Wilberforce Journal of the Social Sciences (WJSS)

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

DOI: 10.36108/wjss/4202.90.0280

# HARVESTED RAINWATER QUALITY FROM DIFFERENT ROOF TYPES WITHIN THE URBAN AREAS OF UGHELLI, DELTA STATE, NIGERIA

USHURHE, OCHUKO, OZABOR FAMOUS AND DIBOSA FRANCIS CHIKE

## Abstract
The Niger Delta Region has a lot of water, but due to pollution, most of it is not useable for domestic purposes (such as cooking and drinking). The alternative to surface water that forms the aquifer is either polluted or too expensive to construct, especially since the devaluation of the Naira. This leaves the locals in most towns with rainwater as an option and Ughelli is no exception. Rainwater therefore is a veritable option for domestic use. This study assesses the quality of harvested rainwater from different roof types within the urban areas of Ughelli, Delta State, Nigeria. The study deploys the cross-sectional design and a total of 43 samples for each roof-types were collected in the peak rainfall months of June, July and August. After collection, the water samples were kept in the refrigerator at $0.4^{0}$C for preservation and sent to the laboratory for analysis. The results of the rainwater physicochemical properties were compared with World Health Organization (WHO) standards, while ANOVA was used to determine the variation in the quality of rainwater in the different roof-types. Results showed that the water samples were safe for all characteristics except for Lead Iron and Zinc; although different in quality at $p<0.05$ (F-9.104; Sig-0.000). The study therefore recommends the need to remove suspended impurities from rainwater through the addition of a required amount of aluminum sulphate.
**Keywords: Rainwater-harvesting. Water-quality. Physicochemical, Ughelli-Urban**

## Introduction

It is common to harvest rainwater, particularly in developing countries (García-Ávila et al., 2023). This arises from several factors which include; traditional beliefs (Xu et al., 2023), polluted surface water (Obisesan & Famous, 2016), living in a saltwater environment (Okumagba & Ozabor, 2014) such as in the Niger Delta Region (Ushurhe et al., 2024), and poverty (Obisesan & Famous, 2016). Rainwater harvesting involves the collection and storage of rainwater during and after rainfall for use, (Raimondi et al., 2023). This is a very old phenomenon and has been in practice for over 5000 years (Karakadzai et al., 2023). The damages to cisterns that were built around the 200BC which were used for run-off storage from hill-sides for agricultural purposes, population growth, urbanization and inefficient pipe-borne water supply have increased the continued reliance on rain-water harvesting for domestic uses (Mishra, 2023).

It is evident that in many developing countries the living standards have improved, however, there are serious cases of poverty and urban poor, with little or no access to potable water supply (Kundu et al., 2024). This forces locals who have built their houses to standard, using good roofing materials, such as aluminium, zinc and asbestos to collect water from their roofs for domestic uses (including drinking) when it rains (Nicholas & Ukoha, 2023). In this regard. Kenya and Tanzania have since harnessed their techniques of rainwater harvesting (Mfinanga et al., 2023) and as of today. use rainwater for many routines of domestic and agricultural purposes, (Njogu et al., 2024). The account from Zimbabwe puts it that around 85% of the total rainfall is harvested and stored for domestic uses (Ziga & Karriem, 2023).

In the Nigerian environment from time immemorial, rainwater has been a substitute for river and stream waters, especially during rainy periods (Obieluem et al., 2023). It is also recorded (Noori & Singh, 2023) that many urban dwellers rely heavily on rainwater sources for many of their domestic water needs. This is exacerbated by the failure of successive urban water projects and poverty (Muyambo et al., 2023). However, there is no denying the fact that rainwater is one of the purest sources of water if not polluted through gas flaring and emissions of poisonous gases into the atmosphere (Ozabor, 2014; Usiabulu et al., 2023).

The components of rooftops rainwater harvesting arrangement include roof catchment area, roof gutters, down pipes and first flush pipes, filter unit, and storage tanks with provision for drawing

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

water and spillover (Swatha, 2015). To ascertain the quality of rainwater, the pathways through which the raindrops pass from rains, rooftops to the storages have to be accessed (John & Pu, 2023). This is because water can absorb contaminants (Azimi et al., 2024) and minerals (Ding et al., 2023) and collects any substance it comes in contact with, which later becomes part of it (Al Hamedi et al., 2023). The danger is whether good or poisonous, man is unable to see *with ordinary eyes* (Bostan et al., 2023). This means that there is a need for the intended user to ensure the cleaning and cleansing of the channels through which the water passes before consumption (Birniwa et al., 2023).

