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Regional Assessment of Remotely Sensed Surface Concentration of Sulphur Dioxide in Nigeria from 2003 to 2019 using Nasa Giovanni Air Quality

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Abstract:- Nigeria, a populous developing West African country is grappling with air pollution. Several activities like gas flaring, oil bunkering, oil explosion, oil exploitation and production, and other anthropogenic activities has led to increase in criteria pollutants. So many studies have shown air quality over Nigeria to be in exceedance to the air quality as recommended by World Health Organization (WHO). Sulphur di oxide (SO_2), a criteria pollutant; present itself as byproducts of fuel combustion. Nigeria is a fuel exploitation country. Surface Concentration of Sulphur Dioxide in Nigeria from 2013 to 2018 was assessed over Nigeria using Giovanni remote sensing. Descriptive analysis, regression and moving averages were used in the analysis using Excel and SPSS version 2.3. For a total observation of 192, a multiple r of 0.126 was obtained, while R^2 of 0.015835 and a standard error of 1.88 $x10^{-10}$ were obtained. A p value of 0.00425 was obtained. In the study, the year 2014 and 2015 recorded the least annual concentration, they recorded 3.4 x $10^{-10}Kgm^{-3}$ respectively. The highest concentration of 4.8 $x10^{-10}$ Kgm^{-3}, 4. $X10^{-10}$ Kgm^{-3}, 4.3 $x10^{-10}$ Kgm^{-3} and 4.2 $x10^{-10}$ Kgm^{-3} were recorded in the years 2005, 2003, 2004 and 2008 respectively. The highest concentration, for all the sampled year, was observed in the season of December, January, February (DJF) with December while the least concentration for all the years was recorded in August which falls into June July and August (JJA) season.

***Keywords**:- Criteria, Pollutant, Air Quality, Sulphur, Dioxide, Surface, Mass, Concentration.*

I. INTRODUCTION

Globally, air pollution exposure has been linked to poor health and even fatality (Wanyonyi, 2019). Urban Cities has linked increased rates of death in developed and developing countries to air pollution (Bryson, 2019). Other studies by some researchers also showed a relationship between air pollution and respiratory illnesses such as allergies, asthma, chronic obstructive pulmonary disease and lung cancer increases with exposure to atmospheric air pollutants (WHO, 2020; Onyango, 2019; Xu, Li, and Huang, 2017; Liu, Bartonova, Schindler, Sharma, Behera, Katiyar, and Dikshit, 2013).

An epidemiological study, by Olowoporoku, Longhurst and Barnes, (2012), showed a growing evidence of relationship between air pollution and mortality in Lagos. Nigeria has been accused of having air quality which exceeds World Health Organization (WHO) guidelines (Efe, 2008; Olowoporoku, 2011; Parke, 2016; Cunningham, 2018). Air pollution has been identified as a crucial environmental problem in Southern Nigeria (Ana, 2011). Some cities in Northern Nigeria has also been identified as having concentration of Particulate Matter (PM) at dangerous concentration to human and the environment (Cunningham, 2018).

Sulphur dioxide (SO_2), a gaseous criteria pollutant, is a toxic gas. It is a colourless gas with a choking or suffocating odour (NIH, 2019). When breathed in high concentration, SO_2 affects human health by irritating the nose, throat, and airways giving a tight feeling around the chest which results in coughing, wheezing and shortness of breath (Miller, 2017; USEPA, 2015; US Code 2018; Australia, 2005). SO_2 reacts easily with other substances in the atmosphere to form harmful compounds, such as particulate matter (EPA, 2019). It is corrosive and heavier than air (NIH 2019; Brandt and Ratnayaka, 2017). Any substance which when present in large quantity in the air harms humans, animals, the environment and material is seen as a criteria air pollutant (NIH, 2019).

Criteria pollutants are known to cause health problems in human beings and damage the environment (Public Health, 2019; Just Facts, 2019; EPA, 2017). SO_2 is an aggressive pollutant which occurs naturally from volcanoes and its anthropogenic sources occurs in form of burning of fossil fuel and other combustible activities (Hooke et al 2019, Riordan and Adeeb, 2004; Vargel, 2004). Their emissions in air if at high concentration lead to formation of other sulphur oxides (SOx). SO_2 in the atmosphere is easily soluble in water. It comes down as acid rain, when in high concentration, giving off Sulphuric acid, sulphurous acid and sulfate particles (Jain and Domens, 2016; Forensic Polymer Engineering, 2010; Dean, 2001). The reactions are as seen in equations 1, 2 and 3.

