ISSN - 2277 - 2755

Journal of Agricultural Science and Environment

QUALITATIVE AND QUANTITATIVE ASSESSMENT OF RAINWATER HARVESTING FROM ROOFTOP CATCHMENTS: CASE STUDY OF OKE-LANTORO COMMUNITY IN ABEOKUTA, SOUTHWEST NIGERIA

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ABSTRACT

Quantitative and qualitative assessment of Rainwater harvesting system from rooftop runoff from a catchment at Oke-Lantoro Community in Abeokuta, Southwest Nigeria was determined using eight roof designs in respect to slope and six selected roofing sheet materials respectively. The result showed that the steeper the roof slope the more the rainwater harvested irrespective of rainfall amount and duration. The roof pattern with a large and steep slope designed with gutter tends to harvest more water and at a higher rate. Physico-chemical analysis of the harvested water samples gave results which varied from various drinking water quality regulatory standards. Sample from galvanized roofing sheet was influenced by zinc and lead in quantity beyond human consumption level, while the asbestos roofing sheet water sample gave higher calcium and magnesium contents which reflected in the total hardness value. Sample from the aluminum roofing sheet gave the best result but it was also affected by the influence of atmospheric dust particles and faecal materials of birds, lizards and other small organisms. Considering the results of the physico-chemical tests, the harvested water samples could be put to other domestic uses, as they cannot be consumed directly.

Keywords: roof patterns, harvesting, water quality, potable, rain.

INTRODUCTION

Rainwater harvesting system in Africa is becoming essential owing to the temporal and spatial variability of rainfall (FAO, 2007). It appears to be the most popular method among the several strategies for mitigating the growing urban water crisis and the supplementary source of water supply to already existing public water supply scheme, particularly in area with dispersed population and hilly terrain (Ayoade et al 1998, Fatokun 2004). Of all the rainwater harvesting methods, the rainwater runoff from household roofs is the most common form of rainwater harvesting. Apart from being cost effective and easy to maintain for effective long-term system operation, the roof top runoff also has less contamination of rainwater runoff as compared with ground catchments system. Furthermore, roof catchments provide water supply at the point of consumption. (Gould and Nissen-Petersen 1999).

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. This is unfortunate as in many cases some simple upgrading and the integrated use of rainwater collection with other technologies is all that is required to obtain a cost effective and reliable water supply solution (Ragab *et al.,* 2003). It therefore becomes important to qualitatively and quantitatively assess rainwater harvesting from rooftop catchments at Oke-Lantoro Community in Abeokuta, Southwest Nigeria. This, when achieved, will contribute to the management of the water resources of the area and Nigeria in general.

Study Area

The study area, Oke-Lantoro community (Figure 1b), is situated within Abeokuta (7^{o} 15'N, 3^{o}25'E) South Local Government Area of Ogun State, South-Western Nigeria (Fig. 1a). It is situated in the tropics and covers an area extent of 1256km^{2}. It is 100km north of Lagos and 80km south-west of Ibadan. To the west of Ogun State is the Republic of Benin (Dahomey), Lagos State lies to the south, Ondo State to the east and Oyo State to the North. The Oke-Lantoro community is predominantly residential in outlook with houses of different structures hence water is mostly required for domestic purpose. Public water supply is either from community boreholes (mini water scheme) or surface water source. There are very few or scanty shallow wells for majority of the area where government water is not assessable (Ayeni 1994).

