Effects of Vehicular Emissions on Human Health

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***Abstract*—The study investigates the concentrations of CO, NO_2, SO_2, CO_2 and HC arising mainly from the activities of motor vehicles, on the ambient air quality of selected sites in the Lagos metropolis and the locations of Oshodi, Ojota, Yaba and Lekki. The final location (Lekki) was used as a control.**

Results from dry season vehicular emission monitoring indicate that the average CO concentration at the Oshodi site peaked at 29.04 ppm. The site also recorded the highest concentrations for NO_2, SO_2, CO_2 and HC at 0.042ppm, 0.040 ppm, 370.92 ppm and 0.030 ppm respectively. In the wet season, Oshodi also recorded highest CO concentrations at 18.72 ppm. NO_2 was highest at 0.03 ppm in Yaba and Ojota. Both Oshodi and Ojota areas recorded the highest SO_2 concentration at 0.032 ppm. Oshodi recorded the highest concentrations for both CO_2 and HC at 370.92 ppm and 0.028 ppm respectively.

***Index Terms*—Vehicular emissions, health effects, survey, lagos.**

I. INTRODUCTION

Smog caused by air pollutants has a significant adverse impact on the health of Nigerians, the Nigerian economy, and the environment [1]. Smog is a noxious mixture of gases and particles, primarily ground-level ozone (O_3) and particulate matter [1]. It has been identified as a contributing factor in thousands of premature deaths across the world each year, as well as in increased hospital and doctor visits and hundreds of thousands of lost days at work and school. Environmental problems attributed to smog include effects on vegetation, buildings and visibility [1]. The operation of motor vehicles is a major source of smog-forming air pollutants. Some of these gases such as CO_2 are called Green House Gases (GHGs). These same gases occur naturally in the atmosphere, and have the capacity to trap heat emitted from the earth's surface, insulating and warming the planet, by a process called the Greenhouse Effect. Without this process (thermal blanketing of the natural greenhouse effect), the earth's climate would be too cold for most living organisms to survive [2].

The greenhouse effect has naturally warmed the earth for over 4 billion years. The GHGs in their normal concentrations in the atmosphere sustain life on earth, but a very big challenge emerges when there is an increase in their concentrations.

Researchers are growing increasingly concerned that human activities, particularly in the transport sector, are modifying this natural process, raising the concentrations of these gases to toxic levels, with potentially dangerous environmental and human health consequences.

Air pollution causes severe environmental hazards such as acid rain, global warming, depletion of the ozone layer, and are leading causes of climate change.

There is a great concern about the climatic problems being faced all over the world such as excessive flooding, droughts etc. Nigeria is already a victim of these environmental disasters. Other environmental hazards include soil pollution, leading to poor agricultural yield, and water pollution that causes aquatic death [2]. In Nigeria, majority of the vehicles used are poorly maintained and are second hand ("tokunbo") with poor engine performance. These categories of vehicles are known to emit huge quantities of harmful air pollutants e.g., (GHGs) in the atmosphere, causing severe air pollution with their attendant environmental and health consequences.

Studies and aerial views of Nigeria have shown that our atmosphere is highly polluted. This is very evident in the number of smoky vehicles using our roads on daily basis, causing visibility problems and sometimes accidents.

In developing countries, enormous environmental problems due to inadequate environmental planning and monitoring have emanated. This situation is being further complicated in many areas of certain developing countries by environmental problems, which are often associated with development (Oluwande, 1977). In such places, environmental problems, like, air pollution in urban centers due to increased volume of traffic on ill-planned roads, are aggravating the already serious problems caused by poor, absent or inadequate sanitary facilities [2], [3].

In most developing countries of the world vehicular growth has not been slowed by environmental regulating authorities causing increased levels of pollution [4]. Traffic emissions contribute about 50-80% of NO_2 and CO concentration in developing countries [5], [6]. This situation is alarming and is caused by the poor economic disposition of developing countries. Poor vehicle maintenance and importation of old vehicles, which results in an automobile fleet dominated by a class of vehicles known as ''super emitters'', with high emission of harmful pollutants, has increased emission concentrations [7]. The increase in this traffic-related pollution is not based on the aforementioned factor only, but also on low quality fuel, poor traffic regulation, and lack of air quality implementation. These are clear indices of the high levels of traffic-related pollution in developing countries.

In Nigeria, as well as in other developing countries, which are not yet fully industrialized, majority of the air pollution problems result from automobile exhaust [8]. In the major towns of some developing countries, because of tropical nature of the climatic conditions, many activities are performed outdoors. People stay along the busy roads every

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day either to do their work or to sell their goods. Therefore, the ill effects on health due to air pollution resulting from automobile exhaust emissions is very serious indeed [8]. In Nigeria much attention is given to general industrial pollution and pollution in the oil industries, while little attention is paid to damage or pollution caused by mobile transportation sources of air pollution [9]-[11]. Pollution from mobile transportation is on the rise due to increase in per capita vehicle ownership, resulting in high congestion on Nigerian roads, increased concentration of pollutants in the air, and consequently, increased health risks for the human population. In addition, compared with the large volume and variety of studies carried out in the developed world, exposure studies carried out in Nigeria are relatively scarce. So as a first step in focusing attention on these problems, it is necessary to know the types of air pollutants present, along with the concentration levels of each type.

