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Qualitative Analysis of the Effect of Heavy Metals, Coliform level and Industrial Activity on Rooftop and Non-Roof Harvested Rainwater in Delta State, Nigeria

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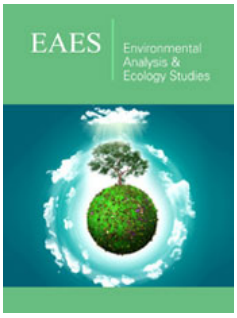

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Abstract

Contaminations from natural and anthropogenic activities have really affected the rainwater quality through the effect of high industrial activities and the leaching from roof type components. This led to this study which determined the physico-chemical properties, coliform level, heavy metals of the rainwater/digested roof types. Rainwater was harvested from non-roof (control) and from various roof types in Okpanam Road, Asaba and Warri Refinery Depot, Uvwie, Delta State, Nigeria between April-July, 2018. Heavy metals were analyzed using the Flame Atomic Absorption Spectrophotometer and some other parameters were assessed using standard methods. Descriptive and two-way ANOVA statistical analysis was used for the obtained values. Results were compared with the water quality standards of WHO, USEPA and NSDWQ. The Water Quality Index (WQI) of the rainwater samples was evaluated. The values obtained gave mean values ranging from 6.40-8.80 for pH, *E.coli* (not detected), heavy metals (mg/L) gave 0.00-0.11 for Fe, Pb(0.00-0.79), Cr (0.00-0.06), Zn (0.01-0.10), Al (0.00-0.81) and metal concentrations (mg/kg) of digested roofs gave 0.00-31.84 (Pb), 0.00-43.45 (Al), 39.22-63.78 (Fe), 0.59-7.04 (Zn) and 1.87-6.20 (Cr). The results showed that all the parameters analyzed were below, within and above the water quality standard and the values were significantly different at ($P<0.05$). The WQI ranged from 0.05-5,975.77 which rated excellent to unfit for drinking and other domestic purposes. It was concluded that harvested rainwater should be treated before drinking and some helpful recommendations were proposed in this study.

Keywords: Harvested rainwater; Leaching; Toxicity; Atmospheric pollution; Water quality index

Introduction

The world at large is facing water scarcity due to various challenges resulting from increased urbanization and different industrial activities, thus making humans depend on rainwater for their survival, especially those in the rural areas where conventional water supply systems is not available [1-7]. Rainwater is contaminated or polluted by these substances, namely, sulphur dioxide, nitrogen oxides, particulate matter, and heavy metals [8-11] which come from air quality, industrial and traffic emissions and fuel combustion, which can affect the rainwater quality by making it to become toxic [12-16]. Toxicity of the rainwater quality is usually caused by the acidity of the rain [1,17,18]. If acid rain falls depending on the atmospheric pollution of the area, the material used in manufacturing the various roof types can have a negative influence on the quality of the harvested rainwater during catchment [1,19-21]. Catchment or harvesting period of rainwater can lead to the deteriorating and contamination of the water quality [22-24]. Water quality is related to the general environmental status of any area depending on the industrial activities of such an area, as presented by several researchers, which led to water quality index ratings [25-

27]. Water Quality Index (WQI) ratings as per Weight Arithmetic Water Quality Index method gave values from 0-25 for excellent water quality and are graded as "A" and their possible usages are for drinking, irrigation and industrial; 26-50 for good water quality (B) and it is suitable for domestic, irrigation and industrial; 50-75 for good water quality (C) and it can be used for irrigation and industrial; 76-100 for very poor water quality (D) and can be used for irrigation; Above 100 for unfit for drinking water quality (E) and it is for restricted use for irrigation and proper treatment is required before use [28,29]. Various findings by various researchers have reported that atmospheric pollution can affect the rainwater quality by numerous contaminants that harbour in the air which are from natural occurrences, industries, automobiles as well as the presence of dirt and debris found on the rooftops [30-39]. Since industrial activity can affect the coating materials of the roof to become potent and leach or corrode into the rainwater quality, therefore, there is a need for investigation and assessment, to check if the rainwater quality is in line with the set limits for drinking water quality by NSDWQ, WHO and USEPA [40-42].

Materials & Methods

Standard procedures were used to conduct the analyses to ensure the reliability and accuracy of the results according to the standard methods by AOAC [43]. All the apparatus and sample containers used for the analyses was decontaminated with 10% HNO_3 solution and rinsed thoroughly several times with distilled water immediately before use according to the standard methods by AOAC, John-De-Zuane and APHA [43-45].

