Journal of Scientific Research & Reports

21(2): 1-11, 2018; Article no.JSRR.44054
ISSN: 2320-0227

Quality of Rainwater Used Within Communities in Calabar, Nigeria

A. A. Unimke[1*], O. A. Mmuoegbulam[1] and O. C Anika[1]

[1]*Department of Microbiology, Faculty of Biological Sciences, University of Calabar, PMB 1115, Calabar, Cross River State, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author AAU designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OAM and OCA managed the analyses of the study. All authors managed the literature searches, and also read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2018/44054
Editor(s):
(1) Dr. Rajkumar Venkatesh Raikar, Department of Civil Engineering, KLE Dr. M. S. Sheshgiri College of Engineering and Technology, Karnataka, India.
Reviewers:
(1) M. Pandimadevi, SRM Institute of Science and Technology, India.
(2) Leonora E. Ngilangil, Don Mariano Marcos Memorial State University Bacnotan, Philippines.
Complete Peer review History: http://www.sciencedomain.org/review-history/27274

Original Research Article

Received 02 August 2018
Accepted 09 October 2018
Published 17 November 2018

ABSTRACT

The risk of microbiological and physicochemical contamination of rainwater especially during collection and storage has long been a persistent challenge. This study was carried out to assess the quality of rainwater used within communities in Calabar. Rainwater samples were aseptically collected from three locations within Calabar; Atimbo, Etta Agbo and Calabar South, the samples were analysed for total heterotrophic bacterial (THB), total fungi (TF), and total coliform (TC). The average total heterotrophic bacterial counts were $1.22x10^6$cfu/ml for samples from Atimbo, $1.01x10^6$cfu/ml in samples from Calabar South and $1.56x10^6$cfu/ml in the samples from Etta Agbo. The total fungal counts produced insignificant results in the three samples analysed. The highest total coliform count was obtained in rainwater harvested from Calabar South ($2.05x10^6$cfu/ml), followed by Etta Agbo ($1.92x10^6$cfu/ml) while Atimbo had the lowest count of $1.66x10^6$cfu/ml. The physicochemical characteristics of the three samples analysed indicate that the rain water was physically not suitable for drinking and other domestic and industrial use, but chemically fit for adequate utilisation.

**Corresponding author: E-mail: austinraney.unimke@gmail.com, aaunimke@unical.edu.ng;*

Keywords: Rainwater; physicochemical properties; heavy metals; coliform; World Health Organization.

1. INTRODUCTION

Water is essential for growing food and for house hold use including drinking, sanitation and plays a critical input into the industry for tourism and cultural purposes and for its role in sustaining the earth's ecosystem [1,2]. In addition, water is for direct human consumption which is beneficial to health and general sustenance of life and for an optimal bodily function for both humans and animals.

Potable water, a necessary reserve is in short supply. The global crisis of potable water shortage has send man on the lookout for new sources and even more intensively. In light of this, one of the free sources explored to cushion the effect of water shortage is rain water. Archaeological evidence attests to the capture of rain water as far back as 400 years ago, and the concept of rain water harvesting in China dates back 6000 years [3,1,2,4].

In most urban areas, population is rapidly increasing and the issue of supplying adequate water to meet societal needs and ensure its access to the teeming population is a significant challenge, as a result of this, rain water harvesting and utilisation is the most environmentally sound solution which is cheap, environmental friendly with minimal application of technology [5-7].

However, one of the primary areas of concern regarding the use of rain water especially for potable application is quality. The quality of water collected in rain water harvesting system is affected by many factors which include nature of the catchment system and the roofing materials, environmental pollutions from industries, automobiles and anthropogenic activities. The presence of dirt, debris, birds and rodent droppings on roofs and water catchments and the type of storage materials are factors to consider [8-10].

Catchment materials, storage materials and treatment are three design considerations that can be optimised to maximise rain water quality [11]. In the past, it was believed that rain water is pure and could be consumed without pre-treatment, while this may be true in some areas that are relatively unpolluted; the same cannot be said for polluted areas because the water contains impurities, microorganisms, and certain dissolved chemicals and elements which can be harmful to health [12-14].

Particularly in the last three decades because of global warming, industrialisation and other human activities "contamination" has affected the quality of rain water to a point it requires treatment and restriction to certain uses [4,15].

Roofs can be made of a variety of materials ranging from simple grass/reeds to the potentially sophisticated toxic roofing materials. The typical roofing materials that are commonly used in rural areas in Nigeria as observed particularly in Calabar are ceramics, metal sheets, galvanised iron, anodised aluminium and asbestos. All these materials are potential sources of certain dissolved ions, alkaline and trace metals [5,16-17].

Calabar is a tourism destination with little industrial activities. Therefore, pollution arising from industrial processes is limited. Though there is high carbon emission resulting from automobile operations within the metropolis.

This study was designed to examine the microbiological and physicochemical quality of rainwater used within communities in Calabar, Nigeria as follows:

a. Enumeration of total heterotrophic bacteria and total fungi.
b. Total coliform count.
c. Antibiotic susceptibility testing.
d. Physicochemical analysis.

