Ambient Air Pollutions along a Major South-Western Nigerian Road

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ABSTRACT

This study investigated the air pollutants in the ambient air of a typical intercity highway in Nigeria. This was to assess the effect of vehicular emission on air quality along the highway. The results showed that NO_x concentrations ranged from 9.9 ± 3.2 to $33.8 \pm 3.3 \mu\text{g}/\text{m}^3$ during the wet season and 19.0 ± 1.2 to $35.4 \pm 2.3 \mu\text{g}/\text{m}^3$ during the dry season. Sulfur dioxide measured along this highway ranged from 49.7 ± 38.1 to $219 \pm 18.1 \mu\text{g}/\text{m}^3$ during the wet season while dry season concentration ranged from 89.1 ± 20.9 to $225.4 \pm 57.9 \mu\text{g}/\text{m}^3$. The TSP during the wet season ranged from 54.4 ± 25.6 to $126.8 \pm 25.6 \mu\text{g}/\text{m}^3$. These values were below the limits of $250 \mu\text{g}/\text{m}^3$ set by FME_{env}, and $150\text{--}230 \mu\text{g}/\text{m}^3$ by WHO. However, the TSP measured during the dry season ranged from 85.9 ± 44.6 to $277.8 \pm 213.5 \mu\text{g}/\text{m}^3$. The average correlations between NO_x , SO_2 , and TSP measured during wet and dry seasons and the traffic density were 0.7, 0.6 and 0.7, respectively. Air pollution along the Nigerian highway is highly linked to vehicular activities.

Keywords: Vehicular, Ambient, Air Pollutions, south-western Nigerian.

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I. INTRODUCTION

Air remains a major source of life to mankind, but the pollution to which it has been subjected has made it become a major source of harm to man's health and his environment. The world population has been on the increase over the years [1]. In Nigeria, the population was estimated to be 140 million with a growth rate of 3.2 percent and having state growth rate ranges between 2.8-3.5% except in Abuja [2] in 2006 compared to 88.9 million with a growth rate of 2.9 percent annum in 1991[3].

Essentially, the growing demand for fast reliable distribution of goods to support the high population and the increasing dependence on motorized vehicles for transportation have made highways a prominent facility for people to carry out their daily activities in Nigeria. These highways are characterized by several human activities, thus exposing man to the high concentration of pollutants

(chemicals, particulate matter, or biological agent that modifies the natural characteristics of the atmosphere) emitted into the air from vehicles plying them. This is evident from the thick and black smoke haze found sometimes in the air along Nigeria road corridors. The adverse effects associated with human exposure to vehicular exhausts may be impaired respiratory, nervous, and reproductive system as well as kidney malfunction [4]. Airborne pollutants such as SO_2 and NO_x contribute to acid rain, which can destroy the forest and slowly degrade building mortar, paint, and infrastructure [5].

Pollution from motor vehicles is adversely affecting the lives of many people both around inter-cities and intra-cities highways in Nigeria [6]. Emissions from vehicles have been reported to aggravate the already elevated level of particulates, oxides of nitrogen, heavy metals, and sulfur dioxide that were generated by several human activities such as construction activities, incineration, domestic heating, and

cooking with firewood along highways [7]. Therefore, vehicle emissions have been identified as major culprits to air pollution along highways [8].

Increased vehicular pollution in Nigeria is also traced to larger individual ownership of vehicles and tonnages of fuel consumption [1]. Single ownership of vehicles in Nigeria is influenced by improved economic conditions. More so, it has also been reported that the cost of petroleum products particularly, gasoline and gas oil are generally lower in Nigeria than in other OPEC countries, hence, also facilitating single ownership of vehicles [9]. Consequently, the rate of fuel consumption increases, which in turn increases emissions from vehicles.

Besides, the average age of vehicles in Nigeria is important when considering the vehicular pollution problems. The use of older and overused vehicles that do not meet emission standards is common in Nigeria. Owing to economic conditions, new vehicles are very expensive and only corporate organizations, the rich, and the government can acquire them. Some corporate bodies that are less buoyant even purchase used vehicles for official use [10].