In Nigeria, rainwater harvesting and its use have been investigated and studied in several works (Efe, 2010; Ansa et al., 2023; Okeola et al., 2023). These works concluded that rainwater harvesting is a means of fetching water for domestic consumption.  Thus. by using the criteria of population and size, Ughelli represents one of the most urbanized areas of Delta State that depend on rainwater for domestic use, (Chukwunweike & Igwe, 2023). As a result, the area poses urban characteristics and also depends on rivers, streams, shallow wells, boreholes and rainwater as sources of water supply for domestic uses (Olajuyigbe, 2010). Generally, in Ughelli, though these sources of water supply abound, the fact remains that more patronage is on water supply from shallow wells (Ochuko & Thaddeus, 2013). However, the quality of the water from these shallow wells is not potable for domestic use. According to epidemiological reports obtained from the Central Hospital, Ughelli in 2006, polluted water accounted for cases of typhoid, diarrhoea and dysentery (Ochuko & Thaddeus, 2013). The need to assess the quality of rainwater harvested in the area (a major alternative for water supply during the rainy season for domestic purposes) calls for urgent attention.

of

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

However. the interest of researchers has mostly been drawn to underground (Mitchell et al., 2012) and surface water quality assessment (Chigor et al., 2012). Most recent studies have neglected the inquest into the quality of rainwater (Peker, 2023) even though it is a major source of water for the urban poor in developing countries (Richards et al., 2021). The reason for this neglect is that only the poor use such water sources (rainwater) and rainwater is considered to be old-fashioned (Raimondi et al., 2023). However, an earlier study (Efe, 2003), had indicated that inhabitants of the Niger Delta (especially in the rural areas) perceive rainwater as a potable water source when collected properly.

In Ughelli, shallow-well water consumption is very rampant as compared to borehole water, river water, or even rainwater. The production of crude oil and poor waste management in the area makes the pollution of the well water and river water rampant (Numbere et al., 2023); consequently, well and river water quality is very questionable (Hou et al., 2023). Also, zonal distribution and effects of water-related diseases showed that areas with low-quality wells correlate with a high incidence of waterborne diseases (Ozoemenam et al., 2023). The need to source for alternative means of water supply through rainwater harvesting forms the main thrust of this research to reduce to a minimum, the incidences of water-related sicknesses in rainwater. Thus, the disparity in the quality of water harvested from different roof types also engages the attention of this study. The researcher also seeks to find answers to questions such as the following:

- Is the water from rain good for human consumption?
- Is there any difference in the quality of rainwater harvested from different roof types in Ughelli?
- How can we attain the portability of rainwater harvesting in the area?

**Aim, Objectives and Hypothesis**

The aim herein is to assess the quality of water harvested from different roof-types in Ughelli. The specific objectives are to:

- assess the quality of rainwater harvested in the urban area of Ughelli.
- ascertain the level of variation in the quality of rainwater harvested from the different roof-types in Ughelli.
- suggest ways of improving the quality of rainwater harvested in the area.

**Hypothesis**

A null hypothesis was formulated and tested for the study as follows:

No significant disparity in the rainwater harvested under different roof-types in Ughelli.

**Study Area**

Ughelli is located between latitudes $5^0$28'N and $5^0$32'N of the Equator and also between longitudes $5^0$58'E and $6^0$03'E of the Greenwich Meridian. Ughelli is the headquarters of Ughelli North Local Government Area of Delta State. Ughelli is bounded in the North by Eruemukohwarien, in the West by Oteri/Ovwor, in the East by Agbarha-Otor and in the South by Oviri-Ogor/Evwreni.

The area falls within the tropical type of climate based on the Koppen classification, with a high amount of annual rainfall which ranges from 1895mm to 2155mm (Ozabor et al., 2023). The area experiences rainfall in all the months of the year (Emmanuel & Alexander, 2024), making rainfall a very good source of water if well harnessed. The locals are farmers and traders, and there are many poor people in the area (Obruche et al., 2023). This means that the sources of water consumption have to be monitored to prevent an outbreak of water-related diseases in the area.

