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Relationship between Meteorological properties and Air pollutants in Uyo Urban, Nigeria

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Abstract: Air is a major component of life on earth both to plants and animals including man; however, constant exposure to polluted air environment might have significant negative impacts. The concentrations of air pollutants and the meteorological parameters in Uyo Urban were evaluated in this study using portable air monitors. The influence of meteorological parameters of air on the measured air pollutants was also examined. Results obtained indicated the following mean concentrations: 0.41±0.02 ppm, 0.52±0.03 ppm, 0.64±0.02 ppm, and 300.9±72.8 µg/m^3 for NO_2, SO_2, H_2S, and SPM, respectively. The average levels of temperature, relative humidity, wind speed, and atmospheric pressure were 26.9±0.35 ºC, 80.6±2.06 %, 0.81±0.02 m/s, and 1004.5±1.27 Kpa, respectively. The reported mean values of the air pollutants and the meteorological parameters of the studied air environment exceeded their recommended limits by the Federal Environmental and Protection Agency (FEPA). Hence, the air environment within Uyo Urban has been polluted by these air pollutants. The results also indicated that the meteorological parameters showed significant negative influence on the air pollutants. The principal component analysis identified the major sources of these air pollutants as natural and anthropogenic, however; the anthropogenic source was more prominent. Continuous air pollution studies should be conducted to identify the point sources of these pollutants and control properly to forestall the negative effects on the environment and human health.

1. Introduction

Clean and unpolluted air is composed of about 78% nitrogen, 21% oxygen, and 0.93% argon with traces of carbon (IV) oxide and water vapour. However, when the constituents of air are altered either qualitatively or quantitatively the air is contaminated and may subsequently be polluted. According to Manisalidis *et al*. (2020), air pollutants emanate from both the natural and anthropogenic sources, however; the anthropogenic sources are several and significant globally (Popescu and Ionel, 2010; Ivanova, 2020). The anthropogenic sources of air pollutants include agricultural, commercial, domestic, automobiles, traffic, and industrial activities (Okedere *et al*., 2021). The negative impacts of air pollutants usually manifest in the quality of air, soil, and water (Ebong *et al*., 2016; Alaqarbeh *et al*., 2022; Ebong *et al*., 2022). Air pollutants can also impact negatively on the health of plants, animals, and human (Abelsohn *et al*., 2011; Elmouaden *et al*., 2013; Saini *et al*., 2019; Al-Kindi *et al*., 2020; Ebong *et al*., 2023a; Shetty *et al*., 2023).

Air pollutants can cause serious human health problems such as respiratory damage, cancer, cardiovascular diseases, stroke, and even premature death (Atuyambe *et al*., 2024). Studies have constantly indicated strong relationship between air pollutants with respiratory problems, cardiovascular diseases, and premature death in elderly people (Gourgue *et al*. 2015). Reports have also shown that millions of people die prematurely from air pollutants globally (Lelieveld *et al*., 2023; Capitanio *et al*., 2024). It has been opined that exposure to air pollutants may result in both carcinogenic and non-carcinogenic human health risks (Kebe *et al*., 2025).

Search on "meteorological AND air AND pollutants" indicated more than 15,000 articles from 1962 to 2024 on Scopus which incited us to carry out a bibliometric analysis to show more indicators on the most published authors, their affiliation and the possible collaborations via the clusters given by VOS viewer as widely studied by several researchers (Julius *et al.,* 2021; N'diyae *et al.,* 2022; Bazzi *et al.,* 2023; Herawan *et al*., 2024; Hammouti *et al*., 2025; Byiringiro *et al*., 2025)

Several studies have been carried out to ascertain the air pollution status of Uyo Urban and the point sources of these pollutants (Eduk, 2017; Nta *et al.,* 2020; Echendu *et al*., 2022; Ebong *et al*., 2023b; Ebong *et al*., 2025). Nevertheless, air quality monitoring should be carried out regularly and the influence of the meteorological parameters on the air pollutants has never been assessed and established in the area. Consequently, this research work was performed to assess the current air pollution status and ascertain the impact of meteorological parameters on air pollutants loads in Uyo Urban. The principal component analysis was utilized to identify the sources of the air pollutants, while Pearson correlation analysis was used to establish the influence of meteorological properties on the air pollutants. It is hoped that the outcome of the study will assist in the proper monitoring of the air environment within and beyond the study area.

