Academic Journal of Science, Engineering and Technology
Vol. 9, Issue 3; May-June 2024;
ISSN: 2837-2964
Impact Factor: 6.67
1252 Columbia Rd NW, Washington DC, United States
https://topjournals.org/index.php/AJSET/index; mail: topacademicjournals@gmail.com

SPATIAL AND TEMPORAL VARIATIONS IN PROPERTIES OF RAINWATER IN IBI LOCAL GOVERNMENT, AREA OF TARABA STATE, NIGERIA.

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DOI: https://doi.org/10.5281/zenodo.11174484

Abstract: Location and Season have a significant effect on Rainwater properties. This study examined spatial and temporal variations in properties of rainwater in the Ibi local Government area of Taraba state, Nigeria, by identifying rainwater properties, spatial and temporal variations. The study was carried out between March and July 2023, using a purposive sampling technique. Statistical data analysis of Pearson correlation and Chi-square test of mean values were used. The parameters analyzed were Temperature, Electrical conductivity, Turbidity, pH, TDS, TSS, SO_4, NO_3, Na, Ca, Cl, Cd, Mg, Fe and Pb. Laboratory test methods used were ASTM and APHA. The result showed that there were significant variations in rainwater properties in Ibi local Government area of Taraba state. The rainwater variations could be attributed to higher anthropogenic and natural factors. Out of 15 parameters tested, one (1) parameter was above WHO and NSDWQ maximum permissible limits for drinking water quality. The parameter is Turbidity. It had the mean values of 22.7NTU and 14.17NTU in urban and rural areas respectively. The maximum permissible limit by NSDWQ and WHO is 5.0NTU. The elevated values in both urban and rural areas could be due to suspended and dissolved organic matters. Turbidity was above all the standards in April and June, but within the standards in July due to rainfall intensity. Dusty and poorly maintained roads could be attributed to high Turbidity concentration in the study area. This study recommends that authorities should monitor and control the sources of atmospheric emissions through good road maintenance culture and proper waste disposal system in the study area.
Keywords: Rainwater, variations, atmosphere, properties

1.1 Introduction

Water is a unique resource whose quality and quantity vary over space and time. It is one of the most precious commodities needed by man. Without it, life cannot survive and economic development will be retarded by its absence. Water is the life-blood of the ecosystem. It forms the largest part of the most living things (Origho, 2019). It is sourced from the earth's surface as surface water, the crustal part of the earth surface as underground water, and the atmosphere as rainwater. Rainfall has been of primary importance in most studies on climate science, with its variability exerting significant impact on the society. It is a major component of the hydrologic

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cycle and contribute to freshwater deposits on earth as well as provides good conditions for all types of ecosystems. It is also essential for hydroelectric power (HEP) generation and irrigation for better crop yield (Chidiebere, 2017).

Spatio-temporal methods in geography are significant because they allow for the analysis of the spatial and temporal patterns and trends of events. These methods are particularly useful in understanding the dynamic nature of geographic events, such as crime, agriculture or disease occurrences, by considering both time and space in the analysis. They enable the identification of spatial distribution changes at a finer scale, which is important for forecasting and minimizing disruptions in broadband service. Additionally, spatio-temporal geo-statistics has emerged as a method to estimate and quantify environmental factors in a spatial domain, enhancing the precision of geographical subjects like precision agriculture. These methods contribute to a better understanding of the evolution of social and environmental phenomena within space (International Water Management Institute, (IWMI, East Africa, 2014). Ademola, Kehinde and Ologunorisa, (2023), observed that there is more rainfall in Nigeria between March and October, and less rainfall between November and February. Rainfall amount in the Niger Delta is observed to be high due to its closeness to the Atlantic Ocean and presence of highlands that aids orographic processes. While Abdullahi, Wali and Nwankwaola (2019), noted that proximity of Niger Delta to the Atlantic Ocean and topography contributed greatly to variation in rainfall characteristics in Nigeria.

With regards to spatial rainwater properties, Pu *et al*, (2019), opined that chemical composition of rainwater varies from site to site and from region to region, indicating local influences and characteristics of atmospheric pollutants. Therefore, Mahato *et al*, (2016) submitted that rainwater composition reflects the quality of atmosphere during the occurrence of rainfall. In China, for instance, rainwater is an essential pathway to remove fine particulate matter and dissolved atmospheric pollutants such as NH_3, SO_4, and NO_x (Rui and Guilin 2021). Meanwhile, fine particles ($PM_{2.5}$) are primary pollutants of substantial public concern in urban cities (Wei *et al*., 2019). Through wet precipitation, rainwater scavenges air pollutants from the air (Niu *et al*., 2014; Rao *et al*., 2016; Wei *et al*., 2020). Atedhor, Aiyeki, and Ayeni, (2019), stated that Urbanized landscapes are known to have relatively high atmospheric pollutants due to high concentrations of anthropogenic activities. Rainwater has its constituents including various substances that fall from the atmosphere as wet deposition during a rainfall event (Tomasi, Fuzzi, and Lupi, 2017). Simultaneously, growth in population and human activities in urban landscapes enhance pollutant release and particulate loading in the atmosphere (Zhang, Liu, He, Pu, and Yu, (2017). Densely settled areas discharge substantial quantities of effluence into the atmosphere (Baklanov, Grimmond, Carlson, and Langendijk, 2017). Thus, the transformation of rural domains into urban spaces significantly influences the local air quality (George, Ziska, Bunce, and Quebedeaux, 2007).

The area of study has low commercial activities, and lacks industrial presence, although it has a good network of roads, but poorly maintained. Consequently, the roads are dusty and they link Taraba state with Plateau, Nasarawa, and Benue states. As a result of interstate link roads coupled with activities of boat engines and other human and natural activities, there is an increase in atmospheric pollution which impacts rainwater constituents.

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The rainwater constituents depend on the intensity, frequency, and location of where it falls. This reason necessitated the need for this study.

1.2 Statement of the problem

The interference of some elements with rainwater in the atmosphere and the environment in which they fall alters the chemistry of the water. Similarly, rainwater constituent is affected by rainwater intensity, particularly in the wet season. Although rainwater is safe, the chemical composition at the point of collection is altered and is influenced by local environment and atmospheric conditions; Hence, different places might have different elemental concentration levels. Therefore, the study is aimed at determining spatiotemporal variations in rainwater chemistry in the study area for a better understanding of rainwater management. The impact of location and season on rainwater chemistry is one significant way of defining natural and anthropogenic contributions to environmental pollution.

