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Assessment of Gaseous Pollutants, Particulate Matter and Meteorological Parameters Around Ibom Power Plant in Ikot Abasi Local Government Area Of Akwa Ibom State, Nigeria

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Abstract*: This study investigates the concentrations of gaseous pollutants, particulate matter, and meteorological parameters around the Ibom Power Plant in Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria, over one year. Using standard analytical methods, key pollutants such as NO_2, SO_2, CO, TVOC, CH_2O, $PM_{2.5}$, and PM_{10} were monitored, alongside meteorological parameters like temperature, relative humidity, pressure, and wind speed. The monthly average concentrations of pollutants exceeded the Federal Environmental Protection Agency (FEPA) standards for NO_2, SO_2, CO, TVOC, CH_2O, $PM_{2.5}$, and PM_{10}. Seasonal analysis showed significant differences in pollutant levels between wet and dry seasons, with higher concentrations generally observed during the dry season. Notably, the Air Quality Index (AQI) indicated severe pollution levels for most pollutants throughout the study period, except for occasional moderate levels of SO_2 and CO. Correlation analysis revealed significant relationships between various pollutants, suggesting common sources or similar influencing factors. Geographic Information System (GIS) mapping further highlighted critical concentrations of NO_2 and CH_2O, with moderate levels of TVOC and low concentrations of SO_2, CO, $PM_{2.5}$, and PM_{10}. These findings underscore the potential health risks associated with prolonged exposure to elevated pollutant levels in the study area.*

Keywords*: Air Pollution, Gaseous Pollutants, Particulate Matter, Meteorological Parameters, Air Quality Index.*

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1.0 Introduction

Atmospheric pollution is one of the most pressing environmental challenges facing contemporary societies. The quality of air in any given area is influenced by a complex interplay of factors, including the concentration and circulation of local emission sources, environmental conditions, and prevailing meteorological factors (WHO, 2013). In recent decades, rapid urbanization and industrialization have significantly deteriorated air quality in many regions worldwide, primarily due to the increased emission of pollutants generated by anthropogenic activities (Heinzerling *et al*., 2016). Among the myriad of substances that contribute to air pollution, particular attention has been given to gaseous compounds such as nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), ammonia (NH_3), and atmospheric particulate matter (PM) due to their detrimental effects on human health (Nhung *et al*., 2018; WHO, 2014).

Numerous studies have documented the adverse health effects associated with exposure to these pollutants. NO_2, SO_2, and O_3 have been linked to cardiovascular and respiratory diseases, with more severe outcomes including premature deaths (WHO, 2005; Jerrett *et al*., 2008). Of particular concern is atmospheric particulate matter, which has been identified as a major contributor to adverse health effects such as increased mortality and morbidity (Pope III & Dockery, 2006; Samoli *et al*., 2013). The World Health Organization (WHO) established air quality standards in 1987 to protect human health and the environment, revising them over time to reflect new scientific evidence (WHO, 2013). Despite these efforts, air pollution was still responsible for approximately 7 million deaths worldwide in 2012, underscoring the persistent and global nature of this problem (WHO, 2014). In addition to the well-documented impacts of air pollution on respiratory health (Bowatte *et al*., 2015; Götschi *et al*., 2008), weather conditions such as temperature, relative humidity, and rainfall also play a significant role in influencing human health. Recent evidence highlights the association between ambient temperatures and a wide range of adverse health effects, including increased mortality and morbidity from cardiovascular and respiratory diseases (Turner *et al*., 2012; Ye *et al*., 2011). The ongoing global climate change, characterized by an increased frequency and intensity of extreme weather events such as heat waves and cold spells, is expected to exacerbate these health impacts shortly (Xu *et al*., 2013). Nigeria is particularly vulnerable to air pollution due to its high levels of natural gas flaring, which contributes approximately 46% of Africa's total gas flaring per ton of oil produced (Angaye *et al*., 2019; Ebong & Mkpenie, 2016). With about 123 flaring sites, Nigeria ranks among the highest emitters of greenhouse gases in Africa (Adoki, 2012). Urban air pollution in Nigeria is primarily characterized by respirable dust and its seasonal variations, posing a significant threat to public health (Abaje *et al*., 2020; Akinfolarin *et al*., 2017). The country's environmental challenges are further compounded by oil spills, deforestation, bush burning, refuse burning, biomass combustion, traffic emissions, industrial emissions, chemical fertilizers, and power plants.

