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RAINWATER HARVESTING, QUALITY ASSESSMENT AND UTILIZATION IN KWALI AREA, FCT ABUJA

M. M. Bello[1*], M. Nike[2]

[1]Centre for Dryland Agriculture, Bayero University, Kano, Nigeria
[2]Department of Agricultural Engineering, Bayero University, Kano, Nigeria
*mmbello.cda@buk.edu.ng

+2348038872599

ABSTRACT

This study was conducted to assess domestic rainwater harvesting (DRWH) in Kwali Area Council, FCT Abuja during the rainy season of 2013. The people's perception about rainwater harvesting, quality of the harvested rainwater, effect of roofing materials on the water quality, were all investigated. Questionnaire was used to collect information about the people's perception and other information related to rainwater harvesting and utilization. Some chemical (pH, total dissolved solids, total hardness, nitrate, iron, chloride, chromium, zinc and copper) and microbiological properties of the harvested rainwater were determined using standard procedures as outline in the Standard Methods for the Examination of Water and Wastewater. Samples were collected from three different roof types (corrugated iron sheets, asbestos roof and aluminum roof) commonly used in the area in order to investigate the effect of roof materials on the water quality. Data obtained were analyzed using descriptive statistics and analysis of variance (ANOVA) and the means were separated using the least significant difference (LSD). Results revealed that rainwater harvesting is widely practiced in the area and a large proportion of the people interviewed indicated their preference of rainwater for cooking and drinking over other sources of water supply. The harvested rainwater was found to be of acceptable quality in terms of its chemical properties as all the parameters investigated were within WHO limit. The microbiological quality was, however, poor as E. coli was detected in all the samples. Analysis of variance indicated that roofing materials have significant effect on some of the water quality parameters. Although people in the area are consuming the rainwater without any prior treatment, the presence of E. coli indicates that other pathogenic bacteria may be present in the water and thus poses threat to public health. It is therefore recommended that the rainwater be at least boiled prior to consumption.

Keywords: Rainwater Harvesting; Water quality; Microbial indices; Roof types; Chemical properties

1. INTRODUCTION

Access to clean water is one of the key challenges in developing countries such as Nigeria and is the major concern of development assistance project in those countries (Song, *et al*, 2009). Large portion of people in developing countries live without proper potable water supply partly due to government failure, developmental challenges and in some cases, population pressure. In sub-Saharan Africa (SSA), the problem of water scarcity is further exacerbated by increasing population and climate change (FAO, 2011). The absence of effective public water supply in most of the countries in SSA has led to the development of alternative sources of water supply such as water harvesting and underground water abstraction.In such cases, rainwater harvesting is an important water source, particularly in urban and peri-urban areas affected by water scarcity (Campisano and Modica, 2012). Rainwater harvesting is an old technology which is, however, currently gaining global momentum

(Ghimire and Johnston, 2013)especially in drylands where rainfall regime is known by its scarcity and unpredictability. Rainwater harvesting (RWH) is the collection, storage, and use of rainwater for productive purposes. Domestic rainwater harvesting (DRWH) is a form of RWH where water is collected from rooftops, courtyards and similar compacted surfaces, stored in tanks or other containers and used for domestic purposes, garden watering and small-scale productive activities (Kahinda, *et al.*, 2007).Many researchers have worked on water harvesting (Mhizha and Ndiritu 2013; Boers*et. al*. 1986; Ray 1986; Kronen 1994; Handia *et al*. 2003; Bulcock and Jewitt 2013).

Rainwater is initially relatively free from impurities, except those picked up by the rain from the atmosphere. However, the quality of rainwater may subsequently deteriorate during harvesting, storage and household use (Gorchev and Ozolins, 1984) . Wind-blown dirt, leaves, faecal droppings from birds and other animals, insects and litter on the catchment areas, such as roofs can contaminate rainwater. Atmospheric particles may equally contaminate rainwater.