Poor maintenance culture also increases the propensity of vehicles causing air pollution. Most roads in Nigeria are unpaved and those paved are not properly maintained, therefore, causing wear and tear of motor engines, brakes, and tires. As reported by [11], the implication of the above is that a high level of gaseous emissions and heavy metals are emitted to the atmosphere along with Nigeria highways. In summary, the high contribution of vehicular emissions to air quality in Nigeria could be attributed to several factors including a large number of motor vehicles, old age and overused vehicles, poor grade fuel, high fuel consumption, lack of maintenance culture, and poor maintenance of Nigerian highways [12].

Pollution arising from vehicular exhausts is mainly from the imperfect combustion of hydrocarbon fuel in engines. In the combustion process (perfect engines i.e., all the constituents of the fuel are burned with sufficient oxygen to completion during combustion) oxygen in the air would convert all the hydrogen in the fuel to water, and the entire carbon to carbon dioxide while nitrogen remains inert [13]. In reality, the combustion process cannot be perfect. Therefore, automotive engines emit several poisonous pollutants such as carbon monoxide, sulfur dioxide, toxic particulate matter (smoke), lead, and oxides of nitrogen [14]. The Perfectly operating motor vehicle engine would emit pollutants at tolerable levels [10]. However, in the real world of imperfect engines, improper fuel grades, lack of regular maintenance of vehicles and roads, physical aging of engines, and intensive use of vehicles, put constraints on perfect fuel consumption.

Though previous studies have dealt with problems of pollution from vehicle emissions in Nigerian road corridors ([15], [16], [12], and [17]), most of these studies focused on the intra-city highways and road corridors thus leaving a data gap on inter-city highways.

Ideally, when fuel is burned with the correct amount of air in a fuel-powered engine, the gases, which are left, are predominantly water vapor, carbon dioxide, and nitrogen, all of which are benign, although carbon dioxide is a greenhouse

gas. This could be represented using methane fuel as illustrated in (1).

Deviations from this complete combustion led to the production of some unborn fuel, or components such as H_2 , CO, Volatile organic compounds (VOCs), and particulate matter [18].

Diesel engines and gasoline engines are similar since both are internal combustion engines, meaning they burn the fuel–air mixture within the cylinder [19]. Also, diesel engines and most petrol engines are reciprocating engines being driven by pistons moving laterally in two directions. Meanwhile, in a diesel engine, only air is compressed while fuel is then injected. Therefore, having a higher compression ratio (from 14:1 to 24: 1), which is a measure of how much the engine compresses the gases in the cylinder [20]. It is heavier than a gasoline engine of the same horsepower. It is only limited by the amount of fuel injected into the cylinder. However, in a gasoline engine, the air-fuel mixture is compressed in the cylinder. The compression ratio (which controls the compression temperature) is lower compared to diesel engines (less than 10:1 or 7:1). It is limited by air fuel entering the cylinder.

Gasoline-powered vehicles tend to be the main source of CO emission and contribute substantially to VOCs and NO_x emissions, but due to substantial improvements in emission control of new vehicles, their contribution to these pollutants is diminishing [21]. They emit only a modest amount of particulate matter (e.g., coarse particles (PM₁₀) and fine particles (PM_{2.5})) but ill-maintained or tampered with vehicles can emit much more. Diesel-powered vehicles, on the other hand, are substantial emitters of PM₁₀, PM_{2.5}, SO₂, and NO_x with little CO and VOCs [22].

Oxides of Nitrogen (NO_x) are produced by a mechanism different from that of CO and exhaust VOCs. Whereas the latter are either from atmospheric nitrogen or from fuel nitrogen (i.e., product of incomplete combustion), it is generated by reactions of nitrogen and oxygen, which occur at high temperature in the presence of residual oxygen [23]. The two major oxides of nitrogen emitted from combustion systems are nitric oxide, (NO) and nitrogen dioxide, (NO₂), and the three mechanisms of formation of NO are thermal NO (NO formed from high temperature (1200 °C) oxidation of nitrogen found in combustion air i.e. Zeldovich mechanism) as shown in equations 2- 4, prompt NO (NO formed by the fast reaction of hydrocarbon with molecular nitrogen in fuel-rich flame (Fenimore mechanism) which could be shown in equation 5-6, and fuel NO (NO formed from nitrogen compound chemically bound in the fuel. This could be shown in equation 7 [24]. Nitrogen is always present in the combustion chamber because air is about 80 percent nitrogen. Residual fuel containing organically bounded nitrogen contributes to over 50% of the total emission of NO_x. NO_x is affected by the air-fuel ratio (A/F) and by engine design factors that influence temperatures, such as compression ratio, spark timing, and cooling system performance [25]. Combustion chamber deposits generally are believed to have a modest insulating effect, thus, raising combustion temperature and increasing NO_x emissions slightly.

