ChemSearch Journal 12(1): 21 – 26, June, 2021
Publication of Chemical Society of Nigeria, Kano Chapter

Received: 26/02/2021 Accepted: 03/04/2021
http://www.ajol.info/index.php/csj

Evaluating the Effects of Roofing Materials on Physicochemical Properties of Harvested Rainwater in Warri, Delta State, Nigeria

[1]Itodo, A.U., [1]Wuana, R.A. [2]Erhabor,O. D., [1*]Obruche, E.K. and [1]Agbendeh, Z. M.
[1]Department of Chemistry, University of Agriculture, Makurdi, Nigeria.
[2]Department of Chemistry, Federal College of Education, Anambra
***Correspondence Email:**kenkennedy767@gmail.com

ABSTRACT

This study was aimed at investigating the effects of roofing materials on water quality, in Warri district. Random sampling technique was used to collect forty two (42) rainwater samples from different roofing materials made from (asbestos, zinc, aluminium and thatch roof) including the control (rainwater collected directly from the sky) in Warri refinery and petrochemical company(WRPC) and military formation area(MLF). The harvested rainwater samples were analyzed using Atomic adsorption spectrophotometer, AAS, TDS meter, heating plates, electrical conductivity meter, retort stand, pH meter, Turbidity meter, Conductivity meter etc. Results obtained revealed that most of physiochemical parameters of rainwater samples analyzed were generally below the WHO threshold. The results also indicate the presence of Pb, Fe and Cr, in the harvested rainwater samples, of which Pb that is a poisonous metal is above the maximum WHO allowable limit of 0.3 mg/L. From the results, scientifically, it is advisable that the first flush from all the rooftops cannot be used because of high levels of dirt, rust etc. Fifth flush and above can be used for domestic chores like washing, mopping, irrigation, cleaning, laundry etc. without further purification, but should be subjected to simple water treatment like boiling and chlorination before it can be consumed.

Keywords: Harvested Rainwater, MLF, Physicochemical Analysis, Roofing Sheet, WRPC

INTRODUCTION

The issue of rainwater harvesting is now a widely used technique for the provision and supply ofboth portable and non-portable supply of water especially in developing countries where thepotable water supplies are insufficient to meet the growing needs of the society due to rapidindustrialization and development as well as population growth (Olaoye and Olaniyan, 2012). The interest in rainwater harvesting is growing in the district, and the use of rainwater haschanged from its function as mere water augmentation to ultimate water source for domesticactivities (UNICEF, 2008).

In many areas of the world today, it can be the only source of water either for the household or more commonly for a supplementary supply to ease the burden of water collection from other sources (Vikaskumar*et al.*, 2007). Of all the rainwater-harvesting methods, the rainwater runoff from household roofs is the most common form of rainwater harvesting. This is because the inhabitants use existing roofs of their houses thereby no additional costs are incurred and the amount and quality of rainwater collected depends on the area and type of roofing material. Despite having some clear advantages over other sources, rainwater use has frequently been rejected due to its quality. Several types of chemical contaminants have been found in harvested rainwater including heavy metals(Lee *et al.*, 2010). The World Health Organization (WHO) estimates 1.8 million deaths each year due to lack of access to safe water, sanitation and hygiene. Microorganisms also are present in roof runoff, and fecal indicator bacteria and potentially pathogenic bacteria and protozoa have been detected *(*Ahmed *et al.*, 2008). However, Chang *et al.*(2004) reported that roofs can be a serious source of water pollution as well to human health This research was aimed at evaluating the effects of roofing materials on physicochemical properties of harvested rainwater in Warri, Delta State, Nigeria. To evaluate the physicochemical parameters of rainwater samples harvested from the two different settlements (WRPC and MLF) and in contact with different roofing materials. Several international studies have been performed to study the quality of harvested rainwater. However, some of these include studies cited by (Aucour*et al.*,2003; Abdul-Hameed *et al.*,2008).