Sampling areas and their industrial activities

Delta State is the major oil-producing state in Nigeria as a whole. In this research, the study areas were Okpanam Road, Asaba local government and Ekpan Community, Uvwie local government area, and it is where Warri Refinery Depot is situated in Delta State, Nigeria. Okpanam Road, Asaba local government area is populated by offices, hotels and other shopping malls and Ekpan Community, Uvwie local government area is where Warri Refinery Depot is situated, Warri being a great socio-economic city in Delta State and has drawn the attention of people from all walks of life for their various purposes. The industrial activities of these areas can produce enormous effluent bearing acidic gases into the atmosphere, causing pollution (Figure 1).

Figure 1: Sampling map and point of collection.

Sample collection

Rainwater samples were collected between the months of April-July, 2018 from the urban and rural areas of Delta State, Nigeria. Non-roof rainwater from the sky (control) was harvested randomly by placing a sterilized rainwater collector 1-2 meters high above the ground. This technique was used in order to prevent possible contaminations from the ground. The rainwater collector was covered with a sieve having 0.45 micron in diameter in the various sampling point during rainfall out in the open, this was done weekly without any shield on the sky for three weeks to order to constitute triplicate. Once the first rain roofs run-off was flushed out which cleansed the roofs, the rainwater was harvested from the different roof type run-offs on a weekly for three weeks in order to get triplicate.

Analytical Methodology

Analytical reagent grade chemicals were used from Sigma-Aldrich in the USA

Analysis of the collected samples

The collected samples were named as RRWDAU/R-RRWDFU/R and then divided into different portions. The collected samples were later transferred into various sample bottles which were accurately labelled and then firmly tightened and covered to avoid any form of contaminations. Conc. HNO_3 (3.0cm^3) were added to the collected samples for preservation. These samples were immediately kept in the refrigerator at 4 °C after the determination of Total Dissolved Solid (TDS), Electrical Conductivity (EC), temperature, pH at the collection point. Flame Atomic Absorption Spectrophotometer (Flame-AAS) was used for the analysis of heavy metals as described in the standard method. All other parameters analysed were done in accordance to standard methods [43-45].

Control and quality assurance

Standard solution of 1000ppm by Sigma-Aldrich, USA, was used for the spiking and calibration standards. The blank samples and standard solutions were analysed to ensure the results accuracy and precision [46].

Determination of chemical composition of roof type

The determination of the heavy metals composition in the various roof types was done according to standard method by AOAC and APHA [43,45].

Coliform level assessment

Escherichia Coli (E. coli) were determined in the rainwater samples according to the standard method by APHA and AOAC [43,45].

Water Quality Index (WQI)

The WQI ratings was calculated using weighted arithmetic method which categorise the water quality according to the degree of purity using the most frequently measured water quality variables by Nicholas & Ukoha [5]; Noori [47]; Alum & Okoye [48] and it is used by several scientists [49-52].

The calculation of WQI was made by using the following Equation (1) according to Nicholas & Ukoha [5]:

$$WQI = \frac{\sum qn \times Wn}{\sum Wn} \quad (1)$$

$$Wn = \frac{1}{(sn)} \quad (2)$$

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

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

Statistical evaluation

Values generated in this study were calculated using Microsoft office excel 2010 for mean and Standard Deviation (SD). Software Statistical Package for the Social Sciences (SPSS), version 20.0 was used for the analysis of obtained results using descriptive and two-way ANOVA statistical analysis.

Results & Discussion

Different physico-chemical properties (pH, temperature, TDS, TSS, electrical conductivity, colour, turbidity, phosphate, sulphate and nitrate), heavy metals (Fe, Zn, Cr, Pb and Al) and coliform level (*E. coli*) were examined and the obtained results are shown in Table 1-3 & Figures 2-8 and the WQI ratings in Table 4.

Table 1: Heavy metals, Physico-chemical properties and coliform level of roofs run-off and non-roofs harvested rainwater in Delta State, Nigeria.

