JASEM ISSN 1119-8362

Full-text Available Online at www.ajol.info and www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. *Sept*, 2016
Vol. 20 (3) 748 - 757

Physicochemical and Bacteriological Characteristics of Rainwater Harvested from Rooftops in Esan-West Local Government Area of Edo State, Nigeria

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ABSTRACT: Due to scarcity of potable water, rainwater harvesting from rooftop has been favoured as an alternative source of water supply by most rural communities in Nigeria. This study investigated the physicochemical and bacteriological characteristics of rainwater harvested from three different rooftop sheets in Esan West Local Government Area, Edo State. Parameters investigated include pH, TSS, TDS, Turbidity, Acidity, Ca2+, Fe, Pb, Cr, TBC, TCC and *E-coli.* The results showed that mean values of harvested rainwater from all sampled rooftops are acidic especially at the onset of the raining season. TSS and TDS were highest in samples collected from Asbestos rooftop, followed by Aluminum rooftop while samples from galvanized Iron had the least irrespective of the rainfall event. Rainwater samples collected at the onset of rain had higher Ca^{2+} concentration than those collected at the peak of rain for all roof type with galvanized Iron rooftop catchment recording the highest concentration. Samples collected at the onset of the rain for all roof type had Fe concentrations above the WHO limit of 0.1mg/l while those collected at the peak of rain had lesser values. Values of pb, Cr were within WHO permissible limit. Analysis of microbial parameters revealed that samples collected from all rooftop and for both seasons exceeded WHO limit of <100cfu/ml for TBC. Rainwater samples collected from corrugated Asbestos rooftop had the highest bacterial load for both onset and peak of rain, followed by samples collected from Aluminum rooftop for the onset on rain. *E-coli* count was highest in water sample collected from corrugated Asbestos rooftop for onset and peak of rain. The Analysis of variance (ANOVA) shows that quality of rainwater harvested from galvanized Iron, Aluminum and Asbestos rooftop catchments does not significantly differ at 0.05 statistical thresholds among rooftop catchment although samples from asbestos rooftop catchment recorded highest contamination level. In view of the physicochemical and bacteriological results, harvested rainwater can be put to all forms of domestic use except for direct ingestion unless treated. © JASEM

http://dx.doi.org/10.4314/jasem.v20i3.29

***Keyword*:** Rainwater harvesting, drinking-water, physicochemical, bacteriological parameters, Heavy metals, rainfall onset, rainfall peak

The increasing scarcity of water in terms of quality is fast becoming an unpleasant reality in many parts of the world and Nigeria is not an exception. According to Oyedotun (2012) Nigerians face daily problems in obtaining water for domestic purposes and other multifarious uses (Oyedotun, 2012). Similarly, Krebs (2010) showed that of the total population of Nigeria, less than 30 percent has access to adequate drinking water. Although Ifabiyi (2012) reported that the coverage of potable water in Nigeria was 20% in 1980 which later rose to 30% in 1991 and approximately 55% in 2007, study by Oyedotun, (2012) has shown that the service level in some rural and urban areas in Nigeria is about 10 and 30 litres per capita per day (lpcd) respectively. In most cases in where they are water-stressed, women and children particularly girls spend most of their productive time trekking long distances sourcing for water (Manzungu 2004; Mathew, 2005), even when these water sources are of questionable quality. Vasudevan and Pathak (2005) reported that local people especially those living in the rural areas are not much aware of the health implication of using water from questionable source for household purposes as their primary concern is usually on getting enough water to meet their needs. The consumption and usage of contaminated and polluted water has been noted to be one of the most important causes of ill health and sicknesses, particularly in developing countries. Gbadegesin and Olorunfemi (2007) also pointed out that the scarcity of safe drinking water in the country is responsible for the spread of many water-related diseases.

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In response to increasing unavailability of potable drinking water there is now a renewed interest in rainwater harvesting RWH as alternative to surface water sources. Studies have argued that the most effective way to obtain fresh drinking water is to harvest rainwater (Zuckel *et at*., 2003; Badal, *et al*., 2016). RWH has received increased attention worldwide as an alternative source of potable and non-potable water supplies (Hatibu *et al*., 2006; Heyworth *et al*., 2006; Ghisi and Ferreira, 2007; Han, 2007; Amin and Han, 2009).Their argument according to Retamal and Turner (2010) include that the method promotes self-sufficiency and encourages water and energy conservation and results in permanent decrease in water demand (Grandet *et al*., 2010) and climate change adaptation measure (Jackson *et al*., 2001). Despite having some promising merits over other sources, rainwater use has frequently been rejected as a source of potable water supply on the grounds of its water quality concerns (Meera and Ahammed, 2006). As reported by several researchers harvested rainwater can contain significant amounts of pollutants such as heavy metals, nutrients and pathogens (Gromaire-Mertz *et al*., 1999; Lye, 2002; Zhu *et al*., 2004; Evans, 2006; Yufen *et al*., 2008). Thus in determining the end use and the potential success of potable use of rainwater in the study area, the possible problems associated with its quality need to be assessed. This study therefore aims at assessing the physicochemical and bacteriological characteristics of rainwater harvested from rooftops in Esan-West Local Government area of Edo state, Nigeria.