MATERIALS AND METHODS

Description of study location and sampling site

The studied areas (Figure 1) are located in Warri axis of Delta state, Nigeria. The region lies within the longitudes 3°E-9°E and latitudes 4° 30’N-5° 21’N of southern oil rich Niger Delta region (Kaizer and Osakwe, 2010). Delta state is known to be characterized by frequent annual rainfall ranging from 3000 to 4500 mm. The high rainfall, humidity and river discharge during the rainy season combined with the low, flat terrain and poorly drained soils result in extensive flooding (Hoff *et al,* 2010). Warri being a great socio-economic city in the Delta state has drawn the attention of many researchers in recent decades for several reasons (Ahmed *et al.,* 2008). The locations selected for these analyses were Warri refining and petrochemical company (WRPC) and Military formation (MLF), known as Effurun.

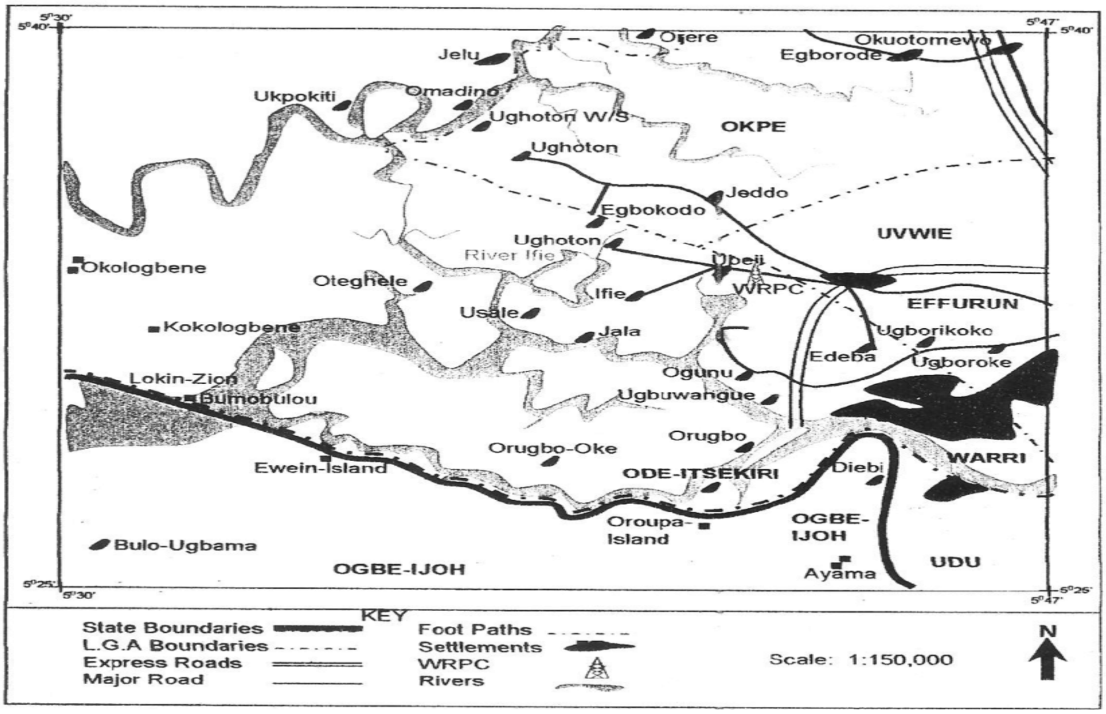

Figure 1: Map of Warri and its Environ Showing Sampling Locations

Pre-treatment of sampling container

To obtain accurate results, proper sample pre-treatment procedures were adopted to eliminate potential contamination of the harvested rainwater samples. Sample containers were washed with nitric acid, HNO_3, overnight and rinsed with distilled water and dried under the sun. Sample containers were clearly and properly labeled to enhance record keeping. Rainwater samples that were collected from Warri refinery were labeled; WRPC1, WRPC2, WRPC3, WRPC4 and WRPC5 for the first to fifth rain respectively. Samples from Military Formation area, were labeled MLF1, MLF2, MLF3, MLF4 and MLF5 respectively. The control sample (rainwater samples that were collected directly from the sky), were labeled CRL.

