ANALYSIS OF THE IMPACT OF CAMEROUN ZINC, STONE-COATED TILES, ASBESTOS, CORRUGATED IRON ROOFS AND GALVANIZED IRON TANK ON HARVESTED RAINWATER IN SOUTH-SOUTH, RIVERS STATE, NIGERIA USING WATER QUALITY INDEX

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ABSTRACT

Harvested rainwater has shown lots of benefits in the universe including providing water in remote areas for their approximately safe usage and it also supports the global water demands due to inadequate amount of water supply for utilization. This present study was aimed at analyzing the impact of various roofing materials, galvanized iron tank and industrial activity on rainwater quality by determining the physicochemical characteristics, bacteriological properties and the metal composition of the roof types and storage medium. Rainwater was harvested from Cameroun zinc, stone-coated tiles, asbestos, corrugated iron roofs run-offs, and stored rainwater in galvanized iron tank and directly from the sky (control) in the urban and rural areas of Rivers State between the months of April-July, 2018. The results will be compared with the standards (NAFDAC, USEPA, WHO and NSDWQ) for drinking water quality and Water Quality Index (WQI) ratings since there is no standard for rainwater quality. Roofs ages from <5, 5-10, 15-20, and >25 years in service conditions and stored rainwater in storage vessels for the duration of one year and above were considered. Heavy metals were analyzed using Flame-AAS; other parameters were analyzed using standard methods. The WQI ratings were calculated using the weighted arithmetic method. Results obtained in both areas gave mean values ranging from 6.10-6.90 for pH, Temp., (20.00-28.00 ºC), EC (17.00-132.00 µS/cm), *E. coli* (no detection). Other results (mg/L) were; TDS (15.50-71.67), TSS (19.00-84.67), Pb (0.00-0.23), Cr (0.00-0.12), Zn (0.01-0.03), Fe (0.01-0.22) and Al (0.00-1.61).The WQI ratings gave excellent water to unfit for drinking water quality in both areas. Generally, harvested rainwater is not free of contaminations because of its catchment/storage systems due to atmospheric pollution and leaching of the roofing material; hence, it should be treated before being used for domestic and potable usages.

Keywords: Harvested rainwater, Heavy metals, Physico-chemical characteristics, Storage vessels, Roof types, Water Quality Index (WQI), Policy

INTRODUCTION

Harvested rainwater is always collected from roofs run-off or directly from the sky for eventual use due to water scarcity but the quality of rainwater may deteriorate during harvesting, storage and household usages [1-4]. Populations in most parts of the developing world especially in remote areas and locations where water is a scarce commodity rely on harvested rainwater as the primary source of fresh water, providing suitable environment for diverse ecosystems and crop irrigation [1]. Rainwater quality can be influenced by the material used in manufacturing the roof types and constructing of the storage vessels and the prevailing industrial activity of the location resulting from atmospheric pollution and leaching of the roofing material [5-7].

Atmospheric pollution has been noted by various contaminants that harbour in the air and are reported by various researchers [8-14]. Many researchers have said that the most significant issue in relation to using untreated harvested rainwater for drinking or other potable uses is the potential public health risks associated with microbial pathogens which affect the water quality [15-19]. Water quality is related to the general environmental status of any area depending on the activities of such an area whether it is an industrial activity area or not, as reported in many scientific publications which led to water quality index rating. Water quality index (WQI) ratings were initially developed by Horton in 1965 [20] in the United States by choosing 10 of the most used water physicochemical parameters and it has been widely used globally. Many modifications to the water quality index recently have been considered by different scientists and experts [21, 22]. The weighted arithmetic method classifies the water quality according to the degree of purity by using the most measured water quality variables and it is widely used by various scientists [23-27] as shown in Table 1 below.

Table 1: Water Quality Ratings as per Weight Arithmetic Water Quality Index Method [23-27]

Water Quality Index (WQI) Value	Water Quality Index Rating	Grading	Possible Usages
0 – 25	Excellent	A	Drinking, Irrigation and Industrial
26 – 50	Good	B	Domestic, Irrigation and Industrial
50 – 75	Poor	C	Irrigation and Industrial
76 – 100	Very Poor	D	Irrigation
Above 100	Unfit for Drinking	E	Restricted use for Irrigation and Proper treatment required before use.

Several researchers have also investigated some of the physicochemical and microbiological parameters of rainwater collected from industrial areas of Imo and Enugu States and their results showed that rainwater samples analyzed, were heavily contaminated which was a result of anthropogenic activities which would be harmful for human consumption if not properly treated [1, 28]. Human activities such as agriculture, industrialization and urbanization are having an alarming effect on the environment thereby causing pollution on the atmosphere, however; harvested rainwater is often harvested from roof run-offs and stored in vessels. These roofs and storage vessel can corrode and become active due to their coating materials, especially as the roof and storage vessel is ageing, and can contaminate the harvested rainwater through leaching, hence; there is a need to ascertain whether the water quality of the harvested rainwater and stored rainwater in vessels is within the limits for drinking water quality by NSDWQ, WHO,

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NAFDAC, USEPA and ICMR [27, 29-32] because the overall health being of our dear citizens is needed for the betterment and growth of our dear country and the world at large.

MATERIALS AND METHODS

In this study, appropriate quality assurance procedures and precautions were carried out to ensure reliability of the results. To eliminate possible contamination from detergents or other sources, all glass wares, polyethylene material and sample containers used were soaked with a 1M nitric acid for 48 h and then rinsed several times with distilled water immediately before use [33].

Study area

The study area was Rivers State in the urban and rural areas with their coordinates respectively, namely, Rivers State; Nwaja, Trans Amadi Ind. Layout, P/H local government area and Umuazu village, Igbo-Etche, Etche local government area in the urban and rural areas in South-South, Nigeria as shown in Figure 1 below.

