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Quality of rainwater harvesting for rural communities of Delta State, Nigeria

S. I. Efe

Abstract This paper assess the level of potability of rainwater samples harvested from catchments roofs in 6 rural communities of Delta State, Nigeria to achieve this goal a stratified sampling technique was adopted in the establishment of 90 sterilized cans into the 3 senatorial districts of Delta; on the basis of one can for thatch, aluminium, asbestos and corrugated iron sheets, and open surfaces. Six rural communities each were chosen from the three senatorial districts, making a total of 18 rural communities that were chosen for the study. The harvested rainwater samples were analysed with the most appropriate equipment and analytical techniques as recommended by World Health Organisation (WHO) and federal ministry of environment in Nigeria. Kruskal—wallis H'test statistical techniques was employed to ascertain whether differences exist amongst the rainwater samples collected from thatch, aluminium, asbestos and corrugated iron roofing sheets, and open surfaces. The result revealed that most of physiochemical and biological characteristics of rainwater samples were generally below the WHO threshold, as such the rainwater characteristics showed satisfactory concentration in these rural communities. Thus, the rainwater from these rural communities should be harvested, stored for human consumption and for other uses by the inhabitants. But treatment is needed in terms of their pH, TSS, Fe and colour. Similarly, significant differences exist amongst the rainwater samples collected from the 5 roofing types, most especially low quality of rainwater were observed in thatch and asbestos roofing sheets. Thus, rainwater from these sources should be purified before consumption.

Keywords Quality · Rainwater · Harvesting · Rural Communities · Delta State

Introduction

Studies have revealed great disparities between urban and rural water quality and supply over the globe (see, Biswas, 1978; Ayoade, 1988; Pickering and Owen, 1994; Oyegun, 2001; Efe, 2003). For instance, while only 20% of 248 million people living in rural area have reasonable access to potable water, 70% of urban inhabitants (390 million) have access to safe drinking water over the globe in a World Health Organization Survey of potable water in 1975 (Biwas, 1978). And according to Oyegun (2001) and Efe (2003), in more recent studies asserted that little has changed since then. Thus, water borne diseases are reported more in the rural communities than in the urban areas.

Similarly, researches in this part of the world have pointed to the fact that there have been increased studies on the quality of water from surface (steam, rivers) and subsurface (bore holes, and wells) sources to the neglect of rainwater quality (see Egborge, 1991; Akporido

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et al., 2000; Ikomi and Emuh, 2000; Adebola, 2001; Ovrawah and Hymore 2001; Efe, 2003). The reason for this neglect according to Efe (2003) is that most of the rural dwellers in this part of the world consider rainwater as the most potable source of water provided they are properly collected. Thus most rural inhabitants in Delta state consume the rainwater without any form of purification. Most of these inhabitants collect their rainwater from roofs of buildings directly into basins, and through ridges connected to hand dug wells, most especially in the northern extremities of the state. These buildings are made off asbestos, corrugated iron sheet, and aluminium sheet amongst others. So most of the rural dwellers consumed rainwater from these sources, without knowing the level of their potability. The question that occasionally agitates the mind of the rural dwellers is that the rainwater collected from these sources good for human consumption and other domestic uses? It is on this premise of the aforementioned problems and question that this study of the quality of rainwater harvesting from some rural communities of Delta State is based. Therefore, this study is aimed at firstly assessing the level of potability of the rainwater harvested from asbestos roofs, aluminium roofs, corrugated iron sheets, thatch roofs and rainwater collected from open surfaces without interference with roofs of building; and secondly to ascertain whether there is any significant difference in the quality of rainwater collected from the 5 sources.

Study area

Delta state lies between longitude 5°00′E and 6°45′E and latitudes 5°N and 6°30′N, it has a landmass areas of 16,842 km square. Delta State lies within the Benin, Agbada and Akata formation in terms of her geology. The state is drain by river Niger; and its distributaries (Forcados, Escravos and Warri river and Creeks), Jamieson and Ethiope (www.onlinenigeria.com). River Niger drains the eastern flank of the state and empty it water into the sea, river Ethiope took its source from Umuja and flow through Umutu, Abraka to Sapele where it enter the sea. River samieson washes the coastal area of Sapele and meet a river Ethiope where they empty their water into the sea. Delta state has a population of about 2,590,491 where 75% of LG population livers in rural areas (1991 census), with good access to potable water. The state is divided into three senatorial districts, Delta central with a population 936,707; Delta north; 793,517 and Delta south, 865,540 population (Omoksone, 2004).

