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An assessment on concentrations of No_2, So_2, Co and their allied health risks alongside Ilorin-Osogbo expressway, Nigeria

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Abstract
This research evaluated in-vehicle and ambient air samples for three pollutants; NO_2, SO_2, CO and deduced the air quality index, emission factors and health risk assessments from the pollutants concentrations. The concentrations of these pollutants were measured in-vehicle using two modes of transportation with open-window scenario while ambient measurements covered three hours of the day at six sampling points covering two states along the highway. NO_2, SO_2 and CO concentrations were measured with Altair-5X MGD. Vehicular volume was conducted per 45 minutes and self-administered forms were used to draw health data on the samples. The values of the in-vehicle exposure in µgm^{-3} ranges from 90–1270 NO_2; 124-810 SO_2 and 3262-23800 CO. The highest average in-vehicle exposure appeared in cars with the following µgm^{-3} average NO_2, 426±109; SO_2 571±61 and CO 10433±1650. The Ambient air pollutants results showed that the mean concentrations of NO_2 and SO_2 exceeded the 1-hour averaging time-limit of 40 µgm^{-3} set by FEPA but within the 1-hour averaging time-limit set by EPA while the mean concentration of CO falls within minimal limit stipulated by WHO. Air Quality Index was deduced with rating for NO_2 and SO_2 which ranged from good "A" through unhealthy for sensitive group "UHFS' to hazardous "F" and rating for CO, F across the sampling points. The study established strong evidence that traffic volume affects the quality of air in the atmosphere at all sampling points. Results from questionnaire indicated some key health risks related with contact to pollutants by commuters and other road users.

Keywords: Altair multi-gas detector, automobile emissions, gaseous air pollutants, health risk, assessments, traffic volume

Introduction
Clean air is taking as a rudimentary condition for human health (Montero *et al.*, 2010) [34]. However, air pollution lingers on posing extensive threat to human health. Epidemiologically, over two million early deaths that occur yearly can be credited to the burden of disease due to the effect of ambient air pollution (in and outdoor). More than 50% of this disease burden is tolerated by the populaces of developing countries (WHO, 2006) [57]. Increase in the number of motor vehicles with respect to motorization have remained mostly unimpeded by environmental regulations, thereby creating high intensities of air pollution (Han and Naeher, 2006) [24]. Traffic emissions contribute extra to ambient air pollution in developing countries, accounting for increase of forty to eighty percent of nitrogen (IV) oxide (NO_2) plus carbon (II) oxide (CO) concentrations according to Goyal and Joshi (2006) [23]. Partly this can be clarified by the vehicle silhouette because of economic constraints, poorly maintained and old dilapidated vehicles that are being used on roads in developing countries like Nigeria (Osuntogun and Koku, 2007) [43], despite the global efforts to reduce environmental problems caused by traffic emissions. Also, in Nigeria, used vehicles are often imported as 'tokumbo' vehicles, leading to an automobile fleet controlled by a class of vehicles known as "super emitters" which discharge higher concentrations of unsafe pollutants in contrast to appropriately maintained vehicles (Goyal and Joshi**,** 2006) [23]. Pollutants released from mobile transportation is growing as the number of vehicle owners are increasing, coupled with bad roads in developing countries; This causes overcrowding on motor ways causing the levels of air pollution to rise (Abdul Raheem *et al*., 2019) [2].

Pollution from automobile arises largely from the non-efficient burning of hydrocarbon (HC) fuels. HC fuels easily bond with oxides of nitrogen (NO_x) over photochemical reactions in sunlight to generate smog (Ojo and Awokola, 2012) [40]. HC fuels comprise also, changeable degree of sulphur. Burning of HC fuels has the potential of generating oxides of sulphur (SOx), which when combine with H_2O in the atmosphere form acids of sulphur (Demirbas, 2005) [15]. CO is also formed as a consequence of inefficient burning of HC fuels and is very noxious even at low concentrations and has been identified to decline human efficacy (Lanphear, 2017) [29]. Air pollutants pose health problems to human communities. Some sets of individuals are specifically sensitive to common air pollutants, which made them vulnerable to respiratory disorder. Sensitive groups of people in a population comprise children, elders and people with underlying heart or lung diseases (Wang *et al.*, 2019) [52]. Experts now believe the world faces an epidemic of sicknesses that is aggravated by air pollution (Lippmann and Chen, 2009). These illnesses include circulatory disease, chronic disruptive airway diseases (CDAD) and episodic asthma. Real-world study required that it provides relevant information from viewpoint of human exposure on particle emission as related to pathogenesis of lung cancer and diabetes (Ris, 2007; Zhang *et al.*, 2009; Kelly and Fussell, 2011) [48, 58, 27]. Chemicals in vehicle exhaust could be volatile and non-volatile particles with a diameter range of 30 – 70 nm, which may have positive or negative effects on human health and the atmosphere (Maricq, 2007; Giechaskiel *et al.*, 2012) [32, 21].

All automobiles, specifically diesel and gasoline engines, emit low size particulate matters that intensely infiltrate lungs and exacerbate the circulatory system, injuring cells and instigating respiratory problems (Chaturvedi *et al.*, 2016) [10]. Short-term acquaintance to vehicle exhaust may even trigger the episodic attack in asthmatics (Rice *et al.*, 2013) [46]. Lung function can adversely be affected by automobile exhaust (D'Amato *et al.*, 2010; Steiner *et al.*, 2016) [13, 50] and may promote allergic reactions by irritation and hypersensitive response with seasonal variations. Traffic emissions account for as many as 50% of all cancers credited to open-air pollution (VOCs) during summer (Li *et al.*, 2015; Wang *et al.*, 2015) [30, 53].

