Resour Environ Inf Eng, 2025, 7(1): 411-422
DOI: 10.25082/REIE.2025.01.006

RESEARCH ARTICLE

Seasonal Variations of Air Quality Measurements of Aba Metropolis and Suburbs Using MATLAB and ANN

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Received: July 20, 2025;
Accepted: October 26, 2025;
Published: November 3, 2025.

Citation: Adiele BM, Egereonu UU, Alisa CO, et al. Seasonal Variations of Air Quality Measurements of Aba Metropolis and Suburbs Using MATLAB and ANN. *Resour Environ Inf Eng*, 2025, **7**(1): 411-422. https://doi.org/10.25082/REIE.2025.01.006

Abstract: Air pollution is a major life-threatening problem in industrialized and commercially vibrant cities like Aba metropolis and its suburbs in Abia State Nigeria. The study of selected air pollutants in these areas were performed using Matrix Laboratory (MATLAB) and Artificial Neural Networks (ANN) pollution models. Primary data was collected by conducting sampling analysis on air samples during dry and rainy seasons from 2024 and 2025. MATLAB and ANN pollution models were generated by integrating measurements and spatial databases using polynomial expressions. The MATLAB 7^{th} degree linear regression polynomial described the relationship between dependent and independent variables for the pollutants. The correlation methods verified that most MATLAB models could accurately predict or forecast concentration levels. Also the Artificial Neural Network demonstrated tracking of the actual plots on MATLAB. The analysis of variance (ANOVA) was also deployed which showed $p < 0.05$ for carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and total particulate matter (TPM), indicating that, there was a significant impact by the seasons on the concentrations of all gaseous pollutants under study(*i.e.* seasonal variations of concentration was highly affected by the two seasons). ANN was able to track all gaseous pollutants represented by MATLAB successfully above 50%.

Keywords: air quality, pollutants, MATLAB, ANN, ANOVA

1 Introduction

The rapid increase in population of Aba Metropolis is expected to translate to increased vehicular traffic and air pollution. This study is carried out to determine the possibility and understanding that the population of Aba Metropolis is rapidly increasing without any visible corresponding air pollution control measure in place. It will also help to generate data in support or otherwise of the existence of air pollution in the city as a result of rapid urbanization and attendant increase in vehicular traffic. The data will ultimately assist the concerned authorities to take informed decisions on possible air pollution control measures. This study will carry out a comparative analysis of the chemical composition of the pollutants in six selected locations classified as Urban (metropolis) and Rural (suburbs) over a period of time.

According to a publication by Iroegbulem et al. [1], Vehicular emissions and industrial activities are considered the most important factors in the ongoing processes of atmospheric alterations, most of which are caused by the emission of nitrogen and sulphur compounds in the atmosphere due to human activities and the increasing number of worldwide industrialization has led to the problem of air pollution. Meteorological conditions affect the dispersion of air pollutants [2]. Chemometrics is the multivariate mathematical and statistical technique encompassing the simultaneous observation and analysis of multiple chemical data. It is the chemical discipline that uses mathematical and statistical methods and other methods based on formal logic to provide maximum relevant information by analyzing chemical data. It gives extensive information from the measured parameters and similarities between sampling locations, sources of pollution, seasonal behavior and time trends. Applying this method to environmental data allows us to identify and describe the interrelationships between the factors

mentioned earlier and our environment. It affords us a greater understanding of the potential impact these factors have on the environment [3–5].

According to Iroegbulem et al. [1], the problem of air pollution is a serious threat to environmental health in many cities of the world. Air pollution is the most pressing environmental risk facing the globe today. It is harmful to humans, plants and the environment at large. Cardiovascular diseases, respiratory diseases, lung cancer, and even death derive from challenges caused by air pollution [6].

According to statistics, about seven million people die annually of air pollution related diseases and air quality problems [7]. Atmospheric pollution is one of the major environmental challenges facing both the developed and developing countries in the world today. This is associated with sudden weather changes which resulted in loss of farm products, damage to properties and sometimes fatalities of unimaginable dimensions. According to Olowoporoku et al. [8] air pollution is responsible for environmental changes like acid rain, precipitation (smog), ozone layer damage or depletion, global warming as well as play major role in climate change. Land use and industrial activities are considered one of the most important factors when atmospheric alteration discuss is on the table [9]. This is caused by the emission of Nitrogen, Sulphur and Carbon compounds in the atmosphere as a result of numerous human activities. The constant increase in worldwide industrialization has led to this problem of air pollution; therefore, more attention is given to acidic deposition due to its direct impact on the Ecosystem and indirect effects on human health. Air pollution has been a serious threat to environmental health in many cities of the world [10], high concentration levels of pollutants have been shown to have adverse impact on respiratory, cardiovascular and neurological systems in humans.

In Oguejiofor et al. [11], it was stated that that human's first experience of harm from environmental pollution came as a result of building fires in poorly ventilated caves. Historical records regard air, water and earth as the very essence of material creation. The Pythagorean school regards the whole world to be made up of four elementary principles: air, water, earth and fire but modern science has proven that these 'elements' are made up of mixtures which could be complex and differ from place to place. Man has always influenced his environment and has been influenced by it. Due to the increase in the number of people and cars occupying a limited space, more attention is paid to environmental pollution of air and water bodies. Acid rain therefore has been a serious atmospheric environmental problem especially in cosmopolitan and metropolitan cities in Nigeria like Lagos, Port Harcourt, Onitsha, Aba etc. for many years. As early as early 1970s, Acid rain has been recognized as a potential environmental problem in South Eastern Nigeria [1]. Aba is not the State Capital of Abia State, but the hotbed of Commerce and Trade as well as other Government institutions of the State. These specializations, have led to improved daily commercial and industrial activities with attendant alterations in the quality of atmospheric air in time).

