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RESEARCH ARTICLE

Variations in Physico-Chemical Properties of Rainwater in Rural and Urban Areas of Wukari Local Government, Taraba State, Nigeria

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ABSTRACT

The study examined the effect of variations in physicochemical properties of rainwater in parts of Wukari Town and Chinkai, in Taraba State, Nigeria. It was carried out using literature on similar topics. From the Wukari town, and chinkai data were used. The study evaluated the spatial variations of rainwater properties mainly within wet seasons using temperature, pH, colour, turbidity, electrical conductivity, Total dissolved solids, Total suspended solids, sulphates, hardness nitrates, copper, sodium, magnesium iron, and lead as parameters used. Results showed that there was spatial variation in the physicochemical properties of rainwater in the study. The research concluded that the rainwater from both regions was acidic. Wukari town rainwater was more polluted than the south-south region due to higher concentrations of TSS, Sulphate, Nitrates, Turbidity, and lead. The physicochemical properties of rainwater were directly related to the prevailing air quality which determined the quality of rainwater. The study also observed that rainfall intensity, agriculture, industries, and other anthropogenic activities could have contributed to Rainwater quality variation. The study recommends that reduction in emission of greenhouse gases, use of scrubbing systems in industries, improved electricity from the national grid a well as employing the use of gas turbines by industries will go a long way in mitigating the impact of rainwater pollution.

Keywords: *Physico-Chemical Properties; Rainwater; Rural; Urban Area; Wakiri Local Government; Taraba State*

Introduction

Rainfall plays a significant role in the hydrological cycle, adds to the earth's freshwater reserves, and creates favorable conditions for many kinds of ecosystems. Additionally, it is necessary for irrigation to increase crop yield and the production of hydroelectric power (Chidiebere, 2017). Rainfall is a 1 to 5-mm-diameter drop of liquid water that falls from the atmosphere to the surface of the Earth. Rainwater, however, was cited by Alexander (2020) as one of the most significant natural resources because it is thought to be the secret to success and wealth. Rainwater is regarded as a blessing in many cultures, a lifesaver, and a frequent alternate source of water worldwide. Although rainwater is harmless, the local environment and atmospheric conditions have an impact on and affect the chemical compositions at the time of collection. As a result, different locations may have varying amounts of elemental concentration (Arif and Asiful, 2020). The technique of data collecting adopted was experimental.

Since knowledge of the chemical composition of rainfall offers information on the sources of the water's chemistry as well as the local and regional dispersion of contaminants, researchers in recent decades have devoted particular attention to studies of rainwater composition, including Szep, Mateescu, Nita, Birsan, and Karesztesi (2018). In investigating hydrological response, rainfall is one of the main sources of uncertainty (Thorndahl, Finfalt, Williams, and Nelson 2017). Rainfall is a key driver for many hydrological processes. Because of the consistently high rate of evaporation and the comparatively high annual temperatures in the tropics, the significance of rainfall in agriculture is even more outstanding. Water plays a crucial role in the daily lives of all living beings. The sources may come from the ground or the atmosphere. Mohammed, Francis, and Aishat 2020. Surface water is essential to daily life and is typically supplied naturally by precipitation. Oceans, rivers, lakes, seas, reservoirs, and wetlands are a few examples. Surface water is the water that accumulates on the earth's surface, is kept there by rainfall or other precipitation, and is lost by ground evaporation, where it is used by both plants and animals (Tahmina, Leela, and Kelvin 2018).

In a related study of the Bichi local government area in the Nigerian state of Kano, Emmanuel (2018) expressed the opinion that the results of the evaluation of rainwater quality were within WHO and NSDWQ (National Standard for Drinking Water Quality) allowed limits. He came to the conclusion that it was because there were no or few industrial operations in the area. As opposed to the states of Bayelsa, Imo, and Akwa-Ibom, where automobile emissions, industrial discharges, and commercial activity were all frequent and had an impact on the quality of the local rainfall. He made an effort to emphasize, though, how geography affects the quality of captured rainwater. It may be difficult to evaluate how the chemistry of rainwater has changed and identify the variables that affect changes in the chemical composition of the atmosphere (Aderonke, Okoya, Bamikole, Osungbemiro, and Temi, 2017). Therefore, the main goal of this study is to identify the spatial variations in the physico-chemical characteristics of rainfall in urban and rural parts of Taraba state, Nigeria's Wukari Local Government area.

