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ASSESSING THE PHYSICOCHEMICAL QUALITY AND HEAVY METAL CONTAMINATION OF RAINWATER HARVESTED AND STORED IN CONCRETE RESERVOIRS: A CASE STUDY OF ISUOCHI COMMUNITY, ABIA STATE, NIGERIA.

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Abstract
Isuochi, despite its population, suffers from a persistent lack of access to potable water provided by governmental sources. This long-standing issue remains unresolved, forcing the community to rely primarily on a limited number of boreholes and harvested rainwater. The availability of rainwater is seasonal, and geological constraints impede borehole access in some areas due to the region's topography. Furthermore, visual inspection suggests widespread contamination of rainwater harvesting systems, stemming from roofing materials and storage reservoirs. The consumption of untreated rainwater poses a potential public health risk. This study investigates the presence and concentration of key water quality parameters and heavy metals in stored rainwater samples collected from various locations within Isuochi. Results indicate that some parameters exceed World Health Organization (WHO) standards in certain communities, while others demonstrate acceptable levels.
Keywords; Harvested rainwater, Physicochemical parameters, Heavy metals.

Introduction

Access to potable water remains a significant challenge for numerous communities worldwide, including the Isuochi community in Abia State, Nigeria. Despite its population, Isuochi has historically faced limitations in accessing consistent government-provided sources of safe drinking water. Consequently, a substantial majority (approximately 99%) of the community relies on rainwater harvesting and borehole water as primary sources. However, geological variations across Isuochi restrict borehole accessibility in certain areas, increasing the dependence on rainwater harvesting systems.

Globally, the scarcity of safe drinking water is a pervasive issue. Studies by UNESCO (2003), WHO (2005), and Hughes and Koplan (2005) have indicated that approximately 1.2 billion individuals lack access to safe drinking water, while 2.6 billion lack adequate sanitation. Furthermore, approximately 50% of the population in developing countries experiences limited access to a reliable and safe water supply. Human activities, such as the improper disposal of wastewater and chemical effluents into water bodies, contribute to the degradation of these already limited resources.

The World Health Organization (WHO) has expressed increasing concern regarding the quality of drinking water due to heightened awareness regarding environmental pollution and the increased incidence of waterborne disease outbreaks (Anada & Harding, 2000). The availability of high-quality water is crucial for disease prevention and improving overall quality of life (Diririfo et al., 2010). In many rural and developing regions, rainwater harvesting is considered a vital source of both potable and non-potable water.

In the context of industrialization, population growth, and climate change, the demand for potable water has placed a strain on existing resources. Rainwater harvesting, involving the direct or indirect collection of rainwater via catchment systems for storage and subsequent use, has emerged as a crucial strategy. Typical rainwater harvesting systems involve the collection of precipitation from rooftops using materials such as galvanized iron, PVC pipes, or zinc sheeting (Mose et al., 2016). The collected water is then channeled into storage reservoirs, often constructed from concrete or blocks and cement.

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However, harvested rainwater is not inherently safe for consumption. As rainwater flows from the clouds to the collection surface, it can accumulate contaminants from the harvesting materials, particularly if these materials are degraded (Ubuoh et al., 2012). The quality of water collected in rainwater harvesting systems is influenced by factors such as the type of catchment surface and roofing material, proximity to vehicular traffic, and the presence of debris, dirt, and fecal matter from birds or rodents on the roof and catchment system (Achadu et al., 2013). The presence of these contaminants can pose health risks to consumers of the harvested water (Sule et al., 2011).

Water scarcity remains a significant challenge in both rural and urban areas of Nigeria, with approximately 52% of the population lacking access to improved drinking water supplies (Lekwot et al., 2012; Orebiyi et al., 2010). The Third World Academy of Sciences (TWAS, 2002) reported that 75% of all diseases in developing countries originate from polluted drinking water. Consequently, approximately 25,000 people die daily due to the consumption of contaminated water, and many more suffer from water-related illnesses (Mason, 1996). Furthermore, water production facilities in Nigeria often operate below capacity due to equipment failures and shortages of power or fuel for pumping (World Bank, 2016). Statistics regarding water access in Nigeria vary due to differing definitions, indicators, and methodologies used by various agencies, and limited monitoring within the sector (Laah, 2012).

