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Comparative Assessment of Air Quality Studies in Ikot-Essien and Anantigha Communities in Cross River State, Nigeria

Etim, A. N[1], Uwah, I. E.[2], Oyo-Ita, E. E.[3], Egbe, A. E.[4], Otiwa, S. O.[5]
[1]*Department of Chemistry/Cross River University of Technology, Nigeria*
[2]*Department of Pure and Applied Chemistry/ University of Calabar, Nigeria*
[3]*Department of Biochemistry/Xian Shiyuo University, China*
[4]*Department of Environmental Resource management/University of Calabar, Nigeria*
[5]*Department of Biochemistry/ Cross River University of Technology, Nigeria*

Abstract:
Background*: One of the major challenging environmental problems facing both the developed and developing countries of the world today is atmospheric pollution. This has been recently linked to increased morbidity and mortality rates. Industrial and Traffic-related vehicular emissions and non implementation of air quality standards in Nigeria are thought to have caused serious health problems, particularly in metropolitan areas where pollution levels are rising. However, due to lack of data on atmospheric pollution levels, collection of ambient air quality data in the research area has become important. This study therefore, seeks to determine the levels of some air quality parameters in the study area.*
Materials and Methods*: Experimental research was employed and it enabled air quality data (VOCs, SO_2, CO, H_2S NH_3, NO_2, PM_{10} and TSP) to be quantitatively gathered in the field using standard methods and handheld in-situ meters. Data obtained were analyzed and presented with tables, means, t-test, ANOVA and Pearson's correlation tools, using SPSS software version 23.*
Results*: Result obtained from the study showed significant variation in the concentration level of air pollutants along the studied sites at p>0.05. There was also significant seasonal variation per site. In addition, Pearson's correlation revealed both positive and negative association between air pollutants across seasons per studied site, which shows that some of the air pollutants have common emission source which is associated with mostly vehicular emission.*
Conclusion: *The study therefore recommend that more roads with connectivity should be constructed to link Calabar with Uyo in order to reduce the traffic density along the only transport corridor that links Calabar to other states; and recommends regular monitoring of atmospheric pollutants.*
Key Word*: Pollution, Air Quality, Pollutants, Concentrations, Industrialization, Emission, Environmental issues*

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I. Introduction

Atmospheric pollution is one of the most pressing environmental issues confronting both industrialized and developing countries today. This has lately been related to higher rates of morbidity and mortality. Atmospheric pollution, on the other hand, is a condition in which certain substances, such as gases (sulfur dioxide, carbon monoxide, hydrocarbons, and so on), particulate matter (smoke, dust, fumes, aerosol, and so on), radioactive materials, and a variety of other substances, are present in such high concentrations that they can have harmful effects on humans and ecosystems[36]. Given the expansion in human population and activities in both developed and developing countries, human exposure to air pollution is inescapable.

Though air pollution can come from natural sources, a major human source is man's ambition for a higher quality of life and the use of natural resources for rapid industrialization and urbanization[29]. As a result of its harmful effects on human health and welfare, air pollution issues have continued to pique people's interest around the world. High blood pressure and other cardiovascular disorders are among the recorded cases of extreme air pollution circumstances that damage humans, according to[28]. As a result, air pollution is a severe hazard to public health in many places throughout the world today.

The amount of air pollution is determined not only by the quantities generated by pollution sources, but also by the atmosphere's ability to absorb or distribute these pollutants. According to Ibe[18], the amount of pollutants in the atmosphere is related to source space fluctuation as well as atmospheric gradients, which most

commonly results in the diffusion and transportation of pollutants to places other than the source of air pollution. According to[27], meteorological conditions (such as temperature, humidity, wind speed and direction, and so on) have a significant impact on the potential for atmospheric pollutants to be released into the environment.

Traffic pollution accounts for 90–95 percent of ambient CO levels, as well as 80–90 percent of NOx, hydrocarbon, and particulate matter, posing a major hazard to human health[33,6]. According to[23], emissions from vehicular movement continue to pose a threat to environmental health problems, and this hazard is predicted to grow as global vehicle ownership rises. Over 600 million individuals are exposed to dangerous levels of traffic-related pollution around the world[33].

Studies have demonstrated that poor air quality has a negative impact on the natural environment[26]. When air pollutants come into direct contact with vegetation or are inhaled by animals, however, ecological damage can result. Pollutants can also settle onto land and aquatic bodies from the air. They can wash into streams or be ingested by animals from the soil. Poor air quality, for example, can have an impact on our climate; some pollutants contribute to warming while others contribute to cooling[31]. Poor air quality can have serious economic consequences due to its effects on human health and the environment. We incur huge costs, such as hospitalization and medical treatment, premature deaths, and lost work days, according to[26]. The productivity of our agriculture, forestry, and industries may be harmed as a result of damage to soils, plants, and rivers.