1.3 Aim and Objective of the Study

The main objective of the study is to examine the effect Spatial and Temporal Variations in Properties of Rainwater in Ibi Local Government, Area of Taraba State, Nigeria. The aim is achieved through the following objectives:

- To identify causes of Spatial and Temporal variations in properties of rainwater in the study area?
- To determine the factors responsible for Spatial and Temporal variations in properties of rainwater

2. Review of Related Literature

The state of the atmosphere over an urbanized area may differ significantly due to a relatively high and increasing load of atmospheric impurities (Atedhor, Ayeni and Aiyeki, 2019). In examining variations of rainwater properties in Wukari, local government area of Taraba state, Abubakar and Ajadike (2023) observed that high chemical composition in rainwater from urban areas as compared with rural areas could be attributed to atmospheric chemical accumulation of pollutants such as gases and particulate matter. Therefore, the study concluded that location is an important determinant of variability of rainwater properties. The chemical composition of rainwater can serve as a tracer for air pollution (Zheng *et al*, 2020). Abubakar and Ogbu (2023), reported that South-east rainwater was more polluted than South-south in southern part of Nigeria. The report concluded that it could be due to activities of industries and rainfall intensity that could have diluted the chemical composition of rainwater in south-south, Nigeria.

Rainwater temporal analysis shows that, we have less rainfall between November and February (Dry season) and the four study areas have bi-modal rainfall peaks. However, results from spatial analysis indicates that Calabar had the highest rainfall amount followed by Port Harcourt, Uyo and Benin, this is due to the closeness of these locations to the Atlantic Ocean that contribute a lot of moisture in these locations (Akinbobola, Lawal and Ologunorisa, 2023. The Nigerian climate comprises of two seasons, the dry and the wet season with little dry season within the wet season (Akinbobola *et al*, 2023).

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Similarly in Benin City, Atedhor *et al*, (2019), examined the spatiotemporal variations in rainwater physico-chemical properties. The result from three sampling areas shows that Fe and NO_x mean values were higher in March than in July from all the sampling points. The study concluded that the efficiency and rate of washout scavenging of atmospheric pollutants increase with rainfall amount considering the fact that the month of July coincides with one of the rainfall peaks in the rainforest belt where Benin City is located, while March, marks the on-set of wet seasons. Aderonke *et al*, (2017) argues that Temporal variation showed that all the chemical parameters had higher concentration values during dry season (October to March) than wet season, except NOx and SO_4 ions. The study also shows that the major sources influencing the chemical parameters in rainwater includes remobilized dust from industrial activities, vehicular activities, agricultural activities and soil re-suspension.

METHODOLOGY

Study Area

Study area, Ibi is one of the 16 local Government Areas (LGA) that makes up Taraba state. It lies within Lat.8°01' and 8°35' North of the equator and long 9°10' and 9°98' East of Greenwich meridian.

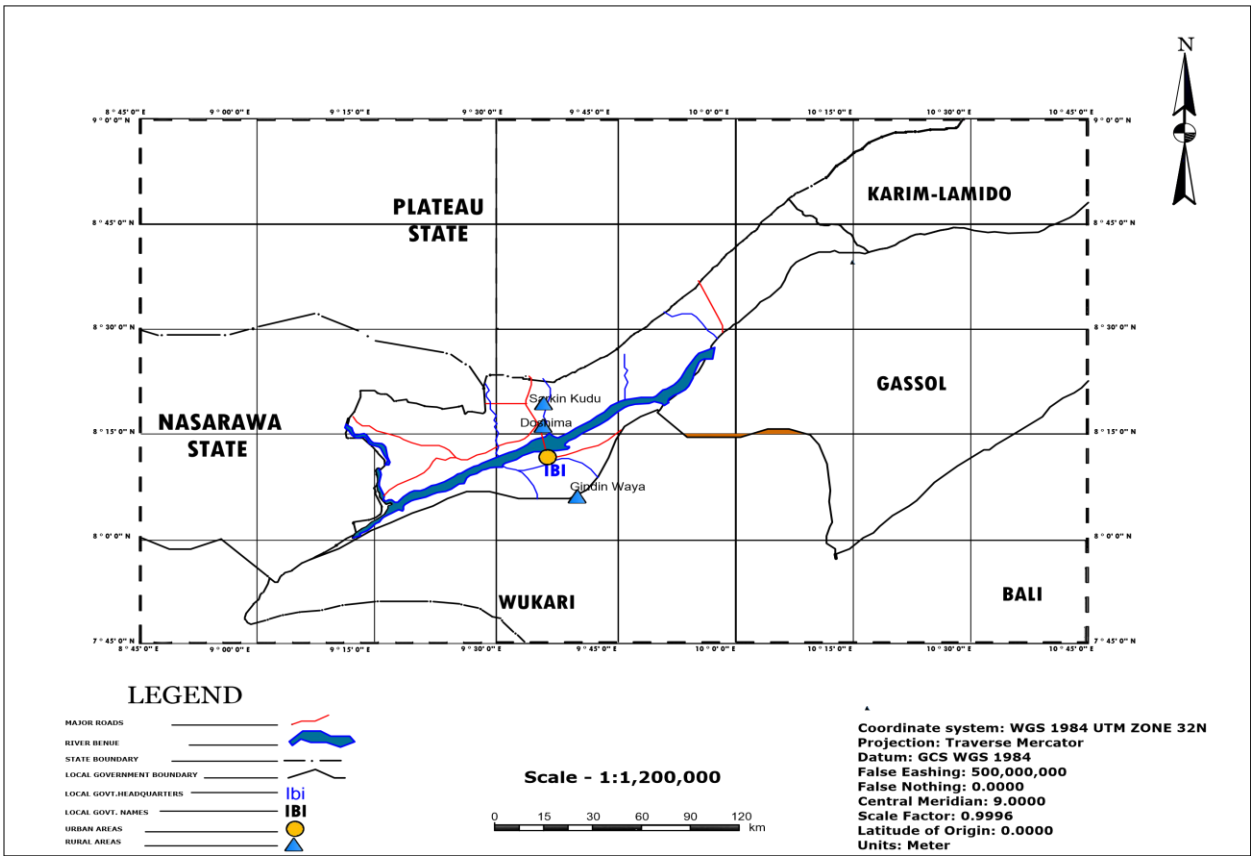

Figure 1: showing area of study

Source: Taraba state Ministry of Land and Survey, (2023)

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To the West, it shares boundary with Nasarawa state, to the East Gassol LGA, to the South, Wukari town and to the North, Plateau State. It has population of 84,054 in 2006, projected to 132,600 people by 2021 (NPC, 2006). Due to the richness of the minerals in the parent rock; its soils are generally well suited for rice, maize, guinea corn likewise arable farming and tree crops production. The LGA covers an area of 2,672km² (Bureau for land and survey, Jalingo Taraba State, 2012). The town Ibi, was founded by Yakubu Bula, the first King who is a Fulani from Gombe. According to oral tradition, Ibbi was originally spelled Ibbe, meaning 'Fig tree' in Fulani language.

