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Health Effects of Tropospheric Ozone in Maiduguri Metropolis, Nigeria

Agada Livinus Emeka

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Abstract: *The troposphere is the nearest layer of the atmosphere and its composition can significantly be influenced by natural and anthropogenic activities that release gaseous substances into the atmosphere. The layer extends up to 15 km above the ground surface. Given the possible public health challenges that tropospheric ozone can impact on the ecosystem, this study is focused on the health impact of tropospheric Ozone in Maiduguri metropolis, Nigeria. The meteorological data used for this study were obtained from the National Aeronautics and Space Administration (NASA) website and the Nigerian Meteorological Agency (NiMet), Abuja. The analysis of the fifteen (15) years (2005-2020) data obtained showed that the study area is polluted by tropospheric Ozone. The results of the time series analysis of the data showed an increasing trend in all the months except April. The concentration of tropospheric ozone in the study area ranges from 17 – 40 DU (26.1 to 61.5 ppb) during the period of study. According to the WHO guideline, the level of tropospheric Ozone should be less than 50 ppb (100 µg/m^3) daily 8-hours average exposure with a potential level of 30 ppb (WHO, 2006). With regards to the WHO standard guideline on tropospheric Ozone concentration in the atmosphere, it is obvious that the study area is polluted. The analysis of the maximum temperature data of the study area showed a continuous increase in maximum temperature which is an indication that the increase in tropospheric Ozone concentration in the area is associated with global warming. The study was focused on enlightenment, sensitization and creation of awareness on public health and the environmental risk of tropospheric ozone.*

Keywords: Ozone, troposphere, concentration, public health, temperature.

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1.0 Introduction

Rapid growth in population and industrialization has increased the rate of air pollution in both rural and urban areas in recent times. Vehicular and industrial emissions have contributed to the increase in the concentration of air pollutants in the atmosphere. Air pollution is one of the largest causes of death worldwide, it claims about seven million lives yearly (WHO, 2016). Ozone is a gas that is made up of three atoms of oxygen, ozone occurs in the upper atmosphere (Stratosphere) and at the ground level (Troposphere). Ozone that occurs in the stratosphere is called stratospheric ozone, they are natural and forms a protective layer that shields the earth's surface from the destructive effects of ultraviolet radiation. About 90% of the ozone in the earth's atmosphere is found in the stratosphere. The remaining 10% are in the troposphere and they are called tropospheric ozone and they are harmful air pollutants that are capable of damaging the respiratory tract tissues, causing cancer, asthma, strokes and other heart diseases. It is the third most powerful greenhouse gas in the earth’s atmosphere after Carbon dioxide and Methane (IPCC, 2007). Tropospheric Ozone is formed as a result of chemical reactions between oxides of nitrogen (NO) and volatile organic compounds (VOC). Emissions from vehicles, power plants, refineries, chemical plants, and other chemical sources react in the presence of sunlight to produce toxic tropospheric ozone (Akanni, 2010). The tropospheric ozone is an air pollutant whose concentration in the atmosphere depends on seasons and latitudes. It contributes to rising global temperature and damage to crop production by reducing plant photosynthesis (Elizabeth, 2019). An increase in tropospheric ozone was observed to have caused a global reduction in the production of staple grains such as wheat and maize between the year 2010 to 2012 (Elizabeth, 2019).

The level of tropospheric ozone in the atmosphere depends on its background conditions and emissions. WHO in 2016 observed that about 98% of cities in middle to low-income countries do not have air quality that meets an acceptable standard. In Nigeria, cities like Lagos, Aba, Port Harcourt, Maiduguri, Kano, Ibadan and Onitsha are struggling with air pollution caused by industrial expansion and population growth. People in air polluted cities and urban areas are faced with a high risk of various respiratory health complications. WHO observed that about 800,000 premature deaths occur each year due to air pollution. Many researchers have studied air pollution in developing countries (Oluwole *et al*., 1976; Odekunle *et al*., 2017; Elizabeth, 2019; Liu *et al*., 2018). A World Bank study on the cost of air pollution in Lagos estimated that diseases and premature deaths due to air pollution caused losses of about 2.1% billion in 2018, representing 2.1% of Lagos State GDP. In the same year, it caused an estimated 11,200 premature deaths, the highest in West Africa (Odekunle *et al*., 2017). The analysis of their study showed that 60% of the total deaths were children under the age of five (5) years. Most cities and towns in Nigeria are suffering from the inadequate power supply from the National Grid. The situation has made many homes, establishments and industries rely on generators for both domestic and industrial power supply. The poor combustion of the gasoline and lubricating oil used for the generators pollutes the air. The World Bank report in 2018 showed that the concentration of particulate matter in the atmosphere of Lagos is about seven times higher than the recommended limit by the World Health Organization.

Many researchers have studied air pollution in Nigeria (Efe, 2008; Onat & Stakeev, 2013; LAMATA, 2002, Odekunle *et al*., 2016, Odekunle *et al*., 2017, Adenira *et al*, 2017; Ayantoyinbo &Adepoju, 2018; Igben, 2019; Owoyemi; *et al*., 2016). The issue of air pollution is a serious global concern since it has no international boundary and age limit in terms of its health effects on the public. A study by WHO in 2005 showed that most industrial cities in Nigeria such as Lagos, Port Harcourt, Maiduguri, Kano, Ibadan, Aba and Onitsha have elevated concentrations of air pollutants that are greater than WHO standards (Efe, 2008; Odekunle *et al.,* 2017).

