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Alteration of Bacteriological Load Quality of Rainwater Due to Atmospheric Exposure: An alternative Synergy to Potable Water Disinfection in Remote Communities of Niger Delta of Nigeria

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Abstract

Background: Rainwater in most developing communities of the globe remains the major source of water for drinking, washing, bathing and cooking purposes but often times; its potability is often not tested and trusted, thus putting the general populace at risk of myriad of water-borne illnesses including those from bacteria, virus, parasite and fungi respectively. However, the growing world population has continued to put the scarcely available water resources at high demand, thus the need to secure the integrity of these very important natural resources cannot be over emphasized given it's critical applications and usage in our everyday life and survival on earth.

Method: This study was aimed at carrying out microbiological analyses of rainwater harvested and kept in two different atmospheric conditions within a period of 21 days. Rainwater samples from three different locations (Diobu, Trans-Amadi and Rumuolumeni) within Port Harcourt, Rivers State in Nigeria were harvested directly using pre-sterilized plastic bottles and transported to the laboratory for bacteriological analysis.

Result: Sample A which was the pre-exposed sample of Diobu had the highest mean bacterial load of 153×10^3 cfu/ml; sample C from Rumuolumeni which was kept in a darkroom for 21 days had a mean bacterial load of 115×10^3 cfu/ml while sample B from Trans-Amadi which was exposed to sunlight for 21 days had the lowest mean bacterial load of 29×10^2 cfu/ml.

Conclusion: The result showed the presence of bacterial load in the sampled rainwater, and as such, contamination of rainwater can be reduced by varying the atmospheric condition by exposing it to sunlight for some period over time. Nevertheless, increasing the temperature of stored rainwater and any other water sample can help reduce the number of microorganisms present as most of them are mesophiles and as such, cannot survive in environments with high temperature. It is therefore strongly suggested that this could be an alternative means of water purification and treatment, especially in the rural communities of low income setting with huge visible lack of infrastructure and basic scientific technology for water disinfection option. However, the routine application of the above approach could massively reduce the increasing trend of water wash, water base and water borne infection among rural inhabitants especially when they are used in synergy with other treatment options like ultrasound and chlorination in a reduce quantity.

Keywords: Rainwater; Atmospheric condition; Temperature; Mesophiles; Microorganisms; Niger Delta

Introduction

On earth, water is the most abundant substance and is therefore needed by both plants and animals for survival and as such is essential and critical element for life [1]. According to Hinrichsen and Tacio [2], who reported that 3% of the world's total water is fresh water but only about 0.01% is available for human use. Although there is rapid increase in world population, nevertheless, there is however no corresponding increases in the quantity of fresh water available. This in addition to financial constraints, lack of proper water management and the absence or decreased number of professionals has further increased the problem of shortage of fresh water across the globe and most importantly in the developing communities. Another reason for fresh water shortage is the increased evaporation rate compared with the rate of precipitation [3]. In some parts of the world (Nigeria inclusive) where there is little or no provision of fresh water, inhabitants are forced to consume brackish water which is not safe for health wise thus, promoting a lot of Public Health issues. In these areas, some who are financially buoyant, drill their personal cum family boreholes and sometimes package them in polythene bags, plastic bottles or even sell them directly from its source to unsuspected citizens. This makes access to the supposed portable water expensive and in some cases, due to improper monitoring by concerned agencies; it may not be potentially safe for human consumption as their integrity remains questionable which undoubtedly cannot be devoid of contamination and huge integrity compromise.

Water is present in the atmosphere, underground, rocks and in rivers. It is useful in manufacturing, transportation, agriculture and even in the household. In addition, it is seen as the most exploited natural resource since the world began as it is used in industrial, agricultural and domestic activities [4]. According to Grafton and Hussey [5], agriculture is believed to be the largest user of the world's fresh water resources as it uses 70% of it. Access to water is either by construction of boreholes, digging of wells, fetching from rivers and streams or from rainfall as applicable in most of our remote communities. Construction of boreholes is usually quite expensive and requires electricity in most cases to pump the water, so not every home can afford one. Wells on the other hand, can be dug but there are also few wells in some areas. The easiest of all these sources to access is rainfall. Fetching of rain water requires bringing out buckets or drums to collect it. These water sources however have to be checked often to determine the potability of the water before it is consumed.

