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Assessment of Quality of Rainwater Harvested from Roof Tops in Ikotun Area of Lagos State

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ABSTRACT

This study was to assess the quality of rainwater in the Ikotun Area of Alimosho Local Government Area of Lagos state and to check the potability of the rainwater within the study area in comparison to World Health Organization (WHO) drinkable water standard. The physicochemical (pH, Dissolved Oxygen, Total Dissolved Solids, Hardness, Lead, Electrical Conductivity) and microbial properties (E. coli, and Faecal coliform); of the harvested rainwater were assessed. The One-Way Analysis of Variance was employed to statistically examine the inherent variation that might exist across the roof type. The Inverse Distant Weight method was used also to carry out a spatial analysis of the data obtained from the laboratory analysis, thus generating a map showing the variation of parameters over the study area. The ANOVA result shows that there is a significant variation ($P < 0.05$), in the level of physiochemical and microbial parameters of the harvested rainwater from the eight categories of roof types with varying characteristics both in appearance and in quality of roof material. The potential of rainwater harvesting from roof catchments in augmenting present water supply status in Nigeria exists. The volume available for harvesting at individual roofs can offset the water supply deficit that has been estimated.

Key words: Lagos state, Rainwater, water quality assessment, physicochemical, microbial, Inverse distant Weight method.

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Introduction

Rainwater is selected as an alternative to reduce the dependence upon the existing water sources, due to its natural state as it comes from the atmosphere and void of contaminants in itself while being recorded throughout the year especially for countries in the tropical rainforest climate, such as Malaysia, Nigeria and others. Rainwater harvesting (RWH) can be described as the ancient practice of capturing rain runoff from roofs and other surfaces and storing it for a later purpose. Rainwater can be used as a substitution of the clean by collecting and utilize it rather than let it go to waste. By using rainwater as an alternative, clean water can be saved and be used for other purposes and simultaneously decrease the demand of clean water which will result in lower cost of water bill and cost of operation in the water plants. It can seriously reduce the dependent for the treated water (Sultana *et al.* 2016).

The interest in the quality of such water sources has initiated the present study. Freshwater sources are getting limited day by day owing to the expeditious urbanization. The first form of water in the nature's hydrologic cycle of water is rain supervised by the other sources of water like groundwater, and surface water present in the form of lakes and rivers but unfortunately with the passing time this first and major form is being neglected irrespective of the truth that it is the one contributing to all the other sources of water.

Harvesting of rainwater is becoming essential in order to handle the extreme crisis of fresh water in larger parts of the country. One of the premium ways of harvesting rainwater in many areas is by using the house rooftops as the catchment, and this is done because they are not as contaminated as any other rainwater harvesting catchment (Green *et al.*, 1993). Contamination of rainwater from roof surfaces can come from two main sources. Particles can accumulate on the roof surface either from direct atmospheric deposition or from overhanging foliage or bird and rodent debris. Alternatively, the roof material itself continuously degrades and can contribute both particulate matter and dissolved chemicals to runoff water. While the former is largely site-specific, the impact of different roof materials is fairly consistent regardless of location.

According to Despins *et al.* (2009), metal roofs are often associated with the leaching of trace elements, detected in the dissolved form in the runoff itself and adhered to the particulate matter washed from the roof. Forster (1996) reported a threefold increase in the concentration

of dissolved and particulate copper from copper flashings, compared with both pure rainwater and runoff collected from clay or concrete tiles. A similar trend has been observed for zinc concentration in runoff from a zinc sheet roof and, to a lesser degree, from zinc gutters. Van Metre and Mahler (2003) did a comparison of galvanized metal roofs with asphalt coated roofs and also found metal roofs to be a greater source of both zinc and cadmium contamination, while asphalt was associated with higher levels of lead and possibly mercury. In contrast, Hart and White (2006) discovered no significant difference between concentrations of lead, zinc or copper in runoff from asphalt roofs and metal roofs, thus indicating a wide variation in results among similar studies based on roof type rainwater contamination.

Investigation of some physicochemical and microbiological parameters of rainwater collected from Industrial areas of Lagos State by Igwo-Ezikpe and Awodele (2010) showed that anthropogenic activities contributed to the rainwater contamination. Akintola and Sangodoyin (2011), in their research reported heavy presence of major microbiological contaminants such as: *Escherichia coli* and *Pseudomonas fluorescense* in domestic roof-harvested rainwater (DRHRW) in Lagos, Ibadan and Port Harcourt, Nigeria, from four roof materials (corrugated iron sheet, long span aluminium, asbestos and step tiles), thereby rendering the harvested water unsuitable for homestead gardening irrigation.

Despite these backgrounds, there exist a gap in the knowledge of research on the heavy metal contents and physiochemical parameters of harvested rainwater in relation to precipitation volume. Furthermore, the problem of water scarcity together with increasing environmental awareness, and the development of more stringent regulations on water quality, use, and the need for sustainable approaches in water management related activities have increased the potential for alternative water resources. In this context, the analysis of alternative water resources, such as rainwater, is becoming increasingly popular as a sustainable source of water with a reduced impact on the environment.

The collection and storage of rainwater to supplement existing water sources (ground water and surface water) will be useful in addressing some of these problems. Rainwater utilization may be one of the best available methods for recovering natural hydrological cycles and aiding in sustainable urban development (Kim *et al.*, 2005a). The aim of this study is to assess the quality of rainwater in the Ikotun Area of Alimosho Local Government Area of Lagos state and check the potability of the rainwater within the study area in comparison to

World Health Organization (WHO) drinkable water standard as laid out in the Guidelines for Drinking-water Quality (WHO, 2017).

