ISSN: 0975-833X

Available online at http://www.journalcra.com

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol. 14, Issue, 01, pp.20511-20517, January, 2022

DOI: https://doi.org/10.24941/ijcr.43017.01.2022

RESEARCH ARTICLE

COMPARATIVE ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES OF RAINWATER IN ISHIAGU SOUTH-EASTERN REGION OF EBONYI STATE, NIGERIA

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ARTICLE INFO

Article History:
Received 18th October, 2021
Received in revised form
19th November, 2021
Accepted 12th December, 2021
Published online 31st January, 2022

Keywords:

Comparative Assessment, Physicochemical Parameters, Raindrops, Ishiagu, Quarrying.

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ABSTRACT

Comparative assessment of rainwater was carried out to investigate the impact of quarrying and mining activities on the physicochemical properties of rainwater in Ishiagu area. To achieve this, six communities were considered based on the busy quarrying activities going in the area. Sampling of the raindrops were properly carried out using plastic funnel of 30cm diameter fitted onto two litre container placed on a woody stool that is five feet above the ground level, sited in an open space away from obstruction. From all indication, the values of the physicochemical parameters analyzed were found mostly below the limits set by both the National (NSDWQ, SON) and International standard (WHO, EPA, USGS) regulatory bodies for drinking and domestic waters. Except in the case of pH concentration, where Amaeze (RWD_1) and Okue (RWD_6) stations exhibited high pH values of 6.79 and 5.4, respectively, which is within the range of the recommended standard, while the rest of other stations like; Amaonye (RWD_2), Amaokwe (RWD_3), Ihietutu (RWD_4), and Ngwogwo (RWD_5), were found to be 4.36, 4.45, 4.70 and 4.36 respectively, which is mainly acidic and below the set standards. In other way round, the water samples in these stations recorded acidic pH value may be experiencing trace of acid rain. However, Amaeze and Okue stations exhibited high level of salinity as the level of electrical conductivity (EC), Total dissolved solids (TDS), total solids (TS) and total hardness (TH) increases. This shows that there is a direct relationship between these parameters in most of the samples result, as the parameters changes with respect to each other. Moreover, the total hardness analysis confirmed the rainwater in all the stations a soft water.

Citation: Ogbeide Osareme Mercy, Kanu Emmanuel Mmesirionye, Ossi Eric Okorie, Ossai Ifeanyichukwu Tina and Nworu Jeremiah Nwokwu. "Comparative assessment of physico-chemical properties of rainwater in ishiagu south-eastern region of ebonyi state, Nigeria.", *2022. International Journal of Current Research, 14, (01), 20511-20517.*

INTRODUCTION

Rainwater is an important resource that is essential, pure and alternative liquid for healthy usage. The composition of rainwater actually reflects the composition of the atmosphere through which it falls, which depends on the atmospheric particulate and gaseous constituents produced locally or transported from distant sources by natural or anthropogenic sources (Rao *et al*., 2016). Excessive amounts of acid gases emitted by industries can dissolve in rainwater as it is falling from atmospheric cloud, causing acid precipitation (Narayanan, 2009) beyond the level (pH<5.5) expected in non-polluted rainfall. Alkaline dust can raise the pH to above 7. Fog, snow, mist and dew, can also trap and deposit atmospheric contaminants. It has also been confirmed that rainwater has been polluting most regions of the world due to numerous pollutants loads in the atmosphere (Abdullah *et al*., 2021; Meng *et al*., 2019), though the chemical composition varies by geographical locations (Abdullah *et al*., 2021). Therefore, the knowledge of the physico-chemical composition of rainwater is indispensable to assist in the investigation of the atmospheric conditions of any region, as well as the concentration of the soluble components that contributes to rainwater chemistry (Al-Khashman, 2009; Chatterjee and Singh, 2012).

