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Rainwater Quality Index of Selected Communities in Langtang North and South Local Government Areas, Plateau State North-Central Nigeria

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Abstract: This study examines the portability of rainwater in Langtang north and south LGAs of Plateau State-Nigeria using arithmetic water quality index method with 10 samples collected directly from zinc and aluminum rooftops in 10 selected communities. Twenty-six water quality parameters were analyzed in the field and laboratory. Temperature, pH, EC, TDS and turbidity were analyzed in the field using appropriate equipment as well as color, odour and taste. The most probable number was used to determine the presence of bacteria, while photometric and the Atomic Absorption Spectrophotometer (AAS) were used to determine the concentration of the various chemical parameters (USEPA, 2012). The results revealed unobjectionable taste, color and odour, temperature (26.8-27.5), pH (6.5-7.8), Turbidity (1.8-2.7), Conductivity (20-30), TDS (10-15), $Caco_3$ (5-10), Ca (2-8), Mg (1-4), SO_4 (1-7), NO_3 (1.3-8.6), Fe (0.01-0.15), Cl (10-32), F (0.001-0.002), Cu (0.01-0.2), Zn (0-1.5), Mn (0-0.02), Cr (0-0.01), Al (0.01-0.06), and total coliform (0-4). Cadmium, Arsenic, Lead, phenols, pesticides, faecal coliform and e-coli were not detected. All parameters tested were within acceptable limits for drinking water. While aluminium catchments do not show any difference in parameter concentrations, zinc catchment revealed increase in Zn concentration with age of materials. Calculated water quality index of samples ranged from 2 to 12 with an overall value of 4.7 indicating excellent water quality for all samples. Based on these results, the paper concludes that the rainwater is of good quality suitable for drinking. However, age of catchment materials may influence rainwater quality in due course through leaching, and therefore recommended regular maintenance of catchments, observance of first flush and avoid use of old roof for RWH.

Keywords: Water Quality Monitoring, Drinking Water Safety, WQI, Roof Catchment

1. Introduction

The role play by fresh water for the existence of living organisms cannot be over emphasized. Gleick; "[1] has maintained that Safe drinking water is a human birth right", but fresh water is increasingly being threatened as human populations grow and demand for more high quality water also increases. The UN observed that 2.5 billion of the world population does not have access to adequate safe drinking water [2]. The Sub-Saharan Africa according to Falkinmark accounts for 40% global population without access to safe

drinking water [3]. The only public water supply scheme in the study area, the Langtang Water Board Commissioned in 1983, stopped functioning in 2012 due to faulty equipment and residence access water from sources such as dams, ponds, streams, dug-wells and boreholes. Gongden and Lohdip noted frequent drought and changing climatic pattern have led to seasonality of stream flow, drying of dams and reduction in groundwater yield that result in occasional scarcity [4], while increasing population has exacerbated the water shortages. Therefore, most residents undertake rainwater harvesting (RWH), an ancient practice of capturing

and storing rainwater for later use to augment other sources. Dellman et al has argued that the management of RWH is flexible and sustainable as simple inexpensive technologies that are easy to maintain are mostly used, and it is considered one of the cleanest source of water [5]. Besides, the gradual shift from the traditional thatched houses to the use of modern roofing materials such as zinc and aluminum sheets which facilitate rainwater collection also encourage increase of RWH in Langtang, but how safe is the water for man consumption since contaminants within the collection system can affect its quality? This cannot be answered without adequate data which is currently not available. Therefore, the objective of this study is to analyze rainwater quality of the study area to determine its suitability for human consumption in line with acceptable standard. This is because the quality of any water body according to Saidu et al is never known by mare look with the naked eye except through analysis with appropriate instrument [6].

