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PHYSICOCHEMICAL CHARACTERISTICS OF ROOF-HARVESTED RAINWATER

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Abstract:

This study aims to determine the physicochemical characteristics of roof-harvested rainwater (RHRW) stored in plastic and steel tank, and to compare the water quality of the harvested rainwater (RW) with the World Health Organization (WHO) guidelines for drinking-water quality. The physicochemical characteristics of RW samples, stored in steel and plastic tanks, were examined using standard methods. The results revealed that the average concentrations of the pH,, electrical conductivity, total dissolved solids, temperature and Iron, corresponding to the plastic and steel tank stored water, were 5.0 and 5.2; 0.15 mS/cm and 0.19 mS/cm; 44 mg/l and 46 mg/l; 28.1°C and 28.4°C; 0.91mg/l and 1.39 mg/l, respectively. The comparison of the results with the WHO guidelines showed that the pH was below the permissible limits while the average concentration of Iron exceeded the maximum limits for the water stored in both tanks. The acidic nature of the RW, perhaps, impacted other water quality parameters of the stored RW. A further prognosis of the potential human health risk associated with exposure to stored rainwater is recommended.

Keywords: rainwater, physicochemical, materials, water quality, roof-harvested

1.0 INTRODUCTION

Water is an indispensable resource required for the sustenance of mankind. The increase in the demand for water has necessitated the consideration of supplementary alternatives to erstwhile traditional water supply sources [1]. Extreme climate events further exacerbates the scale and need for water in regions prone to drought. In recent years, the interest in rainwater harvesting has continued to grow across different localities. However, the seasonality of rainfall necessitates the storage of rainwater during periods of abundant rainfall to supplement the shortfall during the dry season. The water age, consequent upon storage, portends risk of contamination before use. The possibility of rainwater pollution, by chemicals and microorganisms, has been reported [2]. Previously, Zdeb, et al. [3] highlighted the role of season of rainwater harvesting on rainwater quality.

A simple rainwater harvesting (RWH) systems includes a roof, water storage and a gutter [4]. The use of local skills, materials and equipment in RWH has been advocated [2]. Rainwater (RW) can be harvested from rooftops, paved/unpaved areas, water bodies and storm water drains [5]. RW samples from roof catchments, storage tank and free-fall have been previously studied [6]. The performance of actual and estimated RWH system vis-à-vis recommended methods have been conducted [7]. In addition to simple systems, a continuous simulation modelling approach has been utilized for the evaluation of different design methods [8]. Environmental conditions as well as the choice of catchment, storage materials and application of treatment significantly impact on the quality of harvested rainwater [9].

Rainwater harvesting serves as a source of water in most rural communities in Nigeria. The availability of rainwater vary with seasons, for different locations. While some regions have abundant water others experience water scarcity or stress. Hence, the temporal variability in the occurrence of rainwater as well as varying utilization necessitates the need for storage. Also, the water age, consequent upon storage, portends risk of contamination before use. It is therefore necessary to conduct a research to determine the physicochemical characteristics of rainwater, stored in plastic and steel tank as well as compare the water quality of the rainwater (RW) with the World Health Organization (WHO) guidelines for drinking-water quality.

2.0 Materials and Methods

2.1 Study area

The pilot study was conducted at the University of Cross River State, Calabar South. UNICROSS is located in Calabar South LGA, Cross River State, Nigeria. The pilot study site is located at longitudes 8.333⁰ East and latitudes 4.927⁰ North (Figure 1).

