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Study of physico-chemical composition in wet atmospheric precipitation in Akure, Nigeria

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Abstract: The purpose of this study is to determine the physico-chemical composition of wet precipitation in samples obtained at two separate locations (sawmill and a waste recycling plant) in Akure, Ondo State, Nigeria. Samples were collected monthly, for twelve months, using high-density polyethylene (HDPE) bottle (5 L capacity), attached to an HDPE funnel on a stand (1.5 m) to hold the containers. The pH, electrical conductivity (EC) and temperature were determined on the field, while other determinations were concluded in the laboratory. The results showed as follows: sawmill area - 6.77, 51.8 μS/cm, 28.03 °C, 25.6 mg/L, 20.67 mg/L, and 142.5 mg/L and waste recycling plant: 6.99, 59.4 μS/cm, 28.75 °C, 29.17 mg/L, 24.33 mg/L, and 275.5 mg/L pH, for conductivity, temperature, TDS, free CO_2 and acidity, respectively. The physico-chemical load in rainwater samples was found to be high in the waste recycling plant sampling site because of high incineration and other activities. There were significant correlations within the variables that suggest common inputs of parameters considered in this study. It may be concluded that anthropogenic activities could influence the parameters analyzed.

Key words: Wet precipitation; TDS; Free CO_2; anthropogenic activities; waste recycling plant; WHO

1. INTRODUCTION

Worldwide, pollution has been a menace that is being seriously tackled. It is increasing, especially in developing countries, due to modernization in terms of population increase, industrialization, transportation, housing, traffic, waste generation and many more. Constant monitoring of the air, water, soil and others is on the increase worldwide. This is providing necessary information on their quality and quantity.

According to Bermudez et al. (2012), rainwater chemistry is a complex interaction of the anthropogenic and natural chemical constituents, their chemical transformation processes and atmospheric transport. Depending on their locations, rainwater chemistry has a strong influence on natural ecosystems. Wet deposition is playing a role in the know-how of the interactions of scavenged soluble atmospheric components and the contribution of various sources of atmospheric contaminants (Kulshresta et al., 2003, Mashood et al., 2018). The scavenged pollutants, thus, have effects on chemical profile and the pH of the rain, which could have negative effects, such as ecosystem damage, human respiratory problems, and others (Al-Khashman, 2009). Research on dry and wet precipitation has been on for many decades in rural and urban places, in both developed and developing countries, because of the attendant effects of pollution on the ecosystem and human health.

Few studies regarding rainwater chemistry are done in developing and developed countries with the 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). Over the last few decades, the increasing SO_2, NO_x, and other gases emitted through natural and anthropogenic sources (industrial processed, residential heating systems, transportation - terrestrial, naval and aerial - and agricultural systems) have resulted in the deterioration of rainwater, which has caused health-related problems and limited usage, especially in Africa. Therefore, the study of the current situation of precipitation chemistry in the urban center of Akure, Nigeria by monitoring is crucial.

Before wet and dry precipitations can be adjudged to be of good quality, analyses must be performed on the obtained samples. The analyses include physical (colour, odour, taste), chemical (ionic, elemental, organic) and biological (total coliform, fecal coliform, or Escherichia coli). All these are just to mention a few. There are so many others that must be performed. It is not out of place, if wet precipitate obtained in Akure is considered. One of the water resources in Akure, Nigeria is rainfall. It serves many purposes ranging from drinking, washing, livestock use, irrigation and whatsoever that is deemed fit. However, it has been in high demand due to the population explosion. The objective of this study is to determine the pH of the physico-chemical composition, free CO_2, TDS, temperature, and electrical conductivity (EC) of the wet precipitate from two different locations in the city for a year.

2. MATERIALS AND METHODS

Akure, the capital of Ondo State, Nigeria, is located at latitude 7°15′0″ North and longitude 5°11′42″ East (Figure 1), with a population of over 350,000 people as of 2008 (Aribigbola, 2008). Rainwater samples were collected from two locations, a sawmill in Owode, Ondo road (7°14′15.6″ N, 5°13′37.9″ E) and a waste recycling plant located on the Igbatoro road (07°15′12.0″ N, 5°14′24.5″ E), for a period of twelve months (July 2018 to June 2019). Each location has dumpsites. The one at Owode sawmill, Ondo road is a small site where only the wood dusts and shavings are burnt occasionally. That of the Igbatoro belongs to Ondo State Waste Environmental Board, it occupies a vast of land where different types of wastes are recycled and incinerated constantly. The rainwater samples were collected once a month with a sampler, a simple system, made of a high-density polyethylene (HDPE) bottle (5L capacity), attached to an HDPE funnel (Onwudiegwu et al., 2016). Stands, about 1.5 m tall each, were used to hold the containers. The container was placed on the stands. After the end of a month, the rainwater samples were collected and filtered with 0.22 μm membranes. Altogether, 24 samples were collected. The pH was determined using a pen-type pH meter (PH-009 (l)) made in China, TDS, temperature, and EC were obtained using a pen-type TDS and EC meter (EZ-1) made in China, while the acidity of the rainwater sample was determined using standard methods of analyses (Limgis, 2001). The results obtained were statistically analyzed (basic descriptions, correlation coefficient, box and matrix plots), using Minitab 16 Statistical Software.