Methodology and data collection

A total of 90 sterilized cans were used to collect rainwater samples from different roof of buildings made up of Thatch, Aluminium sheets, corrugated iron sheet, Asbestos sheet and one from open spaces from 18 rural communities in Delta State. Delta State was divided into three senatorial district based on the already existing units. These districts are Delta north, central and south senatorial districts. 6 rural communities were selected from each district based on those communities that mostly consume rainwater in these districts. These rural communities selected from the three senatorial districts are Anwai, Illah, Abavo, Idunujunor, Umunede and Aboh (Delta north); Otorho-Abraka, Aladja, Orerokpe, Aghalokpe, Jesse and Obedeti-Orugun (Delta central); Ubeji, koko, Patani, Ozoro, Ogullahai and Emevo (Delta south); and in each community, 4 sterilized cans were used to collect rainwater samples from roof of buildings made up of Thatch, Aluminium sheet, asbestos sheet and corrugated iron sheet, and one from open surface, which serves as control. The rainwater samples were collected in the month of January and July 2004, for the 1st 10 min, 20 min and 30 min rain events and the mean of rainwater collected during these time intervals were calculated and used for the study.

The temperature and pH of the rainwater sample were measured immediately after collection with MP230 pH and a mercury thermometer. Samples for microbial analysis were kept with a sterilized capped bottle to arrest the further growth of bacterial prior to analysis. They were then taking to the laboratory for microbial and physiochemical analysis. The conductivity and turbidity were determined with MC226 conductivity meter and 214 turbidity meter. The SO_4^{2-}, NO_3^-, $CaCo_3^{2-}$, TSS, DO and colour in rainwater samples were determined using standard analytical method. The Elmer 3110 Atomic Absorption Spectrophotometer (AAS) was used to determine the trace and heavy metals of rainwater samples with the approximate wavelength for each of the metals (Ca, pH, Fe, Mg Cu, Cd, Al and Zn). The most appropriate technique was used to determine the presence of microbial in rainwater sample. The members of confirmed coliform per 100 ml were estimated from MPN table. Ovrawah and Hymore (2001), Adebola (2001) and Efe (2003) have used these analytical equipment and they achieved significant results.

The rainwater data were also subjected to percentages and Kruskala wallis H test statistical analysis. According Bluman (1995), the H'test is a non-parametric statistical test that is used when the sample size is five or more and it is the best alternative to the analysis of variance. It is also used to compare three or more means of data set. The model for the H' test is denoted as follow:

$$H = \frac{12}{N(N+1)}\left[\frac{R_1^2}{n_1} + \frac{R_2^2}{n_2} + \cdots \frac{R_5^2}{n_5}\right] - 3(N+1)$$

Where R_{1-5} sum of the rank of rainwater sample from the 5 sources; n_{1-5} : Size of sample from thatch to open spaces; 12 : Constant; N : Total number of individual rainwater quality in all the samples.

Results and discussion

The results of the rainwater samples collected are presented in Figs. 1–10 and discussed below.

Temperature

The temperature of the rainwater samples ranges from 27.0°C in corrugated iron roofs to 27.3°C in asbestos roofs. This indicates 0.7°C to 1°C lower than the atmospheric temperature. Rainwater samples collected from open surface recorded mean temperature of 27.4°C (see Fig. 1). Thus, temperature in rainwater sample showed satisfactory concentration.

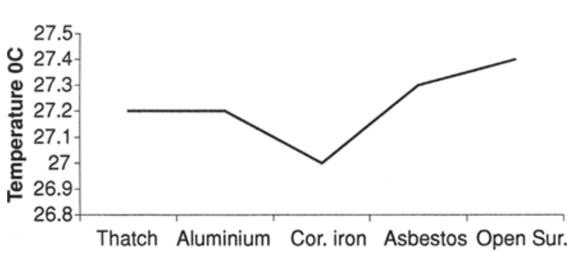

Fig. 1 Temperature variation of rainwater in the different roof types

However, temperature of rainwater samples in the northern part of Delta State (Umunede, Illah, Idumujunor) recorded temperature of 28.1°C which show that they are 0.1°C warmer that the atmospheric temperature.