The current focus of Environmental Protection Agency (EPA) is to reduce the sulfur content from diesel fuels [12]. Effective 2007, EPA has mandated the use of 15 parts per million (PPM) of sulfur content in all diesel fuels. A variety of fuels and fuel blends have been proposed as alternatives to the existing fossil fuels to meet these strict emission and fuel standards. Several countries and private fleet authorities have begun testing various fuels blends and alternatives such as ethanol, compressed natural gas (CNG), hydrogen, biodiesel blends and ultra-low sulfur diesel (ULSD: sulfur content is 15ppm). Nigeria diesel sulphur content is currently at about 1330 parts per million as shown in Table I.

Very few studies have reported tail pipe emission comparisons for vehicles operating on biodiesel and ULSD. The major drawback in most of these studies has been the small size of the vehicle fleet considered and also the need to collect engine and emission data simultaneously to study the effect of engine parameters on emissions [13].

TABLE I: NIGERIAN DIESEL OIL SPECIFICATIONS

Qualities	**Unit**	**Requirement**	**Actual from Nigerian Refineries**
Sulphur	Ppm	3000	1330
Density	Kg/m3 (Maximum)	820 - 870	871
Cetane number	Minimum	47	50
Total Acid Number	Mg KOH/g (maximum)	0.5	
Final Boiling Point	℃ (max)	385	358

II. AIR POLLUTION

The primary pollutants such as particulates, hydrocarbons, carbon monoxide, nitrogen oxides and sulphur oxides, account for more than 90 percent of air pollution problems in the developed countries [14]. An assessment of the potential for increased vehicular pollution requires some basic information relating to traffic volume and the intensity of pollutant emissions on road corridors. With respect to traffic volume, the critical factors will include population size, fuel consumption per capita and the proportion of the population that owns motor vehicles as well as annual average distances covered [15].

A. Air Pollutants and Their Effects

Air pollution is a basic problem in today's world. Exposure to ambient air pollution has been linked to a number of different health outcomes, starting from modest transient changes in the respiratory tract and impaired pulmonary function, continuing to restricted activity/reduced performance, emergency room visits and hospital admission and mortality. There is also increasing evidence of adverse effects of air pollution not only on the respiratory system, but also on the cardiovascular system [16]. Physical damage functions relating health (mortality and morbidity) to air pollution levels have been estimated over a number of years in different countries. Although the net effect of pollutants on health is unclear, the Committee of the Medical Effects of Air Pollution (COMEAP), formed by the United Kingdom (U.K.) government has found the strongest link between health and pollution to be for particulates (PM_{10}), sulphur dioxide (SO_2) and Ozone (O_3) [17]. Cars, trucks, motorcycles, scooters and buses emit significant quantities of carbon monoxide, hydrocarbons, nitrogen oxides and fine particles. Where leaded gasoline is used, vehicles are also a significant source of lead in urban air. The adverse health and environmental consequences resulting from these pollutants are summarized in some of the sections that follow:

1) Particulate matter:
   Particulate matter is a main emission product of automobiles, especially diesel engine vehicles. Vehicular emissions generate two types of particulate matter, the fine particulate matter ($PM_{2.5}$) and standard particulate (PM_{10}). $PM_{2.5}$ consist of particles less than one-tenth the diameter of human hair and poses the most serious threat to human health [18]. The size of particle is directly linked to their potential for causing health problems. Particles that are ten micrometer (PM_{10}) in diameter generally pass through the nose into the lungs. Once inhaled these particles can affect the health and lungs and cause serious health effects. Particles less than 2.5 micrometers in diameter are termed "fine particle or $PM_{2.5}$ as mentioned before, they are so small that they can be inhaled deeper into the lungs than the PM_{10}, hence causing more health problems than PM_{10} [19].
2) Carbon monoxide:
   Motor vehicles significantly contribute to ambient carbon monoxide (CO) concentrations. Although CO emissions from motor vehicles have declined through emission control technologies and regulations in many countries, motor vehicles remain the primary source of this pollutant in most locations. 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 [20].
3) Oxides of nitrogen
   NOx causes severe respiratory problems, especially in

children. When combined with water, it forms nitric acid and other toxic nitrates. NO_2 is a main component in the formation of ozone at ground level. The gas irritates the lungs and has been known to lower immune system effectiveness [21].

4) Sulfur dioxide
Although motor vehicles emit sulfur dioxide (SO_2) and other sulfur-containing compounds, traffic sources typically make only small contributions to ambient concentrations. The gas irritates airways and eyes and is known to cause longer-term heart diseases, other cardiovascular ailments, and bronchitis. It also readily causes shortness of breath and coughing amongst asthma sufferers. SO_2 is also a major contributor to acid rain, which damages the environment and upsets the ecosystem [21].

5) Ozone:
Ozone is not directly emitted from motor vehicles, and O_3 measurements are not typically collected for near road applications. O_3 measurements may be useful under select circumstances as support for health studies investigating the role of O_3 and other co-pollutants on adversely affecting public health given the potentially lower concentrations of this pollutant relative to other pollutants in this microenvironment [20].

6) Lead:
Before the introduction of unleaded gasoline in most countries of the world, motor vehicle lead (Pb) emissions were a major public health concern. While Pb is no longer added to gasoline in many countries, motor vehicle fuels still contain trace amounts of Pb from crude oil.