Pollution according to Spengler and Sexton [12], is the introduction of contaminants into the natural environment that causes adverse change. Pollution can take the form of Chemical substances or energy, such as: noise, heat or light. Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants. Pollution is often classified as point sources or nonpoint source pollution. The Blacksmith institute issues an annual list of the world's worst polluted places. Air pollution has always accompanied civilization and globalization.

2 Materials and Methods

2.1 Study Area

The focus is on five major locations in Aba metropolis and suburbs, namely: Aba Central Park, Ogbor Hill, Osisioma, Faulks Road, and Ngwa Road. (Figure 1)

Aba is the commercial nerve center of Abia State. It is also a home of industrial establishments both defunct and functional like Aba Textile Mills, Unilever Nigeria Plc, Guinness Nigeria Plc, Nigerian Breweries, Tonimas Industries, Seven Up Nigeria Plc, PZ Industries etc. Notably also, is a few educational institutions like Rhema University, Abia State Polytechnic, etc. These have led to changes in the life style, vehicular ownerships and urbanization with its attendant air pollution generated as a result of increased volume of traffic. According to world population review, the population of Aba in Abia State as at year 2000 was **630,237,** but currently it is at **1,230,000** which has doubled within a space of twenty-four years. This rapid increase in population should undoubtedly translate to increased vehicular traffic and air pollution.

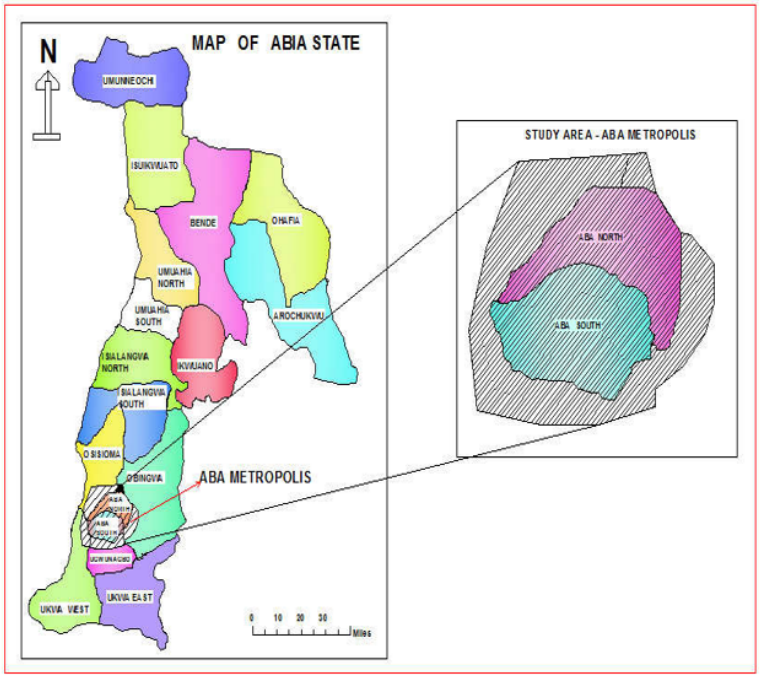


Figure 1 Study Area

2.2 Materials

(1) Single or Multiple Gas Monitors (Aeroqual Series 200/300/500, Temperature: -5^{o}C - 45^{o}C, Humidity: 0 – 95%, non-condensing), Environmental Outdoor Monitor of CO, NO_2, SO_2;
(2) Particulate Gas Monitor;
(3) Tape (For Measurement of Distance);
(4) Humidity Temperature Meter;
(5) MATLAB and ANN Software for comparative analysis.

2.3 Methods

The focus is on five major locations in Aba metropolis and suburbs, namely: Aba Central Park, Ogbor Hill, Osisioma, Faulks Road, and Ngwa Road.

Reading of these gaseous pollutants CO, NO_2, SO_2 and Particulate Matter (TPM) will be taken three times during wet and the dry seasons using their respective Gas monitors. Thereafter, results obtained will be analyzed using MATLAB and ANN (Artificial Neural Network). Also, the Mean and Standard Deviation will be derived. Other statistical methods of analysis like ANOVA may also be applied.

2.3.1 MATLAB

An abbreviation for "MATrix LABoratory" is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. MATLAB allows matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages [13]. It is a high-level programming language and interactive environment designed primarily for numerical computing, data analysis, and algorithm development. MATLAB is widely used in the academia, engineering, scientific research, and industry for its powerful compatibilities in matrix manipulation, visualization, and algorithm design. The key features of MATLAB are its High-level language, Matrix and Array Operations, Built-in Functions, Visualization, Toolboxes, Simulink, Cross-Platform Compatibility, Integration. Also, its application is found in Engineering Design and Analysis, Data Analysis and Visualization, Machine Learning and AI, Control System Design, Finance and Economics. In sum, MATLAB is a powerful tool for technical computing and it is preferred in many scientific and engineering fields due to its extensive compatibilities for numerical analysis, data visualization and algorithm development.

2.3.2 ANNs

An abbreviation for "Artificial Neural Networks" are computational models inspired by the way biological neural networks in the human brain operate. They are a key technology in the field of artificial intelligence and machine learning, particularly for tasks such as pattern recognition, classification, regression and more complex functions. Neural Network is a model inspired by the structure and function of biological neural networks in animal brains. It consists of connected units or nodes called artificial neurons, which loosely model the neurons in the brain. These are connected by edges, which model the synapses in the brain. Each artificial neuron receives signals from connected neurons, then processes them and sends a signal to other connected neurons. The 'signal' is a real number, and the output of each neuron is computed by some non-linear function of the sum of its inputs, called the activation function. The strength of the signal at each connection is determined by a weight, which adjusts during the learning process [14].

