ANALYSIS OF AUTOMOBILE EMISSION LEVELS AND AIR QUALITY IN LAGOS STATE, NIGERIA

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DOCTOR OF PHILOSOPHY (Ph.D.) IN GEOGRAPHY AND ENVIROMENTAL MANAGEMENT

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Declaration

I hereby declare that this thesis titled "ANALYSIS OF AUTOMOBILE EMISSION LEVELS AND AIR QUALITY IN LAGOS STATE, NIGERIA" was written by me and is a product of my research effort. It has not been presented in any previous application for any degree or diploma at this or any other Institution. Allquotations are indicated and the sources of information are acknowledged by means of references.

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This thesis titled**,** "ANALYSIS OF AUTOMOBILE EMISSION LEVELS AND AIR QUALITY IN LAGOS STATE, NIGERIA" by **OsitaStanley ONYEMELUKWE**meets the regulations that govern the award of Degree in Doctor of Philosophy (Ph.D.)in Geographyand Environmental Management of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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Dedication

This research work is dedicated to Almighty God, the most Merciful, the Omnipotent and Omniscience God for His Grace and Kindness during the course of this program. I also dedicate it to Mr. C.D.Onyemelukwe and Mr.Samo Onyemelukwe for their moral and financial supports during the course of this study.

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Abstract

This study analysed automobile emission levels and air quality in Lagos State, Nigeria. Both automobile emission and ambient air samples were collected and used in the study. The automobile emission data was generated from sampling 312 different types of automobiles using Testo 350XL emission sensor, while ambient air data was sourced by analysing air concentration levels along the selected traffic corridors thrice daily for one week, using Aeroqual automated multi gas emission analyser. Both descriptive and inferential statistics were utilized and the results presented infrequency and percentage tables and chart.The result of Pearson Product Moment correlation analysis on relationship between ambient air concentrations of pollutants and traffic volumes shows strong statistical relationships between traffic volumes and CO_2, $PM_{2.5}$and HC pollutants with P-values of 0.000, 0.001 and 0.000 at 0.01 in that order. On the other hand, variables such as CO, NO, PM10, R/H and ˚C show no relationship with traffic volume. This is indicated where the p-values of 0.993, 0.084, 0.105, 0.355 and 0.223 in that order were found. The study revealed that there is no difference between the pollutants found in the air along the traffic corridors with those emitted from the sampled automobiles. ANOVA analysis shows that there is strong variation in the emission concentration from different types of automobiles, with the strongest difference found in CO with 434ppm and NO with 85ppm, while the least difference is found in CO_2 pollutants with 21.7ppm. Also, petrol powered automobiles have the highest emission concentration of HC, NO and $CO_2$with 997.9ppm, 796ppm and 862ppm respectively than diesel powered automobiles, while diesel automobiles have the highest emission levels of CO with 584.19ppm than petrol powered automobiles with 291ppm. Analysis of ambient air quality shows that the mean average weekly concentration of CO along the heavy traffic corridors is below the daily safety limits of 15ppm, but higher than 1 hourly limits of 10ppm. Comparison of vehicular specific emission concentration with the set standards shows

that heavy truck emission of 729.14ppm and 578.28ppm for NO and CO pollutants were slightly below the set standards of LASEPA/EURO III at 753.47ppm and 584.8ppm respectively, while HC concentration of 514.27ppm is found to be above the set limit of 329.47ppm. The emission concentration of tricycles on HC and NO with 4808.5ppm and 220.29ppm respectively far exceeded the regulatory limits set by LASEPA/EURO III of 35.03ppm and 5.25ppm, while CO emission concentration of 230.00ppm is slightly below the set limit 238.1ppm. Motorcycle emission concentration of 150.50ppm and 3079.43ppm for NO and HC far exceeded the LASEPA/EURO III set limits of 5.25ppm and 35.03ppm respectively, while the concentration ofCO (204.00ppm) is below the set limit of 238.1ppm.Omni-bus automobile type has higher emission concentration of CO and HC with 585.7ppm and 507.0ppm than the set limits of 584.8ppm and 329.5ppm by LASEPA/EURO III, while the NO concentration with 729.1ppm is below the regulated limits of 753.5ppm.Cars have higher emission concentration of NO and HC with 90.1ppm and 434.7ppm than the set limits of 6.3ppm and 43.8ppm respectively. It also recorded lower emission concentration of CO with 30.0ppm compared to the regulatory set limits of 431.6ppm of LASEPA/EURO III.It is therefore recommended thatthere is the need to adopt sustainable auto-specific emission control measures with focus on the control of specific dangerous pollutants such as hydrocarbon, carbon dioxide and nitric oxide which are mostly emitted by trucks, tricycles and motor-cycles at high concentrations. There is also the need for LASEPA to constantly monitor and publish air quality data along the sampled corridors where CO and PM_{10} were found to exceed the set standards as exposure to this pollutant at these locations by the public may result to many health effects such as immune system impairment, exacerbated asthma attacks, lungs cancer as well as environmental effects such as formation of smog, degrading of surface water quality among others.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Clean air is a basicrequirement for a healthy life, when it is compromised and organisms get in contact with it on either short-time or long-time basis, acute or chronic health and physical discomfort may be the outcome (Gleick, 2001). Therefore, air quality must be constantly checked to ensure a healthy and harmonious existence of life on earth. Air quality can be compromised mainly by both natural and man-made sources (Botkin and Keller, 2000). The concentration levels of the effects on organisms dependent on the magnitude of local emissions sources and the prevailing meteorological ventilation of the area (Colls, 2002).

In urban centres, human-activities which result to poor or deteriorating air quality could be from mobile and stationary sources. While the former includes automobiles such as; buses, trains, airplanes and other fuel powered modes of transportation, the latter have to do with factories, incinerators, and other kinds of non-mobile sources. The United State Environmental Protection Agency (USEPA, 1994); Awange (2010) unanimously identified automobile emission as a key factor in the deterioration of urban environment, constituting up to 80-90% of pollutants emitted into the atmosphere particularly in the city centres of most developing countries. This situation is alarming and is predicated on the improvement in household living standards which result to a shift from non-motorised to motorised means of mobility, the poor automobile maintenance culture and importation of old vehicles which culminate into an automobile fleet dominated by a class of vehicles known as ‘’super emitters’’ among other reasons (Brunekreef, 2005).

Automobile emissions on the other hand are simply concerned with gaseous and or particulates emitted from an automobile system as a result of combustion of fuels such as petrol and diesel, which are discharged into the atmosphere through an exhaust pipe, flue gas stack or propelling nozzle depending on the type of engine. A large majority of today's automobiles use internal combustion engines that burn petrol or other fossil fuels such as diesel. The process of burning fuel to power motor-cycles, tricycles, cars, heavy duty vehicles, aircrafts and locomotives contributes to air pollution by releasing a variety of emissions into the atmosphere. These emissions compromise air quality and are major ingredients in the creation of smog in some large cities of the world (Sprawl, 2001).

According to Faiz, Weaver and Walsh (1996) in most cities, gasoline (petroleum) vehicles are the main source of lead aerosol and carbon monoxide, while diesel vehicles are a major source of respirable particulate matter. The researchers also pointed that in Asia and parts of Latin America and Africa two-stroke motorcycles and 3-wheelers are also major contributors to emissions of respirable particulate matter. Petrol vehicles are the main sources of volatile organic compounds emissions in nearly every city, while both petrol and diesel vehicles contribute significantly to emissions of oxides of nitrogen which are among the main sources of toxic air contaminants. Among the pollutants emitted from petrol/diesel fuelled automobile exhaust are carbon dioxide (CO_2), nitrogen dioxide (NO_2), hydrocarbons (HC_s), carbon monoxide (CO), whereas hydrocarbons and nitrogen oxides may react with sunlight to form smog (Faiz, Weaver and Walsh, 1996).

On the other hand, particulate matters ($PM_{10,}$) which are microscopic solid or liquid matters suspended in the earth's atmosphere are known to have originated from either natural or man-made sources. The man-made source of particulate matters is believed to account for about

10% of the total mass in the earth atmosphere (Villand, 2010) and its effects are the biggest source of uncertainty in climate predictions (Piers, Ramaswamy, Artaxo Berntsen, Betts,*et al* (2007). This is because, it plays an important role in altering the amount of solar radiation transmitted through the Earth's atmosphere (i.e. radiative forcing). Particles especially those containing sulphate, exert a direct effect by scattering incoming solar radiation back to space, thus providing a cooling effect, whereas, black carbon in particles absorbs solar radiation and consequently warms the atmosphere (Intergovernmental Panel on Climate Change (IPCC, 2001). Acute exposure to particulate matters can cause itchy/irritated eyes/nose/throats, which can also result to exacerbated asthma, chronic respiratory diseases, reduced lung function and cardiovascular diseases (Schwela, 2000; Wargo, Wargo, Aiderman and Brown, 2006).

Notably, of more concern to environmental, transport development and urban planners among other experts is the fact that despite the dangers that automobile emission pose to the environment and health of organisms, the emission levels of these dangerous gases is expected to increase reasonably as vehicle ownership increases in the world. For example, a research conducted by USEPA in 1993, reported that transportation sources in the USA were responsible for 77% of CO levels, 80-90% of NOx, 36% of volatile organic compounds and 22% of particulate matter, while in 2012, it was reported that transport sector contributed to 28% of the total greenhouse gas emission in USA (USEPA, 2012); which indicate significant reduction in pollutant emission from the earlier report. Also, in European countries, the emission reductions from 1990 to 2009 was reported to be around 54% for SO_2, 27% for NOx, 16% for PM_{10} and 21% for $PM_{2.5}$

The figures on emission levels of these poisonous elements in these countries have however reduced in recent time which is attributable to the stringent measures on automobile

emission regulations. For instance, in the United States in the early 1970s, USEPA set national standards that considerably reduced emissions of CO and other pollutants from motor vehicles. Today's cars, for example, typically emit 70-90% less pollutants over their lifetimes than their 1970 counterparts (USEPA, 1994). Also, under the US Clean Air Act and subsequent Amendments in 1977 and 1990, tailpipe standards for cars were set and later tightened, emission standards for diesel-powered trucks and buses were adopted, and inspection and maintenance programs were established and subsequently expanded to include more areas and allow for more stringent tests. Other new approaches to reducing motor vehicle-related air pollution includes improvement in fuel vehicle technology, reduction in vehicular travel mileage, enforcement of law that mandates only improved petrol formulations be sold in some polluted cities, regulation on the vapour pressure of all petrol vehicles during the summer months, limiting of growth in vehicular ownership by encouraging alternatives to solo driving as well as the establishment of low sulphur requirements in diesel fuel starting in 2006 among others (USEPA, 1994).

However, in most developing countries of the world of which Nigeria is not left out, reverse is the case as vehicular growth has not been checked properly by both transport and environmental regulating authorities leading to increase levels of pollution. Traffic emissions contribute about 50-80% of NO_2 and CO concentration in developing countries (Fu, 2001; Goyal, 2006). In Nigeria, traffic emission incidence is often attributed to the low economic disposition, poor vehicle maintenance culture, weak regulations of automobile emission and high importation of used vehicles popularly called "*Tokunbo* vehicles", which is also called super emitters. As noted by Brunekeef (2005) in developing countries, the super emitters (*Tokunbo* vehicles) contribute about 50% of harmful emissions to the entire average emission.

In concurrence with the above assertion, in an Environmental Impact Assessment (EIA) study carried out by Mechelec Consortium (1996), the profile of air pollution by type and source in Lagos metropolis, revealed that road traffic is the major source of air pollution. Wherefore, over 60% of all activities are carried out using motor vehicles complemented greatly by the use of motor-cycles (*Okada*) and Tricycle (*Keke*) for public transport throughout the city, plying the nooks and crannies of the city (Taiwo, 2005).

Hence, it is believed that the use of this mode (road transport) and choices (automobile types) of transport contributes significantly to greenhouse gases (GHGs) emissions in quantities beyond the recommended or permissible limits which are considered to be harmful to human health and the global climate. Consequently, the actions of individuals and corporate organisations in generating these poisonous gases are known to be detrimental to the survival of mankind and the universe (Barth and Boriboonsomsin, 2008).

Given the above, it is pertinent to carry out this study with focus on the emission levels of various types of automobiles as well as the implication of the emission levels on air quality in Lagos State, Nigeria. This is because, although, more emissions are generated in developing regions of the world, the climate change impacts are felt globally. Hence, greenhouse gas emission impacts on the climate of the environment are therefore not restricted to where it is being emitted but the effect is global (U.S. Global Change Research Program, 2005).

1.2 Statement of the Research Problem

An inventory of automobile emission levels by types in Lagos State has not been carried out to the researcher's knowledge, especially given the fact that in Lagos State, there are about 2,600 km of roads that are frequently congested, with over 1 million vehicles plying the roads

ondaily basis which makes the State more vulnerable to higher traffic related emissions (Itua, 2010). Road transport sector accounts for over 7 million estimated passenger movements per day, mainly characterized by the use of private cars, transit buses known as fast lane BRT (Bus Rapid Transit), Danfo and Molue, taxis, tri-cycles (*Keke*) and motor cycle (*Okada*) (Taiwo, 2005).

Furthermore, road transport, which is the main mode of transportation in many developing countries, has experienced increased per capita vehicle ownership with Lagos State not an exemption. Attributable to this increase in per capita vehicle ownership is the fact that as household income increases, the need to use or own an improved form of mobility also increases and households tend to move from non-motorized to motorized form of mobility. Also the state of supply and efficiency of public transport services; availability of quality road infrastructure; government policies (e.g. tax, insurance) towards automobiles ownership; cost of vehicles; cost of fuels; cost of alternative means of transportation; etc. greatly contribute to the increase in ownership and use of personal vehicles for mobility (Singh, 2006). The increase in ownership and use of motorized mobility invariably increases the consumption/demand for energy as well as significantly contributing to greenhouse gas (GHG) emissions (International Energy Agency, IEA, 2012).

According to the United Nation Conference on Trade and development (UNCTAD) (2012) report, Nigeria in 2012 imported about $4 billion worth of automobiles of which about two thirds were pre-owned, while in 2014, an estimated annual vehicular importation for the country rose to about 500,000 unit, out of which about 100,000 were new and 400,000 were used cars (National Automotive Council (NAC) 2014). With a future potential market size of 1million units mark of vehicles annually, if there is an affordable vehicle credit purchase scheme (Lagos

Business School, 2014), then an astronomical increase is inescapable. Specifically in Lagos, it is said that about 40% of all new vehicle registration and total fuel consumption in Nigeria take place in Lagos, with the number of registered vehicles in Lagos increasing from about 27,554 in 1995 to about 259,473 in 2011 and 309,982 in 2013 (Lagos Bureau of Statistics, 2013). This also resulted in a corresponding increase in consumption of petroleum products (petrol and diesel) from 1.9 million metric tonnes in 1995 to 3.4 million metric tonnes in 2011, with a resulting increase in greenhouse gas emissions (Taiwo, 2005).

In addition, the rising importation of both new and used automobiles into the city has increased traffic congestion and prolonged length of stay in traffic, which has in turn increased the amount of emissions from these vehicles and consequent air pollution. Bull (1991) also observed that due to traffic congestion and traffic hold ups, vehicle emissions increase much faster than the actual growth in the number of vehicles. Barth and Boriboonsomsin (2008) further buttressed the observation of Bull (1991) and stressed that for the same amount of time in operation, vehicles in idling condition produce higher average concentrations of carbon monoxide (CO), Nitrogen dioxide (NO_2) and Sulphur dioxide (SO_2).

Frey and Zheng (2002) noted that vehicle emissions are dependent on vehicle design, operation, maintenance habits and fuel composition. To the scholars, diesel cars produces more unburnt fuel during a cold start, which means that diesel cars would make a significant impact on air quality in urban areas where most cold starts occur, especially when it is considered that a catalyst on petrol car would take several minutes to reach its operating temperature. For instance, Quality of Urban Air Review Group (QUARG) (1993) stated that a journey of one kilometre could lead to emissions of CO being as much as 14 times higher from a petrol car, compared with a diesel car.

On the other hand, an overview of previous studies carried out across the country on the air quality assessment reveals high concentrations of pollutants resulting from incomplete combustion from aged vehicles operating within many city centres. For instance, Jerome (2000) carried out a comparative study of air quality levels in Lagos and the Niger Delta region of Nigeria (Oil producing region). Two major cities in the Niger Delta region of Nigeria (i.e. Port-Harcourt and Warri) were sampled. The results obtained show that the concentrations of TSP (Total suspended particulates), NOx, SO_2, and CO in Lagos and Niger Delta (Port-Harcourt and Warri) were above NESREA recommended limit. Concentration of CO emissions for Lagos was in the range of 10 – 250ppm which recorded higher than the ranges of 5.0 – 61.0ppm and 1.0 – 52ppm recorded for Port-Harcourt and Warri respectively. The TSP concentrations from the study were also high for both cities when compared to WHO standard.

Itua (2010) also conducted a research on vehicular emission (air quality) monitoring in Lagos State. It was found from the study that automobile emission source in the State have the highest contribution to urban emission inventories in many locations. The researcher emphasized that automobile source tend to be much smaller in emission per vehicle compared to other sources, but are much more widely dispersed than stationary sources.

Elsewhere, In Kaduna State of northern part of Nigeria, Musa (2014) carried out a study on the contribution of motor vehicles emissions to air pollution in Kaduna Metropolis. The study sampled three gaseous elements CO, NO_2 and SO_2 along the high vehicular traffic routes in the metropolitan areas. The finding indicated that motor vehicle emissions in Kaduna metropolis especially at sample points within the urban core for pollutant such as CO was above NESREA limits of 10ppm, whereas, the concentration levels for SO_2, and NO_2 were within the NESREA

lower safe limits of 100ppm and 40ppm at some points and exceeded at other points, but did not still exceed the upper limits of 101ppm and 60ppm for SO_2 and NO_2.

On the other hand, few studies have been carried out on automobile emission levels across various parts of Nigeria. For instance, Aduagba, Amine and Oseni (2013) investigated the emission values of a passenger vehicle in idle mode in comparison to regulated Euro 2 values. The study focused on Golf 3 GTi Volkswagen 1996 model popularly used as "Taxi" in Nigeria. The result showed that the emission concentrations and the engine Revolution Per Minute (RPM) of the vehicle under study was observed to emit CO concentration increase from 0.23% to 0.35%, CO_2 from 7.54% to 9.11%, NO from 102 to 661ppm and HC from 196 to 248 as the engine speed progressively moved from 1000 to 3000 rpm.

Having reviewed previous studies on air quality and automobile emissions by various authors, it can be seen that the focal point of emission studied by Musa (2014) was limited to the areas outside the spatial coverage of the present study. Whereas, studies by Itua (2010), Jerome (2000) and Taiwo (2005) were all focused on air quality assessments and not on automobile emission levels as well as limited to total suspended particulates, NOx, SO_2, NO_2, H_2S and CO only and the interval of years between the most recent of the reviewed previous studies within Lagos State by Itua in 2010 and this present study is 6 years. On the other hand, the study on automobile emission levels by Aduagba, Amine and Oseni (2013) was limited to the emission values of a passenger vehicle in idle mode, with emphasis on Golf 3 GTi Volkswagen 1996 model. As expected, different types of automobiles emits different types and quantities of pollutants.

In addition to the rise in the importation of fairly used cars which in most cases may not comply with the premium air regulation standards, as well as the variation in the other emission

factors, differential levels of automobile influx across States in Nigeria, to the population explosion especially around the Central Business Districts (CBDs) of Ikeja, Victoria Island and Agege Industrial areas which results to the growth in the wave of landuse conversion of structures from the original plans which consequently leads to chaotic traffic situation and the associated higher emission rates and concentrations. Also, the absence of coordinated automobile emission framework to regulate the emission levels in the country, make it possible that there may exist an increasing trend of greenhouse gases emission which beyond the associated health risks, are critical to air quality (and hence global climate change).

