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Air Quality Index of some Commercial Centres in Uyo Metropolitan Area, Akwa Ibom State, Nigeria

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ABSTRACT: *Commercial activities in urban cities in the world have contributed to the development of the society and at the same time impact negatively on the environment. This study investigated the influence of some commercial centres namely: Akpanadem Market, Uyo Plaza, Itam Market and Itam Abattoir in Uyo Metropolis to ascertain their air quality based on the activities carried out at each location. The levels of* NO_2, SO_2, H_2S, *CO*, Cl_2, NH_3, *HCN*, CH_2O, *TVOCs*, $PM_{2.5}$, *and* PM_{10} *were monitored at the studied locations using standard instruments. Results obtained revealed that the mean concentrations of all the air pollutants determined except* SO_2 *were above their recommended limits by Federal Environmental and Protection Agency (FEPA). It was also observed that, activities at Itam abattoir released the highest levels of these air pollutants. The dumping of organic wastes in markets, cigarette smoking, emissions from generators and vehicles, use of condemned tyres and petroleum products were the major sources of these pollutants at the studied locations. The multivariate analysis revealed the anthropogenic source as the major route for the release of these pollutants into the air environment. Air quality index analysis showed that if human beings are exposed to the levels of these air pollutants at all the locations for a long time, they can affect both the sensitive to non-sensitive groups adversely. The results of this study should be used for the proper planning and management of these commercial centres by the concerned agencies.*

KEYWORDS: air pollutants, commercial centres, air quality index, gaseous emissions, and Uyo metropolis.

INTRODUCTION

Air contamination and subsequent pollution is due to the modifications made to the natural compositions either by human activities or natural factor. The air environment was made clean and perfect for human but, the manipulations by man to satisfy his needs altered the natural compositions. Human activities have introduced numerous obnoxious substances into the air environment. Air pollution has now become a worldwide issue and should manage at the point source of these pollutants. There is little or no place on earth that has not been significantly impacted by air pollutants (Li *et al*., 2019; Manisalidis *et al*., 2020). The situation has been aggravated in the oil producing Area of Nigeria by the flaring of gases (Obi *et al*., 2021; Echendu *et al*., 2022). Studies have indicated that the air environment in the Niger Delta Region is highly degraded by the high concentrations of N_2O, NO_2, NH_3, CO, CO_2, CH_4, PAHs, VOCs, SPM, and toxic metals (Tawari and Abowei, 2012; Ebong *et al*; 2022). This could be accredited to the intensive gas flaring by Oil Companies in the oil producing Area of Nigeria (Efe, 2003). Globally, air pollution has been categorized as a major cause of human death (Burnett *et al.,* 2018; Lelieveld *et al*., 2020; Vohra *et al*., 2021).

Nowadays, the activities in markets due to population explosion, the number of people in urban markets and wastes generated are alarming. These waste materials mostly garbage are kept for a long time before evacuation and as such as they decay, dangerous gases such as CH_4, H_2S, SO_2, NO_2, CO_2, NH_3, are released into the air (Weli and Adekunle, 2014; Sonibare *et al*., 2019; Musa *et al*., 2021). The markets investigated are located by major streets and roads hence, toxic gases, metals, suspended particulates, and volatile organic carbons maybe released into the environment (Bhadu, 2021; Munjal *et al*., 2022; Ebong *et al*., 2023). Uyo Plaza is located within the circus where significant negative impact of vehicular emissions emissions from generators, and cigarette smoking are felt (Tran *et al*., 2019; Deng *et al*., 2022; Munjal *et al*., 2022). The Uyo Plaza is a highly populated location within the State capital during the day and night. Consequently, the negative impact of emissions vehicles, trucks, generators, and cigarette smoking may impact on a larger population of the State.

The activities at abattoir such as the use of petroleum products, condemned tyres, waste materials for the singeing of animals releases toxic gases, volatile organic compounds, particulate matters etc into the air (Umunnakwe and Njoku, 2017). Abattoir has general effects on the air, soil and aquatic environments (Elemile *et al*., 2019; Ebong *et al*., 2020a). Abattoir is also the world leading source of air pollution (WHO, 2005; Nwadinigwe, 2015). Air Quality Index (AQI) assessment was also carried out on each of the air pollutants determined to establish their healthy status or otherwise at each of the studied locations (Tan *et al*., 2021).