Artificial neural networks are used for various tasks, including predictive modeling, adaptive control, and solving problems in artificial intelligence, Healthcare, Finance and Autonomous Systems like in self-driving cars for perception and decision making tasks. They can learn from experience and can derive conclusions from a complex and seemingly unrelated set of information [15]. In sum, Artificial Neural Networks are powerful tools in modern artificial intelligence, enabling machines to learn from data in a way that mimics human thought processes. Their flexibility and ability to capture complex patterns make them suitable for a wide range of applications across various fields. With the advancement of deep learning techniques, ANNs continue to evolve, driven by increased computational power and the availability of large datasets

3 Results and Discussion

3.1 Results

The results obtained from the analysis of pollutants concentration of the atmosphere in fifteen locations within Aba metropolis in both dry season (December 2024 to February, 2025) and rainy season (July to October, 2024) using multiple gas-monitor which is a standard instrument for the measurement of gaseous pollutants like CO, SO_2, NO_2, TPM_{10}, which occur in the atmosphere of the focus area due to industrial, vehicular and photochemical emissions, as well as waste generated from the daily lifestyle of the people of the area. The results obtained from the analysis of these gaseous pollutants using multiple gas monitors are shown in Table 1 and 2.

Table 1 Dry Season (December 2024 to February 2025) Mean Data for Gases and PM_{10}

S/N	Sampling Areas	CO(ppm)	NO_2(ppm)	SO_2(ppm)	PM_{10}(mg/m^3)
Osisioma(5^o9'6"N, 7^o18'53"E)					
1	Umuchichi	33.20	0.034	0.21	9.3
2	Okezie Ikpeazu Flyover	35.10	0.031	0.23	7.2
3	Eze-Iheme	35.30	0.036	0.21	8.5
AbaCentral Park(5^o8'56"N,7^o25'19"E)					
4	Milverton Road	40.40	0.098	0.30	8.5
5	York Road	41.20	0.092	0.30	8.4
6	Ama Hausa	40.30	0.085	0.31	9.3
Ogbor Hills(5^o6'55"N,7^o22'52"E)					
7	7UP Road	29.20	0.027	0.10	7.8
8	Abbatoir	33.40	0.028	0.10	9.8
9	IkotEkpene	30.40	0.025	0.09	8.0
Faulks Road(5^o8'55"N,7^o22'18"E)					
10	Osusu	29.20	0.010	0.01	6.5
11	Nwulu Avenue	30.60	0.010	0.09	7.8
12	Ekenna Road	29.40	0.010	0.10	5.8
Ngwa Road(5^o5'58"N,7^o23'20"E)					
13	Niger Street	23.20	0.008	0.06	7.6
14	Njoku Street	26.40	0.008	0.10	7.4
15	Nnewi Street	24.20	0.007	0.09	7.9

3.2 Plots of Results on MATLAB, ANN and ANOVA

For Rainy Season with MATLAB (Figure 2-8)

For Dry Season with MATLAB (Figure 9-16)

Table 2 Rainy Season (July to October 2025) Mean Data for Gases and PM_{10}

S/N	Sampling Areas	CO(ppm)	NO_2(ppm)	SO_2(ppm)	PM_{10}(mg/m^3)
Osisioma(5^{o}9'6"N, 7^{o}18'53"E)					
1	Umuchichi	24.30	0.030	0.10	6.2
2	Okezie Ikpeazu Flyover	23.40	0.030	0.18	4.1
3	Eze-Iheme	25.20	0.033	0.10	5.3
Aba Central Park (5^{o}8'56"N,7^{o}25'19"E)					
4	Milverton Road	25.60	0.095	0.15	5.5
5	York Road	23.40	0.090	0.18	5.4
6	Ama Hausa	24.66	0.082	0.20	6.1
Ogbor Hills(5^{o}6'55"N,7^{o}22'52"E)					
7	7UP Road	14.90	0.029	0.08	5.6
8	Abbatoir	16.20	0.030	0.07	7.2
9	Ikot Ekpene	15.30	0.026	0.09	6.4
Faulks Road(5^{o}8'55"N,7^{o}22'18"E)					
10	Osusu	19.10	0.009	0.07	5.5
11	Nwulu Avenue	20.10	0.009	0.06	5.2
12	Ekenna Road	19.20	0.010	0.08	5.2
Ngwa Road(5^{o}5'58"N,7^{o}23'20"E)					
13	Niger Street	12.40	0.004	0.06	5.6
14	Njoku Street	14.60	0.005	0.10	5.4
15	Nnewi Street	12.20	0.004	0.10	5.2