Nigeria, a country of over 150 million people is face with problem of potable water supply both in urban and rural settings. Most of the settlements are not connected to public water supply network, and the few that are connected do not get regular supply of water. It has been reported that over 52 % of Nigerian population has no access to improved drinking water supply (Orebiyi*et. al*, 2010) and this might have increased due to the inability of the successive governments to improve or at least maintain the existing structures. In urban and peri-urban areas, the people are left with largely two choices; groundwater abstraction and rainwater harvesting. Although DRWH has been in practice for a long time in Nigeria, few studies have attempted to assess it (Nzediegwu 2011; Kubkomawa, *et al.* 2011; Magnus 2011; Akintola and Sangodoyin 2011) However, these studies were mostly conducted in the southern part of the country. Lekwot *et al*., (2012) evaluated the potential of using DRWH as a supplementary source of water supply in Kanai district of Kaduna State in Northern Nigeria. They reported that 44 % of the population do practice DRWH and about half of them use it for consumption.

Danagana is a suburb area in the Federal Capital Territory of Nigerian which is under Kwali Area Council. Most of the houses in the area have not been connected to the public water supply system and as such rely mostly on other sources of water supply. Furthermore, most settlements in the area are several kilometers away from the nearest stream or river, making access to water very difficult. All previous attempts to sink wells or boreholes in the area have failed because of the extremely low water table in the area (Offodile, 1983). Therefore, majority of households in the area rely to a large extent on rainwater for domestic purposes during rainy season, and on river/streams during dry season. Also due to lack of potable water supply, the harvested rainwater is directly consumed without prior-treatment. This poses risks to public health as the water may contain pathogens and/or heavy metals. Studies conducted in other parts of the country (Akintolaand Sangodoyin, 2011; Kubkomawa*et. al.*, 2011; Tobin*et. al*., 2013)have indicated that harvested rainwater may contain pathogens and heavy metals above the permissible level for drinking water. Other studies have concluded that rainwater from rooftops generally meets the international standards for drinking water (Sazakli *et. al.*, 2007; Handia*et. al.*, 2003). Nevertheless, one of the most significant issue associated with consumption of untreated harvested rainwater is the potential public health risk associated with microbial pathogens. Thus, it is imperative to investigate the quality of harvested rainwater particularly in communities where the water is consumed without any prior treatment. Danagana area is such community where DRWH is widely practiced and the water is consumed without any prior treatment. The objectives of the study was to assess the rainwater harvesting and utilization in the area and also to investigate the quality of the harvested rainwater.

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted at Danagana area in KwaliArea Council of the Federal Capital Territory, Abuja. It is located in the South Western part of the FCT and lies between longitude $8^0 9^{'}$ S and latitude 78^0 E. it has a population of about 12,000 people as at 2006.

2.2. Information on DRWH Practice

A detailed questionnaire was design and administered tothe people around the settlement area to assess the DRWH. 100 people were selected at random and the questionnaire administered to them during field visits. Information related to demographic characteristics of the respondents, practice of RWH, perception of rainwater quality, rainwater harvesting techniques, purposes for harvesting rainwater, and problems related to water harvesting was sought.

2.3. Sampling

The samples were collected from three different types of roofing sheets. Direct sources from the atmosphere was also collected which served as a control. The three different types of roofing sheets from which the rainwater was collected were:

1. Corrugated Iron Sheets
2. Asbestos (Slate)
3. Aluminum roof

The rooftop rainwater collection was done at about 1 to 2 m above ground surface to eliminate possible contamination through splashes from the ground surface. The control samples were collected directly from the sky. Samples were randomly collected from 20 sampling sites (5corrugated iron sheets, 5 aluminum roofs, 5 slates (asbestos), and 5 control samples) within the study area. The samples were collected in 50cl capacity poly propylene containers, which had been previously soaked for 24 hours in 1% HNO_3 (John-De-Zuane, 1990). The physico-chemical and bacteriological properties of the harvested rainwater were then determined immediatelyafter each collection. Sample preparations and handling were done according to standard procedures (John-De-Zuane, 1990; APHA, 1995).