2. Methodology

2.1 Bibliometric analysis

The bibliometric analysis was conducted via Scopus tool offering analysis data and the VOS viewer (Eck & Waltman, 2007; Derviş, 2020). It creates networks of authors, keywords, and citations to reveal patterns and trends in scientific research. Key VOS viewer indicators include node size (representing frequency or importance) and clustering (groups of related nodes), which help map research areas and identify influential figures and concepts (Aria and Cuccurullo, 2017; Salim *et al*., 2022; Dalir *et al*., 2025).

2.1 Study Area

The study was conducted at the following locations within Uyo Urban:
Uyo Municipal waste dumpsite (05° 02! 49.11!! Longitude and 007.56! 13.62!! Latitude), Itam Abattoir (05° 04! 22. 46!! Longitude and 07° 55! 40.00!! Latitude), Akpanadem Market (05º 01! 15.88!! Longitude and 07 º 55! 35.25!! Latitude), and Itam Market (05º 02! 49.68!! Longitude and 07 º 53! 54. 20!! Latitude). Uyo Urban include has high population, high traffic density, and high level of commercial activities. Accordingly, significant volumes of harmful substances are being discharged into the air environment on daily basis. The field work was performed in the dry season when the level

of pollutants in the air was significantly high (Emekwuru and Ejohwomu, 2023). The data collection was constantly carried out in the early period of each day between January and March, 2024 (Soleimanpour *et al*., 2023; Chen *et al*., 2024).

2.2 Analytical procedures

This work monitored the levels of air pollutants namely: nitrogen (IV) oxide (NO_2), sulphur (IV) oxide (SO_2), Hydrogen sulphide (H_2S), and suspended particulate matter (SPM) using portable air monitors shown in **Table 1**. The meteorological parameters which include temperature, relative humidity, wind speed, and atmospheric pressure were also determined with portable equipments as shown in **Table 1**. The influence of meteorological parameters on the air pollutants was assessed using Pearson correlation analysis as reported by Nakyai *et al*. (2025). During data collection, the monitor was kept at each location in an open space and adjusted to the TEST point for 120 seconds. The equipment was later regulated to the GAS position and the level of the measured pollutant will show on the Liquid Crystal Display (LCD) unit. This was performed for three times and the average value recorded. The monitors were properly calibrated for precision and accuracy of values obtained for each parameter. The monitors were accurately maintained by replacing weak battery, troubleshooting, regular cleaning of the sensors, and replacing damaged ones. The equipments were also not exposed to excessive high or low weathers to evade damage. The data collection procedures stated above was done according to the methods of Xie *et al*. (2021) and Kortoçi *et al*. (2022). The equipment used for the collection of air pollutants and meteorological parameters data are shown in **Table 1**.

Table 1. Equipment used for the determination of air pollutants and meteorological parameters

Parameter	Equipment used
Nitrogen dioxide (NO_2)	NO_2 Crowcon Gasman S/N: 19831N
Sulphur dioxide (SO_2)	SO_2 Crowcon Gasman S/N: 19648H
Hydrogen sulphide (H_2S)	H_2S Crowcon Gasman S/N: 19502H
Suspended particulate matter (SPM)	Haz-Dust^{Tm} particulate Monitor
Temperature (Temp)	Portable Thermometer
Relative humidity (RH)	Hygrometer
Wind speed (WS)	Digital anemometer
Atmospheric pressure (AP)	Aneroid barometers

2.3 Statistical analysis

The IBM SPSS Statistic version 29.0.2.0 (20) Software was used for the collection of statistical data of the study. Varimax Factor analysis was used for performing the principal component and Pearson correlation analyses of the data obtained. Values ranging from 0.608 and above were adjudged significant and used for discussions. The reliability of data obtained was affirmed by carrying out each analysis three times.

