TRANSPORT RELATED AIR POLLUTION AND ITS IMPLICATIONS ON PUBLIC HEALTH ALONG SELECTED ROAD CORRIDORS IN LAGOS METROPOLIS, NIGERIA

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ABSTRACT

The study investigated the ambient air quality caused by vehicular emission and its implications on the public health around major roadways in Lagos metropolis Nigeria. Field data on vehicular volumes and mix were collected for three months in the morning, afternoon, and evening peak periods for the five (5) selected major routes. Concurrently, air pollutants from vehicles were measured by portable gas detectors on the routes. Questionnaires were administered to the respondent near the routes to investigate the implications of exposure on their health. The concentration level of the air pollutants is highest between 8-9 am morning peak periods and lowest between 12-1 pm afternoon periods. The ambient air quality is polluted on all the studied routes and revealed a strong correlation ($p<0.05$) between pollutants concentration and traffic flow. The questionnaire results also showed that 74% of the sampled respondents around the corridor suffered from chest pain, frequent cough, nose running and sneezing, sore throat, difficulty in breathing, body weakness, fatigue, eye irritation, loss of appetite, headache, and fast breathing of which 6% of children and 54% of women were the most susceptible. The study recommended measures for the reduction of the negative impacts on ambient air quality and public health in developing African cities.

Keywords: Air Pollution, Air Quality, Public Health, Traffic Volume, Urban Transport, African cities.

1. INTRODUCTION

Traffic emission have become one of the key drivers of urban environmental air pollution, limiting the quality of urban environment by degrading the ambient air quality, as the number of vehicles in Africa has grown rapidly (Ayetor et al, 2021). In 2016, more than 80% of persons residing in urban cities were exposed to the ambient air quality levels that exceeded the World health organization WHO standards (WHO, 2016). In 2017, it was estimated that exposure to ambient $PM_{2.5}$ was linked to 2.9 million death worldwide, accounting for nearly 9% of all deaths of which about 80,000 deaths occurred in the West Africa region (Adama et al., 2018) resulting from ischemic coronary heart ailment. This is a circumstance of habitual chest ache (angina) or pain that occurs whilst part of the heart does not acquire sufficient blood, stroke, persistent obstructive pulmonary disorder, and obstructive lung disorder characterized by long-time period respiration problems and poor airflow, shortness of breath and cough, lower respiratory infections, lung cancer, and diabetes mellitus type II (Stanaway *et al*., 2018). Exposure to particulate matter (PM), as well as ozone (O_3), nitrogen dioxide (NO_2), carbon monoxides (CO), and sulfur dioxide (SO_2) potentially pose substantial health risks. The hassle is mainly acute in Nigeria, which had the highest number of untimely deaths due to $PM_{2.5}$ levels in the region; and especially in Lagos, the country business capital and one of the globe's quickest-growing megacities. Regardless of the transport related air pollution problem in Lagos, there is presently no valid estimate of the impact of ambient air pollution, nor a detailed air pollution mitigation plan in place. Bad fuel quality is another major contributor to vehicle emissions, particularly in Sub-Sahara Africa (Hirota and Kashima, 2020). The Sulphur concentration in petroleum merchandise used by vehicles in Nigeria is 204 times above permitted values for modern emission systems in 2020 (Ayetor et al, 2021).

Euro 3 fuel standards were adopted in Nigeria in 2015, however they have yet to be approved and implemented (Maduekwe et al., 2020). Currently, in West African cities, a large proportion of vehicles used are old and are imported from European and American cities. These old vehicles lack emission and noise reduction technology. Today, research on vehicle emission has been undertaken all around the world. This is based on vehicle emission inventories, as well as numerous emission models and their effects on public health (Bikam, 2022; Ayetor et al., 2021; Meng et al., 2020; Khreis and Nieuwenhuijsen, 2019). Recent studies have found that drivers, commuters, and those who live or work near major highways have shown higher rates of sickness and mortality (Kumar et al., 2021). Unfortunately, there is little or no research on the effects of vehicle emissions on public health in Nigeria currently and the public's health in pollution zones is deteriorating as a result of growing population, increased motorization and industrial development. More emphasis is placed on expanded infrastructural development, with less consideration given to the health risks that urban transportation poses to the general public.

The study aimed to investigate the ambient air quality and its health implications on the public near selected roadways in Lagos Metropolis. This aligns with the Sustainable Development Goals 3, 9 and 11, which collectively seek, by 2030 to establish safe, inclusive, and resilient cities as well as ensuring healthy lifestyles and wellbeing for persons of all ages through proper sanitation and air pollution control (WHO, 2016).