2.4. Laboratory Analysis

2.4.1 Chemical Analysis

pH was measured *in-situ* using a portable hand held pH meter. Chemical analyses of the harvested water samples was conducted at laboratory of the Nigerian Institute of Science Laboratory Technology (NISLT), Abuja. Analyses were done according to the Standard Methods for the Examination of Water and Wastewater (APHA, 1995) and included the determination of total dissolved solids (TDS), total hardness, Nitrate, Iron, Chloride, Chromium, Zinc and Copper. The determination of heavy metals was carried out using atomic absorption spectrometry techniques (APHA, 1995).

2.4.2. Microbiological Analysis

All samples were examined for the widely used bacterial indicator, namely total coliforms by the membrane filter technique (APHA, 1995).

2.5.Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA) using a completely randomized design at 5 % level of significant. Factors considered are the roof types and the sampling locations. The tests of significance of the means were separated using t-Test. The responses supplied by the randomly 100 persons administered with the questionnaire were used to analyze the demographic characteristics of the people, their perception on domestic rainwater harvesting, its utilization and problems associated with it.

3. RESULTS AND DISCUSSION

3.1. Respondents Responses

3.1.1. Demographic Characteristics of the people

52 % of the people interviewed were females whilst the remaining 48 % were males. Household size is a function of many variables related to culture, social and economic status and it is an important criterion for measuring the household condition. In the study area, household widely varies between 2 to 21 members; with an average of 7 persons that uses water for various purposes daily.

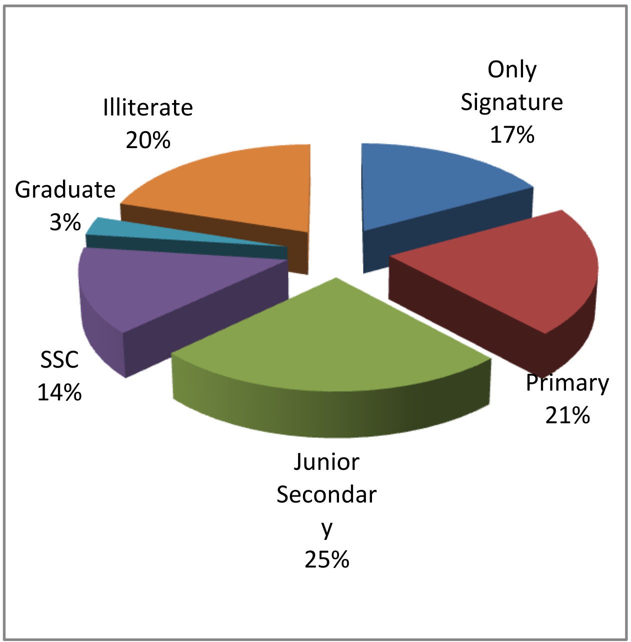

Figure 1. Respondent's Level of Education

Education level of a community is an important factor for implementing any development and social activity especially to implement a project on water supply, sanitation and use of safe water. In the study area, about 37% people (20% illiterate and 17% can give signature only) have never been to school (fig. 1). The remaining 63 % members of the community are literate in different levels and only 3% are found to graduate from tertiary institutions.

The distribution of the occupation of the household is presented in figure 2. The occupation of majority of the young and working people are business (29%), housewife (23%) and farmer (12%). Students constitute (10%) of the interviewed people, drivers (5%) and teachers (4%). Other forms of occupation include laborers (3 %), mechanics (2 %), salesmen (7 %) and security men (5 %). Thus most of the population have low income status.