7) Volatile Organic Compounds:
Volatile Organic Compounds (VOCs) are essentially fuel which was unburnt during combustion process or which has escaped into the atmosphere through fuel evaporation. VOCs can often be divided into separate categories of methane (CH_4) and non-methane (NMVOCs). Vehicles are also a major source of atmospheric hydrocarbons. Stationary sources of hydrocarbons include petrochemical manufacture, oil refining, incomplete incineration, paint manufacture and use, and dry cleaning [14]. Methane is a greenhouse gas has 1500 times the global warming potential of CO_2 and has prominent role in global warming even though majority of gaseous pollutants are inhaled and may affect respiratory system. They can also induce hematological (blood-related) problems [20].

8) Carbon dioxide:
Carbon dioxide, methane, and gas molecules that have similar structures may influence the global climate by internal molecular vibration and rotation which cause these molecules to absorb infrared radiation. When these gases form part of the atmosphere, they absorb some of the heat that the earth normally radiates into space [22]. Carbon dioxide is an atmospheric "greenhouse gas".

B. *EPA Research & Regulations*

In 1990, the Clean Air Act Amendment (CAA) introduced fuel along with engine technology, to be a potential source for the reducing toxic emissions. The increased concern among people with the increase of toxic air emissions has made many countries pass stringent rules. The US EPA in 2006 introduced a regulation requiring all on-road diesel vehicles to use ULSD. Law 11.097/2005 in Brazil similarly established minimum percentages to mix diesel and biodiesel. According to the 2008 Brazilian law, two percent biodiesel blending was mandatory, which increased to five percent beginning in 2003 (Brazilian Law 11.097/2005). The US EPA reduced the emission standard of sulfur content present in diesel and gasoline to 15 parts per million (ppm) since 2007. These stringent rules laid by the US EPA have created awareness and made a need to switch to cleaner burning fuels [29].

The state of Minnesota began blending two percent biodiesel into nearly all the state's diesel fuel in 2005 and came up with ULSD which had lubricating properties inferior to those of the previously used number 2 diesel. A summary of U.S. air pollution control acts established by the EPA over recent years have been tabulated in Table II.

There are a few standards on the emissions that are laid down by the EPA known as the National Ambient Air Quality (NAAQS) for pollutants considered being harmful to public health and the environment. The Clean Air Act (CAA) which was amended in 1990 requires EPA to set these standards and has established two types of national air quality standards. Primary Standards are set to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

The EPA Office of Air Quality Planning and Standards (OAQPS) manages the National Ambient Air Quality Standards for six principal (criteria) air pollutants. The criteria pollutants are listed in Table III. Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb - 1 part in 1,000,000,000) by volume, milligrams per cubic meter of air (mg/m3), and micrograms per cubic meter of air (μg/m3).

Vehicle emissions significantly pollute air and require control [23]. With increasing concern for air toxics and climate modification caused by exhaust emissions, the need for tighter control increases in importance. There is a need for studies involving emission factors and impact. In recent years, there has been considerable research on vehicle emissions and hydrocarbon fumes [24]. Carbon monoxide causes blood clotting when it reacts with hemoglobin and reduces the supply of oxygen in the circulatory system. This is a common occurrence in urban centers with a high level of commercial activity [25]. The worst levels of pollution are seen in such urban areas that are densely populated and with a low standard of living [26], [27].

Among the most common, yet ignored vehicles on the roads are garbage trucks. Heavy-duty diesel-powered vehicles, including garbage trucks, make up only 7 percent of vehicles on the road, but produce 69 percent of on-road fine particulate pollution and 40 percent of the NOx emissions [27].

TABLE II: US GOVERNMENT AIR POLLUTION LEGISLATION

Year	Issue Addressed
1955	First Air Pollution Act, to address national environmental problem of air pollution
1963	First Clean Air Act, to strengthen and accelerate programs for the prevention and abatement of air pollution
1965	Motor Vehicle Air Pollution Control Act to establish standards for automobile emissions
1966	Expanded local air pollution control programs
1967	Air Quality Act, national emissions standards for stationary sources
1969	Extended research on low emission fuels and automobiles
1970	National Ambient Air Quality Standards, to protect public health and welfare, and regulate emissions of new source entering an area
1977	First attempt to prevent destruction of stratospheric ozone
1990	Emissions trading and reduction of sulfur using low-sulfur fuels as well as alternative fuels
1992	Energy Policy Act, to address energy efficiency and encourage fleets to use alternative fuels
1998	Energy Conservation Reauthorization Act, to allow agencies and alternative fuel providers to purchase alternative fuel vehicles
2001	The Highway Diesel Rule, effective from 2007, the sulfur content in diesel fuel to be reduced by 97%
2005	Energy Policy Act, federal tax credits for energy efficient products such as electric vehicles, ethanol, biodiesel

Source: (www.epa.gov)

TABLE III: NATIONAL AMBIENT AIR QUALITY STANDARDS (U.S. EPA)

