Measurement of Air Quality and Determination of Pollution Levels around Traffic Hotspot in Ikot Ekpene Urban, Ikot Ekpene

Edidiong Usip *

Department of Urban and Regional Planning,
Akwa Ibom State Polytechnic, Ikot Osurua, Nigeria.

Ekanem Effiong

Department of Building Technology,
Akwa Ibom State Polytechnic, Ikot Osurua, Nigeria.

&

Mbosowo Ebong, PhD

Department of Estate Management,
Akwa Ibom State Polytechnic, Ikot Osurua, Nigeria.
*edidiong.usip@yahoo.com

Abstract

Road transportation is identified as the largest contributor to urban air pollution which accounts for about 3.7 million pre matured death from 2012 to 2024. This study aims at assessing the air quality around the major traffic hotspots in Ikot Ekpene Urban. Empirical research design was employed for the study, and the hotspots were geospatially identified. The air quality was measured using highly sensitive digital portable meters. From the result, mean value of Nitrogen Dioxide is at 0.1, Sulphur Dioxide (SO_2) at 0.1, Hydrogen Sulphide (H_2S) at 0.12, Carbon Monoxide (CO) at 2.9, Ammonia (NH_3) at 2.6, Chlorine Gas (Cl_2) at 0.16, Hydrogen Cyanide (HCN) at 1, Total Volatile Organic Compounds (TVOC) at 2.2, Formaldehyde (CH_2O) at 14.7, and Particulate Matter ($PM_{2.5}$, $PM2._{10}$) at 66.63 and 110.966 respectively. This reveals that the available Nitrogen Dioxide (0.1) in the atmosphere exceeded the limits set by Federal Ministry of Environment which is 0.6, while other parameters are within their limits. These findings provide baseline for proactive approach to public transportation planning. The urgency for transport plan, traffic management scheme, and the necessity of a shelterbelt to curtail the accumulation of air pollutants around the traffic hotspot.

Keywords**:** air quality, traffic hotspots, road transportation, environmental sustainability.

Introduction

The impact of traffic flow on air quality around traffic hotspots has called for critical response at local, regional and global level. Air pollution and its impact have led to diverse challenges facing humanity, especially health. The rate of air pollution has increased exponentially from the time of industrial revolution, and the major cause has been attributed to anthropogenic factors. (Usip, 2021). Amongst the anthropogenic factors, transportation has been identified as the highest contributor to urban air pollution, generating over 40% of Green House Gases (Swanson, 2019).

Road transportation has a significant impact on the environment, it is a major user of energy, and burns most of the world's problem. This results in air pollution, and it is a significant contributor to global warming through emission of carbon dioxide. Within the transport sector, road transport is the largest contributor to global warming (Ng, & Kim, 2021; Likens, Keene, William, Miller, John, Galloway & James, 1987).

Around 91% of the world's population lives in places where air quality levels exceed World Health Organization's limits (World Health Organization [WHO], 2022). Fumes from automobiles and friction from roads have significantly led to high rate of air pollution, thereby affecting the urban biophysical environment. The concentration of these pollutants in traffic hotspots have been identified to pose a serious health challenge to people operating businesses in, or passing through the traffic hotspots area. With over 51% of the Nigerian population living in urban environment, more people are continually being exposed to polluted air, thereby increasing the rate of complications and fatalities resulting from contamination of the atmosphere.

Ikot Ekpene has witnessed a rapid change in its urbanisation structure, with an astronomical move from 143,077 people in 2006 according to National Population Census to a projected population of 253,234 in 2025. Furthermore, the expansion of road infrastructure has ushered in increased urban activities, and traffic flow, especially around the Ikot Ekpene Plaza Environment. This work therefore assesses the air quality around the traffic hotspot in Ikot Ekpene Plaza.