Finally, given the agreement of 2015 by the United Nations Framework Convention on Climate Change (UNFCCC) to limit the future global warming to 2.0˚C of which Nigeria is committed to, with the member nations required to take inventories of greenhouse gases on a regular basis. Therefore, the need for a study of this nature in the study area which is the commercial hob of Nigeria with the expected high economic activities and the resultant negative environmental and climatic impacts cannot be overemphasized.The findings from this study are expected to deepen the understanding on vehicular emission levels and the effects on air quality in Lagos State in particular and Nigeria in general.

In order to fill this existing gap in knowledge, answers to the following research questions were explored.

1. What are the concentrations of pollutants (CO, CO_2, NO_2 and HC) emitted by different automobiles models in Lagos State?
2. Are the substances emitted from the automobile the same with those found in the air along the sample points?
3. What are differentials in the pollutant emission by automobile types in the study area?

4. Do automobile emission levels on CO, CO_2, NO_2 and HC differ by type of fuel used?
5. Does the automobile emission concentration comply with Lagos State Environmental Protection Agency (LASEPA) and EURO III set limits?
6. What is the air quality concentration of CO, CO_2, NO_2, HC SO_2 and $PM_{10 \text{ and } 2.5}$ pollutants along heavy automobile traffic corridors in the study area?

1.3 Study Aim and Objectives

The aim of this study is to analyse the automobile emission levels and air quality in Lagos State, Nigeria. This aim is achieved through specific objectives which are to;

i. examine the concentrations of CO, CO_2, NO_2 and HC pollutants emitted by automobiles in Lagos State
ii. compare the types of substances emitted from the automobile with those found in the air along the sample points
iii. examine the differentials in types and emission levels of CO, CO_2, NO_2 and HC by automobile models in the study area.
iv. compare emission levels of CO, CO_2, NO_2 and HC from diesel and petrol fuelled automobiles in the study area.
v. compare the automobile emission concentration in the study area to the LASEPA and EURO III set limits.
vi. assess the air quality concentrations of CO, CO_2, NO_2, HC SO_2 and PM_{10} and $PM_{2.5}$ pollutants along heavy automobile traffic corridors in the study area.

1.4 Research Hypotheses

Ho_1 There is no statistically significant difference between automobile emission levels on CO, CO_2, NO_2 and HCin the study area and the EURO III and LASEPA recommended standards.

Ho_2 Ambient air concentration levels of CO, CO_2, SO_2 NO_2, HC, PM_{10} and $PM_{2.5}$ do not differ by traffic volume.

Ho_3 There is no significant difference in air quality around the sample points and the NESREA standards

1.5 Justification of the Study

Per capita automobile ownership in Lagos State is increasing geometrically, as an overview of vehicular ownership statistics in the State according to report by Motor Vehicle Administration Agency and Lagos Bureau of statistics (2013) shows that in 1996 there were 28,644 newly registered vehicles in the State, while in 2007 and 2013 the figure rose to 187,422 and 306,982 respectively. An estimated 8 million people commute along the 9,100km roads each day (World Bank, 2009). With more than one million trips made during the peak travel periods of the day (Ministry of Economic Budget and planning, 2013); over 2,600 km of roads in the State being frequently congested (Itua, 2010). This invariably slows traffic flow and in return increases the amount of fossil fuel consumption and greenhouse gases emitted into the atmosphere.

There is a clear indication that vehicle emission is a major source of ambient air pollution. The combustion of gaseous pollutants such as nitrogen oxides (NOx), carbon monoxide (CO), sulphur dioxide (SO_2) and particulate matters (PM) among others from petrol-

and diesel-powered engines in the city centres, especially on highly congested streets, traffic can be responsible for as much as 90–95% of the ambient CO levels, 80–90% of the NOx and hydrocarbons, and a large portion of the particulates pollutants, which not only pose a significant threat to human health, but also contribute of effect to climate change (Savile,1993). For instance, Schwela (2000) in a related study found a significant relationship between residence proximity to high traffic roads and the prevalence of asthma, respiratory morbidity in infants and cardiovascular disease in children. Particulate matters emitted from automobile exhausts especially diesel fuelled engines can penetrate the lungs and inflame the circulatory system, damaging cells and causing respiratory problems (Riedl and Sanchez, 2005). Also, the produced greenhouse gases (GHGs) among other volatile organic compounds (VOCs) from automobiles are responsible for the global warming.

Moreso, given the recent emission standard violation law suits against Volkswagen (VW) in US by EPA of which the company may face a possible total sum USD18 billion (USD37,500 for each car), many government regulatory agencies from various countries have launched emission standard investigations into not only Volkswagen cars, but on other cars imported into their countries for the purpose of public health and environmental safety (USEPA, 2015). It is hopeful that Nigeria will in no distant future tally along. This research is therefore timely, as the findings therein will;

serves as pointers to policy makers on the need to formulate a legislative framework or standard in the State in particular and country in general to monitor emission from automobile sources, considering the fact that the regulatory framework put in place in 1991 by the Federal government through the then Federal Environmental Protection Agency (FEPA), currently known as NESREA is limited to emission generated through stationary sources. It will also serve

as a guide to urban planners and environmental experts in planning and designing of urban infrastructures to such a standard that does not undermine the safety of human health and environmental wellbeing. It will help to raise the much needed awareness to road users and residents alike on the need to take safety measures to protect themselves from the inhalation of the poisonous pollutants from vehicles through the use of nose masks and eye shades etc. it is expected to provide an up to date and periodic data on ambient air quality along heavy traffic corridors for the benefit of the commuters, residents, policy makers etc. Lastly, findings will serve as current baseline data on air quality at heavy traffic corridors in the State as well as form the basis for the formulation of acceptable national automobile emission standardswhich will be in tune with our socio-economic realities.

1.6 Scope of the Study

This research is limited to the major traffic corridors in Lagos State. The six (6) major corridors with predominant heavy vehicular traffic in Lagos to be considered are; Ojota corridor and the Ikorodu road, others are, Ikeja along express, Awolowo road Ikeja, Oshodi corridor and Dopemu-Ipaja road corridor (Figure 3.1). These points are purposively selected based on their high volume of automobile concentrations especially during the daily peak periods of 7:30am and 5:00pm.

The study analysed air samples of gaseous pollutants such as CO, NO_2, SO_2, HC, CO_2 and Particulate Matter $PM_{10\ and\ 2.5}$ were tested for. On automobile emission level analyses, only CO, CO_2, NO_2 and HCpollutants were analysed. This is due to the fact that these gases are the principal primary pollutants emitted by automobiles and regulated by most regulatory agencies across the world. Secondly, the choice is also due to unavailability of equipment and or high cost of purchasing the equipment to analyse PM_{10}, $PM_{2.5}$ and SO_2emission levels.

Theair quality samples were collected simultaneously from the sample points for a period of one (1) week with samples taken thrice daily from each points at morning and evening peak periods of 6:30am and 4:30pm and noon off peak period of 12:30pm. Also, to test for automobile emission levels, a total of 312 different categories of automobiles were purposively selected and tested for their emission levels of CO, NO, HC and CO_2. The automobiles sampled were limited to only on-road automobiles such as trucks, omni buses, buses, cars, tricycles and motor cycles (Table 3.2 and 3.3). The selection of these forms of automobiles is on the basis that they are mostly known to have the highest contribution to air pollution due to their large numbers compared to other modes of transportation (Mechelec Consortium, 1996).

CHAPTER TWO

2.0 CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Introduction

This chapter is focused on the review of conceptual issues and literatures relating to the topic. The major concepts include air quality, automobile emission, as well as framework of source emission, dispersion and air quality system. The literature review is done to provide empirical comparative basis for the study towards advancing the frontier of knowledge.

2.2 Conceptual Framework

2.2.1 Concept of air quality

Defining air quality is often times a difficult task, because the interpretation varies across different professions, individuals and regulatory agencies. In other words, air quality is more than a statement regarding the extent of air pollution at a given time. It is also judgement regarding both the effects that humans perceive and effects that act below the threshold of human perception that may affect the ecosystem and or indirectly affect human life.

Also, public policy discussions regarding air quality tend to equate the term with simple concentrations of air pollutants and are usually dominated by concerns over human health. However, for many air pollutants, particularly the oxidants and airborne acid-forming chemicals, the direct effects of air pollution on vegetation and freshwater biota are proportionately much greater than those demonstrated on human health (Guidotii, 1995). In a nutshell, many effects of air pollution tend to act over prolonged periods or consequences of repeated exposure. Air quality must therefore be described in terms of relevant time intervals, not just as instantaneous descriptions of levels of air pollutants. Air quality can also be perceived as a description or an

end-point achieved by the action of numerous variables, some or all of which are difficult to quantify that are responsible for determining the final chemical state of the air we breathe.

One way to approach the definition of air quality is to compare it with an ideal state of "clean air'. According to Legge, English, Guidotti and Sandhu (1992) clean air is described as the air that is essentially odourless, colourless and has no measurable short or long term adverse effects on people, animals and the environment. It also approximates the natural state of the atmosphere free of human interferences or exceptional natural emissions (as by fire or volcanic eruption). According to USEPA (2002) air quality index (AQI) for priority pollutants, air quality is categorised into several groups as presented in Table 2.1.

Table 2.1: Air Quality Index for priority pollutants

AQI Category	AQI rating	PM10 $\mu g/m^3$	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)
Very good	A	0 – 15	0 -2	0-0.02	0-0.02
Good	B	51 – 75	2.1-4.0	0.02-0.03	0.02-0.03
Moderate	C	76 – 100	4.1-6.0	0.03-0.04	0.03-0.04
Poor	D	101 – 150	6.1-9.0	0.04-0.06	0.03-0.04
Very Poor	E	>150	>9.0	>0.06	>0.06

USEPA(2000)

The foregoing definitions and categorisations of air quality are in consonance with a commonly held view in regulatory and public policy debates that clean air is basically an atmosphere that does not exceed air pollution standards. It follows from this definition of clean air that 'dirty air' is any significant deviation from this state of clean air as a result of natural phenomenon or human activity. Therefore, for the purpose of this research, the following definitions of air quality are hereby adopted: The degree to which air is suitable or clean enough for the environment, humans, animals, or plants to remain safe and healthy (Collins-dictionary,

2017); and the levels of air pollutants prescribed by regulations that may not be exceeded during a specified time in a defined area.

2.2.2 Concept of automobile emission

Automobile Emission connote exhaust gas or flue gas that are emitted as a result of the combustion of fuels such as natural gas, gasoline, petrol, biodiesel blends, diesel fuel, fuel oil, or coal usually discharged into the atmosphere through an exhaust pipe, flue gas stack, or propelling nozzle (Omidvarborna, 2014). It also means chemicals emitted from automobile exhausts that are harmful to air quality, such as; carbon monixide (CO), hydrocarbons (HC), and nitrogen oxides (NO) among others. Healthy engines or modern automobiles using unleaded gasoline (petrol) and equipped with catalytic converters produce substantially lower amounts of these pollutants, while unhealthy or older engines produce more of certain emissions than others (Driverside, 2017). Automobiles are powered through the combustion of fossil fuels to produce energy which are translated into motion.

Air quality is compromised as a result of incomplete carbon reactions, unburned hydrocarbons or other elements present in the fuel or air during combustion (Gorham, 2002). The most common types of vehicular fuels are the fossil fuel commonly known as petroleum and gasoline. Petroleum is commonly used in light duty vehicles, while diesel/gasoline is commonly used in heavy duty vehicles. Both petroleum and diesel can be in leaded or unleaded form. In the process of combustion in the engines, various types of pollutants such as carbon monoxide, soot, various gaseous and liquid vapour, hydrocarbons, oxides of sulphur and nitrogen, sulphate and nitrate particulates, ash and lead are produced.

2.3 Framework of Emission, Dispersion and Air Quality System

Air quality dynamics is complex. Firstly, it is influenced by the characteristics of the emission source, such as stationary or mobile sources, then the meteorological conditions which determine the dispersal extent of the air pollution and lastly, the effects on the receptor such as the atmospheric system, plants, animals and humans. Very often urban air pollution problems are aggravated by meteorological and topographical factors that concentrate pollutants in the city and inhibit quick dispersion and dilution processes. As complex as the phenomenon may be, it can be easily depicted by means of a simplified systems analysis diagram shown in Figure 2.1.

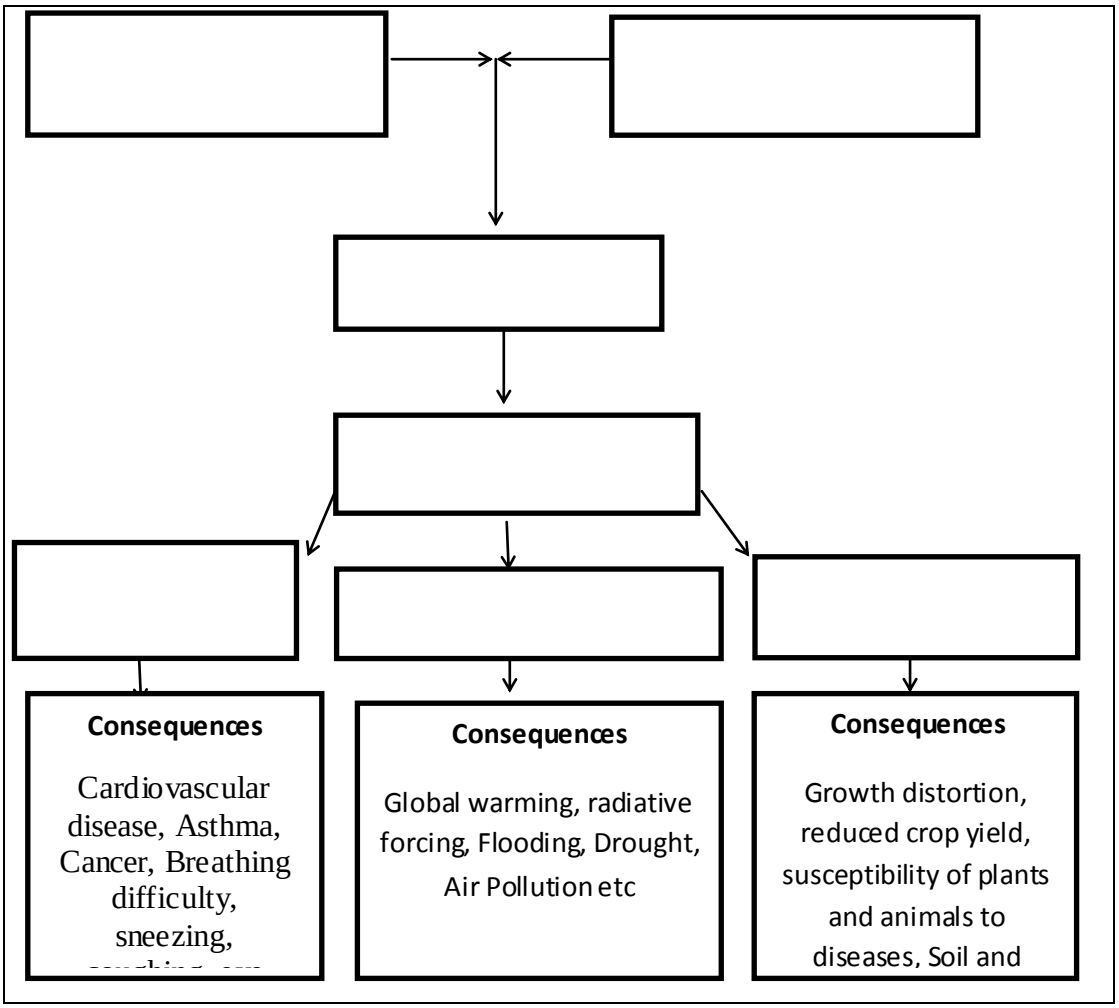


Figure 2.1: Source Emission, Dispersion and Air Quality System
Source: Modification from Fu and Chen (2015)

2.3.1 Source emission

Emission comes from a variety of sources including natural sources and manufactured sources. The natural sources include forest fires and volcanoes, while cars, trucks, trains, planes, boats, factories, and power plants constitutes the manufactured sources (Vasarevicius, 2011). Among the manufactured sources, transport sector contributes around 14% towards the global emissions of greenhouse gases (IEA, 2006). For instance, carbon dioxide represents the largest proportion of basket of greenhouse gas emissions and in the past three decades, its emission from the transport sector have increased faster than those from all other sectors and are projected to increase more rapidly in future. From 1990 to 2004, carbon dioxide emissions from the world's transport sector have increased by 36.5%. For the same period, road transport emissions have increased by 29% in industrialized countries and 61% in the other countries (IEA, 2006).

The mode wise distribution of CO_2 emissions amongst transport section reveals that road transport contributes major share of around 73% towards total CO_2 emissions from transport sector, while aviation, international shipping and railways sector emissions of CO_2 from transport sectors are about 11%, 9% and 2% respectively (IEA, 2006).

2.3.2 Meteorology and topography

Examining the changes in vehicle emissions that will result from highway capacity additions is only the first step in understanding how these emissions are likely to be dispersed in the atmosphere and affect the air quality of a metropolitan area. Meteorological parameters such as ambient temperature, wind speed, cloud cover, solar radiation, and inclement precipitation conditions (rain, snow, hail, etc.) have a major effect on the transport and dispersion of emissions and hence their concentration in a region, which is the primary criterion of concern from a public health perspective (Horowitz 1982; Fu and Chen, 2015). For instance, the wind speed changes

with height and increases with increased elevation. It is also influenced by topography and urbanization.

Generally, concentration of pollutants in the air is mostly higher during winter periods, usually characterized by low wind speeds, low mixing heights and temperature inversions (Gokhale and Khare, 2007; Tiwari, Chate, Pragya, Ali and Bisht, 2012). Also the highest concentrations of CO generally occur in the dry season, when atmospheric conditions tend to be more stable and wind speeds are lower, causing reduced dispersion and increased concentrations (Horowitz 1982). Although, summer condition is favourable for air pollutant dispersion, chemically reactive air pollutants such as oxides of nitrogen (NO_x), secondary particulate matter, having an aerodynamic diameter ≤ 2.5 ($PM_{2.5}$) and ozone are found to be higher during this season (Kumar, Khare, Harrison, Bloss, Lewis, Coe and Morawska, 2015). The higher concentrations of these reactive air pollutants during summer season may be due to the chemical transformation of secondary air pollutants, which is significantly influenced by the presence of their pre-cursor pollutants and favourable climatic conditions i.e., humidity and ambient temperature (Wang, Zhuang, Huang, Liu, Lin, Deng, Fu, *et al.*, 2016).

Also, due to the fact that chemical reaction that creates ozone is stimulated by heat and sunlight, ozone concentrations tend to be higher at the peak of dry season than during the rest of the year (Horowitz 1982). Similarly, a related study by Hassan and Okobia (2008) revealed that the emission concentration results for H_2S, CO and O_2 gases in Kuje area council were different across seasons. During the wet season H_2S and O_2 gases were within the WHO standards, USEPA and NAQS while CO though below 5ppm 8 hourly mean was below all standards. During the dry season CO increased slightly above 15ppm 8 hourly mean between Tukpechi, Kuje town and Chibiri districts.

Finally, local topography both man-made (e.g., tall buildings near a highway) and natural (e.g., mountains) also affects the rate of dispersion of emissions from their source. Mountains, hills, trees, buildings and other obstructions can divert wind patterns, increase atmospheric turbulence, influence general atmospheric stability, and, thereby, affect air pollution dispersion (Fu and Chen, 2015).