Statement of the Problem

Developments in science and technology have brought improved standard of living but have also unsuspectingly introduced some pollutants into our environment. Previous studies on the quality of water resources in the tropical African environment have largely been restricted on the assumption that rainwater is usually very pure and therefore, needs very little investigation. However, studies have shown that rainwater quality can be significantly impaired in industrialized districts (Ubuoh, 2012). Assessment of the chemical composition of rainwater is highly dependent on the concentration of air pollutants and particulate matter in the atmosphere. This type of assessment helps in understanding the relative contribution of different sources of atmospheric pollutants (Bodor, Bodor and Szep (2020); Boga *et al*., 2019). Then, it is for this reason, the study was carried out to determine the variations in physico-chemical properties of rainwater in an urban and rural areas of Wukari Local Government area in Taraba state, Nigeria.

Aim and Objectives

The main objective of this study is to examine the effect of factors responsible of the variations in the physico-chemical qualities on the rainwater in the area.

The specific objectives of this work are achieved through the following.

i. To identify the effect of physico-chemical parameters on the rainwater in the study area
ii. To determine the effect of spatial variations in physico-chemical quality on the rainwater in the study area
iii. To identify the effect of the factors responsible of the variations in the physico-chemical qualities on the rainwater in the area.

Hypotheses of the Study

The following hypotheses were identified to enable us to achieve the aim of the study:

i. Physico-chemical parameters has no significant effect on the rainwater in urban and rural areas of Wukari local Government area of Taraba state, Nigeria.
ii. Spatial variations in the physico-chemical parameters have no significant effect on the rainwater in the area.
iii. Factors responsible of the variations in the physico-chemical qualities has no significant on the rainwater in the area.

Review of Related Literature

Conceptual Review

The chemical relationship between particulate matter and precipitation has been the subject of intense research in the last decades. The assessment of the chemical composition of rainwater is highly dependent on the concentration of air pollutants and particulate matter from the atmosphere, being an indicator of the air quality and helping to understand the relative contribution of different sources of atmospheric pollutants (Bodor *et al*, 2020; Boga *et al*, 2019). In studying chemical properties of rainwater, the composition of rainwater reflects the composition of the atmosphere through which it falls Owing to the effect of local sources, the chemical composition of rainwater varies by geographical locations (Rao, Matwale and Tiwari (2016).

The accentuated spatial variability of atmospheric pollutants is influenced by the regional air mass circulation loaded with different pollutants and by the significant local contribution of atmospheric circulation regimes, developed by at a local scale (Korodi *et al*, 2017; Petres, *et al*, 2017). This variability is also influenced by the mountain systems that interrupts the circulation of air masses (Szep *et al*, 2018). To explain the effect of mountains on local rainwater chemistry in Miercurea eastern Romania, Keresztesi *et al*, 2019, concluded that Hurghita mountains, which acted as a barrier blocking the regional fronts loaded with sea salts, had its local precipitation more frequent, explaining a lower contribution of marine influence.

Population growth and the expansion of urban and industrialised areas have put great pressure on water resources (Luizzo, *et al*, 2016). Climate change will intensify this pressure in some parts of the world including Mediterranean basin, West United states and southern Africa, resulting in a predictable decrease in water resources in the coming decades (EPA, 2017). In a separate study of Warri in south-south, Nigeria, Belonwu, Duru, Onyeike, Denechukwu and Udoinyang (2016), concluded that the results he obtained between populated and non-populated areas showed that rainwater from populated areas have higher chemical composition than non-populated areas.

From the forgoing, it is always assumed that acid rain phenomena only occur in a busy city by heavy traffic congestions and industries activity (Sun, Wang, Li, Yang, Sun, Wang and Wang, 2016), this assumption could be reversed with China's experience in some industrialising areas. In research conducted, there was a strong correlation between windblown dust species of Ca and Mg which is consistent with the extensive development of carbonate rocks (Lu, Zheng, Miller and Aluvardo, 2017).