Statement of the Problem

Road transportation is identified as the largest contributor to urban air pollution, and the concentration of these pollutants increase the risk for cardiovascular and respiratory disease, stroke, chronic obstructive pulmonary disease, cancer and adverse birth outcomes, and also are associated with higher death rates. Ambient air pollution, made of high concentrations of small and fine particulate matter, is the greatest environmental risk to health – causing more than three million premature deaths worldwide every year, United Nations (2016).

More than 80 per cent of people living in urban areas are exposed to air quality levels that exceed guidelines set by the World Health Organization (WHO). The populations in low-income cities are the most at risk for respiratory diseases and other long-term health problems. Decline in urban air quality increases the risk of stroke, heart disease, lung cancer, and chronic and acute respiratory diseases, including asthma (WHO, 2022).

A recent World Bank study, the *Cost of Air Pollution in Lagos (2022)*, estimates that illness and premature deaths due to ambient air pollution caused losses of $2.1 billion in 2018, representing about 2.1% of Lagos State's GDP. In the same year, it caused an estimated 11,200 premature deaths, the highest in West Africa. According to Kemper and Chaudhuri, 2020, children under age five were the most affected as it accounted for 60 percent of total deaths. The adults suffered from heart disease, lung cancer, and chronic obstructive pulmonary disease.

With over 60% of urban air pollution attributed to road transportation, traffic hotspots in urban areas have been identified with higher concentration of pollutants (Kampa & Castanas, 2008). Assessment of air quality around traffic hotspot in Ikot Ekpene plaza, therefore becomes imperative given increased traffic flow and other human activities in the area.

Aim and Objectives

The aim of the research is to assess air quality around traffic hotspot in Ikot Ekpene Plaza. The objectives include to:

i. Geospatially identify the traffic hotspot in Ikot Ekpene Plaza;

ii. measure air quality around the hotspot; and

iii. assess the level of air pollution around the hotspot.

Literature Review

Conceptual Overview

Air quality describes the condition of the atmosphere concerning the presence and concentration of pollutants that can negatively affect human health, the environment, and material integrity (World Health Organization [WHO], 2019). In urban areas, road transport is a dominant source of air contaminants such as nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons, sulfur dioxide (SO_2), and particulate matter ($PM_{2.5}$ and PM_{10}) (Frey et al., 2022).

Locations where vehicular activities are concentrated such as intersections, roundabouts, and bus terminals often experience elevated pollutant concentrations and are therefore, referred to as traffic hotspots (Usip, 2021). The determination of air pollution levels around these hotspots is essential for understanding how transport activities, urban design, and meteorological conditions interact to shape air quality outcomes. Theoretically, this relationship is underpinned by a convergence of environmental, transport, and human exposure frameworks, which together explain how pollutants are generated, dispersed, and experienced in the urban atmosphere.

Theoretical Review

Gaussian Dispersion Theory

Gaussian Dispersion Theory underpins most scientific models used in predicting the spatial distribution of pollutants emitted from point or line sources. The term "Gaussian dispersion" refers to the German mathematician Carl Friedrich Gauss, who first developed a two-parameter exponential function in 1809 in connection with studies of astronomical observation errors (Turner, 1994). The theory assumes that pollutants disperse following a normal distribution, with concentrations decreasing as distance from the source increases. This model has been widely used in air quality assessments to estimate pollutant concentrations around roads, intersections, and industrial zones.

In traffic hotspot studies, it explains how pollutants accumulate under stagnant atmospheric conditions and how dispersion is affected by wind direction and speed. Models such as American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) and California-based Line Source Dispersion Model (CALINE) rely on this theory to simulate concentration gradients

Theoretical Linkage to the Study

The theory assumes that the concentration of a pollutant at any point is determined by the emission rate of the pollutant, the meteorological conditions, and the distance from the source. It models the spatial spread of pollutants from the source, and this provides the framework for this study which measures the level of concentration of air pollution at the traffic hotspot in Ikot Ekpene plaza compared to a control station. It underpins the scientific and practical rationale for determining air pollution levels around high-traffic areas in urban centres.