Previous studies investigated mostly the negative effects of oil activities and wastes dumpsites on the quality of air within the oil producing region of Nigeria (Ojeh, 2012; Rim-Rukeh, 2014; Ebong and Mkpenie, 2016; Angiamowei *et al*., 2019; Ogbemudia and Ita, 2020; Ogbemudia *et al*., 2020). However, this research assessed the effect of air pollutants and sources in relation to commercial centres in oil producing Area of Nigeria.This study aimed at creating awareness on the negative impact of constant exposure to these toxic substances on human health. The study also recommends that these effects could be avoided if timely and appropriate control/management procedures are implemented by the authorities' concerned.

MATERIALS AND METHODS

Study Area

This study concentrated on four commercial centres namely: Akpanadem Market, Uyo Plaza, Itam Market, and Itam Abattoir within Uyo Metropolis. The study covered longitude 05º 01' 03.65" and latitude 07º 55' 45.11" as shown in Table 1. Uyo Metropolis located within the capital of Akwa Ibom State as a State capital has witnessed population explosion since its creation. Consequently, intensive commercial activities and high traffic density within the metropolis with high volume of poisonous gaseous emissions are also found in the area. These indices are closely related to the state being one of the main oil producing regions in Nigeria and the rapid urbanization done by the government. The research was conducted in 2023 in the dry season of the area to avoid rain washing down the air pollutants to the soil environment (Oji and Adamum, 2020; Tian *et al*., 2021). The study was conducted in the early hours of each of the days for accurate data collection (Oyareme and Osaji, 2022). Table 1 shows the coordinate, elevation, and source of air pollutants for each of the locations.

Table 1: Study sites, coordinates, elevations, and their route of air pollutants

Site	**Longitude**	**Latitude**	**Elevation(m)**	**Source of air pollutant**
Akpanadem Market	05° 01! 03.65!!	07° 55! 28.02!!	68	Decay wastes and vehicular emissions
Uyo Plaza	05° 02! 00. 44!!	07° 55! 45.11!!	72	Cigarette smoke and vehicular emissions and emissions from generators
Itam Market	05° 02! 46.73!!	07° 53! 52.44!!	73	Decay wastes and vehicular emissions
Itam Abattoir	05° 04! 22. 49!!	07° 55! 42.00!!	73	Decay animal wastes, smoke from the burning of petroleum products, condemned tyres, and other waste materials

Analytical Techniques

In this study, Gasman potable digital Air Quality monitors were employed for the determination of air pollutants at the studied locations. At each of the locations, a handheld portable device was placed in an open space and regulated to TEST point and kept for one hundred and twenty seconds. The device was later set to the GAS position and readings obtained in triplicates when the display on LCD was stable (Ukpong, 2012). The type of device used for the detection of each of the air pollutants is indicated in Table 2 below.

Table 2: Equipment and air pollutants recorded

Parameter	Equipment	Range	Alarm levels
Sulphur dioxide (SO_2)	SO_2 Crowcon Gasman S/N: 19648H	0-10ppm	2.0ppm
Nitrogen dioxide (NO_2)	NO_2 Crowcon Gasman S/N: 19831N	0-10ppm	3.0ppm
Hydrogen sulphide (H_2S)	H_2S Crowcon Gasman S/N: 19502H	0-50ppm	10ppm
Carbon monoxide (CO)	CO Crowcon Gasman S/N: 19252H	0-500ppm	50ppm
Ammonia (NH_3)	NH_3 Crowcon Gasman S/N: 19730H	0-50ppm	25ppm
Chlorine (Cl_2)	Cl_2 Crowcon Gasman S/N: 19812H	0-5ppm	0.5ppm
Hydrogen Cyanide (HCN)	HCN Crowcon Gasman S/N: 19773H	0-25ppm	5ppm
Total volatile organic carbon (TVOC)	TVOC gas monitor Gasman Model Air Ae Steward air quality monitor	0-9.999 mg/m^3	30.00-99.99 mg/m^3
Formaldehyde (CH_2O)	CH_2O gas monitor Gasman Model Air Ae Steward air quality monitor	0-99.99 mg/m^3	1.000-9.999 mg/m^3
$PM_{2.5}$	$PM_{2.5}$ gas monitor Gasman Model Air Ae Steward air quality monitor	0-500 µg/m^3	200-500µg/m^3
PM_{10}	PM_{10} gas monitor Gasman Model Air Ae Steward air quality monitor	0-999 µg/m^3	350-999 µg/m^3

Air Quality Index (AQI)
The air quality index of the pollutants was evaluated using Equation (1) according to Agarwal *et al*. (2008) and USEPA (2014).

$$AQI = \frac{\text{Concentration of Air Pollutant}}{\text{FEPA Recommended Limit}} \times 100 \text{ --- (1)}$$

The AQI of the pollutants indicates the health risks associated with long term exposure to the pollutants. The six classes of air quality index and their associated human health problems as reported by Longinus *et al*. (2016) are shown in Table 5 below.