3. Results and Discussion

3.1 Bibliometric analysis

The evolution of articles on Scopus during the period 1962 to 2024 is shown in **Figure 1**. The scientific production reaches aver 1200 articles both in 2023 and 2024, explaining the preoccupation of policymakers and researchers to get more information about the consequence of air pollution on environment and human. a significant and sustained increase in industrial activity over the last few decades, characterized by the burning of fossil fuels and disregard for environmental consequences, has directly contributed to climate change. This process has led to rising greenhouse gas concentrations, which trap heat and cause global warming, resulting in observable effects such as rising sea levels, more frequent extreme weather events, and changes to ecosystems. The serious problem can be also explained by the nature of publication which exceeds more 96% as articles and conference papers.

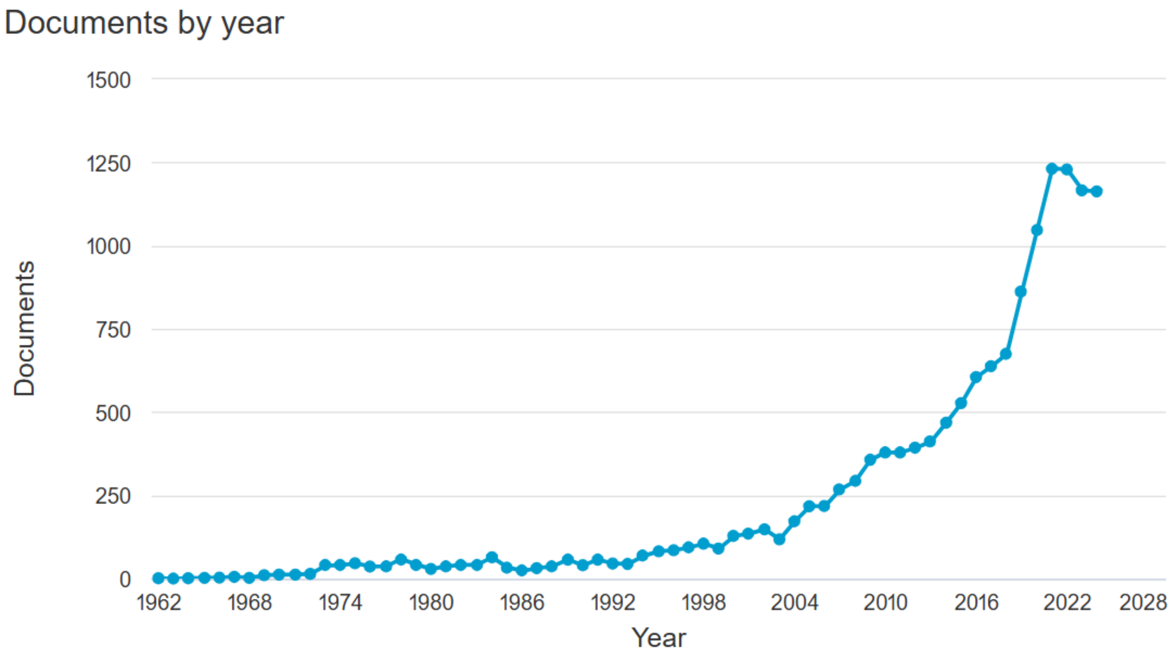

Figure 1. Evolution of article's production from 1962 to 2024

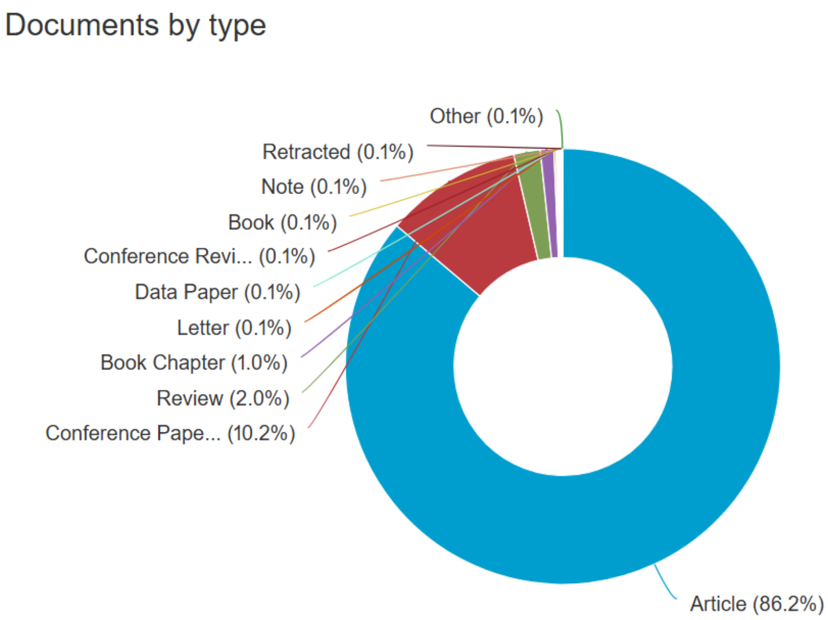

Figure 2. Production by type of publication from 1962 to 2024

Industrialization's rapid, environmentally unchecked expansion over recent decades is a primary driver of climate change, with most developed nations being the largest contributors due to their historical and ongoing emissions. In this optic, China and the US are most concerned by research on this topics as shown in **Figure 3**. Environmental sustainability have become global phenomena considering the fast pace at which environmental degradation is affecting the climate and the subsequent detrimental effects of climate change.

Figure 4 shows the graphic Network of the VOS analysis. Among 41198 collected authors, 2483 published more than five papers and 501 more than eleven papers visualized in **Figure 4.** The authors presented by colored circles, called nodes, in which the diameters indicate the publication power. Anon J.Cr. is the most published one with the largest blue node. VOS viewer also links the production in function of time to see the change of color from dark purple (2010) to light yellow (around 2024) **Figure 5**.