2. MATERIALS AND METHODS

2.1 Site Description

Lagos City was chosen for this study, due to some specific characteristics that the city presents. It is one of Nigeria's most important and highly populated city with severe air pollution problems. It is Nigeria's main commercial centre, accounting for 70 percent of the country's industries and economic activities, making it the most economically important state of the country (Okimiji et al., 2021). It is positioned on longitude 20 42'E and 32 2'E, and between latitude 60 22'N and 60 2'N and has over 224 vehicles per kilometer as against 15 vehicles per kilometer in other states in Nigeria, resulting in daily traffic congestion for over 10 million commuters (Odekanle et al., 2017).

Figure 1 shows the map of Lagos and major transport routes.

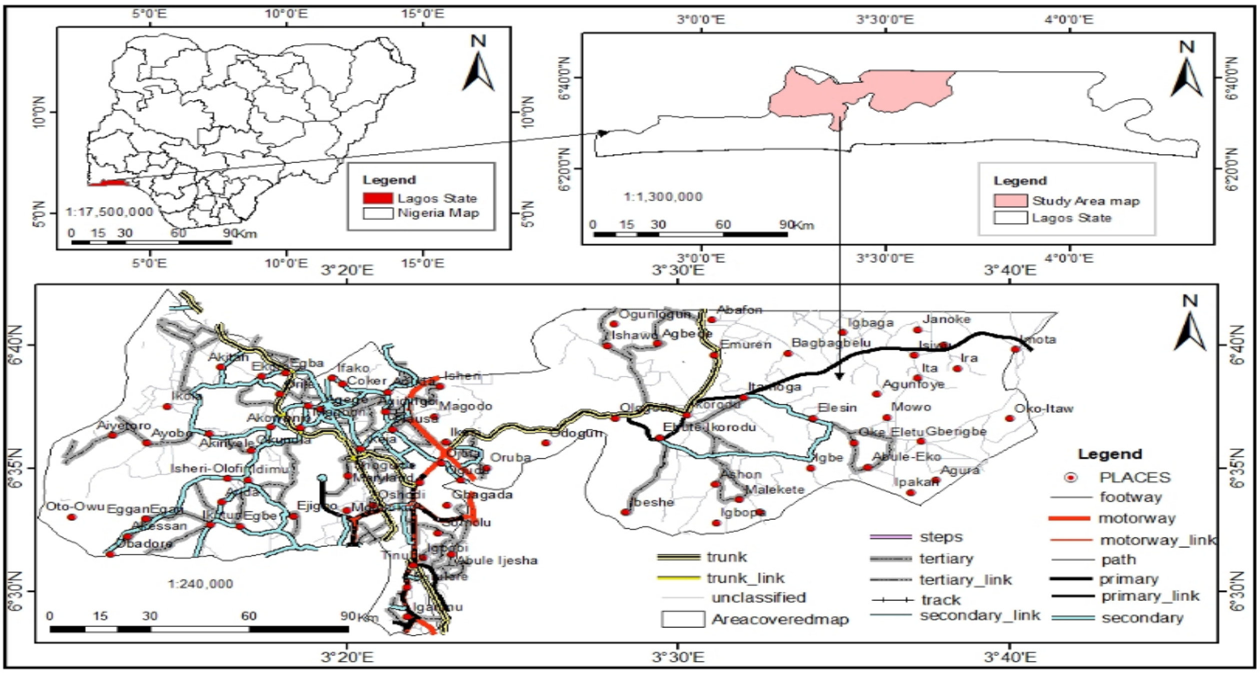

Figure 1: Maps of Lagos and major transport routes

2.2 Selection of Routes

The five routes selected for this study are; Tollgate – Meiran; Ikeja Along – computer village; Agege-pencinema; Ile Epo-Iyana Ipaja and Shogunle-Oshodi. These routes were selected in Lagos based on existing information on congestion, vehicle characteristics and composition, high density of vehicles, speeds of vehicles, road geometry and observed population around the corridors. These routes are representatives of typical commuting routes in residential, commercial and industrial districts in Lagos with high traffic volumes. The modes of transport on these routes are not the same. Motorcycle, tricycle, passenger car, bus/vans, large bus, and heavy goods vehicles HGV are the classes of vehicles plying these routes. Figure 2 shows the traffic situation of Shogunle-Oshodi road.