2. Literature Review

Rainwater is usually of high quality when falling from the sky, but when it get near the earth it comes into contact with different surfaces such as buildings, trees, grasses, roadways, water bodies, parking lots and atmospheric gases among others. Therefore, the quality of rainwater as observed by Aladenola and Adeboye, largely depends on geographic location, catchment characteristics, atmospheric gases, land use practices, local climate, and storage materials [7]. Environmental factors like pollutants from atmosphere, roadways, and wind-blown objects can affect rainwater quality negatively. Besides, Amponsah et al, noted combustion of fuels for energy generation, transportation, heating for industrial needs, wind-blown soils from arid and agricultural regions, volatilization from agriculture and poor waste disposal can also affect rainwater [8]. Nangbes et al as well as Chukwuma et la, found high ammonium and acidic rainwater due to release of hazardous gases in atmosphere from vehicular traffic, local urban and industrial emissions [9-11]. Also, Jamal et al and Zhang et al found high arsenic and mercury in rainwater of urban and industrialized areas from impurities absorbed in the atmosphere, and pesticides, Aromatic polycyclic hydrocarbons (PAHs) [12, 13]. Differences in climate and human activities can create variation in rainwater quality from one location to another. Emerole and Emerole had statistically significant difference in SO4, turbidity, PO4, Cr, Cd, Pb, NO_3, carbonate and pH to climatic differences [14], while Godwin reported similar result for Cd, Ni, Fe, Cr, and low pH to environmental differences [15].

Rooftop catchment according Uzomaka, can provide good quality rainwater, clean enough for drinking as long as the rooftop is clean, impervious and made from non-toxic materials [16]. However, contaminants can be introduced in rainwater either through washing-off of contaminants collected on catchments between rain events such as leaves and pollen from plants, fecal droppings from animals like birds, squirrels and insects or leaching of chemicals and/or metals from the catchment material. Heavy metals like Cd, Zn, Cu, Pb, As, Ni and Cr have been detected in rainwater collected from rooftops due to phenomenon of acid rain according to Uzomaka et al, and Basak and Algha, causes chemical leaching of roof materials with five times solubility in some cases under acidic conditions than neutral in Istanbul, Lagos, New Zeeland and Ghana [16-19]. Therefore, one way of ensuring better rainwater quality is avoiding roof materials such as copper, aged and materials coated with metals and/or treated with fungicides that may release contaminants into the collection system.

Studies by Simmons et al, Bello and Nike, and Rahman et al have reported microbial pollution of rainwater with Fecal coliform, Total coliform, E-coli, Salmonella spp, Enterococcus spp, Giardia lambia, Pseudomonas spp and Cryptosporidium in both urban and rural areas [20, 21, 17]. Roof runoff: "[16; 6; 19] is also affected by roof orientation to sunlight, wind direction, Land use, and rainfall intensity and quantity. The extents to which roofing materials affect rainwater quality vary. Studies; "[22 & 23] found Alluminum rooftops with better rainwater quality to corrugated plastics, asbestos, concretes and corrugated iron sheet. Similarly, "[18; 13] wooden shingle had better quality than cotta clay roof, zinc and galvanized roofs, while ceramic tiles better than concrete, asphalt, and green roofs".

Like catchments, storage media also leached contaminants in stored rainwater which vary from one material to another. Significant variation in pH, EC, TDS, biological parameters, and some metals was reported in metal, plastic and concrete tanks with plastics tanks having highest microbial contamination due to low pH [24]. Elevated levels; "[25;26] of chemical parameters due to leaching from storage tanks as well as biological parameters above limits have been reported. Researches have proved that rainwater quality can be improved by point-of-use treatment, integration of water safety plans, utilization of weather-resistant materials like ceramic tiles as catchment, regular maintenance of catchment [13, 18]. First-flush diversion which several gallons of rooftop runoff are allowed to washed dirt before collection and regular maintenance of storage tanks can significantly assist to ensure better rainwater quality.

3. Material and Methods

3.1. The Study Area

Langtang North and South Local Government Areas (LGAs) often called Langtang area, is located in the lowland part of Plateau State about 200km south of Jos the State capital, and falls within latitudes 8020'00"and 9040'00" north and longitudes 9030'00" and 10010'00" east. It has land mass of 1,626 sqkm and share boundaries with Kanke, Kanam, Pankshin, Mikang, Shendam LGAs as well as Nassarawa and Taraba States (Figure 1). The area has sub-humid climate like the neighboring Nassarawa and Taraba States due to similarities in elevation with mean low and high temperature

of 260C and 300C respectively. The lowest temperature is recorded between December and January, when the dry Harmattan wind from the Sahara Desert dominates the climate scene, and peak of rainy season in August and September. However, in March and April when the south west trades wind approaches from the south, the north easterly weakens, and both temperature and relative humidity rises. Average monthly and annual relative humidity ranges between 20 and 28 with March and April as the hottest months. Mean high and low monthly rainfall range between