2. MATERIALS AND METHODS

The rainwater samples were collected in 9 sterile 750 ml bottles from 3 different locations in Calabar at 2 different sampling points each; Atimbo: (Otu Ansa street and Noble street); Etta Agbor: (Okoro Oba street and Asitata street); and Calabar South: (Waddel street and Idang street).

The collected samples were preserved at a temperature of 4°C immediately after collection and were transported to the laboratory for analysis within 4 hours. The composite samples were obtained from the mixture of an equal volume of each of the samples from the sampling points. All samples were adequately coded in the laboratory.

The microbiological quality and the physicochemical parameters of rainwater used within communities in Calabar were analysed.

The inoculation was carried out with 10^{-4} and 10^{-5} dilution factor of the serially diluted samples and pour plate technique was adopted [18-20].

The emerging colonies were enumerated on harvesting the plates. The number of colonies observed was noted and discrete colonies were isolated and described, then transferred to nutrient agar slant as stock culture for further studies.

Coliform count was carried out using membrane filtration techniques as described below. The funnel was rinsed with sterile buffered water. The vacuum was turned on and the sample was allowed to draw completely through the filter. A forcep was sterilised by flaming and used to remove the membrane filter from the funnel and neatly placed into a prepared petri dish containing MacConkey agar. This procedure was used for all the samples ATM1, ATM2, ETA1, ETA2 and CS1, CS2.

2.1 Colony Enumeration

The emerging colonies were counted on harvesting the plates. The number of colonies observed was noted and discrete colonies were isolated and described, then transferred to nutrient agar slant as stock culture for future purpose.

2.2 Physicochemical Analysis

Some chemical parameters such as total dissolved solids (TDS), total hardness, iron, magnesium, sulfide, nitrite, nitrate, phosphorus, ammonia, aluminum, copper, cadmium, potassium, fluoride and biochemical oxygen demand (BOD) of the 3 composite samples were analysed using Hachspectrophotometer, while the physical parameters such as the temperature, pH, turbidity, conductivity were analysed using their respective devices as described below [18-20].

3. RESULTS

3.1 Total Heterotrophic Bacterial Count

The result of the total heterotrophic bacterial count showed that the water sample from Etta Agbo had the highest bacterial count of $1.56x10^6$ followed by the Atimbo ($1.22x10^6$); while the sample from Calabar South had the lowest bacterial count ($1.01x10^6$) as shown in Table 1.

3.2 Total Fungal Count

The result of the total heterotrophic fungal count showed that all the water samples analysed had too few to count fungal colonies on the potato dextrose agar plates as shown in Table 2.

3.3 Total Coliform Count

The result of the total coliform count indicated that the harvested rainwater sample from Calabar South had the highest coliform count of $2.05x10^6$cfu/ml followed by Etta Agbo ($1.92x10^6$); while, Atimbo had the lowest coliform count of $1.66x10^6$cfu/ml as shown in Table 3.

3.4 Biochemical and Cultural Characterisation of Probable Isolates

The result of the biochemical tests and cultural characterisation of the probable organisms indicated that there were nine different organisms in the water samples analysed and these organisms were *Staphylococcus specie, Aeromonas hydrophila, Klebsiella oxytoca, Lactobacillus specie, Klebsiella specie, Corynebacterium species, Salmonella species, Escherichia coli* and *Cladosporium species* as shown in Table 4.

3.5 Number of Isolates from each Sample

The result of the number of isolated organism from each sample indicated that Calabar South had the highest number of probable organisms followed by Etta Agbo, while Atimbo had the lowest number of probable isolated organisms as shown in Table 4.

Table 1. Total heterotrophic bacterial count

S/N	Sample	Code	Average count (Cfu/ml)
1	Atimbo	ATM	1.22×10^6
2	Etta Agbo	ETA	1.56×10^6
3	Calabar South	CS	1.01×10^6

Table 2. Total fungal count

S/N	Sample	Code	Average count (CFU/ml)
1	Atimbo	ATM	TFTC
2	Etta Agbo	ETA	TFTC
3	Calabar South	CS	TFTC

Where TFTC = Too few to count.

Table 3. Total coliform count

S/N	Sample	Code	Average Count (Cfu/ml)
1	Atimbo	ATM	1.66×10^6
2	Etta Agbo	ETA	1.92×10^6
3	Calabar South	CS	2.05×10^6

Table 4. Number of isolates from each sample

S/N	Samples	Sample code	No of isolates	Isolate code	Probable Isolate
1	Atimbo	ATM	4	IA	*Staphylococcus specie*
				IC	*Klebsiella oxytoca*
				IH	*Escherichia coli*
				II	*Cladosporium specie*
2	Etta Agbo	ETA	5	IA	*Staphylococcus specie*
				ID	*Lactobacillus specie*
				IG	*Salmonella specie*
				IH	*Escherichia coli*
				II	*Cladosporium specie*
3	Calabar South	CS	6	IA	*Staphylococcus specie*
				IB	*Aeromonas hydrophila*
				IC	*Klebsiella oxytoca*
				IE	*Klebsiella specie*
				IF	*Corynebacterium specie*
				II	*Cladosporium specie*

3.6 Frequency and Percentage of Isolates Occurrence in the Samples

The result of the isolated organisms' frequency and percentage of occurrence in the samples indicated that *Staphylococcus species* and *Cladosporium specie* had the highest frequency and percentage of occurrence in the samples followed by*Klebsiella oxytoca* and *Escherichia coli,* while *Aeromonas hydrophila*, *Lactobacillus specie, Klebsiella specie, Corynebacterium specie* and *Salmonella species* had the lowest frequency and percentage of occurrence as stated in Table 5.

