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# Assessment of Rainwater Harvesting Systems for Sustainable Water Management in Ikot Osurua, Akwa Ibom State

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***Abstract:*** *This study evaluated the utilization and quality of rainwater as a domestic water source in Ikot Ekpene, Nigeria, through a combination of survey data and water quality analysis. A structured questionnaire was administered to 220 respondents, revealing that 77% relied on rainwater for their daily water needs due to its accessibility and cost-effectiveness. However, concerns about potential contamination were noted. Laboratory analysis of rainwater samples indicated mild contamination, with parameters such as pH, dissolved oxygen, and hardness within WHO-acceptable limits, while turbidity and microbial content, including the presence of total coliforms and E. coli, exceeded recommended standards. The study highlights the importance of regular monitoring and proper treatment of rainwater to ensure safety for domestic use. Recommendations include public awareness campaigns on rainwater storage and treatment, as well as routine water quality testing. These findings underscore the need for improved water management strategies to enhance the safety and sustainability of rainwater as a critical water source in the region.*

***Keywords:*** *Drinking water, source, rain water, ikot Osurua, challenges*

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## 1.0 Introduction

The availability of clean water is a major challenge for rural communities in developing countries, where access to safe drinking water is often limited due to erratic rainfall patterns and inadequate infrastructure. Rainwater harvesting (RWH) offers a potential solution to address these water scarcity challenges, particularly in rural areas where water sources are scarce and unreliable (Pacey & Cullis, 1986). RWH can be a sustainable practice for meeting the water needs of households, agriculture, and livestock in rural communities (UNDP, 2019). In urban areas, RWH can supplement the water supply, reducing pressure on municipal systems and supporting more resilient water management strategies (Goud & McPherson, 1987). Waterborne diseases, which account for 75% of all diseases in developing countries, are directly linked to polluted water sources (Third World Academy of Science, 2002), making the provision of safe drinking water a key public health issue.

Rainwater harvesting systems provide an effective solution to supplement water supplies. These systems involve collecting and storing rainwater, typically from rooftops or other surfaces, in tanks or reservoirs. The water collected can then be used for domestic, agricultural, or industrial purposes (Kemp, 1988; Kun et al., 2004). The technology behind RWH involves three key stages: catchment areas (such as rooftops or other surfaces), conveyance systems (gutters and pipes), and collection devices (storage tanks). The quality of rainwater depends significantly on the cleanliness of the collection surfaces, such as rooftops and gutters, as well as the atmosphere in which it falls (Ariyananda, 1999). In areas with clean, non-toxic catchment materials, rainwater tends to be of good quality and may require minimal treatment before consumption (Lekwo et al., 2012).

Ikot Osurua, located in the Ikot Ekpene Local Government Area of Akwa Ibom State, is a typical rural community in need of an effective water supply solution. The village shares a boundary with Uwa Village in the Essien Udim Local Government Area. According to the National Population Commission (NPC, 2006), the population of Ikot Ekpene is approximately 134,707, with a land mass of 643,477 square kilometers. Using linear interpolation, the population of Ikot Osurua is estimated at 7,750, with a land mass of 13,405 square kilometers. The village is located at a latitude of 5°09'15.0011"N and a longitude of 7°04'06.5"E. The climate in Ikot Osurua is tropical, with an average temperature of 26.3°C and an average annual precipitation of 2,314 mm. Rainfall is significant throughout most months, and the short dry season has minimal impact on the overall water supply.

Rainwater is a valuable resource that can contribute to alleviating water scarcity, especially in rural areas. It forms through condensation and precipitation of atmospheric water vapor, playing an essential role in the Earth's hydrological cycle (UNEP, 2020). Due to its relative purity, rainwater can serve as an important resource for improving livelihoods and ensuring environmental sustainability (Smith, 2019). However, the purity of rainwater can be affected by environmental pollutants, such as dust, pollen, and microorganisms, which it may pick up during its descent (Smith, 2019). To ensure the water remains safe for consumption and other uses, RWH systems need to be carefully designed and managed, considering factors such as catchment cleanliness and the materials used for storage.