5mm and 50mm, while Mean annual rainfall in the area is between 165 and 322. The highest rainfall of 400mm is recorded in August and July with 322, while March, April and November have lowest rainfall with annual record of 11.36mm, 29.98mm and 11.62mm respectively. The annual total rainfall of the area ranges between 1000mm to 2000mm. Early and late onset of rain is March and early May respectively, while cessation of rains are early October and middle of November in that order.
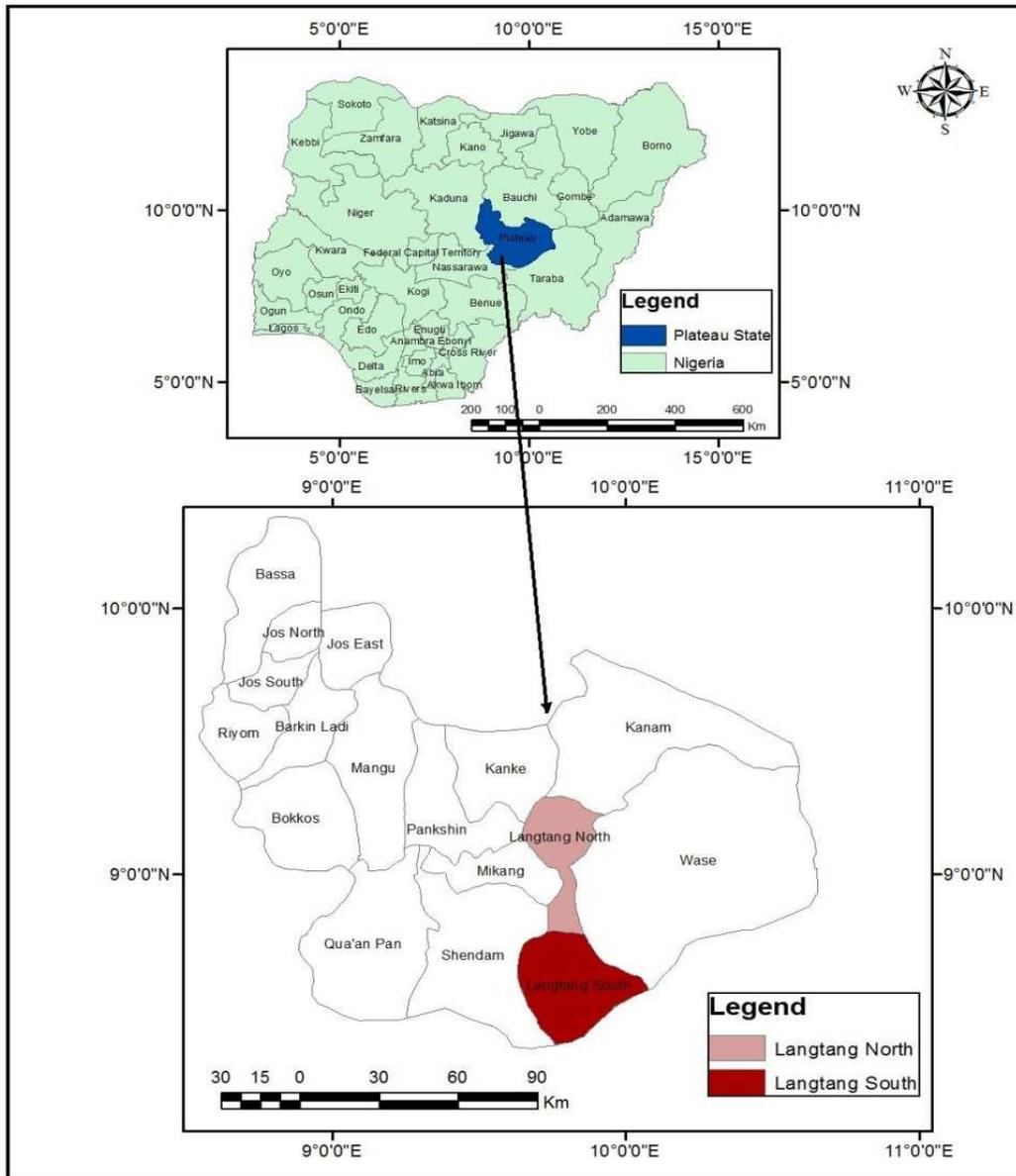