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

**Methodology**

This study is empirical research and adopted the cross-sectional design (Azam & Shaheen, 2019). It involves field data collection and laboratory analysis of rainwater collected from different roof-types in Ughelli. Data were derived from water samples that were collected from rainwater from three different roofing sheet types. The rainwater samples were collected from three different roofs of aluminium roofing sheets, asbestos, corrugated iron sheets and open spaces (as control). The rainwater samples were collected in June, July and August (which is known to be the peak of the rainy season in the area) in 2023. Rainfall from the mouth of the gutter and open surface was collected by researchers using sterilized cans (Vulava et al., 2023). A sample of rainwater was collected at four sources (aluminium roofing sheet, corrugated iron roofing sheet, asbestos roofing sheet and open space (as control) in each of the zones in Ughelli. The open-space rainwater samples were collected at a height of 0.5 meters to prevent sand particles from splashing into the water (Hanning, 2023). The rainwater samples were collected at a time-lapse of 10 minutes from the commencement of rainfall. This interval has been used by Efe (2006) and they achieved significant results.

In all, a total of 43 samples were collected representing the number of rainy days in the period of study. These 43 rainwater samples were collected with the help of 30 field assistants trained in water samples collection. This ensured that rainwater samples were collected simultaneously. After collection, the water samples were kept in the refrigerator at $0.4^0$C for preservation (Cai et al., 2014). The samples were taken to the laboratory for analysis with a cooler containing some ice packs (Ushurhe et al., 2023). The materials and equipment used for the analyses and assessments were based on the analytical equipment recommended and validated by the World Health

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

Organization (WHO), Nigerian Industrial Standard (NIS) and Ministry of Environment, for testing water quality. Data analysis was handled using the Analysis of Variance (ANOVA).

**Results and Discussions**

The water samples collected from the four different roofing sheets in the area were analyzed and are presented in Table 1 and discussed.

**Table 1: Mean Physicochemical Characteristics of Rainwater Harvested from Different Catchment Roofs Within the Urban Area of Ughelli**

| Parameter | Open Space | Asbestos | Zinc | Aluminum | Mean Value | WHO limit | Remarks |
|---|---|---|---|---|---|---|---|
| pH | 6.66 | 5.77 | 6.64 | 5.77 | 6.23 | 6.5-8.5 | Safe |
| Temp. $^{0}$C | 29.43 | 30.00 | 29.50 | 29.78 | 29.8 | 29.8 | Safe |
| Acidity (mg/l) | 18.48 | 19.42 | 20.58 | 19.53 | 19.50 | N/A | Safe |
| Alkalinity mg/l | 31.30 | 31.34 | 29.73 | 30.73 | 30.78 | Min 30 | Safe |
| DO (mg/l) | 7.08 | 7.79 | 6.82 | 8.05 | 7.44 | 5.00 | Safe |
| BOD (mg/l) | 1.07 | 1.09 | 1.06 | 1.04 | 1.07 | N/A | Safe |
| TDS (mg/l) | 0.02 | 0.03 | 0.03 | 0.01 | 0.02 | 0.03 | Safe |
| TSS (mg/l) | 0.02 | 0.06 | 0.10 | 0.06 | 0.06 | 5.00 | Safe |
| Sulphate (mg/l) | 15.57 | 16.48 | 16.14 | 15.98 | 16.04 | 200.0 | Safe |
| Total Hardness | 6.39 | 6.71 | 6.43 | 6.76 | 6.57 | N/A | Safe |
| Vn (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | Safe |
| Ni (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | Safe |
| Pb (mg/l) | 0.001 | 0.054 | <0.001 | 0.017 | 0.018 | 0.01 | Not Safe |
| Fe (mg/l) | 0.547 | 0.653 | 0.641 | 0.603 | 0.611 | 0.03 | Not Safe |
| Zn (mg/l) | 0.444 | 0.568 | 0.554 | 0.461 | 0.507 | 3.00 | Not Safe |
| Turbidity (NTU) | 0.03 | 0.05 | 0.06 | 0.06 | 0.05 | 5.00 | Safe |

**Source:** Fieldwork, 2023.

From the above Table 1, the pH values of rainwater harvested were within the WHO standard. The mean value of 6.25 was within the 6.5-8.0 WHO threshold. However, the lowest pH value of 5.77 was recorded in rainwater samples harvested from aluminium asbestos roofing sheets while the

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

highest pH value of 6.66 was recorded from the open space. The low pH value of asbestos roofing sheets and aluminium could be attributed to the high rate of industrial atmospheric pollution and the materials used in the production of the roofing sheets. This shows that the rainwater harvested from the built-up areas is mildly acidic. This corroborates the works of Efe and Mogborukor (2008) in the industrial refinery area of Warri, which recorded a low pH value. The temperature values of rainwater harvested were generally satisfactory from the different catchment roofs in the urban area except for asbestos roofing sheets. The mean value of $29.8^0$C was recorded in the area. However, the lowest temperature value of $29.43^0$C was recorded in rainwater samples harvested from the open spaces. while the highest temperature value of $30.0^0$C was recorded from asbestos roofing sheets. The recorded values conform with WHO standards except for asbestos roofing sheets.

