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Comparative Analysis of Rain Water Quality in Makurdi Metropolis

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Abstract

Introduction/Background- Rainwater is the purest form of naturally occurring water. It is considered to be produced through natural distillation. However, it contained dissolved gases such as carbon dioxide, sulphur dioxide, nitrogen dioxide, ammonia, fine particulate materials or aerosols, etc from the atmosphere WHO (2011).
Aim/Objectives- Physicochemical, heavy metals and microbiological parameters were analyzed. Sampling was done for three consecutive months (June, July and August, 2024).
Methodology-Standard methods as prescribed by the Association of Official Analytical Chemists (AOAC) were adopted for the research analysis.
Research Findings-The results revealed the mean values for temperature, pH, turbidity, conductivity, total hardness, TDS, SS, Colour, SO_4^{2-}, PO_4^{3-}, and NO_3^- ranged between 21.0 to 24.1°C, 6.0 to 6.10.57 to 4.39 (NTU), 3 to 6 (µS/cm), 20 to 24 (mg/L), 0.2 to 1.0 (mg/L), 0 to 58 mg/L, 104 to 124 (mg/L), 7 to 8 (mg/L), 0.28 to 0.7 mg/L, and 2.1 to 2.9 (mg/L) respectively. Similarly, 2.5 to 3.2 (mg/L), 0.2 to 0.4 (mg/L), 0.4 to 0.8 (mg/L) and 108 to 159 (FTU) were observed as the mean values for DO, BOD, COD, and Chloride, respectively. The results also revealed low values of heavy metal levels in the rainwater with values ranging between 0.182 to 0.426 (mg/L), 0.009 to 0.01 (mg/L), 0.001 to 0.002 (mg/L), 0.008 to 0.011 (mg/L) and 0.018 to 0.376 (mg/L) for Zn, Cd, Al and Fe, respectively. Ni, and total coliform were not detected in all the samples.
Conclusion/Recommendation-The results of the analysis revealed that water quality parameters for the rainwater samples were within the permissible limit prescribed by WHO and NAFDAC, except for Fe and pH therefore recommended for domestic usage. Further research should be carried out on seasonal variation in the quality of rainwater in the study area.

Keywords: *Rainwater, Quality, Physicochemical, Microbiological, Metals*

1.0 Introduction

Water is one of the most important and abundant compounds of the ecosystem. All living organisms on earth need water for their survival and growth (Pawar-Patil and Sagar 2013). Potable water is yearned for globally, it has been difficult for both the government and non-governmental organizations who from day to day strife to provide potable water to meet the daily requirements of the masses (Olaoye et al., 2013). Harvesting of rain water for domestic use is one of the ways adopted in addressing water problem.

Access to safe drinking water is key to sustainable development and essential to food production, quality health and poverty reduction. Safe drinking water is essential to life and is made available to consumers. Therefore, water intended for human consumption must not contain pathogens or harmful chemicals; because water contaminated with microorganisms may cause epidemics. That is, good drinking water is not a luxury but one of the most essential requirements of life itself. The WHO revealed that seventy-five percent of all diseases in developing countries arise from polluted drinking water (Olowoye D.N., 2011). Therefore, water quality concerns are often the most important component for measuring access to improved water sources.

Rainwater is a form of water that is in droplets or ice that have been considered from atmospheric water vapour and then precipitated. Rain is formed through transpiration and evaporation of water to atmosphere. It is a major component of water cycle and is responsible for deposition of most fresh water on the earth. It is a necessary part of the water cycle on planet Earth and vital to a balanced ecosystem. Rain falling from the sky allows water to reenter lakes, rivers and oceans after being cycled via evaporation. It is harvested for use on gardens and for drinking.

Rainwater is the purest form of naturally occurring water. It is considered to be produced through natural distillation. However, it contained dissolved gases such as carbon dioxide, sulphur dioxide, nitrogen dioxide, ammonia, fine particulate materials or aerosols, etc from the atmosphere WHO (2011).

Rainwater harvesting began in Europe where earth and masonry dams were constructed, not only to store runoff but also to raise the general water level. Rainwater harvesting, in its broadest sense is a technology used for collecting, conveying and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques (Adriano et al., 2011).