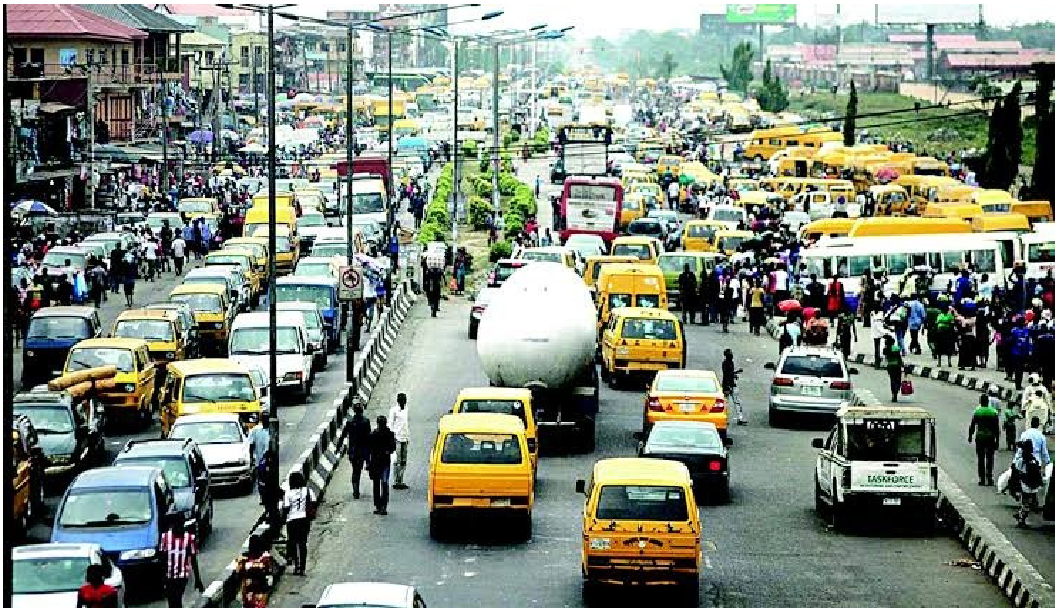

Figure 2: The traffic situation on Shogunle-Oshodi road

2.3 Traffic Mobility Measures

Mobility measures (volume, traffic composition) were collected with the aid of pneumatic tubes on the five road corridors. The classified counts were conducted for the 7 days of the week (Mondays to Sundays) for morning and evening rush hours and afternoon non-rush hours. The volume counts were taken throughout the week to capture all traffic parameter variation on the routes. Traffic counts were usually conducted on Tuesday, Wednesday, and Thursday because Mondays and Fridays had abnormal peaks at rush hours, they were excluded from the survey and, by extension, the analysis. The traffic count was performed along the five routes for 12 weeks.

2.4 Vehicular Emission Measurement

Five emission sampling points were established along the study route with their coordinates determined by using Mobile Mapper 10 hand-held Geographical Positioning Systems (GPS). Vehicle emission measurement for each route was carried out using portable handheld gas analyzers. These detectors were used for outdoor sampling by measuring the pollutants for every 15 minutes interval at a point located 2 m away from the road edge and was positioned on a one (1) meter high wooden platform through the period of assessment for all the routes. The device was a multigas monitor; with a 3.7V lithium battery and a measuring range of 0-999ppm 0-999, resolution of 1.0 µg/m3, and accuracy of ±10% was used to measure CO. Handheld laser particle counter (KANOMAX): measured particulate matter, $PM_{2.5}$, and PM_{10}, ToxiRAE gas detectors: measure SO_2 and NO_2 concentrations. A handheld device (kestrel): measured meteorological parameters such as relative humidity and temperature. The emission measurement ran for 11-hours for morning, afternoon, and evening peaks periods for each corridor/intersection for a period of seven (7) days (Monday to Sunday) on each corridor. This was done for three (3) months; 6th September to 10th October, 2021.

A statistical analysis was run to determine the Pearson correlation between the pollutants levels and traffic flow by the use of R-Studio statistical tool.

2.5 Ambient Air Quality on Each Corridor

The ambient air quality on each corridor was determined by comparing it with the air quality index standard of the National Environmental Standard, (NES) in Nigeria. Air Quality Index is a tool for effective communication of air quality status to people in terms, which are easy to understand. It transforms complex air quality data of various pollutants into a single number (index value), nomenclature and colour. There are six AQI categories, namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe. Each of these categories is decided based on ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints). On each route, the Ambient air quality for all the pollutants were determined by finding the levels of each mean concentration that falls within the air quality index chart (NESREA, 2014).

2.6 Public Health Assessment

The health of the public around the selected routes is very germane. A structured questionnaire (400) were administered to selected respondent, especially those near the road corridors such as traders, hawkers, shop owners, school children, drivers/conductor, office staff, police, traffic officer, pedestrian/passerby, and construction workers. Computer village was chosen for the survey because it's one of the commercial centres in Lagos characterized by a large population of residents and workers. The questionnaire was based on demographics, proximity to road corridor, time spent and activities on the corridor, perceptions of impacts of the inhaled pollutants on their health. Data on health conditions and symptoms such as chest pain, frequent cough, nose running and sneezing, sore throat, eye irritation, difficulty in breathing, body weakness, fatigue, loss of appetite, headache, fast breathing were also collected.

