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RESEARCH ARTICLE

Investigation of Atmospheric Particulates in Two Raingauged Stations, Aba and Umuahia Meteropolis Nigeria Using Artificial Neural Network and Fuzzy Logic

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Abstract: This study conducts a thorough and multifaceted analysis of atmospheric particulate matter within the urban conglomerates of Aba and Umuahia, two prominent metropolitan areas in Abia State, Nigeria, both undergoing significant industrial and economic growth. By leveraging advanced artificial neural network (ANN) and fuzzy logic framework, rainwater samples were meticulously collected from strategically located rain gauge stations, positioned at an optimal elevation of three meters over a carefully designed ten-week sampling period. These rainwater samples were employed to accurately quantify particulate matter concentrations, enabling the assessment of spatial and temporal variations, along with the broader atmospheric deposition dynamics. Results revealed considerable disparities in particulate concentrations, with Aba displaying significantly higher levels than Umuahia, likely attributable to heightened anthropogenic sources such as industrial emissions, vehicular exhaust, and urban activities. The mean particulate concentrations were also computed for both locations, yielding deeper insights into regional atmospheric chemistry. Furthermore, graphical analysis demonstrated an inverse relationship between rainfall frequency and particulate loading, corroborating the hypothesis of precipitation-induced atmospheric cleansing. The effectiveness of ANN-based and fuzzy logic environmental models is further validated, underscoring their critical role in forecasting pollutant dispersion and facilitating sustainable urban air quality management policies.

Keywords: atmospheric particulates, ANN, fuzzy logic, precipitation, urban emissions

1 Introduction

The atmosphere is a complex dynamic natural gaseous system that is essential to support life on planet earth. It is a protective blanket which nurtures life on earth and protect it from the hostile environment of outer space. It is divided into several layers of which the most significant of them is the troposphere and the stratosphere. This atmosphere contains particles which range from aggregates of few molecules to pieces of dust readily visible to the naked eyes.

Atmospheric particulates refer to finely divided solids or liquid droplets suspended in the air. The sizes of these particulates ranges from about one-half millimeter down to molecular dimension [1]. They can be defined as any mixture of solids particles or liquid droplets that remain suspended in the atmosphere for appreciable period of time. The length of time a particle survives in the atmosphere depends on the balance between two processes: gravity forces and atmospheric turbulence. Gravity forces the particles to settle to the earth surface whereas the atmospheric turbulence carries the particles in the opposite direction. Thus under normal conditions only particles with diameter less than 10μm remain in the atmosphere long enough to be considered as atmospheric particulates [2]. Most atmospheric particulates come from natural sources. They are mainly dust or sea salts arising from mechanical processes such as wind, erosion or wave breaking. Although natural processes produce most of the atmospheric particulates on global scale, anthropogenic processes (man-made activities) are also sources of the most particulates in the urban or industrialized areas. The major anthropogenic sources are those that increase the natural loading such as extra dust due to agriculture or constructions. Also a significant amount of particles are present in factories, power plants and motor vehicle emission and are produced from the reactions of anthropogenic gases present in those emissions.

In Nigeria, the effect of particulates matter on human health has been noted by several scholars. For instance the high rate of respiratory diseases occasioned by increased PM_{10} concentrations were experienced by residents of most urban areas [3–6]. The estimate that more than five thousand people die prematurely every year from illness related to atmospheric pollution, Heart attacks, respiratory diseases and lung cancer all are significantly higher in people residing in a more polluted area, when compared to people living in a less polluted or even a cleaner environment. Thus the extent to which an individual is harmed by these particulate matters usually depends on the total exposure to the damaging chemicals. That is the duration of exposure and the concentration of the chemical must be taken into account [7].

Generally scholars believe that particulate matter in urban areas has adverse effects in the environment. Thus it is believed that the four currently major air pollution issues; i.e. Air quality, Acid rain, Global warming and Ozone depletion are consequences of the presence of particulate materials in the atmosphere [8]. The oxides of sulphur and nitrogen combined with water vapour in the atmosphere causes acid rain in the cities. The combustion of fossil fuel which contains sulphur releases sulphur (IV) oxide (SO_2) to the atmosphere which on oxidation with ozone in the troposphere forms sulphur trioxide (SO_3). The SO_3 dissolves in rain water to form sulphuric acid (H_2SO_4) resulting in acid rain [9]. When these acids are consumed they caused acidosis in human body. Excess accumulation in human body can lead to death [10]. Nitrate is sent into the atmosphere initially as Nitrogen (iv) Oxide from gas flaring, biomass burning, fossils fuel combustion [11]. With increased anthropogenic activity in urban areas, more nitrate aerosols were sent into the atmosphere from some fertilizer companies. Nitrate dissolves in rain drops and fall as acid rain [12]. Other consequences of this particulate matter include the pollution of surface and sub-surface systems, destruction of vegetal cover, endangered human lives resulting to asthma and respiratory infections after long-term exposure to a high concentration of this gas [13].

The mechanisms in which the particulates are removed from the atmosphere have been studied. These mechanisms are by dry-deposition process of sedimentation, impaction and diffusion and by rainout and washout. Studies shows that the particulates and other gases are removed from the atmosphere by precipitation in one of the two ways, rainout or washout. Rainout occurs within the clouds where the most important process is condensation of water vapour on the solid aerosol. Washout occurs below the clouds and is very efficient for the removal of large solid aerosols [9].

Particulate matter encompasses of the small solid or liquid substances that are released into the atmosphere through many activities. For instance nearly all industrial processes as well as burning fossil fuels release particulate matter into the atmosphere, and much of these particulate materials are easily visible such as smoke, soot or dust while other particulate matter are not visible [10, 14]. Included within particulate materials are constituent such as airborne asbestos particles and small particles of heavy metals such as arsenic, copper, lead, iron and zinc which are typically emitted from industrial facilities such as smelters. Report shows that gas flaring from petroleum exploitations, automobile emissions, industrial effluents, bush burning, ash and dust are local sources of particulate matter which are dispersed into the atmosphere as aerosols. Also that introduction of heavy metallic pollutants into the environment can occur in dissolved forms as hydroxides, sulphates, nitrates, phosphates, carbonates and other minerals [12].

Studies have shown that there is an interaction between the inorganic particulates and organic particulates. The adsorption of organic compounds on air borne inorganic particulates matter has received attention especially when estimating the health hazards of dust and in dispersion and transport of pollutants, causing a threat to Environmental health [15]. Observation shows that soot particles can contain several polycyclic aromatic hydrocarbon (PAH) and N-containing aromatic compound such as aza-arenes [16].