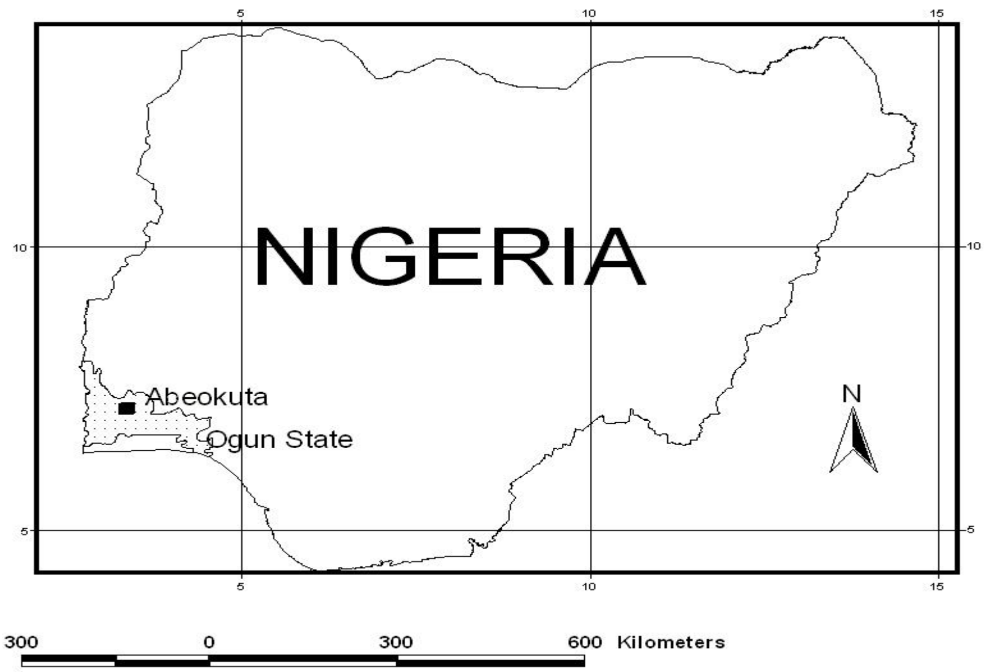


Figure 1a: Map of Nigeria showing the position of Abeokuta

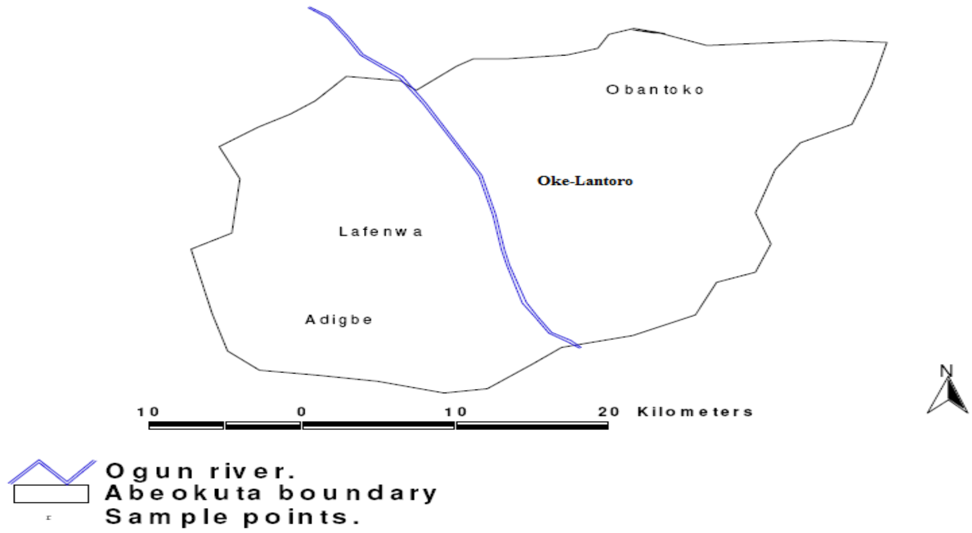


Figure 1b: Map of Abeokuta showing Oke-Lantoro community

MATERIALS AND METHODS

The experiment for quantitative and qualitative analysis of water from rainwater harvesting through roof-top run off from Eight roof patterns and six selected roofing sheet materials were assessed as follow:

Table 1: Description of selected roof pattern and harvesting properties

Roofs	Dimension (m)	Surface Area (m2)	Slope	Design pattern
1	11.2 by 25.2	282.24	0.24	Rain water harvesting is possible from two sides of the roof catchments.
2	10.68 by 14.68	156.78	0.20	Rain water harvesting is possible from two sides of the roof catchments.
3	18.9 by 41.47	783.78	0.24	Rain water harvesting is possible from two sides of the roof catchments.
4	10.97 by 10.9	218.3	0.21	Rain water harvesting is possible from three sides of the roof catchments.
5	11.6 by 24.2	280.72	0.24	Rain water harvesting is possible from all sides of the roof catchments.
6	11.27 by 16.2	182.57	0.21	Rain water harvesting is possible from all sides of the roof catchments.
7	19 by 9.1	172.9	0.46	Rain water harvesting is possible from all sides of the roof catchments.
8	21.85 by 15.2	332.12	0.59	Rain water harvesting is possible from all sides of the roof catchments.
9	CONTROL	1.0	0.0	Rain water was harvested directly from the atmosphere without any interception

Quantitative Analysis

Eight roof patterns were analyzed for quantitative study as shown in Table 1 above. The slopes and surface area extent of each roof catchment was determined using measuring tape. The height and length of truss carrying the roof were measured and the slope determined mathematically. Water vessels having 0.5m diameter were placed at the end of the roof catchments attached with collection gutter to harvest rainwater. Total volume of harvested water was collected and measured at the end of a particular rainstorm in order to determine the actual harvest volume per the equivalent length of such roof. This volume was multiplied by the entire roof length in order to determine the total amount of harvest possible on such catchments considering the surface area. Also the volume of harvest per rainfall duration was monitored to determine the harvest intensity owing to variations in the slope of catchments. A control experiment was also set up to stand as comparison to other set-ups; in which a water vessel was placed to harvest rainwater directly from the atmosphere without any interception (Gould 1999). Harvest intensity was also monitored and likewise the total volume of harvest with respect to the surface area of the water vessel which represent the area of catchments. A rain-gauge was installed at the location for rainfall measurement.