Additionally, the geographical setup at hotspots in most urban regions, especially traffic intersections and congested road surrounded by high rise buildings results to sudden occurrences of extreme air pollution events. The urban hotspots are severely prone to vehicular pollution, because of reduced vehicle speed due to traffic congestion and the release of more exhaust emissions (Pant and Harrison, 2013; Gulia, Nagendra, Khare, and Khanna, 2015).

2.3.3 Air pollution

According to Delay and Zanetti (2007), air pollutants can be classified as primary or secondary. Primary pollutants are substances that are directly emitted into the atmosphere from sources. The main primary pollutants known to cause harm in high enough concentrations are the following:

i. Hydrocarbon (HC) is an organic compound consisting entirely of hydrogen and carbon. Other forms of carbon compounds include; CO, CO_2, CH_4 and VOCs (Volatile Organic Compounds). Majority of hydrocarbon found on earth occur in crude oil, where decomposed organic matters provide an abundance of carbon and hydrogen. Both petrol and diesel fuels consist of mixtures of a large quantities of hydrocarbons which vary according to the manufacturer and to local geography and climate. Additives may also be present and these include lubricants, antirust agents, antioxidants, pre-ignition preventers and anti-knock agents. Aromatic hydrocarbons

are added to petrol to aid refining. These inevitably give rise to a large number of hydrocarbon pollutants, also known as volatile organic compounds.

ii. Sulphur dioxide (SO_2) is a colourless, but noticeable component in the atmosphere. Other sulphur compounds are H_2S and SO_2. The largest source sulphur dioxide is from fossil fuel combustion at power plants, industrial facilities and other locomotives. It has a suffocating, pungent odour and can cause irritation of lung tissues and significant damage to materials, living organisms as well as serve as a precursor to acid rain (USEPA, 2003).

iii. Nitrogen compounds, such as NO, N_2O, and NH_3

iv. Halogen compounds, such as chlorides and bromides

v. Particulate matter (PM or "aerosols"), either in solid or liquid form, which is usually categorized into the under listed groups based on the aerodynamic diameter of the particles:

   i. Particles less than 100 microns, which are also called "inhalable" since they can easily enter the nose and mouth

   ii. Particles less than 10 microns (PM_{10}, often labeled "fine" in Europe). These particles are also called "thoracic" since they can penetrate deep in the respiratory system

   iii. Particles less than 4 microns. These particles are often called "respirable" because they are small enough to pass completely through the respiratory system and enter the bloodstream.

   iv. Particles less than 2.5 microns ($PM_{2.5}$, labeled "fine" in the US)

   v. Particles less than 0.1 microns ($PM_{0.1}$ "ultrafine")

Secondary pollutants are not directly emitted from sources, but instead form in the atmosphere from primary pollutants (also called "precursors"). The main secondary pollutants known to cause harm in high enough concentrations as documented by Delay and Zanetti (2007) are the following:

i. NO_2 and HNO_3 formed from NO

ii. Ozone (O_3) formed from photochemical reactions of nitrogen oxides and VOC_s

iii. Sulphuric acid droplets formed from SO_2 and nitric acid droplets formed from NO_2

iv. Sulphates and nitrates aerosols (e.g. ammonium (bi) sulphate and ammonium nitrate) formed from reactions of sulphuric acid droplets and nitric acid droplets with NH_3, respectively

v. Organic aerosols formed from VOC_s in gas-to-particle reactions.

The United States Environmental Protection Agency (USEPA) has set National Air Quality Standards (NAQS) for six principal air pollutants: nitrogen oxides (expressed as NO_2), ozone, sulphur dioxide, PM, carbon monoxide (CO), and lead (Pb). Four of these pollutants (CO, Pb, NO, and SO_2) are emitted directly from a variety of sources. Ozone is not directly emitted, but is formed when nitrogen oxides (NO_x) and VOC_s react in the presence of sunlight. PM is mostly directly emitted, but $PM_{2.5}$ particles can also be added as secondary pollutants (sulphates, nitrates, and organic particules) USEPA, 2003; Delay and Zanetti, 2007). The 6 principal or "criteria" pollutants regulated by the USEPA and most countries in the world are:

vi. Total suspended particulate matter (TSPM), with additional subcategories of particles smaller than 10 um in diameter (PM_{10}) and particles smaller than 2.5micro meter in diameter ($PM_{2.5}$). PM can exist in solid or liquid form and includes smoke, dust, aerosols, metallic oxides and pollen. Source of PM include combustion, factories,

construction, demolition, agricultural activities, motor vehicles and wood burning. Inhalation of enough PM over time increases the risk of chronic respiratory disease.

vii. Sulphur dioxide (SO_2). This compound is colourless, but has a suffocating, pungent odor. The primary source of SO_2 is the combustion of sulphur-containing fuels (e.g. oil and coal). Exposure to SO_2 can cause the irritation of lung tissues and can damage health and materials.

viii. Nitrogen oxides (NO and NO_2). NO_2 is a reddish-brown gas with a sharp odor. The primary source of this gas is vehicle traffic, and it plays a role in the formation of troposphere ozone. Most of the NO_2 in cities is derived from motor vehicle exhausts. Others sources are petrol and metal refining, electricity generation from coal-fired power stations, other manufacturing and food processing industries. Large concentrations can reduce visibility and breathing raised levels of nitrogen dioxide inflames the lining of the lungs and reduces immunity to lungs infections, which results to flu, bronchitis and more frequent and chronic asthma attacks and other respiratory disease (Aeroqual, 2015).

ix. Carbon monoxide (CO). Carbon monoxide (CO) is a colourless, odourless, poisonous gas produced chiefly from the exhaust of internal combustion engines as well as other natural sources like volcanoes, wildfire and other forms of combustions (Hisashi, Sugawara, Sudos, Aoki and Nakasawa, 2009). It is also produced when fuel containing carbon are burnt where there is too little oxygen or at high temperature. It burns in air or oxygen with a blue flame and is slightly lighter than air. In the presence of an adequate supply of oxygen most carbon monoxide produced during combustion is immediately oxidized to carbon dioxide (CO_2). It is also toxic to

haemoglobic animals (including humans) when encountered in concentration above 100ppm (Prockop and Chichkova, 2007). Its inhalation reduces the amount of oxygen in the bloodstream, and high concentrations can lead to headaches, dizziness, unconsciousness and death.

x. Ozone (O_3) Tropospheric "low-level" ozone is a secondary pollutant formed when sunlight causes photochemical relations involving NO_x and VOC_s. Automobiles are the largest source of VOC_s necessary for these reactions. Ozone concentrations tend to peak in the afternoon and can cause eye irritation, aggravation of respiratory diseases and damage to plants and animals.

xi. Lead (Pb). The largest source of Pb in the atmosphere has been form leaded gasoline combustion, but with the gradual elimination worldwide of lead in gasoline, air Pb levels have decreased considerably. Other airborne sources include combustion of solid waste, coal and oil emission from iron and steel production and lead smelters and tobacco smoke. Exposure to lead can affect the blood, kidneys, and nervous, immune cardiovascular and reproductive systems (Delay and Zanetti, 2007).

2.3.4 Receptor

The impacts of air pollution constitute a major threat to human, plants/animals and the entire atmospheric system. These impacts could be felt on either short or long term basis, depending on the extent or concentration of exposures. For instance, many negative impacts have been attributed to both long-term and short-term exposures to ambient pollutants. Long-term exposure to ambient PM contributes to the initiation and progression of disease over months or years. Short-term exposure affects individuals who are particularly susceptible to the effects of PM; either because of existing chronic disease, compromised respiratory function in the

developing lungs of children or, compromised physiological function in the elderly from the effects of ageing (Brook, Rajagopalan, Pope, Brook, Bhatnagar, Diez-Roux, *et al*, 2010).

2.3.4.1 Human Receptors

Air pollution due to vehicular emission constitutes a great concern in most urban areas especially in view of the adverse health effects it has on the populace (Bilkis, Tazmin, Rabbani, Swapan and Nasiruddin, 2009). Due to complex human activities producing increased emissions, atmospheric pollution in urban areas has become a major issue in many developing countries across the world. In addition, a comparison of the prevalence of chronic bronchitis and asthma among street cleaners, a high exposure group, and cemetery workers, who acted as controls, found that exposure to vehicle pollutants in concentrations higher than WHO-recommended guidelines resulted in a significant increase in respiratory effects (Raaschou, 1995).

Many studies have documented adverse health effects associated with high concentrations of transport-related pollutants. Schwela (2000); Wargo, Wargo, Alderman and Brown (2006) their related studies reported an immune system impairment, exacerbation of asthma and chronic respiratory diseases, reduced lung function and cardiovascular diseases due to exposure to Nitrogen oxides and Sulphur oxides. Exposure to carbon-monoxide at very high concentration can result in fatigue, headaches, dizziness, loss of consciousness and even death (Schwela, 2000). Particulates are especially dangerous because they have been found to be associated with the development of lung cancer and higher rates of mortality (Schwela, 2000; Wargo *et al*., 2006). Lead is similarly dangerous as exposure to high concentration levels can cause irreversible neuro-behavioural consequences, such as decreased intelligence quotient (IQ) and attention deficits and death at high levels of poisoning (Schwela, 2000).

Furthermore, a number of epidemiological studies have similarly linked exposure to vehicle emissions over 10 years decreased lung function among tunnel officers (Evans, Webb, Homan and Ayres, 1988). According to Department of Environmental Conservation (2016) the pollutants in vehicle emissions are known to damage lung tissue, and can lead to and aggravate respiratory diseases, such as asthma.

Moreover, a significant relationship between residence proximity to high traffic roads and prevalence of asthma and cardiovascular disease in children has been documented (Schwela, 2000), in addition to a strong relationship between proximity to congested roads and respiratory morbidity in infants. There is mixed evidence for a relationship between exposure and low birth weight, preterm birth and birth defects (Sram, 2005). Clearly, the public health impacts of exposure to traffic pollution are serious and diverse. Also finding reported by the Environmental and Human Health Effects Incorporation (EHHEI) (2013), concluded that:

i. Scientific experts now believe the world faces an epidemic of illness that is exacerbated by air pollution. These illnesses include cardiovascular disease, asthma, chronic obstructive pulmonary disease, lung cancer and diabetes.

ii. Chemicals in vehicle exhaust are harmful to asthamtics. Exhaust can adversely affect lungs function (USEPA, 2012) and may promote allergic reactions and airway functions (Yang, 2000). All vehicles, especially diesel engines, emit very fine particles that deeply penetrate lungs and inflame the circulatory system, damaging cells and causing respiratory problems (Riedl and Sanchez, 2005). Even short term exposure to vehicle exhaust may harm asthmatic patients (Nordenhall, Pourazar, Ledin, Levin, Sandstrom and Adelroth, 2001). Asthamatic children are particularly sensitive to air pollution.

iii. Vehicles emit numerous carcinogenic chemicals. Diesel contains benzene,formaldehyde and butadiene are all well recognized carcinogens. EPA estimates that vehicles emissions account for as many as half of all cancers attributed to outdoor air pollution (USEPA, 2012).

However, the health effects caused by air pollutants may range from subtle biochemical and psychological changes to difficulty in breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions. These effects can result in increased medication use or increased doctor or emergency visits, more hospital admission and premature death. Individual reactions to air pollutants depend on the type of pollutant is exposed to, the degree of exposure, the individuals health status and genetics.

Furthermore, the widely accepted view about size of PM and the health effects is summarised by the following: the smaller the particle size, the further the particle can penetrate the ever smaller branches of the respiratory airways, and inhalable particles >2.5micro meter deposit primarily in the larger airways of the lung and affect respiratory health, whereas smaller particles penetrate to the alveoli and terminal bronchioles of the lung (where inhaled gases exchange with gases in the blood), where they initiate health effects of the cardiovascular system and other organs (Sandstrom and Forsberg 2008; Kelly and Fussell, 2012).

2.3.4.2 Atmospheric System

Emissions from transport sector are thought to contribute to the greenhouse effect a change in the radiation balance of the earth's energy that is expected to cause unpredictable changes in the global climate (Mark, 2001). Worldwide, transportation accounts for about 21 per cent of emissions from carbon dioxide which is the principal greenhouse gas–and this percentage is expected to have increased in the first several decades of the twenty-first century (Kean,

Harley, Little, John, and Kendall, 2000). It is believed that man-made sources of particulate matters account for about 10% of the total mass in the earth atmosphere (Villand, 2010); its effects are the biggest source of uncertainty in the future climate predictions (Piers, Ramaswamy, Artaxo Berntsen, Betts, Fahey, Haywood *et al*, 2007). This is because, it plays an important role in altering the amount of solar radiation transmitted through the Earth's atmosphere (i.e., radiative forcing). Particles, especially those containing sulphate, exert a direct effect by scattering incoming solar radiation back to space, thus providing a cooling effect, whereas, black carbon in particles absorbs solar radiation and consequently warms the atmosphere (Intergovernmental Panel on Climate Change (IPCC), (2001).

In addition, CO_2 is known to be the principal gas responsible for the "greenhouse" effect, an increase in the average temperature of the planet resulting from the trapping of solar energy, with which the increased presence of this gas in the atmosphere is associated. The more energy consumed for transportation, the more CO_2 emitted. Increases in the average temperature of the planet are believed to lead to unpredictable changes in the global climate, potentially creating, exacerbating or increasing the frequency of natural disasters (Gorham, 2002).

2.3.4.3 Plant and Animals

Emission of pollutants into the air, in addition to having an immediate, localized impact on plants and animals, contribute to regional environmental degradation. Some of these effects as highlighted by Gorham (2002) include; acidification, eutrophication, and forest and crop damage from exposure to ozone.

a. Acidification. Acidification is a reduction in the pH balance of precipitation, affecting surface freshwater bodies, forests and crops. In freshwater bodies, such as lakes and

streams, acidification can increase the concentrations of aluminium, reducing the viability of the water environment to support life. In Europe and the United States of America, this has led to the extinction of a number of species of fish and other freshwater fauna. Acid deposits from rainfall have also been implicated in forest degradation, both by directly injuring certain species of trees, such as high-elevation spruces, and through long-term changes in soil chemistry with resultant effects on agriculture, such as reduction in crop yields.

b. Eutrophication. Nitrate run-off from soil depositions can cause biological "hyperproductivity" in fresh and salt water bodies. This hyperproductivity can stimulate the development of algae, to the detriment of other flora and fauna through complex changes in the ecosystem balance. Eutrophication has traditionally been associated with sewage and fertilizers as the primary source of nitrates.

c. Ozone. Ozone can cause considerable damage to forests, wetlands and agricultural land. It has been shown to interfere with the process of photosynthesis, by which plants create and store food, creating ripple effects down the food chain and rendering many plants more susceptible to disease, insects and weather. Ozone damage in the United States through lost agricultural productivity is estimated at US$ 500 million per year.

2.4 Literature Review

2.4.1 Comparison of vehicular emission and air concentration at heavy traffic corridors.

Vehicular emissions are mainly the by-products of combustion of fuels within the vehicles engine combustion chamber and are released into the atmosphere through the tail pipe or by the fugitive evaporative release of hydrocarbons escaping from the fuel storage/ delivery

system. According to USEPA (2006) and Oak Ridge National Laboratory (2006), a number of factors affect the emission rate of pollutants from automobiles. An empirical review of studies on vehicular emission and the implications on ambient air is made to better understand the magnitude of work done in the area of vehicular emission and air pollution behaviour interplay. Tao, Shah, Wayne, Younglove, Chernich and Ayala (2006), examined the activities of heavy-duty diesel truck and their emission levels in California, USA. The researchers used a set of secondary data obtained from the California Air Resources Board (CARB) and performed data analysis of 270 Electronic Computer Modules (ECM) data sets.

The results from the analysis provided insights into engine/vehicle operation, which indicated that heavy duty diesel vehicles spend a considerable amount of time at high-speed cruise and at idle and that a smaller percentage of time is spent under transient engine/vehicle operation. It was also found that despite their relatively small numbers, heavy-duty diesel vehicles are disproportionate contributors to the emission inventory for oxides of nitrogen and particulate matter due to their high individual vehicle emissions rates, lack of engine after-treatment, and high vehicle miles travelled. It was recommended from the study that CARB should put more effort in overseeing emission compliance of all heavy-duty diesel vehicles in California so as to attain and maintain health-based air quality standards.

Shah, Kent, Miller and David (2006) analysed the emission rates of regulated pollutants from on-road heavy-duty diesel vehicles in the USA. Using the results of on-road emissions testing of 11 heavy-duty diesel vehicles (model years 1996–2000) over the Four Phase driving schedule and the urban dynamometer driving schedule (UDDS). The study found that per mile NOx emission rates for vehicle operation at low speeds, in simulated congested traffic, were three times higher per mile emissions than while cruising on the freeway.

Comparisons of NOx emission factors (EMFAC) baseline shows that the factors were within 5–40% for vehicles of various model years tested over the UDDS. A comparison of NOx emission factors for a weighted average of the ARB four phase driving schedule yielded values within 17–57% of EMFAC values. Generally, particulate matter (PM) emission rates were lower than EMFAC values. The researchers concluded that emissions from heavy-duty diesel vehicles are affected by many factors, which ranges from changes in engine technology, operating mode, fuel properties, vehicle speed and ambient conditions. In concordance to the above, Clark, Kern, Atkinson and Nine (2002) in a related study showed that NOx emissions could vary by a factor of three when measured using different chassis dynamometer test schedules. These observations also enforce the importance of scheduling a test cycle that accurately mimics real-world operations. The data comparisons showed that injection timing variances could increase NOx emissions by a factor of 2 depending on operating conditions.

Also, in a similar submission, Lim, Ayoko, Morawska, Ristovski and Jayaratne in 2007 studied the effects of fuel characteristics and engine operating conditions on the elemental composition of emissions from heavy duty diesel buses. The study utilized two types of diesel fuels – low sulphur diesel (LSD) and ultra-low sulphur diesel (ULSD) fuels with 500 ppm and 50 ppm sulphur contents respectively were used. Elements present in the tailpipe emissions such as Mg, Ca, Cr, Fe, Cu, Zn, Ti, Ni, Pb, Be, P, Se, Ti and Ge were quantified. Multivariate analyses using multi-criteria decision making methods (MCDM), principal component analysis (PCA) and partial least squares (PLS) were used to analyse the data.

The result of MCDM showed that the emissions of the pollutants were strongly influenced by the engine driving conditions while the PCA loadings plots showed that the emission factors of the elements were correlated with those of other pollutants such as particle

number, total suspended particles, CO, CO_2 and NOx. Partial least square analysis revealed that the emission factors of the elements were strongly dependent on the fuel parameters such as the fuel sulphur content, fuel density and distillation point. Strong correlations were also observed between these pollutants and the engine power or exhaust temperature. The study provided insights into the possible role of fuel sulphur content in the emission of inorganic elements from heavy duty diesel vehicles. It was concluded that the engine operating conditions strongly influence the emission rate of pollutants, and an increase in fuel consumption occurs when a vehicle is operated at higher power which leads to increase in the emission of the pollutants.

In the same vain, Chen, Huang, Jinga, Wang, Pan, Streets, *et al*, (2007) also noted that vehicle emission concentrations were largely distributed and varied significantly with factors such as speed and acceleration. Even under the same acceleration, the emission rates of CO, total hydrocarbons (THC), and NOx were found to be different, but showed a closer relationship with vehicle driving cycle and fuel type in use. The measurements showed that low-speed conditions with frequent acceleration and deceleration, particularly in congestion conditions, were the main factors that aggravated vehicle emissions and caused high emissions of CO and THC. Also, it was further explained that when vehicle starts to accelerate, the gas mixture accumulates quickly and the combustion situation deteriorates, thus, resulting in a high THC concentration, followed by a peak in the CO concentration. However, with improvement in the combustion conditions, the concentrations of THC and CO slowly decreases, while the NOx concentration increases due to the higher temperature in the exhaust gas.