The effects of particulate matter on living, non-living and the earth at large have received attention. The effects of particulate matter on vertebrates includes impairment of the respiratory system, damage to the eyes, teeth and bones, increased susceptibility to diseases, pest and other stress related environmental hazards and reduce ability to reproduce [17–19]. Similarly other effects of suspended particles have been observed and noted. For instance, it was observed and noted that suspended particles aggravate bronchitis and asthma [20]. Particulates associated with large construction projects may kill and damage large areas, changing species composition, altering food chain and generally affecting the ecosystem [10].

The aim of this study is to undertake a comparative study of pollution level in Aba and Umuahia both in Abia state, Nigeria. This research work is with the objective of investigating the concentrations of particulate materials (aerosols) present in the atmosphere of this two towns or the extent of pollution as the year runs out and with the view of highlighting the effect or otherwise the consequences of some of these elemental pollutants.

2 Materials and Methods

2.1 Geography of the Study Areas

Aba is a city and a big trading centre in Abia state, south-eastern Nigeria having coordinates 5° 07'N and 7° 22'E. It has an estimated population of about 821,000 people. Umuahia is the capital of Abia State in South-eastern Nigeria. It has a coordinates of 5° 32'N and 7° 29'E, having an estimated population of about 359,230.

2.2 Sample Collections

The investigation of the amount of particulates in Aba and Umuahia metropolis was carried out to ascertain the pollution level or the aerosols concentrations of these study areas. Due to urbanization, rapid population growth, burning of hydrocarbons and other natural and anthropogenic activities, the pollution level of the atmosphere of these study areas ranges from moderate to serious. Average weekly rainwater samples were obtained from rainguage stations from each of these towns for ten weeks. Rainwater sample from Aba-(RWSA) and rainwater sample from Umuahia-(RWSU) were labeled properly. On the sample bottles, the following information were labeled on it; date of sampling (week of collection), and location. These samples were collected between the months of April-June 2011 in order to obtain the trend of concentrations of ions in the atmosphere.

2.3 pH (Hydrogen ion concentration)

A Labtech Digital 211 pH meter was used to monitor the pH of all the water samples. The laboratory determination of the pH was made immediately after opening the sample. Having standardized the instrument, the probe was immersed in the sample and the pH read.

2.4 Electrical Conductivity

The electrical conductivity of the water sample was determined using the Hanna EC 215 Conductivity Meter. The conductivity meter was switched on and the electrode was rinsed with distilled water and cleaned with soft cloth. The probe was immersed in the sample to be determined and then read. The results are expressed in μS/cm.

2.5 Temperature

The temperature of each of the water samples was determined in the laboratory using the mercury-in-glass thermometer. The temperature of the samples was determined by dipping the thermometer in each of the samples for seconds and the readings recorded. Results are expressed in degree Celsius.

2.6 Total Dissolved Solids

This was determined by evaporation method in an oven maintained at 110°C for one hour [21,22]. Evaporating dish was weighed using ADG 5000 electronic weighing balance and later 100cm^3 of water sample was introduced into the weighed dish and dried in an oven operated at 110°C for one hour. After drying, it was transferred to a desicator and left to cool for one hour. The dish was finally weighed with its content. The difference in the weight gives the weight of the total dissolved solids of the sample [21,22].

2.7 Total Suspended Solids

Total Suspended Solids was determined by filtration method [22]. Water samples were filtered by the use of filter paper. The filter paper and the residue were dried in an oven for about 30-40 minutes at a temperature of about 105°C. The difference in the weight of the filter paper before and after drying gives the total suspended solids [21].

2.8 Alkalinity

By titration method, 25 ml of the water sample was pipetted into a 250 ml conical flask, and drops of phenolphthalein indicator added and swirled. The solution was titrated with 0.01 M of HCI acid solution to a colourless end point. The titre values were then recorded.

$$Alkalinity\ (mg/dm^3) = \frac{titre\ value \times molarity\ of\ theacid \times 1000}{Volume\ of\ the\ sample\ used}$$

2.9 Total Hardness

The method used in the determination of the total hardness is titration method using EDTA as titrant and solochrome black T as indicator [23]. 50 cm^3 of water sample was introduced into a beaker and 0.1 cm^3 buffer solution of ammonia added. Two drops of solochrome black T indicator was also added and the solution stirred properly. The mixture was titrated with standard 0.01 M EDTA solution until colour changed from wine red to blue with no reddish ting remaining. Thus the total hardness of the water was calculated.

$$Total\ Hardness \frac{\left(\frac{CaCO_3}{MgCO_3}\right) mg}{dm^3} = \frac{volume\ of\ titrant \times 100}{volume\ of\ sample\ used}$$

For the determination of calcium hardness, 100 cm^3 of the water sample was introduced to a beaker and 1 ml of NaOH buffer added. Three drops of mirazine indicator was added to the solution and stirred. The mixture was again titrated with standard 0.01 EDTA solution until a colour change from light red to deep red was noticed as the end point. Thus the calcium hardness of the water was calculated as:

$$Calcium\ Hardness\left(\frac{mg}{dm^3}\right) = \frac{Volume\ of\ trant \times 100}{Volume\ of\ sample\ used}$$

The difference between the total hardness and the magnesium hardness was taken as the calcium hardness.

2.10 Phosphate

The determination of phosphate was done using JENWAY 6305 Spectrophotometer. To prepare the sample for analysis 2cm^3 of the water sample was measured into a beaker. To it 5cm^3 of deionised water and 2cm^3 of ammonium molybdate solution was added and mixed properly. To the mixture also 1cm3 of stannous chloride dilute solution was added and mixed. This was allowed to stay for a reaction time of about 5-10 minutes. Then the colourchanges to a slight blue. It was now used to fill the sample cell and the absorbance on the spectrophotometer measured at wavelength of 660nm.

2.11 Sulphates

The determination of sulphates are done using the JENWAY 6305spectrophotometer.25cm^3 of the water sample is measured, into and barium chloride is added, followed by HCI-NaCl solution. This prepared solution is now used to fill the sample cell of the spectrophotometer. The absorbance measured at wavelength of 420nm. The blank was also carried out also.