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$SO_2 + OH\cdot \rightarrow HOSO_2$ ……………………….1

$HOSO_2\cdot + O_2 \rightarrow HO_2\cdot + SO_3$……………………2

$SO_3\ (g) + H_2O\ (l) \rightarrow H_2SO_4$ (aqueous)…………………...3

Monitoring of air pollution is limited across Africa (Petkova, Jack, Volavka-Close, and Kinney, 2013). In Nigeria, cities like other West African cities, hardly monitor air pollution. This is due to lack of air quality monitoring stations in these cities (Fowler, 2020).

In developed countries, regular monitoring of air pollutants, has shown a visible decline of SO_2 over the years through controls implemented under the United States Environmental Protection Agency's (EPA). Miller (2015) opined that Sulphur dioxide emissions decreased significantly in developed countries unlike in Africans countries like Nigeria where monitoring of air pollutants is not consistent. This may be due to lack of Air Quality Index of sulphur dioxide in the cities and in Nigeria at large. This lack coupled with lax environmental rules and corrupt governance has continually exposed Nigeria populace to poor air quality.

Ambient (outdoor air pollution) is a major cause of death and disease globally (WHO, 2020). In 2018, WHO revealed that an estimated seven million people worldwide die every year from outdoor and household air pollution (Ojewale, 2019). Nearly 90% of the 4.2 million premature deaths due to ambient air pollution occurred in low and middle income countries (WHO, 2020). This may be due to the fact that developing countries experience burden of chronic and infectious diseases arising from living air pollution especially those living in slum and poor environmental conditions (Onyango, 2019). By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma (WHO, 2017). Federal Environmental Protection Agency of Nigeria (FEPA) bench mark for sulphur dioxide is 0.01ppm.

Sulfur dioxide is present in motor vehicle emissions, as the result of fuel combustion. Fuel consumption becomes extremely high under traffic congestion (Onyango, 2019). There is a significant health problem associated with it (Libby, 2016). Petroleum industry is a major source of air pollution in Niger delta region of Nigeria due to oil exploitation. Hooke et al (2019) opined that in Lagos travels are mainly by road which implies heavy traffic jams in the city and

Nigeria has been importing fossil fuel with high level of sulphur higher than those exported to developed world. Nigeria and other West African Nations are being pushed to ban high sulphur content fuels which has been banned in Europe and United States for years (Libby, 2018). In urban areas, burning fossil fuels emits sulphur dioxide into the atmosphere where, unless it is rinsed with rain, it will accumulate. For developed countries, Transport (cars, industrial vehicles) is not a significant source of sulphur dioxide, especially since in Europe the sulphur concentration in diesel and fuel has been decreased from 0.20 to 0.05 % (Vargel, 2004).

Satellite data can fill the coverage gaps in the existing network to support routine monitoring Measurement of atmospheric trace gases by remote sensing utilizes scattered sunlight from space, using unique absorption features in the ultraviolet region (Lee, 2019).Satellite remote sensing uses spectral fit technique to measure tropospheric trace gases on regional and global scales (Lee, 2019).

II. MATERIAL AND METHOD

- *Study Sites:*

Nigeria, a tropical West African country, is situated between longitude 2.5°E to 14.0°E and latitude 4.0°N to 14.5°N. It shares border in the East with Republic of Cameroun while Republic of Benin while lies to the West. The Northern part of the country shares its boundary between Republic of Niger and Republic of Chad. A natural boundary with Atlantic Ocean is witnessed in the South as the country empties into the Ocean.

Fig 1 Map of Nigeria

- *Methodology:*

Annual Surface Mass Concentration (Ensemble) of SO_2 for Nigeria was assessed from Geo-spatial Interactive Online Visualization aNd aNalysis Infrastructure (GIOVANNI) at https://giovanni.gfsc.nasa.gov for the years 2013 to 2019 using remote sensing. A monthly 0.5 x 0.625 deg. on MERRA-2 Model (M2TMNXAER v5.12.4) in kg m^{-3} for January 1st 2013 to December 31st 2019, for a Region of 2E, 4.2N, 14.7E, 15N

GIOVANNI is a Web-based online tool which aims at aiding several researches by using remote sensing, in-situ and model data sets and tools to inform the collaborative development of the Air Quality scenarios (Acker, et al 2007). It was developed by NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC). It facilitates rapid data exploration and basic data analyses using only a Web browser. Spatial selection of Nigeria was chosen, with Sulphur dioxide (SO_2) as parameter under Atmospheric Chemistry. Data from GIOVANNI was obtained from the platform. A time series plot for surface concentration of SO_2 was obtained and is as plotted in figure 2.

