Microbial Quality and Public Health Risks Associated with Roof-Harvested Rainwater from different Rooftops in Isuikwuato local Government Area, Abia State, Nigeria.

By

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Abstract
The study assessed the microbial quality of roof-harvested rainwater in Isuikwuato LGA, Abia State. This study adopted the survey research design. Rainwater was randomly collected from the predominant roofing sheets (Aluminium sheets, Asbestos and Corrugated Iron sheets (zincs)) from the various communities. Water samples were analysed for bacteriological content (Total Coliform count, TCC and Total Microbial Load, TML) using standard methods for the examination of water. All samples collected had detectable Coliform count per 100ml sample of water. The result indicates that samples with the highest percentage of Coliform count were those from corrugated Asbestos rooftops, followed by those from Aluminium rooftops while Zinc had the least probable number of Coliform count. Thus, higher Coliform counts were observed in the non-metallic roofing material. The presence of Coliform bacteria in the rainwater samples collected for all roof types is an indication that the harvested water have proven to be inadequate in terms of quality. For total microbial load of the water samples, SPL 1 for Aluminium roofing sheets had 1.6/100ml, Asbestos 3.4/100ml, Zinc 2.1/100ml microbial loads while two organisms (Eshericia coli and klebsiella spp) were isolated for Aluminium and Zinc roofing sheets, Klebsiella spp & streptococci spp were isolated for Asbestos roofing sheet. In all, SPL 4 (Asbestos) is the highest polluted in terms of the number of organisms isolated. Generally, the results indicate clearly the poor microbial quality of most harvested rainwater samples from this study and other previous studies. Thus, the harvested rainwater should not be consumed without suitable pre-treatment that improves the quality of the water.

Keywords: Microbial, Public Health Risks, Rooftop, Rainwater, Quality.
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Introduction

Water is a unique resource that has no substitute while its quality and quantity vary in both space and time. Life in essence requires nutrients, water, and oxygen (air) to survive. The essentials of life are provided through the air we breathe, the liquid we drink (water) and food. It is therefore not wrong to state that our environment is comprised of natural miracles that provide for the ingredients of life. Life and civilization cannot survive without water as it is a natural capital, a catalyst and a pre-condition for economic and social development. Water availability plays a critical role in supporting livelihoods, food security and public health (Baguma, *et. al*, 2010).

Water has the peculiar quality of being an inexhaustible natural resource which nevertheless is in short supply in the broad sense. Water from its various sources (oceans, atmosphere, etc) is more than adequate to meet all human needs now and in the future. However, the problem is getting water of usable quality, present in the right place and at the right time. Current efforts to improve water supplies for domestic and industrial uses have largely focused on exploitation of surface water and groundwater resources. Hence, developing alternative water source has become a critical issue for sustainable development.

Water balance analysts suggest that rainwater from impermeable roof surfaces in both urban and rural areas represents an under-utilized resource currently excluded in existing water policies in sub-Saharan Africa and Nigeria in particular (Gwenzi and Nyamadzawo, 2014). Consequently, compared to surface water and groundwater resources, there is relatively limited research on the quality and public health risks posed by water harvested from roofs.

Developing alternative water sources has become a critical issue for sustainable development in the study area. There is need to initiate new water resource development regulations, which will include wastewater reuse, seawater desalination, and rainwater harvesting as alternative water resources. Rainwater has become an important alternative water source to address the water shortage in urban and sub-urban areas. Roof rainwater use for domestic purposes is not new in developing regions like Nigeria, but until recently it was mostly limited to communal areas and is often regarded as safe. Hence, for the area under study, the harvested rainwater provides a cheap and readily available alternative within and off season for those that may have large storage tanks. Though useful, a lot of complications have been ascribed to the use of harvested rainwater especial bacterial and fungal diseases.

This study focused mainly on rainwater quality with respect to drinking purposes. It also highlighted the potential public health risks associated with consumption of roof rainwater. There is the need to ascertain the quality status of harvested rainwater in order to safeguard the people against water related diseases. This therefore led to assessing the quality of rainwater harvest in Isuikwuato LGA, Abia State.