Method of Sampling and Collection of Rainwater Samples

A random sampling technique was employed in selecting the sampled household (APHA, 2005). Fourty two (42) samples were collected from different roofing materials (asbestos, zinc sheets, alumnium sheets and thatch roof) in Warri environ; these include refinery area and military formation area. The samples were collected between the months of February and August 2019. Four homes each with the targeted roof type were selected randomly and rainwater samples were collected at the beginning of rainfall of the year 2019.These were done to account for any annual rainfall variation in the harvested rainwater quality. The plastic containers were raised from the ground by placing them on top of tripod stand in order to avoid sand splash and other ground- based pollution from contaminating the harvested rainwater samples. Fourty two (42) water samples were collected in all. The rainwater samples were collected from the entry points of the household into plastic bowl then were later transferred to the plastic containers and well labeled. A control samples (rainwater sample directly from the sky) were collected into plastic containers in the two sites.

Physicochemical Analysis

In order to assess the quality of harvested rainwater, physicochemical parameters (pH, electrical conductivity, total dissolve solid, turbidity, iron, chromium and lead) were determined according to procedures and protocols outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 2005; USEPA, 2006).

RESULTS AND DISCUSSION

The physicochemical properties of harvested rainwater samples for the month of February to August in the year 2019 were presented in Tables 1 to 5. The results obtained in this study were compared with the World Health organization (WHO,2010) recommended standard for drinkable water.

Table1: Physicochemical Results for First Harvested Rainwater

Parameters	WRPC				MLF				WHO
	Al	Zn	Asb	Tha	Al	Zn	Asb	Tha	
pH	4.10	6.10	6.70	6.40	6.70	6.90	7.10	6.60	6.5-8.5
EC(μS/cm)	56.9	42.5	114.1	73.3	61.7	79.6	126.6	53.7	900
TDS (mg/L)	38.3	27.6	82.2	51.5	40.6	51.8	93.0	36.9	250
Turbidity (NTU)	0.48	0.84	0.95	1.24	2.48	0.76	0.94	1.87	5.00
Total /Alk. (mg/L)	ND	3.0	18.00	12.00	22.00	36.00	41.00	16.00	120
T/Hardness(mg/L)	9.00	5.00	32.00	17.00	11.00	18.00	38.00	8.00	100-300
Cl (mg/L)	4.10	3.31	7.40	5.61	4.47	5.70	8.46	4.06	250
Fe(mg/L)	0.243	0.137	0.153	0.496	0.241	0.209	0.354	0.600	0.3
Pb (mg/L)	0.10	0.13	0.02	<0.01	0.03	<0.01	0.07	<0.01	0.01
Cr (mg/L)	0.062	0.028	0.052	0.049	0.074	0.069	<0.001	0.094	0.05

Key: WRPC: Warri Refinery Petrochemical Company, MLF:Military Formation Area, Asb: Asbestos Roof;tha: Thatch Roof

Table2: Physicochemical Results for Second Harvested Rainwater

Parameters	WRPC				MLF				WHO
	Al	Zn	Asb	Tha	Al	Zn	Asb	Tha	
pH	5.60	6.40	6.90	6.70	7.00	7.10	7.30	6.70	6.5-8.5
EC(μS/cm)	51.9	38.6	103.7	70.2	54.0	70.1	110.7	49.4	900
TDS (mg/L)	34.6	25.7	69.1	46.8	36.0	46.7	73.8	32.9	250
Turbidity (NTU)	0.31	0.52	0.61	0.89	1.37	0.43	0.56	1.03	5.00
Total /Alk. (mg/L)	4.0	12.00	22.00	16.00	26.00	38.00	46.00	18.00	120
T/Hardness(mg/L)	5.00	3.00	18.00	11.00	7.00	10.00	21.00	4.00	100-300
Cl (mg/L)	3.62	2.57	5.96	4.23	3.82	4.16	6.41	3.47	250
Fe(mg/L)	0.211	0.198	0.132	0.417	0.198	0.163	0.286	0.523	0.3
Pb (mg/L)	0.07	0.11	0.01	<0.01	0.01	<0.01	0.05	<0.01	0.01
Cr (mg/L)	0.054	0.019	0.041	0.040	0.061	0.058	<0.001	0.078	0.05