	Primary Standards	Secondary Standards	
Pollutant	**Level**	**Averaging Time**	**Form**
Carbon Monoxide [76 FR 54294, Aug 31, 2011]	9 ppm (10 mg/m3)	8-hour	Only one exceeded per year
	35 ppm (40mg/m3)	1-hour	Only one exceeded per year
Lead [73 FR 66964, Nov 12, 2008]	0.15 μg/m3	Rolling 3-Month Average	Not to be exceeded
	1.5 μg/m3	Quarterly Average	Not to be exceeded
Nitrogen Dioxide [75 FR 6474, Feb 9, 2010] [61 FR 52852, Oct 8, 1996]	53 ppb	Annual (Arithmetic Average)	Annual mean
	100ppb	1-hours	98th percentile of 1 hour daily maximum concentrations averaged over 3 years
Particulate Matter (PM_{10})	150 μg/m3	24-hours	Only one exceeded per year on 3 years average
Particulate Matter ($PM_{2.5}$)	15.0 μg/m3	Annual (Arithmetic Average)	Annual mean averaged over 3 years
Dec 28, 2015	35μg/m3	24-hours	98th percentile averaged over 3 years
Ozone [73 FR 16436, Mar 27, 2008]	0.07 ppm (2008 std)	8-hours	Annual form highest daily maximum 8 hours concentration averaged on a 3 years
Sulfur Dioxide [75 FR 35520, Jun 22, 2010] [38 FR 25678, Sept 14, 1973]	0.5 ppm	3 hours	Only one exceeded per year
	75 ppb	1-hour	99th percentile of 1 hour daily maximum concentrations averaged over 3 years

Note: FR – Federal Register:
Format: FR-Volume, page number, date
Source: http://www.epa.gov/air/criteria.html)

Diesel engines are a major source of pollution, emitting particulate matter (soot), nitrogen oxides, which contribute to the production of ground-level ozone (smog), acid rain, hydrocarbons and air toxics. These emissions can damage plants, animals, crops, and water resources [27]. Emissions from diesel exhaust can lead to serious health conditions, such as asthma and allergies as shown in Table IV. They can also worsen heart and lung diseases, especially for vulnerable populations such as children and older individuals [27].

EPA estimates that every $1 spent on clean diesel projects produces up to $13 of public health benefits. Studies conducted in the past have established the fact that a huge percentage of pollutant emissions in ambient air are emitted by vehicles [12]. They have numerous effects on human health as well as on the environment. In fact, a study in the Journal of the American Medical Association cited that people who live in the most heavily polluted areas have a 12% higher risk of getting lung cancer than people in the least polluted areas.

TABLE IV: A SUMMARY OF HEALTH CONCERNS DUE TO DIFFERENT DIESEL POLLUTANTS

POLLUTANT	HEALTH ISSUE
Nitrogen dioxide	Lung irritation, respiratory illness, and premature death
Carbon Monoxide	Headaches and reduces mental alertness
Particulate matter	Increased respiratory disease, lung damage, cancer and premature death
Sulphur dioxide	Increase in existing heart disease, breathing difficulties and respiratory illness
Ozone	Breathing difficulties, respiratory infections and lung and tissue Damage

(Source: U.S. EPA)

III. METHODOLOGY

The method used for the analysis of vehicular emission in Lagos metropolis is survey.

A. Methods of Sampling and Samples

The research focused on congested cities in Lagos state, where heavy vehicular emissions are common. The sample locations are densely populated. They were observed both in the day and night. A common characteristic of these areas is the presence of a heavy flow of transportation and high industrial activities where the combustion of fossil fuel in internal combustion engines exists. The sample locations are Oshodi, Ojota and Yaba, while Lekki was used as a control location since it has low levels of pollution. In these areas, the concentration of pollutants such as carbon monoxide, sulphur oxides, nitrogen oxides, organic acids, and VOCs (obtained mostly from exhaust gases) in the atmosphere is high.

However, vehicular emissions account for more than 60% of the total pollutants emitted when compared to other sources.

In this study, the effects of emissions on the health of the people living in the sampled location and impacts were assessed:

The data obtained from the questionnaires were analyzed based on the information obtained from them. The questionnaire also sampled people's opinions on what they think should be done to reduce these emission levels.

B. Questionnaire

Questionnaires were administered in four cities of Lagos state: Oshodi, Ojota and Yaba. The fourth city, Lekki, was used as a control site, because Lekki is a relatively low-emission area.

Questionnaires were distributed on a total of 310 people to determine the effects of emissions on their health, particularly in congested areas of Oshodi where heavy vehicular emissions are common. Preliminary observations were done for 2 months in many areas before selecting the sampled areas. These are the areas where there are heavy transportation flows. A total of 100 respondents were carefully selected from each of the three locations, while 10 respondents were chosen from the control area totaling 310 questionnaires.

Questionnaires were administered to them over a period of 12 months. The selected respondents include, office workers, market women, street hawkers, drivers, conductors, traders and residents.

Those that had difficulty in responding to the questionnaires were assisted by the crew members. The questionnaires were analyzed based on the factors/symptoms that constitute health problems.

C. Procedure Related to Questionnaire Administration and Analysis

1) A pre-survey was accomplished by going to the field to understand what types of respondents would answer questionnaire, and estimate the population to determine sample size.
2) Based on (1), questionnaires are designed and a test-survey was distributed to refine the questions posed in the instrument and to determine its adequacy.
3) Based on the target number of respondents, the questionnaire was designed and administered to the respondents. A response rate of 100% was the target, since the questions were simple and enough not to consume too much of the respondents' time.
4) Based on the returned questionnaires, the analysis was accomplished.

IV. Results and Discussion

Tables V show the average traffic volume per hour in the monitored sites.