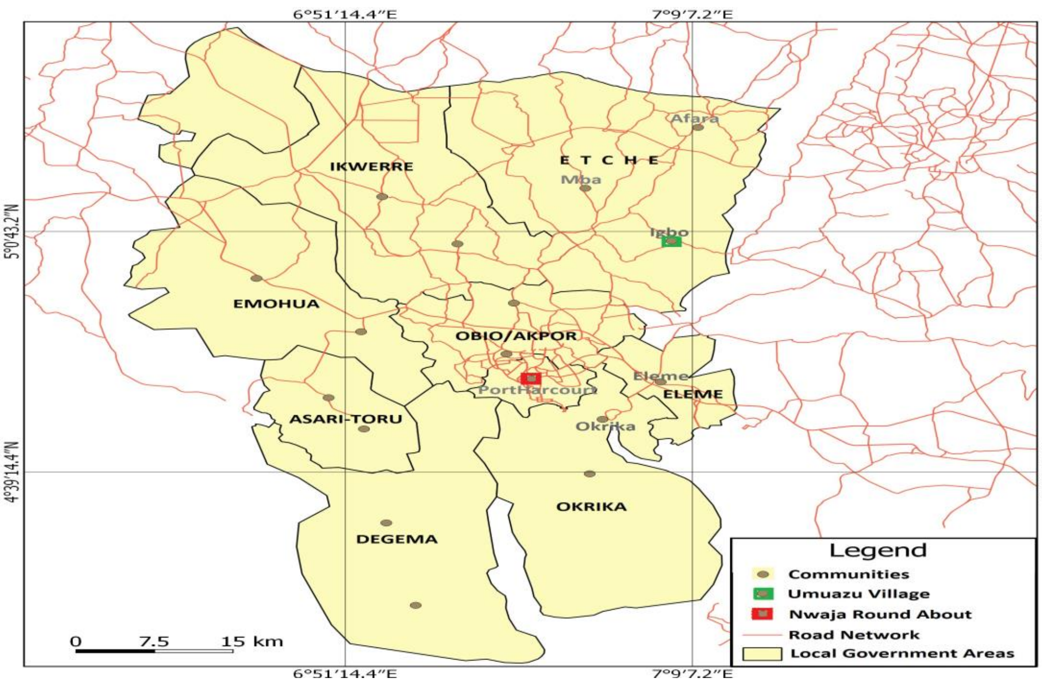

Fig. 1: Map of Rivers State, Nigeria showing sample locations with its coordinates

Sample Collection

Rainwater samples were collected between April-July 2018. Direct rainwater from the sky (control) was harvested randomly by installing a sterilized rainwater collector 1-2 metres high above the ground to avoid contaminations and the sterilized rainwater collector was covered with a sieve of 0.45 micron in diameter in each designated sampling point/locations during rainfall out in the open weekly without any shield on the sky for three weeks to constitute triplicate. After the first rain roofs run-off flush out, rainwater was harvested from the different roofs run-offs weekly for three weeks as well. Rainwater

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samples channeling from the Cameroun zinc roof run-offs using PVC pipes and aluminium funnels connected at the rooftop into the household galvanized iron tanks and stored for one year and above were collected weekly in triplicate at the different sampling locations.

Sample codes and groupings

The collected samples were grouped and named as **DRWRA$_{U/R}$**, **HRWRB$_{U/R}$** and **HRWRF$_{U/R}$** which were divided into two portions as shown in Table 2 below.

Table 2: Sample code, sampling points/locations, areas and sources of the harvested rainwater

Sampling Points/Locations			Sources of the Harvested Rainwater
Sample Code	**Rivers State**	**Area**	
DRWRA$_U$	Nwaja, Trans Amadi Ind. Layout, P/H local government area	Urban	Direct rainwater from the sky (control)
DRWRA$_R$	Umuazu village, Igbo-Etche, Etche local government area	Rural	
HRWRB$_U$	Nwaja, Trans Amadi Ind. Layout, P/H local government area	Urban	Cameroun zinc roof
HRWRB$_R$	Umuazu village, Igbo-Etche, Etche local government area	Rural	
HRWRC$_U$	Nwaja, Trans Amadi Ind. Layout, P/H local government area	Urban	Stone-coated tiles roof
HRWRC$_R$	Umuazu village, Igbo-Etche, Etche local government area	Rural	
HRWRD$_U$	Nwaja, Trans Amadi Ind. Layout, P/H local government area	Urban	Asbestos Roof
HRWRD$_R$	Umuazu village, Igbo-Etche, Etche local government area	Rural	
HRWRE$_U$	Nwaja Trans Amadi Ind. Layout, P/H local government area	Urban	Corrugated iron roof
HRWRE$_R$	Umuazu village, Igbo-Etche, Etche local government area	Rural	
HRWRF$_U$	Nwaja, Trans Amadi Ind. Layout, P/H local government area	Urban	Galvanized iron tank for one year and above
HRWRF$_R$	Umuazu village, Igbo-Etche, Etche local government area	Rural	

Digestion and analysis of the collected samples

Heavy metals in the collected samples were analyzed using Flame-Atomic Absorption Spectrophotometer as described in the standard method by APHA [34].

Bacteriological properties analysis

Escherichia coli (*E. coli*) was carried out according to standard method by APHA [35].