Rainwater has received increased attention worldwide as an alternative source of potable and non-potable water supplies (Cobbina *et al*. 2013; Hatibu *et al*., 2006; Heyworth *et al*., 2006; Ghisi and Ferreira, 2007; Han, 2007; Amin and Han, 2009) in different parts of the world, including rural and urban areas around Europe (Al–Momani, 2003; Hontoria *et al*., 2003; Alastuey *et al*., 1999), Brazil (de Mello, 2001; Campos *et al*., 1998; Lara *et al*., 2001) and other places in the World (Bravo *et al*., 2000; Seto et al., 2000; Tanner, 1999; Halstead *et al*., 2000), including Nigeria (Olowoyo, 2011; Ezemonye *et al*., 2016; Waziri *et al*., 2012). But, despite having some promising merits over other sources, and most preferred source of portable water supply on the grounds of quality (Meera and Ahammed, 2006), rainwater is still in doubt as the most preferred source as some reports may have it that, harvested rainwater contains significant amounts of pollutants like heavy metals, nutrients and pathogens in it (Gromaire- Mertz *et al*., 1999; Lye, 2002; Zhu *et al*., 2004; Evans, 2006; Yufen *et al*., 2008). And populations in most parts of the developing countries especially in rural areas where water is a scarce commodity rely on rain water as the primary source of fresh water to maintain a suitable environment for diverse ecosystems and for crop irrigation.

In Ishiagu area, the problem of water resource is getting good water quality due to environmental pollution and degradation (Efe, 2002). Moreover, groundwater is an important water resource in the area, and is mostly untreated and associated with various health risks (Agbarie and Obi, 2009). Governmental and non-governmental agencies, corporate organizations and individuals are involved in sinking boreholes to provide water for their families, staff, companies and communities in the area. Thus, systematic investigation of the physicochemical characteristics of rainwater are needed to observe the precipitation changes in this region (Xu *et al*., 2011). Whatever findings of this research type would help greatly in assessing the status of rainwater quality within the study areas, and other areas close to quarry sites in Ishiagu. Therefore, the aim of this study is to assess the physicochemical composition (such as; pH, temperature, electrical conductivity, total dissolved solids, total suspended solids, total hardness and salinity) of rainwater drops in Ishiagu communities, and compare the data values obtained with the recommended National (NSDWQ, SON) and International standard (WHO, EPA, USGS) regulatory bodies for drinking and domestic waters.

MATERIALS AND METHODS

Materials and Instruments

Description of the Study area: Ishiagu town is located in southeast region in Ebonyi State. The inhabitants of the area and the surroundings are mostly farmers, stone dealers, students and public servants. The area falls between longitude 7°34'32" to 7°34'57"E and latitude 5°56'56" to 5°57'1"N, and experiences a tropical climate with rainfall all year round. The rainy season lasts from April to October, while dry season last between November to March of every year. The range of the mean annual rainfall for the area is 1750-2000 mm, while that of temperature is 26.5-27.5°C.Solid mineral mining is also an important activity going on in the area. Lead and zinc mines including stone quarrying activities attracts people to the area (Ogbeide *et al*. 2021).

Sampling stations and location: Six sample stations; Amaeze, Amaonye, Amaokwe, Ihietutu, Ngwogwo and Okue communities were considered in this study, because the areas are very close to the solid mineral mining sites. Lead and zinc mines including stone quarrying activities attracts people to the area, and the area also experiences dust pollution caused by heavy duty vehicles and other busy activities. The designated codes, the distance between the station sand their Global Positioning System (GPS) co-ordinates are recorded in Table 1.0.

Sample collection: The sampling method used in this case was described by Williams and Tighiri, (2015), and it is acceptable method by Association of Official Analytical Chemist (AOAC), although little adjustment was done. Sampling of the rain water were carried out using plastic funnel of 30cm diameter fitted onto one litre plastic container placed on a woody stool that is five feet above the ground level, sited in an open space away from obstruction. Meanwhile, the plastic containers were thoroughly washed and rinsed with distilled water and allowed to dry before taking to the sampling stations. In each of the stations, three plastic container (2 L) with funnel were sited at different locations and the rainwater were collected as a composite representative sample of that station. To avoid dry deposition, the collected composite sample were usually turned into another clean container, while the funnels in all sample locations is been washed with distilled water every morning and evening throughout the three consecutive period of sampling during rainy season. The results were expressed in average of the three consecutive sampling period. The average sampling time was 9:30 am.