S/N	Parameters	Non-Roof Rainwater from the Sky (control)		Harvested Rainwater from Stone-Coated Tiles Roof		Harvested Rainwater from Cameroun Zinc Roof		WHO, 2011	USEPA, 2012	NSDWQ, 2015
		RRWDAU	RRWDAR	RRWDBU	RRWDBR	RRWDCU	RRWDCR			
1	pH	7.30±0.40	6.60±0.30	7.90±0.21	7.60±0.20	6.80±0.10	7.40±0.30	6.5-8.5	6.5-8.5	6.5-8.5
2	Temp., °C	26.00±2.00	24.70±1.53	25.00±1.00	25.00±1.00	25.00±2.00	26.00±2.00	30	Ambient	Ambient
3	TDS, mg/L	15.30±5.03	27.60±3.51	26.70±8.51	45.00±6.25	16.00±2.00	35.30±5.03	250	500	500
4	TSS, mg/L	22.70±4.04	36.00±4.60	35.30±5.03	49.00±6.56	17.40±3.05	40.70±4.04	250	500	500
5	Electrical Conductivity, µS/cm	35.70±8.51	62.00±4.58	55.70±17.56	83.70±23.59	19.30±4.16	57.00±9.54	1200	1000	1000
6	Colour, TCU	3.67±0.29	5.38±0.13	7.75±0.18	9.76±0.12	4.88±0.13	8.91±0.14	5	15	15
7	Turbidity, NTU	3.86±0.25	4.23±0.14	6.58±0.22	8.45±0.35	4.94±0.28	6.72±0.38	5	5	5
8	Phosphate, mg/L	5.72±0.29	8.59±0.09	3.37±0.09	6.95±0.09	5.77±0.48	6.83±0.21	5	5	5
9	Sulphate, mg/L	0.11±0.03	0.13±0.02	0.13±0.01	0.17±0.01	0.13±0.02	0.15±0.02	250	250	250
10	Nitrate, mg/L	0.05±0.01	0.07±0.00	0.04±0.00	0.06±0.00	0.06±0.00	0.07±0.00	50	50	50
11	*E. coli* Count, cfu/mL	ND	ND	ND	ND	ND	ND	0	0	0
12	Lead, mg/L	ND	0.08±0.06	ND	ND	ND	ND	0.01	0.01	0.01
13	Chromium, mg/L	ND	0.03±0.02	ND	ND	ND	ND	0.05	0.05	0.05

14	Iron, mg/L	ND	ND	0.01±0.01	0.06±0.02	0.04±0.00	0.11±0.01	0.3	0.3	0.3
15	Zinc, mg/L	ND	ND	0.10±0.01	0.10±0.03	0.04±0.03	0.01±0.00	3.0-5.0	3	3
16	Aluminium, mg/L	ND	ND	ND	0.09±0.04	ND	0.06±0.01	0.1-0.2	0.2	0.2

RRWDDU, RRWDEU, RRWDFU-Okpanam Road, Asaba L.G.A; RRWDDR, RRWDER, RRWDFR -Warri Refinery Depot Area, Ekpan Community, Uvwie L.G.A; ND - No Detection

Table 2: Heavy metals, Physico-chemical properties and coliform level of rooftop run-offs and non-roof harvested rainwater in Delta State,

S/N	Parameters	Harvested Rainwater from Long Span Aluminium Roof		Harvested Rainwater from Corrugated Iron Roof		Harvested Rainwater from Asbestos Roof		WHO, 2011	USEPA, 2012	NSDWQ, 2015
		RRWDDU	RRWDDR	RRWDEU	RRWDER	RRWDFU	RRWDFR			
1	pH	6.40±0.40	8.03±0.80	7.30±0.20	8.23±0.15	8.30±0.20	8.80±0.70	6.5-8.5	6.5-8.5	6.5-8.5
2	Temp., °C	26.00±1.00	25.00±1.00	25.70±1.53	25.80±1.52	27.00±1.00	26.70±1.53	30	Ambient	Ambient
3	TDS, mg/L	25.30±3.21	11.70±2.52	17.30±3.06	15.00±3.61	25.30±3.06	35.30±5.69	250	500	500
4	TSS, mg/L	29.30±3.06	18.00±2.00	24.70±2.52	19.70±4.51	30.30±4.51	42.00±11.14	250	500	500
5	Electrical Conductivity, µS/cm	52.70±4.04	28.00±3.61	25.70±6.03	28.00±3.61	33.30±5.69	147.60±44.52	1200	1000	1000
6	Colour, TCU	4.89±0.16	7.27±0.20	4.85±0.23	11.39±0.25	9.69±0.12	13.79±0.26	5	15	15
7	Turbidity, NTU	4.32±0.17	5.40±0.23	3.77±0.37	6.77±0.39	4.89±0.22	7.52±0.55	5	5	5
8	Phosphate, mg/L	6.67±0.30	8.14±0.09	5.41±0.22	8.00±0.12	3.38±0.13	6.74±0.26	5	5	5
9	Sulphate, mg/L	0.10±0.02	0.12±0.03	0.12±0.02	0.13±0.04	0.11±0.01	0.16±0.02	250	250	250
10	Nitrate, mg/L	0.05±0.01	0.06±0.00	0.13±0.03	0.19±0.01	0.05±0.01	0.07±0.00	50	50	50
11	*E. coli* Count, cfu/mL	ND	ND	ND	ND	ND	ND	0	0	0
12	Lead, mg/L	ND	ND	ND	ND	0.31±0.08	0.79±0.49	0.01	0.01	0.01
13	Chromium, mg/L	ND	ND	ND	ND	0.06±0.01	0.05±0.02	0.05	0.05	0.05
14	Iron, mg/L	0.07±0.03	0.06±0.01	0.06±0.05	0.07±0.04	ND	0.07±0.09	0.3	0.3	0.3
15	Zinc, mg/L	0.03±0.01	0.04±0.01	0.10±0.04	0.10±0.04	0.01±0.01	0.03±0.01	3.0-5.0	3	3