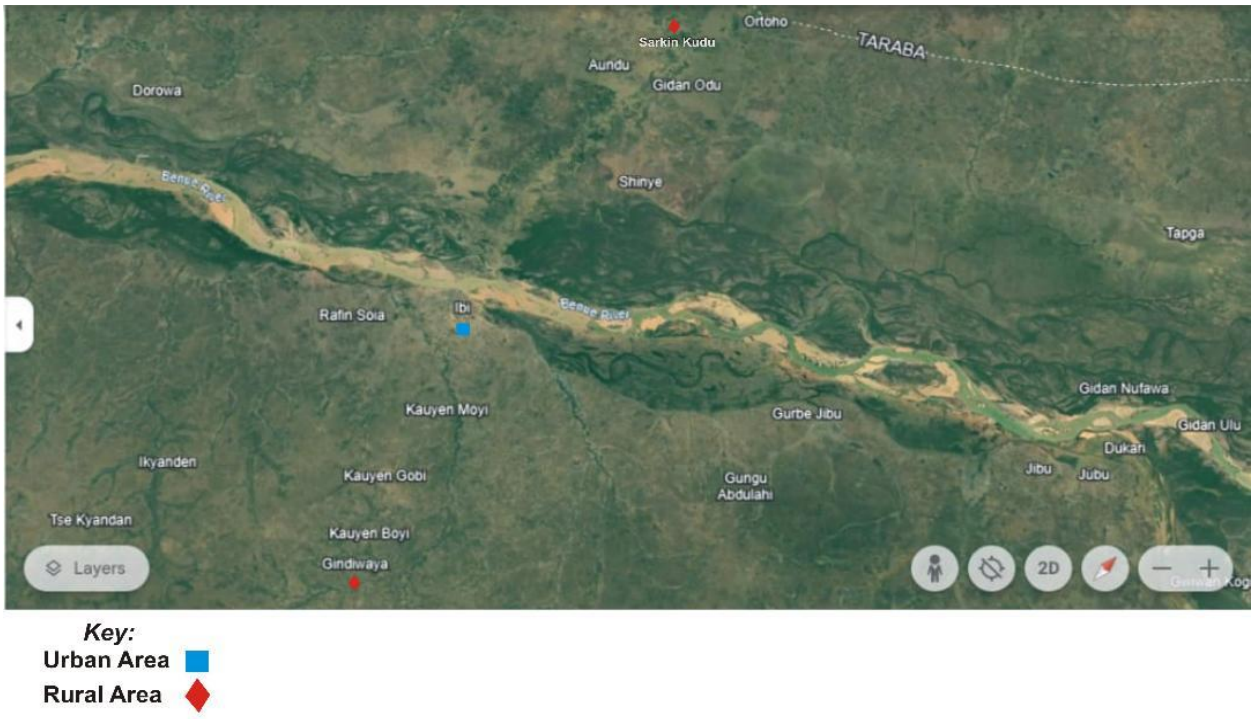

Figure 2: Google Map of the study area showing the sampling points

This tree is very important to the Fulanis because it has many uses as food, medicine, shelter for birds and abode of the spirits. The name became Ibbi because of the impact with Europeans who pronounce it as Ibbi (Ibi Emirate Council, 2006), now spelled as Ibi. The notable economic activities of the inhabitants are fishing and farming. However, Taraba and Donga rivers flowed into the Benue River within the LGA Figure (1). The mean annual rainfall is 1016-1270mm. The confluence in this LGA pose sharp memory to the underground water, couple with high rainfall, yearly flooding is eminent Adelalu, (2014b).

The rural area consists of Sarkin kudu and Gindin waya, under Ibi local Government area. Both are situated along trunk 'B' road that passes through Wukari, Gindin-waya and terminates in Ibi due to River Benue. However, the road continues after crossing the river Benue to Sarkin kudu through to Lafiya in Nasarawa state and part of Benue and Plateau states. By using google map, distance between Ibi to Gindin-Waya is about11,900m, while it is about 12,800m from Ibi to Sarkin kudu.

Sampling and Analysis

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The sampling technique employed was purposive. The sample containers were soaked with 10% HNO_3 for 24hours, well rinsed with water, distilled water and with sample before actual sampling took place. Rainwater sampling locations were Ibi central Mosque, Gindin-waya primary school and Sarkin kudu, adjacent to ward chief's house. To ensure the rainwater samples had no contact with any object before getting into the bucket, an elevated platform of about 2m above the ground level (plastic drum) was used in an open space. Samples were wrapped in a black cellophane bag, to prevent further oxidation and placed in a cooler box packed with iced-chips. Samples were transported to laboratory for analyses. The following parameters were tested: Temperature, pH, Electrical conductivity, Colour, Turbidity, NO_X, TSS, TDS, Ca, Mg, SO_4, Fe, Pb, Cu and Zn. American Society for Testing and Materials (ASTM) and American Public Health Association (APHA) test methods were used.

Data collection

Multi meter PCS TESTER 35 was used for PH, Temperature, EC and TDS, concentration values were recorded in ^0C, µs/cm and mg/l respectively. pH has no unit of measurement. Turbidity was tested using Hi 93709 Hanna Turbidity meter and reading was taken in NTU. Gravimetric method was used for TSS by using filter paper (Whatman) of pore size 0.45mµ with aid of suction pump, reading was taken mg/l. For SO_4 concentration, spectrophotometer, Spectrum Lab S23A was used. A complex titrimetric method was used for NO_X. Acidic Potassium bromates and Sodium nitrite with starch as indicator was titrated until the color in starch iodine paper turned blue, indicating endpoint. For metals; Fe, Zn, Cu, Cd, Pb, Mg and Ca, FAAS (AA-6300 Shimadzu) was used. A light beam from a hollow cathode lamp of the same element as the target metal is radiated through the flame, and the amount of absorbed light is measured by the detector. Concentration was displayed on the monitor in mg/l.

RESULT

Table 1: Spatial Properties of Rainwater in the study area

Parameter	URBAN	RURAL	RANGE	NSDWQ	FEPA	WHO
pH	8.08	7.59	7.59 - 8.25 (0.66)	6.5-8.5	6-9	6.5-8.5
Temp (^0C)	29.07	30.63	28.0-31.5 (3.50)	Ambient	20-35	Ambient
Cl (mg/l)	16.54	8.16	7.01 - 31.95 (24.94)	150.0	-	-
TDS (mg/l)	61.97	23.07	5.4 – 174 (168.6)	500	2000	500
EC (µs/cm)	40.93	22.6	6.3 - 107.4 (101.1)	1000	1500	1000
Turb (NTU)	22.97	14.17	4.9 - 61.9 (57.0)	5.0	5.0	5.0
TSS (mg/l)	18.67	17.53	10.0 - 30.0 (20.0)	500	500	500
SO_4 (mg/l)	1.7	0.15	0.08 - 4.91 (4.83)	100.0	20.0	20.0
NO_3 (mg/l)	6.02	5.52	2.42 - 8.73 (6.31)	50.0	20.0	50.0
Ca (mg/l)	4.11	3.14	3.1 - 4.62 (1.52)	75.0	-	75.0
Mg (mg/l)	2.15	1.71	2.06 - 2.19 (0.13)	20.0	-	20.0
Na (mg/l)	0.09	0.13	0.08 - 0.10 (0.02)	200	-	150.0
Pb (mg/l)	0.01	0.01	0.01 - 0.01 (0.00)	0.01	0.01	0.01
Cd (mg/l)	<0.001	<0.001	0.001 - 0.003 (0.002)	0.003	0.05	0.003

