Determination of Rainwater Quality from Different Roof Materials Common in the Makurdi Area

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Abstract: In recent times, it has been reported that there is a clear correlation between the incidence of water borne diseases and the consumption of harvested rooftop rainwater. While farming practices and other factors may be adding to this problem, it will be helpful to alleviate the contribution of rooftop harvested rainwater. But an understanding of the initial level and nature of contamination of a quantity of rooftop rainwater is crucial to its satisfactory treatment. Since this initial information which varies from place to place, is not locally available for the Makurdi area, this work has provided that. Secondly, it is a surprise that the treatment of rainwater related health problems has been confounded by indigenously popular assumptions that additional treatment may not be required as long as a simple rainwater harvesting system is employed in making collections from new roofs. To address these two problems, experiments were done to examine rainwater harvested from nine rooftop types in three general locations: North-bank, Low-level and Logo 1 area. (each comprising sub locations). The results of this study showed that only rainwater harvested from two specific types of rooftops can be safely consumed without treatment. Doing same with other types of rooftops entailed varying levels of risks.

Keywords: Rooftop, Firstflush, Rainevents, Harvested, Quality ,contamination, concentration

Introduction

Water is certainly important to agricultural activities. But as more non agricultural activities tap into available water supply, the share meant for farm activities is increasingly slashed. To compensate for these losses, attention has now turned to water harvesting. But apart from water quantity Schwab *et al*., (1993) says that water quality affects all humans, animals, wildlife and even crops. This has made rainwater a popular alternative especially in the dry seasons and in most rural or semi arid farming communities. Interest will be focused on rainwater obtained through simple rainwater harvesting as it believed to be portable even without treatment. However, an increase of health complications has resulted from its consumption. A survey conducted by Simmons *et.al*(2001) in Auckland associated the presence of the microbe- Aeromonas- with increased gastro enteric symptoms among domestic users of rooftop harvested rainwater. Therefore, this study is directed at determining the cause of rainwater-borne diseases by examining the role of locally accessible rooftop type. It also intends to provide information on rainwater quality and hence guide water treatment procedures for the Makurdi area.

Rainwater harvesting is not a modern invention. The use of runoff control techniques and small dams dates back to the early times. For example, rainwater harvesting had existed during the Minoan times (3200-1100 BC) in ancient Greece involving various catchment techniques and

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storage cisterns (Antoniou *et al*., 2014). Also, the practice of channeling runoff from rainwater to rice terraces has existed for thousands of years in the Philippines. Leung and Librizzi(2008) confirm this and add that the ancient Romans had sophisticated rainwater harvesting systems that had applications in house air conditioning. They even invented integrated systems connecting surface pools and underground cisterns to both effect filtration and reduce evaporation of harvested rainwater.

As one would expect of a strong and vast empire like Rome, its rainwater harvesting spread to all its territories. However, other reasons also explain its popularity. Ahsan(2013) says that rising population, social, economic, scientific and industrial advancement increased water demand putting pressure on available water resources. He also mentioned drought and falling quality and quantity of contaminated groundwater as additional incentives that drove public interest in rainwater harvesting. But while the quality of harvested rooftop rainwater was better than that of other non-rooftop sources, it still could not meet acceptable health standards.

Contemporary exploits in the rainwater harvesting venture portray it as an ancient success with modern challenges. A major challenge of rooftop rainwater harvesting today is the poor water quality. Busk *et al*.,(2009) outlined the major sources of pollution in rooftop harvested rainwater as : dusts and particulate matter; microbes and microbial aerosols: pathogens; pesticides ;vehicle and factory emissions like polycyclic and aromatic hydrocarbons(PAH's); heavy metals: Birds ,insects and little mammals that deposit fecal matter on rooftops and their gutters; and the rooftop themselves which surfaces or surface coating materials react with elements of weather to shed lethal doses of various chemical contaminants. It is sobering to realize that apart from the whims of weather conditions and independent biotic elements that man cannot control, even the rooftop materials and the pollution that he makes and attempts to tweak also eludes him with a poisoned drink. Nevertheless, this study will be constrained only to the effects of rooftop materials.