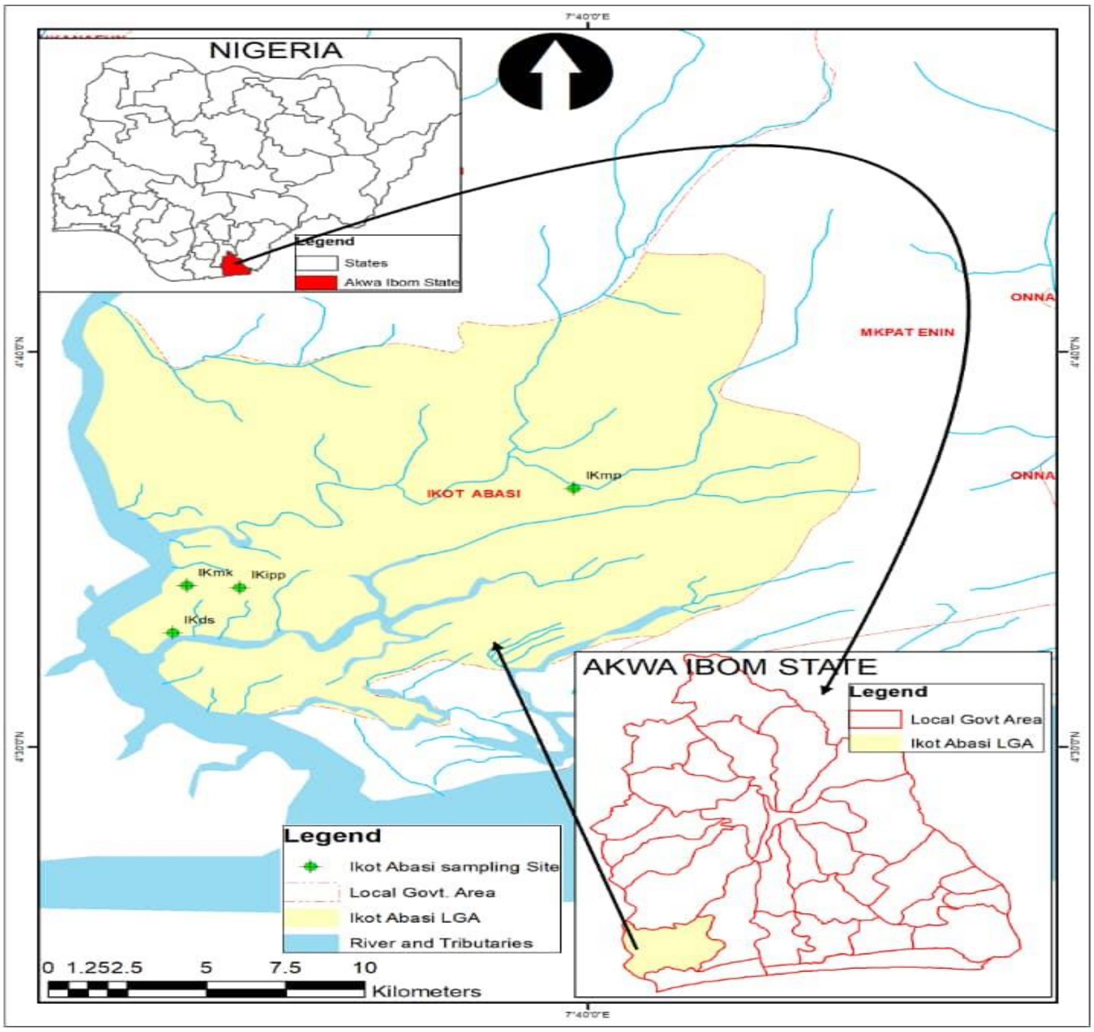
Despite the wealth of research linking air pollution and health outcomes, there is a notable gap in studies specifically addressing the combined effects of gas flaring, urban pollution, and changing weather patterns in Nigeria. Much of the existing literature has focused on the health impacts of air pollution in industrialized countries, with limited attention given to the unique environmental and socio-economic conditions of developing nations like Nigeria (WHO, 2013). Furthermore, while several studies have explored the health impacts of individual pollutants, there is a lack of comprehensive assessments that consider the synergistic effects of multiple pollutants and weather conditions on public health in the Nigerian context (Turner *et al*., 2012; Xu *et al*., 2013). This study aims to fill these gaps by investigating the combined impact of air pollution, specifically from gas flaring and urban sources, and weather conditions on human health in Nigeria. The study is focused on the seasonal variations in pollutant levels, the interplay between air quality and meteorological factors, and their collective influence on respiratory and cardiovascular health. By providing a detailed analysis of these factors, the study seeks to contribute to the development of targeted strategies for mitigating the health impacts of air pollution in Nigeria.

2.0 Materials and Methods

2.1 Study area

Ikot Abasi Local Government Area occupies the South Central territorial part of Akwa Ibom State (Fig. 1) with coordinates between 4°32'02" N, 4°36'02" N.36 and 7.48"E, 8°17'42"E, and based on data from 2006 Nigeria's national census, it is home for 74,840 people (NPC, 2006). Ikot Abasi is host for oil producing, oil servicing companies and electricity power plants which are dynamic in their ways and attract complementary economic activities.

Sampling station: Ibom Power Plant (IK_{IPP}) was selected based on the activity areas and human presence.



Map of Ikot Abasi local government showing sampling Sites

Fig. 1: Map of Ikot Abasi local government showing sampling Site

2.2 Determination of Gaseous Pollutant

The gaseous pollutants were determined using their respective gas detectors which worked by the electrochemical principle of detection, allowing gases to diffuse through a porous membrane to an electrode where it is either chemically oxidized or reduced. The amount of current produced is determined by how much of the gas is oxidized/reduced at the electrode, indicating the concentration of the gas.

2.3 Determination of air quality index (AQI)

The air quality index (AQI) focuses on health effects experienced within a few hours or days after breathing polluted air.

This was calculated using the method suggested by Kaushik *et al,* (2006) for AQI, the air quality rating of each pollutant was calculated using equation 1;

$$AQI = \frac{100V}{V_S} \quad (1)$$

where, AQI =Air Quality Index, V = Observed value of the pollutant and V_S = standard values

Table 1: Materials used in determining the air pollutants, meteorological parameters and particulate matter

Parameters	Equipment's Model
NO_2	Gas monitor Gasman Model 19648H
SO_2	Gas monitor Gasman Model 19831H
CO	Gas monitor Gasman Model 19252H
TVOC	Gas Monitor Gasman Model Air Ae Steward air quality monitor
CH_2O	Gas Monitor Gasman Model Air Ae Steward air quality monitor
$PM_{2.5}$	Gas Monitor Gasman Model Air Ae Steward air quality monitor
PM_{10}	Gas Monitor Gasman Model Air Ae Steward air quality monitor
Temperature /relative humidity	KTJTA318 indoor-outdoor thermometer with hydrometer
Wind direction / Pressure	Sun Road Digital Campus Altimeter (Model CR 2032)
Wind speed	Digital Anemometer (MASTECH MS 6252A)

2.3 Statistical analysis

Statistical analyses were carried out using a statistical package for social sciences (SPSS version 13). Statistical parameters determined through this method include the average, standard deviation (SD). The mean and standard deviations calculated elicit how chemical parameters deviate from stipulated guidelines. Correlation analysis measures the closeness of the relationship between chosen variables. If the correlation coefficient is nearer to +1 or -1, it shows a perfect linear relationship between the two variables and attempts to establish the nature of the relationship between them (Abdul Raheem *et al.*, 2008).

2.4 Geographical Information System Mapping

The GIS mapping was done using ArcMap 10, software which allows one to view spatial data, create layered maps, and perform basic spatial analysis.