Total suspended solid (TSS), turbidity, and colour

The total suspended solids (TSS) rainwater samples collected from the various roofing materials and open space were generally above the 5 mgli acceptable limit of WHO, with the exception of those collected from Aluminium sheets and corrugated iron sheet where lower value of 3.3 NTU and 1 mgli respectively were recorded. For instance, value as high as 13 9.7, and 8.3 were collected from thatch roofs. Open space and asbestos roofs (see Fig. 2). These indicate 160%, 92% and 66% respectively higher that the maximum acceptable threshold of WHO. Thus, TSS concentration of rainwater samples collected from thatch, asbestos roofs and open surfaces are unsatisfactory and thus, their rainwater should be treated before consumption. Turbidity in rainwater samples collected from asbestos and thatch roofing sheets were generally high, higher that the 5NTU acceptable limit of WHO. For instance, turbidity values as high as 17.3 were recorded from the thatch roofs, and 5.5 NTU from asbestos roofing sheet. This represents over 240% and 10% respectively above the WHO threshold. Hence, rainwater, samples from thatch and asbestos roofing sheets showed unsatisfactory level of turbidity, ash such the rainwater should be purified before consumptions. However, rainwater samples collected from aluminium roofs, corrugated iron sheets and open surfaces recorded lower turbidity values of 4.7, 2.5 and 4.7 NTU respectively (see Fig. 3).

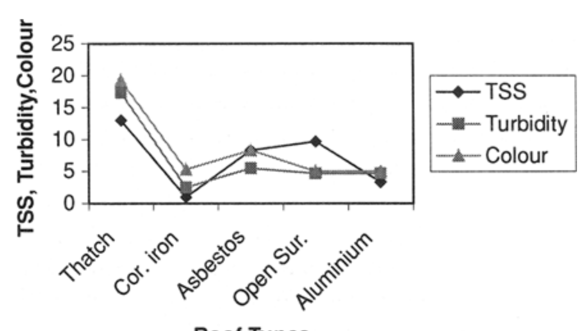

Fig. 2 TSS, turbidity, and colour variation of rainwater in the different Roof Types

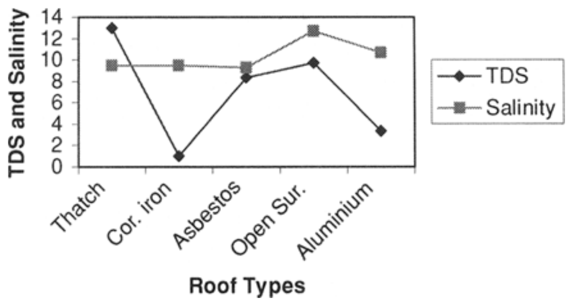

Fig. 3 Variation of TDS and salinity of rainwater in the different roof types

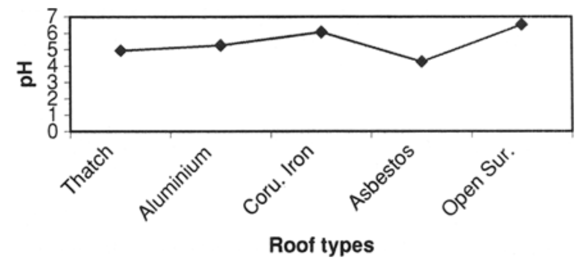

Fig. 4 Variation of pH of rainwater in the different roof types

On the other hand, higher turbidity values (18.3 NTU) were recorded in rainwater samples collected from corrugated iron roofs at Ubeji, Aladja, and Patani amongst others.

The colour concentration of rainwater samples collected from thatch, asbestos and corrugated iron roofs were generally high, higher than the 5 units threshold of WHO. Colour values as high as 19.33, 8.33, and 5.33 units were recorded in thatch, asbestos and corrugated iron roofs (see Fig. 3). These indicated a variation of 4.33, 3.33 and 0.33 unit, representing over 86%, 66% and 6% higher than the 5 units WHO acceptable limits. Thus, colour concentrations from these roofing sheets are unsatisfactory, and as such should be treated before consumption. However, low values of colour (5 units) were recorded from aluminium roofing sheet and open surface. These values showed satisfactory concentration in rainwater samples from the rural communities of Delta state.