However, reducing peak temperature in the combustion chamber, reducing the gas residence time in high-temperature zone, and reducing the oxygen concentration in the chamber set the NO_x emissions under control [25].

Thermal NO

Prompt NO

Fuel NO

Carbon monoxide (CO) results from the incomplete combustion of fuel and the main factor influencing its production is the ratio of air to fuel (A/F) in the combustion chamber. If the air-fuel mixture is fuel-rich i.e., has insufficient air (O₂) to convert all fuel carbon to carbon dioxide (CO₂), the exhaust will contain a high level of CO [26].

Volatile organic compounds (VOCs), for a variety of reasons, manage to escape from the combustion chamber unburned. These VOCs emissions (Exhaust VOCs) consist primarily of unburned hydrocarbons, but partially burned oxygen-containing compounds such as aldehydes may also be present in small quantities. The quantity of exhaust VOCs emission is influenced by many factors, including engine design, operating temperature, air-fuel ratio (A/F), system deposits, the condition of the engine and its controls, and the performance of the catalytic converter. If the vehicle has some significant malfunction that inhibits proper ignition or combustion, like a bad spark plug, VOC emissions can be many times higher than expected. VOCs emission may result from gasoline vapor that is generated due to heating of the fuel as daily temperature variations and operation of the vehicle as well as leakage from the fuel system [26]. Sulfur present in the fuel becomes sulfur dioxide in the vehicle exhausts. Fuel engines are estimated to be the source of SO₂ emissions [26].

Airborne particulate matter includes dust, soot, smoke, and liquid droplet. Particulate matter is a complex mixture of organic and inorganic substances. They can be characterized by their physical attributes which include their transport, deposition, and chemical composition. Particulates exceeding 2.5 microns (μm) in aerodynamic diameter are referred to as coarse particles, while particles smaller than 2.5 micron PM_{2.5} are called fine particles. Particulates are commonly emitted into the air along highways from various human activities, some of which are vehicular exhausts, industrial emissions, and other anthropogenic sources. Particulate matter attributable to vehicle exhausts includes primary carbon

particles (mainly from diesel), secondary sulfate, and nitrate aerosols formed by the reaction of SO₂ and NO_x in the atmosphere and carbonaceous substances (graphite and soot) [27]. The gasoline fuel vehicles were the primary sources of airborne lead (Pb) when gasoline contains the antiknock additive tetraethyl lead. However, lead emissions decrease sharply over the years, as the lead content in leaded gasoline is phased down and as the sale of unleaded gasoline increases [28]. The production of fuel containing lead additives has been finally prohibited in Nigeria. However, elements such as nickel, copper, zinc, cadmium, and vanadium can also be emitted with sulfur from vehicles and these are all potentially toxic, even at quite low concentrations [29].

Pollutants from vehicles are toxic and the human tolerance to these substances is relatively low. They constitute hazards to a large fraction of the population who are kept near vehicular emission sources during their daily activities. In addition to human health impacts, some air pollutants pose a threat to vegetation and property/assets. These pollutants are also criteria air pollutants [30]. In Nigeria, the Federal Ministry of Environment, Housing, and Urban Development (FMEEnv.) regulates the concentration of pollutants in the atmosphere to which human, animal, and plants may be exposed without endangering health or welfare in the nation, thus, prescribes an Ambient Air Quality Standards for Nigeria. The details of pollutants from vehicle emissions and associated health effects are shown in Table 1. This paper presents the air pollutant concentrations and effects on air quality and impairment along inter-city highways.

