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Sampling Five Criteria Air Pollutant over Nigeria from 2005 to 2018 using NASA GIOVANNI Air Quality

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Abstract:- In this study, regional air pollution across Nigeria was studied for five criteria air pollutants. The pollutants are carbon Monoxide (CO), Sulphur Dioxide (SO_2), Ozone (O_3), Aerosol Optical Depth (AOD) at 550nm, and Nitrogen Dioxide (NO_2).These criteria air pollutant were assessed from NASA GIOVANNI air quality platform. The data obtained was analyzed using a time series analysis. Three of the variables, CO, NO_2 and SO_2 showed a slight decline in the concentration of pollutants across the years. A Principal Component Analysis (PCA) statistics conducted in the study revealed that annual CO, NO_2 and SO_2 were positively correlated while AOD showed a very weak correlation with CO, SO_2 and NO_2. Ozone negatively correlated with all other variables. A Hierarchical Cluster Analysis (HCA) conducted grouped the pollutants into two major groups which agreed with the Principal Component Analysis (PCA) which grouped the pollutants into two component.

Keywords:- *Criteria Pollutants, Air Quality, Ozone, Nitrogen Dioxide, Carbon Monoxide , Particulate Matter ,Sulphur Dioxide.*

I. INTRODUCTION

Nigeria, a tropical country in Sub Saharan Africa (SSA), is fast urbanizing and has several overpopulated cities with new ones springing up at a very fast rate. The urbanization and rapid growth of these cities though a welcome situation, has elicited several environmental challenges including air pollution (Marais et al., 2014). Clean air is a great requirement for the health and well-being of the citizens in every environment (Hassan and Abdulahi, 2012; Mohammed and Caleb, 2014). Ambient air pollution, is a major threat to human health (Encyclopaedia.com, 2020; Ana, 2011). Nearly 1.4 billion urban residents in the world breathe air that does not match WHO air quality standards (WHO, 2016).

Air pollution largely affects those living in large urban areas, where road emissions, industrialization, heavy dependence on generating set, urbanization, poor waste management and overpopulation each contribute to the degradation of air quality. IAMAT (2021), an International Association for Medical Assistant to Travelers, defines ambient air pollution "as a combination of chemicals, particulate matter, and biological materials that react with each other to form small hazardous particles".

Numerous political challenges like insecurity, lack of basic amenities, political crisis and so on has engrossed Nigeria and distracted the Government from paying attention to life threatening concerns like air pollution and poor air quality in the country. The country suffers from lack of enforcement of legislative laws to protect the citizens and the environment from air pollutions. The laws though enacted are not enforced. Non enforcement of these laws has led to proliferation of anthropogenic activities that can harm both the environment and the citizens.

Anthropogenic activities like inadequate supply of energy aggravates air pollution. Provision of fundamental amenities like basic electricity are so unpredictable in most of the urban cities. This lack has forced many citizens to depend solely on generating sets. Kemper & Chaudhuri, (2020) in their study opined that Nigeria's lively economy, its large population and unreliable power sector have led to a heavy dependence on backup generators. Fumes from numerous generating sets when there is no electricity is enough to cause regional air pollution. Poor waste management and heavy traffic jams are not left out in hiking up air pollution in the region (Marais et al, 2014).

Air pollution is known to cause several health challenges and even mortality. According to Piotrowska, Kordylewski, Ciolek, and Moscicki (2010) air pollution is assumed to be accountable for more than five million deaths annually. Air pollution is known to cause one in eight deaths globally (WHO, 2016).The World Health Organization (WHO) reports on six major air pollutants, namely particle pollution, Ground-Level Ozone, Carbon Monoxide, Sulfur Oxides, Nitrogen Oxides, and Lead (Manisalidis, 2020). These pollutants are referred to as "Criteria pollutants" (EPA 2018). Criteria pollutant is a term used internationally to describe air pollutants that have been known to cause havoc to health and the environment (EPA 2018).

Carbon monoxide (CO) is a colourless, odourless and tasteless toxic gas which is not easily detected (Katulski, Namieśnik, Sadowski, Stefański and Waldemar 2011). The major source of CO is vehicular emissions especially in the process of incomplete combustion (EPA 2019, Ogunseye 2018, Olowoporoku et al., 2012). Transportation accounts for 70 to 90% of total CO production (Rodrigues 2017; Kho, Law, Ibrahim and Sentian 2007). Carbon monoxide exhibits locally elevated or depleted concentrations in the vicinity of sources or sinks respectively. It has 6 times greater affinity to blood than oxygen (Saif, 2018; Kayode & Kamson,

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2013), stressed that due to CO high affinity for haemoglobin, most of the absorbed carbon monoxide will be found in the blood of the victim as carboxyhemoglobin (COHb). EPA retained the primary standards at 9 parts per million (ppm), 8-hour average and 35 ppm, 1-hour average, neither to be exceeded more than `once per year (EPA 2010).