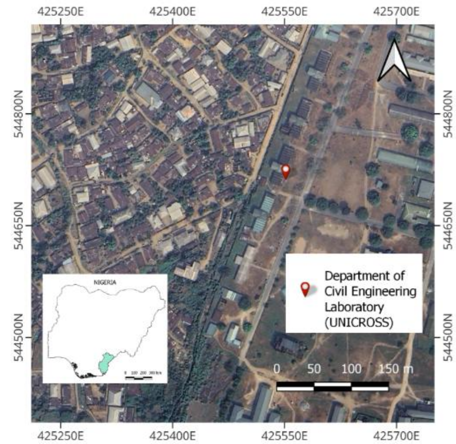

Figure 1: Location of pilot study area

2.2 Experimental investigation and setup

The experimental setup consisted of two storage tanks made of high-density polyethylene (plastic) and steel tank. Both storage tanks have the same dimensions as well as capacity (1,030 liters). The rainstorm event, which occurred on the 7th October, 2024, was harvested using a simple rainwater harvesting system. The tanks received influent from the roof collection system via a 3" diameter pipe. The roofing sheet was made of asbestos cement material. The storage tanks were constructed with inlet and outlet pipes, fitted with flow control faucets. The tanks constituting the experimental setup, sited in the laboratory, were covered to forestall contaminations from externalities.

2.2 Sample collection

At the commencement of the sampling, rainwater samples were collected during a rainstorm event, to serve as control. Afterwards, harvested rainwater samples were obtained from the storage in the plastic and steel tanks. The samples were collected at the outlets of the respective tanks, with the aid of flow control faucets. The samples were collected at an intervals of 5 days up to day 75. Sampling bottles were thoroughly prewashed and then rinsed with the samples. The water samples were collected in 200ml sterilized bottles for physicochemical analysis. The rainwater and harvested rainwater were examined for physicochemical parameters for the period under review. The parameters tested were as follows: temperature, pH, total dissolved solids, electrical conductivity, and Iron. All analyses were be carried out in accordance with the standard methods for the examination of water and wastewater (APHA, 2005).

The pH, EC and TDS were determined using the multi-parameter Analyzer (PH-2603) while the concentration of iron in the samples was obtained using the VIS Spectrophotometer 721 (D). Temperature was measured using the DO Analyzer (JPB-607A).

3.0 Results and Discussion

3.1 Physicochemical characteristics of roof-harvested rainwater

3.1.1 pH

The results of pH, for rainwater stored in the plastic and steel tanks, are shown in Figure 2. A pH of 5.6 was obtained prior to storage. The minimum and maximum pH for the plastic tank stored water were 4.3 and 6.1. Also, the minimum and maximum pH for the steel tank stored water were 4.2 and 7.2. The average concentrations of the pH, corresponding to the plastic and steel tank stored water, were 5.0 and 5.2. An average pH of about 5.0 is expected to occur in locations devoid of pollution [10]. Previously, the pH of rainwater stored in plastic tank was lower than RW stored in ferrocement reservoir [11]. The pH, of the rainwater stored in the plastic and steel tanks, varied with time. A weak increasing trend in the pH was observed for the RW stored in the plastic tank and vice versa for the steel tank stored rainwater. The role of pH in leaching of metals into water cannot be overstated [12]. The results showed that the average pH was below the WHO permissible limits for the water stored in the plastic and steel tanks, respectively (Table 1).

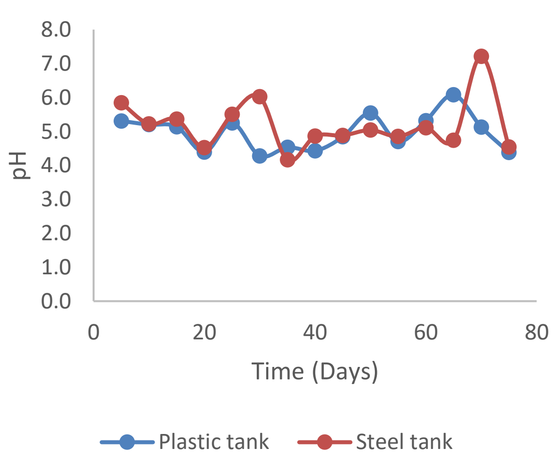

Figure 2: pH variation in storage tanks with time

3.1.2 Iron

Prior to storage, the concentration of Iron in the rainwater was 0.26mg/l. The minimum and maximum iron concentrations for the plastic tank stored water were 0.8mg/l and 1.2 mg/l. Also, the minimum and maximum pH for the steel tank stored water were 1.0 and 1.7, respectively (Figure 3). The average concentrations of the Iron, corresponding to the plastic and steel tank stored water, were 0.91mg/l and 1.39 mg/l. The acidic nature of the stored rainwater, perhaps, resulted to the leaching of Iron from the steel tank, hence, higher concentration of iron the steel tank. High concentrations of heavy metals, above the WHO permissible limits, have been detected in rainwater [13]. The results showed that the average concentration of Iron exceeded the WHO permissible limits for the water stored in the plastic and steel tanks, respectively (Table 1).