This study aims to provide a comprehensive assessment of the physicochemical properties and heavy metal concentrations in harvested rainwater collected in concrete reservoirs within the Isuochi community. The results of this investigation will contribute to a better understanding of the quality of rainwater as a drinking water source in the region and will inform strategies to mitigate potential health risks.

Methodology

Description of the Study Area

The study area was Isuochi in Abia State, Nigeria. Isuochi is a rural community in Umunneochi Local Government Area (LGA) of Abia State Nigeria. It is made up of Umuelem, Ndiawa, Achara, Ihie, Lomara, Mbala, Amuda, Ngodo and Umuaku communities. It is situated in northern part of Umunneochi LGA, approximately 55 km north of Umuahia, the State capital. The population of Ngodo-Isuochi is estimated to be about 60,000 people, projecting from 1999 at 2.4% Abia State growth rate. The study area has no municipal or centralized government-enable drinking water supply system. Thus, households obtain their drinking water through self-help efforts and a few isolated interventions by government agencies, politicians and other concerned stakeholders. The study area receives about 1876 mm of rain annually with average ambient temperature of about 27^0C. Roof rainwater harvesting is a popular practice for potable water in the study area. Isuochi has a lot of immigrant traders, farmers and workers.



Isuochi has two climate seasons in a year divided between the rainy and dry season with the highest temperature of 30^0 C usually been around December and March and the lowest temperature recorded around

June to July. The topography of Isuochi is a mixture of predominantly savannah and a mixture of forests. Isuochi falls within the deciduous forest region the vegetation is predominantly grassland, not essentially savannah with forest in some places; this caused due to the porosity of the soil in the area

Materials and Methods

Sample Collection

Harvested rainwater samples were collected in January 2025 from concrete reservoirs located in six villages within the Isuochi region of Abia State, Nigeria. Prior to sample collection, polyethylene bottles were rigorously rinsed twice *in situ* with the rainwater to be sampled and allowed to air dry to minimize potential contamination. Samples were obtained directly from the reservoir outflow. Immediately following collection, samples intended for metal analysis were acidified to 1% with trace metal grade nitric acid (HNO_3) to prevent metal precipitation and adsorption onto the container walls. A total volume of 500 mL was collected in pre-cleaned, double-capped polyethylene bottles. Samples were then transported to the laboratory and stored at 6°C to minimize changes in physicochemical characteristics until analysis. The duration of storage prior to analysis was kept as short as possible to ensure accurate representation of water quality at the time of sampling. The reservoir tanks from which water was sampled were constructed from cast concrete.

Physicochemical Parameter Determination

Laboratory analysis was performed to determine the following physicochemical parameters in the harvested rainwater samples: pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, total hardness, acidity, and dissolved oxygen (DO).

- **pH:** pH was measured using a portable Jenway model 3540 pH meter, calibrated according to the manufacturer's instructions using appropriate buffer solutions.
- **Electrical Conductivity and Total Dissolved Solids:** EC and TDS were determined using a combined conductivity/TDS meter, calibrated with appropriate standard solutions.
- **Turbidity:** Turbidity was measured using a nephelometer, calibrated with formazin standards.
- **Total Hardness and Acidity:** Total hardness and acidity were determined using standard titrimetric methods as described in APHA Standard Methods.
- **Dissolved Oxygen:** DO was measured using an Extech DO210 dissolved oxygen meter, calibrated according to manufacturer's instructions using the Winkler Titration Method.

Results and Discussions

Table 1: Physicochemical parameters of harvested rainwater samples collected from six communities in Isuochi.

Parameters	Study Communities					
	Ngodo	**Umuaku**	**Amuda**	**Ndiawa**	**Mbala**	**Umuelem**
pH	6.15	6.09	5.78	5.72	5.62	5.75
Electric Conductivity (µs/cm)	32.3	30	26	33	20	32
Total Dissolve Solid (mg/l)	18.24	14.32	10.22	13.65	11.24	15.33
Acidity (mg/l)	57	52	40	49	60	62
Hardness (mg/l)	39	36	40	38	35	36
Turbidity (NTU)	3.4	3.2	2.7	3.6	2.9	2.8
Dissolved Oxygen (mg/l)	9.5	11.0	12.1	10.2	8.3	10.3

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From the result in table 1, the physicochemical analysis of the harvested rainwater from the six communities in Isuochi is discussed below.