Rain water is one of the major sources of water supply to the entire populace of the study areas, owing to the fact that, there is no effective supply of pipe-borne water from the water works and boreholes water development is highly cost effective. Also, the study areas are densely populated most especially Northbank and full of vehicular activities such as heavy duty cars which results in emission of gases that can pollute the environment, as such there is need to analyzed the quality of rain water within the study areas.

2.0 Literature Review

Olaruntade and Oguntunde (2009), found that rainwater harvesting provides a good alternative and replacement in times of drought or when the water-table drops and wells go dry, also in the aridest or semi-arid areas, the prevailing climate condition makes it of crucial importance to use the limited amount of rainwater as efficiently as possible, as people realize that it cannot be managed.

Anhwange, et al., (2022), observed that harvested rainwater could be contaminated with a variety of pathogenic organisms. Since the collection of rainwater for storage has become a common practice in areas where the commodity is scarce.

A study by (Ipav et al., 2012) revealed that the greater the amount of suspended solids in the water, the higher the measured turbidity. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria and dissolved chemicals

In recent time, rainwater harvesting technology has, however, quickly regained popularity as users realize the benefits of a relatively clean, reliable and affordable water source at home. In the six geographical regions of Nigeria, rainwater harvesting has now been introduced as part of an integrated water supply, where the town water supply is unreliable, or where local water sources dry up for a part of the year, while rainwater can also be introduced as the sole water sources for communities or households (Omolare L and Oloke D. 2015).

3.0 Materials and Methods

Description of study area: Makurdi metropolis, the Benue State capital is the study area and is located at latitude 7°38'N - 7°50'N and longitude 8°24'E - 8°38'E. It is situated in the Benue valley in North Central region of Nigeria. It is traversed by the second largest river in the country, the River Benue (Aho et al., 2013). Makurdi is bordered by Guma Local Government Area to the North, Gwer Local Government to the South, Gwer-West Local Government Area to the South-West and Doma Local Government Area of Nasarawa State to the North-West (Terwase S and Terese E.T (2013)

Sample Collection: Rainwater samples were collected from three sampling sites, High Level (HL), North bank (NB) and Wurukum (WK) all within Makurdi Metropolis. This was done for three consecutive months (June, July and August) during the rainy season. The sampling containers (clean acid-washed polyethylene bottles) were fixed at a height of 1.5 m above the ground to avoid contamination from dirt on the ground and the water was collected using glass funnel. For heavy metals analysis, 1 mL of conc. HNO_3 was added and stored in a refrigerator at 4 °C before analysis. All containers for bacteriological analysis in addition to previous treatment were sterilized in an autoclave at 121 ºC for 15minutes.

Methods: Temperature was determined at the sampling sites using mercury in glass thermometer. pH was determined using pH meter, total dissolved solid and conductivity were determined using TDS kit model 50150 made by HACH. Turbidity was determined using Turbidity Meter (NT-100), colour, suspended solid, phosphate, sulphate, nitrate and suspended solids were determined using direct reading spectrophotometer (DR/2000) made by the HACH Company. Dissolved oxygen was determined using dissolved oxygen analyzer (JPB-607) portable while biochemical oxygen demand was determined using mathematical expression:

$$BOD\ mgL^{-1} = DO_i - DO_f / \text{dilution factor}$$

where:

DO_i = dissolved oxygen before incubation

DO_f= dissolved oxygen after incubation for five days

Total hardness was determined using Hardness EDTA titration while total coliform was carried out using the multiple tube technique as described by Cheersbrough (2006). Determination of heavy metals was carried out using Atomic absorption spectrophotometer (AAS Model PG 990).