Methods

Physicochemical analysis of the rainwater sample: Eight physicochemical parameters were analyzed in the samples collected using standard methods recommended by America Public Health Association (APHA, AWWA & WPCF, 1998). These were carried out immediately after sampling, and the pH, temperature, Electrical conductivity (EC), and total dissolved solid (TDS) were assessed with the aid of a portable digital multi-purpose pH meter instrument (Model: EZ-9910) after calibration. Other parameters like; Total suspended solids (TSS), Total solids (TS), and total hardness were determined in the laboratory as follows:

Determination of Total Suspended solids (TSS): This was determined by gravimetric Method: 100mL of the samples were measured into a pre-weighed (W_1) filter paper and was then sundried for four and half hours. The dried filter paper was allowed to cool to room temperature and was weighed (W_2). The total suspended solids was calculated by the increase in the weight of the filter paper using equation (1).

$$Total\ suspended\ solids\ \left(\frac{mg}{L}\right) = \frac{(W_2 - W_1)\ \times 1000}{V_u}$$

W2 = weight (mg) of filter pater + sample, W1 = weight (mg) of filter paper, V_u = volume of the used sample (mL)

Determination of total Hardness: This was determined using EDTA titrimetric method by APHA, (1998). 25 mL of the rainwater sample was pipetted into a conical flask. 2 mL of buffer (pH 10) solution was added and shaken, followed by addition of 3-4 drops of Erichrome black-T solution and shaken. The content was titrated with the standard 0.01M EDTA till the wine red color changes to blue. The titre volume of the EDTA in the burette was recorded. Then the total hardness was calculated using equation (3):

$$Total\ hardness\ \left(\frac{mg}{L}\right) = \frac{volume\ of\ EDTA\ x\ Molarity\ x\ 50\ x\ 1000}{volume\ of\ sample\ taken}$$

RESULTS AND DISCUSSION

Physicochemical results of the rainwater sample: The analysis results of the various physicochemical parameters of rainwater samples of the stations were expressed in average data value of the three consecutive sampling period. They are presented with the recommended standard values in Table 2.0

Assessment of the physicochemical parameters: The appearance of the rainwater samples collected in all the stations were clear, some were found tiny particles. But, the major factor affecting rainwater quality is anthropogenic activities arising from constant quarrying and mining activities, this introduces mineral particles in the atmosphere. Generally, most of the water quality parameters analyzed in this work were below and within the recommended limit for water portability as shown in Figure 2.0. However, the acceptability and use of rainwater for drinking, domestic and other recreational needs are influenced by their physicochemical parameters. From the analysis results, the mean concentration of each parameter varies from one station to another. To further explain this, the individual mean parameters were discussed as follows:

The pH of the rainwater samples at Amaonye, Amaokwe, Ihietutu and Ngwogwo stations were acidic with recorded values of 4.36, 4.45, 4.70 and 4.36 respectivelyas presented in Table 2.0& Figure 2.0. This may be due to proximity of the area studied to a quarry/mining sites where gases are flared and dissolution of these gases and other mineral particles in atmosphere would eventually enhance the acidity, vehicular activities and bush burning by farmers could have also contributed (Cobbina *et al*. 2013) given rise to acid rain. Likewise, the pH value of Okue sample was slightly acidic(5.40), which is close value to the recommended standards (Figure 3.0), while that of Amaeze station was recorded as 6.79, which is within the WHO and NSDWQ recommended standard range of 6.5-8.5for pure water (WHO, 2011). The high pH value of Amaeze could be attributed to dust particles containing large amounts of alkaline compounds such as calcium carbonate (Özsoy and Cemal, 2000).

Temperature of the rainwater samples at Amaeze, Amaonye, Amaokwe, Ihietutu, Ngwogwo and Okue stations were recorded as 28.9^{o}C, 29.0^{o}C, 29.0 ^{o}C, 28.9 ^{o}C, 28.9 ^{o}C and 28.7^{o}C respectively as presented in Table 2.0 with illustration in Figure 2.0. These average temperatures are almost the same in all the stations, and slightly vary from one station to another, which supports the report by Tiffany Means, (2000), that the average temperature of rain vary from near freezing to 30 ^{o}C, but whether it is warmer or colder depends on factors in the air. From Figure 2.0, the temperature levels in all the stations are below and very close to the WHO/NSDWQ recommended range of 30 to 35 ^{o}C.

Electrical Conductivity (EC): Is a measure of a material's ability to carry an electric current. The EC of water is a useful and easy indicator of its total salt (salinity) content. In the present study, the EC of the raindrops samples at Amaeze, Amaonye, Amaokwe, Ihietutu, Ngwogwo and Okue stations were recorded as 40 µS/cm, 17 µS/cm, 2 µS/cm, 5 µS/cm, 15 µS/cm and 24 µS/cm respectively as presented in Table 2.0 with illustration in Figure 2.0.