Methodology

This research involves mostly the use of primary data, collected in the study area which is mainly residential to achieve the objectives. The methods employed for this study were field investigation and sampling. Rainwater was collected from the following rooftop types in designated locations within the study area, two categories of the roof types were selected based on age; Corrugated Iron sheet/Metal Sheet (MS), Asbestos, Galvanized, and Aluminium types of roofing sheets. Rainwater was collected in sample bottles immediately after rainfalls to minimize pollution due to atmospheric sources (dust and particles), sterile plastic bottles and funnels were used for the collection of rainwater; these bottles were washed and air-dried to ensure the absence of any external impurities, which could affect the chemical properties of the water samples. All samples were labelled and taken to the laboratory. The rainwater was collected during rainfall by installing a raised stand in each of the designated sampling stations out in the open, this raised stand was mounted 1.5 metres above the ground to avoid rain splash that could introduce errors into the samples. The procedures of collecting rainwater were done in September, 2018 since rainfall is usually at its peak in this month in the study area in recent times. The collection was done over a period of Ten days across the different rooftop types as stated above. Thus, a total number of 10 samples was obtained from two classes of each rooftop representing the ten days of rainfall incidence, giving a total of Eighty Samples. This was done because some roof type of the same category was observed to be older than others, hence for each rooftop type category, two classes of rooftops were selected and samples collected from them. The older roof types are denoted as 1, while the newer roof types were designated as 2.

Water samples were analysed for physicochemical and microbiological qualities. These samples collected from the rooftops in plastic containers was analysed in the laboratory so as to determine the physicochemical and microbiological characteristics. GIS coordinates of each of the sampling points was taken for support of this research using the Global Positioning System (GPS) device, and then be inputted into the ArcGIS environment so as to obtain map of the study area showing all the sampling points, as well as to generate a map showing the variation of the parameters considered.

Physicochemical parameters: characteristics such as pH, Total Dissolved Solids (TDS), Dissolved Oxygen (D.O), Electrical conductivity (EC), Lead, Total Hardness were determined in the samples. pH, Temperature, Electrical conductivity (EC), were determined immediately in the samples insitu with the aid of JENWAY 3540 pH/conductivity meter, while TDS and D.O were measured using the TDS/DO metre. Lead and Total Hardness were determined in the laboratory following standard procedures.

Microbiological parameters: The enumeration of viable bacteria was done using the plate count technique as described by a standard method for the examination of water and wastewater (Nikoladze and Akastal, 1989) for the determination of Aerobic Mesophilic bacteria. Also, for the determination of coliform bacteria, the most probable number technique as described by Nester et al. (2001) was used to isolate the coliform group of organisms. The Total Coliform count, *Escherichia coli* count, Faecal Coliform count were tested in the laboratory following standard procedures. The categories of organisms were also identified and two major bacteria class were identified; Faecal organism, and Coliform organism.

Results and Discussion

One-Way Analysis of variance was employed to examine the variation in the physicochemical and microbial characteristics of rainwater across roof types in the study area. The Inverse Distant Weight spatial analyst tool was used to show the spatial variation of parameters over the study area.

Physicochemical Properties

It was observed that all the tested physicochemical parameters statistically varied significantly (Sig. = .000) across the unit of analysis, which is roof types. The set condition for the analysis was at a probability level of 0.05, and a confidence interval of 95%. (see table 1)

		ANOVA				
		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	68.030	7	9.719	6.553	.000
	Within Groups	106.778	72	1.483		
	Total	174.809	79			
Dissolved Oxygen	Between Groups	47.988	7	6.855	29.206	.000
	Within Groups	16.900	72	.235		
	Total	64.888	79			
Total Dissolved Solids	Between Groups	1720.600	7	245.800	13.709	.000
	Within Groups	1290.934	72	17.930		
	Total	3011.534	79			
Hardness	Between Groups	18.405	7	2.629	59.310	.000
	Within Groups	3.192	72	.044		
	Total	21.597	79			
Lead	Between Groups	.176	7	.025	20.005	.000
	Within Groups	.091	72	.001		
	Total	.267	79			
Electrical Conductivity	Between Groups	96590.750	7	13798.679	4.638	.000
	Within Groups	214220.800	72	2975.289		
	Total	310811.550	79			
E.Coli Count	Between Groups	9289.150	7	1327.021	35.324	.000
	Within Groups	2704.800	72	37.567		
	Total	11993.950	79			
Faecal Coliform	Between Groups	14652.687	7	2093.241	200.284	.000
	Within Groups	752.500	72	10.451		
	Total	15405.187	79			

Source: Authors' Analysis, 2019

In supporting the One Way Analysis of Variance as carried out above, the ArcGIS (version 10.4.1) Geostatistical Analyst tool was used to estimate the Inverse Distant Weight of the parameters in order to map the spatial variation (variation based on the location of each roof type) of the parameters identified.

Spatial Variation of Physicochemical Parameters

pH

The pH of water is quite important, and most frequently used the test in determining water quality. It indicates the intensity of acidity or basic character at a given temperature. The pH value is a good indicator of water hardness. Water with a pH lower than the neutral level (7) is considered acidic, while water with a pH higher than 7 is considered alkaline. Figure 1 shows the variation of pH across different roof types within the study area. pH was discovered to range from 6.38 to 7.17. A higher pH value (7.17) signifying slightly alkaline tendencies was observed in the sample collected at the new aluminium roof type (ARS 2), while the lowest pH value (6.38) recorded was also from the old aluminium roof type (ARS

1). The high pH value tends to decrease toward the immediate surroundings, as it is concentrated around the newer asbestos roof type decreasing outwards.