Degree of variability
The extent of variability of each air pollutant from one location to the other was computed using Coefficient of variation (CV) as shown in Equation (2) (Pélabon *et al*., 2020; Wambebe and Duan, 2020).

$$CV = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100 \text{ -- (2)}$$

The different categories of CV based on Judice *et al*. (2002) classifications are as follows: CV< 10.25% is low, CV ranging from 10.25% to 31.57% is medium, CV from 31.57% to 61.66% is high, and CV > 61.66% is very high.

Statistical Treatment of Data
The results obtained from the portable Air monitoring Device at the various studied locations were subjected to treatment with IBM SPSS Statistics 20 (IBM USA). The minimum, maximum, mean, and standard deviation were obtained from the Excel sheet of the system. The Multivariate analyses (Correlation analysis, Principal component analysis, and Hierarchical cluster analysis)

were done using Duncan's multiple tests at 0.01 probability limits. Correlation analysis was carried out on 11 parameters, and the significance confidence limit was tested at 99%. The principal component analysis was performed on 11 parameters by Varimax rotation Technique and values from 0.684 and beyond were adjudged significant. Hierarchical cluster analysis was performed by Dendrograms to classify similar clusters with familiar properties.

RESULTS AND DISCUSSION

Table 3: *Mean concentrations of air pollutants at the various studied locations

	NO_2 ppm	SO_2 ppm	H_2S ppm	CO ppm	Cl_2 ppm	NH_3 ppm	HCN ppm	CH_2O mg/m^3	TVOC mg/m^3	$PM_{2.5}$ µg/m^3	PM_{10} µg/m^3
AM	0.20	0.30	0.70	7.00	0.40	12.00	2.00	0.069	0.453	62.00	117.00
UP	0.30	0.40	0.20	9.00	0.50	15.00	3.00	0.050	0.366	68.00	106.25
IM	0.20	0.30	0.40	8.00	0.30	8.00	2.00	0.168	1.917	134.00	229.00
AI	0.40	0.60	1.50	15.00	0.50	20.00	3.00	0.226	1.351	135.00	230.00
Min	0.20	0.30	0.20	7.0	0.30	8.00	2.00	0.050	0.366	62.00	106.25
Max	0.40	0.60	1.50	15.0	0.50	20.0	3.00	0.226	1.917	135.00	230.00
Mean	0.28	0.40	0.70	9.75	0.43	13.75	2.50	0.130	1.020	99.75	170.56
SD	0.10	0.14	0.57	3.59	0.10	5.06	0.58	0.080	0.750	40.20	68.20
CV(%)	36	35	81	37	23	37	23	62	74	40	40

* = Mean of Three Determinations; AM = Akpanadem Market; UP = Uyo Plaza; IM = Itam Market; AI = Itam Abattoir

Table 3: *Mean concentrations of air pollutants at the various studied locations

	NO_2 ppm	SO_2 ppm	H_2S ppm	CO ppm	Cl_2 ppm	NH_3 ppm	HCN ppm	CH_2O mg/m^3	TVOC mg/m^3	$PM_{2.5}$ µg/m^3	PM_{10} µg/m^3
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IM	0.20	0.30	0.40	8.00	0.30	8.00	2.00	0.168	1.917	134.00	229.00
AI	0.40	0.60	1.50	15.00	0.50	20.00	3.00	0.226	1.351	135.00	230.00
Min	0.20	0.30	0.20	7.0	0.30	8.00	2.00	0.050	0.366	62.00	106.25
Max	0.40	0.60	1.50	15.0	0.50	20.0	3.00	0.226	1.917	135.00	230.00
Mean	0.28	0.40	0.70	9.75	0.43	13.75	2.50	0.130	1.020	99.75	170.56
SD	0.10	0.14	0.57	3.59	0.10	5.06	0.58	0.080	0.750	40.20	68.20
CV(%)	36	35	81	37	23	37	23	62	74	40	40

* = Mean of Three Determinations; AM = Akpanadem Market; UP = Uyo Plaza; IM = Itam Market; AI = Itam Abattoir

Table 4: Air quality index (AQI) of air pollutants recorded at the various studied locations