4.0 Results and Discussion

Table 1: Water quality parameters as prescribed by WHO (2011) and NAFDAC

Parameters	WHO (2011)	NAFDAC
Temperature (ºC)	20-32	-
pH	6.5-8.5	6.5-8.5
Turbidity (NTU)	0-5	-
Conductivity (µS/cm)	1000	1000
Total Hardness (mg/L)	100-500	100
Total Dissolved Solids (mg/L)	1000	500
Suspended Solids (mg/L)	150	-
Dissolved Oxygen (mg/L)	5-7	-
Biochemical Oxygen Demand (mg/L)	30	-
Chemical Oxygen Demand (mg/L)	255	-
Chloride (mg/L)	250	200
Sulphate (mg/L)	250	-
Phosphate (mg/L)	5	-
Nitrate (mg/L)	500	50
Zinc (mg/L)	3	5
Cadmium	0.003	0.003
Iron (mg/L)	0.3	0.3
Aluminium (mg/L)	0.5	0.5
Nickel (mg/L)	0.02	-
Total coliform count (cfu/m)	0	0

Table 2: Physicochemical properties of Rainwater harvested in June

Physicochemical Parameters	Sampling Areas			WHO Guidelines (2011)	NAFDAC Guideline
	Wurukum	**High Level**	**Northbank**		
Temp (°C)	22.3 ± 0.39	21.0 ± 0.00	23.2 ± 0.22	20-32	
pH-	6.1 ± 0.10	6.0 ± 0.00	6.0 ± 0.04	6.5-8.5	6.5-8.5
Turb (NTU)	1.31 ± 0.32	1.36 ± 0.44	0.64 ± 0.35	0-5	
Cond (µS/cm)	4.0 ± 1.79	4.0 ± 1.47	6.0 ± 2.24	1000	1000
T.H (mg/L)	20 ± 0.00	20 ± 0.00	20 ± 0.00	100-500	100
TDS (mg/L)	1.0 ± 0.80	0.40± 0.49	1.0 ± 0.98	1000	500
SS (mg/L)	50 ± 5.31	51 ± 17.30	58 ± 24.63	150	-
DO (mg/L)	3.1 ± 0.09	2.9 ± 0.14	2.5 ± 1.17	5-7	
BOD (mg/L)	0.3 ± 0.23	0.3 ± 0.14	0.3 ± 0.20	30	
COD (mg/L)	0.6 ± 0.46	0.6 ± 0.28	0.6 ± 0.39	255	
Cl^-(mg/L)	106 ± 0.00	124 ±11.38	104 ± 1.96	250	200
SO_4^{2-} (mg/L)	7.4 ± 0.49	8.0 ± 0.40	8.0 ± 0.49	250	
PO_4^{3-}(mg/L)	0.70 ± 0.25	0.38 ± 0.08	0.45 ± 0.04	5	
NO_3^-(mg/L)	2.3 ± 0.16	2.9 ± 0.43	2.1 ± 0.05	500	50

TH= Total Hardness, TDS=Total Dissolved Solids, SS=Suspended Solids, DO=Dissolved Oxygen, BOD=Biochemical Oxygen Demand, COD=Chemical Oxygen Demand, ND=Not detected.

Table 3: Physicochemical properties of Rainwater harvested in July

Physicochemical Parameters	Sampling Areas			WHO Guidelines (2011)	NAFDAC Guideline
	Wurukum	**High Level**	**Northbank**		
Temp (°C)	22.4 ± 0.51	21.4 ± 0.30	22.6 ± 0.16	20-32	
pH	6.0± 0.08	5.0 ± 0.08	7.0 ± 0.00	6.5-8.5	6.5-8.5
Turb (NTU)	1.32 ± 0.31	1.57 ± 0.35	1.13 ± 0.37	0-5	
Cond (µS/cm)	4.0 ± 1.20	3.0 ± 1.36	5.0 ± 1.47	1000	1000
T.H (mg/L)	20 ± 0.00	24 ± 8.00	20 ± 0.00	100-500	100
TDS (mg/L)	2.0 ± 0.49	0.0±0.00	2.0 ± 0.10	1000	500
SS (mg/L)	52 ± 10.09	54 ± 12.38	46 ± 5.11	150	-
DO (mg/L)	3.0± 0.10	2.9 ± 0.14	2.5 ± 1.17	5-7	
BOD (mg/L)	0.4 ± 0.22	023 ± 0.17	043 ± 0.16	30	
COD (mg/L)	0.8 ± 0.45	0.4 ± 0.33	0.8 ± 0.32	255	
Cl^-(mg/L)	106 ± 0.63	107 ±4.27	164 ± 0.10	250	200
SO_4^{2-} (mg/L)	7.0± 0.40	8.0 ± 0.63	8.0 ± 0.50	250	
PO_4^{3-}(mg/L)	0.56 ± 0.02	0.49 ± 0.52	0.30 ± 0.11	5	
NO_3^-(mg/L)	2.4 ± 0.22	2.8 ± 0.26	2.8 ± 0.04	500	50