Other researchers have studied either in-vehicle or outdoor pollution chemistry separately and not in detail as this research. However, this research work assessed the open window scenario of in-vehicle and outdoor concentrations of NO_2, SO_2 and CO along the travel path of Ilorin – Osogbo highway in Nigeria. It also looked into the relationship between traffic volume and concentrations of these pollutants. This research further derived the health risks assessments and emission factors from the measured concentrations and other available data, and the results were compared with the safe standard limits. The air quality index was also deduced.

Materials and Methods

Data Acquisition and Experimental Setup

Study Area

Ambient in–vehicle and outdoor air were sampled for gaseous pollutants of interest. The ambient sampling was conducted at six different settlement points that covered two states along Ilorin - Osogbo highway in Nigeria. This was done to capture different settlements or trade centers along the route that can affect the gaseous emissions. The survey phase involved point location, sampling and site observations which involve source (s) of pollution.

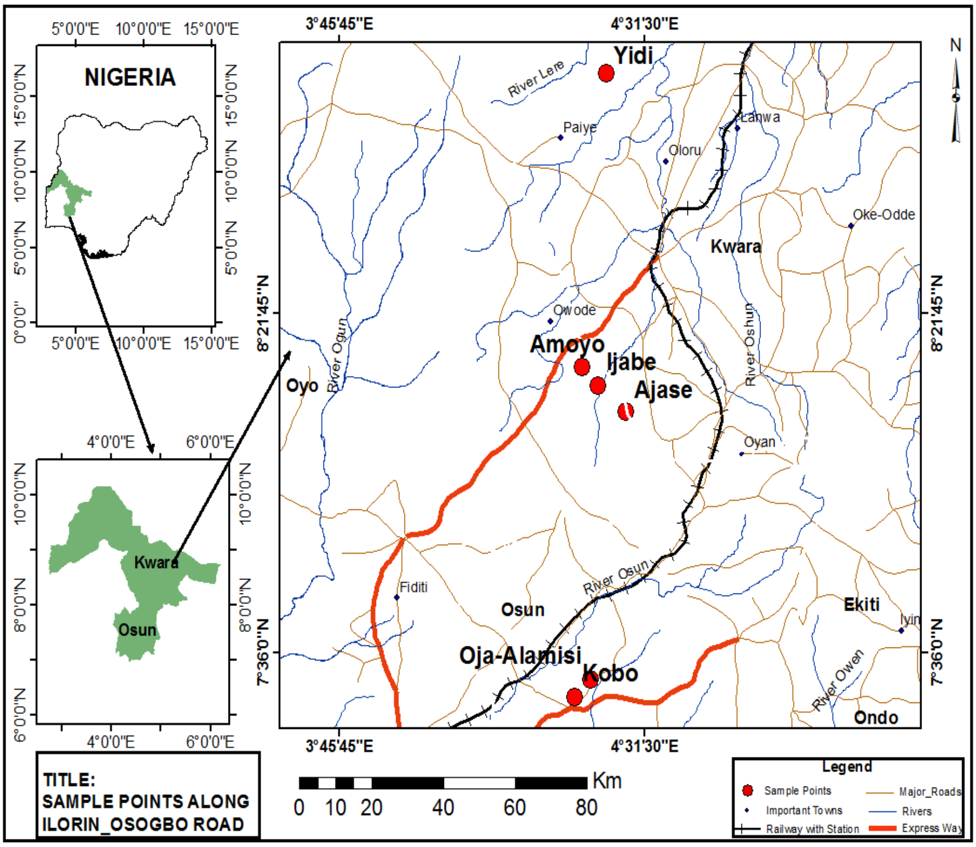

Fig 1: Ilorin – Osogbo road Map displaying the six selection points

Figure 1 showed the six (6) study points along Ilorin-Osogbo highway. A major road which negotiates through towns, villages and long bushes with little pouches of settlements that links Kwara to Osun States.

Table 1: The selected locations and their exact sampling points with hypothetical representation

S/No.	Selected Locations	Selected Points	GPS Locations
1	Ilorin	Amoyo (SP1)	8˚24′ N, 4˚37′ E
2	Ajase-ipo	Ajase (SP2)	8˚14′ N, 4˚48′ E
3	Offa	Yidi (SP3)	8˚9′ N, 4˚43′ E
4	Offa ─ Ikirun	Ijabe (SP4)	8˚2′ N, 4˚41′ E
5	Ikirun	Oja-Alamisi (SP5)	7˚54′ N, 4˚39′ E
6	Osogbo	Kobo (SP6)	7˚50′ N, 4˚35′ E

Table 1 showed the sampling areas and their selected point coordinates with their hypothetical representation. These sampling points were purposely selected due to their sparse settlements and sustainable primitive human activities like buying and selling and use of vehicles and motorcycles that utilizes gasoline, diesel or any other source of fuel that may generate products of incomplete combustion in the air.

Data Collection

In-vehicle gaseous pollutant concentrations were measured by mounting the sampler inside the open-window vehicles (cars and buses) to and fro Ilorin-Osogbo and Osogbo-Ilorin traffic (a complete trip cycle). While the ambient gaseous pollutants data collection was from the 6 sampling points during the three (3) strata periods of the day over 3-hour (hr) duration for three consecutive days at each sampling point which covered complete vehicles movement within a week for two weeks for outdoor sampling. The sampling was done between March and July, (winter-summer transition period) 2019. The three times of the day for outdoor sampling were categorized as follows: (i) 7.30 - 10.30 am, morning peak hours; (ii) 11.30 - 2.30 pm, afternoon off peak hours; (iii) 3.30 pm - 6.30 pm evening peak hours respectively (Abdul Raheem *et al*., 2019) [2].