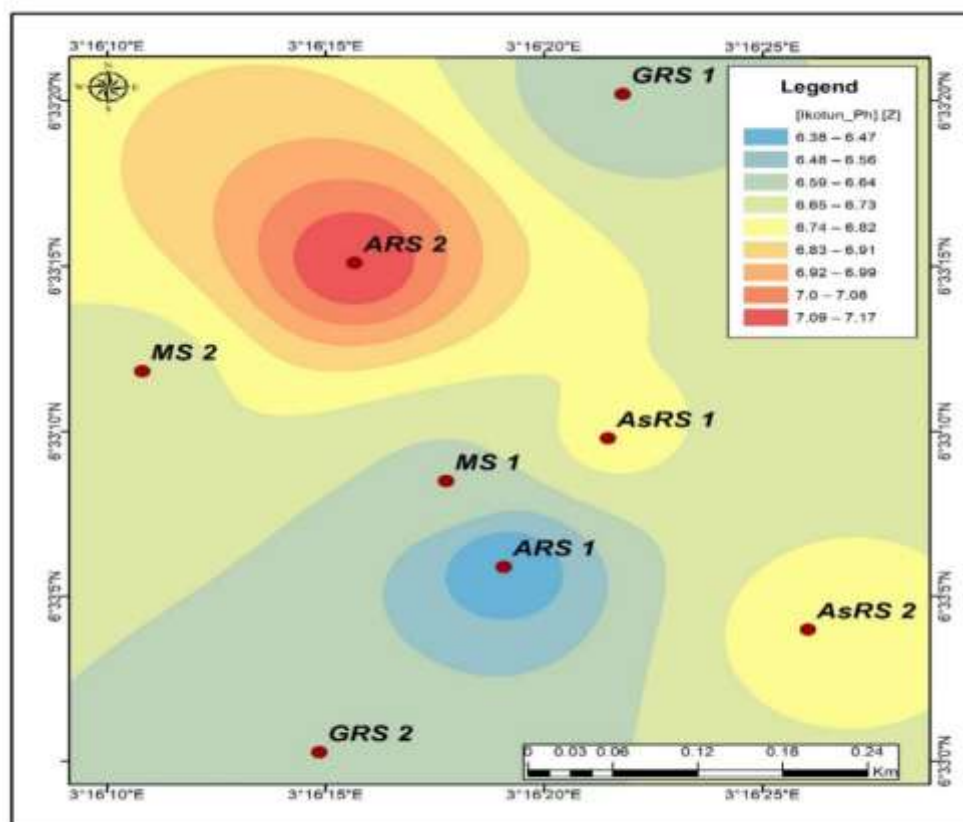


Figure 1: Spatial Variation of pH across roof type (GRS: Galvanised Roofing Sheet; ARS: Aluminium Roofing Sheet; AsRS: Asbestos Roofing Sheet; MS: Corrugated Iron Sheet/Metal Sheet)

Dissolved Oxygen

Dissolved Oxygen, gets into the water by diffusion by diffusion from the atmosphere, aeration of the water as it tumbles over falls and rapids or during rainfall, and as a by-product of photosynthesis. Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on organisms living within a water body. A dissolved oxygen level that is too high or too low can affect water quality (Fondriest, 2013). The mean value for DO ranges from 10.6 to 12.9 mg/l. (Figure 2). The least DO value was observed in the sample from the new asbestos roof type while increasing outward toward the other sample points. However, the highest DO value range was observed across three roof types; the Old Asbestos roof, the new and old Galvanized (GRS 1 and GRS2 respectively) roof types.

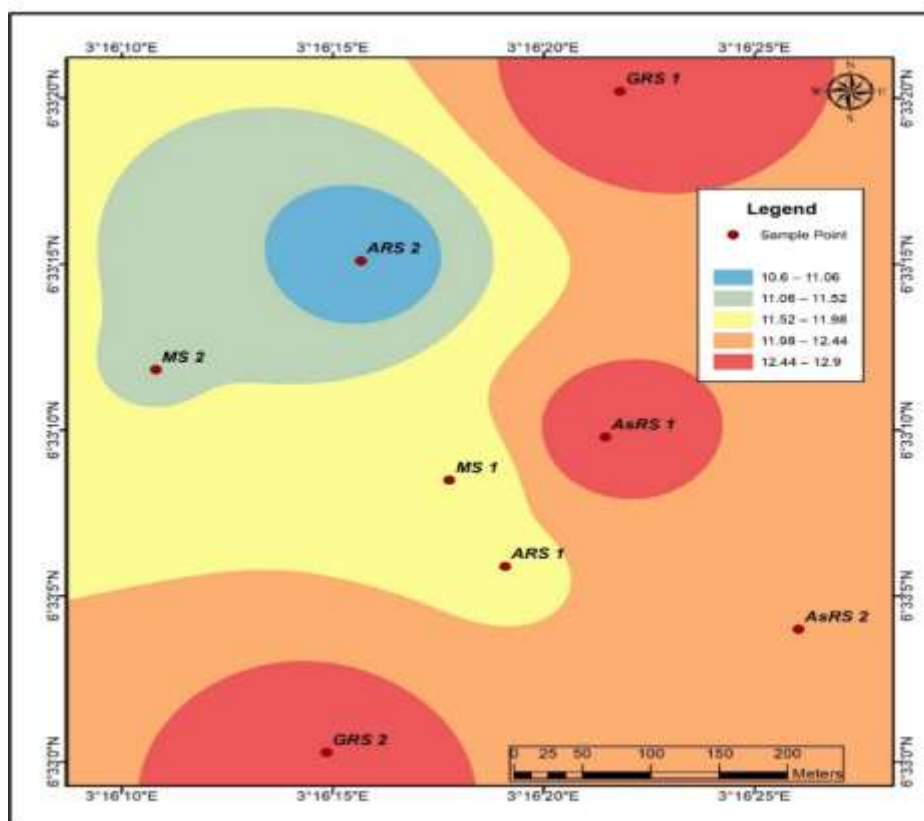


Figure 2: Spatial Variation of Dissolved Oxygen (mg/l) across roof types. (GRS: Galvanised Roofing Sheet; ARS: Aluminium Roofing Sheet; AsRS: Asbestos Roofing Sheet; MS: Corrugated Iron Sheet/Metal Sheet)