However for locally harvested rooftop rainwater to be deemed portable, it cannot just be treated without an initial examination of its probable contaminants in the yet untreated state. Usually, data available for this purpose is exotic and non native to the study area. Mendel *et al.,(2010)* says: "Although, several studies have examined the effect of roofing materials on harvested rainwater quality, domestic studies on the effect of roofing materials on harvested rainwater quality might be more useful because roofing materials, coatings and building practices vary globally".

Hence, this paper will educate the local population in Makurdi and the wider public on the effects of various locally popular rooftops on the quality of water harvested from them. It also intends to show whether it could be fairly safe to drink water harvested from some (all) rooftop types without treatment. The subsequent sections will describe field and laboratory experiments on rainwater samples harvested from several rooftops in different locations. A statistical software (SPSS) is used to illustrate results through appropriate descriptive data, including the Duncan mean separation technique, ANOVA tables and graphs .Other sections discuss these results and their implications.

MATERIALS AND METHODS

All the parameters in this study were measured in triplicate for each sample in one rain event. However three rain events were covered. The parameters are: Temperature, colure, turbidity, total suspended solids, Total coli form, pH, metals (magnesium, calcium, zinc, aluminum, iron, chromium), radicals (nitrate, sulphate,) and Total hardness.

Table 1 summarizes the analytical materials and methods that were used.

Table 1 Analytical instruments and methods.

Parameter	**Meter/method type**	**Source**
Turbidity	Spectrophotometer (DR/2000)	HACH
Colour	Spectrophotometer (DR/2000)	HACH
Temperature	Thermometer	
TSS	Spectrophotometer (DR/2000)	HACH
TC	M-endo broth	*Standard Methods* (1998)
pH	Electronic pH meter	*Standard Methods* (1998)
Hardness	Hardness kit model HA-4P-MG-L	
Nitrate	Titration…(sulfaver.4.method) /Spectrophotometer (DR/2000)	HACH
Sulfate	Titration…(sulfaver.4.method) /Spectrophotometer (DR/2000)	HACH
Metals	Inductively coupled plasma mass spectrometry	*Standard Methods* (1998)

Table 2 Description of rain events.

Date	Temperature(°C)	Number of preceding dry days
15/08/2014	30	9
30/08/2014	29	15
10/09/2014	32	11

First flush: It should be noted that the influence of first flush in rooftop behavior was ignored in this study .first flush is the initial and most contaminated rainwater collection from any rooftop between two rain events or seasons. Since first flush collections are made after a generally longer time, other uncontrollable variables like weather and biotic elements are given more time to play a bigger role. This will complicate results in an experiment in which a good control on variables is desired. Hence, it is rather more important to examine the quality of the rainwater harvested after the first flush since the first flush is diverted from use (Mendez, 2010)

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RESULTS AND DISCUSSION

Note that the following acronyms represent the various rooftops from which mean values of rainwater quality parameters have been obtained: ZN-N for new zinc galvanized iron rooftop; ZN-O for old zinc galvanized iron rooftop; AL-N for new aluminum rooftop; AL-O for old aluminum rooftop; TH-N for new thatch rooftop; TH-O for old thatch rooftop; ASB for asbestos rooftop; CONC for concrete rooftop and CTRL for control

Tables 3-5 illustrate trends for only the first rain event. However, Tables 6-10 bear data for all parameters for the second and third rain events. In each table, the behavior of a single parameter along all 9 various rooftops is described. All parameters were measured in triplicate, the average of these triplicate measurements were then recorded.