Sampling procedure for Altair 5X multi-gas detector (MGD)

As reported by Abdul Raheem *et al*. (2019) [2], the air pollutants (NO_2, SO_2, and CO) were measured with MSA Altair 5X MGD, a unique and portable monitor for detection of NO_2, SO_2, CO and flammable gases. Although, the latter species are not reported in this work. This multi-gas detector is flexible, robust, portable, and intrinsically safe. It has embedded software that is intended to meet the necessities of International Electro-Technical Commission (IEC 61508-3). This equipment was pre-calibrated by the instrument manufacturer and all measurements are reported in units of ppm and converted to μgm^{-3} in this study. On arriving at the field, Altair 5X MGD sampler unit was first of all switched on in a clean environment in order to perform bump and calibration tests, this zero the sampler unit. This instrument then displays the sensor and calibration information which complete the fresh air setup (www.msaSafety.com, 2012). The sensor described above was used for outdoor sampling by measuring the pollutants for every 15 minutes' interval at a point located 2 m away from the road edge at each sampling point located along the route under study and it was used also inside the travelling vehicle for in-vehicle sampling.

Also, vehicular traffic volume was done manually by observation to obtain the volume of traffic at the sampling points and the counting was done in the space of 45 minutes to avoid repetition.

The concentration levels of the gaseous pollutants (NO_2, SO_2, and CO) measured were compared with the safe limits set by NESREA, 2009 [37] standards. The data obtained was an average of three replicates so as to ensure validity and reliability of MGD sensor after standardization.

Evaluation of Health Risk Assessments

Air pollution emission factors (EF) are characteristic values that endeavor to relay the amount of a pollutant discharged into the ambient air with an activity connected with the discharge of such pollutant (Cheremisin off *et al*., 2008). These factors are expressed as the load of the pollutant divided by a unit mass, volume, distance or period of the activity releasing the pollutant. Such factors expedite valuation of emissions from a number of sources of air pollution. In most circumstances these factors are simply averages of all data and usually are presumed to be representative of long - term averages.

Emission Factors

There are two equations depending on emission reduction control, Equation that treat emissions i) before reduction control and ii) After reduction control (Cheremisinoff *et al*., 2008).

Before reduction control

$$E = A \times EF \quad (1)$$

$$EF = E/A \quad (2)$$

After reduction control

$$E = A \times EF \times (1-ER/100) \quad (3)$$

Where, E = Emission; A = activity unit per unit time, volume, distance, or period

EF = emission factor, ER =% overall emission reduction efficiency

Exposure Assessment of air pollutants on health status

The exposure valuation identifies the population susceptible to the hazard, the magnitude and duration of exposure to the hazard. This research presumed the breathing route as the major route of exposure to the examined pollutants. As previously used (Table 2), (Matooane and Diab, 2003) [33] this work used a scenario assessment approach whereby, average expected exposure conditions was developed for intermediate (24-hr) for different age groups.

For disclosure to non-carcinogenic pollutants (NO_2, SO_2, CO), the acute exposure rate equation is given as:

$$AHD = IR / BW \times C \quad (4)$$

Where, AHD is the average hourly dose for inhalation ($\mu g kg^{-1} hr^{-1}$), IR is the inhalation rate ($m^3 hr^{-1}$); BW is the body weight (kg) and C is the concentration of the chemical (μgm^{-3}), (WHO, 1999) [54].

Table 2: Mean inhalation rate and mean body weight for the exposed groups

Exposed Group	Mean inhalation rate (m^3/hour) (Acute exposure)	Mean body weight (kg)
Infants (birth-1 year)	0.3	11.3
Children (6-12 year)	1.2	45.3
Adult (19-75 year)	1.2	71.8

Source: Adapted from (Matooane and Diab, 2003) [33]

Air Quality Index (AQI)

Air Quality Index (AQI) is a pointer that assess the purity and quality of air constituents, based on air pollutants that have adverse effects on the environment and human health. Such pollutants are NO_2, SO_2, CO, ozone, fine particulate matter, and total reduced sulphur compounds. AQI is a means used by Environmental Protection Agency (EPA) and other agencies to make available to the public a timely and easy-to-understand info on local air quality and whether air pollution concentration levels pose a health anxiety. AQI communicates the public on how clean the air we are breathing is and if they should be worried for their health. As reported by Ewona *et al*. 2013 [18], AQI also focused on health problems that can materialize within a few hours or days after inhaling polluted air.

Questionnaire

A developed and standardized questionnaire was used to elicit information from residents in the six sampling locations on the types of ailments they suffered which were related to exposure to noxious pollutants concentrations. To ensure anonymity only limited demographic information were sought i.e., age, sex, period of residence in the area, duration of exposure to other sources of pollution, health illnesses diagnosed with, their present condition, and incidence of hospital admittances.

Statistical Analysis

Statistical package for social sciences (SPSS) version 20 was used for the analysis of Data generated from the field work. Calculation of the mean and analysis of variance (ANOVA) for the set of results were done. ANOVA revealed any significant difference between the data sets and was followed by Tukey post - hoc test. Data were presented in tables as the Mean ± SEM. Statistical significance was considered at $p < 0.05$. Graphs were used as exploratory tool of analysis to sightsee and represent the concentrations of the air pollutants over a period of time at different sampling points.