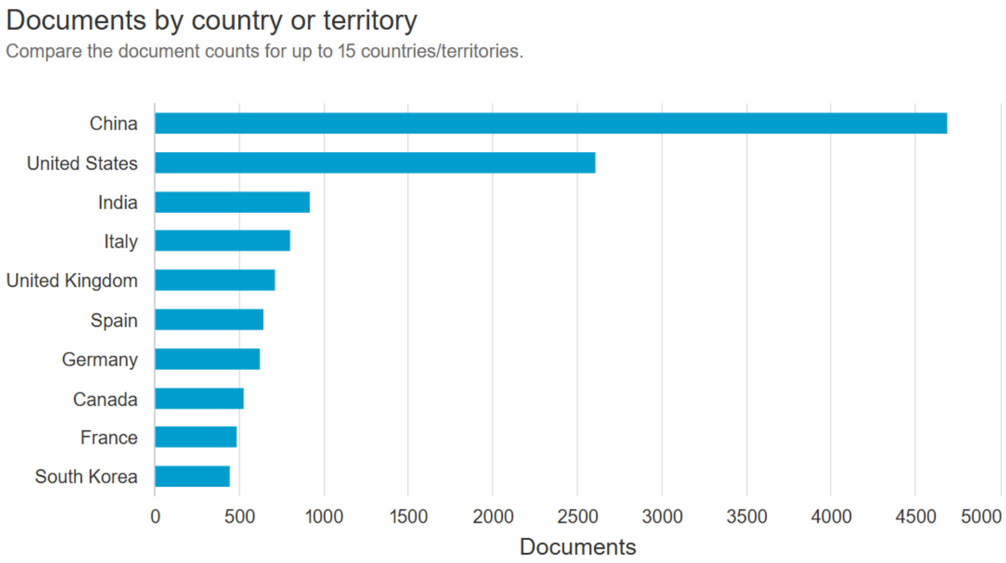

Figure 3. Countries' production from 1962 to 2024

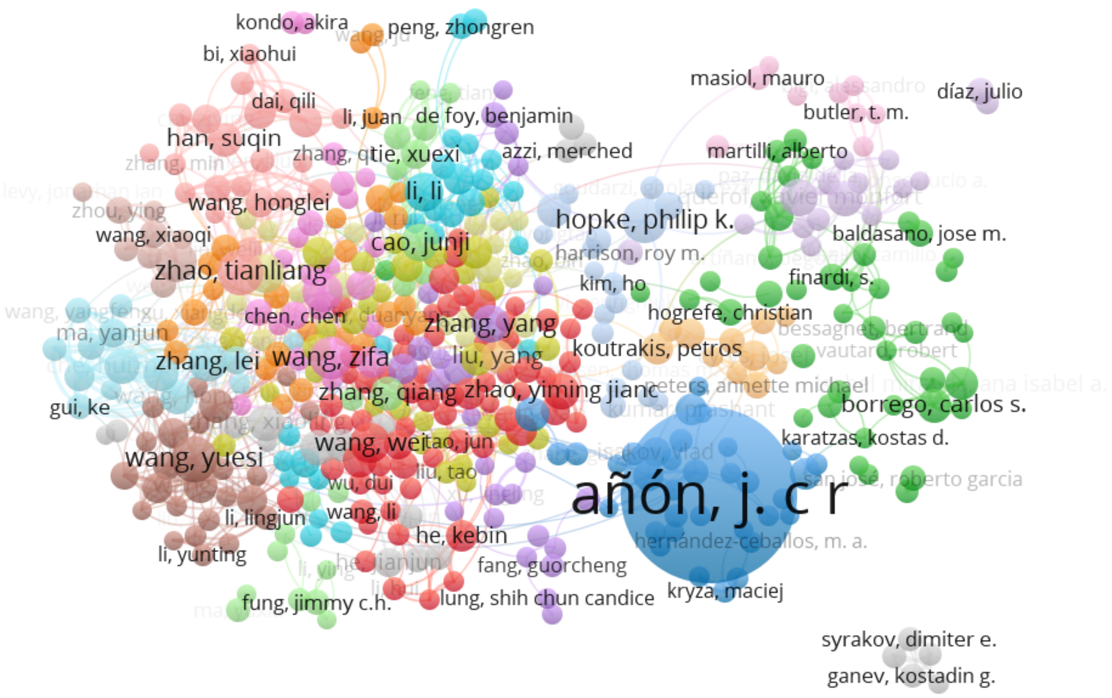

Figure 4. Network visualisation of the authors from 2010 to 2024 (VOS viewer)