Total Dissolved Solids

Total Dissolved Solids is a measure of materials dissolved in water, it is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended form. The observed TDS values as obtained from laboratory analysis ranged between 17.42 to 30 mg/l. TDS was more concentrated in the water sample obtained from the asbestos roof type. However, the concentration was lowest in the Galvanized roof types (figure 3). This observation could be as a result of the particulates of Asbestos which might be easily disembodied by the rain splash, dissolved due to their solubility potential, and carried with the rooftop runoff. Another possible reason may be that dust and other particulate matter easily attach to the asbestos probably due to similar nature and as such result in higher dissolution. On the other hand, Galvanized rooftop types have a metallic surface and as such particulate may not readily attach themselves to it.

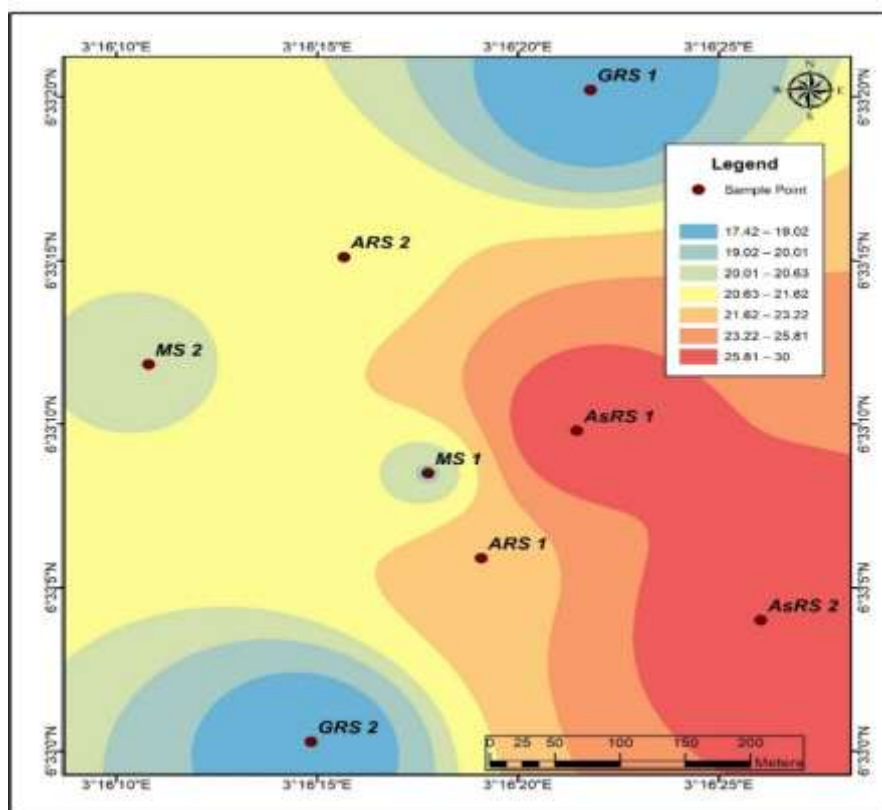


Figure 3: Spatial Variation of Total Dissolved Solids(mg/l) across roof types (GRS: Galvanised Roofing Sheet; ARS: Aluminium Roofing Sheet; AsRS: Asbestos Roofing Sheet; MS: Corrugated Iron Sheet/Metal Sheet)

Hardness

The hardness of water unlike others is not a pollution parameter but is an indicator of the quality of water, mainly with respect to the Ca^{2+} and Mg^{2+} as expressed in carbonates. (Kazi *et al.*, 2008). Water is described as “hard” if the dissolved mineral (calcium and magnesium) content is high. Hard water is however not a health risk but can only be seen as a nuisance when it comes to laundry. On the other hand, hard water is quite good for the development of strong bones owing to its high mineral contents. The level of hardness (Figure 4) observed in this study is relatively low in comparison with the WHO standards and can be considered soft as it ranges between 0.25 to 1.48 mmol/l. The highest level of hardness was observed from the water sample from the Asbestos roof types; while the lowest was observed in Galvanized roof types. A possible explanation for this might be due to the nature of the material constituents of the Asbestos which readily dissolves in water as impact of raindrops might induce disaggregation of particulates over time as opposed to that of the Galvanized roof type which have been coated to prevent rust and corrosion.

