**EFFECT OF RUSTED ROOFING SHEETS ON THE QUALITY OF HARVESTED RAINWATER IN JALINGO METROPOLIS**

**Abstract**

*This study examines the impact of rusted roofing sheets on the quality of harvested rainwater, addressing its chemical composition, microbial contamination, and potential health risks. Rainwater harvesting is a crucial water source in many regions, but contamination from rusted metal roofs can compromise its safety. Provides an introduction to the research, highlighting the problem statement and the significance of understanding how rust affects rainwater quality. The study aims to analyze chemical leaching from rusted roofs, assess microbial contamination, and compare water from rusted and non-rusted surfaces. Presents a literature review on rainwater harvesting, discussing various roofing materials and their influence on water quality. It highlights key studies on the effects of iron, lead, and microbial contaminants leaching from corroded metal sheets, and regulatory standards by WHO and NSDWQ. Outlines the research methodology. Water samples were collected from Jalingo, Nigeria, focusing on free-fall rainwater and water in contact with rusted roofs. Various analytical techniques were used, including pH measurement, turbidity assessment, heavy metal spectrophotometry, and microbial culture analysis. Details the results and discussion. Findings indicate elevated levels of iron and lead in roof-contacted rainwater, exceeding WHO and NSDWQ standards. Microbial contamination was significantly higher in water collected from rusted roofing sheets, raising concerns about public health risks. So, therefore, rusted roofing sheets negatively affect rainwater quality, emphasizing the need for proper filtration and treatment before consumption. Recommendations include using corrosion-resistant roofing materials, regular roof maintenance, and public awareness programs to mitigate health hazards.*

***Keywords****: Rainwater Harvesting, Rusted Roofing Sheets, Water Quality, Heavy Metal Contamination, Microbial Analysis.*

**1.0 Introduction**

Rainwater harvesting is an ancient practice that involves collecting and storing rainwater for future use [5]. This sustainable method of water collection is crucial in areas facing water scarcity, providing an alternative source of water that can be used for various purposes, including drinking, irrigation, and household activities [10]. The importance of rainwater harvesting lies in its numerous benefits, which include water conservation [7]. It helps reduce the demand on conventional water supply systems, conserving groundwater and surface water [4], cost-effectiveness: Rainwater harvesting can reduce water bills and the need for expensive water infrastructure, flood control [1]: Minimizes runoff and reduces the risk of floods by capturing rainwater, environmental benefits [6]: Lessens soil erosion and the impact on rivers and streams by reducing runoff [3], water quality: Provides a relatively clean source of water, particularly in areas with limited access to potable [8].

However, the introduction of rust and associated contaminants from rusted roofing materials can create an environment that is conducive to the growth and proliferation of microorganisms, including potential pathogens [9]. This can pose significant health risks if the collected rainwater is used for drinking, cooking, or other domestic purposes without proper treatment [2]. Studies have shown that rusty roofing sheets can increase the concentration of dissolved iron and manganese in rainwater, exceeding recommended limits for drinking water quality [11]. Furthermore, the presence of zinc and lead, leached from rusted surfaces, poses additional health risks if consumed regularly over time [12]. Apart from chemical contaminants, rusted roofing sheets can harbor microbial growth, including bacteria and fungi, which thrive in moist and oxidizing environments [14]. These microorganisms can further degrade water quality, potentially leading to gastrointestinal illnesses and other health concerns among consumers relying on harvested rainwater for drinking and cooking [15].

Therefore, it is crucial to consider the potential risks associated with rainwater harvesting from rusted roofing materials and implement appropriate treatment methods to ensure the safety and quality of the collected rainwater before its use for domestic purposes [13]

**2.0 Materials and Methods**

**2.1 Study Area**

The research was conducted in Kasuwan Bera ATC Jalingo, the capital of Taraba State, Nigeria, located between latitude 8°53'N and longitude 11°22'E. Jalingo experiences a tropical climate, characterized by high rainfall between May and October, making rainwater harvesting a common practice in the area. The reliance on rainwater, particularly during the rainy season, underscores the importance of assessing its quality for domestic and drinking purposes. The TAWASCO Central Laboratory served as the primary facility for testing.



Fig 1: Map of Taraba State showing Jalingo metropolis

**2.2 Sample Collection**

A total of six (6) water samples were collected and analyzed.

No contact with roof rainwater: Collected directly into (3) different sterile containers without contacting any surface. Roof-contact rainwater: Collected after passing over rusted roofing sheets into (3) different sterile containers [16]. The catchment area (roof surface) was clean prior to a significant rain event to remove loose debris and dust. The first flush diverter was ensured to be functioning properly to discard the initial runoff, which typically contains higher levels of contaminants.