MATERIALS AND METHODS

*Study area***:** The study area is Esan West Local Government Area, Edo State. It is a geographically situated between Latitudes 6^o43^1& 6^043^1 North of the equator and Longitudes 6^o60^1& 6^o80^1East of the Greenwich Meridian (Fig. 1). The local relief of the area is 150meters above sea level; however, some areas are as low as 50meters above sea level. Esan West belong has been identified as the source or head water of many streams and rivers some of which flow into the Benin Lowlands while other flow northwards into the river Niger.

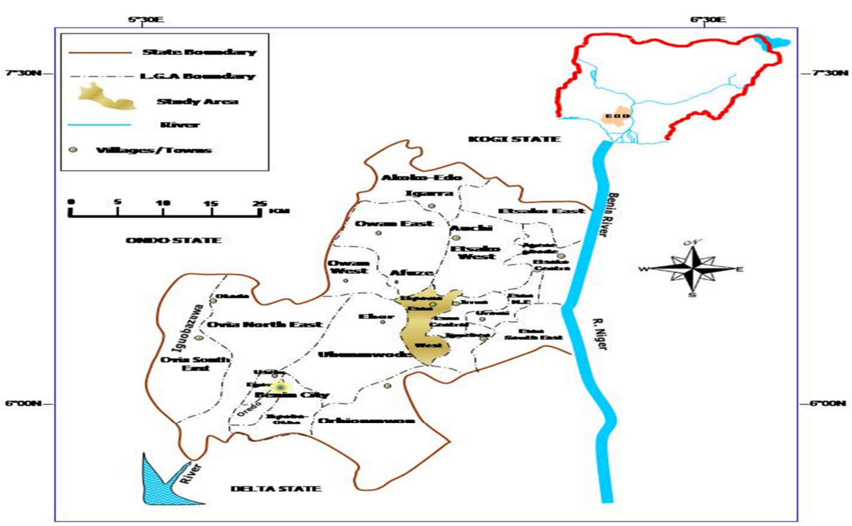

Fig.1: Edo state showing the study area

The study area has the tropical climate characterized by two seasons; these are wet and dry season. The wet seas
on occurs between April and October with a break in August while the dry season lasts from November to April with a cold harmattan spell between December and January. The temperature averages about 25^0C (77^0F) in the rainy season, and about 28^0C (82^0F) in the dry season. The highest mean monthly temperature of 29.1^oC is recorded in March and the lowest of 24.4^oC in June (Aziegbe, 2006).

Data Collection: The Local Government Area was delineated into its already existing ten (10) political wards (Table 1) and rainwater samples collected from different rooftop from each ward. Three (3) roof types (i.e. Galvanized Iron, Aluminum and corrugated Asbestos roofing sheets) were considered for the study as they are common roof tops found in the study area. Three households of different roofing materials were randomly selected. Rainwater samples were collected during rainfall events for two sampling periods; onset and rainfall peak via rooftop runoff from the three selected roofing sheet materials (each for the ten (10) political wards) with the aid of pre-sterilized plastic containers connected to the selected rooftops.

Table 1: The 10 Political Wards in Esan West Local Council

S/NO	Town/Village	Wards
1	Ogwa	1
2	Ujiogba/Ebute	2
3	Egoro/Idoa	3
4	Eguare / Emaudo	4
5	Ihimhudumu /Ugiemen, Ido-ebo/Uke	5
6	Iruekpen	6
7	Ukpenu /Emuhi	7
8	Urhohi	8
9	Uhiele	9
10	Ile	10

Samples were taken in February being onset of rainfall in the study area and July which being the peak of rainfall. A total of 64 samples were collected for analysis (i.e. 32 samples for each sampling period). Water samples were analyzed for physical, chemical, bacteriological and selected heavy metal content using standard method for the examination of water.

Data Analysis: Determination of Ph: The pH of the water samples was determined using the HANNA pH meter (model HI 8424). It was calibrated using buffer solutions 4.7 and 10.