Theoretical Framework

This work is anchored on the following the Framework that 'Rainwater is a mixed electrolyte that contains varying amounts of major and minor ions. Na, K, Mg, Ca, Cl, and SO_4^{2-} are major constituents, together with NH_3, NO_3, NO_2, and other compounds' (Hutchinson, 1957). Electrolytes are minerals that dissolve in water. Specifically, they dissolve into cations (positively charged ions) and anions (negatively charged ions) in water, or in any aqueous solution (a solution in which water is the solvent). When dissolved in water, they create an ionic solution, i.e., a fluid containing ions. Rainwater is an ionic solution because it dissolves various anions and cations in the atmosphere.

Secondly, the theory of Precipitation by Bergeron Findeisen around 1935, states that "Ice crystals high in the atmosphere grow by collecting water vapour molecules, which are sometimes supplied by microscopic evaporating cloud droplets." It provides a mechanism for growth of raindrops in ice/water cloud. Precipitation is the natural process of conversion of atmospheric vapour into water. These chemical constituents come from both natural and anthropogenic sources (Mimura, Almeida, Farreira, Siva, 2016). The presence of dissolved ions also provides information on both local and long-range transported pollutants (Akpo, Lacarux, Laoualli, Delon, Liousse and Adon 2015). However, the theory backing this study is the first framework. This explains how rainwater becomes a cleansing agent in the atmosphere by dissolving the soluble substances

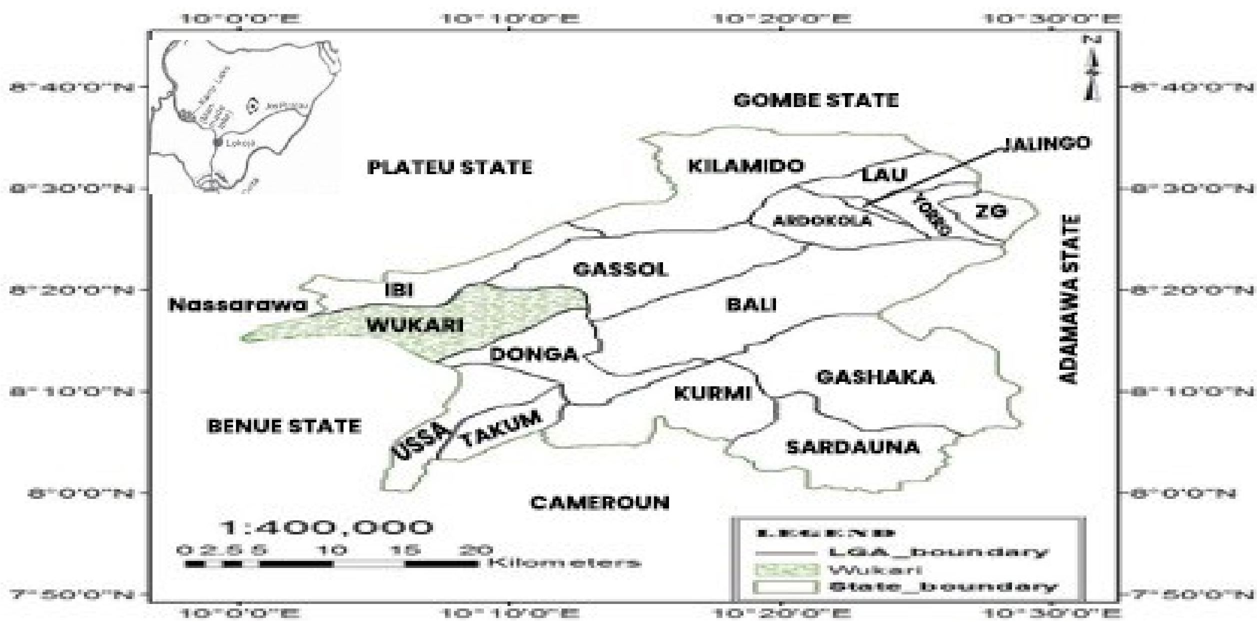
Methodology

The research design employed was experimental design. The sources of data were primary and secondary sources. Data collection method used was experimentation. The estimated of the study area was 31,772 people. The population studied include academic institutions, for instance Federal universities of Wukari and Kwararrafa university which provided academic journals and magazines. The sampling used was stratified random sampling. The technique reduced bias and created accurate sampling.