Another perspective in relation to vehicular emissions and air pollution is the inspection and maintenance history of vehicles. To this effect, Pandey, Pandey and Mishra (2016), analysed tailpipe emission from petrol driven passenger cars in India. The study analysed the emission

levels of 300 different models of petrol-driven passenger cars. The tailpipe emissions along with individual vehicle-related parameters were monitored for idle and fast idle test conditions. The outcome of the study indicated that of several parameters, vehicle age and mileage were found to be the most crucial, with a possibly higher pollution from older, poorly maintained and higher mileage travelled vehicles. Also the emission of CO and HC pollutants were found to be higher from older and more mileage travelled vehicles.

Zavala, Barrera, Morante, and Molina (2013) investigated the effects of using the US-EPA MOVES 2010a model for estimating PM2.5 emission factors in the Mexican vehicle fleet. The results were compared with the PM2.5 emissions estimates in the 2005 Mexican National Emissions Inventory (MNEI). The results show that higher fractions of older vehicles tend to increase PM2.5 emission estimates using MOVES2010a compared to the 2005 MNEI estimates; however, the overall impact on PM emissions varies, depending on the vehicle population and vehicle age composition for each Mexican state fleet. These effects are primarily driven by the higher PM2.5 emission factors from the gasoline-powered vehicles and by the high fractions of older gasoline and diesel vehicles. The results also indicate that PM2.5 emission factors for Mexico were particularly sensitive to vehicle speed, ambient temperature and sulphur content, but not the relative humidity.

Similarly, Chen, Huang, Jinga, Wang, Pan, Zhao*et al.* (2007) also observed a similar occurrence in a related study on truck and reported that older trucks have higher CO emission factors but lower NOx emission factors due to poor engine combustion associated with their high usage rates and limited maintenance. The researchers recommended that further studies be conducted with a wider sample size to better understand the relationship between vehicle emission behaviour and their maintenance history.

2.4.2 Concentration of pollutants emitted by automobiles.

Air pollution due to vehicular emission remains a big concern to urban planners and governments in both developed and developing countries. The sudden rise in vehicle exhaust emissions during peak traffic hour results into extreme air pollution events at urban hotspots (Chelani, 2013; Pant, Shukla, Kohl, Chow, Watson and Harrison, 2015). This occurrence is expected to increase as per capita vehicle ownership continues to increase around the world (WHO, 2000; Abam and Unachukwu, 2009).

It is well established that CO_2 and water vapour, constitutes the main products of incomplete combustion and are emitted from vehicle exhaust (Onursal and Gautam, 1997). Whereas, the major pollutants emitted from gasoline fueled vehicles are CO, HC, NO_2 and lead (Pb) (only for leaded gasoline fuel), whereas the presence of sculpture compounds in diesel fuel results in sulphur dioxide (SO_2) and PM emissions from the exhaust diesel-fueled vehicles. Metal sulphates and sulphuric acid in the form of PM constitute 1 to 3 percent sulphur emissions from heavy-duty diesel fueled vehicles and 3 to 5 percent of sulphur emissions from light-duty diesel fueled vehicles, they also account for about 10 percent of particular matter (PM) emissions from these vehicles (Faiz, Weaver and Walsh, 1996). In addition, SO_2 may also be present in exhaust gases. The air conditioning system, tires, brakes, and other vehicles components also produce emissions.

Generally, the share of pollutants from different automobile types varies widely from region to region and city to city. According to Gorham (2002) the concentration of pollutants are depend on a number of factors, including the vehicle and fuel used and the driving conditions of a particular trip. Also the emissions are dispersed into the ambient air according to atmospheric conditions, which also influence the extent to which they react to form secondary pollutants.

Forecast by the International Energy Agency (IEA) (2010) shows that emission of carbon dioxide (CO_2) from the transport sector will increase to about 92 percent by 2020. Methane and nitrous oxide are also of concern for the transport sector, not because it is currently a large source of these greenhouse gases, but because certain technologies may be adopted into widespread use in vehicles to address local pollutant emissions (such as NOx control technologies and natural gas fuel systems) may increase emissions of these GHGs in the future. Whereas, Lvovsky (2000), opined that automobile emission accounts for about 21 per cent of greenhouse gas emissions worldwide, with this proportion expected to rise significantly across many regions of the world.

2.4.2.1 Concentration of Vehicular Emission in Developed Countries

Swelling urban population and increased volume of motorized traffic in cities have resulted in severe air pollution affecting the surrounding environment and human health. In developed countries, the national annual average ambient air pollution levels decrease due to implementation of advanced and efficient management practices (Parrish, Singh, Molina and Madronich, 2011; EEA, 2013). However, the incidence of sudden occurrence of extreme air pollution events events still persists. Moussiopoulos, Kalognomou, Douros, Samaras, Gionnouli, and Mellios (2005) reported that ambient air pollution levels at urban hotspot in twenty European cities were exceeded the specified NAQS. In the UK, out of total declared air quality management areas (AQMAs), 33% were declared due to exceedance of specified NOx and 21% were due to exceedances of the specified PM standard (Faulkner and Russell, 2010). In spite of all these efforts in place, it observed that 18% to 49% of the population in these countries is still exposed to high levels of PM concentration (EEA, 2013). According to USEPA (2012) report, megacities of North America namely Los Angeles, New York, and Mexico City showed

declining trends in some of the criteria air pollutant concentrations during the last five decades. However, at some designated non- attainment areas (NAAs), the concentrations of NOx and PM2.5 were found to be violating NAAQS (Parrish et al., 2011; USEPA, 2012).

2.4.2.2 Concentration ofVehicular Emissions in Developing Countries

In developing countries, motorization growth has been largely unchecked by environmental regulations, creating thereby creating high levels of air pollution (Han and Naeher, 2006). A vehicular emission contributes more to air pollution in developing countries, accounting for upwards of 40-80 percent of NO_2 and CO concentrations (Fu, 2001; Goyal 2006; Abbaspour and Soltaninejad, 2004). This can partly be explained by the vehicle profile. Because of economic constraints, poorly maintained and old dilapidated vehicles are being used on roads. Also older vehicles are often imported as 'tokumbo' vehicles, leading to an automobile fleet dominated by a class or vehicles known as "super emitters" which release higher concentrations of harmful pollutants in comparison to properly maintained vehicles.

In developed countries, these super emitters represent 10 percent of the vehicles on the road, yet generate 50 percent of emissions (Brunekreef, 2005). It is further compounded by the rapid urbanization of many developing countries because according to (UNFPA, 2007) the next few decades will see an unprecedented scale or urban growth in the developing world, this will be particularly notable in Africa and Asia where the urban population will double between 2000 and 2030: that is, the accumulated urban growth of these two regions during the whole span of history will be duplicated in a single generation. By 2030, the towns and cities of the developing world will make up 81 percent of urban humanity.

In the Asian subcontinent, countries like Singapore, Japan and Hong Kong, are also facing street-level air pollution problems due to an increase in the number of motorized transport

(Edesess, 2011). In developing countries, all most all mega cities are facing acute air pollution problems i.e., high levels of ambient PM and NO_2 concentrations due to rapid urbanization. In Shanghai, New Delhi, Mumbai, Guangzhou, Chongquing, Calcutta, Beijing and Bangkok, the ambient PM and NO_2 concentrations frequently violates WHO values (CAI-Asia, 2010). In Beijing, 90% of times, PM concentrations exceeded the NAQS and WHO-AQG (Zhang, Wang, Hao, Wang, Wang, Chai and Li, 2012). In Indian metropolitan cities (Delhi, Mumbai, Kolkata and Chennai), ambient PM concentrations frequently violate the NAQS as well as WHO guidelines (Guttikunda and Gurjar, 2012; Pant *et al.*, 2015). According to studies carried out by Yale University, USA, and WHO, Delhi is ranked as the "worst" polluted city based on an environmental performance index (Hsu and Zomer, 2014). It was observed that increase in vehicular activity has resulted in deterioration of urban air quality in both developed and developing countries (Ravindra, Wauters, Tyagi, Mor and Grieken, 2015).

Furthermore, Pummakarnchana, Tripathi and Dutta (2005) carried out a study in which air pollution was monitored using nanotechnology based solid state gas sensors. The study concluded that, the current air quality of Bangkok is better than a decade ago. But however, Bangkok still faces serious air pollution problems, with visible black and white smoke from truck and public bus exhaust still constituting a daily occurrence. The researchers attributed this incidence to the rapid economic and industrial growth, combined with a lack of strict implementation of air quality regulation laws. This requires the pollution control department (PCD) to adapt or extend the current PCD's air quality monitoring systems and also facilitate the problem of analysing and mentoring air pollution in Bankok area.

Going forward, Khaled-Ahmad (2012) also conducted a statistical analysis of air pollution study in Brishbane, Australia and concluded that the overall vehicular transportation

pollution situation in his study is high. The findings revealed that there is high concentration of air pollutants in Brisbane, Australia which are much related to air pollution (PM_{10}, NO_2, O_3 and SO_2) and the consequent incidence of deaths from respiratory diseases, cardiovascular diseases and cardio-respiratory diseases is correlated.

2.4.2.3 Concentration of Vehicular Emissions in Sub-Saharan Africa

Despite the risk associated with rapid urbanization, few studies focus on Sub-Saharan Africa (SSA) and there is very little data on the status of air quality and its impacts on human health. This is because air quality is not considered a priority given SSA's low level of economic development and high burden of infectious disease. In general, developing countries first focus on natural resource management, then water pollution and finally air pollution as their economies progress (Dasgupta, 2001).

Since SSA is in the early phases of economic development, air pollution is given low priority and there is little investment in understanding the scale of the problem or its control. Yet, that does not mean that air pollution is not a problem. In fact, there is reason to believe that exposure to transport-related pollutants in SSA cities may be considerably higher than in other parts of the world and because of malnutrition and high prevalence of disease the populations may be more vulnerable. In the Republic of Benin, it was reported in a study by Autrup (2006) that exposure to traffic pollutants, specifically polycyclic aromatic hydrocarbons, has led to comparatively higher levels of DNA damage in urban residents. In a similar study on motor vehicular emission conducted in Kenya by Odhiambo, Kinyua, Gatebe and Awange (2010), it was concluded in the study that traffic and other related congestions is responsible for 80-90% of gaseous pollutants emitted into the atmosphere particularly in city centres of most developing countries.

2.4.3 Emission differentials in types and concentration by automobile types/models.

In addition, studies have also established the existence of quantifiable relationship between fuel usage, types of vehicle features and composition of emissions. Researchers like Yasar, Haider, Tabinda, Kausar, and Khan in 2013, compared engine emissions from heavy, medium, and light vehicles for CNG (Compressed natural Gas), diesel, and gasoline fuels in Pakistan. Using ten samples of each category of vehicle such as bus (CNG, diesel), rickshaw (2-stroke LPG, 4-stroke CNG, 4-stroke gasoline), van (CNG, diesel, and gasoline), motorcycle (2-stroke gasoline, 4-stroke gasoline), and car (CNG, diesel, and petrol) were tested. Smoke opacity was measured in accelerating conditions, while CO, SO_2, NO, and hydrocarbon were measured in idle mode. Vehicular exhaust emissions such as SO_2, HC (ppm), NO (ppm), and CO (%) were tested through the use of Testo 350 XL. Also, smoke pump (Brigon) was used to monitor smoke opacity of vehicular exhaust emissions.

The result of the study revealed that emission of pollutants such as; CO, HC, and smoke opacity were dependent on both fuel and engine type. Petrol and CNG engines had 15 to 20 times higher CO emissions as compared to diesel engines. Smoke opacity and HC were very high for diesel vehicle engines. Reduction of HC and smoke opacity for conversion of heavy (bus) and medium (van) vehicles from diesel to CNG was almost the same, 14 and 3 times, respectively. However, this decreasing trend was almost doubled for light vehicles (cars). It was also found that under most test conditions, low NO levels were observed for gasoline engines as compared to diesel engines, and for two-stroke gasoline rickshaw NO level was almost zero. It is evident from the study that the concentration of most of the pollutants showed a significant decrease after switching of heavy, medium, and light diesel and gasoline vehicle engines to CNG fuel, which would be helpful in reducing vehicular emissions.

Faiz, Weaver and Walsh (1996) submitted that compared with four-stroke spark-ignition engines, two strokes exhibit vastly higher hydrocarbon and particulate matter emissions. Carbon monoxide emissions are comparable to four-stroke engines, while nitrogen oxide emissions are somewhat less. The major sources of hydrocarbon emissions in two strokes are the loss of unburned air-fuel mixture into the exhaust during scavenging and emissions caused by misfire or partial combustion at light loads. In a similar submission, Hesterberg, Lapin and Bunn, (2008) pointed out that auto-rickshaws, 2-strokes and un-maintained vehicles are great contributors of CO, volatile organic compounds (VOCs), HCs, non-methane HC, carbonyl compounds, and PM/smoke opacity as compared to 4-stroke engines. Hence, it is clearer to point out that automobile model and type play significant role in the types and concentrations of emissions they produce.

2.4.4. Emission differentials of automobiles by type of fuel usage.

Emissions of specific pollutants vary by vehicles and fuel types. The use of different types of fuels adds different concentrations of toxic pollutants to the environment. Based on the significant emissions of the fuel components, several vehicle fuels can be identified such as diesel, gasoline, compressed natural gas (CNG), gas to liquid (GTL), rapeseed oil methylester (RME), and dimethyl ether (DME) (Xinling and Zhen, 2009). Different fuel composition and characteristics play an important role in engine design and emissions performance. Changes in the composition and properties of gasoline and diesel fuel can affect vehicle emissions significantly, although the relationships among fuel properties, engine technologies and exhaust emissions are complex (European Automobile Manufacturers Association/European Petroleum Industry Association (ACEA/EUROPIA), 1995). Changes in one fuel characteristic may lower emissions of one pollutant but may increase those of another (for example, decreasing aromatics

content in petrol lowers CO and HC emissions but increases NOx emissions). In some instances, engines in different vehicular classes respond very differently to changes in fuel properties (e.g. increasing the cetane number in diesel fuels lowers NOx emissions for both light and heavy duty diesel engines, but not for light duty petrol engines). Also, gaseous emissions like SO_2 simply depend on the fuel and not the engine.

Emissions from exhaust pipes of automobiles are often recognisable without measurements, either by reduced visibility, adverse smell and eye irritation on most busy roads (Baumbach, Vogt, Hein, Oluwole and Ogunsola, *et al*,1995). For instance, Hameed, Bhatti, Nadeem, Haydar and Khan (2013), comparatively analysed emissions from motor vehicles using LPG, CNG and petrol as fuel in Lahore Pakistan. Flu gas analyser was used to analyse the exhaust emission levels of selected motor vehicles in idling condition, which involved recording of emission data of 31 randomly selected motor-cycles, and motor-cycle rickshaws operating on LPG and petrol, and auto-rickshaws and pickups operating on LPG, CNG and petrol. The survey samples were obtained with the assistance of traffic police. Thereafter, the emission data from vehicles using LPG was compared with the emission data of vehicles using petrol and CNG. The emission results obtained could not be compared with any international standard due to non-compatibility of measurement units.

The result of study revealed that different automobile engine types perform differently in terms of pollutants. For instance, it was found that 2-stroke and 4-stroke engines are worst in emitting CO_2 emissions, 4-stroke auto-rickshaws have higher emission of CO, 2-stroke auto-rickshaws emits more of HC, 4-stroke pickups emitted more of NO_2, 2-stroke pickups and 4-stroke auto-rickshaws emits of SO_2 and 4-stroke pickups with higher emission level of NO. It was also found that amongst the LPG and CNG vehicles, pickups are the worst polluters

followed by motorcycle rickshaws and auto-rickshaws. But, amongst the petrol vehicles, auto-rickshaws are the worst polluters followed by pickups and motorcycle rickshaws.

Whereas, 2-stroke engine vehicles generally produced more emissions as compared to 4-stroke engine vehicles due to inefficient burning of fuel, with the emissions level from 2-stroke motor vehicles also depends on the quality and quantity of mobile oil. The study recommended that the use of LPG should be banned in 2-stroke MCRs (Motor Cycle Rickshaw) since they cause relatively more pollution for carrying load than the desired level as well as that the existing 4-stroke MCRs may be allowed to use LPG as fuel but using only branded LPG kits and cylinders. Similarly, WHO (2007) reported of a growing trend in automobile-derived air pollution in Lagos due to emission from 2-stroke engines motorcycles (which have higher emissions of particulate matter and un-burnt hydrocarbons than other types of engines) and old imported vehicles (Taiwo, 2009).

Ismaila, Bolaji, Adetunji, Adekunle, Yusuf and Sanusi (2013) also conducted a research on vehicular emission of petrol and diesel engines in Ogun State Nigeria. Gaseous substances such as CO and CO_2 of both types of engines were analysed. The results was analysed using a two-sample equal variance one-tail t-test and Pearson Correlation Coefficient. The t-test result showed that there were significant differences between the data of CO for the two types of engines ($p=4.86x10-6$), for CO_2 ($p=1.77x10-14$). The CO and CO_2 emissions were consistently higher for petrol engines as compared to diesel engine vehicles. The Pearson Correlation Coefficient for age and CO of petrol engine vehicles showed that there was very low negative correlation ($r= -0.27$) and no correlation between age and CO_2 ($r=0.00$). Similarly, for diesel engine vehicles there was very low positive correlation between age and CO ($r= 0.29$) and no correlation between age and CO_2 ($r= -0.03$).

Furthermore, petrol-powered, vehicles which constitute the most common vehicle on the road emit primary pollutants such as CO, followed by much smaller emissions of VOCs and NOx, while most heavy-duty diesel vehicles such as trucks and buses that use diesel fuel emits mainly NOx, followed by smaller proportion of CO, PM_{10}, SO_2, and VOCs (Gorham, 2002). Heavy-duty diesel vehicles produce about 5 percent of total emissions from all highway vehicles, roughly proportional to their share of highway travel but small compared with the emissions of gasoline-powered passenger vehicles, which represent nearly two-thirds of total emissions from highway vehicles (FHWA, 1992). Diesel-powered vehicles, however, contribute a disproportionate share of total highway vehicle emissions of PM_{10}, SO_2 and NOx: 72, 47, and 27 percent, respectively (Nizich, McMullen, and Misenheimer, 1994).

Diesel engines are extensively used in heavy-duty vehicles for better fuel efficiency and power yield than gasoline and other engines. High levels of NO emissions from heavy-duty vehicles are caused by the characteristics of diesel engines. Diesel engines typically run at higher combustion chamber pressures and temperatures than gasoline engines, with both conditions conducive for high NO emission levels (Guensler, Sperling, and Jovanis, 1991).

PM_{10} and SO_2 emissions are also higher for heavy-duty diesel vehicles than for gasoline-powered automobiles. Catalytic converters have not been used with diesel engines because of particulates and concentrated sulphur gases in the exhaust gas, which could clog or deactivate the catalyst (Guensler, Sperling, and Jovanis, 1991). Emissions of SO_2 are also substantially higher for diesel than for gasoline engines because of the high sulphur content of diesel fuel (Conte, 1990).

Particulates in diesel exhaust originate mainly from unburned fuel and oil. However, introducing higher combustion temperatures to burn the fuel more completely and reduce

particulates leads to higher NOx emissions (Weaver and Klausmeier, 1988; Conte, 1990). The challenge facing diesel engine manufacturers is to reduce emissions of both pollutants at the same time to meet NOx and particulate standards. However, mandatory use of low sulphur or "clean" diesel fuel, which began in October 1993, should substantially reduce SO_2 emissions as well as PM-10 emissions from heavy duty, diesel powered vehicles.