3. RESULTS AND DISCUSSION

3.1 Emission and Volume

Pollutants were assessed for 11- hours through the week. Table 1 shows the inventory of pollutant concentration which indicate the maximum, minimum and the average on the routes for a week and the traffic volume result of each route. The number of lanes, length of the route and proportion of heavy good vehicles (HGV) have a direct affect the emission levels on each corridor. The SO_2 and NO_2 concentrations were influenced by the emission of heavy equipment for the ongoing road rehabilitation on both routes. The road rehabilitation on the routes caused traffic gridlock on routes as vehicles in both directions have to take the available lanes. The CO, PM2.5 and PM10 levels were influenced by the traffic volume and the vehicular characteristics which put into consideration the type of fuel and engine characteristics. There are more heavy Goods vehicles (HGV) on Tollgate-Meiran road compared to the other routes due to the proximity of this route to the industry areas. This also affected the emission levels for the pollutants which is the highest compared to the other routes.

Figure 3 shows the typical vehicle fleet composition for the routes. There is a larger proportion of cars/taxis (39%), followed by bus (25%). Figures 4 and 5 show a typical emission levels for each pollutant on the study routes at the rush hour and non-rush hour periods. The emission levels for all the pollutants increased in the morning rush hour from 7 to 9 am, greatly contributing to the high emissions of CO, $PM_{2.5,}$ and PM_{10} as workers travel to work, with high vehicular traffic, while the emissions levels ebb from 12-2pm, they start to increase from 4-8pm due to the density of vehicles at this period where people move from workplaces to their residents.

The Particulate matter is high for all the routes. The major components of PM are sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air (WHO, 2016). The CO emission is high for all the routes and is expected to react with oxygen to form CO2, which is atmospheric greenhouse gas that influences the global climate by internal molecular vibration and rotation thus causes these molecules to absorb infrared radiation.

The Pearson's correlation analysis as shown in Table 2 indicated statistically significant positive correlations between the traffic volume and the concentration of pollutants with r values of and p-value as shown in the result.

Table 1: Inventory of emission and traffic on roadways in Lagos City

Route	No. of Lanes	Length (Km)	Volume of Traffic (veh/hr)	% HGV	So_2 (ppm)	No_2 (ppm)	CO (ppm)	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)
Computer Village	2	2	4231	2.3					
Max					0.28	0.18	56	289	289
Min					0.04	0.01	18	103	114
Average					0.12	0.06	35.55	192.09	224.09
Tollgate-Meiran	4	6.5	3249	7.5					
Max					0.3	0.1	62	273	283
Min					0.04	0.02	21	98	110
Average					0.12	0.07	46.09	190.18	209.91
Agege Pencinema	4	2.2	3076	3.3					
Max					0.1	0.07	31	268	267
Min					0.03	0.01	12	89	112
Average					0.08	0.04	18	182.67	198.65
Ile Epo-Iyana Ipaja	4	2.5	4132	5.1					
Max					0.2	0.08	52	278	281
Min					0.03	0.02	15	97	117
Average					0.1	0.05	31.23	191.65	218.45
Shogunle-Oshodi	4	2.3	4624	4.8					
Max					0.2	0.1	55	283	296
Min					0.03	0.02	14	98	121
Average					0.12	0.06	33.12	197.79	228.13

