***ASJ**: International Journal of Health, Safety and Environment (IJHSE)*
Vol. 06 (08) 30 September, 2020, Pp. 649 – 656
www.academiascholarlyjournal.org/ijhse/index_ijhse.htm
ISSN: 2360-9311©Academia Scholarly Journals
Indexed In: Directory of Research Journals Indexing - http://www.drji.org
Also Available@: Archive.org/Udo_et_al.
Open access

Full Length Research

Sulphur Dioxide Characterization in Ambient Air for Calabar, Nigeria

[1(a)]Sunday O. Udo, [2(a)]Mfon D. Umoh*, [3]Igwe O. Ewona, [2(b)]Udoh F. Evans and [1(b)]Chinelo T. Okpalaonwuka

[1(a, b)] Department of Physics, University of Calabar, Calabar, Nigeria.
Authors Contact Details: E-mail Addresses: **a** = [soudo95@yahoo.com]; **b** = [chineloonwuka2007@yahoo.com]

[2(a, b)]* Directorate of strategy, research and statistics, Maritime Academy of Nigeria, Oron, Akwa Ibom State, Nigeria.
Authors Contact Details: E-mail Addresses: = **a**: [mfonslago@yahoo.com; mfonslago20@gmail.com; Mobile Phone no ☎: +234(0) 8023719490]; **b**: udohevans@gmail.com

[3]Department of Physics, Cross River State University of Technology, Calabar, Nigeria. P.M.B. 1123 Calabar, Cross River State, Nigeria.
Authors' Contact Detail: E-mail Address: steveewona2007@yahoo.com

*Corresponding Author

Accepted September 27, 2020

The present investigation was carried out for the Characterization of Sulphur dioxide (SO_2) in Calabar, Nigeria. The measured concentration of SO_2 as recorded in this research is above the World Health Organization (WHO) standard. For air quality index, Marina Resort station was found to be "moderately polluted" with AQI of 157.20. The remaining five (5) stations were classified as "poor" with the AQI ranging from 214 to 229. Basin Authority showed the highest positive correlation of SO_2 and relative humidity, with R = 0.753. This shows that at Basin Authority station, relative humidity had the greatest effect on SO_2. The highest correlation between SO_2 and wind speed was obtained at basin authority with R = 0.609. Wind speed also had effect on SO_2 in that station. Marina resort recorded the highest negative correlation of SO_2 and temperature, with R = -0.643. Basin Authority recorded the highest positive correlation with R = 0.631. Hence the best model for the prediction of SO_2 for Calabar is 5 – 10 – 1. This translates to, five (5) input variables that include; SO_2, wind speed, temperature, relative humidity and total suspended particulate matter (TSP), ten (10) hidden neurons in the neural network and one (1) target variable which is SO_2.

Keywords: Sulphur dioxide, relative humidity, correlation, neural network.

INTRODUCTION

The quality of air we breathe is directly linked to the concentration of certain chemicals in ambient or indoor air. These chemicals are called pollutants. Sulfur dioxide (SO_2) is one of the pollutants set aside by the World Health Organization (WHO, 2005) as a criteria pollutant. A criteria pollutant is a pollutant that could cause harm or injury to living things and the environment. Sulfur is assimilated by living organisms and is then released as a product of metabolism. The most important sulfur gases in the atmosphere are SO_2, H_2S, dimethyl sulfide (CH_3SCH_3 or DMS for short), COS, and carbon disulfide (CS_2). The principal natural sources of SO_2 are the oxidation of DMS and H_2S. Volcanoes and biomass burning are also sources of atmospheric SO_2 (Wallace and Hobbs, 2006). Important sources also include power plants smelters, petroleum refineries, and pulp and paper mills (Lutgens and Tarbuck, 2013; Olatunji et al., 2015). Road side vulcanizers also produce SO_2 (Gobo et al., 2012). However, the largest source of SO_2 is fossil fuel combustion. This is because SO_2 constitutes 18% of the quantity of gases and smoke discharged daily into the atmosphere (Asuoha and Osu, 2015). In summary, the anthropogenic SO_2 emissions world-wide amount to 70-80 million tons per year, while the natural emissions have been estimated to be 18-70 million tons per year (Abdul Raheem et al., 2009). United States Environmental Protection Agency (EPA, 2006) states that SO_2 reacts with other compounds in the atmosphere to form fine particles that reduces visibility. Except for marine aerosols, the masses of which are dominated by sodium chloride, sulfate is one of the prime contributors to the mass of atmospheric aerosols. These aerosols which are also called particulate matter, are categorized as follows; $PM_{2.5}$ are aerosols that have diameter less than or equal to 2.5 µm. PM_{10} are aerosols that have diameter 10 µm or less and Total Suspended Particulate (TSP) which has diameter 30 µm or less. High concentrations of SO_2 can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated SO_2 levels while at moderate exertion may result in reduced lung function that may be accompanied by such symptoms as wheezing, chest tightness, or shortness of breath. Other effects that have been associated with longer-term exposures to high concentrations of SO_2, in conjunction with high levels of particulate matter, include respiratory illness and aggravation of existing cardiovascular disease (Lutgens and Tarbuck, 2013). Deposition of aerosols can stain and damage stone and other materials such as statues and monuments. This is because SO_2 is one of the precursors of acid rain. It causes the formation microscopic acid aerosols. SO_2 also contributes to climate change (LJubisa et al., 2011). The emissions of Sulphur dioxide (SO_2) into the air and the subsequent impact on the environment and health from the consumption of refined petroleum products in Nigeria could be mitigated, if there is proper and consistence investigation (Olatunji et al., 2015). Due to this serious need to mitigate the high mortality and morbidity rate associated with SO_2 together with the aerosols they produce, there is serious need to characterize SO_2 in ambient air for Calabar Nigeria.