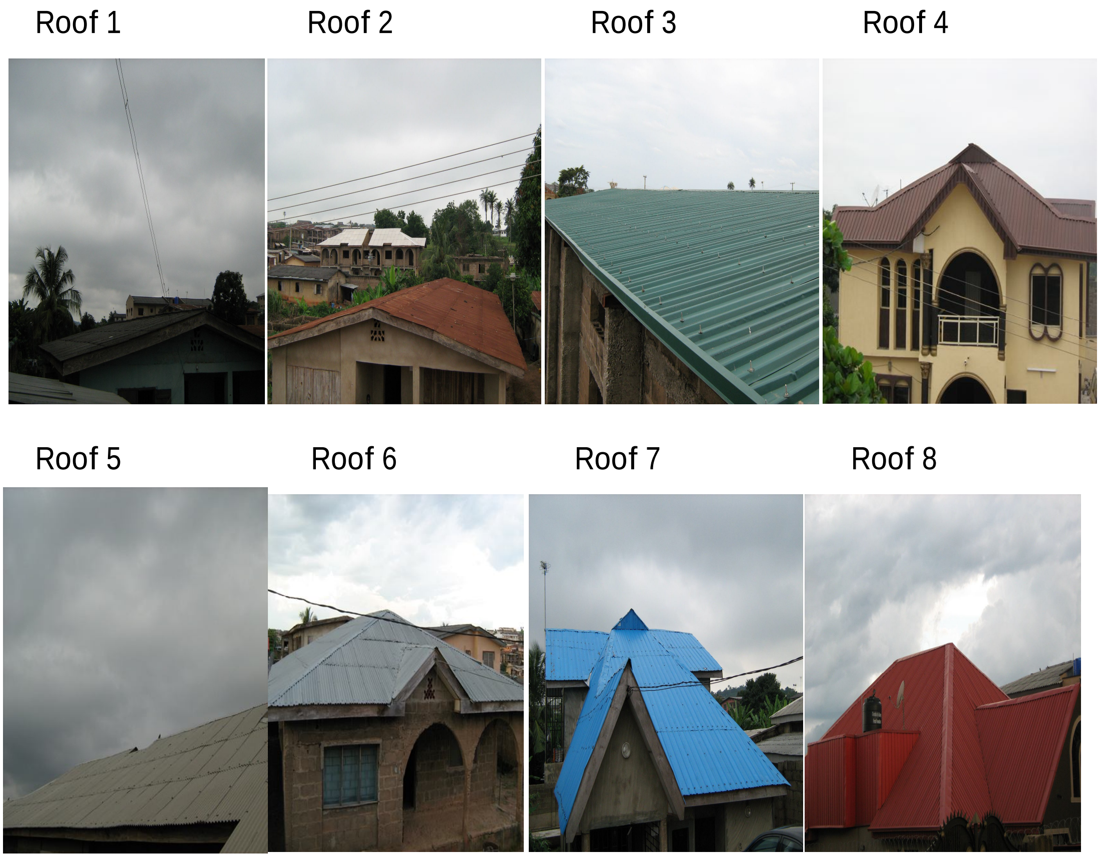


Figure 1c: Selected roof tops with different structures

Qualitative Analysis

Harvested rainwater samples were collected via roof-top run off made of six selected roofing sheet materials were analyzed for physical, chemical and bacteriological contents using standard method for the examination of water. The roofing materials included new galvanized iron (A), old galvanized iron (B), new corrugated asbestos (C), old corrugated asbestos (D), blue aluminum (E) , red aluminum (F) roofing sheets and a control sample (G) which is the water collected directly from rain drop without contact with any roof material. The sampling periods are the months of May (1), which was taken as the onset of rainfall in the area for the experimental year; July (2), the first peak period of rainfall and September (3) the rising period of rainfall after the August break.

Table 2: Relationship between harvested volume and Roof slope for selected roof patterns at different durations of rainfall

Roof Pattern	Slope of roof	Harvested volume of 20min. duration (litre/min)	Harvested volume of 30min. duration (litre/min)	Harvested volume of 40min. duration (litre/min)
1	0.24	0.6	0.25	0.19
2	0.2	0.5	0.21	0.16
3	0.24	0.6	0.25	0.19
4	0.21	0.53	0.22	0.17
5	0.24	0.6	0.25	0.19
6	0.21	0.53	0.22	0.17
7	0.46	1.15	0.48	0.36
8	0.59	1.48	0.62	0.49
Control	0	0.06	0.21	0.02

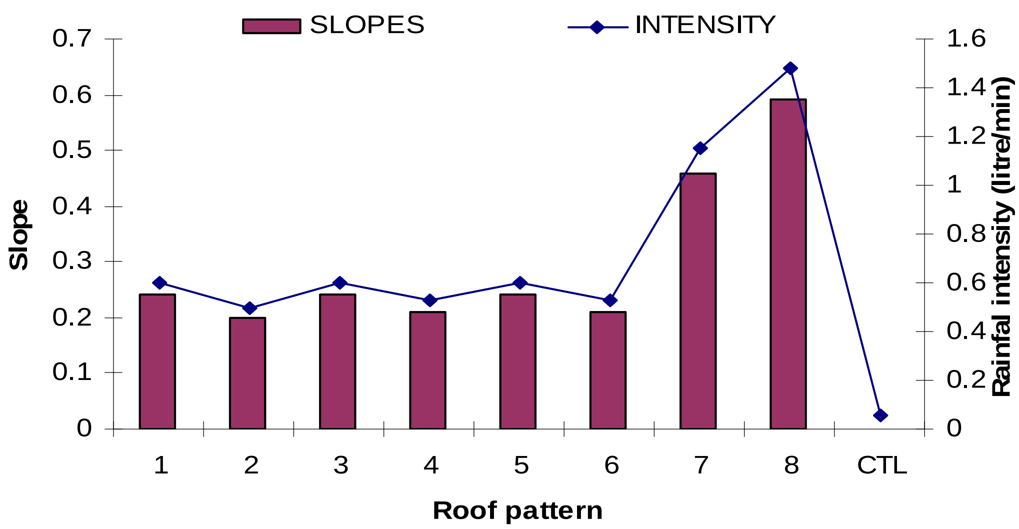


Figure 2: Relationship between harvested volume and Roof slope for selected roof patterns at 2.1mm rainfall amount and 20 minute duration (24th May, 2008)