Sulphur dioxide is a colourless toxic gas with a suffocating odour when inhaled (Exhaust Gas Cleaning System Association (EGCSA), 2019), Anthropogenic sources of SO_2 is produced by numerous activities from fossil-fuel. These activities include burning coal and petroleum, petroleum refining and transportation sources (EPA, 2019). It can cause severe irritation of the eyes nose and throat (EPA 2019, Riordan and Adeeb 2004). It irritates and burns the skin (Canadian Centre for occupational Health and Safety (CCOHS), 2019). SO_2 in the atmosphere easily dissolve in the rain and falls in form of sulphurous acid (H_2SO_3) and Sulphuric acid (H_2SO_4). The equation is as shown below:

$$SO_2 + H_2O + \tfrac{1}{2}O_2 \rightarrow H_2SO_4 \text{..........................} 1$$

SO_2 hinders the process of chlorophyll production. It slows down photosynthesis process of the plants by damaging plant cells. Highly concentration sulphur dioxide stiffens flower buds leading to eventual falling off of the flower buds, a process which not only affect the plant but eventually affects the crop yield (EPA 2019, Environmental Chemistry 2019).Sulphur di oxide (SO_2) pollution reduces visibility. They form secondary particles mainly sulphates which reduce visibility (EPA 2019). Concentrated SO_2 in the atmosphere attack and damage monuments and artifacts. SO_2 pollutants is often the dominant variable affecting the rate of corrosion and is seen as the most important, in deterioration of artifact materials like stones used in historic and cultural monuments (EPA, 2019). SO_2 can be transported and dispersed through long distances. In the process of transportation SO_2 reduces over the distance. SO_2 reacts with other atmospheric components like water, Nitrates, Oxygen and hydroxyl radicals (OH) to form Sulphuric acid, sulphurous acid (H_2SO_3) and various sulphates. This process act as a mode of dispersion as some of them fall out as particulate matter (PM).

Ozone (O_3), is classified into two types' namely: stratospheric ozone and tropospheric or ground level ozone. Low level ozone or ground level ozone is an atmospheric pollutant while stratospheric ozone is the good ozone (O_3). Stratospheric ozone regulates the transmittance of ultraviolet light to the surface of the earth, Air Pollution Information System, (APIS 2019). The lifetime of atmospheric tropospheric ozone is about 22 days. From studies, the high concentrations of O_3 in surface air arise from high emissions of NOx and of various reactive hydrocarbons. It can trigger a variety of health problems, particularly for children, the elderly, and people of all ages who have lung diseases such as asthma.Exposure to high concentrations of ground level ozone tend to reduce physical performance. Exposure to outdoor activities, as the increased ventilation rate during physical exercise increases the effects of exposure to ground-level ozone.Ozone effects can be short-term exposure or long term exposure during the growing season of plants. Some of the exposure lead to visible leaf damage and premature aging of leaves. Ozone also affects the environment by the formation of Smog. Smog occurs when high concentrations of ozone precursor's pollutants coincide with weather conditions for ozone production, like sunshine.

Particulate Matter (PM), occur in variable sizes. They have small diameter. They penetrate into the respiratory system through inhalation, causing respiratory diseases, cardiovascular diseases, central nervous system dysfunctions, and cancer (Manisalidis, 2020). Anchordoqui 2020 in their study classifiedthe novel SARS-CoV-2 virions as PM since they have similar characteristic likeother air pollutant with a determined settling velocity depending on the particulate size (Onyeuwaome et al 2021).Scientists have found that the air pollution especially aerosols of small diameter absorbs and disperses sunlight, and thereby reduces the amount that reaches the Earth's surface (Technology Networks, 2021). Major sources of particulate matter include wind-blown dust, emission from heavy transportation, power plants, mining sites, volcanic eruptions, bush burning and from agricultural activities (Ngene & Onwu, 2015). Transportation of fine aerosol particles can go over thousands of miles away from the source depending on the size of the particles (Ibe, Opara, Duru, Obinna & Enedoh, 2019). Aerosol particles can disperse or scatter sunlight, resulting in less of it actually arriving on Earth if the concentration of the pollutant (Tech network). Solar radiation from the sun delivers energy to Earth's surface in the form known as surface solar radiation (SSR).

