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# Assessment of physico-chemical compositions of wet precipitation at a metropolis in Nigeria

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**Abstract:** This study's objective was to assess the physicochemical composition of wet precipitation in samples taken from two different locations (residential and industrial) at Akure, Ondo State, Nigeria. Monthly rainwater samples were collected for ten months using a high-density polyethylene (HDPE) plastic container with a capacity of 5 liters and an HDPE funnel attached to it on a rack that was 1.5 m high. The remaining measurements were carried out in the laboratory, while the pH, electrical conductivity (EC), and temperature were measured immediately. The average results for the two locations are: Housing Estate, Oba Ile (EC = 30.90±16.64 µS/cm), temperature (28.6±0.97 $^{o}$C), Total Dissolved Solids -TDS (15.20±7.15 mg/L), free $CO_2$ (17.80±3.05 mg/L), and acidity (260.10±3.05 mg/L) and COOP industrial, expressway (EC = 38.60±42.10 µS/cm), temperature (28.60±1.26 $^{o}$C), TDS (19.50±20.91 mg/L), free $CO_2$ (21.20±3.91 mg/L), and acidity (305.80±65.90 mg/L). At the COOP sampling point, it was found that the physicochemical load in the water samples was significant due to the high anthropogenic and non-anthropogenic activities. High correlations among the variables suggest that the traits considered in this study shared common inputs. It is possible to infer that human activity might affect the variables that are being measured.

**Key words:** Wet deposition; high traffic; pH; anthropogenic constituents; rain water; HDPE funnel.

## 1. INTRODUCTION

Global efforts are being made to address the serious problem of pollution. As a result of improvements in population growth, industrialization, transportation, housing, traffic, waste production, and other areas, it is rising, especially in developing nations. Around the world, it is becoming more and more common to continuously monitor the air, water, soil, and other elements. This offers crucial details about their quantity and quality. According to Bermudez et al. (2012), the chemistry of rainwater is a dynamic interaction of chemical and anthropogenic constituents, chemical transformation processes, and atmospheric transport. Depending on where it falls, rainwater chemistry has a significant impact on natural ecosystems. Rainfall helps the understanding of the relationships between scavenged soluble atmospheric constituents and the role of various sources of air pollution (Kulshresta et al., 2003; Mashood et al., 2018). As a result, scavenged pollutants alter the chemical composition and pH of the rain, which may have adverse effects like harm to ecosystems, respiratory issues, and others (Al-Khashman, 2009). Scientists have studied dry and rainfall in rural and urban areas in both developed and developing countries for many years due to the associated effects of pollution on the ecosystem and human health.

There are not many studies on the chemistry of rainwater in developing and developed countries, while there are detailed studies in Africa, Asia, and Europe (Sigha-Nkamdjou et al., 2003; Menz and Seip 2004; Celle-Jeanton et al. 2009; Rao et al., 2016; Masood et al., 2018; Abulude et al. 2018a; Han et al., 2019; Abulude et al., 2019; Keresztesi et al., 2019, 2020a, b; Bu et al., 2019; Oduber et al., 2020).

The degradation of rainwater over the past few decades has led to health issues and limited use, particularly in Africa, as a result of the rising $SO_2$, NOx, and other gases emitted through natural and anthropogenic sources (industrial processing, residential heating systems, transportation - terrestrial, naval, and aerial - and agricultural systems). Therefore, it is essential to monitor the current state of precipitation chemistry in the Nigerian city of Akure. Wet and dry precipitations must first undergo analysis on the collected samples in order to be determined to be of high quality. Physical (color, odor and taste), chemical (ionic, elemental and organic), and biological analyses are performed (total coliform, fecal coliform, or Escherichia coli). These are merely a few examples. There are plenty of other tasks that need to be completed. If one takes into account the wet precipitation from Akure, it is not out of place. Rainfall is one of the water resources in Akure, Nigeria for a variety of uses, including drinking, washing, feeding livestock, irrigation, and anything else that is deemed appropriate. However, the population boom has led to a high water demand. This study's goal is to measure the temperature, free $CO_2$, electrical conductivity (EC), and pH of the physico-chemical composition of the wet precipitate from two different city locations for ten months.