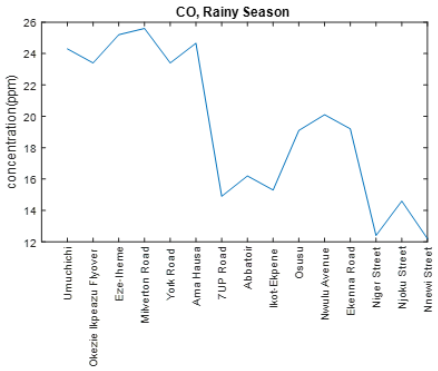


Figure 2 CO in Rainy Season With MATLAB

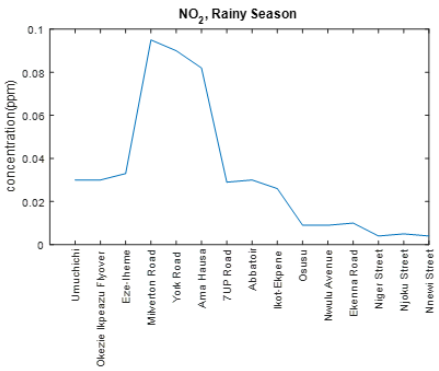


Figure 3 NO_2 in Rainy Season with MATLAB

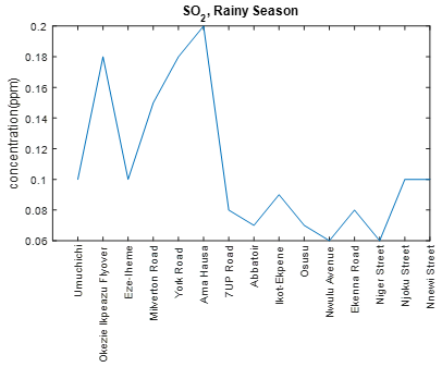


Figure 4 SO_2 in Rainy Season with MATLAB

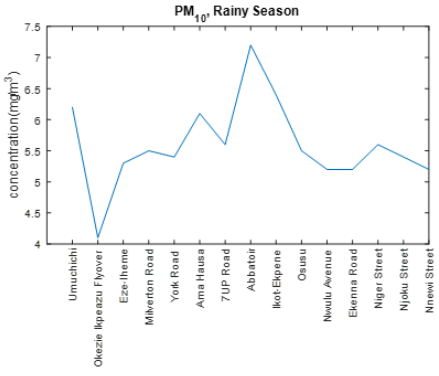


Figure 5 PM_{10} in Rainy Season with MATLAB

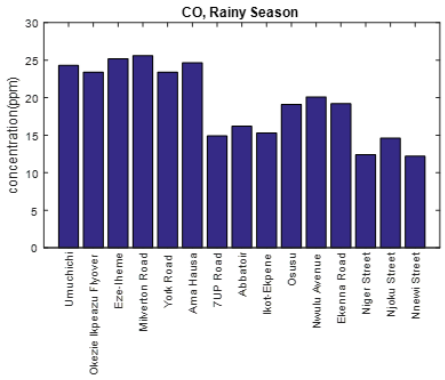


Figure 6 CO in Rainy Season

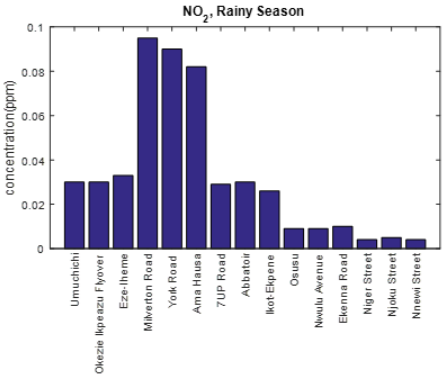


Figure 7 NO_2 in Rainy Season

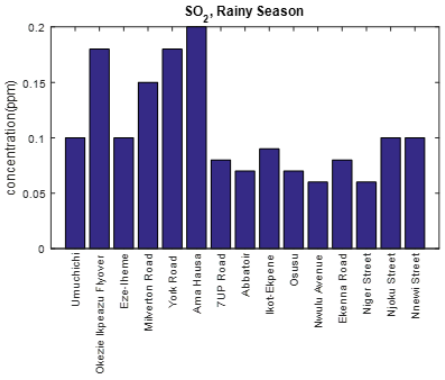


Figure 8 SO_2 in Rainy Season

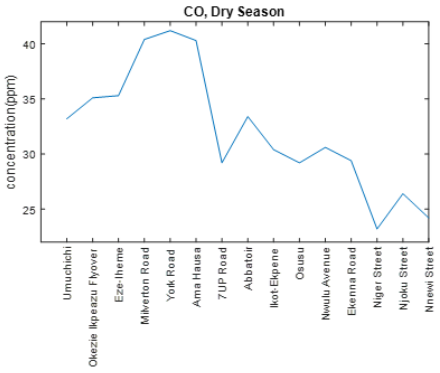


Figure 9 CO in Dry Season With MATLAB

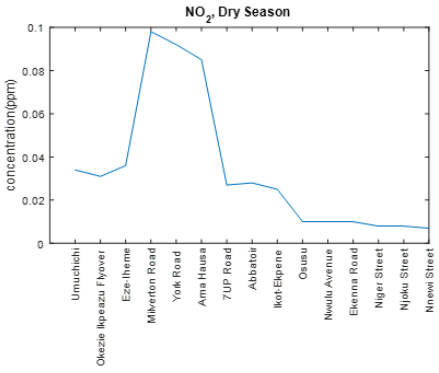


Figure 10 NO_2 in Dry Season with MATLAB

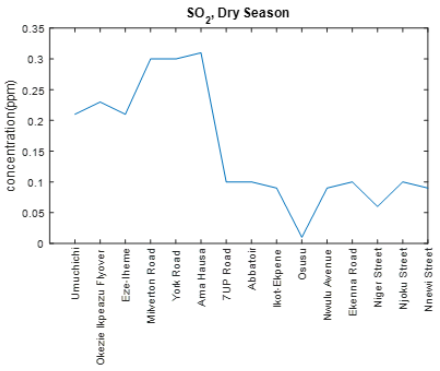


