.001	<0.001	0.05

Table2. Physicochemical Results for Second Harvested Rainwater

Parameter	UGH				WHO
	Al-s	Zn-s	Asbestos	Thatch	
pH	6.30	6.60	6.20	6.10	6.5-8.5
EC(μS/cm)	10.8	14.3	19.2	52.2	900
TDS (mg/L)	7.2	9.5	12.8	34.8	250
Turbidity (NTU)	0.49	0.34	1.21	1.63	5.00
Total/Alk. (mg/L)	12.00	14.00	10.00	8.00	120
T/Hardness(mg/L)	0.50	1.00	22.00	5.00	100-300
Cl (mg/L)	0.51	0.97	1.37	3.71	250
NO_3 (mg/L)	ND	ND	0.1	ND	50
SO_4 (mg/L)	0.02	0.02	0.17	0.06	250

BOD (mg/L)	1.30	1.40	1.50	1.50	5
COD (mg/L)	3.10	3.33	3.57	3.57	10
DO (mg/L)	5.20	5.10	5.60	5.40	4
Ca (mg/L)	0.104	0.208	1.564	1.020	75
Mg (mg/L)	0.059	0.117	4.661	0.598	50
Pb (mg/L)	0.11	0.06	0.12	<0.01	0.01
Fe (mg/L)	0.175	0.048	0.026	0.419	0.3
Cr (mg/L)	0.006	0.041	<0.001	<0.001	0.05

Table3. Physicochemical Results for Third Harvested Rainwater

Parameter		UGH			WHO
	Al-s	Zn-s	Asbestos	Thatch	
pH	6.50	6.80	6.50	6.40	6.5-8.5
EC(µS/cm)	10.4	12.5	15.9	47.7	900
TDS (mg/L)	6.9	8.3	10.6	31.8	250
Turbidity (NTU)	0.38	0.28	1.03	1.46	5.00
Total/Alk. (mg/L)	17.00	23.00	14.00	12.00	120
T/Hardness(mg/L)	0.30	0.80	17.00	4.00	100-300
Cl (mg/L)	0.42	0.75	1.19	3.48	250
NO_3 (mg/L)	ND	ND	ND	ND	50
SO_4 (mg/L)	0.01	ND	0.02	0.05	250
BOD (mg/L)	1.10	1.30	1.30	1.60	5
COD (mg/L)	2.68	3.25	2.95	3.35	10
DO (mg/L)	5.60	5.40	5.70	5.60	4
Ca (mg/L)	0.064	0.170	1.224	0.800	75
Mg (mg/L)	0.034	0.092	3.404	0.488	50
Pb (mg/L)	0.07	0.04	0.09	<0.01	0.01
Fe (mg/L)	0.157	0.032	0.017	0.379	0.3
Cr (mg/L)	0.004	0.036	<0.001	<0.001	0.05

Table4. Physicochemical Results for fourth Harvested Rainwater

Parameter		UGH			WHO
	Al-s	Zn-s	Asbestos	Thatch	
pH	6.70	6.80	6.60	6.50	6.5-8.5
EC (µS/cm)	9.6	11.9	14.7	41.3	900
TDS (mg/L)	6.4	7.9	9.8	27.5	250
Turbidity (NTU)	0.35	0.26	0.93	1.29	5.00
Total/Alk. (mg/L)	26.00	30.00	22.00	20.00	120
T/Hardness(mg/L)	0.20	0.50	9.00	3.00	100-300
Cl (mg/L)	0.37	0.59	0.97	3.36	250
NO_3 (mg/L)	ND	ND	ND	ND	50
SO_4 (mg/L)	ND	ND	0.01	0.03	250
BOD (mg/L)	0.90	1.10	1.20	1.30	5
COD (mg/L)	2.20	2.75	2.73	3.17	10

DO (mg/L)	5.80	5.60	5.80	5.70	4
Ca (mg/L)	0.042	0.102	0.648	0.612	75
Mg (mg/L)	0.023	0.060	1.802	0.359	50
Pb (mg/L)	0.04	0.02	0.06	<0.01	0.01
Fe (mg/L)	0.139	0.021	0.011	0.337	0.3
Cr (mg/L)	0.001	0.029	<0.001	<0.001	0.05