Using Taro Yamene equation (1968).

$n= N/1+N^{(e)2}$, The population of Wukari LGA was 238,283 -people (NPC, 2006), however, the selected study area has the estimated population of 31,772 people.

By substitution, n = 31,772/1+79.43; n = 31,772/80.43; n = 395 as sample size



Source: Abuh, Joshua and Joseph (2011**)**

Figure 1: Map of Taraba state showing Wukari local Government Area

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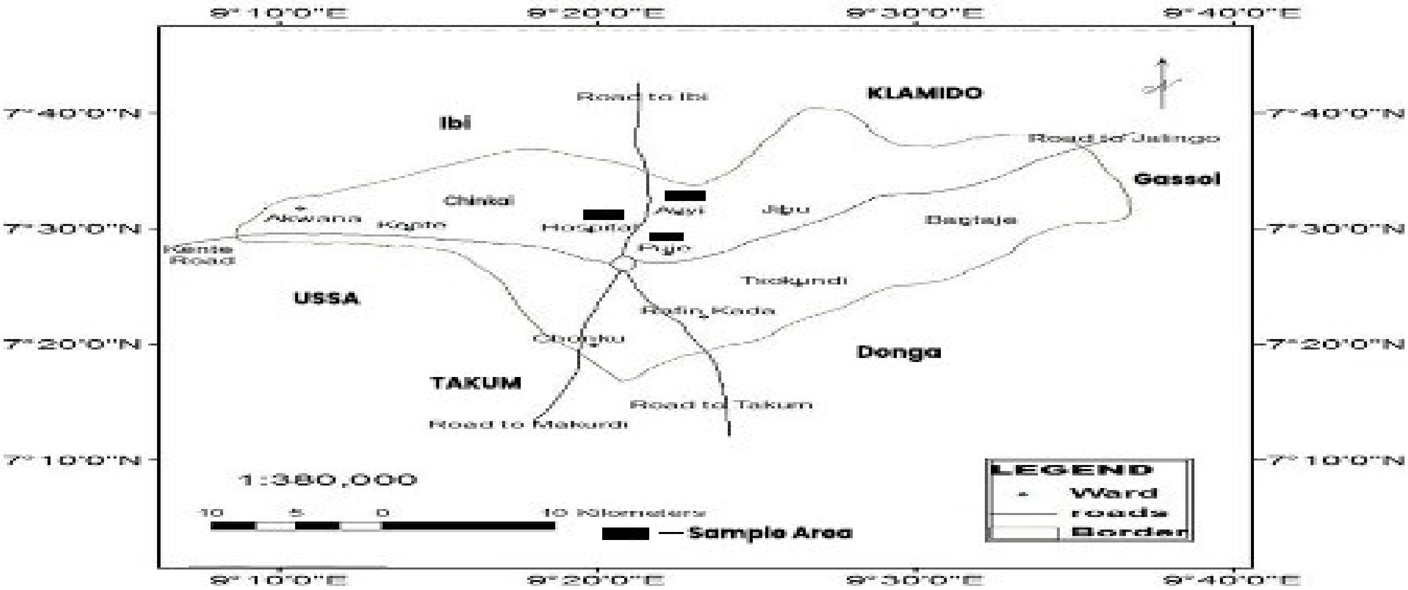


Source: Abuh, Joshua and Joseph (2011)