2.12 Nitrates

This was done using the Hach corporation Nitraver 5 Nitrate method which is adapted from the cadmium reduction method using the powder pillows [22,24]. A DR2010 spectrophotometer was used for the determination with programme number 355 and wavelength 500nm. Sample cell was filled with the 25cm^3 of the water sample, to one was added Nitraver 5 Nitrate reagent powder pillow. This was swirled to dissolve and then introduced into the instrument for a reaction time of one minutes. When the time beeped at the expiration of the minutes, the shaft and the timer button was depressed again for about five minutes reaction period. The display gave the reading of the nitrate in mgL^{-1} nitrate nitrogen. The blank was also carried out.

2.13 Chlorides

This was determined by the Mohr's method by using silver trioxonitrate (v) ($AgNO_3$) as titrant and potassium heptaoxodichromate (vi) ($K_2Cr_2O_7$) as the indicator [25]. 25 cm^3 of the rain water sample was measured into the conical flask and 1 ml of 5% K_2Cr_2O, was added to it. Then this is titrated against 0.02 M of $AgNO_3$ until the colour changes from yellow to yellowish brown. The blank was also performed. The concentration of the chloride in mgL^{-1} is calculated thus;

$$Chloride\ content\left(\frac{mg}{dm^3}\right) = \frac{tire\ value \times Molitiy\ of\ AgNO_3 \times 35.46}{Volume\ of\ war\ sample\ used}$$

3 Results and Discussion

This comprises of presentations, analysis and the interpretations of the results produced by the laboratory experiments of rainwater sample from Aba and Umuahia in Abia State, in order to determine the extent of atmospheric pollution in these study areas. The results were with the World Health Organization standard for drinking water quality [26]. Figure 1 to 12 shows the graphs of each of the parameters analysed for the rainwater samples from both stations.

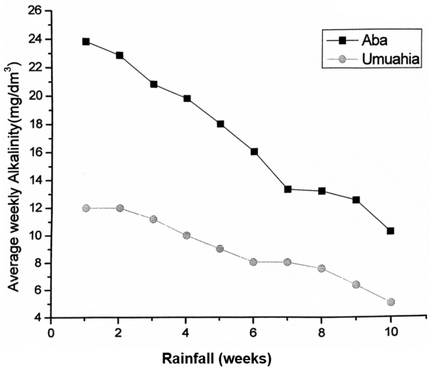


Figure 1 Graph of Average Alkalinity of rainwater samples from Aba and Umuahia versus Weekly rainfall

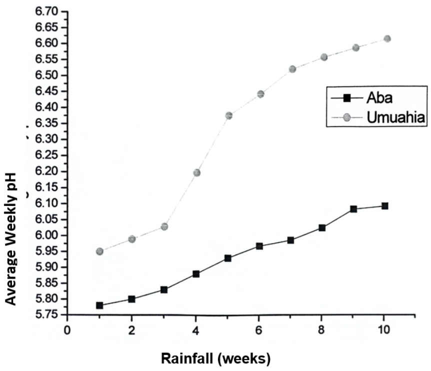


Figure 2 Graph of Average pH of rainwater samples from Aba and Umuahia versus weekly rainfall

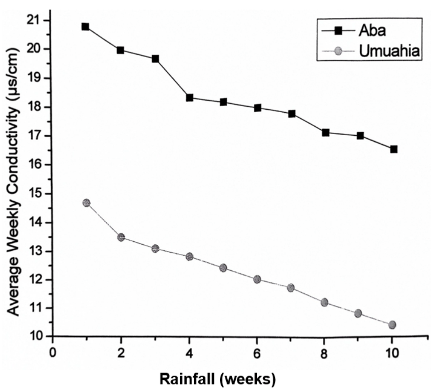


Figure 3 Graph of Average Conductivity of rainwater samples from Aba and Umuahia versus weekly rainfall

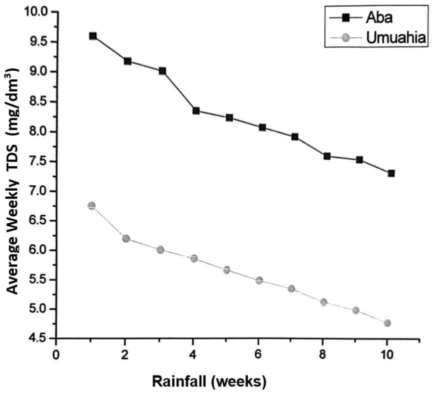


Figure 4 Graph of Average TDS of rainwater samples fromn Aba and Umuahia versus weekly rainfall

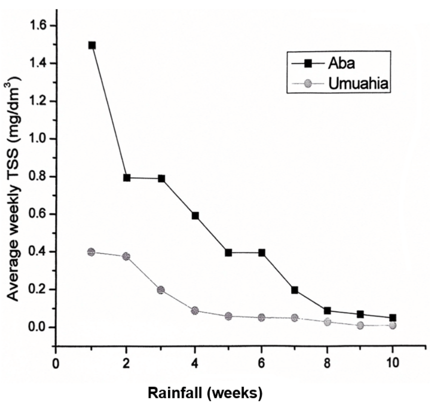


Figure 5 Graph of Average TSS of rainwater samples from Aba and Umuahia versus weekly rainfall

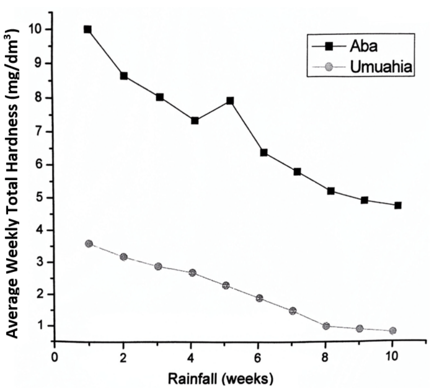


Figure 6 Graph of Average Weekly Total Hardness of rainwater samples from Aba and Umuahia versus weekly Rainfall

The results of the analysis in Table 1 and 2 shows the presence of cations and anions in mgl in the rainwater sample collected from both study sites. The graphs from Figure 1 to 12 indicate that the two stations have anions and cations which decrease with the frequency of rain as the year runs out.