A report by the Lagos Metropolitan Area Transport Authority (LAMATA) in 2003 showed that 43% of air pollution in Lagos is from vehicular emissions (Odekunle *et al*., 2017). The situation is similar to other cities in Nigeria which have high population density and a high number of vehicles and industrial activities. Maiduguri is the largest commercial hub in northeastern Nigeria, it is an international commercial center and it provides commercial services to Chad, Niger, Cameroun and the Central Africa Republic. A large population of the people in cities and towns in Nigeria is increasingly exposed to air pollution, caused by increased vehicular emissions due to high transportation activities and over-reliance on fossil fuel generators for electricity and power supply for both domestic and industrial purposes. Studies have shown that air pollution in Nigeria is at an abnormal level (Ogunsola *et al*, 1994; Efe 2008). Oluwole *et al*., (1976) carried out a study on the impact of the petroleum industry on air quality in Nigeria, and they observed that the levels of volatile oxides of carbon, Sulphur and nitrogen exceeded the Federal Environmental Protection Agency (FEDA) limits. Ede and Edokpa (2015) investigated the regional air quality of Nigeria's Niger Delta, and they observed that the particulate load in the Niger Delta region exceeded the World Health Organization (WHO) specification for both $PM_{2.5}$ and PM_{10} annual mean and 24-hour mean. Ogugbuaja and Barsisa (2001) also investigated atmospheric pollution in northeastern Nigeria by measuring and analyzing suspended particulate matter in Maiduguri and Yola. Their study showed that the air in northeast Nigeria was contaminated by a variety of metals. They concluded that the air in Maiduguri is polluted. Exposure to air pollution could lead to various health complications which depend on the nature of the pollutants, magnitude, duration and frequency of exposure. Children, the elderly and those who have health challenges are most susceptible to health complications associated with air pollution. Little or no research has been carried out on the impact of tropospheric ozone in Maiduguri and its environs. Therefore, understanding the relationship between tropospheric ozone and its health effects is an important step toward reducing air pollution and its associated health hazards. Considering the adverse health effects of troposphere ozone, the study is focused on providing information that can be used to evaluate, monitor and investigate air pollution in Maiduguri and its environs. In both developed and developing countries, combustion of fossil fuels and biomass burning were considered to be responsible for most air pollution (IEA, 2016). This study is also tailored toward creating enlightenment, sensitization and awareness on public health and the environmental risk of air pollution caused by tropospheric Ozone.

2.0 Methodology

2.1 Study area

Maiduguri is located on Longitude 13^{o} 10' E and on Latitude 11^{o} 50′ N (Agada *et al*., 2011). It is known to be underlain by the sediments of the Chad Basin. It has a semi-arid climate characterized by a long dry season and a short rainy season. The duration for the rainfall lasts about three to four months. The annual rainfall ranges from 500-1000 mm and the rainy season is from June to September (Agada *et al*., 2011). Maiduguri metropolis in the Borno State of Nigeria is a frontier border of the Sahara desert in Nigeria. It is the first to experience the hot Northeast Trade Wind that blows across the Sahara desert into Nigeria. It is also the last to experience the cool Southwest Trade Wind which blows across the Atlantic Ocean into Nigeria (Malgwi *et al*., 1997). Maiduguri has a population of about 786,000 with an increase of about 1.81% from 2019.

2.2 Data collection

Tropospheric Ozone data for Maiduguri from 2005-2020 were obtained from the National Aeronautics and Space Administration (NASA) Website https://acd-ext.gsfc.nasa.gov/Data_services/cloud_slice/data_monthly/L3_tropo_ozone_column and the temperature data were obtained from Nigerian Meteorological Agency (NiMet), Abuja. The data were divided into three parts: Dry season (March to June), Wet season (July to October), and Harmattan season (November to February). Ozone Monitoring Instrument (OMI) on board an Aura Space-craft was used to measure the monthly tropospheric Ozone. The OMI instrument employs hyper-spectral imaging to measure the backscatter radiation in the visible and the ultraviolet regions.

2.3 Data analysis

Time series analysis and basic statistics such as maximum, minimum, mean and standard deviation were used to evaluate the data obtained. The Standard anomaly index (SAI) was calculated using equation (1),

$$SAI = \frac{x_i - x_m}{\sigma} \quad (1)$$

where, x_i is the mean Ozone for each year and x_m is the long-term mean Ozone. σ is the standard deviation of the annual Ozone for the long term.

Fig. 1. Map of Nigeria Showing Maiduguri the study Area.