The pungent red-brown NO_2 is a very important air pollutant that causes severe air quality degradation (Ibe et al., 2021)

Air quality in Nigeria is considered unsafe (IAMAT, 2021). Air pollution in Nigeria is estimated to cause about 11,200 premature deaths which is the highest in West Africa (Kemper & Chaudhuri, 2020). Some studies on air pollution in Nigeria has shown air pollution exceeding WHO guidelines in some cities in Nigeria. (Parke, 2016; Ana, 2011). There is seasonal variation of air pollutants. Air pollution is seen to be in high concentration during the dry season. David-Okoro et al (2020) in their work found that the concentration of CO was higher during the dry season than in the rainy season. A recent data on $PM_{2.5}$ showed a concentration of 72ug/m^3 which is in exceedance to the recommended maximum of 10ug/m^3 (IAMAT, 2021). Nigeria is endowed with large fossil fuel resources which through its management has led to degradation of its environment. Exploitation of crude oil has become a menace to Niger- delta area where this crude oil is domiciled. Gas flaring in this area introduces air pollutants regularly in the atmosphere (Osuji & Avwiri, 2005). Other areas in oil and gas sector which degrades the environment include gas leakage, pipeline explosion and illegal refining of crude oil (Marais et al 2014, EIA 2012).

There is no official records of city or Country air pollution level. This makes it difficult for individuals with health conditions to take care of themselves. Cunningham in her observation describes Nigeria as a fast growing nation with its fast growing and haphazardly regulates cities…, with air pollution problem ranking about the worst in the world. Borgen project advises the country to provide regular inspections of automobiles to ensure that older cars are not releasing harmful chemicals into the atmosphere. It is also integral that Nigeria removes cars from the road that are toxic to the environment (Wanyonyi, 2019). The nation creates over 3 million tons of waste yearly and most Nigerians burn their waste in their neighborhoods rather than discarding it, contributing more pollution to the atmosphere. Another aspect that contributes to the air pollution crisis in Nigeria is the use of firewood and coal to cook.

II. MATERIALS AND METHODS

➢ *Area of Study*

Nigeria is bounded on the North by the Republic of Niger and the Republic of Chad. To the west, the country has a boundary with Benin republic while to the East; it is bounded by the Cameroun Republic. Southern has a boundary with the Atlantic Ocean.

Retrievals from NASA Giovanni was assessed for CO, SO_2, O_3, AOD and NO_2 from 2005 to 2018 across Nigeria. A time series analysis was run on the sampled data. The data obtained were then standardized, descriptive statistics were used in analyzing the data

Fig 1 A Map of Nigeria

A Pearson correlation analysis was used on the standardized data. A Principal Component Analysis (PCA) was conducted on the five variables. A Hierarchical Cluster Analysis (HCA) was also conducted on the five variables. From the time series graph there is a visible decrease in sampled variable like CO, SO_2 and NO_2

Nigeria is a tropical country (Climate to travel, 2021). Most parts of the country have diverse vegetation and climates as seen in Figure 1. The Northern zone has sparse vegetation. They witness longer dry seasons giving them semi-arid Sahelian vegetation (Climate to travel, 2021). Annual precipitation is below 500 millimeters in the extreme North-East (Climate to travel, 2021). The central part of moves towards the South with the Far East enjoying the highest precipitation annually. Conversely, sunshine days and insolation differ from the southern zones to the Northern zones with the coastal cities recording fewer sunshine days than the North and far Northern cities. The Northern part of Nigeria is blessed with a large expanse of land, The Southern part on the other hand, is clustered, heavily industrialized and overpopulated. Southern Nigeria have lush vegetation which should aid in curbing air pollutants like CO and act as obstruction to the free movement of other air pollutants.

