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# Rainwater Harvesting in Ibadan City, Nigeria: Socio-economic Survey and Common Water Supply Practices

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**Abstract** The largest environmental challenge that Nigeria is facing today is water scarcity. Current water use already exceeds renewable supply. Many methods have been suggested to increase the sources of water supply; and one of these alternative sources is rainwater harvesting (RWH). Rainfall harvesting from rural/urban catchments has received little attention in Nigeria. To better understand common practises in the RWH community and motivation for collecting harvested rainwater a socio-demographic survey was conducted in the 11 local government areas of Ibadan city in Nigeria to determine the rate of water consumption and supply from current water sources. The methodology adopted was the mixed method approach, involving a detailed literature review, followed by a questionnaire survey of 1067 household respondents. The data collected through the survey were analysed using SPSS and selected statistical methods such as Chi-square test. The survey was carried out from July-September 2012 and a response rate of 89% (950 households) was recorded. The survey questions focused on the socio-economic characteristics of households and the sources of water supply, catchment materials, rainwater harvesting technology, purpose of RWH, demand and usage of water, effectiveness of management strategy and environmental health. The most commonly reported source of water supply is groundwater with>83.8% of respondents depend on it as their main source of supply, which are vulnerable to drought and pollution while only 6.6% harvest rainwater. 69% of the respondents have corrugated iron sheet while <14% of the respondent's roof are made of roofing tiles and cement concrete respectively. 54% of those with roofing tiles use the harvested water for drinking, while 43% of those with cement roofs use it for cooking and drinking respectively. A larger proportion (61.2%) of respondents chose prevalence of typhoid fever in the study area; some have a prevalence of diarrhoea (19.4%), while few of respondents' water sources is free from water-borne diseases (2.3%). This indicates that there is a prevalence of 97.8% of water-borne diseases. Over 77.1% of respondents did not receive water at all from Water Corporation of Oyo State, while few of respondents did receive water supply. This survey provides critical data about current potable and non-potable RWH practices in Nigeria and can serve as guidance for future RWH research. In particular, the inadequacy of water supply in the City should be investigated further as the demand for sustainable RWH system in Nigeria continues to grow.

***Keywords:*** *rainwater harvesting, survey, catchment, sustainable water supply*

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## 1. Introduction

The provision of adequate water supply and sanitation services to the people of the developing world has been an ongoing quest, which has occupied the minds of development experts and governments for the past 40 years. Although a great deal has been done, enormous amounts of money have been spent, and Drinking Water Decades have been proclaimed, coverage levels remain inadequate. In recent years, a new trend has emerged throughout the developing world, increasing amounts of money are now being spent on the rehabilitation of water services which have previously been installed but which have fallen into disrepair. Water supplies are often inadequate, over 25,000 people die daily from their use of contaminated water and many millions; more suffer from frequent and devastating water-borne illnesses [1]. About half of the people in developing countries lack access to safe drinking water. An attractive solution for resolving water scarcity in various parts of the world is the use of water harvesting systems for runoff water collection and storage [2,3].

The largest environmental challenge that Nigeria is facing today is water scarcity. Current water use already exceeds renewable supply. Many methods have been suggested to increase the sources of water supply; and one of these alternative sources is RWH. Rainfall harvesting from rural/urban catchments has received little attention in Nigeria. In the absence of run-off sewer systems in Nigerian rural and urban areas, RWH from roads, parking lots and rooftops can increase water supply for various domestic uses and help combat the chronic national water shortage. The inadequacy of public water systems in urban areas and the ineffective functioning of water facilities in urban areas of Nigeria have made it impossible for most of the population to have access to sufficient potable water. About 52% of Nigerians do not have access to improved drinking water supply [4].

RWH is a technology used for collecting and storing rainwater from rooftops, land surfaces or rock catchments using simple storage utensils such as pots, tanks and cistern as well as more complex options, such as underground check dams [5,6,7]. Harvested rainwater is a renewable source of clean water that is ideal for multiple uses. The greater attractions of a RWH system are accessibility, low cost and easy maintenance at the household level. RWH enhances water supply by mitigating the temporal and spatial variability of rainfall [8,9] and provide water for basic human needs and other small-scale productive activities [10]. RWH and storage have proved to be an affordable and sustainable intervention in areas with dispersed populations or where the costs of developing surface or groundwater resources are high [11]. Rainwater promotes potable water savings in buildings [12,13,14,15].

The quality of harvested water on different catchment systems in rural areas of Southern Nigeria was studied [16]. The potential of RWH as a reliable source of potable water is high and ~90% of rooftop catchments in Nigeria are composed of corrugated sheets. Rainwater exploitation was studied as a water source in Akufo, a village in Ibadan, Nigeria [17]. The community streams were highly polluted and diseased, hence rainwater was considered as a viable option in the design of a community water supply scheme. The study revealed that there are enormous potential for rainwater usage to meet water needs. The challenges of RWH in Nigeria were studied and storage facilities were found inadequate [18]. The potability of rainwater samples collected from thatch, aluminium, asbestos, corrugated iron roofing sheets, and open surfaces from catchment roofs in six rural communities of Delta State, Nigeria was assessed [19]. They found a satisfactory concentration of rainwater characteristics in the rural areas, as most of the physicochemical and biological characteristics of rainwater samples were below the WHO threshold.

The efficiency of pollutant removal in raw harvested rainwater was investigated through adsorption of a fixed-bed filled with bone char in Agbor [20]. His study revealed raw harvested rainwater subject to such treatment had good quality compared to WHO standards for drinking water. The technique and materials used for RWH, was examined with a focus on the geographical spread of its use in Edo State, Nigeria [21]. The study revealed that most people had emptied their tanks mid-way into the dry season. RWH system was designed using local materials in the Otukpa community, Benue State, Nigeria [22]. Although rooftop RWH is a practise of most households in Otukpa community, the supply is still inadequate for sustenance through the dry season. Analysisof rainwater quality from four roofing materials (asbestos, aluminium, concrete and corrugated plastic) within Ogbomosho, Oyo State was carried out [23]. The analysis of rainwater samples suggested that boiled harvested water could be used for domestic purposes, if gutters and catchment areas were cleaned regularly to remove animal droppings and leaves from over-hanging trees. A study on the use of rainwater harvested from rooftops to recharge ground-water in a household well in Ibadan was carried out [24]. The use of rainwater for recharging ground-water in the well led to water conservation through reduced evaporation. The well thus yields water all year, compared to the control well that dried up during the dry season. The potential for RWH in Kanai (Mali) district in Kaduna State was evaluated [25]. The amount of rainwater harvested was sufficient to supplement the needs of rural communities if community involvement in RWH activities could be increased. A RWH system was designed and constructed for a household in which there is no public main supply [26]. RWH proved a cheap and viable water supply option for domestic, industrial and agricultural purposes in both rural and urban areas.