## 2. MATERIALS AND METHODS

In 2008, there were more than 350,000 people living in Akure, the capital of Ondo State in Nigeria, which is situated at latitude 7°15′0″ North and longitude 5°11′42″ East (Figure 1) (Aribigbola, 2008). Over the course of ten months, samples of rainwater were taken from two locations: a residential neighborhood in Oba Ile, Akure's (Housing Estate), and a cocoa industry (COOP), located near the expressway (July 2018 to April 2019). There were not many man-induced activities in the residential area, but there were plenty in the industrial area, including the movement of vehicles, generators, and other machinery. A simple system consisting of a high-density polyethylene (HDPE) bottle (5 L capacity) attached to an HDPE funnel was used to collect rainwater samples once per month (Onwudiegwu et al., 2016). The containers were held in place by 1.5 m tall stands. Rainwater samples were taken at the end of each month and filtered through 0.22 m membranes. Twenty samples in total were gathered. A pen-type pH meter (PH-009 (l)) was used to measure pH, TDS, temperature, and EC; a pen-type TDS and EC meter (EZ-1) was used to measure EC; and standard analytical techniques were used to measure the acidity and free $CO_2$ of the rainwater sample (Limgis, 2001). Minitab (version 16) and Excel (version 2013) were used to statistically analyze the results.

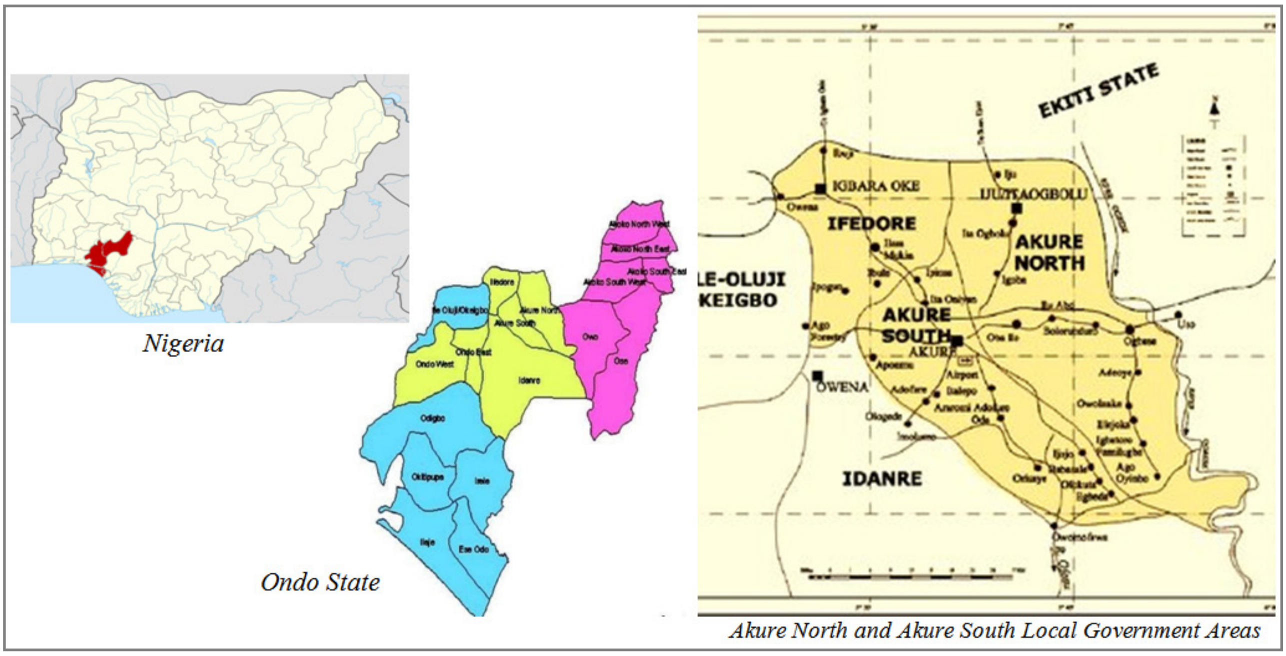


*Figure 1. Map of the sampling points in the local government areas (Akure South and Akure North).*