Figure 1. *Plateau State; Study Area (Insert Nigeria and Plateau).*

The relief is composed of uplands and lowlands created by interplay of tectonic elevation and erosion now intensified by deforestation and deep differential chemical weathering of rocks [28]. The uplands at the extreme north-west with average elevation of 500 amsl are composed of hills, mountains, and undulating terrains. The lowland from middle Langtang north to the whole of Langtang south has average

elevation of 150 amsl, characterized by plain land with pockets of outcrops of basement complex rocks and isolated hills. Major drainages in the area are rivers Wase and Shemankar and their tributiers such as Pil-Gani, Bapkwai, Zamko etc with dentritic pattern. Located within guinea savannah zone of Nigeria, the original vegetation characterized by tall trees inter-spaced with tall grasses has

been replaced by a grassy savannah with occasional shrubs due to man interference through land clearance and burning for farming, firewood and grazing. This resulted in regrown vegetation at various levels but the original woodland vegetation (gallery forest) is still found along major streams. Most trees are deciduous, examples include; Shea butter, locust bean, isoberlina, and baobab. Land use in the area is dominated by crop cultivation in line with the occupation of over 80% of people, followed by livestock grazing and settlements. Farming method is mainly non-mechanized, and major crops are; maize, guinea corn, millet, rice, groundnut, soya beans, hot and sweet pepper.

Langtang is the home of Tarok ethnic group who constitutes over 90%, but other ethnic groups like Bogghom, Gomei, Gargaye, Tal among others are found in smaller numbers. Residents are predominantly peasant farmers with few combining farming with trading, public service, blacksmithing, hunting, carving, basketry, pottery, weaving, and animal husbandry. Settlements are mainly rural in nature with dispersed pattern and few nucleated. Aerial distribution of the settlements is strongly controlled by security, presence of arable land and water availability. There is no public water supply scheme in the entire study area. Domestic water needs are obtained from dug wells, boreholes, streams, ponds, dams and lakes. Due to poor lithology, most groundwater sources have low yield while some the surface either dry off completely the witness significant reduction in volume during dry season. Hence, there is annual circle of severe water scarcity during dry season and drought period in the area leading to low access to water. Women and the girl child spend a better part of the day in search of water in most rural communities during dry season, the situation has reached a point where girls find it difficult to accept marriage proposals from communities with worst cases, owing to the fact that they may spend most parts of their lives looking for water (Mr Dandam Gyemkum, personal Communication, 20th April 2018). Rainwater harvesting is undertaken to augment domestic water supply sources.

3.2. Sample Collection and Laboratory Tests

Two days reconnaissance to get acquainted with the settings of the area such as terrain, road networks, settlement distributions and rainwater catchments which aided adequate gathering of equipment and planning of route for the main field work was undertaken. Three community key informants were identified and engaged in this survey. The informants facilitated the conduct of the preliminary survey through provision of relevant information, guides, movements and arrangement of meetings with stakeholders for permission.

Ten rainwater samples, five each from zinc and aluminium rooftops were collected in 10 selected communities of Pil-Gani, Gazum, Batkilang, Bapkwai, Zamko, Mabudi, Nassarawa, Magama, Faya and Barrack. Purposely sampling method was used to ensure spread with five communities in each of the LGAs under study. Samples were collected directly into 1000ml plastics containers previously cleaned with dilute acid solution and rinsed with distilled water during rains from 7th to 12th September, 2018. Samples were acidified with 5ml Nitric acid (HNO_3), stored in cooler with ice packs and transported to laboratory. This was to preserve the samples and keep the ions in solution, prevent their adsorption and precipitation in solution as well as bacterial growth. Labile parameters such as pH, turbidity, temperature EC and TDS were determined in the field with the aid of hand held digital pH, Turbidity meter (Phep 98201), EC/TDS meter (Medfab 190), and a digital thermometer (CE 0434) for temperature. Field testing; "[29] of labile variables is essential if precise measurements of natural conditions are desired. Standard methods; "[30] the most probable number (MPN) approach was used to test for bacteria, while photometric and atomic absorption spectrophotometer (AAS) methods were used in analyzing the chemical parameters".