Results and Discussion

Vehicular emissions pose serious health problems to humans. Over six hundred million individuals globally are exposed to lethal concentrations of traffic correlated pollutants (AlNaimi, 2013) [4]. In most developing countries of the world, vehicular evolution has not been checked correctly by environmental regulating authorities leading to enlarged levels of pollution (Han and Naeher, 2006, Chainchan, 2018) [24].

Table 3, showed the average traffic volume per 3 days and mean concentrations estimate at the six sampling points along Ilorin - Osogbo highway, Nigeria using the Altair 5X multi-gas detector (MGD) considering three different exposure time in a day while table 4 showed the emission factors deduced from the concentrations measured. It was found that the concentrations measured is directly proportional to the emission factors deduced.

Average Traffic volume and average estimate of NO_2 emission concentration across six sampling points

Table 3, showed the mean concentrations of all pollutants for morning, afternoon and evening per 3 days against the volume of vehicle count, across all the sampling points. The mean concentration of NO_2 across all sampling points ranged from 117 ± 30 to 303 ± 112 μgm^{-3} (morning); 59 ± 3 to 2140 ± 481 μgm^{-3} (afternoon) and 50 ± 13 to 2713 ± 394 μgm^{-3} (evening) respectively. All exceeded the 1-hr averaging time limit 40 - 60 μgm^{-3} set by FEPA and NESREA 2009 [37], but within the 1-hr averaging time limit 100 μgm^{-3} set (EPA, 2014) [17]. The NO_2 pollutant emission concentration is related to the traffic volume suggesting the efficiency of the vehicles that passes the road.

At SP4, ATV was 325 ± 24 (evening), 318 ± 17 (morning) and 264 ± 13.11 (afternoon) respectively while the NO_2 emission concentration was reversed in the following order: 117 ± 30 (morning); 95 ± 41 (afternoon) and 67 ± 22 (evening) respectively. This implies that the ATV was unrelated to the NO_2 pollutant emission measured. Also that the traffic exhaust probably undergoes complete combustion of fuel and less of nitrogen is oxidized to NO and NO_2 (NO_x). Therefore, no sufficient NO_2 concentration in atmosphere to form acid rain or hazy air that may alter visibility in the ecosystem (ATSDR, 2002) [3]. No unhealthy effect on community living in this sampling point.

The highest concentrations were recorded at SP2 at all periods of the day. This may be attributed to the fact that the road at this location experiences a higher traffic especially in the morning and evening hours when workers, traders and travelers are going to, and fro their places of work, businesses, and destinations, which causes traffic congestion. The road also serves as a major entry and exit points for Western, Eastern and Southern travelling vehicles.

The health implication is that inhalation rate will be high and since the primary route of entering into living cells is through the nose>larynx>trachea>bronchial>lung in sequential order, the environs is unhealthy for sensitive groups (the infants, children, older adults, hypersensitive airway). It can be depicted from the results that as the number of motor vehicles and motorcycles increases, the emission problems to the environment also increases. (Sami *et al*., 2003) [49]. This can equally be supported by a recent research carried out by Mahato *et al*. 2020 [31] in Delhi, India on Covid-19 Pandemic lockdown effect on air quality, their results showed that the air quality is significantly improved i.e. pollutants concentrations declined during the lockdown (all activities put on hold including transportation). This infers that transportation activity is directly proportional to atmospheric burden of gaseous pollutants especially NO_2 and CO.

The results also showed that ATV was dense in the morning (368) at SP1 and the level of NO_2 pollutant measured was found to range between 50 μgm^{-3} (evening) and 145 μgm^{-3} (morning), indicating that the exhaust release was highest in the morning but reduced at evening peak hour respectively.

At SP2 and SP5, similar pattern was observed with significance difference across the exposure time sequentially, in which the average traffic volume decreases down the exposure time and emission release concentration respectively. This implies that the ATV is directly related to the concentration of NO_2 pollutant measured at these 3 points (SP1, SP2 and SP5). These findings fall within the recommended standard of EPA, (EPA, 2014) [17].

However, the pattern observed at SP3, SP4 and SP6 highways were at variance. At SP3, ATV was highest in the evening (459) and lowest (337) in the afternoon while the emission concentration follows the following order: maximal in the evening > afternoon > morning (3187 ± 526 μgm^{-3} > 1504 ± 694 μgm^{-3} > 604 ± 308 μgm^{-3}) in decreasing order respectively. This implies that the ATV is not directly related to NO_2 pollutant emission measured at SP3. Also that the hydrocarbons in traffic exhaust probably undergo complete combustion of fuel.

Menace of air pollution are now facing several rural towns that had in the past enjoyed fresh and dry air in Nigeria (Obajimi 1998; Isife, 2012) [38, 26]. According to Amil *et al*. (2016) [5], the quantity of NO_2 measured at some of these study areas are higher than the 40-60 μgm^{-3} minimum standard stipulated while at some other points it is within the range. G. Zhu *et al*. (2020) [59] equally affirmed in their work that man-made pollution has become a vital problem governing human health risks and ecosystem.

