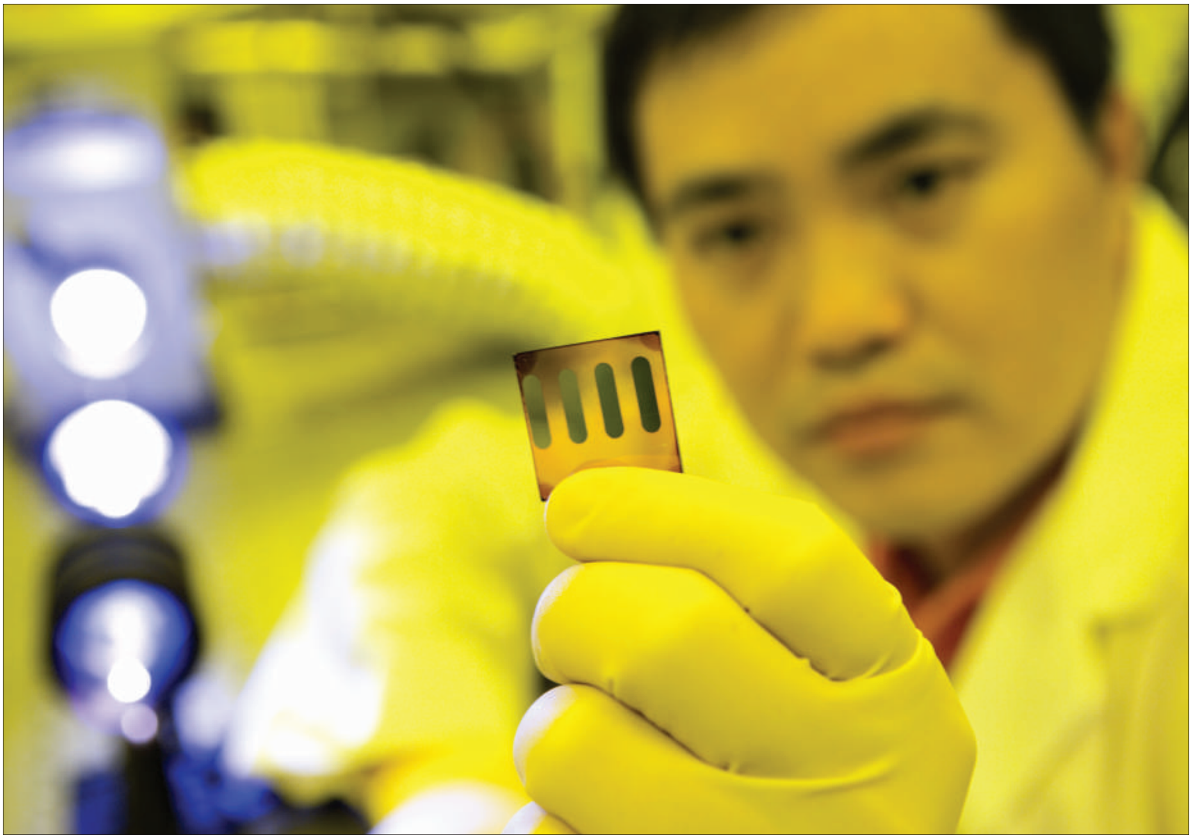

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Research Article
Microbiological Quality of Harvested Rainwater Used for Drinking and Domestic Purposes in Southeastern Nigeria

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Abstract
Background and Objective: The rural communities in Southeastern Nigeria use harvested rainwater as the primary source of water for drinking and domestic purposes. There is high incidence of water borne diseases in these communities and information on the quality of the harvested rainwater is lacking. The aim of this study was to assess the microbiological quality of the harvested rainwater from the rural communities in Southeastern Nigeria. **Materials and Methods:** Harvested rainwater samples were aseptically collected from six rural communities and analysed in the laboratory using standard microbiological methods. The analysis involved determination of total heterotrophic bacteria count, total coliform count and total faecal coliform count. The results were expressed in coliform forming unit per millilitre (CFU mL^{-1}). Biochemical tests were carried out to identify the isolates. **Results:** The total heterotrophic bacterial counts of the water samples ranged from 1.9×10^3 to 7.0×10^{-6} CFU mL^{-1} while the total coliform and total faecal counts ranged from 1.8×10^2 to 2.6×10^4 and 1.0×10^2 to 8.0×10^3 CFU mL^{-1}, respectively. The organisms isolated from the water samples included *Escherichia coli*, *Enterococcus faecalis*, *Bacillus subtilis*, *Shigella* spp., *Klebsilla* spp. and *Vibrio* spp. **Conclusion:** The microbiological quality of the water samples does not meet the standard criteria for drinking and domestic purposes because the total bacteria counts exceed the limit. Moreover, most of the organisms isolated are pathogenic and could cause serious health problems in humans. Preventive and treatment approaches should be adopted to minimize the dangers associated with the use of the harvested rainwater.