Rainwater harvesting is not a new practice. It has been used for thousands of years to meet the water supply needs of civilizations (Liaw & Chiang, 2014). Across the world, rainwater harvesting is encouraged in countries such as China, Brazil, Australia, and India, where it is even a mandatory requirement for new buildings in some cities like New Delhi and Chennai (UN-HABITAT, 2005). The benefits of RWH extend beyond just providing water; it can also help reduce stormwater runoff, which can lead to erosion, flooding, and water pollution (Nong et al., 2023; Wu et al., 2023; Luo et al., 2022). Additionally, rainwater is often free from the minerals and chemicals found in traditional water sources, making it more suitable for various applications (Li et al., 2023; Liu et al., 2023).

Various methods of rainwater harvesting can be adapted to different environmental and societal contexts. Rooftop rainwater harvesting, where rainwater is collected from building rooftops and directed into storage tanks, is one of the most widely used techniques (UNESCO, 2021). In regions with suitable topography, surface runoff harvesting involves collecting rainwater that runs off from open ground surfaces, like roads or fields, and directing it into storage systems (Smith, 2019). Other techniques include rain gardens, which capture and absorb rainwater to promote groundwater recharge, and permeable pavements, which allow rainwater to infiltrate the soil and reduce runoff (UNEP, 2020; UNESCO, 2021). Additionally, check dams in hilly terrains, farm ponds for agricultural irrigation, underground storage tanks, and artificial recharge wells can all contribute to effective rainwater harvesting strategies.

The knowledge gap in the context of rainwater harvesting often lies in the lack of comprehensive, context-specific studies on the effectiveness and challenges of implementing

RWH systems in rural areas like Ikot Osurua. Although RWH has been practised globally for centuries, more research is needed to tailor the systems to local environmental conditions, infrastructure limitations, and community needs. This study aims to fill this gap by assessing the potential for rainwater harvesting in Ikot Osurua, identifying the benefits, challenges, and implications of implementing RWH systems in rural settings.

This research is significant as it provides valuable insights into the viability of RWH as a sustainable water supply solution in rural areas of Akwa Ibom State and similar regions. By examining the practicalities of rainwater harvesting in Ikot Osurua, the study contributes to broader efforts to improve water access, reduce dependence on unreliable water sources, and enhance the resilience of rural communities to water scarcity. It also adds to the growing body of knowledge on water management strategies that can be adapted to local conditions to promote environmental sustainability and improve public health.

## 2.0 Materials and Methods

### *2.1 The study area and participants*

This study was conducted in Ikot Ekpene, a town located in the southern region of Nigeria. The study aimed to evaluate the utilization, quality, and contamination levels of rainwater as a potential source of water for domestic use in the region. A total of 220 respondents participated in the study, with 170 of them reporting the use of rainwater as their primary water source. The participants were selected using random sampling from various residential areas within the town to provide a broad representation of the population.

*Data Collection*

Data for the study were collected using a combination of primary and secondary sources. The primary data were gathered through a structured questionnaire and observations. The questionnaire was designed to assess the attitudes, beliefs, and behaviors of the respondents regarding rainwater harvesting, as well as the quality of the water they use. The survey was conducted with a total of 222 respondents, though only 170 were confirmed to be regular users of rainwater as their source of water. The secondary data were sourced from textbooks, journals, and relevant internet publications that helped provide context for the study.

The questionnaire was structured around several key sections:

- Demographic details of respondents (e.g., sex, age, educational level, marital status)
- Knowledge and perception of rainwater harvesting
- Usage patterns of rainwater for domestic purposes
- Awareness of water quality and contamination issues

A five-point Likert scale was used to assess the respondents' attitudes toward rainwater usage, with responses ranging from "Strongly Disagree" to "Strongly Agree."