The analysis of the temporal trend in the standard anomaly index of the Ozone was done using the Mann-Kendall test (Koudahe *et al*., 2017). It is a non-parametric method for trend analysis. This test is based on a null hypothesis H_0 which assumes that there is no trend. It is tested against the alternative hypothesis H_1 which assumes that there is a trend. The Mann-Kendall test statistic S is given as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sign}\left(x_k - x_j\right) \quad (2)$$

where, x_k is the data value at time k, n is the length of the dataset and the sign ( ) is the sign function which can be determined as:

$$\text{Sign}\left(x_k - x_j\right) = \begin{cases} 1 \; if \left(x_k - x_j\right) > 0 \\ 0 \; if \left(x_k - x_j\right) = 0 \\ -1 \; if \left(x_k - x_j\right) < 0 \end{cases} \quad (3)$$

For n > 10, the test statistic Z approximately follows a standard normal distribution.

$$Z = \begin{cases} \frac{S-1}{\sqrt{S_v}} & if \;\; S > 0 \\ 0 & if \;\; S = 0 \\ \frac{S-1}{\sqrt{S_v}} & if \;\; S < 0 \end{cases} \quad (4)$$

where, S_v is the variation of statistic S. A positive value of Z indicates that there is an increasing trend in the time series and a negative value indicates a decreasing trend.

3.0 Results and Discussion

The time series analysis showed that the concentration of tropospheric ozone increased during the Harmattan period, November to February (Fig. 2). The increase in the emission of ozone precursors such as carbon monoxide (CO), oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) from transportation, industries, generators and power plants are responsible for the elevated concentration of tropospheric ozone in the study area. The tropospheric ozone production depends on the photochemical reaction of the Ozone precursors. Satellite images from NASA also showed that the tropospheric Ozone concentration increased from November to December (Fig. 3). The long-term trend also showed an increase in its concentration in March, May, and June (Fig. 4). There was a slight decline in the concentration of the tropospheric Ozone in April in the study area (Fig. 4).

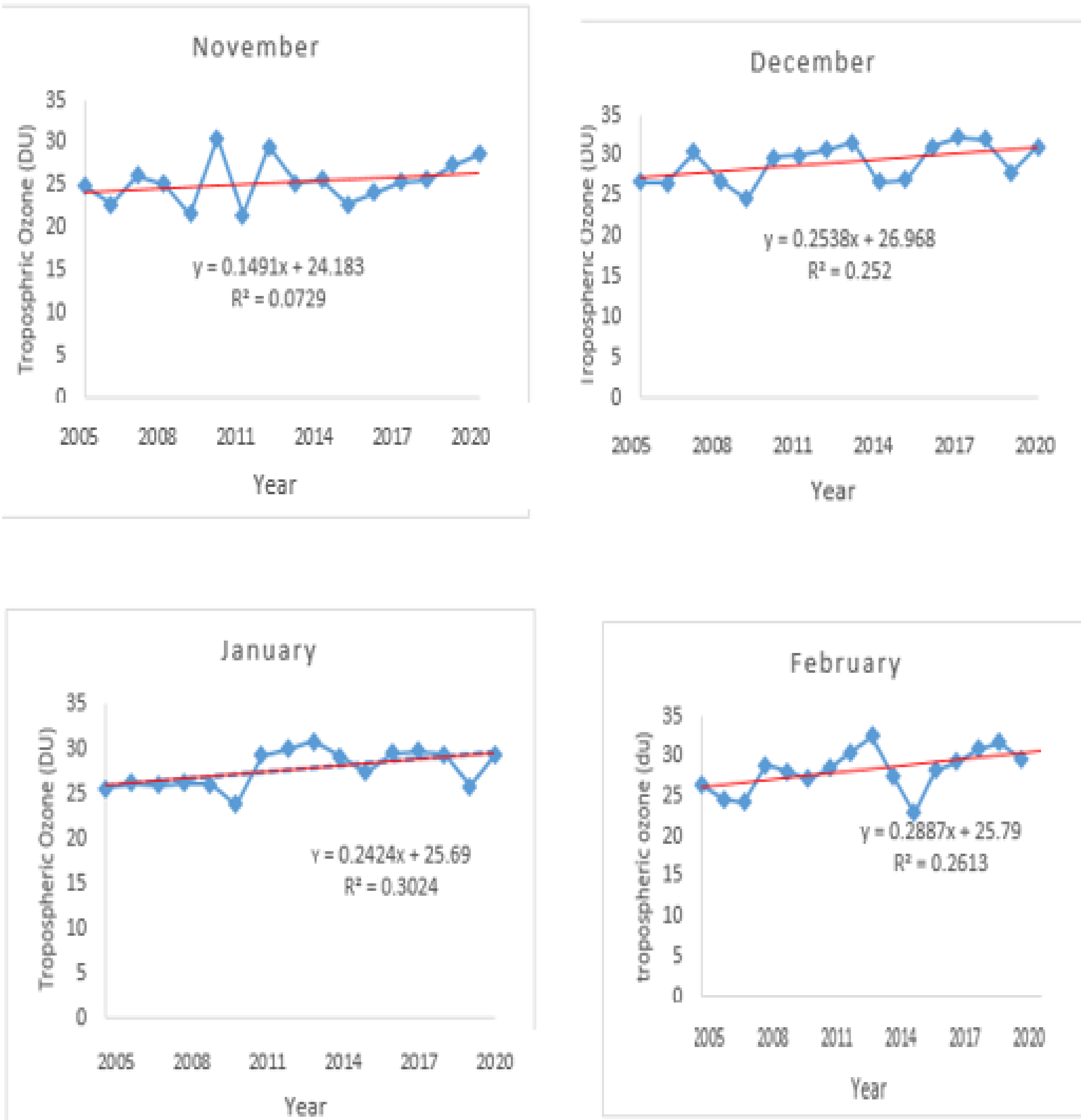

Fig. 2: Tropospheric Ozone concentration in the atmosphere for November to February during Harmattan showing an increasing trend during the period of the study.

