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Article

The Spatial Effect of Rusty Roof on Water Quality in Otukpo Local Government Area of Benue State, Nigeria

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Abstract: Runoffs from metal roof sheets (aged and New) in Otukpo LGA of Benue State, to carter in Nigeria were analyzed to determine the level of heavy metals (Cd, Cu, Fe, Mn, Ni, Pb, and Zn). All the runoff samples though varying in time and space contain heavy metals concentrations. The results ranged from 0.003-0.009, µg/L, 0.165-0.291µg/L, 2.000-2.987 µg/L, 0.091-0.199 µg/L, 0.101-0.187 µg/L, 0.011-0.035 µg/L and 2.733-3.892 µg/L for Cd, Cu, Fe, Mn, Ni, Pb, and Zn in aged roof metal sheets, while in the new roof metal sheets, the values are 0.002-0.008 µg/L, 0.071-0.191 µg/L, 1.010-1.994 µg/L, 0.073-0.995 µg/L, 0.076-0.111 µg/L, 0.012-0.036 µg/L, and 1.875-2.941 µg/L respectively. There were significant difference ($P<0.05$) between run off from aged and new roof metal sheets. The mean concentration of Fe, Cu, Ni and Zn of aged metal roof sheet were higher than the mean concentration of new metal roof sheets. All the metals determined except Fe have mean concentration lower than the recommended standard by WHO, CPA and FAO. The variations in mean concentration between aged and new metal roof sheets in this study, suggest anthropogenic inputs of these metals.

Keyword: heavy metal, rusty roof, runoff, and pollution

1. Introduction

Water is life has been a common phrase that is not peculiar to Nigerian environment, but to the world at large. Geographical distribution of water resources varies both in time and space. Considering that virtually the whole of human civilization vis-à-vis daily activities that is dependent on water (Agricultural, Industrial, and Domestic), yet scarcity is inevitable and perennial (Ndabula and Jidauna, 2010). The global crisis of water shortages have sent men on the lookout for new water sources and equally explore other potential water sources. Drinking water plays a major role in the intake of a number of nutritional and toxic trace elements in men (Nikono and Asubiojo, 1997); this has made man to resort to different ways of getting water to meet his need. One of the free sources explored by man is rain water harvesting (Gould and Mc Pherson, 1999), when rain falls, water is collected either directly or from a roof for storage and eventually use. The harvest is necessary in areas having significant rainfall but lacking conventional water supply system. Rain water harvesting consists of a collection area, in most cases the roof of buildings. The effective roof area and material used in construction influence the efficiency of collection, water quality, and quantity.

Roof guttering is considered a potential source of pollution for two primary reasons. First, compounds contained in roofing materials may be leached into runoff, and airborne pollutants and organic substances such as leaves, dead insects, and bird's wastes are added to roof by interception and deposition during storms, rain water not only adds a variety of chemicals and contaminants to the roof watershed, the acidic nature of rainwater will react with compound retained in or by the roof and cause many elements in the roof runoff to leach out (king and Benient, 1982). Second, roof temperature are much higher than temperature of other surfaces due to lower albedo, greater surface inclination to direct solar radiation, and less shading effects from surrounding trees (Chaing and crowely, 1993). The higher the roof temperature may accelerate chemical reactions and organic decomposition of the materials and compounds that have accumulated on rooftops. Combining these constituents from rooftops with elements from precipitation deposition, chemical decomposition, and acid leaching make the quality of roof runoff a great concern for the household cistern system and on receiving streams.