3. RESULTS AND DISCUSSION

Table 1 summarizes the concentrations of the samples with the mean, standard deviation, minimum, maximum, skewness and kurtosis. The results revealed the values of parameters at the sawmill area (6.77, 51.8 μS/cm, 28.03 ^{o}C, 25.6 mg/L, 20.67 mg/L and 142.5 mg/L) and the recycling plant (6.99, 59.4 μS/cm, 28.75 ^{o}C, 29.17 mg/L, 24.33 mg/L and 275.5 mg/L) for pH, EC, temperature, TDS, free CO_2, and acidity, respectively. The skewness and kurtosis had low values (below 3). This showed that the samples were not reasonably symmetrical. From the foregoing, it could be observed that the physico-chemical parameters recorded for the Igbatoro waste dump site were well above those of the Owode sawmill site. The simple facts are: (i). the rate of incineration at the Igbatoro waste dump site is always higher than the other location, (ii) the type of materials burnt in Igbatoro dump site are numerous (woods, tyres, plastics, papers, just to mention a few) as against that of Owode dump site where just only woods sawdust and shavings are incinerated (iii) lastly, the Igbatoro site is located near a road (vehicular movements). No doubt, the activities within the locations had significant effect on the air pollution within the vicinity. The differences between the minimum and maximum values of the samples may be linked to the diversity of the sources. The pH profile of the samples shows marked variations between the sawmill and the recycling area, which can be viewed from Table 1. The waste incineration within the plant indicated the alkaline nature of the wet precipitation in the areas of sampling. The pH values in the samples are within the recommended limits of pH 6 and 9 (bathing water) and 6.5-9.5 (drinking water) of the WHO (2011), the European Community (EPA, 2010) and the Standard Organization of Nigeria (2007) water limits. The results of the study are in agreement with those obtained in wet depositions by Beyens et al. (2010) 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. Variations in the atmospheric composition of aerosols and the amount of time where the rain droplets were exposed to the environment could be the reasons for the results variations (Beysens et al., 2006). EC represents the measurement of soluble ionic components in precipitation. The EC values of precipitation samples ranged from 4 to 194 µS/cm (sawmill area) and 4 to 246 µS/cm (waste recycling plant site) both location values are higher than the observed value of between 13.7 to 476 µS/cm at a mega-city of Pakistan, Southeast Asia (Masood et al., 2018). High EC values reflect worse atmospheric environmental quality in the study area (Masood et al., 2018). TDS varied in the range from 2.0 mg/l to 124 mg/l in the sawmill area, with a mean value of 25.6 mg/l, but in waste recycling plant it ranged from 2.0 mg/l to 96 mg/l, with a mean value of 29.17. These are lower than the reports from a study in Kyanamira Sub-County, Kabale District, Uganda, in which the TDS mean values ranged from 43.5 - 46.3 mgL^{-1} during the study. This could have been due to the higher temperatures observed during the dry season, which facilitated dissolution, ion exchange capacity, desorption and weathering processes. Also, during the dry season water evaporated and ion concentrations increased (Ngabirano et al., 2016).