In Nigeria, RWH is practised in the south, as rainfall is regular for eight months of the year, with a mean annual fall of 1200-2250 mm. The rainy season is from May/June to September/October, depending on the rainfall pattern each year. The other months are generally dry, with cool Harmattan winds between November-March. RWH is practised at individual, household, commercial and occasionally at local or state government level, to augment dwindling water supplies to urban centres. Ibadan city receives heavy rainfall during the rainy season with a mean annual rainfall of 1350 mm. Figure 1 shows rainfall data for Ibadan for the period 1980-2009, indicating that there is ample rainwater. The ponds replenished by rainwater each year are major sources of water supply in rural areas. However, poor waste management and unhygienic practises are increasingly polluting ponds, streams and groundwater [24]. Hence attention and effort are needed to address these unhygienic practices, as they deplete sources of water supply. In addition, more sources of potable water supply are needed to augment current under-supply. In the present context, therefore, RWH is being considered as an alternative option for increasing water supply in Ibadan. Research is being conducted to evaluate the potential for RWH by conducting a socio-demographic survey in the study area to determine the rate of water consumption and current water sources.

## 2. Study Area

In context, Nigeria (Figure 2) has a land mass of 923,768km$^2$; Oyo is one of these states located in the South-western axis. Ibadan is the capital of Oyo state with an estimated population of 2,559,853 in 2007 [28]and a projected population of 7,656,646 by 2015. Ibadan is located in south-west Nigeria (longitude 3°45’-4°00’E, latitude 7°15’-7°30’N and is reputed to be the largest indigenous city in Africa, South of Sahara (Figure 3). It is the second largest city in Nigeria in terms of land mass; consisting of 11 Local government areas. Urban water supplies in Ibadan City are based on groundwater and surface water [29] due to adequate water availability in shallow aquifers. In Ibadan, 41.4% of the urban population are serviced by tube well water [29]. At present, however, the success achieved in hand tube well based urban water supply is on the verge of collapsing, due to the high pollution level of groundwater and because wells go dry during the dry season [24]. The cost of developing surface water is prohibitive due to poor waste management, which are usually dumped into streams and other surface water bodies. These habits have made the exploitation of both groundwater and surface water resources very expensive. Rainfall harnessing, thus, constitutes a viable water source and can inadvertently contribute to flood control.