The turbidity values of rainwater harvested were generally low and fell within the WHO-acceptable threshold of drinking water standards. The mean value of 0.05 was lower than the 5.00 WHO threshold. However, the lower turbidity value of 0.03 was recorded from the open space, while the highest turbidity value of 0.06 was recorded from aluminium roofing sheets and zinc roofing sheets in the area. The high turbidity value recorded from zinc and aluminium could be attributed to the slight pollution effect from automobiles. The acidity value of rainwater harvested was generally lower than the WHO-acceptable threshold. A mean value of 19.5 which is lower than the acidity value of 20.58 was recorded from zinc roofing sheets from rainwater samples harvested; while the highest acidity value of 20.58 was recorded from zinc roofing sheets. This could be attributed to the pollution effect from the fumes of automobiles. These values are lower than those recorded in similar areas in the Niger Delta by Efe and Mogborukor (2008) in communities in the oil-producing region of Nigeria.

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

The alkalinity values of rainwater harvested are generally lower than the WHO-acceptable threshold. This is evident in the 30.78 mean values recorded. However, the lowest alkalinity value of 29.73 was recorded in rainwater samples harvested from zinc roofing sheets, while the highest alkalinity value of 31.34 was recorded from asbestos roofing sheets. Dissolved oxygen values of rainwater harvested were generally higher than the WHO-acceptable threshold. A mean value of 7.44 was recorded. The recorded value was higher than the 5.00mg/l WHO threshold. However, a low value of 6.82mg/l was recorded in rainwater samples harvested from zinc roofing sheets; while the highest dissolved oxygen value of 7.79mg/l was recorded from asbestos roofing sheets. The total dissolved solids of rainwater harvested were generally within the WHO-acceptable threshold. A mean value of 0.02 mg/l was recorded in the area. This value is lower than the WHO threshold value of 0.03 mg/l. The lowest total dissolved value of 0.01mg/l was recorded from aluminium roofing sheets in the area, while the highest total dissolved solids value of 0.03 was recorded from asbestos and zinc roofing sheets.

The total suspended solids value of rainwater harvested was generally lower than the WHO acceptable threshold. This is evident in the 0.06mg/l mean value of total suspended solids as compared to the 5.00mg/l WHO threshold. The lowest total suspended value of 0.02mg/l was recorded in rainwater harvested from open space, while the highest total suspended solids value of 0.10mg/l was recorded in rainwater harvested from zinc roofing sheets. Sulphate values of rainwater harvested were generally lower than the WHO-acceptable threshold. This is evident in the 16.04mg/l mean value recorded in the area as compared to the 200mg/l WHO acceptable threshold. The lowest sulphate value of 15.98mg/l was recorded in rainwater samples harvested from aluminium roofing sheets, while the highest sulphate value of 10.48mg/l was recorded from asbestos roofing sheets. The total hardness value of rainwater harvested was generally within the

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

WHO-acceptable threshold. A mean value of 6.57mg/l was recorded in the area. However, a lower value of 16.39mg/l was recorded from the rainwater harvested from the open space, while the highest value of 6.76mg/l can be attributed to fumes from automobiles.

The vanadium value of the rainwater harvested and analyzed had a mean value of <0.001mg/l when compared to 0.001mg/l, WHO acceptable limit. This is an indication that there was no vanadium contamination in the harvested rainwater samples from the different catchment roofs. Nickel values of rainwater harvested were generally lower than that of the WHO acceptable threshold. A mean value of <0.001mg/l was recorded as against 0.001mg/l WHO acceptable limit. However, the lowest and highest values of the rainwater samples were the same. This implies that there was no indication of Nickel contamination in the rainwater samples harvested in the area.

From Table 1, the lead value of the rainwater harvested was higher than that of the WHO acceptable threshold. This is evident in the mean value of 0.018mg/l recorded in the sampled rainwater harvested in the area as compared to 0.01mg/l WHO acceptable threshold. However, a low value of <0.001mg/l was recorded in rainwater samples harvested from zinc catchment roofs in the area, while a high lead value of 0.054mg/l was recorded from asbestos roofing sheets. This can be attributed to the materials used in the production of the roofing sheets and gas flaring sites. This goes to confirm the views of Efe (2006) of high lead contamination of rainwater in the Niger Delta region of Nigeria. In terms of iron concentration in the rainwater harvested, the values were generally higher when compared to the WHO acceptable limit. This can be seen in the 0.611mg/l mean values recorded in the rainwater samples analyzed. This value is higher than the WHO value of 0.03 mg/l. Zinc values of rainwater harvested were generally higher than the WHO acceptable limit. A mean value of 0.507mg/l was recorded as against the 3.00mg/l WHO acceptable limit. However, the lowest zinc value of 0.444mg/l was recorded in water samples from the open space,

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

while the highest zinc value of 0.568mg/l was recorded from asbestos. This could be attributed to the materials used in the production and the corrosive nature of the water (Gómez-Guarneros et al., 2023).