Amaeze stations has quite high EC than other stations, followed by Okue station, and same level rise is observed in pH level as shown in Figure 2.0. This could also be attributed to dust particles containing large amounts of alkaline compounds, which raises the pH content of the raindrops by contact in the air (Özsoy and Cemal, 2000). However, the values obtained in all the stations are far below the WHO and NSDWQ standard permissible range (level) of 1200 µS/cm as shown in Figure 3.0.

Total dissolved solids (TDS): Describes the inorganic salts and small amounts of organic matter present in dissolved form in water. The value of TDS in rainwater depend upon air pollution index of that area (Waziri *et al*., 2012). In Amaeze, Amaonye, Amaokwe, Ihietutu, Ngwogwo and Okue stations, the rainwater samples were recorded as 20 ppm, 8 ppm, 2 ppm, 3 ppm, 7 ppm and 12 ppm, respectively as presented in Table 2.0 with illustration in Figure 2.0. Amaeze stations has quite high TDS than other stations, followed by Okue station.

Same level rise was observed in pH and electrical conductivity (EC) in Figure 2.0. This could also be attributed to dust particles. However, the TDS concentrations stations are below the value range (20 to 50 ppm) reported by Chaitanya, (2018) for rainwater, and also below the WHO and NSDWQ standard permissible level of 500 mg/L for portable water, as shown in Figure 3.0.

Total suspended solids (TSS): Are solids in water that can be trapped by a 0.45 µm filter. Total suspended solids causes water to be cloudy, andreduces water transparency. From the analysis result, TSS of the raindrops samples recorded at Amaeze, Amaonye, Amaokwe, Ihietutu, Ngwogwo and Okue stations were 3.4 mg/L, 4.6 mg/L, 3.4 mg/L, 4.2 mg/L, 7.1 mg/L and 7.6 mg/L, respectively as presented in Table 2.0 with illustration in Figure 2.0. Okue station recorded high TSS than other stations, followed by Ngwogwo station as depicted in Figure 2.0. However, the values obtained in all the stations are below the WHO and NSDWQ standard permissible level of 250 mg/L for portable water as shown in Figure 3.0.

Total solids (TS): Are the combined content of all the organic and inorganic substances contained in a liquid in the form of ionized molecule (Beychok *et al* 1967). Total solids can affect the organisms living in the harvested rainwater bodies as these can influence the level of dissolved oxygen.

From the analysis result, TS of the raindrops samples recorded at Amaeze, Amaonye, Amaokwe, Ihietutu, Ngwogwo and Okue stations were 23.4 mg/L, 12.6 mg/L, 5.4 mg/L, 7.2 mg/L, 14.1 mg/L and 19.6 mg/L, respectively as presented in Table 2.0 with illustration in Figure 2.0. Amaeze station recorded high TS than other stations, followed by Okue station, and same level rise was observed in pH, EC, and TDS levels as depicted in