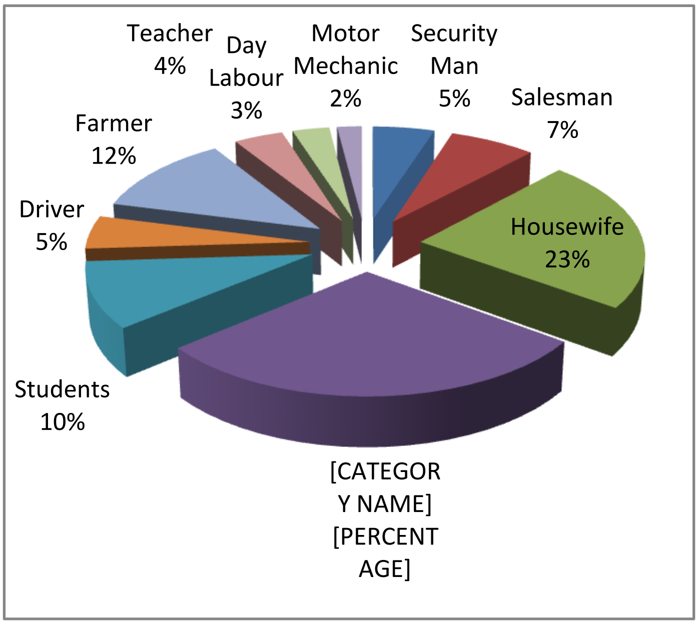

Figure 2. Occupation of community member

3.1.2 Sources of Water Supply and Utilization of Rainwater

Data obtained from the study indicated that about 24.95% of the people interviewed use well water for drinking purpose and about 54.8% use rainwater and

12% people use pond/river water (Table 1). This indicates that the dependent of the people on rainwater for drinking purpose is very high in this area. However, the availability of rainwater is only in the rainy season which extends over six months. During dry season, other sources, like pond are widely utilized. Most of the family uses pond water for cooking (97.95%) and washing (89.5%). The dependence of thepeople on pond water for domestic purposes other than drinking is relatively high indicating the high risk of spreading water borne disease due to use of unsafe pond water for those types of domestic purposes.

Table 2 shows the respondents responses regarding the availability of water sources for various domestic purposes. Most of the people prefer rainwater (56.75 %) and well (45.56%) for drinking and cooking purposes, however most of the people (67.88%) prefer pond/river water for other domestic purposes like cleaning, bathing and washing, etc.

Table 1 Sources of Water for Various Purposes

Uses of water	Tap Water (%)	Pond/River (%)	Well (%)	Borehole (%)	Rain Water (%)
Drinking	6.00	12.00	27.20	0.00	54.80
Cooking	2.50	76.40	20.00	0.00	1.10
Utensils washing	1.04	95.60	3.36	0.00	0.00
Raw vegetable washing	1.05	92.50	6.45	0.00	0.00
Bathing	2.05	97.950	0.00	0.00	0.00
Hand washing	1.04	89.50	9.46	0.00	0.00
Washing clothes	0.00	1000	0.0	0.00	0.00

Table 2: Availability of Water Supply Sources for Domestic Purposes

Sources of water supply	For dinking and cooking purpose (%)	For cleaning, bathing and washing purpose (%)	For all purposes (%)
Tap water	6.23	2.25	8.86
Pond/ River	6.23	7.68	4.08
Well	45.56	13.50	48.06
Deep tubewell	4.50	2.15	5.04
Borehole	0.00	0.00	0.00

Rain water	56.75	17.56	41.67

The priority ranking of using harvested rainwater is presented in table 3. The first priority of using rainwater is for drinking and cooking purposes whilst the second priority is for household washing. Most of the people (about 96 %) claim to have sufficient rainwater for about 4 to 6 months of the year. During dry seasons, however, they would have to collect water from sources such as river.

Table 3 Priority Ranking for Utilization of Rainwater

Purpose	Rank
Drinking and cooking	1
Washing	2
Bathing	3
Others	4

3.2 Quality of Harvested Rainwater

The quality of rainwater is important from public health perspective especially when it is to be used for consumption and other household activities. Table 4 shows the means of the physical and chemical properties of the rainwater collected from the different types of roofing material and the control. The average pH value of rainfall samples collected were 6.70, 6.81, 7.19, and 6.00 for corrugated iron sheet, asbestos, aluminum and control respectively. These values are within the WHO standard limit for safe drinking water given as 6.5-8.5 (Gorchev and Ozolins, 1984).