Total dissolved solids (TDS) and salinity of rainwater in rainwater samples

The level of total dissolved solids (TDS) and salinity in rainwater samples collected from the different roofing materials from the rural communities of Delta state are represented in Fig. 3. The values of TDS and salinity in rainwater samples were generally low, below the maximum acceptable threshold of WHO. For instance, TDS recorded the following values in rainwater samples harvested from thatch (37.1 gli), Aluminium 5.6 mgli), corrugated iron sheet (7.5 mgli), asbestos (19.6 mgli) and open surface (10.7 mgli). These values are far lower than the 500 mgli WHO limits and thus, showed a satisfactory concentration in rainwater samples harvested from the different roofing materials. Similarly, the following salinity low values were recorded in the different rainwater samples (Thatch (9.51 mgli), aluminium (10.7 mgli) corrugated iron sheet (9.5 mgli), asbestos (9.3 mgli) and 12.7 mgli) were recorded from open surfaces in the rural area of Delta State (see Fig. 3). Thus, salinity in rainwater samples harvested from thatch, aluminium, corrugated iron sheet, asbestos sheet and open surfaces were satisfactory.

Generally speaking, rainwater samples harvested from the different roofing sheets are acidic with the exception of open surface and show high level of unsatisfactory concentration. Low values of pH were generally recorded in thatch (4.93); aluminium sheet (5.25), corrugated iron sheet (6.07) and asbestos (4.25) (see Fig. 4). These values indicate over 150%, 120%, 40% and 100% times lower than the 6.5–8.5 pH threshold of WHO. Hence, rainwater harvested from thatch, aluminium, corrugated iron sheet and asbestos roofing materials should be treated before consumption.

However, the pH value (6.5) of rainwater samples harvested from open surface confirmed to safe limit, thus, rainwater can be harvested directly from the open surfaces in the rural areas of Delta State for human consumption. But those of asbestos, thatch and aluminium roofing sheets must be treated.

Odour concentration of rainwater samples from the different roofing materials in the rural areas of Delta State were un-objectable and such they were generally odourless.

Anions

All the anions (bicarbonate, carbonate, nitrate, sulphate and total hardness) of rainwater samples harvested from thatch, aluminium sheets, corrugated iron sheets, asbestos roofing sheets and open surfaces in the rural areas of Delta State were generally low, lower than the

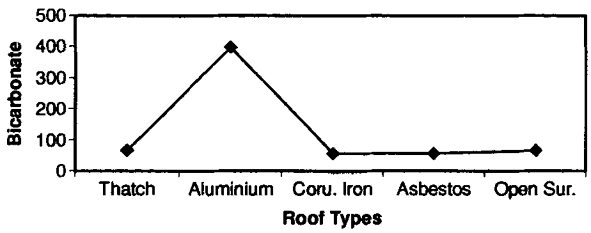

Fig. 5 Variation of bicarbonate of rainwater in the different roof types

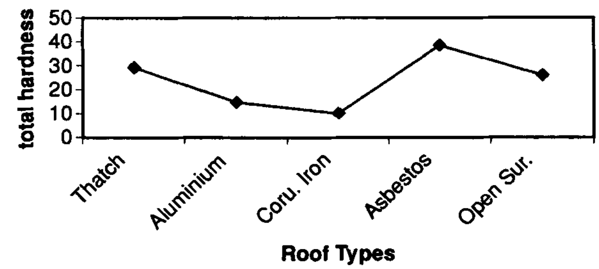

Fig. 7 Variation of total hardness of rainwater in the different roof types

500, 10 and 200 mgli WHO thresholds for these water characteristics.

For example, bicarbonate recorded 65.1 mgli (thatch); 396.5 mgli (aluminium) 54.9 mgli (corrugated iron sheet and asbestos); and 65.1 mgli (open surfaces) (see Fig. 5).

The carbonate in rainwater samples generally showed 0.01 mgli in the different roofing materials, this is far below the 500 mgli thresholds of WHO. Nitrate values ranges from 0.10 mgli in open surfaces to 0.20 mgli in thatch roofing materials; these values are far lower than the 10 mgli of WHO (see Fig. 6). Similarity, sulphate concentration in rainwater samples spans from 1.15 mgli in aluminium to 5.03 mgli in asbestos, which is also below the 200 mgli of WHO (see Fig. 6).

