Rainwater Quality as a Function of Time of Harvest

Anhwange, BA and Magashi, NL.*

Department of Chemistry, Benue State University, Makurdi

ABSTRACT

Rainwater samples were collected at five minute intervals up to 25 minutes and assessed for physicochemical, total coliform load and some heavy metals. This was aimed at evaluating the purity of the rainwater through the progress of the rain duration. The result of temperature for the three months was found to range from 21.9 - 23.4 25°C, pH was found to range between 6.0-6.20, turbidity was observed to range between 0.67-2.11NTU. Conductivity was observed to range from 2-7 µs/cm, total hardness was constant be 20 mg/L, while total dissolved solids was found to be between 1 to 2 mg/L. Total suspended solids range between 36 to 62 mg/L. The mean values of BOD and COD were found to range between 0.1- 0.80 mg/L and 0.4-1.6 mg/L respectively. Chloride and sulphates were found to range between 102 mg/L to 112 mg/L and 7 to 9 mg/L respectively. Phosphates and nitrates were found to range between 0.13mg/L to 0.60 mg/L and 2.0 mg/L to 3.0mg/L respectively. Result of total coliform count was negative in all samples. Varying concentrations of heavy metals was observed; Zn (0.159 - 0.30) mg/L, Cadmium, lead, aluminum and iron were found to range between 0.009-0.11mg/L, 0.001 - 0.002 mg/L, 0.006-0.016 mg/L and 0.154-0.224 mg/L respectively. Nickel and chromium were not detected. The concentrations of heavy metals were observed to be very low compared to WHO permissible limits and Nigerian National Agency for Food and Drug Administration and Control. All parameters analyzed were observed to decrease as the time of the rainfall increases.

Keywords: *Rainwater quality, Physicochemical analysis, Microbiological parameters, Heavy metals, Makurdi*

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***Correspondence:** Anhwange BA. Department of Chemistry, Benue State University, Makurdi.*
***Tel**: +2348057050242*
***Email:** banwhange@bsum.edu.ng.*

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INTRODUCTION

Water is one of the most important and abundant compounds in the ecosystem. All living organisms on earth need water for survival and growth(Pawar-Patil and Sagar 2013). It is a precious natural resource which is essential for all living organisms from the simplest microorganisms to the most complex living systems like the human body. Despite the importance of water to the living organism as well as production of food and quality of health, safe drinking water is difficult to find in developing countries, despite the various efforts made by both government and non-governmental organizations in this regard (Olaoye *et al.,*2013). Even where available water sources exist, they may not meet the requirements for human consumption (Amin and Alazba 2011). Olowoye(2011), reported that most of the available water sources in rural communities in Nigeria are known to be contaminated with pathogens or harmful chemicals which are likely to cause epidemics on consumption.

Harvesting of rainwater as a source of water could alleviate water crisis, reduce the burden on traditional water sources, lessen nonpoint source pollutant loads, control water logging problems, prevent flooding, help in controlling climate change impacts, contribute to stormwater management (Sadia *et al*., 2014). Olaruntade and Oguntunde (2009) found that the harvesting of rainwater for storage provides an alternative source of water during drought or when the water table drops and wells go dry. Also, in the arid and semi-arid areas, the prevailing climate conditions make it crucial to use the limited amount of rainwater as efficiently as possible (Adriano et al., 2011).

Rooftop rainwater harvesting is one main form of water collection that relatively gives clean safe drinking water. In this regard, it has also been known that most rainwater collected on roof systems generally matches the WHO standards for drinking water, but only if the first flush water is removed before storing the rainwater (Vilane and Mtshali 2015). Recently, the technology of harvesting rainwater has regained popularity as users have realized the benefits of a relatively clean, reliable and affordable water source at home.

In the six geopolitical regions of Nigeria, the harvesting of rainwater has now been introduced as part of an integrated water supply system, where the urban water supply is unreliable, or where local water sources dry up especially during the dry season from December to April. In such areas, rainwater is collected during the rainy season and stored for use during the dry season when the commodity is scarce (Omolare and Oloke 2015).