Both total dissolved solids and total hardness were detected in each of the samples. Values of TDS were 13.89 mg/L, 24.80 mg/L, 10.73 mg/L and 5.060 mg/L for corrugated iron roof, asbestos roof, aluminum roof and control respectively (Table 4). These values are well below the WHO permissible level for drinking water (500 – 1000 mg/L). The total hardness (TH) values were 55.84, 83.40, 28.56 and 28.68 mg/L for the corrugated iron roof, asbestos roof, aluminum roof and control respectively (Table 4). The WHO stipulated TH of 100 – 300 mg/L for drinking water, thus all the samples are safe for drinking with respect to TH.

Nitrate was detected in all the samples, though still within the standard limit of WHO. The values were 5.52, 7.65, 5.21, and 3.05 mg/L for corrugated iron roof, asbestos roof, aluminum roof and control respectively (Table 4). Chloride was detected in all the samples and the values were 0.89, 0.28 and 0.02 for corrugated iron roof, asbestos roof, and aluminum roof respectively. These are all below the WHO limit of 200 mg/L. There was no chloride in the control sample.

All the heavy metals investigated were detected in low concentrations in all the samples except Chromium which was zero in all the samples. The concentrations of the metals were all within the WHO guidelines for drinking water quality (Table 4). These findings are similar to those reported byHandia, *et. al.*, (2003)and Sazakli, *et. al*., (2007) elsewhere. Thus the rainwater can be said to be of acceptable quality in term of the investigated chemical parameters.

However, the microbiological quality of the harvested rainwater is rather poor as *E. Coli* is detected in all the samples (Table 4). The values were 12.80, 26.30, 9.80 and 4.40 c.f.u/mL for corrugated iron roof, asbestos roof, aluminum roof and control respectively. The WHO guidelines for drinking water quality advocates zero *E. Coli* for safe drinking water. Thus this water is of poor quality and therefore unsuitable for drinking without any treatment. This findings are similar to that of a study conducted by Sazakli et al., (2007) in Greece where the harvested water was found to be of good quality in terms chemical properties but unsuitable for drinking interms of microbiological properties. Similarly, Akintola and Sangodoyin, 2011; Kubkomawa, *et al.*, 2011; Tobin, *et al.*, 2013 reported presence of microbial pollutant in harvested rainwater in some parts of Nigeria.

3.3 Effect of roofing material and location on the quality of rainwater

Analysis of variance from the study shows that location has no significant effect on the pH, but on the roof type it has an effect on pH at 5% level of significance as shown in table 5. From table 5, the aluminum roofing sheet has the highest pH and it has a significant difference from corrugated iron sheet and asbestos but there was no significant difference with the control sample.

Also there is no significant difference on the level of total dissolved solids between the locations and the roof types (table 5). However, Asbestos roof has the highest TDS but there was no significant difference between the corrugated iron sheet, asbestos and aluminum but significant difference was observed with the control sample.

There was no significant difference between the sampling locations in terms of total hardness whilst on the otherhand, significant difference was observed between roof types as shown in table 5. Samples from asbestos has the highest value of total hardness while aluminum roof has the least value.

Table 5 shows that there is no significant difference in nitrate between the locations, but roof type shows a significant difference. Also Table 6 reveals that asbestos with 7.65 nitrates content is significantly different from corrugated and aluminum roofing sheet as well as from control while those of corrugated and aluminum roofing sheets are not significantly different from each other.

Although Asbestos roof has the highest concentration of Iron, there is no significant difference between both the locations and roof types. Similar observations were madeabout the Chloride concentration, except that the LSD further reveals a significant difference between sample from corrugated iron sheet roof and the other types of roofs. Analysis of variance also shows that there is no significant difference between the locations in terms of Zinc and Copper. Also there was no significant difference in the Zincand Copper values between the roof types.