Figure 11 SO_2 in Dry Season with MATLAB

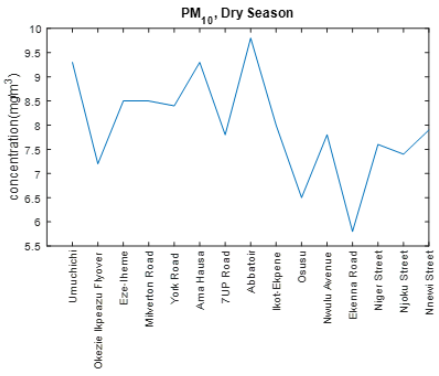


Figure 12 PM_{10} in Dry Season with MATLAB

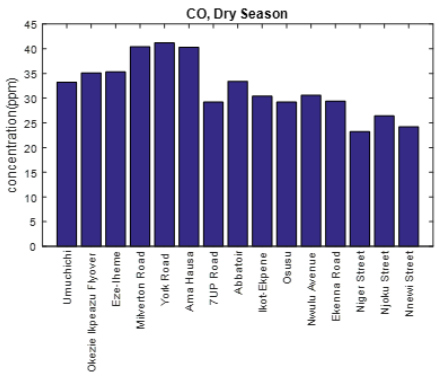


Figure 13 CO in Dry Season

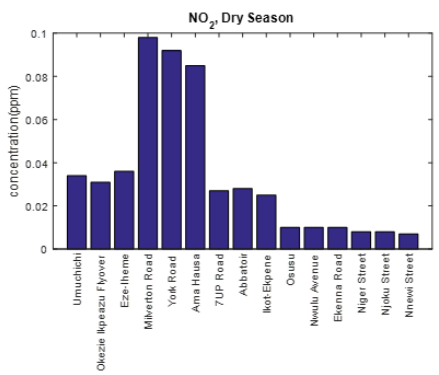


Figure 14 NO_2 in Dry Season

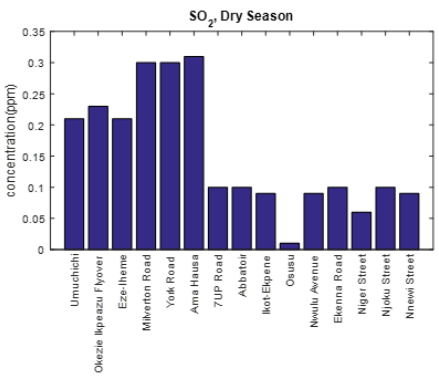


Figure 15 SO_2 in Dry Season

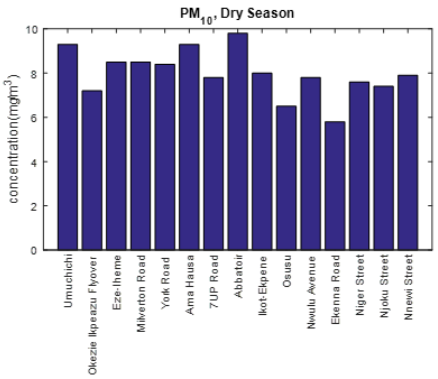


Figure 16 PM_{10} in Dry Season

Comparing Rainy and Dry Season (Figure 17-24)

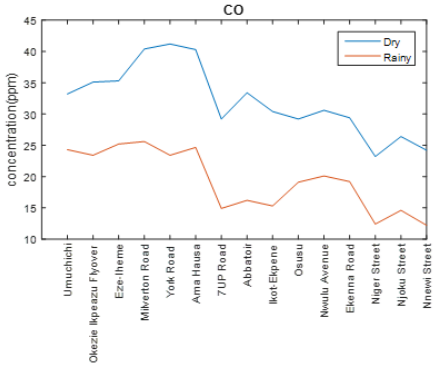


Figure 17 CO

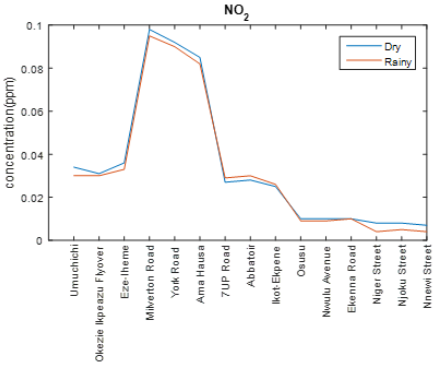


Figure 18 NO_2

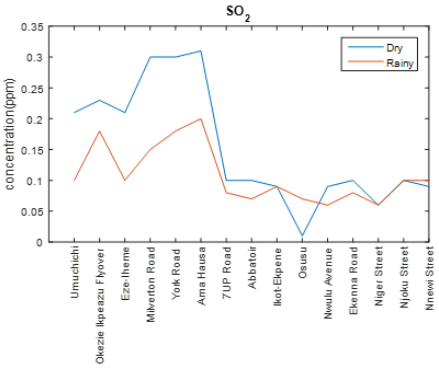


Figure 19 SO_2

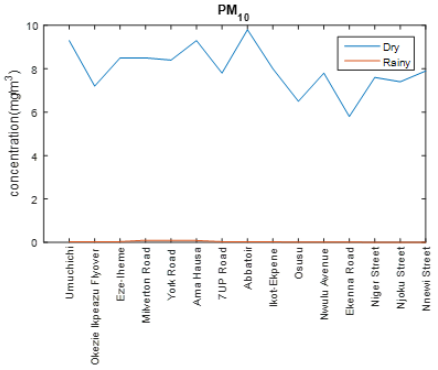


Figure 20 PM_{10}

Anova Analysis (Figure 25-28)

Comparing Actual and Ann Model Outcome(Figure 29-36)