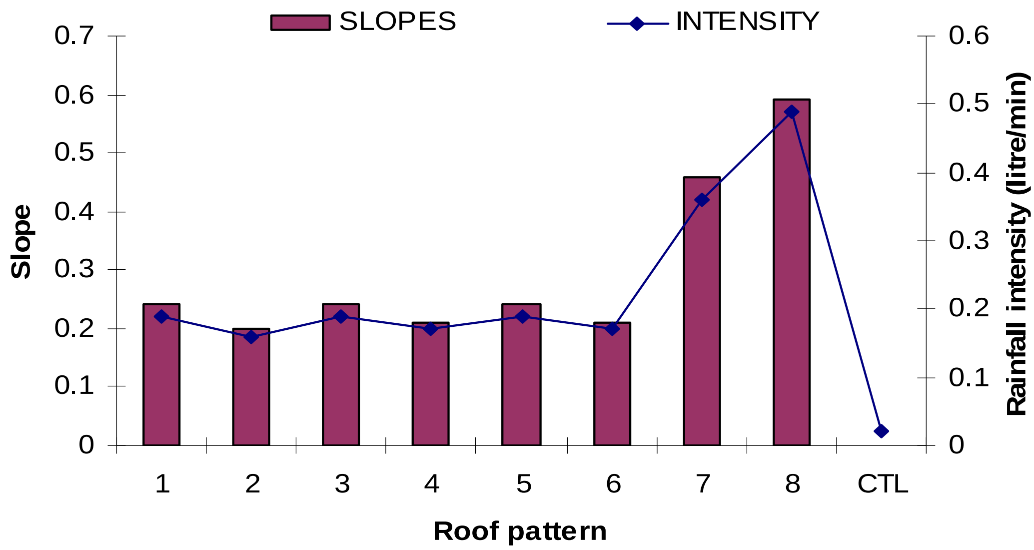


Figure 3: Relationship between harvested volume and Roof slope for selected roof patterns at 1.7mm rainfall amount and 30 minute duration (8th July, 2008)

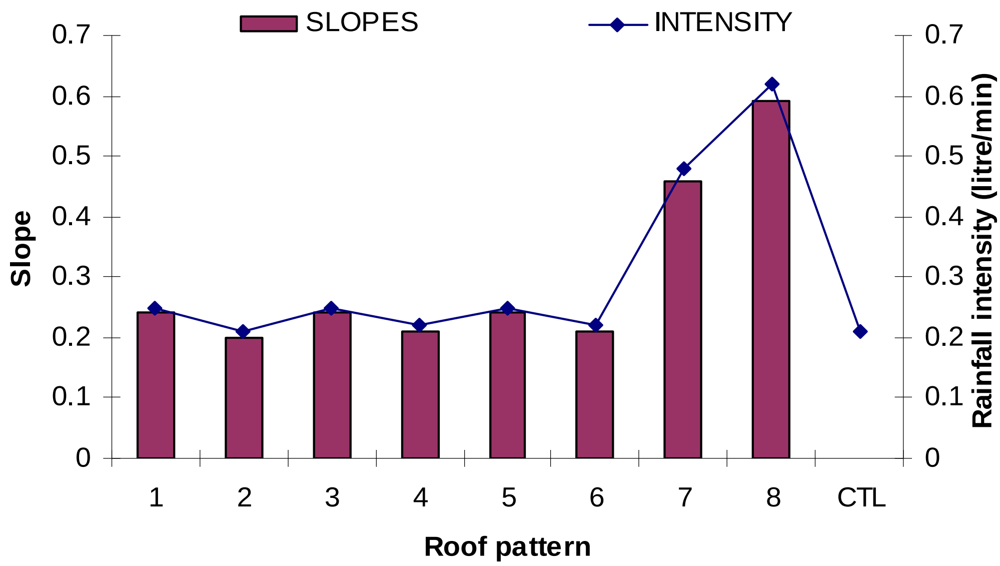
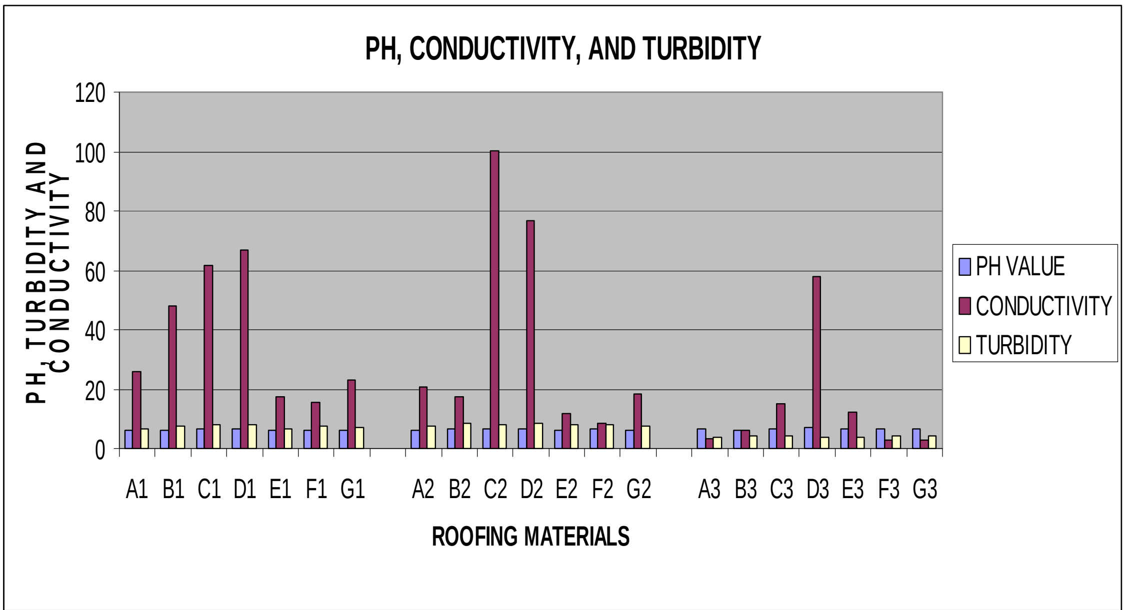


Figure 4: Relationship between harvested volume and Roof slope for selected roof pattern at 12.5mm rainfall amount and 40 minute duration (3rd September, 2008)