In metropolitan locations, cases of air pollution can be expensive, as seen by the cost associated with repairing corroded buildings and other materials. Industrial and Traffic-related vehicular emissions and non implementation of air quality standards in Nigeria are thought to have caused serious health problems, particularly in metropolitan areas where pollution levels are rising. However, due to lack of data on atmospheric pollution levels, collection of ambient air quality data in the research area has become important. This study therefore, seeks to determine the levels of some air quality parameters in the study area.

II. Material And Methods

Study area: The study was carried out in Ikot-Essien community (Site 1), Odukpani Local Government Area (LGA) and Anantigha (Site 2=Control), Calabar South LGA both in Cross River State (CRS). The need for this research and the chosen locations was necessitated by the fact that the National Integrated Power Plant in CRS is located in Ikot-Essien community, as well as the continuous usage of the Calabar Itu Federal highway by all kinds of vehicles. Anantigha community with no industrial activities, and less vehicular movement was however, chosen as control station. Calabar south and Odukpani LGAs share similar geographic setting. Ikot-Essien and Anantigha communities are located at an elevation of more than 99 meters above sea level. Its coordinates are 4^{o} 48' 60''N; 8^{o} 16' 60''E for Ikot-Essien community and 4^{o}58'59.88''N; 8^{o}16'59.988''E for Anantigha community (see Figure I for map of study area).

Sampling method: To effectively determine the air quality status of the study area, four sampling points were delineated for each of the study locations. Out of these two study sites, Anantigha community in Calabar South LGA was taken as control site. Sampling was carried out three times a day across sampling points and study locations during the dry and wet season. Geographic coordinates and elevation for each sampling points were determined with the aid of Garmin GPSmap 78SC for which sampling map was produced (see figure 1).

Sampling procedures: The study adopted the method recommended by Federal Ministry of Environment (FMEnv) and American Society for Testing and Materials (ASTM) as used in[4]**.** SO_2, CO, VOCs, H_2S, NH_3 and NO_2 were determined *in situ* with the aid of a hand held Aeroqual aerocet series 531Universal Gas Analyzer MX6 (*in situ* digital meter), while particulate matter (PM_{10}) and Total suspended particles (TSP) were measured with Haze-dust particulate monitor (model HD1000, Environmental Device Corporation). Measurements were carried out by holding the meter at a height above the head in the direction of the prevailing wind and readings recorded at stability. Data were then collected for afternoon, morning and evening hours of the day (between the hours of 08:00 and 18:00hrs Nigerian time).

Statistical Analysis: Raw data obtained were analyzed using descriptive statistics (mean), t-test was performed to compare means for season per sites. One-way ANOVA was employed to check the variation in levels of air pollutants between the two studied sites, while Pearson's correlation analysis was carried out to determine association between air quality parameters for each season and per site. All data analyses were performed using the Statistical Package for the Social Scientist (SPSS) software, Version 23.