Determination of Turbidity: Turbidity was read using a visible spectrophotometer VS721G. The cuvettes were washed and rinsed with distilled water. One of the cuvettes was filled to mark with the sample and the other was filled to mark with distilled water which was used to standardize the spectrophotometer. The sample was read at a wavelength of 420nm.

Determination of Total Dissolved Solids (TDS): The total dissolved solid (TDS) was analyzed using the HACH 44600-00 Conductivity/TDS meter. The probe was dipped into the container of the samples until a stable reading in mg/l was obtained and recorded.

Determination of Total Suspended Solids (TSS): This is obtained by a simple subtraction method. The total solid was first determined and the total dissolved solid obtained was subtracted from it.

$$TSS = TS - TDS$$

The total solid was obtained by gravimetric method: 10ml of the samples was measured into a pre-weighed evaporating dish which was oven dried at a temperature of 103^{o}C to 105^{o}C for two and half hour. The dish was cooled in a desiccator at room temperature and was weighed. The total solid was represented by the increase in the weight of the evaporating dish.

$$Total\ solids(mg/l)\frac{(W2 - W2)mgx1000}{ml\ of\ sample\ used}$$

Where W1 = initial weight of evaporating dish
W2 = Final weight of the dish (evaporating dish + residue)

Determination of Heavy Metals (Fe, Pb, Cr): To assess the levels of iron, lead and chromium, a portion of all the water samples (50 ml) were initially subjected to fixing using concentrated nitric acid and concentrated hydrochloric acid in a ratio of 1:10 respectively. This was done in order to digest particulate matter inside the sample by heating carefully in a water bath to obtain thick yellow solution, and later was cooled and made up to 100 ml with distilled water. After this fixing, the samples were directly analyzed using the Bulk Scientific AAS. JENWAY 6310 spectrophotometer and JENWAY PFP-7 flame photometer was used to determine magnesium.

Total Bacteria Count: 1ml of each sample was plated out using a serial dilution of 1:1000 (10^{-3}). Molten nutrient agar was added to the petri dish and shaken for even distribution. Solidified nutrient agar plate was then incubated at a temperature of 37^{0}C for 24hours. After incubation, emergence colonies were counted and colonies forming unit per ml calculated and recorded. Identification was done based on the cultural, morphological and biochemical tests of the isolates (Tables 2-4). *Identification of Bacteria*

Table 2: Cultural Characteristics

ISOLATE	SIZE	SHAPE	COLOUR	MARGIN	ELEVATION	SURFACE COLONY
A	1 mm	Round	Pink	Smooth	Raised	Moist
B	1 mm	Round	Yellow	Smooth	Raised	Dry
C	1 mm	Round	Golden yellow	Smooth	Raised	Dry
D	1 mm	Round	Green	Smooth	flat	Moist
E	1 mm	Round	Cream	Rough	flat	Moist

Source: Author's Laboratory Analysis (2014).

Table 3: Morphological Characteristics

ISOLATE	GRAM REACTION	CELLS TYPE	CELLS ARRANGEMENT
A	Negative	Rods	Singly
B	Positive	Cocci	Cluster
C	Positive	Cocci	Cluster
D	Negative	Rods	Singly
E	Negative	Rods	Singly

Source: Author's Laboratory Analysis (2014).

Table 4: Biochemical Characteristics

ISOLATES	Coag.	Cat.	Ind.	Cit.	Oxid.	Lact.	Mot.
A	Negative	Negative	Negative	Positive	Negative	Positive	Positive
B	Negative	Positive	Positive	Positive	Negative	Negative	Negative
C	Positive	Positive	Negative	Negative	Positive	Positive	Negative
D	Negative	Negative	Negative	Negative	Positive	Positive	Positive
E	Negative	Negative	Negative	Negative	Negative	Positive	Positive

Source: Author's Laboratory Analysis (2014).

Suspected Bacteria
a = Enterobacter; b = Micrococusspp;
c = Staph Epidy; d = Pseudomonas;
e = Klebsiella.

Key:
Coag. = Coagulase test; Cat. = Catalase test;
Ind. = Indole test; Cit. = Citrate test;
Oxid. = Oxidase test; Lact. = Lactose test;
Mot. = Motility test.

Positive = Present **Negative = Absent.**

Total coliform count (Using MacConkey broth): The multiple tube technique (MTT) was employed and the 3 tube method was used. All tubes were incubated at a temperature of 37^0C for 24hrs after which tubes showing colour changes (acid production) were regarded as positive tubes while those without a change in colour were discarded. The Magady Statistical Table was then used to get the value for the Most Probable Number (MPN) per 100ml and recorded.