Access to potable water especially in underdeveloped and developing countries including Nigeria and especially in remote areas, is an issue. This is either due to pollution or even lack of water [6]. In most places of the world, especially in developing countries, rain water has been the only source or a complementary source of water since public water supply is either not available or not consistent [7]. According to the United Nations [8], about 20% of the world's population does not have access to safe drinking water. However, the microbiological quality of water has to be taken into consideration, especially if it is going to be used for drinking and domestic purposes. Its quality is mainly determined by its origin as well as the climate and geography [4]. Therefore, there is a need for monitoring water quality as a means of managing water resources in an area [9].

Microbiologically, the presence of viruses, protozoa, bacteria and even helminthes can cause water borne illnesses such as hepatitis, cholera, typhoid fever, schistosomiasis, dysentery, gastroenteritis, giardiasis guinea worm and some other diseases. Prominent and more occurring among these are those caused by bacteria. In parts of Zimbabwe, Nigeria and India, there has been cholera outbreaks caused by Vibrio cholera from taps and wells [10]. It is interesting to note that these microbiological contaminants can be removed by disinfecting the water [11]. Processes such as chlorination, boiling and sedimentation have been used in the past to disinfect water and proven to be able to purify water at least to a reasonable level.

Although rainwater is considered safe and a good source of portable water and often used as such [12], environmental pollution caused by increased developments in science and technology such as gas flaring, release of harmful gases from the exhaust of vehicles, deposition of particulate matter and other activities has led to climatic change [13], which in turn has affected the quality of rainwater, especially in Niger Delta communities with huge concentration of oil and gas companies. This study was thus aimed at determining the bacteriological load of rainwater from three locations in Port Harcourt and the effect of altered atmospheric exposure in form of exposure to sunlight on the bacteriological load of rainwater. This will serve as a basis for determining the public health risk of rainwater consumption within this area especially considering the fact that, many in these areas depend on rainwater as their only source of water since it is cheap and easily accessible. Thus, it strongly believed that the outcome of this study would help to stimulate the need for the relevant government agencies and ministries to straighten their policies towards public health protection, with respect to potable water provision and periodic monitoring and evaluation of their facilities. This would certainly help towards the reduction of water borne infections which has continued to be on the increase of recent, in the region.

Methods

Study area

The sampling sites were Diobu, Trans-Amadi and Rumuolumeni, all in Port Harcourt metropolis. Diobu is located in Port Harcourt Local Government Area, while Trans-Amadi and Rumuolumeni are both located in Obio/Akpor Local Government Council Area of Rivers State. Rivers State is made of 23 states and is located in the South-South geopolitical zone of Nigeria. Diobu was chosen because it is densely populated with most of the residents having harvesting drums for rainwater; Trans-Amadi was chosen because it is a major industrial area with lots of industries located within the area; while Rumuolumeni was chosen because it is also densely populated and with lots of industries including the presence of a cement factory, offshore engineering company and an oil and gas company in the area.

Sample collection

The samples were collected in the month of April and bacteriological analysis was carried out on the collected samples. The rainwater was allowed to fall for about three minutes and then collected in pre-sterilized plastic bottles in duplicates directly as the rain fell; six (6) bottles of rainwater were collected from each area [batch A (Diobu), B (Trans-Amadi) and C (Rumuolumeni)]; a total of 18 samples were collected. Bacteriological analysis was carried out on the first batch (A) within 6 hours of sample collection, batch B was kept in a dark room for 21 days while batch C was exposed to sunlight for 21 days. A known commercially packaged bottle water which had been tested and determined to be potable for drinking was used as control, divided into three batches and kept under same conditions (pre-exposed, post-exposed and darkroom) as the rainwater samples.