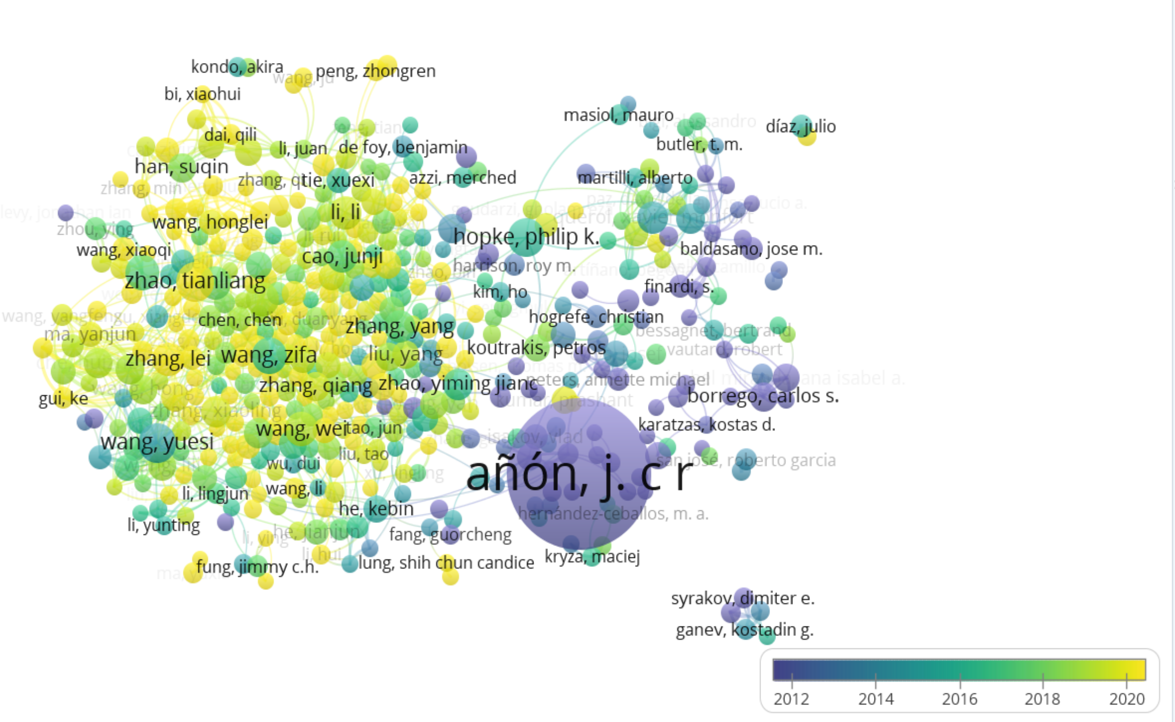

Figure 5. Overlay visualisation of the authors from 2010 to 2024 (VOS viewer)

The mean concentration of NO_2 recorded (0.41±0.02 ppm) is higher than the recommended 0.10 ppm limit by FEPA (1991). Hence, prolonged exposure to the reported high concentrations of NO_2 might result in respiratory problem (Muhammad *et al*., 2020; Jonah and Obot, 2024). The reported high levels of NO_2 in the studied locations could be attributed to the combustion of fossil fuels in automobiles (Anenberg *et al*., 2022). Concentrations of sulphur (IV) oxide (SO_2) varied from 0.48 to 0.54 ppm. The average value of SO_2 obtained (0.52±0.03 ppm) exceeds the 0.10 ppm acceptable limit by FEPA (1991). This could be attributed to the excessive burning of fossil fuels in the area (Kuttippurath *et al*., 2022).

3.2 Concentrations of air pollutants and meteorological parameters

The results of the concentrations of the air pollutants in the locations examined are shown in **Table 2**. The concentrations of nitrogen (IV) oxide (NO_2) ranged between 0.38 and 0.43 ppm. The mean concentration of NO_2 recorded (0.41±0.02 ppm) is higher than the recommended 0.10 ppm limit by FEPA (1991). Hence, prolonged exposure to the reported high concentrations of NO_2 might result in respiratory problem (Muhammad *et al*., 2020; Jonah and Obot, 2024). The reported high levels of NO_2 in the studied locations could be attributed to the combustion of fossil fuels in automobiles (Anenberg *et al*., 2022). Concentrations of sulphur (IV) oxide (SO_2) varied from 0.48 to 0.54 ppm. The average value of SO_2 obtained (0.52±0.03 ppm) exceeds the 0.10 ppm acceptable limit by FEPA (1991). This could be attributed to the excessive burning of fossil fuels in the area (Kuttippurath *et al*., 2022).

Constant exposure to these high levels of SO_2 might cause serious human health risks including cardiovascular, nervous systems, and respiratory (Khalaf *et al*., 2022). The levels of hydrogen sulphide (H_2S) in the studied locations ranged from 0.62 to 0.67 ppm. The average concentration of H_2S recorded (0.64±0.02 ppm) is higher than 0.06 ppm recommended by FEPA (1991). According to Nunes *et al.* (2021), this might be due to the decomposition of organic wastes by bacterial.