E-coli count: The same method used in total coliform count was also employed here in determining the total *E-Coli* count except that all tubes were incubated at a temperature of 44^0C for 24 – 48 hours.

RESULTS AND DISCUSSION

The results of the laboratory analysis of physicochemical characteristics of rainwater samples collected at the onset of the raining season (February) and peak of rain (July) for different rooftop sheets are presented in Tables 5 and 6. pH levels for onset of rain (February) ranged from 5.0 – 6.5 with a mean value of 5.9 for galvanized Iron rooftop; 5.0 – 6.4 with a mean of 5.8 for Aluminum rooftop and 5.1 – 6.5 with a mean of 5.8 for corrugated Asbestos rooftop. Similarly, at the peak of the rain, pH levels ranges from 5.5 – 6.3 with a mean 6.0 for Zinc rooftop; 5.2 – 6.1 with a mean of 5.6 for Aluminum rooftop and 5.4 – 6.5 with a mean of 6.0 for corrugated Asbestos rooftop respectively. The pH values of water samples obtained for all roof types indicate that they are below the World Health Organization (WHO) minimum permissible level for potable water (6.15 – 9.50). Generally, mean values of harvested rainwater from all sampled rooftops are acidic especially at the onset of the raining season. Also the pH of samples collected showed variation from one roofing material to the other. Samples from Aluminum rooftop had the least pH values of 5.8 and 5.6 for onset and peak of the raining season respectively, indicating that it is more acidic than other roof types, while water samples from galvanized Iron and corrugated Asbestos rooftops had similar values of 5.8 and 6.0 for onset and peak of the raining season respectively. Acidic water can help prevent bacteria growth when used for kitchen cleaning, washing fresh fruits and vegetables. Thus, water samples collected from Aluminum rooftops had the best pH levels.

Table 5: Physicochemical parameters quality of rainwater harvested from 3 different rooftop sheets (Onset of rainfall)

Parameter	Rooftop type	Range	Mean	SD	SE
pH	Galvanized Iron Rooftop	5.0-6.5	5.9	0.48	0.15
	Aluminum rooftop	5-6.4	5.8	0.46	0.15
	Asbestos rooftop	5.1-6.5	5.8	0.49	0.15
TSS Mg/l	Galvanized Iron Rooftop	0.01-0.08	0.052	0.02	0.008
	Aluminum rooftop	0.02-0.1	0.06	0.027	0.009
	Asbestos rooftop	0.04-0.1	0.07	0.022	0.066
TDS Mg/l	Galvanized Iron Rooftop	10.8-26.5	16.9	4.88	1.54
	Aluminum rooftop	12.2-23.5	17.19	3.6	1.13
	Asbestos rooftop	19.5-37	23.12	5.2	1.66
Turbidity NTU	Galvanized Iron Rooftop	0.09-0.95	0.49	0.29	0.09
	Aluminum rooftop	0.1-1.0	0.5	0.3	0.096
	Asbestos rooftop	0.4-1.2	0.67	0.24	0.077
Acidity Mg/l	Galvanized Iron Rooftop	4-5.7	4.83	0.61	0.19
	Aluminum rooftop	4.1-5.8	4.85	0.61	0.19
	Asbestos rooftop	4.09-5.5	4.79	0.47	0.15
Ca2+ Mg/l	Galvanized Iron Rooftop	69.5-122.3	93.57	16.8	5.32
	Aluminum rooftop	59.9-132.2	91.21	22.7	7.17
	Asbestos rooftop	55.5-145.5	89.9	29.8	9.42
Fe Mg/l	Galvanized Iron Rooftop	0.114-0.19	0.14	0.026	0.008
	Aluminum rooftop	0.095-0.156	0.13	0.02	0.007
	Asbestos rooftop	0.095-0.154	0.14	0.012	0.0056
Pb Mg/l	Galvanized Iron Rooftop	0.004-0.015	0.007	0.004	0.001
	Aluminum rooftop	0.003-0.014	0.007	0.003	0.0009
	Asbestos rooftop	0.003-0011	0.008	0.0024	0.0008
Cr Mg/l	Galvanized Iron Rooftop	0.011-0.026	0.019	0.005	0.002
	Aluminum rooftop	0.012-0.024	0.018	0.005	0.002
	Asbestos rooftop	0.014-0.025	0.019	0.003	0.001

The values of Total Suspended Solids (TSS) for the onset of the rain ranged from 0.01 – 0.08mg/l with a mean of 0.052mg/l for galvanized Iron rooftop; 0.02 – 0.1mg/l with a mean of 0.06mg/l for Aluminum rooftop and 0.04 – 0.1mg/l with a mean of 0.07mg/l for Asbestos rooftop.