Table 3: Chemical Parameters for the First Rain Event

Rooftops	CHEMICAL PARAMETERS									
	PH	Hardness	Ca	Mg	ZN	AL	Fe	Cr	NO_3	SO_4
ZN-N	7.3000^{bc} ±0.20	20.0000^{a} ±0.00	20.0000^{a} ±0.00	.0000^{a} ±0.00	.5733^{c} ±0.08	.0800^{b} ±0.02	.0400^{bc} ±0.03	.0000^{a} ±0.00	8.8533^{bc} ±1.53	6.0000^{a} ±2.00
ZN-O	6.8000^{a} ±0.20	26.6667^{ab}±11.55	20.0000^{a} ±0.00	6.6667^{ab} ±11.55	2.7667^{d} ±0.08	.1500^{c} ±0.01	.0867^{d} ±0.12	.0467^{bc} ±0.01	16.8367^{e} ±2.16	10.0000^{b} ±2.00
AL-N	7.6333^{c} ±0.21	20.0000^{a} ±0.00	20.0000^{a} ±0.00	.0000^{a} ±0.00	.0867^{a} ±0.01	.0800^{b} ±0.02	.0267^{bc} ±0.02	.0033^{a} ±0.01	7.6000^{bcd} ±0.92	5.3333^{a} ±0.58
AL-O	6.9667^{ab} ±0.06	20.0000^{a} ±0.00	20.0000^{a} ±0.00	.0000^{a} ±0.00	.1800^{a} ±0.02	.2300^{d} ±0.03	.0433^{bc} ±0.06	.0200^{ab} ±0.00	2.9600^{a} ±5.13	6.6667^{a} ±0.58
TH-N	7.4000^{c} ±0.20	20.0000^{a} ±0.00	20.0000^{a} ±0.00	.0000^{a} ±0.00	.0467^{a} ±0.01	.0000^{a} ±0.00	.0300^{bc} ±0.00	.0000^{a} ±0.00	7.7333^{bc} ±0.31	12.6667^{b}±0.58
TH-O	6.7333^{a} ±0.31	20.0000^{a} ±0.00	20.0000^{a} ±0.00	.0000^{a} ±0.00	.4033^{b} ±0.07	.0367^{ab} ±0.06	.0500^{ac} ±0.00	.0167^{ab} ±0.01	11.1333^{cd}±1.45	4.6667^{a} ±1.15
ABS	7.0000^{ab} ±0.20	33.3333^{b} ±11.55	20.0000^{a} ±0.00	13.3333^{b} ±11.55	.6467^{c} ±0.26	.1533^{c} ±0.03	.0233^{a} ±0.01	.0667^{a} ±0.06	12.5400^{d} ±2.16	10.6667^{b}±3.06
CONC	7.6667^{c} ±0.21	20.0000^{a} ±0.00	20.0000^{a} ±0.00	.0000^{a} ±0.00	.0000^{a} ±0.00	.0000^{a} ±0.00	.0000^{a} ±0.00	.0000^{a} ±0.00	11.2667^{cd}±2.93	7.0000^{a} ±1.73
CTR	7.4333^{c} ±0.06	20.0000^{a} ±0.00	20.0000^{a} ±.00	.0000^{a} ±0.00	.0000^{a} ±0.00	.0000^{a} ±0.00	.0000^{a} ±0.00	.0000^{a} ±0.00	6.4000^{ab} ±0.72	4.3333^{a} ±1.15

Values with Similar Superscript within the same Column are not significantly difference at p=0.05.

Table 4: Physical Parameters for the First Rain Event

PHYSICAL PARAMETERS

Table 5: Biological Parameters for the First Rain Event

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Rooftops	Turbidity (FTU)	Suspended Solid (mg/L	Colour (pt)	Temperature (°C)
ZN-N	1.3333^{a} ±.58	1.3333^{a} ±0.58	10.3333^{a} ±3.51	27.7667^{a} ±0.86
ZN-O	5.6667^{a} ±3.79	24.0000^{b} ±30.35	96.6667^{a} ±90.74	27.5333^{a} ±0.46
AL-N	$.0333^{a}$ ±0.58	$.0000^{a}$ ±0.00	$.0000^{a}$ ±0.00	26.3333^{a} ±0.58
AL-O	4.0000^{a} ±2.00	4.6667^{a} ±1.15	6.6667^{a} ±1.53	27.7667^{a} ±0.25
TH-N	66.6667^{c} ±2.52	71.3333^{c} ±1.53	274.0000^{c} ±22.54	26.7667^{a} ±0.25
TH-O	68.6667^{c}±5.13	18.0000^{ab} ±2.00	268.3333^{c} ±38.84	27.6000^{a} ±0.53
ABS	16.6667^{b}±7.57	1.8667^{a} ±1.63	51.6667^{ab} ±33.23	26.1667^{a} ±7.08
CONC	$.0000^{a}$ ±0.00	1.3333^{a} ±0.58	3.3333^{a} ±3.06	26.8667^{a} ±0.12
CTR	$.0000^{a}$ ±0.00	$.0000^{a}$ ±0.00	$.0000^{a}$ ±0.00	25.5000^{a} ±0.50