Table 2 shows the variation in the rainwater quality in the different roof types in Ugheli Urban. The ANOVA model showed significance at $p<0.05$ (F-9.104, sig-0.00). This reveals that there is a significant difference in the water quality across the different roof-types in the city. Table 3 (the Duncan test) showed that the open space was the cleanest rainwater source, while Asbestos was the dirtiest. The reason for this occurrence may be attributed to the retention of pollutant capacity of waste which Asbestos possesses and the materials used for manufacturing Asbestos, (Townsend & Anshassi, 2023).

**Table 2: Summary of ANOVA result explaining the level of variation in the quality of water harvested from Open Space, Aluminum Asbestos and Zinc Roofing Sheets**

**ANOVA**

Water_quality

| | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 4691.144 | 3 | 1563.715 | 9.104 | .000 |
| Within Groups | 28857.354 | 168 | 171.770 | | |
| Total | 33548.497 | 171 | | | |

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

**Table 3: Duncan statistics of ANOVA result explaining the variation in quality of water harvested from different roof-tops in Ughelli**

**Water_quality**

Duncan

| Identifiers | N | Subset for alpha = 0.05 | |
|---|---|---|---|
| | | 1 | 2 |
| Opean_space | 43 | 7.3153 | |
| Zinc | 43 | 7.3930 | |
| Aluminum | 43 | 7.4283 | |
| Asbestos | 43 | | 7.5011 |
| Sig. | | .854 | 1.000 |

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 43.000.

## Conclusion and Recommendations

Based on the aim and objectives of the study and the hypothesis posited, the research has been able to answer the posited questions that all the parameters examined showed satisfactory concentration. This implies that rainwater in the area can be harvested, stored and utilized for domestic purposes. However, there is a need for some treatment to attain portability. It was also observed from the rainwater harvesting that there is a significant difference in the quality of rainwater under the different catchment roofs in Ughelli. Open catchment with a mean was cleaner in all. This showed that the contaminants which are transported by winds sometimes settle on the rooftops, and are consequently washed off by the collected rains.

Furthermore, the study revealed that most physico-chemical characteristics of rainwater harvested from the open, zinc and aluminium in Ughelli could be consumed if minimal purification is done,

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

especially on the pH, lead, zinc and iron contents. To actualize this, the following suggestions are posited:

- There is the need for the removal of suspended impurities from rainwater through the addition of a required amount of aluminium sulphate to enable the impurities to settle down at the bottom of the bucket before usage.
- The water should be disinfected through sterilization to kill the bacteria in it.
- Rainwater should be exposed to sunlight and ultraviolet rays to kill various types of bacteria in the water without giving an undesirable taste or odour to the water.

**Reference**

Al Hamedi, F. H., Kandhan, K., Liu, Y., Ren, M., Jaleel, A., & Alyafei, M. A. M. (2023). ''Wastewater Irrigation: A Promising Way for future Sustainable Agriculture and Food Security in the United Arab Emirates.'' *Water*, *15*(12), 2284.

Ansa, I. E., Ituen, U. J., & Abraham, C. M. (2023)''. An Assessment of Small-Scale Water Harvesting Systems in Uruan Local Government Area, Akwa Ibom State.'' *International Journal of Social Sciences*, *15*(1).

Azam, M. S., & Shaheen, M. (2019)''. Decisional Factors Driving Farmers to Adopt Organic Farming in India: A Cross-sectional Study. *International Journal of Social Economics*, *46*(4), 562-580.

Azimi, B., Sepahvand, S., Ismaeilimoghadam, S., Kargarzadeh, H., Ashori, A., Jonoobi, M., & Danti, S. (2024).'' Application of Cellulose-based Materials as Water Purification filters; A State-of-the-art Review.'' *Journal of Polymers and the Environment*, *32*(1), 345-366.

