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Quality of Rainwater Harvested in Cisterns in Onicha-Ugbo, Aniocha-North Local Government Area of Delta State, Nigeria

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Abstract:
This study was aimed at assessing the level of potability of harvested rainwater in rainwater harvesting cisterns in Onicha-Ugbo, Aniocha-North Local Government Area, Delta State, Nigeria. Harvested rainwater samples were collected from twenty (20) different cisterns across the study area in the months of February (dry season sampling) and April (rainy season sampling) respectively. Parameter for quality checks includes; pH, temperature, turbidity, colour, total dissolved solids, total suspended solids, chemical oxygen demand, biological oxygen demand, dissolved oxygen and total coliform count. Physiochemical characteristics were determined using their respective standard methods for the examination of water quality. Simple descriptive statistic was employed to ascertain whether differences exist amongst the harvested rainwater samples collected during the dry and rainy seasons respectively. Results obtained indicated the following: most of the physico-chemical characteristics of the harvested rainwater samples were generally within the WHO (2010) and NSDWQ (2007) acceptable limits for drinking water. As such, the harvested rainwater characteristics showed satisfactory physicochemical levels in the study area. However, pH levels of the harvested rainwater samples were below the minimum acceptable limits of 6.5 as prescribed by the WHO and NSDWQ, hence treatment is needed in terms of the pH. Also, coliform bacteria were observed in all the harvested rainwater samples in the study. Although the levels of coliform bacteria didn't meet the WHO drinking water specifications of 0cfu/100ml, it fell within the 10cfu/100ml permissible limit as prescribed by the NSDWQ. Similarly, the Pollution index (pi) of the physicochemical and bacteriological water quality parameters reveals a 'no significant degree of pollution' for all the harvested rainwater samples in the study area using the water quality specifications by the NSDWQ. However, it indicates a significant degree of pollution for total coliform when making reference to the WHO water quality guidelines. Consequently, it is recommended that harvested rainwater in cisterns in the study area should undergo simple purification/disinfection techniques such as boiling and liming before consumption.

Keywords: *rainwater, harvesting, quality, cisterns, onicha-ugbo*

1. Introduction

Water is an indispensible substance to man and all life processes; it is the essence of life, without which human beings cannot live for more than a few days (Eletta and Oyeyipo, 2008). It plays a vital role in nearly every function of the body, protecting the immune system, the body's natural defenses and helping to remove waste matter. It is essential in maintaining and sustaining human, animal and plant life (Patil and Patil, 2010). Undoubtedly, water represents a unique and significant feature in any settlement: for drinking, sanitation, washing, planting, fishing, recreation, industrial process, etc. Succinctly, water is greatly important and is in great demand in all sectors of human endeavour and in every human settlement (Aderogba, 2005).

Water as one of the most valuable resources that is widely distributed all over the world is available to mankind for sustenance and survival. However, many of Nigeria's major cities and urban centres face shortage of safe and potable water supply, with existing storages unable to meet increasing demands (Lamikanra, 1999). The provision of improved water to millions of households in Nigerian rural communities with no access to it remains one of the greatest challenges for sustainable development. The lack of access to safe water supply is a precursor to waterborne diseases, with the children and the elderly mostly affected especially within poor rural communities in developing countries (Rafee and Hassan, 2010).

Poor quality of water has been principally associated with public health concerns through transmission of waterborne diseases that are still major problems in Africa and in many developing world (Ongley, 1999). The World Health Organization (2000) estimates that four billion cases of diarrhoea are reported each year around the world, in addition to millions of other cases of illness associated with lack of access to clean water. Gleick (2002) estimated global deaths arising from water- related diseases at between 2 - 5 million yearly. Although there are no accurate data on water related cases and deaths in Nigeria, studies have however shown that cases of typhoid, cholera and other water related disease and deaths have been on the increase in recent times (Ojeifo, 2011).