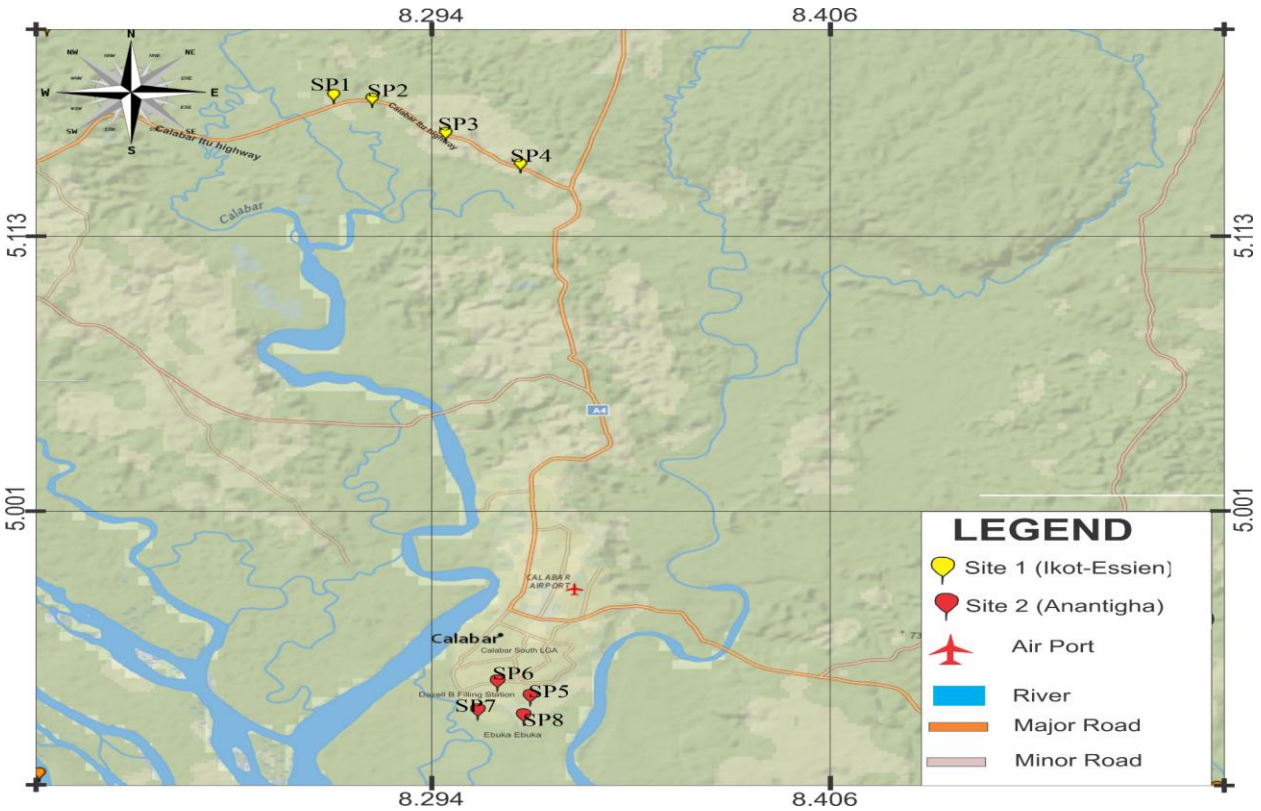

Figure I: Map of Study locations showing sampling points

III. Result

Results of air quality parameters [Volatile Organic Compounds (VOCs), Sulphur-dioxide (SO_2), Carbon-monoxide (CO), Ammonia (NH_3), Hydrogen Sulphide (H_2S), Nitrogen-dioxide (NO_2), Particulate Matter (PM_{10}) and Total Suspended Particles (TSP)] obtained for the study at site 1 (Ikot-Essien) and site 2 (Anantigha) are presented.

Seasonal variation in the level of air quality parameters:

Seasonal variations of VOCs, SO_2, CO, NH_3, H_2S, NO_2, PM_{10} and TSP levels across study sites are presented in Tables I and 2. The results showed highest levels for CO and PM_{10} during wet season; VOCs, H_2S, $SO_2$and TSP during dry season and NO_2 levels were the same during both seasons for Site 1 (Ikot-Essien). On the other hand, site 2 (Anantigha) had highest levels for VOCs, and PM_{10} during wet season, and highest levels of SO_2, CO and TSP during dry season. All parameters monitored at site 1 except SO_2, H_2S, and VOCs were within World Health Organization/Federal Ministry of Environment (WHO/FMEnv) permissible limits, while for site 2 all parameters except VOCs and SO_2 were within World Health Organization/Federal Ministry of Environment (WHO/FMEnv) permissible limits. However, NH_3 was below equipment detection limit for both sites, while H_2S and NO_2 were below equipment detection limit for site 2 only. VOCs level ranged from 0.00ppm – 0.01ppm with mean values of 0.01 during wet season and 0.08ppm - 0.10ppm with mean value of 0.09ppm during dry season for site 1 (Figure 5a), with the highest level of 0.10ppm at SP1 and SP3 each during the dry season. At site 2, VOCs level ranged from 0.50ppm – 0.54ppm with mean values of 0.52.

Table 1: Mean seasonal variations (ppm) of air quality parameters in Study sites 1 (Ikot-Essien Community)

Parameter	Wet season	Dry season	P-value
	Mean	Mean	
VOCs (ppm)	0.01	0.09	0.005*
SO_2(ppm)	0.09	0.14	0.118
CO (ppm)	2.31	0.65	0.071
NH_3(ppm)	0.00	0.00	-
H_2S (ppm)	0.04	0.11	0.054*
NO_2(ppm)	0.04	0.04	0.423
Pm_{10}(µglm^3)	13.4	12.2	0.901
TSP (µglm^3)	10.3	25.4	0.076

Note: FMEnv=Federal Ministry of Environment, Min=Minimum, **Max**=Minimum, P-value= Probability Value, WHO=World Health Organization, NA= Not Available, **ppm**=Part per million, **μglm^3=**Microgram per meter cube
Parameter with asterisk (*) differs significantly at 0.05 level.
Source: Compiled by the Researcher

Table 2: Mean seasonal variation (ppm) of air quality parameters in study sites 2 (Control site=Anantigha)

Parameter	Wet season	Dry season	P-value
	Mean	Mean	
VOCs (ppm)	0.51	0.13	0.051*
SO_2(ppm)	0.01	0.02	0.667
CO (ppm)	0.01	0.36	0.008*
NH_3(ppm)	0.00	0.00	-
H_2S (ppm)	0.00	0.00	-
NO_2(ppm)	0.00	0.00	-
$Pm_{10}(\mu glm^3)$	0.4	2.3	0.296
TSP (μglm^3)	1.2	6.3	0.145