3.7 Physicochemical Analysis

From the physicochemical analysis result obtained, it was indicated that Atimbo had the highest temperature while Etta Agbo and Calabar South had the same and lowest temperature.

Etta Agbo had the highest pH, followed by Calabar South; while Atimbo had the lowest pH. Etta Agbo had the highest turbidity and total dissolved solids (TDS) followed by Atimbo; while Calabar South had the lowest turbidity and TDS as recorded respectively. The result of the Figs. 1 - 14 show the results of the physicochemical parameters of each sample analysed from the various locations in comparison with the overall physicochemical results obtained.

The three samples had the same total hardness and aluminum content respectively. Calabar South had the highest biochemical oxygen demand (BOD) and magnesium content, followed by Atimbo; while Etta Agbo had the lowest BOD and magnesium content respectively. Atimbo had the highest calcium and fluoride content, followed by Calabar South; while Etta Agbo had the lowest calcium and fluoride content respectively. Atimbo had the highest phosphate concentration, followed by Etta Agbo; while Calabar South had the lowest phosphate concentration.

Table 5. Frequency of Isolates Occurrence in the Samples

Probable organism	Frequency	Percentage (%)
Staphylococcus specie	3	20.00
Aeromonas hydrophila	1	6.67
Klebsiella oxytoca	2	13.33
Lactobacillus specie	1	6.67
Klebsiella specie	1	6.67
Corynebacterium specie	1	6.67
Salmonella specie	1	6.67
Escherichia coli	2	13.33
Cladosporium specie	3	20.00
Total	15	100

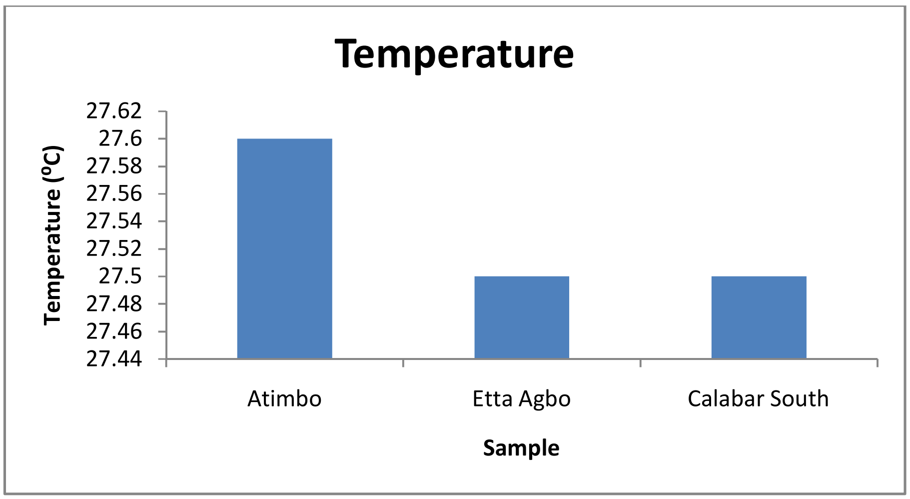

Fig. 1. Temperature comparison of the water samples.