Traffic Congestion and Hotspot Formation

Traffic congestion arises when the number of vehicles on a roadway exceeds its capacity, creating a demand for space greater than what the infrastructure can accommodate. This condition occurs when traffic volume surpasses available road space or when demand approaches the maximum capacity of the roadway. Persistent congestion on a given route often leads to the emergence of traffic hotspots. Usip (2021) describes traffic hotspots as areas characterised by intense vehicular activity and frequent congestion, particularly during peak hours.

Several factors can intensify congestion, most of which either reduce road capacity or increase the number of vehicles required to transport people and goods (Federal Highway Administration [FHWA], 2022; Transport and Traffic Planning Associates, 2021). The presence of diverse transport modes—such as trucks, buses, private cars, minibuses, tricycles, motorcycles, and non-motorised vehicles—competing for limited carriageway space complicates traffic management and frequently triggers congestion within these hotspots.

The absence of lane demarcation and dedicated routes for public and non-motorised transport, combined with weak policy implementation, limited infrastructure, and socio-economic challenges, exacerbates congestion in many developing cities. Additional contributors include poor road design and maintenance, aggressive driving behaviour, inadequate traffic information systems, and fragmented governance among multiple agencies (Manoj, Kranti, & Pritkana, 2021; Usip, 2021; Bull, 2003). Hotspots also develop at intersections, checkpoints, traffic lights, or areas with poor road conditions, unexpected traffic surges, or rapid land-use and socio-economic changes.

Air Quality Parameters and Vehicular Emissions

Air quality parameters define the acceptable concentration limits of air pollutants considered safe for human health and environmental quality. When these limits are exceeded, pollutants pose risks to public health and ecological balance. Urban transportation, particularly road traffic, is a major source of elevated pollutant concentrations. Research indicates that pollutant levels are typically higher in areas such as motor parks and traffic hotspots compared to schools, markets, religious centres, and residential areas (Ogunseye, Ajayi, & Lawal, 2018). Emenike and Orjinmo (2017) attributed these elevated concentrations to the cumulative effects of frequent vehicular activities at such locations.

According to the World Health Organization (WHO, 2019), major pollutants associated with road transport include nitrogen dioxide (NO_2), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), carbon monoxide (CO), ammonia (NH_3), chlorine gas (Cl_2), hydrogen cyanide (HCN), total volatile organic compounds (TVOCs), formaldehyde (CH_2O), and particulate matter ($PM_{2.5}$ and PM_{10}). These substances become hazardous only when their concentrations exceed stipulated thresholds (WHO, 2019).

In Nigeria, the Federal Ministry of Environment (1991) established national limits for certain air pollutants: 0.04–0.06ppm for nitrogen dioxide, 0.01–0.1ppm for sulfur dioxide, 10–20ppm for carbon monoxide, 200 ppm for ammonia, and 250mg/m³ for particulate matter. These standards serve as benchmarks for assessing ambient air quality in urban environments.

Empirical Literature

Batterman, (2014) in the work points to busy road junctions and intersections as areas where traffic-related air pollution (TRAP) tends to concentrate the most. Measurements taken at these high-flow points usually show much higher levels of nitrogen oxides (NO_x), carbon monoxide (CO), black carbon (BC), ultrafine particles (UFP), and fine particulate matter ($PM_{2.5}$) compared to nearby non-traffic areas, especially during rush hours (Blanco et al., 2022; Frey et al., 2022). These sharp rises in pollution are largely the result of vehicles idling in queues, repeated acceleration and braking, and the high number of diesel-powered and heavy-duty vehicles, all of which emit more pollutants per kilometre travelled (Karin & Shubham, 2020).

Advanced monitoring efforts—using both fixed roadside sensors and mobile monitoring systems—have helped to shed light on how air pollution behaves around intersections (Vardoulakis, Solazzo, & Lumbreras 2011). Fixed monitors record changes in concentration throughout the day, while mobile devices capture how pollution levels drop sharply within 50 to 200 metres of the junction. Findings from these studies show that concentrations of UFP and BC often rise when traffic lights change and queues build up, demonstrating how stop-and-go driving directly influences emission levels (Usip & Edem, 2022).