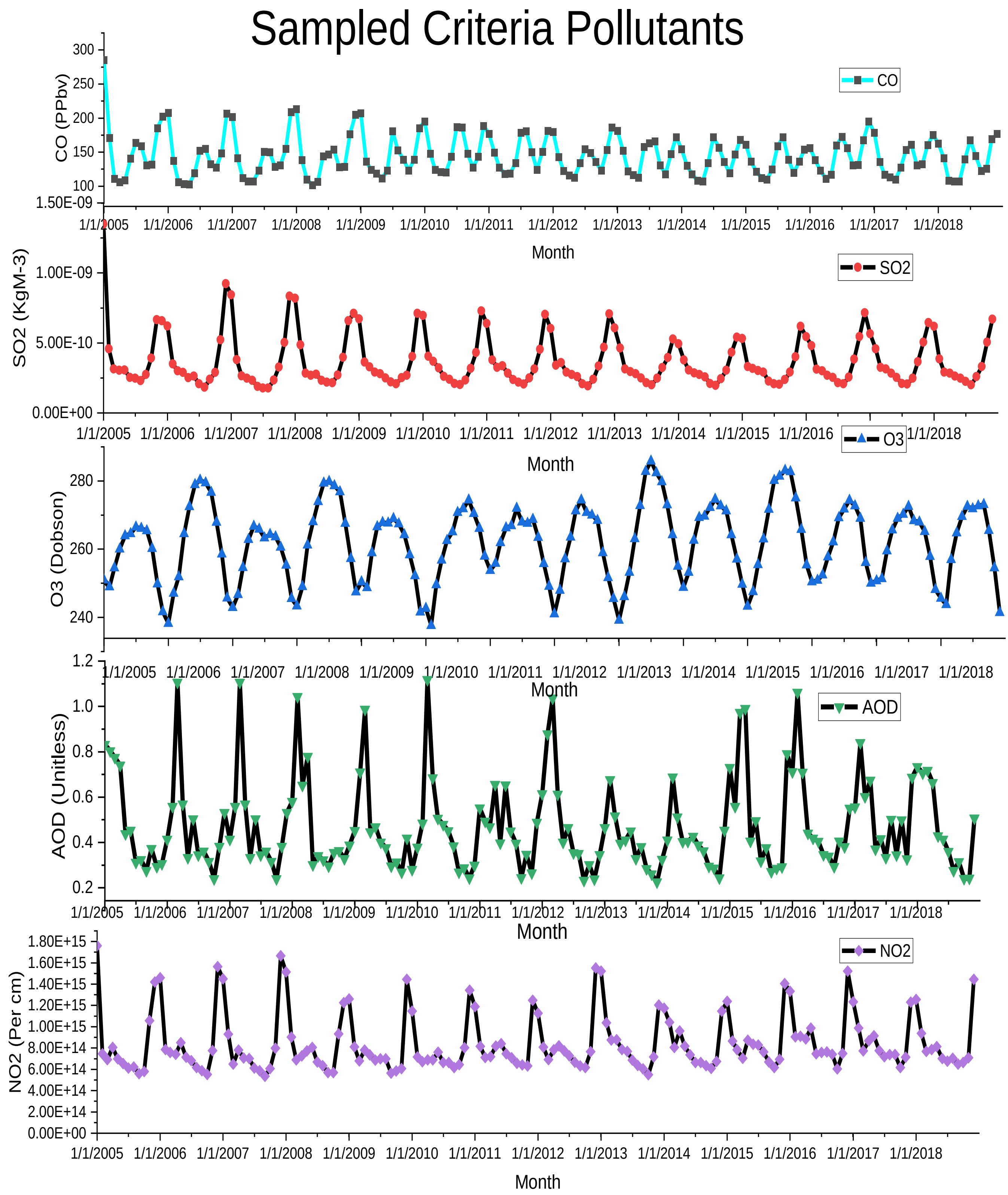

Fig 2 Time Series of Sampled Variables from 2005 To 2018

From Figure 2, all the pollutants had annual u or w shape or pattern except ozone which showed an annual n shape. The highest concentration for the aforementioned were recorded in the dry seasons for all the pollutants as can be seen in Figure 2 except ozone which recorded its highest concentration during the rainy seasons. The months of January and December recorded the highest annual concentrations in January and December for CO, NO_2, and SO_2. A time series graph for both CO and NO_2 is as shown in Figure 3, this graph shows that ozone negatively correlated with CO. This also applies to SO_2, NO_2 and AOD as can be seen from Figure 3.

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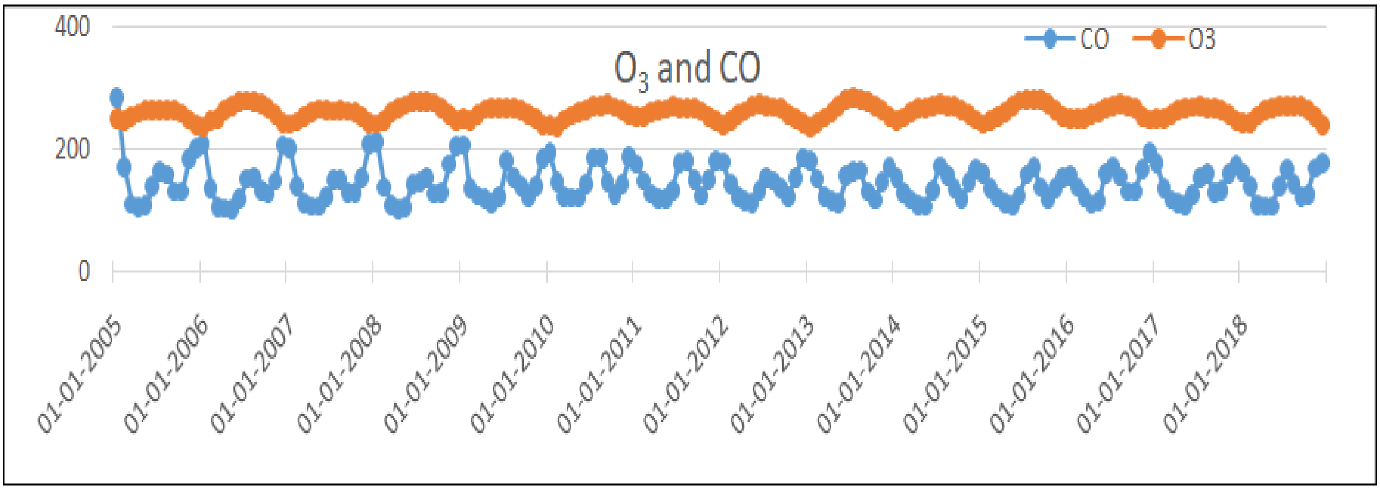