RRWDDU, RRWDEU, RRWDFU-Okpanam Road, Asaba L.G.A; RRWDDR, RRWDER, RRWDFR -Warri Refinery Depot Area, Ekpan Community, Uvwie L.G.A; ND - No Detection.

Table 3: Metals concentrations of the digested roof types.

S/N	Samples	Concentration (mg/kg)				
		Pb	Al	Fe	Zn	Cr
1	Long span aluminium roof	0.32	43.45	39.22	0.59	1.66
2	Cameroon zinc roof	2.3	Nil	63.78	5.94	1.02
3	Corrugated iron roof	31.84	4.34	63.57	7.04	6.09
4	Asbestos roof	Nil	2.9	51.64	0.78	1.87
5	Stone-coated tiles roof	Nil	7.93	63.56	5.9	6.2

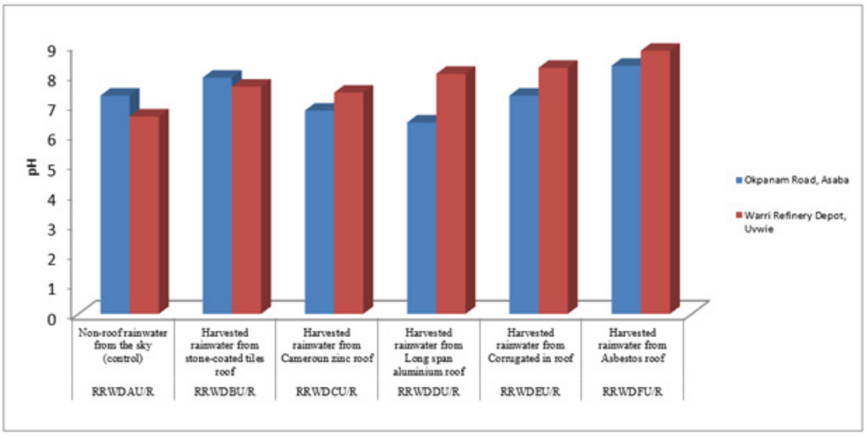

Figure 2: pH values of analyzed samples in Delta State, Nigeria.

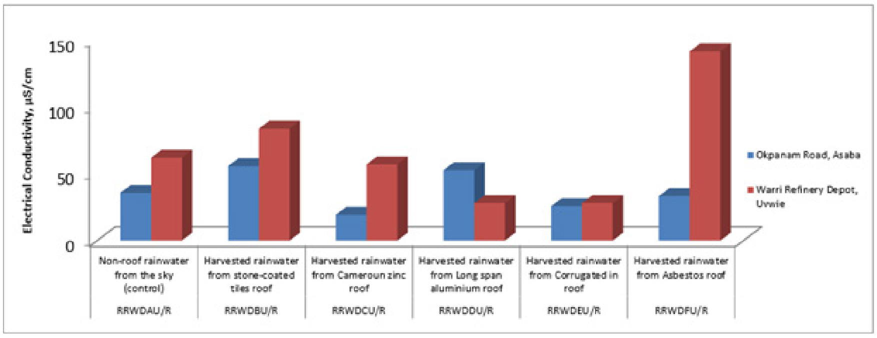

Figure 3: Electrical Conductivity (µ□/cm) values of analyzed samples in Delta State, Nigeria.