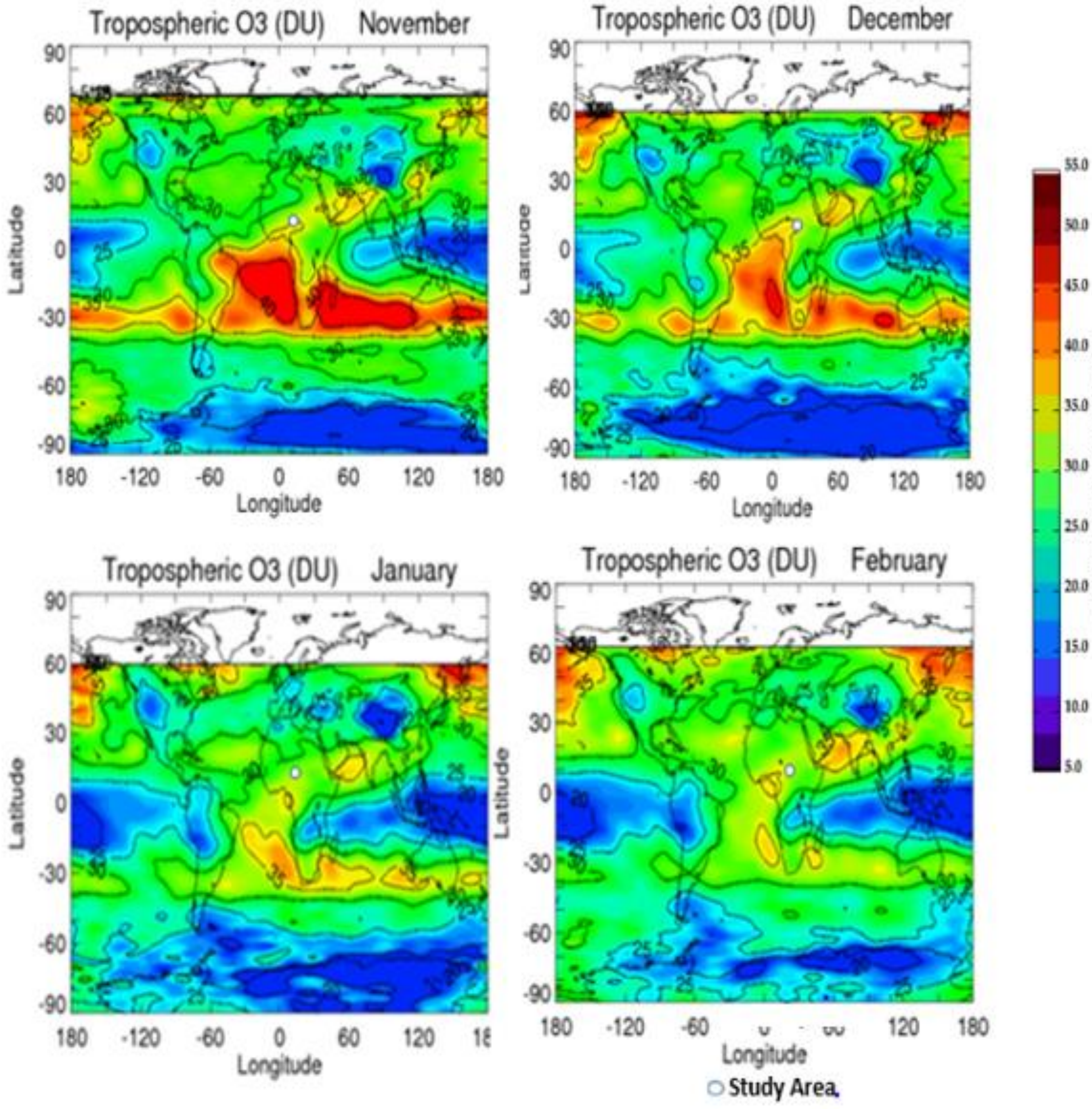

Fig. 3. Spatial distribution of tropospheric Ozone from November to February during the Harmattan period. There was a remarkable increase in tropospheric Ozone concentration from November to December (Image from NASA)