Figure 2: Map of Wukari showing its wards and sampling areas

Data Presentation and Analysis

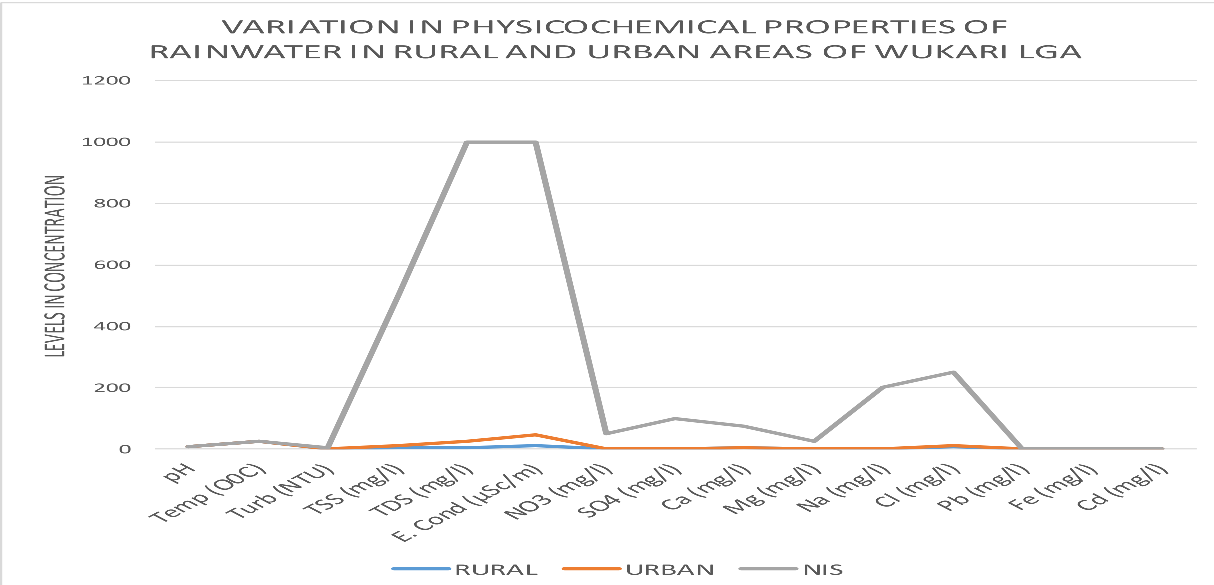
Data Presentation

Table 1: Variation in Physico-chemical Properties of RW in Rural and Urban Areas of Wukari LGA

PARAMETER	*RURAL AREA*	*URBAN AREA*	*STD DEV.*	*WHO*	*NIS-2015*
pH	7.20	7.20	0.00	6.5-8.0	6.5-8.5
Temperature (O^0C)	26.30	26.20	0.05	Ambient	Ambient
Turbidity (NTU)	1.61	1.81	0.10	5.0	5.0
TSS (mg/l)	3.33	10.00	3.34	NS	500
TDS (mg/l)	5.67	24.30	9.32	600	500
E. Cond (µs/cm)	11.53	45.17	16.82	NS	1000
Nitrates (mg/l)	1.62	1.71	0.05	50.0	50.0
Sulphate (mg/l)	0.09	0.36	0.14	250	100
Calcium (mg/l)	3.17	3.61	0.22	100	75.0
Magnesium (mg/l)	2.09	2.00	0.05	50.0	20.0
Sodium (mg/l)	0.12	0.49	0.19	200	200
Chloride (mg/l)	7.10	10.06	1.48	250	250
Lead (mg/l)	*0.016	*0.177	0.08	0.01	0.01
Iron (mg/l)	0.110	*0.50	0.195	0.30	0.30
Cadmium (mg/l)	0.002	0.001	0.0005	0.003	0.003

NB: * = Higher value than WHO and NIS-2007 specification

Source: Field Survey, 2022



Source: Field survey, 2022

Figure 3: Variation in Physico-chemical Properties of Rainwater in Rural and Urban areas of Wukari LGA

Data Analysis

pH- The data shows that the RW samples from the study area had mean pH value of 7.20 for both rural and urban areas as shown in Table 1. This implies that the water was alkaline. The pH of normal RW is acidic; the reason is that water reacts to a slight extent with atmospheric CO_2 and NO_3 to produce carbonic and H_2CO_3. The result obtained from the study area could be due to dilution effect rainy season. This agrees with Egwuogu, Emenike and Abayomi (2016), when they were studied RW quality in Obio-Akpor area of Rivers state. The mean values of pH at 7.20, was within MPL of WHO and NIS at 6.5 to 8.5. Turbidity - Turbidity results of 1.61NTU and 1.81NTU for rural and urban areas respectively were recorded (Table 1). These were low compared to 4.05NTU recorded by Efe and Mogborukor, (2011) in Niger Delta when they studied RW quality within the same season. Low turbidity could be due to low industrial, agricultural and commercial activities that could have generated suspended and dissolved particles in the atmosphere. This agrees with Arif *et al*, 2021, who carried out analysis on RW in Bangladesh.