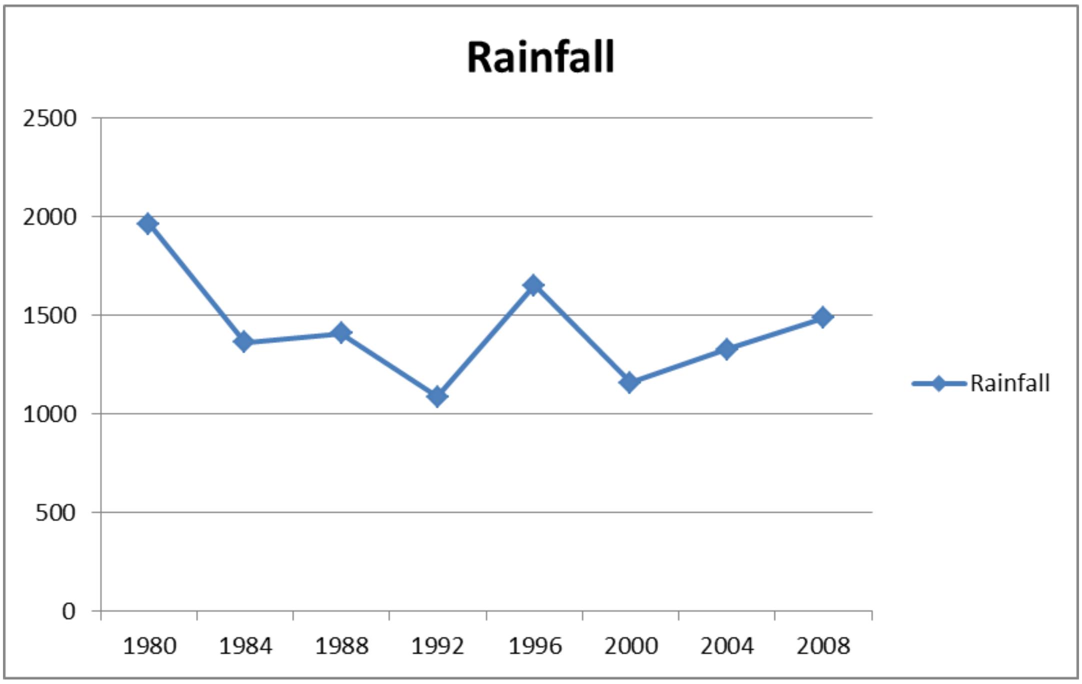


**Figure 1.** Ibadan City historic annual rainfall depths 1980-2009 (Source [27])


**Figure 2.** Map of the States of Nigeria (Source [31])

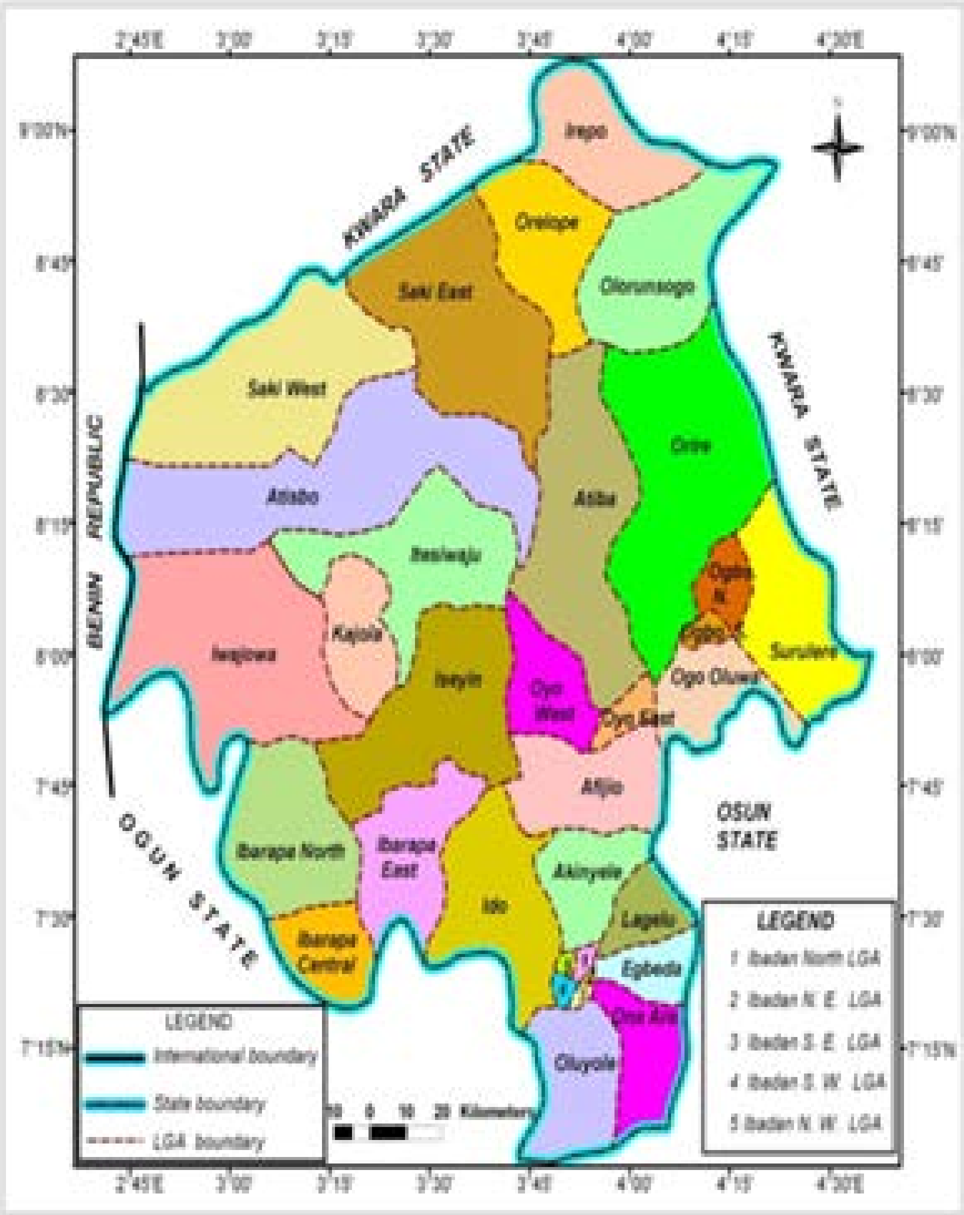


**Figure 3.** Map of Oyo State showing Ibadan

The water demand of Ibadan Metropolis in 2009 was 183,545,923m$^3$ while 12,171,345m$^3$ (6.63% of the demand) was supplied by Water Corporation of Oyo State (WCOS). In 2010, the water demand rose to 189,990,051m$^3$ with 10,782,963m$^3$ (5.68% of the demand) was supplied (WCOS, 2012).These result in lack of access to adequate water supply to meet the societal needs and users have to walk over 3 km to obtain river water thus an increase in water borne disease in the City [30]. The protection of health and well-being of the urban population living in high pollution rate areas is of paramount importance, as waterborne disease is one of the leading causes of death worldwide, especially in children under the age of five. In addition, at any given time, patients suffering from water borne diseases occupy half of the world's hospital beds [30]. Hence, provision of pollution free water is imperative, especially in Ibadan, to mitigate the unwanted consequences of water shortage.

In the light of the above, there is a need to study the RWH potential of Ibadan, so that it can be used to complement existing supplies and to lay a proper framework for future development of water resources.

## 3. Materials and Method

In order to determine a suitable sample size, a sample size calculator [32]was utilised. By using a City population of 2,555,853 [31]and a confidence level of ($p < 0.05$) [33], a sample size of 1067 was calculated for household respondents. Household questionnaires were to be completed by the household head or a responsible adult in their absence. Data were analysed using the SPSS (version 19) statistical data-modelling tool whilst inferential statistics (Chi-square test) was used to estimate how likely the sample pattern will hold in the population. The analysis performed by this tool was descriptive statistics and inferential statistics.

Specifically, a cross-sectional questionnaire survey of households was adopted. At households level Questionnaire was designed to:

1. Assess information on RWH technology.
2. Investigate the benefits of RWH.
3. Investigate the barriers affecting the implementation of RWH.

4. Assess water usage and management strategy.
5. Assess factors affecting water supply management.
6. Investigate water supply issues and environmental health.

### 3.1. Inferential Statistics: Significance Level Testing

This is used to estimate how likely the sample pattern will hold in the population. In carrying out the test, a particular pattern in the population called a null hypothesis is assumed. A significance level is typically set at 0.05, which can be adjusted to as much as 0.1 or as little as 0.01. The adjustment is based on the tolerance for the two types of error (i.e rejecting the null hypothesis that is true or not rejecting the hypothesis that is false) [34]. Type I is rejecting the null hypothesis when it is true, while Type II error is accepting the hypothesis that it is false. Adopting a significance level of 0.5 implies that there is a higher probability of rejecting a true hypothesis while adopting a significance level of 0.01 implies a lower probability of rejecting a true hypothesis but, a higher probability of accepting a false hypothesis [35,36]

### 3.2. One Sample Chi-square Test

In this test, a variable with three or more categories can be tested to check if the differences between the percentages across the categories are due to sampling error or is likely to reflect real percentage differences in the population [36]. A description of the null hypothesis is given below:

$H_0$: The percentages of all categories of each variable are equal in the underlying population.

Chi-Square formula

$$X^2 = \frac{\Sigma(\text{Observed value-Expected value})^2}{(\text{Expected value})}$$

Statistical convention states the use of 0.05 probability level as our critical value. If the calculated chi-square value is <0.05, we accept the hypothesis. If the value is >0.05, we reject the hypothesis.

## 4. Results and Discussion

This questionnaire investigates the socio-economic factors to be considered for RWH. This information is needed to assess alternative water sources and develop a framework to improve the RWH regime.

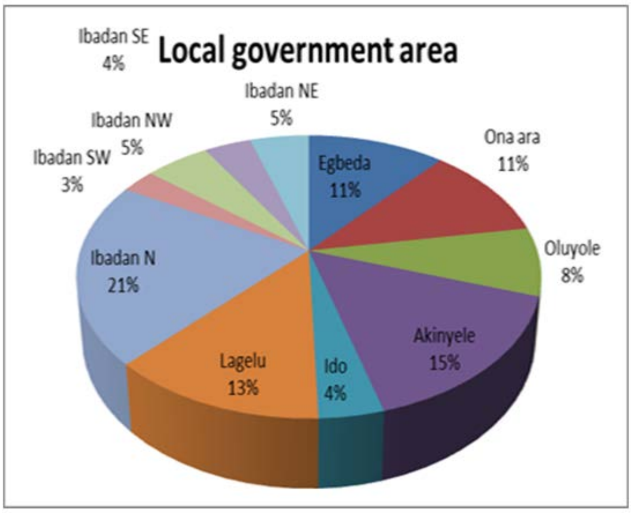


**Figure 4.** Local government area of respondent

**Table 1. Respondents local government areas cross tabulation with respondent population distribution**

| Respondent local government area | Respondent population distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | > 6 | Total |
| Egbeda | 5 | 5 | 15 | 27 | 19 | 19 | 18 | 108 |
| Ona-ara | 0 | 12 | 12 | 28 | 19 | 16 | 17 | 104 |
| Oluyole | 0 | 4 | 7 | 21 | 28 | 9 | 5 | 74 |
| Akinyele | 4 | 17 | 15 | 31 | 40 | 13 | 27 | 147 |
| Ido | 1 | 6 | 6 | 5 | 14 | 4 | 0 | 36 |
| Lagelu | 5 | 13 | 22 | 41 | 19 | 11 | 10 | 121 |
| Ibadan North | 25 | 30 | 40 | 38 | 33 | 13 | 20 | 199 |
| Ibadan South-West | 1 | 5 | 4 | 3 | 7 | 3 | 4 | 27 |
| Ibadan North-West | 3 | 5 | 15 | 7 | 9 | 4 | 7 | 50 |
| Ibadan South-East | 2 | 4 | 4 | 11 | 8 | 2 | 6 | 37 |
| Ibadan North-East | 0 | 2 | 2 | 18 | 17 | 4 | 4 | 47 |
| Total | 46 | 103 | 142 | 230 | 213 | 98 | 118 | 950 |

### 4.1. Respondents Distribution by Local Government Areas

Figure 4 represents the distribution of total respondents to the main questionnaire according to local government areas. Table 1 presents household size (number of occupants) distribution by local Government areas. Egbeda has the highest proportion of six person households (19%), which might be indicative of greater proportion of low income earners in this local government area. Lagelu, Ibadan North and Akinyele had the highest proportion of three, four and five person households (41, 40 and 40%, respectively). The three areas are where most high income households reside. Culturally, due to prevalence of the extended family system in Nigeria, such households support larger populations [37]. A chi-square test was carried out to determine the degree of association between Local Government areas and household size (Table 2). There is a strong significant relationship between the two variables ($p < 0.05$).