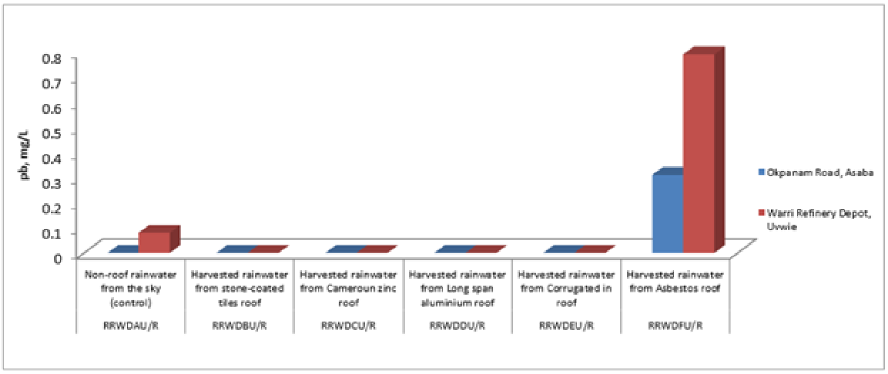

Figure 4: Pb (mg/L) values of analyzed samples in Delta State, Nigeria.

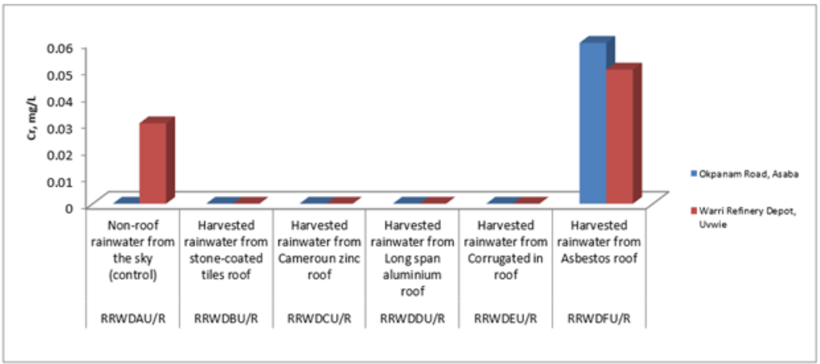

Figure 5: Cr (mg/L) values of analyzed samples in Delta State, Nigeria.

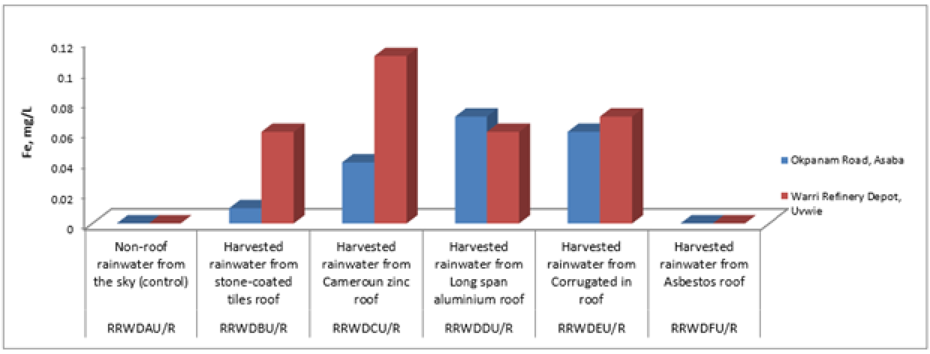

Figure 6: Fe (mg/L) values of analyzed samples in Delta State, Nigeria.

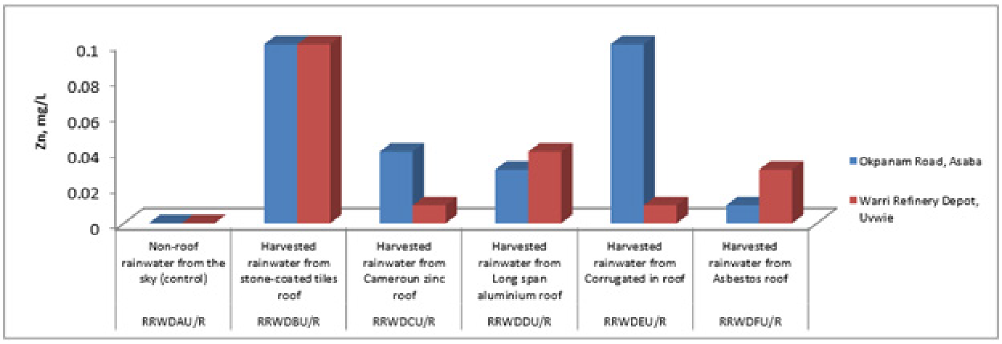

Figure 7: Zn (mg/L) values of analyzed samples in Delta State, Nigeria.