TABLE I: POLLUTANTS FROM VEHICLE EMISSIONS AND ASSOCIATED HEALTH EFFECTS

Pollutants	Primary health effects
Nitrogen Oxides (NO _x)	Aggravation of respiratory illness among infants,
Carbon Monoxide (CO)	Causing headaches, Dizziness Reduced ability to think
Sulfur dioxide	Irritation of eyes, premature death, morbidity. Aggravation of respiratory disease among children (asthma, emphysema).
Lead	Impairment of brain function, nerve contraction, behavioral and hearing problems in children.
Particulate matter	Increase cough and chest discomfort. Reduced lung function, aggravation of respiratory diseases

II. MATERIALS AND METHODS

A. Sampling Sites

This study involved sampling ambient air for airborne TSP, SO₂, and NO_x at different locations along the Ife-Ibadan highway. The ambient air sampling was carried out in ten different chosen locations (S₁-S₁₀) along the highway from Toll-Gate Ile-Ife to Toll-Gate Ibadan with each location having two sampling points (one at each side of the road). The sampling points and locations were chosen as shown in Fig. 1 and 2. The selection of these sampling locations was based on several criteria including proximity to vehicular emissions and other anthropogenic sources and their importance as the center of human activities such as frying.

B. Sampling Period

Atmospheric conditions changes are more pronounced between wet and dry seasons in Nigeria. The persistence of

either of the season is influenced by the absolute fraction of time during an annual cycle that the line of the Inter-Tropical Convergence Zone (ITCZ) or the Inter-Tropical Discontinuity (ITD) is below or above its line of latitude [31]. The dry season (under the influence of the northeast trade winds, when the ITD is southward), on the average, starts around the middle of October and lasts until the middle of April of the following year, though more pronounced between mid-November and mid-February. Rains initiated by the predominance of southwest monsoon winds, dominate the remaining six months of the year when the ITD lies north. The dry season period is characterized, not only by the near absence of rain, but also by the transport of dust haze from the Sahara Desert [31]. Thus, in this research study, a two-season sampling period was adopted.

Fig. 1. Mapping of all the sampling points along Ife-Ibadan highway.

Fig. 2. Sampling locations along with Ife –Ibadan highway.

TABLE II: DESCRIPTIONS OF THE SAMPLING LOCATIONS

S/ N	Locations	Co-ordinates	Description of Locations	Possible Sources/or Activities
1	S ₁	N07°29.37, E004°29.34	Toll-Gate Ile-Ife	Soil entrainment, vehicular emission, metal works, and wood burning, vaporized oil from cooking, construction work (petrol station), open waste, and refuse burning.
2	S ₂	N07°29.60, E004°27.14	The point joining Ife-Ibadan highway to Ilesha road (Roundabout)	Soil entrainment, vehicular emission, metalwork, vaporized oil from cooking, construction work (university of technology structures), open refuse burning, wood and bush burning.
3	S ₃	N07°29.13, E004°24.60	The point joining Ife-Ibadan highway to Akinlalu-Ipetu (Akinlalu Junction)	Soil entrainment, vehicular emission, metalwork, construction work (bridge), fuel evaporation from petrol stations, waste burning, and wood-burning
4	S ₄	N07°28.02, E004°19.55	The point joining Ife-Ibadan highway to Gbonan-Osogbo road (Gbonan Junction)	Soil entrainment, vehicular emission, metalwork, vaporized oil from cooking, waste burning, and wood-burning
5	S ₅	N07°26.12, E004°15.51	Wasinmi	Soil entrainment, vehicular emission, metalwork, wood-burning, refuse decomposition, fuel evaporation from the petrol station, waste and refuse burning, vaporized oil from cooking, and household heating and cooking.
6	S ₆	N07°22.48, E004°11.02	The point joining Ife-Ibadan highway to Ikire-Iwo road (Ikire Junction)	Soil entrainment, vehicular emission, metalwork, wood-burning, residential houses, construction work (petrol station), oil and fuel burning, petrol station, refuse and waste burning, and sawmills.
7	S ₇	N07°21.16, E004°09.04	The point joining Ife-Ibadan highway to Ikoyi (Ikoyi Junction)	Vehicular emission sawmills residual houses at some distance from the junction, wood-burning, soil entrainment, and mechanics workshop.
8	S ₈	N07°21.41, E004°07.05	Asejire bottling company	Nigeria Bottling Company, soil entrainment, vehicular emission, wood-burning, heavy oil combustion from plants, and refuse burning.
9	S ₉	N07°22.29, E004°02.52	Egbeda	Mechanic and vulcanize shops, soil entrainment, vehicular emission, wood-burning, waste and refuse burning, oil vaporized from cooking, petrol station, and residential houses.
10	S ₁₀	N07°22.35, E004°02.12	Toll-Gate Ibadan	Soil entrainment, vehicular emission, metalwork, wood burning, and oil vaporization from cooking, mechanic and vulcanize workshop, refuse and waste burning.