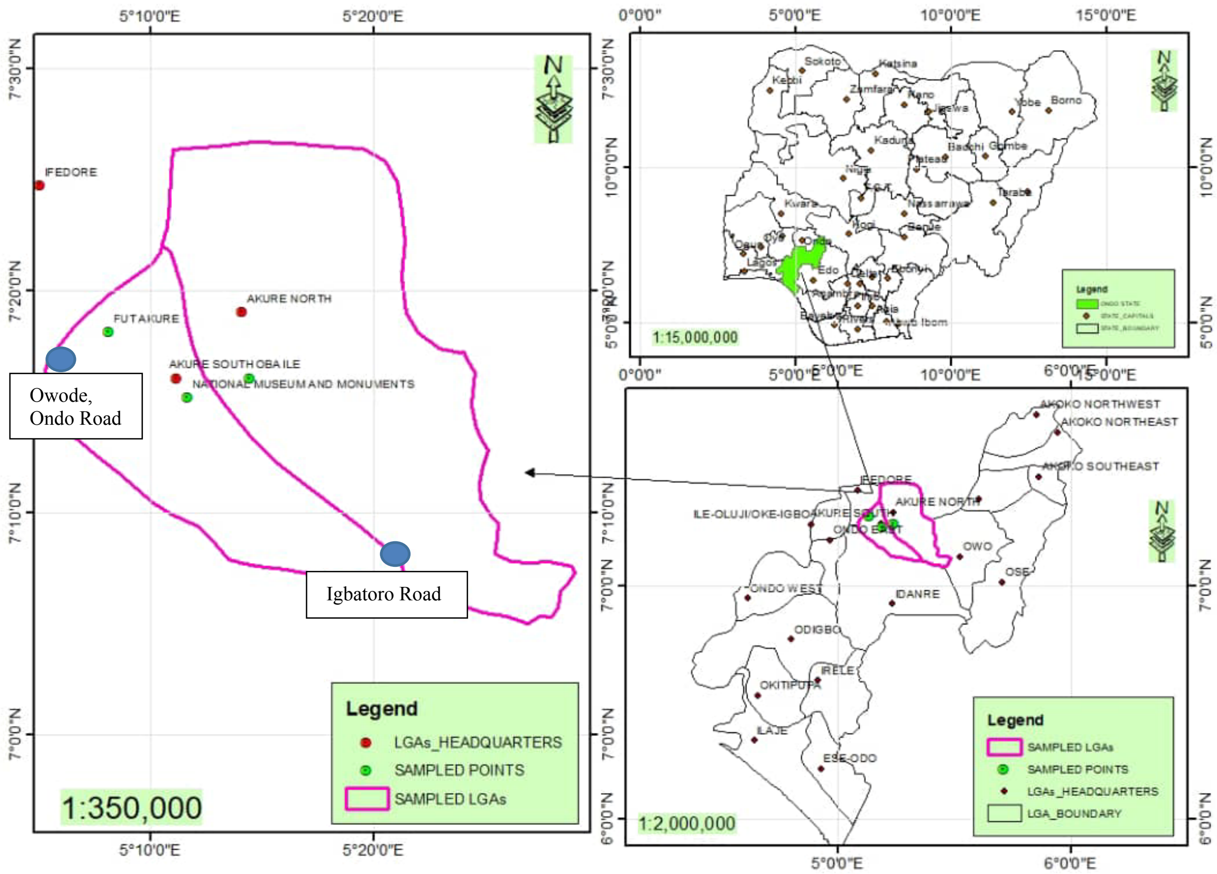


Figure 1. Map showing the location of the study area and the waste recycling plant

Table 1. Basic description of the parameters

Parameters	Mean	Std Dev.	Coff. Variation	Minimum	Maximum	Skewness	Kurtosis
Sawmill, Ondo Road, Akure							
pH	6.77	0.49	7.17	6.1	7.6	0.53	-1.06
EC (µS/cm)	51.8	72.4	139.94	4	194	2.07	4.4
Temperature (^oC)	28.03	1.51	5.36	25	31	0.02	1.49
TDS (mg/L)	25.6	36.5	143.13	2	124	2.08	4.46
Free CO_2 (mg/L)	20.67	5.28	25.55	16	32	1.1	0.35
Acidity (mg/L)	142.5	15.02	10.54	125	172	0.89	-0.07
Waste Dump Site, Igbatoro Road, Akure							
pH	6.99	0.49	6.99	6.1	7.9	0.09	0.04
EC (µS/cm)	59.4	63	105.98	4	246	1.28	6.59
Temperature (^oC)	28.75	1.77	6.14	27	33	1.53	2.06
TDS (mg/L)	29.17	30.61	104.95	2	92	1.2	0.54
Free CO_2 (mg/L)	24.33	8.3	34.13	16	48	2.35	6.59
Acidity (mg/L)	275.5	59.2	21.47	180	356	-0.53	-0.91

Table 2. Correlation coefficient of the parameters

	TDS	Temp	pH	EC	Free CO_2	Acidity
Sawmill, Ondo Road, Akure						
TDS	1					
Temp	**0.67**	1				
pH	0.01	**0.63**	1			
EC	0	**0.68**	0.01	1		
Free CO_2	0.46	0.1	**0.65**	0.47	1	
Acidity	0.04	**0.55**	0.01	0.04	**0.79**	1
Waste Dump Site, Igbatoro Road, Akure						
	TDS	Temp	pH	EC	Free CO_2	Acidity
TDS	1					
Temp	**0.6**	1				
pH	0.13	0.16	1			
EC	0	**0.59**	0.13	1		
Free CO_2	**0.58**	**0.52**	0.03	**0.57**	1	
Acidity	0.07	**0.88**	0.06	0.06	0.22	1