Average Traffic volume and average estimate of SO_2 emission concentration across the six sampling locations

Table 3, showed ATV and mean SO_2 level across three periods at the six sampling points using the Altair 5x multi gas detector. SO_2 pollutant concentration range was 19 ± 4 to 401 ± 132 μgm-^{3} (morning); 49 ± 8 to 391 ± 118 μgm-^{3} (afternoon) and 144 ± 19 to 1236 ± 196 μgm-^{3} (evening) respectively. This concentration exceeded the limit (10 - 100 μgm-^{3}) set standards (NESREA, 2009) [37]. At SP1, SO_2 level was at variant but highest in the evening peak hour with decreasing average traffic volume. At SP2, the SO_2 level increased across the period with ATV variation.

At SP3, SO_2 concentration was highest across the three periods of the day and related to the ATV. Similar observation was made at SP2, SO_2 concentration increased down the day without direct correlation to ATV; while at SP4, SP5 and SP6, SO_2 pollutant measured declined down the day with ATV variation. The results at all the points showed that the vehicle emissions are not the only contributing factor to the concentrations of SO_2. These findings are also in agreement with the results of the research conducted by Okunola *et al.* (2012) [41]; Kumar & Kriti (2016) [28] who reported that concentrations of SO_2 gases were higher in the evening period and relatively lower during morning period. Also, Abdul Raheem *et al*. (2009) [1] equally reported that the SO_2 in the ambient air at specific point on time is partially dependent on automobiles emissions and more on other artificial activities occurring at the period of interest.

Average Traffic volume and average estimate of CO emission concentration across the six sampling locations

From table 3, ATV and mean CO concentrations across three periods of sampling at the six sampling points falls within the limit (10,000- 20,000 μgm-^{3}) set standard (NESREA, 2009) [37], and the results reported by another researcher and the team (Ezeh *et al.*, 2012) [19].

The CO variation across the periods at all sampling points also revealed that the air quality contained less than 10,000 μgm-^{3} minimum standard stipulated by WHO (WHO, 2000) [55] and reported by Iorga (2016) [25].

The highest level of CO was recorded at SP1 with mean value of up to 8690.00 μgm^{-3}. This result accords with the report of Pope (2002) [45] but is contrary to the report of Riediker *et al*. (2003) [47] where low level of CO was observed. This finding can be attributed to the ATV due to the commercial activities as cars, taxies, intra-city commercials buses; trucks use this point as their temporary park. A car with an efficient catalytic converter could release up to 0.01 vol.% CO, while a rickety and deteriorated car could discharge as much as 15 vol.% CO (Coyle *et al*., 2002) [12]. It means that, the quality of vehicles tracking the sampling points as at the time of field work lacks good maintenance and the hydrocarbons contain in fuel could not undergo complete combustion in air to generate CO_2.

However, this variation may be attributed to the following reasons; first, the relationship between traffic volumes and pollutants concentrations. The second reason may also be linked to the constant change of the atmospheric boundary layer and related convective disorder which extensively mix and redistribute pollutant gases to a more vertical extent. When sunset is high, air mixed layers tends to deform. Also as night keeps on advancing, the boundary layer becomes stratified till it finally results in the formation of a nightly inversion and a superficial steady boundary layer close to the surface and residue layer overhead. As series of activities continues during the night, the inversion gains altitude and prevents vertical transport of gases and aerosols (Coyle *et al*., 2002) [12].

This implies that fuel consumption was ineffective and combustion of hydrocarbons in the gasoline and /or diesel utilities to power the engine by the automobiles in this area of study was incomplete. Thus considering the odourless, and colourless nature of CO, its high concentration in the atmosphere results into polluted air that when inhaled into human body system, poses a health challenge to the people leaving in the area. The extended health impact is that CO competes and displaces oxygen from binding to red blood cell pigment called hemoglobin in blood circulation. This interaction will lead to reduced oxygen bioavailability and hence ineffective cellular processes with consequent anoxia, hypoxia, hypoxic-ischaemic injury (Peter *et al.*, 2004; Gorr, 2017) [44, 22]. This can be corroborated with AQI which revealed that across the sampling points and timing of the evaluation, CO AQI status was hazardous to human health (Table 6). This result corroborates the report of Olajire *et al.* (2011) [42], where the level of CO surpasses the US national ambient quality standard (US NAQS) of 9000 μgm-^{3} (8 -hr average) and fell below 35000 μgm-^{3} (1- hr average). G. Dantas *et al*. (2020) [14] in their research on air quality on the city Rio de Janeiro, Brazil, the impact of Covid-19 partial lockdown, they found that CO concentration is significantly reduced which was attributed to their relationship to light duty vehicular emissions.

Table 3: Mean concentration of all pollutants and Traffic volume for morning, afternoon, and evening per 3 days of the week

Sampling points	NO_2 (µgm^{-3}) Mean ± SEM	SO_2 (µgm^{-3}) Mean ± SEM	CO (µgm^{-3}) Mean± SEM	Average Traffic Volume Mean ± SEM
SP1				
M	145 ± 39	245 ± 33$^{\$}$	2700 ± 322	369 ± 12
A	114 ± 40	194 ± 17	4500 ± 650	340 ± 36
E	50 ± 13	430 ± 44$^{*\#}$	8690 ± 540	325 ± 37
SP2				
M	213 ± 62	19 ± 4	529 ± 12	319 ± 20$^{\#\$}$
A	151 ± 31	49 ± 8	2086 ± 211	263 ± 6*
E	92 ± 16	144 ± 19	3645 ± 35	246 ± 7*
SP3				
M	303 ± 112$^{\$}$	401 ± 132	320 ± 99$^{\#\$}$	456.67 ± 1$^{\#}$
A	2139 ± 481	391 ± 118	2411 ± 241$^{*\$}$	337 ± 25$^{*\$}$
E	2713 ± 394*	480 ± 138	4662 ± 502$^{*\#}$	459 ± 10$^{\#}$
SP4				
M	117 ± 30	159 ± 58	328 ± 105	318 ± 17
A	95 ± 41	156 ± 3	2725 ± 562	264 ± 13
E	67 ± 22	364 ± 4	1075 ± 454	325 ± 24
SP5				
M	111 ± 6	193 ± 37	2640 ± 510	418 ± 14
A	59 ± 3*	153 ± 44	2081 ± 1002	405 ± 39
E	53 ± 1*	1236 ± 196	4652 ± 462	410 ± 16
SP6				
M	130 ± 5$^{\#}$	301 ± 67	2994 ± 74	393 ± 8
A	76 ± 12*	283 ± 5	3078 ± 58	331 ± 21
E	100 ± 11	292 ± 124	2745 ± 321$^{\#}$	346 ± 25