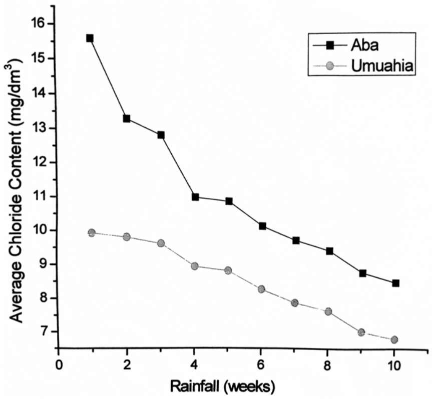


Figure 7 Graph of Chloride content of rainwater samples from Aba and Umuahia versus weekly rainfall

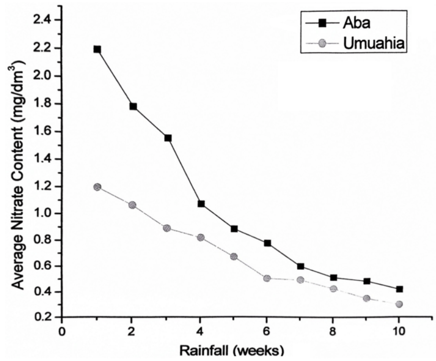


Figure 8 Graph of Average Nitrate content of rainwater samples from Aba and Umuahia versus weekly rainfall

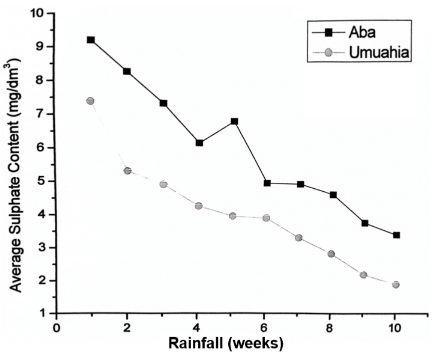


Figure 9 Graph of Average Sulphate content of rainwater samples from Aba and Umuahia versus weekly rainfall

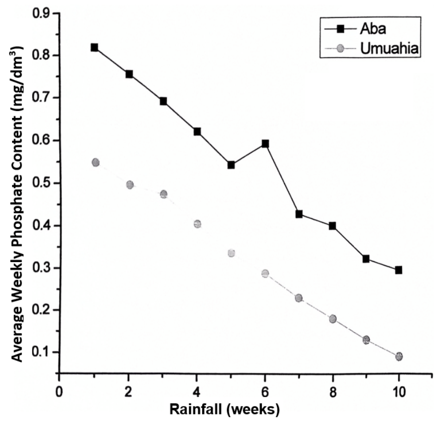


Figure 10 Graph of Average Phosphate content of rainwater samples from Aba and Umuahia versus weekly rainfall

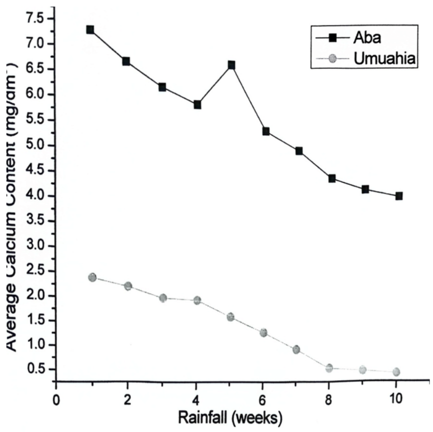


Figure 11 Graph of Average Calcium content of rainwater samples from Aba and Umuahia versus weekly rainfall

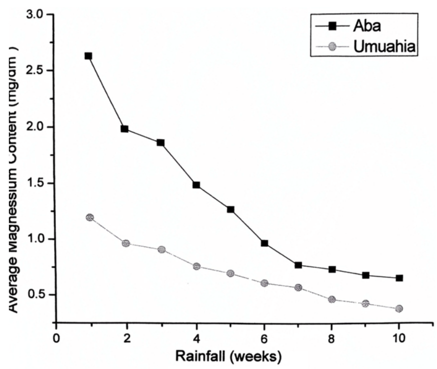


Figure 12 Graph of Average Magnesium content of rainwater samples from Aba and Umuahia versus weekly rainfall

Table 1 Analytical Data for Physicochemical Analysis of Rainwater Samples from Aba collected for ten weeks

Parameters	RWS WK1	RWS WK2	RWS WK3	RWS WK4	RWS WK5	RWS WK6	RWS WK7	RWS WK8	RWS WK9	RWS WK10	Mean	WHO STD
Alkalinity (mg/dm^3)	23.90	23.00	21.00	20.00	18.10	16.00	13.20	13.00	12.30	10.00	17.10	100
pH	5.78	5.80	5.83	5.88	5.93	5.97	5.99	6.03	6.09	6.10	5.94	6.5-8.5
Conductivity (μS/cm)	20.80	20.00	19.70	18.30	18.10	17.80	17.50	16.80	16.70	16.20	18.19	50
Temperature (°C)	28.00	28.00	27.90	28.00	28.00	27.80	28.00	28.10	28.00	28.00	27.90	25
TotalDissolvedSolids (mg/dm^3)	9.60	9.20	9.06	8.42	8.33	8.19	8.05	7.73	7.68	7.45	8.37	500
TotalSuspended Solids(mg/dm^3)	1.50	0.80	0.80	0.60	0.40	0.40	0.20	0.09	0.07	0.05	0.49	500
Chlorides (mg/dm^3)	15.62	13.35	12.90	11.08	10.98	10.25	9.82	9.50	8.83	8.53	11.09	200
Nitrates (mg/dm^3)	2.20	1.80	1.58	1.09	0.90	0.79	0.61	0.52	0.49	0.42	1.04	50
Total Hardness (mg/dm^3)	10.00	8.70	8.10	7.40	8.00	6.40	5.80	5.20	4.90	4.70	6.92	500
Phosphates (mg/dm^3)	0.82	0.76	0.70	0.63	0.55	0.60	0.43	0.40	0.32	0.29	0.55	1.0
Sulphates (mg/dm^3)	9.21	8.31	7.42	6.25	6.93	5.02	4.98	4.65	3.80	3.45	6.00	200
Calcium Hardness (mg/dm^3)	7.30	6.70	6.21	5.88	6.70	5.41	5.01	4.45	4.21	4.04	5.59	500
Magnesium Hardness (mg/dm^3)	2.63	2.00	1.89	1.52	1.30	0.99	0.79	0.75	0.69	0.66	1.32	500

Table 2 Analytical Data for Physicochemical Analysis of Rainwater Samples from Umuahia collected for ten weeks