Statistical data analysis was done using SPSS version 2.3 Statistical scatter graphs and average mean were plotted using descriptive statistics

III. RESULTS AND DISCUSSIONS

From figure 2, Nigeria experienced a regular sinusoidal plots for SO_2.This can be seen in both figures 2 and 3. A visible slight decreasing trend was also witnessed in figure 2. The year 2003 witnessed a regular increase through 2004 culminating in 2005.

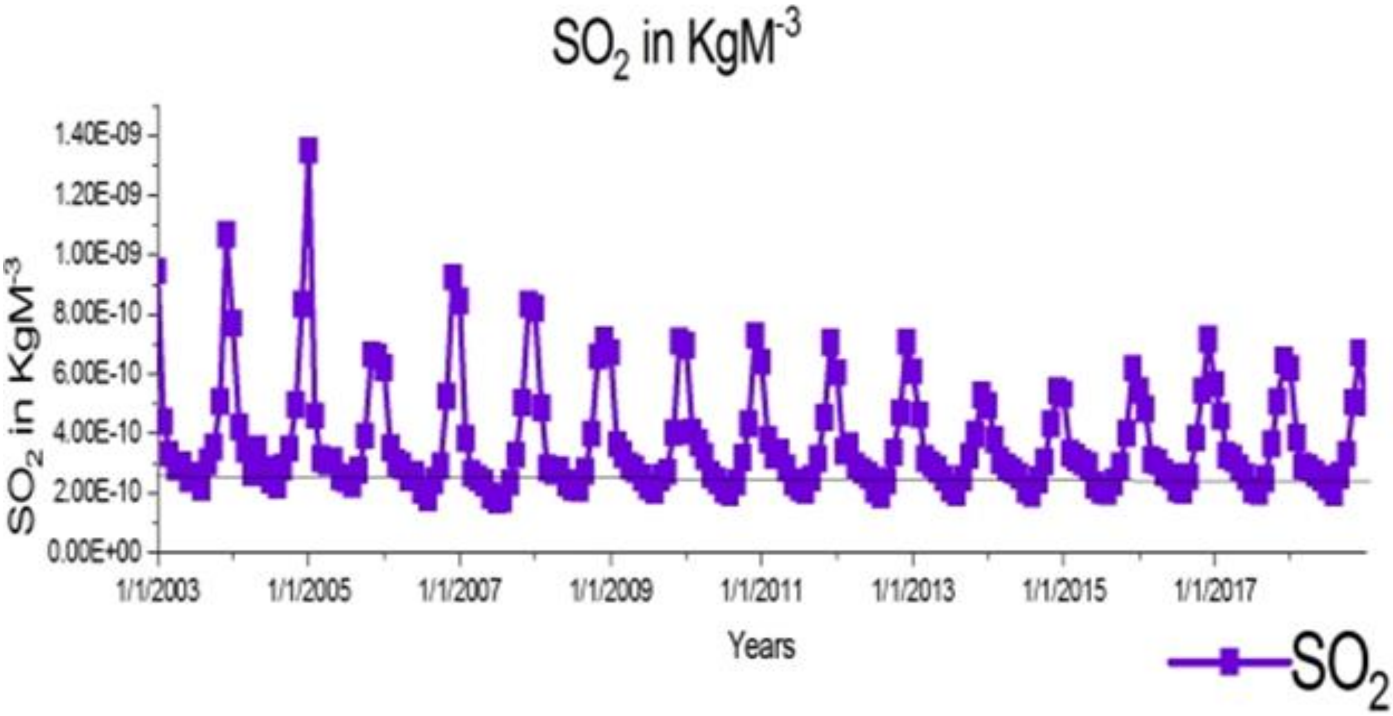

Fig 2 A time Series Plot of Surface Mass Concentration of SO_2 from 2003 to 2019

From 2005, there is a gradual decrease till 2014 and then a slight gradual increase culminating in January 2017. A slight decrease was witnessed from 2017 through 2018 to 2019. For the seventeen years of study, the general trend for all the study years is a negative secular trend indicating a gradual decrease in mass concentration of SO_2. Also shown in figure 2 are peaks and troughs occurring at regular intervals around the same months indicating an annual seasonal variability.