Emissions from petrol cars have been dramatically reduced by the introduction of catalytic converter, which oxidize pollutants such as CO to less harmful gases such as CO_2. When compared to petrol cars without catalysts, catalyst cars have much lower CO, HC and NOx emissions, at the expense of CO_2 emissions, which increases due to the oxidation of carbon monoxide to CO_2. As a consequence of this, a catalyst car will also use slightly more fuel and become less efficient. However, despite these improvements, petroleum powered cars with catalysts still produce more CO and HC than diesel cars, although exhaust emissions of NOx and particulates are much lower than diesel cars. Whereas, diesel fuel contains no lead and emissions of the regulated pollutants (carbon monoxide, hydrocarbons and nitrogen oxides) are lower than those from petroleum cars without a catalyst (Enviropedia, 2017).

Furthermore, Hydrocarbon (HC) emissions can also be influenced by ambient temperature which varies with the period of the day and season. Very low ambient temperatures (e.g., below 20^oF) can influence emissions at ignition and cause the catalytic converters, in vehicles that have it, to cool during short stops (Utang and Peterside, 2011). Very high ambient temperatures can also have a secondary influence on exhaust emissions because engine load is increased by the use of air conditioner. Although CO concentrations are generally high in areas with heavy traffic congestion, the emissions are substantially greater in cold weather because cars need more fuel to start at cold temperatures and some emission control devices such as

oxygen sensors and catalytic converters operate less efficiently when they are cold (Gorham, 2002).

2.4.6 Perspectives on automobile emission regulations.

The growing cities, sharp increasing traffic, rapid economic development, industrialization and higher levels of energy consumption has resulted an increase of pollution load in the urban environment (UNFPA, 2007). It is also accepted that automobiles have emerged as a critical source of urban air pollution especially in the developing world (Karlsson, 2004). Realizing the gravity of the problem, steps are being taken globally by environmental regulatory experts/agencies to introduce various regulatory emission standards, for the control of environmental pollution in many parts of the world.

Noteworthy is the fact that in different continents and countries, different types of automobile emission regulatory agencies exists, For instance, countries in Europe, the United States, Asia, Middle-east and Africa have largely patterned their emissions policies commensurate to their economic status. An overview of Canadian emission regulatory framework for on-road automobiles, shows that efforts geared towards this effect was handled by the Canadian Environmental Protection Act of 1999 (CEPA, 1999), which later transferred the legislative authority for regulating emissions from on-road vehicles and engines to Transport Canada's Motor Vehicle Safety Act. The Regulations align emission standards with the U.S. federal standards and apply to light-duty vehicles (e.g., passenger cars), light-duty trucks (e.g., vans, pickup trucks, sport utility vehicles), heavy-duty vehicles (e.g., trucks and buses), heavy-duty engines and motorcycles (Environment Canada, 2013).

In the United States, emissions standards were managed by the Environmental Protection Agency (EPA). Under federal law, the state of California is allowed to promulgate more

stringent vehicle emissions standards (subject to EPA approval), and other states may choose to follow either the national or California standards. California had produced air quality standards prior to EPA, with severe air quality problems in the Los Angeles (LA) metropolitan area (USEPA 2017). LA is the country's second-largest city after New York and relies much more heavily on automobiles and has less favourable meteorological conditions than the largest and third-largest cities (New York and Chicago). Both EPA and State of California led the national efforts to reduce vehicular pollution by adopting increasingly stringent standards as early as 1970s.

In Israel, the implementation of automobile emission standards took effect from January 2012 within which vehicles which do not comply with Euro 6 emission values are not allowed to be imported or driven in Israel(International Council on Clean Transportation, 2014). A target of 95 grams per kilometre will apply from 2021. For light commercial vehicle, an emissions target of 175 g/km applies from 2017, and about 147 g/km from 2020 (International Council on Clean Transportation, 2014); which has a reduction of 16%. The EU introduced Euro 4 effective January 1, 2008, Euro 5 effective January 1, 2010 and Euro 6 effective January 1, 2014. In the United Kingdom, several local authorities have introduced Euro 4 or Euro 5 emissions standards for taxis and licensed private hire vehicles to operate in their area (European technology emission standards, 2013).

Across the Asian continent country such as China enacted its first emissions controls on automobiles in 2000, equivalent to Euro I standards. China's State Environmental Protection Administration (SEPA) upgraded emission controls again on July 1, 2004 to the Euro II standard (Xinhua, 2004). More stringent emission standard which is the National Standard III, equivalent to Euro III standards, went into effect on July 1, 2007, while Euro IV standards took effect from

2010, with Beijing being the first city in mainland China to adopt this standard the Euro IV standard in advance on January 1, 2008. According to Yang (2018) the International Council for Clean Transportation (ICCT), China adopted China 4/IV in 2012 and China 5/V in 2015. China's "airpocalypse" in 2016 generated attention andpressured the government to act on air pollution. From the transport sector, China then sought toaccelerate the adoption of 10 ppm sulphur fuel to as early as 2017. The availability of 10 ppm sulphur fuelwould be available in Beijing, Shanghai, and other polluted areas. A China V standard was subsequently required from all LDVs and HDVs beginning 2017 (Yang, 2018).

Elsewhere, in India, a Bharat state emission standard was instituted by the Government of India to regulate the output of air pollutants from internal combustion engine. The standards and the timeline for implementation were set by the Central Pollution Control Board under the Ministry of Environment and Forests. The European regulations standards (Euro II) were first introduced in the city Delhi in 2000. Subsequently, because of judicial pressure, other cities in India also complied with Euro II emission standards (Roychowdhury, 2018).In 2003, National Auto Fuel Policy was developed which mandated that all new vehicles in thecities that were on Euro II to move to Euro III emission standards in 2005, and that the rest of the countryshall move to Euro II. The policy also mandated that, by 2010, the cities then on Euro III shall follow EuroIV standards, while the rest of the country shall move to Euro III. Also in March 2017, Euro IV was introduced focusing in only 13 cities and the Supreme Court directed full transition at once for all existing and new models from 1 April 2017, anddenied transition time. Prior to 2017, in 2016, the government issued the notification for the leapfrogging directlyto Euro VI with total compliance regulations in 2020. This also mandates Euro VI emission standards formotorcycles (two-wheelers), and 10 ppm sulfur fuels from April 2018 (Roychowdhury, 2018).

In Africa, South Africa is the first country on the continent to adopt emission regulations, with the action being the enforcement of first clean fuels programme which was implemented in 2006 with the banning of lead from petrol and the reduction of sulphur levels in diesel from 3 000 parts per million (ppm) to 500ppm, along with a niche grade of 50ppm. The regulations were restricted to cover passenger cars (M1 Category) Light commercial vehicles (N1 Catedory) Heavy duty commercial vehicles and Passenger vehicles of N2, N3 and M2, M3 categories and Tractors with a mandated compression ignition (CI) engine installed (Bond and Rayner 2005).

Finally, in Nigeria, automobile emission regulation is yet to be set by the country's environmental regulation body known as the National Environmental Standards Regulation and Enforcement Agency (NESREA). However, in 2014, the Lagos State Environmental Protection Agency (LASEPA) set up a standard to regulate vehicular emission with focus on petrol and diesel engine vehicles. This effort was in response to the rise in the number of vehicular ownership with the record of over 1 million vehicular daily movement and a vehicular density of over 222 vehicles/km against country average of 11/km with a resultant impact on high incidence of air and noise pollution.

2.4.5.1 European vehicular emission limits

Among all the emission regulatory agencies in the world, European regulatory standards is the most commonly adopted standards by many countries. For instance, the G-20 countries account for 90 percent of global vehicle sales, and 17 out of the 20 members have chosen to follow the European regulatory pathway for vehicle emissions control (DieselNet, 2017). Also, a number of Asian and Latin American countries currently have Euro II, III and IV standards in force. This body defines the acceptable limits for exhaust emissions of new vehicles sold in EU and EEA (European Economic Areas) member states. The emission standards are defined in a

series of European Union directives staging the progressive introduction of increasingly stringent standards. These standards consists of six stages of increasingly stringent emission control requirements, starting with Euro 1/I in 1992, and progressing through to Euro 6/VI in 2015.

The regulation covered emission standards for both light-duty and heavy duty vehicles which are applicable to all vehicle categories all reference mass indexes. Limits for *compression ignition* (diesel) and *positive ignition*(petrol) vehicles were also specifically defined in the directives. Diesels have more stringent CO standards but are allowed higher Nox, while positive ignition vehicles (petrol) were exempted from PM standards through the Euro 4 stage. On the other hand, Euro 5/6 regulations introduce PM mass emission standards, equal to those for diesels, for positive ignition vehicles (petrol vehicles) (DieselNet, 2017).

According to European Union (1991-2015) some of the important regulatory steps in implementing emission standard for automobiles are chronologically listed as follows,

1. Euro 1: This first Europe-wide euro emission standard was introduced in July 1992 and its introduction brought about the compulsory fitment of catalytic converters on all new cars as well as the switch to unleaded petrol, with only hydrocarbons and nitrogen oxide being tested, along with particulate matter in the case of diesel engines. These standards have over the years become stricter and the limits lowered. The Euro 1 emission standards for petrol vehicles includes; CO: 2.72g/km HC + NOx: 0.97g/km, while the Euro 1 emissions standards for diesel vehicles are; CO: 2.72/gkm, HC + NOx: 0.97g/km and PM: 0.14g/km.
2. Euro 2: This standard was Implemented in 1st of January 1996 with a target to reduce the limits for carbon monoxide and the combined limit for unburned hydrocarbons and nitrogen oxide, as well as introducing different levels for petrol and diesel engines. Euro

2 emissions standards for petrol vehicles include; CO: 2.2g/km. HC + NOx: 0.5g/km, whereas, for diesel vehicles CO: 1.0g/km, HC + NOx: 0.7g/km and PM: 0.08g/km.

3. Euro 3: This standard was implemented in 1st of January 2001. It split the hydrocarbons and nitrogen oxide limits for petrol and diesel engines, as well as adding a separate nitrogen oxide limit for diesel vehicles. The warm-up period was removed from the test procedure. Euro 3 emissions standards for petrol vehicles includes; CO: 2.3g/km, HC: 0.20g/km and NOx: 0.15g/km, while the emissions standards for diesel vehicles are CO: 0.64g/km, HC + NOx: 0.56g/km, NOx: 0.50g/km and PM: 0.05g/km.
4. Euro 4: It was formulated in 1st of January 2005 and Implemented in 1st of January 2006. It further tightened emissions standards for both petrol and diesel vehicles. The petrol vehicles emission standards for principal pollutants are; CO: 1.0g/km, HC: 0.10g/km and NOx: 0.08g/km, while the standards for diesel vehicles include; CO: 0.50g/km, HC + NOx: 0.30g/km, NOx: 0.25g/km and PM: 0.025g/km.
5. Euro 5: This was formulated in 1st of September 2009, while the implementation took effect to cover all new vehicular registrations 1st of January 2011. At this stage the use of particulate filters (DPFs) for diesel vehicles was introduced along with lower limits across the board. DPFs capture 99% of all particulate matter and are fitted to every new diesel car. Cars meeting Euro 5 standards emit the equivalent of one grain of sand per kilometre driven (RAC Motoring Services, 2017). Petrol vehicle emission standards are as follows; CO: 1.0g/km, HC: 0.10g/km, NOx: 0.06g/km and PM: 0.005g/km (direct injection only), while the diesel vehicles are; CO: 0.50g/km, HC + NOx: 0.23g/km, NOx: 0.18g/km and PM: 0.005g/km.

6. Euro 6: This is the current Euro emissions standard. The approval was given in 1st of September, 2014 and the implementation for all new registrations took effect from 1st of September 2015. For diesels, the permitted level of NOx was tightened from 0.18g/km in Euro 5 to 0.08g/km. This standard focused more on diesel NOx emission which was as a direct result of studies connecting these emissions with respiratory problems (RAC Motoring Services, 2017). To meet the new targets, some vehicle manufactures introduced Selective Catalytic Reduction (SCR), in which a liquid-reductant agent is injected through a catalyst into the exhaust of a diesel vehicle. A chemical reaction converts the nitrogen oxide into harmless water and nitrogen, which are expelled through the exhaust pipe. Also an alternative method of meeting Euro 6 standards was also introduced, which is "Exhaust Gas Recirculation" (EGR), which allows a portion of the exhaust gas to be mixed with intake air to lower the burning temperature depending on the engine load or speed. (RAC Motoring Services, 2017). Euro 6 emissions standards for petrol vehicles are; CO: 1.0g/km, HC: 0.10g/km, NOx: 0.06g/km and PM: 0.005g/km (direct injection only), while the emissions standards for diesel vehicles include; CO: 0.50g/km, HC + NOx: 0.17g/km, NOx: 0.08g/km and PM: 0.005g/km.

2.4.5.1.1 EU Vehicular categorisations and emission standards

European Commission categorised vehicles as part of emission standards and other vehicle regulations. Passenger cars receive an "M" categorization, while commercial vehicles receive an "N" categorization. The EU "L"-category vehicles include all two-, three- and four-wheel vehicles such as motorcycles, mopeds, quads, and Mini-cars and the "O" categories are Trailers, Tractors, Tippers and Caterpillars etc as in Table 2.2.

Table 2.2: European Union Classification of Vehicle Types, Categories and Weight

Category	Vehicle type	Weight
Category L	Mopeds, Motorcycles, Motor Tricycles and Quadricycles	>150kg-450kg
Category M	Motor vehicles having at least four wheels and for the carriage of passengers and goods (Vans, Omni buses etc)	≤3.500kg- <5000kg
Category N	Vehicles having at least four wheels and for the carriage of passengers and goods (i.e. cars, buses, saloon etc.)	1250kg- ≤3.500kg
Category O	Trailers (including semitrailers)	>5000kg

European Parliament and Commission (2007)

European Union between 1991/2015 introduced various stages of emission standards for heavy duty vehicles. The emission standards apply to all motor vehicles with a "technically permissible maximum laden mass" over 3,500 kg, powered with diesel or petrol engines. The regulation was firstly introduced in 1992 (Euro I), followed by the introduction of Euro II regulations in 1996. These standards applied to both truck engines and urban buses, with compliance by the urban bus standards made voluntary as presentation in Table 2.3a

In 2013 Euro VI emission standards were introduced with new emission limits, comparable in stringency to the US 2010 standards which became effective in 2013. The Euro VI standards also introduced particle number (PN) emission limits and ammonia (NH3) concentration limit of 10 ppm applies to diesel and petrol engines (DieselNet, 2017).

European Union between 1991 and 2015 set different emission standards for light-duty vehicles are applicable to all vehicles category M1, M2, N1 and N2 with a reference mass not exceeding 2610 kg. EU regulations introduced different emission limits for compression ignition (diesel) and positive ignition (petrol) vehicles (Table 2.3 and 2.4)

Table 2.3: EU Emission Standards for Heavy-Duty Diesel and Gas Engines (Category O)

Stage	Date	COg/kWh	HCg/kWh	NO_xg/kWh	PMg/kWh
1991		17.3-32.6	2.7-3.7		
1996		11.2	2.4	14.4	
2000	Euro I	4.5	1.1	8	0.36
2005	Euro II	4	1.1	7	0.15
2006	Euro III	2.1	0.66	5	0.1
2009	Euro IV	1.5	0.46	3.5	0.02
2010	Euro V	1.5	0.46	2	0.02
2013	Euro VI	1.2	0.34		0.01

Source: European Union (2013)

Also, diesel vehicles have more stringent CO standards but are allowed higher NOx. Positive ignition vehicles were exempted from PM standards through the Euro 4 stage. Euro 5/6 regulations introduce PM mass emission standards, equal to those for diesels, for positive ignition vehicles with direct injection engines as presented in Table 2.5a and 2.5b.

Table 2.4: EU Emission Standards for Two and Three-Wheelers (L Categories)

Two-Wheelers	Categories	CO (g/km)	HC (g/km)	NOx (g/km)	PM (g/kg)
Euro 2 (2004.04.01)	< 150 kg	5.50	1.20	0.30	-
	≥ 150 kg	5.50	1.00	0.30	-
Euro 3 (2006.01.01)	< 150 kg	2.00	0.80	0.15	-
	≥ 150 kg	2.00	0.30	0.15	-
Three-Wheelers		**CO (g/km)**	**HC (g/km)**	**NOx (g/km)**	
Euro 2 (2003.01.01)	All Gasoline	7.00	1.50	0.40	-
	All Diesel	2.00	1.00	0.65	-
Euro 4 (2013)	Two Wheels	1.14	0.38	0.07	-
	Tricycles	1.14	0.17	0.09	-
Euro 5 (2013)	All Gasoline	0.05	0.10	0.060	0.0045
	All Diesel	0.05	0.10	0.060	0.0045

*Euro 4 emission standards for motorbikes from 2016 and mopeds from 2017; Euro 5 standards for all two- or three-wheel vehicles from 2020.

European Union (2004-2013)

Table 2.5a: EU Emission Standards for Light Commercial Vehicles (Category M/N)

Category	Stage	Date	CO g/km	HC g/km	HC+NOx g/km	NOx g/km	SO_2 ppm	PM g/km
Compression Ignition (Diesel)								
N_1, Class I ≤1305 kg	Euro 1	1994.10	2.72	-	0.97	-	-	0.14
	Euro 2 IDI	1998.01	1.0	-	0.70	-	-	0.08
	Euro 2 DI	1998.01[a]	1.0	-	0.90	-	-	0.10
	Euro 3	2000.01	0.64	-	0.56	0.50	350ppm	0.05
	Euro 4	2005.01	0.50	-	0.30	0.25	350ppm	0.025
	Euro 5a	2009.09[b]	0.50	-	0.23	0.18	≤10ppm	0.005[f]
	Euro 5b	2011.09[d]	0.50	-	0.23	0.18	≤10ppm	0.005[f]
	Euro 6	2014.09	0.50	-	0.17	0.08	≤10ppm	0.005[f]
N_1, Class II 1305-1760 kg	Euro 1	1994.10	5.17	-	1.40	-		0.19
	Euro 2 IDI	1998.01	1.25	-	1.0	-		0.12
	Euro 2 DI	1998.01[a]	1.25	-	1.30	-		0.14
	Euro 3	2001.01	0.80	-	0.72	0.65	350ppm	0.07
	Euro 4	2006.01	0.63	-	0.39	0.33	350ppm	0.04
	Euro 5a	2010.09[c]	0.63	-	0.295	0.235	≤10ppm	0.005[f]
	Euro 5b	2011.09[d]	0.63	-	0.295	0.235	≤10ppm	0.005[f]
	Euro 6	2015.09	0.63	-	0.195	0.105	≤10ppm	0.005[f]
N_1, Class III >1760 kg	Euro 1	1994.10	6.90	-	1.70	-		0.25
	Euro 2 IDI	1998.01	1.5	-	1.20	-		0.17
	Euro 2 DI	1998.01[a]	1.5	-	1.60	-		0.20
	Euro 3	2001.01	0.95	-	0.86	0.78	350ppm	0.10
	Euro 4	2006.01	0.74	-	0.46	0.39	350ppm	0.06
	Euro 5a	2010.09[c]	0.74	-	0.350	0.280	≤10ppm	0.005[f]
	Euro 5b	2011.09[d]	0.74	-	0.350	0.280	≤10ppm	0.005[f]
	Euro 6	2015.09	0.74	-	0.215	0.125	≤10ppm	0.005[f]

(a). until 1999.09.30 (after that date DI engines must meet the IDI limits)
(b). 2011.01 For all models. (c). 2012.01 for all models. (d). 2013.01 for all models
(e). Applicable only to vehicles using DI engines. (f). 0.0045 g/km using the PMP measurement procedure.