**Table 2. Chi-Square test results for relationship between household size and local government areas**

| | Value | Df | Asymp. Sig. (2-sided) (P) |
|---|---|---|---|
| Pearson Chi-Square | 145.951[a] | 60 | <0.001 |
| Likelihood Ratio | 152.591 | 60 | <0.001 |
| Linear-by-Linear Association | 14.437 | 1 | <0.001 |

a. 17 cells (22.1%) have expected count <5. The minimum expected count is 1.31.

## 4.2. Respondents Household Income Distribution

Table 3 represents a cross tabulation of respondents local government area with monthly income range. Egbeda has the highest proportion of households earning <10000 Nigerian Naira monthly, at 44%. Ibadan South-East and Ibadan South-West, on the other hand have the least numbers of low income households at 10% and 11% respectively. The highest concentrations of mid-income (30,000-100,000 N per month) households are in Ibadan North and Lagelu. Ibadan North has the highest concentration of high income households in the City.

**Table 3. Respondents Local Government Area cross tabulation with respondent monthly income range**

| Respondent Local Government Area | Respondent Monthly Income Range (Naira, 000) | | | | | | |
|---|---|---|---|---|---|---|---|
| | <10 | 10-30 | 31- 100 | 101-150 | 151-200 | >200 | Total |
| Egbeda | 44 | 31 | 18 | 9 | 5 | 1 | 108 |
| Ona-ara | 25 | 25 | 30 | 11 | 9 | 4 | 104 |
| Oluyole | 34 | 21 | 13 | 5 | 1 | 0 | 74 |
| Akinyele | 40 | 63 | 26 | 5 | 8 | 5 | 147 |
| Ido | 12 | 10 | 11 | 1 | 1 | 1 | 36 |
| Lagelu | 19 | 24 | 52 | 17 | 4 | 5 | 121 |
| Ibadan North | 51 | 50 | 52 | 20 | 15 | 11 | 199 |
| Ibadan South West | 11 | 7 | 9 | 0 | 0 | 0 | 27 |
| Ibadan North West | 21 | 12 | 16 | 1 | 0 | 0 | 50 |
| Ibadan South East | 10 | 17 | 10 | 0 | 0 | 0 | 37 |
| Ibadan North East | 23 | 20 | 4 | 0 | 0 | 0 | 47 |
| Total | 290 | 280 | 241 | 69 | 43 | 27 | 950 |

## 4.3. Respondents Experience with Water Saving Devices

Overall, 48.2% of the survey population stated they had little or no understanding of water saving devices. Figure 5 presents respondents awareness of RWH technologies and Figure 6 present respondents' interest in property with RWH system.

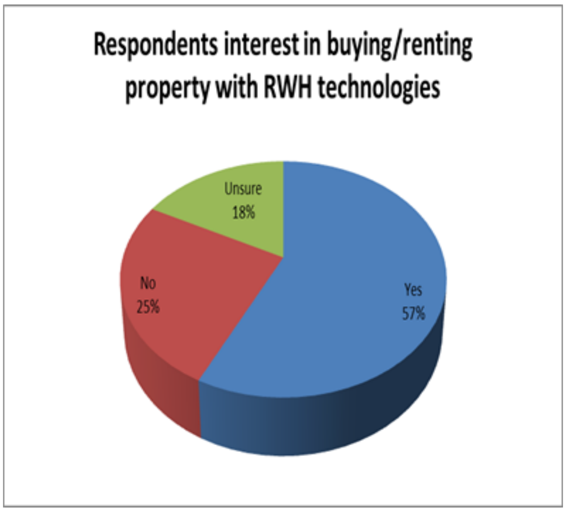


**Figure 5.** Respondent awareness of RWH technologies

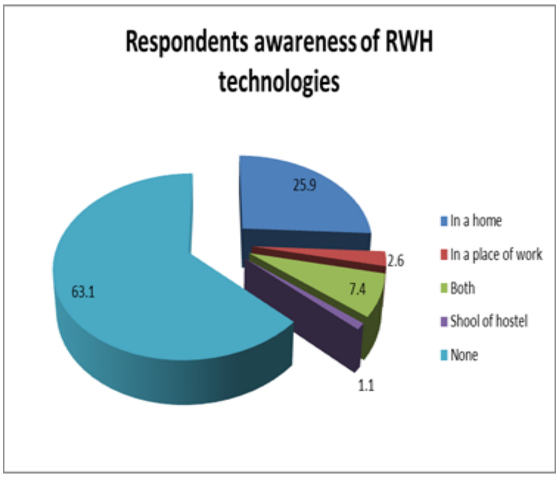


**Figure 6.** Respondents interest in buying/renting

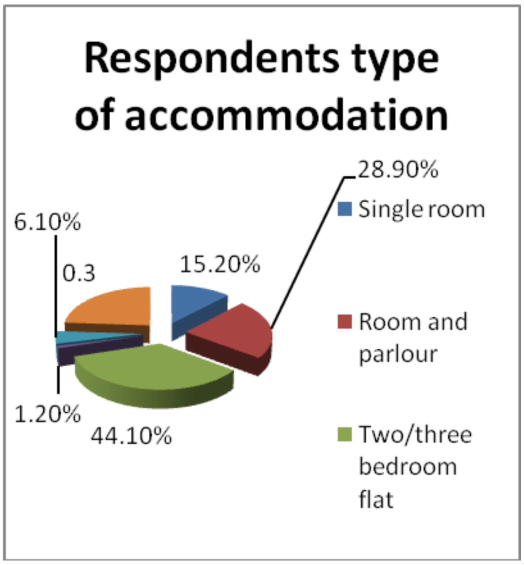


**Figure 7.** Respondents type of accommodation

## 4.4. Respondent's Catchment/Collection Surface for RWH

This section ascertained information on the type of roofing material and the purposes harvested water can be used for. In some instances, improving the quality of the roofing material will be required for harvested water to be potable. Therefore, it is particularly important to understand the type of roofing material and the uses that will be acceptable. In addition, it is essential to understand their income range to ascertain the affordability of improving roof quality. Figure 7 presents type of accommodation. Figure 8 presents respondent's type of roofing materials. As the roofs are prone to corrosion, the harvested water needs filtration and purification with chlorine to make it potable. 69% of the respondents have corrugated iron sheet while <14% of the respondents roof are made of roofing tiles and cement concrete respectively. Table 4 represents a cross tabulation of the type of roofing materials with household income range. Some 32 and 33% of low income earners use roofing tiles and cement concrete materials, respectively, for their roofs. Some 38% of mid-income earners used roofing tiles and 11% of high income earners used cement concrete. This indicates that people with low income used high quality materials for their roofs, which is expected as people usually take loans from banks and co-operative societies to build larger houses. A chi-square test was carried out to determine the degree of association between type of roofing material and household income (Table 5). This result shows a strong, statistically significant, relationship between the two variables (p <0.05)