## 3. RESULTS AND DISCUSSION

For pH, EC, temperature, TDS, free $CO_2$, and acidity, Table 1 lists the concentrations of the Housing Estate with the mean, standard deviation, minimum, maximum, skewness, and kurtosis as: 6.11, 30.90 µS/cm, 28.60 $^oC$, 15.20 mg/L, 17.80 mg/L, and 260.10 mg/L and the COOP Industry 6.75, 38.60 µS/cm. The two points' skewness and kurtosis had low values that were typically below 3. This demonstrated that the samples were not symmetrical enough. The results showed that, with the exception of pH and EC, the physico-chemical parameters of the water samples recorded for the COOP industry area were higher than those for the residential area. The following factors may have contributed to the differences: increased waste production in the industrial area, a higher rate of incineration, significant fume emission, and a strong influence of the expressway's heavy traffic. Without a doubt, the nearby wet deposition was significantly impacted by the activities at the locations. The variations in the samples' minimum and maximum values may be related to the variety of their sources. Residential areas and the COOP industrial area exhibit significant differences in the pH profiles of the samples, as shown in Table 1.

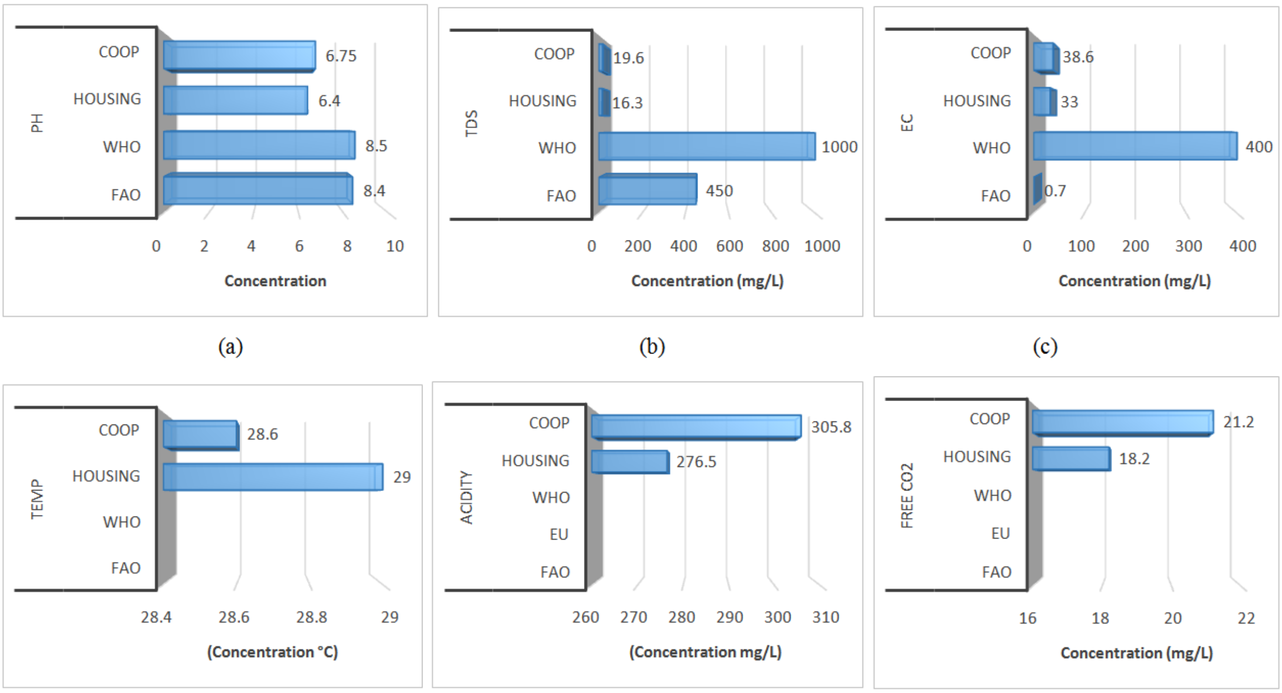
*Table 1. Basic description of the parameters in the two locations.*

