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Baseline Levels of Nitrogen Dioxide (NO_2) in Niger Delta Communities of Bayelsa State

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Abstract

The levels and distribution of Nitrogen dioxide (NO_2) in Yenagoa and its environs were measured using passive monitoring technique. The results obtained showed temporal and spatial variation in concentrations. The levels were consistently high in some locations, and low in others. The highest concentration of 20.85 μg/m^3 was measured at a location with relatively higher traffic density (AQIJ), and the least concentration of 0.71 μg/m^3 obtained at a location AQMS. Generally, the levels measured were found to be in this order: AQIJ (20.85 μg/m^3); AQTR (16.49 μg/m^3); AQGF (9.46 μg/m^3); AQBP (8.24 μg/m^3); AQMS (7.91 μg/m^3); AQWC (7.69 μg/m^3) and AQIF (4.96 μg/m^3). All the concentrations measured were found to be below W.H.O set limit (40 μg/m^3). The main factors responsible were identified, with gas flaring contributing to over 38.15%. Correlation matrix and cluster analysis shows that sources of NO_2 in all the locations were diverse

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Introduction

Studies have shown that air pollution increases the risk of cardiovascular diseases and exposure to it can contribute to cognitive and psychiatric disorders, including depression and suicide (Bacarelli *et al.*, 2007, Szyszkowicz, 2018). Researcher interest in NO_2 as an air pollutant is growing, not only because of its phytotoxic nature and adverse effect on crops yield, but the fact that its concentration is well correlated with the concentration of carbon monoxide, particulate polycyclic aromatic hydrocarbon (Lewis *et al.*, 1995, Stroyer *et al.*, 2001) and Soot (Bower *et al.*, 1991). Nitrogen dioxide (NO_2) is known to have long and short-term effect on individuals exposed to it due to its oxidation capacity (WHO, 1997).

Acidic gases such as sulphur dioxide, carbon dioxide and nitrogen dioxide are released by either anthropogenic or natural sources into the atmosphere where they undergo several transformations as a result of complex atmospheric reactions. Several studies tend to suggest that anthropogenic sources especially vehicular emissions and industrialisation are responsible for air pollution in most Africa cities (Uzoekwe and Ajayi 2018, Taylor *et al.*, 2017, Taylor and Nakai, 2012, Olajire *et al.*, 2011, Abam and Unachukwu, 2009). The air quality will likely worsen because of the continuous migration of people from rural areas to cities in search of better lives (UNEP, 2011). Though it was hitherto believed that motorized vehicles were the only major sources of NO_2 in the atmosphere, gas flaring can equally contribute significantly to the atmospheric NO_2 burden (Uzoekwe *et al.*, 2008).

Oxides of nitrogen are produced by combustion of all fossil fuels including coal and gas-fired power stations and motor vehicles (Farmer, 1997). Whereas fuel itself can produce some nitrogen (for example, oil and coal contain around 0.5 – 1.5% of nitrogen, and natural gas contains less than that), most of nitrogen oxides' production comes from the reaction of atmospheric nitrogen and oxygen within the combustion chamber (Farmer, 1997).

The two main nitrogen oxides are nitric oxide (NO) and nitrogen dioxide (NO_2), the sum of which is equal to NO_x. Nitric oxide (NO) is a colorless gas and nitrogen dioxide (NO_2) gas has reddish-brown colour with a distinct sharp, biting odour. Combustion of fuels always produces both NO_2 and NO. But almost 90% of the NO_X combustion product is in the form of NO which is then oxidized to nitrogen dioxide (NO_2) in the air (Colls, 2002, Farmer, 1997). Therefore, only a small percentage of NO_2 found in the atmosphere is directly emitted. The rest has been formed as a result of chemical reactions in the atmosphere (Colls, 2002). Road transport (motor vehicles) is by far the largest contributor of nitrogen emissions, but in contrast, it contributes a very small proportion to sulfur dioxide (SO_2) emissions.