TH= Total Hardness, TDS=Total Dissolved Solids, SS=Suspended Solids, DO=Dissolved Oxygen, BOD=Biochemical Oxygen Demand, COD=Chemical Oxygen Demand, ND=Not detected.

Table 4: Physicochemical properties of Rainwater harvested in August

Physicochemical Parameters	Sampling Areas			WHO Guidelines (2011)	NAFDAC Guideline
	Wurukum	High Level	Northbank		
Temp (°C)	22.5 ± 0.45	21.1 ± 0.21	2342 ± 0.34	20-32	
pH-	6.0± 0.45	6.0 ± 0.04	6.0± 0.45	6.5-8.5	6.5-8.5
Turb (NTU)	4.91 ± 0.15	4.27 ± 0.11	0.56 ± 0.10	0-5	
Cond (µS/cm)	4.2 ± 0.10	4.0 ± 1.36	6.0 ± 1.94	1000	1000
T.H (mg/L)	20 ± 0.00	20 ± 0.00	20 ± 0.00	100-500	100
TDS (mg/L)	1.0± 0.10	0.2 ± 0.40	1.0 ± 0.08	1000	500
SS (mg/L)	46 ± 5.11	53 ± 22.44	40 ± 2.28	150	-
DO (mg/L)	3.2 ± 0.12	3.0 ± 0.06	26 ± 0.31	5-7	
BOD (mg/L)	0.4 ± 0.16	0.3 ± 0.20	0.2 ± 0.07	30	
COD (mg/L)	0.8 ± 0.32	0.6 ± 0.41	0.4 ± 0.15	255	
Cl^-(mg/L)	106 ± 1.00	117 ± 6.60	108 ± 5.43	250	200
SO_4^{2-} (mg/L)	8.0 ± 0.50	8.0 ± 0.50	8.0 ± 0.50	250	
PO_4^{3-}(mg/L)	0.28 ± 0.11	0.56 ± 0.04	0.50 ± 0.05	5	
NO_3^-(mg/L)	2.8 ± 0.04	2.7 ± 0.41	2.1 ± 0.14	500	50

TH= Total Hardness, TDS=Total Dissolved Solids, SS=Suspended Solids, DO=Dissolved Oxygen, BOD=Biochemical Oxygen Demand, COD=Chemical Oxygen Demand, ND=Not detected.

Physicochemical Properties

The mean values for temperature were found to be 22.3 °C, 21.0 °C and 23.2 °C, at Wurukum (WK), High Level (HL), and Northbank (NB), respectively in June, while in July, 24.1°C, 21.4 and 22.6 °C were also recorded at WK, HL, and NB, respectively. Similar results of temperature were found to be 22.5 °C, 22.1 °C and 23.4 °C at WK, HL, and NB, respectively in August.

Temperature is an important factor which influences the chemical, biochemical and biological characteristics of an aquatic system. It controls the rate of all chemical reactions (Ochori, and Aholo 2012).The rate of microbial activities increase with increase in temperature (Lodh R., et al., 2014). Although the temperature was found to vary with time of collection. However, the results of this study showed the temperature to be within the WHO permissible limit 20 °C to 32 °C.

The result indicates mean values for pH to be 6.0 at HL and NB in June and 6.1 at WK. In July, the mean values were found to be 6.0 at WK, HL and NB. Similarly, the pH of the rainwater was found to be 6.0 in all the sampling areas in August. The results revealed slight acidity of rainwater.

pH is a measure of the concentration of the hydrogen ion, which determines how acidic or basic the water is. The pH scale for household water range between 0-14. pH values less than 7 are considered acidic while values greater than 7 are considered basic. Water with pH values below 6.5 may be corrosive whereas pH above 8.5 may cause encrustation, scaling and a bitter taste (Mustafa et al., 2013). Even though pH has no direct effect on human health, its indirect action on the physiological process cannot be over emphasized (Olumuyiwa et al., 2012).