3.3 Discussion

The mean values of gaseous pollutants from Dry and Rainy seasons were illustrated using MATLAB and ANN Models. Significant variations were noticed in both seasons; further inspection of the graphs, showed that lower concentration for all gaseous pollutants were observed in rainy seasons due to the frequency of the rainfall within the period. Also, concentration of the pollutants was lowest in the suburbs when compared to the metropolis due to less vehicular and commercial activities. In this work, artificial intelligence like Artificial Neural Network (ANN) was used to replicate what was done in the field during collation of data. The use of MATLAB is not to predict but to analyze what is done in the field while ANN is used to predict

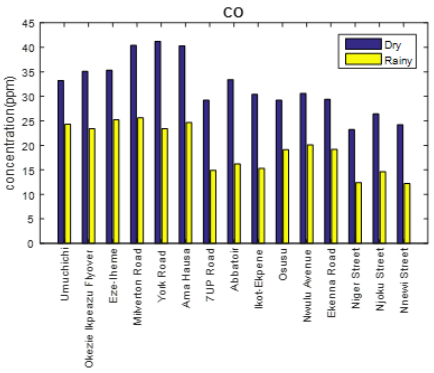


Figure 21 CO

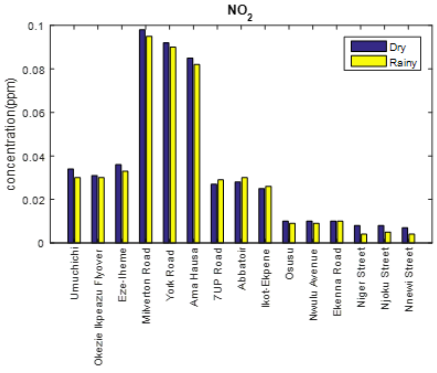


Figure 22 NO_2

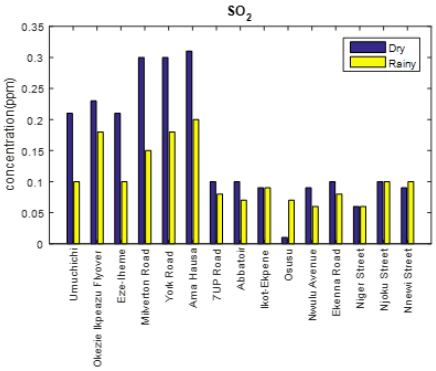


Figure 23 SO_2

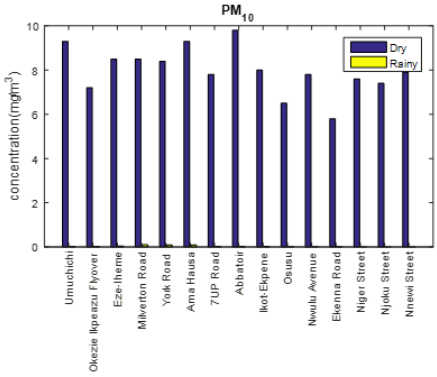
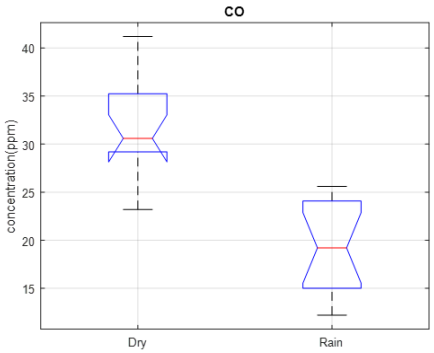


Figure 24 PM_{10}



ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	1215.27	1	1215.27	44.08	3.33785e-07
Error	771.98	28	27.57		
Total	1987.25	29			

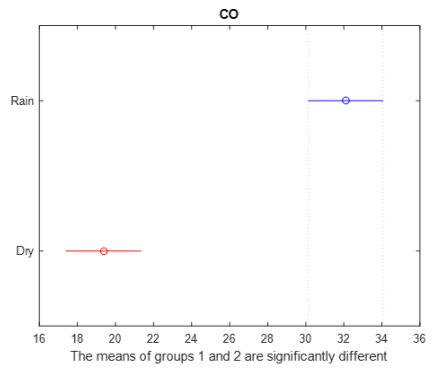
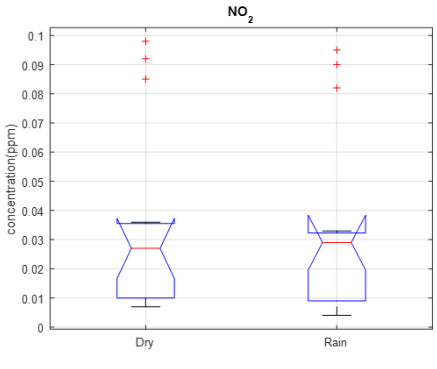


Figure 25 For CO



ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	0.00002	1	0.00002	0.02	0.8949
Error	0.02778	28	0.00099		
Total	0.02779	29			