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AIR POLLUTANTS	RANGE
NO_2	200 - 400
SO_2	60-120
H_2S	100 - 750
CO	140 - 300
Cl_2	300 - 500
NH_3	160 - 400
HCN	20,000 – 30,000
CH_2O	417 - 1883
TVOC	73 - 383
$PM_{2.5}$	248 - 540
PM_{10}	213 - 460

Table 5: Ranking of Air quality Index and their human health implications

AQI RANGE	AQI RATING	HEALTH STATUS	RELATED HEALTH RISK
0 - 50	A	Good	Slight or no health hazard
51 – 100	B	Moderate	Favorable for all manners of people except those sensitive to ozone of air particulate may experience respiratory signs.
101 – 150	C	Unhealthy for sensitive groups	It may affect those in the sensitive group however; the non-sensitive class may not be susceptible to the impact.
151 – 200	D	Unhealthy	Those in the sensitive class may experience serious health problems.
201 – 300	E	Very unhealthy	It causes health alert to everyone hence, it can affect everyone health.
>300	F	Hazardous	Serious human health problems for both sensitive and non-sensitive classes.

Results for the levels of air contaminants/pollutants at the studied locations are shown in Table 3. The mean concentration of Nitrogen (IV) oxide (NO_2) at the studied locations ranged between 0.2 and 0.4ppm. The lowest mean value was recorded at Akpandem and Itam markets while the highest value was obtained at Itam Abattoir. The high mean level at Itam Abattoir could be attributed to the burning of vehicle tyres as documented by Bozkurt e*t al*. (2018) and Shakya *et al*. (2008). The mean values of NO_2 obtained from all the studied locations as indicated in Table 2 are higher than the recommended 0.1ppm by FEPA (1991). Consequently, those exposed to this high NO_2 could be susceptible to health problems such as stroke, lung cancer, asthma, heart disease, premature death, respiratory infection in children (Jonah, 2020). The air quality index (AQI) analysis in Table 4 shows that, NO_2 in the studied locations varied between class D and F indicating the unhealthy and hazardous classes of the pollutant in the air and may result in severe health problems (Table 5).

Sulphur (IV) oxide (SO_2) varied from 0.30ppm at Akpandem and Itam markets to 0.6ppm at Itam Abattoir. The high level of SO_2 reported at Itam Abattoir could be as a result of unused tyres (Shakya *et al*., 2008). The average concentrations of SO_2 obtained at all the locations apart from Itam Abattoir were within the safe range of 0.05 – 0.5ppm by FEPA (1991). The level of this air contaminant at Itam Abattoir could result in human health problems reported by Adelagun *et al*. (2012). However, the AQI range of 60 – 120 in Table 4 indicates that, SO_2 at these locations varied between classes B and C. Hence, it could be unhealthy to the groups of human beings sensitive to this contaminant (Table 5).

Hydrogen sulphide (H_2S) ranged from 0.2ppm at Uyo Plaza to 1.5ppm at Itam abattoir. The elevated concentrations of H_2S at Itam Abattoir may be related to bacterial decomposition of human and animal wastes, livestock production and burning of biomass (Ausma and De Kok, 2019). The mean levels of H_2S at all the locations except Uyo Plaza were higher than the acceptable range (0.15 – 0.2ppm) by FEPA (1991). Consequently, human beings exposed to the studied air environment for a long time may experience health hazards related to high H_2S are opined by Huang *et al*. (2015) and Mooyaart *et al*. (2016). The AQI analysis in Table 4 shows that, H_2S is in the B and D classes at Uyo Plaza and Itam Market, respectively. However, at Akpandem Market and Itam Abattoir it belongs to the class F (Table 5). This shows that the levels of this gas at all the locations were unfit for the sensitive and the non-sensitive classes (Table 5).

The mean concentration of Carbon monoxide (CO) in the studied points varied from 7.0 to 15.0 ppm (Table 3). The highest level was recorded at Itam Abattoir while the lowest was obtained at Akpandem Market. The reported high level of CO at Itam Abattoir may be attributed to the series of burning at the abattoir (Khodmanee and Amnuaylojaroen, 2021). The levels of CO obtained in this study are above the acceptable limit (1.0 – 5.0 ppm) by FEPA (1991). Consequently, prolong exposure to these locations could result in health risks associated with high CO and even death (Herath *et al.,* 2021; Thomas and Jaiswal, 2021). The AQI of CO revealed that, the air pollutant existed in C class at Akpanadem Market, D class at Uyo Plaza and Itam Market but, F class at Itam Abattoir (Table 5). Hence, the levels of CO reported could be harmful to the sensitive and non-sensitive groups at the studied locations.