Also, TSS values of rainfall peak ranges from < 0.005 – 0.009mg/l with a mean of 0.0063mg/l for galvanized Iron rooftop; < 0.005 – 0.03mg/l with a mean of 0.009mg/l for Aluminum rooftop and 0.005 – 0.05mg/l with a mean of 0.015mg/l for Asbestos rooftop. It is thus observable that irrespective of rainfall event (i.e. both onset and peak of rain) TSS was highest in samples collected from Asbestos rooftop; this is followed by samples from Aluminum rooftop while samples from galvanized Iron had the least. It is also observed that samples collected at the onset of the rain had higher amount of suspended solids than those collected at the peak of the rain for all roof type. This may be attributed to the accumulation of particulates from the air and droppings from birds, lizards etc. on the roofs during the long dry spell (October - January) before the onset of the rain. Although the threshold is not emphasized by the World Health Organization (WHO), TSS is known to reduce water transparency. Also, pathogens are often clumped or adherent to suspended solids in water (WHO, 2004). This implies that water samples collected from the three roof types does pose some health concerns, especially in households where harvested water is consumed directly without any form of purification.

The mean values for Total Dissolved Solids (TDS) of rainwater samples collected from galvanized Iron rooftop catchments were 16.9mg/l and 7.9mg/l for onset and peak of rain respectively, while the values ranged from 10.8 – 26.45mg/l for onset of rain and 4.0 – 14.05mg/l for peak of rain.

Table 6: Physicochemical parameters quality of rainwater harvested from 3 different rooftop sheets (Peak of rainfall)

Parameter	Rooftop type	Range	Mean	SD	SE
pH	Galvanized Iron Rooftop	5.5 – 6.3	6.0	0.24	0.078
	Aluminum rooftop	5.2 – 6.1	5.6	0.29	0.09
	Asbestos rooftop	5.4-6.5	6.0	0.30	0.09
TSS Mg/l	Galvanized Iron Rooftop	0.005-0.009	0.006	0.002	0.0005
	Aluminum rooftop	0.005-0.03	0.009	0.008	0.002
	Asbestos rooftop	0.005-0.05	0.015	0.012	0.005
TDS Mg/l	Galvanized Iron Rooftop	4-14.1	7.9	3.4	1.06
	Aluminum rooftop	3.5-13	6.7	2.9	0.92
	Asbestos rooftop	5-37	11.8	9.92	3.13
Turbidity NTU	Galvanized Iron Rooftop	0.03-0.1	0.064	0.03	0.008
	Aluminum rooftop	0.01-0.4	0.13	0.15	0.05
	Asbestos rooftop	0.03-0.3	0.10	0.09	0.03
Acidity Mg/l	Galvanized Iron Rooftop	3.6-5.6	4.46	0.63	0.19
	Aluminum rooftop	3.02-5.58	4.3	0.81	0.25
	Asbestos rooftop	3.8-5.6	4.7	0.67	0.21
Ca2+ Mg/l	Galvanized Iron Rooftop	40.1-115.7	59.5	21.2	6.7
	Aluminum rooftop	35.9-112.9	58.3	20.7	6.5
	Asbestos rooftop	38.6-117.5	60.9	21.1	6.7
Fe Mg/l	Galvanized Iron Rooftop	0.045-0.82	0.14	0.24	0.07
	Aluminum rooftop	0.029-0.095	0.06	0.02	0.006
	Asbestos rooftop	0.03-0.12	0.06	0.03	0.008
Pb Mg/l	Galvanized Iron Rooftop	0.003-0.008	0.005	0.002	0.0006
	Aluminum rooftop	0.002-0.013	0.006	0.003	0.001
	Asbestos rooftop	0.008-0.024	0.007	0.004	0.001
Cr Mg/l	Galvanized Iron Rooftop	0.008-0.024	0.012	0.004	0.001
	Aluminum rooftop	0.008-0.021	0.02	0.005	0.002
	Asbestos rooftop	0.012-0.026	0.019	0.005	0.002

Samples collected from Aluminum rooftop catchments had mean values of 17.19mg/l and 6.66mg/l of total dissolved solids for onset and peak of rain respectively and a range of 12.2 – 23.5mg/l for onset of rain and 3.5 – 13.0mg/l for peak of rain. Also, corrugated Asbestos had mean values of 23.12mg/l and 11.75mg/l for onset and peak of rain respectively with a range of 19.45 – 37.0mg/l for onset of rain and 5.0 – 37.0mg/l for peak of rain.