3.0 Results and Discussion

3.1 Heavy metals in Suspended Particulate Matter

Figs. 2 to 4 shows plots displaying the average concentrations of the investigated air contaminants over the study period. Fig. 2a showed that the concentration of SO_2 had the range 0.16±0.06 to 0.65±0.65 ppm from November 2019 to October 2020 respectively. This range exceeded the FEPA/WHO threshold of 0.10 ppm in all the sampling months. The concentration of NO_2 had the range from 0.07±0.02 to 7.16±4.44 ppm which were all higher than the FEPA standard of 0.06 ppm. The highest value occurred in August 2020 and the lowest concentration was in October 2020.

The concentration of carbon monoxide (CO) ranged from 3.24±0.40 ppm to 12.90±4.87 ppm (Fig. 2a) with November 2019, January, February, March, April, and July 2020 higher than the FEPA / WHO recommended standard of 10 ppm. The lower limit for the rest of the months (December 2019, May, June, August, September and October 2020) was within the FEPA and WHO threshold.

The concentration of TVOC had the range from 0.81±0.65 to 2.99±0.27 ppm which were all higher than the FEPA standard of 0.5 ppm. The highest value occurred in June 2020 and the lowest concentration was in April 2020.

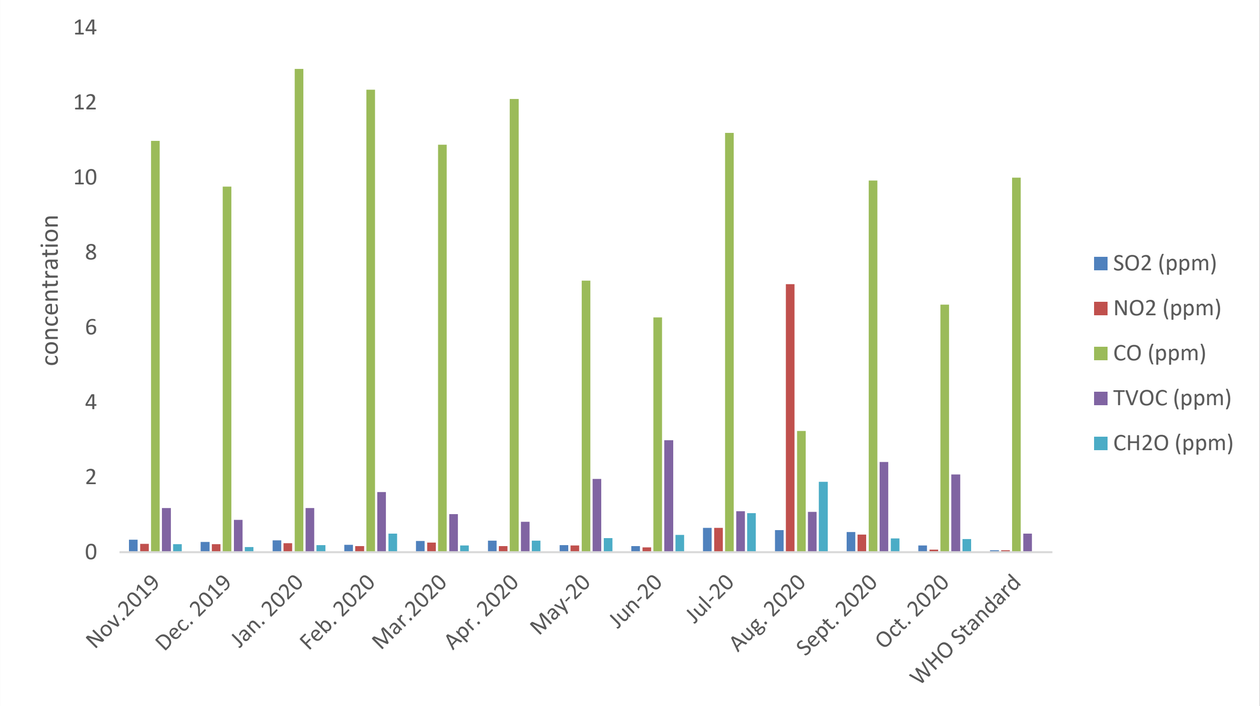


Fig. 2: Average monthly concentration of gaseous pollutants in suspended particulate matter in Ibom Power plant in Ikot Abasi

The concentration of CH_2O had the range from 0.10±0.07 to 1.88±0.35 ppm which were all higher than the FEPA standard of 0.012 ppm. The highest value occurred in August 2020 and the lowest concentration was in December 2019.

The average temperature of the ambient air (Fig. 3) every month (November 2019 to October 2020) ranged from 23.25±0.75 to 35.37±3.06, while the average relative humidity levels of ambient air ranged from 58.33 - 78.75 % in November 2019 to October 2020.