The mean levels of chlorine (Cl_2) obtained in this study ranged from 0.3ppm at Itam Market to 0.5ppm at Itam Abattoir. The high mean level at Itam Abattoir could be as a result of the use of polyvinyl chloride, tyres and other wastes for the roasting of animals (Luo 2019; Jonah, 2020; Angelucci, 2021). The concentrations of Cl_2 reported were higher than the recommended range of 0.03 – 0.1ppm by FEPA (1991). Thus, prolong exposure to this pollutant can cause serious health problems reported by Odoemelam and Jonah (2020). The AQI of Cl_2 as shown in Table 4 reveals that, the entire studied locations were in the F class (Table 5). Consequently, Cl_2 can affect a greater population of those exposed to this pollutant over a long time in the study area (Table 5).

Ammonia (NH_3) indicated mean concentrations between 8.0ppm at Itam Market and 20.0ppm at Itam Abattoir. The reported high NH_3 at Itam Abattoir may be due to the rearing of animals as opined by Behera *et al*. (2013). The concentrations of the air pollutant were higher than 2.0 – 5.0ppm recommended for a clean air by FEPA (1991) at all the studied locations. Hence, persistent exposure may result in difficulty in breathing, wheezing, pulmonary edema, cough, airway irritation, cough, eye and skin irritation (Hoyle and Svendsen, 2016; Bednarz *et al.*, 2022). The AQI assessment in Table 4 shows that, Akpanadem Market and Uyo Plaza were in the E class while Itam Market and Itam Abattoir were in the D and F classes, respectively (Table 5). Consequently, the levels of NH_3 obtained at the different locations can have serious health implications on both the sensitive and non-sensitive groups (Table 5).

Mean concentrations of hydrogen cyanide (HCN) in this study fluctuated between 2.0 and 3.0ppm (Table 3). The highest level was obtained at Uyo Plaza and Itam Abattoir while the lowest was recorded at Akpanadem and Itam Markets. The high concentration of HCN at Itam abattoir may be due to the combustion of plastics and rubber (Dalefield, 2017). However, HCN could also be released photochemically in the atmosphere (Pearce *et al*., 2019). The mean concentration of this poisonous gas was higher than the permissible limit of 0.01ppm in air by FEPA (1991). Hence, persistent exposure may result in respiratory problems and death (Gidlow, 2017; Jonah, 2020). Table 4 shows that, HCN as being in the F class at all the locations (Table 5). Correspondingly, HCN in the different studied locations may have serious harm on those exposed to it for a long time (Table 5).

Concentrations of formaldehyde (CH_2O) in this study ranged from 0.05 to 0.226 mg/m^3 at Uyo Plaza and Itam Market, respectively (Table 3). The high level reported at Itam abattoir can be caused by smoke from the burning of wastes and cigarettes (Park and Ikeda, 2006; Parrish *et al*., 2012). Concentrations of CH_2O recorded at all the studied locations were higher than the 0.012 mg/m^3 limit by FEPA (1991). The obtained values of CH_2O may result in severe health problems including cancer and cancer related risks (Norliana *et al*., 2009; Kang, *et al*. 2021). The AQI assessment indicated that, CH_2O at all the locations was in the F Class (Table 5). Accordingly, it can impart serious negative effects on the sensitive and non-sensitive groups (Table 5).

The total volatile organic carbon (TVOC) in the studied locations varied between 0.366 and 1.917 mg/m^3. The highest mean concentration was recorded in Itam Abattoir while the lowest was at Uyo Plaza. The high level of TVOC at abattoir could be accredited to the use of tyres and other rubber-related wastes for the Singeing of animals (Bozkurt *et al*., 2018, Ebong *et al*., 2020b). The levels of TVOC obtained at Itam Market and Abattoir were higher than the normal range of 0.33 – 0.5 mg/m^3 recommended by FEPA (1991). Hence, if people are constantly exposed to this air pollutant at these locations they may experience nausea, wheezing, skin irritation, coughing, burning sensations of the eyes, nose, and throat, watery eyes, skin irritation, cancer and leukemia (Abdu *et al*., 2014; Subasi, 2020). AQI evaluation revealed that, CH_2O levels at Akpanadem Market and Uyo Plaza were in the B class while Itam Market and Abattoir belong to the E and F

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classes, respectively (Table 5). This shows that only those in the sensitive group can be affected by CH_2O at Akpanadem Market and Uyo Plaza whereas, both the sensitive and non-sensitive groups can be experience the negative effects at Itam Market and Abattoir.