The values of turbidity for the month of June were found to be 1.31 NTU, 1.36 NTU and 0.64 NTU at WK, HL and NB, respectively while 1.32 NTU, 1.57 NTU and 1.13 NTU were obtained at WK, HL and NB, respectively in July. The results for August showed the range values of 4.39 NTU, 4.27 NTU, and 0.57 NTU for WK, HL and NB, respectively. Turbidity refers to water clarity. The greater the amount of suspended solids in the water, the higher the measured turbidity. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria and dissolved chemicals (Ipav et al., 2012). The mean value for turbidity is slightly higher than the values reported by Ipav et al., 2012 and can be deduced from the result of the study that the water has a very low turbidity.

The mean values for conductivity were found to be 4 µS/cm at both WK and HL and 6 µS/cm at NB in June. The values obtained in July were found to be 4 µS/cm, 3 µS/cm, and 5 µS/cm at WK, HL and NB, respectively. Similarly, 4.2 µS/cm, 45 µS/cm and 6 µS/cm were obtained at WK, HL and NB, respectively in August.

The highest value 6 µS/cm was recorded in both June and July (Tables 2-4) and the lowest value was 2µS/cm. Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. Electrical conductivity increases with an increase in total dissolved solids and vice versa (Anhwange et al., 2012) .The electrical conductivity of the sample was found to decreases with decrease in total dissolve solids (Tables 1-3). Conductivity values below 50 µS/cm are regarded as low, while those between 50 to 600 µS/cm are said to be medium and values above 600 µS/cm are considered to be high (Eze and Chigbu 2015). The electrical conductivity of the rainwater was found to be very low, and it is clear that the rain water is free from considerable contamination of cations and anions from the atmosphere and this indicate its purity.

The value for Total Hardness was found to be 20 mg/L in June, July and August in all the three sampling sites. The mean value was found to be 24 mg/L at HL in June (Table 3). Water hardness is due to the presence of multivalent metal ions which comes from minerals dissolved in the water (Sa'eed M.D and Mahamed A.D. 2014). The World Health Organization (WHO) International Standard for Drinking Water (1998) classified water with a total hardness of $CaCO_3$ less than 50 mg/L as soft water, 50 to 150 mg/L as moderately hard water and water hardness above 150 mg/L as hard (Zhian etal., 2024). Natural sources of hardness principally are lime stones which are dissolved by percolating rainwater made acidic by dissolved carbon dioxide. Industrial sources include discharges from operating and abandoned mines (Adhena et al., 2015). Ipav et al., 2012 reported that the total hardness of rainwater harvested in Gboko area of Benue State is 40 mg/L indicating soft water. It can be deduced that all the rain water samples analyzed are soft, and safe for drinking and other domestic purposes since the values did not exceed the permissible limit prescribed by WHO.

The results for total dissolved solids (TDS) recorded in June were found to be 1.00 mg/L at WK and NB, and 0.40 mg/L at HL. Similarly, 1 mg/L was also recorded at WK and NB and was not detected at HL in July. The results for August indicate that 1 mg/L was observed both at WK and NB, while 0.2 mg/L was also recorded at HL.

Total Dissolved Solids (TDS) include both dissolved organic and inorganic components that are small enough to pass through a very fine filter (2.0 microns). TDS of rainwater depends upon the quantity of rain fall (Prasad et al., 2014). The highest value for TDS is 1 mg/L. Water with high TDS value indicates that the water is highly mineralized (Ftsum et al., 2015). High total dissolved solid reduces water clarity.

The mean values for suspended solids (SS) were found to be 50 mg/L, 51 mg/L and 58 mg/L at WK, HL and NB, respectively in June, while in July, the values of SS were 52 mg/L, 54 mg/L, and 46 mg/L at WK, HL, and NB respectively. Similar results were also observed in August with values of SS to be 46 mg/L, 53 mg/L and 40 mg/L at WK, HL and NB, respectively. The suspended solid content of water depends on the amount of suspended particle, soil and silt which is directly related to turbidity of water**.** The greater the amount of total suspended solids, the higher the turbidity, thus suspended solids have a relation with clarity of water. Water with high suspended solids is not suitable for bathing or drinking.