Note: HGV: Heavy good vehicles

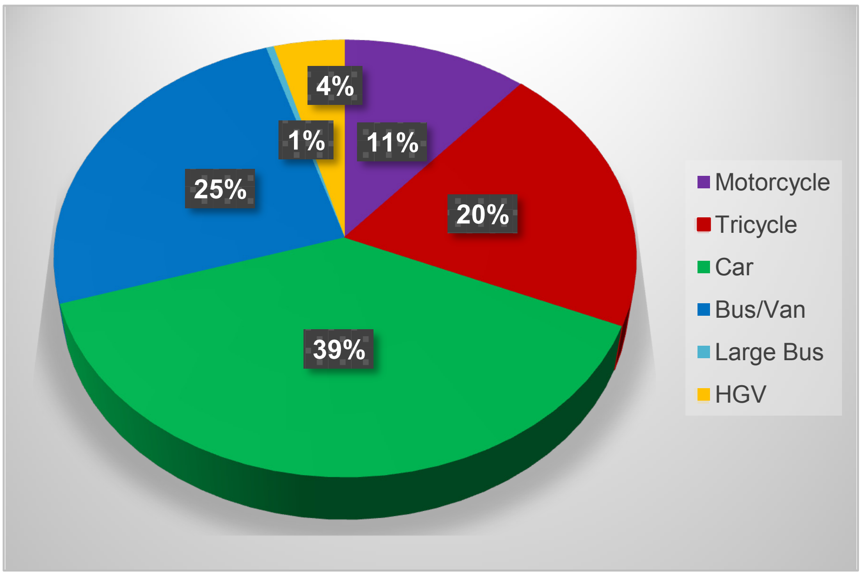

Figure 3: Typical vehicle composition for the routes

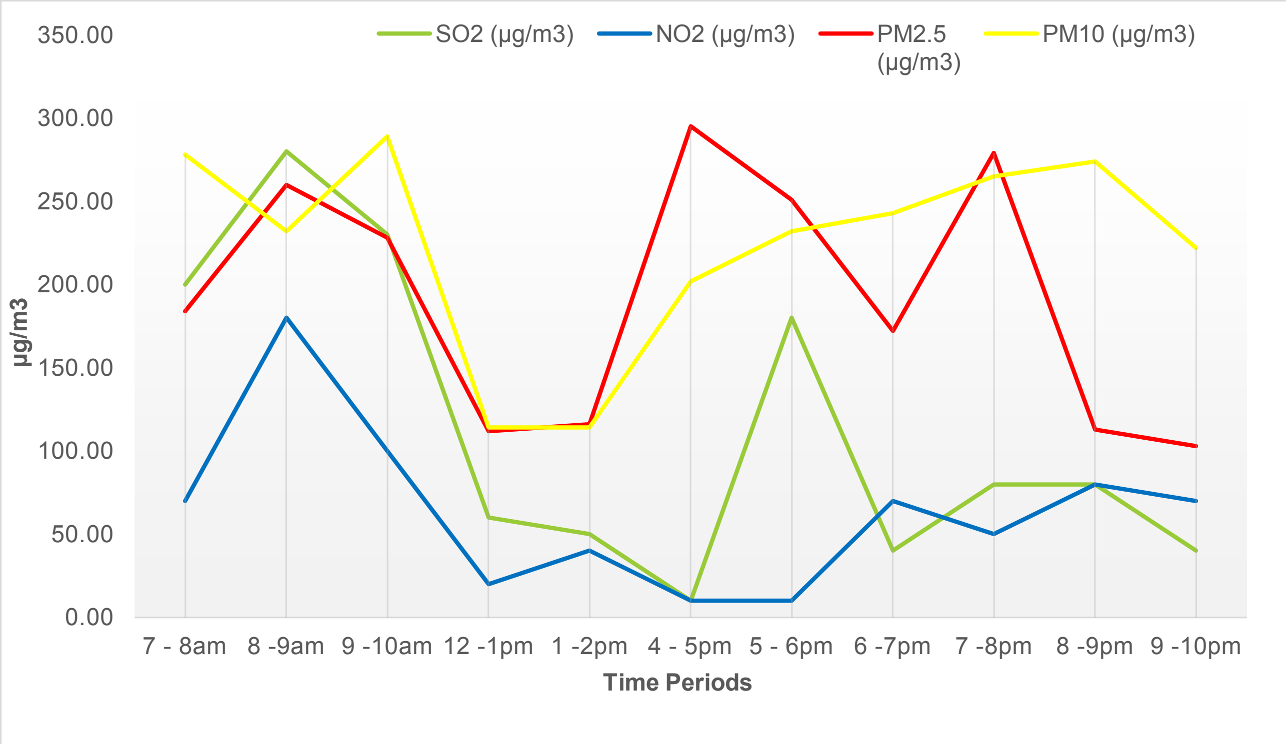

Figure 4: Typical emission levels for SO_2, NO_2, $PM_{2.5}$ and PM_{10} for the 11-hour periods