Nigeria has estimated 170 trillion cubic feet of proven natural gas reserves, 10thlargest in the world (NAPIMS, 2007). Due to limited gas infrastructure, Nigeria today flares about 2.6 billion cubic feet of gas per day representing 12.5% of all globally flared gas, which is 68% of the total gas produced (CEE, 2006). However, in recent times, Nigerian government's interest in developing the gas sector in order to diversify the economy has resulted to the installation of natural gas infrastructures in Niger delta region. These infrastructures such as Shell Petroleum Development Company (SPDC) gas installation at Gbaran-Ubie in Bayelsa State Nigeria still flares a reasonable quantity of gas annually as waste with attendant air pollution problems.

The objective of this investigation is to provide a reliable NO_2 baseline data so as to assess the air quality status of an area in the Niger delta region known for oil and gas production with attendant air pollution consequences

Materials and Methods

Study Area: The studied locations are within Yenagoa town and its environment, Bayelsa state, South-South Nigeria. The state is geographically located within the latitude 4°15 North and latitude 5°23' South, It is also within longitude 5°24 West and 5°45' East. The state is bounded by Delta State on the north, Rivers state on the East and Atlantic Ocean on the west and southern parts. Bayelsa state is one of the states in oil rich Niger delta region of Nigeria with a total area of 706km^2, population of about 353, 344 (NPC, 2006). The weather of the study area is tropical with two distinct seasons the wet season and the dry season. Seven sample locations were created and the study was carried out from December 2016 to August 2017. Bayelsa is believed to have been formed during the Holocene of the quaternary period by the accumulation of sedimentary deposits. It is a low land state characterized by tidal flats and coastal beaches, beach ridge barriers and flood plans. The major soil types in the state are young shallow, poorly drained soils (inceptisol Aquepts) and acid sulphate soils (Sulphaquepts), with four ecological zones: coastal barrier island, mangrove forest, fresh water swamp and brackish water swamp. Although rain falls every month of the year, there are two distinct seasons; wet season, usually lasting from April to October and dry season, witnessed between November to March. The temperature throughout the year ranges between 26.6°c to 37.50°c and the vegetation is typical wetland. The predominant occupations are fishing and crop farming but carried out in small scale. The relative humidity ranges between 61 to 91%.

Sampling Sites: The following sampling locations; Federal University, West Campus, Otuoke (AQWC), Mega Star (AQMS), Shell Flow Station Imiringi (AQIF), Bayelsa Palm (AQBP), Tombia Round About (AQTR), Igbogene Junction (AQIJ), and LNG Gas Plant at Gbaran-Ubie (AQGF) were created. The locations are shown in Figure 1 and the coordinates of the locations are shown in Table1.

Sampling of NO_2 Using Passive Technique

This technique first introduced to the health and safety profession by researchers, Palmes and Gunnison in 1973, is one of the most significant developments in air sampling technology. Today, passive samplers are now a key component in the arsenal of air sampling devices. Some of the advantages of passive samplers over others include the fact that they are small, inexpensive, and easy to use, does not require electricity and highly reliable (Ukpebor *et al.,* 2007). The sampler is basically an acrylic tube of 8.2cm long with cross-sectional area of 0.82cm^2, machined at each end to accommodate closely fitting polyethelene cap. One end with white polyethylene cap for easy identification holds two stainless steel grid coated with adsorbent, in this case Triethanolamine $N(C_2H_4OH)_3$(TEA) which absorbs NO_2 efficiently. The outer end of the tube is covered with either a yellow or red polyethylene cap. This cap is removed during sampling (figure 2). The NO_2 molecules diffuse through the air into the tube, following the concentration gradient and are trapped as nitrite ion on TEA.