**2.3 Control Samples**

**2.3.1 No-rusted Roofing Materials**

Rainwater was collected from systems with non-rusted roofing materials to serve as control samples. This helped in comparing the levels of contamination from rusted and non-rusted roofs.

**2.3.2 Environmental Controls**

Rainwater was collected directly from the atmosphere using clean, open containers placed away from any potential sources of contamination to provide baseline data on atmospheric deposition.

**2.4 Physical Tests**

**2.4.1 pH Measurement**

The pH, which indicates the acidity or alkalinity of water, was measured using a digitalpH meter (Hanna Instruments HI 98129). A pH range between 6.5 to 8.5 is considered acceptable according to the Nigerian Standard for Drinking Water Quality (NSDWQ).

**2.4.2 Turbidity**

Turbidity, indicating the clarity of water, was determined using a nephelometric turbidity meter (Hach 2100N).

**2.4.3 Temperature**

Temperature was recorded using a digitalthermometer at the point of collection to assess its influence on chemical and biological parameters

**2.5 Chemical Tests**

**2.5.1 Total Dissolved Solids (TDS)**

TDS, which reflects the concentration of dissolved inorganic and organic substances, was measured using an electrometric method with a TDS meter.

**2.5.2 Electrical Conductivity (EC)**

EC was measured to assess the water's ionic content using a conductivity meter. The acceptable limit is 1,000 µS/cm.

**2.5.3 Iron and Zinc**

Iron content was measured using the Ferro Ver method, while zinc was quantified using the Zincon method. Both were analyzed using a UV-Vis spectrophotometer (Hach DR 6000).

**2.5.4 Lead**

Lead was analyzed using the PAR (4-(2-pyridylazo) resorcinol) spectrophotometric method due to its toxicity.

**2.5.5 Potassium, Magnesium, Calcium, Sodium**

These metals were quantified using Atomic Absorption Spectrophotometry(AAS). Their permissible levels were compared to NSDWQ standards.

**2.5.6 Color**

Water color was evaluated spectrophotometrically. Significant color changes indicate possible contamination from metals or organic compounds.

**2.5.7 Residual Chlorine**

Chlorine residual was tested using the DPD (N,N-diethyl-p-phenylenediamine) method to ensure adequate disinfection.

**2.6 Microbiological Analysis**

Microbiological analysis was conducted to assess the bacterial quality of harvested rainwater samples collected from rusted roofing sheets and direct free-fall sources within Jalingo metropolis. The analysis focused on the enumeration of total heterotrophic bacteria using standard laboratory procedures.

Rainwater samples were collected aseptically in sterile, wide-mouth plastic containers. Two categories of samples were obtained: free-fall rainwater (which had no contact with roofing materials) and roof-contact rainwater collected through gutters and downpipes connected to visibly rusted roofing sheets. Samples were appropriately labeled and transported to the microbiology laboratory in an ice-cooled container and analyzed within 1–2 hours of collection to ensure reliability.

Nutrient agar was used for culturing the bacteria. The medium was prepared by dissolving the appropriate amount of dehydrated powder in distilled water, followed by sterilization in an autoclave at 121 °C for 15 minutes. After cooling to about 45–50 °C, the agar was poured into sterile Petri dishes and allowed to solidify under aseptic conditions.

Each rainwater sample was subjected to serial dilution to reduce the microbial concentration to a countable range. One milliliter (1 mL) of the sample was added to 9 mL of sterile distilled water to make a 10⁻¹ dilution. Further dilutions were carried out as necessary, depending on the expected bacterial load. From the appropriate dilution, 0.1 mL was aseptically inoculated onto the surface of solidified nutrient agar using the spread plate technique and a sterile glass spreader.

The inoculated plates were incubated at 37°C for 24 hours. After incubation, colonies were counted using a manual colony counter. Only plates with colony counts between 30 and 300 CFU were selected for analysis. The number of colony-forming units (CFU) per milliliter of the original water sample was calculated by multiplying the number of colonies by the dilution factor and dividing by the volume of the inoculum plated.

All procedures were conducted under aseptic conditions to prevent contamination. Sterility of the media was confirmed by incubating blank control plates alongside the test samples. This ensured the accuracy and validity of the results. The methodology followed the standard protocols recommended by the American Public Health Association (APHA) for microbiological examination of water samples.