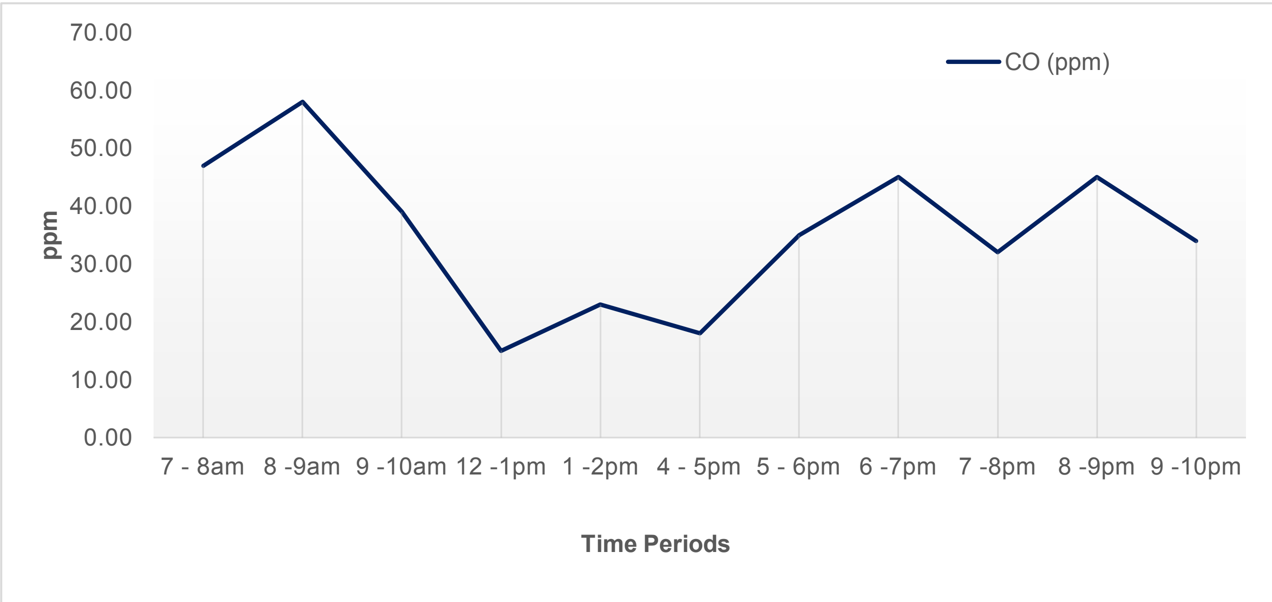

Figure 5: Typical emission levels for CO for the 11-hour periods

Table 2: Typical correlation result for total volume and the pollutants on the routes

IC	Pavr-SO_2		Pavr-NO_2		Pavr-CO		Pavr-$PM_{2.5}$		Pavr-PM_{10}	
	Corr Coeff	P-value	Corr Coeff	P-value	Corr Coeff	P-value	Corr Coeff	P-value	Corr Coeff	P-value
Total Volume veh/hr	0.850	0.001	0.656	0.028	0.758	0.007	0.882	0.000	0.883	0.000

3.2 Ambient Air Quality

Table 3 to 7 showed the average one-hour concentration of pollutants levels and the air quality index AQI for each road corridor with their public health implications. The SO_2 levels are moderately polluted for all the routes, this implies that the air quality is accepted. However, there may be a risk for some people, particularly those who are usually sensitive to air pollution, i.e. children and the elderly. However, SO_2 and NO_2 levels (280µg/m^3) are highest especially during the heavy traffic in computer village due to the ongoing construction and lowest (100µg/m3) in Agege-pencinema road due to low volume of HGVs. The recommendation here is that sensitive people should consider reducing prolonged or heavy exertion because of the SO_2 emission as the emissions trigger symptoms such as coughing or shortness of breath. NO_2 (100 µg/m^3) is highest on Shogunle-Oshodi road due to considerable numbers of HGVs, followed by Tollgate road (90 µg/m^3) due to the large proportion of industrial vehicles plying the routes.

Table 3: SO_2 -Ambient Air Quality for the routes

Routes	**AQI**	SO_2 (µg/m3)-1 hour mean	AQI category	Description of Air Quality
Computer village	81-380	280	Moderately polluted	Air Quality is accepted. However, there may be a risk for some people, particularly those who are usually sensitive to air pollution, i.e. children
Tollgate-Meiran	81-380	300	Moderately polluted	
Agege/pen-cinema	81-380	100	Moderately polluted	
ile epo-lyana-ipaja	81-380	200	Moderately polluted	
Shogunle-Oshodi	81-380	200	Moderately polluted	

Table 4: NO_2 -Ambient Air Quality for the routes

Routes	**AQI**	NO_2 (µg/m3)-1 hour mean	AQI category	Description of Air Quality
Computer village	81-180	180	Moderately polluted	Air Quality is acceptable
Tollgate-Meiran	81-180	100	Moderately polluted	Air Quality is accepted. Sensitive groups like children and the elderly may be affected
Agege/pen-cinema	41-80	70	Satisfactory	Air Quality is satisfactory and air pollution pose little or no risk
ile epo-lyana-ipaja	81-180	80	Satisfactory	
Shogunle-Oshodi	81-180	100	Moderately polluted	Air Quality is accepted. Sensitive groups like children and the elderly may be affected