Birniwa, A. H., Habibu, S., Abdullahi, S. S. A., Mohammad, R. E. A., Hussaini, A., Magaji, H., ... & Jagaba, A. H. (2023). Membrane Technologies for Heavy Metals Removal from

**Website**: www.nduwjss.org.ng **ISSN**: 2504 – 9232 **Volume 9 No. 2 (2024)**

Water and Wastewater: A Mini Review. *Case Studies in Chemical and Environmental Engineering*, 100538.

Bostan, N., Ilyas, N., Akhtar, N., Mehmood, S., Saman, R. U., Sayyed, R. Z., ... & Pandiaraj, S. (2023). Toxicity Assessment of Microplastic (MPs); A Threat to the Ecosystem. *Environmental research*, 116523.

Cai, L., Wu, X., Li, X., Zhong, K., Li, Y., & Li, J. (2014)''. Effects of different Freezing Treatments on Physicochemical Responses and Microbial Characteristics of Japanese Sea Bass '' (Lateolabrax japonicas) fillets during refrigerated storage. *LWT-Food Science and Technology*, *59*(1), 122-129.

Chigor, V. N., Umoh, V. J., Okuofu, C. A., Ameh, J. B., Igbinosa, E. O., & Okoh, A. I. (2012). ''Water Quality Assessment: Surface Water Sources used for Drinking and Irrigation in Zaria, Nigeria, are A Public Health Hazard.'' *Environmental monitoring and assessment*, *184*, 3389-3400.

Chukwunweike, A. B., & Igwe, C. P. (2023).'' Examination of the State of the Art in Land Use and Allocation Procedures in Delta State. *Tropical Built Environment Journal*, *9*(1).

Ding, S., Han, X., Zhu, L., Hu, H., Fan, L., & Wang, S. (2023).'' Clean up of Oils and Organic Solvents from Contaminated Water by Biomass-based Aerogel with adjustable Compression Elasticity.'' *Water Research*, *232*, 119684.

Efe, S. I. (2003). ''Effects of Gas Flaring on Temperature and Adjacent Vegetation in Niger Delta Environment.'' *International Journal of Environmental Issues*, *1*(1), 91-101.

Efe, S. I. (2006).'' Quality of Rainwater Harvesting for Rural Communities of Delta State, Nigeria. ''*Environmentalist*, *26*, 175-181.

Efe, S. I. (2010).'' Spatial Variation in Acid and some Heavy Metal Composition of Rainwater Harvesting in the Oil-producing Region of Nigeria.'' *Natural hazards*, *55*(2), 307-319.

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

Efe, S. I., & Mogborukor, J. O. A. (2008).'' Acid Rain in the Niger Delta Region: Implication on Water Resource Crises.'' In *Proceedings, international conference on the Nigerian state, oil industry and the Niger Delta*.

Emmanuel, N. O., & Alexander, E. O. (2024).'' Variability Of Rainfall And Temperature Distributions In Delta State, Nigeria. ''*Global Journal of Social Sciences*, *23*(1), 1-15.

García-Ávila, F., Guanoquiza-Suárez, M., Guzmán-Galarza, J., Cabello-Torres, R., & Valdiviezo-Gonzales, L. (2023).'' Rainwater Harvesting and Storage Systems for Domestic Supply: An Overview of Research for Water Scarcity Management in Rural Areas''. *Results in Engineering*, *18*, 101153.

Gómez-Guarneros, M. A., Sánchez-Tizapantzi, P., Vásquez-Chacón, I. A., Godínez-Salcedo, J. G., Gallardo-Hernández, E. A., & Farfan-Cabrera, L. I. (2023). Corrosive effects of artificial rainwater on rolling contact fatigue on wheel and rail materials. *Wear*, *530*, 205046.

Hanning, J. (2023). *Storage improvement of urban water catchments in Ede using the SOBEK model* (Bachelor's thesis, University of Twente).

Hou, Liyao, Zhanjun Liu, Bingnian Zhai, Yuanjun Zhu, and Xinpeng Xu. "Contrasting Water Quality in Response to Long-term Nitrogen Fertilization in Rainfed and Irrigated Apple-producing Regions on China's Loess Plateau." *Agriculture, Ecosystems & Environment* 354 (2023): 108561.

John, C. K., & Pu, J. H. (2023). *Household Reusable Rainwater Technology for Developing and Under-Developed Countries*. Taylor & Francis.

Karakadzai, T., Matamanda, A. R., & Chirisa, I. (2023). Rainwater Harvesting for Water Security in Informal Settlements: Techniques, Practices, and Options. In *The Palgrave Encyclopedia of Urban and Regional Futures* (pp. 1371-1381). Cham: Springer International Publishing.