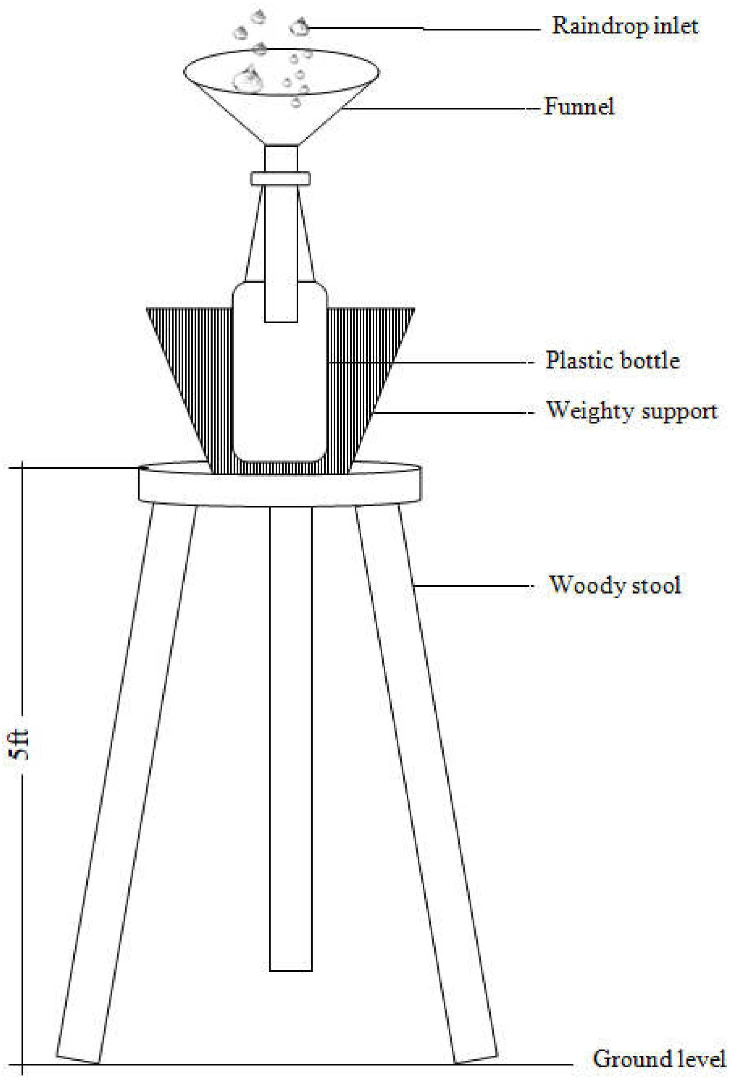

Figure 1. Schematic diagram of rainwater sampling

Table 1.0. Designated Codes and GPS Co-ordinates of the sample stations

Designated Codes	Location	Coordinate		Distance
		Latitude	Longitude	
RWD_1	Amaeze	5°57'27" N	7°33'23" E	600m
RWD_2	Amaonye	5°57'7" N	7°33'28" E	
RWD_3	Amaokwe	5°57'16" N	7°34'8" E	533m
RWD_4	Ihietutu	5°57'12" N	7°33'17" E	
RWD_5	Ngwogwo	5°57'34" N	7°34'21" E	354m
RWD_6	Okue	5°57'6" N	7°34'31" E	

Table 2.0. Physicochemical parameters of the analyzed rainwater samples of the different stations

PARAMETERS	RWD_1	RWD_2	RWD_3	RWD_4	RWD_5	RWD_6	WHO & NSDWQ
pH	6.79	4.36	4.45	4.70	4.36	5.4	6.5 – 8.5
Temp (°C)	28.9	29.0	29.0	28.9	28.9	28.7	30 – 35
EC (µS/cm)	40	17	2	5	15	24	< 1200
TDS (ppm)	20	8	2	3	7	12	< 500
TSS (mg/L)	3.4	4.6	3.4	4.2	7.1	7.6	< 250
TS (mg/L)	23.4	12.6	5.4	7.2	14.1	19.6	< 500-1000
TH (mg/L)	38	40	30	16	54	56	150 – 300
Salinity (ppm)	20	8	2	3	7	10	< 1000

Figure 2.0. That is, increment in one parameter lead to increment of the other. However, the values obtained in all the stations are below the WHO and NSDWQ standard permissible range <500-1000 mg/L for portable water as shown in Figure 3.0.

Total hardness (TH): Affects rainwater acceptability to the consumer in terms of taste and scale deposition. It can render rainwater unreadily to leather with soap. In this study, total hardness recorded at Amaeze, Amaonye, Amaokwe, Ihietutu, Ngwogwo and Okue stations were 38 mg/L, 40 mg/L, 30

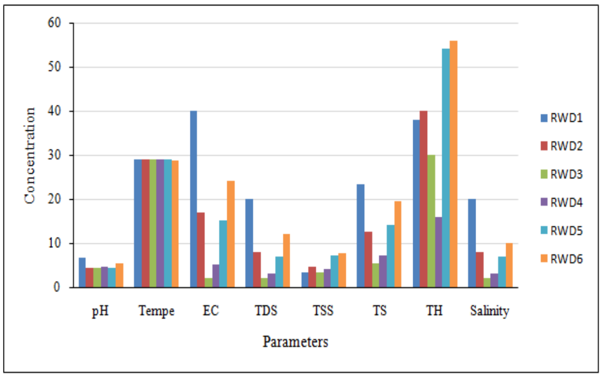

Figure 2.0. Clear illustration of rainwater parameters of the various stations with WHO/NSDWQ standards