**Table 4. Type of roofing material cross tabulation with monthly income range**

| Respondent Type of Roofing Material | Respondent Monthly Income Range (Naira's, 000) | | | | | | |
|---|---|---|---|---|---|---|---|
| | <10 | 10-30 | 31-100 | 101-150 | 151-200 | >200 | Total |
| Corrugated iron sheet | 216 | 190 | 172 | 50 | 20 | 10 | 658 |
| Roofing tiles | 33 | 46 | 38 | 8 | 9 | 4 | 138 |
| Brick | 5 | 4 | 3 | 3 | 2 | 0 | 17 |
| Grass | 1 | 0 | 3 | 3 | 2 | 0 | 6 |
| Wood bamboo | 3 | 1 | 2 | 0 | 2 | 1 | 9 |
| Cement concrete | 32 | 39 | 23 | 7 | 9 | 11 | 121 |
| Asbestos cement | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Total | 290 | 280 | 241 | 69 | 43 | 27 | 950 |

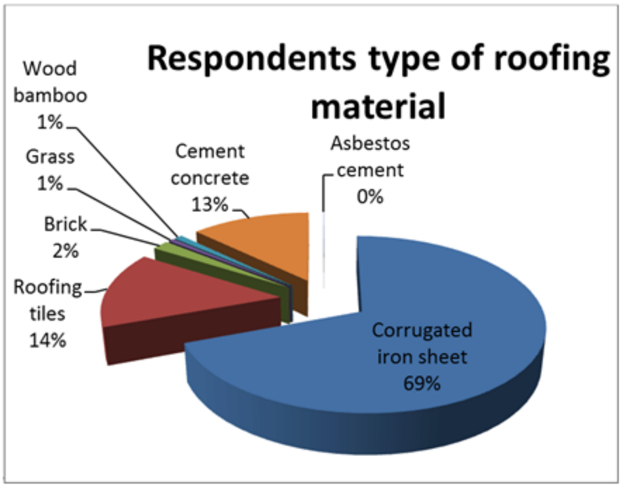


**Figure 8.** Respondents type of roofing material

**Table 5. Chi-Square Tests for relationship between roofing material and monthly income range**

| | Value | Df | Asymp. Sig. (2-sided) (P) |
|---|---|---|---|
| Pearson Chi-Square | 91.788[a] | 30 | <0.001 |
| Likelihood Ratio | 56.567 | 30 | 0.002 |
| Linear-by-Linear Association | 15.269 | 1 | <0.001 |
| N of Valid Cases | 950 | | |

[a]. 24 cells (57.1%) have expected count <5. The minimum expected count is 0.03.

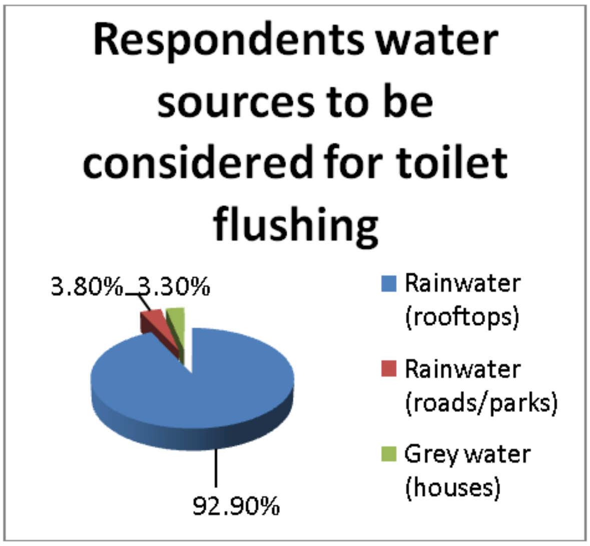


**Figure 9.** Sources considered by respondentsfor toilet flushing

## 4.5. Respondents Perceived Use of Rainwater

This section is concerned with ascertaining information on the sources of water and the types of reuse that would be acceptable to respondents. Figure 9 presents sources respondents considered for toilet flushing. In terms of the use that people would be willing to consider RWH for, Figure 10 illustrates that the most widely accepted would be (in order of popularity) drinking, cooking, toilet flushing, washing clothes. Few would be willing to use it for bathing animals, car washing, personal washing, garden watering and general outdoor use, respectively.

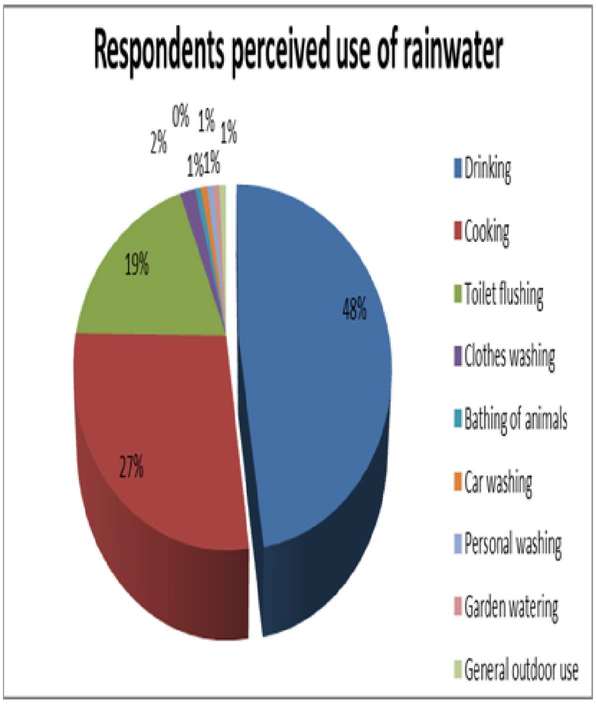


**Figure 10.** Perceived use of rainwater by respondents

## 4.6. Water Supply and Environmental Health

Figure 11 reveals that 70% of the respondents chose unsatisfactory with the level of main water supply from Water Corporation of Oyo State (WCOS), while 29.9% of respondents were satisfied. This implies that the WCOS is not providing adequate water supply for the community. To really confirm this, the respondents were further asked "how often they receive water from the Water Corporation in the City?

### 4.7. Respondents Consistency of Main Water Supply

Figure 12 show that 732 of respondents (77.1%) did not receive water at all from WCOS, while few of respondents did receive water supply. This indicates the inadequacy of water supply in the City and the need to have alternative sources to meet increasing demands. To further justify the need for alternative sources of water supply, the participants were asked "the common method of water supply in their area".