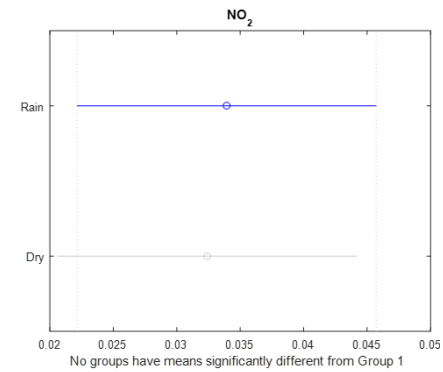


Figure 26 For NO_2

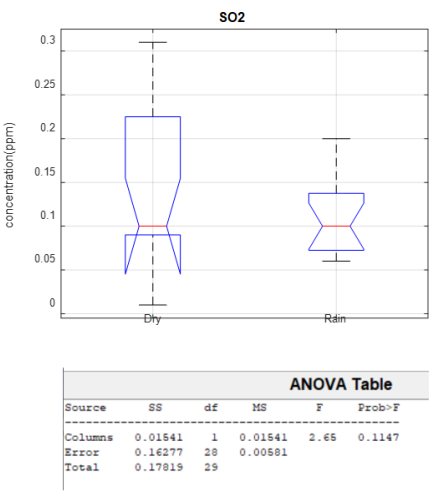


Figure 27 For SO_2

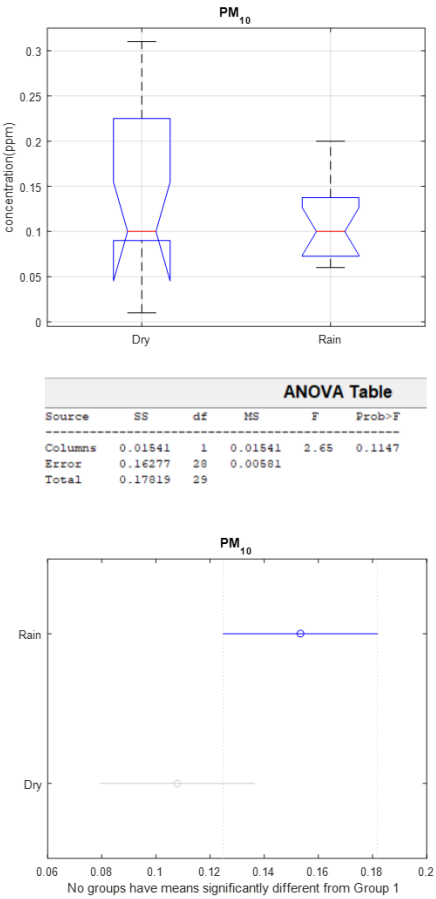


Figure 28 For PM_{10}

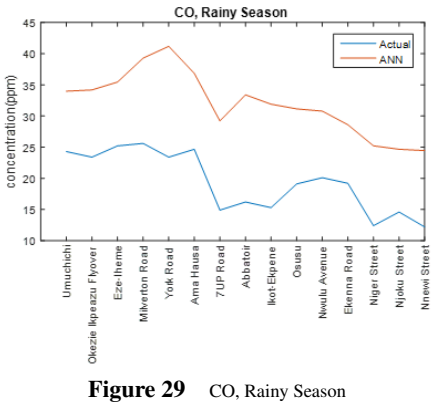


Figure 29 CO, Rainy Season

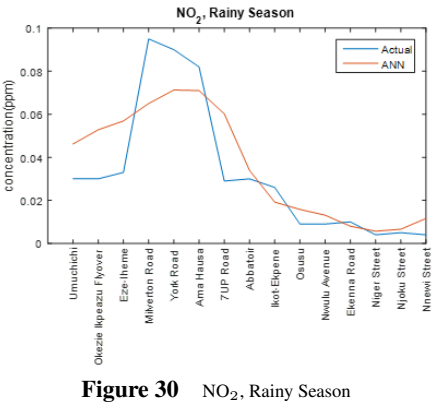


Figure 30 NO_2, Rainy Season

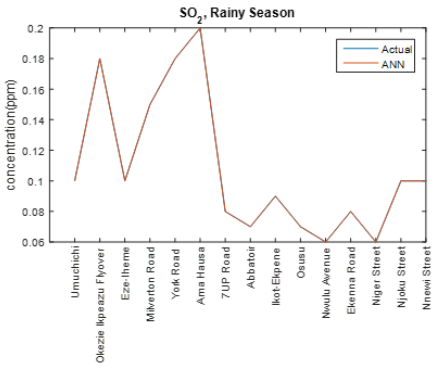


Figure 31 SO_2, Rainy Season

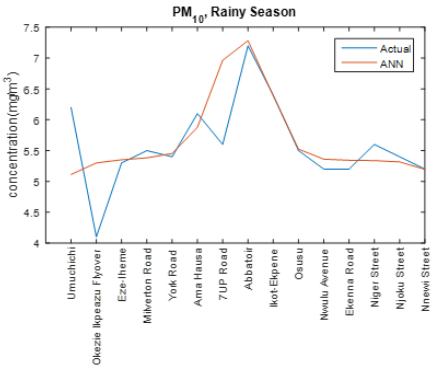


Figure 32 PM_{10}, Rainy Season

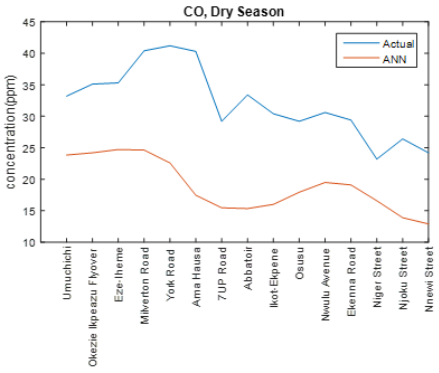


Figure 33 CO, Dry Season

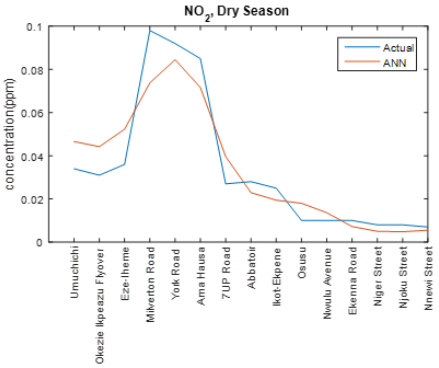


Figure 34 NO_2, Dry Season

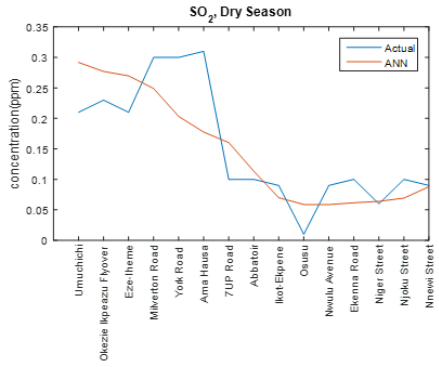


Figure 35 SO_2, Dry Season

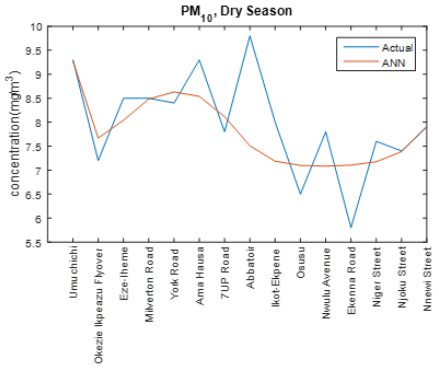


Figure 36 PM_{10}, Dry Season

what is done in the field without necessarily going to the field. According to the outcomes, all the pollutants crossed the 50% rate, which implies that ANN was able to track the MATLAB representation satisfactorily. In an event, ANN was not able to produce 50% satisfactory results, that is, was not successful. It can be concluded that; other Artificial Intelligence Models can be tried.

3.3.1 Nitrogen (iv) Oxide (NO_2)

For the period under study, the result of the rainy season was lower than that of the dry season. The mean concentration values ranged from (0.004-0.098) ppm. The highest concentration value was recorded at Milverton due high level of fossil fuel burning, microbial actions in nitrogenous wastes littering the environment [16]. Nitrogen dioxide according to Okimiji et al. [17] is denser than air. It also arises from the oxidation of nitric oxide by oxygen in the air and wind speed.

$$NO + O_2 \rightarrow NO_2$$

3.3.2 Carbon (ii) Oxide (CO)

The concentrations of Carbon monoxides during the dry seasons in most locations under study were found to be higher than corresponding values in rainy seasons. These values were as a result of several factors like; Increased combustion activities, meteorological factors, biomass burning, transport from other regions, increased traffic and energy use. In general, higher concentration of carbon monoxide in dry season relative to rainy season can be attributed to a combination of increased emissions from human activities, meteorological conditions and the chemical dynamics of the atmosphere. The highest level of carbon monoxide was recorded in the dry season at Aba Central Park.

3.3.3 Sulphur (iv) Oxide (SO_2)

The mean levels of SO_2 were within the range of (0.06-0.031)ppm in the suburbs and the metropolis and it was highest at Ama Hausa close to Aba Central Park. The sources of SO_2 are: forest fires, volcanic eruptions, vehicular emissions and biological decays. The value at Ama Hausa is traceable to the burning and use of charcoal in making evening roast meat popularly known as Suya by the Hausa community in the area.

3.3.4 Total Particulate Matter (PM_{10})