The concentrations of constituents in roof runoff were reported to be much higher than those in rain fall in Germany (Forster, 1998), and some elements especially metals, have exceeded the World Health Organization (WHO) drinking water quality standard in Australia (Thomas and Greene, 1993). The average concentration of Zn in roof runoff was nine times higher than the maximum allowed value for waste water in Germany. (Quck and Forster 1993, and Mclmquist 1993) showed that roof runoff was a major source of Zn and Cu in storm runoff. In New Zealand, water quality conditions were analyzed for three metals four bacterial indicators and five pathogen species for 125 domestic roof-collected rainwater supplies in four rural Auckland districts. The results showed that those roof-collected rainwater system as well as, provided potable supplies of relatively poor water quality between the range of 17.6% and 56% of the area studied. The systems had one or more values exceeding the New Zealand drinking water standards on chemical pollutants and fecal coliforms, respectively. (Simmons etal; 2001, and Zbrist etal, 2000) showed that runoff from a tile roof and a polyester roof was initially very high in concentrations, but declined to lower constant levels as storms proceeded on.

Some other studies, however, showed that roof-runoff quality was quite different, than those reported above roof runoff from 12 cistern water supply systems located on St. Thomey in the US Virgin Islands were monitored for 23 chemical element, i.e. Ca, Mg, Na, K, Cl, SO_4^{2-} total P, NO_2-, NO_3-, NH_4+, organic N, F, Zn, Cd Pb, Cr, Ni, Fe Mn, Hg, Specific conductance, alkalinity, and pH. The concentrations of all these elements, except for Hg, were found to be below the US EPA water quality standard for public water supplies (Lee and Jones, 1982). It was concluded that roof materials or painting of the roof top collection system did not have a significant impact on water quality (Pazwesh and Boswell, 1997), and also it was observed that roof runoff is fairly pure and practically free of suspended matter and impurities found in other surfaces. The variation of roof runoff quality seems to reflect differences in roofing materials, age and management, the surrounding environmental conditions, seasons, storm duration, and intensity and air quality conditions of the region.

Change and Crowley (1993) conducted a preliminary study to monitor runoff quality from four residential roofs and incident rain water over a 6-month period in Nacogdoches Texas. They showed:

1) Wood shingles yielded the most precipitated elements while terra cotta clay roof yielded the least
2) Both mean and median concentrations of Zn from the four roof types exceeded the EPA fresh water quality standard and
3) One half of the 24 chemical variables analyzed exceeded the standard at least once in all samples collect.

Their results on Zn in roof runoff as a potential contaminant in receiving streams agreed with those studies conducted in Germany and Australia.

Although there have been considerable number of studies on the concentration of trace heavy metals in roof water runoff, the vast majority have been carried out in developed countries with long histories of industrialization and extensive use of leaded gasoline since 1935 (Page et al, 1971; Goldsmith et al; 1976) and very few studies or none were carried out in developing countries such as Nigeria and data on pollutant metal concentrations and distribution in such countries are extremely scarce. Therefore, this study was initiated to assess/ examine the effect of rusty roof on the quality of rain water harvesting (roof guttering) in Otukpo Local Government Area in Benue State of Nigeria.

2. Study Area

Otukpo Local Government Area (LGA) is one of the oldest LGA in Benue State, but also the traditional headquarters of Idoma people where its paramount Chief the Och'Idoma has his palace. The LGA came into existence in 1923, with its headquarters at Otukpo. In addition to metropolitan Otukpo town other prominent places in the local government area include Ogobia, Upu, Otukpoicho, Otobi, Adoka, Oyagede and Akpa-Igede. It is located on $7^0 13^1$N & $8^0 9^1$E, and $7^0 21^1$N & $8^0 15^1$E. It is equally is bounded in the North by Apa and Ohimini local government areas in the Southeast, Ado local government in the South and Olamaboro local government area in Kogi state in the West (Figs 1 & 2). It has an estimated landmass of about 390 sq. km, and with an estimated population of 266,411 (2006, Census).