Table3: Physicochemical Results for ThirdHarvested Rainwater

Parameters	WRPC				MLF				WHO
	Al	Zn	Asb	Tha	Al	Zn	Asb	Tha	
pH	5.90	6.50	6.80	6.80	7.20	7.10	7.20	6.80	6.5-8.5
EC(μS/cm)	47.1	35.7	86.3	59.6	48.2	62.0	89.0	43.2	900
TDS (mg/L)	31.4	23.8	57.5	39.7	32.1	41.3	59.3	28.8	250
Turbidity (NTU)	0.27	0.45	0.54	0.76	1.13	0.39	0.50	0.81	5.00
Total /Alk. (mg/L)	6.00	16.00	25.00	24.00	34.00	33.00	38.00	24.00	120
T/Hardness(mg/L)	4.00	2.00	13.00	8.00	5.00	10.00	14.00	3.00	100-300
Cl (mg/L)	3.41	2.34	4.79	3.86	3.61	3.97	5.18	3.18	250
Fe(mg/L)	0.187	0.194	0.109	0.386	0.176	0.139	0.262	0.491	0.3
Pb (mg/L)	0.05	0.08	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.01
Cr (mg/L)	0.047	0.013	0.034	0.032	0.049	0.046	<0.001	0.063	0.05

Table4: Physicochemical Results for Fourth Harvested Rainwater

Parameters	WRPC				MLF				WHO
	Al	Zn	Asb	Tha	Al	Zn	Asb	Tha	
pH	6.10	6.60	7.00	6.90	7.20	7.20	7.40	6.90	6.5-8.5
EC(μS/cm)	43.2	33.8	79.8	55.5	44.6	56.3	83.0	39.9	900
TDS (mg/L)	28.8	22.5	53.2	37.0	29.7	37.5	55.3	26.6	250
Turbidity (NTU)	0.23	0.39	0.46	0.69	0.97	0.37	0.42	0.73	5.00
Total /Alk. (mg/L)	12.00	24.00	38.00	34.00	45.00	42.00	48.00	32.00	120
T/Hardness(mg/L)	3.00	2.00	11.00	7.00	4.00	8.00	12.00	2.00	100-300
Cl (mg/L)	3.27	2.27	4.52	3.62	3.46	3.73	4.94	2.85	250
Fe(mg/L)	0.158	0.164	0.86	0.347	0.142	0.114	0.229	0.434	0.3
Pb (mg/L)	0.04	0.06	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01
Cr (mg/L)	0.038	0.009	0.026	0.023	0.041	0.037	<0.001	0.052	0.05

Table5: Physicochemical Results for Fifth Harvested Rainwater

Parameters	WRPC				MLF				WHO
	Al	Zn	Asb	Tha	Al	Zn	Asb	Tha	
pH	6.60	6.80	7.10	7.20	7.40	7.10	7.40	7.10	6.5-8.5
EC(μS/cm)	35.3	25.5	70.1	47.4	35.7	52.4	72.9	34.4	900
TDS (mg/L)	23.4	16.9	46.7	31.4	23.8	34.7	48.3	22.8	250
Turbidity (NTU)	0.21	0.29	0.38	0.54	0.78	0.32	0.35	0.62	5.00
Total /Alk. (mg/L)	19.00	26.00	39.00	40.00	49.00	45.00	50.00	32.00	120
T/Hardness(mg/L)	2.70	1.90	8.00	6.00	3.00	5.00	10.00	1.40	100-300
Cl (mg/L)	3.10	2.09	3.78	2.96	2.67	2.46	4.12	2.17	250
Fe(mg/L)	0.136	0.146	0.071	0.321	0.119	0.089	0.203	0.412	0.3
Pb (mg/L)	0.02	0.03	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01
Cr (mg/L)	0.026	0.006	0.019	0.014	0.029	0.025	<0.001	0.038	0.05