Source: European Commission (2015).

Table 2.5b: EU Emission Standards for Light Commercial Vehicles (Category M/N)

Positive Ignition (Gasoline)		Date	CO g/km	HC g/km	HC+NOx g/km	NOx g/km	SO_2 ppm	PM g/km
N_1, Class I ≤1305 kg	Euro 1	1994.10	2.72	-	0.97	-		-
	Euro 2	1998.01	2.2	-	0.50	-		-
	Euro 3	2000.01	2.3	0.20	-	0.15	50ppm	-
	Euro 4	2005.01	1.0	0.10	-	0.08	50ppm	-
	Euro 5	2009.09[b]	1.0	0.10[g]	-	0.06	≤10ppm	0.005[e,f]
	Euro 6	2014.09	1.0	0.10[g]	-	0.06	≤10ppm	0.005[e,f]
N_1, Class II 1305-1760 kg	Euro 1	1994.10	5.17	-	1.40	-		-
	Euro 2	1998.01	4.0	-	0.65	-		-
	Euro 3	2001.01	4.17	0.25	-	0.18	50ppm	-
	Euro 4	2006.01	1.81	0.13	-	0.10	50ppm	-
	Euro 5	2010.09[c]	1.81	0.13[h]	-	0.075	≤10ppm	0.005[e,f]
	Euro 6	2015.09	1.81	0.13[h]	-	0.075	≤10ppm	0.005[e,f]
N_1, Class III >1760 kg	Euro 1	1994.10	6.90	-	1.70	-		-
	Euro 2	1998.01	5.0	-	0.80	-		-
	Euro 3	2001.01	5.22	0.29	-	0.21	50ppm	-
	Euro 4	2006.01	2.27	0.16	-	0.11	50ppm	-
	Euro 5	2010.09[c]	2.27	0.16[i]	-	0.082	≤10ppm	0.005[e,f]
	Euro 6	2015.09	2.27	0.16[i]	-	0.082	≤10ppm	0.005[e,f]

(a). until 1999.09.30 (after that date DI engines must meet the IDI limits)
(b). 2011.01 For all models. (c). 2012.01 for all models. (d). 2013.01 for all models
(e). Applicable only to vehicles using DI engines. (f). 0.0045 g/km using the PMP measurement procedure.

Source: European Commission (2015)

Lastly, European Union in 2002 set emission standards aimed at reducing the level of pollutant emissions from two- and three-wheel motor vehicles by tightening the limit values for such emissions from 2003 through 2006. There were no updates to motorcycle emissions standards from 2007 and through 2012 (DieselNet, 2017). Meanwhile in 2013, the regulation was expanded to other L-categories of automobiles with the implementation dates for Euro 4 and 5 standards set. The regulation sets more stringent emission standards for hydrocarbons, carbon monoxide, nitrogen oxides (NOx) and particulate matter (PM).

2.4.5.2 Vehicular emission standards in Nigeria

Much of the government and environmental regulation agency's attentions in Nigeria has been centred on general industrial pollution and pollution in oil industries as well as from stationary sources with little reference on damages of pollution caused by mobile transportation source to air pollution (Taiwo, 2005). In 2011, the federal government considered a direct regulation on vehicular emissions known as the National Environmental Regulations (For the Control of Vehicular Emissions from Petrol and Diesel Engines) with the aim of controlling air quality. Unfortunately, till date, such a regulation is yet to be implemented and when enforced based on its basic provisions, vehicular emissions challenges would be reduced to a large extent.

In Nigeria, environmental experts have identified failure of vehicular roadworthiness scheme of the Federal Road Safety Corps (FRSC) as a leading cause of air pollution, particularly as it relates to vehicular emission (Jeremiah, 2016). The implication is the unregulated importation of second hand vehicles (super emitters) and high prevalence in the use of road unworthy vehicles in and around the roads across the country. Specifically, in Lagos State, vehicular ownership is on a steady increase which results to frequent traffic bottleneck on most of the major roads and emission of dangerous pollutants into the air. The statistics from Motor Vehicle Administration Agency and Lagos Bureau of Statistics (2013) shows that as at 1996 there were 28,644 newly registered vehicles in the state, while in 2007 and 2013 the figure rose to 187,422 and 306,982 respectively. Also, according to Lagos State Government (2016) about 240,000 vehicles plying roads in the state are not roadworthy. In realisation of the above facts as well as the potential threats of the reports, the State environmental protection agency known as LASEPA (Lagos State Environmental Protection Agency) made concerted efforts towards the

formulation of vehicular emission standards which all vehicles plying the State roads must comply with (Table 2.6).

Table 2.6: LASEPA Emission Standards for Automobile Categories

Petrol	**Class ≤1305 kg**	**>1359kg-1760kg**	**>1760kg**
COg/kwh ppm	2.3 (238.095)	4.17(431.617)	5.22(540.3727)
CH_4g/kwh ppm	0.2(35.0263)	0.25(43.7828)	0.29(50.78809)
NO_xg/kwh ppm	0.15(5.252)	0.18(6.302)	0.29(7.3529)
Diesel			
COg/kwh ppm	10.(278.4739)	4.0(1113.859)	2.1(584.796)
CH_4g/kwh ppm	0.7(349.650)	1.1(549.4505)	0.66(329.67033)
NO_xg/kwh ppm	7.0(1054.852)	7.0(1054.852)	5.0(753.466)
SO ppm	500	500	1500
PMg/kwh ppm	0.08	0.15	0.10/0.13

Source: LASEPA (2014)

2.4.6 Ambient air quality and automobile emissions.

In Nigeria much attention is given on general industrial pollution and pollution in oil industries, with little reference on dangerous impacts of mobile transportation sources on air pollution (Iyoha, 2009; Magbabeola, 2001). The situation of pollution from mobile transportation sources is on the increase due to increase in per capital vehicle ownership, thus resulting to high congestion on Nigeria city roads and increase in the concentration of pollutants in the air, which consequently increases health risk on human population.

A cursory review of previous available studies carried out on air quality assessment and transport emission reveal high level of air pollution resulting mostly from emissions from incomplete combustion from aged vehicles. Studies conducted in Kaduna and Abuja cities by Akpan and Ndoke in 1999 show higher values of CO_2 concentration in heavily congested road

traffic areas: l840ppm for Sambo Kaduna, l780ppm for Stadium round-about, Kaduna, and in Abuja, A.Y.A, junction recorded l530ppm, while Asokoro district has 1160ppm of the same pollutant.

In Minna, Ndoke and Jimo (2000) observed the maximum value of 500ppm for CO_2 in congested areas, which was still lower than WHO stipulated maximum value of 2000ppm.The maximum value for CO emission obtained was l5ppm still lower than the base line of 48ppm stipulated by WHO and 20ppm stipulated by Federal Environmental protection Agency of Nigeria (FEPA). The reason for this low emission concentration in Minna is due to low traffic and industrial activities in the city. Similarly, WHO (2016) database, report also shows that of all other cities in Nigeria (Onisha, Sokoto, Ilorin, Abuja, Bauchi, Benin City, Enugu, Warri, Lagos, Kano and Maiduguri) have PM_{10} and $PM_{2.5}$ levels that are above the standards, with Kaduna Metropolis recording the highest with 90 microgramme per cubic metre for $PM_{2.5}$ pollutant, while Onitsha and Aba recorded $PM_{2.5}$ values that are 15 to 30 times higher than the set standards.

On the other hand, Ndoke, Akpan and Kato (2006) reported that carbon doxide (CO_2) from automobile source contributes to the pollution of environment in some areas of Kaduna and Abuja in Northern Nigeria. The study sampled five census stations which were selected in each of the two towns and concluded that the CO_2 concentration is high enough to cause serious health effects and they provided a baseline study for policy makers and town planners.

A similar study was conducted by Jerome (2000), on the impacts of urban road transportation on air pollution in two major cities of the Niger Delta namely, Port Harcourt and Warri the results of the findings indicated that the concentrations of TSP (Total Suspended Particulates), NO_2, SO_2 and CO in the Niger Delta were above FEPA recommended limit.

Koku and Osuntogun, (1999) in three cities of Nigeria: Lagos, Ibadan and Ado — Ekiti all in South-west region of Nigeria. Air quality indicators namely CO. SO_2, NO, and total suspended particulates (TSP) were determined. The highest levels obtained for the air pollution indicators in Lagos were CO-233ppm at Idumota, SO_2-2.9ppm at Idumota, NO_2 2-1.5ppm at lyana—Ipaja and total particulates 852ppm at Oshodi corridor. At Ibadan, the CO and SO_2 levels at 271 and 1.44ppm were highest at Mokola round about while NO_2, at 1.0ppm was highest at Bere round about. An earlier study by Baumbach *et al*, (1995) also indicated high concentrations of aromatic hydrocarbons, CO and PM especially in areas within close proximity of corridors and industries within and around Lagos. These findings highlight the significance of other sources, such transport, to air pollution beyond that of oil and gas operations.

In Ado-Ekiti the highest level obtained were CO-3l7ppm at Oke Isha, NO_2 - 0.6ppm at Ijigbo Junction and $S0_2$ -0.8ppm at Old Garage Junction. The obtained results of CO, SO_2, NO_2, and particulate counts per minute were found by Koku, to be higher than FEPA limits. Limits set also by FEPA are CO-l0ppm, SO_2-0.0lppm and NO_2-0.04-.06ppm. A comparative study of emission figures in Lagos and the Niger Delta (Oil producing region) area has been reported (Jerome, 2000). Two major cities in the Niger Delta were considered, Port-Harcourt and Warri shows that the concentrations of TSP (Total suspended particulates), NO SO_2, and CO in Lagos and Niger Delta were above FEPA recommended limit as presented in Table 2.7.

Moen (2008) carried out a study in which ambient hourly concentrations for CO, NO_2 and SO_2 at six major intersections in Abuja were monitored during morning, low-traffic hours and during afternoon, high-traffic hours. These concentrations served as a model of exposure for traffic wardens, a high exposure group. The result showed that vehicle emissions are having a negative impact on air quality, and that traffic wardens have a high prevalence of symptoms that

are possibly related to and are exacerbated by exposure to vehicle emission. Clearly, air quality management should be a greater priority in Abuja and the effect of vehicle emissions on air quality and health should be studied further if public health is to be protected.

Table 2.7: Ambient air pollutants in Lagos and Niger Delta Area

Lagos Area pollutant	**Non-traffic urban zone**	**Traffic zone**	**Niger Delta Area Oil communities**	**Cities**	**FEPA**
TSP g/m3	31.4-746.5	72-950	92.2-348.5	396.8-583.3	250
NOx(ppm)	81-81.5	34-131.6	22.0-295.0	35-370	40-60
SO_2(ppm)	0.5-43	20-250	7.0-97.0	16-300	100
CO(ppm)	0.5-3.9	10-250	5.0-61.0	1.0-52	10
CO/NOx(ppm)	0.0-6.0	50-200	20	15-130	-

Source: Jerome, 2000.

Abam and Unachukwu (2009) reported the results of the investigation of vehicular emissions in selected areas in Calabar Nigeria. All the five monitored air pollutants when compared with AQI level (Air quality index) were in the range of CO poor to moderate and moderate to poor in different locations. SO_2^- was from very poor to poor, NO_2, from very poor to poor, PM_{10} and noise level was poor at all locations. The study concluded that transport-related pollution in Calabar is indeed significant with possible severe health consequences.

Okunola, Uzairu, Gimba and Kagbu (2012) conducted a research in Kano-Nigeria using the Crowcon gas sensor to collect emission values of various gases. It was concluded that the concentrations of the CO, H_2S, NO_2 and SO_2 measured, with few exceptions, at some sites were above the AQI stipulated by USEPA especially during the dry seasons. This implies that traffic emission within Kano metropolis is not within the safe limits. Hence, the results reveal that transport-related pollution in Kano metropolis has significant potentially hazardous health consequences.

Yahya (2013) on the other hand, evaluated the ambient air quality and hazards from vehicular emissions in urban Zaria-Nigeria using Geographic information Technology. The study focused on CO, H_2S, NO_2, SO_2 and particulate Matter (PM_{10}) and the result showed that the concentrations of CO and SO_2 in most sampled points were measured above FEPA limit, with the exemption of NO_2 which was within FEPA limit. Okelola and Okhimamhe (2013) examined the trend of level of vehicular carbon footprints emissions in Minna, Niger State, Nigeria. Gasman meters was used to analyse pollutants such as; carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), ammonia (NH_3), nitrogen dioxide (NO_2), chlorine (Cl_2) and hydrogen sulphide (H_2S). The measurements were carried out at the peak and off peak traffic times within the city due to temporal variations.

The average emission values for the peak and off-peak times were calculated and also represented with the Arc-GIS software. The results of the study established that emission levels of carbon dioxide from vehicular emissions exceeded the internationally accepted safe limits of 350 parts per million in the atmosphere. The researcher recommended the promotion of urban afforestation by tree planting especially along transport corridors as this will help to salvage the environment by absorbing CO_2 being emitted from vehicles on the roads.

Given the above, it is pertinent to set up an institutional and legislative framework for pollution control in Nigeria with the purpose of addressing the scale and nature of urban air pollution as recorded in many cities across the country. This is in-view of the fact that high population growth, mass migration to unplanned urban developments and under-regulated industrial pollution and unregulated vehicular emission levels in many large cities of Nigeria, presents clear and present threats to the environment and public health of millions (Adegoroye, 1994).

It is worthy to note that there exists pollution and general environmental Legal and regulatory frameworks in Nigeria. However, these are considered rather weak and in most cases uncertain on the statutory responsibilities and duties of the government with regard to environmental management and protection (Ogunba, 2004). For instance, in 1988, Federal Environmental Protection Agency (FEPA) Act was formulated with an attempt at coordinating a statutory and institutional response to environmental pollution (Chokor, 1993).

However, most policies of the agency were directed at regulating pollution from the oil and gas industries without adequate consideration for other sources and their impacts in densely populated areas (Adegoroye 1994; Ogunba 2004). In 2007 the National Assembly repealed the FEPA Act and replaced it with the National Environmental Standards and Regulation Enforcement Agency (NESREA) Act (The Federal Government Printer, 2007). The new agency, NESREA, was given the primary responsibility for all environmental laws, guidelines, policies and standards. Part II of the NESREA Act provided statutory enforcement powers and functions of the Agency (The Federal Government Printer, 2007). This include responsibilities for "compliance monitoring, the environmental regulations and standards on noise, air, land, seas, oceans and other water bodies other than in the oil and gas sector" (The Federal Government Printer, 2007). The corporate strategic plan document published by NESREA identified "improved air quality" as one of the major environmental priorities within its corporate vision (NESREA, 2009).

In December 2010 the agency undertook a consultation process on various National Environmental Regulations including sections on the Control of Vehicular Emissions from Petrol and Diesel Engines. The establishment of NESREA is thus seen as a progression from the previous laissez-faire approach to air quality management of previous governments. Worthy to

note, is the fact that vehicular emission regulation framework is yet to be implemented in Nigeria. However, the major emphasis has been on emissions from industries and stationary sources as they have impacts on ambient air. Hence, the FEPA guidelines for Nigerian ambient air limits for conventional pollutants as presented in Table 2.8.

Table 2.8: Ambient Air Standards in Nigeria

Pollutants	Time of Average	Limit
Particulates	Daily average values and 1 hour.	250ppm
Sulphur oxides	Daily average of hourly	0.01 ppm (26 ug/m^3)
(Sulphur dioxide)	values 1 hour	0.1 ppm (26 ug/m^3
Non-methane	Daily average of 3-	160 ug/m^3
Hydrocarbon	hourly values	
Carbon monoxide	Daily average of hourly	10 ppm (11.4 ug/m^3)
	values 8-hourly average	20 ppm (22.8 ug/m^3)
Nitrogen oxides	Daily average of hourly	0.04 ppm-0.06 ppm
(Nitrogen dioxide)	values (range)	(75.0 ug/m^3-113 ug/m^3)
Photochemical oxidant	Hourly values	0.06 ppm

FEPA (1991)

CHAPTER THREE

3.0 THE STUDY AREA AND RESEARCH METHODOLOGY

3.1 Introduction

Air quality is a product of both natural and man-made forces. This means that the quality of air in any given environment can be influenced by physical, demographic and social phenomenadominant within the environment. To this end, there is a need to understand the environment of the area under study. This chapter therefore, gives a brief discussion of the size, location, historical developments, relief, climate, soil, vegetation, population, land use activities and vehicular traffic, transportation system and socio-economic activities of the study area. The second part is the discussion on the methodology of the study.

3.2 The Study Area

3.2.1 Size and location

Lagos State is located in the south-western part of Nigeria. It lies within latitudes 6°20′ N and 6°40′N and longitude 2°40′E and 4°20′E. The state shares boundaries with Benin Republic to the West, Ogun State to the north and east and Bight of Benin of the Atlantic Ocean to the south. It has a land area of about 3,577.28sq.km out of which 22% is occupied by water (Figure 3.1) (Lagos State Ministry of Land and Survey 2013). The State has a total population of 9,113,605 (NPC, 2009). It is known to occupy the enviable position as the most commercial and industrial hob in comparison to other states in Nigeria and generates about 25% of Nigeria's gross domestic products (World Population Review, 2015). The population density of Lagos is much higher than other cities in Nigeria and while Nigeria's population density is 100 persons per square kilometer (psk) that of Lagos is about 2,400 persons/km² with annual population growth rate of between 5.0 to 5.5% (Taiwo, 2005).