Note: FMEnv=Federal Ministry of Environment, Min=Minimum, **Max**=Minimum, P-value= Probability Value, WHO=World Health Organization, NA= Not Available, **ppm**=Part per million, **μglm^3=**Microgram per meter cube
Parameter with asterisk (*) differs significantly at 0.05 level.
Source: Compiled by the Researcher

Spatial variation of air quality concentrations

Spatial variation of air pollutants along study sites gradient is presented in Table 3 and 4. The data obtained across the study sites (Ikot-Essien and Anantigha) when subjected to a one-way Analysis of Variance (ANOVA) for wet and dry season indicated that the mean level of VOCs was relatively high in site 2 during the wet and dry seasons when compared to site 1. Although, these levels varied significantly between sites 1 and 2 during the wet season ($F=1359.1$, $P<0.05$), they did not significantly vary between the study sites during the dry season ($F=0.278$, $P>0.05$).

Mean concentration of SO_2 was relatively high in site 1 for both wet and dry season compared to site 2. These levels vary significantly between the study sites during wet ($F=28.4$, $P<0.05$) and dry ($F=96.1$, $P<0.05$) season respectively. Similarly, the mean content of CO was relatively high at site 1 for both seasons compared to site 2. Although, the levels of CO varied significantly along site 1 and 2 during the wet season ($F=49.2$, $P<0.05$), it did not significantly vary during the dry season ($F=0.200$, $P>0.05$) between the study sites.

The mean content of NH_3 was observed to be below equipment detection point for wet and dry seasons across the study sites. H_2S on the other hand, recorded a relatively high mean content at site 1 for both seasons compared to site 2. Significant variation in the level of H_2S was observed between the study sites for both wet ($F=48$, $P<0.05$) and dry ($F=60.8$, $P<0.05$) seasons. Although, the mean content of $NO_2$was relatively high in site 1 for both seasons, the levels did not significantly vary between the study sites for wet ($F=1.0$, $P>0.05$) and dry ($F=3.0$, $P>0.05$) season respectively.

Table 3: Mean spatial variation (ppm) of air quality parameters for wet season

Parameters	Site 1	Site 2	F-value	P-Value
VOCs (ppm)	0.01	0.52	1359.1*	0.00003
SO_2(ppm)	0.09	0.01	28.4*	0.005
CO (ppm)	2.31	0.01	49.2*	0.002
NH_3(ppm)	0.00	0.00	---	---
H_2S (ppm)	0.04	0.00	48*	0.002
NO_2(ppm)	0.03	0.00	1	0.3
$Pm_{10}(\mu glm^3)$	13.4	0.4	199.4*	0.0001
TSP (μglm^3)	10.3	1.2	352.9*	0.0004

Note: Parameters with F-values having no asterisk are not significantly different at 0.05 levels, while those with single asterisks are significantly different at 0.05 level.
Source: Compiled by the Researcher

Table 4: Mean spatial variation (ppm) of air quality parameters for dry season

Parameters	Site 1	Site 2	F-value	P-Value
VOCs (ppm)	0.09	0.13	0.278	0.6
SO_2(ppm)	0.14	0.02	96.1*	0.0006
CO (ppm)	0.65	0.35	0.200	0.7
NH_3(ppm)	0.00	0.00	-	-
H_2S (ppm)	0.11	0.00	60.8*	0.001
NO_2(ppm)	0.04	0.00	3.0	0.2
Pm_{10}(µglm^3)	12.2	2.3	22.1*	0.009
TSP (µglm^3)	25.4	6.3	11.7*	0.02

Note: Parameters with F-values having no asterisk are not significantly different at 0.05 levels while those with single asterisks are significantly different at 0.05 level.
Source: Compiled by the Researcher

Temporal variation of air quality parameters

The temporal variations (morning, afternoon and evening) in the levels of air quality parameters in two different locations are presented in Table 5 and 6. The results showed considerable variation in the level of pollutants at different time of the day. For instance, in site 1 (Ikot-Essien), the levels of air quality parameters monitored in the area except for PM_{10} and TSP were observed to be significantly high in the morning and evening time for both seasons at $p<0.05$. The levels of PM_{10} and TSP were high in the afternoon followed by the evening. However, NH_3 levels for both seasons were below equipment detection point. Similar trend was observed in site 2 (Anantigha) for all the parameters except for PM_{10} and TSP for both seasons. PM_{10} and TSP levels on the contrary were observed to be significantly high in the afternoon and evening period at $p<0.05$. However, NH_3, H_2S and NO_2 levels were below equipment detection point at site 2 across seasons.