**Table 6. Respondents Local Government area cross tabulation with consistency of main water supply**

| LG.A | Respondent Consistency of Main Water Supply | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Daily | Weekly | Fort-nightly | Monthly | Quarterly | Yearly | None at all | Total |
| Egbeda | 9 | 2 | 0 | 11 | 0 | 5 | 81 | 108 |
| Ona-ara | 2 | 1 | 0 | 2 | 0 | 0 | 99 | 104 |
| Oluyole | 3 | 4 | 0 | 8 | 1 | 0 | 58 | 74 |
| Akinyele | 9 | 7 | 2 | 7 | 0 | 1 | 121 | 147 |
| Ido | 2 | 3 | 0 | 3 | 1 | 0 | 27 | 36 |
| Lagelu | 2 | 9 | 26 | 19 | 1 | 4 | 60 | 121 |
| Ibadan North | 8 | 10 | 5 | 13 | 1 | 10 | 152 | 199 |
| Ibadan South-West | 5 | 0 | 1 | 5 | 0 | 1 | 15 | 27 |
| Ibadan North-West | 2 | 6 | 1 | 1 | 0 | 1 | 39 | 50 |
| Ibadan South-East | 1 | 0 | 0 | 0 | 0 | 0 | 36 | 37 |
| Ibadan North-East | 0 | 0 | 2 | 1 | 0 | 0 | 44 | 47 |
| Total | 43 | 42 | 37 | 70 | 4 | 22 | 732 | 950 |

**Table 7. Chi-Square tests for relationship between local government areas and consistency of water supply**

| | Value | Df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 236.181[a] | 60 | <0.001 |
| Likelihood Ratio | 209.795 | 60 | <0.001 |
| Linear-by-Linear Association | 0.249 | 1 | 0.618 |
| N of Valid Cases | 950 | | |

[a]. 52 cells (67.5%) have expected count < 5. The minimum expected count is 0.11.

Table 6 represents a cross tabulation of local government areas with consistency of main water supply. Egbeda and Ibadan North residents reported the highest rate of daily water supply. Lagelu reported the highest rate of monthly water supply, while 99% of Ona-ara reported no supply at all. This might imply that variations in consistency of water supply arising occurred both within and between districts.

A chi-square test was performed to determine the degree of association between local government areas and consistency of water supply (Table 7). The result shows a strong statistically significant relationship between the two variables ($p < 0.05$).

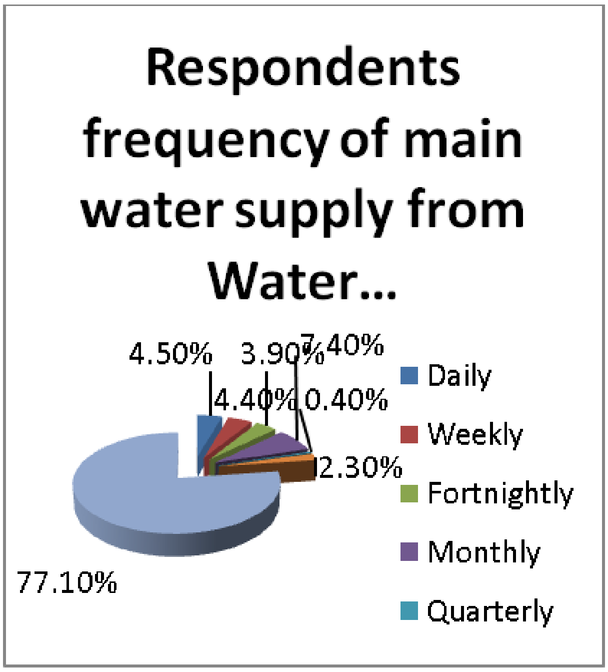


**Figure 12.** Respondents frequency ofmain water supply from WCOS

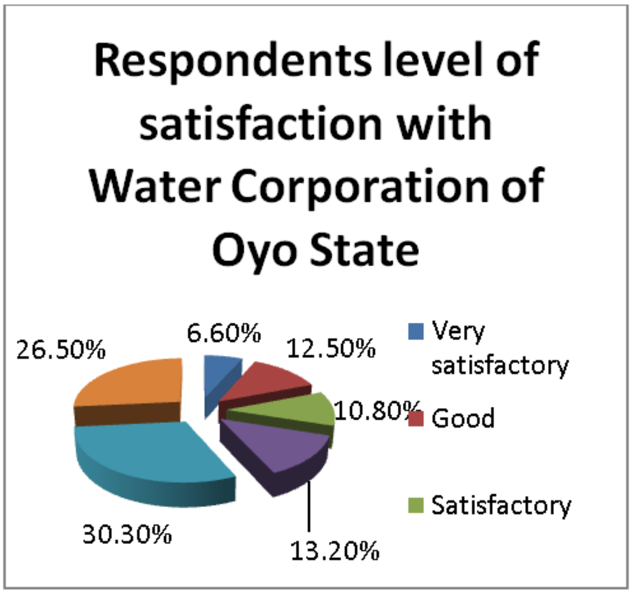


**Figure 11.** Respondents level of satisfaction with Water Corporation of Oyo State

### 4.8. Respondents Sources of Water Supply

Figure 13 shows a low proportion of respondents chose main supply confirming inadequate supply of main water supply in the study area. Few respondents chose stream/river; tank/truck vendors and rainwater. This also confirms that RWH technology is yet to be tapped as an alternative source of supply in the area. Some 579 (60.9%) of respondents depend on well water and 22.9% of respondents depend on boreholes. This indicates that 83.8% of respondents depend on ground-water as their main source of supply. This implies that a large proportion of households possibly have water supply from unhealthy and untreated sources. Figure 14 presents respondents expense on water supply.

Table 8 represents a cross tabulation of household monthly income with source of water supply. A chi-square test was performed to determine the degree of association between household income and sources of water supply

(Table 9). This result indicates a strong statistically significant relationship between the two variables (p <0.05).

**Table 8. Respondents monthly income range cross tabulation with sources of water supply**

| Respondent Monthly Income Range (Naira) | Respondent Sources of Water Supply | | | | | | |
|---|---|---|---|---|---|---|---|
| | Main supply | Well water | Stream/River | Rainwater | Tank/Truck vendors | Bore-hole | Total |
| <10,000 | 16 | 187 | 9 | 21 | 5 | 52 | 290 |
| 10,000-30,000 | 9 | 178 | 5 | 24 | 6 | 58 | 280 |
| 31,000-100,000 | 10 | 146 | 3 | 17 | 7 | 58 | 241 |
| 101,000-150,000 | 5 | 34 | 2 | 1 | 6 | 21 | 69 |
| 151,000-200,000 | 1 | 23 | 3 | 0 | 2 | 14 | 43 |
| >200,000 | 0 | 11 | 0 | 0 | 1 | 15 | 27 |
| Total | 41 | 579 | 22 | 63 | 27 | 218 | 950 |