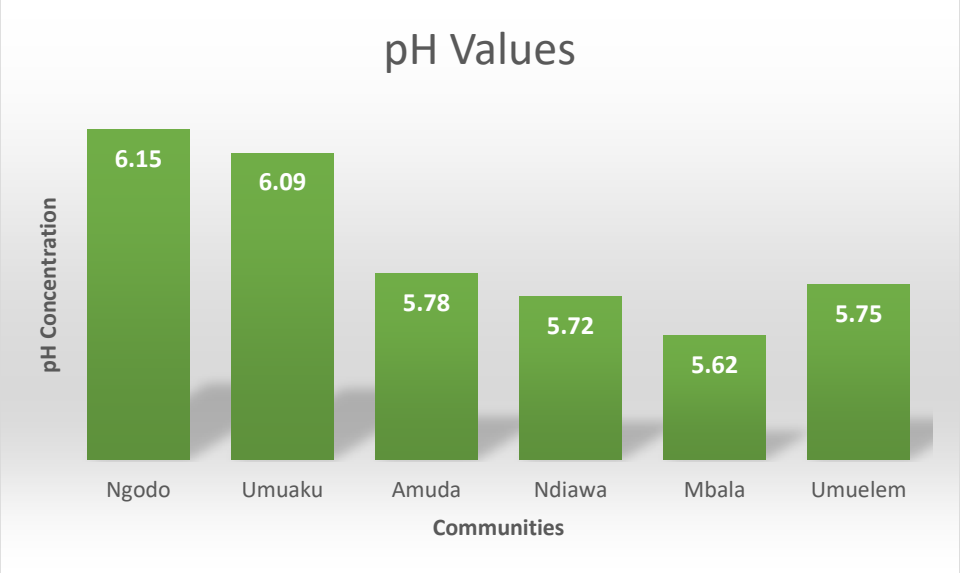


Figure 1: pH concentration level in the harvested rainwater.

The pH of harvested rainwater samples, as depicted in Figure 1, ranged from 5.72 to 6.15, with a mean value of 5.85. The highest pH was recorded in the reservoir tank at Ngodo, while the lowest pH was observed in the Ndiawa reservoir tank. These pH values indicate that the harvested rainwater is slightly acidic, falling below the World Health Organization's (WHO) recommended guideline range of 6.5 to 8.5 for drinking water quality (WHO, 2005).

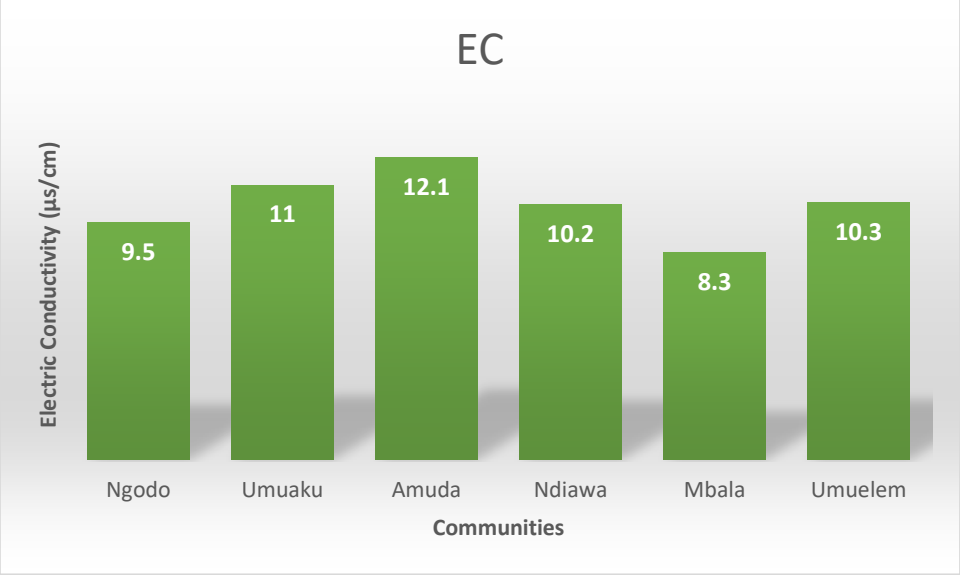


Figure 2: Electrical Conductivity concentration level in the harvested rainwater.