3.3. Statistical Analysis of Data

Result of laboratory tests were further subjected to numerical analysis using the water quality index (WQI). The WQI, "[31] is a unit-less number that expresses overall water quality at a certain location and time based on several water quality parameters for a specific and intended use of water". In other word, it is a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of a water body, and this concept is useful in knowing the degree of water contamination at a particular period as well as comparing water quality across sources or location and time. The WQI evaluation is for human consumption hence, "permissible limit for the drinking water is 100 [32]". Therefore, WQI value greater than 100 is unfit for drinking, and Nigerian Standard for Drinking Water Quality 2015 was used as the benchmark. The weighted arithmetic water quality index method (WAWQIM); "[32] for easy of computation and understanding of results even by non-experts, flexibility in parameter selection and the most widely used method in developing countries where instrument of data collection is not robust enough for application of Delphi method" was use for index calculation.

$$\text{Viz: WQI} = \sum q_i w_i / \sum w_i = \sum \left(\left(\frac{1}{w_i} \right) \times \left(\frac{c_i}{s_i} \times 100 \right) \right) / \sum w_i \quad (1)$$

Where: C_i = Monitored value for every parameter, S_i = maximum allowable limit for each parameter (standard), q_i = quality rating for each parameter and w_i = relative weight of each parameter. The quality rating scale q_i of each parameter is determined by dividing the monitored value (C_i) by its respective standard S_i and the result multiplied by 100. Thus:

$$q_i = (C_i / S_i) \times 100 \quad (2)$$

The relative weight w_i is determined by a constant $k = 1$ inversely proportional to the standard S_i of the parameter ($w_i = 1/S_i$). Lastly, the sub-index of every parameter was obtained by multiplying the quality rating (q_i) by the relative weigh (w_i), and the final WQI for each sample and source was obtained by lineal aggregation of all the sub-index values divided by the aggregate weight.

4. Results and Discussion

4.1. Physio-chemical and Microbial Characteristics of Rainwater Samples

The physical parameters, colour, odour and taste were all unobjectionable, and pH, turbidity, conductivity and total dissolve solids were also within limits (Table 1). The normal pH of 6.5-7.5 is attributed to absent of industries, low vehicular traffic and other anthropogenic activities that releases pollutants in the atmosphere, while turbidity of 1.8-2.7mg/l, colour, odour and taste was due to the frequent rain that wash away all dirt on catchments. Temperature ranged from 26.8-27.5°C with mean of 27°C. Temperature of 15°C is more acceptable to consumers but higher temperature has no any health effect but can induce chemical reactions. Iron, an essential element in man nutrition and its deficiency causes goiter, ranged from 0.01 mg/l to 0.1mg/l with mean of 0.05mg/l. Iron; "[32] above 0.3 mg/l does not have negative health effect but can impact colouration and corrode fixtures". An essential constituent for strong bone and tooth formation is calcium which ranged from 2-8 mg/l, while magnesium ranged from 1-4 mg/l. Calcium and magnesium above 75 and 20mg/l respectively impact taste to drinking water. Nitrate ranged from 1.3-8.6 mg/l with mean of 3.6mg/l is within limit, while chloride is between 10 and 32mg/l with mean of 24. When above 250mg/l in drinking water chloride; "[33] impact salty taste and lead to rejection by consumers".

Fluoride concentration ranged from 0.001-0.002mg/l with mean of 0.001 mg/l. This is below the normal range of 0.05-1.5 mg/l for good health. Fluoride is beneficial; "[34] through reduction of dental decay and facilitation of proper bone development. However, deficiency or excess fluoride results in physiological disorders, skeletal and dental fluorosis". Fluoride; "[35;28] of up to 10 mg/l has been reported in groundwater in some parts of the study area due to hydrolysis of fluoride from fluoride occurring minerals in rocks by researchers". The low fluoride in rainwater can be to absent of anthropogenic activities like mining that exposes fluoride into atmosphere. Copper ranged from 0.01-0.1 mg/l with mean of 0.14mg/l while zinc varied from 0.0-0.15mg/l with an average of 0.37 mg/l. Increase in zinc concentration was observed in old zinc roofing materials similar to results of rainwater quality; "[3] of Minna Nigeria". Manganese ranged from 0.0-0.02mg/l with mean of 0.003mg/l. Manganese; "[37] above 0.2 mg/l causes undesirable taste and enhances bacterial growth". The concentrations of Cr and Al ranged from 0.01-0.01 mg/l and 0.01-0.06mg/l with average of 0.001 mg/l and 0.031 mg/l respectively which are all within limits.