Table5. Physicochemical Results for fifth Harvested Rainwater

Parameter	UGH				WHO
	Al-s	Zn-s	Asbestos	Thatch	
pH	6.90	7.00	6.90	6.80	6.5-8.5
EC (µS/cm)	9.0	10.2	13.8	33.1	900
TDS (mg/L)	5.9	6.7	9.1	21.8	250
Turbidity (NTU)	0.28	0.21	0.79	0.96	5.00
Total/Alk. (mg/L)	28.00	32.00	27.00	24.00	120
T/Hardness(mg/L)	0.20	0.40	8.00	2.70	100-300
Cl (mg/L)	0.29	0.42	0.75	2.83	250
NO_3 (mg/L)	ND	ND	ND	ND	50
SO_4 (mg/L)	ND	ND	ND	0.1	250
BOD (mg/L)	1.10	1.30	1.50	1.20	5
COD (mg/L)	2.62	3.10	3.66	3.41	10
DO (mg/L)	5.20	5.70	5.40	5.20	4
Ca (mg/L)	0.042	0.082	0.524	0.551	75
Mg (mg/L)	0.023	0.048	0.938	0.323	50
Pb (mg/L)	0.02	<0.01	0.03	<0.01	0.01
Fe (mg/L)	0.117	0.019	0.008	0.289	0.3
Cr (mg/L)	<0.001	0.017	<0.001	<0.001	0.05

The physical and chemical properties of harvested water samples for the months of February to August 2019 are presented in Tables 1 to 5. Values obtained in this study were compared with the World Health organization standard (WHO). Results showed that all parameters in the harvested water were significantly different from that of the control (rainwater samples, collected directly from the sky).

pH and electrical conductivity

According to the results, harvested water for the months of February (first flush) appears to be relatively acidic with pH ranging from 5.90 – 6.40 for all the roofing sheets in table1. This higher acidity may be due to the release of chemical gasses, e.g. sulphur-dioxide, nitrogen dioxide, carbon monoxide and carbon dioxide from gas generated from human activities like burning of wood, coal, and industrial wastes that generates acidic ions that react with rainwater, which infiltrate into the water and lowers the pH of the water (Joanne and Gakungu, 2013). This shows that harvested rain water within this period is acidic and can be compared to the research of work of Jones and Hunt,(2010) which showed that the pH of four industrial areas of Lagos state namely: Ilupeju, Costain, Ikeja and Ikorodu were 4.94, 4.20, 4.22 and 4.30 respectively. However, from August (fifth flush) when rainfall was at its peak, harvested water tended towards slight alkalinity. pH values of 6.80 – 7.00 for were obtained for all the roofing sheets respectively. pH values were observed to increase as the number flush increases for all the roofing sheets. All the values from the four roofing materials fell within the recommended standard value of WHO of 6.50-8.50. Electrical conductivity (EC) values of harvested water from thatch sheets were significantly higher than that obtained from other roofing sheets in table1-5. A value of 63.5 µS/cm was obtained for thatch roof, compared to 27.6, 20.3, and 11.8 for asbestos, zinc and aluminium respectively, in the month of February (first flush). This might be due to the type of roofing material, which could have an impact on the chemical properties of harvested water. EC values were observed to reduce as the number flush increases for all the roofing sheets. The EC values fell below WHO standard of 900 µS/cm.

Total dissolved solid (TDS) and turbidity

The total dissolved solids (TDS) also recorded high values in water from thatch and asbestos roofing sheets than others. In February (first flush) in table1, a TDS of 41.3 and 16.8 mg/L was recorded for thatch and asbestos respectively, compared to 12.6 and 7.8 mg/L for zinc and aluminium. The TDS results are compared to the research reported by Jusara *et al.*, (2003) of 50, 80, 90 and 121 mg/L in physicochemical and trace metal levels of rainwater for Ile-Ife, South-western Nigeria. The TDS of water samples collected from the different roofing sheets were significantly different from that of the control. The results fell below WHO recommended standard of 250 mg/L. Components of asbestos might dissolve in water during harvesting accounting for the higher TDS. Aluminum and metal sheets have smooth surfaces and high heat capacity, which ensures that depositions on the sheets dry off quickly and swept off the surfaces by rain or wind, which results to its low TDS values. Asbestos surfaces however have the potential to retain most contaminants Cobbina *et al.*, (2013). These in turn may alter the quality of harvested water from these surfaces. The TDS content of water can be a good indication of contamination or low quality of water. According to most authors, metals are strongly associated with particles in runoffs. As expected, the TDS of harvested water from all the roofing sheets reduced as the months and number of flush increases. There is a noticeable high turbidity value for Thatch and asbestos sheets, a value of 2.84 NTU and 2.16 NTU in table1, which can be attributed to the ability of them to retain high amount of suspended solids particles. Compared to the other roofing sheets and the control with a low turbidity of 0.32 NTU. This high turbidity reduces light penetrating ability in the samples and leads to a higher temperature as particles tend to absorb heat. In addition, as expected, the turbidity tends to reduced as the months and number of flush increases. Turbidity values fell below the WHO recommended standard of 5.0 NTU.