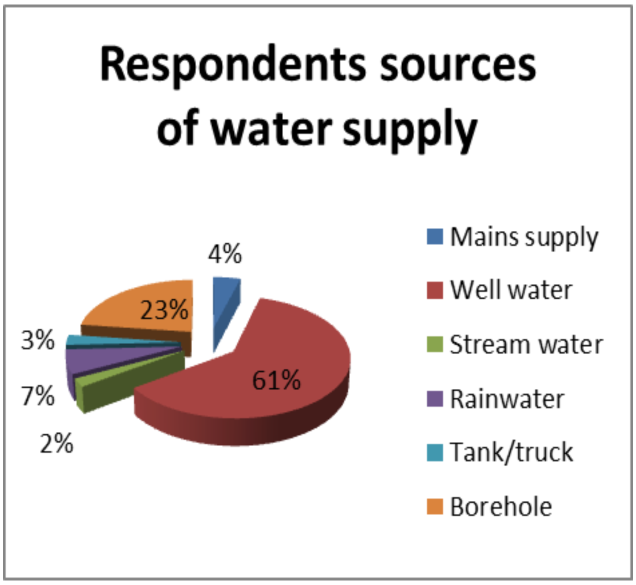


**Figure 13.** Respondents sources of water

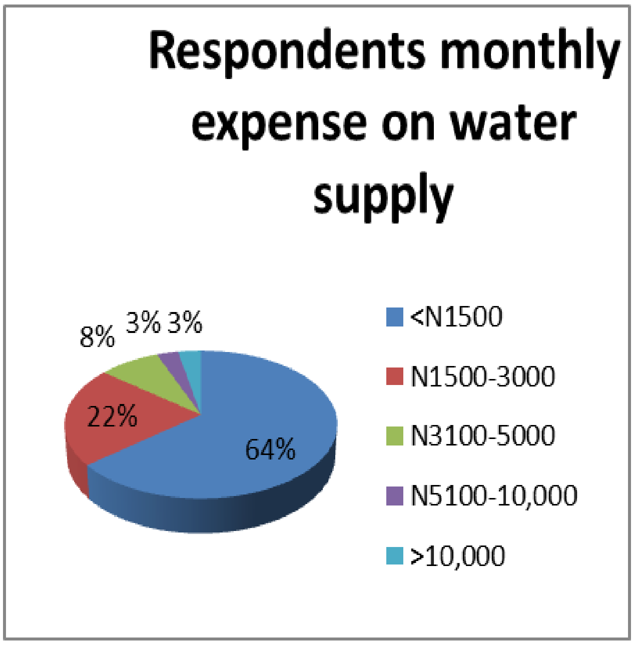


**Figure 14.** Respondents monthly expense on water supply

Table 10 represents a cross tabulation of local government areas with perception of well yield in the dry season. Several wells dried up in Ona-ara, while some wells in Oluyole and Lagelu have low yield in the dry season. This implies that the variation in the well yields occurred due to topography and geographical location of the wells

Figure 15 presents respondents perception of wells yield during the dry season.

**Table 9. Chi-Square tests results for relationship between household income and sources of water supply**

| | Value | Df | Asymp. Sig. (2-sided) (P) |
|---|---|---|---|
| Pearson Chi-Square | 56.181[a] | 25 | <0.001 |
| Likelihood Ratio | 56.266 | 25 | <0.001 |
| Linear-by-Linear Association | 20.263 | 1 | <0.001 |
| N of Valid Cases | 950 | | |

a. 12 cells (33.3%) have expected count <5. The minimum expected count is 0.637.

**Table 10. Respondents Local Government areas cross tabulation with perception of well yields in the dry season**

| Respondent Local Government Area | Respondent Perception of Well Drying up in Dry Season | | | Total |
|---|---|---|---|---|
| | Yes | No | Unsure | |
| Egbeda | 62 | 38 | 8 | 108 |
| Ona-ara | 87 | 15 | 2 | 104 |
| Oluyole | 8 | 64 | 2 | 74 |
| Akinyele | 120 | 14 | 13 | 147 |
| Ido | 20 | 8 | 8 | 36 |
| Lagelu | 48 | 65 | 8 | 121 |
| Ibadan North | 68 | 97 | 34 | 199 |
| Ibadan South-West | 13 | 7 | 7 | 27 |
| Ibadan North-West | 23 | 14 | 13 | 50 |
| Ibadan South-East | 20 | 15 | 2 | 37 |
| Ibadan North-East | 13 | 34 | 0 | 47 |
| Total | 482 | 371 | 97 | 950 |

### 4.9. Respondents Major Health Hazards Associated with Drinking Contaminated Water

Figure 16 shows a larger proportion (581), of respondents, chose prevalence of typhoid fever; some have a prevalence of diarrhoea, while few of respondents water source is free from water-borne disease. This indicates that there is a prevalence of 97.8% of water-borne disease due to the consumption of unsafe water in the study area. This is quite alarming; hence, an alternative source of potable water is urgently needed.

Table 11 represent a cross tabulation of water source with health hazard associated with drinking contaminated water. Some respondents with borehole as a source of supply have cholera and diarrhoea. Many respondents with well water as source of supply have typhoid fever, while few respondents with rainwater as source of supply have typhoid fever. A chi-square test determined the degree of association between sources of water supply and associated health hazard.

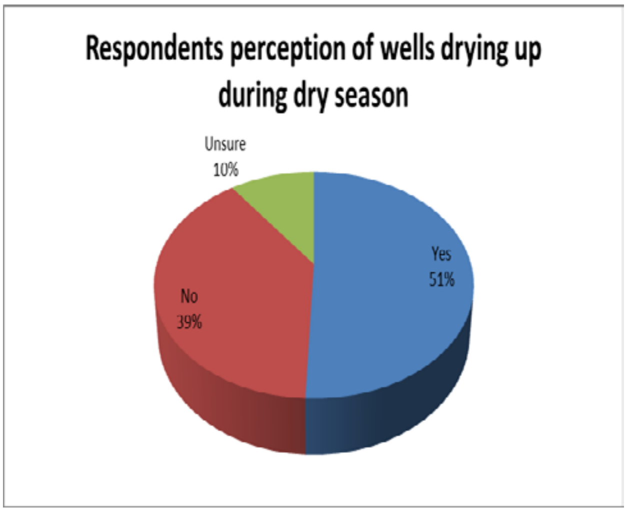


**Figure 15.** Respondents perception of well yields in dry season

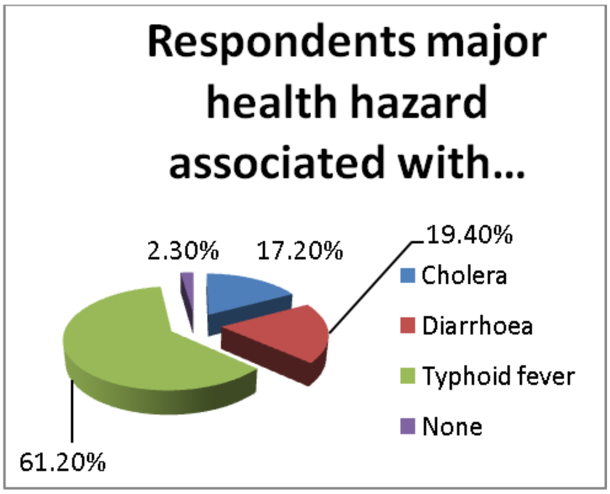


**Figure 16.** Respondents major health hazard associated with drinking contaminated water

**Table 11. Respondents sources of water supply cross tabulation with major health hazards associated with drinking contaminated water**

| Respondents Sources of Water Supply | Respondents Major Health Hazard Associated with taken Contaminated Water | | | | |
|---|---|---|---|---|---|
| | Cholera | Diarrhoea | Typhoid fever | None | Total |
| Main supply | 8 | 11 | 21 | 1 | 41 |
| Well water | 100 | 126 | 339 | 14 | 579 |
| Stream/river | 6 | 9 | 7 | 0 | 22 |
| Rainwater | 13 | 2 | 48 | 0 | 63 |
| Tank/truck vendors | 3 | 3 | 19 | 2 | 27 |
| Borehole | 33 | 33 | 147 | 5 | 218 |
| Total | 163 | 184 | 581 | 22 | 950 |

## 4.10. Respondents Cost Availability for Yearly Routine Maintenance of RWH System

Figure 17 reveals a lower proportion of respondents can afford N10,100 -N12,500 per year, while several of respondents can afford N2500-5000. Some respondents can afford N5000-7,500, while a few can afford N7600 - 10,000 per year. Ability to pay is an important factor in implementing a RWHS. The whole life cost, maintenance cost and detailed breakdown of long-term costs of systems need to be investigated to know the payback period and arrive at conclusions on cost effectiveness.