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Fe (mg/l)	0.21	0.12	0.05 - 0.51 (0.46)	0.30	0.05	0.30

Source: Fieldwork (2023)

Figure 2 shows changes in rainwater properties with respect to location. pH, Cl, TDS, EC, Turb, TSS, SO_4, Mg, Ca, Mg, and Fe had high values in urban than in rural areas. However, temperature and Na were high in rural than in urban areas. Pb and Cd had the same values in both areas

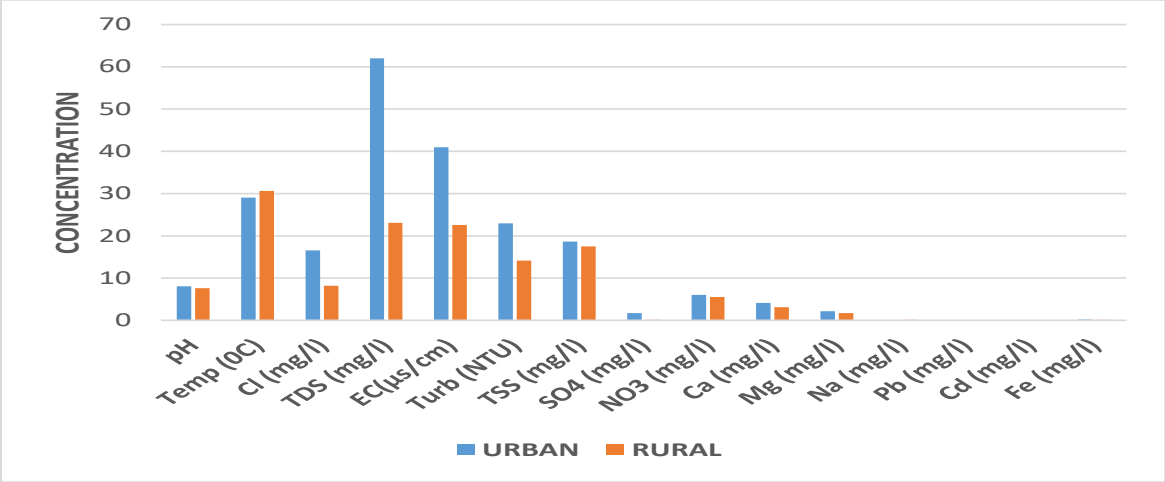

Figure 2: Spatial variation in Rainwater Properties

Source: Field work (2023).

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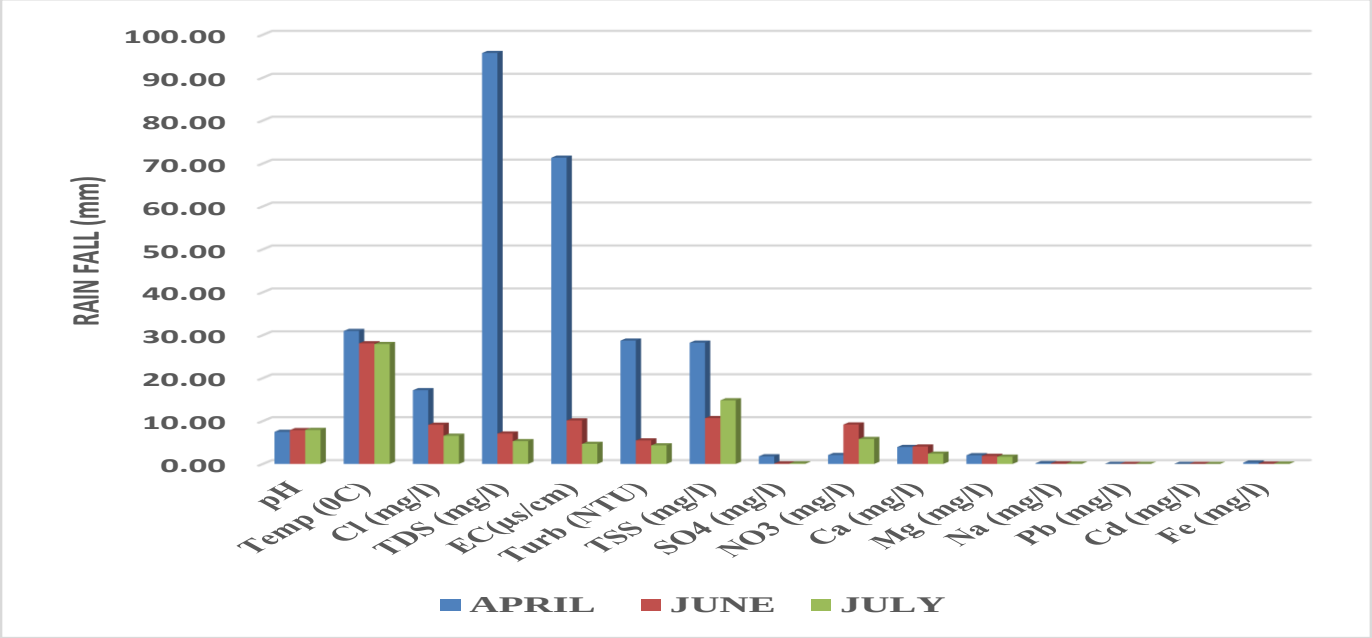

Figure 3: Temporal variation in Rainwater Properties
Source: Field work (2023)

Figure 3 shows that, rainwater properties were affected by rainwater frequency and intensity which increases from March through to June as reported by Aderonke *et al*, (2017). The figure also indicates decrease in rainfall intensity in the month of July, which proportionally influences rainwater properties. For instance, from the 15 properties tested, 67% had high values in April, 20% (pH, NOx and Ca) in June and 6.5% (Pb and Cd values of <0.001) in July.

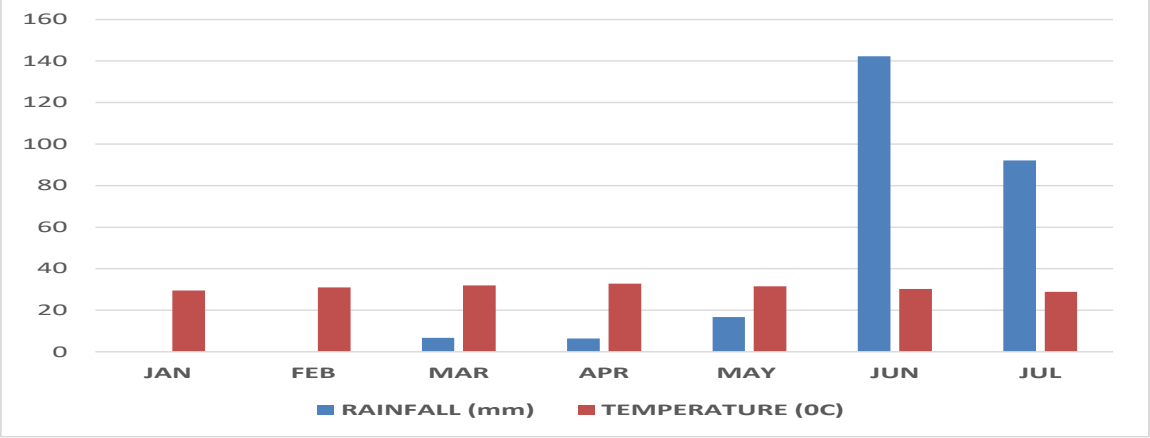

Figure 4: Rainfall and Temperature Variations;
Source; Nimet (2023)

