Centre for Atmospheric Research

2018 MONOGRAPH OF ATMOSPHERIC RESEARCH

Edited by **A.B. Rabiu and O. E. Abiye**

A Publication of
CENTRE FOR ATMOSPHERIC RESEARCH
National Space Research and Development Agency
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PREFACE

The Centre for Atmospheric Research was established in January 2013 with a compelling mission to improve our understanding of the behaviour of the entire spectrum of the Earth's atmosphere; promote capacity development in relevant atmospheric sciences as a way of facilitating international competitiveness in research being conducted by atmospheric scientists; and disseminate atmospheric data/products to users towards socio-economic development of the Nation. CAR's extant core research focus includes: space weather, tropospheric studies, atmospheric research software and instrumentation development, microgravity and human space technology, and atmospheric chemistry and environmental research.

Pursuant to the above, The *Monograph of Atmospheric Research* published by the Centre for Atmospheric Research (CAR), is a collection of peer-reviewed manuscripts in Atmospheric Sciences and closely related fields. This maiden edition comprises articles presented during two separate workshops; *1st National Workshop on Microgravity and Environmental Research* (26 - 29 November, 2017) and *1st National Workshop on Air Quality* (13 - 16 March, 2018). Such workshops are integral part of CAR's capacity building program and they were primarily aimed at advancing the course of atmospheric research in Nigeria towards sustainable development. The Microgravity workshop was geared towards introducing new research opportunities in space life science by simulating microgravity conditions here at the earth's surface as a means of investigation space biological environment. The Air Quality workshop was organized in collaboration with Ministry of Environment and Nigerian Meteorological Agency (NIMET). The workshop analysed current Air Quality scenario in Nigeria, explored new opportunities for collaborative research and offered novel means of improving the present quality of life of the populace without jeopardizing the chance of the future generation. Cumulatively 196 participants participated in these two workshops and about 52 articles were eventually submitted for publication consideration in this monograph. The twenty-one articles in this very monograph are the articles that eventually made it through the rigorous peer-review process. We remain grateful to the reviewers for doing thorough work on the articles.

Thus, we are very pleased to present the *2018 Monograph of Atmospheric Research* which contains twenty-one articles, including some review papers, to readers in all spheres of interest across Nigeria and beyond. It is our hope that this effort will continue and will serve as a reference to atmospheric researchers in Nigeria.

Prof. A. B. Rabiu and Dr. O. E. Abiye,
Editors

Centre for Atmospheric Research

Temporal variations in concentrations of NO and NO_2 in the Business District Area of Abuja, Nigeria

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ABSTRACT

Nitrogen dioxide is one of the major air pollutant associated with urbanization, particularly in developing countries, long exposure to it may decrease lung function and increase the risk of respiratory diseases. It utilizes data from a month-long experimental measurement of NO and NO_2 concentrations from mid-March to mid-April 2015 from Nigerian Meteorological Agency. Wind speed, wind direction, temperature, and relative humidity were monitored concurrently. It is observed that the concentrations during the week days were 2 - 3 times higher than that of the weekends with distinct diurnal and day-of-week variations, and no variation in the night concentrations throughout the weeks. Results identified the major cause of NO_2 concentrations in the city to be emissions from vehicles and generator plants. Consistent increase in NO_2 concentrations was noted from 0700 – 1100LT and 1500-1800LT during the weekdays which are associated with "rush hours (resumption and closing hours). While rises in NO_2 concentrations through the midnight hours from 2100 – 0400LT all days of the week are linked to the emission from generator plants in the residential quarters close to the site. Although there are variations in concentrations of NO_2 with variation of weather parameters and vehicular movements, it did not exceed National Environmental Standards and Regulations Enforcement Agency (NESREA) and World Health Organization (WHO) guidelines for human health average recommendations throughout the period.

Keywords: Nitrogen oxides; Nitric oxide; Nitrogen dioxide; Air pollutant; World Health Organization

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INTRODUCTION

Air pollution has been identified to be one major problem associated with urbanization, particularly in developing countries. The rapid growth of urban areas is among the most important anthropogenic impacts on the environment, and it has a profound impact on both the urban climate and air quality (*Balogun et al., 2014*). A major problem that generally follows rapid urbanization is deterioration of air quality with adverse effects on human health due to increased emissions from traffic. This is especially true in the developing countries, mainly due to the high proportion of old, poorly maintained vehicles, the abundance of two-stroke motorcycles and the poor fuel quality (*Gwilliam, 2003*). The main pollutants from vehicular emission include carbon monoxide (CO), Nitrogen oxides (NO_X) and Sulphur dioxide (SO_2) (*Han et al., 2011*). Air pollution is defined as the emission of particulate toxic elements in to the atmosphere by natural or anthropogenic sources. These sources can be further differentiated in to either mobile or stationary sources. Today the major sources of man –made air pollution are motorized street traffic, burning of fuels, and larger factory emissions (*Ahmed, 2015*).

Nitrogen oxides (NO_X) consist of nitric oxide (NO) and nitrogen dioxide (NO_2). Nitric oxide (NO) has no colour, odour, or taste and is non-toxic. In the lower atmosphere it is rapidly oxidized to NO_2 by reaction with proxy radicals (RO_2) or O_3. The NO_2 generated is then photolyzed in the atmosphere and the atomic oxygen released combines with molecular oxygen to form O_3 (*Aneja et al., 2001*). Nitrogen dioxide is a reddish-brown gas with a pungent, irritating odour. It absorbs light and leads to the yellow-brown haze sometimes seen hanging over cities. It is one of the important components of photochemical smog (*Robert et al., 2012*). The main source of man-made nitrogen oxides is from the burning of fossil fuels: coal, oil and gas. The amount of nitrogen dioxide emitted varies with the temperature of combustion; as temperature increases so does the level of nitrogen dioxide. More than 80% of the nitrogen dioxide in cities comes from motor vehicle exhaust (*Costabile and Allegrini, 2007*).

At high concentration levels, nitrogen dioxide is potentially toxic to plants, can injure leaves and reduce growth and yield. In combination with either ozone (O_3) or sulphur dioxide (SO_2), nitrogen dioxide may cause injury at even lower concentration levels. As one of the components of smog, nitrogen dioxide is known to irritate the lungs and increase susceptibility to respiratory infections (*Ricciardolo et al., 2004; Gurjar et al., 2008; Roberts et al., 2012*). Health based guidelines for maximum ambient NO_2-levels are: 100ppb for 1 hour and 53ppb for 1year exposure (NAAQS, 2011). It was concluded that cities in Sub-Saharan Africa are among the most polluted in the world and great need of air quality management measures in their development at the Better Air Quality Sub-Saharan Africa regional conference in Nairobi 2006 (CAI-SSA, 2006).