Table 12 represents a cross tabulation of households monthly income range with yearly routine maintenance cost affordability. Some respondents earning <10,000N can afford 2,500-5,000N for routine maintenance of RWHS. Some respondents in the mid-income range (31,000-100,000 N) can afford 5,100-7,500 N, while few respondents in the high income range can afford >12,500 for routine maintenance. A chi-square test was performed to determine the degree of association between respondents cost affordability for yearly routine maintenance and monthly income range. Table 13 shows a strong significant relationship between the two variables, ($p < 0.05$).

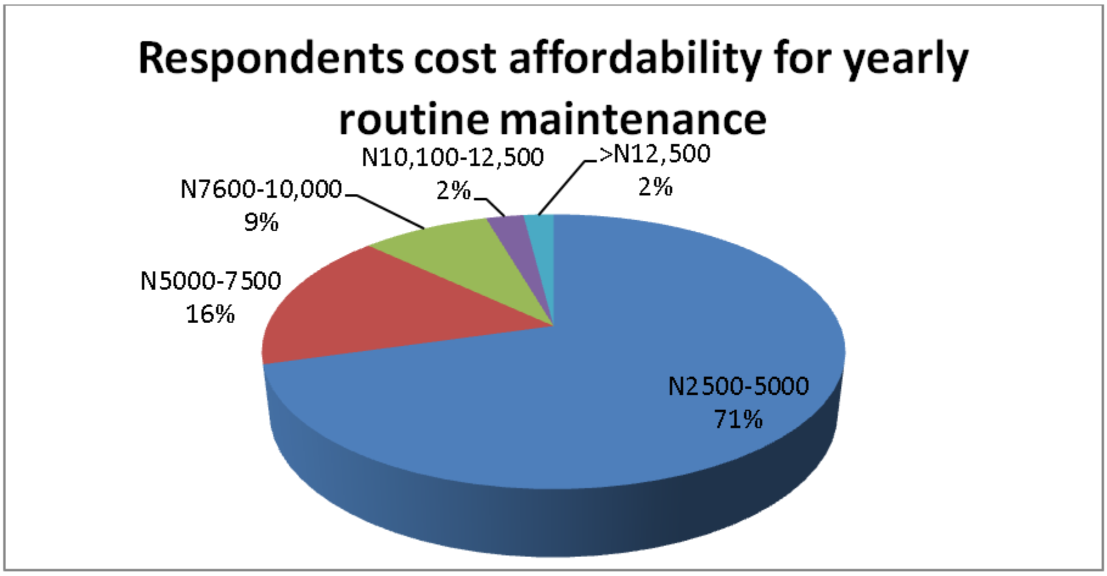


**Figure 17.** Respondents views on costs for yearly routine maintenance of RWH systems

**Table 12. Respondents cost affordability for yearly routine maintenance cross tabulation with monthly income range**

| Respondent Cost Availability (Naira) | Respondent Monthly Income Range (Naira, 000) | | | | | | |
|---|---|---|---|---|---|---|---|
| | <10 | 10-30 | 31-100 | 101-150 | 151-200 | >200 | Total |
| 2,500-5,000 | 240 | 215 | 155 | 32 | 15 | 13 | 670 |
| 5,100-7,500 | 31 | 44 | 52 | 17 | 9 | 3 | 156 |
| 7,600-10,000 | 13 | 13 | 24 | 17 | 10 | 4 | 81 |
| 10,100-12,500 | 4 | 6 | 5 | 2 | 3 | 4 | 24 |
| >12,500 | 2 | 2 | 5 | 1 | 6 | 3 | 19 |
| Total | 290 | 280 | 241 | 69 | 43 | 27 | 950 |

**Table 13. Chi-Square tests for relationship between cost affordability for yearly routine maintenance cost and monthly income range**

| | Value | Df | Asymp. Sig. (2-sided) (P) |
|---|---|---|---|
| Pearson Chi-Square | 150.567[a] | 20 | <0.001 |
| Likelihood Ratio | 113.069 | 20 | <0.001 |
| Linear-by-Linear Association | 97.317 | 1 | <0.001 |
| N of Valid cases | 950 | | |

10 cells (33.3%) have expected count <5. The minimum expected count is 0.54.

# 5. Conclusions and Future Research

A survey was conducted to investigate current water sources, catchment materials and motivation for harvesting rainwater in Nigeria. Our goal is to evaluate the potential for RWH in the study area and to determine the rate of water consumption. Questionnaires were administered at household levels. The survey had an 89% response rate, indicating the willingness of the households to share their experiences. Results of this survey indicate that corrugated iron sheet and roofing tiles are the most common roofing materials for rainwater harvesting. Some 54% of those with roofing tiles use the harvested water for drinking, while 43% of those with cement roofs use it for cooking. The result shows a strong statistically significant relationship between household perceived use of rainwater and type of roofing material. A larger proportion (61.2%) of respondents chose prevalence of typhoid fever in the study area; some have a prevalence of diarrhoea (19.4%), while few of respondents' water sources is free from water-borne diseases (2.3%). This indicates that there is a prevalence of 97.8% of water-borne diseases in the study area. The result shows a strong significant relationship between sources of water supply and associated health hazard. Over 77.1% of respondents did not receive water at all from WCOS, while few of the respondents did receive water supply. This indicates the inadequacy of water supply in the City and the need to have alternative sources to meet increasing demands. A cross tabulation of local government areas with consistency of main water supply shows Egbeda and Ibadan North residents' reported the highest rate of daily water supply. Lagelu reported the highest rate of monthly water supply, while 99% of Ona-ara reported no supply at all. This might imply that variations in consistency of water supply arising occurred both within and between districts. The result shows a strong statistically significant relationship between local government areas and consistency of water supply.

The water supply situation in Ibadan is typical scenario of other cities in Nigeria in general. However, this problem of inadequate water supply can be alleviated through RWH. This survey provides critical data about current potable and non-potable RWH practices in Nigeria and can serve as guidance for future RWH research. In particular, the inadequacy of water supply in the City should be investigated further as the demand for sustainable RWH system in Nigeria continues to grow. Further surveys of this type could be conducted with different population by using Civil engineers and Architects to investigate the techno-economic potential of rainwater harvesting. In addition, surveys of individuals in more remote areas and in the northern part of Nigeria could provide valuable information on RWH practices. It is recommended to further investigate if RWH contributes significantly to household water supply in the area understudy. Also if there is a need for policy to promote RWH in Ibadan City (or in Nigeria as a country). Incentives such as provision of RWH infrastructure at subsidized rates can go a long way in encouraging households to adopt the activity.

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