The quality of rainwater collected depends on when it is collected, how it is stored as well as method of use (Ariyananda, 2003). The quality of rainwater also depends on the atmospheric pollution of the individual area, the proximity to pollution sources and the level of cleaning and attendance (Zhu *et al*., 2004). Microbial contamination and other water quality problems associated with rainwater harvesting systems are most often derived from the catchment area, conveyance or storage components (Lye, 2009). Public health risks associated with microbial pathogens remains the most significant issue in relation to using untreated harvested rainwater for drinking or other potable purposes (Muhammad and Mooyoung, 2008); hence the quality of rainwater in tanks has been the subject of much controversy.

Although rainwater harvesting has been receiving increased attention worldwide, as an alternative source of water, its use as potable water supply is very limited and the main reason is obviously the quality of stored rain water in domestic tanks believed not to meet the drinking water quality standards (Amin and Alazba, 2011). Also, despite having some clear advantages over other sources, rainwater use has frequently been rejected on the grounds of its limited capacity or due to water quality concerns (Regab*et al*., 2003).

It has also been reported that, due to geographical difference and anthropogenic activities, rainfall in various regions have their special characters. Even in the same region, synoptic situations and air-borne pollution scattering vary seasonally, resulting in large chemical components in rainfalls (Changling*et al*., 2005). Atmospheric deposition have also been considered to be a major source of toxic metals such as Mercury (Hg), Cadmium (Cd), Lead (Pb) and several other trace metals to our ecological system and poses great risks to people who depend on this source of water resources (Chukwuma*et al.*, 2012).

Previous studies on the quality of water resources in the tropical African environment have largely been restricted to surface and groundwater to the negligence of rainwater (Olobaniyi and Owoyemi, 2006). This is predicated by the assumption that rainwater was pure and could be consumed without pre-treatment. While this may be true in some areas that are relatively unpolluted, rainwater collected in many locations contains impurities (Bankole, 2010). The vulnerability of rainwater and groundwater to quality degradation from human activities makes a periodic assessment of their qualities necessary (Ige and Olasehinde, 2010). Therefore, this study is aimed at assessing the level of potability of rainwater harvested in rainwater harvesting cisterns in Onicha-Ugbo, Aniocha-North Local Government Area, Delta state, Nigeria. The research will attempt to address the following questions:

i. What are the forms of rainwater harvesting cisterns employed in the study area?
ii. What are the levels of turbidity, colour, temperature, pH, total dissolved solids (TDS), total suspended solids (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD), dissolve oxygen (DO) and total coliform count in the study area?
iii. In comparison with national and internationally recommended standards for drinking water, is the level of turbidity, colour, temperature, pH, total dissolved solids, total suspended solids, chemical oxygen demand, biological oxygen demand, dissolve oxygen and total coliform count within the approved permissible limit for drinking water?
iv. What is the pollution index of turbidity, colour, temperature, pH, total dissolved solids (TDS), total suspended solids (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD), dissolve oxygen (DO) and total coliform count in the study area?

1.1. Study Area

The study area, OnichaUgbo is a growing town in Aniocha North Local Government Area, Delta State, Nigeria. It is situated on a highland at the western boundary of Aniocha North Local Government Area, and is covered with clayey brick-red sand. Ugbo is located between latitudes $6^o15'$ - $6^o15'$N and longitudes $6^o23'$ - $6^o25'$E and covers an area of 85.19 Square Kilometres (Figure 1).The area is situated about 40 kilometres from Asaba the state capital on the Asaba-Benin highway connecting the West to the East of Nigeria. It has a population of about 10,000 inhabitants. It is bordered to the East by Issele-uku and Idumuje-Unor; to the West by Igbodo (in Ika Local Government Area) and Obior; to the North by Idumuje-Ugboko and Ewohinmi (in Edo state) and to the South by Ubulu-Uku (http://en.wikipedia.org/wiki/onicha-ugbo). As a junction town, Onicha-Ugbo is easily accessible from all the bordering communities through a network of roads.