TABLE V: Average Traffic Volumes per Hour in Selected Points in Lagos State

Sampling Site	Average traffic volume per hour			
	Motorcycles/bicycles	Cars/buses	Trucks	Total
Yaba	3998 ±16	4126 ± 12	500 ±2	8624 ±30
Oshodi	4106 ±19	5312 ± 14	1001 ±1	10419 ±34
Ojota	3919 ±20	5128 ± 18	1125 ±1	10172 ±39
Lekki	884 ±8	3913 ± 10	196 ±4	4993 ±22

For clarity of understanding of the data generated from the field survey and the statistical analysis carried out on the data, the study preceded as follows:

1) Compared pollutant concentrations at all the sampled points and during various times of the day.
2) Compared data with the Federal Ministry of Environment Standards
3) Compared air quality data with the air quality index (AQI) of the United States.
4) Compared data at traffic points with those at the background site, as well as at the control location.
5) Performed predictive modeling of pollutant concentration with increasing distance from source of emission.

A. Comparison of Pollutants Concentration at Sampled Points for Dry and Wet Season

1) Dry season

A summary of the average data obtained during the dry season for morning, afternoon and evening hours are presented in Tables VI through VIII.

It is shown from the results in Tables V to VII that the average concentration of CO at the traffic spots was highest at Oshodi for morning, afternoon and evening hours (30.67, 30.77 and 33.67ppm respectively), and least at Lekki during the same periods (11.25, 11.95 and 15.30 ppm respectively). The same was the case for all other pollutants (NO_2, SO_2, and HC) for both morning and evening hours, with the highest concentrations recorded at Oshodi and lowest at Lekki.

The highest concentration recorded at Oshodi in the morning hours coincides with when workers and traders usually go to work and business. With Oshodi location being at the major intersection between the roads to various parts of Lagos, vehicles are at "idle speed" due to the slow pace of traffic and they tend to emit more pollutants. The same is true for the evening hours.

All the sites, however, experience higher traffic in the afternoon, therefore most emissions in the afternoon are higher. Business is usually at its peak at this time of day and more vehicular movement is experienced in and around the sites. Ojota and Yaba are areas that both experience high traffic during the morning hours. Afternoon and evening hours also have high pollutant concentrations. These areas also have high residential populations in the Lagos metropolis.

TABLE VI: AVERAGE CONCENTRATION OF POLLUTANTS DURING THE MORNING HOURS IN DRY SEASON

AIR Quality Parameter						Meterology		
Location	**CO (ppm)**	**NO_2 (ppm)**	**SO_2 (ppm)**	**CO_2 (ppm)**	**HC (ppm)**	**Air Temp. (^oC)**	**Relative Humidity (%)**	**Wind Speed (km/h)**
Yaba	43.80	0.039	0.099	338.00	0.037	28.0	79.8	13
Ojota	44.73	0.038	0.099	337.33	0.027	28.1	77.8	14
Oshodi	50.67	0.043	0.094	334.67	0.039	28.4	79.8	13
Lekki	21.25	0.028	0.044	373.00	0.004	27.3	73.2	15

TABLE VII: AVERAGE CONCENTRATION OF POLLUTANTS DURING THE AFTERNOON HOURS IN DRY SEASON

AIR Quality Parameter						Meterology		
Location	**CO (ppm)**	**NO_2 (ppm)**	**SO_2 (ppm)**	**CO_2 (ppm)**	**HC (ppm)**	**Air Temp. (^oC)**	**Relative Humidity (%)**	**Wind Speed (km/h)**
Yaba	47.30	0.042	0.089	350.00	0.028	29.0	60.8	15
Ojota	49.53	0.043	0.089	355.67	0.026	29.1	69.8	14
Oshodi	50.77	0.039	0.088	340.10	0.012	31.4	69.8	13
Lekki	21.95	0.029	0.047	397.00	0.008	28.3	73.2	14

Lekki experiences the lowest pollution in the metropolis while Oshodi, Ojota and Yaba in descending order experience the most vehicular traffic. A careful assessment of the pollutant concentration recorded at various days of the week indicates that although Saturday is a weekend day and public civil servants do not go to work, emission concentrations value was quite high.

Sunday, however recorded the least traffic, and the least pollutant concentration because most places of work and businesses were closed.

2) Wet Season

A summary of the results obtained during the wet season are presented in Tables IX through XI.

The results indicate that the CO concentrations had the highest recorded values at Oshodi and Ojota. The highest concentration recorded during the morning hours was 19.90ppm at Oshodi, 15.33ppm at Ojota, and 14.93ppm at Yaba. Lekki recorded the lowest CO concentrations of 7.3ppm during the morning hours.

A similar observation was noticed during the afternoon and evening hours where CO concentrations peaked at 20.27ppm and 24.0ppm for both afternoon and evening at Oshodi, while the Ojota recorded concentrations of 19.37ppm and 22.27ppm in the afternoon and evening hours respectively. It is interesting to note that the peak values recorded for both Oshodi and Ojota were recorded on a Saturday.

This is due to the fact that commercial and business activities normally reach its peak in the afternoon, and with traders and buyers wanting to return home after the day's business, therefore traffic and pollutant concentration levels will rise. Yaba equally recorded a high CO concentration of 20.87ppm in the evening. CO concentration is highest during week days at Oshodi due to the high level of commercial activities and the large presence of buses which emit a high level of air pollutants.