The required steel grids were cleansed with acetone and then dried properly. The samplers (tubes and caps) were washed with soap and dried. A mixture of two parts of acetone and one part of TEA (Triethanolamine, $C_6H_{15}NO_3$) was added in a 100ml beaker and stirred till clear homogenous solution was obtained. The grids were dabbed in the mixture and were laid on a tissue with a pair of tweezers. They were laid on the tissue with the convex side down. The dried steel grids were put inside the white coloured cap of the sampler with the help of a tweezers again with the convex side down. The acrylic tube of the sampler was pushed into the white cap and the other end closed with the red cap. The prepared tubes were stored in the dark and care was taken not to expose them to extreme heat or cold. Two tubes used as blank were left behind. At the site, with the red caps removed, the tubes were exposed at a height of about 1.9metres above the ground for two weeks where movement of the air was unrestricted. At the end of the 2-weeks sampling period, the red caps of the tubes were replaced and the tubes removed from site (harvested) and brought to the laboratory for analysis

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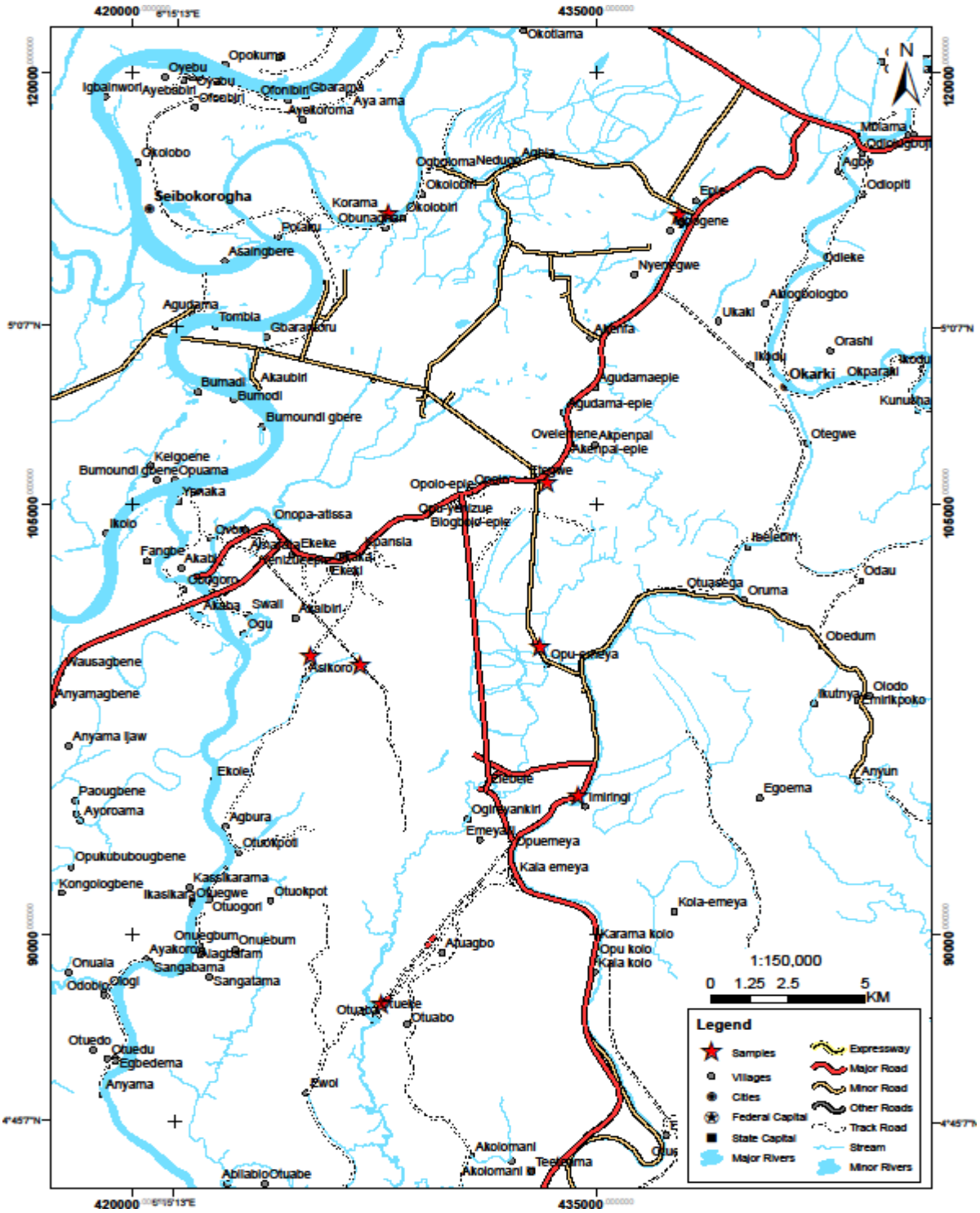