Electrical conductivity measurements of harvested rainwater samples (Figure 2) exhibited consistently low values, ranging from 20 to 33 µS/cm, with a mean value of 28.88 µS/cm. These conductivity levels were significantly below the World Health Organization (WHO) guideline value of 900 µS/cm for potable water.

ISSN: 2992-3727 Published 25th May, 2025

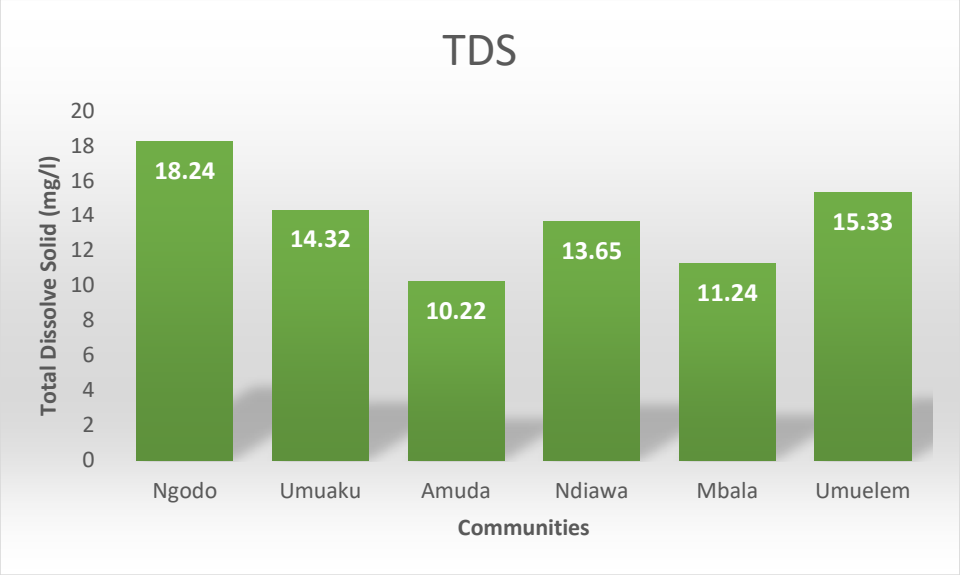


Figure 3: Total Dissolved Solid concentration level in the harvested rainwater

Analysis of rainwater samples (Figure 3) revealed Total Dissolved Solids (TDS) concentrations ranging from 10.22 to 18.24 mg/L, with a mean value of 13.83 mg/L. These values are significantly below the World Health Organization (WHO) recommended limit of 600 mg/L for potable water (WHO, 2017), suggesting that the harvested rainwater meets the TDS criteria for acceptable water quality. The low TDS levels observed may be attributable to the storage of rainwater, as dissolved solids can precipitate out of solution over time and accumulate as sediment within the storage reservoir (Ademoroti, 1996). This precipitation process effectively reduces the concentration of dissolved solids in the water column.