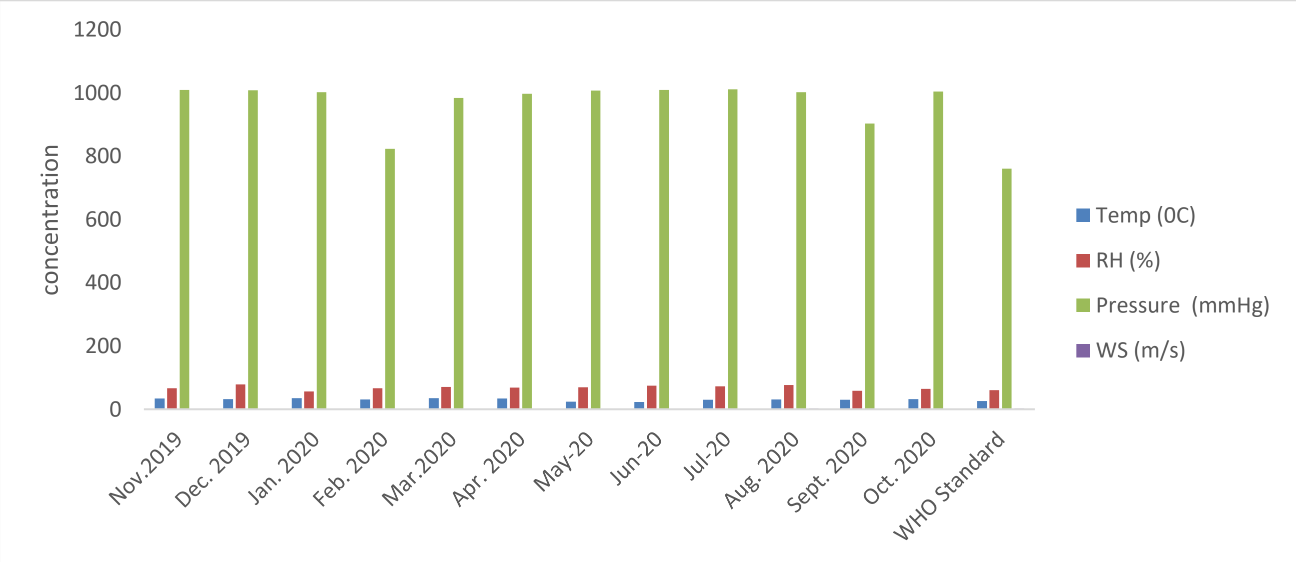


Fig. 3: Average monthly concentration of meteorological parameters in Ibom Power plant in Ikot Abasi

The range of atmospheric pressure was from 823.64±3.36 to 1009.91±4.37 mmHg which was higher than 760 mmHg in all the months under study, while the average monthly wind speed at the duration of the study was from 0.45±0.27 to 2.33±1.75 m/s in November 2019 to October 2020 which were within the wind speed level of 2.8 m/s. Similar work has been reported by (Abulude *et al*. 2024; Adeyemi *et al*. 2020; Owoade *et al*., 2012; Agrawal *et al*. 2021). The concentration of $PM_{2.5}$ (Fig. 4) had a monthly range of 43.06±22.38 to 122.93±27.62 μg/m^3 corresponding to November 2019 to October 2020 respectively. These values were higher than the FEPA/WHO standard of 25 μg/m^3. The concentration of PM_{10} had a monthly range of 62.66±29.67 to 211.68±56.57 μg/m^3 which were all higher than the FEPA/WHO standard of 50 μg/m^3. The highest value occurred in August 2020, while the lowest concentration was in November 2019.

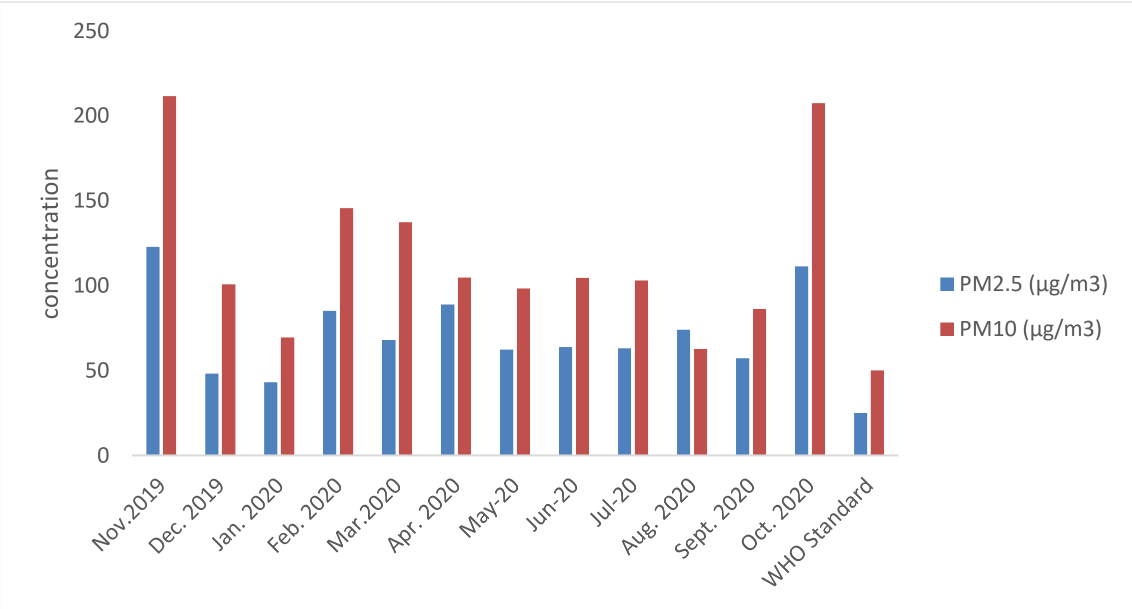


Fig. 4: Average monthly concentration of particulate matter in Ibom Power plant in Ikot Abasi

In Table 2, the average values obtained during wet and dry seasons are presented. Average atmospheric and particulate matter concentration during wet and dry seasons for Ibom Power in Ikot Abasi shows that the concentration of SO_2 in the dry season (0.78 ppm) was significantly different in the wet season (0.40 ppm); and the NO_2 concentration in dry season (4.01 ppm) was significantly different in wet season (0.36 ppm), although both pollutants (SO_2 and NO_2) values obtained exceeded the FEPA/WHO recommended standards of 0.10 and 0.06 ppm respectively.

The concentration of CO obtained in the dry season (19.45 ppm) significantly differed compared to the wet season (16.29 ppm) and all exceeded the FEPA/WHO permissible threshold of 10 ppm. The result also indicated that the concentration of TVOC in the dry season (2.18 ppm) significantly differed from that of the wet season (0.71 ppm); the concentration of CH_2O was significantly different in the dry season (13.74 ppm) compared to the wet season (0.27 ppm); there was no significant different in $PM_{2.5}$ concentration at both dry season (82.70 μg/m^3) and in the wet season (82.37 μg/m^3), while PM_{10} was significantly different in dry season (101.37 μg/m^3) than in wet season (99.70 μg/m^3) and all exceeded the FEPA/WHO permissible threshold of 0.5 ppm, 0.012 ppm, 20 and 50 μg/m^3 respectively. The temperature in the dry season (32.62 ^{o}C) was not significantly different ($p>0.05$) from the wet season (31.04 ^{o}C) and was higher than the FEPA/WHO permissible limit of 26.5 ^{o}C. Pressure in the dry season (975.68 mmHg) was not significantly different ($p>0.05$) from the wet season (841.58 mmHg) and the value in the dry and wet seasons was higher than the FEPA/WHO permissible limit of 760 mmHg.