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Figure 4 shows that there was no rainfall in January and February in the study area. However, 6.7mm of rainfall was recorded in March. The rainfall progressed through April, May and June (142.3mm). In July, there was reduction in rainfall amount to 92.1mm. The temperature values used was average of the highest temperature in the study area, this is because, Nimet data received is highest and lowest temperatures. Temperature values rose with rainfall amount. In January, February and March, the temperatures recorded were 29.5, 31.0 and 32.0^{0}C respectively. It increased to 31.5^{0}C in May, while June and July recorded 30.2 and 28.9^{0}C respectively.

DATA ANALYSIS

pH – The rainwater samples were alkaline, with mean value of pH range as 7.59 to 8.25 (0.66). The mean value of pH for urban and rural areas were 8.08 and 7.60 respectively. The pH of typical rainwater is acidic; the reason is that water reacts to a slight extent with atmospheric carbon dioxide and Nitrogen dioxide to produce carbonic and Nitric acids. This phenomenon occurs mainly due to dependence on fossil fuels as energy source, which have resulted in acid rain formation (Zhao *et al*, 2019). The result suggests that the study area has low industrial and commercial activities; acidic gases were minor in concentration and the effect of particulate matter of alkaline nature like dust particles were dominant as found by Abulude *et al*, (2018). The mean pH of 8.08 and 7.60 were within maximum permissible (MPL) of WHO, NSDWQ and FEPA. Temporarily, the pH values were 7.47, 7.87 and 7.97 in March, June and July respectively. The pH remained constantly alkaline, indicating lack of strong acidic ions to neutralize the rainwater. Acidic components in rainwater are from SO_4 and NO_x ions; products of fossil fuel combustion. This opinion agrees with findings of Francis *et al*, (2018), who stated that the alkaline result obtained in samples, could be due to lack of industrial activities, lack of high traffic and low commercial activities. This is supported by Egwuogu, Okhake, Emenike and Abayomi (2016).

Turbidity – Turbidity of water refers to how clear the water is and it is caused by the presence of particulate matter such as clay, silt, plankton and colloidal particles. Heavy rainfall, strong winds and convection currents can increase the turbidity of rainwater to a high degree (Waziri, Akinniyi and Ogbodo, (2012). These particulates cause light to be scattered and absorbed rather than transmitted in straight lines through the sample (FSAI, 2015). The range of turbidity values were between 4.9 and 61.9 (57.0) NTU. The mean values obtained were 22.97NTU and 14.17NTU for urban and rural areas respectively. The urban area had higher turbidity than the rural area. These were equally higher when compared with 4.05NTU recorded by Efe and Mogborukor, (2011) in Niger Delta on rainwater quality within the same period. However, the values were lower than what was reported by Ebong *et al*, (2016), from south-south region of Nigeria. The higher value in urban area is an indication of higher human activities than in the rural area. Human activities such as bush burning and fish smoking, and could also be attributed to exhaust from vehicle emission. Arif *et al*, (2021), who studied rainwater chemical properties in Bangladesh, concluded that high turbidity reflects the presence of particulate matters in the atmosphere and that, it was influenced by anthropogenic activities such as transportation, commerce and agriculture. Adeyeye *et al* (2019), reported the turbidity of Ikole in Ekiti state as 0.47NTU, indicating low human activities. Unlike in Niger Delta, where industrial and commercial activities were high, the turbidity recorded by Azuonwu, *et al*, (2017) was 9.0NTU. The major effect of turbidity is aesthetic and high levels of turbidity for a short period of time may

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not be significant than a lower persistent level. In April, June and July, the turbidity were 28.73, 5.47 and 4.32NTU respectively. Rainwater was more turbid April; this could be due to lower rainfall amount and bush burning associated with planting season (Mojeed and Tanimola 2018). It could be effect of early rainfall which carries polluted air as a result of anthropogenic activities (Zheng *et al*, 2017).

The average temperature of 29.7^{0}C for urban area and 30.63^{0}C for rural area were recorded. The temperature was measured in-situ. The temperature range was 28.0.0-31.5 (3.50)^{0}C. It affects some of the important physical and chemical properties of water; thermal capacity, density and weight. The higher the temperatures', the higher the solubility of solutes. The temperature range was in line with Adetunji, Adebayo and Tanimola, (2017), when studying rainwater quality around a cement producing firm in Ewekoro, south-west Nigeria. The result indicated that the ambient temperature was 26.3^{0}C. This also agrees with WHO's MPL of 20-30^{0}C as reported by Azuonwu *et al*, (2017). In Bichi LGA of Kano state, Emmanuel (2019) recorded the average temperature of 25.03^{0}C. The temperature recorded in April, June and July were 30.97, 28.10 and 27.93^{0}C respectively. It reduces with increase in rainfall. Global increase in temperature is as a result of increase in Greenhouse gases (GHGs), due to human activities such as industrial pollution, destruction of nature, combustion of fuel, gas flaring, used chemicals (Cabasch, 2013).

SO_4 – The result showed that the range of SO_4 was between 0.08 and 4.91(4.83) mg/l. The recorded mean values were 1.70mg/l for urban and 0.15mg/l for rural. Emissions of SO_4 are attributed to sources of rainwater acidity. However, low value in rural area could imply that there were minimal anthropogenic and low sources of emissions of Oxides of SO_4, Carbonates and NO_X and ozone to some extents are the primary causes of acid rain. This result asserts that the findings of Zhong *et al*, (2017) who found that SO_4 and NO_X are from anthropogenic activities, while Fu *et al*, (2017) suggests that SO_4, NO_X and Ca are primarily derived from urban construction, agricultural activities and vehicle emissions. The recorded mean values were within NSDWQ, FEPA and WHO MPL of 100mg/l and 250mg/l respectively. Urban area had high commercial, traffic and particulate matter emission sources than the rural areas. In an industrial area of Shanghai in China, the SO_4 recorded was 200mg/l and in some selected communities of Niger Delta, it was 2.10mg/l, according to Azuonwu *et al*, (2017). April, June and July had mean values for SO_4 as 1.77, 0.11 and 0.12mg/l respectively. High SO_4 values in rainwater were observed due to low rainfall intensity in April. This is supported by Aderonke *et al*, (2021) and Abubakar and Ajadike (2023).