TABLE VIII: AVERAGE CONCENTRATION OF POLLUTANTS DURING THE EVENING HOURS IN DRY SEASON

AIR Quality Parameter						Meterology		
Location	**CO (ppm)**	**NO_2 (ppm)**	**SO_2 (ppm)**	**CO_2 (ppm)**	**HC (ppm)**	**Air Temp. (^oC)**	**Relative Humidity (%)**	**Wind Speed (km/h)**
Yaba	44.60	0.039	0.080	330.00	0.024	31.0	92.8	13
Ojota	49.50	0.044	0.080	349.67	0.033	29.1	99.8	14
Oshodi	53.67	0.047	0.082	340.00	0.042	28.4	99.8	13
Lekki	25.30	0.025	0.048	380.50	0.015	28.2	83.2	14

Observation of the Nitrogen dioxide (NO_2) concentration indicates that even though formation of NO_2 takes place at high temperatures, it could not be clearly established whether a high temperature was actually responsible for the results obtained from the field. Because, even where ambient temperature was measured as low, it was discovered that NO_2 concentrations were higher when compared to high ambient temperatures. However, when the results were compared with David and Frederikse (1997), taken at 15°C, it was observed that the results recorded were higher (between 0.03ppm and 0.04ppm) as compared to David and Frederikse (1997) which were recorded at 0.02ppm and 15°C [28]. A comparison of the general assessment of the air quality situation at the sites for both seasons indicates that the pollutant concentrations during the dry season was higher compared to the wet season concentration.

TABLE IX: AVERAGE CONCENTRATION OF POLLUTANTS DURING THE MORNING HOURS IN WET SEASON

AIR Quality Parameter						Meterology		
Location	**CO (ppm)**	**NO_2 (ppm)**	**SO_2 (ppm)**	**CO_2 (ppm)**	**HC (ppm)**	**Air Temp. (°C)**	**Relative Humidity (%)**	**Wind Speed (km/h)**
Yaba	34.93	0.025	0.084	353.00	0.023	28.97	99.50	13
Ojota	35.33	0.025	0.086	350.67	0.024	28.23	90.87	13
Oshodi	39.90	0.030	0.083	351.67	0.024	29.10	92.30	13
Lekki	17.53	0.026	0.045	373.67	0.019	27.93	96.50	13

TABLE X: AVERAGE CONCENTRATION OF POLLUTANTS DURING THE AFTERNOON HOURS IN WET SEASON

AIR Quality Parameter						Meterology		
Location	**CO (ppm)**	**NO_2 (ppm)**	**SO_2 (ppm)**	**CO_2 (ppm)**	**HC (ppm)**	**Air Temp. (°C)**	**Relative Humidity (%)**	**Wind Speed (km/h)**
Yaba	37.10	0.028	0.089	333.33	0.024	29.97	85.40	13
Ojota	39.37	0.025	0.088	351.67	0.018	29.77	84.97	14
Oshodi	40.27	0.027	0.080	352.67	0.023	29.2	88.57	14
Lekki	16.78	0.020	0.041	362.33	0.014	28.50	81.07	13

TABLE XI: AVERAGE CONCENTRATION OF POLLUTANTS DURING THE EVENING HOURS IN WET SEASON

AIR Quality Parameter						Meterology		
Location	**CO (ppm)**	**NO_2 (ppm)**	**SO_2 (ppm)**	**CO_2 (ppm)**	**HC (ppm)**	**Air Temp. (°C)**	**Relative Humidity (%)**	**Wind Speed (km/h)**
Yaba	40.87	0.032	0.084	354.67	0.030	29.90	86.17	13
Ojota	42.27	0.032	0.084	360.00	0.028	28.73	85.03	14
Oshodi	44.00	0.031	0.084	352.67	0.025	28.47	86.33	13
Lekki	21.33	0.025	0.044	373.00	0.023	28.97	89.5	15

B. Comparison of Air Quality Data (Dry and Wet Season) at Traffic Sites

1) Dry season

Results of the comparison of air quality data recorded at the test sites during the dry and wet seasons are presented in Fig. 1 through Fig. 5. The air quality data for Lagos metropolis was compared with National Ambient Air Quality Standard (Table III) as shown in the Fig. 1 through Fig. 5.

Fig. 1 shows that the CO level in all the sites exceeds the 1hour average of 35ppm. This occurs at each site except Lekki metropolis. The same is observed for the 8hour average of 9ppm. Most of the vehicles at each of the sites are not well maintained and this may have contributed to incomplete combustion producing high concentrations of CO. The people live in these areas and carry out their business activities are constantly exposed to these concentrations levels emitted at ground level (i.e. human breathing level) and are subject to health impacts. The short-term limit of 35 ppm based on one-hour average is meant to prevent the immediate health effects that may occur from exposure to CO for a short period of time (e.g. one hour). Though, even at 9 ppm, a short-term effect may not be experienced but it is important to know that the effect of CO is not only related to the level and duration of exposure but also on an individual's health status. An individual's exposure to a CO level as recorded at the sites could cause headache, dizziness and exertion. It may even be more severe in individuals with health conditions such as asthma.

Similarly, a comparison of the nitrogen dioxide (NO2) concentration reveals that the 0.01 ppm limit for a 1hour average is being exceeded at each of the sites. For the annual averaging time of 0.053ppm, however, the four sites were well within the US EPA limits as shown in Fig. 2.