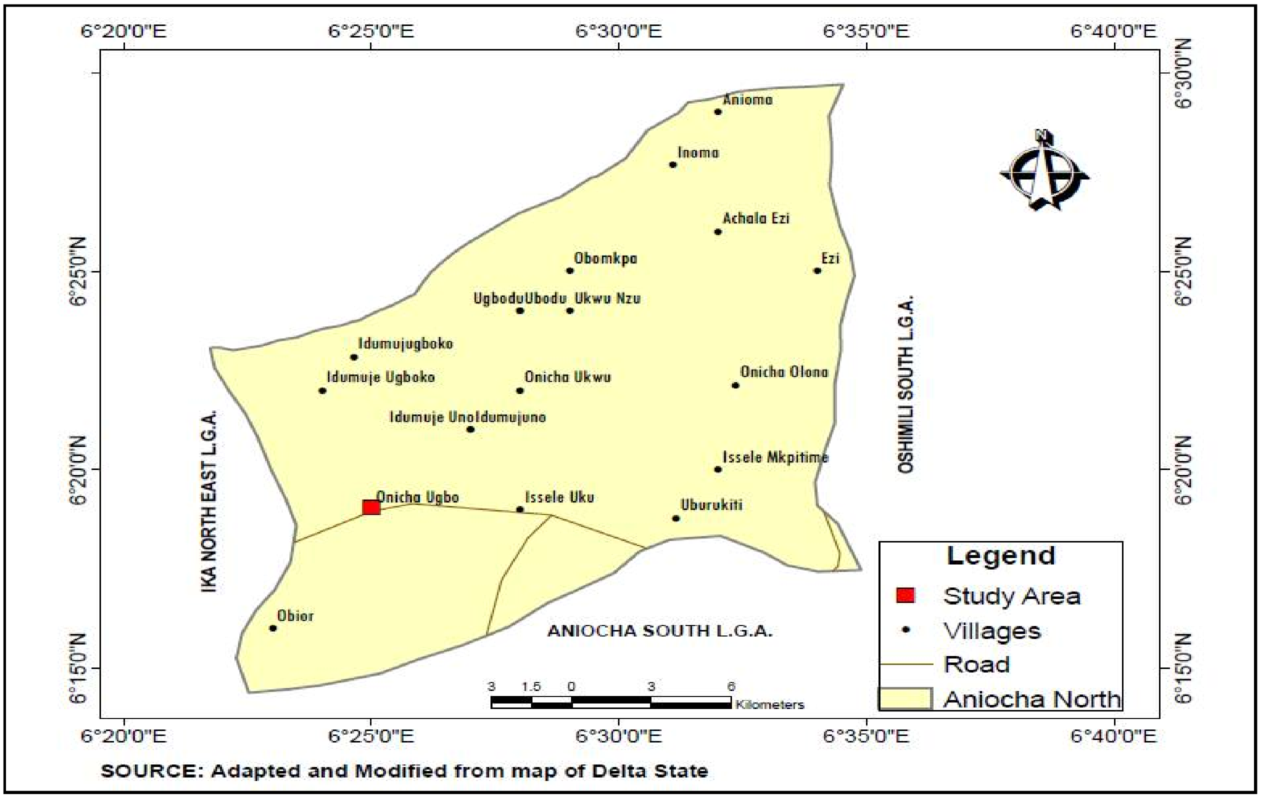

Figure 1

The climate of the area is defined by high values of evapotranspiration, humidity, temperature and rainfall that characterized humid tropical equatorial climate of the deltaic environment. The rainfall is mostly convectional and usually falls at any time of the day resulting from the effects of convectional rainfall and blown land and sea breezes. Onichaugbo experiences a humid tropical equatorial climate with fluctuations from humid in the south due to local influence of the river Niger to the sub-humid in the northeast (Ejemeyovwi, 2015).

The two seasonal winds of NE tropical continental airmass that blows from October to February and the SW tropical maritime airmass that blows from march to September maintains an average tropical temperature during the dry season and an average rainfall during the rainy season. The mean annual rainfall is 1254mm – 3032mm and temperature of 26.7^{o}C with relative humidity of 69-80% and sunshine of 4.8 bars (Ejemeyovwi, 2015).

The subsurface geology of the Niger Delta Basin to which Onicha-Ugbo belongs is well established. The Basin fill is made up of three formations, namely from the oldest to the youngest, Akata, Agbada And Benin Formations (Nwajide, 2006).