SP1=Amoyo; SP2= Ajase; SP3 = Yidi; SP4= Ijabe; SP5= Oja-Alamisi; SP6= Kobo. M=morning; A=Afternoon; E= evening. Data were presented as mean ± SEM of three replicate *#$ significance at $p<0.05$ to morning, afternoon and evening respectively using Tukey, post Hoc tests.

The gross average values of CO in the six sampling points within the 72-hour experimental period were identified to be in the range 473 - 5298 µgm^{-3} greater than the USEPA environmental air quality of 150 µgm^{-3} on annual averaging period. This shows that the average level of CO exposure was higher along Ilorin-Osogbo expressway. The commuters will benefit from Health talk and measures to improve the quality of automobiles accessory so that both primary and secondary sources of automobile CO exhaust would be contained.

Impact of Ambient atmospheric pollutants on Ecosystem and Health status along Ilorin-Osogbo highway

Table 4: Pollutants Emission Factors across the six sampling points

		Sampling points					
Pollutants	Timing	SP1	SP2	SP3	SP4	SP5	SP6
NO_2	M	54	80	114	44	42	49
	A	43	57	802	36	22	29
	E	19	35	1017	25	20	37
SO_2	M	92	7	151	59	72	72
	A	73	18	147	59	56	58
	E	161	54	180	137	464	397
CO	M	1013	198	120	109	880	998
	A	1688	782	904	908	694	1026
	E	3259	1367	1748	358	1551	915

The health impact of air pollution could be equally severe and persistent. This impact, varies from minor irritation of eyes, hyper-responsive upper respiratory tract to chronic heart disease, respiratory diseases, lung cancer, and death. Air pollution has been reported to cause severe respiratory infections in children and pulmonary emphysema in adults. The effect of air pollution is dependent on the type of pollutant, its atmospheric concentration, period of exposure, the magnitude of interactions and photochemical reaction with other atmospheric pollutants coupled with individual allergy (Anhwange *et al*., 2012) [6].

M=morning; A=Afternoon; E= evening

Vehicular traffic accounts for majority of the total emission of NO_2 (Cape *et al*., 2004) [7]. The fact that automobile emissions contribute about 50 – 80% of NO_2 concentration in developing nations is also supported by Goyal and Joshi (2006) [23]. Long term exposure to NO_2 from automobile emissions react in the body system thereby given symptoms like cold, headache, cough, and fever and if untreated may result into respiratory diseases such as aggravate asthma, inflammation of lung tissue and cardiovascular disease.

Exposure Assessment of Traffic exhausts on Infant, Children and Adults

Table 5: Exposure Assessment of NO_2, SO_2 and CO Measured at six sampling points

Pollutants /AHD	Sampling points	SP1	SP2	SP3	SP4	SP5	SP6
NO_2	AE (µgm^{-3}hr^{-1})	103	152	345	93	74	102
AHD((µgkg^{-1}hr^{-1})	Infants	3	4	9	2	2	3
	Children	3	4	9	2	2	3
	Adults	2	3	6	2	1	2
SO_2	AE (µgm^{-3}hr^{-1})	290	70	424	226	469	292
AHD((µgkg^{-1}hr^{-1})	Infants	8	2	11	6	12	8
	Children	8	2	11	6	12	8
	Adults	5	1	7	4	8	5
CO	AE (µgm^{-3}hr^{-1})	5297	993	473	1376	3103	2939
AHD((µgkg^{-1}hr^{-1})	Infants	138	26	12	36	81	76
	Children	138	26	12	36	81	76
	Adults	90	17	8	23	53	50

The risk assessment detects the populace exposed to the hazard and the magnitude and duration of exposure. This study assumed the breathing route as the main source of exposure to the examined air pollutants. This study used a strategic assessment approach whereby average expected exposure conditions was developed for intermediate (24-hr) for different age groups as previously used (Matooane and Diab, 2003) [33] as shown in table 2. For exposure to non-cancerous pollutants, (NO_2, SO_2, CO) the acute exposure rate equation 4 was used.

Exposure Assessment of NO_2, SO_2 and CO in ambient air on Infant, Children and Adults

The data obtained for mean body weight in this study was similar with the one obtained by Matooane and Diab (2003) [33], and USEPA (2001) [51] which account for the reason the data in table 2 was adopted for the estimation of table 5.