| | TDS | EC | Temperature | pH | Acidity | Free $CO_2$ |
|---|---|---|---|---|---|---|
| | | | **Housing** | | | |
| Mean | 15.20 | 30.90 | 28.60 | 6.11 | 260.1 | 17.80 |
| StDev | 7.15 | 14.64 | 0.97 | 0.60 | 69.1 | 3.05 |
| CoefVar | 47.01 | 47.38 | 3.38 | 9.74 | 26.57 | 17.12 |
| Minimum | 7.00 | 14.00 | 27.00 | 5.10 | 188.0 | 14.00 |
| Q1 | 10.50 | 21.50 | 27.75 | 5.65 | 203.0 | 16.00 |
| Q3 | 21.25 | 42.50 | 29.00 | 6.68 | 339.0 | 20.00 |
| Maximum | 30.00 | 62.00 | 30.00 | 6.90 | 372.0 | 24.00 |
| Skewness | 1.04 | 1.13 | -0.81 | -0.16 | 0.79 | 0.91 |
| Kurtosis | 0.53 | 0.86 | -0.02 | -0.77 | -1.10 | 0.24 |
| | | | **COOP** | | | |
| Mean | 19.50 | 38.60 | 28.60 | 6.75 | 305.80 | 21.20 |
| StDev | 20.91 | 42.10 | 1.26 | 0.51 | 65.90 | 3.91 |
| CoefVar | 106.70 | 108.94 | 4.42 | 7.59 | 21.53 | 18.44 |
| Minimum | 6.00 | 10.00 | 27.00 | 5.80 | 222.00 | 16.00 |
| Q1 | 7.00 | 13.50 | 27.75 | 6.30 | 248.00 | 17.50 |
| Q3 | 32.50 | 64.80 | 29.25 | 7.20 | 362.30 | 24.00 |
| Maximum | 68.00 | 136.00 | 31.00 | 7.40 | 422.00 | 28.00 |
| Skewness | 1.75 | 1.75 | 0.54 | -0.51 | 0.15 | 0.15 |
| Kurtosis | 2.43 | 2.44 | -0.03 | -0.55 | -0.73 | -0.70 |

*StDev-Standard Deviation, CoefVar-Coefficient of Variation, TDS-Total Dissolved Solids, EC-Electrical Conductivity, COOP-Cooperative Industry, Housing-Housing Estate, Oba Ile*

The samples' pH levels fall within the ranges of pH 6 and 9 for bathing water and 6.0 to 9.5 for drinking water recommended by the WHO (2011), the European Community (EPA, 2010), and the Standard Organization of Nigeria (2007). The study's findings concur with wet deposition findings made by Beyens et al. (2006) in Croatia, Meena et al. (2014) in India, Cerqueira et al. (2014) in Brazil, Bhuyan and Bakar (2017) in Bangladesh, and Abulude et al. (2018) in Nigeria. The reasons for the variations in the results could be related to changes in the aerosol composition of the atmosphere and the length of time that raindrops were exposed to the environment (Beysens et al., 2006). The measurement of soluble ionic components in precipitation is known as EC. Both locations' values are lower than the observed values, which ranged from 13.7 to 476 µS/cm at a megacity in Pakistan, Southeast Asia. The EC values of precipitation samples ranged from 14 to 62 µS/cm (Housing Estate area) and 10 to 136 µS/cm (COOP industrial site) (Masood et al., 2018). In the residential area, TDS varied between 7.0 and 30 mg/L, with a mean value of 15.0 mg/l, whereas in the industrial area, it ranged between 6.0 and 68 mg/L, with a mean value of 20.91. These are greater than the findings of a study conducted in Uganda's Kabale District's Kyanamira Sub-County, where the TDS mean values ranged from 43.5 to 46.3 mg/L. This might have happened as a result of the higher temperatures seen during the dry season, which aided in the processes of dissolution, ion exchange capacity, desorption, and weathering. Additionally, water evaporated and ion concentrations rose during the dry season (Ngabirano et al., 2016).

The results of the physico-chemical parameters are displayed in bar charts in Figure 2. The pH values that were lower than the WHO (8.5) and FAO (8.4) limits were 6.75 (COOP) and 6.4 (Housing). The study's locations were somewhat in an acidic area. These water samples could be used in ways that are safe for both human and animal consumption. Below the WHO and FAO recommended limits for TDS, Free $CO_2$, and acidity. The samples of water would be very helpful for bathing, washing, feeding livestock, raising fish, cooking, farming, and other activities.