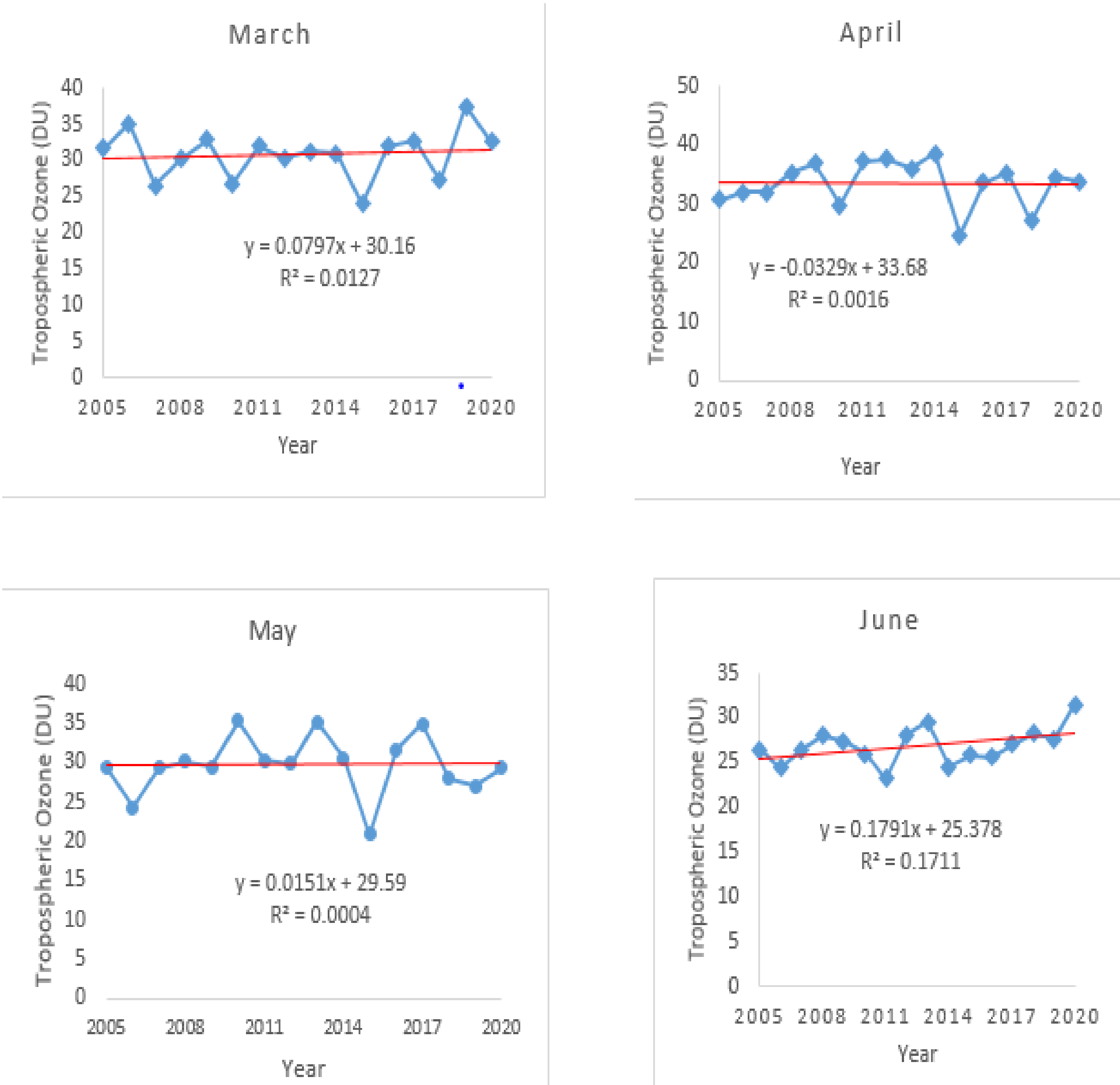

Figure 4. Tropospheric Ozone concentration in the atmosphere for March to June. During the dry season, there was a gradual increase in trend for March, May and June and a decreasing trend in April.

During the dry season, the concentration of the tropospheric ozone in the atmosphere in the study area is more than the World Health Organization standard limit of 50 ppb (100 µg/m^3). The average concentration of the tropospheric Ozone during the dry season is about 38 DU which is equivalent to 58.5 ppb (117 µg/m^3). This amount of tropospheric ozone in the atmosphere in the study area is considered deleterious to human health (Fig. 5).

The continuous increase in the concentration of tropospheric Ozone in the study area from 6.7% in July to about 25% in October during the study period showed that an increase in economic activities is associated with a large production of anthropogenic pollutants which give rise to elevated concentration of tropospheric ozone (Fig. 6).