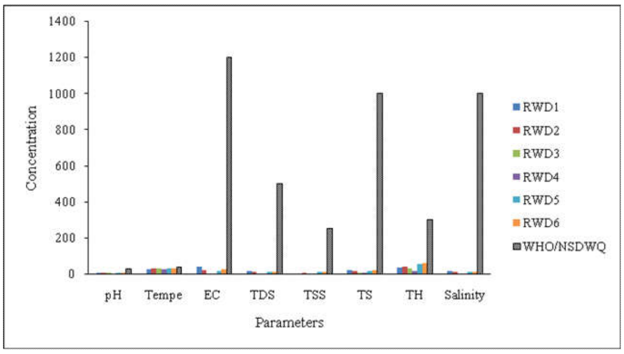

Figure 3.0. Comparative illustration of rainwater parameters of the various stations with WHO/NSDWQ standards

mg/L, 16 mg/L, 54 mg/L and 56 mg/L, respectively as presented in Table 2.0 with illustration in Figure 2.0. Okue station recorded high TH value than other stations, followed by Ngwogwo station. The same trend was observed in TSS level obtained at Okue and Ngwogwo station as depicted in Figure 2.0, combined with the total dissolved solids in the water sample. However, the TH values obtained in all stations are below the WHO and NSDWQ standard permissible range of 150-300 mg/L for portable water as shown in Figure 3.0. To further interpret these, the TH values obtained in all stations were compared to classification Table of the United States Environmental Protection Agency (USEPA, 2009), and were found belonging to range of 0 to 60 mg/L category, which best described the rainwater samples as soft water.

Salinity: is a measure of salt content of water. Salinity may affect the dissolved oxygen level of water as fresh water holds more oxygen than salt water (Chinedu *et al*., 2011). From the analysis results, the salinity of the raindrops samples recorded at Amaeze, Amaonye, Amaokwe, Ihietutu, Ngwogwo and Okue stations were 20 ppm, 8 ppm, 2 ppm, 3 ppm, 7 ppm and 10 ppm, respectively as presented in Table 2.0 with illustration in Figure 2.0. Amaeze station recorded high salinity content than other stations, followed by Okue station, and same level rise was observed in pH, EC, TDS and TS levels as shown in Figure 2.0. This could be attributed to trace of total solids (both TDS and TSS) in the form of particulates (EPA, 2001) in the atmosphere. However, the recorded values were far below the recommended standard level (<1000 ppm) prescribed by World Health Organization (WHO, 1979) and U.S. Geological Survey (USGS, 2018) for drinking water, as shown in Figure 3.0.

CONCLUSION AND RECOMMENDATION

CONCLUSION

In all indication, the values of the physicochemical parameters analyzed were found mostly below the limits set by both National (NSDWQ, SON) and International standard (WHO, EPA, USGS) regulatory bodies for drinking and domestic waters. Except in the case of pH concentration, where Amaeze (RWD_1) and Okue (RWD_6) stations exhibited high pH value within the range of the recommended standard, while the rest of other stations like; Amaonye (RWD_2), Amaokwe (RWD_3), Ihietutu (RWD_4), and Ngwogwo (RWD_5), were found to be mainly acidic and far below the set standards. Meaning that the water samples in these stations recorded acidic pH value could have been experiencing trace of acid rain as a result of gas flaring. Meanwhile, there is a direct relationship between the electrical conductivity, total dissolved solids and salinity in most of the samples result. This phenomenon is expected, as these parameters changes with respect to each other, and is an appraisal to the accuracy and reliability of our findings. Moreover, the total hardness analysis confirmed the rainwater in all the stations a soft water.

RECOMMENDATION

Physicochemical assessment of raindrops (rainwater) parameters is important because it gives information about the quality of water, and the level of air pollutants and its effects on global warming and contamination to the environment. Therefore, I suggest that rainwater fetched in these studied areas (communities), if possible should be subjected to further treatments that will reduce drastically the concentration of the few identified elements as they may pose some danger to public health.

Acknowledgement: The authors acknowledges the department of Science Laboratory Technology, Federal College of Agriculture Ishiagu in Ebonyi State, Nigeria, for their support and assistance throughout the period of carrying out this analysis in their laboratory. We also appreciate the efforts of Dr. Okpara Onyedikachi Godwin, for his contribution in sampling and data analysis.

Conflict of interest: The authors declare that there is no conflict of interest for the publication of this study.

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