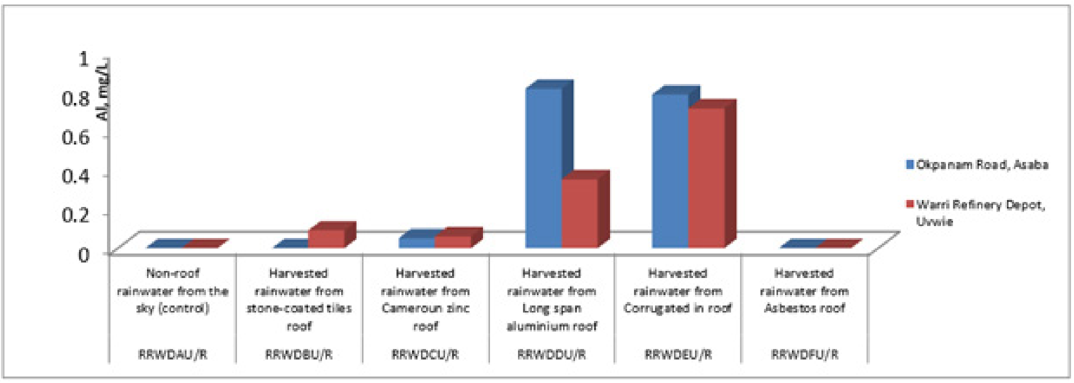

Figure 8: Al (mg/L) values of analyzed samples in Delta State, Nigeria.

Table 4: Water Quality Indices (WQI) of rooftop run-offs and non-roof rainwater (control) in Delta State, Nigeria.

Sample Code	Areas/Field	Sample Source of Collection	Water Quality Index (WQI)	Quality Rating
RRWDAU	Okpanam Road, Asaba L.G.A	Non-roof rainwater from the sky (control)	0.05	Excellent
RRWDAR	Warri Refinery Depot, Uvwie L.G.A	Non-roof rainwater from the sky (control)	612.03	Unfit for drinking
RRWDBU	Okpanam Road, Asaba L.G.A	Stone-coated tiles roof	0.31	Excellent
RRWDBR	Warri Refinery Depot, Uvwie L.G.A	Stone-coated tiles roof	7.41	Excellent
RRWDCU	Okpanam Road, Asaba L.G.A	Cameroon Zinc roof	7.8	Excellent
RRWDCR	Warri Refinery Depot, Uvwie L.G.A	Cameroon Zinc roof	4.82	Excellent
RRWDDU	Okpanam Road, Asaba L.G.A	Long span aluminium roof	60.81	Poor
RRWDDR	Warri Refinery Depot, Uvwie L.G.A	Long span aluminium roof	30.54	Good

RRWDEU	Okpanam Road, Asaba L.G.A	Corrugated iron roof	59.34	Poor
RRWDER	Warri Refinery Depot, Uvwie L.G.A	Corrugated iron roof	53.81	Poor
RRWDFU	Okpanam Road, Asaba L.G.A	Asbestos roof	46.38	Good
RRWDFR	Warri Refinery Depot, Uvwie L.G.A	Asbestos roof	5,975.77	Unfit for drinking

Physicochemical properties

pH: pH levels of non-roof harvested rainwater in Okpanam Road, Asaba local government area and Warri Refinery Depot, Ekpan Community, Uvwie L.G.A of Delta State were 7.30±0.40 (slight alkalinity) and 6.60±0.30 (slight acidity) respectively (Table 1 & 2) and Figure 2 above. Roofs run-offs harvested rainwater from Cameroon zinc and long span aluminium roofs had pH mean values ranging from 6.40±0.40-6.80±0.10 (slightly acidic). However, corrugated iron roof, asbestos roof and stone-coated tiles roof of 7.30±0.20-8.30±0.20 (slightly alkalinity) in Okpanam Road, Asaba while Warri Refinery Depot, Ekpan Community, Uvwie) had pH values of 7.40±0.30-8.80±0.70 for Cameroon zinc, long span aluminium, corrugated iron, asbestos and stone-coated tiles roofs which showed alkalinity as shown in Table 1-2 & Figure 2 above. The pH values of the non-roof rainwater (control) in Warri Refinery Depot, Ekpan Community, Uvwie and in Okpanam Road, Asaba local government area when compared with the air quality assessment values, it showed that, there was significant difference ($P<0.05$) in the results obtained as shown in the asbestos, corrugated iron, stone-coated tiles roofs in both areas and Cameroon zinc roof, long span aluminium roof indicating increase and decrease influence of flared gases, debris, silt and vehicular emissions in the atmosphere. The mean concentration of pH in rainwater samples from roof run-offs as recorded by the earlier studies reported 6.50±0.10-6.60±0.20, 6.00±0.30-6.50±0.20, 6.2-7.6 for rainwater samples in Rivers State and Imo State respectively [1,5,20]. Findings by Moses et al also reported harvested rainwater to be slightly acidic in Uyo, Akwa Ibom State [21] and the study of Ojo in Akure, Ondo State [19] which showed slight acidity and these results were not in total supports with the values obtained in this study. All the values for pH concentrations were within the set standard except for asbestos and corrugated iron roof (rural) were above the limits of 6.5-8.5 for drinking water by NSDWQ, WHO and USEPA [40-42] as shown in Tables 1 & 2 above.