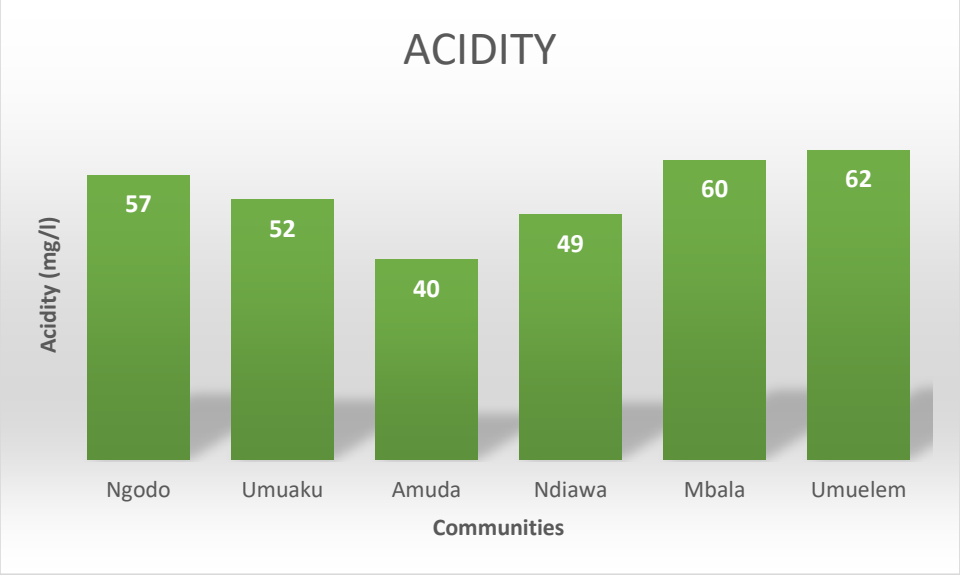


Figure 4: Acidity concentration level in the harvested rainwater

Figure 4 illustrates the acidity levels measured in harvested rainwater samples. The titratable acidity, expressed as mg/L $CaCO_3$, ranged from 40 mg/L to 62 mg/L. These observed acidity levels are below the World Health Organization (WHO) maximum contaminant level (MCL) guidelines for drinking water. This relatively low acidity suggests a reduced potential for corrosive effects on plumbing and storage materials.

ISSN: 2992-3727 Published 25th May, 2025

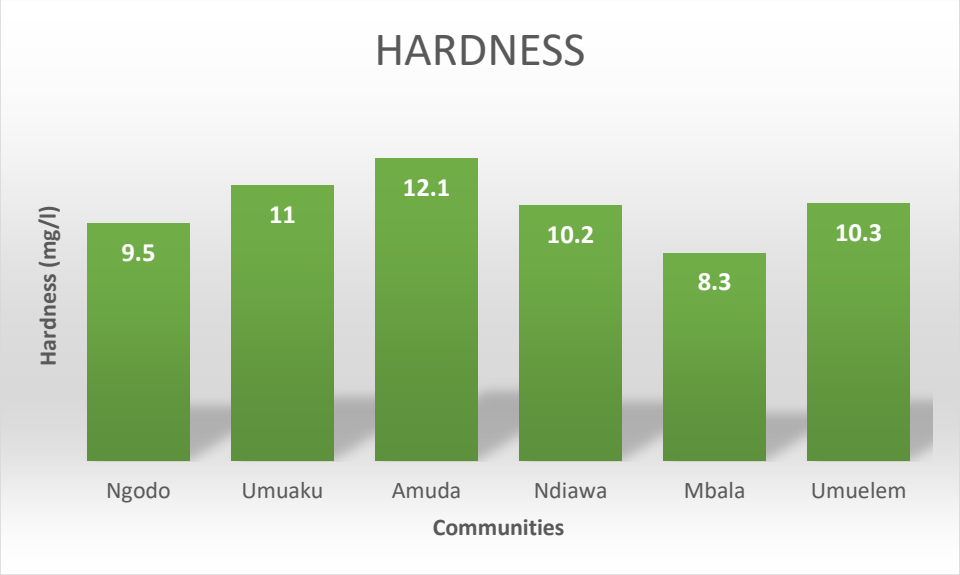


Figure 5: Hardness concentration in the harvested rainwater

Figure 5 illustrates the hardness characteristics of the harvested rainwater, which is primarily attributable to the presence of dissolved minerals generally considered innocuous to human health. Water hardness is frequently quantified as calcium carbonate ($CaCO_3$) concentration, given that calcium and carbonate ions are typically the dominant dissolved species contributing to this parameter. According to the World Health Organization (WHO), the recommended limit for hardness in drinking water is 500 mg/L as $CaCO_3$ (WHO, 2005). In the present study area, the measured hardness of harvested rainwater ranged from 35 mg/L to 40 mg/L, with a mean value of 37.33 mg/L. These values are significantly lower than the WHO-recommended limit, indicating soft water conditions.