Interrelationship between air quality parameters per study sites

Associations or interrelationships between air pollutants within each sampling season per study sites was determined using Pearson's correlation analysis and presented in Tables 7 and 8. Some of the variables were positive or negative, significantly or insignificantly correlated at 0.01 and 0.05 p-levels.

Table 7 presents wet season results of associations between air quality parameters in site 1. The results showed that at $p<0.05$, there was a negative and insignificant correlation between SO_2 and VOCs, CO and VOCs, H_2S and VOCs, H_2S and SO_2, H_2S and CO, NO_2 and CO, PM_{10} and SO_2, PM10 and CO, TSP and CO, TSP and H_2S. On the other hand, positive and insignificant relationship was observed at $p<0.05$ between CO and VOCs, NO_2 and VOCs, NO_2 and SO_2, NO_2 and H_2S, PM_{10} and VOCs, PM_{10} and H_2S, PM_{10} and NO_2, TSP and VOCs, TSP and SO_2, TSP and NO_2, TSP and PM_{10}.

Table 5: Mean temporalvariation (ppm) of air quality parameters in Site 1 (Ikot-Essien)

Time of the day	VOCs (ppm)		SO_2 (ppm)		CO (ppm)		NH_3 (ppm)		H_2S (ppm)		NO_2 (ppm)		Pm_{10} (µglm3)		TSP (µglm3)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Morning	0.12a	0.18a	0.14a	0.12a	3.30a	2.79a	0.00	0.00	0.06a	0.11a	0.08a	0.08a	6.8a	9.2a	10.6a	22.5a
Afternoon	0.01b	0.10b	0.10b	0.18b	2.44b	0.68b	0.00	0.00	0.01b	0.08b	0.04b	0.03b	13.3b	16.8b	20.7b	31.4b
Evening	0.14a	0.13a	0.10b	0.17b	4.02a	2.20c	0.00	0.00	0.04a	0.13a	0.05a	0.03b	7.0a	12.6c	11.6a	26.1a

ppm= Part per million, µglm3=Microgram per meter cube

Means with the same superscript are not significantly different at P>0.05, while those with different superscripts are significantly different at P<0.05

Table 6: Mean temporalvariation (ppm) of air quality parameters in Site 2 (Control site=Anantigha)

Time of the day	VOCs (ppm)		SO_2 (ppm)		CO (ppm)		NH_3 (ppm)		H_2S (ppm)		NO_2 (ppm)		Pm_{10} (µglm3)		TSP (µglm3)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Morning	0.53a	0.52a	0.04a	0.07a	0.30a	0.20a	0.00	0.00	0.00	0.00	0.00	0.00	0.6a	0.4a	1.2a	0.3a
Afternoon	0.17b	0.13b	0.01b	0.02b	0.00b	0.00b	0.00	0.00	0.00	0.00	0.00	0.00	4.4b	0.6b	10.2b	0.7b
Evening	0.52a	0.47a	0.05a	0.05a	0.31a	0.35b	0.00	0.00	0.00	0.00	0.00	0.00	2.7b	0.5b	6.6b	0.3a

ppm= Part per million, µglm3=Microgram per meter cube

Means with the same superscript are not significantly different at P>0.05, while those with different superscripts are significantly different at P<0.05

Table 7: Wet season correlation between air quality parameters in study site 1

Parameter	VOCs	SO_2	CO	H_2S	NO_2	PM_{10}	TSP
VOCs (ppm)	1						
SO_2 (ppm)	-0.14003	1					
CO (ppm)	0.377426	-0.87203	1				
H_2S (ppm)	-0.8165	-0.1715	-0.27735	1			
NO_2 (ppm)	0.256307	0.442646	-0.65136	0.069758	1		
PM_{10} (μglm^3)	0.422919	-0.17096	-0.12107	0.136822	0.806502	1	
TSP (μglm^3)	0.852503	0.375592	-0.15538	-0.76397	0.588003	0.441508	1

Correlation without asterisk is Insignificant at $p>0.05$ and $p>0.01$
Source: Compiled by the Researcher

In a similar trend, Table 8 presents dry season results of association between air quality parameters in site 1. The results showed a negative and insignificant correlation at $p<0.05$ between H_2S and SO_2, NO_2 and H_2S, PM_{10} and VOCs, PM_{10} and SO_2, PM_{10} and CO, PM_{10} and NO_2. A positive and significant relationship at $p<0.05$ was observed between CO and VOCs, while positive and insignificant correlation at $p<0.05$ was observed between SO_2 and VOCs, CO and SO_2, H_2S and VOCs, H_2S and CO, NO_2 and VOCs, NO_2 and SO_2, NO_2 and CO, PM_{10} and H_2S, TSP and VOCs, TSP andSO_2, TSP and CO, TSP and SO_2, TSP and CO, TSP and H_2S, TSP and NO_2, TSP and PM_{10}.