Table 3 shows that the mean concentrations of total volatile organic carbon (TVOC) ranged between 0.366 to 1.917 mg/m^3 (Table 3). The highest concentration of TVOC was obtained at Itam Abattoir while the lowest was obtained at Uyo Plaza. The elevated level of TVOC at Itam Abattoir could be attributed the use of tyres for the singeing process of animals (Bozkurt e*t al*., 2018). The range of TVOC reported is higher than 0.33 – 0.50 mg/m^3 recommended for clean air by FEPA (1991). This shows that the entire air environment in the studied locations has been polluted by the gas. Hence, prolong exposure may affect the nose, eye, and throat and may also result in the nausea, loss of coordination, headaches, harms the kidneys, liver, or nervous system (Li *et al*., 2020; Wickliffe *et al*., 2020). AQI values in Table 4 indicate that, TVOC varied from class B at Akpanadem Market and Uyo Plaza, class E at Itam Market, to class F at Itam Abattoir (Table 5). Hence, those in the sensitive group could be affected by the level at Akpanadem Market and Uyo Plaza (Table 5). However, both the sensitive and non-sensitive groups may experience health problems associated with prolong exposure to high level of TVOC at Itam Market and Abattoir (Table 5).

Mean levels of particulate matter ($PM_{2.5}$) varied from 62.0 at Akpanadem Market to 135.0 µg/m^3 recorded at Itam abattoir (Table 3). The high concentration of this air pollutant at Itam abattoir could be related to intensive burning of petroleum products and woods for singeing of animals (McDuffie *et al*., 2021; Makkonen *et al*., 2023). The mean values of $PM_{2.5}$ reported at all the locations were higher than 25.0 µg/m^3 recommended for a clean air by FEPA (1991). Thus, constant exposure to these levels of $PM_{2.5}$ may lead to the irritation of the eye, nose, lungs, and throat, sneezing, coughing, and shortness of breath (Yang *et al*., 2020; Thangavel *et al*., 2022). The AQI results in Table 4 indicate that $PM_{2.5}$ was in the class E at Akpanadem Market and Uyo Plaza but, class F at Itam Market and Abattoir (Table 5). Consequently, both the sensitive and non-sensitive groups may be negatively impacted by the level of $PM_{2.5}$ at all the locations (Table 5).

Concentrations of a larger size of particulate matter (PM_{10}) obtained in this study ranged from 16.25 to 230.0µg/m^3 (Table 3). The lowest mean concentration was recorded at Uyo Plaza while the highest was obtained at Itam Abattoir. The reported high level of PM_{10} could be credited to the use unused tyres and other waste materials for the singeing of animals at the abattoir (Makkonen *et al*., 2023). The average levels of PM_{10} at the locations investigated were higher than the recommended limit (50.0 µg/m^3) by FEPA (1991). Accordingly, those exposed to this level of PM_{10} at the different centres persistently may suffer from series of ailments such as wheezing, coughing, asthma, high blood, bronchitis , stroke, heart problems, and premature death (Ryou *et al*., 2018; McDuffie *et al*., 2021). Table 4 shows that PM_{10} indicated that, was in the E class at Akpanadem Market and Uyo Plaza but, in the F class at Itam Market and Abattoir (Table 5). Hence, at all the locations PM_{10} can affect both the sensitive and non-sensitive groups seriously (Table 5).

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Table 6: Correlation among the gaseous pollutants investigated.

	NO_2	SO_2	H_2S	CO	Cl_2	NH_3	HCN	CH_2O	TVOC	$PM_{2.5}$	PM_{10}
NO_2	1.000										
SO_2	0.985*	1.000									
H_2S	0.670*	0.784*	1.000								
CO	0.945*	0.984*	0.828*	1.000							
Cl_2	0.818*	0.739*	0.365	0.605	1.000						
NH_3	0.946*	0.932*	0.703*	0.857*	0.912*	1.000					
HCN	0.905*	0.816*	0.303	0.723*	0.905*	0.856*	1.000				
CH_2O	0.005	0.116	0.292	0.289	-0.570	-0.244	-0.267	1.000			
TVOC	0.001	0.105	0.253	0.276	-0.571	-0.258	-0.253	0.999*	1.000		
$PM_{2.5}$	0.336	0.434	0.490	0.583	-0.266	0.082	0.050	0.944*	0.942*	1.000	
PM_{10}	0.279	0.394	0.532	0.551	-0.323	0.047	-0.041	0.956*	0.949*	0.992*	1.000