Table 2. Concentrations of Air pollutants and Meteorological parameters

	NO_2 (ppm)	SO_2 (ppm)	H_2S (ppm)	SPM (µg/m^3)	Temp (ºC)	RH (%)	WS (m/s)	AP (Kpa)
UMD	0.43	0.53	0.67	268.5	26.5	81.4	0.80	1005.0
IAB	0.42	0.51	0.62	361.6	27.0	79.6	0.79	1003.0
ITM	0.38	0.54	0.64	360.0	27.3	83.1	0.81	1006.0
AKM	0.41	0.48	0.63	213.4	26.7	78.4	0.84	1004.0
MIN	0.38	0.48	0.62	213.4	26.5	78.4	0.79	1003.0
MAX	0.43	0.54	0.67	361.6	27.3	83.1	0.84	1006.0
MEAN	0.41	0.52	0.64	300.9	26.9	80.6	0.81	1004.5
SD	0.02	0.03	0.02	72.8	0.35	2.06	0.02	1.29

UMD = Uyo municipal dumpsite; ABI = Itam Abattoir; ITM = Itam Market; AKM = Akpanadem Market ; Temp = Temperature; RH = Relative humidity; WS = Wind speed; AP = Atmospheric

Constant exposure might lead to respiratory problems, eye irritation, neurological problems and even death (Uddin *et al*., 2023). The suspended particulate matter (SPM) in the areas investigated ranged from 213.4 to 361.9 µg/m^3. The mean value of SPM obtained (300.9±72.8 µg/m^3) exceeds the 250 µg/m^3 safe limit recommended by FEPA (1991). This might originate from the burning of fossil fuels, industrial and vehicular emissions (Munsif *et al*., 2021). The levels of SPM reported hava related human health problems such as respiratory, heart disease, lung cancer, and stroke (Ebong *et al*., 2023b; Sangkham *et al*., 2024). The results obtained revealed that the studied locations might have been polluted with NO_2, SO_2, H_2S, and SPM as previously opined (Ebong and Mkpenie, 2016; Ebong *et al*., 2025).

The distributions of meteorological prameters of the studied locations are shown in **Table 2**. The temperature (Temp), relative humidity (RH), wind speed (WS), and atmospheric pressure (AP) varied as follows: 26.5-27.3 ºC, 78.4-83.1 %, 0.79-0.84 m/s, and 1003-1006 Kpa, respectively. The average values of 26.9±0.35 ºC, 80.6±2.06 %, 0.81±0.02 m/s, and 1004.5±1.29 Kpa were recorded for temp., RH, WS, and AP, respectively. These mean values exceed their recommended limits of 26.4 ºC, 60 %, 2.8 m/s, and 769 Kpa for temp., RH, WS, and AP, correspondingly by FEPA (1991). Consequently, these high levels of meteorological parameters of the studied air environment might influence the concentrations of the air pollutants (González-Alonso *et al*., 2024; Nakyai *et al*., 2025).

3.3 Principal component analysis of air pollutants

Principal component analysis was employed to ascertain the sources of the measured air pollutants as opined by Shihab (2022). The results of principal component analysis (PCA) of the air pollutants are indicated in **Table 3**. The results obtained revealed two major sources for the air pollutants in the studied environment. The first source (S1) with Eigen value of 1.90 had a total and cumulative variance of 47.6 %. This source showed significant loadings on all the air pollutants except H_2S. This might be the anthropogenic influence on the air quality as documented by Manisalidis *et al*. (2020). The second source (S2) with Eigen value of 1.47 had a total variance of 36.8 % and a cumulative variance of 84.4 %. This second source had a strong loading on only H_2S and this could be the natural source of air pollution as reported by Farid *et al*. (2023). The work has corroborated the findings by Manisalidis *et al*. (2020) that the main sources of air pollutants are natural and anthropogenic.