The Nitrates range for the study area was between 2.42 and 8.73 (6.31) mg/l. The data showed mean values of 6.02mg/l for urban and 5.52mg/l for rural area, which were within the NSDWQ and WHO MPL of 50.0mg/l. The high value in urban area could be due to high commercial, road construction and transportations activities. Settled areas discharge higher pollutants to the atmosphere (Zhong *et al*, 2017). Similarly, Zhao *et al*, (2019), is of the opinion that emission of SO_4 and NO_X affect rainwater properties and Imo *et al*, (2021), believes that chemical composition of rainwater varies from site to site and region to region depending on the influence sources point and anthropogenic activities. This position is supported by Daniel *et al*, (2020), who stated that the Nitrate concentration level in some parts of Port-Harcourt, and that they were in decreasing order based on locations from

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Chokocho, Ogale, Rumuodamaya and Diobu. The study concluded that it could be attributed to fertilizer, agro-allied industries based in the area. This opinion also corroborates with Zhao *et al*, (2019), who said that, dependence on fossil fuel has resulted in frequent rainwater physico-chemical properties change or alteration. Since, rainwater quality is influenced by the local activities (Cobbina *et al*, 2013), the result obtained shows that April, June and July values were 2.07, 9.18 and 5.81mg/l respectively. April had the highest NO_X concentration due to less quantity of rainfall in the month that could have cleaned the atmosphere (Akinbobola *et al*, 2023). Higher concentration of NO_X experienced in June was due to less intensity of rainfall within the month as shown (fig 4).

EC- The EC value of rainwater is directly related to the total amount of soluble ions. Thus, lower EC values indicates that the air quality is improved or rainwater has a higher dilution effect (Zhang *et al*, 2017). The range of EC in the study area was between 6.30 and 107.40 (101.10) µs/cm. EC of urban area mean value was 40.93µs/cm, while the mean values for rural areas was 22.60µs/cm. These figures were lower than 1000µs/cm, the MPL by NSDWQ, FEPA and WHO standards. High mean value of EC in rural area could mean high human activities (Zhang *et al*, 2017), particularly farming activities in the rural area. Another factor that could have contributed to high EC in the rural area could be long range particles and dusts transport as suggested by Li *et al*, (2016). Ayeki *et al*, (2017), reported that the higher conductivity in rural area could be attributed to sources of particulate matter that interacts with rain to form ions. Adetunji *et al*, (2017), reported the EC of 6.9µs/cm in Ikole -Ekiti state respectively, the town is a commercial centre with high population and industries. The reported area had values lower that the study areas, this could be attributed to rain intensity dilution effect. It could also be as a result of wind action that could have transported dissolved chemical substances in the atmosphere. This agrees with Egwuogu, (2016), when he studied rainwater quality in different communities of Obio-Akpor, River state. These figures were all higher than the study area, which further validates that the study areas lack industrial presence. EC values in April, June and July were 71.34, 10.13 and 4.67µs/cm respectively. The temporal data indicates that April had the highest EC as compared to June and July. Since rainfall started in March and intensity progresses with season as shown in fig 4. Low value in July could be attributed to rainwater dilution effect (Abubakar and Ogbu, 2023).

TDS – It consists of inorganic salts and small amounts of organic matter present in dissolved form in rainwater. The value of TDS depends upon atmospheric composition of that area. The data showed that the range of TDS in the study area was between 5.40 to 174.0 (168.6) mg/l. The mean value for TDS in urban area was 61.97mg/l, while it was 23.07mg/l for rural area. The figures were within the NSDWQ, FEPA and WHO MPL of 600/2000/500mg/l respectively. The reason for elevated TDS in urban area could be reflection of high anthropogenic activities, such as presence of local Government offices, banks, schools' markets, boat engines and motor parks. This assumption agrees with Belonwu *et al*, (2016) on research conducted on three sites in core Benin city. The investigation reported that there was reduction in water pollution concentration from the core to periphery which was attributed to lower anthropogenic activities in the area. The research concluded that, although, densely populated area had value lower than non-populated areas, this could be attributed to wind

Academic Journal of Science, Engineering and Technology
Vol. 9, Issue 3; May-June 2024;
ISSN: 2837-2964
Impact Factor: 6.67
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action. This assertion supports Ayeki *et al*, (2019) argument, on ability of wind trajectory action to carry suspended particles far away from the source. This is also in line with report of Vincent *et al*, (2016), on impacts of emissions from crude oil tanks and gas flaring sites on Bonny Island. The research concluded that, the turbulence generated from the flare instigated the initial dispersion of the pollutants which were transported to the residential areas found downwind of the industrial area in the Bonny Island. Low values in July, shows that the atmosphere was cleaner due to intensive rainfall. For the monthly variation of rainwater properties in the study area, the April, June and July had TDS value as 95.73, 7.07 and 5.30mg/l respectively. The high value in April is an indication of high dissolved chemical components of rainwater in the atmosphere. However, the values decrease with increase in rainfall quantity as reflected in June and July results. This assumption is supported by Gowin *et al*, 2019 and Aderonke *et al*, 2017.

TSS – It can cause water to be cloudy, and reduces water transparency. TSS is a measure of turbidity or cloudiness of water. The range of TSS in the study area was between 10.0 and 30.0 (20.0) mg/l. Urban and rural areas had TSS mean value of 18.67 and 17.53mg/l respectively. Low TSS value in rural areas could be an indication of low sources of SPM and other human activities. This opinion, also agrees with the work of Ebong *et al*, (2016) and Adeyeye *et al*, (2019), that particulate matters concentration in atmosphere influences the quality of rainwater harvested. This opinion is similar to that of Emerole, (2015), who emphasized the impacts of population density on quality of rainwater in Orji community in Imo state. TSS obtained results were within NSDWQ and WHO MPL of 500mg/l. Onah, Obasi and Ossai (2019), studied physico-chemical quality of rainwater in five selected sites of Enugu; Agbani, IMT, Coal city, Abakpa and Emene. The mean TSS value in these sites was 305.6mg/l. Elevated values are indication of higher population, presence of industries and other anthropogenic activities. Data for temporal variation of rainwater properties shows that the TSS mean result for April, June and July were 28.24, 10.67 and 14.82mg/l (fig. 3) April had the highest TSS concentration, followed by June and then July. This shows the effect of rain intensity on the rainwater properties. This assumption is supported by Ebong *et al*, (2016).