Analyses of pollutant composition reveal distinct emission patterns at junctions. Studies using black carbon monitors and gas analysers show higher amounts of freshly emitted particles and gases close to intersections than along open roadways (Batterman, 2014). The presence of heavy-duty vehicles further amplifies levels of NO_x and BC, a trend repeatedly confirmed in various field measurements.

To explain these patterns, several researchers have combined real-world traffic counts, vehicle type data, and weather information in dispersion models such as AERMOD and near-field Gaussian systems (Vardoulakis et al., 2011). These models generally reproduce the pollution gradients found near intersections, although their precision decreases in areas with complex urban layouts—like narrow street canyons—or when traffic flow changes rapidly. This underlines the importance of using detailed, time-specific data to ensure model accuracy (Frey et al., 2022).

Recent experiments at busy intersections suggest that improving signal timing, limiting idling through better flow control, and adding features such as roadside greenery or barriers can reduce people's exposure to pollutants (Usip & Edem, 2022; World Health Organization [WHO], 2019). The effectiveness of these measures varies depending on the pollutant, but reductions are often greatest for UFP and BC, which are closely linked to idling vehicles. Even with these advances, important gaps remain. Long-term studies that directly connect short bursts of pollution at intersections with health impacts are still scarce. There is also little empirical data from developing cities, where mixed vehicle types and informal driving habits are common. In addition, non-exhaust emissions—like particles from tyres, brakes, and suspended dust—are not yet fully accounted for in many intersection studies (Batterman, 2014).

In summary, existing research confirms that heavily trafficked junctions are critical zones of elevated air pollution. These sites are influenced by driving behaviour, vehicle composition, and road design. Moving forward, future studies should aim to integrate on-site monitoring with modelling tools and evaluate practical interventions under real urban conditions to guide cleaner and healthier transport planning (WHO, 2019).

The Study Area

Ikot Ekpene urban is an historic town otherwise referred to as Raffia City. The urban area is also the headquarters of Ikot Ekpene Local Government Area, as well as the regional headquarters of Ikot Ekpene Senatorial District in Akwa Ibom State. The city is a nodal town which lies between the major traffic corridors providing convergence for routes to Uyo, Aba, Umuahia, Abak and Calabar. The radial road pattern obtainable in the city converges at Ikot Ekpene Plaza, thereby creating a serious traffic hotspot. Figure 1 shows the major road pattern in Ikot Ekpene, and the major traffic hotspot in the city.