However, relatively little is known about urban air quality status in developing countries as systematic measurement and monitoring of urban environmental health risks connected to air pollution has received very limited attention (*Arku et al., 2008*). Amongst the few work done in Africa is the work done by Meon (2012) on CO, NO_2, and SO_2 at six major intersections in Abuja. The study found that vehicles emission were the major sources these pollutants, concentrations of pollutants were significantly higher during the afternoon than during the morning and concentrations of SO_2 and CO exceed the 1-hour average limit of air quality standard set by both Nigerian and WHO at the study area. *Okunola et al. (2012)*, assessed concentrations of gaseous pollutants such as: CO, H_2S, NO_2, SO_2, FL and NH_3 along some busy roads in Kano metropolis from December 2009 to September 2010. The results indicated that the concentrations of CO, H_2S, NO_2 and SO_2 measured, with few exceptions, at some sites were above the air quality index AQI stipulated by USEPA, especially during the afternoon periods. This implies that traffic emission within Kano metropolis is not within the safe limits, revealing that transport-related pollution in Kano metropolis can be potentially hazardous to health. Recent research conducted by Kafeelah *et al.* (2013), investigated the distribution of SO_2, NO_2, PM_{10}, CO, H_2S, CH4 and noise in ambient air of Tin-Can port industrial estate Apapa, Lagos, Nigeria at seven selected sampling sites. Results revealed that concentrations for SO_2 and NO_2 exceeded the USEPA national ambient air quality standards. Also, suggest that appropriate vehicle emission management coupled with industrial air pollution control should be applied to coarse particulate (PM_{10}) and gaseous pollutants in the study area.

Level of nitrogen dioxide (NO_2) in Calabar city is quite high when compared with the limits set by FEPA (1991) for $NO_{2.}$ Also, the quality of air is very poor at all the studied sites when compare with Air Quality Index in research conducted by *Etiuma et al. (2006)*. This is most likely due to high traffic density and stationary fuel combustion process emissions from running of generators which is very common within the metropolis due to erratic power supply (*Etiuma et al., 2006*). Suggest that the distribution pattern of NO_2 shows an increase during Warm and Wet Season across the sites, which could be due to air/wind velocity during this period. NO_2 poses a threat to public health; Populations living near major roadways have been shown to experience numerous health effects, including exacerbation of asthma, cardiovascular, and non-asthma respiratory symptoms (HEI, 2010).

This research aims to examine the diurnal and weekly variation of NO_2 comparatively with weather parameters and vehicular movements at the busy business district area of Abuja, Nigerian capital.

MATERIALS AND METHODS

Description of the study area

Abuja, the capital city of Nigeria located on latitude 9.05˚N and longitude 7.32 ˚E (Figure 1). Abuja is located in the centre of Nigeria and has a land area of 8,000 square Kilometers. The Territory was formed in 1976 from parts of former Nasarawa, Niger, and Kogi States (*Oniyemi 2011*). It is bounded on the north by Kaduna state, on the west by Niger state, on the east and south-east by Nasarawa state and on the south-west by Kogi state. It officially became Nigeria's capital on 12 December 1991, replacing Lagos. Since then, the city has witnessed immense growth in the size of built-up areas, number of inhabitants, transportation, and commercial activities. At the 2006 census, the city of Abuja had a population of 1,405,201 making it one of the ten most populous cities in Nigeria (*Meon, 2012*).

The study site was in Abuja Geographical information system (AGIS), Area 11 Garki, Abuja, a central business district in the city. The site is 13m away from Ayangba Street (Figure 2). This heavily busy Street leads to AGIS, Nigerian Television Authority (NTA), Ministry Of Agriculture and Rural Development, Federal Secretariat and Federal Capital Territory Administration (FCTA) from Tafawa Balewa to Ahamdu Bello express way. The lane A of the street record traffic volume range between 7850 and 6785 during the weekdays and 2145 and 1508 during weekends while lane B record traffic volume range between 5920 and 4876 during the weekdays and traffic volume range between 1784 and 1143 during weekends. According to National population census report in year 2006 revealed that Area 11 has total population of 7020 (NPC, 2006) of which the street under investigation is among the most populated areas. There are residential buildings such Nigerian National Petroleum Cooperation (NNPC) Quarters, Area 11 housing estate and private estate located to the south west of the street where as government parastatals offices such as NTA, FCTA and Ministry Of Agriculture and Rural Development also commercial buildings which includes Area 11 shopping complex, supermarkets, malls, banks, insurance and private companies are located to the north and northeast of the street.

Data Description and Methodology

Five weeks long NO and NO_2 measurement was conducted between 11th of March to 12th of April 2015 with Nigerian Meteorological Agency (NIMET) instrument installed inside Abuja Geographical Information System (AGIS) Area 11 Abuja. Meteorological parameters (wind speed, wind direction, air temperature and relative humidity) were measured as well. The NO_X analyzer; Environmental Safety Monitoring Instrument (ESMI NOX-400) was used for this study which employs chemilluminescence detection for continuous measurement of NO and NO_2. Nitrogen oxides were determined by detecting the chemiluminescence in a range of 600 nm to 3000 nm for continuous measurement and recording of 15-min average data of NO and NO_2 concentrations. Automatic Weather Observation Station (AWOS) was placed on top of the container housing the ESMI NO_X-400 at distance of 1.5m away from roof level of the container. The distance of air quality monitoring site is 13m from the road side while the sensor of ESMI NO_X-400 was placed at about 7m away from the ground level.

Continuous NO_X analyzer recorded 15-min average data. Hourly and 8hr averaged data were derived from the original 15–minute interval data recorded by the instrument. The method was previously described by *Balogun et al., (2014)*. In addition, the results were compared with World Health Organization

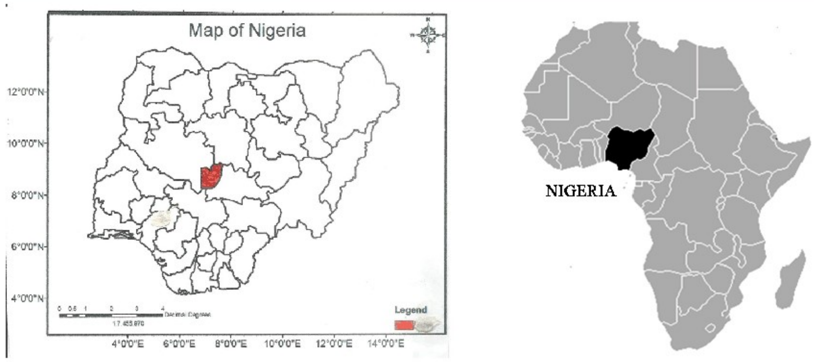


Figure 1: Map showing position of Abuja (red) in Nigeria left and Nigeria (black) in Africa right.