Total alkalinity and total hardness

Total hardness values of harvested water from asbestos sheets were higher than that obtained for other roofing sheets (Table1-5). A value of 24.00 mg/L was obtained for asbestos in tabe1, compared to 7.00 mg/L, 2.00 mg/L, and 0.90 mg/L for thatch, zinc and aluminium (table1) respectively. Total hardness values were observed to reduce as the number flush increases for all the roofing sheets. This fell below the WHO standard that ranged between (100-300 mg/l). The range values for total alkalinity of the samples were between 2.00 mg/L – 10.00 mg/L, from the first flush in all the four roofing roofs in table1. There is a noticeable increase in the values of total alkalinity from the first flush to the fifth flush. Values ranges between 24 mg/L – 32 mg/L from the fifth flush in all the four roofing roofs in table5. All the values fell below the recommended maximum standard value of 120 mg/L of WHO.

Radicals / anions (NO_3^-, SO_4^{2-} and Cl^-)

The anions concentrations in the harvested rainwater sample were consistently low (Table1-5). Nitrate values obtained from all the water samples analyzed (Table1-5) fell below the WHO standard (50 mg/L), with a values 0.09 and 0.02 mg/L for asbestos and thatch roofing sheet (i.e. first flush). Nitrate values were not detected (ND) for zinc and aluminum roofing sheets and the control (water collected directly from raindrop).

Sulphate values obtained from all the water samples analyzed were consistently low (Table1-5). With ranged values from 0.03 - 0.28 mg/L for the first flush in table1. The presence of this little amount of sulphates on the roofing sheets may be due to evaporating oceans and seas sprays that leave tiny particles of sulphate salts such as Sodium Sulphate in the air that are later deposited on the rooftops and some human and industrial activities. While no sulphate was detect in the control sample. It was observed that the sulphate content decreases with respect to increase in number of rainfall. The WHO limit for sulphate is 250mg/L (WHO, 2010).

All the rainwater samples from the four roof types for chloride fell below the limit of WHO. Chloride range values analyzed were 0.86mg/L – 4.79 mg/L respectively for the first flush from the four roofing sheets (in table1) and 0.29 mg/L – 2.83 mg/L for the fifth flush from the four roofing sheets (in table5), which fell below the limit the recommended value between for chloride of 200 mg/L – 300 mg/L. There is a noticeable decrease in the values of chlorides with increase in the number of rainfall.

Biochemical (BOD, COD and DO)

The biochemical concentrations in the harvested rainwater sample were considerably Moderate i.e. The Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) in (Table1-5) in all the roofing sheets. Although, the COD values were generally higher in all the samples than Biochemical Oxygen Demand, due to the presence of organic compounds and certain inorganic ions such as Fe^{2+} which are not biochemically oxidizable. The BOD values ranged from 1.40–1.90 mg/L for the first flush in table1. The COD values ranged from 3.41–4.32 mg/L for the first flush in table1. These values were similar to that of the control samples 2.56mg/L and 1.10 mg/L for COD and BOD respectively. That suggests that the roof material had little or no effect on BOD and COD concentration of water samples. In addition, as expected, the BOD and COD tend to reduced as the months and number of flush increases. All the values of COD and BOD recorded fell below WHO maximum and minimum limit of 10 mg/L and 5mg/L (WHO, 2010).

Dissolved oxygen values ranges from 4.30mg/L – 5.20 mg/L for the first flush in all the roofing sheets in table1, and 5.20mg/L – 5.70mg/L respectively for the fifth flush in table5. There is slow increase in the DO from the first flush to fifth flush. These values were also similar to that of the control samples of 5.60 mg/L. This also suggests that the roof material had little or no effect on dissolved oxygen concentration of water samples. According to the Conway *et al*., (2009) no health based guideline value is recommended.