Table 3: Physical and chemical analyses of harvested roof top water samples

SAMPLES	pH	Conductivity (µsi/cm)	Turbidity (NTU)	Colour (Hu)	DO (mg/l)	BOD (mg/l)	Total Solid (mg/l)	TDS (mg/l)	TSS (mg/l)	Total Hardness (mg/l)	Ca ion Hardness (mg/l)	Mg ion Hardness (mg/l)	Chloride (mg/l)	Carbonate (mg/l)
A1	6	25.8	6.52	5	2.31	0.4	35	11.4	23.6	5	4	1	29	24.4
B1	6	48	7.43	5	1.53	0.45	35	21.4	13.6	9	9	0	25	48.8
C1	6.8	61.5	8.04	5	1.85	1.2	50	28.3	21.7	17	16	1	31	24.4
D1	6.8	66.9	8.1	5	2.02	1.01	50	30.3	19.7	17	15	2	26	24.4
E1	6.2	17.42	6.77	5	3.39	1.2	20	7.6	12.4	1	1	0	21	24.4
F1	6.2	15.61	7.43	5	2.76	0.67	25	6.7	18.3	5	1	4	23	24.4
G1	6.2	23.1	7.23	5	3.8	1.61	28.4	10.2	18.2	6	3	3	22	24.4
A2	6.2	20.5	7.31	5	2.43	0.31	25	9	16	5	5	0	30	24.4
B2	6.6	17.61	8.24	5	1.74	0.48	25	7.6	17.4	4	3	1	23	24.4
C2	6.8	100.1	7.91	5	3.35	1.25	60.5	45.6	14.9	30	21	9	28	24.4
D2	6.8	76.8	8.31	5	3.06	0.96	60.5	34.8	25.7	19	18	1	26	24.4
E2	6.2	11.94	7.91	5	3.28	0.8	22.5	5	17.5	2	1	1	26	24.4
F2	6.4	8.63	7.86	5	3.85	1.51	10	3.4	6.6	1	1	0	28	24.4
G2	6.2	18.18	7.47	5	3.23	0.83	50	7.9	42.1	6	4	2	26	24.4
A3	6.8	3.14	3.68	5	3.13	0.54	17.5	0.9	16.6	1	1	0	35	24.4
B3	6.2	6.06	4.2	5	3.29	0.4	20	2.3	17.7	7	6	1	26	24.4
C3	6.8	14.99	4.35	5	3.75	1.24	20	6.3	13.7	2	2	0	20	24.4
D3	7	57.8	3.72	5	3.71	1.33	37.5	25.8	11.7	23	18	5	30	24.4
E3	6.6	12.03	3.8	5	2.85	0.47	25	5	20	4	2	2	28	24.4
F3	6.6	2.74	4.02	5	3.88	1.1	17.5	0.7	16.8	0	0	0	25	24.4
G3	6.6	2.78	4.15	5	2.3	0.47	17.5	0.8	16.7	3	2	1	24	24.4
WHO LIMIT	7.0– 8.9	900	5.0	NS	NS	NS	500	NS	NS	100	NS	20	200	NS

* NS – Not specified



A1 to G1 = rainwater samples collected in May for the selected roofing materials
A2 to G2 = rainwater samples collected in July for the selected roofing materials
A3 to G3 = rainwater samples collected in September for the selected roofing materials

Figure 5: **Assessment of pH, Conductivity and Turbidity of water harvested from different roofing materials at various rainfall periods**

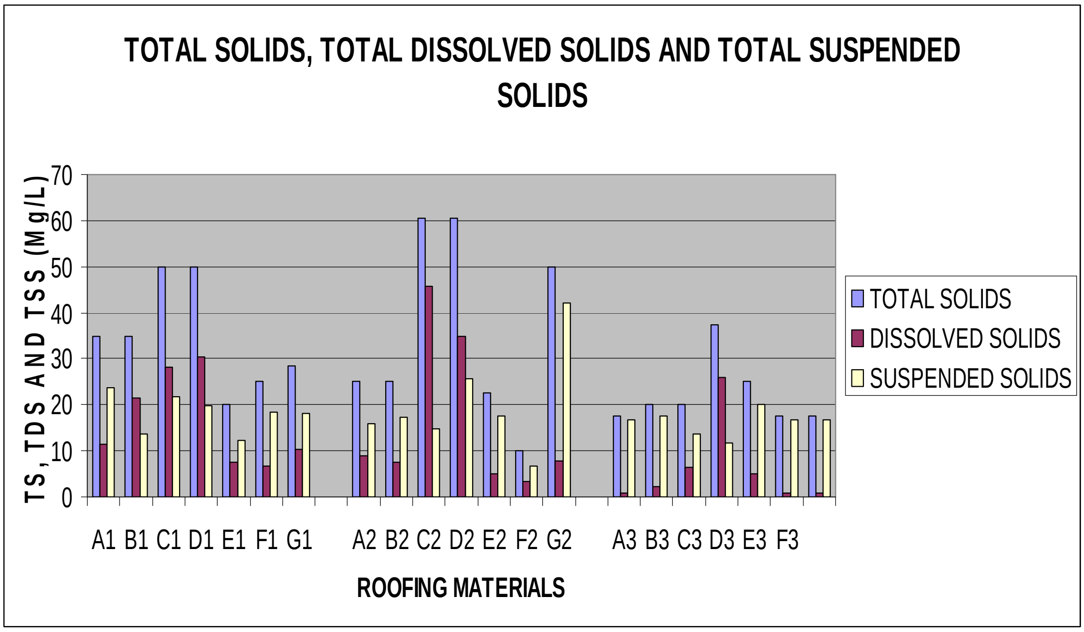


Figure 6: **Assessment of total solids, total dissolved solids and total suspended solids of water harvested from different roofing materials at various rainfall periods**