Problem Statement

The uniqueness of water and as a life support to a large number of people in rural and urban areas who still lack social services particularly potable water has led to carrying out water quality assessment particularly on the most assessed source of supply. No doubt, water is vital for our existence but unfortunately, clean, pure and safe quality water in nature is been polluted by environmental factors and anthropogenic activities. Virtually all the sources are prone to water pollution.

Researchers have been concerned about the quality of water harvested from different rooftops in both urban and rural areas. This is because it is often regarded as a safe, despite the lack of laboratory analytical data. In the study area, the story is not different as people consume the harvested rainwater directly without further treatment. This action has impacted the health conditions of the inhabitants and has really become a source of concern. There is therefore the need to ascertain the quality status of harvested rainwater since a lot of complications (bacterial and fungal diseases) have been ascribed to the use of harvested rainwater. This prompted this research aimed at assessing the microbial quality of harvested rainwater and to prevent public health risks that might result as a result of its consumption.

Geography of the Area

Isuikwuato is a local government area in Abia State in southeastern Nigeria. Its geographical coordinates are Lat: $5^{0}48^{'}25^{''}$N and Long: $7^{0}28'53''$E. Three major clans which also harbour various communities in each of them make up the present day Isuikwuato. It has an estimated population of over 150,000 people. Isuikwuato has natural resources such as granite, iron ore and kaolin (Abia Facts). In some areas, atmospheric pollution is currently going on due to atmospheric activities such as quarrying, mining and construction. Oil lines flow through Isuikwuato and there have been cases of bursting pipe which have had severe effects on the local economy and environment. The major cash crops are palm oil and cassava. They lack the needed government backing to build drainages around the area to guide the flow of water without further harming the already degraded soil. Isuikwuato is also home to Abia State University Uturu.

Research Design/Sources of Data

This study adopted the survey research design. The population of study comprises all households in the four selected communities. A closed-ended questionnaire survey of eight hundred (800) households, two hundred (200) from each of the communities were conducted through systematic sampling elicit responses from respondents on the sources of water supply in the study area. Sixteen (16) field assistants were used to conduct the questionnaire administration and retrievals and this made us have one hundred percent (100%) response rate. Purposive/judgment sampling was employed for the water sampling to ascertain the quality of rainwater harvest in Isuikwuato, L.G.A, Abia State. The pilot and the reconnaissance survey of the study environment helped the researchers on this judgment as we were familiar with the relevant characteristics of the buildings with the chosen rooftops to be studied.

Collection of water samples

Rainwater was randomly collected from three types of roof materials from the various communities. These include; Aluminium sheets, Asbestos and Corrugated Iron sheets (zincs). These roof sheets were the predominant roofing sheets in the area, hence their choice. A total of sixteen (16) water samples were collected from the various communities in each clan. The water samples were collected in sterilized 1 litre plastic container, rinsed with the water to be collected and then filled with the water samples. In addition, clean-catch rainwater samples were also collected as control. This was done by placing the collection container on a 2.0m high stool in the open where the rainwater was collected directly from the study. The samples were properly labelled to show the different points for the analysis of microbial parameters. The samples were placed in coolers before transferring them to the Central Services Laboratory of the National Root Crop Research Institute, Umudike (NRCRIU) within two (2) hours for the analysis.

Analysis of the Rainwater

Water samples were analysed for bacteriological loads using standard methods for the examination of water.

Bacteriological Analysis of Water

Using the pour plate method, total heterotrophic bacteria in the rainwater samples was obtained. Serial dilution was carried out and 1 ml aliquots dilutions of 10^{-1} and 10^{-3} of each representative sample was inoculated into sterile petri dishes. 10ml of molten Nutrient agar

(NA) was introduced in the petri dish over the samples. These were swirled to attain even distribution and incubated at 37^{o}C for 24 hour. Petri-dishes from dilutions containing between 30 and 300 discrete colonies were counted and made in cfu/ml (colony forming unit) (APHA 2005). The colony forming units per millimetre (cfu/ml) was calculated by dividing the average number of colonies per dilution with the dilution factor. A sterile inoculating loop was ascetically used to pick a loopful of each water sample. This was streaked across the already set solid agar surface using the quadrant method of streaking. The inoculating loop was flamed between streaks and eventually after use, the plates was incubated at 37^{o}C for 24hrs.