Mg – The range of Mg in the study area was between 2.06 and 2.19 (0.13) mg/l, while the data shows that urban area had the Mg ions of 2.15mg/l, rural had 1.71mg/l. The figures obtained were within NSDWQ and WHO MPL of 20.0 and 50.0mg/l respectively. The urban area had elevated result due to human activities in the area (Zeng *et al*, 2019 and Imo *et al*, 2020). Mg and other alkali (e.g. Ca) are responsible for water hardness. Ca and Mg ions are soluble in water but they constitute hardness. Ikole town, where a cement company is sited in south-west Nigeria, had mean Mg value of 2.40mg/l. The value was slightly higher than the study area. This could be attributed to the presence of industrial and other commercial activities around Ikole town. The assertion also agrees with Kabir and Madugu (2010), that physico-chemical constituents of rainwater often reflect environmental impact of land use activities in an area. Although, the effect of atmospheric pollutants can be trans-boundary, studies here indicated that concentration of certain chemicals can be more in certain vulnerable environment than the less vulnerable region. Garcia-Martinez *et al*, (2020), who recently worked on chemical composition of rainwater in Mexico, reported a comparative data on Mg ion concentration in coastal, mountainous, dusty and urban areas of Mexico as 26.0, 7.73, 24.1 and 9.90mg/l respectively. Coastal area having

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the highest Mg ion value, followed by dusty areas. Temporarily, April, June and July had mean Mg values of 2.02, 1.87 and 1.68mg/l respectively. Low values in June and July showed the effect of rainfall intensity on Mg ion concentration. Rainfall frequency and intensity have dilution effect on physical and chemical constituents of rainwater in the study area as supported by Vincent *et al*, (2020) and Abubakar and Ogbu, (2023).

Iron – Fe concentration range in the study area was between 0.05 and 0.51(0.46) mg/l. Fe values of 0.21mg/l and 0.12mg/l were recorded for urban and rural areas respectively. They are within WHO, FEPA and NSDWQ MPL of 0.30mg/l. The high value of Fe in urban area could be attributed to higher population, commercial activities and transportation sources in the area. This view agrees with Xu *et al*, (2020), who stated that industrialisation, urbanisation and transportation are key sources of rainwater pollution in the atmosphere. Other sources of Fe concentration in urban rainwater could be through crustal source, quarrying and construction activities, or through fossil fuel combustion. In some locations in Akwa-Ibom state, Ebong *et al*, (2016), had the concentration of Fe in Eket and Ibino-Ibom as 0.59mg/l and 0.22mg/l respectively. Eket town, an oil producing area had Fe concentration higher than in Ibino-Ibom, a non-oil producing area. Similarly, Arif *et al* (2021), reported Fe range from 0.00 to 440mg/l, in Jordan, India and Japan with mean iron value of 4.30, 69.2 and 7.50mg/l respectively. India. From monthly variation, Fe concentration had the highest value in April. There was increase in concentration of Fe from April, June and July as 0.27, 0.07 and 0.07mg/l respectively. This explains the effect intensity of rainwater (dilution) on properties of rainwater in the study area. This argument is supported by Aiyeki *et al*, (2019).

Pb – The range in the study area was between 0.01 and 0.01(0.0) mg/l. Urban and rural areas had the mean values of 0.01mg/l, the values were within NSDWQ and WHO MPL of 0.01mg/l. Although Pb concentration is within NSDWQ and WHO MPL, it is on the threshold limit (0.01mg/l), and this calls for concern from well-meaning authority. The study area had no industrial presence and most of the people living in the area are predominantly farmers and fishermen, presence of Pb in rainwater is an indication of atmospheric pollution with combustible materials from petroleum products and crustal activities (Subodh, 2021). This assumption is supported by Subodh, (2021). Therefore, the Pb in the study area could be due to wind trajectory action that might have transported Pb from other locations (Zheng *et al*, 2017). In evaluating spatial rainwater quality in six selected areas of Akwa-Ibom state, between March and November, 2008-2010, Ubuoh, *et al*, (2012), found out that the range in Pb concentration was 0.01-0.014mg/l. April, June and July had mean Pb value of 0.01mg/l in the three months. The same value throughout the study period is an indication of recalcitrant presence; rainfall intensity and frequency had no effect on its concentration. This calls for concern.

Cadmium – It is extracted during production of metals such as Cu, Pb and Zn. It can be found in certain foods and also emitted by burning fossils fuels like oils, coal and during smoking cigarette. Cd range was between 0.001 and 0.003 (0.002) mg/l. Urban and rural areas had mean value of 0.001mg/l each. The obtained shows that the values were within NSDWQ, FEPA and WHO MPL of 0.003mg/l. This could be attributed to low human activities and low population density in the study area. This assertion is supported by researchers such as, Ubuoh, (2012; 2016), Arif *et al*, (2020) and Zu *et al*, (2020). Ona *et al*, (2019), reported the mean concentration of Cd in

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Enugu as <0.001mg/l. Similarly, Arif *et al*, (2019), reported comparative concentration of Cd in Jordan, Mexico and India as 52.0, 80.5mg/l and <0.001mg/l in India. Therefore, data suggests that, the study area lack industrial activities and other human activities that could have generated dusts and particulate matter in the atmosphere. The data from monthly variation of physical and chemical properties of rainwater in the study shows that, April, June and July had Cd concentration of 0.001mg/l.

Ca – The range was between 3.10 and 4.62 (1.52) mg/l in the study area. Urban area had mean value of 4.11mg/l, while the rural area had 3.14mg/l. The value of Ca in Urban area was higher than the value from rural area. The obtained values shows that the urban and rural areas had value within NSDWQ and WHO MPL of 75.0 and 100mg/l respectively. This could be attributed to low human activities and low population density in the study area that could have generated dusts and other suspended particles to the atmosphere. Ca is a pH stabiliser; it has a neutralising effect on rainwater. Ca and Na are mostly from marine contribution that have long-range transportation of sea salts and limestone mining from quarries (Patrick and El shalom, 2020). This assertion is supported by Whiley, Edwards and Ross (2018), that the characteristics of rainwater depends on the atmospheric particulate, gaseous constituents produced locally or transported from distant sources by natural or anthropogenic sources. This shows the effect of atmospheric chemical component during the dry season, usually higher due to dusts and particulate matter present. (Aderonke 2017). Similarly, the data from monthly variation of physical and chemical properties of rainwater showed that, April, June and July had Ca concentration of 3.94, 4.05 and 2.39mg/l respectively. April and June values were within the same range. This could be due to wind transport effect as supported by Zheng *et al*, (2017).

Cl – The ion is naturally occurring in most natural waters and is most often found as a component of salt (NaCl) or in some cases in combination with Ca and Mg. The source could be from agro-allied fertilizer and industrial activities which are from dissolution of aerosol in the atmospheric interaction with rainwater (Patrick and El Shalom, 2020). Cl ion range was between 7.01 and 31.95 (24.94) mg/l. Urban and rural areas had mean value of 16.54 and 8.16mg/l respectively. The higher Cl value in urban could be traced to higher human and crustal activities in the area. Although, the Cl values for both urban and rural were within the NSDWQ and WHO MPL of 150mg/l, the Cl ions could have spread to the atmosphere from natural or anthropogenic sources in the area as asserted by Martins and Nagorotto, (2019). Chemical composition of rainwater clearly reflects the degree of air pollution in urban, rural and industrial biomes. To corroborate this assertion, Rao *et al* (2016), and Mahato *et al*, (2016), opined that, owing to the effect of local sources, the chemical composition of rainwater varies with geographical location. The data from monthly variation of physico-chemical properties of rainwater in the study area shows that, April, June and July had Cl ion concentration of 17.17, 9.12 and 6.56mg/l respectively. April had highest Na ion values when compared to June and July. It could be due to the effect of low rainfall as April marks the beginning of rainy season, as suggested by Abubakar and Ogbu, (2023), and Ayeki *et al*, (2019) or could be due to high agricultural activities with intensity of rainfall in June on physico-chemical properties of rainwater in the study area as opined by Zhang *et al*, (2017).