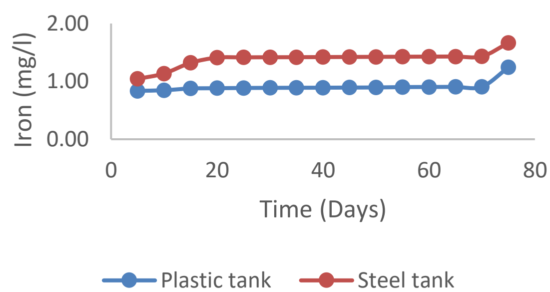

Figure 3: Iron variation in storage tanks with time

3.1.3 Total dissolved solids and electrical conductivity

The results of total dissolved solids (TDS) and electrical conductivity, for rainwater stored in the plastic and steel tanks, are shown in Figures 4 and 5. Prior to storage, the concentration of TDS and EC in the rainwater were 40mg/l and 0.07mS/cm, respectively. The minimum and maximum TDS concentrations for the plastic tank stored water were 20 mg/l and 80 mg/l, respectively (Figure 4). Also, the minimum and maximum TDS for the steel tank stored water were 10 mg/l and 120 mg/l , respectively (Figure 5). The average concentrations of the TDS, corresponding to the plastic and steel tank stored water, were 44 mg/l and 46 mg/l, respectively.

Also, the minimum and maximum EC for the plastic tank stored water were 40 μS/cm and 400 μS/cm, respectively. The minimum and maximum EC for the steel tank stored water were 10 μS/cm and 860 μS/cm, respectively. The average concentrations of the TDS, corresponding to the plastic and steel tank stored water, were 153.3 μS/cm and 190.7 μS/cm, respectively (Table 1). The average values of TDS and EC are comparable with those obtained by Nnaji and Nnam [14]. The rainwater obtained from the study area was characterized as freshwater, considering that it has a TDS value not greater than 1000mg/l [15].