MATERIALS AND METHOD

The equipment used for the measurements is the Gas Analyser – Aeroqual series 500 – ENV which comes with the Aeroqual SO_2 0 – 10 ppm Model 1905152 – 006. The equipment was purchased as part of TETFUND Assisted Air Quality Project. Another set of data for this research was obtained by an AQM65 Equipment, Micro-climate – Extech 4-in 1 Environmental Meter Model 45170 for measuring Wind speed, Air Temperature, and Relative Humidity. The data for this research were obtained in two parts. The first was obtained from the mobile Aeroqual hand-held devices while the second part was obtained from the stationary AQM65 device stationed at the University of Calabar Main Station. The data from the mobile devices were obtained at specific time intervals and at specific days. The days data were taken are; 23/05/2015, 06/06/2016, 20/06/2016, 04/07/2016, 18/07/2016, 1/08/2016, 15/08/2016 and 29/08/2016. The extended project covered fifty (50) stations within the stipulated time-frame hence the monitoring of the pollutants in the selected stations fell on the selected dates. On the other hand, the AQM65 stationary device was programmed by the company to record data at a minute by minute interval. The machine could also be re-programmed to record data at an hourly interval. For the purpose of this research, the data was obtained in a minute by minute interval. The data from both devices were

Table1. Mean concentration of Sulphur dioxide for the study location.

Location	Mean	Median	1st Quartile	3rd Quartile
Army Junction	0.3912	0.4200	0.3300	0.4800
Basin Authority	0.3513	0.3100	0.2125	0.4150
Goodluck Bypass	0.3463	0.3450	0.2175	0.4250
IkaIkaukwa Market	0.3450	0.3250	0.2125	0.4000
Marina Resort	0.2350	0.2550	0.1425	0.2925
Tinapa Resort	0.3050	0.3050	0.2175	0.3675

presented as monthly means. For the purpose of these research, six locations within Calabar metropolis were selected for the mobile data taking. These stations include; Army Junction, Basin Authority, Goodluck Johnathan Bypass, Ikaika Ukwa Market, Marina and Tinapa Resorts. Linear Regression Method was used to establish the correlation between meteorological parameters and Sulphur dioxide (SO_2). Artificial neural network algorithm was used for SO_2 prediction. Five variables were used as input variables in the neural network toolbox. These variables include; SO_2, TSP, wind speed, relative humidity and temperature. SO_2 was used as the target variable. 75% of the data was used for training, 15% was used for validation and 15% was used for testing. During the training of the data, the number of neurons was varied from 10 to 100. All the work related to statistical analysis and visualization was carried out with R Data Analysis Software.