2. Methodology

Harvested rainwater samples was collected by carefully selecting the 50th rainwater harvesting cistern (left and right side) in each of these four main roads across the study area. As a result, twenty (20) samples of harvested rainwater was collected; six (6) samples was collected at Umuolo, five (5) samples was collected at Ogbe-obi, five (5) samples was collected at Ogbekenu while four (4) rainwater samples was collected at Ishiekpe quarters. Note that, the disparity in the number of samples collected in the various quarters is predicated by the fact that the number of rainwater harvesting cisterns present in each of the road differs (in each sides of the road).

Consequently, a total of forty (40) harvested rainwater samples were used for this study. Twenty (20) samples as explained above were collected during the dry season (February). Subsequently, during the rainy season (April) period, twenty water samples was collected from the same rainwater harvesting cisterns (as shown in Table 1). This was done to account for any seasonal variation in the quality of the harvested rainwater in the rainwater harvesting cisterns.

2.1. Data Collection

In order to obtain accurate results, proper sampling procedures were adopted to eliminate or minimise potential contamination of the samples. The water samples were collected using plastic bailers and stored in one (1) litre capacity plastic bottles. The plastic bottles were first washed with deionised water, and then rinsed several times with the sample water before collection in order to avoid contamination (Anon, 1992). Nevertheless, temperature, colour and pH of the harvested rainwater samples were determined in-situ.

The bottles were labelled according to the code numbers allotted to each sampling cistern and were then stored in an ice packed cooler and transported immediately to the laboratory and analyzed for turbidity, total coliform counts, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), chemical oxygen demand (COD) and biological oxygen demand (BOD) by a competent laboratory scientist using modern state-of-the-art equipment and following standard methods for the examination of water quality (Soladoye and Yinusa, 2012).

3. Results and Discussion

The forms of rainwater harvesting cisterns in the study area are predominantly below-ground concrete tanks. This concrete tanks are poured-in-place, thus are very attractive and easily integrated into new construction.

From the physico-chemical and bacteriological analysis of the harvested rainwater samples collected for the selected parameters, variations in the level of concentration of turbidity, pH, TDS, TSS, DO, COD, BOD, temperature and total coliform count was observed. The results of the laboratory analysis of the harvested rainwater samples revealed that all the water quality parameters examined were detected in each of the samples analyzed though with varying degrees of concentration. The values of each of the parameters examined in this study from Cisterns 1 to cistern 20 summarized in Table 3a and 3b which shows the variation in terms of maximum, minimum and mean level of concentration of each parameter. The analyses revealed that all the harvested rainwater samples were acidic (i.e. having pH concentrations below 6.5). The pH of water samples fell below the permissible limit of 6.5 – 8.5 as prescribed by the World health organization (2010) and NSDWQ (2007) standards for potable water. ThepH levels ranged between 5.55 to 6.75 with a mean pH value of 6.21 and Standard deviation of 0.39086 during the wet season. While during the dry season, pH levels of the water samples ranged from 5.20 to 6.20 with an average pH concentration and Standard deviation of 5.63 and 0.46760 respectively. Also, during this period, cistern 6 had the highest pH value while cistern 20 had the lowest pH value of 5.20 in the study area.

However, Temperature of all the samples was fairly uniform in almost all the sampled wells during both the wet and dry season periods. None of the samples had temperatures that exceeded the permissible limit of 30^{o}C for potable water. All the samples had temperatures within the specified range of 20^{o}C - 30^{o}C as prescribed by the World Health Organization (2010). Temperatures of the Water Samples ranged from 23^{o}C – 24^{o}C with a mean of 23.47^{o}C and standard deviation of 0.30483 during the wet season. Similarly, low values of turbidity within the range of 0-2 NTU were observed in all harvested rainwater sampled. This conforms to the acceptable standards and guidelines for potable water quality of 5.0 NTU. In this study, mean turbidity levels was 0.9500, with standard deviation of 0.7592 during the wet season. However, during the dry season, mean turbidity levels was 0.4000 while the standard deviation was 0.5026. During the wet season, the maximum turbidity levels was recorded at cisterns3, 7, 8, 11 and 18 respectively with turbidity value of 2NTU.