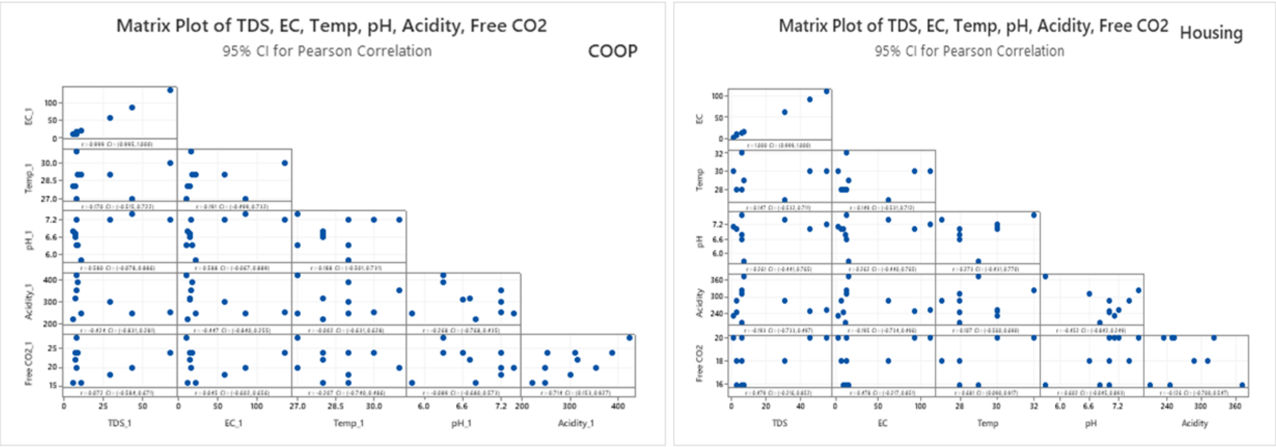
(a) (b) (c)

(d) (e) (f)

*Figure 2. Results of the physico-chemical parameters.*

The data's Pearson correlation analysis showed that there were correlations between the parameters at the two sites (Figure 3). According to the COOP site, there were strong positive relationships between EC and TDS (r=1.00), free $CO_2$ and pH (r=0.60), temperature (r=0.68), and TDS (r=0.48), as well as mild positive relationships between free $CO_2$ and EC (r=0.48), pH (r=0.48), and free $CO_2$ (r=0.48). However, there were also weak negative relationships between pH and acidity (r= -0.45). The following were the positive correlations for the residential housing area: EC and TDS (r=0.99), pH and TDS (r=0.58), pH and EC (r=0.59), Free $CO_2$ and acidity (r=0.71). Acidity and TDS (r= -0.42) and acidity and EC (r= -0.45) had the negative relationships. At a 95% level of confidence, every correlation for these sites points to shared inputs for the study's parameters. Anthropogenic sources (burning of waste and biomass, vehicle traffic inside and outside the site) and natural sources were among the potential sources (suspended soil and dusts, emission of VOC from plants). The correlations found in this study were comparable to those from Meena et al. (2014) study in India, Cerqueira et al. (2014) study in Brazil, Bhuyan and Bakar's (2017) study in Bangladesh, and Abulude et al. (2018b) study in Nigeria.

Figures 4a and b depicted the distributions and variations of the physico-chemical parameters in the different months at the two locations. At the Housing Estate sampling point, EC (December 2018, 34%; January, 28%; and February 2019, 34%) and TDS (December 2018, 34%; January, 28%; and February 2019, 34%) had the highest contributions of the physico-chemical parameters. Likewise, a similar scenario was observed at the COOP industrial area; the difference was that the percentage contributions were higher in the COOP industrial area. The highest percentage for the months might be due to low wet precipitation recorded. In dry season periods, the atmosphere is considerably more polluted, so the wet scavenging process has an increased effect on the measured parameters. At the two locations, the months of July, August and September contributed to the total mass of acidity between 8 and 14%. Again, in November and December, 11% was the highest distribution for pH and temperature at both sites. This could be a result of the anthropogenic and non-anthropogenic activities during these months in the respective locations.