Water Quality Index (WQI)

The overall water quality index (WQI) was done using weighted arithmetic method which classifies the water quality according to the degree of purity by using the most commonly measured water quality variables and this method has been widely used in evaluating water quality globally and particularly in research works [1, 36-38]. The calculation of WQI was made by using

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the following Eq. (1) according to Tripaty and Sahu [38]:

$$WQI = \frac{\Sigma qn \text{ x } Wn}{\Sigma Wn} \qquad (1)$$

$$Wn = \frac{1}{(Sn)} \qquad (2)$$

$$qn = 100\frac{(Vn - Vid)}{(Sn - Vid)} \qquad (3)$$

Where,

W_n = the weightage unit of each parameter obtained as shown in Eq.(2) according to the WHO set standard values; S_n = denotes the WHO set standard values for the nth parameter; q_n represents the quality ratings obtained using Eq. (3). *Vn* represents the nth parameter of the given sampling station and V_{id} is the ideal value of the nth parameter in pure water (Vid for pH = 7 and zero (0) for all other parameters).

Laboratory methods for chemical composition of different roofs and storage vessel

Determination of chemical composition of the different roofs and Galvanized iron pan sheet was done using standard method [34].

Statistical analysis

The results obtained in this study were analyzed for mean and standard deviation (SD). Significant level ($P<0.05$) was evaluated among the harvested rainwater samples stored in storage vessels and direct rainwater from the sky (control) using descriptive and one-way ANOVA and were reported in two significant figures (SPSS statistical software version 20.0).

RESULTS AND DISCUSSION

The results of the physicochemical characteristics obtained for pH, temperature, total dissolved solids, total suspended solids, electrical conductivity, colour, turbidity, nitrate, phosphate, sulphate, iron, zinc, lead, chromium, aluminum and *E. coli* investigated in rainwater harvested directly from the sky (control), rainwater from different roof types and stored rainwater in galvanized iron tank for one year and above at Nwaja, Trans Amadi Ind. Layout, P/H local government area and in Umuazu village, Igbo-Etche, Etche local government area in Rivers State are shown in Tables 4-5 and Figures 2-8 below and the results of the metals concentrations (mg/kg) in different digested roofs and storage vessel are also shown in Table 6 below.

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Table 4: Physico-chemical Properties and *E. coli* concentrations in harvested rainwater directly from the sky, Cameroun zinc and stone-coated-tiles roofs run-offs in Rivers State, Nigeria

S/N	Parameters	Direct rainwater from the sky (control)		Harvested rainwater from Cameroun Zinc roof		Harvested rainwater from Stone-coated tiles roof		WHO, 2011	USEPA, 2012	NSDWQ/ SON, 2007	NAFDAC, 2006
		$DRWRA_U$	$DRWRA_R$	$HRWRB_U$	$HRWRB_R$	$HRWRC_U$	$HRWRC_R$				
1.	pH	6.60±0.20	6.50±0.10	6.60±0.30	6.60±0.20	6.90±0.20	6.60±0.20	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
2.	Temp., ºC	21.30±0.58	22.00±0.60	25.00±1.00	26.30±1.53	27.00±1.00	28.00±1.00	30	Ambient	Ambient	Ambient
3.	TDS, mg/L	32.30±1.53	18.30±4.04	71.67±7.51	19.33±9.07	38.00±6.56	30.30±4.04	250	500	500	500
4.	TSS, mg/L	31.00±4.36	23.67±8.50	35.67±11.06	23.30±11.50	37.30±4.16	28.67±7.37	250	500	500	500
5.	Electrical Conductivity, µS/cm	21.30±4.16	17.00±1.00	122.70±24.99	98.30±13.65	89.33±7.51	34.67±3.21	1200	1000	1000	1000
6.	Colour, TCU	0.35±0.11	0.28±0.12	6.79±2.78	0.59±0.23	0.49±0.14	2.46±2.12	5	15	15	15
7.	Turbidity, NTU	5.92±1.24	2.40±1.02	5.64±0.74	1.19±0.45	7.35±3.09	5.44±1.40	5	5	5	5
8.	Phosphate, mg/L	0.40±0.17	0.29±0.19	3.50±0.20	3.49±0.89	4.08±1.42	1.19±1.20	5	5	5	5
9.	Sulphate, mg/L	0.99±0.81	3.09±1.34	1.58±1.29	2.03±1.20	3.72±0.77	3.13±1.00	250	200	100	100
10	Nitrate, mg/L	0.35±0.11	0.28±0.12	6.79±2.78	0.59±0.23	0.49±0.14	2.46±2.12	50	50	50	50
11.	*E. Coli* Count, cfu/mL	ND	ND	ND	ND	ND	ND	0	0	0	0
12.	Lead, mg/L	ND	ND	0.01±0.00	ND	ND	ND	0.01	0.01	0.01	0.01
13.	Chromium, mg/L	ND	ND	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.05	0.05	0.05	0.05
14.	Iron, mg/L	0.02±0.01	0.01±0.00	0.13±0.04	0.12±0.03	0.11±0.03	0.10±0.00	0.3	0.3	0.3	0.3
15.	Zinc, mg/L	0.02±0.00	0.01±0.00	0.02±0.00	0.03±0.00	0.03±0.00	0.02±0.00	3.0 - 5.0	3.0	3.0	5.0
16.	Aluminium, mg/L	ND	ND	0.61±0.03	ND	0.29±0.01	ND	0.1 - 0.2	0.2	0.2	0.05-0.2

$DRWRA_U$, $HRWRB_U$, $HRWRC_U$ -Nwaja, Trans Amadi Ind. Layout, P/H L.G.A; $DRWRA_R$, $HRWRB_R$, $HRWRC_R$ - Umuazu village, Igbo-Etche, Etche L.G.A, ND-No Detection

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Table 5: Physico-chemical Properties and *E. coli* concentrations in rainwater harvested from asbestos roof, corrugated iron roof and stored rainwater in Galvanized iron tank for one year and above in Rivers State, Nigeria