Electrical conductivity: Electrical conductivity levels gave mean values of 35.70±8.51 and 62.00±4.58µS/cm respectively for non-roof rainwater (control) in both areas of Delta State. Roofs run-offs harvested rainwater had electrical conductivity mean values ranging from 19.30±4.16-55.70±17.56µS/cm in Okpanam Road, Asaba L.G.A and 28.00±3.61-147.60±44.52µS/cm in Warri Refinery Depot, Ekpan Community, Uvwie local government area which were of low values as shown in Table 1 & 2 and Figure 3 above. The roofs run-offs when compared with the non-roof harvested rainwater, it was observed that, there was significant difference ($p<0.05$) in the obtained results in both areas and was seen in the asbestos roof which had the highest conductivity in Warri Refinery Depot, Ekpan Community, Uvwie and stone-coated tiles roof both areas of the state. These results were also in support with the findings by Nicholas & Ukoha [5], Ojo [19]; Emerole et al. [20]; Moses et al. [21], Waziri et al. [37] who reported a low degree of electrical conductivity in harvested rainwater samples from Akure, Ondo State; Owerri, Imo State; Maiduguri and Uyo, Akwa Ibom State respectively. The values obtained were all below the permissible limits of 1000-1200µS/cm for drinking water by NSDWQ, WHO and USEPA [40-42] as shown in Table 1 & 2 above.

Nitrate: Nitrate levels of non-roof rainwater (control) gave mean values of 0.05±0.01 and 0.07±0.00mg/L respectively in the urban and rural areas of Delta State. Roofs run-offs harvested rainwater from Cameroon zinc, long span aluminium, corrugated iron, asbestos and stone-coated tiles had nitrate mean values ranging from 0.04±0.00-0.13±0.03mg/L in the urban area and 0.06-0.19mg/L in the rural area as shown in Table 1 & 2. Comparing the results of the roofs run-offs with the non-roof harvested rainwater (control), it was observed that there was little influence on the rainwater quality mainly from atmospheric pollution and exhaust gas from vehicles that could be transferred into the harvested rainwater from the rooftop run-offs which had lesser effect on the sampled rainwater quality. The values obtained were below the permissible limits of 15-50mg/L for drinking water by NSDWQ, WHO and USEPA [40-42].

Sulphate: Mean sulphate concentrations of non-roof rainwater (control) in both areas of Delta State were 0.11±0.03 and 0.13±0.02mg/L respectively. Roofs run-offs harvested rainwater from long span aluminium, stone-coated tiles, asbestos, Cameroon zinc and corrugated iron roofs had mean values ranging from 0.10±0.02-0.13±0.04mg/L in the urban area and 0.12-0.64mg/L in the rural area as shown in Table 1 & 2. Comparing the results of the roofs run-offs with the non-roof harvested rainwater (control), it shows that, there was significant difference ($p<0.05$) in the results obtained was due to particulate matters produced during gas flaring and vehicular emissions that could contribute deposition present in the harvested rainwater. The sulphate values of harvested rainwater obtained were within and below the permissible limits of 100-250mg/L for drinking water by NSDWQ [40], WHO [41] & USEPA [42] as shown in Table 1& 2 above.

Coliform level: *E. coli* was not detected in any of the analysed samples in both areas of Delta State as shown in Table 1 & 2 above. The coliform level of the harvested rainwater in this study was within the permissible limits of 0cfu/mL for drinking water by NSDWQ [40], WHO [41] & USEPA [42].