- *Monthly Concentration of SO_2*

Figures 2 and 3 shows the peaks and troughs occurring in a regular annual pattern showing seasonality. From January there is a decreasing downward trend which culminated with a minimum curve varying between July and August depending on the years. A visible upwards trend is witnessed from the minimum curve culminating in a maximum in December as seen in figure 4. This pattern gives an annual sinusoidal curve repeated annually for all years with high concentrations recorded around January and December, the peak of dry season. Similarly minimum curves were recorded between July and August indicating rainy season. The implication of low concentration during the rainy season shows that SO_2 can be dispersed by wet deposition or rain washout. The monthly curves for all the years is as shown in figure 4.

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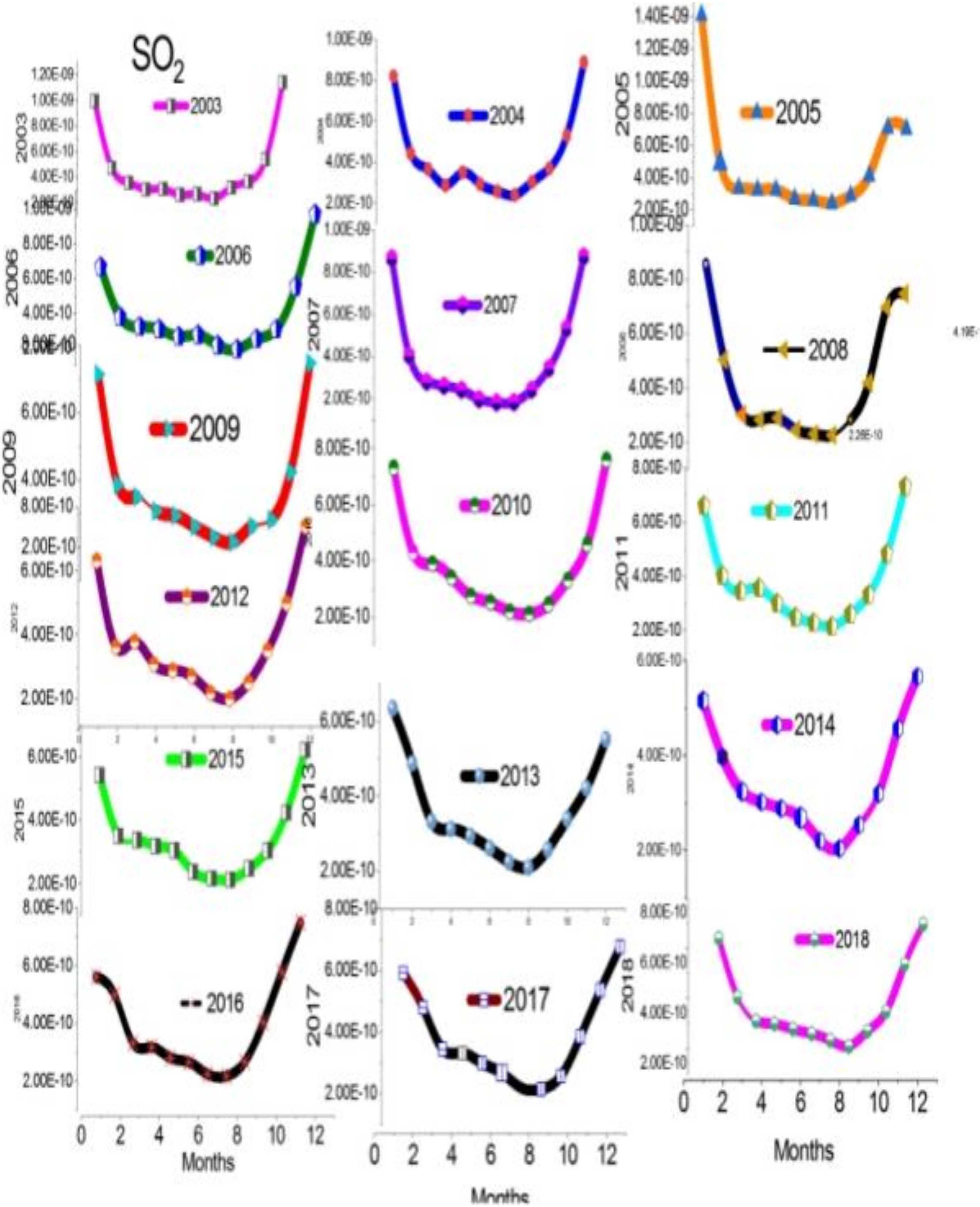