Although, rainwater is regarded as one of the purest forms of water on earth, it is known to contain dissolved gases such as carbon dioxide, sulphur dioxide, nitrogen dioxide, ammonia and fine particulate materials or aerosols from the atmosphere (WHO 2011). As such, Amin and Alazba (2011), 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, the present study sought to ascertain the time of harvesting rainwater which will present the least contamination and highest safety

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MATERIALS AND METHODS

Sample Collection

Rainwater samples were collected across the rainy season from three sampling sites within Makurdi metropolis in Benue State. In each of the sites, rainwater samples were harvested at an interval of five (5) minutes up to five times using a 24 cm diameter funnel hung on a twenty liter can. That is, the rainwater was collected at 5, 10, 15, 20 and 25 minutes into the rain. This was done for three months (July, August and September 2017). The samplers were fixed at a height of 1.5 m above the ground to prevent contamination from dirt on the ground. For each of the month, samples were collected three times after which the mean value for the month was calculated. The samples were poured into 2 L plastic containers and taken to the laboratory for analysis. For heavy metals analysis, 1 mL of conc. HNO_3 was added to the water samples and stored in a refrigerator at 4 °C before analysis. All containers for bacteria analysis in addition to previous treatment were sterilized in an autoclave at 121 °C for 15 minutes before use.

Method of Analysis

Standard methods were adopted for the analysis. Temperature was determined at the sampling sites using mercury in glass thermometer. pH was determined using pH meter.Total dissolved solids and conductivity were determined using the TDS kit model 50150 made by HACH. Turbidity was determined using Turbidity Meter (NT-100). Colour, suspended solids, phosphate and sulphate were direct reading spectrophotometer (DR/2000) made by the HACH Company

Suspended solids were determined using an Explorer GLX spectrophotometer module interfaced with a computer (PASCO)(Cheesbrough 2006).Dissolved oxygen was determined using a dissolved oxygen analyzer (JPB-607) portable, while biochemical oxygen demand was determined using the mathematical expression: BOD $mgL^{-1} = DO_i - DO_f$ /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 Mustafa *et al*., (2013). The determination of heavy metals, nitrate and chloride was carried out using Ion selective electrodes.

RESULTS AND DISCUSSION

The mean value of temperature was found to range from 23.4 to 25°C, 21.0 to 21.9, and 22.3 °C to 22.8 °C for July, August and September respectively (Table 1-3). In all cases, the temperature was found to be higher at the beginning of the rain and decreased as the time the rain progresses. Temperature is an important factor that influences the chemical, biochemical and biological characteristics of an aquatic system. Temperature controls the rate of all chemical reactions (Ochori and Aholo, 2012). The rate of microbial activities increased with an increase in temperature(Lodh *et al.,* 2014).Although, the temperature was found to vary with time of collection, the results of this study showed the temperature to be within the WHO permissible limit (20 °C to 32 °C).

The result of pH (Tables 1-3) was found to range between 6.0-6.20 for the period under study. This implies that the rainwater was slightly acidic. This is as a result of the dissolution of oxides of non-metals like carbon, nitrogen and sulphur in the rainwater. The values obtained are comparable with those reported by (Ikhioya *et al.,*2015)**.**The result of turbidity was observed to range between 0.99 to 1.76 NTU in July, 1.27 to 2.11NTU in August and 0.67 to 1.62 NTU in September (Tables 1-3). Generally, turbidity values were found to decrease as the rain progressed. Turbidity values recorded in August were higher than those in July and September. This may be attributed to the metropolitan nature of the sample area (Ipav *et al*., 2012).

The mean values of conductivity were observed to range from (3 - 6) µs/cm in July, through (2 - 5) µs/cm in August, to (3 - 7) **µs/cm** in September (Tables 1-3). In all the samples, conductivity values were below 50 µS/cm. This implies that the electrical conductivity of the rainwater samples was very low and decreased with time. Generally, the low conductivity value is an indication that the rainwater is relatively free from atmospheric contaminants (Olumuyiwa et al., 2012).