Figure 1: Niger Delta Communities Bayelsa State showing sampling stations.

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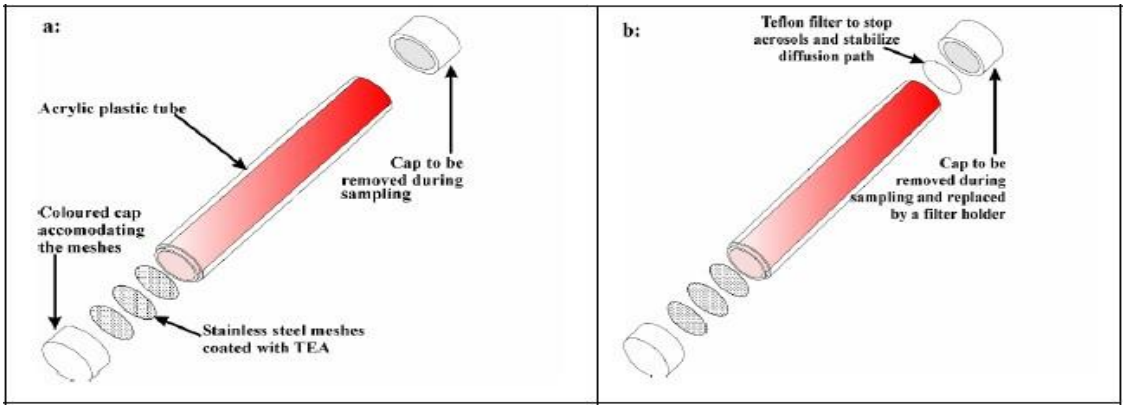

Figure 2:The traditional Palmes diffusion tube

Data Collection: For this study, Palmes diffusion tube purchased from Passam. Ag. Switzerland was used. Earlier the sensitivity and reliability of this sampler has been verified (Ukpebor *et al.,* 2004). The red cap of the tube was removed and 5ml of the Saltzman's reagent prepared was poured into the tube. The red cap was replaced, and the tube shaken. The tube was placed in a rack and kept in the dark for 30 minutes until colour developed in the reagent. This procedure was repeated for all the tubes. Extinction/absorbance of the coloured reagent in the tubes harvested from sites and the blank (the unexposed tubes kept in the laboratory) were read at a wavelength of 540nm in a UV/visible scanning spectrophotometer (Model: Jasco 21UVD, Japan).

The Working Principle of the Tube: The diffusion process on which the working of the tube is based starts as soon as the absorbent (Triethanolamine and acetone) in the steel grid in the white cap end of the tube catches the nitrogen dioxide (NO_2) away from the air. This will happen so efficiently that the concentration of NO_2 in the air at the grid can be assumed to be zero. Therefore, a concentration gradient arises from the open end of the tube to the metal grid. This concentration difference causes diffusion of NO_2 into the tube in accordance with diffusion process predicted by Fick's law. Using the Fick law model, the average monthly weighted concentrations of NO_2 was calculated (Palmes *et al*., 1976).