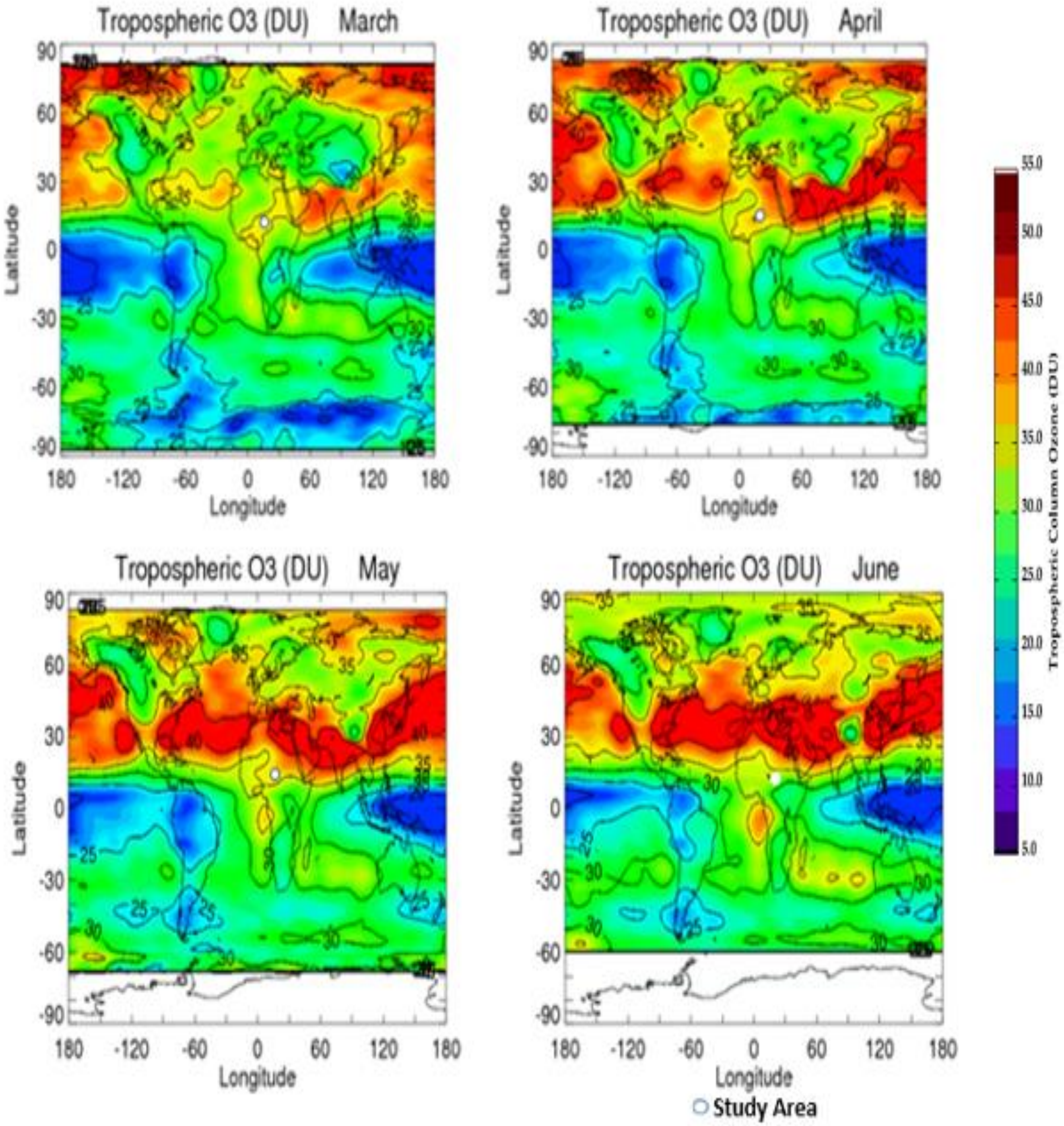

Fig. 5: Spatial distribution of tropospheric ozone from March to June during the dry season (Image from NASA).

Fig. 6. Tropospheric Ozone concentration in the atmosphere for July to October (Wet season) showed an increasing trend during the period of study.

The concentration of tropospheric ozone in the atmosphere decreases during the wet season. The rainfall washes away some of the Ozone precursors in the atmosphere and thereby lowers their concentration during the season. The tropospheric ozone is considerably reduced from July to October (Fig. 7). During the the wet season, the ambient air pollution in the study area is within the WHO permissible limits (Fig. 7). The time series analysis shows that the monthly tropospheric Ozone concentration during the wet season increases annually during the period of study.

The monthly average concentration of the tropospheric Ozone was maximum in April and minimum in September during the period of the study. The time series analysis of the tropospheric Ozone concentration in the study area showed that the Ozone concentration increased throughout the study except in the years 2006, 2015 and 2018 (Fig. 8). The concentration of tropospheric Ozone in the study area ranges from 17– 40 DU (26.1 to 61.5 ppb) during the period of the study. According to the WHO guideline, the level of tropospheric Ozone should be less than 50 ppb (100µg/m^3) daily 8-hours average with a potential level of 30 ppb (WHO, 2006). With regards to the WHO standard guidelines on tropospheric Ozone concentration in the atmosphere, it is obvious that the study area is polluted. Time series analysis of the maximum temperature data obtained from the study area showed an increasing trend in the maximum temperature of the area (Fig. 9)