The Pearson correlation analysis of the data depicted that there are relationships of parameters in the two sites (Table 2). From the sawmill site, it was discovered that strong relationships existed between temperature and TDS (r=0.67), pH and temperature (r=0.63), EC and temperature (r=0.68), free CO_2 and pH (r=0.65), and acidity and free CO_2 (r=0.79). While in waste recycling plant it varied, thus: Temperature and TDS (r=0.6), EC and temperature (r=0.59), free CO_2 and TDS (r=0.58), free CO_2 and temperature (r=0.52), free CO_2 and EC (r=0.57), and acidity and temperature (r=0.88). All the correlations at a 95% confidence level for these sites suggest common inputs of parameters considered in this study. The possible sources were anthropogenic sources (burning of wastes and biomass, vehicular movements within and outside the site) and natural sources (suspended soil and dusts, emission of VOC from plants).

The contribution of each parameter to the physico-chemical ratio and the total mass in precipitation is shown in Figures 2 and 3. At the sawmill sampling point, EC and TDS had the highest contributions of the physico-chemical parameters in February (40%), January (19%) and December (17%). Likewise, a similar scenario was observed at the recycling plant, the difference was that the percent contributions were lowered in the recycling plant. The highest percentage for the months could 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. The months of July, August and September contributed to the total mass of acidity with between 9 and 10%, whereas it was June, July and August (10 and 11%) for the recycling plant site. This could be as a result of the burning of waste dumps and probably due to the atmospheric oxidation of particulates from fossil fuel combustion during these periods. The monthly variation in the parameters is influenced by rainfall rate and anthropogenic activities.

Figure 4 depicts the boxplots of the two sample locations. The physico-chemical properties (pH, alkalinity, free CO_2, EC and TDS) of the wet precipitations skewed to the right, depicting non-symmetrical. Free CO_2 has its interquartile range within the sample, while TDS, temperature and EC, ranged in the upper quartile. The skewing of the boxplots to the right was that there were large variations in the values of physicochemical properties recorded in the study. The boxplot is a visual display that presents five different statistical tools in a study - the minimum, the lower quartile, the median, the upper quartile and the maximum. It is an indicator of centrality, symmetry, spread and tail length of the population and sample (Abulude et al., 2018b).