Toxic metals like As, Pb and Cd were not detected just as pesticides and phenols. However; "[38] 3.0mg/l, 2.5mg/l and 2.0mg/l of As, Pb and Cd respectively have been reported in surface water of the area. The absence of these metals indicates less effect of domestic waste. Similarly, feacal coliform and e-coli were not detected while total coliform was within limit. This is attributed to the period of sample collection, first week of September when rainfall has peaked with high intensity and quantity. At such period, all dirt and animal droppings on catchments have been completely washed away in addition to the observance of first flush. This result is similar to study in; "[39] Tanzania but at variance with that in; "[40] Canada".

Table 1. Statistical summary of physio-chemical and bacteriological parameter.

Parameter	Min	Max	Mean	STD	Range	Variance	NSDWQ
Temp	26.8	27.5	27.0625	0.244584	0.7	0.059821	Amb
pH	6.5	7.8	7.13	0.416467	1.3	0.173444	8.5
Turbidity	1.8	2.7	2.73	1.026374	0.9	1.053444	5
Conductivity	20	30	26.1	10.69216	10	114.3222	1000
TDS	10	15	13.5	5.29675	5	28.05556	500
Hardness (caco$_3$)	5	10	6.5	1.95789	5	3.833333	150
Calcium Ca^{2+}	2	8	9.53	7.701955	6	59.32011	75
Magnesium Mg^{2+}	1	4	2.1	0.994429	3	0.988889	20
Sulphate, SO$_4^-$	1	7	3.82	3.375006	6	11.39067	100
Nitrate NO$_3^-$	1.3	8.6	3.64	3.112412	7.3	9.687111	50
Iron Fe^{2+}	0.01	0.15	0.048	0.047563	0.14	0.002262	0.3
Chloride Cl-	10	32	24	7.149204	22	51.11111	250
Fluoride F-	0.001	0.002	0.0013	0.000483	0.001	2.33E-07	1.5
Copper Cu^{2+}	0.01	0.2	0.143	0.218482	0.19	0.047734	1
Zinc Zn^{2+}	0	1.5	0.376	0.588221	1.5	0.346004	3
Manganese Mn$^+$	0	0.02	0.0034	0.005873	0.02	3.45E-05	0.2
Arsenic, As	0	0	0	0	0	0	0.01
Lead Pb$^+$	0	0	0	0.000422	0	1.78E-07	0.01
Aluminium Al$^+$	0.01	0.06	0.031	0.015239	0.05	0.000232	0.2
Chromium Cr$^+$	0.01	0.01	0.01	0.012867	0	0.000166	0.05
Cadmium Cd$^+$	0	0.00	0.000	0.000516	0	2.67E-07	0.003
Phenols	0	0	0	0	0	0	0.001
Pesticides	0	0	0	0	0	0	0.01
Total Coliform	0	4	1.1	1.523884	4	2.322222	10
Faecal Colifom	0	0	0	0	0	0	0
E–Coli	0	0	0	0	0	0	0

4.2. Water Quality Index

Index values of individual water sample (Table 2) ranged from 2 to 12 which show excellent water quality suitable for drinking. Besides, all biological parameters tested were within limits. Similarly, the overall calculated water quality index for the whole study (Table 3) is 4.7 also indicating excellent rainwater quality.