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ISSN: 2837-2964
Impact Factor: 6.67
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Na –It is commonly taken as the best reference element to marine source of atmospheric composition (Cobbina *et al*, 2013). Na range was between 0.08 and 0.10 (0.02) mg/l in the study area. Urban area had mean Na value of 0.09mg/l, while the rural area had 0.13mg/l. The Na ion from rural area had mean value higher than the value from urban area. The higher Na value in rural area could be traced to higher human or natural activities such as farming, wind action, nearness to geological formation with Na. Other sources could be transportation and the effect of particulate matter like dusts particles in the area as argued by Abulude *et al*, (2018). The Na values for both urban and rural were within the NSDWQ and WHO MPL of 200mg/l, Godwin *et al*, (2019), reported mean value of Na in Benin city as 1.83mg/l. Nwineewii and Egwuatu (2019), also reported the mean value of Na in industrial area of Port-Harcourt as 33.49mg/l. Temporarily, in April which marks the onset of wet season in the study area had Na concentration as 0.17mg/l. June and July had 0.12 and 0.70mg/l respectively. The data suggests the effect of rainfall intensity on rainwater chemical composition (Aderonke *et al*, 2017; Godwin *et al*, 2019 and Abubakar and Ogbu, 2023) and Low rainfall in July, shows that the atmosphere was cleaner.

SUMMARY

The 15 rainwater properties tested were within WHO, NSDWQ and FEPA MPL. Turbidity was the only parameter above the three standards for drinking water and for environmental pollution. Turbidity mean value were 22.7 and 14.17NTU for urban and rural area respectively. The elevated values in both areas could be due to high TSS and TDS in the atmosphere particularly in April which marks the period of rainfall onset. These particles and aerosols were generated by human and natural sources. This assumption supports the opinion of Aiyeki *et al*, (2019), Adeyeye *et al*, (2019), that particulate matters concentration in atmosphere influences the quality of rainwater harvested. However, the data from table 1, showed that 73% of the parameters (pH, Turbidity, Cl, TDS, TSS, EC, SO_4, NO_3, Ca, Mg and Na) were higher in urban area than rural area, while 7% were high in rural (Temperature) than in urban area. High anthropogenic activities such as transportation, road construction, fertilizer application, bush burning, fish smoking and power generation from power plants could be responsible (Keresztezi *et al*, 2019). However, 20% of the physical and chemical parameters (Pb, Cd and Fe) have the same values in both areas. This could be attributed to crustal activities (Ebong *et al*, 2016 and Mahato *et al*, 2016), as there is bridge construction that links Taraba state with Plateau, Nasarawa and Benue states within the study area. Uban area (Ibi town), experiences higher human activities such as transportation, farming activities, population density (due to location of LGHQ offices), presence of large markets, motor parks, banks, general hospital and schools. These factors contributed to emission of elevated quantity of pollutants, thereby contributing to the atmospheric chemical composition of urban areas. Rural environment lacks industrial activities, production of gases such as carbon monoxide, Nitrogen oxides, and Sulphur dioxides could barely be significant to affect the quality of rainwater. This assumption is supported by researchers. For instance, presence of dissolved ions in rainwater (Abbasi *et al*, 2017), farming activities (Abulude and AbdulKadir, 2018, Agnes *et al*, (2020) and Mojeed and Tanimola, (2018), influence of dust particles in the atmosphere (Abbasi *et al*, 2017, and Abiodu and Olabode, 2020), wind trajectory air mass movement (Panam *et al*, 2017), and bush burning associated with planting season (Mojeed and Tanimola 2018 and Aderonke 2017). Temporarily, the pH values were alkaline

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Impact Factor: 6.67
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during the months of April, June and July. This could be an indication of low anthropogenic activities. Natural rainwater is normally considered to be weakly acidic with a pH value of 5.6 (Niu *et al*, 2014), when the atmosphere is free from pollution. This could also suggest that the influence of anthropogenic sources due to acidic gas was minor and the effect of particulate matter of alkaline nature-like dust particles was dominant (Abulude *et al*, 2020). Turbidity was above all the standards in April and June (28.73 and 5.47NTU), while July was 3.89NTU. From table 1, 60% of the parameters; Turbidity, pH, temperature, TDS, EC, Mg, Cl, Na and Fe show decreasing order in mean values. This could be attributed to low mean rainfall in April through to July; an effect of early rainfall which carries polluted air as a result of human and natural sources, (Zheng *et al*, 2017 and Ubuoh, 2012) as shown in figures 3 and 4. 13% of the parameters (Cd and Pb) showed the same values of rainwater properties within the sampling period, while 27% (Ca, NO_x, SO_4 and TSS) were not linear with respect to rainfall in mean values. This could mean that the amount released into the atmosphere is insignificant whether during rainfall onset or at its peak.

RECOMMENDATION

Based on the result obtained and data analysis carried out, I recommend the following;

Turbidity in rainwater is a product of suspended and dissolved particles in the atmosphere. Dusts generation are caused by bad road condition and the high traffic in the study area. Therefore, there is need for urgent road rehabilitation, this will reduce dusts that could have increased dissolved and suspended particulate matter in rainwater. In addition, it will further reduce the risks of bronchitis and related health challenges. Domestically, turbidity can be removed by using Moringa seed flocculation method.

Lead value at thresh hold level of 0.01mg/l is of great concern. Relevant authorities should monitor it closely for proper management.

CONCLUSION

The rainwater tested was alkaline, acidic component were not strong enough to neutralize the rainwater. Ibi LGA rainwater meet NSDWQ, WHO and FEPA standards for drinking quality and environmental pollution, except for turbidity. It is the quantity of suspended solids in water, affecting its aesthetic. Spatially, the study shows that urban area experienced high values of physical and chemical properties, which could be attributed to human activities such as population, farming, poorly maintained roads that generates dusts, vehicular and engine boat transportation. This could have contributed to emission of gases, particulate matter and aerosols into the atmosphere; they dissolve in rain and fall to the earth surface as rainfall. Temporarily, April has high value of rainwater physical and chemical properties as compared to June and July. The reason could be that, onset of rainfall, usually carries polluted air, whose particulate air loading is high due to the season (dry due to harmattan dusts), and human activities. The t-test analysis was carried out using SPSS Version 23, the p value was 0.81, which suggests that there was no significant relationship between the variables. Water quality varies with increase in rainfall. The wet season from study area has shown two distinct seasons with little dry season within the wet season. Rainwater gets its chemistry based on the nature of atmospheric air composition which depends on location and season.

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