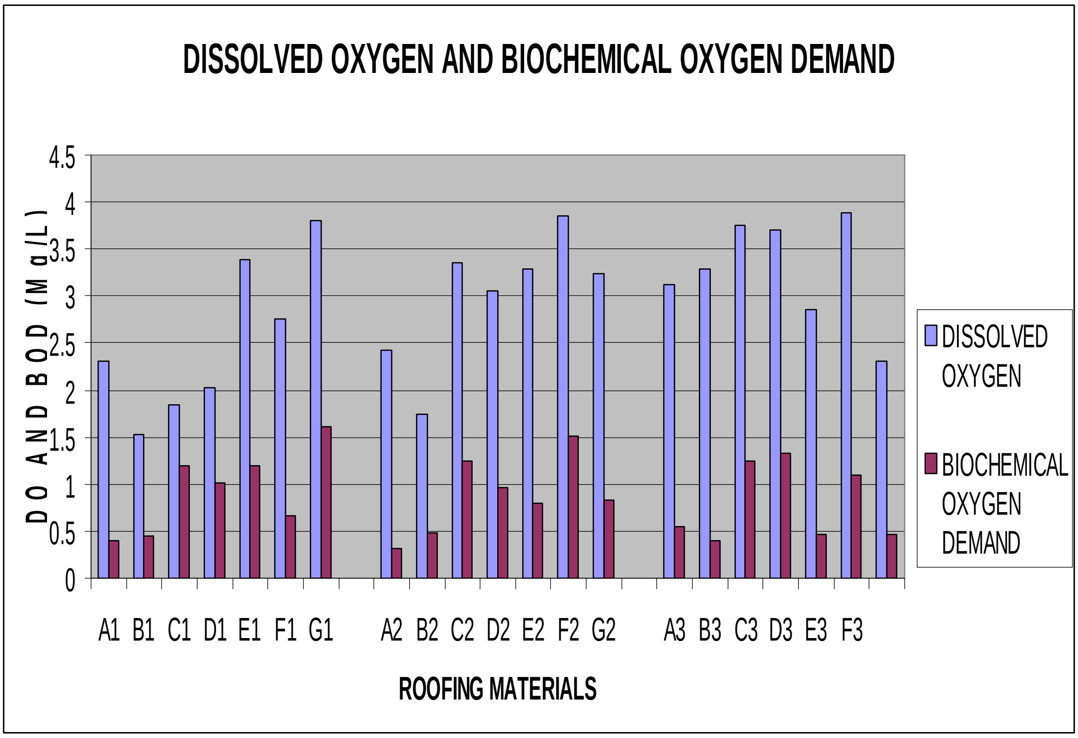


Figure 7: **Assessment of Dissolved oxygen and Biological oxygen demand of water harvested from different roofing materials at various rainfall periods**

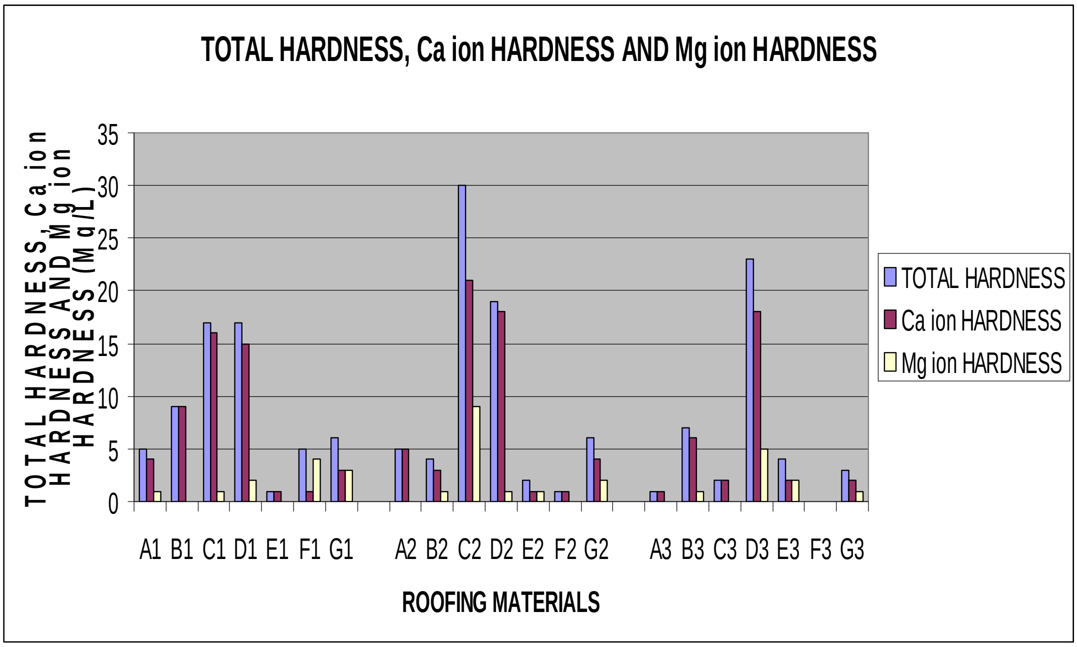


Figure 8: Assessment of Total hardness, Ca hardness and Mg hardness content of water harvested from different roofing materials at various rainfall periods