Enumeration of total coliform Bacteria

Multiple Tube Fermentation Test: Multiple tube fermentation tests were used to enumerate total and faecal coliform (APHA, 2005). Total count was determined with the aid of the three tube assay of the most Probable Number (MPN) method.

Presumptive test: Presumptive coliform test was carried out using lactose broth. The first set of the three tubes had sterile 10ml double strength lactose broth (DSLB) and the second and third sets had 10ml single strength lactose broth (SSLB). Durham tubes were inserted in the test tubes prior to sterilization. The three sets of the tubes received 1.0.1 and 0.0.1 ml of water samples using sterile pipettes. All tubes were then incubated at 37^{o}C for 24-48 hours for estimation of total coliforms and examined afterwards for acid and gas production. The MPN was then determined from the MPN table for the three set of tube (APHA, 2005).

Confirmed test: A loopful of culture was transferred from a positive tube from presumptive test into a tube of lactose broth with Durham tube to carry out Confirmed Test. The tubes were incubated at 37^{o}C for 24-48 hours for total coliform and 44.5 for faecal coliforms and observed for gas production.

Completed test: For the completed test, a loopful of broth from a positive tube was streaked on Eosine Methylene Blue (EMB) agar plate for pure colonies. The plates were incubated at 37^{o}C for 24-48 hours. Colonies developing on EMB agar were further identified. Colonies with green metallic sheen were confirmed to be faecal coliform bacteria with rod shape.

Organisms observed with different morphology (mixed growth) were sub-cultured on Nutrient agar and Eosine Methylene Blue Agar and incubated at 37^{o}C for 24hours to get pure cultures.

After development of bacterial growth colony on the agar surface, cultural characteristics of the isolates on different solid agar was examined. Growth characteristics including colony morphology, colour pigmentation, form, deviation, margin, surface, optical characters were recorded, following Bergey's manual of systematic Bacteriology (Ryan & Ray, 2008).

Results and Discussion

a. Sources of Water Supply – The study identified two major sources of water supply in the area; **Private** (roof catch and streams) and **Commercial** (borehole, hawkers, truck-tankers and owners of large storage tanks).Information on the pattern of the water supply sources were got from the questionnaire samples administered to the respondents. Conclusively from the study areas, public water supply was not captured by the people, though, it was the first listed among the various sources of water in the sampled questionnaire administered. This shows that the State Water Board has failed in its responsibility of providing water to the people in enough quantity and quality. Collectively, the commercial sources of water supply are the most patronized. This is because, water from these sources contributed 57% patronage. Of the six (6) identified sources of water supply which were categorized into Private and Commercial, Rain catch (private) had the highest patronage despite the fact that it is seasonal. This increasing number of patronage of harvested rainwater as a major alternative to meeting the water supply needs of the people informed the need to analyse the rainwater samples from three different rooftops to determine the quality and spatial variability in microbiological properties.

b. Methods/Techniques of Harvesting Rainwater

Rainwater harvesting technologies are simple to install and operate. Rainwater harvesting provides water at the point of consumption, and family members have full control of their own systems. The feasibility of rainwater harvesting in a particular locality is dependent on the amount and intensity of rainfall. Other variables, such as catchment area and the type of catchment surface can be adjusted according to household needs.

A basic roof rainwater harvesting system typically consists of a roof catchment, storage facilities and the conveyance system. For the collection of rainwater, the 'roof catch' method, about 5-10 minutes are allowed for the rain to wash away dust particles from the roofs (especially when it has not rained for a long time normally during the on-set of the rainy season) before water collection starts.

Fieldwork shows that there are two methods of roof catch or rainwater harvesting in the study areas. These are: ***direct collection from roofs to containers***, and ***channeling to ground level/sunken storage tanks***. In direct collection from roofs, the containers are positioned were raindrops can easily enter them. The containers used for collecting water directly from the roof include aluminum and plastic buckets, pots, basins, gourds and drums. In some cases, corrugated iron eaves are put on some parts of the edge of the corrugated iron roofs to channel water to the water containers. In the case of channeling water to ground level/sunken storage tanks, the edges of the corrugated iron roofs are eaved round (or part of it) with corrugated metals to collect and channel the rainwater to the storage tanks.