Fig 3 Time Series for Ozone and Carbon Monoxide Statistical Analysis

- *PCA using XLSTAT*

The value of the five criteria pollutants as obtained from NASA GIOVANNI from 2005 to 2018 were standardized. The aim of this standardization is to allow each of the variables to contribute equally to the analysis. For this study, 168 observations were assessed for each of the sampled pollutants. From the standardization a mean of zero and standard deviation of 1 were obtained. This can be seen in the summary statistics is as shown in table 1. A correlation matrix between the five variables is shown in table 2 while the correlation map is shown in Figure 4

Table 1 Data Analysis

Variable	**Observations**	**Minimum**	**Maximum**	**Mean**	**Std. deviation**
CO	168	-1.468	4.801	0.000	1.000
SO	168	-1.051	5.446	0.000	1.000
O3	168	-2.174	2.125	0.000	1.000
AOD	168	-1.199	3.191	0.000	1.000
NO_2	168	-1.148	3.502	0.000	1.000

- ***Correlation Analysis***

Table 2 Pearson's Correlation Matrix

Variables	**CO**	**SO**	**O_3**	**AOD**	**NO_2**
CO	1	0.677	-0.365	-0.129	0.629
SO	0.677	1	-0.727	0.179	0.845
O_3	-0.365	-0.727	1	-0.418	-0.646
AOD	-0.129	0.179	-0.418	1	0.210
NO_2	0.629	0.845	-0.646	0.210	1

The correlation analysis from table 2 showed a strong correlations of 0.677 between CO and SO_2 and also 0.629 between CO and NO_2 was observed. A weak negative correlation of -0.365, and -0.129 were obtained between CO and O_3 and CO and AOD respectively. For sulphur di oxide (SO_2), a Strong positive correlations of 0.845 was obtained between SO_2 and NO_2. A weak correlation of 0.179 was observed between SO_2 and AOD while a strong negative correlation of -0.727 was witnessed between SO_2 and O_3. For ozone. A Strong negative correlation of -0.727 and -0.646 was observed between O_3 and SO_2 and O_3 and NO_2 respectively while a weak negative correlation of 0.418 was obtained between O_3 and AOD. Aerosol Optical Depth (AOD) showed a weak positive correlation of 0.210 were observed between AOD and NO_2. All these can be observed by the color code as shown in Figure 2

Ozone observed a negative correlation with all other pollutants. This could be from the source of formation of ozone. All the other pollutants are primary pollutants except ozone which is a secondary pollutant. Ozone is also formed from primary pollutants of NOx and SOx which shows that these pollutants are used up to produce ozone, this shows the negative correlation between these pollutants.