Parameters	RWS WK1	RWS WK2	RWS WK3	RWS WK4	RWS WK5	RWS WK6	RWS WK7	RWS WK8	RWS WK9	RWS WK10	Mean	WHO STD
Alkalinity (mg/dm^3)	12.00	12.00	11.20	10.00	9.00	8.00	8.00	7.50	6.30	5.00	8.90	100
pH	5.95	5.99	6.03	6.20	6.38	6.45	6.53	6.57	6.60	6.63	6.33	6.5-8.5
Conductivity (μS/cm)	14.70	13.50	13.10	12.80	12.40	12.00	11.70	11.20	10.80	10.40	12.26	50
Temperature (°C)	27.50	28.00	28.00	27.90	28.10	28.00	28.00	27.77	28.00	28.00	27.90	25
Total Dissolved Solids (mg/dm^3)	6.76	6.21	6.03	5.89	5.70	5.52	5.38	5.15	5.01	4.78	5.64	500
TotalSuspended Solids(mg/dm^3)	0.40	0.38	0.20	0.09	0.06	0.05	0.05	0.03	0.01	0.01	0.13	500
Chlorides (mg/dm^3)	9.94	9.83	9.66	8.98	8.86	8.31	7.90	7.65	7.03	6.80	8.50	200
Nitrates (mg/dm^3)	1.20	1.07	0.90	0.83	0.68	0.51	0.50	0.43	0.35	0.30	0.68	50
Total Hardness (mg/dm^3)	3.60	3.20	2.90	2.70	2.30	1.90	1.50	1.00	0.90	0.80	2.08	500
Phosphates (mg/dm^3)	0.55	0.50	0.48	0.41	0.34	0.29	0.23	0.18	0.13	0.09	0.32	1.0
Sulphates (mg/dm^3)	7.40	5.35	4.97	4.32	4.02	3.95	3.34	2.85	2.21	1.90	4.03	200
Calcium Hardness (mg/dm^3)	2.40	2.23	1.98	1.93	1.59	1.28	0.92	0.53	0.47	0.42	1.38	500
Magnesium Hardness (mg/dm^3)	1.20	0.97	0.92	0.77	0.71	0.62	0.58	0.47	0.43	0.38	0.71	500

Note: WHO STD = World Health Standard; RWS-WK = Rain Water Sample for the respective Weeks (from week 1-10).

3.1 pH

The pH is the measure of hydrogen ion activity. It is the measure of the intensity of acidic and alkaline reaction of water. From the results in Table 1 and 2, and in Figure 2, the pH of rainwater in both stations increases with increase in the frequency of rainfall as the week moves or as the year runs out. This indicates the removal of hydrogen ion from the atmosphere with increased rainfall. The pH of rainwater sample from both areas after ten weeks is slightly acidic with mean values of 5.94 and 6.33 for Aba and Umuahia respectively. The least and highest value of pH of rainwater sample from Aba is 5.78 and 6.10respectively, while that of Umuahia is 5.95 and 6.63 respectively.

The higher acidity of Aba rainwater sample may be attributed to dissolution of acidic gases including CO_2, SO_2, NO_2,this agrees with [27, 28] which may have originated from much human activity through much vehicular exhaust and hydrocarbon burning. The pH value of rainwater sample from Aba shows acidity and falls below the permissible limit of WHO standard which falls within the range of 6.5-8.5, thus making the early rainwater in Aba unsuitable for consumption. Due to the acidity of the early rain in Aba, they are also capable of inducing corrosion on the metallic materials such as metallic reservoirs, roofs, etc. The first six weeks of rainwater sample from Umuahia has pH value below the permissible limit of WHO standard ,thus are not suitable for drinking, also can induce corrosion.

3.2 Alkalinity

The alkalinity of water is due to the presence of carbonates, hydroxides, and bicarbonates. It is the ability of rainwater to neutralize acid. From Table 1 and 2, the total alkalinity of rainwater sample from Aba for the ten weeks lie between 10.0 - 23.90 mg/dm^3 with mean value of 17.10mg/dm^3, while the total alkalinity of rainwater sample from Umuahia after the ten weeks lie between 5.0-12.0 mg/dm^3, with mean value of 8.90 mg/dm^3.

The mean value obtained from Aba is higher than that obtain from Umuahia, indicating that there is more concentrations of carbonate, bicarbonates and hydroxides in the atmosphere of Aba than Umuahia. This may be as a result of more industrial activity in Aba than Umuahia.

Figure 1 shows a decrease in the alkalinity with increase in the frequency of rainfall for both stations. This indicates that increase in rainfall removes the carbonates, bicarbonates and hydroxides present in the atmosphere. Nevertheless, the values obtained from both study areas are within the WHO permissible level for alkalinity.

3.3 Electrical Conductivity

The electrical conductivity is the ability of the rainwater to convey current at certain temperatures. It is the measure of the total concentration of ionizable salt content in the water. Electrical conductivity depends on the amount of dissolved materials or particulates. From the analysis, the mean value of the conductivity of rainwater sample from Aba is 18.19 μS/cm. Thus this is greater than the mean conductivity value of rainwater sample from Umuahia which is 12.26 μS/cm. This indicates that there is more number of particles in Aba atmosphere than Umuahia atmosphere. These particulates in Aba atmosphere may be as a result of much human activities and more traffic congestion. But the electrical conductivity of the two areas lies within the permissible limit of WHO standard.

3.4 Total Dissolved Solids (TDS)

This refers to the matter that remains as residue after evaporation. From the results in Table 1 and 2, and the graphs in Figure 1 to 4, as the total dissolve solids decrease, the electrical conductivity decreases while the pH increases. The total dissolved solids include all solid materials in solution weather ionized or not. The mean TDS value of both study areas which is 8.37 mg/dm^3 and 5.64 mg/dm^{3}for Aba and Umuahia respectively is very low when compared to WHO standard of 500 mg/dm^3.

From Figure 4, it is observed that the TDS decreased with increase in the frequency of rainfall indicating that these early rainfall are the major route for the removal of atmospheric particles from the atmosphere. Also the mean value of TDS for rain water sample from Aba is higher than rainwater sample from Umuahia. This shows that Aba atmosphere contains more particulates than Umuahia atmosphere.

3.5 Total Suspended Solids (TSS)

The TSS depicts solid particles in the atmosphere that were not able to dissolve in the rainwater. The TSS ranges from 0.05-1.50 mg/dm^3 with mean value of 0.49mg/dm^3 for rainwater sample from Aba and 0.01-0.40 mgdm^3 with mean value of 0.13 mg/dm^3 for rainwater sample from Umuahia. The TSS value is higher in rainwater sample from Aba than Umuahia. This could be attributed to more anthropogenic activities and dust raised during harmattan (dry) season [29]. It is also observed that the mean TSS value for the two study areas is much lower than the permissible limit of WHO standard which is 500 mg/dm^3 which shows much less undissolved solids in the atmosphere of these study areas.