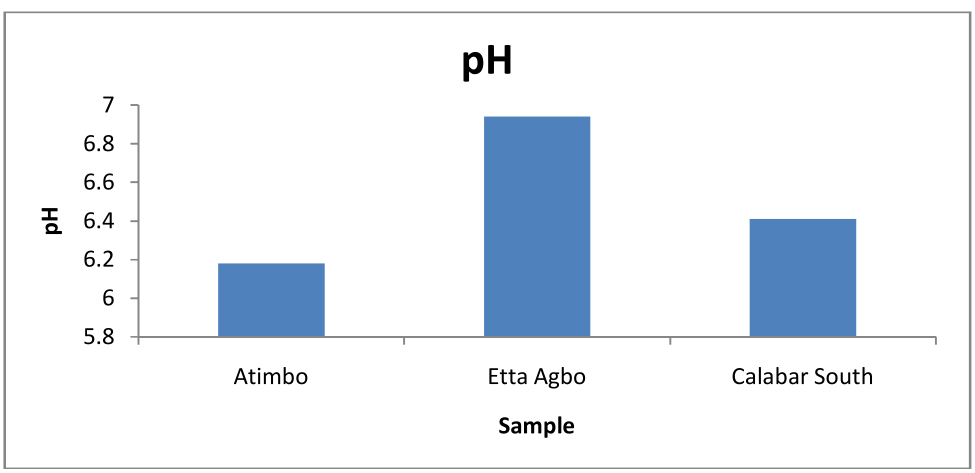

Fig. 2. pH comparison of the water samples

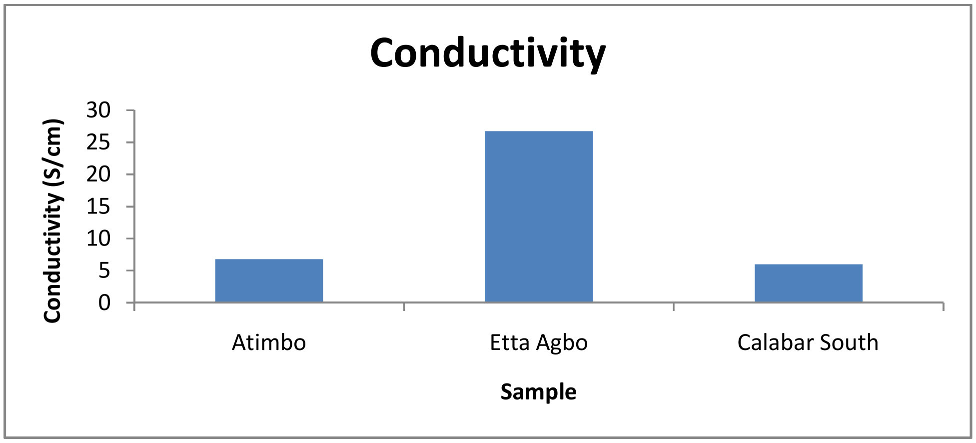

Fig. 3. Conductivity comparison of the water samples

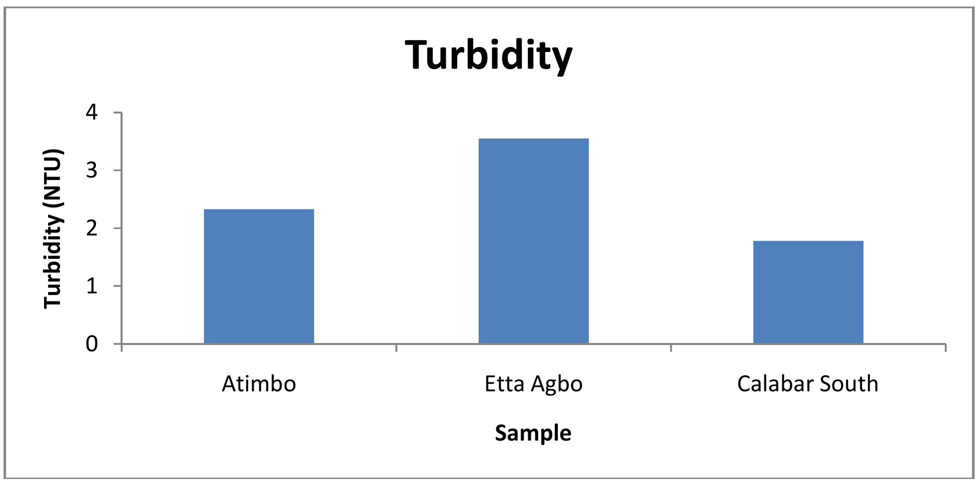

Fig. 4. Turbidity comparison of the water samples.