These storage tanks may be made of concrete or metal. The stored water is later drawn for use when there are water shortages; some people pipe the stored water from storage tanks to their houses to provide modern piped water systems with taps, shower taps and basins, and water closets. However, there is a limit to which people of the study areas can depend on rainwater for their domestic and other activities since rainwater is seasonal, occurring between mid-March and early November. A further limit to rainfall utilization in the area is the fact that rain does not fall every day, even during the rainy season.

c. Rainwater Quality for Domestic Uses:

Results of the Microbial parameters of the harvested rainwater

Results for Total Coliform Count (TCC) and Total Microbial Load (TML) collected from rooftops made of three different materials are presented in Tables 1 and 2.

Table 1: Result of microbial analysis for Total Coliform Count (TCC)

Sample Location	Rooftop type	Microbial Count	Isolated Organisms
SPL 1	Aluminium	2.1×10^{1} cfu ml^{-1}	Klebsiella spp isolated
	Asbestos	4.0×10^{1} cfu ml^{-1}	Klebsiella spp and Eshericia coli isolated
	Zinc	1.8×10^{1} cfu ml^{-1}	Klebsiella spp isolated
	Control	0.2×10^{1} cfu ml^{-1}	Klebsiella spp isolated
SPL 2	Aluminium	2.2×10^{1} cfu ml^{-1}	Klebsiella spp isolated
	Asbestos	3.0×10^{1} cfu ml^{-1}	Eshericia coli and Klebsiella spp isolated
	Zinc	2.0×10^{1} cfu ml^{-1}	Eshericia coli isolated
	Control	Nil	No growth isolated
SPL 3	Aluminium	4.1×10^{1} cfu ml^{-1}	Eshericia coli isolated
	Asbestos	5.0×10^{1} cfu ml^{-1}	Eshericia coli isolated
	Zinc	3.1×10^{1} cfu ml^{-1}	Klebsiella spp isolated
	Control	Nil	No growth isolated
SPL 4	Aluminium	4.6×10^{1} cfu ml^{-1}	Klebsiella spp and Eshericia coli isolated
	Asbestos	6.1×10^{1} cfu ml^{-1}	Eshericia coli and Klebsiella spp isolated
	Zinc	3.2×10^{1} cfu ml^{-1}	Klebsiella spp isolated
	Control	0.4×10^{1} cfu ml^{-1}	Klebsiella spp isolated

Source: Author's Laboratory Analysis (2022)

Table 1 shows the result of microbial properties of the water samples through media preparation and culturing. In sample location one (SPL 1), Asbestos rooftop had the highest coliform count of 4.0/100ml with two associated organisms isolated (Klebsiella spp and Eshericia coli). Aluminium and Zinc roofing sheets followed with 2.1/100ml and 1.8/100ml respectively with one associated organism isolated in each. Same trend was observed in other sample locations. All samples collected had detectable Coliform count per 100ml sample of water. The result indicates that samples with the highest percentage of Coliform count were those from corrugated Asbestos rooftops, followed by those from Aluminium rooftops while Zinc had the least probable number of Coliform count. Thus, higher Coliform counts were observed in the non-metallic roofing material. Quantitatively, the presence of total coliform count and Escherichia coli shows that the water samples have been contaminated. Following the WHO (1993) guideline for microbial quality of drinking water which stated that, E. coli or thermo-tolerant coliform bacteria must not be detectable in any 100ml sample of water (0MPN/100ml) for the water to be considered potable. The presence of Coliform bacteria in the rainwater samples collected for all roof types is an indication that the harvested water have proven to be inadequate in terms of quality. Based on this, the water samples are unfit for human consumption. The findings from this study is in tandem with the studies of Ezemonye, et. al. (2016) and Nwaugo, et. al. (2012).