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Experimental analysis

Bacteriological analysis was carried out using the Spread plate technique (for total heterotrophic count).

Total heterotrophic count

Known quantity (0.1 ml) of the samples were placed on both nutrient agar and MacConkey agar; a sterilized glass rod was used to spread the rainwater evenly on the agar and the plates were incubated at 37°C for 24 h. Identification of Bacterial Isolates was done using the Gram's stain method; biochemical test (catalase, coagulase and motility tests) were carried out [14]. All procedures were carried out aseptically to prevent false results resulting from contamination of samples. After 24 h, visible colonies on the culture plates were counted, used to estimate the number of bacteria on each culture plate and recorded as colony-forming units per ml (CFU/ml). The formula used in estimating the number of colonies is as follows:

Colony-forming units per ml= dilution factor (1/dilution in ml) x number of colonies counted

Statistical analysis

Data from the results were analyzed using statistical version SPSS 21 to determine the mean, standard deviation and the student T-test. The presentation of results was done using charts and table respectively as shown below respectively.

Results

Rainwater samples collected from Trans-Amadi, Rumuolumeni and Diobu were analyzed according to standard microbiological procedures. The post-exposed samples despite the low dilution factor used had reduced bacterial counts compared with the pre-exposed and darkroom samples. The bacterial load of the darkroom samples however, reduced significantly compared with the pre-exposed samples.

Table 1 Analysis of microbiological quality of rainwater from the three locations.

Exposure	Mean (cfu/ml)	Mean±SD	P-value
Pre-exposed (10^3)	153	153 ± 22.07	0.007
Post-exposed (10^2)	29	29 ± 3.61	0.005
Darkroom (10^3)	115	115 ± 11.79	0.003
P>0.05 = Statistically not significant P<0.05 = Statistically significant			

The bacteriological analysis of the samples from Diobu, Trans-Amadi, Rumuolumeni and the control indicated that the pre-exposed samples had total viable counts of 176 × 10^3 cfu/ml, 132 × 10^3 cfu/ml, 151 × 10^3 cfu/ml and 0 respectively. The post-exposed samples had total viable counts of 26 × 10^{-3} cfu/ml, 28 × 10^{-3} cfu/ml, 33 × 10^{-3} cfu/ml and 95 × 10^{-3} respectively while the samples kept in the dark room had viable counts of 128 × 10^{-3} cfu/ml, 105 × 10^{-3} cfu/ml, 112 × 10^{-3} cfu/ml and 148 × 10^{-3} cfu/ml respectively.

The biochemical tests carried out on the isolates indicated that two types of microorganisms were isolated from the different samples. The isolated and identified microorganisms from the samples were Bacillus species and *Staphylococcus aureus* **(Figures 1-3 and Table 1).**

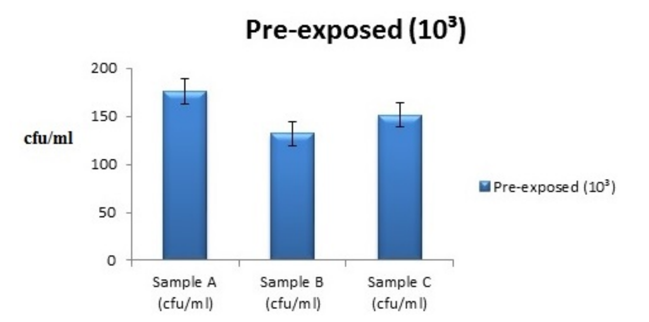

Figure 1 Bacterial load of pre-exposed samples A, B and C.