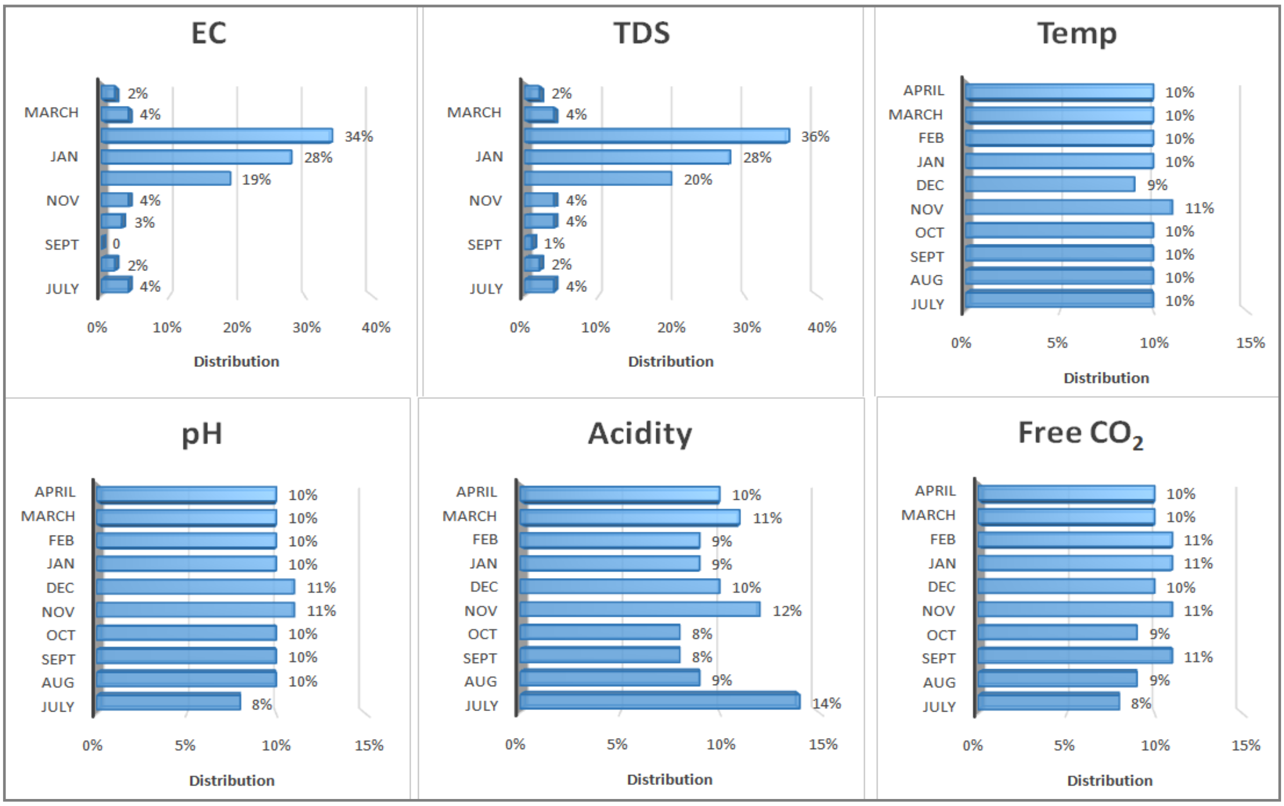
**Correlations (COOP)**

| | TDS | EC | Temp | pH | Acidity |
|---|---|---|---|---|---|
| EC | 1.000 | | | | |
| Temp | 0.147 | 0.149 | | | |
| pH | 0.261 | 0.262 | 0.273 | | |
| Acidity | -0.193 | -0.195 | 0.107 | -0.452 | |
| Free CO2 | 0.479 | 0.478 | 0.681 | 0.602 | -0.126 |