The mean values for Dissolved oxygen were found to be 3.1 mg/L, 2.9 mg/L and 2.5 mg/L at WK, HL and NB, respectively in June. 3.0 mg/L, 2.9 mg/L, and 3.24 mg/L was also recorded in July and 3.2 mg/L, 3.0 mg/L and 2.6 mg/L were recorded in August for WK, HL, and NB respectively. The highest concentration 3.2 mg/L (Tables 3 and 4) was recorded in the months of June and August, and lowest concentration of 2.6 mg/L in July (Table 4). Dissolved oxygen (DO) refers to the volume of oxygen present in water and it is a basic indicator of ecosystem health. The presence of dissolved oxygen is required to prevent odour and is suitable for use by aquatic plants and other life forms. The higher rate of decomposition of organic matter and limited flow of water leads to consumption of dissolved oxygen (Omolara, and Olatunde, 2017).

The BOD mean values were found to be 0.3 mg/L at WK, HL and NB in the month of June, 0.4 mg/L at WK and NB, and 2.9 mg/L at HL in July. In August, the mean values of BOD were found to be 04 mg/L, 0.3 mg/L and 0.2 mg/L at WK, HL, and NB, respectively. Biochemical Oxygen Demand refers to the amount of oxygen that would be consumed if all the organic matter present in water were oxidized by bacteria and other micro-organisms which are present in water. When the BOD is high, the dissolved oxygen becomes low. Hence, the greater the BOD, the greater the pollution level of the water (Ravindra and Arvind 2015).

The mean values for COD obtained were found to be 0.6 mg/L in all the sampling areas in June. In July, the values were found to be 0.8 mg/L at both WK and NB and 0.4

mg/L at HL. While in August, the values 0.8 mg/L, 0.6 mg/L and 0.4 mg/L were obtained for WK, HL and NB, respectively. Chemical oxygen demand (COD) is a measure of the oxygen equivalent of the organic matter content of water that is susceptible to oxidation by a strong chemical oxidant. It is used in measuring the level of water pollution. The COD increases with increasing concentration of organic matter (Pawan, et al., 2017). COD values indicate the amount of dissolved oxidizable organic matter including the non-biodegradable matter.

The results for chloride were found to be 106 mg/L, 124 mg/L and 104 mg/L at WK, HL, and NB respectively in June. About 107 mg/L was recorded at HL while a mean value of 106 mg/L was observed for both WK and NB in the month of July. In August, 106 mg/L, 117 mg/L and 108 mg/L were recorded for chloride at WK, HL and NB, respectively. Chloride usually occurs as NaCl, $CaCl_2$ and $MgCl_2$ in widely varying concentration, in all natural waters. Chloride is found in water by the solvent action of water on salts present in the soil. it is non-toxic to humans, but elevated levels make water unpotable due to the salty taste (Yasmeen, et al., 2021).

The values for SO_4^{2-} were found to be 8 mg/L at HL and NB, and 7 mg/L at WK in both June and July while in August, 8 mg/L was recorded in all the sampling areas. The value for sulphate recorded is slightly higher than the value reported by Chukwuma, et al., (2013).

Sulphur enters the atmosphere principally as sulfur dioxide (SO_2), an air pollutant with a lifetime of about 1 to 2 days, before it is normally deposited or oxidized into sulfate (SO_4^{2-}). Presence of sulphate in drinking-water can cause noticeable taste. It is generally considered that taste impairment is minimal at levels below 250 mg/L. No health-based guideline value has been derived for sulphate. However, the study recorded low sulphate concentrations that suggest that the SO_2 discharged into the atmosphere by human activities in the metropolis could be moderate or insignificant (Emerole, et al., 2015).