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

Kundu, A., Rahaman, M., & Khan, K. (2024). Access of Urban Poor to Basic Services: Concerns of Sustainability and Equity. *Social Change*, *54*(1), 7-35.

Mfinanga, F., Bengesi, C. P. M., & Madaha, R. M. (2023).'' Determinants of the Adoption of Charco Dam Rainwater Harvesting Technology by Pastoralists in Semi-Arid Areas of Monduli District in Tanzania.'' *East African Journal of Science, Technology and Innovation*, *4*(4).

Mishra, R. K. (2023). ''Fresh Water Availability and its Global Challenge.'' *British Journal of Multidisciplinary and Advanced Studies*, *4*(3), 1-78.

Mitchell, M., Curtis, A., Sharp, E., & Mendham, E. (2012)''. Directions for Social Research to Underpin Improved Groundwater Management.'' *Journal of hydrology*, *448*, 223-231.

Muyambo, F., Belle, J., Nyam, Y. S., & Orimoloye, I. R. (2023). Climate-change-induced Weather Events and Implications for Urban Water Resource Management in the Free State Province of South Africa. *Environmental Management*, *71*(1), 40-54.

Nicholas, E. O. S., & Ukoha, P. O. (2023). Evaluation of the Effect of Different Conventional Roof Types and Industrial activity on Harvested Rainwater in Southern Nigeria. *Discover Water*, *3*(1), 12.

Njogu, J. W., Karuku, G., Busienei, J., & Gathiaka, J. K. (2024). Assessing Determinants of Scaling up Pathways for Adopted CSA Climate Smart Agricultural practices: Evidence from Climate Smart Villages in Nyando Basin, Kenya. *Cogent Food & Agriculture*, *10*(1), 2316362.

Noori, A. R., & Singh, S. K. (2023). Rainfall Assessment and Water Harvesting Potential in an Urban Area for Artificial Groundwater Recharge with Land Use and Land Cover Approach. *Water Resources Management*, *37*(13), 5215-5234.

Numbere, A. O., Gbarakoro, T. N., & Babatunde, B. B. (2023).'' Environmental Degradation in the Niger Delta Ecosystem: The Role of Anthropogenic Pollution.'' In *Sustainable* *utilization and conservation of Africa's biological resources and environment* (pp. 411-439). Singapore: Springer Nature Singapore.

Obieluem, U. H., Uzuegbu, J. O., & Ugwuagbo, W. (2023). Evolving Trends in Rain Water Harvesting and Storage System in Nsukka Area, South-east, Nigeria. *African Renaissance (1744-2532)*, *20*(3).

Obisesan, A., & Famous, O. (2016).'' Factors Affecting Water Supply in Owah-Abbi, Delta State. ''*Open Journal of Social Sciences*, *4*(7), 137-146.

Obruche, E. K., Emakunu, S. O., Ugochukwu, G. C., Etinagbedia, A., & Akakabota, A. O. (2023). Determination of the Effects of Rooftops on the Quality of Rainwater Collected in Ughelli, Delta State, Nigeria.'' *Nigerian Journal of Science and Environment*, *21*(3).

Ochuko, U., & Thaddeus, O. (2013).'' A Comparative Assessment of the Quality of Harvested Rainwater, Underground Water and Surface Water for Domestic Purposes in Ughelli, Southern Nigeria.'' *Journal of Environment and Earth Science*, *3*(12), 9-13.

Okeola, O. G., Sulaiman, L. T., Sholagberu, T. A., & Salami, W. A. (2023). ''Spatial Hydrological Analysis on Storm Water Harvesting Investigation for Sustainable Water Resources Management Strategy.'' *International Review of Applied Sciences and Engineering*, *14*(1), 114-124.

Okumagba, P. O., & Ozabor, F. (2014).'' The Effects of Socio-economic Activities on River Ethiope. ''*Journal of Sustainable Society*, *3*(1), 1-6.

Olajuyigbe, A. E. (2010). ''Attributes of Domestic Water Sources in a Rapidly Urbanizing State Capital in a Developing Economy.'' *Journal of Social Sciences*, *6*(2), 212-220.

Ozabor, F. (2014). Analysis of Rainfall Regimes in Nigeria. *Unpublished M.Sc Dissertation submitted to the Department of Geography and Environmental Management*.

**Website**: www.nduwjss.org.ng **ISSN**: 2504 – 9232 **Volume 9 No. 2 (2024)**

Ozabor, F., Efe, S. I., Kpang, M. B. T., & Obisesan, A. (2023).'' Social and Economic Wellbeing of Seafarers across Coastal Nigeria amidst Corona Virus Disease.'' *Heliyon*, *9*(8).