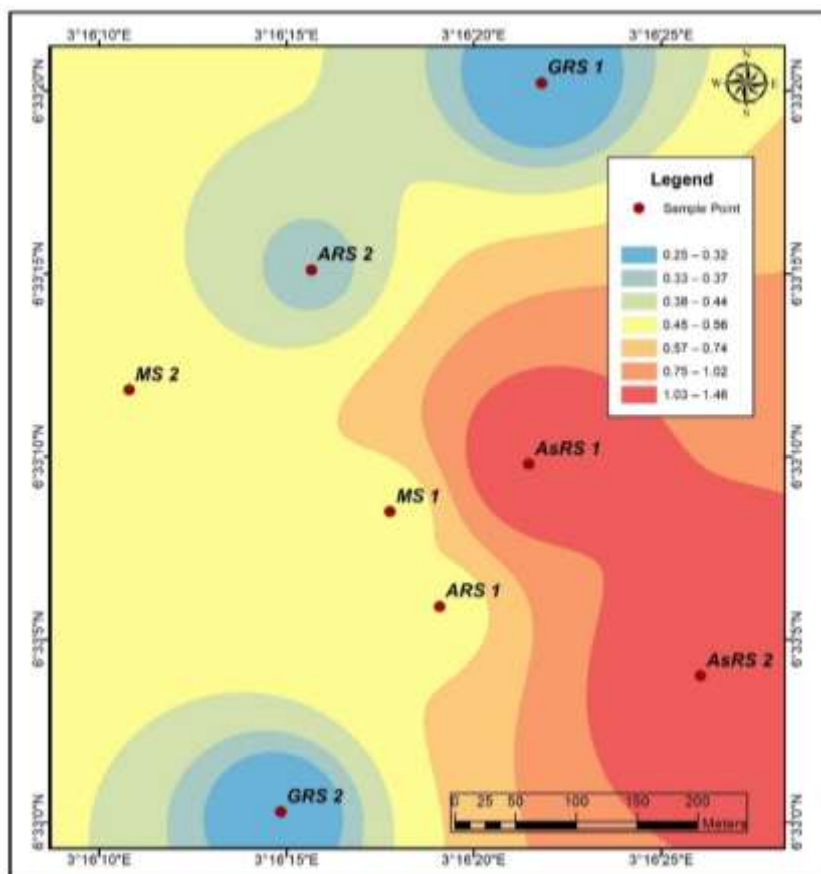


Figure 4: Spatial Variation of Hardness (mmol/l) across roof types (GRS: Galvanised Roofing Sheet; ARS: Aluminium Roofing Sheet; AsRS: Asbestos Roofing Sheet; MS: Corrugated Iron Sheet/Metal Sheet)

Lead

Lead is usually found in ores alongside zinc, silver, and copper. Lead is a heavy metal whose effect may either be short term or long term. Short term if the pollutants exist in the water at high concentration at a particular period, and long term where toxins accumulate and become concentrated in the food chain. The concentration of lead (figure 5) was observed to be highest in the water samples from the Older Aluminium roof (ARS 1), while it is lowest in the newer Aluminium roof type (ARS 2), and in the older metal sheet (MS 1). The result might be due to the influence of time on the quality of the roof types as seen in the case of the aluminium roof types. It is possible that lead as an element might have be a manufacturing component of the roof type.

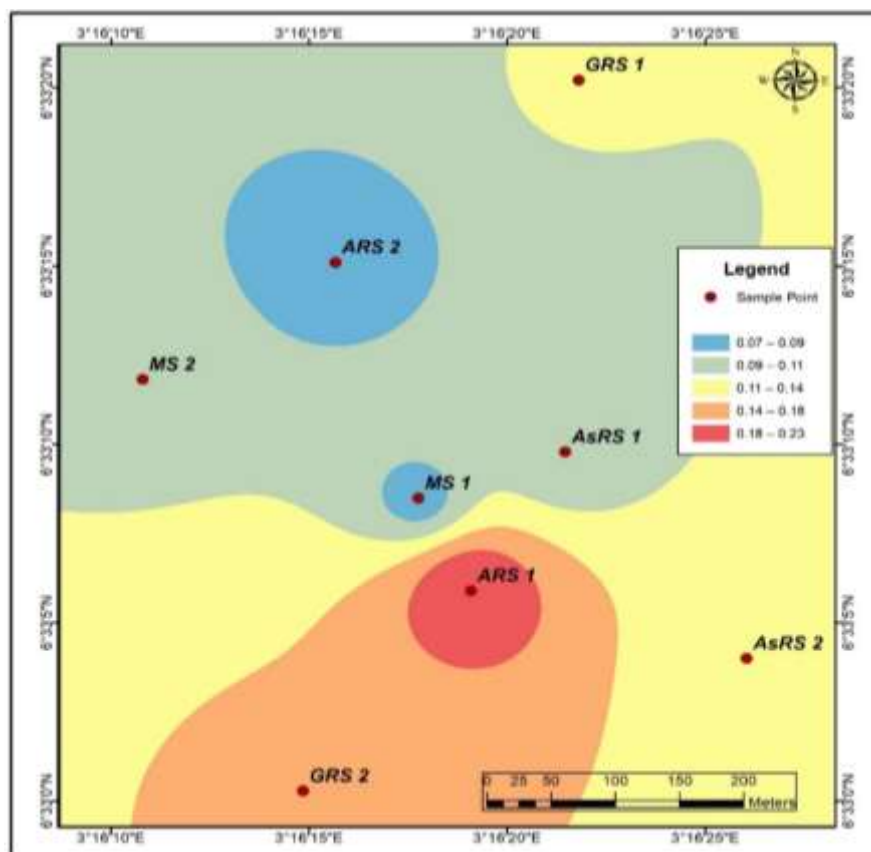


Figure 5: Spatial Variation of Lead (mg/l) across roof types (GRS: Galvanised Roofing Sheet; ARS: Aluminium Roofing Sheet; AsRS: Asbestos Roofing Sheet; MS: Corrugated Iron Sheet/Metal Sheet)

Electrical Conductivity

Electrical conductivity is an essential indicator of mineralisation and salinity or total salts in a water sample. It is dependent on the presence of ions, and their total concentration mobility as well as the temperature of measurement. In other words, the more the concentration ions, the higher the conductivity, and the warmer the water. (Mosley *et al.*, 2004). It can also be seen as the ability of water to transmit electric current which is dependent on the amount of total dissolved solids in the water. The mean values of Electrical Conductivity ranged from 231.8 S/m – 342.5 S/m. Electrical conductivity was observed (figure 6) to be highly concentrated in the corrugated iron sheet denoted by “MS”, and the older corrugated iron sheet roof type (MS 1) exhibited the highest electrical conductivity, and this was closely followed by the newer corrugated iron sheet (MS 2). However, the lowest value for Electrical conductivity was observed in the newer galvanized roof type.