It was observed that rainwater samples collected from rooftop with corrugated Asbestos roofing sheets had higher concentration of dissolved solids, followed by samples collected from Aluminum rooftops while galvanized Iron rooftop had the least TDS concentration irrespective of the rainfall event. It is clear from the tables that the amount of dissolved solids decreases (for all roof type) from the onset of the rain to the peak. All samples collected (both for onset and peak of rain) had total dissolved solid concentrations below WHO limit (500mg/l). Although no health based guideline value for Total Dissolve Solid (TDS) has been proposed, the presence of high levels of TDS (above 500mg/l) may become objectionable to consumers owing to excessive scaling in heaters, boilers and other household appliances (WHO, 2004 and 2011).

Turbidity values for rainwater samples collected from rooftop with galvanized Iron roofing sheets ranges from 0.09 – 0.95NTU with a mean of 0.49NTU for onset of rain and 0.03 – 0.10NTU with a mean of 0.064NTU for peak of rain. Aluminum rooftop had turbidity values ranging from 0.1 – 1.0NTU with a mean of 0.5NTU for onset of rain and 0.01 – 0.4NTU with a mean of 0.13NTU for peak of rain while corrugated Asbestos had values ranging from 0.4 – 1.2NTU with a mean of 0.67NTU and 0.03 – 0.3NTU with a mean of 0.1NTU for onset and peak of rain respectively. The turbidity values decreases from the onset of rain to the peak for all roof type. Rainwater samples collected from Asbestos rooftop yielded highest turbidity levels. This was followed by samples collected from galvanized Iron rooftop whiles samples collected from Aluminum yielded the least turbidity levels for both onset and peak of rain. The turbidity values of all rainwater samples collected including the onset and peak of rain season are within the WHO limits of 0.2 – 1.0NTU. Mean turbidity values at the onset of the rain for all roof type were above the WHO lower limit of 0.2NTU, while samples collected at the peak of the rain were below the WHO lower limit of 0.2NTU for all roof type.

Rainwater samples collected from galvanized Iron rooftop catchments had mean acidity level of 4.83mg/l with a range of 4.00 – 5.70mg/l for onset of rain and a mean of 4.46mg/l with a range of 3.60 – 5.60mg/l for peak of rain. Samples from Aluminum rooftop catchments had a range of 4.10 – 5.80mg/l with a mean of 4.85mg/l for onset of rain and 3.02 – 5.80mg/l with a mean 4.30mg/l for peak of rain, while samples from Asbestos rooftop catchments had a range of 4.10 – 5.50mg/l with a mean of 4.79mg/l for onset of rain and 4.00 – 5.60mg/l with a mean of 4.71mg/l for peak of rain.

The concentration of Ca^{2+} in samples collected from galvanized Iron rooftop catchments ranged from 69.5 – 122.3mg/l with a mean of 93.57mg/l for onset of rain and 40.1 – 115.7mg/l with a mean of 59.5mg/l for peak of rain. Samples collected from Aluminum rooftop catchments had values ranging from 59.8 – 132.2mg/l with a mean of 91.2mg/l for onset of rain and 35.9 – 112.9mg/l with a mean of 58.3mg/l for peak of rain. Samples from Asbestos rooftop catchments had a range value of 55.5 – 145.5mg/l with a mean of 89.9mg/l and 38.6 – 117.5mg/l with a mean of 60.9mg/l for onset and peak of rain respectively. Generally, samples collected from galvanized Iron rooftop catchments had the highest Ca^{2+} content and followed by samples collected from Aluminum rooftop catchments while samples from Asbestos rooftop had the least concentration. The rainwater samples collected at the onset of rain had higher Ca^{2+} concentration than those collected at the peak of rain for all roof type. Calcium ion (Ca^{2+}) concentration at the onset of rain were higher than WHO limit of 75mg/l for Ca^{2+} in potable water while the concentration were lower than the limit at the peak of rain for all roof type.

The rainwater samples collected at the onset of the rain had Iron (Fe) values ranging from 0.114 – 0.199mg/l with a mean of 0.14mg/l for galvanized Iron rooftop catchments; 0.095 – 0.155mg/l with a mean of 0.13mg/l for Aluminum rooftop catchments and 0.099 – 0.154mg/l with a mean of 0.14mg/l for corrugated Asbestos rooftop catchments. Samples collected at the peak of rain had Iron (Fe) concentration ranging from 0.045 – 0.082mg/l with a mean of 0.14mg/l for galvanized Iron rooftop catchments; 0.029 – 0.095mg/l with a mean of 0.06mg/l for Aluminum rooftop catchments and 0.032 – 0.121mg/l with a mean of 0.06mg/l for corrugated Asbestos rooftop catchments. Samples collected at the onset of the rain for all roof type had Fe concentrations above the WHO (2011) limit of 0.1mg/l while those collected at the peak of rain had lesser values. Samples collected from galvanized Iron rooftop had the highest mean Fe value (0.15mg/l) at the onset of the rain, while those collected from both Aluminum and Asbestos rooftops had similar mean values (0.13mg/l).