Statistical Analysis: The results of NO_2 measured were subjected to a set of statistical analysis: descriptive statistics and multivariate analysis including factor analysis, cluster analysis and correlation matrix using Microsoft office Excel 2007 and SPSS 2.0.

Results and Discussion

Atmosphere has been and remains the most important component of the environment. Thus, for sustainable development to be achieved, all the critical components of the environment, especially the atmosphere must be protected and preserved. Description of sampling locations and two weeks weighted average of NO_2 concentrations measured in the created sampling locations are presented in the table 1 and 2 respectively. The sampling locations are representative of industrial activities including gas and oil production activities and 'prestine' environment (AQBP) used as the control. The result of baselines NO_2 concentrations (Table 2), shows a marked spatial and temporal variations in the NO_2 concentrations. These values represent the NO_2 levels at the time of monitoring and can be used as bench mark for future assessment. In the first month of monitoring, a baseline range of 4.96 – 16.49 µg/m^3 was measured. In the second month 4.37 – 20.85 µg/m^3 range with the highest concentration (20.85µg/m^3), recorded at Igbogene Junction (LCIJ). For other periods, a similar trend was observed but with marked decrease in concentration range. Expectedly, the highest concentration of 20.85 µg/m^3 was measured in January, a relatively dry season period while the concentration of 0.71 µg/m^3 was measured in June.

A similar range of concentration and temporal pattern of NO_2 have been reported in residential areas of Benin City (Ukpebor *et al*., 2007) and rural areas with industrial activity (Uzoekwe *et al*., 2008).

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Table 1: Sample Locations and Their Coordinate

S/N	Sample locations	Location code	Coordinates	Dist. b/w Location and Control. Ref. AQBP (KM)	Activities
1	West Campus	AQWC	4° 42' 31'' N 6° 19' 13'' E	15	School, moderate commercial activity, low traffic
2	Mega Star	AQMS	4° 46' 51'' N 6° 18' 50'' E	6	Low vehicular movement, Construction
3	Imiringi Flow Station	AQIF	4° 50' 26'' N 6° 22' 27'' E	8	Intermittent gas flaring, low vehicular movement.
4	Tombia Round About	AQTR	4° 53' 51'' N 6° 21' 15'' E	6	High traffic, commercial activities of dump site.
5	Bayelsa Palm	AQBP	4° 53'39'' N 6° 17' 35'' E	0	Farm settlement, low vehicular movement.
6	Igbogene Junction	AQIJ	4° 65' 41'' N 6° 24' 16'' E	10	High traffic, residential areas.
7	Gbaran-Ubie Gas Flare	AQGF	4° 54' 11'' N6°17 ' 50'' E	14	Gas flaring, low vehicular movement

Table 2: Measured Ambient NO_2 Concentration ($\mu g/m^3$)

S/N	Sample Location	Location code	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
1	West Campus	LCWC	7.69	4.37	4.04	3.46	2.17	1.74	2.55	4.93	2.89
2	Mega Star	LCMS	7.91	7.16	7.35	4.18	0.91	0.71	1.20	4.41	3.32
3	Imiringi Flow Station	LCIF	4.96	4.32	3.30	3.99	4.24	3.16	3.66	4.60	3.02
4	Tombia Round Abou	LCTR	16.49	12.50	13.47	8.51	13.14	11.55	10.28	9.79	12.51
5	Bayelsa Palm	LCBP	8.24	5.04	7.93	4.79	5.30	5.28	4.54	6.95	2.63
6	Igboghene Junction	LCIJ	13.78	20.85	12.96	3.03	12.50	11.06	11.94	13.14	9.16
7	Gbarain gas Flare	LCGF	7.95	9.64	9.42	4.42	7.60	7.14	7.03	7.25	2.86

Table 3: Measured Seasonal Ambient NO_2 Concentration ($\mu g/m^3$)