Rooftops	BIOLOGICAL PARAMETER
	Total Coliform (Per 100ml)
ZN-N	$.3333^{ab}$ ±0.58
ZN-O	2.3333^{bc} ±0.58
AL-N	$.0000^{a}$ ±0.00
AL-O	6.3333^{d} ±1.15
TH-N	10.3333^{e} ±1.53
TH-O	7.0000^{d} ±2.00
ABS	3.3333^{c} ±1.15
CONC	2.3333^{bc} ±1.53
CTR	$.0000^{a}$ ±0.00

Values with Similar Superscript within the same Column are not significantly difference at p=0.05.

Table 6: Chemical Parameters for the Second Rain Event

Rooftops	CHEMICAL PARAMETERS									
	PH 7.43 – 8.92	Hardness 20 – 40	Ca 0-20	Mg 0-20	ZN 0.00 – 3.75	AL 0 – 0.32)	Fe **0-0.08**	Cr 0 – 0.07	NO_3 0.0 – 12.56	SO_4 6.35 – 14.68
ZN-N	7.80	20.00	20.00	00.00	00.65	00.12	00.05	00.00	00.07	08.00
ZN-O	7.88	40.00	20.00	20.00	03.75	00.23	00.08	00.05	16.86	12.00
AL-N	7.93	20.00	20.00	00.00	00.17	00.10	00.02	0.003	07.62	07.35
AL-O	7.67	20.00	20.00	00.00	00.26	00.32	00.03	00.02	08.75	08.69
TH-N	8.40	20.00	20.00	00.00	0.06	00.02	00.02	00.00	07.75	14.68
TH-O	8.92	40.00	20.00	20.00	00.52	00.06	00.04	00.02	11.15	06.68
ABS	7.43	40.00	20.00	20.00	00.73	00.23	00.01	00.07	12.56	12.68
CONC	7.83	20.00	20.00	00.00	00.00	00.00	00.00	00.00	06.42	06.35
CTR	7.52	20.00	20.00	00.00	00.00	00.00	00.00	00.00	05.82	05.37

Table 7: Chemical Parameters for the Third Rain Event

Rooftops	CHEMICAL PARAMETERS									
	PH 6.83 – 7.83	Hardness 20 – 40	Ca 0-20	Mg 00-20.00	ZN 0.00 – 2.94	AL 0 – 0.53	Fe **0-0.10**	Cr 0 – 0.08	NO_3 0.0 – 18.88	SO_4 4.33 – 16.67
ZN-N	7.20	20.00	20.00	00.00	00.77	00.08	00.04	00.00	00.05	08.00
ZN-O	7.00	26.67	20.00	06.67	02.94	00.25	00.10	00.06	18.88	12.00
AL-N	7.83	20.00	20.00	00.00	00.09	00.08	00.03	0.003	07.60	07.33
AL-O	7.27	20.00	20.00	00.00	00.38	00.53	00.05	00.03	08.73	06.67
TH-N	7.60	20.00	20.00	00.00	0.09	00.00	00.03	00.00	07.73	16.67
TH-O	6.83	20.00	20.00	00.00	00.20	00.04	00.05	00.02	12.15	06.67
ABS	7.30	40.00	20.00	20.00	00.65	00.15	00.02	00.08	14.59	10.67
CONC	7.63	20.00	20.00	00.00	00.00	00.00	00.00	00.00	06.40	06.33
CTR	7.48	20.00	20.00	00.00	00.00	00.00	00.00	00.00	06.40	06.33

Table 8: Physical Parameters for the Second Rain Event

Rooftops	PHYSICAL PARAMETERS			
	Turbidity (FTU) 00.00 –68.67	**Suspended Solid (mg/L)** 01.33 – 71.33	**Colour (pt)** 0 – 274.00	**Temperature (^oC)** 26.17 – 27.77
ZN-N	01.33	01.33	10.33	27.77
ZN-O	05.67	24.00	96.67	27.53
AL-N	00.03	00.00	00.00	26.33
AL-O	04.00	04.67	06.67	27.77
TH-N	66.67	71.33	274.00	26.77
TH-O	68.67	18.00	268.33	27.60
ABS	16.67	01.87	51.67	26.17
CONC	00.00	01.33	03.33	26.88
CTR	00.00	00.00	00.00	25.50