In this study, TDS levels ranged between 18.00 to 150.50mg/l, with a mean of 76.81mg/l and standard deviation of 36.58527 during the wet season. During this period, TDS levels were highest at cistern 18 while the lowest concentration of TDS was recorded at cistern 1. On the other hand, during the dry season period, TDS levels ranged from 24.00 to 200mg/l with a Standard deviation of 48.29805. However, TDS was highest at cistern 17 while it was lowest at cistern 1 (Figure 2).In summary, all the water samples had TDS levels below the 500mg/l permissible limit set by the World Health Organization and the Nigerian Standard for Drinking Water Quality.

Also, total suspended solids (TSS) of the harvested rainwater samples varied between 4.00mg/l and 29.50mg/l, with a mean TSS level of 10.86mg/l and Standard deviation of 5.8576 during the rainy season. But during the dry season, TSS ranged from 2.20mg/l to 18.00 mg/l. the mean TSS concentration was 7.02mg/l while the standard deviation was 3.7360. Moreover, 18 of the harvested rainwater samples exceeded the WHO maximum acceptable limit of 5mg/l for drinking water during the wet season, while only 14 exceeded the limit during the dry season. However, none of the water samples has TSS concentration above the WHO maximum allowable limit of 30mg/l for drinking water.

The results from the laboratory analysis conducted in this study reveals that Dissolved Oxygen (DO) ranged from 0.4mg/l to 1.6mg/l during the rainy season with a mean of 0.90mg/l and standard deviation of 0.3667. During this period, cistern 18 and cistern 6 had the lowest DO concentration (0.40mg/l) while the maximum DO level was recorded at cistern 9. However during the dry season, DO range between 1.0mg/l and 2.4mg/l, with a mean DO level of 1.72mg/l and standard deviation of 0.3744. Nonetheless, the Dissolved Oxygen concentration of all the harvested rainwater samples conformed to the maximum permissible limit of 5.0mg/l for drinking water as specified by the WHO.

Also, all the harvested rainwater sampled (both during the wet and dry season) had BOD concentration within the maximum acceptable limits (5.0mg/l) for drinking water as prescribed by the World Health Organization (see Figure 4.6). The concentration of the harvested rainwater samples range from 0.2mg/l to 3.10mg/l with the mean and standard deviation at 1.35mg/l and 0.7299 respectively during the wet season. However, during the dry season period, BOD levels were between 0.30mg/l and 2.00mg/l while the mean and standard deviation was 0.86mg/l and 0.4353 respectively.

Similarly, the result of the physicochemical analysis carried out in this study revealed that COD concentration range from 0.90mg/l to 5.10mg/l with a mean of 2.71mg/l and standard deviation of 1.1102. But, during the dry season period, COD concentration range between 0.60mg/l to 4.80mg/l with mean of 2.14mg/l and standard deviation of 0.4064. Consequently, all the water samples had COD concentration below the maximum permissible limit of 10.0mg/l as specified by the World Health Organization (2010).

The bacteriological analysis of harvested rainwater in studied area revealed that the Total coliform count of sampled harvested rainwater was more than the World Health Organization specified limit of 0cfu/100ml. total coliform count ranged between 0.40-1.85cfu/100ml with mean values of 1.01cfu/10ml during the wet season. However during the dry season, total coliform count ranged from 0.12cfu/100ml to 1.67cfu/100ml with mean level of 0.6145cfu/100ml and standard deviation of 0.4064.

In addition, the maximum total coliform count was observed in cistern 1 and cistern 11 during the wet and dry season respectively. Nevertheless, total coliform count was shown to be slightly higher during the wet season. This is attributed to the washing down of bird droppings, leave fall after precipitation, sewage leakage into the cisterns. The presence of coliform bacteria in the water indicates that faecal pollution has occurred, which poses great danger to human health. These pathogenic organisms are responsible for the infection of the intestinal tracts and diseases caused include: diarrhoea, cholera, bacillary dysentery, typhoid, hepatitis to mention but a few.