Key words: Microbiological quality, bacterial count, faecal coliforms, harvested rainwater, water borne diseases, rural communities, Southeastern Nigeria

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rain water harvesting is a common practice in most developing countries. The practice has been described as the activity of collecting rainwater directly for beneficial use or recharging it into the ground water storage in the aquifer[1]. Harvested rainwater is a major source of water for domestic purposes in many regions of the world. The water is collected from the rooftops and stored in surface tank or underground tanks made of concrete or in various water storage containers. It has been opined that rooftop catchment of rainwater can provide good quality water as long as the rooftop is clean, impervious and made from non toxic materials[2].

In response to increased unavailability of potable water in some regions of the world, there is now a renewed interest in rainwater harvesting as alternative to surface and ground water. Rainwater harvesting has received increased attention worldwide as an alternative source of potable and non-potable water supplies[3-6]. Researchers have assessed the rainwater harvesting potential and systems in various parts of Nigeria[1,7]. Their finding showed that rain water harvesting was practiced by 80% households, with the rooftop as the catchment area. It has been argued that the method promotes self-sufficiency and encourages water and energy conservation and results in decrease in water demand and climate change adaptation measure[8-9].

Despite having some promising merits over other sources, rainwater use has frequently been rejected as a source of potable water supply on the grounds of its water quality concerns[10]. It has been reported that rainwater can contain significant amount of pollutants such as heavy metals, nutrients and pathogens[11-15]. In some rural areas of Southeastern Nigeria, the primary source of water used by the inhabitants of this region is rainwater, which they use for domestic purposes as well as drinking. Literature on the microbiological quality of the harvested rainwater is scanty. The aim of this present study is to assess the microbiological quality of harvested rainwater in some rural communities in Southeastern Nigeria.

MATERIALS AND METHODS

Study area: The study was carried out at Microbiology laboratory, Department of Microbiology, Federal University of Technology, Owerri, Nigeria from April, 2018 to August, 2019.

Collection of sample: A total of 18 samples of harvested rainwater were collected from 6 rural communities in the southeastern part of Nigeria. Three harvested rainwater samples were collected from each community and labelled $A_{1,2,3}$ to $F_{1,2,3}$ respectively. The samples were collected aseptically into sterile containers and transported to laboratory for microbiological analysis within 4 h of collection.

Bacteriological analysis of the water samples: One millilitre of each of the water samples was pipette into 9 mL of sterile physiological saline and swirled to mix thoroughly. The solutions were diluted decimally until appropriate dilution was obtained. Aliquot portion (0.1 mL) of appropriate dilution was inoculated into a pre-sterilized and surface dried nutrient agar medium using the spread plate method. Plates were incubated at 37°C for 24-48 h for heterotrophic bacteria. Colonies obtained on the media were counted and expressed as colony forming units per millilitre of water (CFU mL^{-1}). The counting of the colonies was based on their physiological characteristics and their number on the culture plate, taking note of their serial dilution number. Counts were made from the plates containing 30-300 colonies. After counting, the respective isolates were aseptically sub-cultured into fresh nutrient agar and incubated at a temperature of 37°C for 24 h to obtain pure cultures of the isolates.

Identification of the isolates: The organisms were identified based on their colony morphology, microscopic characteristics, Gram staining reactions, motility and biochemical characteristics. The biochemical tests carried out on the isolates included catalase activity, oxidase test, sugar fermentation, urease test, indole test and triple sugar iron agar test.

RESULTS

Microbiological assessment of the harvested rainwater revealed high bacteria count in all the water samples analysed. The total heterotrophic bacteria counts of the water samples from various locations ranged from 1.9×10^3 to 7.0×10^6 CFU mL^{-1} while the total coliform and total faecal coliform counts of the harvested rainwater samples ranged from 1.8×10^2 to 2.6×10^4 and 1.0×10^2 to 8.0×10^3 CFU mL^{-1}, respectively (Table 1).

Results of biochemical tests for the purpose of identifying the isolates are shown in Table 2. The bacteria isolated from

Table 1: Total heterotrophic bacteria count of harvested rainwater from some rural communities in Southeastern Nigeria

	Count (CFU mL^{-1})		
Samples	Total heterotrophic bacterial	Total coliform	Total faecal coliform
A_1	1.1×10^4	2.5×10^2	2.0×10^2
A_2	3.0×10^5	2.0×10^3	2.2×10^3
A_3	2.9×10^4	2.8×10^2	1.8×10^2
B_1	7.0×10^6	2.9×10^3	1.5×10^3
B_2	1.5×10^6	1.8×10^2	1.0×10^2
B_3	1.2×10^7	2.4×10^4	3.2×10^3
C_1	3.5×10^3	2.9×10^2	2.0×10^2
C_2	4.0×10^5	1.8×10^3	1.4×10^2
C_3	4.8×10^3	2.8×10^2	1.0×10^2
D_1	3.5×10^4	7.0×10^3	6.4×10^2
D_2	4.0×10^4	2.2×10^4	8.0×10^3
D_3	4.8×10^4	2.4×10^2	1.2×10^2
E_1	7.0×10^3	5.6×10^2	1.0×10^2
E_2	3.0×10^4	5.0×10^3	2.4×10^3
E_3	2.9×10^4	2.5×10^2	1.5×10^2
F_1	1.9×10^3	1.0×10^3	4.5×10^2
F_2	2.9×10^3	3.0×10^2	1.8×10^2
F_3	2.9×10^5	2.6×10^4	1.5×10^3