S/N	Parameters	Harvested rainwater from Asbestos roof		Harvested rainwater from Corrugated iron roof		Harvested rainwater stored in Galvanized iron tank for one year and above		WHO, 2011	USEPA, 2012	NSDWQ/ SON, 2007	NAFDAC, 2006
		HRWRD$_U$	HRWRD$_R$	HRWRE$_U$	HRWRE$_R$	HRWRF$_U$	HRWRF$_R$				
1.	pH	6.90±0.30	6.70±0.10	6.70±0.10	6.50±0.20	6.10±0.14	6.30±0.28	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
2.	Temp., °C	21.00±0.57	20.00±1.00	24.00±1.00	25.00±0.60	26.00±2.83	25.50±2.12	30	Ambient	Ambient	Ambient
3.	TDS, mg/L	54.00±3.0	39.67±3.21	41.30±2.08	59.00±4.00	17.50±10.62	15.50±4.95	250	500	500	500
4.	TSS, mg/L	84.67±8.51	51.00± 13.75	94.00±8.75	69.33±6.51	24.00±2.12	19.00±1.41	250	500	500	500
5.	Electrical Conductivity, µS/cm	51.00±3.61	61.30±3.22	106.20± 8.37	101.30± 9.02	28.50±4.95	26.50±8.46	1200	1000	1000	1000
6.	Colour, TCU	8.41±0.24	7.34±2.27	5.36±2.13	0.49±0.09	8.00±0.37	7.10±0.82	5	15	15	15
7.	Turbidity, NTU	8.71±0.91	2.66±0.79	7.65±0.72	2.75±1.21	7.31±0.89	6.29±0.19	5	5	5	5
8.	Phosphate, mg/L	4.98±1.65	3.93±1.54	4.24±0.87	5.24±1.44	6.06±0.27	4.54±0.05	5	5	5	5
9.	Sulphate, mg/L	6.35±0.48	4.93±0.65	0.61±0.04	0.65±0.02	9.15±1.30	7.65±1.49	250	200	100	100
10	Nitrate, mg/L	8.41±0.24	7.34±2.27	5.36±2.13	0.49±0.09	11.90±0.59	7.18± 1.83	50	50	50	50
11.	*E. Coli* Count, cfu/mL	ND	ND	ND	ND	ND	ND	0	0	0	0
12.	Lead, mg/L	ND	0.01±0.00	ND	0.01±0.00	0.23±0.06	0.09±0.01	0.01	0.01	0.01	0.01
13.	Chromium, mg/L	0.01±0.00	0.01±0.00	ND	ND	0.12±0.04	0.04±0.02	0.05	0.05	0.05	0.05
14.	Iron, mg/L	0.02±0.01	0.01±0.00	0.12±0.04	0.15±0.04	0.22±0.17	0.18±0.11	0.3	0.3	0.3	0.3
15.	Zinc, mg/L	0.03±0.00	0.02±0.00	0.03±0.00	0.02±0.00	0.03±0.01	0.01±0.01	3.0-5.0	3.0	3.0	5.0
16.	Aluminium, mg/L	0.41±0.06	ND	0.79±0.06	ND	1.61±0.68	0.10±0.06	0.1-0.2	0.2	0.2	0.05-0.2

HRWRD$_U$, HRWRE$_R$, HRWRF$_U$ – Nwaja, Trans Amadi Ind. Layout, P/H L.G.A; HRWRD$_U$, HRWRE$_R$, HRWRF$_R$ - Umuazu village, Igbo-Etche, Etche L.G.A; ND - No Detection

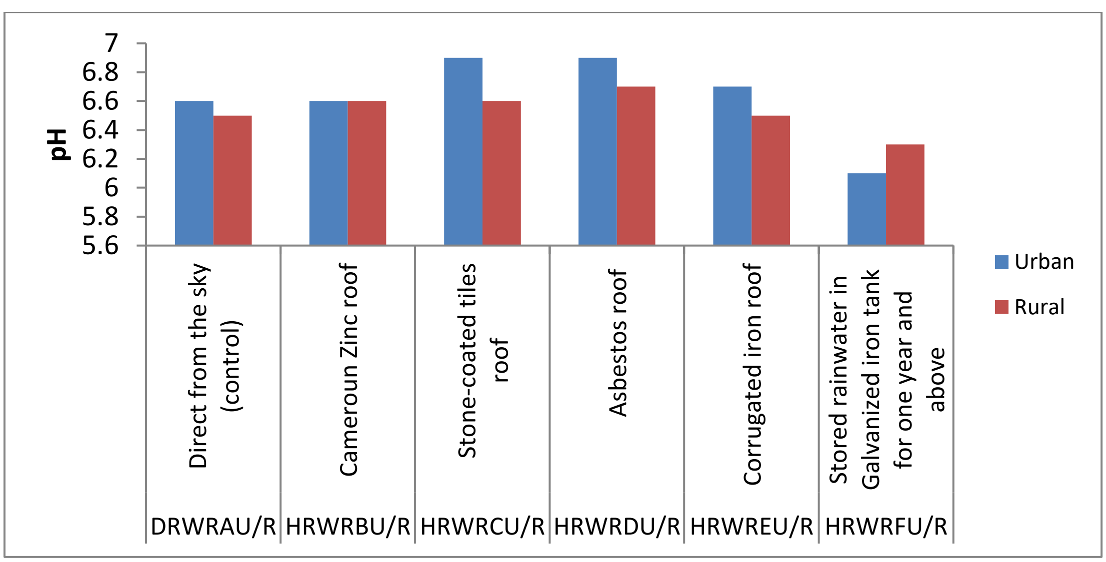

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Fig.2: pH Concentrations of harvested rainwater in the urban and rural areas