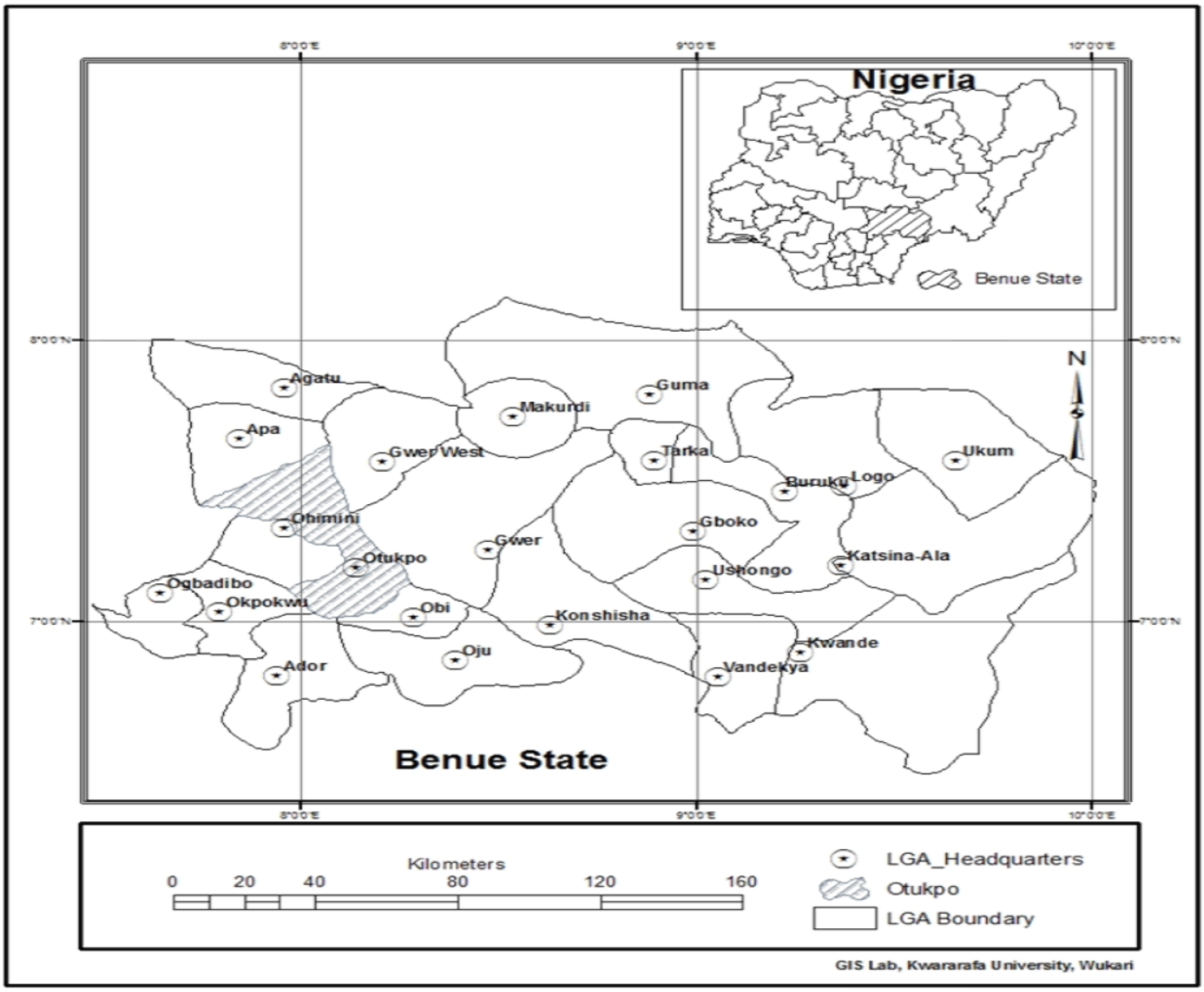

Fig. 1: Study area Benue State location map

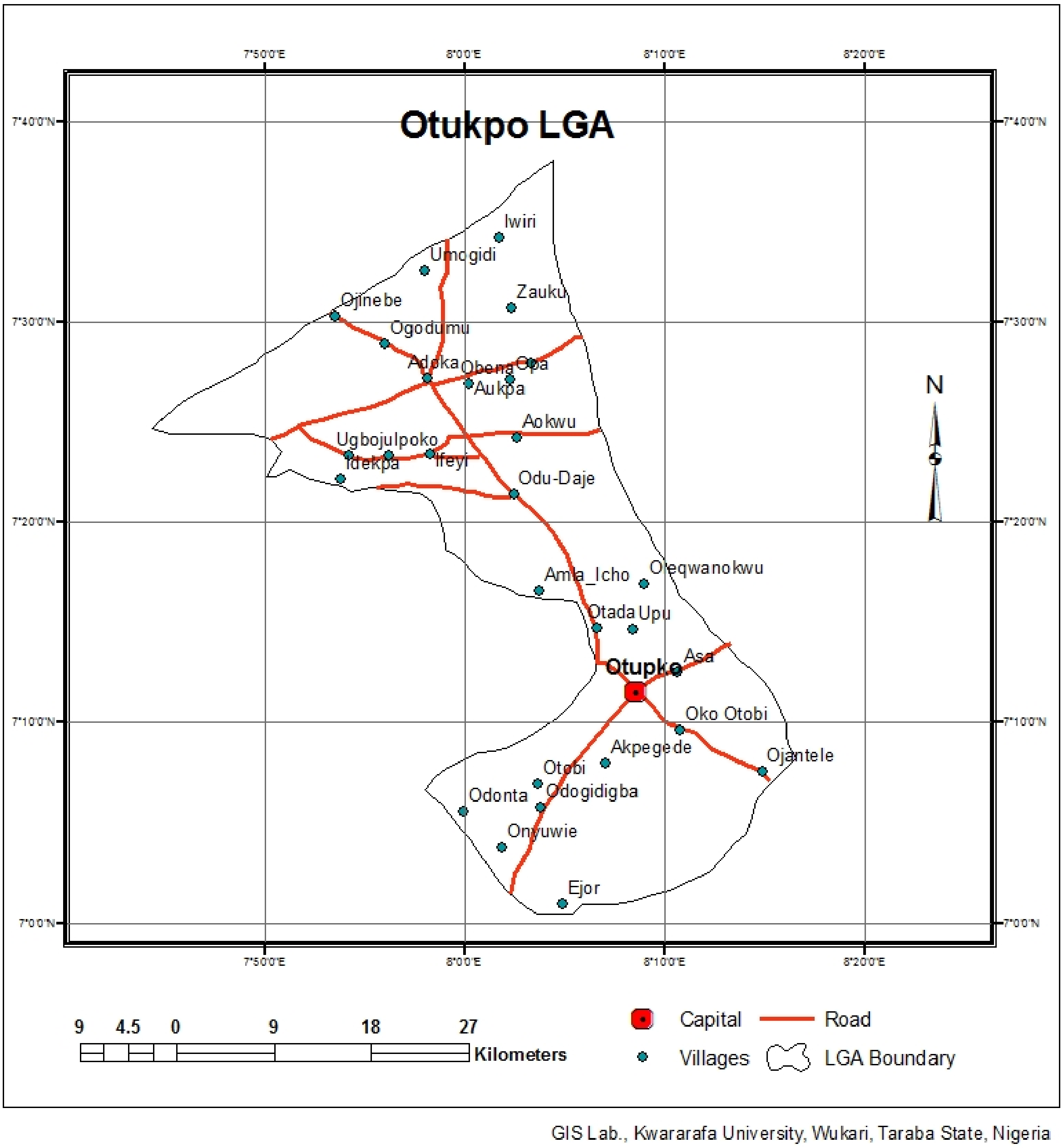

Fig. 2: Study area Otukpo LGA location map

LGA has a tropical sub-humid climate, with two distinct seasons, namely a wet and dry season. The wet season which lasts for seven months starts from April and ends in October. The annual rainfall total ranges from 1,200mm to 1,500mm. Temperatures are generally very high during the day, particularly in the months of March and April. Along the river valleys, these high temperatures plus high relative humidity produce inclement/debilitating weather conditions. Makurdi, the state capital, for example, records average maximum and minimum daily temperatures of 35°C and 21°C in summer and 37°C and 16°C in winter, respectively.