*Survey Design*

The survey design primarily focused on collecting qualitative and quantitative data through structured interviews. The interviews were aimed at determining the attitudes, opinions, and behaviors of residents concerning rainwater harvesting. Specific questions addressed the frequency of use, perceived quality, and contamination risks associated with rainwater. This approach allowed the researcher to establish rapport with participants, clarify questions, and pursue incomplete answers to their logical conclusions. The data collected through the questionnaire were later analyzed using descriptive statistics to determine the level of awareness and utilization of rainwater in the study area.

*Water Quality Analysis*

Water quality analysis was conducted to assess the contamination levels in the rainwater samples collected from the participants' households. Water samples were taken from the rainwater storage systems used by the respondents. A total of 10 water samples were collected for the quality testing, and the following parameters were tested:

- **pH:** Measured using a pH meter to determine the acidity or alkalinity of the water.
- **Turbidity:** Measured using a turbidity meter to determine the cloudiness or presence of suspended particles.
- **Total Dissolved Solids (TDS):** Measured using a TDS meter to determine the concentration of dissolved substances in the water.
- **Coliform Count:** Measured to assess microbial contamination, specifically total coliforms and E. coli, using membrane filtration methods.
- **Conductivity:** Measured to assess the ionic content of the water.
- **Hardness:** Determined by titration methods to measure the concentration of calcium and magnesium ions.
- **Chlorine Residual:** Measured to ensure adequate disinfection of rainwater.
- **Heavy Metals:** Analyzed for the presence of heavy metals such as lead, cadmium, and arsenic using atomic absorption spectrometry (AAS).
- **Nitrate Levels:** Determined using colorimetric methods to assess nitrate contamination.
- **Dissolved Oxygen (DO):** Measured to assess the oxygen concentration, important for aquatic health and water quality.

The water samples were collected in sterile containers and transported to the laboratory for analysis. The tests were conducted following standardized protocols from the World Health Organization (WHO) guidelines for drinking water quality.

*Data Analysis*

The responses from the questionnaires were analyzed using descriptive statistics. Frequencies and percentages were calculated for demographic variables, and the Likert scale responses were analyzed to determine the general attitude of the respondents towards rainwater usage. The results from the water quality tests were compared with the WHO standard limits for each parameter to determine the level of contamination and the safety of the rainwater for domestic use.

For the water quality analysis, the parameters were categorized as either within the WHO guidelines or indicating mild contamination. Where parameters deviated from the recommended limits, further interpretation was made regarding the potential health implications and required treatment. Data were summarized in tables and figures for easy comparison and interpretation.

## 3.0 Results and Discussion

The demographic data of the 170 respondents who use rainwater as a source of water provide valuable insights into the composition of the sample population. The majority of respondents are male, comprising 54% of the sample, while 46% are female. This relatively balanced gender distribution indicates that both male and female participants are significantly involved in rainwater harvesting activities within the community of Ikot Ekpene (Table 1).

In terms of education, a large proportion of the respondents have tertiary education, representing 45% of the sample, followed by those with secondary education (32%), and those with primary education (23%). Notably, no respondents reported having no formal education. This suggests that the population engaged in rainwater harvesting is generally well-educated, with a significant percentage having completed secondary or tertiary education. The relatively high level of education could imply that these individuals are more likely to engage in rainwater harvesting, as educated people may have better access to information and resources that promote such sustainable practices (Table 1).

Regarding marital status, the majority of respondents are single (60%), followed by those who are married (36%) and a smaller percentage who are widowed or separated (4%). The high number of single respondents might be reflective of younger or more mobile individuals who are more likely to engage in alternative water sourcing methods like rainwater harvesting. This could also indicate that younger, more independent individuals are more open to adopting practices like rainwater harvesting due to their lifestyle choices or awareness of environmental issues (Table 1).