The value for total hardness was found to be constant 20 mg/L within the three months of study. This value could be due to the dissolution of carbonates in the atmosphere (Adhena *et al.,* 2015). The values observed are very low. This implies that the rainwater is soft water (Dimowo 2013). This result agrees with Ipav *et al*., (2012)

Table 1: Physico-chemical Parameters of Rainwater in July

	Time Interval (minutes)					WHO (2011)	NAFDAC
	5	10	15	20	25		
Temp (^oC)	25.0 ± 0.00	24.0 ± 0.00	24.1 ± 0.05	24.0 ± 0.00	23.4 ± 0.22	20-32	
pH	6.2 ± 0.08	6.0 ± 0.00	6.0 ± 0.00	6.0 ± 0.00	6.0 ± 0.05	6.5-8.5	6.5-8.5
Turbidity (NTU)	1.76 ± 0.07	1.63 ± 0.02	1.10 ± 0.05	1.10 ± 0.09	0.99 ± 0.00	0-5	
Conductivity (μs/cm)	6 ± 0.00	5 ± 0.00	5 ± 0.47	3 ± 0.00	3 ± 0.47	1000	1000
Total Hardness (mg/L)	20 ± 0.00	20 ± 0.00	20 ± 0.00	20 ± 0.00	20 ± 0.00	100-500	100
TDS (mg/L)	1 ± 0.00	1 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	1000	500
SUspendedSolids (mg/L)	62 ± 0.47	62 ± 0.00	54 ± 1.49	43 ± 2.49	37 ± 1.25	150	-
DO (mg/L)	3.1 ± 0.08	3.0 ± 0.09	3.0 ± 0.00	2.8 ± 0.12	3.0 ± 0.00	5-7	
BOD (mg/L)	0.8 ± 0.08	0.5 ± 0.05	0.4 ± 0.05	0.2 ± 0.05	0.2 ± 0.00	30	
COD (mg/L)	1.6 ± 0.00	1.0 ± 0.00	0.8 ± 0.00	0.4 ± 0.00	0.4 ± 0.00	255	
Chlorides (mg/L)	107 ± 4.11	106 ± 0.00	106 ± 0.00	106 ± 2.87	105 ± 0.47	250	200
Sulphates (mg/L)	8 ± 0.00	7 ± 0.00	7 ± 0.47	7 ± 0.00	7 ± 0.00	250	
Phosphates (mg/L)	0.53 ± 0.01	0.56 ± 0.09	0.56 ± 0.00	0.56 ± 0.02	0.60 ± 0.02	5	
Nitrates (mg/L)	2.6 ± 0.00	2.6 ± 0.08	2.3 ± 0.05	2.3 ± 0.17	2.0 ± 0.00	500	50
Coliform (TCU)	ND	ND	ND	ND	ND	-	