3. Materials and Methods

The samples were collected for seven months, covering the period of April to October (on-set of the raining season to the end of the rains) 2011. Three set of samples were collected directly from a new roof and from an old roof ensuring that there was no industrial activities and high traffic density noticeably to influence the results. The water was collected directly as it falls, and was taken to control contamination. Roof runoff was caught by a commercial galvanized gutter installed at the end of each roof the collected run off was drained into a plastic sample container through a galvanized down spout. About 500-1500cm^3 of roof runoff per storm was collected for metal analysis. While the rain water sample obtained directly from atmosphere was used as the control in this study. Thus, the samples collected under the system reflected the total metal concentration of the collected sample.

Water sample were collected in plastic container that had been washed with detergent, followed by a soak and rinse in a 0.1MHCL and then rinse in distilled water. The collected sample were taken to the laboratory for immediate pH determination and then stored in a refrigerator for chemical analysis of trace heavy metals “Cd, Mn, N, Pb and Zn. A total of 350 samples were collected from April – October, 2011 covering the studying period. All pH measurements were made at laboratory temperature. All the runoff water was acidified and digested by HNO_3 as specified by APHA (1992). Samples and control were treated in triplicate and analysis was carried out following standard methods (APHA, 1992).

The instrument was first calibrated with stock solutions of the prepared standards before analysis. The final processed samples were quantitative analyzed using buck scientific VGP 210 Flerme Atomic Absorption Spectrophotometer. After every five sample analyzed using AAS, the first sample was repeated for quality check. Only when the result were within 10% earlier readings did the analyses proceed further

4. Result and Discussion

The pH samples range from 6.600-7.300 all the runoff samples studied from the metal roof sheets (aged and new metal sheet) were either weakly acid or neutral. The concentrations of the various heavy metals found in the samples (aged and new metal sheet) are presented in tables 1 and 2. Table 1 represent samples collected from aged metal roof sheets and table 2 represent sample collected from new metal roof sheets with the control values. Control was the direct rain water collected. It revealed clear elevated levels of these heavy metals Cd, Cu, Fe, Mn, Ni, Pb and Zn. The mean concentration of heavy metals obtained from the control (direct rain water) was consistently low, much lower than those obtained from the runoff water sample under consideration (aged and new metal roof sheets). This reflects a general contamination of the runoff from metal roof sheet (aged and new) by the heavy metals studied. The results also showed that the trace heavy metal concentration of the rain water increased as it contacted the metal roofing sheet.

Table 1: Summary of trace heavy metal (μg/L) in runoff from aged metal roofs in Otukpo

Metal	**Cd**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
Number	31	31	31	34	31	32	33
Mean	0.008	0.237	2.608	0.147	0.141	0.026	3.203
Std Dev	0.007	0.043	0.36	0.035	0.025	0.007	0.375
Range	0.001-0.009	0.165-0.291	2.000-2.987	0.091-0.199	0.101-0.187	0.011-0.035	2.733-3.892
Control	N.D	0.069	0.751	0.135	0.074	0.013	1.007
F.A	0.008	3.434	3.475	1.089	1.89	2	3.181

Table 2: Summary of trace heavy metal (μg/L) in runoff from new metal roofs in Otukpo

Metal	Cd	Cu	Fe	Mn	Ni	Pb	Zn
Number	32	34	30	33	33	36	33
Mean	0.006	0.103	1.502	0.179	0.091	0.027	2.215
Std Dev	0.004	0.029	0.358	0.25	0.008	0.006	0.247
Range	0.003-0.008	0.071-0.191	1.010-1.994	0.073-0.995	0.076-0.111	0.012-0.036	1.875-2.941
Control	N.D	0.069	0.751	0.135	0.074	0.013	1.007
F.A	0.006	1.5	2	1.32	1.244	2.1	2.2