			Dry Season					Wet Season			
S/N	Sample Location		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	West Campus	AQWC	7.69	4.37	4.04	3.46	2.17	1.74	2.55	4.93	2.89
2	Mega Star	AQMS	7.91	7.16	7.35	4.18	0.91	0.71	1.20	4.41	3.32
3	Imiringi Flow Station	AQIF	4.96	4.32	3.30	3.99	4.24	3.16	3.66	4.60	3.02
4	Tombia Round About	AQTR	16.49	12.50	13.47	8.51	13.14	11.55	10.28	9.79	12.51
5	Bayelsa Palm	AQBP	8.24	5.04	7.93	4.79	5.30	5.28	4.54	6.95	2.63
6	Igbogene Junction	AQIJ	13.78	20.85	12.96	3.03	12.50	11.06	11.94	13.14	9.16
7	Gbaran-Ubie Gas Flare	AQGF	7.95	9.64	9.42	4.42	7.60	7.14	7.03	7.25	2.86

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Table 4: Descriptive Statistics of Data Obtained

S/N	Code	N	Dry Season Mean	Wet Season Mean	Seasonal mean	Ratio	Max	Min	Range	STD
1	AQWC	9	4.35	3.07	3.76	1.42	7.69	1.74	5.95	1.81
2	AQMS	9	5.50	2.41	4.13	2.28	7.91	0.91	5.50	2.91
3	AQIF	9	4.16	3.61	3.92	1.15	4.96	3.02	4.16	1.03
4	AQTR	9	12.73	11.03	11.98	1.15	16.49	8.51	12.73	3.79
5	AQBP	9	6.26	4.85	5.63	1.29	8.24	2.63	6.26	1.78
6	AQIJ	9	12.62	11.33	12.05	1.11	20.85	3.03	12.62	4.66
7	AQGF	9	7.81	5.82	6.92	1.34	9.64	2.86	7.81	2.20

Table 5: Rotated Factor Loadings and Communalities for the sampling locations

Variables	Factor 1	Factor 2	Factor 3	Communality
AQWC	0.792	0.031	0.578	0.962
AQMS	0.555	0.133	0.666	0.770
AQIF	0.873	0.214	0.017	0.808
AQTR	0.033	0.324	0.861	0.848
AQBP	0.676	0.388	0.322	0.710
AQIJ	0.072	0.873	0.276	0.844
AQGF	0.288	0.916	0.127	0.937
Eigen Value	2.2431	1.9211	1.7159	5.8801
% Variance	38.15	32.67	29.18	0.840

Table 6: Correlations: AQWC, AQMS, AQIF, AQTR, AQBP, AQIJ, AQGF (Spatial)

	AQWC	AQMS	AQIF	AQTR	AQBP	AQIJ
AQMS	0.827					
	0.006					
AQIF	0.722	0.415				
	0.028	0.267				
AQTR	0.515	0.463	0.228			
	0.156	0.209	0.554			
AQBP	0.680	0.583	0.524	0.446		
	0.044	0.099	0.148	0.229		
AQIJ	0.302	0.382	0.334	0.482	0.294	
	0.430	0.311	0.380	0.189	0.443	
AQGF	0.299	0.406	0.368	0.391	0.681	0.773
	0.435	0.279	0.329	0.298	0.043	0.015

Table 7: Correlations: Dec, Jan, Feb, Mar, Apr, May, Jun, Jul, Aug (Temporal)

Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Jan	0.771						
0.043							
Feb	0.906	0.847					
0.005	0.016						
Mar	0.597	0.048	0.487				
0.157	0.918	0.268					
Apr	0.853	0.817	0.870	0.476			
	0.015	0.025	0.011	0.281			
May	0.848	0.810	0.889	0.474	0.996		
	0.016	0.027	0.007	0.283	0.000		
Jun	0.823	0.883	0.864	0.328	0.986	0.983	
	0.023	0.008	0.012	0.472	0.000	0.000	