Table 2: Physico-chemical Parameters of Rain water sampled in August

Physicochemical Parameters	Time Interval (minutes)					WHO (2011)	NAFDAC
	5	10	15	20	25		
Temp (^oC)	21.3 ± 0.05	21.3 ± 0.12	21.5 ± 0.24	21.0 ± 0.05	21.9 ± 0.05	20-32	
pH	6.2 ± 0.05	6.0 ± 0.00	6.0 ± 0.00	6.0 ± 0.00	6.0 ± 0.00	6.5-8.5	6.5-8.5
Turb idity (NTU)	2.22 ± 0.008	1.65 ± 0.02	1.42 ± 0.008	1.31 ± 0.13	1.27 ± 0.02	0-5	
Cond uctivity (μs/cm)	5 ± 0.00	5 ± 0.00	3 ± 0.47	2 ± 0.00	2 ± 0.47	1000	1000
Total Hardness (mg/L)	40 ± 0.00	20 ± 0.00	20 ± 0.00	20 ± 0.00	20 ± 0.00	100-500	100
TDS (mg/L)	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	1000	500
Suspended Solids (mg/L)	76 ± 2.45	58 ± 1.25	47 ± 0.47	47 ± 1.63	41 ± 0.47	150	-
DO (mg/L)	3.0 ± 0.00	3.0 ± 0.05	2.8 ±0.08	2.8 ± 0.00	2.8 ± 0.05	5-7	
BOD (mg/L)	0.4 ± 0.00	0.4 ± 0.05	0.1 ± 0.05	0.1 ± 0.00	0.0 ± 0.00	30	
COD (mg/L)	0.8 ± 0.00	0.8 ± 0.00	0.2 ± 0.00	0.2 ± 0.00	0.0 ± 0.00	255	
Chloride (mg/L)	112 ± 2.94	112 ± 2.45	108 ± 1.25	103 ± 4.19	102 ± 1.06	250	200
Sulphate (mg/L)	9 ±0.00	8 ± 0.00	8 ± 0.47	8 ± 0.00	7 ± 0.58	250	
Phosphate (mg/L)	0.40 ± 0.01	0.49 ± 0.01	0.49 ± 0.00	0.52 ± 0.02	0.56 ± 0.00	5	
Nitrates (mg/L)	3.2 ± 0.16	2.8 ± 0.00	2.8 ± 0.05	2.5 ± 0.05	2.5 ± 0.08	500	50
Coliform (TCU)	ND	ND	ND	ND	ND	-	

who reported that the rainwater is soft water.

The mean values of total dissolved solids (TDS) recorded during the period of the study were found to range between 1 to 2 mg/L (Tables 1-3). The value decreases with increasing time of harvesting the rainwater. Studies have shown that TDS of rainwater depends upon the quantity of rainfall (Prasad *et al.*, 2014). The results of the study indicate that the rainwater is relatively free from dissolved solids.

The results of the total suspended solids were observed to range between 37 - 62 mg/L (Table 1.0) in July, 41 76 mg/L in August (Table 2.0), and 36.0 - 49.0 mg/L in September (Table 3.0). TSS recorded in July was higher than the other two months. TSS of water content is dependent on the amount of suspended particle, soil, and silt which is directly related to the turbidity of water. The greater the amount of total suspended solids, the higher the turbidity.

Table 3: Physico-chemical Parameters of Rain water sampled in September

Physicochemical Parameters	Time Interval (minutes)					WHO (2011)	NAFDAC
	5	10	15	20	25		
Temp (°C)	22.8 ± 0.08	22.6±0.08	22.6 ± 0.05	22.5 ± 0.08	22.3 ± 0.17	20-32	
pH -	6.0 ± 0.00	6.0 ± 0.00	6.0 ± 0.00	6.0 ± 0.00	6.0 ± 0.05	6.5-8.5	6.5-8.5
Turbidity (NTU)	1.62 ± 0.02	1.47 ± 0.01	0.99 ± 0.01	0.92 ± 0.005	0.63 ± 0.01	0-5	
Conductivity (µs/cm)	07 ± 0.00	6 ± 0.00	6 ± 0.00	3 ± 0.47	4 ± 0.00	1000	1000
Total Hardness (mg/L)	20 ± 0.00	20 ± 0.00	20 ± 0.00	20 ± 0.00	20 ± 0.00	100-500	100
TDS (mg/L)	02 ± 0.00	2 ± 0.00	0 ± 0.00	1 ± 0.00	0 ± 0.00	1000	500
Suspended Solids (mg/L)	49 ± 0.00	49 ± 0.47	48 ± 0.00	49 ± 0.94	36 ± 2.15	150	-
DO (mg/L)	03.4 ± 0.08	3.2 ± 0.12	3.1 ± 0.05	3.1 ± 0.00	3.1 ± 0.00	5-7	
BOD (mg/L)	0.6 ± 0.05	0.5 ± 0.05	0.4 ± 0.05	0.2 ± 0.08	0.2 ± 0.08	30	
COD (mg/L)	01.2 ± 0.00	1.0 ± 0.00	0.8 ± 0.00	0.4 ± 0.00	0.4 ± 0.00	255	
Chlorides (Mg/L)	107 ± 0.47	106 ± 0.82	106 ± 0.00	106 ± 1.89	104 ± 0.82	250	200
Sulphates (mg/L)	08 ± 0.00	8 ± 0.00	8 ± 0.47	7 ± 0.00	7 ± 0.00	250	
Phosphates (mg/L)	0.13 ± 0.01	0.16 ± 0.005	0.32 ± 0.02	0.38 ± 0.005	0.41 ± 0.01	5	
Nitrates (mg/L)	02.8 ± 0.00	2.8 ± 0.05	2.9 ± 0.00	2.8 ± 0.00	2.8 ± 0.08	500	50
Coliform (TCU)	ND	ND	ND	ND	ND	-	