3.6 Chlorides

The chloride concentration of rainwater sample from Aba for the ten weeks ranges from 8.53-15.62 mg/dm3 with mean value of 11.09 mg/dm^3, while that of Umuahia ranges from 6.8-9.94 mg/dm^3 with mean value of 8.50 mg/dm^3. These concentrations are within the permissible limit of WHO standard which is 200mg/dm^3. Although chloride ions in a very small concentration or as an impurity in a raw material can cause active corrosion. This greater chloride concentration may have come from detergent and bleaching industrial wastes.

3.7 Phosphates

The presence of phosphates in the atmosphere decreases the pH of rainwater. From the data in Table 1 and 2, rainwater sample from Aba has a range of phosphate concentration value for the ten weeks between 0.29-0.82 mg/dm^3 and mean value of 0.55 mg/dm^3,while that from Umuahia is within the range of 0.09-0.55 mg/dm^3 with mean value of 0.32 mg/dm^3. The higher value of phosphate concentration in Aba rainwater sample may be due to more economic activity there than in Umuahia. The phosphate concentration may have come from waste water from soap and detergent industries there or from fertilizer company fumes. From the results in Table 1 and 2, and also from the graph in Figure 10, it is observed that the concentrations also decreased with the frequency of rainfall.

3.8 Sulphates

Sulphates in the atmosphere has its origin from gas flaring, fossil fuel and automobile emission. Sulphur is present in coal and petroleum as hydrogen sulphide, mercaptans, alkyl sulphides, alkyl sulphates, thiophenes and as free sulphur [12]. During combustion, sulphur is oxidized to sulphur (iv) oxide (SO_2), which on further oxidation gives sulphur (vi) oxide (SO_3). This dissolves in rain drops to produce tetraoxosulphate (vi) acid (H_2SO_4) and fall as acid rain [30].

$$S + O_2 \rightarrow SO_2$$

$$SO_2 + O_3 \rightarrow SO_3 + O_2$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

Acid rain is one of the most devastating forms of pollution. It has adverse effect on the ecosystem, damaging vegetation and killing sea creatures.

From the data in Table 1 and 2 and the graph in Figure 9, it shows that the two stations have sulphate concentrations which decreases with the frequency of rainfall. The two stations have a mean concentration values of 6.0 mg/dm^3 and 4.03 mg/dm^3 for Aba and Umuahia respectively. The mean values are within the permissible limit of WHO standard of 200 mg/dm^3. From the data,sulphate concentration of rainwater sample from Aba is greater than that of Umuahia. This may be as a result of greater urbanization and anthropogenic activities in Aba.

3.9 Nitrates

Nitrates are sent into the atmosphere initially as Nitrogen (iv) Oxide (NO_2) from gas flaring, biomass burning, fossil fuel combustion. With increased anthropogenic activities in the urban areas, more Nitrates aerosols are sent into the atmosphere. Nitrates dissolve in rain drops, decrease the pH and fall as acid rain. Nitrates concentration increases with urbanization and greater anthropogenic activities resulting in rainwater sample from Aba having the greater concentration value than that from Umuahia. From Table 1 and 2 and the graph in Figure 8, it is observed that the values of Nitrate concentration decreased with the frequency of the rain. The Nitrate content of rainwater sample from Aba and Umuahia after ten weeks lie between 0.42-2.20 mg/dm^3 and 0.30-1.20 mg/dm^3 respectively. These values lie within the permissible limit of WHO standard which is 50 mg/dm^3.

3.10 Total Hardness

Total hardness depends mainly on the presence of dissolved calcium and magnesium salts. The level of total dissolved solids increase the hardness of water. Hardness of water spoils fabrics, causes chocking and clogging troubles in the pipelines. Hardness also causes formation of scales on electric boilers leading to wastage of fuel and the dangers of overheating of boiler [9].

Total hardness was detected in both stations with values ranging between 4.70-10 mg/dm^3 and 0.80-3.60 mg/dm^3 for rainwater sample from Aba and Umuahia respectively. Higher values were obtained for rainwater sample from Aba than Umuahia. Calcium and magnesium was also detected as being responsible for the hardness of the rainwater. From Table 1 and 2, the value of the concentration of calcium and magnesium detected was higher in rainwater sample from Aba than Umuahia. This may be as a result of calcium carbonates fumes and dust from paint making industries and cement industries in Aba as well as some soap industries.

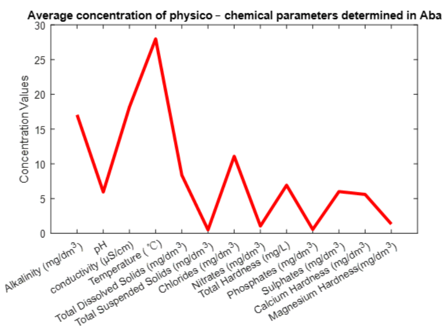


Figure 13 Actual plot for Aba

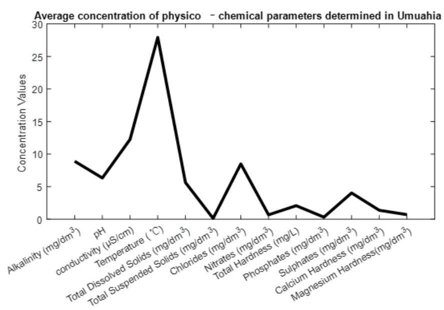
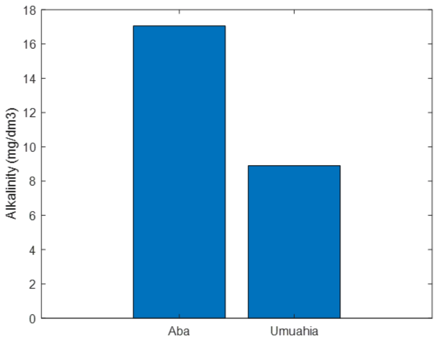


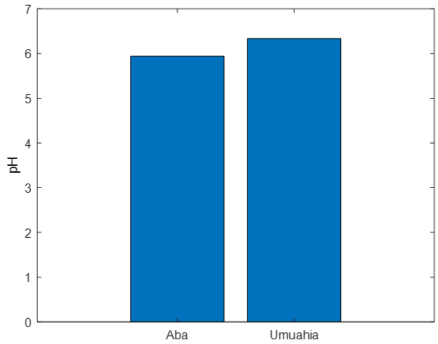
Figure 14 Actual plot for Umuahia



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	208	7	29.7143	13.74	0.0695
Error	4.325	2	2.1625		
Total	212.325	9			