Heavy metals: Heavy metals concentrations for non-roof rainwater indicate the absence of Pb and Cr in Okpanam Road, Asaba local government area and Fe, Zn and Al in the Okpanam

Road, Asaba local government area (urban) whereas Cr (0.03mg/L) and 0.08mg/L for Pb were found in Warri Refinery Depot, Ekpan Community, Uvwie L.G.A samples of the rural area in the non-roof harvested rainwater (control) as shown in Table 1-2 & Figure 4-8. Earlier findings showed that, there was no detection of Pb, Cr and Al in the analyzed direct harvested rainwater from the sky (control) while Fe (0.01±0.00-0.02±0.01 mg/L) and Zn (0.01±0.00-0.02±0.00mg/L) in the urban and rural areas of Rivers State respectively [5] and these results were not in total supports with the values obtained in the harvested rainwater in this study. Roofs run-offs of long span aluminium, corrugated iron, stone-coated tiles and Cameroon zinc roofs had no detection of Pb and Cr in the harvested rainwater. Asbestos roof had Pb values of 0.79 (urban) and 0.31(Warri) while Cr had 0.06 (urban) and 0.05 (Warri). Long span aluminium roof had highest mean values of 0.35-0.81mg/L in both areas for Al and corrugated iron roof also had high mean values of 0.71-0.78mg/L in the urban and rural areas, Cameroon zinc had 0.05-0.06mg/L for Al in both areas and stone-coated tiles roof had 0.09mg/L for Al in the rural area as shown in as shown in Table 1-2 & Figure 4-8. There was no detection of Al in asbestos roofs in the urban and rural areas as shown in Tables 4.41-4.46. Comparing the roof run-offs harvested rainwater with the metal concentrations (mg/kg) of digested roofs gave 0.00-31.84 (Pb), 0.00-43.45 (Al), 39.22-63.78 (Fe), 0.59-7.04 (Zn) and 1.87-6.20 (Cr) as shown in Table 3, there was an indication of leaching of the heavy metals from the roof types into the rainwater quality. Findings reported Okudo et al. gave higher concentrations of Pb (Emene: 0.58±0.11and Iva Valley: 0.48±0.04) and Cr (Emene: 0.10±0.02) in rainwater samples from Enugu State [6]. Nanji et al. also gave higher values of chromium in the road run-offs rainwater in Nsukka, Enugu State [7]. Nicholas & Ukoha [5] also reported higher values of heavy metals in rainwater samples in Rivers and Imo State, Nigeria. Emerole et al. also reported 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, which were of higher concentrations from Owerri, Imo State [20] and were in supports with the values in this study. The values obtained were within the set limits for drinking water in some parameters in both areas except for non-roof rainwater (control) for Pb in Warri and in long span aluminium roof and corrugated iron roof in the urban and areas for Al, asbestos roof (both areas) for Pb and Cr for Okpanam Road, Asaba local government area which were above the permissible limits for drinking water of 0.30mg/L, 0.01mg/L, 0.05mg/L and 0.1-0.2mg/L for Fe, Pb, Cr and Al respectively for drinking water by NSDWQ, WHO and USEPA [40-42].

Water Quality Index (WQI) ratings

The results of the Water Quality Index (WQI) ratings, when compared with the NSDWQ [40], WHO [41] & ICMR [29] set standards gave the following; Non-roof harvested rainwater (control, Okpanam Road, Asaba local government area), Cameroon zinc roof (Warri Refinery Depot) and (Okpanam Road, Asaba) and stone-coated tile roof (Warri Refinery Depot) and (Okpanam Road, Asaba local government area) were classified as excellent water quality, and it is suitable for drinking, irrigation and industrial usages. Harvested rainwater from long span aluminium roof (Okpanam Road, Asaba) was rated good water quality, and it is fit for domestic, irrigation and industrial usages and not potable usages. Rainwater from a long span aluminium roof (Warri Refinery Depot, Ekpan Community, Uvwie L.G.A) and corrugated iron roof (Warri Refinery Depot) and (Okpanam Road, Asaba) and it is suitable for domestic, irrigation and industrial usage. Non-roof harvested rainwater (control, Warri Refinery Depot, Warri) and asbestos roof in both areas were rated unfit for drinking, and it is restricted to use for irrigation purposes as shown in Table 4 above.

Conclusion/Recommendation

In this study, the concentrations of some heavy metals in the roof run-offs and non-roof harvested rainwater were seen to be within and above the set limits by NDSWQ, WHO and USEPA due to the possibility of the industrial activities of these areas affecting the roof type component thus causing leaching. It was concluded that, rainwater should be treated before drinking because, there is a tendency for industrial activity, traffic emissions and component used in producing the roof types to have an effect on the rainwater quality. Governments and other stakeholders should create awareness for the people on the need to treat and drink clean water. Monitoring and evaluation of the environment should be done regularly by the relevant government agencies.

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