The temperature of 26.3^{0}C for rural area and 26.2^{0}C for urban area were recorded. The temperature of water affects some of the important physical characteristic and properties of water; thermal capacity, density and weight. The analysis indicated that the experimental temperature was 26.3^{0}C. This agrees with WHO's MPL of 20-30^{0}C as stated by Azuonwu *et al*. (2017).

Sulphate - The mean values were 0.09mg/l for rural and 0.36mg/l for urban (Table 1). Emissions of sulphate were attributed to sources of rainwater acidity. However, lower level in rural than urban areas could imply that there were low sources of emissions of NO_X and ozone to some extents are the primary causes of acid rain. Adeyeye *et al* (2019), recorded SO_4 value of 1.77mg/l in Ekiti state. Ikole area is an industrial and commercial Centre.

NO_3- The values of 1.62mg/l for rural and 1.71mg/l for urban area show that the figures were within the NIS and WHO MPL of 50.0mg/l (Table 1). High intensity of RW within sampling period could have caused dilution effect on the Nitrates levels. Low industrial and commercial activities could also be the reason for low levels of these pollutants. Nitric acid which is produced by the oxidation of nitrogen in presence of water during lightning storms (Subodh, 2017).

EC- EC of RW depends on dissolved ions (Kur, Alaanyi and Awuhe, 2019). EC of rural area was 11.53µs/cm, while for urban areas was 45.17µs/cm (Table 1). Results were lower than 1000µs/cm MPL by NIS and WHO. Although Azuonwu *et al,* 2017 reported the EC of 9.7µs/cm in Diobu- Port-harcourt, which is a commercial and densely populated areas, they have values lower that the study areas. This could be attributed to low commercial activities and rainy effect on dilution of chemical substances in the atmosphere.

TDS- TDS in rural area was 5.67mg/l, while in urban it was 24.30mg/l. The figures were within the NIS and WHO MPL of 600mg/l (Table 1). The reason for higher TDS in urban could be reflection of higher commercial activities, such as presence of banks, schools' markets and motor parks. This assumption agrees with Belonwu *et al*, (2016) when he conducted research on core Benin city, intermediate and the outskirts.

TSS- The mean value of 3.33mg/l for urban, while rural area had 10.0mg/l (Table 1). Lower TSS value in rural could be an indication of low commercial, industrial and construction activities. This agrees with the assertion of Ebong *et al*, (2016) and Adeyeye, (2019), that PM concentration in atmosphere influences the quality of RW harvested.

Mg -Rural area had the Mg of 2.09mg/l and 2.00mg/l for urban (Table 1 and figure 3). These were within WHO and NIS MPL of 50.0mg/l and 20.0mg/l respectively. Mg and other alkali (e.g. Ca) are responsible for water hardness. Ikole town, with a cement company in south-west Nigeria, had Mg value of 2.40mg/l. Although the value might look lower, it could be attributed to effect of rainfall intensity. This is supported by Ebong *et al*, 2016.

Ca- The mean values were 3.17mg/l for rural and 3.61mg/l for urban (table 1). Ca is soluble in RW and they constitute hardness. Ca levels were within the MPL of WHO and NIS. The Ca MPL is 100.0/75.0mg/l for WHO and NIS respectively. The higher value in urban area could be due to higher anthropogenic activities. This agrees with Joo and Nothayati, (2014). They opined that RW chemical composition is influenced by geographical location and the human activities.

Cl- Rural area had mean value of 7.10mg/l, while urban had 10.06mg/l of chlorides as shown in table 1. The chlorides values were within WHO and NIS MPL of 250mg/l. However, the urban value was higher than rural values this could be due to higher anthropogenic activities in urban areas. This assertion agrees with Kabir and Madugu 2010, that physico-chemical properties of RW often reflect environmental impact of land use activities in that area.

Iron levels of 0.11mg/l for rural and 0.50mg/l for urban. The urban area value was above WHO and NIS levels of 0.30mg/l as shown in table 1. Sources of Fe level in urban RW could have been through crustal source and quarrying activities, wind transportation from long distances. Ebong *et al*. (2016) reported that Eket town, been an oil producing area had iron level higher than in Ibino-Ibom, a non-oil producing area.