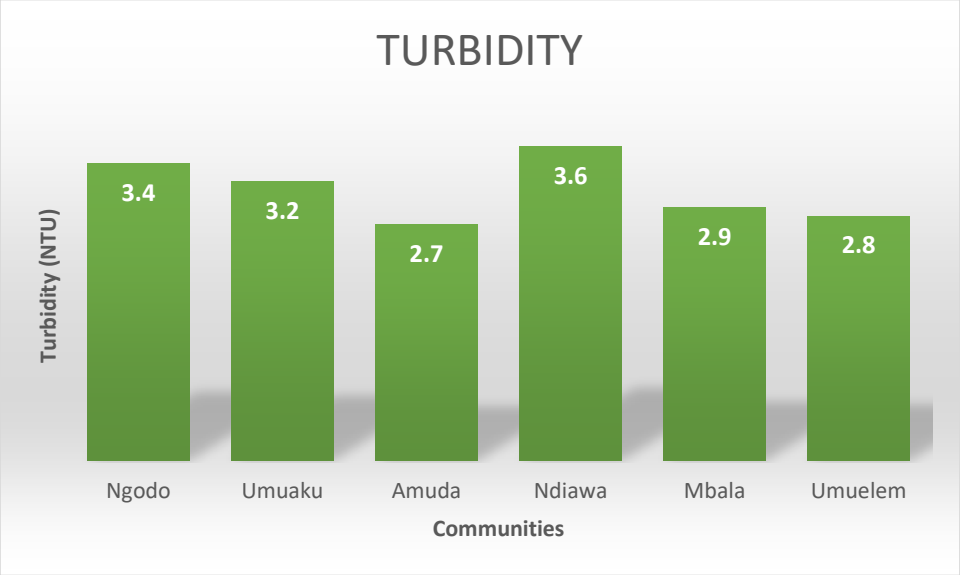


Figure 6: Turbidity concentration level in the harvested rainwater

The turbidity measurements, as presented in Figure 6, exhibited a range of 2.7 to 3.6 NTU. These values were consistently below the World Health Organization (WHO) guideline limit of 5 NTU for drinking water quality (WHO, 2017). Elevated turbidity is indicative of increased particulate matter concentration, which, in the context of this study area, may be attributed to atmospheric activities associated with mining and quarrying operations (Mose et al., 2016).