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Jul	0.826	0.939	0.874	0.174	0.916	0.921	0.958	
0.022	0.002	0.010	0.708	0.004	0.003	0.001		
Aug	0.956	0.739	0.817	0.626	0.859	0.832	0.815	0.773
0.01	0.058	0.025	0.132	0.013	0.020	0.025	0.041	

Table 8: Comparison of Monitored NO_2 with Set Limits

S/N	Sample Location	Code	Seasonal mean	FMEnv. Limit	WHO daily/hourly Limit	WHO annual mean
1	West Campus	AQWC	3.76	75-113	150	40
2	MegaStar	AQMS	4.13	75-113	150	40
3	Imiringi Flow Station	AQIF	3.92	75-113	150	40
4	Tombia Round about	AQTR	11.8	75-113	150	40
5	Bayelsa palm	AQBP	5.63	75-113	150	40
6	Igbogene Junction	AQIJ	12.05	75-113	150	40
7	Gbarain gas Flare	AQFG	6.92	75-113	150	40

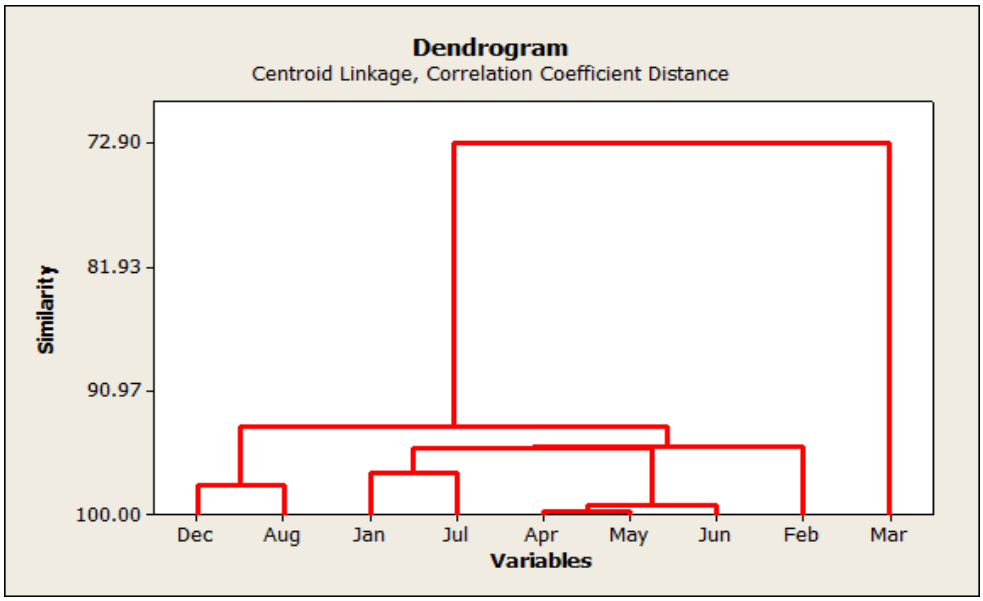

Figure 3: Dendrogram Showing the Clusters

Similar results were obtained for several monitoring stations in the UK where urban and rural NO_2 background concentrations have decreased over the time series to 21.6µg/m^3 and 7.5µg/m^3 respectively (DEFRA, 2018).