**3.0 Results and Discussion**

**Table 1: Results of the Physio-chemical and Bacteriological Analysis of Harvested Rain Water**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **Method** |  |  |
| **No contact with roof** | **Contact with roof** | **Maximum permissible limit (NSDWQ)** |
| pH | pH meter | 6.89 + 0.02 | 7.62 + 0.005 | 6.50-8.50 |
| Temperature (0C) | Thermometer | 26.40 + 0.01 | 26.7 + 0.02 | Ambient |
| Turbidity (NTU) | Nephelometric | 3.50 + 0.003 | 2.64 + 0.01 | 5.00 |
| T.D.S (mg/L) | Electrometric | 8.80 + 0.02 | 9.00 + 0.11 | 500.00 |
| E. conductivity (µS/cm) | Electrometric | 12.70 + 0.01 | 38.50 + 0.04 | 1000.00 |
| Iron (mg/L) | Ferro Ver | 2.10 + 0.11 | 3.16 + 0.14 | 0.30 |
| Zinc (mg/L) | Zincon | 0.00 | 0.18 + 0.02 | 3.00 |
| Copper (mg/L) | Cuprizone | 0.00 | 0.00 | 0.05 |
| Lead (mg/L) | PAR | 0.00 | 3.00 + 0.01 | 0.01 |
| Potassium | Spectrometry | 0.06 + 0.21 | 0.13 + 0.21 | 10.00 |
| Magnesium | Spectrometry | 0.13 + 0.05 | 0.31 + 0.03 | 30.00 |
| Calcium | Spectrometry | 1.62 + 0.03 | 4.48 + 0.14 | 100.00 |
| Sodium | Spectrometry | 0.17 + 0.01 | 0.34 + 0.02 | 200.00 |
| Color | Spectrometry | 0.00 | 3.00 + 0.03 | 15.00 |
| Total Bacteria Load | Membrane | 13.00 + 0.04 | 20.00 + 0.01 | 10.00 |
| Chlorine | DPD | 0.00 | 0.00 | 0.20-0.25 |

**3.1 Discussion**

The results of the physicochemical and bacteriological analysis reveal clear differences between rainwater samples with no roof contact and those in contact with rusted roofing sheets, highlighting the impact of roofing materials on water quality.

The pH values of 6.89 (no contact) and 7.62 (roof contact) are both within the NSDWQ permissible range (6.5–8.5). The slight alkalinity in roof-contact water is likely due to the leaching of metal ions, especially iron and zinc, from rusted roofing materials, which can raise the pH.

Temperature readings of 26.4 °C and 26.7 °C for non-contact and roof-contact samples, respectively, reflect normal ambient conditions and indicate minimal influence on water chemistry.

Interestingly, turbidity was higher (3.50 NTU) in the free-fall sample compared to roof-contact water (2.64 NTU), though both are within the acceptable limit of 5 NTU. The lower turbidity in roof-contact water could be due to metal particles acting as flocculants, causing suspended particles to settle.

Total Dissolved Solids (TDS) values were 8.80 mg/L (no contact) and 9.00 mg/L (roof contact), well below the maximum limit of 500 mg/L, suggesting low salt content and minimal inorganic contamination from the roof.

However, a notable difference appears in electrical conductivity (EC), which was higher in the roof-contact water (38.5 µS/cm) than the free-fall sample (12.7 µS/cm). Though still below the NSDWQ limit of 1,000 µS/cm, the elevated EC in roof-contact water points to increased ionic content, likely from leached metals such as iron and lead.

Iron concentrations exceeded safe limits in both samples: 2.10 mg/L (no contact) and 3.16 mg/L (roof contact), compared to the standard of 0.30 mg/L. These high levels are directly attributed to rust from deteriorating roofing sheets, and pose risks such as staining, metallic taste, and potential health issues from chronic exposure.

Lead, a highly toxic heavy metal, was absent in the non-contact sample but reached an alarming 3.00 mg/L in roof-contact water, which is 300 times above the NSDWQ limit (0.01 mg/L). This is a critical health concern, as even low levels of lead can cause neurological damage, developmental disorders in children, and organ toxicity in adults.

Zinc was detected at a safe level of 0.18 mg/L in the roof-contact water and was absent in the non-contact sample, both well within the 3.00 mg/L permissible limit. Copper was absent in both, remaining below the 0.05 mg/L threshold.

Other essential elements potassium, magnesium, calcium, and sodium were present in trace amounts and remained within NSDWQ safe limits. Their slightly higher presence in roof-contact water may also result from mineral leaching, but not at harmful concentrations.

In terms of color, free-fall water was colorless, while roof-contact water showed slight discoloration (3.00 units), still well below the 15-unit maximum but indicating some physical contamination from the roof surface.