In addition, strong and significant associations at $p<0.05$ for site 1 were observed between NO_2 and H_2S, PM_{10} and NO_2, TSP and VOCs and TSP and NO_2 during the wet season. On the other hand, during the dry season, strong associations at $p<0.05$ were observed between CO and VOCs, SO_2 and VOCs, CO and SO_2, NO_2 and SO_2, and TSP and PM_{10} respectively.

Table 8: Dry season correlation result between air quality parameters in study site 1

Parameter	***VOCs***(ppm)	***SO_2***(ppm)	***CO***(ppm)	***H_2S***(ppm)	***NO_2***(ppm)	***PM_{10}***(μglm^3)	***TSP***(μglm^3)
VOCs (ppm)	1						
SO_2 (ppm)	0.751809	1					
CO (ppm)	0.984441*	0.624558	1				
H_2S (ppm)	0.366508	-0.26141	0.497745	1			
NO_2 (ppm)	0.455842	0.916081	0.298796	-0.62651	1		
PM_{10} (μglm^3)	-0.33872	-0.26554	-0.34262	0.312658	-0.34741	1	
TSP (μglm^3)	0.167002	0.285048	0.109758	0.29438	0.104946	0.838626	1

Correlation with single asterisk is significant at $p<0.05$
Source: Compiled by the Researcher

Table 9 presents wet season results of correlation analysis of air quality parameters at site 2. The results revealed a negative and insignificant associations at $p<0.05$ between CO and VOCs, PM_{10} and VOCs, PM_{10} and CO, TSP and CO during the wet season for site 1.on the other hand, positive but insignificant association at $p<0.05$ were observed between SO_2 and VOCs, PM_{10} and SO_2, TSP and VOCs, TSP and SO_2, TSP and PM_{10}, while a negative and significant correlation at $p<0.05$ was observed between CO and SO_2 during the wet season for site 2.

Table 9: Wet season correlation result between air quality parameters in study site 2

Parameter	***VOCS***(ppm)	***SO_2***(ppm)	***CO***(ppm)	***PM_{10}***(μglm^3)	***TSP***(μglm^3)
VOCs (ppm)	1				
SO_2 (ppm)	0.457496	1			
CO (ppm)	-0.4575	-1**	1		
PM_{10} (μglm^3)	-0.12326	0.80829	-0.80829	1	
TSP (μglm^3)	0.666627	0.907265	-0.90726	0.638095	1

Correlation with double asterisk is significant at $p<0.01$
Source: Compiled by the Researcher

Table 10 presents dry season results of association between air quality parameters in site 2. The results revealed a negative and insignificant correlation at $p<0.05$ and $p<0.01$ between CO and VOCs, PM_{10} and CO, TSP and SO_2, TSP and CO. However, a positive but insignificant relationship was observed between SO_2 and VOCs, CO and SO_2, PM_{10} and VOCs, PM_{10} and SO_2, TSP and VOCs, and TSP and PM_{10} respectively. In site 2, strong association was observed at $p<0.01$ between PM_{10} and SO_2, TSP and VOCs, TSP and SO_2, TSP and PM_{10} during the wet season, whereas, during the dry season association at $p<0.05$ and $p<0.1$ was observed between CO and SO_2, PM_{10} and VOCs, TSP and VOCs, and TSP and PM_{10} respectively

Table 10: Dry season correlation result between air quality parameters in study site 2

Parameter	***VOCS***(ppm)	***SO_2***(ppm)	***CO***(ppm)	***PM_{10}***(µglm^3)	***TSP***(µglm^3)
VOCs (ppm)	1				
SO_2 (ppm)	0.307794	1			
CO (ppm)	-0.14599	0.853771	1		
PM_{10} (µglm^3)	0.933316	0.231735	-0.0872	1	
TSP (µglm^3)	0.664225	-0.01517	-0.1059	0.885299	1

Correlation without asterisk is Insignificant at $p>0.05$ and $p>0.01$

Source: Compiled by the Researcher

IV. Discussion

The aim of the study was to assess the air quality in Ikot-Essien community, Odukpani Local Government Area (LGA), Cross River State with reference to a control site in Anantigha in Calabar South LGA. All parameters monitored at site 1 except VOCs, SO_2, and H_2S were within World Health Organisation/Federal Ministry of Environment (WHO/FMEnv) permissible limits, whereas those monitored at site 2 except VOCs and SO_2 were within World Health Organisation/Federal Ministry of Environment (WHO/FMEnv) permissible limits. However, NH3 was found to be below the detection limit of the equipment at both sites 1 and 2, whereas H2S and NO_2 were found to be below the detection limit of the equipment at only site 2. Most of these characteristics increased in level mostly during the dry season at site 2 and across seasons at site 1. The dynamics of the atmospheric boundary layer and related convective turbulence may be to blame for the changes in these parameters.