The rainwater samples collected at the onset of rain from the three (3) roof types had Lead concentration levels ranging from 0.004 – 0.015mg/l with a mean of 0.007mg/l for galvanized Iron rooftop catchments; 0.003 – 0.014mg/l with a mean of 0.007mg/l for Aluminum rooftop and 0.003 – 0.011mg/l with a mean of 0.008mg/l for corrugated Asbestos rooftop. Samples collected at the peak of the rain had Lead concentration ranging from 0.003 – 0.008mg/l with a mean value of 0.005mg/l for galvanized Iron rooftop; 0.002 – 0.013mg/l with a mean of 0.006mg/l for Aluminum rooftop and 0.002 – 0.019mg/l with a mean of 0.007mg/l for corrugated Asbestos rooftop. All rainwater samples collected (irrespective of roof type and sampling season) had lead levels within the WHO limit of 0.01mg/l for potable water.

The mean values of chromium concentration of rainwater samples collected from three different roof types. Chromium levels of rainwater samples collected at the onset of the rain ranged from 0.011 – 0.026mg/l with a mean of 0.019mg/l for galvanized Iron rooftop; 0.012 – 0.024mg/l with a mean of 0.018mg/l for Aluminum rooftop and 0.014 – 0.025mg/l with a mean of 0.020mg/l for Asbestos rooftop. At the peak of rain, Chromium levels ranged from 0.008 – 0.024mg/l with a mean of 0.018mg/l for galvanized Iron rooftop; 0.008 – 0.021mg/l with a mean of 0.015mg/l for Aluminum rooftop and 0.012 – 0.026mg/l with a mean of 0.019mg/l for Asbestos rooftop. All rainwater samples collected had Chromium levels within the WHO limit of 0.05mg/l.

Table 7: Bacteriological parameters quality of rainwater harvested from 3 different rooftop sheets (Onset of rainfall)

Parameter	Rooftop type	Range	Mean	SD	SE
TBC Cfu/ml	Galvanized Iron Rooftop	100-200	130	48.3	15.3
	Aluminum rooftop	100-300	150	70.7	22.4
	Asbestos rooftop	100-500	260	117.4	37.11
TCC MPN/100ml	Galvanized Iron Rooftop	0.4-1.0	0.74	0.27	0.087
	Aluminum rooftop	0.2-2.0	0.96	0.61	0.19
	Asbestos rooftop	0.5-30	1.49	0.82	0.26
E-coli MPN/100ml	Galvanized Iron Rooftop	0.03-0.4	0.08	0.11	0.04
	Aluminum rooftop	0.03-0.1	0.05	0.02	0.08
	Asbestos rooftop	0.03-0.7	0.24	0.24	0.08

Tables 7 and 8 shows the mean bacteria count in rainwater samples collected from rooftops made of three different materials. The Total Bacteria Count (TBC) in rainwater samples collected at the onset of the rain range between 100 – 200cfu/ml with a mean of 130cfu/ml for galvanized Iron rooftop catchments; 100 – 300cfu/ml with a mean of 150cfu/ml for Aluminum rooftop catchments and 100 - 500cfu/ml with a mean of 260cfu/ml for corrugated Asbestos rooftop catchments. Samples collected at the peak of the rain had TBC ranging from 100 – 200cfu/ml with a mean of 110cfu/ml; samples from Aluminum rooftops had a count of 100cfu/ml for all sampled Aluminum rooftop while samples from corrugated Asbestos rooftop catchments had a range of 100–200cfu/ml with a mean 1700cfu/ml. Samples collected from all rooftop (for both seasons) exceeded WHO limit of <100cfu/ml for TBC. Also, samples collected at the onset of rain for all roof type had higher bacterial load than those collected at the peak of rain. Generally, rainwater samples collected from corrugated Asbestos rooftop had the highest bacterial load for both onset and peak of rain, followed by samples collected from Aluminum rooftop for the onset on rain

Table 8: Bacteriological parameters quality of rainwater harvested from 3 different rooftop sheets (Peak of rainfall)