Out of the heavy metals considered Fe, Cu, Zn, Pb and Ni showed the highest contamination in the runoff samples (aged and new roof metal sheets). The overall results ranged from 0.003-0.009 μg/L, 0.165-0.291 μg/L, 2.000-2.987μg/L, 0.091-0.199μg/L, 0.101-0.187μg/L, 0.011-0.035μg/L and 2.733-3.892μg/L for Cd, Cu, Fe, Mn, Ni, Pb and Zn in aged roof metal sheets while in the new roof metal sheets, the concentration of these same heavy metals ranged from 0.002-0.006 μg/L, 0.071-0.191 μg/L, 1.010-1.994 μg/L, 0.073-0.995μg/L, 0.076-0.111μg/L, 0.012-0.036μg/L and 1.875-2.941μg/L respectively. Generally, in the runoff sample studied, the concentration of the heavy metals where high especially Fe, Cu, Zn, Pb and Ni. This is an indication that these heavy metals are the contaminant in the runoff sample which was also reflected in the low level of these heavy metals obtained from control "direct runoff" in comparison with those obtained from runoff sample (aged & new metal roof sheets). Also, the degree of heavy metal concentrations in runoff from metal roof sheets which were determined by its enrichment factors were also high for Fe, Cu, Zn, Pb, and Ni (table 3). From the mean results and enrichment factors, there is a clear indication that Fe, Cu, Zn and Ni are the major contaminants in runoff from metal roof sheets. The sources of these heavy metals on the metal roof sheets are believed to come from galvanized sulters, and down spouts, nails, solder, dry deposition of aerosols, fungi resistant materials, coating decomposition of organic matter and age of the metal roof sheets.

Table 3: The factor of accumulation or enrichment factor of heavy metal in runoff from metal roof (aged and new) in the study site Otukpo

Metal	**Cd**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
Aged metal roofs	0.008	3.434	3.475	1.089	1.89	2	3.181
New metal roofs	0.006	1.5	2	1.32	1.244	2.1	2.2

There was however appreciable difference in the concentration of heavy metals in runoff samples from aged metal roof sheets and new metal roof sheet. Analysis of Various (ANOVA) as presented (table 4) showed a significant variation ($P<0.05$) between runoff samples for the heavy metals determined in aged metal roof sheet and new metal roof sheets. The mean concentration of Fe, Cu, Ni and Zn of aged metal roof sheets were significantly different from that of new metal roof sheet. The difference is high. Mean concentration of Fe, Cu, Ni and Zn in aged roof-metal sheets may be attributed to the rusting and corrosion of the metal roof sheet as its getting old, this is an indication that impinging of rain drops on the metal roof sheets gradually erodes the materials used in the making of the roof sheets.

Table 4: Analysis AMOVA

Element	No. of Sample	Mean	Std Dev	Std Error Mean	Mean Difference	Std Error Diff	T-test	diff	P-value
Cd (Aged)	31	0.01755	0.00711	0.00128					
Cd (New)	29	0.01707	0.01107	0.00206	0.00048	0.00239	0.201	58	0.841
Cu (Aged)	31	0.23655	0.04418	0.00793					
Cu (New)	34	0.10329	0.62869	0.00492	0.13325	0.00934	14.548	63	0
Fe (Aged)	31	2.6079	0.36005	0.06467					
Fe (New)	30	1.50223	0.35775	0.06532	1.10567	0.09192	12.028	59	0
Mn (Aged)	34	0.14715	0.03429	0.00588					
Mn (New)	33	0.17927	0.25007	0.04353	-0.0321	0.04329	-0.742	65	0.461
Ni (Aged)	31	0.14077	0.02482	0.00446					
Ni (New)	33	0.09136	0.00847	0.00147	0.04941	0.00458	10.789	62	0
Pb (Aged)	32	0.02644	0.00663	0.00117					
Pb (New)	36	0.02731	0.00605	0.00101	-0.0009	0.00154	-0.565	66	0.574
Zn (Aged)	33	3.20263	0.37336	0.06499					
Zn (New)	33	2.21527	0.2465	0.04291	-0.9874	0.07788	12.68	64	0