The data also showed marked spatial variation with the mean concentration of NO_2 concentrations ranging between 3.76µg/m^3, measured at Federal University, Otuoke to 12.05µg/m^3 measured at high traffic site AQIJ in Yenagoa urban. Generally, ambient concentrations of atmospheric pollutants depend on strength of the sources, efficiency of dispersion and other meteorological factors such as wind speed, turbulence, inversion (WHO, 2000) and humidity. Bayelsa State is known for high humidity ranging between 61-91% all year round. This may account for relatively lower NO_2 concentration measured due to scavenging effect of atmospheric moisture on NO_2, leading to terrestrial and aquatic acidification. Although there is intensive gas flare at Gbaran-Ubie and other flow stations, the concentrations measures were lower than locations with relatively higher traffic density. Similar observations were recorded in the studies done by Oiamo *et al;* (2015) and Chong *et al;*

(2017). Gas flare at Gbaran-Ubie takes place at very high flame stack and thus there is higher dilution rate. The prevailing winds carry the high temperature pollutants from the stack and produce a leeward plume towards the cooler upper troposphere (Uzoekwe, 2005). Depending on the wind direction, wind turbulence, topography and other meteorological factors, ambient concentration may be higher at locations further than the vicinity of emission source. Therefore, the prevailing wind direction is an important factor that determines areas mostly affected by an air pollution sources (Uzoekwe and Ahonkhai, 2004).

Seasonal variation: The results of dry season and wet season means are presented in table 3. The result shows that NO_2 distribution for dry season period (Dec – April) were consistently higher ($P < 0.05$) than the wet season (May – August) period and thus, the dry-wet season ratio ranged from 1.11 – 2.28. Although on recent time, precipitation in most areas of Bayelsa State is all year round, there is two distinct periods in a year. Yenagoa is a typical tropical moonsun climate classified as Am by Köppen and Geiger. The average precipitation and temperature are 2899mm and 26.7^0C respectively. The NO_2 concentrations increased during the dry season period and gradually reduced with minimum concentration measured between May and August. This trend observed could be influenced by meteorological factors mainly precipitation which is intense between May and August, resulting to the wet deposition of NO_2 as HNO_3 (Percy and Ferreti, 2004; Uzoekwe, 2005). Wet season witnesses decline in traffic, relatively lower level of activities due to power outage and reduction in combustion processes especially bush burning due to atmospheric humidity (Uzoekwe, 2005). Similar seasonal trend in NO_2 have been reported in previous studies for Benin City Urban Nigeria, where baseline NO_2 concentrations were distinguished moderately through seasons (Ukpebor and Ahonkhai, 2000). Gualtieri *et al.*, (2017) reported that meteorological parameters play the major role on NO_2 concentrations for densely inhabited areas of the city of Florence, Italy.

Source Identification, Classification and apportionment: The results of multivariate analysis (factor analysis, correlation matrix, cluster analysis) are presented in the tables 4 – 7 and Figure 3 respectively. To determine sources of NO_2 in ambient air of Yenagoa and its environs, the values of variance after rotation were examined and only factors with variance ≥ 0.5 were considered significant as suggested by Roscoe *et al;* (1982). Three main factors were identified (Table 5): gas flaring/bush burning, traffic and commercial activities. Generally, there is low correlation between the locations, but locations with similar activities seems to correlate more. The factor analysis and correlation matrix seems to suggest diverse nature of sources of NO_2 in ambient air of Yenagoa and its environs. The correlation matrix for the sampling months shows that the dry season periods and wet season periods correlated well with each other, suggesting that the sources of NO_2 and their fate in the atmosphere for the sampling periods were identical. Cluster analysis is a technique which groups persons or objects into unknown number of groups such that the members of each group are having similar characteristics or attributes. Two major clusters (March and others) were identified.

Comparison of NO_2 levels with set limits and Risk Assessment: The limit set for NO_2 by the Federal Ministry of Environment (FMEnv) is 75 – 113μg/m^3 daily average. The world Health organization (WHO) recommended an annual average threshold value of 40μg/m^3 (WHO, 2000). All the concentrations measured in this study (Table 8) are below the set limits both locally and internationally and may suggest that inhabitants of this area are at lower risk presently. Considering the high humidity and precipitation in this area of Niger delta region, the efficiency of the acid gas washes out, there is need to maintain or lower the NO_2 load in Yenagoa and its environs.

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