Also, the total hardness of rainwater samples showed satisfactory concentration; they were generally below the 500 mgli WHO threshold. For instance, total hardness ranges from 10.1 mgli in corrugated iron roofs to 38.6 mgli (see Fig. 7).

So, in terms of the anions concentration in rainwater samples harvested from open surfaces, thatch, aluminium, asbestos and corrugated iron roofing sheet in the rural communities of Delta State, showed satisfactory level.

Heavy metals

The heavy metals (Ca, Mg, Pb, Cu, Cd, Zn and Al) were also generally low, below the 200, 150, 0.05, 1.50, 0.01, 15.00 mgli WHO thresholds for Ca, Mg, Pb, Cu, Cd, and Zn respectively. For example, Ca in rainwater samples ranges from 5.77 mgli in aluminium roofing sheet to 12.87 mgli; Mg showed values that spans from 0.09 mgli in aluminium roofing sheets to 16.75 mgli in open surfaces, and Pb recorded 0.01 mgli in rainwater samples from all the roofing sheets (Fig. 8).

However, Fe concentration in rainwater samples was higher than the 100 mgli threshold of WHO in thatch (1.12 mgli) and asbestos (1.25 mgli) roofing sheets. However, Fe values in aluminium, corrugated iron sheets and open surfaces showed lower values of 0.59 mgli, 0.71 mgli and 0.07 mgli respectively (see Fig. 9). Thus, the concentration of heavy metals in rainwater samples harvested from thatch aluminium, asbestos and corrugated iron sheets and open surfaces showed satisfactory level, with the exception of Fe that show unsatisfactory concentration, as such, the rainwater should be treated in terms of the iron level.

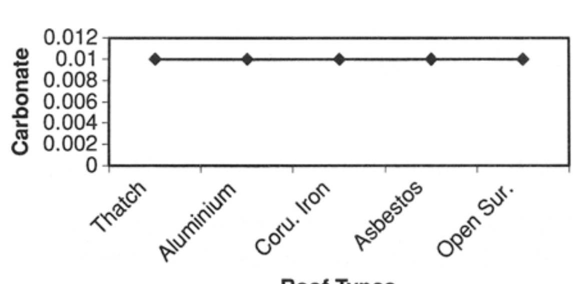

Fig. 6 Variation of carbonate of rainwater in the different roof types

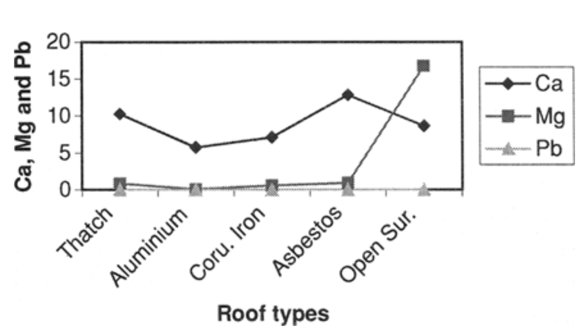

Fig. 8 Variation of Ca, Mg and Pb of rainwater in the different roof types

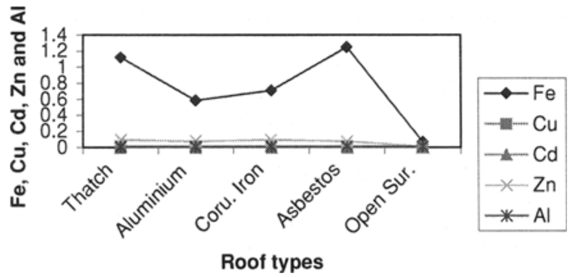

Fig. 9 Variation of Fe, Cu, Cd, Zn and Al of rainwater in the different roof types

Others are Cu recorded 0.01 mgli; Zn recorded values that ranges from 0.08 mgli in aluminium and asbestos to 0.1 mgli in thatch, corrugated iron roofing sheet and open surfaces and Al recorded 0.01 mgli in all the roofing sheets (see Fig. 9).

Total coliform count and dissolved oxygen (DO)

The total coliform count in rainwater samples in the rural communities of Delta State showed satisfactory concentration. This is evident from the fact that in all the rainwater samples collected, the equipment could not detect total coliform count. However, DO in rainwater samples spans from 4.31 mgl to in thatch roofs to 5.28 mgli in the open space. Other roofing material recorded the following: aluminium sheet and corrugated iron sheet recorded DO values of 4.33 mgli and asbestos roofs recorded DO values of 4.76 mgli (Fig. 10).