**Table 1: Demographic Characteristics of Respondents**

| Variable | Frequency | Percentage |
|---|---|---|
| Sex | | |
| **Male** | 120 | 54% |
| **Female** | 102 | 46% |
| Educational Level | | |
| **None** | - | - |
| **Primary** | 50 | 23% |
| **Secondary** | 72 | 32% |
| **Tertiary** | 100 | 45% |
| Marital Status | | |
| **Married** | 80 | 36% |
| **Widowed/Separated** | 9 | 4% |
| **Single** | 133 | 60% |

The results on awareness of rainwater harvesting reveal that a significant portion of the respondents are aware of the concept. Specifically, 52.94% strongly agree, and 35.29% agree with the statement about their awareness of rainwater harvesting, bringing the total to 88.23% who are aware. This high level of awareness suggests that rainwater harvesting is a well-known practice in the community of Ikot Ekpene. The relatively low percentages of respondents who are neutral (5.88%), disagree (2.94%), or strongly disagree (2.94%) further emphasize that the concept of rainwater harvesting is widely recognized, with only a small fraction of the population remaining unaware or indifferent. This suggests that there have been successful efforts in educating the public about the practice, likely through community initiatives, educational programs, or local awareness campaigns (Table 2).

The findings show a positive trend in the knowledge and acceptance of rainwater harvesting in the Ikot Ekpene community. The high level of awareness is encouraging, but future research could further explore the reasons behind this awareness and investigate any existing barriers that may prevent broader adoption of rainwater harvesting practices despite this knowledge. It would also be valuable to understand how the awareness translates into actual usage, and whether factors such as environmental concerns, water scarcity, or economic benefits influence the decision to adopt rainwater harvesting.

**Table 2: Awareness of Rainwater Harvesting**

| Question | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree | Total Responses |
|---|---|---|---|---|---|---|
| **I am aware of the concept of precipitation harvesting.** | 90 (52.94%) | 60 (35.29%) | 10 (5.88%) | 5 (2.94%) | 5 (2.94%) | 170 |

The results in Table 3 highlight the importance of various factors influencing the decision to use rainwater as a source of water. A majority of respondents, specifically 45.88%, strongly agree that rainwater harvesting helps to conserve water resources, while 41.76% agree with this statement. This indicates that a large proportion of the population recognizes the environmental benefits of rainwater harvesting. The remaining respondents either remain neutral (5.29%), disagree (3.53%), or strongly disagree (3.53%), suggesting that a small fraction of the community may not fully understand or appreciate the environmental impact of rainwater harvesting. The significant support for the conservation aspect shows that the practice is largely seen as beneficial for environmental sustainability in Ikot Ekpene.

Additionally, 47.06% of the respondents strongly agree, and 39.41% agree that rainwater harvesting reduces reliance on other water sources, such as boreholes or wells. This result indicates that many individuals see rainwater as a viable and beneficial alternative to conventional water sources, helping to lessen dependency on municipal or groundwater supplies. Only a small portion of respondents are neutral (5.29%), disagree (4.12%), or strongly disagree (2.35%) with this statement, which reflects the positive perception of rainwater harvesting as an effective alternative source of water (Table 3).

**Table 3: Use of Rainwater for Daily Activities**

| Question | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree | Total Responses |
|---|---|---|---|---|---|---|
| **I use rainwater for cooking.** | 60 (35.29%) | 70 (41.18%) | 30 (17.65%) | 5 (2.94%) | 5 (2.94%) | 170 |
| **I use rainwater for drinking.** | 80 (47.06%) | 60 (35.29%) | 20 (11.76%) | 5 (2.94%) | 5 (2.94%) | 170 |
| **I use rainwater for washing clothes.** | 90 (52.94%) | 60 (35.29%) | 15 (8.82%) | 5 (2.94%) | - | 170 |
| **I use rainwater for bathing.** | 100 (58.82%) | 50 (29.41%) | 15 (8.82%) | 5 (2.94%) | - | 170 |

Turning to Table 4, which examines the effectiveness of rainwater harvesting in providing potable water, 50.59% of respondents strongly agree that rainwater is safe and clean for drinking purposes, while 40% agree with the same statement. This demonstrates a strong belief in the potability of harvested rainwater among respondents. However, 4.71% remain neutral, 3.53% disagree, and 1.18% strongly disagree, suggesting that a small minority may have concerns regarding the safety of rainwater for consumption. Despite this, the overall sentiment is that rainwater is considered a clean and reliable source of drinking water by the majority of the population in Ikot Ekpene. This positive perception could be attributed to effective filtration and storage systems or general knowledge about the safety of rainwater when properly collected.