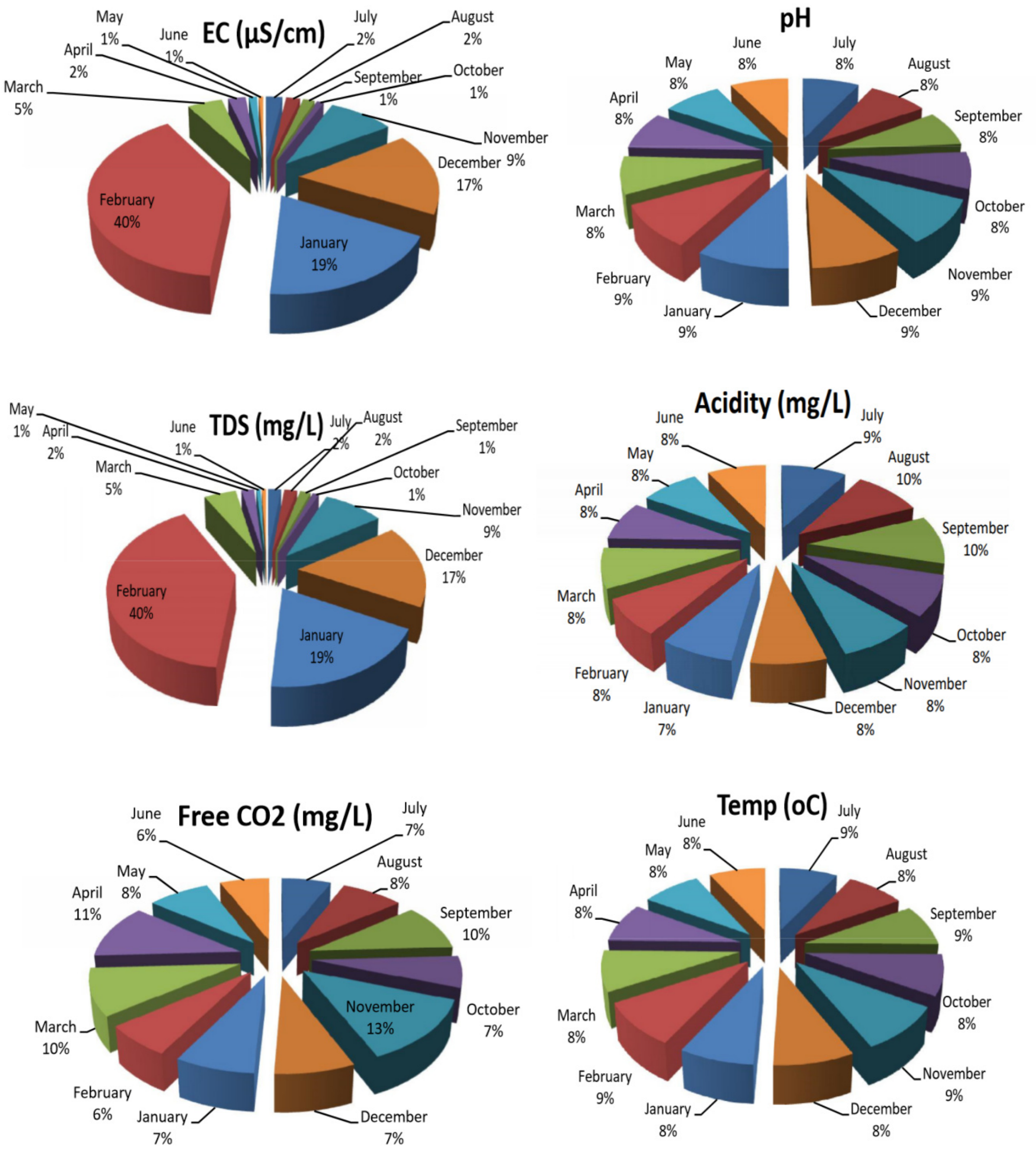


Figure 2. Contributions of physico-chemical parameters during the months at Sawmill area