Fig 3 Monthly Concentration of SO_2

➢ *Annual Concentration of SO_2*

For all the years, the highest annual concentrations were recorded in the months of January and Decembers, followed by November and February as seen in figure 3. The least concentrations were witnessed in August, July and June which occurs in the rainy season other months with lower concentrations were April, May, September, March and October. The highest concentration for all the studied years was recorded in the month of January for the year 2005.

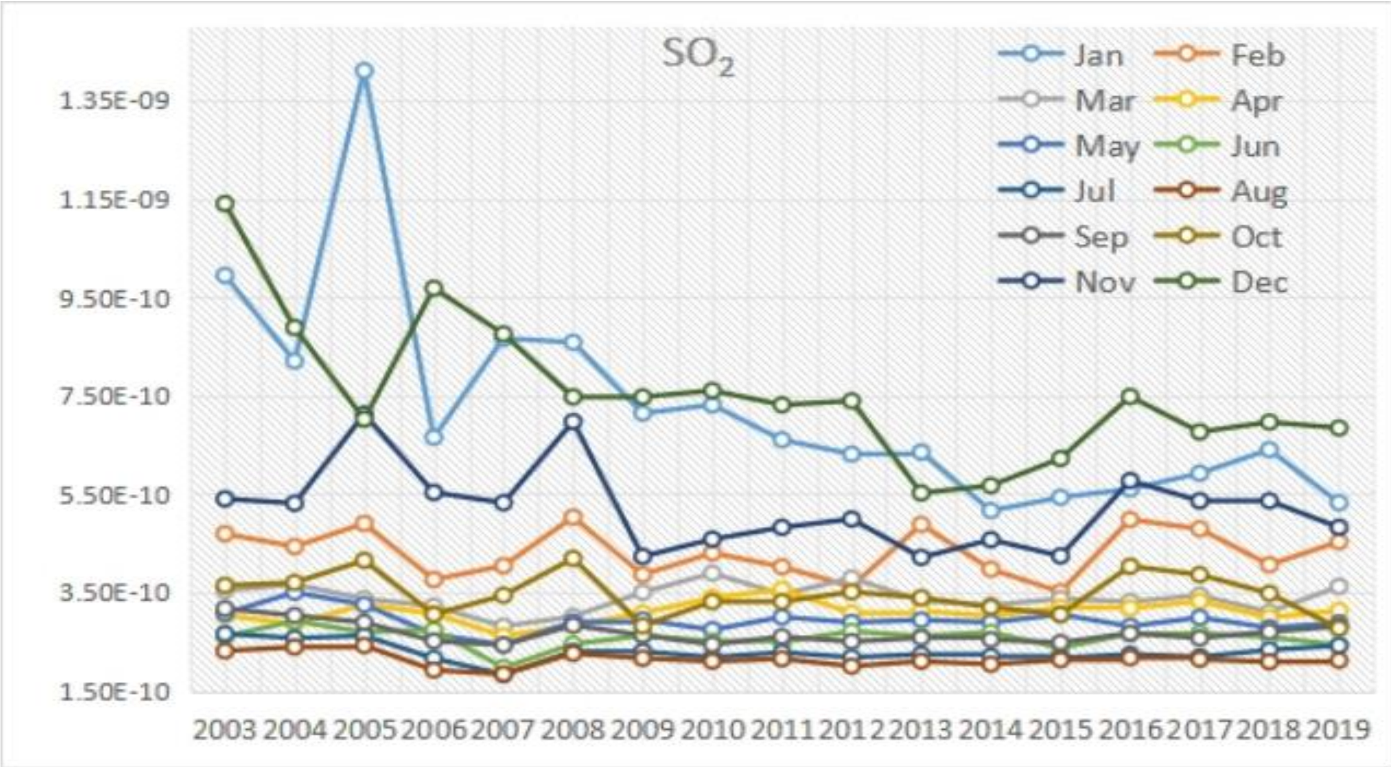

Fig 4 Annual Concentration of SO_2

➢ *Annual Average Surface Concentration SO_2*

The average annual concentration for each year is shown in figure 5. From this figure, the years 2014 and 2015 each recorded the least annual concentration, they recorded 3.4 $x10^{-10}$ Kgm^{-3} respectively. Other years which witnessed low concentration are 2013 and 2019, each recorded 3.6 $x10^{-10}$ Kgm^{-3}.