RESULTS AND DISCUSSION

Characterization of SO_2 in ambient air has been carried out in Calabar, Nigeria. Table 1 shows the mean concentration of SO_2 for the study locations. It can be seen from the table that the mean concentration of SO_2 at Army Junction was 0.39 ppm, at Basin Authority it was 0.35 ppm, at Goodluck Johnathan Bypass it was 0.35 ppm, at IkaIka Ukwa Market it was 0.35 ppm, at Marina Resort it was 0.24 ppm and at Tinapa Resort it was 0.31 ppm. the measured concentration of SO_2 as recorded in this research is above the WHO (2005) standard of 0.009 ppm 24 hrs standard as well as 0.213 ppm 10 minutes standard. These values are high compared to that of Kano which ranged from 0.001 to 0.002 ppm (Ayodele and Abubakah, 2010). In Ilorin, Nigeria, SO_2 concentration was measured as 1.29 ±0.17 ppb in the wet season and 7.17 ±0.87 ppb in the dry season (Abdul Raheem et al., 2009). In APO District in Federal Capital Territory, Abuja, Nigeria, it ranged from 0.60 to 0.66 ppm (Ishaya et al., 2017). In Orlu, Imo State, Nigeria, SO_2 was found to be within the range of 0.17 – 0.75 ppm (Chizoruo et al., 2017). In Ibadan, Oyo State, it was found to be within the range of 0.009 – 0.02 ppm (Ipeaiyeda and Adegboyega, 2017). In Umuahia, Abia State, SO_2 concentration which was measured from vehicular emissions was 0.44ppm.

Figure 1 shows a graph of the mean concentration of SO_2 as measured in the study locations. The graph shows that 20% of the SO_2 concentration was measured at Army Junction. That makes Army Junction the most polluted in terms of SO_2. Marina Resort had 12% of the concentration making it the least polluted. Figure 2 shows SO_2 concentration as measured from the different study locations. This can be comparable to the measurements at Abuja Campus of the University of Port Harcourt which recorded a concentration of 0.25 ppm in April 2019 and 0.63 ppm in March of 2019 (Ugbebor et al., 2019). The mean concentration of SO_2 is presented in Table 1. Also presented are the median, 1st Quartile and 3rd Quartile values.

AIR QUALITY INDEX

AQI Equation

$$Ip = \frac{IHi - ILo}{BPHi - BPLo}(Cp - BPLo) + Lo \text{ -------- equation (1)}$$

Where: IP = the index for pollutant P
CP = the rounded concentration of pollutant P
BPHi = the breakpoint that is greater than or equal to CP
BPLo = the breakpoint that is less than or equal to CP
IHi = the AQI value corresponding to BPHi

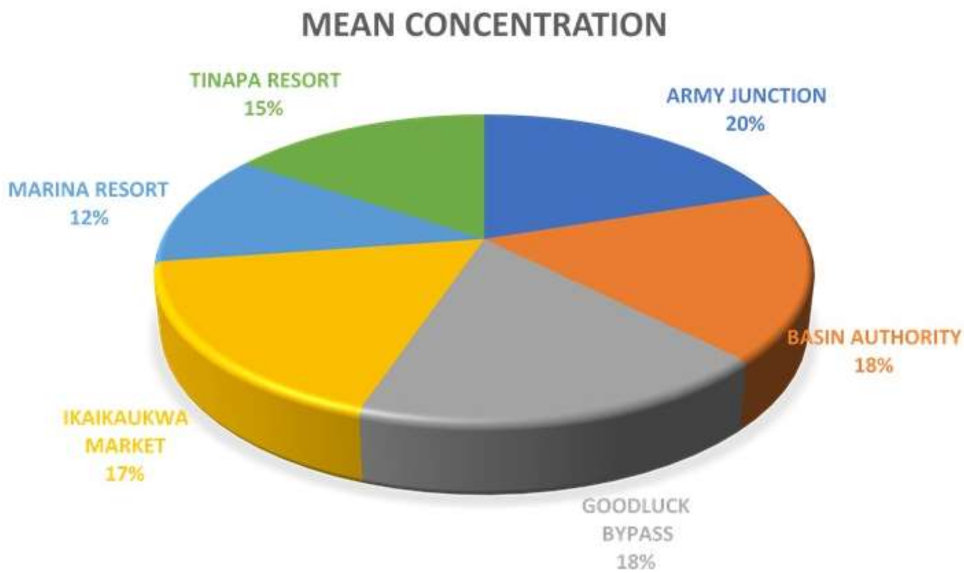

Figure 1. Mean concentration of Sulphur dioxide.