During the investigation, seasonal differences revealed that the dry season had greater levels of air pollutants than the wet season. For example, during the dry season, VOCs, H2S, and TSP levels were all greater at study site 1, but SO_2, CO, PM10, and TSP levels were all higher at study site 2. This is consistent with research conducted in most regions of the Niger Delta by[33,10,34]. During the rainy season, the increased levels could be attributed to the atmosphere's scavenging action and the dissolving of gaseous contaminants[10]. The investigation also discovered that the increase in air pollution levels at site 1 was not due to the season. The high levels recorded at site 1 for most of the sampling stations during both the wet and dry seasons, especially stations along the Calabar-Itu highway, could be due to emission from vehicles and the Integrated Independent Power Plant in Odukpani LGA, which is close to site 1. This finding is supported by a report from[16], which claims that air quality in industrial zones and highways is worse due to wind-blown dust from roads, emissions from industrial machinery, and industrial vehicles.

Increased levels of SO_2, VOCs, and H_2S, which were found to be beyond WHO/FMEnv acceptable limits in both study locations, particularly in site 1, demand immediate attention and proper air quality monitoring. According to[5], the high level and variation of gases in the study area, particularly at site 1, is a reflection of the activities taking place in the area, which include a high volume of traffic, numerous commercial activities, rampant use of power generating sets, and other domestic activities such as biomass combustion. Additionally, the increasing levels of the examined air pollutants detected in the afternoon indicate that the origins of these pollutants are related to increased business activity during working hours.

In addition, the high levels of VOCs found in this study may cause respiratory, allergy, or immunological problems in newborns and children. When volatile organic molecules and nitrogen oxides are released into the atmosphere, they undergo chemical transformations in the presence of sunlight to generate ozone. When sulphur dioxide and nitrogen oxides released as a result of fossil fuel combustion are dissolved in precipitation, they undergo chemical changes in the atmosphere and appear as sulphur, nitrate, and hydrogen ions[15].

In a study conducted in Uyo city, Akwa Ibom State[9] observed a similar range of SO_2 level measured for the study. According to[35,12] the high level of SO_2 in the research region for site 1 could be linked to fossil fuel burning from automobiles that ply the busy Calabar-Itu route. Furthermore, according to[9], around 99 percent of sulphur dioxide in the air comes from human sources, such as industrial activity that processes

sulphur-containing materials, such as the creation of power from oil or gas. The National Integrated Power Plant (NIPP), an electricity generating plant, has a concession at Study Site 1.

Nitrogen gas makes up around 80% of the air we breathe. It can interact with oxygen in the air at high temperatures and under certain other conditions to generate a variety of gaseous compounds known as nitrogen oxides (NOx), including nitrogen monoxide (NO), nitrogen dioxide (NO_2), and others. Although, nitrogen dioxide (NO_2) was below equipment detection point at site 2, given the diverse anthropogenic activities carried out in site 1, its concentration was expected. Large amounts of NO_2 however, are released into the atmosphere as a result of road transportation activities and growing automobile use, as well as industrial operations from the NIPP. According to[1], all types of high-temperature combustion produce nitrogen oxides (NOx), which include nitrogen monoxide (NO), dinitrogen oxide (N_2O), and nitrogen dioxide (NO_2). Smog is formed when nitrogen dioxide, one of the most active photochemical species prevalent in a polluted atmosphere, is released into the atmosphere. This study's nitrogen dioxide levels can interact with sulphur dioxide and water vapour to produce acid rain. When nitrogen oxide reacts with hydrocarbons in the atmosphere, photochemical oxidants produced, irritating the eyes and respiratory tracts and compromising human health. Furthermore, when the seasonal mean of NO_2 was compared to values reported in the literature, it was found to be within 0.20–0.521 ppm reported for Calabar metropolis, Nigeria[30], but still quite high when compared to the WHO/FMEnv limits. In general, it can be determined from NO_2 results that the distribution pattern of NO_2 indicates an increase during Warm and Wet seasons probably due to air/wind velocity during this period.

Only site 1 had H_2S concentrations reported throughout the sampling seasons, with the dry season being the highest. Variations in the locations and across seasons could be due to seasonal and source fluctuation. Decomposition of food, garbage, and refuse created along the Calabar - Itu Highway and left for a long time by roadside petty vendors and commuters may also be to blame for excessive H_2S emissions at site 1. The level of hydrogen sulphide measured in this study agreed with[9] report on vehicular emissions conducted in Calabar. [19] on the other hand, found that hydrogen sulphide emissions harm human health. It also causes respiratory discomfort as well as damage to the central nervous system. The amounts of H_2S detected in the research area are mostly attributable to long-term traffic congestion, as the fuel burned in the area has minimal levels of sulphur[1]. At levels well above ambient, hydrogen sulphide irritates the respiratory tract and damages the central nervous system. Sulphur dioxide is a major air pollutant found mostly in oil and coal combustion products. Its presence in the area could possibly be attributable to roadside vulcanizers' activity. Inhalation of 0.2mg/m3 SO_2 could result in death, according to[5].