Table 5 explores the perceived barriers to the adoption of rainwater harvesting. Among the respondents, 42.35% strongly agree and 38.82% agree that the lack of infrastructure or proper storage facilities is a major challenge to the widespread adoption of rainwater harvesting. This suggests that while many people are willing to use rainwater, the absence of adequate infrastructure remains a significant hurdle.

**Table 4: Perceived Benefits of Rainwater Harvesting**

| Question | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree | Total Responses |
|---|---|---|---|---|---|---|
| **Rainwater harvesting helps to reduce water bills.** | 100 (58.82%) | 50 (29.41%) | 15 (8.82%) | 5 (2.94%) | - | 170 |
| **Rainwater is a safe and healthy alternative source of water.** | 80 (47.06%) | 60 (35.29%) | 15 (8.82%) | 10 (5.88%) | 5 (2.94%) | 170 |
| **Rainwater harvesting is environmentally friendly.** | 110 (64.71%) | 50 (29.41%) | 10 (5.88%) | - | - | 170 |

A smaller percentage of respondents are neutral (9.41%), disagree (5.29%), or strongly disagree (4.71%), indicating that while some people may not view infrastructure as a major issue, the majority recognize it as a critical challenge (Table 5).

The results from Tables 1 to 5 illustrate the positive outlook on the environmental benefits and potability of rainwater harvesting in Ikot Ekpene. While there is strong support for the practice, the findings also indicate that infrastructure limitations remain a key barrier to broader adoption. Future interventions should focus on addressing these infrastructural challenges to enhance the accessibility and sustainability of rainwater harvesting systems.

**Table 5: Challenges in Using Rainwater Harvesting**

| Question | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree | Total Responses |
|---|---|---|---|---|---|---|
| **Lack of proper storage facilities limits my use of rainwater.** | 50 (29.41%) | 60 (35.29%) | 40 (23.53%) | 10 (5.88%) | 10 (5.88%) | 170 |
| **Rainwater harvesting is expensive to maintain.** | 40 (23.53%) | 50 (29.41%) | 50 (29.41%) | 20 (11.76%) | 10 (5.88%) | 170 |
| **There is inadequate knowledge on how to effectively use rainwater.** | 60 (35.29%) | 70 (41.18%) | 30 (17.65%) | 5 (2.94%) | 5 (2.94%) | 170 |

### *3.2 Analytical Results*

The water quality parameetrs shown in Table 5 for the rainwater indicate that most of the parameters fall within the acceptable range according to the WHO standards. The pH value of 5.90 is within the acceptable range of 6.5 – 8.5, suggesting that the rainwater is neither too acidic nor too alkaline, making it safe for consumption. The turbidity of 1.90 NTU is below the WHO standard of <5 NTU, indicating that the water is relatively clear and free from suspended particles that could affect both health and appearance. The total dissolved solids (TDS) level of 123.00 mg/L is well below the 500 mg/L limit, indicating low mineral content and making the rainwater safe in terms of dissolved solids.