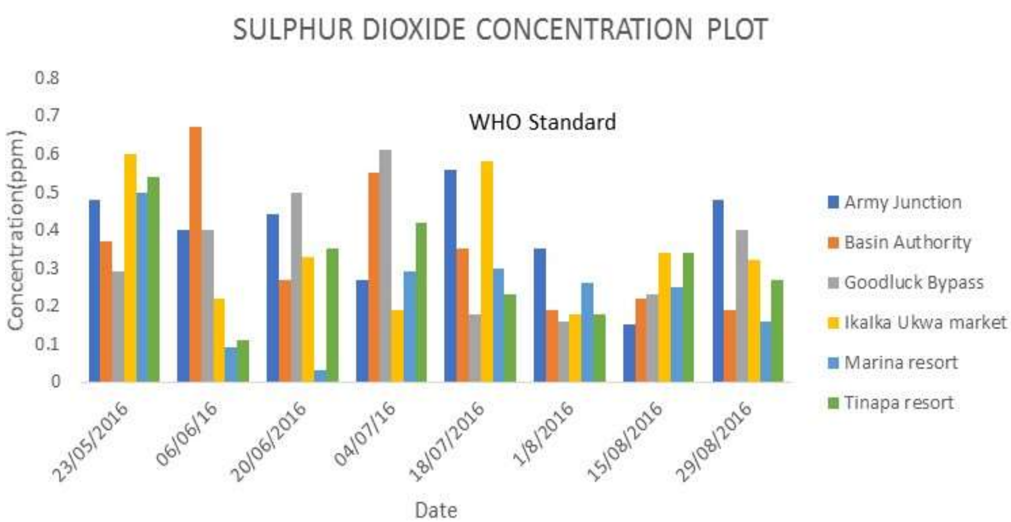

Figure 2. Concentration of SO_2 at different stations.

ILo = the AQI value corresponding to BPLo

Ip is the AQI that is to be calculated based on the pollutant. Cp is the concentration of the pollutant rounded to a reasonable decimal. BPHi is the breakpoint that is greater than or equal to the rounded concentration of the pollutants. BPLo is the breakpoint that is less than or equal to the rounded concentration of the pollutant Cp. IHi is the AQI value that corresponds to BPHi. While ILo is the AQI value that corresponds to BPLo. The measured concentration of the four pollutants was used in the computation of the AQI. The AQI was based on the breakpoints published by the United States EPA (2006).

Air quality index (AQI) is a number issued by the Government or/and the stakeholders in the environmental sector, to inform the public on the state of the air in which they are breathing. It is an

Table 2. break points for the different pollutants (USEPA, 2006).

O_3 (ppm) 8-hour	O_3 (ppm) 1-hour	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)	AQI	Category
0.000–0.064	-	0.0 – 15.4	0 – 54	0.0 – 4.4	0.00 – 0.034	(^{2})	0 -50	Good
0.065 – 0.084	-	15.5 – 40.4	55 – 154	4.5 – 9.4	0.035 – 0.144	(^{2})	51 – 100	Moderate
0.085 – 0.104	0.125 – 0.164	40.5 – 65.4	155 – 254	9.5 - 12.4	0.145 – 0.224	(^{2})	101 – 150	Unhealthy For sensitive groups
0.105 – 0.124	0.165 – 0.204	65.5 – 150.4	255 – 354	12.5 – 15.4	0.225 – 0.304	(^{2})	151 – 200	Unhealthy
0.125 – 0.374	0.205 – 0.404	150.5 – 250.4	355 – 424	15.5 – 30.4	0.305 – 0.604	0.65 – 1.24	201 – 300	Very unhealthy
(^{3})	0.405 – 0.504	250.5 – 350.4	425 – 504	30.5 – 40.4	0.605 – 0.804	1.25 – 1.64	301 – 400	Hazardous
(^{3})	0.505 – 0.604	350.5 – 500.4	505 - 604	40.5 – 50.4	0.805 – 1.004	1.65 – 2.04	401 - 500	Hazardous

NOTE: $N0_2$ has no short-term NAAQS and can generate an AQI only above a value of 200.

Table 3. AQI Categorization Table.

Category	AQI	Description of Ambient Air
I	0-50	Good
II	51-100	Moderate
III	101- 150	Unhealthy for sensitive groups
IV	151-200	Unhealthy
V	201-300	Very unhealthy
VI	301-400	Hazardous
VII	401-500	Hazardous

indication on how safe the air is. For this research, air quality is calculated using equation 1. Table 2 shows the breakpoint of all the criteria pollutants as published by the United States EPA (2006). These break points are used in the estimation of the AQI. The air quality categorization is presented on Table 3. The result shows that only Marina Resort station was found to be "moderately polluted" with AQI of 157.20 and the remaining five (5) stations were classified as "poor" with the AQI ranging from 214 to 229. This result is presented in Table 4. This shows that the quality of air is poor in Calabar considering SO_2.This is comparable with the AQI for SO_2 in APO District in the Federal Capital Territory, Abuja, Nigeria which was categorized as very poor (Ishaya et al., 2017).