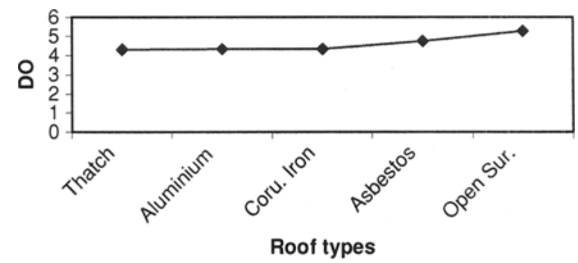

Fig. 10 Variation of DO of rainwater in the different roof types

Comparative analysis of the various sources of rainwater samples

This section discusses the level of differences in the rainwater samples Collected from the different roof types. Kruskal Wallis H' test was adopted in explaining

Table 1 Summary of H'test analysis showing biological decision of the level of differences in physiochemical and critical value

Parameters	Calculated value	Critical value	Significance
pH	15.7	13.28	There is a significant difference
Temperature	11.00	"	No significant difference
Turbidity	15.7	"	There is a significant difference
Salinity	15.7	"	There is a significant difference
DO	15.6	"	There is a significant difference
TSS	15.7	"	There is a significant difference
TDS	15.7	"	There is a significant difference
Colour	15.6	"	There is a significant difference
Odour	12.9	"	No significant difference
Bicarbonate	15.4	"	There is a significant difference
Carbonate	12.9	"	No significant difference
Nitrate	15.7	"	There is a significant difference
Sulphate	15.7	"	There is a significant difference
Total hardness	15.7	"	There is a significant difference
Calcium	15.7	"	There is a significant difference
Magnesium	15.7	"	There is a significant difference
Iron	15.7	"	There is a significant difference
Lead	12.9	"	No significant difference
Copper	12.9	"	No significant difference
Cadmium	12.9	"	No significant difference
Zinc	15.6	"	There is a significant difference
Aluminium	12.9	"	No significant difference
Coliform count	12.9	"	No significant difference

this level of differences. The result of the H' test analysis is presented in Table 1.

Table 1 shows the differences that exist in the concentration of physicochemical and biological characteristics of rainwater harvested from thatch, aluminium, corrugated iron sheet, asbestos and open surfaces. Out of the 23 physiochemical and biological characteristics of rainwater analysed, 15 showed high level of variation, or differences in their concentration in the rainwater harvested from 5 sources. These are pH turbidity, salinity DO, TSS, TDS, colour, $HCo^{-}{}_{3}$ nitrate sulphate, $CaCo_3{}^{-}$, Ca, Mg, Fe and Zn. Their calculated H'values were higher than the critical table value of 13.28 (see Table 1). However, temperature, odour, Pb, Cu, Cd, Al and total coliform count showed no significant difference in their concentration in these 5 sources of rainwater harvested.

Similarly, the pH values recorded in the coastal areas of Delta State were generally low, lower than those values recorded in the northern extremities with 1.0 pH. This shows that rainwater samples in the coastal areas of Delta State were 10 times more acidic than those in other rural communities of Delta State. The reason for the high level of acid rain in the coastal areas is the gas flaring that is being carried out in most of these areas. Generally, low quality of rainwater samples was recorded in thatch and asbestos roofs during the period of study.

Conclusion and recommendations

The study revealed that most characteristics of rainwater samples in the rural communities of Delta State showed satisfactory concentration in rainwater samples harvested from thatch roofs, aluminium roofs, open surfaces, asbestos roofs and corrugated iron sheets, with the exception of pH, TSS, colour and Fe that showed unsatisfactory concentration. Thus, the rainwater should be harvested stored for human consumption and other domestic uses. However, little treatment is needed in term of its acidity TSS, colour and Fe to bring them into the WHO level of potability. Similarly, there is a significant variation in the quality of rainwater samples collected from thatch roofs, aluminium roofs, asbestos, corrugated iron sheet roofs and open surface. Generally low quality of rainwater samples were observed in thatch roofs and asbestos. However, it is recommended that the rainwater from the rural communities of Delta State should be harvested, stored from human consumption and other domestic, industrial and agricultural uses. Since, it needs little level of purification in terms of it pH, Fe, TSS and colour.

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