Table 2: Average gaseous pollutants, particulate matter and meteorological parameters concentration during wet and dry season for Ibom Power

Parameter	Wet Season	Dry Season
SO_2 (ppm)	0.40 ± 0.13b	0.78 ± 0.62a
NO_2 (ppm)	0.36 ± 0.13b	4.01 ± 1.60a
CO (ppm)	16.29 ± 8.41a	19.45 ± 3.10b
TVOC (ppm)	0.71 ± 0.45b	2.18 ± 0.97a
CH_2O (ppm)	0.27 ± 0.13b	13.74 ± 0.59a
PM2.5 (μg/m^3)	82.37 ± 21.16a	82.70 ± 18.65a
PM10 (μg/m^3)	99.70 ± 39.30a	101.37 ± 24.55a
Temperature (°C)	31.04 ± 1.62a	32.62 ± 1.34a
RH (%)	73.26 ± 35.25b	70.58 ± 9.17a
Pressure (mmHg)	841.58 ± 3.41a	975.68 ± 4.11a
WS (m/s)	0.19 ± 0.12a	1.23 ± 0.49b

The wind speed in the dry season (1.23 m/s) differs significantly ($p<0.05$) from the wet season (0.19 m/s) and the values in the dry and wet seasons were within the FEPA/WHO permissible wind speeds of 2.8 m/s. Similar work has been reported in the literature (Abulude *et al*. 2024; Keshtkar *et al*., 2022; Adeyemi *et al*. 2020; Owoade *et al*., 2012; Agrawal *et al*. 2021).

The statistical analysis of the data comparing average concentrations of air contaminants and meteorological parameters between the wet and dry seasons at Ibom Power reveals some notable differences. For pollutants like NO_2, TVOC, CH_2O, temperature, pressure, and wind speed, the differences between the seasons are statistically significant, as indicated by p-values less than 0.05. This suggests that these parameters exhibit substantial variability depending on the season, which could be due to changes in emission sources, meteorological conditions, or both. For instance, NO_2, a common indicator of combustion-related pollution, shows a significant increase during the dry season, which might be attributed to higher emission rates or less dispersion due to stagnant air conditions. Similarly, the substantial differences in TVOC and CH_2O concentrations between the seasons highlight the influence of temperature and humidity on the volatility and reactivity of organic compounds. The observed increase in wind speed during the dry season could also contribute to the dispersal of pollutants, although this effect seems to vary across different types of contaminants. In contrast, other parameters such as SO_2, CO, PM2.5, PM10, and relative humidity do not show significant differences between the wet and dry seasons, as their p-values exceed the 0.05 threshold. This indicates a relative stability in their concentrations across seasons, suggesting that these pollutants may be less influenced by seasonal factors, or that their sources remain consistent throughout the year.

The observed significant variability in some of the parameters underscores the importance of considering seasonal effects in air quality monitoring and management. These results suggest that targeted strategies might be necessary to address specific pollutants more effectively, particularly during periods when they are most likely to exceed safe levels.

3.2 Correlation Analysis

The study shows a significant positive correlation between SO_2 and NO_2, indicating that as SO_2 levels increase, NO_2 levels also tend to rise, suggesting a common source or similar influencing factors for these pollutants. Additionally, the relationship between NO_2 and CH_2O is extremely strong, implying that these two pollutants are closely related, likely originating from the same sources or being influenced by the same atmospheric conditions. A similar strong positive correlation exists between NO_2 and relative humidity, suggesting that higher humidity levels are associated with increased NO_2 concentrations, potentially due to the impact of humidity on pollutant dispersion. This pattern is also observed between CH_2O and relative humidity, indicating that CH_2O levels increase with higher humidity, possibly due to its prevalence in more humid conditions.

Temperature shows a strong positive correlation with both NO_2 and CH_2O, suggesting that higher temperatures are associated with increased levels of these pollutants, potentially due to temperature-dependent emissions or atmospheric reactions. There is also a significant correlation between PM2.5 and PM10, indicating that areas with higher levels of one form of particulate matter are likely to have higher levels of the other. This is expected as both are forms of particulate pollution. Temperature and relative humidity also exhibit a strong positive correlation, suggesting that as temperature increases, relative humidity tends to rise, reflecting the atmospheric conditions in the study area.

In terms of moderate correlations, SO_2 and CO show a positive relationship, suggesting that higher SO_2 levels are moderately associated with increased CO levels, indicating possible shared sources or related atmospheric processes. Similarly, a weak positive correlation between TVOC and CO suggests a slight association between higher CO levels and higher TVOC levels, indicating some level of interaction or shared sources. The correlation between NO_2 and PM2.5 indicates that higher NO_2 levels are moderately associated with higher PM2.5 levels, possibly due to similar sources or conditions that increase both pollutants. PM10 and atmospheric pressure also show a moderate positive correlation, suggesting that higher pressure may be associated with increased PM10 concentrations, possibly due to reduced dispersion under high-pressure conditions.

Negative correlations in the study indicate that higher temperatures are associated with lower CO levels, suggesting that increased temperature may lead to enhanced dispersion or reduced emissions of CO. There is also a moderate negative correlation between TVOC and temperature, indicating that higher temperatures are linked to lower TVOC levels, possibly due to increased volatility or atmospheric dispersion. The relationship between PM10 and NO_2 is negative, suggesting that higher PM10 levels are associated with lower NO_2 concentrations, which might reflect different sources or behaviours for these pollutants in the atmosphere. Finally, a moderate negative correlation between temperature and pressure suggests that higher temperatures are associated with lower atmospheric pressure, which aligns with basic meteorological principles.

The results seem to display complex interactions between pollutants and environmental factors, providing valuable insights that could inform targeted air quality improvement strategies in the region.

The correlation table provided for the dry season in Ikot Abasi examines the relationships between various atmospheric oxides, suspended particulate matter, and meteorological parameters. Based on the correlation results, there is a strong positive correlation between SO_2 and NO_2 ($r = 0.624$), indicating that higher levels of SO_2 are associated with higher levels of NO_2. This suggests that both pollutants likely originate from similar sources or are influenced by related environmental factors. SO_2 also shows a moderate positive correlation with CO ($r = 0.301$), implying that higher concentrations of SO_2 tend to accompany higher CO levels, potentially due to shared sources or atmospheric conditions.