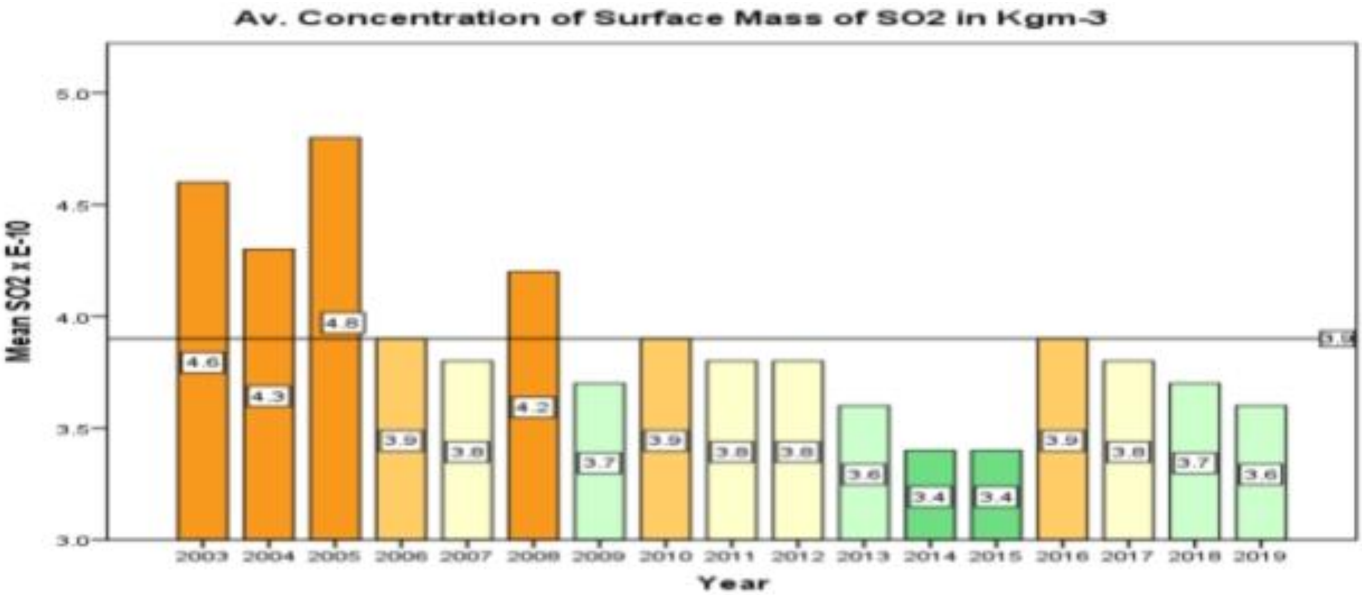

Fig 5 Annual Average Surface Concentration SO_2

A concentration of $3.7x10^{-10}$ Kgm^{-3} was recorded in 2008 and 2018 while the years 2007, 2011, 2012 and 2017 recorded 3.8 $x10^{-10}$ Kgm^{-3}. An average annual concentration of 3.9E-10Kgm^{-3} was recorded in 2006, 2010 and 2016. The years 2008, 2004 and 2003 recorded high concentrations of 4.2 $x10^{-10}$ Kgm^{-3}, 4.3 $x10^{-10}$ Kgm^{-3}, 4.6 $x10^{-10}$ Kgm^{-3} the year 2005 recorded the highest concentration of 4.8 $x10^{-10}$ Kgm^{-3} respectively.

A moving average of four years MA (4) was used to forecast the mass concentration of SO_2. The forecast showed regular pattern indicating a sinusoidal wave with regular crests and troughs. This moving average (MA) eliminated noise in the plot a showed a declining negative trend in the concentration of SO_2 over the years.