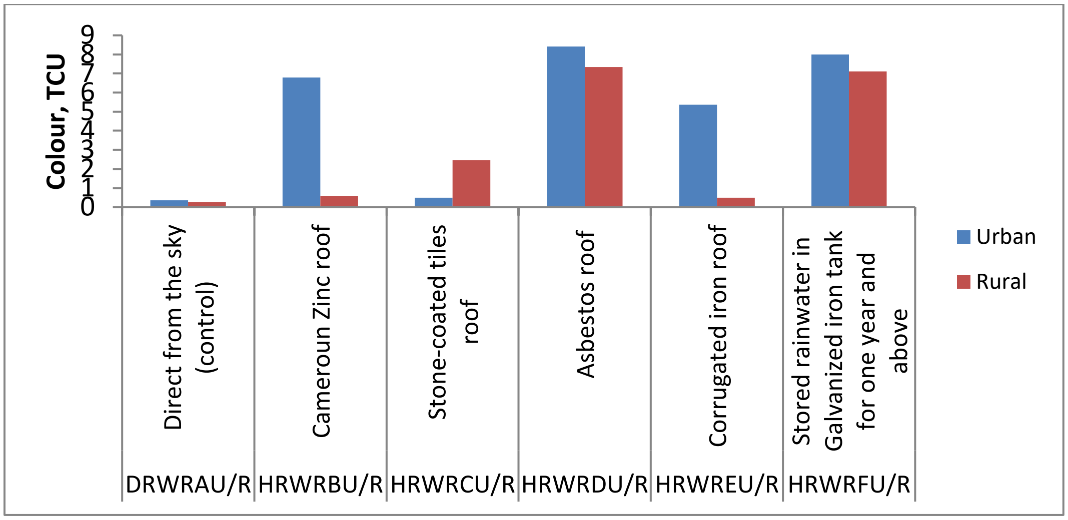

Fig.3: Colour (TCU) Concentrations of harvested rainwater in the urban and rural areas

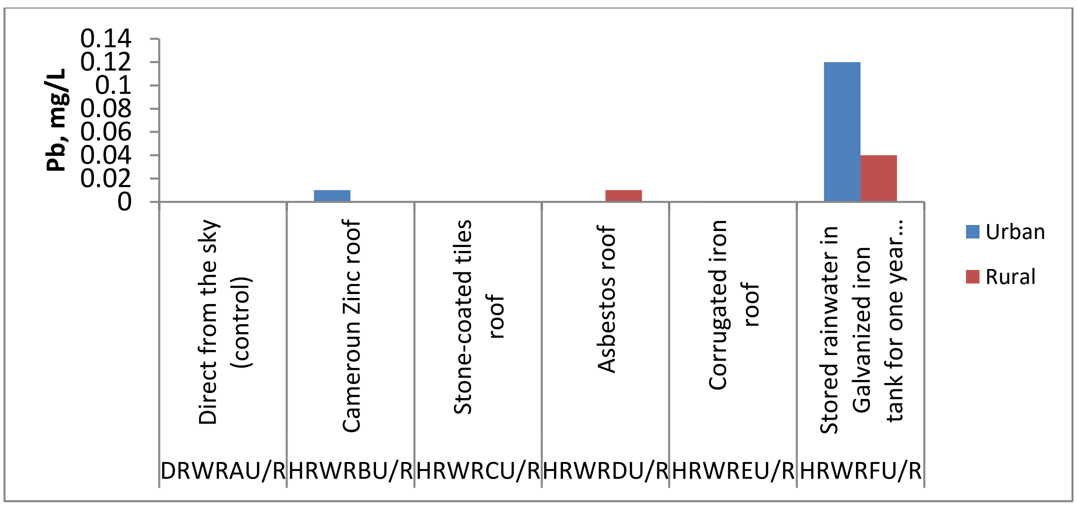

Fig.4: Pb (mg/L) Concentrations of harvested rainwater in the urban and rural areas

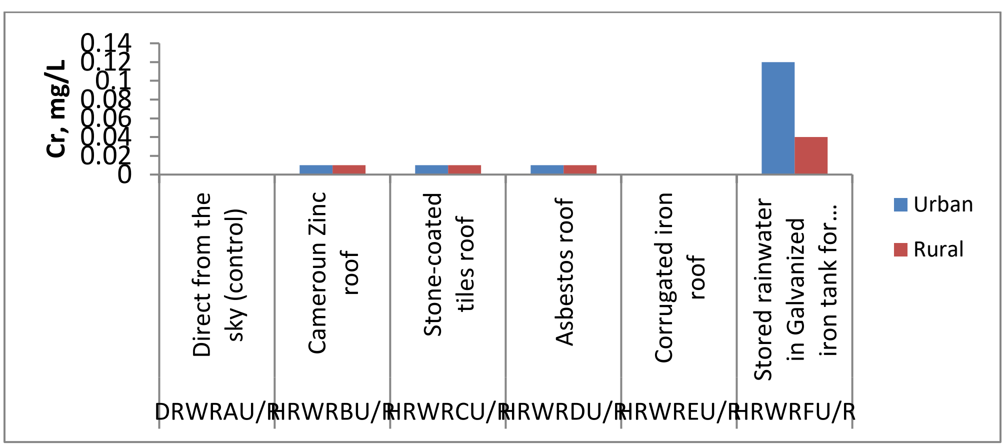

Fig.5: Cr (mg/L) Concentrations of harvested rainwater in the urban and rural areas