The concentration of Cd, Mn, and Pb in the runoff simples from aged metal roof sheet were also detected to be higher than what is obtained in the runoff from new roof sheets. Though there was no significant difference, Pb concentrations in the runoff from metal sheet (aged and new may be explained as a result of exhaust from vehicles and gasoline combustion which cause air pollution with lead particle reaching metal roof sheet through deposition (Aulofolo 2004).

The concentrations of Cd and Mn were very low. The Cd was not detected in the control direct rain water. However, the variations in the concentrations with time suggest anthropogenic inputs: that is other deposits pollutants in contact with roofing sheets. Geographical location along with spatio-temporal dynamics could have accelerated the level of contamination. The present result may not pose any serious health hazard, but attention should be given to iron that present at higher concentration than recommended concentration by WHO and FAO as show in table 5.

Table 5: Maximum allowable concentrations (μg/L) of trace metals in drinking water

Metal	WHO	EPA	FAO (1985)	New roof	Aged Roof
Cd	-		0.01	0.006	0.008
Cu	1	0.05-1.500	0.2	0.103	0.237
Fe	0.3	0.1		1.502	2.608
Mn	-	-	0.2	0.179	0.147
Ni	-	-	0.2	0.091	0.141
Pb	0.05	-	5	0.027	0.026
Zn	5	5.00-15.000	2	2.215	3.203

Pearson correlation among heavy metal in the runoff sample from metal roof sheets was calculated to see if some metals were interrelated with each other and the results are presented in Table 6. Correlation study of the data indicated a relatively weak correlation between metals. The negative correlation observed in most of the metals shows that the metals are probably not from the same source and the presence of one does not necessarily indicate the presence of the other.

Table 6: Correlation among Aged and New metal roof sheet

Roof sheets	**Cd**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
Aged metal sheet		0.188	-0.022	-0.002	-0.156	-0.133	0.294
			0.053	0.25	-0.325	-0.073	0.274
				0.071	0.149	-0.066	0.114
					-0.328	-0.032	-0.107
						-0.129	-0.044
							0.211
New metal sheet		0.062	0.1075	-0.015	0.1511	- 0.0025	-0.1254
			-0.0579	0.068	-0.1191	0.3177	-0.1266
				0.0452	0.1025	0.0066	-0.2532
					0.0112	- 0.1049	-0.1785
						0.0475	-0.0714
							-0.2242

5. Conclusion

The results obtained from the analysis of runoff samples collected from metal roof sheets (aged and new) in various location in Otukpo area of Benue State in Nigeria indicates that the concentration of Cd, Cu, Fe, Mn Ni Pb and Zn were higher than those of control sample "direct rain water" metal contents. The degree of contamination of Fe, Cu, Zn, Pb and Ni were the highest. The concentrations of Cd and Mn in metal roof sheets were very low. There were significant difference in the concentration of Fe, Cu, Zn, Pb, and Ni in the samples collected from aged roof and new roof. This is an indication that the impinging of rain drop on the roof gradually erodes the material used in the making of the roof overtime. It is important to note the environmental impact of such materials used in their production especially when such materials are not biodegradable. Rain harvesting is an age long practice due to the unavailability of adequate water supply in most part of Nigeria, pollutants of Fe was found to be present in the samples in high concentration in comparison with WHO and FAO. However, the variations in the concentrations with time suggest anthropogenic inputs: that is other deposits pollutants in contact with roofing sheets. Geographical location along with spatio-temporal dynamics could have accelerated the level of contamination.

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