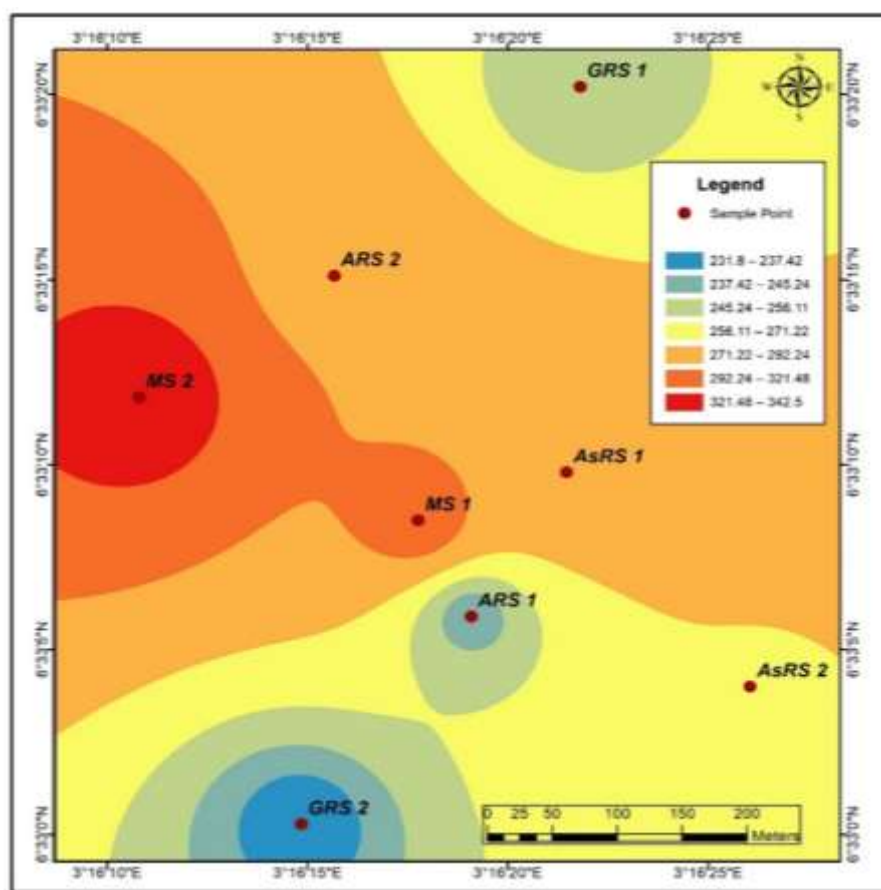


Figure 6: Spatial Variation of Electrical Conductivity (S/m) across roof types. (GRS: Galvanised Roofing Sheet; ARS: Aluminium Roofing Sheet; AsRS: Asbestos Roofing Sheet; MS: Corrugated Iron Sheet/Metal Sheet)

Variation of Microbial Properties

It was further observed that all the tested microbial parameters statistically varied significantly across the unit of analysis, which is roof types in the study area. The set condition for the analysis was at a probability level of 0.05, and a confidence interval of 95%. (see Table 1.2)

Spatial Variation of Microbial Parameters

The Inverse Distance Weighting result conducted for the distribution of parameters is presented below:

Escherichia Coli

Escherichia coli, which is also known as *E. coli* is a rod-shaped coliform bacterium of the genus *Escherichia*. This microbe is commonly found in the lower intestine of warm-blooded organisms and is expelled into the environment via faecal matter. The bacterium grows massively in a fresh faecal matter under aerobic conditions for 3 days which is the case of water, but its numbers decline slowly afterward. The mean values of *E. coli* ranged from

19.2 – 50 CFU/100ml. *E. coli* was observed (Figure 7) to be highly concentrated in the Aluminium Roofing Sheet denoted by “ARS”, and the newer Aluminium Roofing Sheet type (ARS 2) exhibited the highest *E. coli*, and this was closely followed by the older Aluminium Roofing Sheet (ARS 1). However, the lowest value for *E. coli* was observed in the older asbestos roof type.