Table 3. Result of principal component analysis of the air pollutants

Air pollutant	S1	S2
NO_2	-0.641	0.440
SO_2	0.850	0.526
H_2S	0.021	0.978
SPM	0.877	-0.211
% Total Variance	47.6	36.8
Cumulative Variance %	47.6	84.4
Eigen value	1.90	1.47

3.4 Pearson correlation analysis of air pollutants and meteorological parameters of the air

In this work, Pearson correlation analysis was utilized to establish the relationship between air pollutants and meteorological parameters in the studied air environment as reported by Ramli *et al*. (2024). The results of Pearson correlation analysis between air pollutants and the meteorological parameters are indicated in **Table 4**. The results revealed that NO_2 correlated with Temp and AP negatively and significantly at $p < 0.10$ and 0.05, respectively. Thus, a decrease in Temp and AP at the studied locations can elevate the concentrations of NO_2. Thus, NO_2 concentration in the studied locations could have been significantly influenced by the temperature and pressure as reported by She *et al*. (2021) and Liu *et al*. (2022). Sulphur (IV) oxide (SO_2) correlated positively and significantly with RH, and AP, but negatively with WS at $p < 0.05$. Consequently, the reported high levels of RH and AP might have resulted in the high concentrations of SO_2 recorded at the studied locations. The concentration of SO_2 could also be increased by the decrease in WS. Obviously, the concentration of SO_2 at the locations assessed must have been greatly influenced by the levels of RH, AP, and WS as indicated in literature (Asuoha and Osu, 2015; Zateroğlu, 2023).

Table 4. Pearson Correlation Analysis between air pollutants and the meteorological parameters of air

	NO_2	SO_2	H_2S	SPM
Temp	-0.838**	0.378	-0.529	0.788**
RH	-0.517	0.957**	0.494	0.564*
WS	-0.286	-0.642**	-0.143	-0.745**
AP	-0.598*	0.683**	0.598*	0.089

*** Significant correlation at $p < 0.10$; ** significant correlation at $p < 0.05$.**

Temp = Temperature; RH = Relative humidity; WS = Wind speed; AP = Atmospheric pressure

Hydrogen sulphide (H_2S) showed a significant positive relationship with AP at $p < 0.10$. The study indicated that the elevated levels of AP obtained might have caused the high concentrations of H_2S reported at the studied locations. The significant influence of AP on H_2S observed in the study is similar to the findings by Traven *et al*. (2023). The SPM of the studied locations showed a strong positive association with Temp and RH at $p < 0.05$ and 0.01, respectively. However, the relationship between SPM and WS was a significantly negative. Thus, the high levels of Temp and RH recorded in the locations investigated might have resulted in the high concentrations of SPM obtained. Based on the results, a reduction in the levels of WS could also elevate the concentrations of SPM. Consequently, the concentrations of SPM reported in the study could have been significantly influenced by the Temp, RH, and WS as previously reported by Li *et al*. (2015) and Merenda *et al*. (2024). Generally, the results in Table 4 has shown that the meteorological parameters of the studied air environment have strong influence on the air pollutants determined (Shihab, 2022; Nakyai *et al*., 2025). The coefficient of correlation (r) for each of the correlations is indicated in **Table 4** above.

Conclusion

Based on the results obtained from the study, it could be concluded that the air environment within Uyo Urban has been highly polluted. It could also be concluded that the meteorological parameters of the air have significant influence on the pollution status of the studied air environment. Although, the air pollutants emanated from both the natural and anthropogenic sources, the human induced source was the dominant. It could be inferred from the outcome of the study that, commercial activities performed within Uyo Urban are the major point sources for air pollutants. It might be opined that human health in the study has been greatly affected by the reported high pollutants loads in the atmosphere. The actual and major point sources of these air pollutants should be identified and controlled properly. Regulations related to air pollution control and management should be timely and effectively implemented to forestall further damage to the environment and human health.

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