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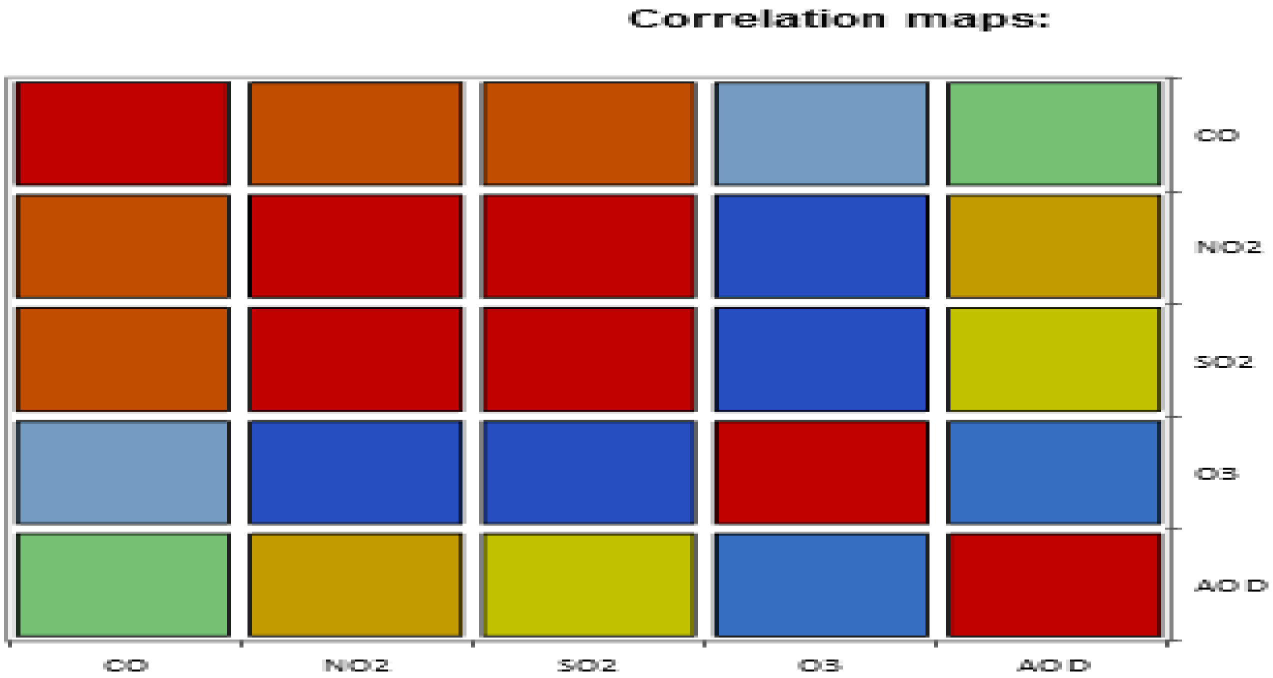

Fig 4 A Correlation Map Showing the Sampled Parameters

From Figure 4 a blue to red colour correlation map showing red for +1 while blue indicates a negative one (-1). AOD had very weak correlation with CO, NO_2 and SO_2 while it negatively correlates with ozone. From the map ozone weakly correlated with all other pollutants.This can be seen in table 3.

Table 3 Coefficient of Determinant (Pearson)

Variables	CO	SO_2	O_3	AOD	NO_2
CO	1	0.459	0.133	0.017	0.396
SO	0.459	1	0.528	0.032	0.714
O_3	0.133	0.528	1	0.175	0.418
AOD	0.017	0.032	0.175	1	0.044
NO_3	0.396	0.714	0.418	0.044	1

For the Eigen vectors, a 5 x 5 matrix was obtained to accommodate all sampled air pollutants. The Eigen vector matrix is shown in table 4

Table 4 Eigen Vectors

	F1	F2	F3	F4	F5
CO	0.419	-0.484	0.558	-0.504	-0.159
SO_2	0.543	-0.087	-0.123	0.143	0.813
O_3	-0.473	-0.301	0.61	0.479	0.291
AOD	0.173	0.814	0.548	-0.052	0.063
NO_2	0.525	-0.064	0.051	0.702	-0.474

For the Eigen vectors five factors were obtained the factors are as shown in table 4

A scree plot showing the factors is seen in Figure 5. From the scree plot only two factors F1 and F2 are relevant to the study. F3, F4 and F5 are discarded due to the fact