3.1. Pollution Index

Pollution index (Pi) is expressed as a function of the concentration of individual parameter as against the baseline standard. It shows the relative contribution by each item. The critical value is one (1.0). Values greater than 1.0 indicate significant degree of pollution while a value less than 1.0 shows no pollution (Akpoveta, Okoh and Osakwe, 2011). The pollution index (pi) physic-chemical and bacteriological analysis is shown in Table 4a and 4b for rainy and dry seasons respectively. The pollution index (pi) for all the physicochemical water quality parameters was below the critical value of 1.0. Thus, it indicates that there is 'no significant pollution' for pH, turbidity, colour, temperature, chemical oxygen demand (COD), dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TSS) and total dissolved solids (TDS) in samples of harvested rainwater in cisterns in the study area.

However, Pollution index (pi) results obtained for Total coliform count indicates significant degree of pollution in all the harvested rainwater samples in the study area during both sampling periods (the dry and rainy season). All the harvested rainwater samples had Pollution index value above the critical value of 1. Also, the degree of pollution of coliform bacteria presence in individual water quality parameters was higher during the rainy season period.

4. Summary of Findings

Based on the aim and objectives of the study, the following findings emerged:

- Most of the physico-chemical water quality parameters examined such as temperature, colour, turbidity, TDS, TSS, DO, COD and BOD showed satisfactory concentration in line with the specifications of the World Health Organization (2010) as well as the Nigerian Standards for Drinking Water Quality (NSDWQ, 2007).
- The concentrations of pH however, were higher and hence showed unsatisfactory concentration when compared to the prescription of the World Health Organization (2010) and the Nigerian Standards for Drinking Water Quality (NSDWQ, 2007). Most of the harvested rainwater samples had pH levels below the 6.5 acceptable limits for drinking water quality.
- Total coliform counts, which are used to assess the bacteriological water quality of the harvested rainwater, indicated that the sanitary quality of the rainwater samples was compromised. The total coliform counts revealed the presence of coliform bacteria in harvested rainwater in the area. Hence, total coliform counts did not fall within the specifications of the World Health Organization (2010) of 0cfu/100ml.
- The study also confirmed that the quality of harvested rainwater in cisterns in the area varies during the dry and rainy season period. For example, the levels of total suspended solids (TSS) were higher during the rainy season as compared to the dry season.

5. Conclusion

The study revealed the following:

- The harvested rainwater in rainwater harvesting cisterns in the study area showed satisfactory concentration in terms of the physicochemical water quality parameters examined. However, most of the harvested rainwater had pH below the acceptable limits for drinking water as prescribed by the World Health Organization (2010) and the Nigerian Standards for Drinking Water Quality (NSDWQ, 2007). Hence, the harvested rainwater from the cisterns should undergo further purification/treatment before consumption to safeguard the health of the people.
- The unacceptable coliform counts in the harvested rainwater samples in the study area may be linked to incidence of respiratory tract diseases in the area. This is because many inhabitants rely on this harvested rainwater for drinking and other domestic purposes.

6. Recommendation

Arising from the research findings, the following are the recommendations for improving the present state of the rainwater from rainwater harvesting cisterns in the area.

- Harvested rainwater in cisterns should be purified before drinking. Local methods of purification includes: boiling and filtering, addition of *Moringaoleifera* seeds into the water.
- Rainwater harvesting should be done at least 10 – 15 minutes of rainfall to minimise impurities from the catchment roofs into the cisterns.
- Additional liming of the water and other methods of cleansing acidic water may be employed in the interim. Also, knowing that water treatment chemicals are very dangerous when not properly used, it is recommended that they are administered by exerts and professionals in water quality control.
- Human activities within the vicinities of the sources of rainwater should be monitored to check factors responsible for impairment of the rainwater in the cisterns.
- There is need for proper education of the populace on the dangers of consumption of water from the rainwater harvesting cisterns without subjecting such to treatment.

- Septic tanks, pit latrines and drainage network should be sited far away from the rainwater harvesting cisterns.
- The metallic content of harvested rainwater in the area not analysed for this study should be investigated in future research works to ascertain their concentrations in the study area.

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