The mean highest value of Total Particulate Matter was recorded in dry season at abattoir with the value 9.8mg/m^3 and the lowest mean value was recorded at Okezuo Abia flyover with the value of 4.1mg/m^3 as illustrated graphically. When compared with Air Quality Index standard, the values are within safe zone. This is basically attributable to efforts of governments; both past and present, to improved waste management programs and environmental control efforts of government.

4 Conclusion

This work has revealed that the air quality in Aba Metropolis and Suburbs are significantly different. The levels of these pollutants were seen to be higher in Aba Metropolis which are usually characterized by high volume of vehicular traffic, industrial and commercial activities; indicating that, the sources of these pollutants are induced by these sources. Also, the levels of these gaseous pollutants were higher in Dry Season than in Rainy Season which may be related to the frequency of rainfalls. These pollutants may lead to health problems if not checked. We call on the Environmental Management Agency of Abia State to nip this in the bud. The study has also shown that; human activities like automobile emission, fossil fuel combustion, industrial effluents, bush burning, wind-blown dust which are natural and agrochemicals sources of aerosol in the atmosphere. The results showed that the Artificial Neural Network (ANN) was able to track the outcomes of Matrix Laboratory (MATLAB) sufficiently since all pollutants crossed the 50% satisfactory level on Artificial Neural Network.

Authors Contribution

B. M Adiele: Conceptualization, Prepared Manuscript, Methodology, Writing, Review and Editing.

U.U. Egereonu: Supervision, Conceptualization, Prepared Manuscript, Methodology, Writing, Review, Editing, Generated the ANN and MATLAB graphs.

C. O Alisa: Data Analysis, Prepared Manuscript, Supervision, Writing Review, Editing, Generated the ANN and MATLAB graphs.

U.C. Onyeije: Supervision, Data Curation, Performed Basic Computations, Generated the ANN and MATLAB graphs.

S.K. Egereonu: Performed Basic Computation, Generated the ANN, MATLAB graphs, Writing, Review and Editing.

U. L. Onu: Performed Basic Computation, Generated the ANN, MATLAB graphs, Writing, Review and Editing.

C. Onwuka: Validation, Writing, Review, Editing and Data Curation.

C. Enyia: Writing, Review, Editing and Data Curation.

A. O. Emeagubor: Writing, Review, Editing and Data Curation.

O. C. Nwokonkwo: Writing, Review, Editing, Validation, Generated the ANN and MATLAB graphs

Acknowledgements

We acknowledge the Technologists of the Department of Chemistry Federal University of Technology, Owerri, Imo State, and Rhema University Aba, Abia State, Nigeria for their technical support.

Conflict of Interest

The authors declare that they have no conflict of interest.

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