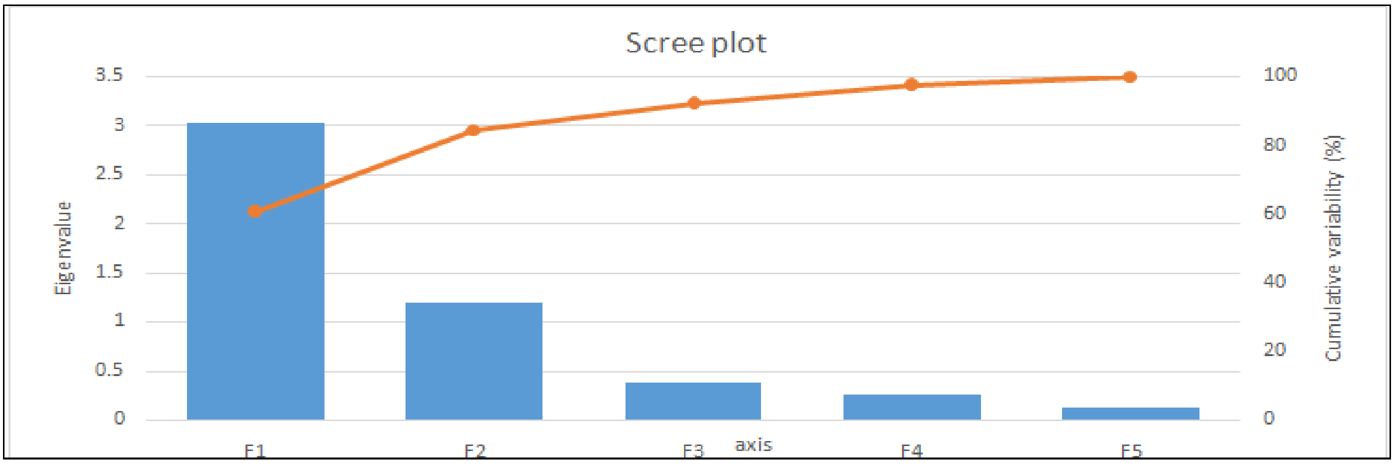

Fig 5 A Scree Plot Showing the Factors

Table 5 Correlations between Variables and Factors

	F1	F2	F3	F4	F5
CO	0.728	-0.529	0.345	-0.259	-0.057
SO_2	0.946	-0.096	-0.076	0.074	0.293
O3	-0.823	-0.329	0.377	0.246	0.105
AOD	0.302	0.89	0.339	-0.027	0.023
NO_2	0.914	-0.07	0.031	0.361	-0.171

From table 5, the first Principal Component (PCA1), is strongly correlated to three original variables of SO_2, NO_2 and CO. this can be seen in from the table and the chart in Figure, NO_2 and SO_2 are more correlated and similar than CO. CO is not as correlated as these two variables. The second PCA (PCA 2) strongly correlates with AOD while the third PCA (PCA 3) shows ozone as a different component. PCA 4 and PCA 5 are not relevant and may not really influence the characteristics of the data and are discarded.

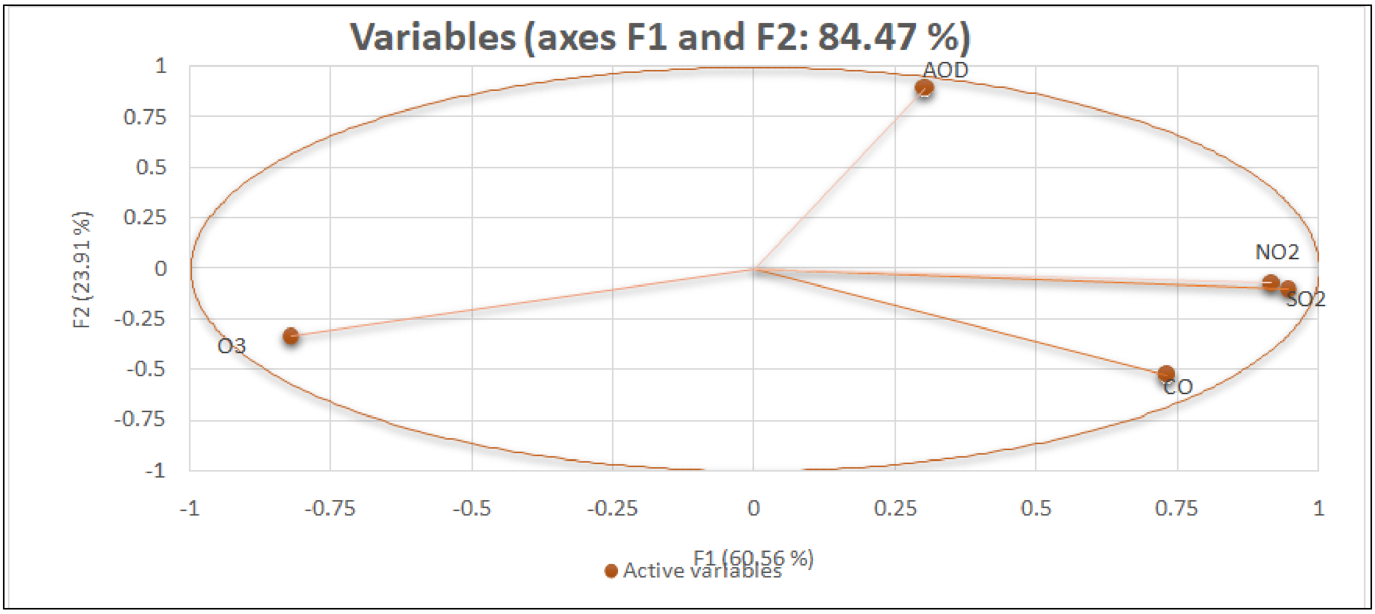

Fig 6 A Biplot of Variables

From the biplot, CO, SO_2 and NO_2 were shown to have the same coordinates. This could be their relationship being influenced from the same source which is fossil fuel. Ozone was observed to negatively correlate with other pollutants. This may be due to Nitrogen oxides and sulphur oxides are precursors of ozone. Hierarchical Cluster Analysis (HCA)

A HCA analysis using SPSS was conducted. Two clusters were identified as cluster 1 and cluster 2. The agglomeration schedule is shown in table 6.