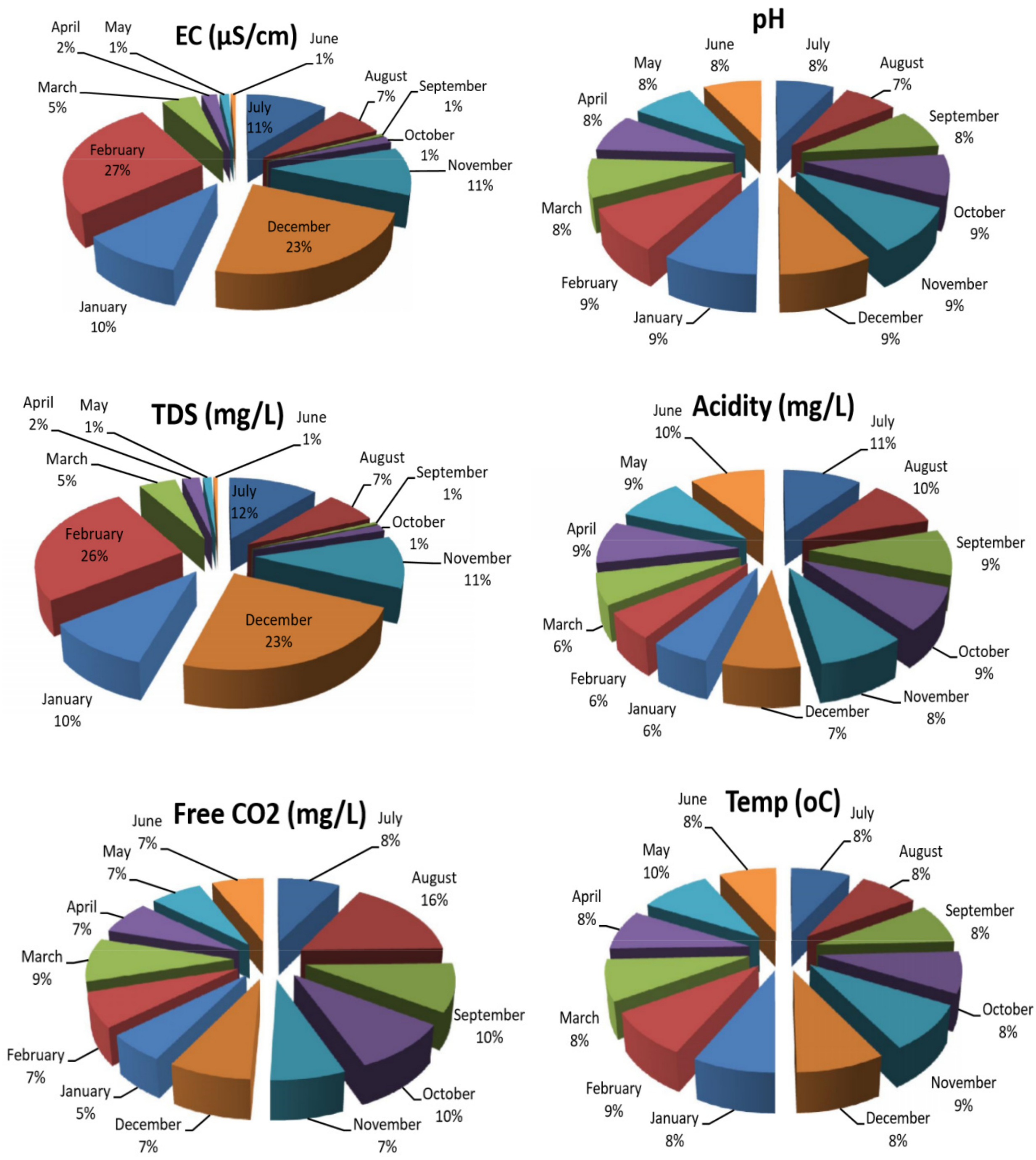
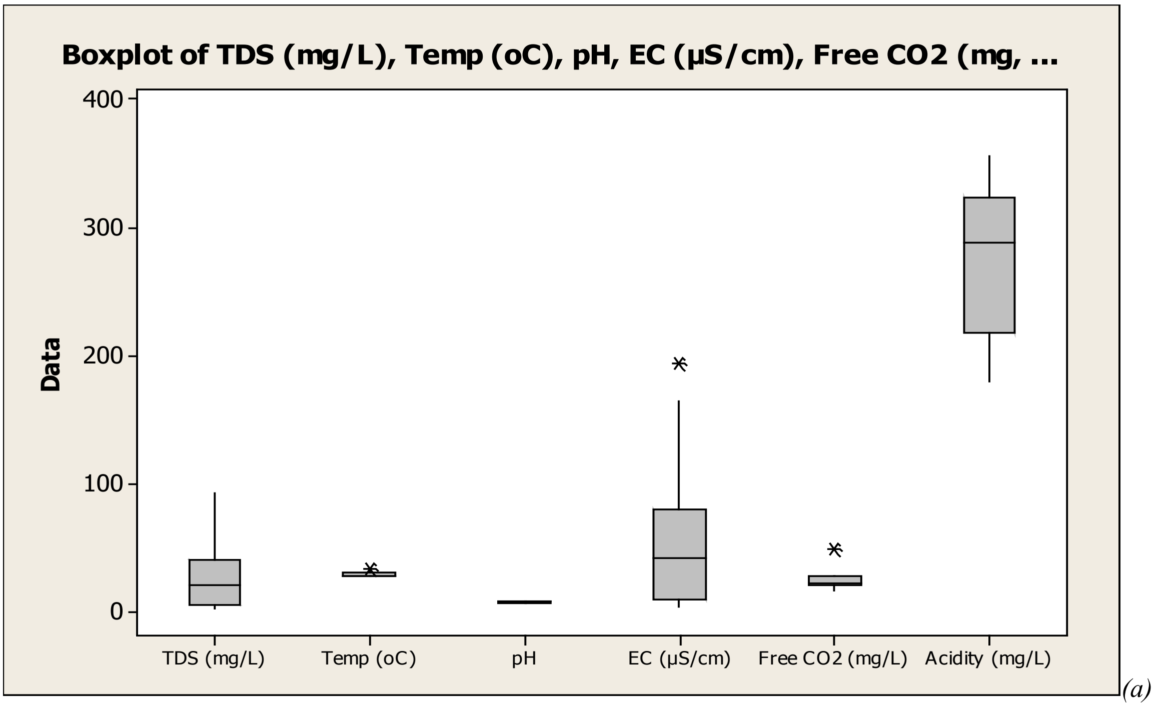


Figure 3. Contributions of physico-chemical parameters during the months in waste recycling plant area

The matrix scatterplot contains factors that are composed from the upper left to base right, in a corner to corner line (Figure 5). It plotted the factors (physico-chemical boundaries) against one another. The principal segment was a free TDS and EC scatterplot, with TDS being the X-hub, and EC being the Y-pivot. The scatterplot has been recreated in that diagram in the top column. This implies the containers on the upper right half of the whole scatterplot were reflected duplicates of the plots on the lower left. In the chart, the relationship between's TDS and EC was shown. Moreover, the framework disperses plot indicated frail connections among EC and acidity, and pH and EC.