CORRELATION OF SO_2 WITH METEOROLOGICAL PARAMETERS

Effect of Meteorology on Sulphur Dioxide

Correlation was made between SO_2 and the meteorological parameters. This is shown in Table 5. The result shows that at basin Authority, the highest positive correlation was with SO_2 and relative

Table 4. AQI table for the study locations.

Location	Air quality index	AQI category
Army Junction	229.54	Poor
Basin Authority	216.33	Poor
Goodluck bypass	214.67	Poor
Ikalkaukwa market	214.24	Poor
Marina Resort	157.20	Moderately Polluted
Tinapa Resort	201	Poor

Table 5. AQI correlation of SO_2 with meteorology.

Location	SO_2 vs WS	SO_2 vs RH	SO_2 vs TEMP
Army Junction	0.198	-0.222	0.221
Basin Authority	0.609	0.753	0.631
Goodluck Bypass	-0.534	-0.323	0.250
Ikalkaukwa Market	-0.165	0.642	0.561
Marina Resort	0.495	0.716	-0.643
Tinapa Resort	0.198	0.639	-0.333

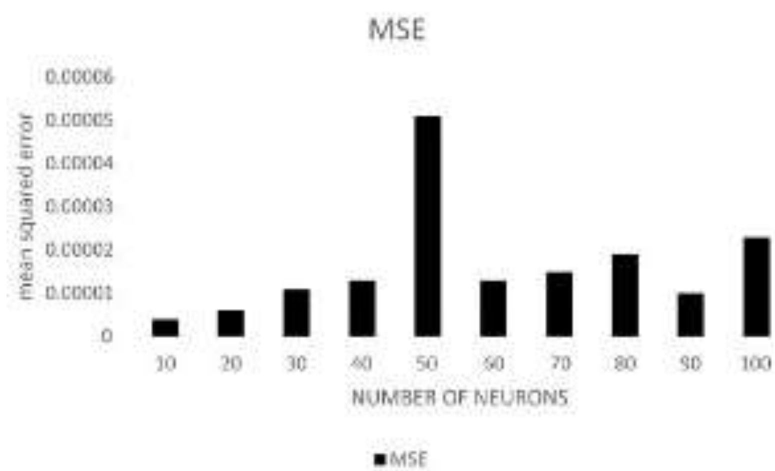

Figure 3. Plot of the mean squared error (MSE) with the number of hidden neurons.

humidity, with R = 0.753. This shows that at Basin Authority station, relative humidity had the greatest effect on SO_2. The highest correlation between SO_2 and wind speed was obtained at basin authority with R = 0.609 which shows that wind speed also had effect on SO_2 in that station. Marina Resort recorded the highest negative correlation of SO_2 and temperature, with R = -0.643 and Basin Authority recorded the highest positive correlation with R = 0.631. The positive correlation with meteorological parameters was recorded by (Nwokocha et al., 2015). Ljubisa et al., 2011, also recorded strong correlation of SO_2 with temperature.

Modelling and Prediction of So_2

Figure 3 shows a histogram plot of the mean squared error (MSE) and the number of hidden neurons used