*** Correlation is significant at the 0.01 level (2 tailed)**

Results for the correlation analysis in Table 6 indicate that, NO_2 exhibited a significant positive correlation with SO_2, H_2S, CO, NH_3, and HCN at $p < 0.01$ with r values shown in the Table. This is in agreement with the findings of Ebong and Mkpenie, (2016) in their study. This signifies that the level of NO_2 increases simultaneously with these air pollutants and vice versa (Ebong *et al.*, 2018). It also reveals that NO_2 may have a common source in the studied locations as these parameters (Odoemelam and Jonah, 2020). SO_2 correlated positively and significantly with H_2S, CO, Cl_2, NH_3, and HCN at $p < 0.01$(r values in Table 6). Hence, an increase in the level of SO_2 may result in a corresponding increment in the level of H_2S, CO, Cl_2, NH_3, and HCN. SO_2 they may also have a common source with these air contaminants at the studied locations. H_2S showed a strong relationship with CO and NH_3 at $p < 0.01$ with r values 0.828 and 0.703. Consequently, the concentration of H_2S is directly proportional to that of CO and NH_3 and these air pollutants may emanate from a similar source. Carbon (II) oxide (CO) exhibited strong positive associated with NH_3 and HCN at $p < 0.01$ with r values of 0.857 and 0.723, respectively. Chlorine (Cl_2) demonstrated a significant positive correlation with NH_3 and HCN at $p < 0.01$($r = 0.912$ and 0.905, respectively). Thus, concentration of CO and Cl_2 increases with increase in the concentration of NH_3 and HCN; and may also come from a common source (Jonah, 2020). NH_3 correlated positively and significantly with HCN at $p < 0.01$with r value of 0.856. Hence, ammonia and HCN may have emanated from the same source and the concentration of both air pollutants has a direct relationship. Formaldehyde (CH_2O) showed significant positive association with TVOC, $PM_{2.5}$, and PM_{10} at $p < 0.01$(r values in Table 6. This is consistent with the findings by Jonah (2020) in his study on air quality monitoring. Thus, the levels of TVOC, $PM_{2.5}$, and PM_{10} at the studied locations may have been increased by CH_2O and vice versa. Total volatile organic carbon (TVOC)

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correlated positively and strongly with $PM_{2.5}$, and PM_{10} at $p < 0.01$ ($r = 0.942$ and 0.949, respectively) similar to the report by Odoemelam and Jonah, (2020). Hence, levels of $PM_{2.5}$, and PM_{10} in studied locations may have been elevated by the presence of TVOC and vice versa. $PM_{2.5}$ correlated positively and significantly with PM_{10} at $p < 0.01$ with r value of 0.992. This agrees with the findings by Muhammad *et al*. (2022) and Plocoste *et al*. (2023) during their studies. This shows that an increase in the concentration of $PM_{2.5}$ may result in a similar increment in the concentration of PM_{10} and vice versa in the studied locations.

Table 7: Principal component analysis showing relative loading for air contaminants studied

Air pollutant	**F1**	**F2**
NO_2	0.979	-0.168
SO_2	0.999	-0.048
H_2S	0.790	0.214
CO	0.991	0.131
Cl_2	0.706	-0.704
NH_3	0.914	-0.391
HCN	0.800	-0.440
CH_2O	0.164	0.983
TVOC	0.153	0.979
$PM_{2.5}$	0.477	0.870
PM_{10}	0.438	0.899
% Total Variance	54.6	40.2
Cumulative %	54.6	94.8
Eigen value	6.0	4.4

In this study, principal component analysis (PCA) undertaken to identify the fundermental sources of air pollutants determined at the different locations investigated revealed two main routes (Kahangwa, 2022). Table 7 shows the two main routes with Eigen values above one and a total variance of 94.8%. Factor 1 (F1) contributed 54.6% of the total variance with strong positive loadings on NO_2, SO_2, H_2S, CO, Cl_2, NH_3, and HCN (Table 7). This denotes the man-induced influence on the status of air environment (Agan, 2019). Table 7 shows that the second factor added 40.2% to the total variance with significant positive loadings CH_2O, TVOC, $PM_{2.5}$ and PM_{10} but, a strong negative loading on Cl_2 (Table 7). This represents the negative impact of natural and anthropogenic factors on air quality as reported by Abaje (2020). The PCA results also confirmed the association of the parameters determined by the correlation analysis in Table 5.