TVOC shows a significant positive correlation with CH_2O ($r = 0.586$), indicating that these two volatile organic compounds are likely related, possibly from similar sources or chemical interactions in the atmosphere. However, TVOC has a significant negative correlation with CO (r = -0.362), suggesting that higher levels of TVOC are associated with lower CO levels, possibly reflecting different sources or atmospheric behaviours of these pollutants.

CH_2O is positively correlated with both NO_2 (r = 0.285) and SO_2 (r = 0.307), further supporting the idea that CH_2O is related to the same sources or atmospheric processes affecting these oxides.

For particulate matter, PM2.5 shows a weak but significant positive correlation with NO_2 (r = 0.216) and CH_2O (r = 0.235), suggesting a slight association between these pollutants and fine particulate matter. PM10 is moderately positively correlated with PM2.5 (r = 0.517), as expected, indicating that areas with higher levels of one type of particulate matter are likely to have higher levels of the other.

Interestingly, PM10 has a significant positive correlation with TVOC (r = 0.342) and a significant negative correlation with SO_2 (r = -0.340), suggesting that higher levels of PM10 are associated with higher TVOC but lower SO_2 concentrations. This could reflect different sources or processes influencing these pollutants during the dry season.

Temperature shows a weak negative correlation with NO_2 (r = -0.240), CO (r = -0.256), and atmospheric pressure (r = -0.296), indicating that higher temperatures are associated with lower concentrations of these pollutants and lower pressure. This is consistent with the idea that higher temperatures may enhance the dispersion or chemical transformation of these pollutants.

Relative humidity (RH) shows a significant negative correlation with temperature (r = -0.296), reflecting the typical inverse relationship between temperature and humidity. However, RH does not show strong correlations with most pollutants, suggesting that humidity alone may not be a major driver of pollutant levels during the dry season in this region.

Wind speed (WS) shows a significant positive correlation with SO_2 (r = 0.459), NO_2 (r = 0.266), and CH_2O (r = 0.265), indicating that higher wind speeds are associated with higher levels of these pollutants. This could suggest that wind is transporting these pollutants from their sources to the area or that wind is influencing their atmospheric behaviour.

The correlation results also showed the complex interactions between different pollutants and meteorological factors in the dry season. The significant positive and negative correlations provide insights into the potential sources and atmospheric processes affecting air quality in Ikot Abasi during this period.

3.3 Air Quality Index

The Air Quality Index (AQI) analysis for Ikot Abasi, as shown in Table 2 and further detailed in Table 3, indicates significant levels of pollution across various pollutants from November 2019 to October 2020. The AQI ratings show that SO_2 concentrations fluctuated, with periods of moderate pollution in February, May, June, and October 2020. In contrast, the months of November 2019, December 2019, January 2020, March, and April 2020 were categorized as polluted, while July, August, and September 2020 were classified as severely polluted.

For other pollutants, including NO_2, CO, TVOC, CH_2O, PM2.5, and PM10, the AQI consistently indicated severe pollution throughout the study period, except SO_2 in October 2020 (AQI = 78) and CO in August 2020 (AQI = 64.88), which were categorized as polluted but not severely so. This persistent high pollution level suggests that air quality in Ikot Abasi is compromised and may pose significant health risks to the local population, especially with prolonged exposure to these pollutants.

3.4 Geographical Information System Mapping

The result of geographical information system mapping for the average concentration of suspended particulate matter and gaseous pollutants for Ikot Abasi is presented in Fig.s 3a to g respectively.

The geographical information system (GIS) mapping further supports the AQI analysis by revealing the spatial distribution of these pollutants. For carbon monoxide (CO), the spatial distribution shows a very low concentration around the Ikot Abasi Ibom Power Plant (IKIPP) site, which may be attributed to stronger wind action and changes in wind direction, causing wider dispersion of CO from the source. This pattern aligns with findings from Zheng *et al*. (2015), who also observed similar spatial dispersion due to wind effects.

Table 1: Air Quality Index (AQI) Ratings

AQI of Ambient Air	AQI Rating	Prescription of Ambient Air Quality
0-15	A	Very good
16-31	B	Good
32-49	C	Moderate
50-99	D	Polluted
100 or above	E	Severely polluted

Source: CPCB (2009) and USEPA (2000)

Table 2: Average Monthly Concentration of Air Quality Pollutants in Ikot Abasi

Month	SO_2	NO_2	CO	TVOC	CH_2O	PM2.5	PM10
Nov. 2019	66.2	227	219.74	237	1825	491.72	423.38
Dec. 2019	55.2	219	195.32	173.2	866.67	192.75	201.75
Jan. 2020	65.8	246	258.16	237	1616.67	172.25	138.88
Feb. 2020	41.2	162	247.06	322.4	4166.66	340.7	291.35
Mar. 2020	60.6	261	217.62	204.4	1508.33	272	274.75
Apr. 2020	63.6	166	242.2	163.2	2608.33	355.5	209.63
May 2020	38.2	183	145.14	392.6	3191.66	249.67	196.83
June 2020	32.6	138	125.58	599.2	3883.33	255.66	209.33
July 2020	130	650	224.8	219.8	8741.67	252.67	206.17
Aug. 2020	118.6	7161	64.88	217.8	224050	296.33	125.33
Sept. 2020	108.2	475	198.56	483.6	3116.67	229.33	172.5
Oct. 2020	36.8	78	132.22	417.8	2916.66	445.32	415

For formaldehyde (CH_2O), the GIS mapping shows a critical concentration hotspot around IKIPP-10, likely due to industrial activities and possible temperature inversion in the area. This pattern is consistent with previous studies by Song (2008), which found that industrial emissions and meteorological conditions can lead to elevated formaldehyde levels in specific areas.