Ozoemenam, J. C., Akudinobi, B. E. B., Nnodu, V. C., & Obiadi, I. I. (2018). Water Quality Assessment of Shallow and Deep Boreholes in Ekpan Community, Effurun, Delta State, Nigeria. *Environmental earth sciences*, *77*, 1-12.

Peker, E. (2023). Enabling widespread use of rainwater harvesting (RWH) systems: challenges and needs in twenty-first-century Istanbul. *European Planning Studies*, *31*(1), 103-122.

Raimondi, A., Quinn, R., Abhijith, G. R., Becciu, G., & Ostfeld, A. (2023).'' Rainwater Harvesting and Treatment: State of the Art and Perspectives.'' *Water*, *15*(8), 1518.

Raimondi, A., Quinn, R., Abhijith, G. R., Becciu, G., & Ostfeld, A. (2023).'' Rainwater Harvesting and Treatment: State of the Art and Perspectives.'' *Water*, *15*(8), 1518.

Richards, S., Rao, L., Connelly, S., Raj, A., Raveendran, L., Shirin, S., ... & Helliwell, R. (2021). ''Sustainable Water Resources through Harvesting Rainwater and the Effectiveness of a Low- cost Water Treatment. ''*Journal of Environmental Management*, *286*, 112223.

Swatha, V. S. (2015). *Improvement of purification system for roof water harvesting* (Doctoral dissertation, Department of Land and Water Resources and Conservation Engineering, Kelappaji College of Agricultural Engineering and Technology, Tavanur).

Ushurhe, O., Famous, O., Gunn, E. O., & Ladebi, S. O. M. (2024).'' Lead, Zinc and Iron Pollutants Load Assessment in Selected Rivers in Southern Nigeria: Implications for Domestic Uses.'' *Journal of Water Resource and Protection*, *16*(1), 58-82.

Ushurhe, O., Ozabor, F., & Origho, T. (2023).'' A Comparative Study of Upstream and Downstream Water Quality of Warri River, in Delta State, Southern Nigeria''. *African Journal of Environmental Research*, *4*(2), 42-53.

Website: www.nduwjss.org.ng ISSN: 2504 – 9232 Volume 9 No. 2 (2024)

Usiabulu, G. I., Amadi, A. H., Adebisi, O., Ifedili, U. D., Ajayi, K. E., & Moses, P. R. (2023). ''Gas Flaring, and its Environmental Impact in Ekpan Community, Delta State, Nigeria.'' *Technology*, *8*(1), 42-53.

Vulava, V. M., Squiggins, K. T., & Fullerton, H. (2023). The Presence of Ampicillin-Resistant Coliforms in Urban Floodwaters of a Coastal City in the Southeastern United States. *Frontiers in Water*, *6*, 1359196.

Xu, J., Dai, J., Wu, X., Wu, S., Zhang, Y., Wang, F., ... & Tan, Y. (2023). Urban Rainwater Utilization: A Review of Management Modes and Harvesting Systems. *Frontiers in Environmental Science*, *11*.

Ziga, M., & Karriem, A. (2023).'' Role of Urban Agriculture Policy in Promoting Food Security in Bulawayo, Zimbabwe.'' In *The Palgrave Encyclopedia of Urban and Regional Futures* (pp. 1462-1468). Cham: Springer International Publishing.

Townsend, T. G., & Anshassi, M. (2023).'' Hazardous and Dangerous Materials in CDD.'' *Construction and Demolition Debris*, 137-189.

**Authors' Profile**

**Dr. Ochuko Ushurhe** is the Head of the Department of Environmental Management at Dennis Osadebay University, Anwai, Asaba. He has demonstrated his technical capabilities in issues relating to environmental management. Additionally, he has significantly advanced the department's frontiers through academic research. **Dr. Ushurhe** is dedicated to sustainable practices and is highly respected for his leadership and innovative contributions to the discipline.

**Dr. Ozabor Famous** is the Head of the Geography Department at Dennis Osadebay University, Anwai, Asaba. Renowned for his expertise in geographical and climatological studies, he has made significant contributions to academia. He also possesses several publications indexed in reputable indexing agencies, such as Web of Science and Scopus. He may be contacted on +2348169312952 or email: Famous.Ozabor@dou.edu.ng

**Mr. Dibosa Francis Chike** is a distinguished lecturer in the Department of Urban and Regional Planning, at Dennis Osadebay University, Anwai, Asaba, Delta State, Nigeria. Using his expertise in regional and environmental management issues, he has carved a niche for himself in the fields of Geography and Regional Planning.