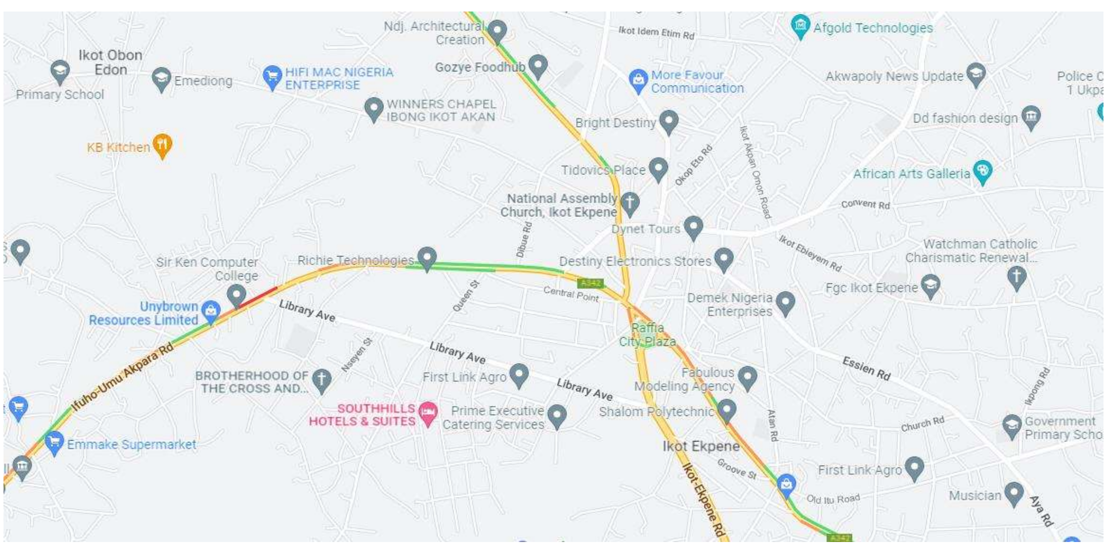

Fig. 1: Ikot Ekpene Road Pattern

Source: Google Earth (2025)

Specifically, the traffic hotspot is the area between Umuahia road and Aba Road converges at the plaza. The hotspot witnesses high traffic flow as it serves as a connection spot for Aba and Umuahia roads which lead to the two most important cities in Abia State, Uyo Road which leads to Uyo the Akwa Ibom State capital, and Abak Road which leads to another major town, Abak. The immediate environment has been cleared of temporary motor parks, however, street trading, hawking, touting still dominate activities in the environment which complicates the hotspot. Different means of road transportation are used in the city, ranging from articulated vehicles, private vehicles, public means of transportation such as buses, taxis, minibuses, tricycles, motor cycles and bicycles.

Methodology

This study adopted empirical research design which addresses the plan, and strategy of investigation of issues related to air pollution around the foremost traffic hotspot in Ikot Ekpene urban environment. Purposive sampling was adopted as the convergence of Aba Road, Umuahia Road and Uyo Road formed the sample point for air quality measurement. Measurements were taken too at Queen Street by Library Avenue to serve as control point.

The air pollutants measured include Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Hydrogen Sulphide (H_2S), Carbon monoxide (CO), Ammonia (NH_3), Chlorine (Cl_2), Hydrogen Cyanide (HCN), and suspended particulate monitor (SPM). The measurements were taken for two weeks, from 1st of July to 15th of July 2025. The Highly sensitive digital portable meters were used in the measurement of gaseous pollutants as presented in Table 1.

Table 1

Gaseous emissions and noise measuring instruments

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
Suspended particulate monitor (SPM)	Haz-Dust TM 10µg/m³ particulate monitor	0.1-200 10µg/m³	+1-0.0210µg/m³

The above instruments were used to determine the concentration of the selected gases at the traffic hotspot and the control station. GIS was utilised to acquire and prepare the necessary maps, while level of concentration of the gases was measured against the standard set by World Health Organization, and Federal Ministry of Environment.

Analysis

The geospatial location of the traffic hotspot in Ikot Ekpene

The location of the hotspot is presented in fig. 2.