Pb -Impacts on rainwater, are through anthropogenic activities. Rural areas had the mean value of 0.016mg/l, while the urban had 0.177mg/l as shown in table 1, figure 3. Both values were above WHO and NIS MPL of 0.01mg/l. Presence of lead in RW is an indication of atmospheric pollution with combustion of petroleum products and crustal activities (Subodh, 2021).

Cd – It can be found in certain foods and also emitted by burning fossils fuels like oils, coal and can be through natural erosion of Cd containing rocks, industrial dusts, fertilizer as in phosphate rocks. Urban area had mean value of 0.002mg/l, while the rural had 0.001mg/l, as shown in table 1. RLW value was higher than WHO and NIS of 0.003mg/l. This could be due to rainfall severity as argued by Ebong *et al*, (2016), due to erosive ability of rivers banks and effects of weathering, especially during wet season as supported by Anyadike and Obeta (2013).

Hypotheses Testing

i. SO_4, NO_X, Pb and CH_4 are not some of the physico-chemical parameters in RW in an urban and rural areas of Wukari LGA of Taraba state, Nigeria.
ii. There is no spatial variations in the physico-chemical parameters of RW in the area.
iii. The p-value in our chi-square output is $p = 0.07$. This means that the relationship between physico-chemical properties of rural and urban areas is significant. It has statistically significant, not due to chance.

Summary of Findings

Data from table 1, shows that 15 properties were tested, 2 properties were above MPL of WHO and NIS for drinking water. These properties were Pb and Fe. For Pb, it had 0.016mg/l and 0.177mg/l for rural and urban areas respectively. The mean values for Fe in urban areas was 0.50mg/l, while the rural had its mean value as 0.11mgl. the rural areas mean values is within WHO and NIS MPL. The standards were 0.01mg/l for Pb and 0.30mg/l for Fe respectively. The elevated value in urban area could be due to its higher population, moderate commercial activities and vehicular movement; cars, lorries and tricycles. This suggests that the RW in the area was not suitable for drinking until it is treated.

The data from Table 1 and Figure 3 show that, there were higher values of pH, Turbidity, TSS, TDS, EC, SO_4, NO_3, Na, Ca, Fe, EC, Cl and Pb in urban areas than in rural areas. These were indication of higher anthropogenic activities, commercial, transportation activities and higher population in urban areas than in the rural areas (Zu *et al*., 2018). The mean values of pH were 7.20 in both rural and urban areas tested, alkaline range. This could be an indication of low anthropogenic activities. Natural RW is normally considered to be weakly acidic with a pH value of 5.6 when the atmosphere is free from pollution. Turbidity could be an indication of dissolved salts and suspended solids. It has no health or environmental effects, but a major determinant of a consumer's choice of drinking water. The higher concentration of NO_3 and SO_4 were found in the urban areas where vehicular emissions could have influenced RW quality compared with the rural areas. In the urban, vehicles are often more in numbers which consequently increases vehicular emissions. The presence of SO_4 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 (WHO, 2011). Iron causes reddish-brown stains on laundry, dishes, utensils, glassware, cultural artifacts and concrete, thereby impacting color to the RW.

Conclusion

There were 13 properties with higher concentration in urban areas than in rural areas. It could be due to atmospheric accumulation of pollutants, gases and PM with increasing urbanization. This could have contributed to environmental pollution and thereby affecting quality of RW which could also pose risks to people's health who depend on this source of water supply. Fe and Pb concentration in the study area calls for concern. The authorities should endeavor the monitor them. Statistically, the relationship between physico-chemical properties of rural and urban areas was significant. The study concludes that location is a determinant of variability of RW properties and it exists between rural and urban areas of Wukari local Government.

Recommendation

There is need to have data that would provide information on wet and dry seasons of the year. We, therefore, recommend that physico-chemical properties of RW in the study area to be subjected to further studies in wet and dry seasons for comprehensive data. Although the study area is not populated and it lacks industrial and commercial activities, some parameters have started shown elevated levels, this calls for concern. The authorities should start monitoring the atmospheric effluents. This will keep the environment on check and avoid further pollution.

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