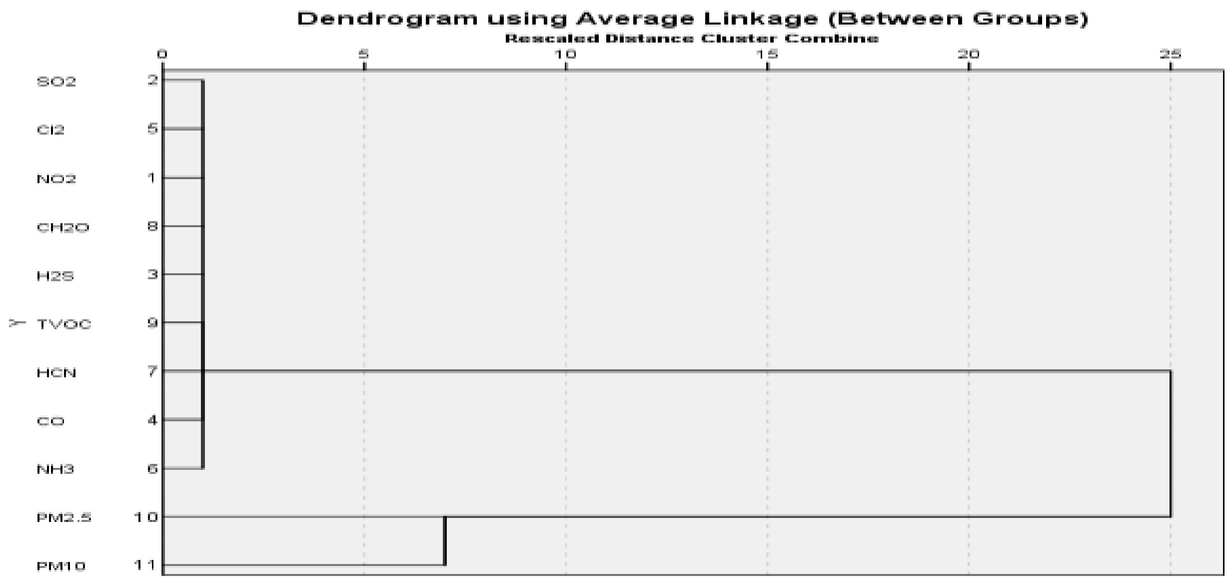

Figure 1: Hierarchical clusters of air pollutants recorded at the various locations

Hierarchical cluster analysis (HCA)

The relationships among the air pollutants at the studied locations were also verified by the Hierarchical cluster analysis (HCA) demonstrated in Figure 1. Figure 1 indicates two key clusters namely: The one that links all the air pollutants determined except $PM_{2.5}$ and PM_{10}. The second cluster joins $PM_{2.5}$ and PM_{10} together as previously indicated by correlation analysis in Table 6. The two clusters obtained also corroborate the two factors indicated by the results of PCA in Table 7.

Degree of Variability of air pollutants

The degree of variability from one location to the other was evaluated using coefficient of variation (CV) (Pélabon *et al*., 2020). The CV results for the air pollutants in Table 3 indicate high degree of variability for NO_2, SO_2, CO, NH_3, $PM_{2.5}$ and PM_{10} (Judice *et al*., 2002). The degree of variability for Cl_2 and HCN was in the low class while the CV for H_2S, CH_2O, and TVOC was very high based on the Judice *et al*. (2002) classifications.

CONCLUSIONS

This work undertaken to examine the influence of commercial activities on air quality of some commercial centres within Uyo Metropolis has revealed the negative effects of some of the human activities on the environment. It has also shown the negative effects of the current air status on human health on prolonged exposure. Activities at Itam Abattoir have been identified as the highest source of air pollutants. Dumping of biodegradable wastes in markets has also been recognized as one of the key routes of air pollutants. Emissions from generators, vehicles, trucks and smokes from the smoking of cigarettes and burning of wastes have been documented as major sources of air pollutants in this research. Factor analysis has recognized the anthropogenic factor as being a serious route of air pollutants in the studied locations. The air quality index assessment has indicated that, both the sensitive and non-sensitive groups could be affected by the levels of air contaminants in the studied locations. Similar study should be conducted in other commercial centres not captured in this work and findings made public for proper environmental planning and management. Human activities within the abattoir ought to be carefully monitored and controlled by the Inspectors and other related agencies. The Environmental workers should discourage smoking in open places, dumping of organic wastes, and use of tyre and petroleum products for the singeing of animals. Uncontrolled and improper emission of toxic gases from generators and vehicles ought to be properly checked and managed to evade a devastating situation to a larger population within the State.

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