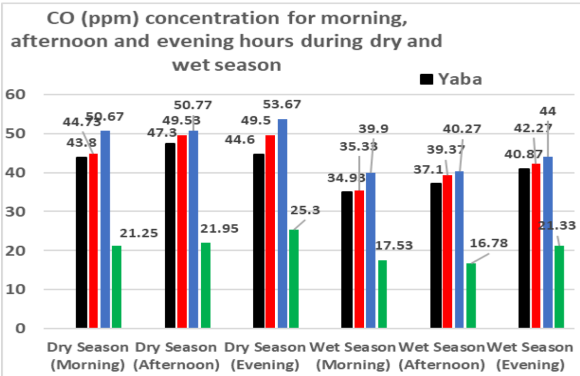

Fig. 1. CO concentration for morning, afternoon and evening hours during dry and wet season.

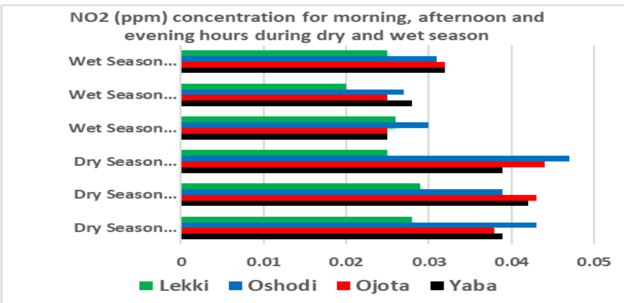

Fig. 2. NO_2 concentration for morning, afternoon and evening hours during dry and wet season.

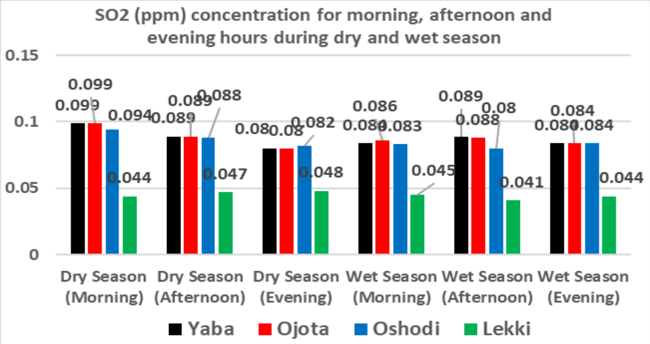

Fig. 3. SO_2 concentration for morning, afternoon and evening hours during dry and wet season.

Fig. 3 shows comparison for SO_2. The concentration level fell short of the 0.075ppm for an averaging time of 1 hour except the Lekki site which recorded lower limits all days including 0.5 ppm limits for 3 hours' duration.

The sites were all within the limits for VOC concentration. This is clearly seen in Fig. 4. Except at crude oil drilling sites or in the event of an oil spill resulting from an accident, it may be difficult for VOC concentrations to exceed the limit of 0.6ppm.

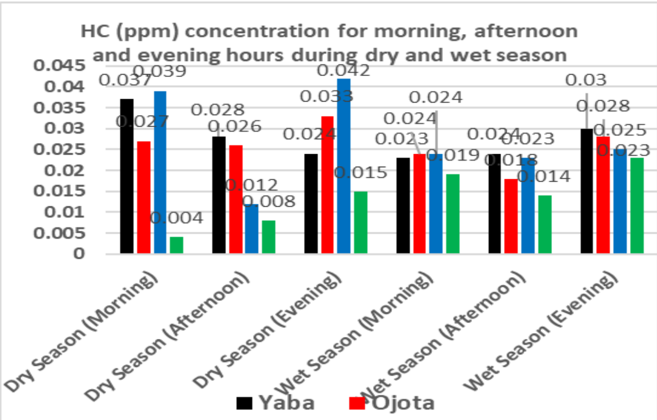

Fig. 4. The VOCs concentration for morning, afternoon and evening hours during dry and wet season.

Fig. 5 shows the CO_2 level for the sites. Low level emissions were recorded at Oshodi, while high emission levels were recorded at Lekki. This could be due to the fact that most of the trucks and buses operating in the Oshodi area are not well maintained which could lead to incomplete combustion, producing high levels of carbon monoxide and low levels of carbon dioxide. Most of the vehicles in Lekki metropolis are cars that are well maintained, lead to complete combustion that producing high CO_2 and low CO.

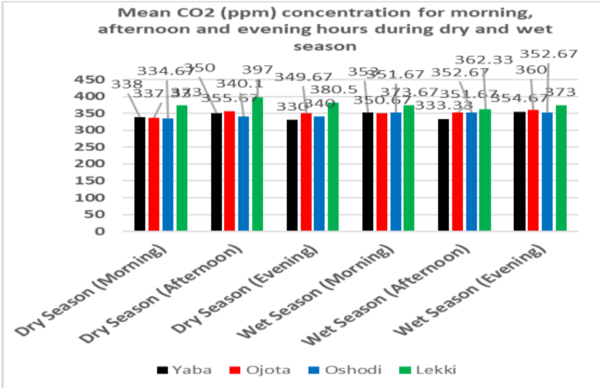

Fig. 5. CO_2 concentration for morning, afternoon and evening hours during dry and wet season.

There are however no national ambient air quality standards for CO_2 concentration in the atmosphere, but the literature shows that the average concentration of CO_2 in ambient air stands at 314 ppm (David and Frederikse, 1997). This implies that the average concentration of CO_2 in the Lagos metropolis is above the ambient standard shown in David and Frederikse, 1997 [28].

2) *Survey Results*

Table XII, shows details of the survey responses. Table XIII shows the results of the responses from the questionnaires administered to the respondents. It should be noted that in all cases, Lekki is chosen as a control area in view of its relatively low emission levels.