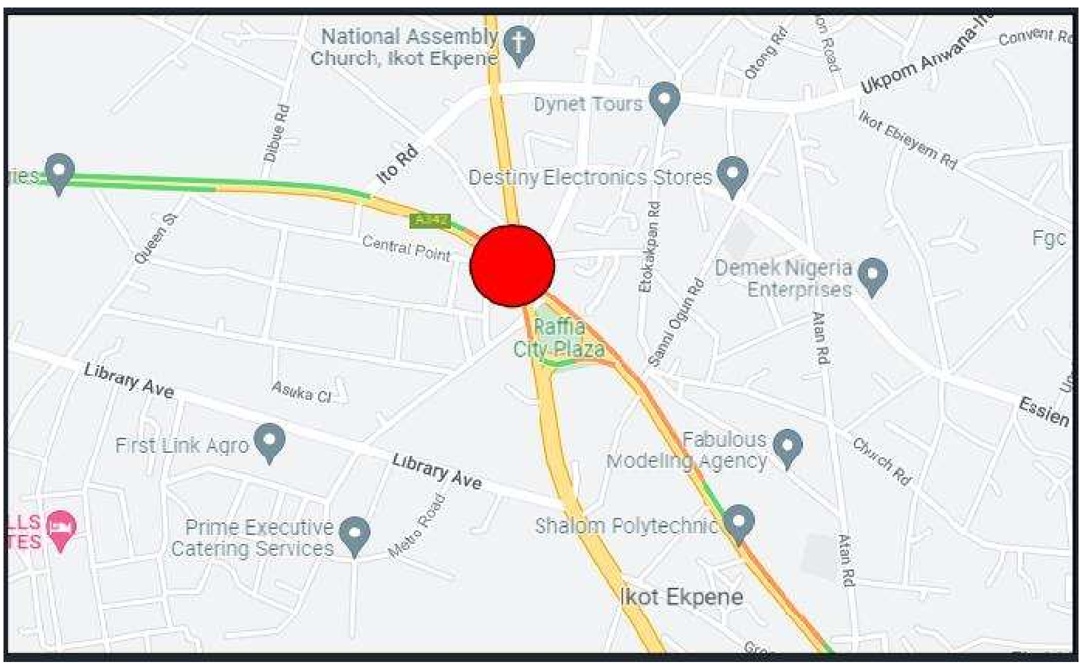

Fig. 2: Ikot Ekpene major traffic hotspot

The road traffic hotspot is the environment where Aba Road, Umuahia Road, and Uyo Road converge in Ikot Ekpene Plaza. The development of the Ikot Ekpene Plaza provides short by-passes which regulate traffic flow in the city centre.

Measurement of Air Quality around the Hotspot

Table 2 *Cumulative mean value of air quality measurements*

Sample Code	NO_2 (ppm)	SO_2 (ppm)	H_2S (ppm)	CO (ppm)	NH_2 (ppn)	CI_2 (ppm)	HCN (ppm)	TVOC (mg/m³)	CH_2O (mg/m³)	$PM_{2.5}$ (mg/m³)	$PM_{2.10}$ (mg/m³)
AQ1	0.1	0.1	0.1	3.4	2.55	0.2	0.85	2.45	0.4	72.65	126.6
Control	0.0	0	0	1.1	0.9	0.1	0.2	1.9	0.2	73.4	129.5
MEAN	0.1	0.1	0.1	3.4	2.55	0.2	0.85	2.45	0.4	72.65	126.6
MIN.	0.1	0.1	0.1	3.4	2.5	0.2	0.8	2.4	0.4	71.8	124.7
MAX.	0.1	0.1	0.1	3.4	2.6	0.2	0.9	2.5	0.4	73.5	128.5
SD	0	0	0	0	0.070711	0	0.070711	0.070711	0	1.202082	2.687006
FMENV limit (1991)	**0.04-0.06**	**0.01-0.1**	**-**	**10.0-20.0**	**200.0**		**-**	**-**	**-**	**-**	**250(ug/m³)**

The measurements were taken for fifteen days, in the mornings and in the evenings, from the 1th of July to 15th of July, 2025. Table 2 and figure 3 show the cumulative mean value of the recordings taken for the 15 days.