Figure 2: Map showing Abuja Geographical Information System (AGIS) in red.

(WHO) guidelines for NO_2. Health based guidelines for maximum ambient NO_2 levels are: 100ppb for 1hr and 64ppb for 8hr. Time series plotting techniques were used to visualize the diurnal, weekday and weekend patterns of NO, NO_2, and NO_X concentrations. WD1-03 - Wind Vane was used to measure the direction of the wind and A100AC anemometer was used to measure the speed of the wind while Relative humidity was measured with psychrometer.Temperature sensor (LM35) was constructed and calibrated with standard mercury in glass thermometer at Meteorological Observatory of department of Meteorology, Federal university of Technology, Akure before taking it to the field. The results show very good agreement between the actual and calibrated instrument, as the values of the coefficient of multiple determinations (R^2) was 0.71.

The meteorological instruments were connected to Cambell Science data Logger RC1000 and Solar panel was used to powered mercury battery (MML 12-7.0) which serves as power source to the logger in order to store data continuously. Time series plotting techniques were used to visualize the diurnal and weekday and patterns of NO, NO_2, and NO_X concentrations. The values of Meteorological variables were correlated with NO_2 concentrations to ascertain the influence of Meteorological parameters on the concentrations of NO_2. In this project, traffic volume was determined by counting the number of vehicles passing through the road of the monitoring site. The vehicles were counted from 7am to 7pm throughout the period and figures were compared with NO_2 concentration. Data were analyzed using Microsoft excel and statistical software R programming language including openair R, and its package openair (Carslaw and Ropkins, 2012).

RESULTS AND DISCUSSION

Observed Characteristics of Nitrogen Oxides over Abuja

Week one Scenario

The hourly average diurnal variations of NO, NO_2 and NO_X concentrations on weekly basis were plotted for the measured period. The average diurnal variation of 1hour of NO, NO_2, NO_X concentrations and correlation between meteorological variables with NO_2 for the first week is presented in (Fig 3a-d). NO_2 concentrations at the city centre in Abuja exhibited distinct diurnal variations with three main peaks during the weekdays and two main peaks during weekends (Fig 3a). At this period, it is clearly shown that atmospheric contents of Nitrogen dioxide concentrations during weekdays exceed that of weekends during the day time. However, there were no differences in level of NO_2 concentration at night. The first peak was observed at 7-11am, second peak at 3-6pm and the third one at 9pm to 4am in weekday but weekends display only two peaks, one at 7am to 1pm and the other one correspond to that of 9pm to 4am. However, similar trend were observed for NO and NO_X in (Fig 3b-c).

Comparison of NO and NO_2 is presented in (Fig 3c). It was observed that levels of NO were higher than NO_2 in almost all the period except around 3-6pm as observed by Dawn *et al.*, (2012). The relation between ozone and its two main precursors, NO_X (NO and NO_2) and volatile organic compounds (VOC), represents one of the major scientific challenges associate with urban air pollution (Sillman, 1999). The formation of ozone in the troposphere depends on the intensity of solar radiation, the absolute concentrations of NO_X and VOCs, and begins with NO_2 photolysis, after which the NO product quickly reacts with ozone to regenerate the NO_2. The highest NO_2 concentrations were observed during the day time which corresponds to period of highest traffic volume and maximum temperature (Fig 3d). Wind speed showed inverse relationship with concentrations of NO_2 and is influence is mostly pronounced at night (Fig 3d). This is in line with findings of *Ito et al.; (2007)*. However, 1hour, and 8hours average of NO_2 concentrations were within the limit of WHO standards throughout the first week.

Week two Scenario

The hourly average diurnal variations of NO, NO_2 and NO_X concentrations and correlations between NO_2 concentration and meteorological variables for the second week are evaluated and presented in (Fig 4a-e). Similar features as discussed earlier in the first week were observed. In Fig 4a, the first two peaks are associated with Morning and Evening rush hours. However, period of occurrence of these peaks corresponds with the time at which highest vehicles are being recorded.

Result agrees with (*Klidonas, 1993*) identifying motor vehicle emission as one of the main sources of atmospheric pollution in the urban environment. Khoder, (2009) also found many sites with elevated motor vehicle emissions near busy streets are known to contribute to high NO_X concentrations. Of the two components of NO_X, however, NO_2 showed less pronounced weekday variations than NO (Fig 4c).

Abdul–Wahab et al. (2005) found in their stepwise multiple regression analysis that solar levels contributes significantly to high daytime NO_2 concentrations with NO as the principal precursor. Atmospheric stability restricts vertical motions and increases pollution concentrations near the surface, particularly when accompanied by radiation induced inversions during early morning hours, thus enhancing NO_X concentrations (*Guttikunda and Gurjar, 2011*).

It was observed that lowest concentrations of NO_2 for each day

(3a)