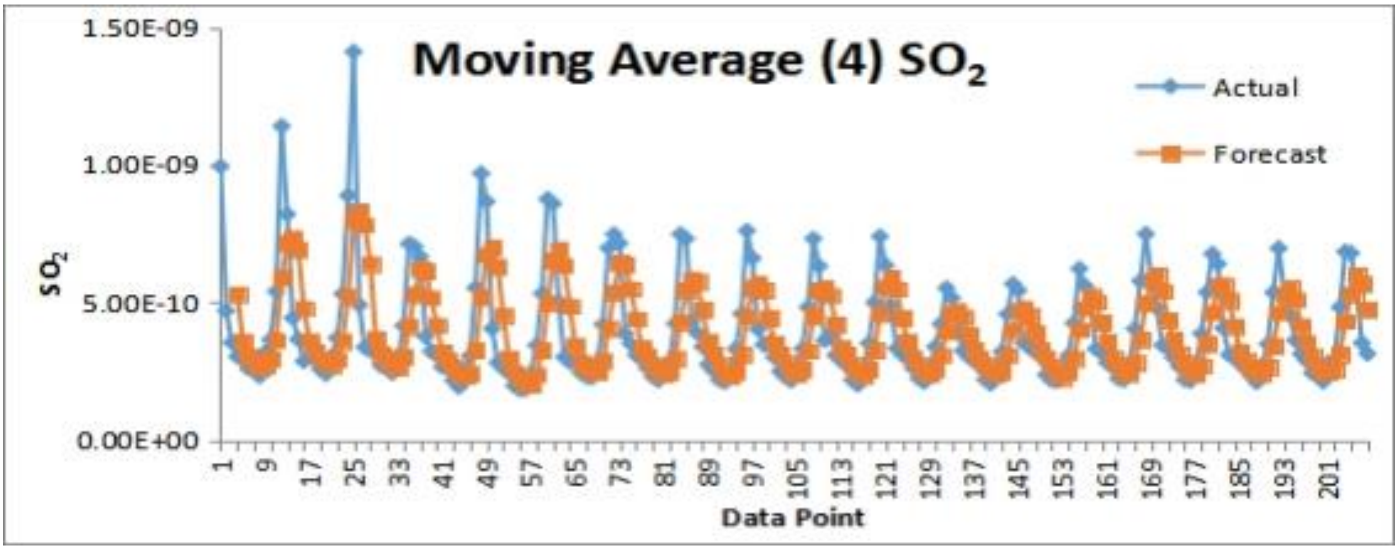

Fig 6 Moving Average of SO_2

From a regression analysis conducted for Surface Mass Concentration of SO_2 from 2003 to 2019, for a total observation of 192, a multiple r of 0.126 was obtained. R^2 of 0.015835 and a standard error of 1.88 $x10^{-10}$ were obtained. A p value of 0.00425 was also obtained.

IV. RECOMMENDATION

- *Gas flaring in Nigeria should be stopped*
- *Modern ways of oil exploitation should be embarked upon*
- *De congestion of road transport should be encouraged*
- *building of more railway lines and use of trains should be adopted*
- *develop monitoring mechanism for air pollutants*
- *enforce measures and regulations on environmental air pollution*

- *Trend*

Recently in Nigeria, Lagos State Governor has promised to build, six air quality monitoring stations in Lagos to help the state monitor air pollution (PM news, 2019). Globally, NASA, South Korea, and the European Space Agency will be working together to produce Hourly data base that will capture air pollution Hourly (Calmar, 2020). This will aid in giving a more accurate picture of air pollution globally. A railway line connecting Abuja to Kano state and beyond has been concluded.

V. CONCLUSION

There is a pronounced seasonal oscillation of SO2 with high levels observed during the dry season this shows that there is a cleansing of the environment during the rainy season as pollutants are washed out from the atmosphere during the rains. This can account for the low concentration of SO_2. Concentration of SO_2 is affected by rainy and dry seasons Surface concentration of sulphur dioxide in dry season was found to be high especially during the peak of dry season in December and January. The years 2005 and 2003 recorded high concentrations of 4.8 $x10^{-10}$ Kgm^{-3} and 4.6 $x10^{-10}$ Kgm^{-3} respectively, while the years 2014 and 2015 each recorded the least concentration of 3.4 $x10^{-10}$ Kgm^{-3}. Proactive measures on combating air pollution in the country should be ensured by both Government and individuals in areas like industries, gas flaring, vehicles and transportation sectors, refuse disposal, energy sector and domestic burning of bushes for agriculture.

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