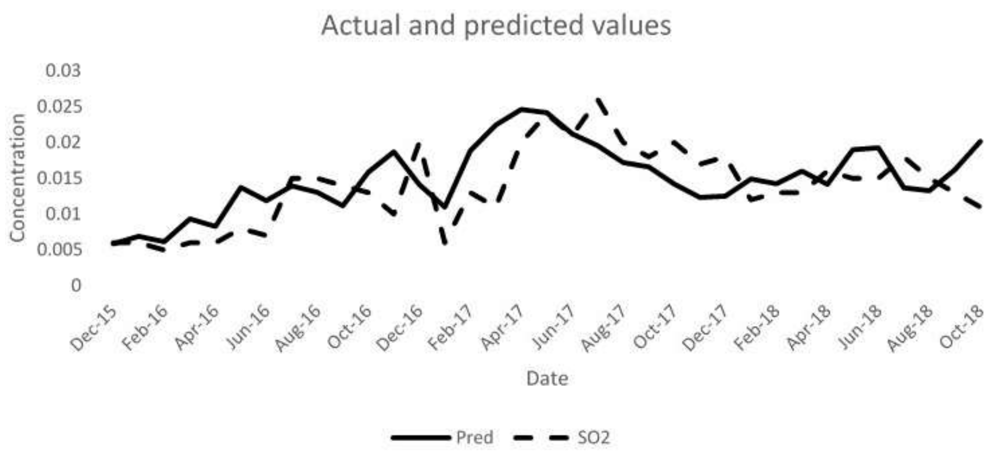

Figure 4. Plot of actual and predicted values of SO_2

in the training of the network. The graph shows that the neural network performed better when the hidden neurons were set to ten. Hence the best model for the prediction of SO_2 for Calabar is 5 – 10 – 1. This translates to, five (5) input variables that include; SO_2, wind speed, temperature, relative humidity and total suspended particulate matter (TSP), ten (10) hidden neurons in the neural network and one (1) target variable which is SO_2. The output of the neural network which is predicted values were plotted with the actual values of SO_2. The plot is shown in Figure 4.

CONCLUSION

The following conclusion has been drawn in this research. The concentration of SO_2 in Calabar has over-shot the WHO (2005) threshold limits of 0.008 ppm for 24 hrs and 0.188 ppm for 10 minutes measurement. The air quality in Calabar based on SO_2 is poor. This may be very dangerous to the health of Calabar residents. The best model for the prediction of SO_2 is 5 – 10 – 1. This model will help scientist in the accurate prediction of SO_2 concentration in Calabar and locations with the same meteorological conditions as Calabar.

ACKNOWLEDGMENT

The authors are grateful to the Tertiary Education Trust Fund (TETFund) for providing funds for this research.

REFERENCES

Abdul Raheem AMO, Adekola FA, Obioh IB (2009). Monitoring of Sulphur dioxide in the Guinea Savanah zone of Nigeria: implications of the Atmospheric photochemistry. Bull. Chem. Soc. Ethiop., 23 (3): 383 – 390.

Asuoha AN, Osu CI (2015). Seasonal variation of meteorological factors on air parameters and the impact of gas flaring on air quality of some cities in niger Delta (Ibeno and its Environs). African Journal of Environmental Science and Tech., 9(3): 218 – 227.

Ayodele JT, Abubakar F (2010). Sulphur dioxide as indoor pollutant in Kano municipality Kano-Nigeria. Journal of Environmental Chemistry and Ecotoxicology, 2(1): 009 – 013.

Chizoruo IF, Iheanyichukwu OP, Chukwuemeka NP, Ikechukwu AJ (2017). Ambient air quality assessment of Orlu, South Eastern Nigeria. J. Applied Sci., 17: 441 – 457.

EPA (2006) United States Environmental Protection Agency Report.

Gobo AE, Ideria TJK, Francis TE, Stanley HO (2012). Assessment of air quality and noise around Okrika communities, Rivers State, Nigeria. J. Appl. Sci. Environ. Manage., 16(1): 75 – 83.

Ipeaiyeda AR, Adegboyega DA (2017). Assessment of air pollutant concentration near major roads in residential, commercial and industrial areas in Ibadan city, Nigeria. Journal of Health Pollution 13: 11 – 21.

Ishaya S, Adakayi PE, Ojie AF (2017). Assesment of air quality along Urbanization gradient in APO District of the Federal Capital Territoty of Nigeria. Annals of Ecology and Environmental Science, 1(1): 76 – 87.

Ljubisa P, Predrag I, Svetlana M, Zoran J (2011). Meteorological parameters and pollution caused by Sulphur dioxide and their influence on construction materials and Heritage. FACTA UNIVERSITATIS (NIS) SER.: Elec. Energ., 24(1): 9 – 20.

Lutgens FK, Tarbuck EJ (2013). The Atmosphere, an Introduction to meteorology. PEARSON publishers 12th edition.

Nwokocha CO, Edebeatu CC, Okujagu CU (2015). Measurement, survey and assessment of air quality in PortHarcourt, South-South Nigeria. International Journal of Advanced Research in Physical Science (IJARPS). 2(7): 19-25.

Olatunji SO, Fakunle BS, Jimoda LA, Adeniran JA, Adesanmi AJ (2015). Emissions of Sulphur dioxide from Gasoline and Diesel consumption in the South Western States of Nigeria. Petroleum Science and technology, 33: 678 – 685.

Ugbebor JN, Yorkor B, Amadi G (2019). Assesment of air quality and its health implications on the Abuja campus residence, University of PortHarcourt, Nigeria. J. Sci. Technol. Environ. Inform., 07 [01]: 500 – 509.

Wallace JM, Hobbs PV (2006). Atmospheric Science an introductory survey. Academic press, Elsevier.

WHO (2005). World Health Organization Global report.