Overall, most of these gases have increased in concentration due to emissions from vehicles and residential activities such as roadside cooking[3,4]. Motor cars, on the other hand, are a major source of air pollution in cities, accounting for roughly 48 percent CO, 32 percent NOx, and 59 percent VOC, with negative consequences for the environment and individuals[8]. Also, the high levels of ambient air pollutants identified in the study, particularly at site1, could be as much linked to the activities that produce these pollutants as to the meteorological variables in these locations, which are not significantly different.

There was a significant difference in the level of air quality indices at different times of the day. The data revealed that high levels of most parameters were generally recorded in the morning and evening hours of the day in site 2, whereas high levels for the affected air quality pollutants were reported throughout the day in site 1 during the wet and dry seasons. Because the majority of people rush out of their homes in the morning for their businesses, schools, and a greater percentage of these people returned home in the evening, these variations in level suggest that the major source of air pollutants for site 2 was vehicular emission, as well as low traffic density in the area and the presence of trees and shrubs planted along the street that serve as carbon sinks. The result at study site 1 showed that the level rises with the time of day, with low levels in the morning and high levels in the afternoon and evening. As a result, air pollution levels are higher in the evenings and afternoons. This is projected due to increased vehicular movement and traffic congestion, industrial and residential operations, and other human activities that favor the emission of these gases into the atmosphere, particularly during the dry season, along the Calabar – Itu Highway and its environs. According to[22,2,14] all found a similar trend in the levels of air pollutants at different times of the day and opined that pollution levels were particularly high in the evening.

As indicated by the positive correlations between various air pollutants, the results of correlation analysis show that most of these air pollutants have comparable sources of pollution. Although most of the associations were minor, during the rainy season, a substantial relationship and negative association between CO and SO_2 was observed at site 2, but during the dry season, a positive and significant relationship was observed at site 1. Positive signs or coefficients in the study mean that an increase in the level of any associated parameter will result in a proportional increase in the contents of the associated parameters, and vice versa. For example, the positive and substantial relationship between CO and VOCs in study site 1 during the dry season indicates that an increase in CO levels resulted in an increase in VOC levels during the dry season. This pattern holds true for a variety of positive and significant circumstances. The results also revealed that most of the

parameters per site and among seasons had a favorable but negligible relationship. The general positive coefficients indicate that similar anthropogenic and environmental factors influence air quality parameters[21].

V. Conclusion

Most of the pollutants detected in this study, such as sulphur dioxide (SO_2), volatile organic compounds (VOCs), hydrogen sulphide (H_2S), and nitrogen dioxide (NO_2), had high levels, notably at study site 1. The increased levels of the examined air pollutants at site 2 in the morning and early hours of the day indicate that automobile emissions are the primary source of air pollutants at site 2. While for site 1, the high levels obtained for majority of the sample stations during both the rainy and dry seasons, particularly along the Calabar-Itu highway, could be attributable to frequent and persistent vehicular emission from commercial and private vehicle owners plying the Calabar-Itu Highway. In addition, the National Integrated Independent Power (NIPP) Plant in Odukpani LGA, which is close to study site 1, has been active thus contributing to the concentrations level of these observed parameters.

High automobile traffic, the prevalence of three-stroke engine tricycles notorious for incomplete combustion, and biomass combustion all contributed to higher levels of most of these pollutants reported throughout the study. This observed level indicates that elevated quantities of the measured air pollutants are causing pollution in the atmosphere. As a result, best environmental management strategies are required to reduce and mitigate the looming threats.

The study also found that as you move from study site 1 to study site 2, the amount of pollutants in the air tends to decrease. The level of pollutants in the atmosphere was accounted for by the various anthropogenic activities carried out in the sampling locations. When individuals are exposed to these gases for an extended period of time, the high levels of VOCs, H_2S, and SO_2 at the study sites and surrounding areas can cause major health problems. This is evident because their levels in the atmosphere are over the WHO/FMEnv acceptable threshold across the study sites. As a result, necessary intervention to lower the excessive level of pollutants in the area is required. Pollutant levels are seen to change in quantity or amount. During these times, there is an increase in anthropogenic activity and high traffic density, which favors the accumulation of toxins in the atmosphere. Site 1 (Ikot-Essien), of the two study locations evaluated for this study, was found to produce the maximum amount of pollutants into the atmosphere, implying that the areas where the samples were obtained are not safe from traffic-related pollution hazards.

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