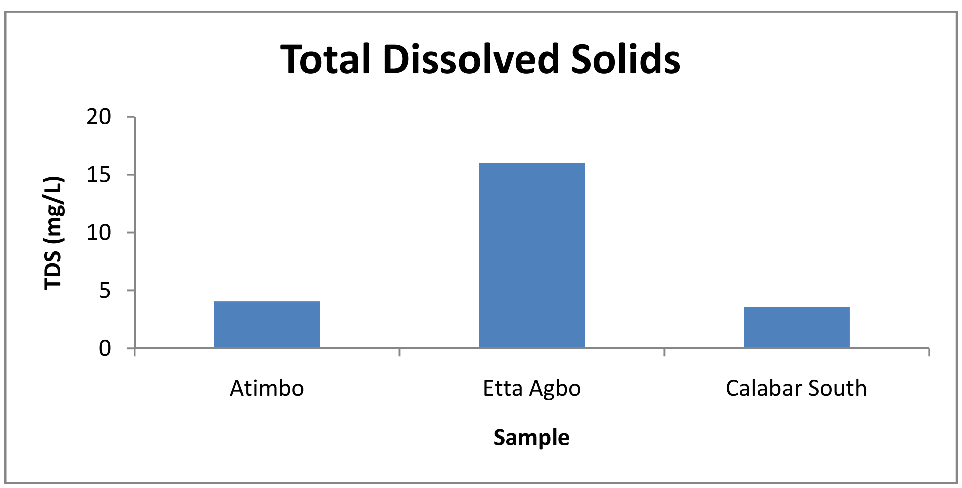

Fig. 5. TDS comparison of the water samples

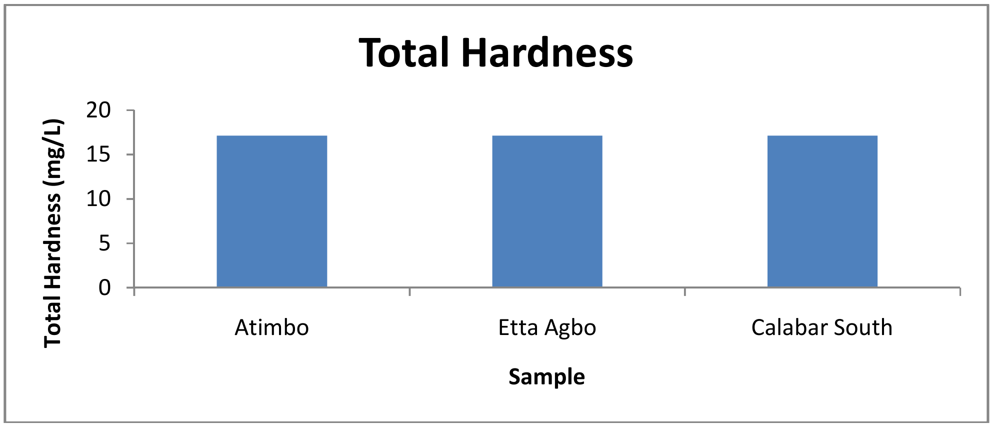

Fig. 6. Total hardness comparison of the water samples

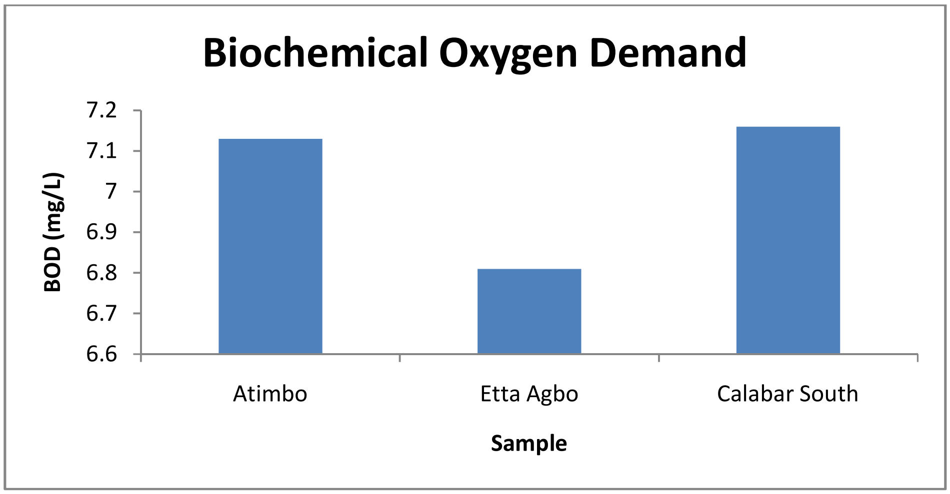

Fig. 7. BOD comparison of the water samples

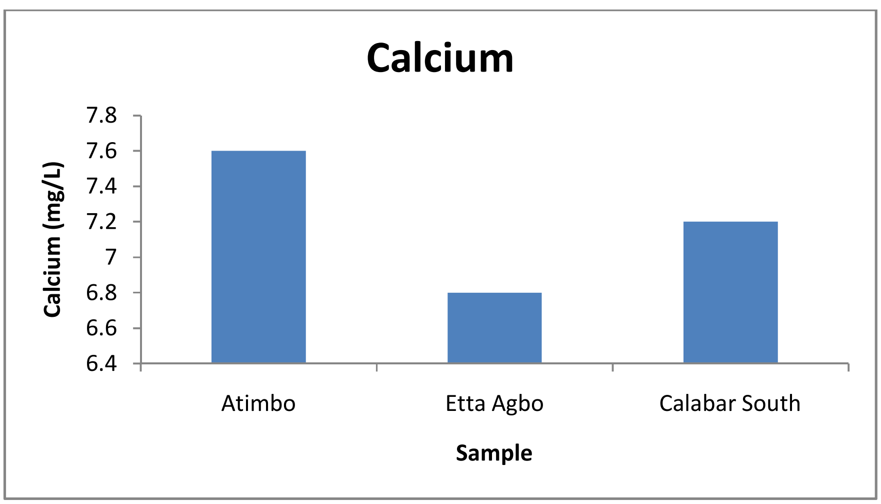

Fig. 8. Calcium comparison of the water samples

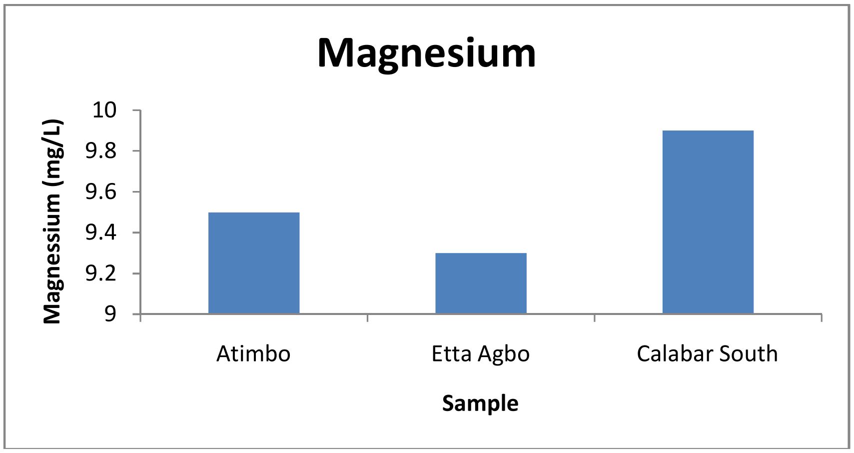

Fig. 9. Magnesium comparison of the water samples

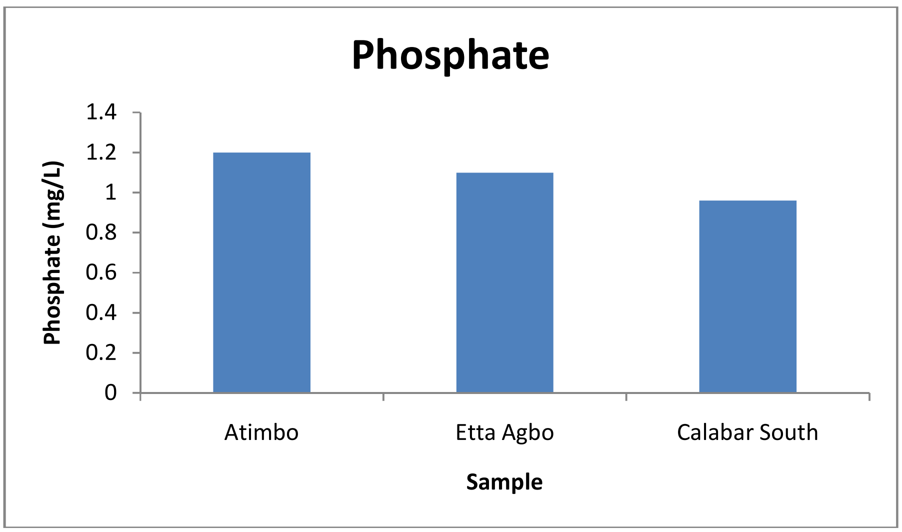

Fig. 10. Phosphate comparison of the water samples

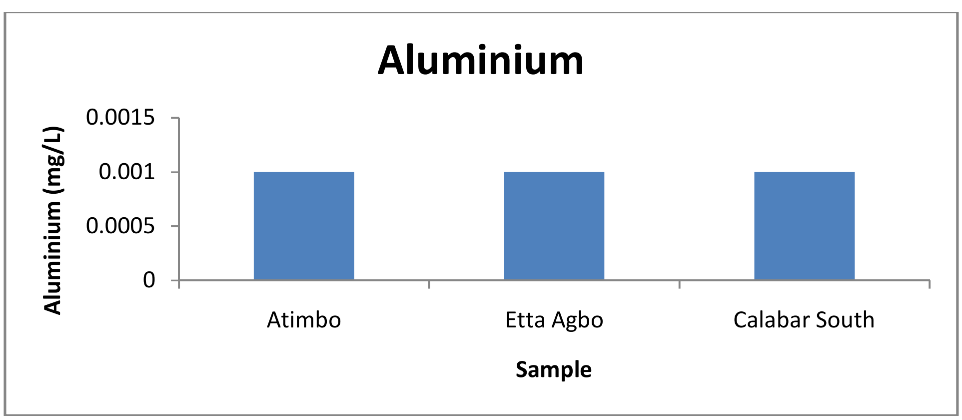

Fig. 11. Aluminum comparison of the water samples

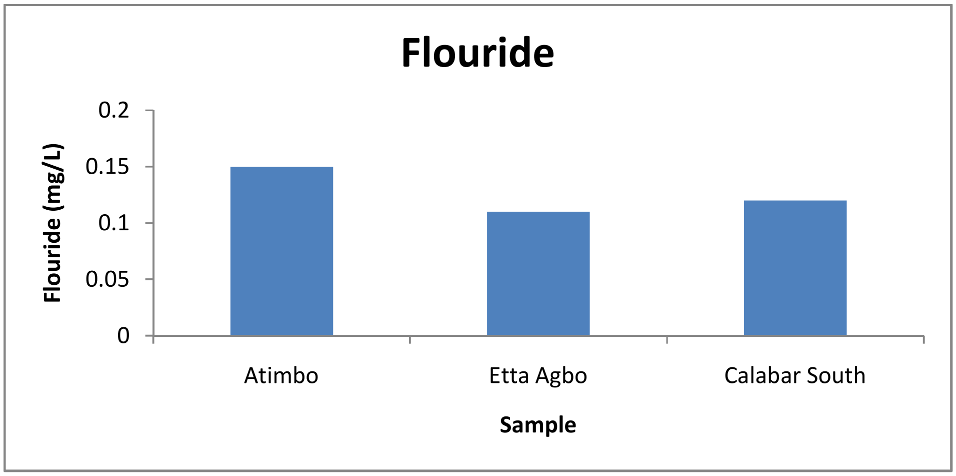

Fig. 12. Fluoride comparison of the water samples

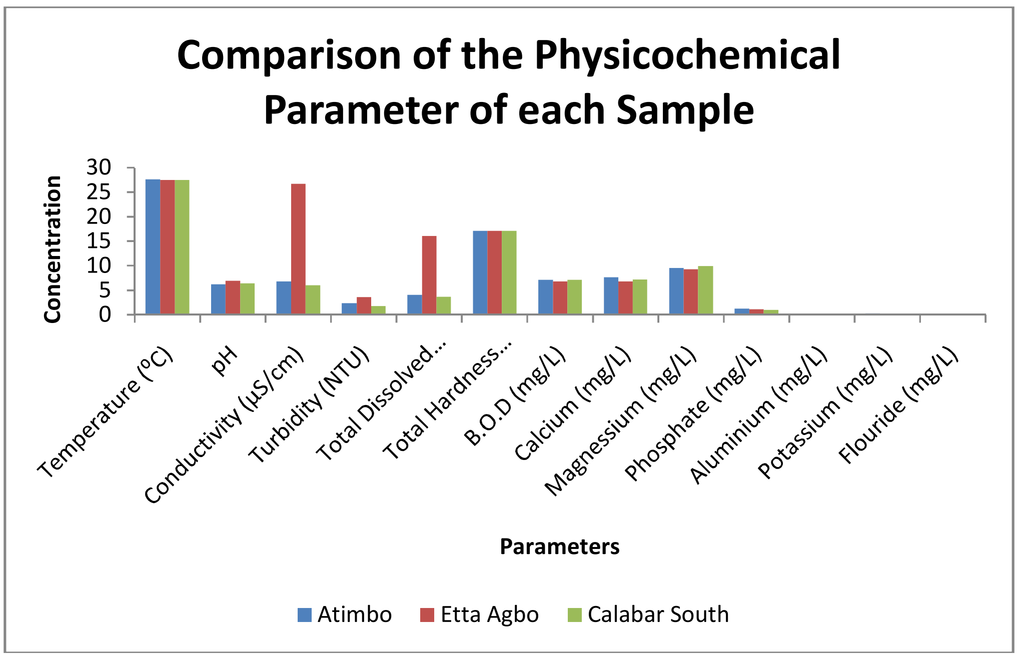

Fig. 13. Physicochemical Parameters comparison of the water samples

4. DISCUSSION

From study, none of the three locations analysed, was totally free from microorganisms. The total coliform count in Calabar South harvested rainwater sample revealed that it had the highest total coliform count of $2.05x10^6$cfu/100 ml, while Atimbo had the lowest coliform count of $1.66x10^6$cfu/100 ml. This means that the three water samples did not meet the [21] standard of 0 cfu/100 ml for coliform count.

Etta Agbo had the highest heterotrophic bacteria count of $1.56x10^6$cfu/ml, while Calabar South had the lowest heterotrophic bacteria count of $1.01x10^6$cfu/ml. This means that the three water samples did not meet the WHO standard of <100cfu/ml for bacteria count [21]. Also, the three water samples were found to be contaminated with few fungi which were significantly too few to count. Out of the 9 isolates, 6 were associated with the Calabar South water samples, giving rise to the highest contaminated samples compared to Etta Agbo and Atimbo samples with 5 and 4 isolates respectively.

The frequency and percentage of occurrence of each isolated probable organism revealed that *Syaphylococcus species* and *Cladosporium species* were found in the 3 analysed samples with the frequency and percentage of occurrence of 3 and 20.00% respectively; followed by *Klebsiella oxytoca,* and *Escherichia coli* with frequency and percentage of 2 and 13.33% respectively; while *Aeromonas hydrophila, Lactobacillus species, Klebsiella species, Corynebacterium species* and *Salmonella species* had the lowest frequency and percentages of occurrences of 1 and 6.67% respectively.

The temperature of the three water samples which were 27°C was completely above WHO (2006) standards of 25°C range. Only Etta Agbo samples with pH of 6.94 met the WHO pH standards range of 6.5 to 8.5, [21] while Calabar South and Atimbo was below the standard range. It was observed that the rainwater sample from Etta Agbo had the highest turbidity which tends to decrease the biochemical oxygen demand as a result of high concentration of dissolved solids in the water sample. This also had impact on the conductivity of this sample as higher TDS increases conductivity [20]. This was further proven by the bacterial isolated from the sample (*Staphylococcus species, Lactobacillus species, Escherichia coli* and *Salmonella species)*, which were all facultative anaerobes [22-23].