Elemental (Ca and Mg)

The elementals results in (Table1-5) shows calcium and magnesium concentration of the different roofing materials during the various rainfall periods in the study area. The calcium values are 0.198, 0.432, 1.456 and 2.112 mg/L for aluminum, zinc, thatch and asbestos roofing sheets for the first flush in table1. The magnesium values ranged from 0.099 – 4.571 mg/L for the four roofing sheets in the first flush in table1. Calcium and Magnesium in water gives rise to hardness of water. It was observed from (Table1-5) that water samples collected from asbestos roofing sheet gave the highest magnesium and calcium concentrations in all the four roofing. This could be traceable to the level of magnesium and calcium carbonate content that can be leached from the roofing material. Calcium higher values were observed in thatch and zinc roofs as well. There is a noticeable decrease in the values of calcium and magnesium with increase in the number of rainfall. They all fell below the recommended maximum standard value of 75 mg/L and 50mg/L of WHO for calcium and magnesium respectively.

Heavy metals (Pb, Cr and Fe)

Heavy metal concentration in the harvested rainwater sampled signified some degree of contamination in the area under investigation (Olaoye and Olaniyan, 2012). Fe was relatively higher in concentration than all other heavy metals (Table1-5). Higher concentrations of iron that exceeded WHO (2010) limit of 0.3mg/L were detected in thatch roof i.e. 0.470 mg/L from the first flush in table1. This sharp high concentration of Fe values in thatch roof may be due to iron mineral in soil which the thatch plant tapped from the ground through its root to the leaf, which were later cut off and used as roofing materials. The concentration of the control was very low 0.009 mg/L, which indicate that roofing material has an effect in the harvested rainwater. All others iron values from the rest roofing sheets conform to the recommended maximum standard value. However, after the fifth flush they conformed to the WHO standard 0.3mg/L. Pb values in all the samples were relatively high above the WHO (2010) limit of 0.01mg/L, except for thatch roof that is < 0.01 mg/L in their first flush. However, after the fifth flush, it was observed that zinc fell within the WHO standard but the lead concentration asbestos and aluminium roofs materials are still high above the WHO standard. The concentration of the control was very low <0.01 mg/L, which indicate that roofing material has an effect in the harvested rainwater. This observation agrees with the reports of Sorenson *et al*, (2011) its heavy metal analysis. It was observed from (Table1-5) that samples from asbestos and thatch roofs had the lowest value of chromium .i.e. <0.001 mg/L as compared to zinc and aluminium which had high values of 0.047 and 0.008 mg/L respectively for first flush in table1. There is a noticeable decrease in the values of chromium with increase in the number of rainfall. All the values from the four roofing materials fell below the recommended maximum standard value of 0.05mg/L of WHO.

Rainwater harvested from aluminium and zinc roofing material gave least amount of pollutants (e.g, 0.72 NTU and 0.59 NTU for turbidity in table 1 for zinc and aluminium) in majority of the water parameters compared to thatch and asbestos roofing material (e.g, 2.16 NTU and 2.84 NTU for asbestos and thatch roof turbidity respectively) which gave high amount of pollutants in majority of the water parameters.

CONCLUSION

Rooftop runoff quality is dependent on both the roof type and the environmental conditions (i.e. both local climate and atmospheric pollution). From the results, it was observed that quality of water harvested from the selected roofing materials at different rainfall periods fell below the WHO standard limit. However some levels of contamination were prominent. The water samples from asbestos roofing sheet relatively had the highest level of contamination, followed by thatch roofing material and then aluminum-roofing sheet had the least contamination. The result also indicated that that the concentrations of the physicochemical parameters as well as the metals from the rooftops were considerably higher than those of control samples. This could mean that raindrop on rooftops gradually leach or erodes the material used in the making of the roof. In addition, geographical location could have affected the level of contamination. Rainwater from aluminum roofing sheet proved to be most suitable. Nevertheless, to ensure rainwater satisfies health requirement for consumption, simple disinfection methods such as boiling and chlorination are recommended if water is to be used for drinking purposes. However, all rainwater samples are quite safe for all other domestic uses such as laundry, bathing, toilet flushing and other cleaning works after the fifth flush

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