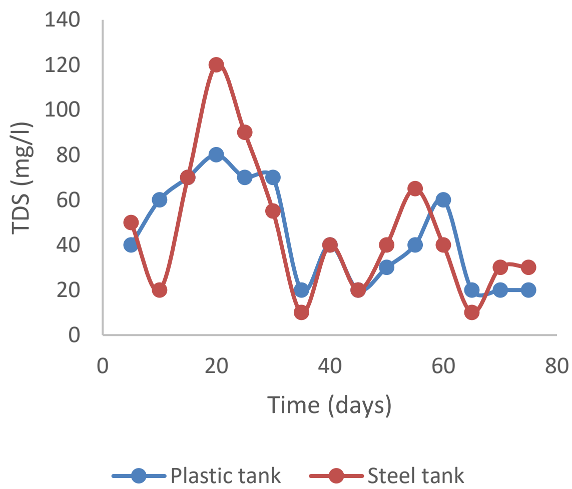

Figure 4: Total dissolved solids variation in storage tanks with time

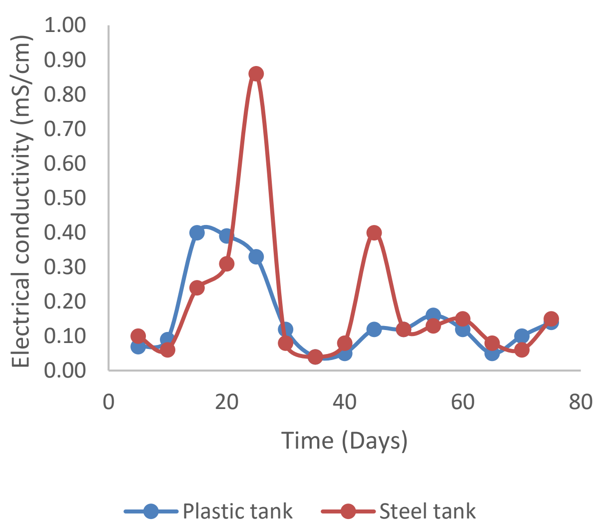

Figure 5: Electrical conductivity variation in storage tanks with time

Table 1: Comparison of water quality parameters with the WHO standard

Parameter	Control	Plastic reservoir	Steel reservoir	WHO (2011)
pH	5.3	5.0	5.2	6.5 - 8.5
EC (mS/cm)	0.07	0.15	0.19	
TDS (mg/l)	40	44.0	46.0	1000
Temperature (Deg)	25.3	28.1	28.4	
Fe (mg/l)	0.26	0.91	1.39	0.3

4.0 CONCLUSION

The preliminary assessment of the physicochemical characteristics of rainwater, stored in plastic and steel tank, was carried out and compared with the WHO guidelines for drinking-water quality. The acidic nature of the rainwater as well as the exceedance of the guideline value for Iron call for concern. There is need for continuous monitoring of the quality of rainwater, especially, those stored for duration, long enough to further impact the water quality. A further prognosis of the potential human health risk associated with exposure to stored rainwater is recommended.

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References

[1] O. O. Aladenola and O. B. Adeboye, "Assessing the potential for rainwater harvesting," *Water resources management,* vol. 24, pp. 2129-2137, 2010.

[2] B. Helmreich and H. Horn, "Opportunities in rainwater harvesting," *Desalination,* vol. 248, no. 1-3, pp. 118-124, 2009.

[3] M. Zdeb, J. Zamorska, D. Papciak, and A. Skwarczyńska-Wojsa, "Investigation of microbiological quality changes of roof-

harvested rainwater stored in the tanks," *Resources,* vol. 10, no. 10, p. 103, 2021.
[4] T. H. Thomas and D. B. Martinson, *Roofwater harvesting*. 2007.
[5] I. Urban, "Rainwater harvesting and utilisation," 2002.
[6] G. Owusu-Boateng and M. Gadogbe, "Domestic rainwater harvesting in a water-stressed community and variation in rainwater quality from source to storage," *Consilience,* no. 14, pp. 225-243, 2015.
[7] S. Ward, F. Memon, and D. Butler, "Performance of a large building rainwater harvesting system," *Water research,* vol. 46, no. 16, pp. 5127-5134, 2012.
[8] S. Ward, F. Memon, and D. Butler, "Rainwater harvesting: model-based design evaluation," *Water Science and Technology,* vol. 61, no. 1, pp. 85-96, 2010.
[9] C. Despins, K. Farahbakhsh, and C. Leidl, "Assessment of rainwater quality from rainwater harvesting systems in Ontario, Canada," *Journal of Water Supply: Research and Technology—AQUA,* vol. 58, no. 2, pp. 117-134, 2009.
[10] R. Charlson and H. Rodhe, "Factors controlling the acidity of natural rainwater," *Nature,* vol. 295, no. 5851, pp. 683-685, 1982.
[11] M. Rezaul Karim, "Quality and suitability of harvested rainwater for drinking in Bangladesh," *Water Science and Technology: Water Supply,* vol. 10, no. 3, pp. 359-366, 2010.
[12] S. Dewangan, S. Shrivastava, V. Tigga, M. Lakra, and P. Namrata, "Review paper on the role of pH in water quality implications for aquatic life, human health, and environmental sustainability," *International Advanced Research Journal in Science, Engineering and Technology,* vol. 10, no. 6, pp. 215-218, 2023.
[13] H. Malassa, F. Al-Rimawi, M. Al-Khatib, and M. Al-Qutob, "Determination of trace heavy metals in harvested rainwater used for drinking in Hebron (south West Bank, Palestine) by ICP-MS," *Environmental monitoring and assessment,* vol. 186, pp. 6985-6992, 2014.
[14] C. Nnaji and J. Nnam, "Assessment of potability of stored rainwater and impact of environmental conditions on its quality," *International Journal of Environmental Science and Technology,* vol. 16, no. 12, pp. 8471-8484, 2019.
[15] C. E. Boyd and C. E. Boyd, "Dissolved solids," *Water Quality: An Introduction,* pp. 83-118, 2020.