Table 9: Physical Parameters for the Third Rain Event

Rooftops	PHYSICAL PARAMETERS			
	Turbidity (FTU) 00.00 – 67.00	**Suspended Solid (mg/L)** 01.00 – 73.00	**Colour (pt)** 0 – 260.00	**Temperature (^oC)** 26.17 – 27.77
ZN-N	02.00	01.00	07.00	27.60
ZN-O	03.00	59.00	200.00	27.80
AL-N	00.00	00.00	00.00	27.52
AL-O	02.00	06.00	07.00	28.00
TH-N	67.00	73.00	260.00	27.00
TH-O	63.00	18.00	225	28.00
ABS	08.00	00.00	34.00	30.50
CONC	00.00	01.00	34.00	26.80
CTR	00.00	00.00	00.00	25.00

Table 10: Biological Parameters for the Second and Third Rain Event

Rooftops	Second Rain Event	Third Rain Event
	BIOLOGICAL PARAMETER 0 – 10.36 Total Coliform (Per 100ml)	BIOLOGICAL PARAMETER 0 – 10.36 Total Coliform (Per 100ml)
ZN-N	01.00	01.20
ZN-O	02.00	04.02
AL-N	00.00	00.00
AL-O	07.00	08.2
TH-N	10.00	10.36
TH-O	06.00	10.02
ABS	04.00	05.34
CONC	03.00	03.63
CTR	00.00	00.00

DISCUSSION

Colour (pt):

The colour of rain water samples harvested from the different rooftops for all three rain events ranged from (0 – 284.05) pt colour as shown in Tables4,8,&9). Table 4 illustrates colour trends for the first rain event, which shows that rainwater harvested from most of the rooftops had colour values that meet WHO standard for drinking water (5pt colour).Statistical analysis in table 4. also reveal that there's a significant difference between the colour of rainwater from the various rooftops. While rainwater from old thatch rooftop was the most coloured(247 pt colour),rainwater from the new aluminum rooftop was the least coloured (0.000 pt colour).This table also shows that all the rooftops(except old and new thatch rooftop) delivered rainwater samples that were similarly colourless, hence meeting WHO standards. Only old and new thatch rooftops delivered badly coloured rainwater.

A similar study by Uba and Aghogho(2000) also shows that Asbestos and thatch materials caused an increase in colour of the rainwater. Colour is caused by dissolved or suspended colloidal particles from decaying leaves or microscopic plants and this tend to give the water a brownish-yellow hue (REF) This explains why(from physical Observation), rainwater samples harvested from both old/new Thatch rooftops were slightly yellow while all rainwater samples from old/new Zinc, Aluminum, Asbestos and Concrete rooftops were colourless.

Turbidity (FTU) :

The turbidity of rainwater samples from the different rooftops for all three rain events ranged from (0.00 – 70.69) FTU as shown in tables 4,8&9.This range compare sufficiently with the (4 to 94) NTU (or FTU) reported in Yaziz et al. (1989). Table 4 illustrates turbidity trends for the first rain event, which shows that rainwater harvested from some of the rooftops had turbidity values that did not meet WHO standard for drinking water (5 FTU).Statistical analysis in table 4 also reveal that there's a significant difference between the turbidity of rainwater from the various rooftops. While rainwater from old thatch rooftop was the most turbid(68.6667 FTU),rainwater from the new aluminum rooftop was the least turbid (0.000 FTU).This table also shows that all the rooftops(except asbestos, old and new thatch rooftop) delivered rainwater samples that were similarly clear, hence meeting WHO standards. Only old and new thatch rooftops delivered badly cloudy rainwater.

Turbidity is caused by small particles suspended in water such as clay, silt, organic matter that tends to scatter and absorb light rays in water and give it a mucky appearance, this is the reason why it is higher in old/new thatch rooftop.