C. Sampling Procedures

A low volume air sampler was used to suck ambient air through prepared absorbents for each of SO₂, NO_x, and a weighted sampling filter (Whatman Cellulose Filter paper of diameter 2.54 cm) for TSP. A Flow Meter graduated in liters of air per minute was employed to verify a stable and accurately measured continuous flow rate of air during the sampling period. The sampling train also includes a Filter Holder, which is a small and cylindrical metallic tube with an outlet for air to which plastic tubing is connected. It holds the

sampling filter at an elevated height of about 1.6 m above the ground. The sampling filter type used was No 41 Whatman cellulose filter paper, 2.54 cm in diameter, already weighed in the laboratory and encased in an airtight polyester bag. The Plastic Tubing is about one meter in length and 1.0 cm in diameter. It serves to join the filter holder to the main unit, thus transferring suction pressure from the unit through the filter holder. Retort stand holds and elevates the filter at the desired height of 1.6 m. At each location, the traffic volume was determined by counting manually the number of

cars/buses, motorcycles, and Lorries that passed within each sampling period. The traffic density (Number of vehicles per hour) was also determined by dividing total traffic volume by the corresponding sampling time for each specific pollutant.

NO_x was sampled at all the locations using the Griess-Saltzman method. In this method, a metered volume of air was pumped through two fritted bubblers connected, each containing 10 ml of the prepared absorbent for 30 minutes [32]-[34]. The air average flow rate was taken. All the samples were kept inside dark brown sampling bottles for analysis. The absorbance of all the samples was determined at 420 nm wavelength using a UNICAM UVI UV-Visible Spectrometer available at the Central Laboratory, Obafemi Awolowo University, Ile-Ife, Nigeria. Then, the concentration of nitrogen dioxide in each sample was calculated using WHO [33] method (equation (8) [33]).

$$NO_{2conc.} = \frac{(A)(Y)(46.0)}{(S)(V)(69.0)(0.74)} = \frac{(0.901)(A)(Y)}{(S)(V)} \quad (8)$$

where, A = sum of absorbance (corrected for reagent blank) for pair of bubblers, Y = volume of absorbing reagent contained in one bubbler (10 ml), S = slope of NaNO₂ calibrating curve (0.7 absorbance per µg/ml), V = standard volume of air sampled. (0.1 m³), 46.0 = molecular weight of nitrogen dioxide, 69.0 = molecular weight of sodium nitrite, 0.7 = empirical factor.

The absorbent used for sampling for SO₂ in this study was prepared by diluting 2 ml of H₂O₂ containing 30 % w/v in distilled water to 1 Liter to have a hydrogen peroxide solution containing 0.06 % w/v in distilled water. This calculation is shown in equation 9. The 0.06 % w/v H₂O₂ was chosen to avoid the interference of NH₃ and to allow an absorbent that will have a low blank for NH₃. Then, 4.2 ml of 0.01NaOH was added to the 950 ml of the remaining absorbent. The hydrogen peroxide solution produced grey color when tested with indicator solution (0.06 g bromoresol green and 0.04 g methyl red in 100 ml of methanol) [33].

$$C_1 \times V_1 = C_2 \times V_2 \quad (9)$$

where C_1 is the amount of H₂O₂ in the initial solution (30% w/v), V_1 is the amount of the initial solution to be diluted to have 0.06 % H₂O₂, C_2 is the amount of H₂O₂ in the diluted solution (0.06 %), V_2 is the final volume of diluted H₂O₂ solution(1000 ml).