The distribution of nitrogen dioxide (NO_2) also shows a critical concentration hotspot near IKIPP-10, again suggesting a link to industrial activities and temperature inversion effects, similar to what was observed with formaldehyde. For sulfur dioxide (SO_2), the GIS mapping shows a low concentration near IKIPP-10, which is widely dispersed, potentially due to increased wind speed and changes in wind direction. This pattern has been observed in previous studies, such as those by Narayanan (2009), which found that wind patterns significantly influence the dispersion of sulfur dioxide.

The spatial distribution of total volatile organic compounds (TVOC) shows moderately high concentrations around IKIPP-10, likely due to high commercial and traffic activities or wider dispersion from both point sources and mobile vehicular emissions, as observed by Zeng *et al*. (2017). For suspended particulate matter (PM2.5 and PM10), the GIS mapping reveals moderately low and very low concentrations, respectively, near IKIPP-10, with widespread dispersion, likely due to strong wind action. This pattern is consistent with the behaviour of particulate matter, which can be easily transported by wind, leading to lower concentrations in areas with high wind speeds.The results showed that the AQI and GIS mapping results indicate that air quality in Ikot Abasi is heavily compromised, with severe pollution levels for multiple pollutants.

The consistent presence of critical concentration hotspots near industrial areas like IKIPP suggests that industrial activities are a significant source of these pollutants. The findings also highlight the need for immediate intervention to mitigate the health risks associated with prolonged exposure to such high pollution levels.