The mean values for PO_4^{3-} were found to be 0.70 mg/L, 0.38 mg/L and 0.45 mg/L at WK, HL, and NB respectively in June. Similarly, 0.56 mg/L, 0.49 mg/L and 0.30 mg/L were also recorded at WK, HL and NB, respectively while in July. In August, about 0.28 mg/L, 0.56 mg/L, and 0.50 mg/L were recorded for WK, HL and NB, respectively. The highest value of phosphate was found to be 0.7 mg/L (Table 4) while the lowest 0.28 mg/L (Table 4) was found at Northbank. Phosphate is a generic term for the oxy-anions of phosphorous. Enrichment of water with organic phosphates and nitrates results in an excessive growth of plants and other micro-organisms leading to eutrophication and increased biochemical oxygen demand Cheesbrough M. (2006).

The mean values for Nitrate were found to be 2.3 mg/L, 2.9 mg/L and 2.1 mg/L at WK, HL, and NB, respectively in June while in July, 2.4 mg/L, 2.8 mg/L, and 2.8 mg/L were observed for WK, HL and NB, respectively. Similar values were also observed in August with WK, HL, and NB having values of nitrate as 2.8 mg/L, 2.7 mg/L and 2.1 mg/L, respectively. The results obtained are lower than the values reported by Ipav, et al., (2012).

Table 5: Mean Concentrations of Heavy Metals in Rain water harvested at Wurukum.

Months	**Concentrations (mg/L)**				
	Zn	**Cd**	**Fe**	**Al**	**Ni**
June	0.244±0.003	0.011±0.005	0.023±0.001	0.001±0.000	ND
July	0.549 ± 0.005	ND	0.019 ± 0.000	0.024 ± 0.000	ND
August	0.484 ± 0.300	ND	0.012 ± 0.002	ND	ND
WHO (2011)	3	0.003	0.3	0.5	0.02
NAFDAC Guidelines	5	0.003	0.3	0.5	

WHO= World Health Organization. NAFDAC= National Agency for Food and Drugs, Administration and Control, ND=Not detected

Table 6: Mean Concentrations of Heavy Metals in Rain water harvested at High Level.

Months	**Concentrations (mg/L)**				
	Zn	**Cd**	**Fe**	**Al**	**Ni**
June	0.159±0.001	0.009±0.004	0.196 ±0.019	0.016±0.000	ND
July	0.204±0.040	0.011±0.005	0.135 ±0.000	0.006±0.000	ND
August	0.300±0.009	0.009±0.000	0.244±0.001	0.012±0.000	ND
WHO (2011)	3	0.003	0.3	0.5	0.02
NAFDAC Guidelines	5	0.003	0.3	0.5	

WHO= World Health Organization. NAFDAC= National Agency for Food and Drugs, Administration and Control, ND=Not detected

Table 7: Mean Concentrations of Heavy Metals in Rain water harvested at North bank.

Months	Concentrations (mg/L)				
	Zn	**Cd**	**Fe**	**Al**	**Ni**
June	0.181±0.009	ND	0.328±0.001	ND	ND
July	0.239 ± 0.008	ND	0.244 ± 0.002	0.02 ±0.000	ND
August	0.125 ± 0.004	ND	0.557 ± 0.002	0.023±0.000	ND
WHO (2011)	3	0.003	0.3	0.5	0.02
NAFDAC Guidelines	5	0.003	0.3	0.5	

WHO= World Health Organization. NAFDAC= National Agency for Food and Drugs, Administration and Control, ND=Not detected

Heavy Metals

Zinc (Zn)

The results revealed the concentration of Zn to range between 0.244-0.484 mg/L, 0.159-0.239 mg/L, and 0.125-0.239 mg/L at WK, HL, and NB, respectively in June, July and August. However, the highest value obtained was 0.549 mg/L at WK (Table 5-7). This value is below the NAFDAC and WHO limits (3.0 mg/L) for drinking water. Zinc is an important trace element that plays a vital role in the physiological and metabolic process of many organisms. Nevertheless, higher concentrations of zinc can be toxic to organisms (Samuel, et al., 2015)

Cadmium (Cd)

The concentration of Cd was found to range between 0.009-0.011 mg/L and 0.001-0.002 mg/L at HL, and NB in June, July, and August. The value recorded at WK was 0.011 mg/L. Mean Cd levels in rainwater samples at High Level was 0.009 mg/L (Table 6). This value is slightly above WHO permissible limit for drinking water. Cadmium is a toxic and carcinogenic metal (Pratiksha, et al., 2013) .The high concentration of Cd could be as a result of combustion product in the accumulators of motor vehicles or in carburetors. Cadmium affects the nervous system, causes damage to DNA and the immune system, and enhances the development of cancer. It can also cause other non-cancerous diseases that include loss of sense of smell and taste, fibrosis, upper respiratory diseases, shortness of breath, skeletal effects, lumbago, hypertension, tubular proteinuria, and cardiovascular diseases Sheshe, and Magashi, (2014).