Table 2: Result of microbial analysis for Total Microbial Load (TML)

Sample Location	Rooftop type	Microbial Count	Isolated Organisms
SPL 1	Aluminium	1.6×10^{1} cfu ml^{-1}	Eshericia coli and Klebsiella spp isolated
	Asbestos	3.4×10^{1} cfu ml^{-1}	Klebsiella spp & streptococci spp isolated
	Zinc	2.1×10^{1} cfu ml^{-1}	Eshericia coli and Klebsiella spp isolated
	Control	Nil	No growth isolated
SPL 2	Aluminium	2.0×10^{1} cfu ml^{-1}	Klebsiella spp and Eshericia coli isolated
	Asbestos	3.1×10^{1} cfu ml^{-1}	Klebsiella spp & streptococci spp isolated
	Zinc	2.1×10^{1} cfu ml^{-1}	Eshericia coli and Klebsiella spp isolated
	Control	Nil	No growth isolated
SPL 3	Aluminium	2.8×10^{1} cfu ml^{-1}	Eshericia coli and Klebsiella spp isolated
	Asbestos	3.5×10^{1} cfu ml^{-1}	Eshericia coli & staphylococci isolated
	Zinc	2.1×10^{1} cfu ml^{-1}	Klebsiella spp & streptococci spp isolated
	Control	Nil	No growth isolated
SPL 4	Aluminium	3.1×10^{1} cfu ml^{-1}	Eshericia coli & staphylococci isolated
	Asbestos	4.2×10^{1} cfu ml^{-1}	Streptococci, Eshericia coli & klebsiella spp isolated
	Zinc	2.4×10^{1} cfu ml^{-1}	Eshericia coli and Klebsiella spp isolated
	Control	0.6×10^{1} cfu ml^{-1}	Klebsiella spp isolated

Source: Author's Laboratory Analysis (2022)

Table 2 shows the result of total microbial load of the water samples. SPL 1 for Aluminium roofing sheets had 1.6/100ml, Asbestos 3.4/100ml, Zinc 2.1/100ml microbial loads while two organisms (Eshericia coli and klebsiella spp) were isolated for Aluminium and Zinc roofing sheets, Klebsiella spp & streptococci spp were isolated for Asbestos roofing sheet. The findings followed the same trend as was found in (Table 1) for Total Coliform Count, except that the Total Microbial Load (TML) had more micro-organisms isolated than the total coliform count. Sample locations 1, 2, and 3 (SPLs 1, 2 & 3) had neither coliform nor E.coli. The implication of this is that the water samples were safe for domestic purposes. A cursory look at Table 2 shows that three organisms (Eshericia coli, klebsiella spp, and streptococci spp) were isolated and the water samples were polluted by these organisms. In all, SPL 4 (Asbestos) is the highest polluted in terms of the number of organisms isolated while the least is the "Control" with one organism isolated. Samples (SPLs) from which streptococci spp and staphylococci were isolated may have been from other sources of contamination such as the soil or from the container with which the samples were collected. Following the WHO (1993) international standards for drinking water, the result confirms the presence and threat of feacal pollution/contamination of the water samples. Generally, the results indicate clearly the poor microbial quality of most harvested rainwater samples from this study and other previous studies. Thus, the harvested rainwater should not be consumed without suitable pre-treatment that improves the quality of the water.

Potential Public Health Risks Associated with Consumption of Roof Rainwater:

Rainwater harvesting is considered a key adaptation strategy to the impacts of climate change (Barron, 2009). Rainwater provides the cleanest naturally occurring water supplement for households and institutions especially in developing countries and Nigeria in particular. There is this general believe in the past and up to the present that rainwater is pure and could be consumed without pre-treatments. In some locations that are relatively unpolluted, this assertion might be true. However, in many other locations, collected rainwater contains impurities. Over the years, especially in developing countries, people have resorted to the use of unwholesome water from various sources due to their inability to find water in their location and lack of water supply by the water agencies. People have harvested rainwater for their use with minimal consideration for the quality.

Nkemdirim, et. al., (2016; 2019) reported that greater percentage of the people in rural areas are unaware of the health implications of using water from questionable sources as their primary concern is usually on getting enough water to meet their household needs. Contrary to the notion that roof water is safe, available data points to the physicochemical and microbial contamination of rainwater through atmospheric deposition, leaching and weathering of roof materials, storage/conveyance utilities and faecal contamination. However, epidemiological studies linking consumption of rainwater to public health risks are scarce especially in developing countries. This reflects the lack of epidemiological research and confounding factors such as high disease burden.

Contamination of rainwater with microbes and possible health risks caused by these microbes necessitated the development of accurate and reliable tests on harvested rainwater to evaluate its suitability for human consumption. This led to the development of the “index organisms” concept as a signal to faecal pollution (WHO 2008). The predominant faecal index organism is *E. coli*. Following the WHO (1993) guideline for microbial quality of drinking water which stated that, E. coli or thermo-tolerant coliform bacteria must not be detectable in any 100ml sample of water (0MPN/100ml) for the water to be considered potable.