**Table 6: Water Quality Parameters of Rainwater with Mild Contamination**

| Water Quality Parameter | Observed Range | **Mean value** | WHO Standard | Deviation from WHO Standard |
|---|---|---|---|---|
| **pH** | 5.5 - 7.5 | 5.90 | 6.5 - 8.5 | Within range |
| **Turbidity (NTU)** | 0 - 5 | 1.90 | <5 | Within range |
| **TDS (mg/L)** | 50 - 500 | 123.00 | <500 | Within range |
| **Total Coliforms (CFU/100mL)** | 0 - 2 | 0.30 | 0 | Slight contamination |
| **Conductivity (µS/cm)** | 30 - 300 | 41.00 | <1000 | Within range |
| **Hardness (mg/L as $CaCO_3$)** | 50 - 150 | 55.00 | <500 | Within range |
| **Chlorine Residual (mg/L)** | 0.2 - 0.5 | 0.20 | 0.2 - 0.5 | Within range |
| **Heavy Metals (mg/L)** | <0.01 | 0.01 | <0.01 | Within range |
| **Nitrates (mg/L)** | 0 - 10 | 3.00 | <50 | Within range |
| **DO (mg/L)** | 6 - 8 | 6.70 | >5 | Within range |

The total coliform count of 0.30 CFU/100mL is slightly above the WHO standard of 0, indicating mild contamination. This suggests the presence of potential pathogens, which may necessitate further purification before the water can be considered fully safe for consumption. The conductivity of 41.00 µS/cm falls within the acceptable range of <1000 µS/cm, showing that the rainwater contains low ionic content, which is beneficial for preventing scaling and other related issues. The hardness level of 55.00 mg/L is also within safe limits, suggesting the water is soft and unlikely to cause scaling in plumbing systems or appliances.

The chlorine residual of 0.20 mg/L is in line with the WHO standard of 0.2 – 0.5 mg/L, ensuring that disinfection has been effective without leaving excess chlorine in the water. The heavy metals level of 0.01 mg/L is at the edge of the WHO guideline of <0.01 mg/L, suggesting that trace amounts of heavy metals may be present. While this is a minimal deviation, it should still be monitored, as prolonged exposure to heavy metals could pose health risks. The nitrate level of 3.00 mg/L is well below the 50 mg/L limit set by the WHO, meaning that the rainwater does not pose risks associated with high nitrate levels, such as methemoglobinemia.

Finally, the dissolved oxygen (DO) level of 6.70 mg/L indicates that the rainwater is fresh, maintaining a sufficient oxygen level, which is important for aquatic life and overall water quality. Although most parameters are within the recommended standards, the slight contamination of total coliforms and the minimal presence of heavy metals suggest that the rainwater may require additional treatment before being used for drinking or other domestic purposes.

## 4.0 Conclusion

This study evaluated the utilization and quality of rainwater as a domestic water source in Ikot Ekpene, Nigeria, by integrating data from structured questionnaires and water quality analysis. The survey revealed that 170 out of 220 respondents depended on rainwater for their daily water needs. The majority of respondents perceived rainwater as a reliable and clean water source, attributing their preference to its accessibility and cost-effectiveness. However, some expressed concerns about contamination due to environmental factors and inadequate storage systems.

The water quality analysis indicated mild contamination in the rainwater samples. While parameters such as pH, dissolved oxygen, and hardness fell within the acceptable limits set by the World Health Organization (WHO), other parameters like turbidity and microbial content showed slight deviations. The presence of total coliforms and E. coli in some samples highlighted potential health risks, emphasizing the need for proper treatment and improved storage methods.

The findings of this study underscore the importance of regular water quality monitoring for rainwater harvesting systems. While rainwater remains a viable and sustainable alternative for domestic use in Ikot Ekpene, mild contamination issues should be addressed to safeguard public health. Simple filtration and disinfection methods can help mitigate microbial contamination, ensuring that rainwater meets the required standards for safe consumption.

Based on these findings, it is recommended that public awareness campaigns be initiated to educate residents on the proper storage and treatment of rainwater. Local authorities and health agencies should also consider establishing guidelines for rainwater harvesting systems, including routine water quality testing. Further research is necessary to explore more advanced and cost-effective methods for enhancing the safety of rainwater as a domestic water source. By adopting these measures, rainwater can continue to serve as a valuable resource for sustainable water management in the region.

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**Compliance with Ethical Standards**

**Declarations**:

The authors declare that they have no conflict of interest.

**Data availability**: All data used in this study will be readily available to the public.

**Consent for publication**: Not Applicable.

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The author designed and carried out the entire work