Parameter	Rooftop type	Range	Mean	SD	SE
TBC Cfu/ml	Galvanized Iron Rooftop	100-200	110	31.6	10
	Aluminum rooftop	100-200	110	31.6	10
	Asbestos rooftop	100-200	170	48.3	15.3
TCC MPN/100ml	Galvanized Iron Rooftop	0.1-0.5	0.3	0.16	0.054
	Aluminum rooftop	0.1-0.5	0.33	0.17	0.05
	Asbestos rooftop	0.1-0.5	0.45	0.13	0.04
E-coli MPN/100ml	Galvanized Iron Rooftop	0-0.05	0.024	0.02	0.006
	Aluminum rooftop	0-0.08	0.033	0.02	0.006
	Asbestos rooftop	0.03-0.05	0.035	0.009	0.003

The total coliform count of samples collected at the onset of the rain ranged from 0.4 – 1.0 Most Probable Number per 100ml (MPN/100ml) with a mean of 0.74MPN/100ml for galvanized Iron rooftop; 0.2 – 2.0MPN/100ml with a mean of 0.96MPN/100ml for Aluminum rooftop and 0.5 – 3.0 MPN/100ml with a mean of 1.49MPN/100ml for corrugated Asbestos rooftop. Samples collected at the peak of rain had Total Coliform Count (TCC) which ranged from 0.1 – 0.5MPN/100ml with a mean of 0.3, 0.33 and 0.45MPN/100ml for galvanized Iron, Aluminum and corrugated Asbestos rooftop respectively. All samples collected had detectable Coliform count per 100ml as against WHO standard which states that total coliform bacteria must not be detectable in any 100ml sample of water (0 MPN/100ml). Samples with the highest percentage of Coliform count were those from corrugated Asbestos rooftop, followed by those from Aluminum rooftop while galvanized Iron had the least probable number of coliform count for both onset and peak of rain. Generally, samples collected at the onset of rain, for all roof type, had more coliform count than those collected at the peak of the rain. The presence of coliform bacteria in the rainwater samples collected (for all roof type) is an indication that the harvested water are in a poor sanitary state. Table 8 shows the mean of the Most Probable Number of E-coli count on rainwater samples collected from rooftops made of three different roofing materials. The *E-coli* count in all samples ranged from non-detectable (0) – 0.7MPN/100ml for onset and peak of rain.

Table 9: Analysis of variance of harvested rainwater quality from different rooftop catchment types

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	874.0492	2	437.0246	0.131607	0.877144	3.284918
Within Groups	109582.8	33	3320.691			
Total	110456.9	35				

E-coli count was highest in water sample collected from corrugated Asbestos rooftop for onset and peak of rain, followed by samples collected from galvanized Iron rooftop while samples collected from Aluminum rooftop had the least count. Generally, water samples collected at the onset of the rain had more *E-coli* count than those collected at the peak of the rain for all roof type. However, the presence of *E-coli* (at any level) in water is an indication of fecal contamination from animals or humans waste and this has serious health implication. Mean values showed detectable *E-coli* count per 100ml on water samples collected for all roof type as against WHO standard which states that it must not be detectable in any 100ml sample of water (0 MPN/100ml). *E-coli* can cause serious hemorrhagic diarrhea and can have long term, if not fatal, complications. The Analysis of variance result as shown in Table 9 shows that quality of harvested rainwater does not significantly differ among rooftop catchment.

Conclusion and *Recommendations*: The study analysed and compared water quality of harvested rainfall from three different rooftops in Edo State Central, Edo State. Physical, chemical and bacteriological parameters of the rainwater samples collected from galvanized Iron, Aluminum and Asbestos rooftop catchments for onset of rain (February) and peak of rain (July) showed no much detectable variation pattern of water quality amongst the three selected roof types and thus no roof type can be said to produce superior water quality than the others. Analysis of physical parameters showed that harvested rainwater had slightly higher acidic level when compared to WHO permissible limit for drinking water. Bacteriological qualities of harvested rainwater showed evidence of contamination. The study further shows that for the two (2) rainfall periods (Onset and Peak of rain), none of the roofing materials emerged as clearly superior to the other in terms of the quality of the rainwater harvested. However, samples harvested from Asbestos rooftop had more parameters in which it had the highest contamination level (parameters such as total coliform count and *E. coli*). These all have serious health implications. For households that intend to harvest rainwater from their rooftop, the use of Aluminum roofing sheets in their building designs should be encouraged. However, if not feasible due to cost constraint, the coated galvanized Iron (Zinc) roofing sheet should be adopted. The use of corrugated asbestos is not recommended. Finally, harvested water should be filtered locally and boiled beyond 100^0C before potable use. Additional treatment like chlorination may be of great importance.

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