Total Suspended Solids (TSS):

The Suspended Solid for the rainwater from the different rooftops ranged from (01.33 to 74.35) mg/L as shown in tables 4,8&9. This range compares with the (53 to 276) mg/L reported in Yaziz et al. (1989). It also corresponds to the quality data range of (13 to 120) mg/L reviewed by Farreny et al.,(2011). Table 4 which illustrates TSS trends for the first rain event shows that rainwater harvested from some of the rooftops had TSS values that did not meet WHO standards for drinking water (50 mg/L).Statistical analysis in the same table reveal that there's a significant difference between the TSS of rainwater from the various rooftops. While rainwater from new thatch rooftop had the highest amount of suspension (71.333mg/L),rainwater from the new zinc rooftop contained the lowest amount of suspension (1.333mg/L).This table also shows that all the rooftops(except old zinc and new thatch rooftop) delivered rainwater samples with similarly low amounts of suspension, hence meeting WHO standards. Only old zinc and new thatch rooftops delivered rainwater with high amounts of suspension.

TSS values for rainwater harvested from new thatch roofs were among the highest because of the presence of suspended particles which it usually shed in large amounts. Old zinc rooftop (which is actually zinc galvanized iron rooftop) also caught rainwater that had high TSS values because of the presence of suspended corrosion particles converged by the rainwater (Ariyananda, 2005)

Temperature (^{o}C) :

The temperature of rainwater samples harvested from the different rooftops for all three rain events falls between (26.17 – 27.77) ^{o}C as shown in tables 4,8&9. This range is within WHO standard for drinking water. Table 4 illustrates variations in temperature for the first rain event, and shows that rainwater harvested from all the rooftops had WHO compliant temperature values. Statistical analysis in table 4 also reveals that there's no significant difference in the temperature of collected rainwater samples for all the rooftops. Rainwater water samples from new zinc and new thatch rooftop were hottest.(27.7666),while that from old thatch rooftop was coolest (26.000).This table also shows that all the rooftops delivered rainwater samples that were similarly hot, hence meeting WHO standards. The slight differences in temperature between the various rooftops are caused by variations in their abilities to absorb ambient and radiated solar heat (Kennedy, 2002).

BIOLOGICAL VARIABLES

For all the rooftops, TC (total coli form) concentrations of water samples ranged from (0.00 to 10.67) CFU/100mL for all three rain events (See tables5&10). This range is sufficiently comparable to that reported by Tobin *et.al*, (2013): a mean TC count of 12.7 ± 32.0 CFU/100mL. Table 5 illustrates variations in TC (total coli form) contamination for the first rain event, and shows that no rainwater sample harvested from any of the rooftops under study had WHO or NAFDAC compliant TC values. Statistical analysis in table 5 reveal that there's a significant difference in the effects of the various rooftops: While rainwater from new thatch rooftop was the most contaminated (10.333 per 100 ml), rainwater from the new aluminum rooftop was the least contaminated (0.000 per 100 ml).This table also shows that new zinc and new aluminum had the similarly least contamination. This behaviour of new aluminum rooftop confirms a similar observation by Olaoye and Olaniyan(2012) Also, The new aluminum and zinc roofs clearly differ in effect from the old aluminum and thatch rooftops. It also clearly shows that no rainwater harvested from any of the rooftops under study had WHO or NAFDAC compliant TC values. The ease of accumulation of dust and microbial particles on rooftops explains this.

CHEMICAL PARAMETERS

pH:

The pH values in rainwater harvested from the various rooftops range from 6.73 to 8.92 for all three rain events, as shown in tables 3, 6&7.These values are in agreement with those reported by Mendez *et al*.,(2010) and Yaziz *et al*.,(1989). Table 3 illustrates pH trends for the first rain event, and shows that rainwater harvested from most of the rooftops had pH values that meet the NAFDAC standard for drinking water (6.5 – 8.5). Statistical analysis in table 3 reveal that there's a significant difference in the effect of the various rooftops on the pH of rainwater: While concrete rooftop delivered a water sample of the highest pH (7.666), old thatch rooftop delivered a water sample of the lowest pH (6.733).This table also shows that all new rooftops including concrete delivered water samples of low alkalinity (similarly high pH).But all the old rooftops delivered water samples of low acidity (similarly low pH). From the results, none of the pH values was strongly acidic or strongly alkaline. They all fall between the very weak acid, neutral and weak alkaline levels. This approximate pH neutrality indicates that the age of a rooftop does not greatly affect the pH of rainwater harvested from them. Instead, Chester *et.al* (1997) named atmospheric chemicals (aerosols) naturally emitted from the earth as major determinants of rainwater pH.