AQI value and Health effects

NO_2 air pollutant across the six sampling points along llorin- Osogbo Highway

Cooperatively, internal combustion engines and conservative fuels are the prevailing contributor to transport-related air pollution. Table 6, showed the air quality index (AQI) for all sampling points at all periods of the day. As the AQI value increases, so does the level of air pollution and the greater the health adverse effects. Concerning the quality of NO_2 in air, SP1 had an NO_2 air quality condition that was unhealthy to sensitive groups (UHSGs) at dawn and midday, but good in the sunset peak hours. It can be inferred that for the community, the AQI value ranged from 101-150 so members that are allergic may experience health effect, thus it poses health effects to people with asthma in the morning and afternoon while the AQI value was between 0-50 in the evening and the community was exposed to clean satisfactory air with little or no health risk respectively. At SP2 NO_2 air quality condition was very unhealthy VUH (morning), UHSGs (afternoon) and moderate (evening). This suggest that averagely the air pollution level for the community varies from 201-300, which calls for health alert and that every member may suffer from serious health effects in the morning; in the afternoon, the air pollution index value varies from 101-150 and susceptible groups may experience health effects but the general populace may not be affected. At SP3, the air pollution value of NO_2 ranged 301-500 in the community. Any AQI value greater than 300, triggers health warning to emergency conditions and the health effect will cut across all groups. Health policy makers needs to implement strategic plan for mitigation and regulation of air pollutants. Hence, everyone should limit outdoor exertion.

At SP4, SP5 and SP6 sampling points observation were similar, the AQI value was between 101-150 and members of sensitive groups may experience health effects but the general public is unlikely to be affected and between 51-100 for afternoon and evening peak hours. Here the air pollution level is moderate; therefore, pollution within this limit may cause limited health effect. This implies that the amount of NO_2 exhaust released from automobiles is within acceptable recommended air quality values for environmental and health effects of the commuters.

SO_2 air pollutant across the six sampling points along Ilorin- Osogbo Highway

Concerning the quality of SO_2 content of air in sampling points (Table 6): SP1 had an SO_2 air quality condition that was very unhealthy (VUH) in the morning, unhealthy (UH) in the afternoon but hazardous in the evening peak hours. This means that the AQI value for community was 201-300, meaning that individuals may experience critical health problem. At SP2, SO_2 air quality in the community was between 0-50 (morning), 51-100 (afternoon) and 101-150 (evening) respectively. This implies that SO_2 vehicular emission was within acceptable range. The commuters may experience little or moderate health impact. At SP3, the AQI value SO_2 in the community was 301-500. Any AQI value greater than 300, triggers health warning to emergency conditions and the health effect will cut across all groups.

At sampling points SP4, SP5 and SP6, the SO_2 air pollutants in the community was similar in the following manner: unhealthy in the morning and afternoon with their related AQI value between 151-200 but hazardous in the evening peak hours with AQI value greater than 300 respectively. This indicates that the AQI value was high and the quality of air was unhealthy. Everyone may begin to experience health effect that progresses to emergency situations.

CO air pollutant across the six sampling points along Ilorin- Osogbo Highway

The AQI value for CO air pollutant across all sampling points and periods of evaluation was observed to be greater than 300 (Table 6). Therefore, CO air pollutant in the community was highly concentrated, hazardous to the environment and health status respectively. This indicates that the CO AQI value was highest and the quality of air was unhealthy. This shows that the CO concentration may be hazardous, e.g. everyone may begin to experience health effects that progresses to emergency situation (Neisi, 2018) [36]. This higher amount may be attributed to the periods of study and seasonal variation; in that the study was carried out between March and July during which the internally generated exhaust gas and catalytic converters rate was imbalance.

Table 6: Air Quality index (AQI) Assessment of six sampling points along Ilorin-Osogbo Highway, Nigeria

Sampling point	Sampling periods	AQI Rating (NO_2)	AQI status (NO_2)	AQI Rating (SO_2)	AQI status (SO_2)	AQI Rating (CO)	AQI status (CO)
SP1	M	C	UHFS	E	VUH	F	HAZ
	A	C	UHFS	D	UH	F	HAZ
	E	A	Good	F	HAZ	F	HAZ
SP2	M	E	VUH	A	Good	F	HAZ
	A	C	UHFS	B	Moderate	F	HAZ
	E	B	Moderate	C	UHFS	F	HAZ
SP3	M	F	HAZ	F	HAZ	F	HAZ
	A	F	HAZ	F	HAZ	F	HAZ
	E	F	HAZ	F	HAZ	F	HAZ
SP4	M	C	UHFS	D	UH	F	HAZ

	A	B	Moderate	D	UH	F	HAZ
	E	B	Moderate	F	HAZ	F	HAZ
SP5	M	C	UHFS	D	UH	F	HAZ
	A	B	Moderate	D	UH	F	HAZ
	E	B	Moderate	F	HAZ	F	HAZ
SP6	M	C	UHFS	D	UH	F	HAZ
	A	B	Moderate	D	UH	F	HAZ
	E	B	Moderate	F	HAZ	F	HAZ

UHFS=unhealthy for sensitive group; VUH=very unhealthy; HAZ=hazardous

The dense content of CO in inhaled air may possess respiratory symptoms due to its high affinity for hemoglobin in circulation; rapidly displace oxygen and result in anoxia; reduced oxygen content at tissues and cellular level for metabolic processes. Finally, inadequate oxygen supply to the brain may lead to death of nerve cells from hypoxic-ischeamic insult encephalopathy (Neisi, 2018) [36]. The reactive inflammatory response leads to edema formation and narrowing of airway, hence difficulty in breathing which will further compromise the pulmonary function. The entire population category should limit outdoor exposure (EPA, 2004) [16].