Iron (Fe)

The concentration of Fe was found to range between 0.012-0.023 mg/L, 0.135-0.224 mg/L and 0.244-0.557 mg/L at WK, HL, and NB respectively in June, July and August. The values for Fe in rainwater sampled at WK and HL were within the

WHO permissible limit for drinking water. The results obtained at NBM were relatively high 0.244 mg/L to 0.557 mg/L and is attributed to vehicular component wearing and detachment such as tires. Northbank is faced with the problem of high vehicular emission due to the upsurge in vehicle ownership recently and activities of heavy duty vehicles. Thus vehicular emission is expected to be the major source of air pollution in the metropolis (Anhwange, et al, 2012)

Aluminium (Al)

The concentration of Al was found to range between 0.001 to 0.024 mg/L, 0.006-0.016 mg/L, and 0.023-0.27 mg/L at WK, HL, and NB respectively in June, July and August. The concentrations for Al in all the samples across the three sampled areas were below WHO permissible limit of 0.5 mg/L for drinking water.

Naturally occurring aluminium, as well as aluminium salts used as coagulants in treatment of drinking water are the primary sources of aluminium in water. The presence of aluminium at concentrations in levels of 0.1-0.2 mg/L often leads to deposition of aluminium hydroxide floc in water (Vaishnavi, and Shelly, 2015).

Nickel (Ni)

The results of the study indicate that the areas of study are free from Ni contamination (Tables 5-7). Nickel was not detected in all the samples for the various sites and months.

Table 8: Microbiological analysis of Rain water harvested within Makurdi Metropolis

Parameter	**Sampling Area**			**WHO Guideline (2011)**	**NAFDAC Guideline**
	WK	**HL**	**NB**		
Total Coliform Count (cfu/m)	ND	ND	ND	0	0

WK=Wurukum, HL=High Level, NB=Northbank, WHO=World Health Organization. NAFDAC= National Agency for Food and Drugs, Administration and Control, ND= Not Detecte

Microbiological Counts

The microbiological parameter assessed in this research showed negative confirmation test to taotal coliform 0 cfu/m (Table 8) across the three sampling sites. Total and faecal coliform bacteria tests are used to assess bacteriological water quality. These tests are used to index hygienic quality because total and faecal coliform are usually used to indicate the degree of pathogenic risks (Samuel, et al., 2015). Coliforms are a broad class of bacteria found in our environment, including the faece of man and other warm-blooded animals. The presence of Coliform bacteria (*E. coli*) in water can lead to disease condition. The symptoms of these diseases may include; diarrhea, nausea, vomiting, cramps or other gastro intestinal distress and in severe cases can be fatal (Shrihari, 2023).

5.0 Conclusion

The results of the study revealed that the physicochemical, microbiological and heavy metals quality of rainwater harvested within Makurdi metropolis are within the permissible limit prescribed by WHO and NAFDAC except Fe which was slightly above the recommended value. This is attributed to vehicular component wearing and detachment such as tires. Northbank is faced with the problem of high vehicular emission due to the upsurge in vehicle ownership recently and activities of heavy duty vehicles. Thus vehicular emission is expected to be the major source of air pollution in the metropolis

Despite the anthropogenic activities in the metropolis, the study revealed that the activities have not impacted on the rainwater. Therefore harvested rainwater within the study areas could be classified as safe for domestic usage.

6.0 Recommendation

The researchers therefore recommend that members of the community within the study area should adopt rainwater storage system so as to alleviate scarcity especially during the dry season. It is also recommended that government should provide and locate water supply projects in the three communities. More research should be carried out on seasonal variation in rainwater quality in Makurdi metropolis.

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