Table 2. *Water quality classification based on calculated WQI value.*

WQI Value	Category	Number of Sample	Percentage
<50	Excellent	10	100%
50-100	Good water	Nil	0%
100-200	Poor water	Nil	0%
200-300	Very poor water	Nil	0%
>300	Unsuitable for human	Nil	0%

Table 3. *Summary of Computed Rainwater Quality Index Values.*

Parameter	Mean (Ci)	NSDWQ (Si)	Ci/Si	qi	Wi	qiwi
pH	7.13	8.5	0.838824	83.88235	0.117647	9.868512
Turb	2.73	5	0.546	54.6	0.2	10.92
EC	26.1	1000	0.0261	2.61	0.001	0.00261
TDS	13.5	500	0.027	2.7	0.002	0.0054
Caco$_3$	6.5	150	0.043333	4.333333	0.006667	0.028889
Ca	9.53	75	0.127067	12.70667	0.013333	0.169422
Mg	2.1	20	0.105	10.5	0.05	0.525
SO$_4$	3.82	100	0.0382	3.82	0.01	0.0382
NO$_3$	3.64	50	0.0728	7.28	0.02	0.1456
Fe	0.048	0.3	0.16	16	3.333333	53.33333
Cl	24	250	0.096	9.6	0.004	0.0384
F	0.0013	1.5	0.000867	0.086667	0.666667	0.057778
Cu	0.143	1	0.143	14.3	1	14.3
Zn	0.376	3	0.125333	12.53333	0.333333	4.177778
Mn	0.0034	0.2	0.017	1.7	5	8.5
As	0	0.01	0	0	100	0
Pb	0.0002	0.01	0.02	2	100	200
Al	0.031	0.2	0.155	15.5	5	77.5
Cr	0.021	0.05	0.42	42	20	840
Cd	0.0006	0.003	0.2	20	333.3333	6666.667
Phen	0	0.001	0	0	1000	0
Pest	0	0.01	0	0	100	0
TC	1.1	10	0.11	11	0.1	1.1
					1669.191	7887.378

$$\text{WQI} = \frac{\sum qiwi}{\sum wi} = 7887.378/1669.191 = 4.7$$

4.3. Usability of the Rainwater for Human Consumption

Drinking water suitability is always measured by two criteria's viz: the water should be free from any substance that may pose health risk, while the taste, odour and color must also be acceptable to consumers. Thus, these criteria's must be met for any water body to be considered suitable for human consumption. The results of this study show both health and acceptability parameters analyzed were within acceptable limits. This implies that rainwater of the study area is safe and acceptable for residents consumption. The complete absence of industries, less vehicular traffic and other anthropogenic activities such as mining, excessive burning etc that may release hazardous gases into the atmosphere air and in turn pollute rainwater significantly contributed to low chemical and/or metal content of the rainwater samples. This result is similar; "[24] to a study in Zanzibar Island, Tanzania that found physio-chemical parameters of rainwater all within limits due to absence of environmental influence. But; "[9, 15] contrary to Jos and South-South region of Nigeria."

Similarly, non-leaching of catchment materials and period of sample collection is observed to have contributed positively in having good rainwater quality. The non-leaching of catchments is due to non-coating of the materials with toxic metals, new age of most catchment materials, climate of the area and non-acidic nature of rainwater. This result is similar to "Ibadan Metropolis with suitable water for drinking due to absence of leaching of roof materials...[41]" but contrary; "[22] to that of Enugu". The good bacteriological quality of the rainwater to the period of sample collection, first week of September when rainfall had peaked with high intensity and quantity. At such period, all dirt on catchment is been completely washed away and the rainfall frequency does not allow any time lapse between rain events for dirt to accumulate on the catchments. Moreover, the observance of first flush also assisted in washing dirt may have gathered on catchments which are also similar to results

of studies in; "Tanzania and Canada [39, 40]".

5. Conclusion and Recommendations

The study identified zinc and aluminium rooftops as the major catchments for rainwater harvesting in the study area. All biological parameters tested were within acceptable limits and 100% samples have excellent water quality index. The overall WQI is 4.7 also indicating excellent rainwater quality. Parameters like colour, odour and taste which are not included in index determination show unobjectionable results. Therefore, the study concluded that rainwater of the study area is suitable for human consumption.

The absence of industries and mining sites in the area, none leaching of catchment materials, the time of sample collection at the peak of rainy season and the observance of first flush are responsible for good rainwater quality of the study area. Therefore, regular catchment maintenance to prevent biological contamination with animal feaces and observance of flush are recommended. Caution should be exercise in using water from old zinc catchments due to the observed increase in zinc concentration with age of materials. Besides, further research should be undertaken to increase the sample size and also compare quality of rainwater from new and old catchments so as to broaden the scope of this topic and the benefit therefrom.

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