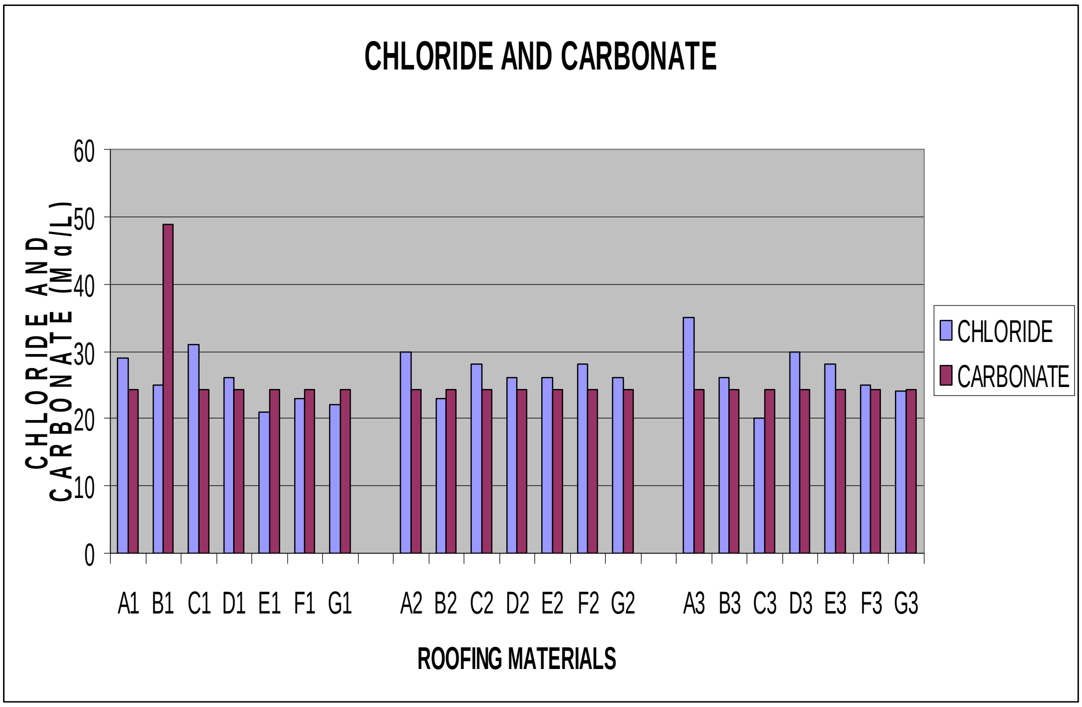


Figure 9: Assessment of Chloride and Carbonate content of water harvested from different roofing materials at various rainfall periods

Table 4: Physical, chemical and bacteriological analysis of harvested roof top water sample

Samples	Acidity (mg/l)	Alkalinity (mg/l)	Fe ion (mg/l)	Na ion (mg/l)	Zn ion (mg/l)	Pb ion (mg/l)	Bacteria Count Per 100 ml	E Coli (24 hours)
A1	1	NIL	NIL	1.0	0.59	0.12	TNTC	50
B1	1	NIL	NIL	2.0	0.60	0.08	TNTC	50
C1	0.3	NIL	NIL	NIL	NIL	NIL	NIL	NIL
D1	0.3	NIL	NIL	1.0	NIL	NIL	TNTC	NIL
E1	0.7	NIL	NIL	NIL	NIL	NIL	TFTC	NIL
F1	0.7	NIL	NIL	NIL	NIL	NIL	15	NIL
G1	0.7	NIL	NIL	1.0	NIL	NIL	NIL	NIL
A2	0.7	NIL	NIL	1.0	0.60	0.14	NIL	NIL
B2	0.4	NIL	NIL	NIL	0.36	0.05	NIL	NIL
C2	0.3	NIL	NIL	NIL	NIL	NIL	TNTC	NIL
D2	0.3	NIL	NIL	NIL	NIL	NIL	TFTC	NIL
E2	0.7	NIL	NIL	NIL	NIL	NIL	NIL	NIL
F2	0.6	NIL	NIL	NIL	NIL	NIL	NIL	NIL
G2	0.7	NIL	NIL	NIL	NIL	NIL	NIL	NIL
A3	0.3	NIL	NIL	NIL	0.58	0.18	54	50
B3	0.8	NIL	NIL	NIL	0.47	0.07	TNTC	20
C3	0.3	NIL	NIL	NIL	NIL	NIL	35	20
D3	0.2	NIL	NIL	NIL	NIL	NIL	23	NIL
E3	0.3	NIL	NIL	NIL	NIL	NIL	2	NIL
F3	0.3	NIL	NIL	NIL	NIL	NIL	1	>160
G3	0.8	NIL	NIL	NIL	NIL	NIL	10	50
WHO LIMIT	NS	100	1.0	NS	0.01'	0.01	NS	NS

RESULTS AND DISCUSSION

Quantitative assessment

Table 2 and Figures 2 - 4 show the relationship between the slope and the intensity of water harvested for rainfall of different amount and duration for all the roof patterns. It was obvious from the result that the steeper the roof slope the more rainwater harvested irrespective of rainfall amount and duration.

The control set-up has the least harvesting capacity since the rainfall water was harvested directly from the rain drop, hence a zero slope (Konig 1998). The effect of roof slope was obvious in this study as Roof slope influences the intensity of harvest via different roofs. Roof 8 with highest slope of 0.59 had the highest rate of rainwater harvest irrespective of rainfall amount and duration, while Roof 2 with less of slope of 0.2 on the other hand had the lowest rate.

Qualitative assessment

Table 3 shows the result of physical, chemical and bacteriological analyses carried out on the water samples collected as related to the standard limit of WHO and result was further expressed graphically for clear interpretation.