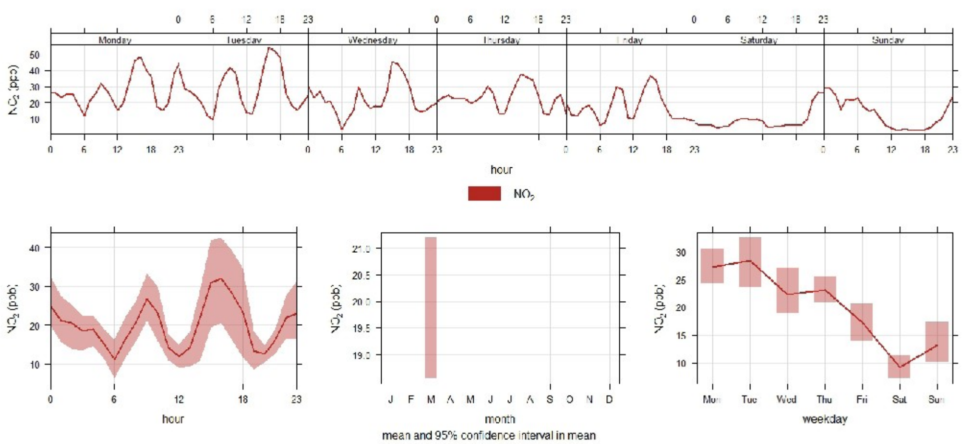
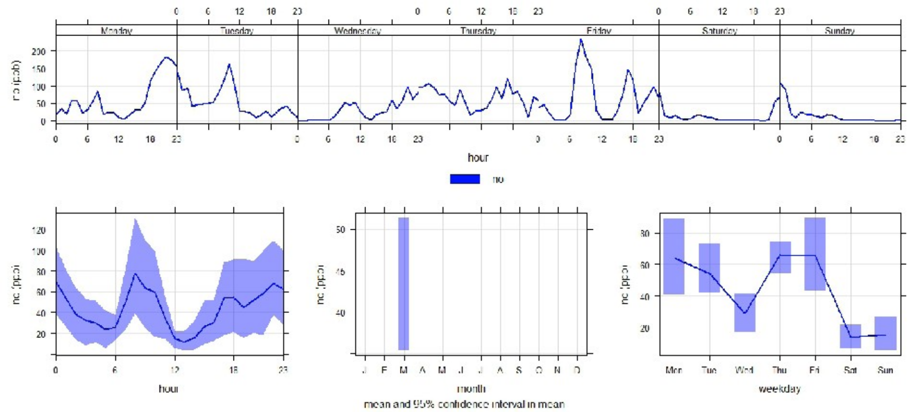
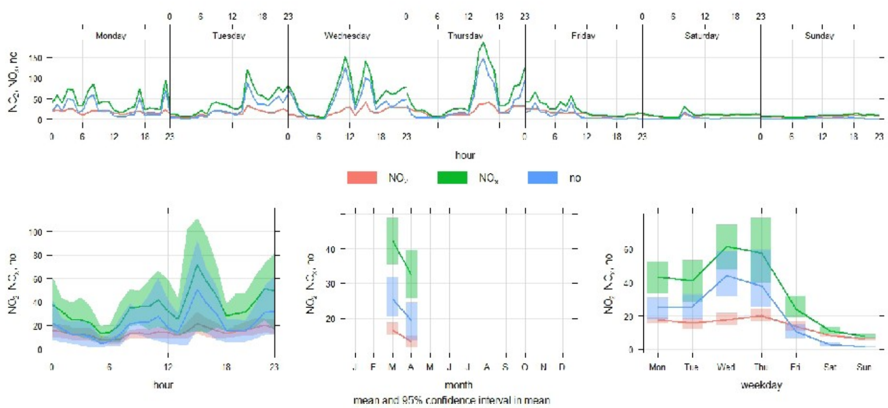


Fig 3: Diurnal variations of 1 h mean concentrations of; NO2 (3a), NO (3b) and relationship between NO, NO2 and NOX (3c), for the first week.

(3b)



(3c)



(3d)

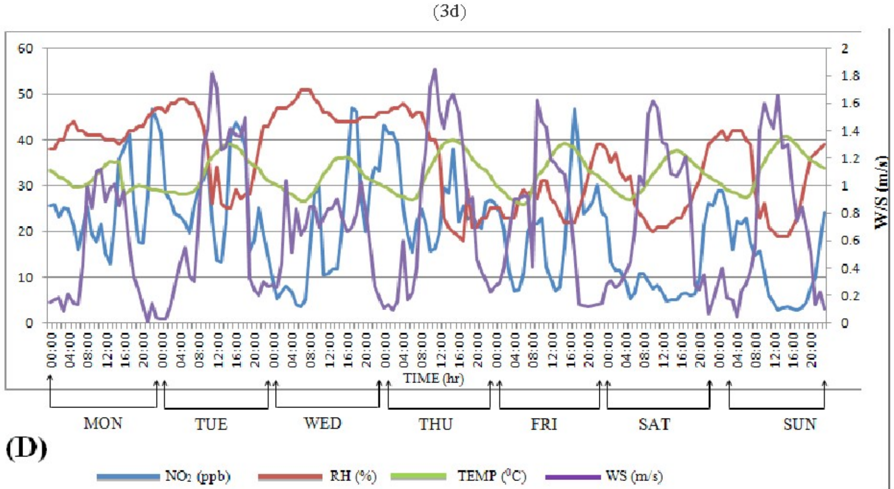


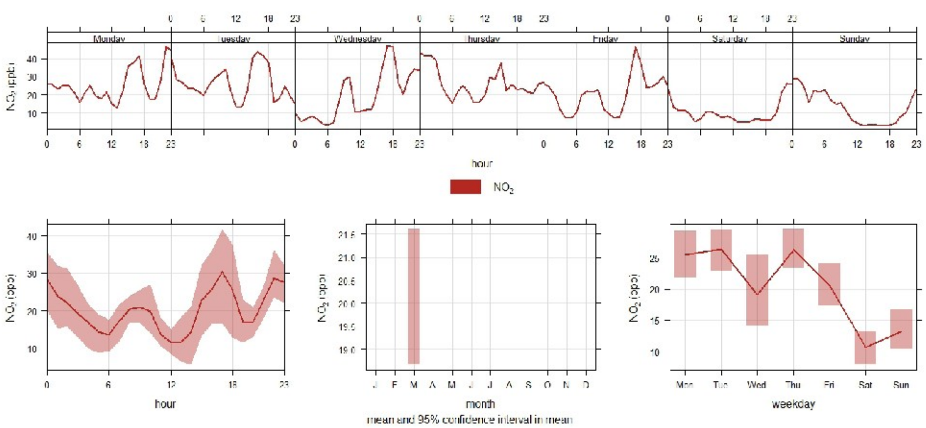
Figure 3: continues; Diurnal variations of 1 h mean concentrations of NO2 with Meteorological variables for the first week from Monday 9th of March to Sunday 15th of march 2015.

were observed at the period of maximum wind speed (Fig 4c). However, the dispersal of pollutants by high winds through vertical mixing and forced convection apparently contributed to lower NO_2 concentrations. Concentrations of NO_2 show positive correlation with temperature and negative correlation with relative humidity for all days of the second week (Fig 4c).

Week three Scenario

Fig 5a-d presents the hourly average diurnal variations of NO, NO_2 and NO_X concentrations also correlations between NO_2 concentration and meteorological variables for the third week. The pattern of NO_2 concentrations for the third week is the same as the previous weeks in term of the number of peaks, period of occurrence and the influence of meteorological variables (air temperature, wind speed and relative humidity) on them. The only observed differences is the extension of time of the first peak from 7am to 1pm throughout the week days compared to the previous weeks which the time of occurrence of the first peak are 7am to 11am. The above differences could be due to blockage of one lane of Tafawa Balewa way for a week which allows more vehicles to pass through the street at that time which suggest that vehicular emission is the main source NO_2 pollutant during the day time. There were no changes in the second peak (3-6pm) since the street was only used as way in to FCDA from Abubakar Tafawa Balewa express way. Evidence for this variation was noted from traffic volume as more vehicles were recorded at this period of the week compared to the earlier weeks.