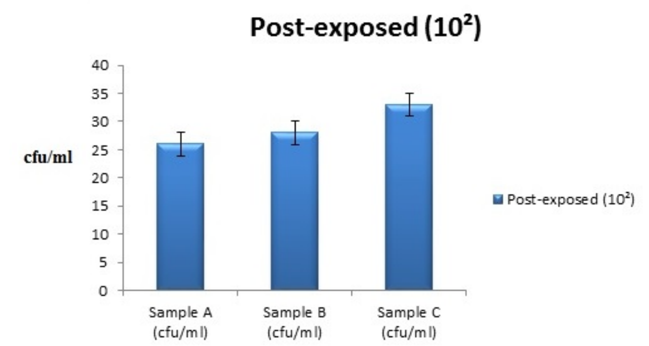

Figure 2 Bacterial load of post-exposed samples A, B and C.

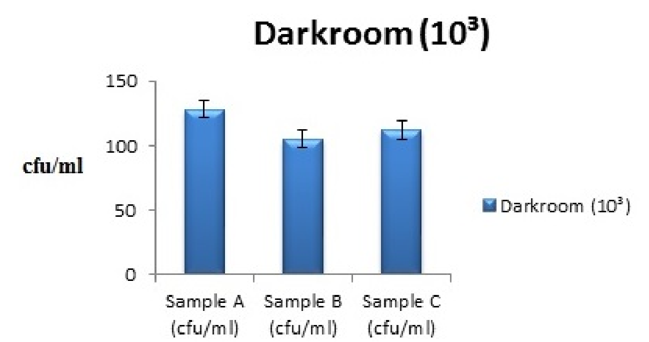

Figure 3 Bacterial load of darkroom samples A, B and C.

Discussion

Bacteriological analysis of water is often carried out to determine the presence of microorganisms in the water sample through standard procedures. The presence of total and/or faecal coliforms can also be determined. The presence of *Escherichia coli* is an indication of water pollution by either animal or human wastes [15]. Infants, aged adults and humans who are immunocompromised are more at risk of the diseases or illnesses resulting from the consumption of these polluted water.

The isolated and identified bacteria from the rainwater samples analyzed were *Staphylococcus aureus* and *Bacillus* species. These organisms were also the most isolated species from water samples in a study conducted by Akubuenyi et al. [16] on the microbiological assessment of water sources in Calabar. Wokem and Lawson-Jack [17] also isolated *Staphylococcus aureus* from water samples in Abonema which is also an area within Rivers State. Both microorganisms can be pathogenic depending on the quantity ingested and the immune system integrity of the subjects concerned. Of public health concern is also their ability to produce toxins. Bacillus species are endospore-forming organisms and are able to increase rapidly in both water and non-processed or poorly processed foods [18]. The spores produced by them are often heat-resistant and as such require very high temperatures of exposure to radiation or chemicals to destroy them literally to become weak in pathogenicity. These species are able to produce heat stable and heat labile enterotoxins after ingestion [19]. *Staphylococcus aureus*, in addition to being pathogenic when consumed as a whole organism, is also able to produce a variety of exotoxins which are lethal [20]. Thus, consumption of rainwater from these locations without proper purification and increased heating should not be encouraged. Measures to reduce bacterial load in water samples, should therefore be strongly be underpinned by the stakeholders concerned.

Sample A (Diobu) had the highest bacterial load which can probably be linked with the highly dense population of the area, thus majority of the inhabitant of the area lacks access to personal hygiene information, even as majority of them are petty traders and are not educated. The location of sample C is not as dense as that of sample A but with lots of industries such as the famous West African Glass industry. Although the pre-exposed sample A had the highest bacterial load compared with the other pre-exposed samples, exposure to sunlight reduced its bacterial load more than the others. This could be due to the presence of species of microorganisms that are resistant to high temperature in the other samples, especially sample C. deposition on dust (microbes on them) **(Figures 1-3).**