Nitrate (NO_3):

The concentration of Nitrate in rainwater harvested from the various rooftops in all three rain events has a range of (0.00-18.88) mg/L NO_3--N (Compare tables 3,6&7). Case study roofs appraised by Farreni *et al*.,(2011) reported a range of (0.01-9.34) mg/L NO_3--N which adequately agrees with this range. Also, the range we reported does not meet the WHO standard of 3mg/L $NO_{3.}$ Table 3 which describes only the first rain event, also confirms this. Statistical analysis in table 3 reveal that there's a significant difference in the effect of the various rooftops on rainwater: While old zinc rooftop delivered water samples of the highest nitrate concentration (16.8367mg/L), old aluminum rooftop delivered a water sample of the lowest nitrate concentration (2.96mg/L).The nitrate concentration of rainwater samples from both the old aluminum rooftop and the control sample are similar.

Total Hardness (mg/L):

The Total hardness and calcium hardness values for the harvested rainwater from the various rooftops for the three rain events ranges from (20.00 – 40.00) mg/L as tables 3,6&7 shows, and they all fall within the class of soft water. Table 3 which describes hardness trends for only the first rain event, also confirms this. Statistical analysis in table 3 reveal that there's a significant difference in the effect of the various rooftops on the hardness of rainwater: While asbestos rooftop caused the most hardness on water samples, all other rooftops caused similarly low hardness on them. Asbestos rooftop mostly comprises Magnesium -a compound that can convert to hardness elements like Mg_2OH and $Mg(HCO_3)_2$ on exposure to Rainwater components like CO2 and water. Viani and Gualtieri(2014) even described a thermal method of harvesting Magnesium oxide from asbestos wastes.

Iron (mg/L):

The iron concentration in the harvested rainwater from the various rooftops for the three rain events ranges from (0.00-0.10) mg/L as Tables 3,6&7 shows. This compares to the average of 0.1937mg/L reported by Mendez et al., (2010) for pilot scale rooftops. This range falls within the WHO and NAFDAC standard (5 mg/L) for drinking water. Table 3 which describes only the first rain event, also confirms this. Statistical analysis in table 3 reveal that there's a significant difference in the effect of the various rooftops on the iron concentration of rainwater samples: While old zinc rooftop delivered water samples of the highest iron concentration(0.0867mg/L), concrete rooftop delivered a water sample of the lowest iron concentration(0.000mg/L).All tested rooftops except old zinc ,asbestos and concrete rooftops caused similarly negligible amounts of iron contamination in rainwater samples while asbestos and concrete rooftops caused similarly higher iron contamination. The high iron contamination from old zinc (actually zinc coated galvanized iron) rooftop is not surprising: as this rooftop ages, corrosion of the inner iron layer is increased allowing rooftop runoff to leach iron contaminants into collected rainwater. Veleva et.al (2009) says that corrosion is accelerated with the partial removal of the corrosion layer during the runoff phenomena.

Sulfate (mg/L):

The concentration of sulfate for rainwater harvested from different rooftops for the three rain events ranges from (4.33 – 16.67) mg/L as tables 3,6&7 shows. This is closely similar to the range of (0.00-11.5)mg/L reported by Farreni *et al*.,(2011) for case study roofs. This range shows that the entire values fall within WHO and NAFDAC standard of 200mg/L. Table 3 which describes only the first rain event, also confirms this. Statistical analysis in table 3 also reveal that there's a significant difference in the effect of the various rooftops on the sulfate concentrations of delivered rainwater: While new thatch rooftop delivered water samples of the highest sulfate concentration (12.6667mg/L), old thatch rooftop delivered a water sample of the lowest sulfate concentration (4.6667mg/L). All rooftops except new thatch, old zinc and asbestos rooftops caused similarly high sulfate contamination on delivered rainwater samples. But old zinc new thatch, and asbestos rooftop caused similarly low sulfate concentrations. The high sulphate contamination of rainwater harvested from New thatch may be due to the suphate content of the preservatives used in treating the thatched rooftop. Nolan et al(2015) noted that thatch is regularly treated with a copper sulphate solution, known as 'bluestone' which deters the growth of moss and algae