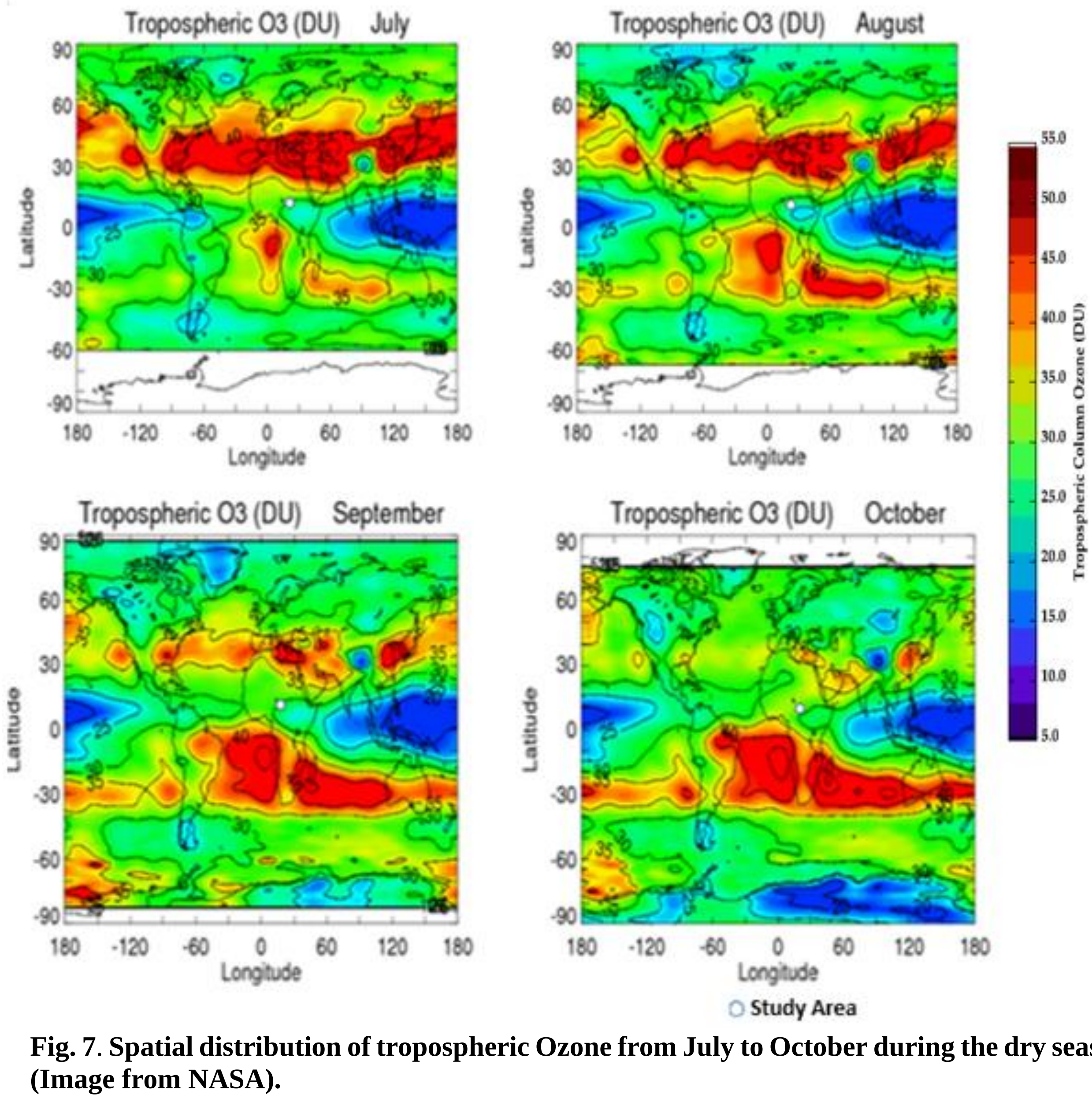

Fig. 7. Spatial distribution of tropospheric Ozone from July to October during the dry season (Image from NASA).

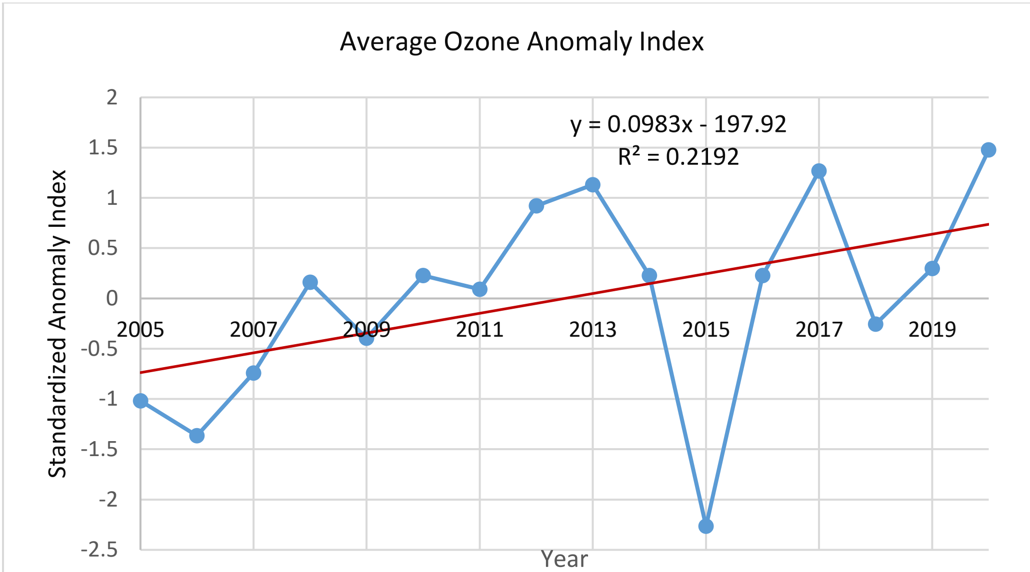

Fig. 8. Average annual Tropospheric Ozone anomaly index for the study period (2005-2020), the anomaly index showed an increasing trend throughout the study except for the acute decline in the year 2015.