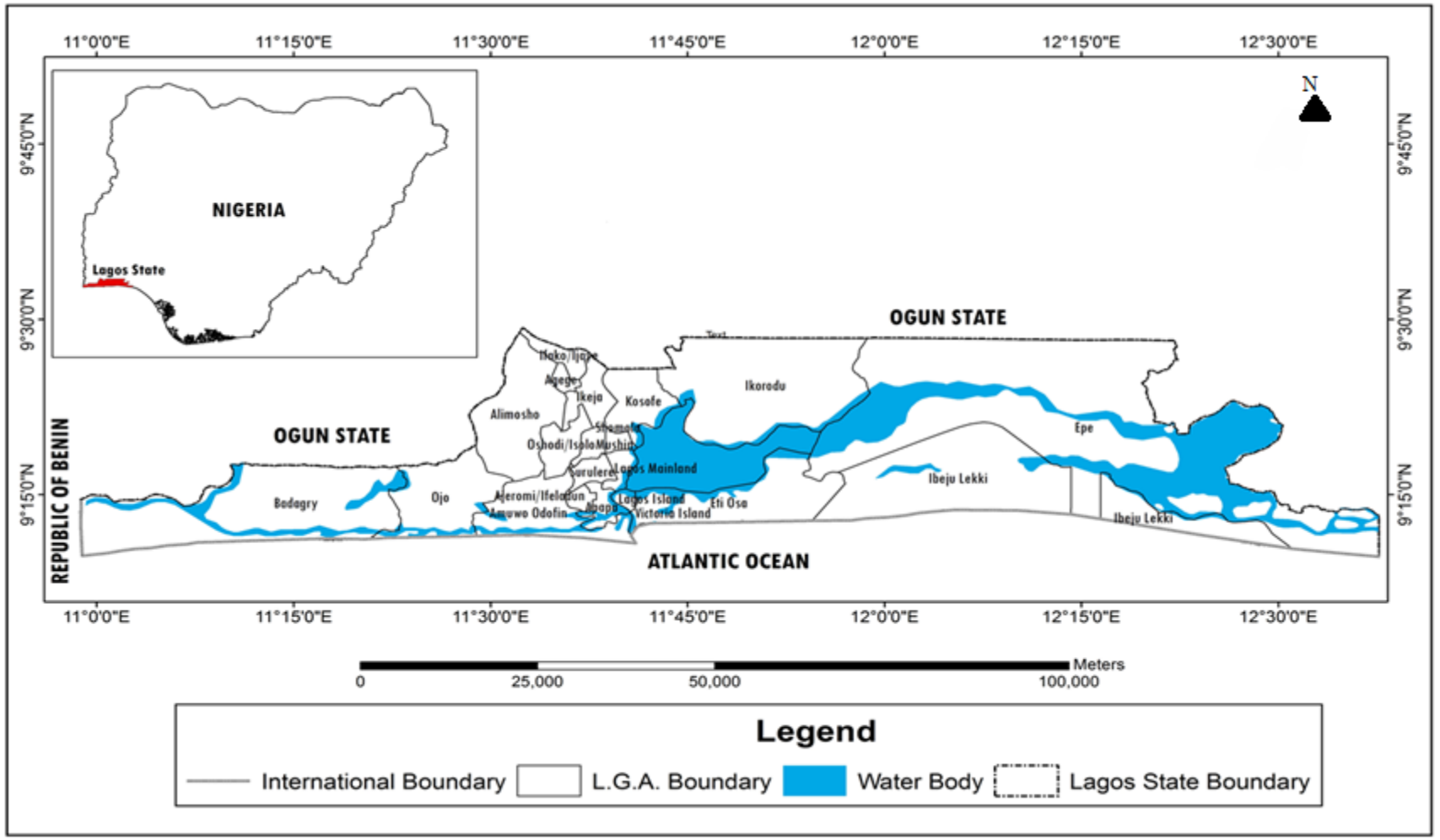


Figure 3.1 Map of Lagos State

Source: Extracted from Administrative Map of Lagos State, 2018.

3.2.2 Historical development of the area

Lagos State was created on 27 May, 1967 based on the State Creation and Transitional Provisions Decree No. 14 of 1967, which restructured Nigeria into a Federation of 12 States (National Bureau of Statistics, 2015). Before the promulgation of this Decree, Lagos city, which was the country's capital had been administered directly by the Federal Government through the Federal Ministry of Lagos Affairs. However, Ikeja, Agege, Mushin, Ikorodu, Epe and Badagry were administered by the then Western Region Government (National Bureau of Statistics, 2015). Lagos, the city, along with these other towns were captured to create the State of Lagos, with the State becoming fully recognized as a semi-autonomous administrative division on 11 April 1968. Lagos served the dual role of being the State and Federal Capital until 1976, when the capital of the State was moved to Ikeja. After the full establishment of the Federal Capital Territory, the seat of the Federal Government was also formally relocated to Abuja on 12 December 1991. Nevertheless, Lagos still remains the financial centre of the country, and also grew to become the second most populous State in the country (National Bureau of Statistics, 2015).

3.2.3 Topography and drainage

Lagos State lies entirely within the coastal plain which is characterized by sand bars, lagoons and creeks. The land on the northern fringe of the State has soils which do not rise very much above sea level. In addition, steady coastal retreat is occurring in some areas as a result of grand scale instability (Nigeria Physical Setting Lagos State, 2003).The drainage system of the State is characterized by a maze of lagoons and waterways which constitute about 22 percent of 787 sq. kms (75,755 hectares) of the State total landmass. The major water bodies are the

Lagos and Lekki Lagoons, Yewa and Ogun Rivers. Others are Ologe Lagoon, Kuramo Waters, Badagry, Five Cowries and Omu (Association of Lagos State Origin, 2015)

3.2.4 Climate

According to the Köppen's climate classification system, Lagos has a tropical wet and dry climate (Aw) that borders on a tropical monsoon climate (Am). Lagos experiences two rainy seasons, with the heaviest rains falling from April to July and a weaker rainy season in October and November. There is a brief relatively dry spell in August and September and a longer dry season from December to March. Monthly rainfall between May and July averages over 400 mm (16inch), while in August and September it is down to 200 mm (7.9inch) and in December as low as 25 mm (0.98inch). The main dry season is accompanied by harmattan wind from the Sahara Desert, which between December and early February can be quite strong. The highest maximum temperature ever recorded in Lagos was 37.3 °C (99.1 °F) and the minimum 13.9 °C (57.0 °F) as shown in Table 3.1).

In addition, the quality of air in any given area depends on many factors such as the amount and nature of emission, meteorological and climatic conditions in those areas. For instance, climatic parameters like temperature, relative humidity, wind system, sunshine and rainfall distribution greatly contributes to the concentration levels of pollutants in the air. Awange (2010) acknowledged that there is a relationship between concentration of some climatic parameters and vehicular emission. Vehicular emission is highly dependent on weather condition of a place as well as varies greatly with time and distance from the sources.

Table 3.1: Climatic Attributes of the Study Area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C	32.2	33.1	32.7	32.1	30.9	29.2	28.1	28.1	28.9	30.4	31	31.9	30.72
Avg low °C	22.3	23.5	23.8	23.6	23.1	22.6	22.1	21.7	21.9	22.3	22.6	22.4	22.66
Rainfall (mm)	14.3	42	77.1	142.4	204.8	312.2	256.9	112.4	167.1	135.8	54	19	1,538
Avg. rainy days	1.5	2.7	6.4	8.9	12.4	16.2	13.2	11.6	12.7	10.9	4.9	1.4	102.8
Mean monthly sunshine hours	164.3	169.5	173.6	180	176.7	114	99.2	108.5	114	167.4	186	192.2	1,845.4

Source: World Meteorological Organization, 2016.

3.2.5 Soils

Lagos State is endowed with very little arable land. Altogether, four soil groups are identifiable. On the western half of the coastal margin, juvenile soils on recent windborne sands occur. The rest of the coastal area towards the east is also covered by juvenile soils on fluvio-marine alluvium (mangrove swamp). A narrow and rather discontinuous band of mineral and/or organic hydromorphic soils occurs in the middle and north-eastern part of the State. The fourth group, occurring in two rather tiny and discontinuous patches along the northern limits of the State, consists dominantly of red ferrallitic soils on loose sandy sediments (Nigeria physical setting – Lagos State, 2003). Invariably, highly polluted air can result to soil contamination through acidification process. This acidification process can result to change in soil chemistry such as increase the concentration of aluminium or soil pH with resultant effects on agricultural productivities such as reduction in crop yield etc.

3.2.6 Vegetation

Two main identifiable vegetation types in Lagos State are Swamp Forest of the coastal belt and dry lowland rain forest. The swamp forests in the State are a combination of mangrove forest and coastal vegetation developed under the brackish conditions of the coastal areas and the swamp of the freshwater lagoons and estuaries (Nigeria physical setting – Lagos State, 2003). Red mangrove (sometimes attaining heights of 592m) as well as mangrove shrubs, stilt rooted trees with dense undergrowth, raffia and climbing palms are characteristic of the swamp forest zone (Nigeria physical setting Lagos State, 2003).

The dominant vegetation of the State is the tropical swamp forest consisting of fresh water and mangrove swamp forests both of which are influenced by the double rainfall pattern of the State, which makes the environment a wetland region, hence, the reference to Lagos as an

environment of aquatic splendour. The State has five forest reserves covering about 11,295 ha (113 sq. km). The pressure on vegetation is intensifying with increasing loss of biodiversity. The State has embarked on an aggressive tree-planting campaign in Metropolitan Lagos that has led to the planting of over 3 million trees in the last few years (Building Nigeria's Response to Climate Change (BNRCC), 2012). Its wetland environment is characterized by rich alluvial and terrallitic red-yellow soil, on which would be found dense luxuriant undergrowth, climbers, epiphytes and tropical hard woods (Lagos State Government, 2011). Lying to the north of the swamp forests is the lowland (tropical) rain forest zone. This zone, which stretches from the west of Ikeja through Ikorodu to an area slightly north of Epe has been modified by man. Yet this is the area of the State where such economically valuable trees as teak, *tripochiton, seletrocylon* (Arere), *bancleadiderrichil* (Opepe) and *termina* (Idigbo) are found (Nigeria physical setting-Lagos State, 2003). It is generally known that high ozone concentration in the atmosphere is known to cause considerable damage to forest, wetlands and agricultural land. Ozone is known to interfere with the process of photosynthesis by which plants create and store food, thereby exposing the plants to diseases, insect and weather forces.

3.2.7 Population

The indigenous people of Lagos are Aworis, there is, nevertheless, an admixture of other pioneer immigrant settlers collectively called Lagosians but more appropriately the Ekos. While the State is essentially a Yoruba speaking environment, it is nevertheless a socio-cultural melting pot attracting people from other tribes and socio-cultural backgrounds both within and outside Nigeria. The State is the smallest State in Nigeria in terms of landmass, yet it has the second-highest population. According to NPC (2009), the provisional figure of Lagos State population is 9,113,605. The State has a population growth rate of in the rage of 5.0 to 5.5%, with a

population density of 2,400 persons per/km^2. In the urban area of Metropolitan Lagos, the average density is 8,000 persons per square kilometer on average (Oruruo, 2014). Increase in human population lead to increase in the need for motorised form of transport services and this consequently may lead to higher number of vehicles on highways which lead to heavy traffic and higher emission concentrations.

3.2.8 Land use activities and vehicular traffic

It is well known that the majority of residential, agricultural, industrial areas and transport facilities found in the Lagos area are located on the northern and eastern portions of Lagos metropolis. Their location makes the northern and eastern sections more important than the southern section due to the fact that the movement of people, bus routes, and the location of establishments are influenced by these.

The influence this has on the traffic situation therefore, is a heavier traffic flow towards the northern and eastern section and towards the western section. As for the bus routes, most bus routes revolve around the activity areas than the residential areas. According to Olukoju (2003) there are about 500,000 cars, buses and other vehicles combined in Lagos out of which 75% are private. Landuse pattern on the Lagos metropolis to a great extent influences the traffic situation there. This is true because the routes on the northern, central and eastern portions of Lagos metropolis area which are characterised by a great concentration of residential and commercial activities as well as institutional activities have a heavier flow of traffic than those on the western portion of the State.

Cursory observation of the traffic situation at different times of the day by different modes of transport reveals an ever-increasing vehicular traffic. The three peak periods morning, afternoon and evening were observed. From the report, areas like Third Mainland Bridge,

Western Avenue, Murtala Mohammed way as well as Herbert Macauley, Agege Motor Road, Ikorodu roads are generally known to record remarkable volume of vehicular traffic that ranges between 4,225 and 62,786 depending on the day and time of the week. Most of the cars are privately owned. The number of taxis ranges between 418 and 6983 in terms of volume in the 12 hours two way traffic volume study.

The number of minibuses ranged between 7,805 and 20,375. These minibuses were owned by private individuals and used by the public. The number of Omnibuses ranged between 354 and 7492. The minibuses have a carriage capacity of between 14-18 seaters, and like the taxi they were old and rickety (Oni and Okanlawon, 2004).

Other compounded land use activity in Lagosis the uncontrollable rise in the wave of land conversion and modification of structures from their original plans. This situation is leading to chaotic traffic situation coupled with the excessive reliance on road based network that is less capable of meeting the transportation needs of Lagos. Gbadamosi and Ibrahim (2013) reported that land conversion from residential to commercial land uses in Lagos State is on the increase, especially on Victoria Island including streets such as: Ajose Adeosun, Akin Adesola, Ademola Adetokunbo, Afribank Street, Adeola Hopewell, Tiamiyu Savage, Adeola Odeku, Ahmadu Bello Way, Sanusi Fafunwa, Engineering Close, Bishop Aboyade Cole, Muri Okunola, Etim Inyang and Ozumba Nbadiwe among others have been mostly affected. The emergence of this new land use plan has impacted negatively on the facilities planned for the area as stipulated in the 1928 Town Planning Ordinance. As a result of this, the area is characterized by high traffic congestion during the peak and off peak periods causing delays and elongation of travel time, pollution and other environmental problems associated with transport externalities.

In addition, heavy commercial activities are common in most streets especially around Central Business Districts (CBDs) like Ikeja, Victoria Island and Oshodi-Agege Industrial Districts, which as expected have brought about a large urban population and consequent transportation challenges such as traffic congestion with implication for unnecessary elongation of journey time.

3.2.9 Transportation system

Lagos has one of the largest and most extensive road networks in West Africa (Lagos State Government, 2010). Consequently, road transport dominates more than 90 percent of all intra-urban movement (Oni, 2004). It also has suburban trains and some ferry services. Highways are usually congested in peak hours, partly due to the geography of the city, as well as to its explosive population growth (Economic Intelligence Unit, 2013). Lagos is also linked by many highways and bridges. As at 2001 the total length of tarred roads in Lagos State was 5,514 kilometres, with the primary road network (Federal and State roads) which link the major population centres covering about 4,921 kilometres. Majority of the primary roads are 3-lane, while some are 2-lane with width of 1.32 metres (Lagos Urban Transport Project, 2002; Oni, 2004). The major identified corridors with predominant heavy vehicular traffic in Lagos are; Lagos- Abeokuta road, the Lagos-Badagry road axis and the Ikorodu road, others are, Ikeja along express, Awolowo road ikeja, Oshodi Corridor, Dopemu corridor and Third mainland bridge (Modified from Lagos Urban Transport Project, 2002).

A new rail system which is supposed to span the length of the Badagry expressway is currently under construction. The Lagos–Ibadan Expressway and the Lagos–Abeokuta Expressway are the major controlled-access highways in the north of the city and serve as inter-State highways to Oyo State and Ogun State respectively. To the west the congested Lagos–

Badagry Expressway serves outlying towns such as Festac Town. The State is known as an important commercial centre and port and its strategic location have led to it being the end-point of three Trans-African Highway routes using Nigeria's national roads (African Development Bank/United Nations Economic Commission, 2003). The Trans–West African Coastal Highway leaves the city through the Badagry Expressway to Benin and beyond as far as Dakar and Nouakchott; the Trans-Sahara Highway to Algiers, which is close to completion, leaves the city as the Lagos-Ibadan Expressway (Itai, 2012).

Lagos State has a Bus Rapid Transit (BRT) system with the first phase completed in February 2008 (LAMATA, 2012). It is expected to operate along eight routes using specially designated bus rapid transit lanes running through the city. This route runs about 19 km (12 mi) through Ikorodu Road and Funsho Williams Avenue up to CMS. It has been estimated that the system transports about 10,000 passengers in each direction per hour during peak travel times (Perry, 2011). The system is run by two operators, NURTW Cooperative (Nigerian Union of Road Transport Workers) and Lagbus, a Lagos State Government owned Asset Management Company which contributes about 180 high capacity buses for the implementation of the first phase Mile 12 to CMS BRT Lite system.

On the other hand, there is also an extensive urban rail system, with several intercity and commuter trains running through the Lagos Terminus Railway Station. Lagos Rail Mass Transit, running through the Lagos metropolis which is currently under construction (Lagos Area Metropolitan Transit Authority, 2016; LAMATA, 2012). Also, Lagos State Ferry Services Corporation runs a few regular routes, for example between Lagos Island and the mainland, served by modern ferries and wharves. Private boats run irregular passenger services on the lagoon and on some creeks (LAMATA, 2012).

Also, the State is served by Murtala Muhammed International Airport, one of the largest and busiest airports in Africa and a top international air passenger gateway to Nigeria. The airport is located in the northern suburb of Ikeja and has Domestic and International Terminals. With 5.1 million passengers in 2008, the airport accounts for almost 50% of all air traffic in Nigeria. Murtalla Muhammad International Airport Lagos is known as the largest West African airport that serves millions of passengers (Perry, 2011). Given this, the pressure mounted on the road transport infrastructures are expected to reduce and hence lower traffic related pollution.

3.2.10 Socio-Economic activities

Lagos State is the nation's economic nerve centre with over 2,000 industries. Estimate of about 65% of the country's commercial activities are carried out in the State hence, contributing a significant portion of the entire country's GDP (Lagos State Chamber of Commerce and Industries, 2004). Most commercial and financial business activities are carried out in the central business districtsituated on the island, with most of the country's commercial banks, financial institutions, and major corporations mostly have their headquarters situated. Lagos is also the major Information Communications and Telecommunications (ICT) hub of West Africa and potentially, the biggest ICT market in the continent. It has one of the highest standards of living in Nigeria and in Africa (*Ogunlesi, 2014*).

The volume of commerce and industrial activities in Lagos State accounts for over 20% of the earnings in the Value Added Tax (VAT) of the entire Federation. This sector is growing rapidly, putting a great deal of pressure on the State and Local Governments to provide basic infrastructure. Hence traffic congestion has become a daily phenomenon in most parts of the State.

3.3 Methodology

3.3.1 Reconnaissance survey

Before embarking on this research, a reconnaissance survey was carried out for a period of Two (2) weeks (October 23 - November 4, 2015). During this visit an observationof the traffic situations in the study area was made. Also, consultations were made with relevant personnel and agencies responsible for environmental regulations Lagos State Environmental Protection Agency (LASEPA) and Lagos State Traffic Management Authority (LASTMA) for updates on environmental and traffic related issues, as well as a visit to the State chapter of FRSC (VIS Unit) for assistance in the data collection processes. The survey helped to determine the sampling points to be used as well as the techniques to be employed in data collections and analysis. Lastly, this exercise also enabled the researcher to obtain the geo-coordinates of sampling points.

3.3.2 Data collection instruments and uses

3.3.2.1 Primary datacollection instruments

These instruments used in the study include:

i. Handheld GPS(Garmin 76S):For geographic coordinates of the sampling points

ii. Testo 350XL:For analysing automobile emission concentrations for emission levels of CO, HC, CO_2, and Particulate Matter PM_{10}

iii. Aeroqual Multi gas sensor:For analysing air sample of concentration levels for 5 major gaseous pollutants such as; CO, NOx, SO_2, HC and CO_2 and Particulate Matter such as- $PM_{10 \text{ and } 2.5}$

iv. Manual counting of the automobile statistics at the sample points

v. Samsung Camera: To take photographs of automobile traffic flow at various sampling points.

3.3.2.2 Secondary type of data

This includes information from published and unpublished documents/publications on emissions and air quality standards from both international agencies like USEPA, Euro2 as well as the national agencies such as NESREA, Ministries of Transport, State Chapter of Budget and Economic Planning among others, for sample size selection of the sampled automobiles as well as the review of related literature.

3.3.3 Hardware

i. Handheld GPS (Garmin 76S)
ii. Testo 350XLEmissions Analyser
iii. Crowcon (Gasman) Multi Gas Remote Sensor
iv. Digital Camera Samsung Digital Camera 11.4Mega Pixel
v. Portable petrol generator (Tiger)

3.3.4 Software

i. Microsoft Excel 2007 and SPSS Statistical Packages for Social Sciences (Version 19) were used for statistical analysis.

3.3.5 Experimental design

3.3.5.1 Exhaust emission study

Exhaust emission study required extensive planning, preparations and coordination with traffic officials and security agencies. The first step was to understand the fleet of automobile

types, models, maker/manufacturer, fuel use types, vehicular size and weight as well as an understanding of the operational modes of the fleets.

3.3.5.1.1 Data collection procedures

This includes the discussion of details the instrumentation and other important additional accessories used in data collection processes.

i. *Instrumentation:* Exhaust emissions were measured using a standard Testo 350XL unit with four sensors for CO_2, CO, HC and NO gases. The instrument was setup to provide emission analysis output on a 1-second interval. In order to facilitate efficient data logging, the instrument was connected to the computer and data download was performed on a real-time basis. Plate 1 and 2 shows the Testo 350XL connected to the computer system displaying the measured pollutant concentrations.