It was noted NO_2 peaks were higher than NO at night in Figure 5c. This might be caused by nighttime balancing, due to the oxidation of NO to NO_2 by O_3, in the absence of solar radiation (*Song et al., 2011*); these levels were maintained until early morning hours. The accumulation of NO_2 might contribute to



(4b)

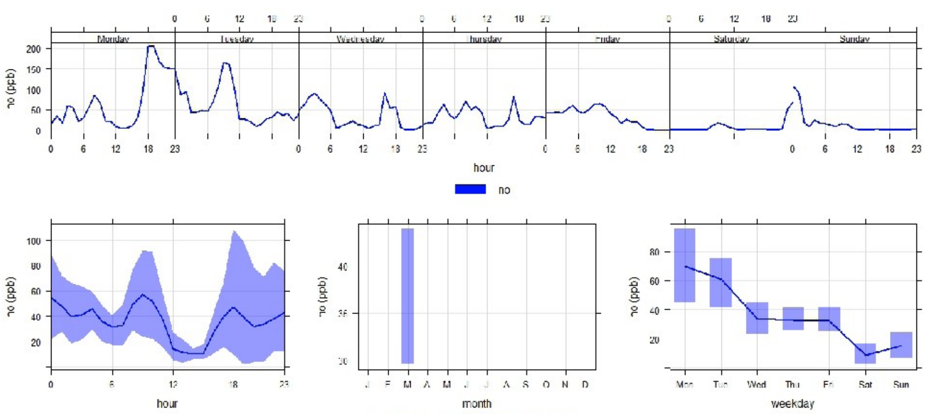
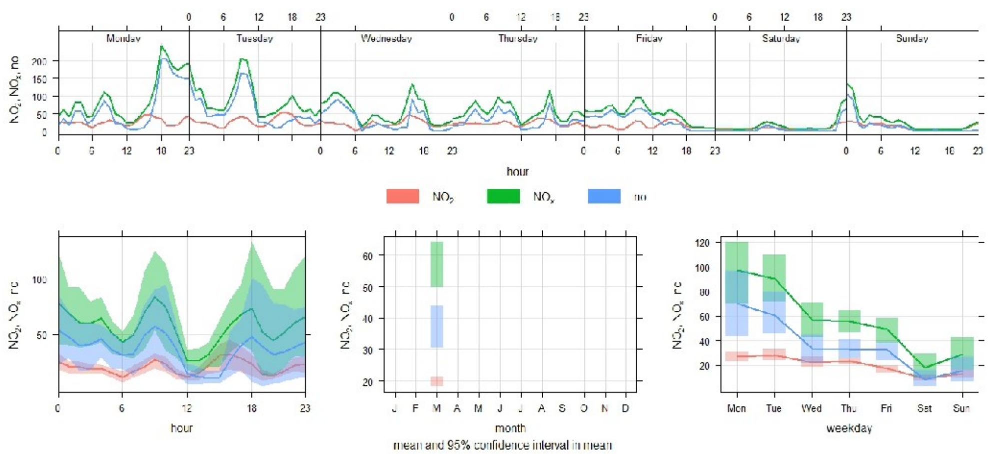


Figure 4: Diurnal variations of 1 h mean concentrations of; NO2 (4a), NO (4b) and relationship between NO, NO2 and NOX (4c), for the second week

(4c)



(4d)

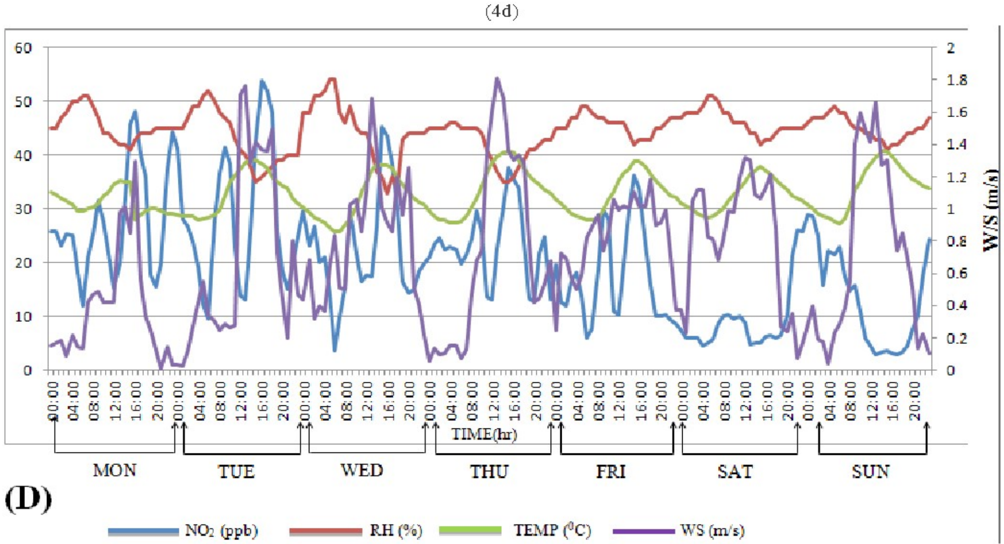


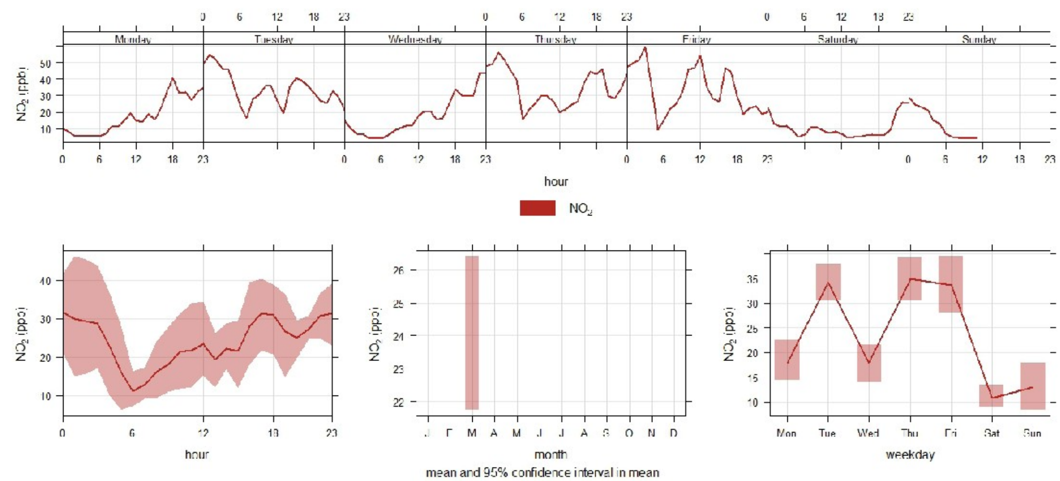
Figure 4: continues; Diurnal variations of 1 h mean concentrations of NO_2 with Meteorological variables for the second week from Monday 16th of March to Sunday 22nd of march 2015.