5. CONCLUSION

From the results in this study, the three rainwater samples analysed were chemically fit for drinking and other potable uses. Moreover, the physical parameters and biological parameters such as the total heterotrophic bacterial count and coliform count revealed that the three water samples analysed were unsafe for drinking according to WHO standards for drinking water [21]. In conclusion, harvested rainwater, especially in Calabar, is unsafe for drinking due to high microbial contamination resulting from industrial pollution, harvesting processes and the general storage environment.

6. RECOMMENDATIONS

Having successfully carried out this study, we, therefore, recommend that harvested rainwater should be properly treated before drinking.

When rainwater harvesting system is set up, the following considerations should be followed strictly;

- System risk assessment which includes proper design and installation
- Operation monitoring which includes checking the cleanliness of the catchment area and storage
- Verification which monitors the microbial quality of rainwater
- Management which involves routine assessment and repairs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Aina DA, Olawuyi OJ, Coker OA, Ojelabi DO, Alatise FA. Bacteriological analysis of borehole water from different towns in Ogun State, Nigeria. American Public Health Association; 2012.
2. Bankole OD. Chemical and physical properties of harvested rainwater from different roofing sheets in Abeokuta, Ogun State. Unpublished Project Work of the College of Environmental Resources Management. 2010;5-18.
3. Abbott SE, Caughley J, Douwes J. The microbiological quality of roof-collected rainwater of private dwellings in New Zealand. Proceedings of the 13th International Conference on Rain Water Catchment System; 2007.
4. Enhealth. Enhealth. Sub-committee of National Public Health Partnership of the Austrialian Government; 2004.
5. Mark WR, Ximing C, Sarah AC. World Water and Food to 2025. International Food Policy Research Institute, NW, Washington DC, USA; 2002.
6. Gordon M, Neil W, Michelle C, Adam C, Scott B, Jill V. Re-inventing rainwater management: A strategy to protect health and restore nature in the capital region. Environmental University of Victoria; 2010.
7. Lye DJ. Rooftop runoff as a source of contamination: A review. Science of the Total Environment. 2009;5429-5434.
8. Coleridge M. Scientific facts on water: state of the resources. GreenFacts. The University of Michigan; 2008.

9. T.C.E.Q. TCEQ Regulatory Guidance. Rainwater Harvesting Guidance for Public Water System Texas Commission on Environment Quality; 2007.
10. McMurry J, Fay RC. Hydrogen, oxygen and water in mcmurry fay Chemistry. K.P Hamann. 4th Edition. New Jersey. Pearson Education. 2004;575-599.
11. Aderogba KA. Ground water development in Nigeria: A study of Abeokuta-Ewekoro-Ifo-Agbara Axis in Ogun State Nigeria. International Journal of Environment. 2005;3:51-68.
12. Abdulsalam IR, Altaher A, Ramadan AG. The presence of total coliform and faecal coliform bacteria in rainwater harvesting in Jefara District of Libya. Journal of International Conference on Ecological, Environmental and Biological Sciences; 2012.
13. Olaoye RA, Olaniyan OS. Quality of rainwater from different roof material. International Journal of Engineering and Technology. 2012;2:29 -33.
14. Gbadebo AM, Akinhanmi TF. Gender issues in management and use of groundwater resources: A case of abeokuta metropolis. Journal of Applied Sciences in Environmental Sanitation. 2010;5:191-199.
15. Ariyananda T, Aheeyer MM. Effectiveness of rain water harvesting (RWH) systems as a domestic water supply option; 2011. Available:http://www.waterboard.uk/scripts/html
16. Coombes P, Abott S. An ideal and sustainable water supply; 2010. Available:http://rainharvesting.com.au/rainwater-knowledge-centre-rainwater-harvesting
17. Dean JME, Deare F, Kydd K, Robinson J, Hunter PR. Rain water harvesting in Rural Trinidad: A Cross Sectional Observational Study; 2012.
18. Unimke AA, Mmuoegbulam OA, Bassey IU, Obot SE. Assessment of the microbial diversity of spent-oil contaminated soil in Calabar, Nigeria. Journal of Advances in Microbiology. 2017;4(4): 1-9.
19. Unimke AA, Bassey IU, Mmuoegbulam OA, Ikat HN. Microbial community profiling of spent-oil contaminated soil in Odukpani, Nigeria. Asian Journal of Environment & Ecology. 2017;3(2):1-7.
20. Unimke AA, Antai SP, Agbor RB. Influence of seasonal variation on the microbiological and physicochemical parameters of Imo River Estuary of the Niger Delta Mangrove Ecosystem. American International Journal of Biology. 2014;2(1):61–74.
21. WHO. Guidelines for Drinking Water Quality. Fourth edition. World Health Organization Geneva. 2011;22.
22. Vanloon GW, Duffy SJ. The hydrosphere in environmental chemistry. A Global Perspective, Second Edition. New York. Oxford University Press. 2005;197-211.
23. WWAP. The State of the Resource, World Water Development Report 2, World Water Assessment Program. 2006;2.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/27274