In this method, a metered volume of air was pumped through a fritted bubbler, which contained 50 ml of the absorbent for 2 hours [33], [34]. The average flow rate during sampling was determined. All the samples were kept inside the dark brown sampling bottles for analysis.

The concentration of the SO₂ in the air sampled was determined at the Central Laboratory, Obafemi Awolowo University, Ile-Ife, Nigeria, using a U.V method (Alpha 4, Chem. Tech Analytical 4200) also called Coulometric method [35]. In this method, 4 ml of each sample was acidified by adding 0.5 ml of concentrated hydrogen chloride, followed by the addition of 0.5 g of barium chloride. The solution was shaken vigorously until the chloride dissolved

and left for 12 minutes. Then, the turbidity of each sample was read at wavelength 420.0 nm. The concentration of SO₂ ppm was calculated from equation 3.5 as:

$$SO_{2conc} = ABS \times 4.4843 \times 10^{-3} \times 2 \times 10^4 \quad (10)$$

where 4.5×10^{-3} = constant of the standard curve plotted;
2 = mole ratio of SO₂: ABS is the measured absorbance;
10⁴ is the conversion factor from % to ppm.
Then to microgram per cubic meter using (11) [36]:

$$\frac{\mu g}{m^3} = \frac{ppm \times MW}{24.5} \times 10^3 \quad (11)$$

where MW = molecular weight of sulfur dioxide

TSP was measured using the Gravimetric method. The Whatman-41 cellulose filter paper of size 2.5 cm in diameter was specifically chosen for this air sampling study. This is because it has the lowest background concentration of the elements [37]. It is available and relatively cheap. The filter papers were acclimatized or equilibrated in desiccators for 24 hours after which their initial weights were determined. At each site, the sampler was loaded with a weighed filter paper and allowed to sample for four hours [38]-[40].

The loaded filters were re-weighed using METTER TOLEDO AB54 to determine the final weight after sampling. A blank filter was similarly handled, and filters were kept in separate polythene bags for later analysis. The concentration of the TSP present in the ambient air sampled along the Ife-Ibadan highway was calculated from (12).

$$TSP = \frac{\Delta W_p}{\Delta V_{air}} = \frac{W_f - W_i}{V_T} \times 10^6 \quad (12)$$

where, TSP is the Total Suspended Particular Matters concentration (µg/m³), W_f = Final weight of the loaded filter (g), W_i = Initial weight of the filter (g), V_T = Total volume of air sampled (i.e. the product of average flow rate and sampling time (t)). 10⁶ = conversion factor [41].

III. RESULTS AND DISCUSSIONS

Table III summarizes the average concentration of NO_x measured in ambient air at ten different locations along the Ife-Ibadan highway during wet and dry seasons, respectively. The concentration ranges from 9.9 µg/m³ to 33.8 µg/m³ and 16.7 µg/m³ to 35.4 µg/m³ during wet and dry seasons respectively which is generally below the applicable Nigerian ambient air quality standard limits of 75.0 µg/m³-113 µg/m³ as required [35] and the guideline of 200 µg/m³ set by the World Health Organization [41] during both seasons. The annual cycle mean values of NO_x concentration and traffic density are 28.7 µg/m³ and 375veh./hr, respectively. A strong relationship exists between measured NO_x concentrations and traffic density for both wet and dry seasons.

The correlation coefficient of 0.5 and 0.9 respectively were reported for both wet and dry seasons, which indicate that vehicular exhausts probably contribute significantly to the concentration of NO_x present in the ambient air around each

location along the highway. The relatively strong correlation between the traffic density and the concentration of NO_x measured during the dry season as compared to the correlation value during the wet season could be attributed to the effect of precipitation of this gas in the ambient air by heavy rain which was experienced during sampling. Also, it could be an indication of additional contribution from sources such as vaporized oil from cooking and cooking with firewood which was very rampant during sampling.