According to the results, harvested water for the months of February (first flush) appeared to be relatively acidic with pH a 4.10 – 6.70 for WRPC and 6.60 – 7.10 for MLF respectively. This higher acidity of 4.10 recorded in water samples from the WRPC, possibly due to dissolution of carbon dioxide in rainwater leading to the formation of carbonic acid (H_2CO_3), this suggest that the activity of the hydrogen ions in water samples of the area were more than that of the hydroxyl ions. The mean pH value of water samples from Warri refinery and petrochemical company (WRPC) is 5.83 from the first flush. This shows that harvested rain water within WRPC is acidic and can be compared to research work conducted by Igwo-Ezikpe and Awodele (2010), which showed that the pH of four industrial areas of Lagos state namely: Ilupeju, Costain, Ikeja and Ikorodu were 4.94, 4.20, 4.22 and 4.30 respectively. pH values were observed to increase as the number of flush increases for all the roofing sheets. pH conforms to WHO standard of 6.50 to 8.50.

Electrical conductivity (EC) values of harvested water from asbestos sheets were significantly high compared to those obtained from other roofing sheets. A value of 126.6 and 114.1 μS/cm was obtained for asbestos in MLF and WRPC respectively compared to 42.5 μS/cm(Zn WRPC), 61.7 μS/cm (Al, MLF), and 19.0μS/cmin the control in the month of February(first flush). This might be due to the type of roofing material, which could have an impact on the chemical properties of harvested water. EC values in MLF were significantly higher than EC values of WRPC. This is possibly due to the facts that human activities, which releases dust particles, harmful substances etc into the atmosphere, which later settled on the roofing materials in more in MLF than WRPC. Pure rain water is estimated to have an EC < 15 μS/cm and a TDS < 10 mg/L (Deas and Orlob, 1999). EC values were observed to reduce as the number flush increases for all the roofing sheets, also, fell below WHO recommended standard of WHO 900 μS/cm.

The total dissolved solids (TDS) also recorded high values in rainwater from asbestos roofing sheets than others. In February (first flush), a TDS values of 82.2 mg/L and 93.0 mg/L were recorded for WRPC and MLF asbestos respectively compared to other roofing materials of 27.6 mg/L(Zn, same WRPC), 40.6 mg/L (Al, same MLF,) and 12.7 mg/L in the control, and this corresponds with the result of study carried out by (Bada *et al.*, 2012) in Abeokuta- a high range 9.67mg/L to 71.00mg/L for asbestos. The high turbidity value for asbestos sheets can be attributed to the high amount of suspended solids present in it. The TDS results was compared to the research reported by Okoye *et al.* (2011), of 50, 80, 90 and 121 mg/L in physicochemical and trace metal levels of rainwater for Ile-Ife, South-west of Nigeria. The TDS content of water can be a good indication of contamination or low quality of water. According to most authors, metals are strongly associated with particles in runoffs (Ayenimo*et al*.,2006). The TDS values of WRPC were similar to that of MLF. TDS has a huge effect on the characteristics of water samples such as the temperature, turbidity and electrical conductivity. TDS values of harvested water from all the roofing sheets were observed to reduce as the months and number of flush increases. However, TDS values fell below the stipulated value of 250 mg/L of WHO.

There was a noticeable low turbidity value for WRPC and MLF in Table1, a mean value of 0.88 NTU for WRPC and a mean value of 1.52 NTU for MLF. The low turbidity values can be attributed to less human activities, which generate the suspended solids particles. In addition, turbidity tends to reduce as the months and number of flush increases. Turbidity values fall below the recommended standard value of 5.00 NTU by WHO.

Total hardness values of harvested water from asbestos sheets were higher than that obtained from other roofing sheets. In Table1, values of 32.00 mg/L, and 38.00 mg/L were obtained for WRPC and MLF respectively compared to 9.00mg/L and 11.00mg/L, for aluminium in WRPC, and MLF respectively. This is possibly due to the facts that some asbestos materials leached into the harvested rainwater, this in alter the water quality. In addition, 5.00mg/L, and 18.00mg/L for zinc in WRPC, and MLF respectively. Total hardness values for MLF are higher than that of WRPC. Total hardness values reduced as the number flush increases for all the roofing sheets. These values fell below the WHO standard, which ranged between 100-300 mg/L.