Chromium (mg/L):

Tables 3,6&7 shows that the concentration of chromium (hexavalent) in rainwater samples harvested from the various rooftops for all three rain events ranges from (0 – 0.08) mg/L .Interestingly, Pitt *et al*.,(1995) recorded an average of 0.085mg/L for Assortment roof. Describing the first rain event, table 3 shows a range of (0.00-0.07)mg/L which is close to the WHO standard of 0.05mg/L Statistical analysis in this table also reveal that there's a significant difference in the effect of the various rooftops on the chromium level of harvested rainwater: While asbestos rooftop delivered a water sample of the highest chromium concentration (0.007mg/L), concrete and new zinc rooftop delivered a water sample of the lowest chromium concentration (0.000mg/L).It also shows that old thatch and old aluminum rooftops can similarly affect the chromium level of harvested rainwater. The high chromium contamination from the asbestos rooftop is due to its high chromium content: The concentration of As and Cr in Italian asbestos were considerably high in a variant of asbestos studied by Teherani (1985)

Zinc (mg/L):

Tables 3,6&7 shows that the concentration of zinc in rainwater samples harvested from the various rooftops for all three rain events ranges from (0.00 – 3.75) mg/L. Chang *et al.*, (2004) reported a value of 0.297mg/L for rainwater collected from New anodized aluminum rooftop, a value which falls within our range. Our range also shows that all recorded values were within the WHO and NAFDAC standard of 5.0 mg/L. Table 3 describes the roof wise trend in zinc concentrations for the first rain event also indicates a range that confirms this. Statistical analysis in table 3 also reveal that there's a significant difference in the effect of the various rooftops on the zinc concentration of rainwater: While old zinc rooftop delivered a water sample of the highest zinc contamination.(2.7666mg/L), concrete rooftop delivered a water sample of the lowest zinc concentration(0.000mg/L).This table also shows that aluminum rooftops(old and new), new thatch and concrete rooftops had similarly low effects on zinc concentration of water samples. But new zinc and asbestos rooftops caused similarly higher zinc contamination of water samples. However, old zinc rooftop caused the highest zinc contamination. Old zinc rooftop caused the highest zinc contamination because of corrosion induced leaching. Veleva et.al (2009) developed an exponential equation that describes zinc mass loss induced by runoff process as a function of the time of wetness.

Aluminum (mg/L):

The aluminum concentrations in rainwater harvested from the various rooftops range from (0.00 – 0.53) mg/L for all three rain events, as shown in tables 3,6&7. All of them fall within the WHO standard for drinking water (0.5mg/L).This range compares with the (0.354-0.435)mg/L reported by Chang *et al*.,(2004) for rainwater harvested from three different rooftops (Composition shingle, galvanized iron, and aluminum rooftops). Table 3 describes aluminum concentration patterns for various rooftops for the first rain event also agrees with the overall range. Statistical analysis in table 3 also reveal that there’s a significant difference in the effect of the various rooftops on the hardness of rainwater: While old aluminum rooftop caused the most aluminum contamination on water samples, concrete and new thatch rooftops caused no contamination. Old and new thatch rooftops and concrete rooftop caused the similarly least aluminum contamination. Chang et al(2004) discovered that more metals leach from older rooftops than the new ones

SUMMARY AND CONCLUSION

Despite historical efforts at improving rooftop harvested rainwater, quality which is one of its important aspects has yet to be completely tamed. Nine frequently used rooftop types were examined for harvested rainwater quality using standard methods in three rain events that subtracted the First flush effect. Results indicated that none of all nine rooftops could deliver completely portable water. Apart from New Aluminum rooftop, all other rooftop types examined in the study caught rainwater that flouted portability standards. This indicates that rainwater harvested from all locally available rooftops under study (except New Aluminum) can cause or predispose consumers to health problems.

Secondly, the data from this study (which considers the extent of rooftop rainwater contamination from common rooftops in Makurdi) differs considerably from those of other non -indigenous studies. This information will help in the design of better water treatment processes/standards that match the unique contamination profile of locally harvested rooftop rainwater in Makurdi, Benue State.

We strongly recommend the consumption of rainwater harvested from New Aluminum rooftop if it is treated for coli form contamination.

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