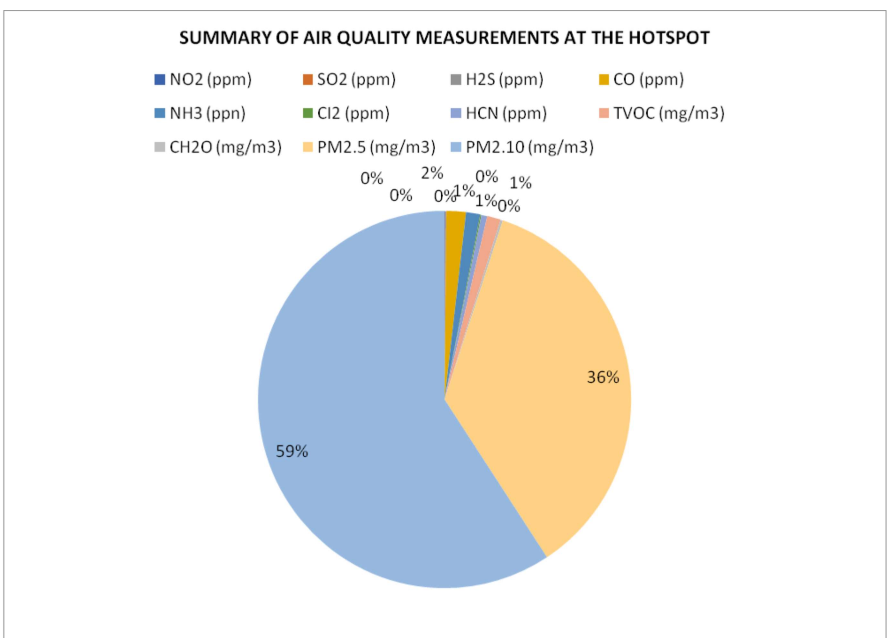

Fig. 3: Air quality level around the traffic hotspot

From Table 2, the level of nitrogen dioxide (NO_2), 0.1ppm has exceeded the limits, and sulphur dioxide (SO_2) 0.1ppm present in the atmosphere around the hotspot environment is at the brink of exceeding the limits stipulated by Federal Ministry of Environment. The control stations recorded no traces of the gases.

The mean value (3.4) of Hydrogen Sulphide (H_2S) in the atmosphere in the hotspot environment is within the stipulated limit. This is applicable also for Carbon Monoxide (CO), Ammonia (NH_3), Chlorine Gas (Cl_2). Hydrogen Cyanide (HCN), Total Volatile Organic Compounds (TVOC), Formaldehyde (CH_2O), and Particulate Matter (PM2.5, PM2.10) respectively.
Furthermore, the result also revealed that the air quality at the control station were far less polluted compared to the hotspot environment.

Assessment the Level of Air Pollution around the Hotspot
Findings from the study revealed higher concentration of air pollutants around the traffic hotspot in Ikot Ekpene Plaza when compared to the control station which witnessed less traffic.

Of all the air pollutants measured, the level of Nitrogen Dioxide (NO_2), and Sulphur Dioxide (SO_2) were the most dominant pollutants in the atmosphere when compared to others, and they exceeded the limits set by Federal Ministry of Environment, World Health Organization and National Institute for Occupational Safety and Health (NIOSH).

The meteorological records revealed an ambient environment which will encourage ambient air quality in the city if anthropogenic activities are moderated.

Conclusion

With the increasing cases of air pollution related health challenges and fatality globally, the need for ambient air quality in urban environment is imperative. Some of the gases measured have exceeded permissible exposure limits set by Federal Ministry of Environment, World Health Organization and National Institute for Occupational Safety and Health (NIOSH). This therefore calls for quick response such as development of transportation plan to address the decaying urban air quality witness around Ikot Ekpene Plaza.

Recommendations

- There is urgent need for the sensitisation of the public, vendors, and transport workers about the health risks associated with exposure to outdoor air pollution. Continuous exposure to pollutants such as Nitrogen Dioxide (NO_2), and Sulphur Dioxide (SO_2) which is found to be significant at the traffic hotspot is highly detrimental to human health as it exposes the human system to risk of health challenges such as cardiovascular and respiratory disease, stroke, chronic obstructive pulmonary disease, cancer and adverse birth outcomes.

- There is an urgent need for public transportation plan, policy and scheme in Ikot Ekpene. This will regulate the operation of mass transit, and further reduce traffic congestion which contributes significantly to air pollution. Good traffic management plan, which will reduce idling of vehicles, a major contributor to high Nitrogen Dioxide (NO_2), and Sulphur Dioxide (SO_2) in the atmosphere, will be guaranteed by a good transportation plan. Furthermore, an overpass is required to connect Aba Road and Uyo Road to ease traffic demand at the plaza as more articulated vehicles ply the route which also connects Cross River State to Abia State.

- Shelterbelt is required as buffer along the roads around Ikot Ekpene Plaza to help absorb pollutants from the air and act as a physical barrier. Also, community-based initiatives and awareness campaigns about air pollution and its effects should be encouraged.

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