The bacteriological load of both samples exceeded the standard of 10 CFU/mL: 13 CFU/mL in free-fall and 20 CFU/mL in roof-contact water. The increased microbial content in roof-contact water can be linked to environmental contamination, decaying organic matter, bird droppings, and biofilms on rusted surfaces.

Furthermore, chlorine was undetectable in both samples, indicating a complete lack of disinfection. This underscores the need for treatment before human consumption, especially considering the elevated bacteria and heavy metal levels.

**4.0 Conclusion**

The study confirms that rusted roofing sheets significantly compromise the quality of harvested rainwater. Elevated levels of iron and lead pose serious health risks, including organ damage and neurological disorders. While iron in excess may lead to gastrointestinal issues and organ overload, lead—being highly toxic—can impair brain development in children and cause kidney and cardiovascular problems in adults. Additionally, increased bacterial contamination can result in gastrointestinal infections if consumed untreated.

To mitigate these risks, the use of rusted or lead-based roofing materials should be discouraged. Alternative materials like food-grade plastics or coated metal sheets are safer options. Routine cleaning of roofs and gutters is essential to reduce contamination.

For local communities, practical filtration methods such as first-flush diverters, sand-gravel-charcoal filters, and ceramic pot filters are recommended. These systems are low-cost, locally adaptable, and effective in reducing microbial and heavy metal contamination.

Looking ahead, policies should be developed to regulate roofing materials used in rainwater harvesting. Public awareness, routine water testing, and integration into WASH programs will ensure safer use of harvested rainwater. With proper intervention and affordable treatment options, rainwater can remain a viable and safe water source for communities.

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**References**

1. Abdulla, F. A., & Al-Shareef, A. W. (2009). Roof rainwater harvesting systems for household water supply in Jordan. Desalination, 243(1-3), 195-207.
2. Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusk, K., & Furumai, H. (2017). Urban rainwater harvesting systems: Research, implementation and future perspectives. Water Research, 115, 195-209.
3. WHO. (2017). *Guidelines for Drinking-water Quality* (4th ed.). Geneva: World Health Organization.
4. Ayenimo, JG; Adekunle, AS; Makinde, WO; Ogunlusi, GO (2006). Heavy metals fractionation in roof runoff in Ile-Ife, Nigeria. Environ. Sci. Technol. J. 3:221 -227.
5. Eletta, OA; Oyeyipo. JO (2008). Rainwater Harvesting: Effects of Age of Roof on water quality. Inter. J. Appl. Chem. 4 (2): 157 -162.
6. Fletcher, TD; Deletic, A; Mitchell, VG; Hatt, BE (2008). Reuse of urban runoff in Australia: a review of recent advances and remaining challenges. J. Environ. Qual. 37: 116-127.
7. Hughes, JM; Koplan, JP (2005). Saving Lives through Global Safe Water. J. Emerging Infectious Diseases. 11(10): 1636-1637.
8. Ma, JZ; Wang, XS; Edmunds WM (2005). The characteristics of groundwater resources and their changes under the impacts of human activity in the arid North-West China – a case study of the Shiyang river basin. J. Arid Environ. 61, 277–295.
9. Mark, WR; Xining, C; Sarah, AC (2002). World Water and Food to 2025: Dealing with scarcity. International Food Policy Research Institute, NW, Washington DC, USA.
10. Ojo, OM. (2016). Harvested Rainwater Quality: A Case Study of Aule in Akure, South Western Nigeria. Europ. Sci. J. (11):451-462.
11. Ojo, OM; Adekunle, TO (2016). Evaluation of Heavy Metals Concentration in Harvested Rain water in Aule Area of Akure, South Western Nigeria. Inter. J. Sci. Technol., 5 (6): 292 – 295.
12. Polkowska, Z; Grynkiewicz, M; Zabiegala, B; Namiesnik, J (2001). Levels of pollutants in roof run off water from roads with high traffic intensity in the city of Gdansk, Poland, Pol. J. Environ. Stud. 10-35.
13. Obasikene, JI; Adinna, EN; Uzoechi, IFA. (2000): Man and the Environment, Computer Edge Publishers, Enugu, pp.115-117. UNESCO (2003). Water for People, Water for Life: UN world water development report, executive summary. Paris: United Nations Educational, Scientific and Cultural Organization.
14. WHO/UNICEF (2012). Joint Monitoring Programme (JMP) for Water Supply and Sanitation. WHO Press. Printed in the United States of America.
15. WHO (2005). The WHO Report 2005-make every mother and child count. Geneva.
16. WHO (2011). Guidelines for drinking-water quality. 4th ed. WHO Press Geneva, Switzerland. 541p. Available at: www.who.int/water\_sanitation\_health/publications.