Key: ND = Not Detected

Table 4: Concentrations of Heavy Metals in the Harvested Rain Water

Months	Concentrations (mg/L)						
	Zn	Cr	Cd	Pb	Ni	Al	Fe
July	0.300 ± 0.001[a]	ND	0.009 ± 0.004[a]	0.001 ± 0.000[a]	0.000 ± 0.000	0.016 ± 0.000[a]	0.244 ± 0.019[a]
August	0.204 ± 0.040[b]	ND	0.011 ± 0.005[a]	0.002 ± 0.000[b]	ND	0.006 ± 0.000[a]	0.1965 ±0.000[a]
September	0.159 ± 0.009[b]	ND	0.009 ± 0.000[a]	ND	ND	0.012 ± 0.000[a]	0.153 ± 0.001[a]
WHO (2011)	3	0.05	0.003	0.05	0.02	0.5	0.3
NAFDAC	5		0.003	0.01		0.5	0.3

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

The result obtained in this study is in agreement with this relationship (Ftsum *et al*., 2015).

The mean values for dissolved oxygen were observed to range between 2.8 - 3.10 mg/L, 2.8 3.00 mg/L, and 3.10 - 3.40 mg/L for July, August, and September respectively. The BOD mean values range between 0.20-0.80 mg/L in July (Table1), 0.10-0.40 mg/g in August (Table 2), while in September BOD was found to range between 0.20 - 0.60 mg/L (Table 3). The values decrease as the time of harvesting the rainwater tended towards the end of the rain. The mean values of chemical oxygen demand of (COD) ranged between 0.4-1.6 mg/L in July, 0.2- 0.8 mg/L in August, and 0.4-1.20 mg/L in September. Chemical oxygen demand 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 pollution of water. COD values indicate the amount of dissolved oxidizable organic matter including the non-biodegradable matter (Reeta, 2012).

The results of chloride were found to range between 106 mg/L to 107 mg/L in July (Table 1), while the range of 102 mg/L to 112 mg/L (Table 2) was observed in August and 104 mg/L to 107 mg/L (Table 3) in September. The chloride values were also found to decrease with an increase in the time of raining (Ravindra and Arvind, 2015)

The values for sulphate (SO_4^{2-}) were found to range from 7 mg/L to 8 mg/L in July, 7mg/L to 9 mg/L in August and 7 mg/L to 8 mg/l in September. The value of sulphate recorded was slightly higher than the value reported by Chukwuma *et al.,* (2013). Sulphur enters the atmosphere principally as sulphur dioxide (SO_2), an air pollutant with a lifetime of about 1 to 2 days before it is normally deposited or oxidized into sulphate. The presence of sulphate in drinking water can cause noticeable taste. Generally, its impairment is considered to be minimal at levels below 250 mg/L (Emerole *et al.,* 2015). No health-based guideline value had been derived for sulphate. However, the study recorded a very low sulphate concentration which is an indication that its sources may probably be the SO_2 discharged into the atmosphere by human activities in the metropolitan area. The mean values for phosphate (PO_4^{3-}) recorded within the three months were found to range between 0.13mg/L to 0.60 mg/L. The values were lower than the maximum permissible level of 5mg/L fixed by WHO (Table1 -3). Phosphate is a generic term for the oxy-anions of phosphorous. Enrichment of water with organic phosphates and nitrates results in excessive growth of plants and other micro-organisms leading to eutrophication and increased biochemical oxygen demand (Cheesbrough, 2006).