The average concentration of SO_2 measured in the study area during the fieldwork is presented in Table IV for both wet and dry seasons, respectively. The concentration ranged

between $49.7 \mu\text{g}/\text{m}^3$ and $219 \mu\text{g}/\text{m}^3$ with the minimum at sampling location S_4 and maximum at location S_8 during the wet season and $89.1 \mu\text{g}/\text{m}^3$ and $225.4 \mu\text{g}/\text{m}^3$ with a minimum at sampling location S_3 and maximum still at location S_8 for the dry season. The average concentration of SO_2 in the ambient air at all the locations for both wet and dry seasons are below the limit range of $26\text{--}260 \mu\text{g}/\text{m}^3$ set by Nigeria Federal Ministry of Environment, Housing and Urban Development [35], but above $20 \mu\text{g}/\text{m}^3$ guideline set by the World Health Organization [41]. The annual mean values of SO_2 concentration and traffic density are $151.0 \mu\text{g}/\text{m}^3$ and 271 veh./hr , respectively.

TABLE III: MEASURED AMBIENT AVERAGE CONCENTRATION OF OXIDES OF NITROGEN (NO_x) ALONG IFE-IBADAN HIGHWAY FOR BOTH WET AND DRY SEASON ($\mu\text{g}/\text{m}^3$)

Locations	Wet season				Dry Season			
	Total Traffic Volume	Traffic Density (Num. Veh./hr)	Av. Conc. $\pm$ S.D ($\mu\text{g}/\text{m}^3$)	Correlation Coeff.	Total Traffic Volume	Traffic Density (Num. Veh./hr)	Av. Conc. $\pm$ S.D ($\mu\text{g}/\text{m}^3$)	Correlation Coeff.
S_1	89	178	9.9 ± 3.2	0.5	117	234	19.0 ± 1.2	0.9
S_2	291	582	28.6 ± 1.4		220	440	29.0 ± 1.0	
S_3	127	254	20 ± 11.4		138	276	25.7 ± 8.1	
S_4	220	440	17 ± 3.9		204	408	18.9 ± 2.8	
S_5	196	392	29.6 ± 7.5		264	528	33.4 ± 5.3	
S_6	106	212	26.2 ± 0.4		205	410	26.5 ± 0.34	
S_7	199	398	16 ± 1.3		112	224	16.7 ± 0.95	
S_8	201	402	21.1 ± 3.2		142	284	22.7 ± 2.3	
S_9	139	278	22.2 ± 3.6		200	400	23.9 ± 2.5	
S_{10}	260	520	33.8 ± 3.3		315	630	35.4 ± 2.3	
Mean	183	366	22.4 ± 3.9		192	383	35.1 ± 3.9	

TABLE IV: MEASURED AMBIENT AVERAGE CONCENTRATION OF SULPHUR DIOXIDE (SO_2) ALONG IFE-IBADAN HIGHWAY FOR BOTH WET AND DRY SEASON ($\mu\text{g}/\text{m}^3$)

Locations	Wet season				Dry Season			
	Total Traffic Volume	Traffic Density (Num. Veh./hr)	Av. Conc. $\pm$ S.D ($\mu\text{g}/\text{m}^3$)	Correlation Coeff.	Total Traffic Volume	Traffic Density (Num. Veh./hr)	Av. Conc. $\pm$ S.D ($\mu\text{g}/\text{m}^3$)	Correlation Coeff.
S_1	410	205	52.4 ± 70.5	0.6	450	225	106.1 ± 1.8	0.6
S_2	1012	506	206.0 ± 121.5		1032	516	209.7 ± 47.7	
S_3	448	224	62.6 ± 177.7		350	175	89.1 ± 20.9	
S_4	423	211	49.7 ± 38.1		402	201	94.6 ± 16.6	
S_5	415	207	177.6 ± 11.4		520	260	201.8 ± 133.3	
S_6	462	231	162.3 ± 88.6		512	256	194.3 ± 107.8	
S_7	301	150	124.0 ± 27.1		360	180	100.2 ± 5.0	
S_8	550	275	219.8 ± 18.1		426	213	225.37 ± 57.9	
S_9	518	259	167 ± 92		732	366	155.8 ± 32.8	
S_{10}	677	338	207 ± 138.6		828	414	214.3 ± 43.5	
Mean	522	261	142.8 ± 78.4		561	281	159.1 ± 44.2	