All the rainwater samples from the four roof types for chloride fell below the limit of WHO. The four roofing sheets fell below the limit of recommended WHO values for chloride of 200mg/L – 300 mg/L. There is a noticeable decrease in the values of chlorides with increase in the number of rainfalls.

In Table1, the ranged value for total alkalinity of the samples from asbestos was between 0 mg/L – 41 mg/L, for the first flush from the four roofing roofs. There is a noticeable increase in the values of total alkalinity from the first flush to the fifth flush. All the values are below WHO recommended standard value of 120mg/L of WHO.

Heavy metals (Fe, Cr and Pb) concentration in the harvested rainwater sample signifies some degree of contamination in the area under investigation. Iron (Fe) was relatively higher in concentration than all other heavy metals. In Table1, higher concentrations of iron that exceeded WHO (1996) limit of 0.3mg/L were detected in thatch roof of WRPC and MLF viz: 0.496, and 0.600 mg/L respectively. However, after the fifth flush they conformed to the WHO standard except for thatch roof in MLF (Table 5) that was still higher at 0.412 mg/L. This sharp high concentration of iron values in thatch roof may be due to transpiration i.e. iron mineral in soil which the thatch plant tapped from the ground through its root to the stem, then to leaf, which were later cut off and used as roofing materials. The concentration of the control was very low 0.009 mg/L, which indicate that roofing material has an effect in the harvested rainwater. All others iron values from the rest roofing sheets conform to the recommended maximum standard value.

In Table1, lead values in all the samples were relatively high and above the WHO (2010) limit of 0.01 mg/L, except for thatch roof (WRPC and MLF,) which are < 0.01 mg/L and zinc roof in MLF which is also < 0.01 mg/L in their first flush. However, after the fifth flush(Table5), it was observed that all roofing materials in MLF fall within the WHO standard except for aluminium and zinc roofing materials in WRPC that were still very high above the WHO standard. The concentration of the control was very low <0.01 mg/L, which indicated that roofing material has an effect in the quality of harvested rainwater. This observation agreed with the reports of Gadd and Kennedy (2001) of its heavy metal analysis.

It was observed from (Table 1-5) that samples from the four roofing materials in WRPC (except for Al) in all their roofing sheet had the lowest value of chromium and the control 0.002 mg/L as compared to MLF which had high values of chromium in its first flush in table1. There is a noticeable decrease in the values of chromium with increase in the number of rainfalls. All the values from the four roofing materials in the two settlements were little beat below the recommended maximum standard value of 0.05mg/L of WHO after the fifth flush in Table5.

CONCLUSION

This study at Warri and its environ showed that rooftop runoff quality is dependent on both the roof type and the environmental conditions. All the Physicochemical vz; pH, TDS, electrical conductivity, turbidity, total hardness, total alkalinity, chloride in all the rainwater samples analyzed fell below the recommended WHO standard except for pH which conform. The results of the heavy metal (Lead, Chromium and Iron) analysis of the rainwater samples, indicated Lead to be the main contaminant because of its high value in the harvested rainwater, chromium and iron were also high in the first flush but subsequently decreased with increase in the number of rainfalls. However, only the concentration of lead in MLF was within WHO standards after the fifth flush. Conclusions drawn from this study are as follows; The study revealed the presence of Pb, in the harvested rainwater samples, of which Pb that is a poisonous metals is above the maximum allowable limit of WHO, which is dangerous to human health (can cause lead poison), therefore, the first flush from all the rooftops should not be used for any domestic activities because of their high level of accommodation of dirt, rust and lead (Pb). Secondly, All rainwater samples from WRPC and MLF (i.e. from the fifth flush and above) are safe for domestic uses such as irrigation, washing, mobbing, laundry, bathing, toilet flushing and other cleaning works after subjecting them to simple water treatment like boiling only.

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