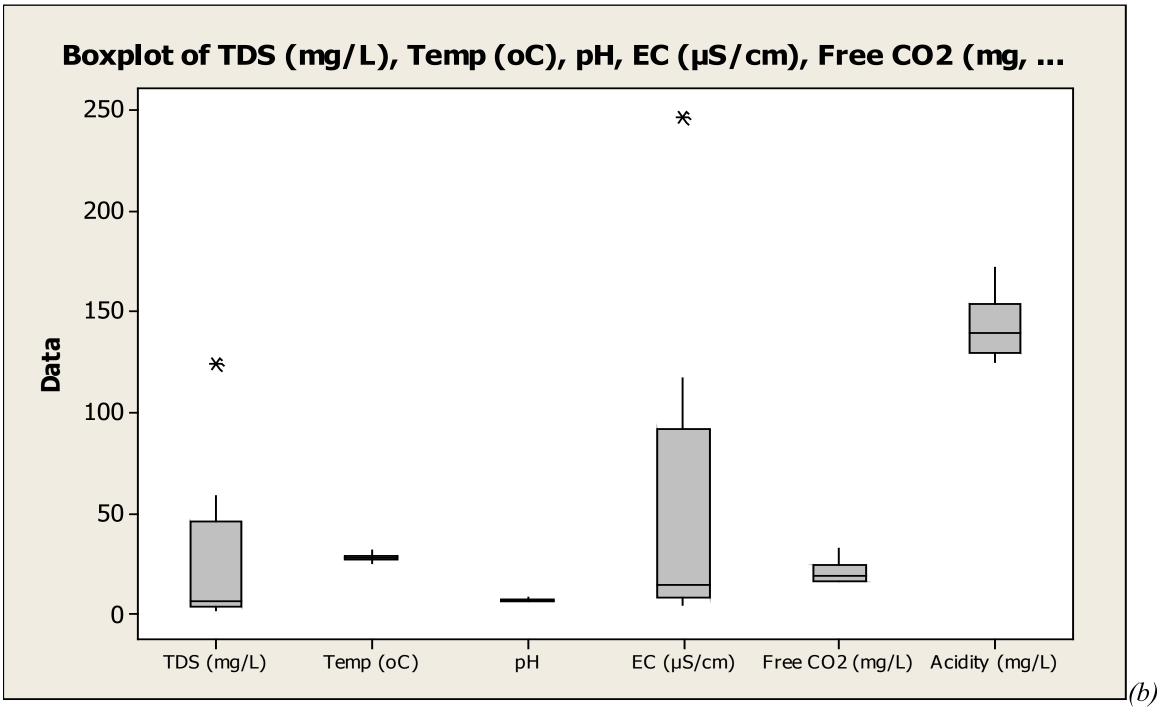
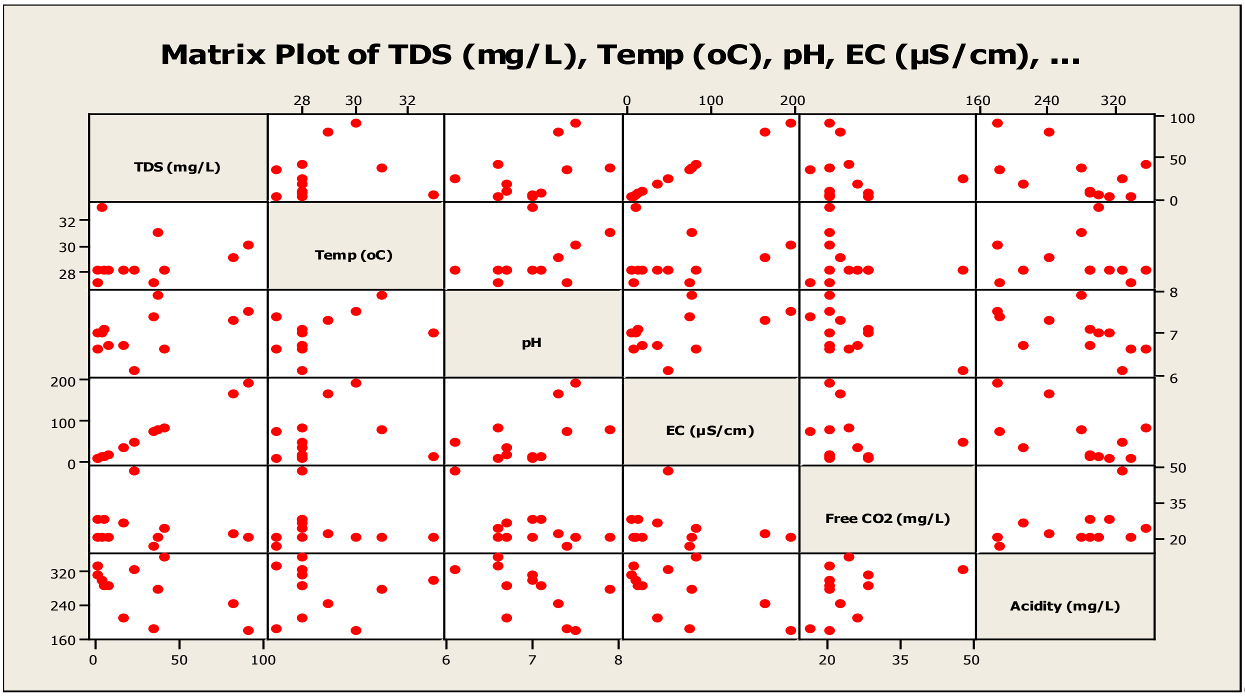
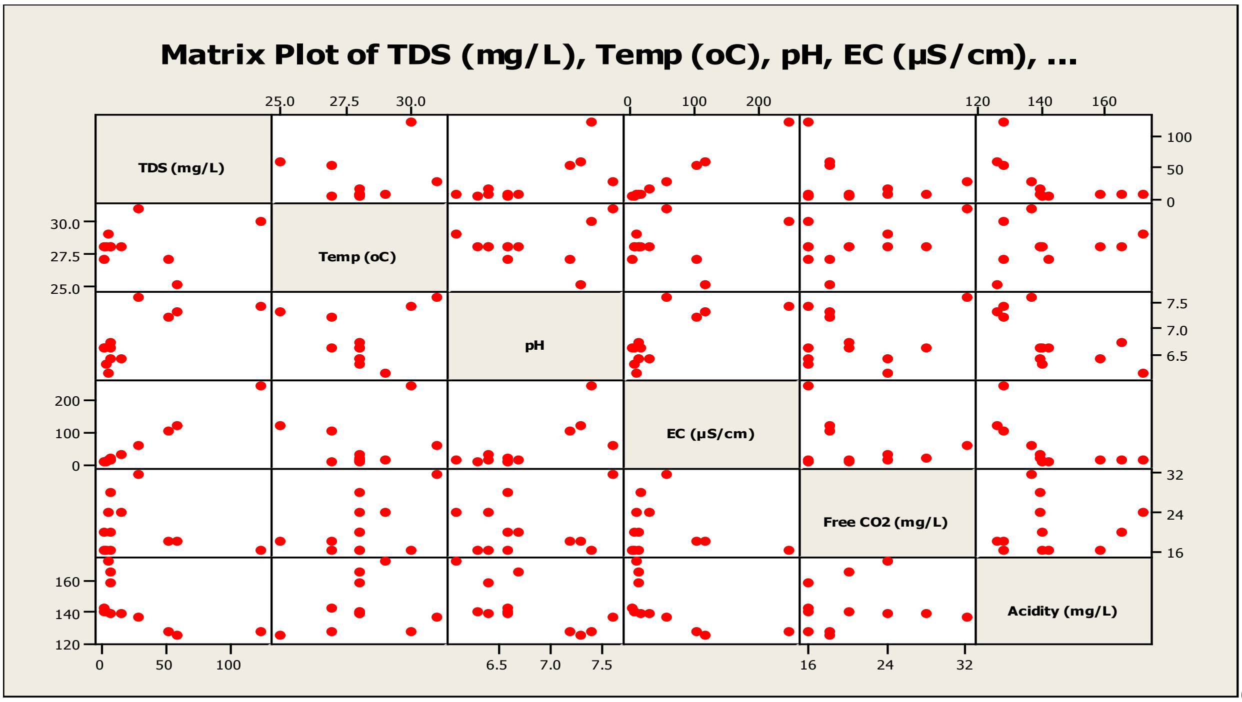


Figure 4. The boxplots of the parameters from the two sites: (a) Waste Dump Site, Igbatoro Road, Akure (b) Sawmill, Ondo Road, Akure



(a)



(b)

Figure 5. The matrixplots of the parameters from the two sites: (a) Waste Dump Site, Igbatoro Road, Akure (b) Sawmill, Ondo Road, Akure

4. CONCLUSION

The study determined the physico-chemical properties of the wet precipitation at a sawmill and a waste recycling plant sampling sites, located at Akure, Nigeria. The results showed that the physico-chemical parameters recorded for the waste dump site were well above those of the sawmill site. This difference between the minimum and maximum values may be linked to the diversity of sources and, especially, the anthropogenic influence. The average concentration of parameters in the wet precipitation in the locations showed higher concentrations during the warmer months. The pH of the wet precipitation of the areas may be categorized as not to be acidic. The presence of correlations in the parameters showed that the possible sources were anthropogenic and natural sources. The results implied that the rainwater obtained had an acceptable physico-chemical quality that makes them consumable and useful for other domestic purposes. The pollution risk in the study areas may be limited.

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