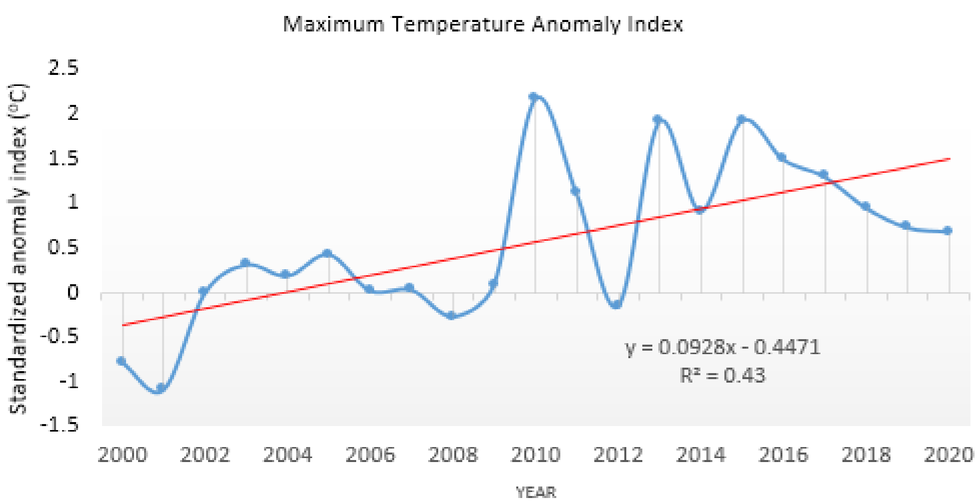

Fig. 9: Annual maximum temperature anomaly index of the study area for the period 2000 to 2020 indicating that the increasing trend in the tropospheric ozone concentration is associated with an increase in temperature.

The continuous increase in the maximum temperature of the study area is an indication that the increase in tropospheric ozone is associated with global warming. Given the observed results, the tropospheric ozone pollution might have affected the health of the people in Maiduguri and its environs. Since air pollution is known to be associated with health hazards, it might have caused a wide range of health complications which includes Pneumonia, chronic obstructive, pulmonary diseases, asthma, allergic rhinitis, and other respiratory diseases associated with premature mortality in the study area. The findings of this study give credence to the UNICEF report in 2019 which indicated that about 185 children under the age of five (5) years die every day from Pneumonia due to air pollution in Nigeria. The results showed seasonal variations which indicate that the concentration of the tropospheric Ozone is higher during the dry season than in the wet season. The results obtained in this study are in agreement with similar findings by Elizabeth (2019) who stated that an increase in tropospheric Ozone concentration contributes to rising global temperature. The findings of this study also agreed with the report of Ogugbuaja and Barisa (2001) which stated that the air in Maiduguri is polluted.

Given the large population of Maiduguri and its high industrial and commercial activities, it is obvious that vehicular and industrial emissions are the main sources of the tropospheric ozone pollution in the area. In Maiduguri, there is a large number of heavy duty vehicles, commercial buses, cars and tricycles. These vehicles emit an enormous amount of chemical compounds due to the incomplete combustion of fossil fuels. Emissions from factories and industries, many of which depend on diesel fuels produce large amounts of gaseous and liquid waste pollutants which are not monitored by the Environmental Protection Agency (EPA). These released pollutants pollute the atmosphere and groundwater resources in the area. Most of the solid industrial and domestic wastes generated in the metropolis area are not properly disposed of. They are mostly disposed of by burning. These wastes which are rich in organic and inorganic materials such as plastics, rubbers, electronic waste and batteries release toxic fumes into the atmosphere when burnt and thereby pollute the air in the area. Tropospheric Ozone is mostly released into the atmosphere through vehicular emissions and improper management of industrial effluents and solid wastes. A large number of the ozone precursors are transformed into tropospheric Ozone through a photochemical reaction.

The continuous emissions of these air pollutants affect the air quality in the study area, and if not monitored and abated there will be an escalation of health hazards associated with air pollution. The results of the analysis of the distribution of the tropospheric Ozone data obtained from Maiduguri showed that the urban atmosphere is polluted and the tropospheric Ozone concentration in the atmosphere gradually increases during the period (2005-2020) of the study.

4. 0 Conclusion

This study presents the variation in tropospheric ozone concentration in different months during the period 2005 to 2020. The results of the study showed that tropospheric ozone concentration in the atmosphere in the study area is increasing and if not monitored, it could lead to serious health effects. The monitoring of ozone pollution in the atmosphere in an industrial city such as Maiduguri is very important due to its effects on public health and the environment. The results of the study showed that the concentration of tropospheric ozone in the atmosphere in the study area exceeds the acceptable standard. Therefore, there is a need for monitoring tropospheric ozone levels in Maiduguri metropolis to ensure that compliance with air quality regulations is enforced. Children, the elderly and people living with health challenges such as cardiovascular diseases are mostly at great risk of the adverse health impacts of tropospheric ozone. Variations in the tropospheric ozone peaked during the dry season at about 40 DU, possibly due to intensive solar radiation. Given the adverse health effects of tropospheric ozone, there is a need for regular assessment of ozone concentration in the atmosphere to make informed decisions and policies that will help to protect public health from air pollution. Considering the elevated concentration of tropospheric ozone in the study area, it is therefore recommended that there should be strict and increased regulations on anthropogenic emissions mostly from fossil fuels. Because of the results obtained, the findings of this study are in agreement with similar findings reported by other researchers (Ogugbuaja and Barsisa, 2001; Elizabeth, 2019; and UNICEF, 2019).

5.0 *Acknowledgement*

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