O_3 formation; however, O_3 is "scavenged" where there is an abundance of NO, resulting in lower O_3 concentrations in heavy traffic (*Abdul–Wahab et al., 2005*). Concentrations of NO_2 were within the limit of WHO standards throughout the third week. Results agrees with *Gupta et al., (2008)* who found that NO_2 concentrations were highly dynamic with significant seasonal variations characterized by high winter level also *Elampari et al., (2010)* showed that mean concentrations of NO_2 at night were greater than that of day time which may be attributed to photochemical reaction taking place for the production of ozone during the day time.

Week four Scenario

In Fig 6a-d, the hourly average diurnal variations of NO, NO_2, relationship between NO, NO_2 NO_X concentrations also correlations between NO_2 concentration and meteorological variables for the Fourth week are evaluated and clearly shown. concentrations of NO_2 on Monday were small compared to the previous Mondays in Fig 6a as the street was not busy as it used to be due to the fact that a lot of workers and other people travelled for March 28th presidential and National elections, which suggest that vehicular emission is the main sources of NO_X concentration. Also characteristic of NO_2 concentrations for Friday was similarly to that of weekend as it was declared good Friday of year. Concentration of NO_2 for the weekends were very much lower compared to the previous week and the most important fact discovered during this period of holiday is disappearance of high level of NO_2 normally observed from around 9pm to 4am every day. This provide a hint that emission from generator plants from residential Areas (NNPC Quarters, Area 11 Quarters and others private Estate) close to study site are responsible for the high level of NO_2 concentration normally observed in the night as lowest value of vehicles were recorded for weekends at period of the study. This could be associated with travelling of the majority populations to their home towns to celebrate Good Friday and Easter Monday. The average NO_x concentrations were much lower on weekends than on weekdays, reflecting reduced levels of vehicular emissions on weekends Fig 6c. The influence of meteorological parameters was the same as earlier discussed (Fig 6d).

(5a)



(5b)

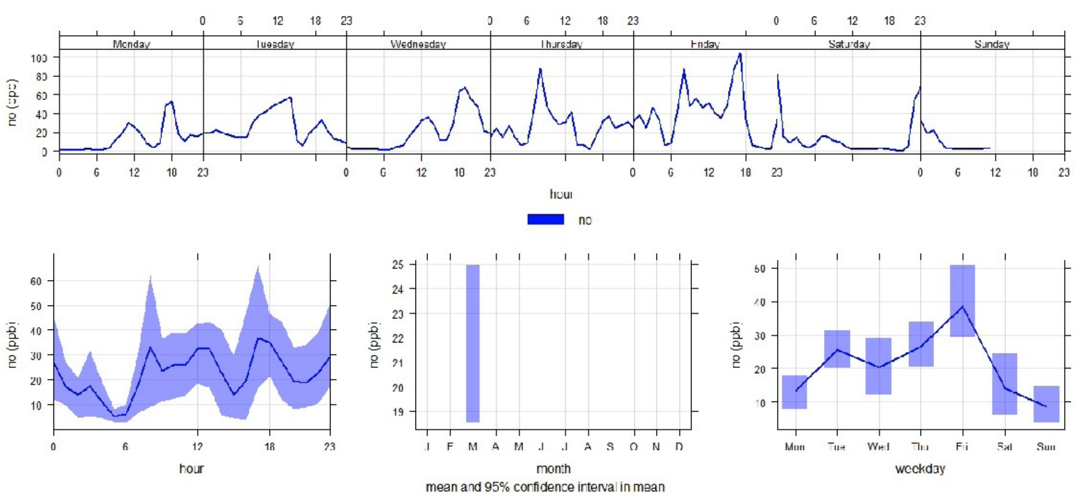
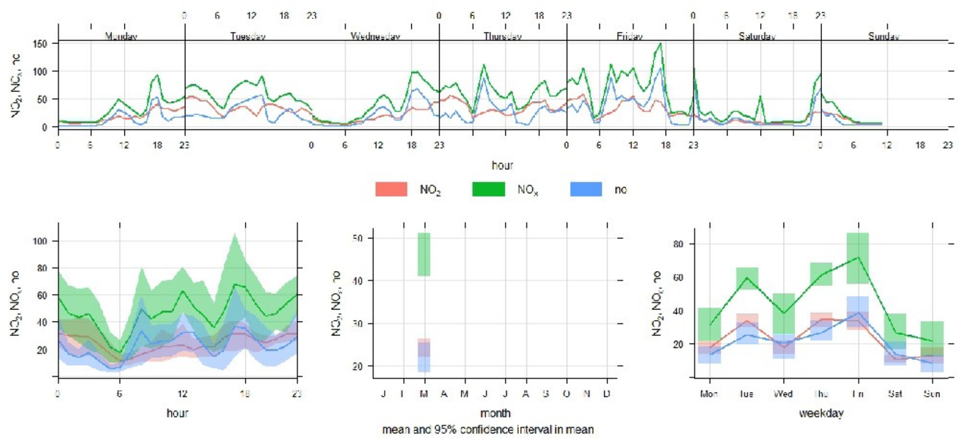


Figure 5: Diurnal variations of 1 h mean concentrations of; NO_2 (5a), NO (5b) and relationship between NO, NO_2 and NO_x (5c), for the third week.