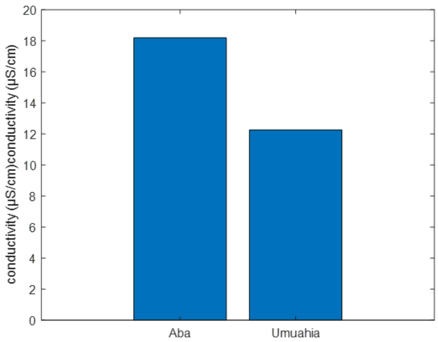
Figure 15 For Alkalinity



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	0.1206	9	0.0134		0
Error	0	0	NaN		
Total	0.1206	9			

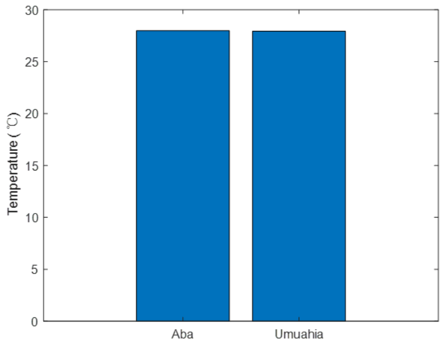
Figure 16 For pH



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	21.129	9	2.34767		0
Error	0	0	NaN		
Total	21.129	9			

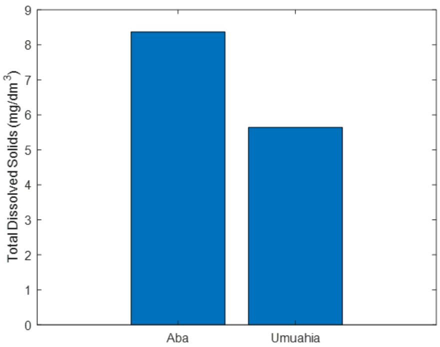
Figure 17 For conductivity (μS/cm)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	0.021	4	0.00525	0.75	0.5983
Error	0.035	5	0.007		
Total	0.056	9			

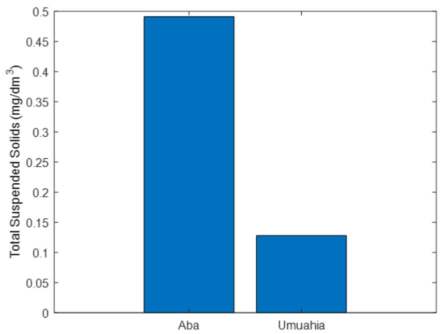
Figure 18 For Temperature (°C)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	4.54889	9	0.50543		0
Error	0	0	NaN		
Total	4.54889	9			

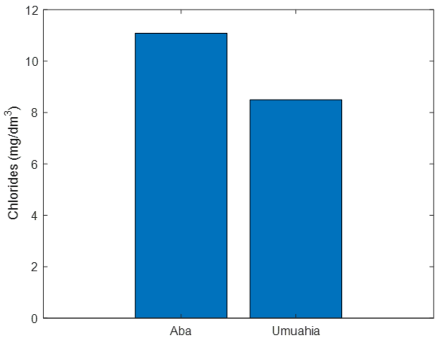
Figure 19 For Total Dissolved Solids (mg/dm^3)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	1.83449	7	0.26207	25.95	0.0376
Error	0.0202	2	0.0101		
Total	1.85469	9			

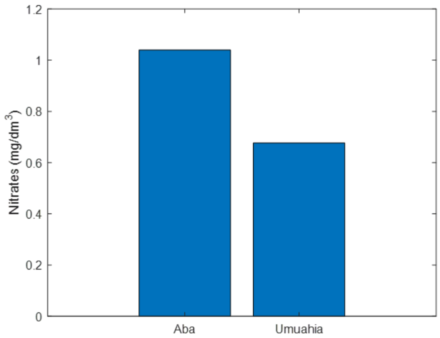
Figure 20 For Total Suspended Solids(mg/dm^3)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	45.4244	9	5.04716		0
Error	0	0	NaN		
Total	45.4244	9			

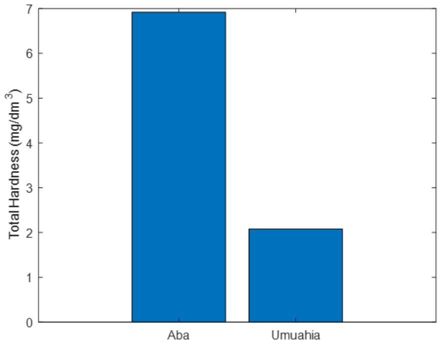
Figure 21 For Chlorides (mg/dm^3)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	3.4416	9	0.3824		0
Error	0	0	NaN		
Total	3.4416	9			

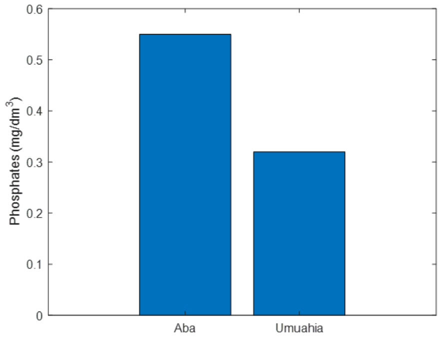
Figure 22 For Nitrates (mg/dm^3)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	28.936	9	3.21511		0
Error	0	0	NaN		
Total	28.936	9			

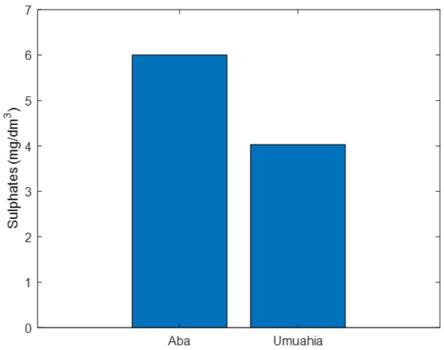
Figure 23 For Total Hardness (mg/dm^3)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	0.3058	9	0.03398		0
Error	0	0	NaN		
Total	0.3058	9			

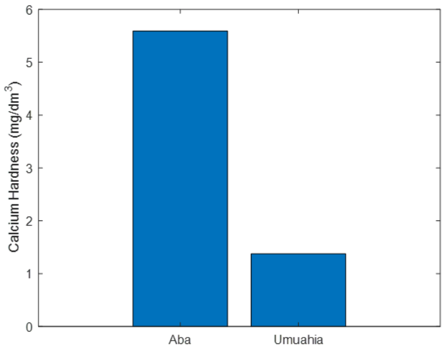
Figure 24 For Phosphates (mg/dm^3)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	33.7498	9	3.74997	NaN	NaN
Error	-0	0	NaN		
Total	33.7498	9			