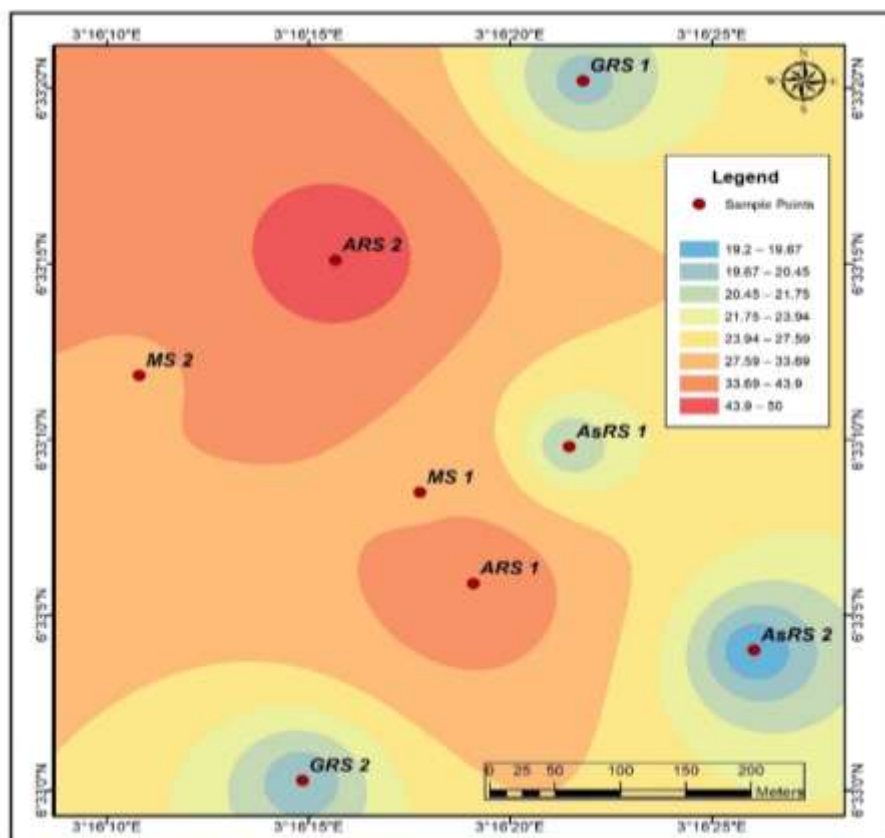


Figure 7: Spatial variation of *E. coli* (CFU/100ml) across roof types (GRS: Galvanised Roofing Sheet; ARS: Aluminium Roofing Sheet; AsRS: Asbestos Roofing Sheet; MS: Corrugated Iron Sheet/Metal Sheet)

Faecal Coliform

Faecal coliform can be described as a facultative anaerobic, rod-shaped, gram-negative, non-sporulating bacterium. Coliform bacteria generally originate in the intestines of warm-blooded animals. Presence of faecal coliforms in water may not be directly harmful, and does not necessarily indicate the presence of faeces but however can be harmful if it exceeds the permissible limits. The mean values of faecal coliform ranged from 11.2 – 48.8 CFU/100ml. Faecal coliform was observed to be highly concentrated in the corrugated iron Sheet types denoted by “MS”, and both the older and newer corrugated iron Sheet type (MS 1 and MS 2 respectively) exhibited the highest faecal coliform count. and this was followed by the newer

Aluminium Roofing Sheet (ARS 2). However, the lowest value for faecal coliform was observed in the newer galvanised roof type (GRS).

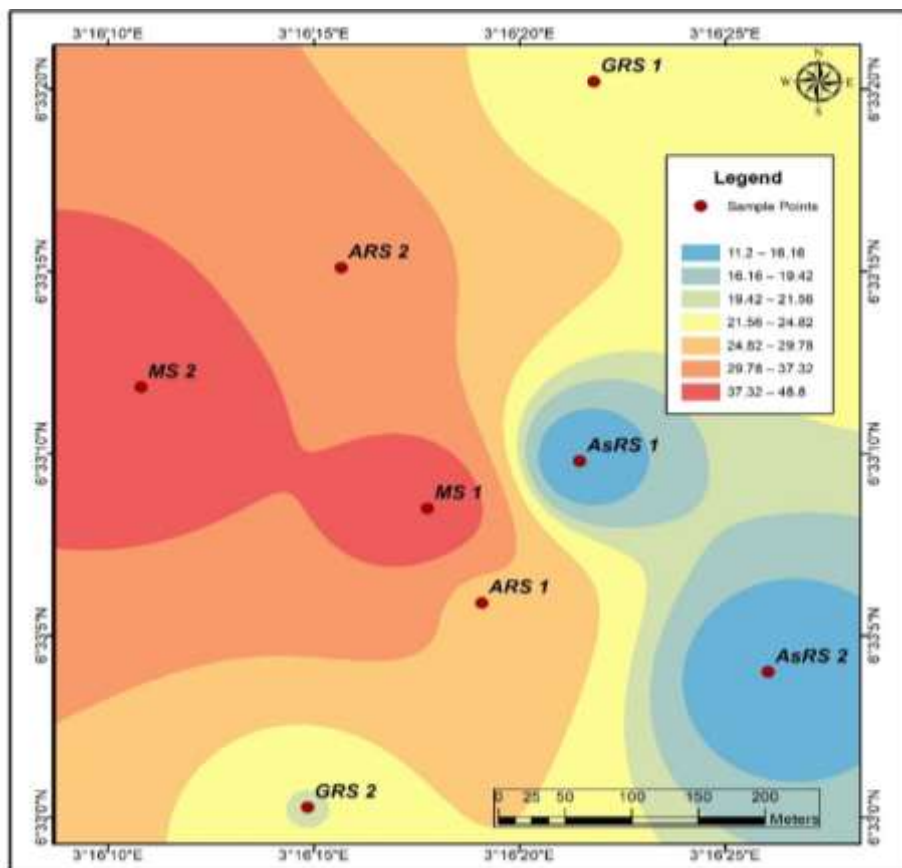


Figure 8: Spatial variation of Faecal coliform (CFU/100ml) across roof types. (GRS: Galvanised Roofing Sheet; ARS: Aluminium Roofing Sheet; AsRS: Asbestos Roofing Sheet; MS: Corrugated Iron Sheet/Metal Sheet)

Comparison of Observed Water Quality and World Health Organisation Standard

The quality of the harvested rainwater as observed from the laboratory analysis was pitched against the set standard limit put forward by the World Health Organisation as a prerequisite for potability of water and domestic usage. In order to achieve this, the difference between the WHO set standard for the domestic water usage with respect to water quality parameters and the observed quality level of the harvested rainwater was observed using the Water Quality Index by comparing the mean concentration level of selected parameters of study in the rainwater samples, with the WHO set permissible limit.