(5c)



(5d)

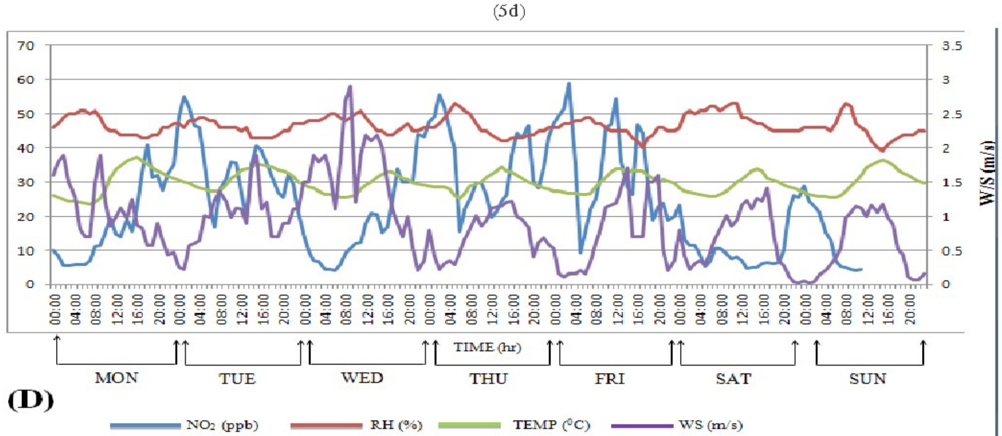
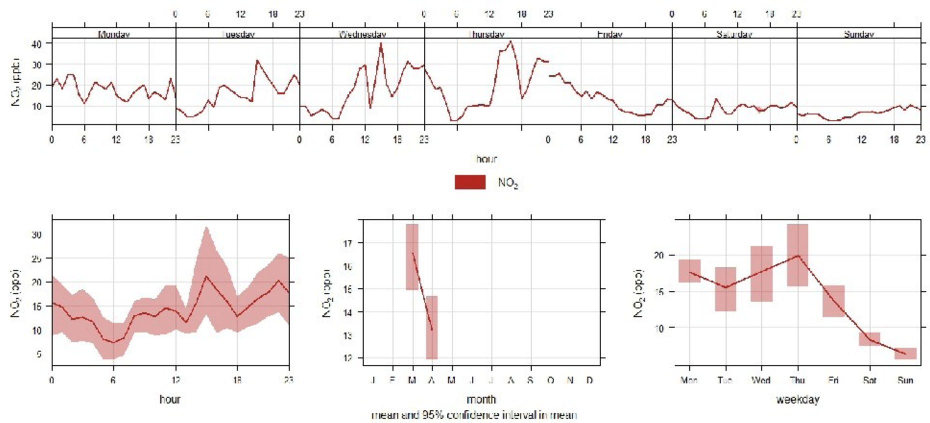


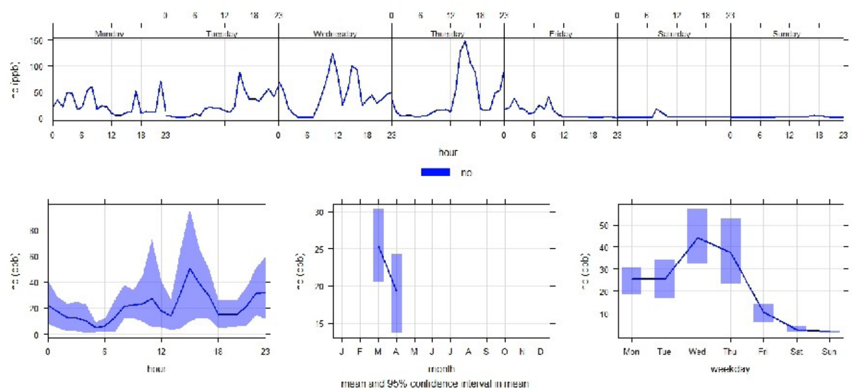
Figure 5: continues; Diurnal variations of 1 h mean concentrations of NO_2 with Meteorological variables for the third week from Monday 23rd of March to Sunday 29th of march 2015.

The relationship between NO_x concentrations with wind speed and wind direction is depicted in the polarplot (Fig 8a). This plot is used to investigate emission sources of pollutants (NO_x) concentrations a well as the dependence of the pollutant on wind speed and directions (*Turki et al., 2014*). The plot is based on conditional probability functions (CPF) of NO_x concentrations by showing the wind speed and directions that are dominated by high concentrations (Fig 8a). It is clear that the NO_x concentrations (greater than the 90th percentile of all observations) are dominated in all wind directions. Indeed, the plot clearly reveals that main potential sources and highest NOx levels are observed when wind is blowing from east or northeast at a speed of 2 – 3 m/s. Fig (8a) shows that NOx concentrations are also high at lower wind speed (wind speed < 2 m/s) from all direction, probably high wind speed disperse locally emitted air NOx concentrations.

(6a)



(6b)



(6c)

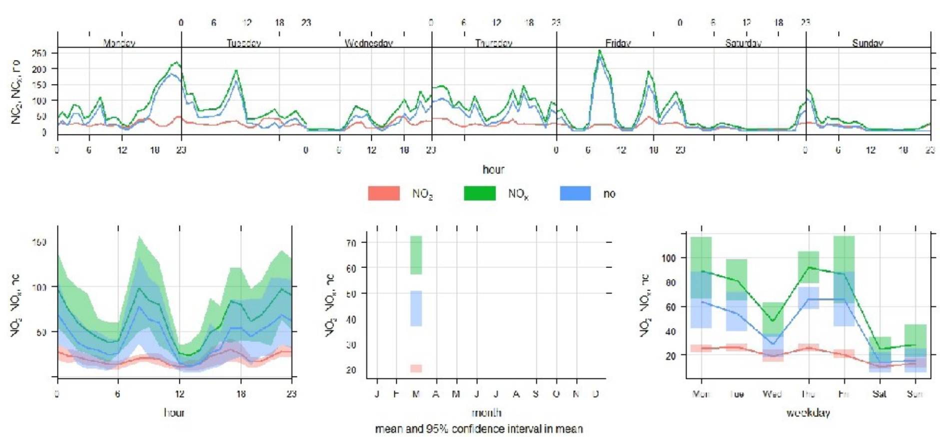


Figure 6: Diurnal variations of 1 h mean concentrations of; NO_2 (6a), NO (6b) and relationship between NO, NO_2 and NO_X (6c), for the fourth week.

(6d)

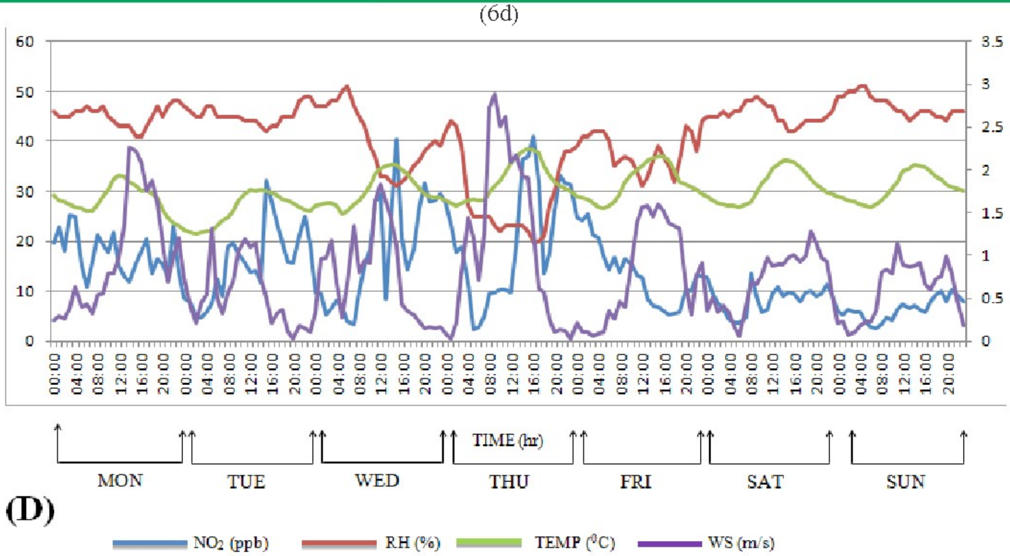


Figure 6: continues; Diurnal variations of 1 h mean concentrations of NO_2 with Meteorological variables for the third week from Monday 30th of March to Sunday 5th of April 2015.