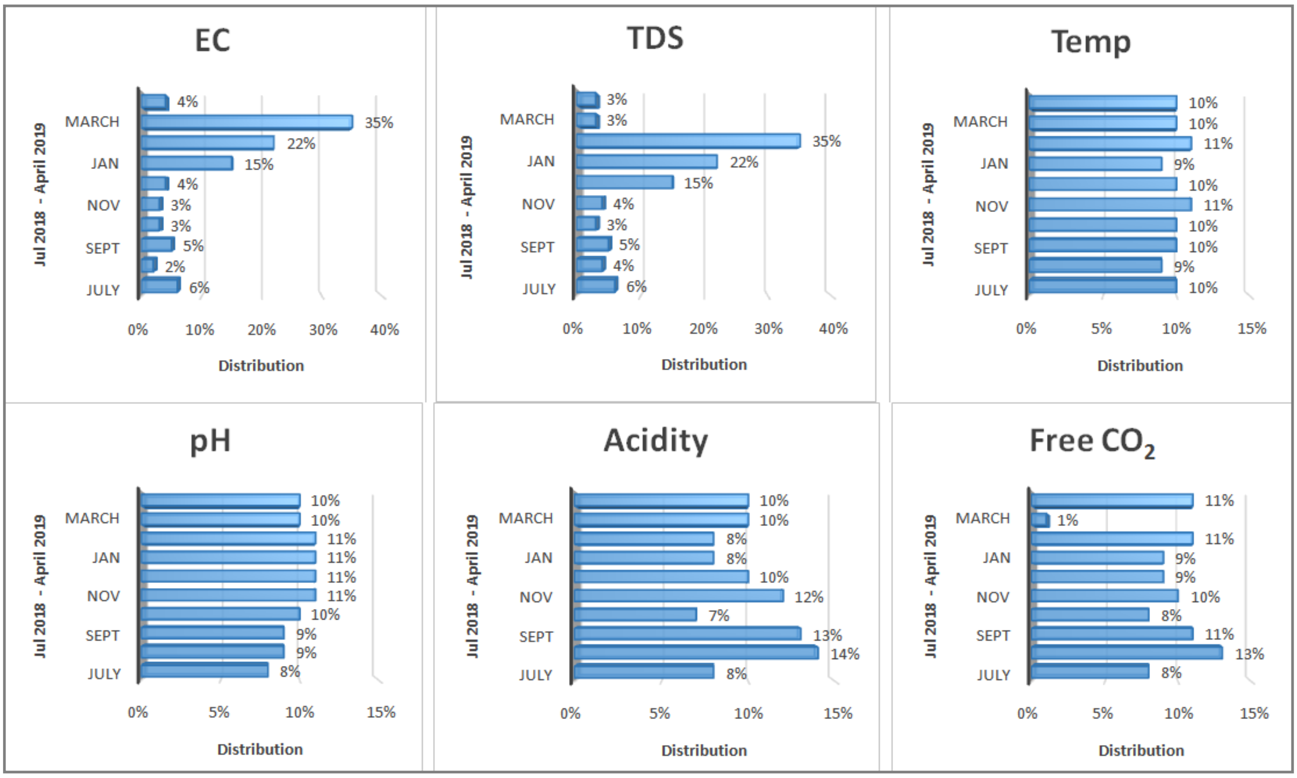
**Correlations (Housing)**

| | TDS | EC | Temp | pH | Acidity |
|---|---|---|---|---|---|
| EC | 0.999 | | | | |
| Temp | 0.170 | 0.191 | | | |
| pH | 0.580 | 0.588 | 0.188 | | |
| Acidity | -0.424 | -0.447 | -0.002 | -0.268 | |
| Free $CO_2$ | 0.072 | 0.045 | -0.207 | -0.089 | 0.714 |

*Figure 3. Correlation Coefficients Diagrams of the Physico-Chemical Parameters*



*(a)*



*(b)*

*Figure 4. Distributions and variations of the physico-chemical parameters in the different months (July 2018-April 2019) at the two locations: a) Housing Estate, Oba Ile, b) COOP Industry.*

## 4. CONCLUSION

In Akure, Nigeria, the study identified the physico-chemical characteristics of the wet precipitation at residential and industrial sampling locations. The findings demonstrated that the industrial site's physico-chemical parameters were significantly higher than those of the residential site. The variations between the minimum and maximum values could be related to the variety of sources and, particularly, the influence of anthropogenic activity. The locations' average parameter concentrations in wet precipitation recorded higher levels during the hot season. Wet precipitation in those areas has a pH that can be classified as neutral. The existence of correlations in the parameters demonstrated that anthropogenic and natural sources were potential sources. The findings suggested that the rainwater was of a physico-chemical quality that was suitable for consumption and other domestic uses. There may not be much of a pollution risk in the study areas. Within the study areas, efforts should be made to lessen or eliminate the source of pollution.

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