Mean Rating of Health Symptoms Experienced by Some of the People along Ilorin- Osogho Highway

The various health problems experienced by the samples (table 7), as illustrated through self-administered questionnaires, perceived by people either living or working near the Ilorin-Osogho Highway. Of the 70 people who responded to questionnaires, the perceived symptoms, the percentage occupied, the mean score and mean ranked is as follows in order of descending magnitude. Headache, 62.9%, 0.63, 1st; Cough, 61.4%, 0.61, 2nd; Flu-like illness (cold), 57.1%, 0.43, 4th; dizziness and redness of the eyes; 12.9%, 0.13, 5.5th along with dryness of the nose (10%, 0.1, 7th) and difficulty in breathing and chest pain, 7.1% each, 0.07, 8.5th respectively.

Table 7: Mean Rating of Health Symptoms Experienced by Some of the People along Ilorin-Osogho Highway

Experiences of Residents	Yes (%)	No (%)	Mean	Rank
Headache	44 (62.9)	26 (37.1)	0.63	1st
Cough	43 (61.4)	27 (38.6)	0.61	2nd
Cold	40 (57.1)	30 (42.9)	0.43	3rd
Throat dryness	10 (11.2)	60 (85.7)	0.14	4th
Dizziness	9 (12.9)	61 (87.1)	0.13	5.5th
Eye redness	9 (12.9)	61 (58.5)	0.13	5.5th
Nose dryness	7 (10)	63 (90)	0.10	7th
Chest Pain	5 (7.1)	65 (92.9)	0.07	8.5th
Breathing difficult	5 (7.1)	65 (92.9)	0.07	8.5th

The response and data generated from this questionnaire accord earlier report that there is direct correlation between the quality of atmospheric air and health status of the community (Oguntoke and Yussuf, 2008; Abdul Raheem, 2019) [2].

Obviously, the predominant systems involved are respiratory, cardiovascular and/or cerebrovascular systems according to the category of symptoms experienced by the residents. Furthermore, these symptoms reflect the concentrations of SO_2, NO_2 and CO obtained across the six sampling points to have negative long term effect on the public health status.

In-vehicle concentrations of the pollutants measured

The In-Vehicle gaseous air pollutants were measured along Ilorin-Osogbo in the morning (AM) and afternoon (PM) hours. A total of 12 measurements were taken of 6 completed cycles in both cars and buses respectively using Altair 5X multi-gas detector for NO_2, SO_2 and CO in μgm^{-3}. The level of the pollutants in the vehicle was evaluated for the selected means of transport in order to detect which type of transportation mode was the most polluted (Table 8).

In the cars; the range and mean μgm^{-3} values were NO_2, 85 - 1270 (426 ± 109); SO_2, 124 – 800 (571 ± 61) and CO, 3262 – 15366 (10433 ± 1650) whilst for buses they were NO_2, 105 - 470 (263 ± 37); SO_2, 98 - 520 (324 ± 38); CO, 3262 - 23800 (6346 ± 874).

Table 8: Exposure levels of Gaseous Air Pollutants in-vehicle

Mode	Journey Time	Sample Number	NO_2 μgm^{-3} x ε	SO_2 μgm^{-3} x ε	CO μgm^{-3} x ε
Cars	AM	6	397 182	549 99	9697 1961
	PM	6	455 138	594 82	11169 2813
	Both	12	426 109	571 61	10433 1650
Buses	AM	6	199 26	368 60	5781 1106
	PM	6	327 61	280 43	6910 1418
	Both	12	263 37	324 38	6346 874

x = mean; ε= standard error of mean

The buses have more space, air ventilation and their passenger's seats are higher than that of the car, this may account for reasons why buses have a higher concentration of pollutants measured. In comparing this to the other studies, Chan and Liu (2001) [9], G´omez-Perales *et al.* (2007), reported that the dimension of the automobile interior most strongly impacts microenvironment concentration of the pollutants and that buses are always found with the lowest pollutants concentration values.

Conclusion and Recommendations

Based on this research, the variations in the amounts of NO_2, SO_2 and CO measured along Ilorin-Osogbo road showed that vehicular emissions contribute significantly to the level of the air quality. Hazards linked with continuous exposure of humans to gaseous pollutants are largely impairment of respiratory system. In order to minimize the problems of gases emitted by automobiles, the developing countries should ensure that imported and locally assembled vehicles meet the USEPA emission standards. However, ministry of Health in conjunction with epidemiologists should establish a multidisciplinary survey team in order to establish the monitoring of local air quality for forecasting and mitigation for improved environmental clean air and health status. Moreover, there should be establishment of monitoring and evaluation team for maintaining and accessing the automobiles operating in the country. Traffic volume in some busy locations within the city should be minimized through the creation of alternative roads to ease off congestions. It will be appropriate for authorities in the developing countries to source alternative energy for automobile use other than fossil fuel. The use of simple and cheap nose mask should be introduced to workers whose jobs require staying several hours near motorways as preventive and protective measures. Health policy makers, National Environmental Agency and Epidemiologists need to implement strategic plan for mitigation and regulation of air pollutants in assessing the quality of air and health risk impacts.

Ethical Approval

Ethical Clearance was approved through the Research and Ethical Committee of the University of Ilorin, Ilorin-Nigeria (UERC/ASN/2019/1919).

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Declaration

The authors declared no conflicts of interest.

Contribution of the Authors

Abdul Raheem A.M.O.: supervision, Conceptualization, Methodology, Writing- Reviewing and Editing; Owolabi A.A.: Data curation, Writing- Original draft preparation, Visualization, Investigation; Abdulrahim H.A.: Writing-Reviewing and Editing.

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