Standard deviation as a statistical tool revealed the difference or how dispersed the values obtained are from each other. The samples from the three locations exposed to sunlight had a mean bacterial load of 29 × 10^2 cfu/ml with a standard deviation of 3.61; the darkroom samples had a mean bacterial load of 115 × 10^3 cfu/ml with a standard deviation of 11.79 while the pre-exposed samples had a mean bacterial load of 153 × 10^3 cfu/ml with a standard deviation of 22.07 respectively. These results shows that, regardless of the source or environment from where the water sample was obtained, sunlight (increased temperature) was able to reduce their bacterial load to as low as reasonably possible number. This indicates that increasing the temperature of water can lower the bacterial load of water samples more than just storing in a room or consuming water directly from its source. This could be due to the fact that most microorganisms are susceptible to high temperature especially since they were found in rainwater which is normally cold, thus changing the temperature of their habitat must have probably made them stressed and so made them unable to survive the alteration in the environmental condition such as temperature **(Figures 1-3)** Although the WHO has avoided setting drinking water standards for plate counts probably due to variations in climate and topography and other critical environmental variables of different locations across the globe, however, most articles cum researchers adopted a standard of 100 cfu/ml [21] as the number that could induce bacterial pathogenicity in an unsuspected host, when water that is not potable is been consumed.

A recent study on the exposure of *Streptococcus faecalis*, *Enterococcus faecalis*, *Pseudomonas aeruginosa* and *Salmonella typhimurium* found in polluted water to sonication showed reduction in viable cell count when cell suspension of these microorganisms were exposed to ultrasound at a frequency of 20 kHz [21]. Sonication may thus be combined with increased temperature to reduce the bacterial load of water rather than the use of increased temperature alone. However, one critical challenge of the use of ultrasound as a mean of potable water disinfection remains the poor power infrastructure in developing communities and cost of the device, hence with the lack of regular supply of energy and poverty in Africa, the combined application of the two approach would certainly witness a huge set back in our rural communities.

According to WHO reports of 2003 and 2006 [22], the total heterotrophic count of a portable water must not exceed 100 cfu/ml. This entails that the pre-exposed and darkroom samples are not safe for consumption; except the samples which were exposed to sunlight which had a mean count of 29 × 10^2 cfu/ml. The bacterial pollution of the pre-exposed samples may be due to the evaporation of water contaminated with sewage or other bacterial sources of contamination which precipitates and subsequently come back to earth in form of rainfall. Worldwide, water-related infections make up about 60% of infant mortality [23]. The increasing trend of water borne infection across the developing communities of the world would probably remain unabated, given the decay in water infrastructure, poverty and lack of trained professionals in the area of effective diagnosis and analyses of the environmental cum public health circumstances. However, highly pronounced week government policies towards underpinning the already existing health institutions to cater for the increasing upsurge of health issues arising from the problems of lack of potable water has continued to exacerbate the entire situation [24]. Thus the health impact of the above situation on the subjects, especially in the rural communities has remained huge and critical, thus calls for urgent attention by all stakeholders to resolve.

Conclusion

This study provided data on the bacterial load of rainwater from three locations within Port Harcourt and the effect of exposure to sunlight and storage in a darkroom on its bacterial load. The presence of viable microorganisms including the spore forming *Bacillus* species and *Staphylococcus aureus* in rainwater in these locations makes it unsafe for domestic purposes, especially drinking but exposure to sunlight or high temperature according to this study can help reduce bacterial contaminations thereby making it safe for drinking and other domestic purposes. Therefore, the general public should be encouraged to always take measures to reduce the bacterial load of rainwater by boiling or any other heat-treatment method rather than consuming it directly from its source as this may lead to bacterial infections such as gastroenteritis, cholera, diphtheria and dysentery respectively.

The government and non-governmental organizations should help provide water treatment plants in communities especially to those in the rural areas so as to reduce or prevent outbreaks resulting to public health concerns such as cholera, hepatitis A and others. Where the water treatment plants cannot be provided, portable water should be provided in form of boreholes or taps. Further studies, on microbiological quality of stored rainwater and other water sources for varied period of time can be carried out to determine the quality and portability of the rainwater stored as more persons prefer to store water in drums over long periods of time so that they have enough, pending when next it will rain.

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