The research data suggests that the health effects measured in the areas experiencing higher levels of vehicle emissions, could be attributable to vehicle emissions as shown in Table XIV.

Variations in the effects of automobile emissions in the four Lagos cities were observed in this study as shown in Fig. 6.

TABLE XII: EFFECTS OF AUTOMOBILE EMISSIONS ON THE RESPONDENTS AT OSHODI (OS), YABA (YA), OJOTA (OJ) AND LEKKI (LK)- (CONTROL AREA)

Respondent	Number of people affected by: Sleeplessness (OS,YA,OJ,LK)	Number of people affected by: Catarrh (OS,YA,OJ,LK)	Number of people affected by: Heavy eye (OS,YA,OJ,LK)	Number of people affected by: Asthmatic attack (OS,YA,OJ,LK)	Number of people affected by: Headache (OS,YA,OJ,LK)
Office workers	(2,1,1,0)	(4,3,4,0)	(1,6,5,0)	(0,0,1,0)	(5,4,5,0)
Market women	(2,4,3,0)	(6,3,6,0)	(3,2,2,0)	(0,0,0,0)	(1,1,3,0)
Street hawkers	(3,2,3,0)	(4,6,6,0)	(6,5,5,0)	(1,0,0,0)	(4,3,4,0)
Drivers	(2,2,1,1)	(1,2,3,3)	(4,3,3,2)	(0,0,0,1)	(2,5,3,0)
Conductors	(2,2,2,2)	(3,3,3,2)	(2,3,2,2)	(1,1,1,0)	(0,2,2,2)
Traders	(4,2,5,2)	(5,4,6,5)	(3,5,2,8)	(1,1,1,5)	((3,4,4,2)
Residents	(4,3,1,0)	(2,4,3,0)	(4,7,6,0)	(2,1,2,0)	(3,3,4,0)
Totals	(29,16,16,5)	(25,25,31,10)	(21,31,25,12)	(4,2,4,6)	(18,22,25,4)

TABLE XIII: DISTRIBUTION OF THE RESPONDENTS IN THE STUDY AREAS

Respondents	Oshodi		Yaba		Ojota		*Lekki (Control)		Totals
	Male	Female	Male	Female	Male	Female	Male	Female	
Office workers	3	8	9	7	9	6	-	-	42
Market women	-	12	-	14	-	10	-	-	36
Street hawkers	6	12	10	8	9	10	-	-	55
Drivers	10	-	10	-	12	-	4	-	32
Conductors	9	-	9	-	10	-	3	-	29
Traders	10	9	6	12	7	10	6	6	50
Residents	6	12	10	7	8	10	-	-	53
Totals	44	53	54	48	55	46	13	6	319

TABLE XIV: EFFECTS OF AUTOMOBILE EMISSION ON THE RESPONDENTS IN THE STUDY AREAS

No. of respondents affected					
Ailment	Oshodi	Yaba	Ojota	*Lekki (Control)	Totals
Sleeplessness	19	16	16	9	51 (17%)
Flu	31	25	25	0	31 (27%)
Heavy eye	21	31	25	18	87 (29%)
Asthmatic attack	4	3	2	10	9 (3%)
Headache	25	18	22	7	65 (21.7%)

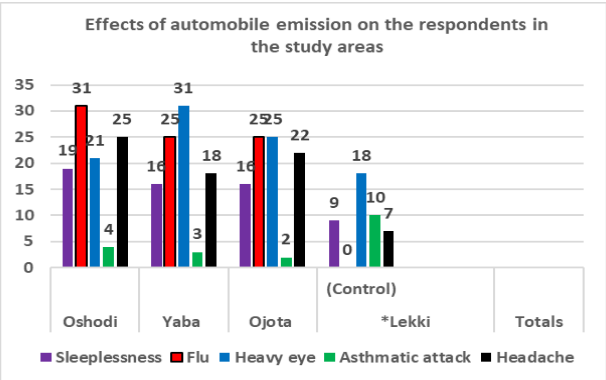

Fig. 6. Effects of automobile emission on the respondents in the study areas.

V. CONCLUSIONS

Comparison the vehicular emissions at the survey sites with the National Ambient Air Quality Standards, indicated that CO concentrations exceeded both the 1-hour limit of 35ppm and the 8-hour limit of 9ppm at all of the sites during the dry season, except for Lekki, where only the 8-hour limit was exceeded. In the wet season most sites exceeded the 35ppm limit. Most sites however were within the 8-hour limit of 9ppm. For sulphur dioxide (SO_2), both seasons experienced concentrations exceeding the 1-hour standard of 0.075ppm. All of the sites were above the 1-hour limit of 0.01ppm for nitrogen dioxide in both the dry and wet season. VOC concentrations in both seasons were within the 0.6ppm limit. Carbon dioxide (CO_2) in both seasons was above the 314ppm.

An assessment of the carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) quality of the ambient air of Lagos metropolis using the Air Quality Index of the United States EPA, indicated a poor air quality in both dry and wet seasons. While all sites except Lekki, were graded "very unhealthy" in terms of CO concentration during the wet season, Oshodi, Ojota and Yaba were graded "very unhealthy" in the wet season. NO_2 quality was "good" in both seasons in all the sites surveyed. On the other hand, SO_2 quality in the dry season was "moderate" in all sites except Lekki which was rated as "good".

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