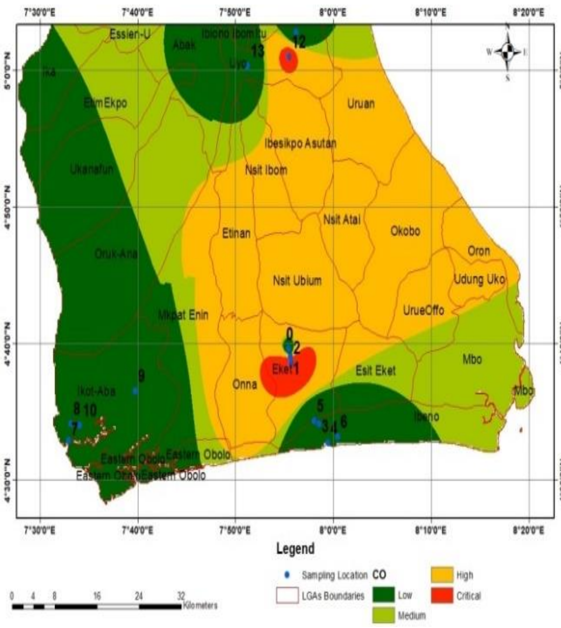


Fig. 3a: Spatial interpolation of CO

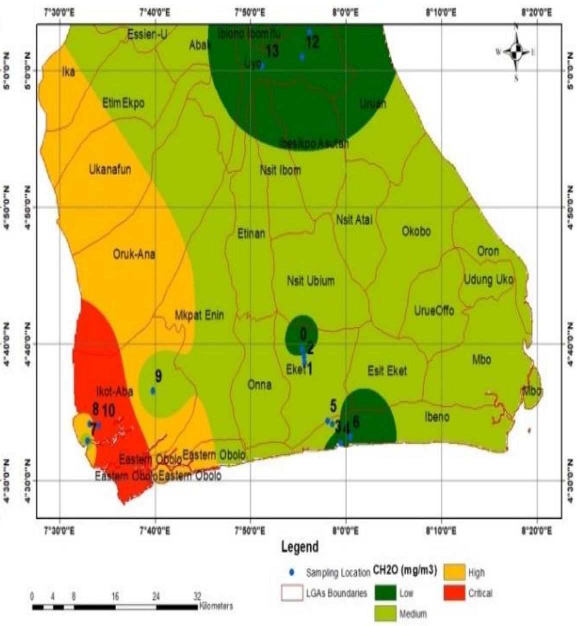


Fig. 3b: Spatial interpolation of CH_2O

**10 = IK$_{IPP}$ (Ikot Abasi Ibom Power Plant)

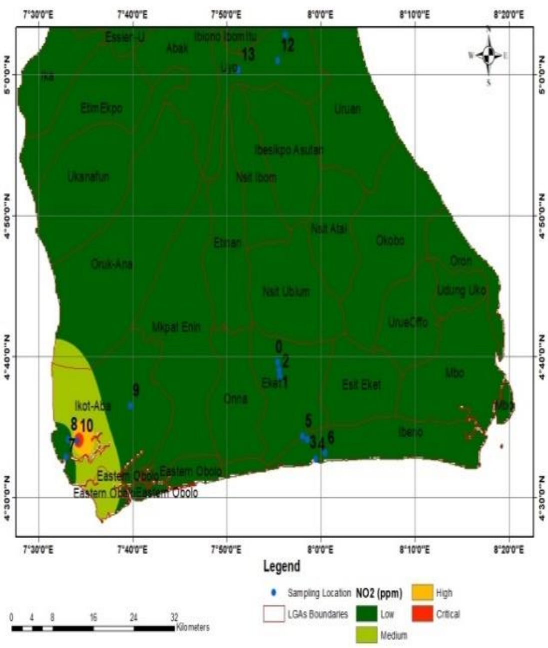


Fig. 3c: Spatial interpolation of NO_2

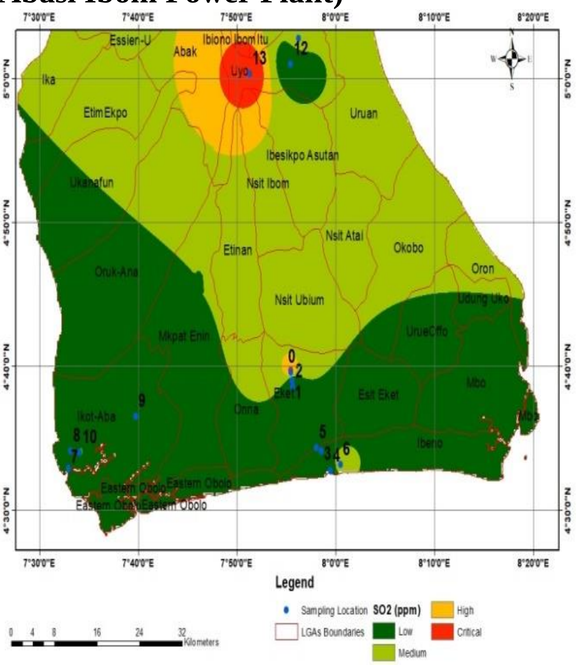


Fig. 3d: Spatial interpolation of SO_2

**10 = IK$_{IPP}$ (Ikot Abasi Ibom Power)

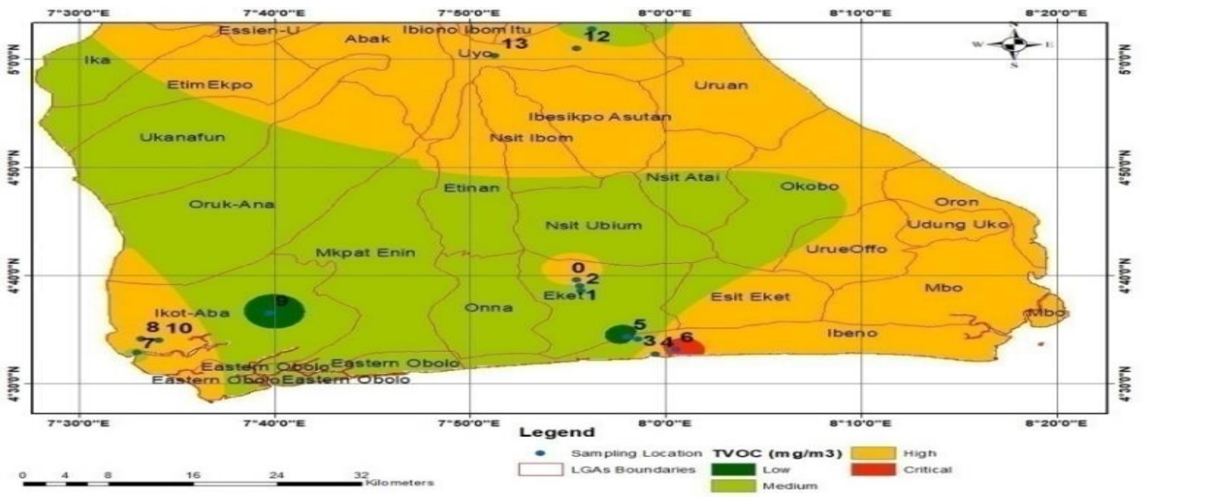
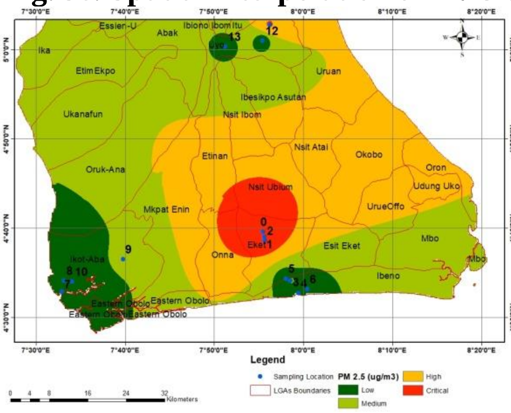


Fig. 3e: Spatial interpolation of TVOC (where: 10 = IK_{IPP} (Ikot Abasi Ibom Power Plant)



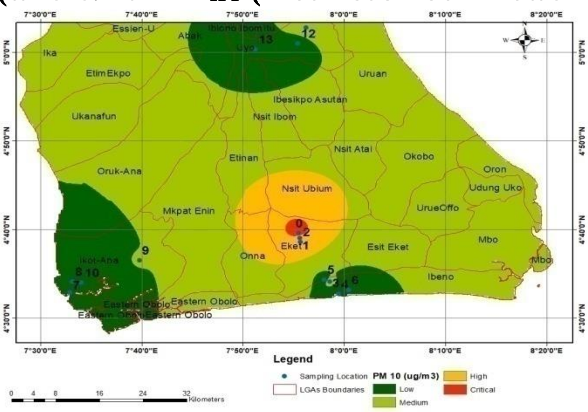


Fig. 3f: Spatial interpolation of $PM_{2.5}$ Fig. 3g: Spatial interpolation of PM_{10} where: 10 = IK_{IPP} (Ikot Abasi Ibom Power Plant

4.0 Conclusion

The study provides a comprehensive assessment of gaseous pollutants, particulate matter, and meteorological parameters around the Ibom Power Plant in Ikot Abasi Local Government Area of Akwa Ibom State, Nigeria. It highlights the impact of various pollutants, including sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), total volatile organic compounds (TVOC), formaldehyde (CH_2O), and particulate matter (PM2.5 and PM10) on air quality. The findings indicate that pollutant levels frequently exceed the Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO) standards, with significant variations observed between wet and dry seasons. The study also reveals that higher concentrations of pollutants are often associated with industrial activities and meteorological factors such as temperature, humidity, and wind speed.

The results underscore the critical need for improved air quality management in Ikot Abasi. The persistent exceedance of pollution standards and the significant fluctuations in pollutant levels between seasons suggest that both emission sources and weather conditions play a substantial role in air quality. The spatial distribution of pollutants, as illustrated by GIS mapping, indicates that industrial activities contribute significantly to localized pollution hotspots, further emphasizing the urgency of targeted interventions.

To address the issues identified, it is recommended that regulatory measures be enhanced to control emissions from industrial sources and improve air quality standards. Implementing more rigorous monitoring systems and pollution control technologies at industrial sites, coupled with public awareness campaigns about the health risks of air pollution, is crucial. Additionally, strategies should be developed to mitigate the impact of meteorological factors on pollutant dispersion, such as optimizing emission controls during adverse weather conditions. Further research is needed to explore long-term health effects and develop innovative solutions tailored to the specific environmental and socio-economic conditions of Ikot Abasi.

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Compliance with Ethical Standards Declaration

Ethical Approval

Not Applicable

Competing interests

The authors declare that they have no known competing financial interests

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Availability of data and materials

Data would be made available on request**.**

Authors Contribution

The work was designed by the first and second authors, supervised by the second and third authors while the draft was jointly written by all the authors.