Table 5: CO -Ambient Air Quality for the routes

Routes	**AQI**	CO (mg/m3)- 8 hours mean	AQI category	Description of Air Quality
Computer village	34 +	56	severe	Health Alert: the risk for health effects is increased for everyone and should avoid outdoor activities; especially individuals with heart and breathing ailments, children and older adults
Tollgate-Meiran	34 +	62	severe	
Agege/pen-cinema	17-34	31	very poor	Everyone may experience more serious health effects
ile epo-lyana-ipaja	34 +	52	severe	Health Alert: the risk for health effects is increased for everyone and should avoid outdoor activities
Shogunle-Oshodi	34 +	55	severe	

Table 6: $PM_{2.5}$ -Ambient Air Quality for the routes

Routes	**AQI**	$PM_{2.5}$ (µg/m3)- 24 hours mean	AQI category	Description of Air Quality
Computer village	250 +	289	severe	Health Alert: the risk for health effects is increased for everyone and should avoid outdoor activities; especially individuals with heart and breathing ailments, children and older adults
Tollgate-Meiran	250 +	273	severe	
Agege/pen-cinema	250 +	268	severe	
ile epo-lyana-ipaja	250 +	278	severe	
Shogunle-Oshodi	250 +	283	severe	

Table 7: PM_{10} -Ambient Air Quality for the routes

Routes	**AQI**	PM_{10} (µg/m3)- 24 hours mean	AQI category	Description of Air Quality
Computer village	251-350	289	poor	Members of sensitive groups may experience health effects. The general public is less likely to be affected
Tollgate-Meiran	251-350	283	poor	
Agege/pen-cinema	251-350	267	poor	
ile epo-lyana-ipaja	251-350	281	poor	
Shogunle-Oshodi	251-350	296	poor	

CO (54ppm) concentration is highest at computer village due to a large proportion of motorcycles. Motorcycles are found to emit more CO into the atmosphere and are one of the causes of Greenhouse gases. (Ribeiro et al, 2021). Given the severe air quality emanating from the CO concentration for all the routes, the risk for health effects is increased for road users and exposed community members living along the roads. It is thus advisable to avoid outdoor activities, especially individuals with heart and breathing ailments, children, and older adults as carbon monoxide tends to bind to hemoglobin in red blood cells, reducing their ability to transport and release oxygen throughout the body. It is important to note here that even moderate exposure of CO to the occupants along the study area can aggravate cardiac ailments such as the brain and heart. All motor vehicles emit CO, but the majority of CO emitted from this source occurs from light-duty, gasoline-powered vehicles. In addition to health concerns from CO exposures, CO may be a useful indicator of the transport and dispersion of inert, primary combustion emissions from traffic sources since CO does not react in the near-road environment (Smit et al., 2019).

The $PM_{2.5}$ levels (197.79 μg/m3) are highest in Shogunle-Oshodi routes and it can be considered as severe or hazardous for all the routes as it exceeds 50 μg/m3 WHO Air Quality guidelines and exceeds the 250 air quality index. The implication is that it is unhealthy for road users and communities living along the routes, and especially the sensitive groups. Given that $PM_{2.5}$ consists of particles less than one-tenth the diameter of human hair, they can be inhaled deeper into the lungs and can affect lungs and cause serious health effects. It is also crucial to underline the fact that fine particles less than 2.5 micrometers in diameter poses the most serious threat to human health as the size of the particle is directly linked to their potential for causing health problems (Olukanni et al., 2021). The air quality for PM_{10} is poor for most of the surveyed routes and moderately polluted for Agege-pencinema road. Particles that are ten micrometers (PM_{10}) in diameter generally pass through the nose into the lungs and once inhaled can affect the lungs and cause serious health effects.

3.3 Health Impact Assessment

The respondents returned 355 out of 400 questionnaires administered. The age groups ranged from≤16 to ≥60, with the majority (35.2%) in the ≤40 age group. 84.5% of the respondent have their business, workplace, and residence close to the corridor at about 10-50 meters away from the corridor. 88.2% have their daily activities within the corridor with 53% spending more than 8 hours daily. 59.4% have spent less than 5 years while 23.1% have spent between 5 to 10 years on the corridor. This implies that a larger proportion of respondents is exposed to air pollution on road corridor daily. Figure 6 showed the respondent varying health symptoms such as chest pain, frequent cough, nose running and sneezing, sore throat, difficulty in breathing, body weakness, fatigue, loss of appetite, headache, fast breathing: traders (14%); hawkers (10%); shop owners (25%); school children (5%); drivers/conductor (16%); office staff (21%), police (1%); traffic officer (2%); pedestrian/passerby (5%) and construction workers (1%). Also of significant concern is the fact that the premature death burden of exposure to air pollution is also highly gendered with women and children being the most susceptible. This is shown in figure 7 which revealed that 54% women and 6% children perceived and experience varying health symptoms.