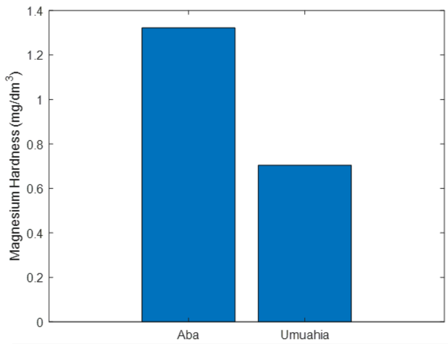
Figure 25 For Sulphates (mg/dm^3)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	11.8321	9	1.31468		0
Error	0	0	NaN		
Total	11.8321	9			

Figure 26 For Calcium Hardness (mg/dm^3)



ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	4.09096	9	0.45455		0
Error	0	0	NaN		
Total	4.09096	9			

Figure 27 For Magnesium Hardness (mg/dm^3)

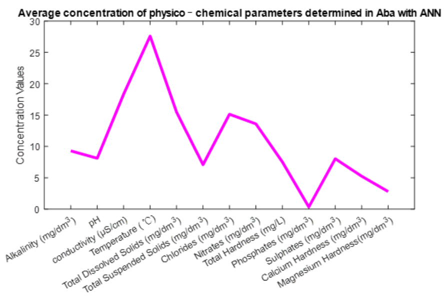


Figure 28 ANN for Aba

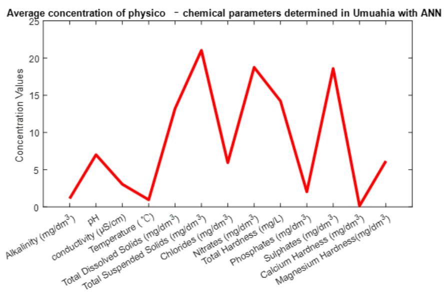


Figure 29 ANN for Umuahia

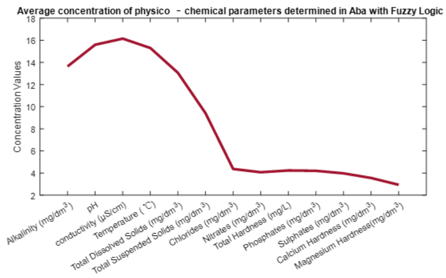


Figure 30 Fuzzy logic for Aba

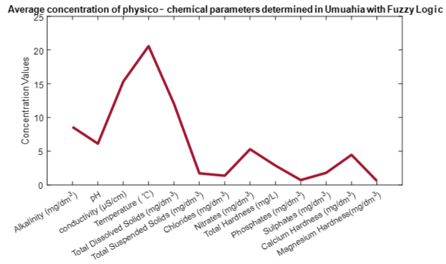


Figure 31 Fuzzy logic for Umuahia

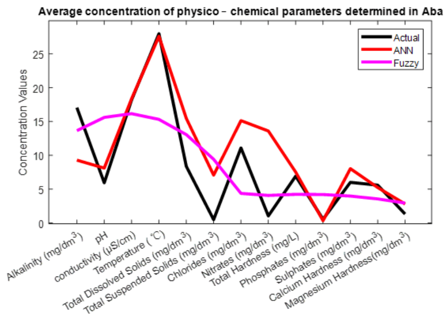


Figure 32 Comparative Analysis For Aba

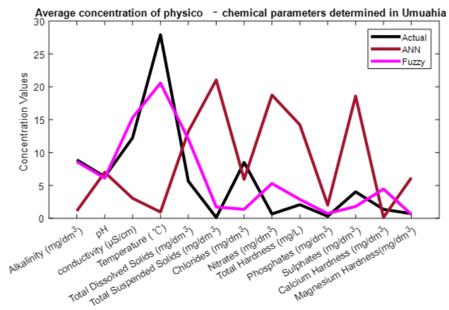


Figure 33 Comparative Analysis for Umuahia

4 Conclusion and Recommendations

From the research, it was discovered that the two study areas are characterized with some certain amount of atmospheric particulates pollution, with Aba having greater concentration. Analysis of rainwater from the sampled stations revealed higher atmospheric aerosols in rainwater sample from Aba than the one from Umuahia. The work has revealed that anthropogenic or human activities, in particular automobile emission, fossil fuel combustion, industrial effluents, biomass or bush burning, agrochemicals and wind-blown dust during the harmattan (dry) season which is rather natural as the major sources of aerosols in the atmosphere. Although ions detected in this samples are within the WHO permissible limit.

The research study also discovered that the early rainfalls are the major routes of removing these aerosols from the atmosphere. That is why the concentrations of the parameters decrease with increase in the frequency of rainfall. The pH which later increased with the frequency of rain especially in Umuahia fell within the WHO permissible limit of 6.5-8.5 for potable water.

On comparison of the health conditions of people living in these two towns, it was discovered that there are more hospital admissions and more hospital check-ups in hospitals in Aba than Umuahia. This may actually be attributed to more concentration of atmospheric pollutants in Aba than in Umuahia.

On recommendation, an emission standard for Nigerian towns and cities either through automobile exhausts or from industries should be introduced in order to check-mate the rate at which smokes and fumes are introduced into the atmosphere. Traffic congestions should be decongested either by constructing more roads whereby the commercial and private cars will have different routes of operations or having a particular range of time for the operation of each of them. Freer flowing urban traffic will result in slightly lower particulate emission.

There should be regular environmental education provided on the need to do the following; keep cars and other engines properly tuned and avoid using engines that smokes, avoid extended periods of engine idling, combine errands to reduce the number of trips taken by car, reduce or eliminate fire places and wood stove, avoid burning of leaves, trash and other materials, instead mulch or compost leaves and yard waste.

The incineration of refuse in market areas should be stopped. The Local Government Authority should engage in regular collection and processing of waste at approved government depots on the outskirts of the city, far away from residential areas. This could be done through state or local government monthly environmental sanitation collection.

For proper control, there should be moral persuasion through publicity and social pressure coming from the government to industries that generate pollutants. Industries emitting significant ambient particulate pollution should set up chambers or collectors to control emission of coarse particulates from power plants and industrial sites. This will provide a mechanism that causes particles in gas to settle out in a location where they may be collected for disposal in landfills. In order to control atmospheric particulates, effective urban planning is very necessary.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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