ISSN: 2992-3727 Published 25th May, 2025

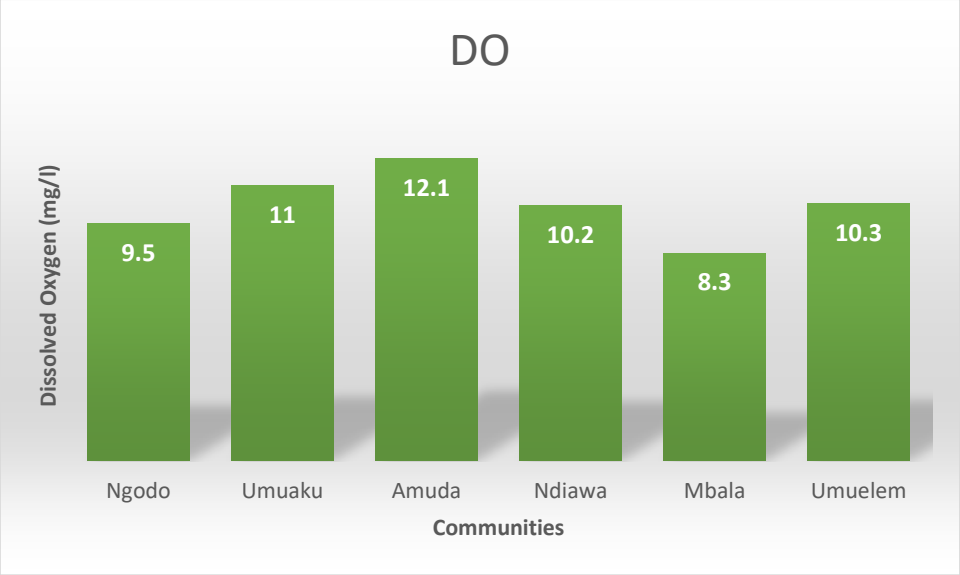


Figure 7: Dissolved Oxygen concentration level in the harvested rainwater

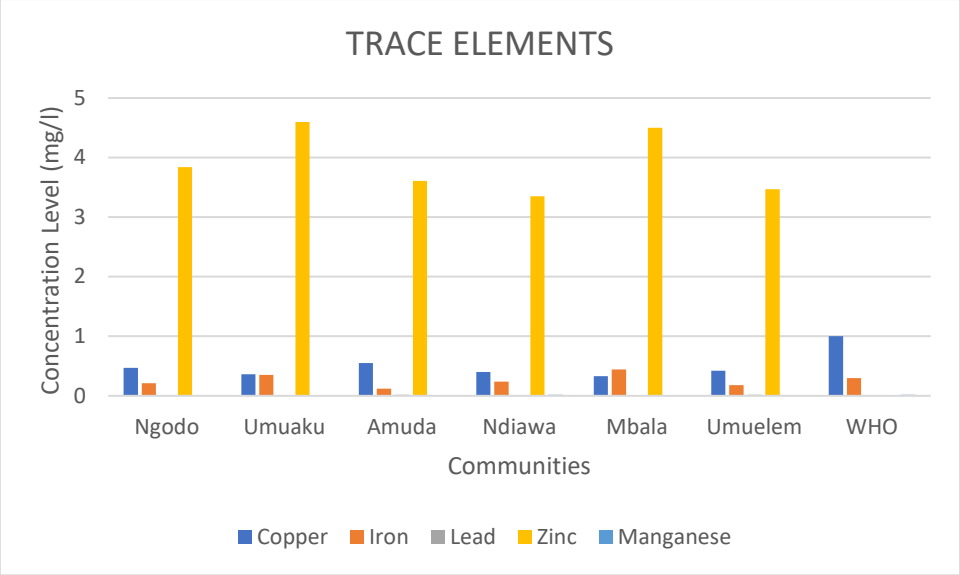
Figure 7 illustrates the dissolved oxygen (DO) concentrations measured in harvested rainwater samples. DO levels ranged from 8.3 to 12.1 mg/L, notably exceeding the World Health Organization (WHO) guideline limit of 1-4 mg/L for drinking water (WHO, 2011). This elevated DO concentration may be indicative of increased microbial activity within the rainwater storage reservoir (Gotkowska-Rodzewicz, M et al, 2013). While DO contributes to the palatability of water, these results suggest that treatment of the harvested rainwater is necessary to ensure its suitability for consumption or other uses. Dissolved oxygen is a critical physicochemical parameter for assessing water quality, influencing aquatic life and biogeochemical processes (Chapman D, 1996).

Table 2: Results of heavy metals.

Parameters	**Communities**						
	Ngodo	**Umuaku**	**Amuda**	**Ndiawa**	**Mbala**	**Umuelem**	**WHO Limits**
Copper	0.47	0.36	0.55	0.40	0.33	0.42	1
Iron	0.21	0.35	0.12	0.24	0.44	0.18	0.3
Lead	0.004	0.01	0.02	0.007	0.01	0.02	0.01
Zinc	3.84	4.6	3.61	3.35	4.50	3.47	3.0-5.0
Manganese	0.01	0.008	0.005	0.017	0.011	0.002	0.02

Trace metal analysis of harvested rainwater samples revealed a mean iron (Fe) concentration of 0.27 mg/L, with values ranging from 0.12 to 0.44 mg/L. Notably, elevated Fe concentrations were observed in Mbala (0.44 mg/L) and Umuaku (0.35 mg/L), exceeding the World Health Organization (WHO) permissible limit of 0.3 mg/L for drinking water (WHO, 2017). The elevated Fe levels in these communities may be attributed to corrosion of steel roofing materials or deterioration of steel water collection infrastructure, which was observed to be in poor condition in many locations. All other sampled communities exhibited Fe concentrations below the WHO limit.

ISSN: 2992-3727 Published 25th May, 2025



Copper (Cu) and zinc (Zn) concentrations in the harvested rainwater samples were within the WHO recommended limits of 1 mg/L and 3.0-5.0 mg/L, respectively (WHO, 2017). The mean Cu concentration across the study area was 0.42 mg/L, while the mean Zn concentration was 3.89 mg/L. Lead (Pb) was detected in trace amounts, with a mean concentration of 0.01 mg/L. The highest Pb concentrations (0.02 mg/L) were recorded in Amuda and Umuelem, potentially resulting from the use of lead-containing plumbing fittings in rainwater harvesting systems (Fewtrell & Kay, 2015). Pb concentrations in rainwater samples from Umuaku and Mbala were within WHO limits, while Ngodo and Ndiawa were below the WHO limit. Manganese (Mn) concentrations were low across all sampled areas.

Conclusion and Recommendations

The work investigates the quality of harvested rainwater stored in a concrete made reservoir within a period of three months of harvest. Physicochemical and trace of metals was analyzed, and some of these parameters were above world health organization limit while some are within and below WHO standard. From the result of the analysis, it should be a matter of interest to researchers to checkmate the remote course identified and equally provide a lasting solution to avoid health risk to the communities. The government on their part should also provide a good quality drinking water that will sustain the communities since ninety – nine percent of these communities depends on harvested rain water and borehole water.

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