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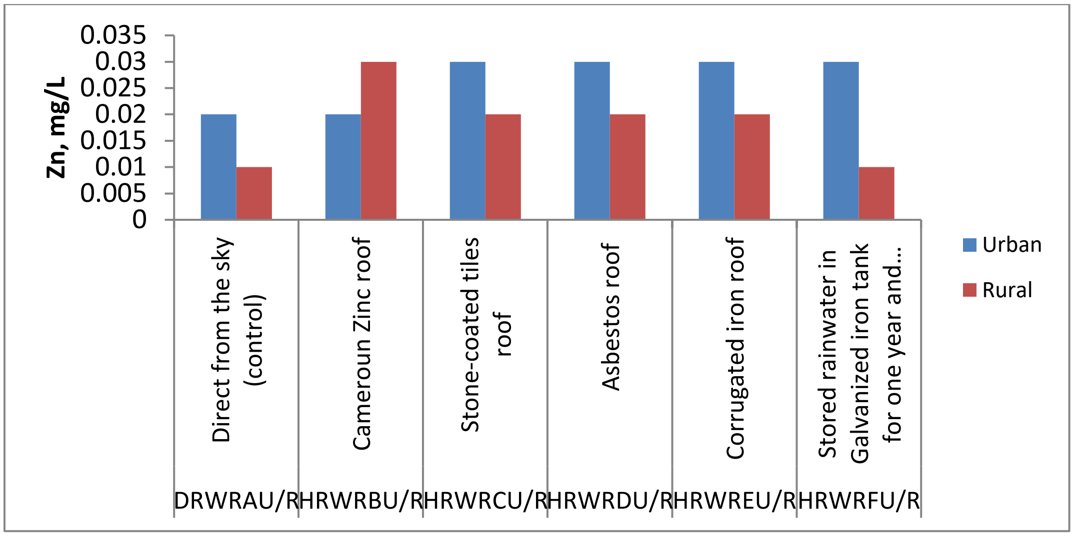

Fig.6: Zn (mg/L) Concentrations of harvested rainwater in the urban and rural areas

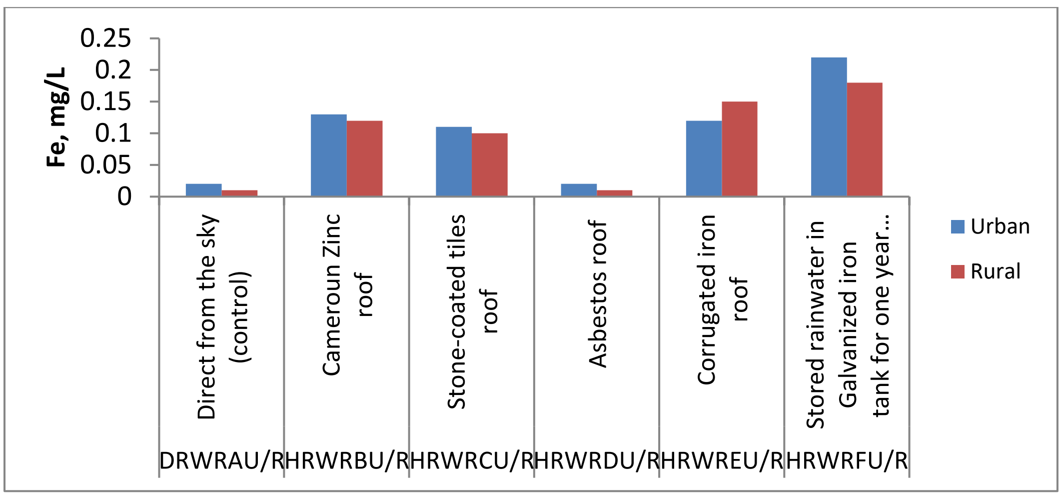

Fig.7: Fe (mg/L) Concentrations of harvested rainwater in the urban and rural areas

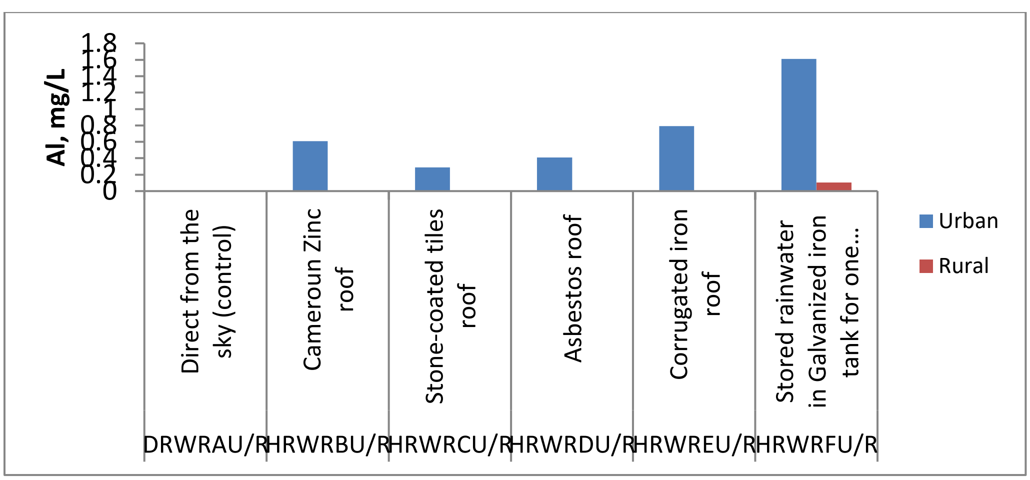

Fig.8: Al (mg/L) Concentrations of harvested rainwater in the urban and rural areas

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Table 5: Water Quality Indices (WQI) ratings of harvested rainwater directly from the sky (control), from different roof types and stored rainwater in Galvanized iron tank in Rivers State, Nigeria