Figure 5 shows pH, Conductivity, Turbidity comparative assessment of different roofing materials during various rainfall periods in the study area. The conductivity values obtained from all the samples ranged from 2.74 to 66.9µs/cm. It is observed that conductivity was highest in the water collected from roof top with corrugated asbestos roofing sheets irrespective of the period of collection. This was followed by the galvanized iron roofing sheet, and then the water collected directly from the raindrop and the red aluminum roofing sheet samples having the lowest conductivity value. However, all the values were less than 900µs/cm which falls below the WHO drinking water standard. Furthermore, the graph also showed that the pH and Turbidity were uniform irrespective of the material used and the time of collection. However, from Table 3, it was observed that the pH value ranged between 6.0 to 7.0 which in most sample did not conform with WHO standard except the water sample collected in September from old corrugated asbestos (D3) with marginal value of 7. Furthermore, the turbidity values were higher than the 5µsi/cm WHO standard for most of the water collected from the different roofing materials and the control. This implies therefore that high pH and turbidity of rainwater harvest was not only as a result of rooftop material particularly when sample collected directly showed similar results.

Figure 6 shows Total solids, Total dissolved solids and Total suspended solids comparative assessment of different roofing materials during various rainfall periods in the study area. It was observed that the total solids, total dissolved solids and total suspended solids were highest in the water collected from roof top with corrugated asbestos roofing sheets irrespective of the period of collection. This was followed by the galvanized iron roofing sheet, and then the water collected directly from the raindrop. However, all the values were less than 60mg/l which falls below the WHO 500mg/l drinking water standard particularly for the total solid. It was observed that the values of total solids, total dissolved solids and total suspended solids were highest in the peak periods of rainfall in July, followed by the onset of rainfall in May, then the period after the August break in September. This may be as a result of higher sediments available in the environment prior to the beginning of rainfall as in the case of May and the high volume of runoff during the peak of rainfall in July.

Figure 7 shows Dissolved oxygen (DO) and Biological oxygen demand (BOD) comparative assessment of different roofing materials during various rainfall periods in the study area. The dissolved oxygen content of analyzed water samples fell within the range of 1.53 to 3.58 mg/l. An appreciable increasing trend of dissolved oxygen content was observed as the months progressed, with the highest value obtained from red aluminum roofing sheet sample for September. While the lowest was obtained from old galvanized roofing sheet sample for May. A lower BOD value was observed from all analyzed samples with a range of 0.31 to 1.61. There is a normal distribution in the trend of BOD for the three sampling periods with the corrugated asbestos having the highest, followed by aluminum roofing sheets, then the galvanized roofing sheet except a little variation in the month of May when highest value was obtained from the control sample.

Figure 8 shows Total hardness, Ca hardness and Mg hardness comparative assessment of different roofing materials during various rainfall periods in the study area. This study also revealed that asbestos roofing sheet samples posses the highest level of total hardness. This is traceable to the level of magnesium and calcium carbonate contents of the roofing sheet. Hardness of water results from the effect of calcium and magnesium carbonate on water which makes it difficult to form lather with soap. Studies have also confirmed the relationship between water hardness and heart diseases (König 1998 and Ayeni 1994). However, all analyzed samples are safe for human consumption owing to the regulatory limits.

Figure 9 shows Chloride and Carbonate contents comparative assessment of different roofing materials during various rainfall periods in the study area. The chloride and carbonate concentration are very low in all analyzed samples which ranged from 20 to 35mg/l. Majority of the water samples analyzed gave values that were relatively similar except with high value of carbonate obtained from old galvanized iron roofing sheets samples for September, and high value of chloride obtained from new galvanized iron roofing sheet sample for May. The lowest value was obtained from new asbestos roofing sheet sample for September. Naturally occurring chloride is caused by dissolving minerals. It may be found in large amount in industrial brine, where it combines with sodium. Chloride gives a salty taste to water and may increase the corrosiveness of water.

Table 4 further shows Physical, chemical and bacteriological analyses of some parameters of harvested roof top water sample. The alkalinity, iron, sodium, zinc and lead contents were not detected in all the water harvested from the different roofing materials during various rainfall periods in the study area except the old and new galvanized iron roofing sheet samples having values of sodium, zinc and lead contents ranging from 0.05-2ppm. These values were higher than the WHO standard for drinking water. The data also showed that the water harvested is liable to bacteriological contamination only during the beginning of rainfall after a long dry spell as observed from the September values of bacteria count and E coli for the different roofing materials.

CONCLUSION

In the present study area, the choice of roofing materials and design are not considered based on the water needs of the individual rather it is based on individual financial status and taste despite the problem of water supply encountered in the area. The steeper the roof slope the more the rainwater is harvested irrespective of rainfall amount and duration. Though the quality of water harvested from the selected roofing materials at different rainfall periods fell within the WHO standard limit, some level of contamination was prominent. The water from asbestos roofing sheet had the highest level of pollution, followed by galvanized iron roofing sheet and the aluminum roofing sheet was the least polluted. As revealed from the analysis, most of the samples require at least some level of treatment particularly in respect to the bacteriological contamination in order to ensure their portability considering the regulatory standards. However, all water samples were quite safe for all other domestic uses such as; laundry, bathing, toilet flushing and other cleaning works.

RECOMMENDATION

Based on this study, the following suggestions are recommended to the people of this community;

1. Community should explore the rainwater harvesting system as an alternative to the acute shortage of water supply in the area.
2. Ensure roof design with appreciable roof slope in order to enhance efficient rainwater harvesting.
3. Cultivate the use of Aluminum roofing sheets in the building design, but if incapacitated due to cost of aluminum, the coated galvanized iron roofing sheet should be adopted.
4. Safety and health measures should be paramount in storage of harvested water.
5. The state and the local government should launch an enlightenment campaign on the essentials of rainwater harvesting as means of water conservation.

Finally, harvested rainwater system is a solution to the insistence problem public water supply thereby enhancing better living environment free of over abstraction of groundwater and flood disaster.

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(Manuscript received: 5th July, 2010; accepted: 28h March, 2011).