The mean values for nitrate were found to range from 2.0 mg/L to 3.0mg/L, for the three months. The results obtained were lower than the values reported by WHO. The mean concentrations of colour observed in the study areas range between 92 FTU to 132 FTU in July, 99 FTU to 138 in August, and 100 FTU to 162 in September (Tables 1-3). It was observed that the concentrations decreased as the time of the rain increases. This means that as the rain continued more of the substances that imparted colour like dust particles and soluble minerals suspended in the atmosphere were washed away.

The result of the microbiological analysis showed a negative confirmation test to total coliform (Table 1.0 - 3.0) in all the samples investigated. 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 an indication of the degree of pathogenic risks (Samuel *et al*., 2015). Coliforms are a broad class of bacteria found in our environment, including the faeces of man and other warm-blooded animals. The presence of coliform bacteria *(E.coli*) in water can lead to disease conditions showing various symptoms such as diarrhoea, nausea, vomiting, cramps, or other gastrointestinal distress and in severe cases can be fatal (Jamal, 2012).

The results of analysis of Zn indicated its concentration to range between 0.159 mg/L to 0.30 mg/L (Table 4) for July, August, and September, respectively. There was no significant difference in the value between August and September at $p<0.5$. The presence of Zn in the rainwater could be due to its particles in the atmosphere. Generally, the values were observed to be very low. Although, zinc is known to be an important trace element and plays a vital role in the physiological and metabolic process of many organisms, nevertheless, at high concentrations, it could be toxic to organisms (Samuel *et al*., 2015).

Chromium was not detected in any of the samples analysed. This implies that the rainwater samples are free from chromium. Cadmium was detected in all the samples (0.009 0.11)mg/L. However, there was no significant difference in the values of cadmium within the three months at $p<0.5$. The presence of cadmium in the atmosphere could be linked to the incineration of municipal waste such as plastics and nickel-cadmium batteries (Abdullah, 2015).

The concentration of lead in the study area was found to range between (0.001 - 0.002) mg/L and was not detected in October. There was significant difference in the value of lead between July and August. All the values were much lower than the values reported by Chubaka *et al*., (2018), and even the maximum permissible limit reported by WHO and NAFDAC.

Nickel was not detected in all samples analysed, while the concentration of aluminum recorded within the three months of study ranged between (0.006-0.016) mg/L. There was significant difference at $p<0.5$ in the value of Al in July whereas no significant difference exits between August and September. The concentrations of Al recorded were below the WHO permissible limit of 0.5 mg/L for drinking water. The presence of aluminum in drinking water at concentration levels of 0.1 to 0.2 mg/L often leads to the deposition of aluminum hydroxide floc in water (Vaishnavi *et al*., 2015). Iron was also found to be present in all samples (0.154- 0.224) mg/L, however, there was no significant difference at $p<0.5$ in the value of iron within the three months. The amount of iron recorded in the study was relatively lower than the maximum permissible limit reported by both WHO and NAFDAC.

CONCLUSION

The results of the study revealed that the quality of the physicochemical, microbiological, and heavy metals of rainwater harvested in the sampled areas are within the permissible limits. The quality increased as the rain progresses. Hence the harvested rainwater sample of the study areas can be classified as safe for domestic usage. It is therefore recommended that the harvesting of rainwater should not be done at the beginning of the rain. The rain should be allowed to fall for sometimes before collection could be done to minimised contamination of the rainwater.

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