TABLE V: MEASURED AMBIENT AVERAGE CONCENTRATION OF TOTAL SUSPENDED PARTICULATE (TSP) ALONG IFE-IBADAN HIGHWAY FOR BOTH WET AND DRY SEASON ($\mu\text{g}/\text{m}^3$)

Locations	Wet season				Dry Season			
	Total Traffic Volume	Traffic Density (Num. Veh./hr)	Av. Conc. $\pm$ S.D ($\mu\text{g}/\text{m}^3$)	Correlation Coeff.	Total Traffic Volume	Traffic Density (Num. Veh./hr)	Av. Conc. $\pm$ S.D ($\mu\text{g}/\text{m}^3$)	Correlation Coeff.
S_1	719	180	54.4 ± 25.6	0.7	807	202	87.2 ± 46.4	0.7
S_2	2188	547	90.6 ± 25.6		2064	516	103.4 ± 18.2	
S_3	809	202	54.4 ± 25.6		736	184	87.3 ± 46.6	
S_4	834	209	54.4 ± 25.6		782	196	85.9 ± 44.6	
S_5	828	207	90.58 ± 25.6		1013	253	147.5 ± 80.5	
S_6	697	174	54.4 ± 25.6		996	249	86.7 ± 45.7	
S_7	607	152	54.4 ± 25.6		708	177	79.3 ± 35.3	
S_8	1020	255	54.4 ± 25.6		817	204	89.4 ± 49.6	
S_9	1154	289	90.6 ± 25.6		1987	497	107.4 ± 23.8	
S_{10}	1769	443	$126.825.6$		2282	571	277.8 ± 213.5	
Mean								

The strong correlation between the measured average SO_2 concentration and traffic density for both seasons with $r = 0.6$ Suggests a high influence of vehicular exhausts on the SO_2 concentration along the highway.

The mean concentrations of TSP in the ambient air measured during the wet season along the highway are presented in Table V. The mean concentrations for all the ten locations are below the Nigerian recommended ambient air

quality standard of $250 \mu\text{g}/\text{m}^3$ [35] and range $150\text{--}230 \mu\text{g}/\text{m}^3$ World Health Organization [41]. All the sampling locations are situated at the outskirts of major towns and the highway is tarred thus reducing the propensity of dust remobilization and re-suspension. The average concentrations of TSP present in the ambient air during the season at all these locations ranged from 54.3 ± 25.6 – $126.8 \pm 25.6 \mu\text{g}/\text{m}^3$ with a significant correlation existing with traffic density ($r = 0.7$). Meanwhile, a similar situation was observed during the dry season, except at location S₁₀. However, the correlation with the traffic density was reported to be 0.7. These suggest that particulate matter in the air could be traced to vehicular exhausts and other vehicles related sources.

IV. CONCLUSION

The NO_x concentration measured in the ambient air along Ife-Ibadan highway ranges between 9.9 ± 3.2 and $33.8 \pm 3.3 \mu\text{g}/\text{m}^3$ during the wet season and 19.0 ± 1.2 and $35.4 \pm 2.3 \mu\text{g}/\text{m}^3$ during the dry season. The sulfur dioxide concentration in the ambient air also ranges between 49.7 ± 38.1 and $219 \pm 18.1 \mu\text{g}/\text{m}^3$, and 89.1 ± 20.9 and $225.4 \pm 57.9 \mu\text{g}/\text{m}^3$ during both wet and dry seasons. TSP concentration measured during both wet and dry seasons ranges between 54.4 ± 25.6 and $126.8 \pm 25.6 \mu\text{g}/\text{m}^3$ and 85.9 ± 44.6 and $277.8 \pm 213.5 \mu\text{g}/\text{m}^3$, respectively. The average correlations NO_x, SO₂, and TSP measured during wet and dry seasons and the traffic density were 0.7, 0.6 and 0.7, respectively. It could be concluded from this study that the emission of air pollutants is strongly attributed to vehicular activities along the Ife-Ibadan highway in Nigeria.

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