Sample Code	Areas	Sample Source of Collection	Water Quality Index (WQI)	Quality Rating
DRWRA$_{U,}$	Urban	Directly from the sky (control)	0.03	Excellent
DRWRA$_R$	Rural		0.05	
HRWRB$_U$	Urban	Cameroun Zinc roof	125.12	Unfit for drinking
HRWRB$_R$	Rural		3.75	Excellent
HRWRC$_U$	Urban	Stone-coated tiles roof	25.56	Excellent
HRWRC$_R$	Rural		2.86	
HRWRD$_U$	Urban	Asbestos roof	46.38	Good
HRWRD$_R$	Rural		78.18	Very Poor
HRWRE$_U$	Urban	Corrugated iron roof	59.32	Poor
HRWRE$_R$	Rural		75.35	
HRWRF$_U$	Urban	Galvanized iron tank stored for one year and above	3,893.57	Unfit for drinking
HRWRF$_R$	Rural		699.39	

Table 6: Metals Concentrations of the Different Digested Roof Types and Storage Vessel

S/N	Sample	Concentration (mg/kg)				
		Pb	Al	Fe	Zn	Cr
1.	Cameroun zinc roof	2.30	Nil	63.78	5.94	1.02
2.	Corrugated iron roof	31.84	4.34	63.57	7.04	6.09
3.	Asbestos roof	Nil	2.90	51.64	0.78	1.87
4.	Stone-coated tiles roof	Nil	7.93	63.56	5.90	6.20
5.	Galvanized iron pan sheet	0.06	2.12	63.40	5.89	1.23

The mean pH values of directly harvested rainwater from the sky in the urban (Nwaja, Trans Amadi Ind. Layout, Port Harcourt L.G.A) and rural (Umuazu village, Igbo-Etche, Etche L.G.A) areas of Rivers State were 6.50±0.10 and 6.60±0.20 respectively (Table 4). However, harvested rainwater from corrugated iron, Cameroun zinc, stone-coated tiles and asbestos roofs were slightly acidic having pH mean values between ranging from 6.50-6.90 in both as areas of the state shown in Tables 4-5. Stored harvested rainwater in galvanized iron tank for one year had mean pH values of 6.10±0.14- 6.30±0.28 in the urban and rural areas respectively (Table 6). The acidity of pH is likely due to rainwater that fell through the roofing system and was mixed in with

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dust, flared gases, vehicular emissions and atmospheric pollutions. However, pH has no direct effect on human health, but because it is closely related with other chemical constituents of water, it is often referred to having an indirect effect on health and would impact frequently on human health [1-3, 11, 31]. Earlier researchers have reported pH values for harvested rainwater in Nigeria [1-3, 8, 11, 40-42]. Nicholas and Ukoha reported pH mean values of 6.00±0.30-6.50±0.20 for direct rainwater from the sky in Douglas Road, Owerri Municipal Council and in Uzii village, Ideato North in Imo State, Nigeria [1] which showed slight acidity and were in supports with the findings of this study. Chukwuma *et al* also reported pH values of 5.46-5.98 for harvested rainwater from Oko, a town in Anambra State which were not in line with the results obtained in this study whereas Waziri *et al* (2012) quoted 5.90 ± 0.18 - 6.71 ± 0.18 for harvested rainwater indicating slight acidity from Maiduguri in Borno State [41, 43]. The values obtained for pH in harvested rainwater in Rivers State fell within the set standard of 6.5-8.5 for drinking water and all other parameters results obtained for Physico-chemical concentrations were within and above the set standard [29-32].

The results of direct harvested rainwater from the sky indicate no detection of Pb, Cr and Al in the urban and rural areas while Fe and Zn had values ranging from 0.01-0.02 mg/L respectively (Table 4) which were insignificant in quantities. Harvested rainwater from corrugated iron, asbestos, stone-coated tiles and Cameroun zinc roofs had values of 0.01 mg/L for Pb and Cr in the urban and rural areas while that of rainwater harvested from Cameroun zinc roof to store in galvanized iron tank had the highest values of 0.09-0.23 mg/L for Pb and 0.04-0.12 mg/L for Cr in the urban and rural areas as shown in Table 5 and Figures 4-8. Harvested rainwater of the roofs run-offs showed highest values of Al ranging from 0.29-0.79 mg/L in the urban area. There was no detection of Al in all the roofs run-offs in the rural area and in the asbestos roof (urban and rural areas). However, Al highest values ranging from 0.14-1.61 mg/L were seen in stored harvested rainwater in galvanized iron tanks for one year and above in the urban and rural areas (Table 5). The mean values of Fe ranging from 0.12-0.13 mg/L for Cameroun zinc, 0.12-0.15 mg/L for corrugated iron, 0.10-0.11 mg/L for stone-coated tiles in both areas while the highest level of Fe ranging from 0.18-0.22 mg/L was found in the stored harvested rainwater in galvanized iron tank for one year and above respectively were obtained as seen in Tables 4-5 and Figures 4-8.

The values (ppm) of metal concentrations of digested roofs as shown in (Table 6) do not readily leach into the harvested rainwater except on extended contact in the presence of acid rain and that the metals burden also increases with storage duration. For instance, harvested rainwater stored in galvanized iron tank for one year and above had the values of 0.18-0.22 mg/L (Fe) in the urban and rural areas (Table 5 and

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Figures 4-8). This shows that the accumulative effect of the metals on standing as flared gases, dust particles, silt, debris and leaching of the storage vessel had a negative impact on the harvested rainwater quality. Deposition of heavy metals fragments in the form of dust and flared gases on roof tops is likely the reason for the increase of metal burden, but the effect will be minimal, if the roof tops are properly washed by heavy rain before harvesting rainwater for domestic use. Comparing the obtained results for direct harvested rainwater from the sky (control) with the values of roofs run-offs harvested rainwater and rainwater stored in galvanized iron tanks, it was observed that, there was significant difference in the results obtained. This was seen in corrugated iron roof and in stored rainwater in galvanized iron for one year and above which was due to flared gases, vehicular emissions, atmospheric and anthropogenic pollutions found in the environment because of its industrial activities.