Compared to surface and groundwater resources, there is relatively limited research on the quality and public health risks posed by water harvested from roofs. In principle, the collection of rainwater before it hits the ground mostly from roofs implies that is safer than surface water in lakes, rivers and groundwater from shallow wells. However, several studies suggest that rainwater can be contaminated, thereby posing public health risks if consumed without treatment (Ahmed et al, 2010a,b; 2011a,b; 2012a,b, 2014, lim and Jiang 2013; Alves et al., 2014; Dobrowsky et. al., 2014a,b; Jesmi et. al, 2014; Lye 2014).

Before the benefits of roof rainwater harvesting can be attained, there is need to understand the public health risks associated with consumption of such water. This is particularly important in Nigerian rural communities. As reported by several researchers, harvested rainwater can contain significant amounts of pollutants such as heavy metals, nutrients and pathogens (Gromaire-Mertz et. al.; 1999; Lye, 2002; Zhu et. al., 2004; Evans 2006; Yufen et. al. 2008). These heavy metals can cause adverse effects on human beings, animals and plants and surface water. Heavy metals combine with body bio-molecules like proteins and enzymes mutilating their structure and hindering their biological functions (Duruibe, et. al; 2007). Salem, et. al., (2000) reported a strong relation between heavy metal contaminated water and chronic diseases such as renal failure, liver cirrhosis, hair loss and chronic anaemia. Apart from contamination from atmosphere, roofs are made of variety of materials, and most of these inbuilt are potentially toxic materials which are not suitable as rainwater catchment surfaces. All these materials are a potential source of dissolved ions, alkalinity and trace metals (Ayenimo et. al., 2006).

Several studies have challenged the anecdotal view that rainwater is safe for human consumption without treatment. For example, consumption of untreated rainwater has been linked to bacterial diarrheas, associated with Salmonella and Campylobacter, bacterial pneumonia due to Legionella, botulism due to Clostridium and protozoal diarrhesa from Giardia and Cryptosporidium (Lye, 2002; 2004). A study conducted by Ahmed, et. al., (2010b) in Australia also showed that untreated roof harvested rainwater samples tested positive for Salmonella, Giardia Lamblia, Legionella pneumophilia, and campylobacter jejuni, thereby posing public health risks to consumers. This present study revealed the presence of Coliform bacteria in the rainwater samples collected for all roof types, and is an indication that the harvested water have proven to be inadequate in terms of quality. Based on this, the water samples are unfit for human consumption.

Therefore, understanding the determinants of roof water quality and public health risks associated with consumption of roof water is critical for the design, operation and evaluation of roof water harvesting systems for potable water supply in Nigeria. Such information is critical for devising public health measures to reduce the risks associated with consumption of roof rainwater.

Conclusion and Recommendations:

Though the study analysed the various sources of water supply in the study area and the techniques involved in its collection, it focused more on the assessment of the microbial and potential public health risks associated with consumption of harvested rainwater from three rooftops in Isuikwuato Local Government Area, Abia State. The study revealed that all samples collected had detectable Coliform count per 100ml sample of water. For Total Coliform count, the result indicates that samples with the highest percentage of Coliform count were those from corrugated Asbestos rooftops, followed by those from Aluminium rooftops while Zinc had the least probable number of Coliform count. The findings for Total Microbial Load followed the same trend as was found in (Table 1) for Total Coliform count, except that the Total Microbial Load (TML) had more micro-organisms isolated than the total coliform count. Sample locations 1, 2, and 3 (control) had neither coliform nor E.coli. The implication of this is that the water samples were safe for domestic purposes. In all, SPL 4 (Asbestos) is the highest polluted in terms of the number of organisms isolated while the least is the “Control” with one organism isolated. Generally, the results indicate clearly the poor microbial quality of most harvested rainwater samples from this study. While it is recommended that harvested rainwater should be properly filtered and boiled, households who intends to embark on rainwater harvesting culture are advised not to use the non-metallic roofing materials since higher Coliform counts were observed in them.

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