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Table 6 Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	2	5	51.803	0	0	2
2	1	2	115.786	0	1	3
3	1	4	305.419	2	0	4
4	1	3	514.033	3	0	0

A dendrogram using average linkages (between groups) was got and the relationships between the groups can be seen.

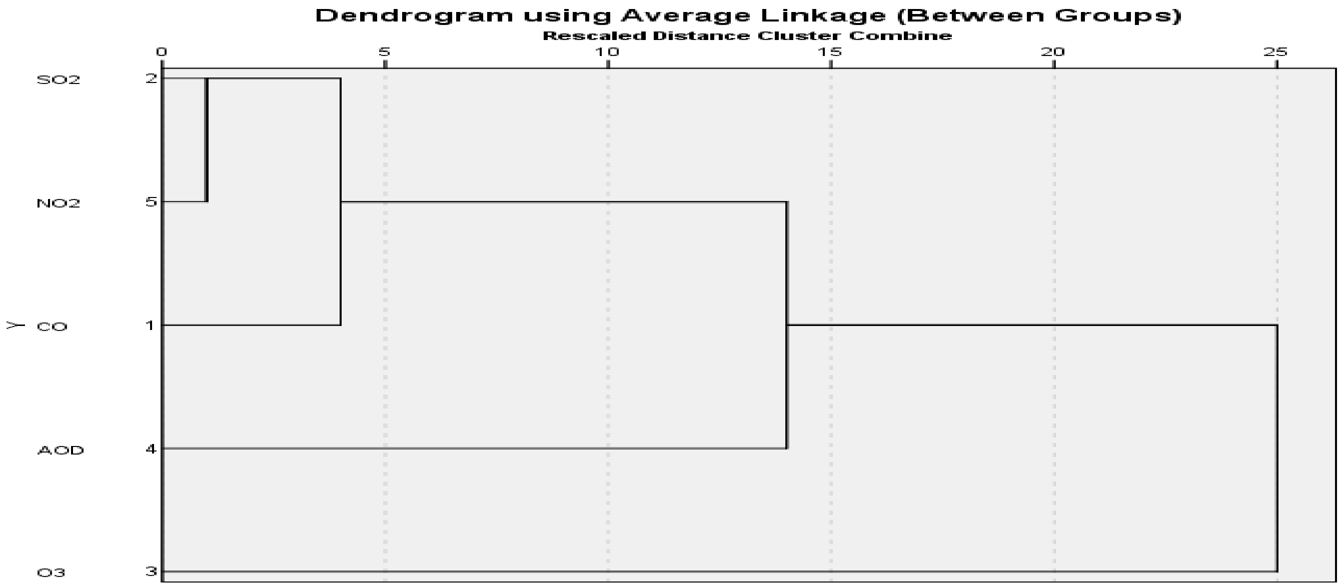

Fig 7 A Dendrogram Using Average Linkages (between groups)

From Figure 7 two main clusters were observed from the cluster analysis. The clusters are: Cluster between AOD, CO, NO_2, and SO_2; Cluster of Ozone.

- *Cluster between AOD, CO, NO_2, and SO_2*

There exist a cluster between SO_2 and NO_2. This can be seen in Figure 7. There is a very close cluster between both of them. It shows that NO_2 is closer to SO_2 than CO. CO clustered with SO_2. There is a very weak clustering between AOD and SO_2, CO and NO_2. This could be due to the formation of aerosols. These three parameters form each form their own type of aerosol

- *Cluster of Ozone*

A cluster of ozone standing alone can be observed from Figure 7. This could be due to the type of formation or production of ozone. Ozone is a secondary pollutant formed in the air by the presence of ozone precursors like NO_2, SO_2, and occasionally CO.

III. CONCLUSION

From the study, there was a slight decrease of the concentrations of CO, SO_2, and NO_2 across the years. The year 2005 witnessed very high concentration of CO, NO_2 and SO_2 around January 2005. A weak correlation was observed between AOD and other pollutants like CO, SO_2 and NO_2. Ozone was found to correlate negatively with all other pollutants. NO_2 andSO_2 were found to have a high correlation. CO had a weak correlation between it and both SO_2 and NO_2.

A Principal component analysis showed two factors which showed a strong relation relationship between SO_2 and NO_2. A weak correlation between them and CO. a very weak relationship existed between them and CO. AOD showed a very weak relationship between it and the other three pollutants. Ozone did not correlate with positively with other pollutants.CO recorded an average concentration of 144.596ppbv for all the years. SO_2 recorded 3.67E-10, Ozone recorded 262.0176 Dobson, and AOD recorded 0.47145, while NO_2 recorded an annual concentration of 8.38 E + 14per cm^2

RECOMMENDATIONS

- There should be regular monitoring of air Pollutants in every city.
- Monitoring stations are needed in every city.
- Public awareness of the state of each criteria pollutant is needed in each city.

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