There was no significant difference in the microbiological quality of the rainwater harvested from different roof types and locations, with samples from asbestos roof having the highest number of *E. Coli*. This may be due to the presence of dirtiness on the asbestos roof which may be absence in other roofs.

Table 4 Chemical and Microbiological Parameters of the Rainwater

Water Parameters	Corrugated iron roof	Asbestos roof	Aluminum roof	Control	WHO Limit
Ph	6.7	6.81	7.19	6.0	6.5-9.2
Total Dissolved (mg/l)	13.89	24.8	10.73	5.06	500-1000
Total Hardness (mg/l)	55.84	83.4	28.56	28.68	100-300
Nitrate (mg/l)	5.52	7.65	5.21	3.05	50
Iron (mg/l)	0.01	0.02	0	0	0.3
Chloride (mg/l)	0.89	0.28	0.02	0	200

Chromium (mg/l)	0	0	0	0	0.05
Zinc (mg/l)	1.16	1.06	1.07	0	5.0
Copper (mg/l)	0.02	0.03	0.01	0	0.1
E.coli (c.f.u/ml)	12.8	26.3	9.8	4.4	0

Table 5 Analysis of Variance (ANOVA) Water Quality Parameters

Source of variation	**Df**	**pH**	**TDS**	**Total Hardness**	**Nitrate**	**Iron**	**Chloride**	**Zinc**	**Copper**	**E.coli**
Location(L)	4	3.21^{ns}	3.46^{ns}	1.32^{ns}	1.40^{ns}	0.64^{ns}	2.15^{ns}	1.12^{ns}	1.00^{ns}	0.64^{ns}
Rooftype(R)	3	23.28*	2.50^{ns}	113.21*	10.37*	2.88^{ns}	4.90^{ns}	4.51^{ns}	7.42^{ns}	1.04^{ns}
Error	12	11.81	3.05	49.27	5.25	1.60	3.33	2.57	3.75	0.81
C.V		3.59	86.14	11.27	24.70	159.41	140.18	70.47	69.93	126.91

^{ns}Not significant   *Significant at 5% level of significance

Table 6t Tests (LSD) for Samples

Factors Rooftype	**pH**	**TDS mg/l**	**TH mg/l**	**Nitrate mg/l**	**Iron mg/l**	**Chloride mg/l**	**Zinc mg/l**	**Copper mg/l**	**E.coli c.f.u/ml**
Corrugated Iron Sheet	6.700^b	13.934^a	55.840^b	5.5060^b	0.0140^a	0.8880^a	1.1636^a	0.0220^a	12.8000^a
Asbestos	6.8120^b	24.800^a	83.840^a	7.6520^a	0.0220^a	0.2820^b	1.0576^a	0.0300^a	21.0000^a
Aluminum	7.188^c	10.734^a	28.560^c	5.0280^b	0.0000^b	0.0222^b	1.0772^a	0.1000^c	9.8000^a
Control	5.9540^c	5.068^a	28.680^c	3.0500^c	0.0000^b	0.0000^b	0.0000^b	0.0000^c	4.4000^a

Mean values with the same superscript letter within the same column are not significantly different at 5% level of significance

4. CONCLUSION

Domestic rainwater harvesting is widely practised in KwaliArea Council and the usage of the harvested water ranges from consumption to personal hygiene and other household activities. This complements other sources of water used by the community. The rainwater has acceptable chemical quality based all the chemical parameters investigated and iswithin the permissible level of WHO standard for safe drinking water. However, the microbiological water quality is poor as microbial indices were detected in all the sample collected. To protect public health, the harvested rainwater needs some form of treatment prior to consumption. The roof type has significant effect of some of the chemical quality of the water whilst the sampling location does not have any significant effect on the water quality. It is strongly recommended that the rainwater be treated if it is to be consumed.

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