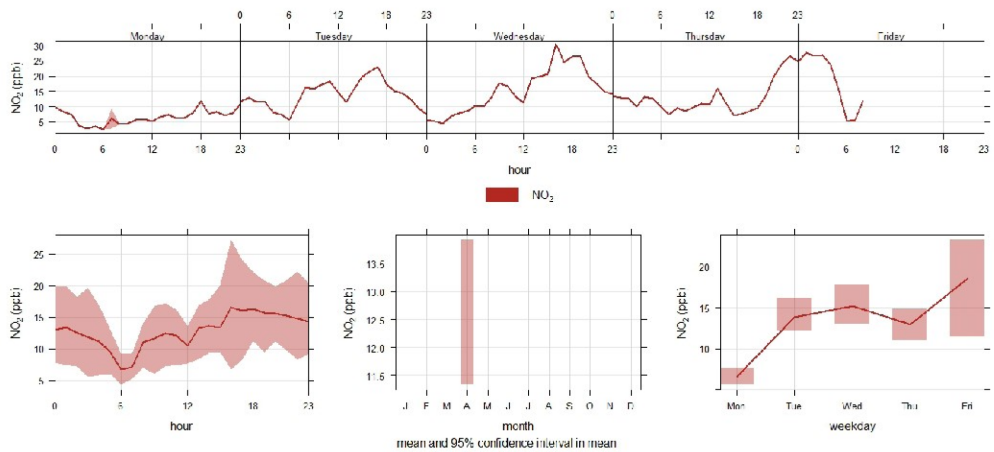


Figure 7: Diurnal variations of 1 h mean concentrations of NO_2 (6a) for the fifth week 6th Monday to 10th Friday April 2015 in Abuja.

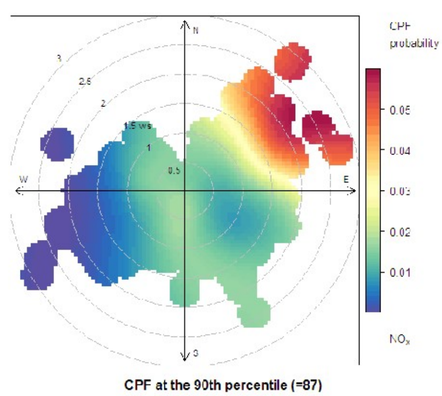


Figure 8: PolarPlot of NO_x concentrations at the study area, based on the Conditional Probability Function

CONCLUSION AND RECOMMENDATION

This study has revealed the air quality status of the Area 11, Garki, Abuja in terms of the Nitrogen dioxide (NO_2) concentration levels, and also assessed the status with respect to World Health Organization (WHO) standard health-based guidelines on NO_2 pollution. Concentrations of NO_2 do not exceed 1hour and 8hour average recommendation given by the WHO throughout the study period. It is clearly shown that atmospheric contents of Nitrogen dioxide concentrations during weekdays exceed that of weekends during the day time. The NO_2 concentrations at the study area exhibited distinct diurnal variations with three main peak periods during weekdays and two main peaks periods during weekends. Results from this study identified the major cause of NO_X concentration in the city to be emission from vehicles and generator plants as there is a consistent increase of the air pollutant from 07:00 to 11:00 and from 15:00 to 18:00 during the weekdays that are associated with "rush hours (resumption and closing) related to office workers" also through the night hours starting from 21:00 to 04:00 in all days of the week which is linked with use of generator plants in the Residential Quarters close to the site.

Concentration of NO_2 shows positive correlations with temperature and negative correlations with speed and relative humidity. It is concluded that levels of NO_2 concentrations not only depend on the amount of NO emitted from various sources but also on meteorological parameters. Meteorological parameters play important role in secondary pollutants formation, horizontal and vertical movement, dispersion and removal of pollutants from the atmosphere.

This air quality degradation identified as a major problem that gradually follows rapid urbanization will in no doubt have adverse effects on human health due to increased emissions from traffic and burning of fossil fuel from other sources. However, findings presented in this study could serve as a valuable tool in reducing urban environmental health risks connected to NO_2 pollution, if used in planning, as well as development of strategies for air pollution mitigation in Abuja. Further studies are required to relate traffic volume and meteorology to the levels of NO_X in the boundary layer of the atmosphere.

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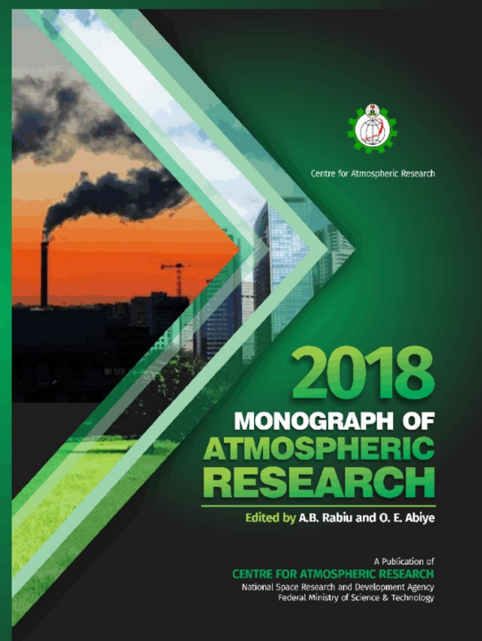

Our Mandates

The Center for Atmospheric Research, CAR, is a research and development center of NASRDA committed to research and capacity building in the atmospheric and related sciences. CAR shall be dedicated to understanding the atmosphere—the air around us—and the interconnected processes that make up the Earth system, from the ocean floor through the ionosphere to the Sun's core. The Center for Atmospheric Research provides research facilities, and services for the atmospheric and Earth sciences community.

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