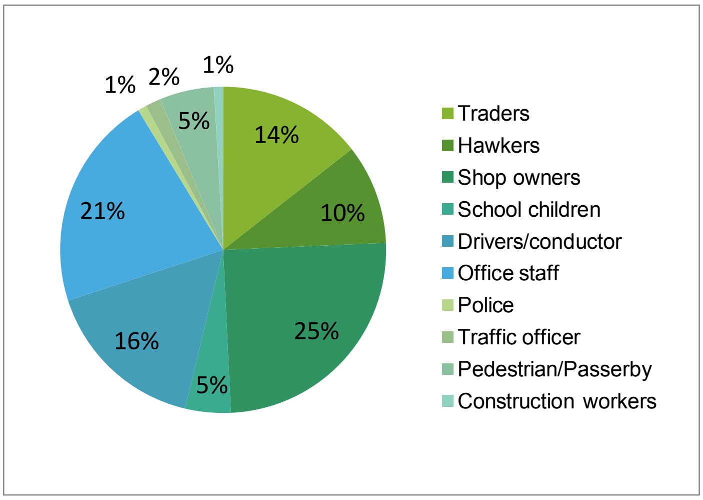

Figure 6: Respondent health symptoms

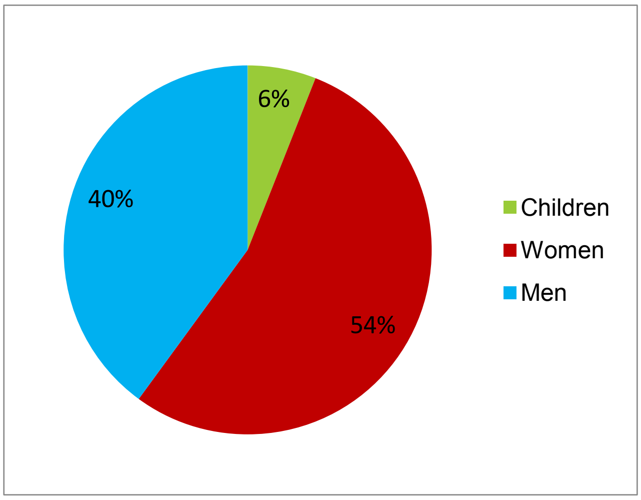

Figure 7: Gender-health symptoms

4. CONCLUSION

The study assessed the ambient air quality caused by vehicle emission and its health implication on the public near selected roadways in Lagos Metropolis. The correlation analysis indicated statistically significant positive correlations between the traffic volume and the concentration of pollutants. The Ambient Air Quality was determined based on the WHO and Air Quality index. SO_2 impact on the ambient air quality was moderately polluted for all the routes; NO_2 impact on ambient air quality was good at Agege-pencinema; satisfactory at computer village and ile epo-iyana ipaja and moderately polluted at tollgate-meiran and Shogunle-oshodi routes. The air quality is not safe and it is hazardous to health as the impact of CO, $PM_{2.5}$, and PM_{10} on the routes were severe, severe, and poor respectively for all the routes.

The health impact assessment on the corridor revealed traders, hawkers, shop owners, school children, drivers/conductor, office staff, police, traffic officer, and pedestrian/ passerby and construction workers showed symptoms of chest pain, frequent cough, nose running and sneezing, sore throat, difficulty in breathing, body weakness, fatigue, loss of appetite, headache, fast breathing on the computer village route. These symptoms are indication of health burden emanating from exposure to these hazardous traffic air pollutants. The inventory of Traffic flow which provides flow information, vehicle composition are important parameters that engender various regimes of traffic situation which are germane to transport professionals on the condition of traffic and congestion on the studied routes. The knowledge of congestion levels in the city will inform the public of routes of the hot spot of air pollution. Inventory of emission levels combined with real-time traffic data, can obtain the temporal and spatial characteristics of the pollutant concentration on the road network.

Therefore, it is recommended that real-time monitoring program be set up in Lagos to know the nature of traffic and emission levels on the routes which should be geared towards reduction of traffic congestion through intelligent traffic control system, overall of old and used vehicles by shifting to cleaner heavy-duty diesel and low-emissions vehicles. Also non-discriminatory policies toward the education and guidance of people about vehicle emission pollution and related health challenges for reduction of the negative impacts on ambient air quality and public health in developing African cites. Future work can therefore look further into the impact of vehicle characteristics such as age and mileage, maintenance condition, vehicle fleet, weight and size, engine power on the emission levels   It will also be interesting to investigate the impact of roadway conditions such as terrain configuration, lane channelization, lane width, road gradient and super-elevation as well as correction factor such as temperature, humidity and wind velocity and direction on vehicle emission levels.

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