A_1-A_3: Harvested rainwater samples from Eziobodo, B_1-B_3: Harvested rainwater samples from Okwele, C_1-C_3: Harvested rainwater samples from Obibi Ochasi, D_1-D_3: Harvested rainwater samples from Emekuku, E_1-E_3: Harvested rainwater samples from Omagwa, F_1-F_3: Harvested rainwater samples from Irete

the water samples were *Bacillus subtilis*, *Escherichia coli*, *Vibrio* spp., *Staphylococcus* sp., *Enterococcus faecalis*, *Klebsiella* spp. and *Shigella* spp.

DISCUSSION

The results obtained from this study showed high total bacteria counts for all the water samples. The counts exceed the World Health Organization (WHO) permissive limit[16] of 1.0×10^2 CFU mL^{-1}. This indicates that the harvested rainwater is not safe for drinking. The presence of faecal coliforms in the water samples shows that the harvested rainwater is polluted with faecal substances. This might have originated from faecal substances of animal origin deposited on the rooftops or storage vessels used for harvesting the rainwater in the study area. It is not unlikely that droppings from flying birds or domestic animals can contaminate the rooftops or storage vessels for the harvested rainwater. Researchers have opined that water collected from roof tops can potentially become contaminated through dust, bird droppings and chemical leachates from the roofing materials, adhesive and coatings[17]. These can be leached or washed down from the roofs during rainfall into storage containers, posing a potential health risk for the consumers[18].

Table 2: Morphological and biochemical characterization of bacteria isolates from harvested rainwater samples from some rural communities in Southeastern Nigeria

				Triple sugar iron agar					Sugar fermentation									
Isolate code	Colony morphology	Microscopic characteristics	Gram staining	H_2S	Gas	Glucose	Sucrose	Lactose	Acid	Gas	Urease	Oxidase	Motility	Indole	Citrate	Methyl red	Catalase	Most probable organism
A	Fuzzy white, opaque	Clustered	+	-	+	+	+	+	+	-	-	-	+	-	+	-	+	*Bacillus subtilis*
B	Creamy, circular	Rods	-	+	+	+	+	+	+	+	-	+	+	+	-	+	-	*Vibrio* spp.
C	White, shiny, circular	Rods	-	+	+	+	+	+	+	+	-	-	-	+	-	+	-	*Escherichia coli*
D	Creamy, raised	Clustered cocci	+	-	-	+	+	+	+	+	-	-	-	-	+	-	+	*Staphylococcus* sp.
E	Entire, creamy, medium, raised	Cocci	+	-	+	+	+	+	+	+	-	-	-	-	-	-	-	*Enterococcus faecalis*
F	Creamy, shiny, round	Rod	-	-	+	+	+	+	+	+	-	+	-	+	+	+	+	*Klebsiella* spp.
G	White, raised, shiny	Long rod	-	-	-	+	-	-	+	+	-	-	-	-	-	+	+	*Shigella* spp.

+: Positive, -: Negative, H_2S: Hydrogen sulphide test

Results of the biochemical tests for identification of the isolates revealed that the isolated organisms are mostly pathogenic and could cause serious health problems in humans. *Escherichia coli* is excreted in large numbers by man and animals[19]. Its presence in water confirms that faecal matter has entered the water source and that the source is liable to contamination with dangerous intestinal pathogens[20]. In other words, the presence of *E. coli* in the harvested rainwater samples from rural communities in Southeastern Nigeria shows that there is the possibility of the water source serving as a potential carrier of pathogenic microorganisms associated with faecal matter. This implies that the harvested rainwater may carry pathogens which cause diseases like typhoid fever, dysentery, cholera and other water borne diseases[21]. Several studies have reported illnesses linked to the consumption of harvested rainwater[22-26]. Apart from the drinking of the contaminated water, its use in the preparation of food, which might allow the multiplication of intestinal pathogens present an obvious danger.

CONCLUSION

The results of this study revealed that the microbiological quality of harvested rainwater used for drinking and domestic purposes in rural communities in Southeastern Nigeria does not meet the standard criteria for such purpose as potential pathogenic microorganisms were isolated from the water samples. This calls for preventive and treatment approaches to minimize the dangers associated with the use of the harvested rainwater.

SIGNIFICANCE STATEMENT

This research work discovers the possibility of harvested rainwater serving as potential source of waterborne diseases apart from surface and underground water sources such as rivers, streams and boreholes which have received much attention from previous researchers and are already established in scientific literature. This study will help the researchers to uncover the critical aspects of contamination of harvested rainwater that many researchers were not able to explore. Thus, preventive and treatment methods that can minimize the dangers associated with the use of harvested rainwater may be arrived at.

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