The result obtained in this study in the urban and rural areas of Rivers State for direct rainwater from the sky (control) which showed no detection of Pb and Cr in the analyzed samples were not in line with the earlier findings by Nicholas and Ukoha [1] who reported high level of Cr (0.79±0.13 mg/L, urban area) and Pb (0.02±0.01-0.09±0.11 mg/L) in direct rainwater from the sky in Imo state, Nigeria and Nanji et al. also reported high concentrations of chromium in the road run-offs harvested rainwater in Nsukka, Enugu State, Nigeria [3]. Okudo et al. also reported high values of Pb (Emene: 0.58 ± 0.11and Iva Valley: 0.48± 0.04) and Cr (Emene: 0.10 ± 0.02) in the analysed rainwater samples from Enugu State, Nigeria [2] which were not in supports with the present values obtained in this study for Cr and Pb in direct rainwater from the sky. This research work gave mean values of Fe ranging from 0.12-0.13 mg/L for Cameroun zinc roof, 0.12-0.15 mg/L for corrugated iron roof, 0.10-0.11 mg/L for stone-coated tiles roof in both areas while the highest level of Fe ranging from 0.18-0.22 mg/L was found in the stored harvested rainwater in galvanized iron tank for one year and above which were in accordance with the findings of Nicholas and Ukoha who also reported higher values of Fe (0.16±0.17 mg/L, Cameroun zinc) and 0.21±0.13 mg/L (urban) for corrugated iron roof in Imo State, Nigeria [1] and that of Emerole et al. who also reported higher values of heavy metals in direct rainwater and roof run-offs harvested rainwater (mg/L) of Fe (2.12±1.17), Al (1.70±1.83) and Pb (0.44±0.36) from Owerri, Imo State, Nigeria [42] which were above the set standards of 0.30 mg/L, 0.01 mg/L, 0.05 mg/L and 0.1-0.2 mg/L for Fe, Pb, Cr and Al respectively for drinking water by NSDWQ, WHO, NAFDAC and USEPA [29-32].

The corrosiveness/leaching of the roofing metals to dissolved metals into the harvested rainwater quality were as follows: Al, Zn, Fe and Cr (metal roofing > stone-coated tiles roof > asbestos roof), Cr and Pb (asbestos roof > stone-coated tiles roof)

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and particulate metals is as follows; Cr and Pb were high in corrugated and asbestos roofs than other roofing sheet in both areas. For storage vessel, dissolved metals were as follows; Fe, Al, Zn, Cr and Pb (Galvanized iron tank). The mean heavy metals values of harvested rainwater obtained were within the limits in Umuazu village, Igbo-Etche, Etche L.G.A (rural area) and some parameters in the urban area except for harvested rainwater stored in galvanized iron tanks for one year and above, Cameroun zinc roof, corrugated iron roof, asbestos roof in Nwaja, Trans Amadi Industrial Layout, Port Harcourt L.G.A (urban area) for Pb, Cr and Al which were above the permissible limits for drinking water [29-33].

E. coli was not detected in any of the analyzed samples as shown in Tables 4-5. This is an indication of likely less contamination from wind-blown dirt, air pollution, dead leaves falling from trees, and faecal origin, therefore, it reflects the potential of the rainwater not to be harbouring any pathogenic organisms. This result is in accord with earlier findings of no detection of *E. coli* in harvested rainwater from Owerri, Imo State, Nigeria by Nicholas and Ukoha [1]; Emerole et al.[42] but not in line with the findings of Nanji et al. who detected *E. coli* in the harvested rainwater from Ikenga Road (2 cfu/mL), Enugu road (1 cfu/mL) and Ikpa/Orba road (6 cfu/mL) in Nsukka, Enugu State in road runof harvested rainwater [3] and that of Achadu *et al.* who also reported found *E. coli* in harvested rainwater in Wukari, Taraba State, Nigeria [43].

The Water Quality Index (WQI) value ratings set standards by ICMR, USEPA, WHO, NSDWQ and NAFDAC [27, 29-32] which states that, the water quality within the range 0-25 are classified as excellent water quality, 26-50 as good water quality, 51-75 as poor water quality, 76-100 as very poor water quality and water quality within the range >100 as unfit for drinking. In this study, it was observed that, direct rainwater from the sky (control) in the urban and rural areas, Cameroun zinc and stone-coated tiles roofs harvested rainwater in the rural areas were rated excellent water quality. Corrugated iron roofs harvested rainwater were rated poor water quality in both areas while Cameroun zinc roof harvested rainwater (urban) and stored rainwater in galvanized iron for one year and above in both areas were rated unfit for drinking water quality. Asbestos roof harvested rainwater in the urban area was rated poor water quality while that of the rural area was rated very poor water quality as shown in Table 5 above.

CONCLUSION

Based on the results obtained in this study, *E. coli* was not detected in any of the analyzed harvested rainwater samples. The physicochemical characteristics analyzed were all within the set standards for drinking water quality with an exception to a few which were above the limits and Pb, Cr, Zn, Fe and Al concentrations in this study gave mean values which were below,

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within and above the permissible limits by WHO, USEPA, NAFDAC and NSDWQ in both areas of Rivers State. It was concluded that, the atmospheric pollutants from the sources of particulate matter due to natural and anthropogenic factors resulting from the industrial activity of the areas, and the components used in the manufacturing of the roof type and storage vessel had a negative effect on the harvested rainwater quality from roofs run-offs and storage vessel and also on the direct rainwater from the sky (control); hence, harvested rainwater should be treated before being used for domestic, industrial and potable usages.

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