Table 2: Water Quality Index Table

Water Quality Index	STATUS
0 - 25	Excellent
26 - 50	Good
51 - 75	Poor
76 - 100	Very Poor
Above 100	Unsuitable for drinking

Source: Brown et al (1972), Chatterjee and Raziuddin (2002)

The calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965) and developed by Brown et al (1972). The weighted arithmetic water quality index (WQI) is in the following form:

$$WQI_A = \frac{\sum_{i=1}^n w_i q_i}{\sum_{i=1}^n w_i}$$

where n is the number of variables or parameters, w_i is the relative weight of the i^{th} parameter and q_i is the water quality rating of the i^{th} parameter. The unit weight (w_i) of the various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters. According to Brown et al (1972), the value of q_i is calculated using the following equation:

$$q_i = 100[(V_i - V_{id}) / (S_i - V_{id})]$$

where V_i is the observed value of the i^{th} parameter, S_i is the standard permissible value of the i^{th} parameter and V_{id} is the ideal value of the i^{th} parameter in pure water.

Water Quality Index (WQI) = $\sum wq / \sum w$

$$WQI = 360.88 / 6.58$$

$$WQI = 54.8$$

This obtained value (54.8) lies in the poor section of the classification of water quality based on weighted arithmetic WQI method as given in Table 2 (Chatterjee and Raziuddin (2002)). It follows that the rainwater from each of the sample point in line with the WHO standard is of poor quality and therefore, unsuitable for consumption, and if in any case it will be utilised, it must be treated before use to avoid water-related diseases.

Table 3: Calculation of Water Quality Index (WQI) of the Harvested Rainfall

Parameter	Observed Values	WHO Standard	Unit weights (w_i)	Quality rating (q_i)	$w_i q_i$
pH	6.37±1.48	6.50	0.98	126	123.48
Dissolved Oxygen (mg/l)	12.04±0.91	5.0	0.2	-252	-50.4
Total Dissolved Solids (mg/l)	22.21±6.17	500	0.044	4.44	0.2
Hardness (mmol/l)	0.64±0.52	0.5	2	140	280
Lead (mg/l)	0.12±0.05	0	1	0	0
Electrical Conductivity (S/m)	275.58±62.72	1000	0.276	27.56	7.6
E.Coli (CFU/100ml)	29.53±12.32	0	1.08	0	0
Faecal Coliform(CFU/100ml)	27.69±13.96	0	1	0	0
			$\Sigma w_i = 6.58$	$\Sigma w_i q_i = 360.88$	

Source: Author's Analysis, 2019

Conclusion

Rainwater harvesting appears to be one of the most promising alternatives for supplying freshwater in the face of increasing water scarcity and escalating demand even in a polluted area hence it is collected from an open space. The chemical quality of harvested rainwater in Ikotun area of Alimosho LGA of Lagos state is quite unsatisfactory as no parameter was found to exceed the corresponding maximum allowable concentration for drinking purposes according to WHO standard but the overall quality index still shows poorness in quality. In general, examination of the physicochemical and microbial composition of the rainwater is a prerequisite before its utilization for drinking purposes. The physicochemical quality of the rainwater samples examined in this study indicates that Ikotun area of Alimosho LGA of Lagos is polluted in terms of rainwater to a certain extent, however this pollution can be ousted if proper treatment measures are put in place, thereby improving the harvested rainwater quality. The physicochemical properties of rainwater were mostly influenced by the catchment and storage materials and site environment. Catchment surfaces employing Aluminium and Galvanized roofs provided rainwater runoff of higher quality than did Asbestos roofs. The material properties of Corrugated Iron roof/Metal Sheet may have contributed to poorer quality runoff, owing to the adsorption of atmospheric particulates deposited on the catchment surface between rainfall events.

To produce a more realistic assessment of the Rain Water Harvesting potential, three concepts have been discovered to be relevant to the quantification and assessment of Rain Water Harvesting potential, namely, the theoretical, available, and environmental bearable potential have been proposed and defined based on the climatic, building characteristic, economic, and ecological aspects of Rain Water Harvesting in Ikotun area of Lagos State, and Nigeria at large. Theoretical potential, which represents the maximal rainwater harvest, considers only the rainfall, roof area, and runoff coefficient without considering the economic and downstream ecological impacts. Available potential reflects a more realistic assessment of rainwater potential because it considers the amount of rainwater required by various types of building. Environmental bearable potential considers the downstream ecological impact of Rain Water Harvesting and other factors. The potential of rainwater harvesting from roof catchments in augmenting present water supply status in Nigeria exists. The volume available for harvesting at individual roofs can offset the water supply deficit that has been estimated. The space for installing reservoirs is available for most buildings. The need for non-potable uses of water such as landscaping/irrigation, laundry and many more, is above average.

Recommendations

Sole dependence on surface and groundwater water should be discouraged, while awareness to encourage rainwater harvesting from roof catchments at the domestic or industrial level should be encouraged. This will greatly increase water quantity and decrease flooding in the urban environment. Rainwater harvesting systems should be included in the initial building designs in order to encourage rainwater harvesting to runoff from paved surfaces. The other way of encouraging residents to start harvesting rainwater from their roof catchments lies on the provision of storage reservoirs at affordable prices. This ought to be done through Government interventions which may be through subsidies.

The interest in Rainwater and Rain Water Harvesting systems as an alternative water source should be more pronounced, owing to its economic and environmental advantages. Indeed, these systems can provide supplementary water supply in urban areas when integrated with an existing conventional water supply system, or the main water supply in rural areas affected by water scarcity. In the context of climate change, the installation of Rain Water Harvesting tanks could represent a valuable adaptation measure against the reduction of water availability.

Further research on best rainwater harvesting technologies for urban areas, minimizing space requirements and maximizes water quality should be embarked upon by the government and concern bodies. Modern pumping designs allowing different inlets for potable and non-potable water into the building and safety.

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