Plate 1: Equipment on-screen display of measured pollutants



Plate 2: Computer Display of Emission Concentration measuring Process

ii *Automobile Selection and Sampling Process:* The emission data collection for the sampled automobiles was conducted between February 4th -23rd, 2017. In order to collect maximum data within a short span of time, avoid the obstruction of traffic flow and ensure reasonable compliance of drivers, the Lagos State vehicle inspection officers were involved. The specific categories of vehicles outlined for the study as presented in Table 3.3 and 3.3 were stopped and their emission samples analysed.

iii *Exhaust Pipe Attachment:* Testo 350 XL sensor pipe was inserted inside the vehicular exhaust which was wide enough to allow the probes to pass through while the vehicle was on idle mode. The test is done between 3-4 minutes within which the result is displayed on the screen of the analyser. Thereafter, theprobe pipe is removed while the reading is recorded and downloaded into the computer system.

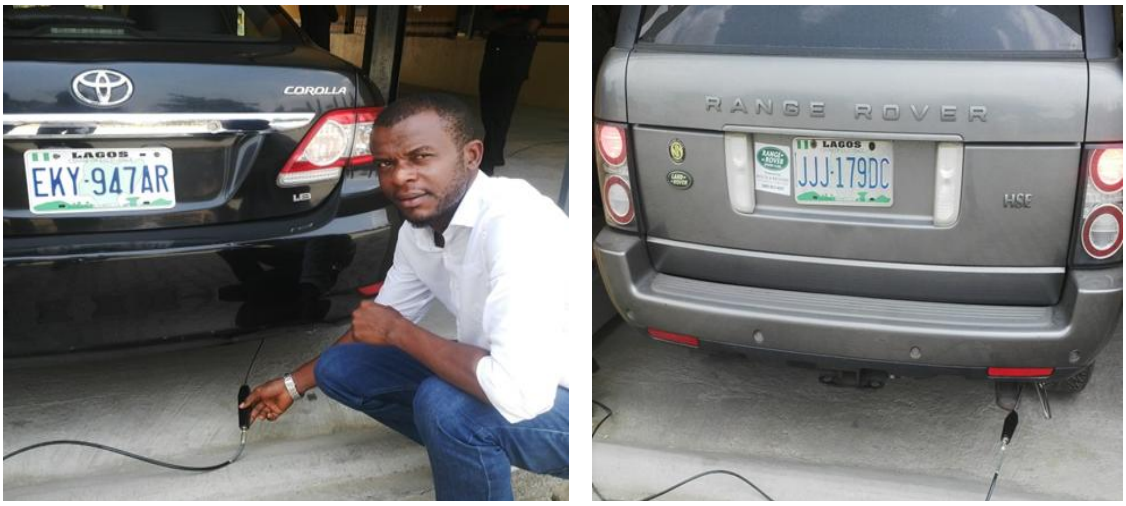


Plate 3: Emission Testing on Toyota Camry and Range Rover Car

iiv *Exhaust pipe Testing Procedures:* The emission data were collected on Idling testing procedure: Idle testing refers to the emission testing cycle in which the bus in the idling mode is connected to an emission analyser pipe which is attached to a computer from where the reading is displayed. Thereafter, a list of pollutants to be monitored is then generated and prepared for data-logging. Emission monitoring instrumentation was connected to the sampling probes that were setup at the tailpipe/exhaust. Both sets of instruments were started simultaneously for easy comparison of the data. The bus was then started in the desired idling mode (fast or normal idle) and the engine and emission characteristics were monitored for at least 3-5 minutes period as in Plate 3 and plate 11 as appendix.

3.3.5.2 Air quality study

3.3.5.2.1 Data collection procedures

This includes the processes, instrumentation and other additional accessories used in data collection processes.

i. *Sampling Points coordinates:* This was obtained using a handheld GPS (Garmin 76S). The sampled road corridors were purposively selected at locations far away from interference of other emission sources such as residential or industrial stationary emission sources.

ii. *Ambient Air Analysis*: Gaseus pollutant levels of Air Quality such as CO, NO, SO_2, HC and $CO_2$was obtained with use of Aeroqual automated multi gas sensor which was rented from Walden Oiltech Services Limited (WOSL). It is a unique, portable and an internationally acceptable multi-gas sensor for detection of gaseous pollutants in the air, while the Particulate Matters ($PM_{10\ and}$ $PM_{2.5}$) were measured through the use of a PM Analyser.

iii. *Time frame for data collection*: Ambient air data was collected from six (6) different sampling points (road corridors) known to be most frequently congested at peak hours of the day compared to road corridorsin the State. The data collections were carried out concurrently for a period of one week that is Monday to Sunday 27th February to 2nd March 2017 as found in Figure 3.2. The samples were collected at a categorised schedules as follows:

   i. 6:30am – 9:30am Morning peak hours

   ii. 12.30pm – 3:30pm off-peak hours

   iii. 4:30pm – 7:30pm evening peak hours

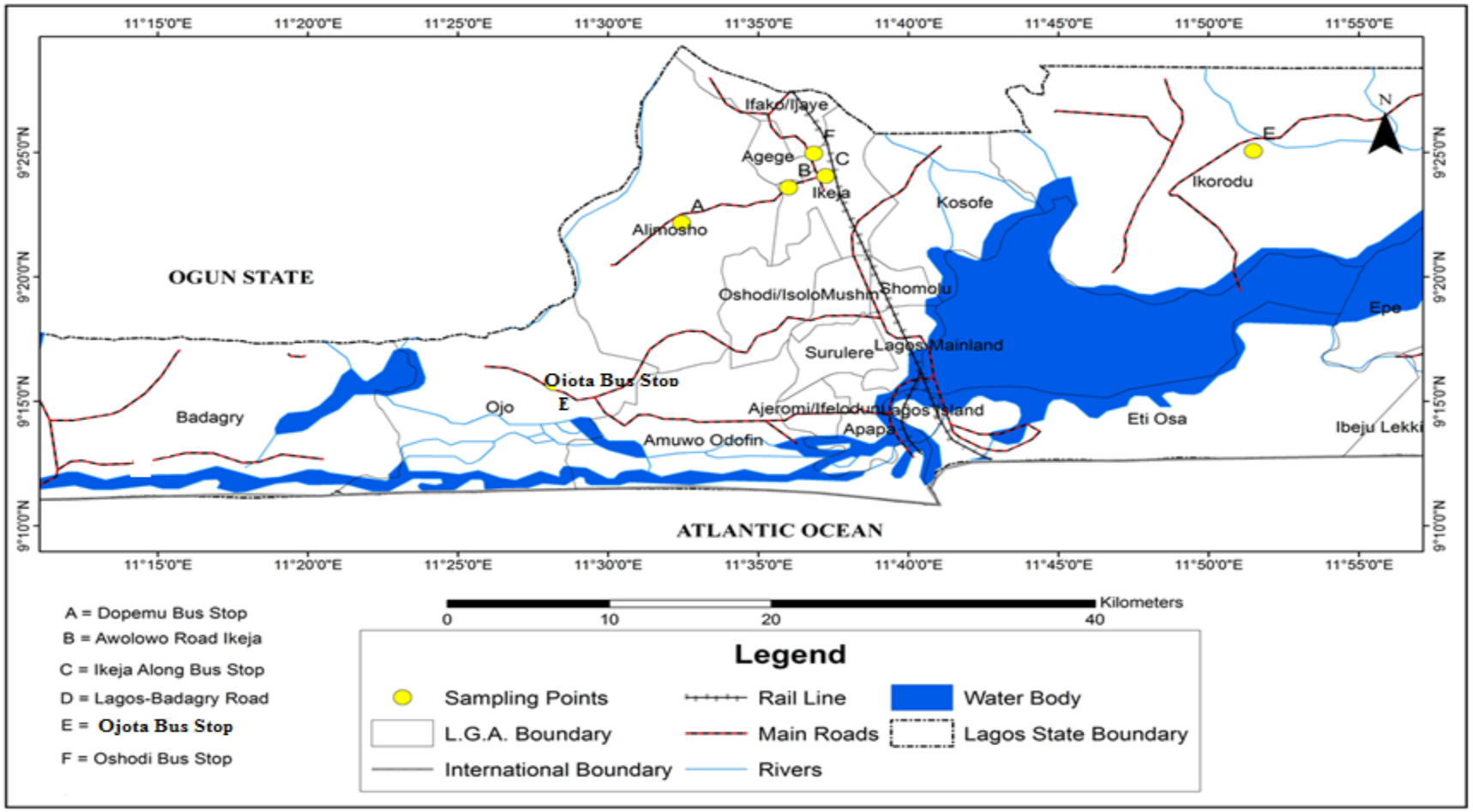


Fig. 3.2 Lagos State showing the sampling points

Source: Extracted from Administrative Map of Lagos State, 2018.



Plate 4: (Left-Right) Morning Ambient Air Measurement and Vehicular Counts at Ikeja Awolowo and Ikeja along Corridors

iv. *Motor vehicle counts:* Statistics of the automobile movements at each of the road corridors were recorded using manual counting. The counting was done within the space of 20 minutes within which the reading to obtain valid data especially when analysing for particulate matter sampling was possible. This was done concurrently with the ambient air analysis at some stipulated intervals of time as in plate 3 and 4 as well as plate 5-10 in appendix.

v. *Atmospheric Temperature and Humidity:* These variables were obtained from the particulate matter sensor which also has the capability of analysing temperature and relative humidity simultaneously with the particulate matter output. This information was used to analyze the influence of atmospheric temperature and humidity on ambient air quality along the selected traffic corridors.

vi. *Photographs.* The photographs of automobile traffic flow at various sampling points were obtained from the sample points with Samsung Digital Camera (11.4Mega Pixel) and shows as plates (Plate 3, 4, 5-10) to support explanations and discussions.

3.3.6 Sampling design and automobile data collection

In order to select the specific automobiles to be sampled, statistics of registered automobiles by types in the Statebetween 1996 to 2013 was obtained from the State Ministry of Budget and Economic Planning. The total number of the registered automobiles in Lagos State was calculated as 3,016,095 (Lagos State Ministry of Budget and Economic Planning, 2014). The sample size of 400 was generated using Yamene (1976) formula for sample size selection which states thus;

$$\frac{N}{1+N\,(e)^2} \quad - \quad - \quad - \quad - \quad - \quad - \quad 3.1$$

Where N = number of population under study, e = proportion of population given as (0.05%) (Error margin)

There are various types of automobiles from the data obtained from the State ministry, and emission level is assumed to differ by types of automobiles and type of natural gas used. Therefore, to ensure a proportional representation the automobiles by types and numbers, Yamene (1976) formula for determining the proportion of population to be sampled for each type of automobiles was used.

$$\frac{n\times 400}{N} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad 3.2$$

where n = Number of each type of automobiles

N = total number of selected types of automobiles

Using the above two formulas, the sample size and proportion of automobile samples by types were selected for emission analysis as presented in Table 3.2.

Table 3.2: Number of Registered Automobiles by Type from 1996 - 2013 in Lagos State and Selected Sample Size

Type of Automobiles	Total Number of Auto	Total Samples of Auto
Car	2175776	289
Truck (Heavy Duty Vehicles)	110,737	15
Minibus	231,453	30
Omnibus	8,219	1
Motor Cycle (Okada)	470,494	62
Tri-Cycle (KEKE NAPEP)	19,416	3
Total	**3,016095**	**400**

Source: Modified from Lagos State Ministry of Budget and Economic Planning (2014)

Lastly, to select the samples of automobiles to be tested, purposive sampling technique was used to identify the automobiles (vehicles, tricycles and motor cycles) with Lagos State registration numbers and with the assistance of personnel from the State VIO (Vehicle Inspection Officials) for sampling. This was done until the targeted numbers of automobiles are attained. While, the automobile emission levels was analysed with the use of Testo Emission Analyser.

Due to stiff resistance from drivers of specific target types of automobiles as well as general lack of cooperation from other drivers despite the involvement of vehicle inspection officers and traffic management officers. A total of 312 automobiles were analysed for specific pollutants of interest as shown in Table 3.3. The emission testing and data collection were conducted between 10am and 4pm on weekdays and 11am to 5pm during weekends.

Table 3.3: Number and Types of Automobiles Sampled

Automobiles Types	**Sampled Number**
Car	140
Trucks	2
Mini Bus	140
Omni bus	12
Motorcycle	14
Tri-cycle	4
Total	**312**

Source: Field Compilation

3.3.8 Analysis procedures

Various procedures were used to process, understand, collate and model the collected data. Tools such as Microsoft Excel, Microsoft Access and SPSS were used to develop inventories and analyse the data. All analyses were carried out at a 0.05 significance level.

3.3.8.1 Method of data analysis

Objective 1: To examine the concentrations of CO, CO_2, HC, and NOpollutants emitted by automobiles in Lagos State,the data was subjected to a descriptive analysis to show the possible mean variation in the contribution types of sampled automobiles to air pollution.

Objective 2: To compare the types of substances emitted from the automobile with those found in the air along the sample points.

i. PearsonProduct Moment Correlation Analysis was carried out using the Statistical Package for Social Science (SPSS), at 0.05significance level.

$$r=\frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2(Y-\bar{Y})^2}} \quad - \quad - \quad - \quad - \quad - \quad - \quad 3.3$$

where

r= Correlation coefficient

X= Automobile emitted pollutant concentration value

Y= Ambient air pollutant concentration value

$\bar{X}$= Mean automobile emitted pollutant concentration value

$\bar{Y}$= Mean ambient air pollutant concentration value

Objective 3: To examine the differences in types and emission levels of CO, CO_2,NO and HCby automobile types in the study area. Testo 350XL automobile emission analyser was used to

analyse the types and levels of emitted pollutants. One way ANOVA analysis was used to test for a possible differential in emission levels by types of automobile.

Objective 4: To compare emission levels of CO, CO_2, HC, and NO from diesel and petrol powered automobiles in the study area. This was achieved by summing the mean emission levels of sampled automobiles based on the types of fuel usage.

Objective 5: To compare the compliance levels of automobile emission with the Euro III and LASEPA emission standard which is the commonly used automobile emission standard in many countries of the world.

Objective 6: To assess the air quality concentrations of CO, CO_2, NO,SO_2 HC, $PM_{10 \text{ and } 2.5}$ along heavy automobile traffic corridors in the study area. The emission values obtained through the use of remote sensed multi gas analyser were computed and displayed on histogram/bar charts.

i. Hypothesis I, (Ho_1): T test was used to test for possible differentials in automobile emission levels on CO, CO_2, NO and HCin the study area with the internationally recommended standards.

$$t_{exp} = \frac{|\overline{X}_A - \overline{X}_B|}{S_{AB}\sqrt{\frac{1}{n_A} + \frac{1}{n_B}}} \quad - - - - - - \quad 3.4$$

where;

t_{exp}= Calculated 't'

$\overline{X_A}$ = Mean value of ambient air pollutants levels

$\overline{X_B}$= Mean value of NESREA standards

S_{AB}= Pooled Standard Deviation of sample 'A' (ambient air pollutants levels) and 'B' (NESREA standards)

ii. To test for Ho_2: A Pearson Product Moment Correlation Analysis was used to analyse the relationship between the ambient air concentration levels of CO, CO_2, NO,SO_2 HC, PM_{10} and $PM_{2.5}$ with the traffic volume.

$$r=\frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2(Y-\bar{Y})^2}} \quad - \quad - \quad - \quad - \quad - \quad - \quad 3.5$$

where;

r= Correlation coefficient

X= Ambient air pollutant concentration value

Y= Traffic volume

$\bar{X}$= Mean ambient air pollutant concentration value

$\bar{Y}$= Mean Traffic volume

iii. To test for Ho_3: T-test analysis was used to test the differences between the air quality samples with FEPA standards.

$$t_{exp} = \frac{|\bar{X}_A - \bar{X}_B|}{S_{AB}\sqrt{\frac{1}{n_A}+\frac{1}{n_B}}} \quad - \quad - \quad - \quad - \quad - \quad 3.6$$

where:

t_{exp}= Calculated 't'

$\overline{X_A}$ = Mean value of automobile pollutants levels

$\overline{X_B}$= Mean value of LASEPA/EURO III standards

S_{AB}= Pooled Standard Deviation of sample 'A' (automobile pollutants levels) and 'B' (LASEPA/EURO III standards)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

1.1 Introduction

This chapter presents the statistical analysis and interpretations of the results according to the stated objectives. The results are presented in the order of the stated objectives. Advanced statistical techniques were employed in the chapter to further deepen the understanding of the focal points of the study.

4.2 Comparison between Ambient Air and Automobile Emitted Pollutants at Sample Locations

Table 4.1 shows the result of ambient air and automobile emitted pollutants analysed at the sample locations in the study area. The result shows that the same types of pollutants Carbon monoxide (CO), Carbon dioxide (CO_2), Hydrocarbon (HC) and Nitric oxide (NO) detected in the air along the traffic locations (sampled locations) were also detected from the sampled automobiles.

Table 4.1: Detected Ambient Air and Automobile Emitted Pollutants

Ambient air pollutants		**Automobile Emitted pollutants**	
Pollutants	**Status**	**Pollutants**	**Status**
CO	Detected	CO	Detected
CO_2	Detected	CO_2	Detected
HC	Detected	HC	Detected
NO	Detected	NO	Detected

Source: Field Survey (2017)

It is clear from Table 4.1 that emission from automobiles is solely responsible for ambient air pollution along the heavy traffic corridors in the study area. This conclusion is drawn because the selected sampled locations were purposively selected far away from the interference of other sources of emissions such as residential or industrial stationary engines sources. The finding from this study is in tandem with the reports by USEPA, (1994), Lvovsky (2000) and Awange (2010) that automobile emission is a key factor in the deteriorating urban environment, constituting up to 80-90% of pollutants emitted into the atmosphere particularly in many city centres across the world.

4.2.1 Relationships between automobile emission and ambient air quality

Table 4.2 shows the result of correlation analysis between automobile emission and ambient air quality. The result shows that there is a strong statistical relationship between V1 and V2 variables (automobile emission and ambient air CO_2 pollutant). This is indicated with r=0.365; p value 0.000. This implies that increase or decrease in the emission concentration of CO_2 from automobiles will result to increase or decrease in the concentration of the pollutants in the air along the sampled locations.

In addition, it also means that there is a direct relationship between CO_2 emission from automobile and ambient air pollution in the study area. This finding is in agreement with the report by IEA (2006) that road transport sector contributes a major share towards total CO_2emission.It also concurs with the studies conducted in Kaduna and Abuja city centres (Akpan and Ndoke, 1999) and at Minna in Niger State (Ndoke and Jimoh, 2000) which reported higher concentration of CO_2in heavily congested road corridors in their respective study areas.

Table 4.2: Correlation Matrix on Automobile Emission and Air Quality Relationships

Variables	Values	V1	V2	V3	V4	V5	V6	V7	V8
V1	r-value								
	p-value								
V2	r-value	**.365***							
	p-value	**.000**							
V3	r Value	.236**	-.241**						
	p-value	.000	.007						
V4	r Value	.216*	.190*	**-.086**					
	p-value	.015	.033	**.341**					
V5	rvalue	-.256**	-.072	-.011	-.056				
	p-value	.000	.426	.844	.531				
V6	r-value	.266**	.610**	-.225*	.038	**-.107**			
	p-value	.003	.000	.011	.676	**.231**			
V7	r-value	.299**	.134	.673**	.117	-.026	.018		
	p-value	.000	.134	.000	.194	.650	.839		
V8	r-value	.023	.104	.084	-.157	.014	.179*	**-.073**	
	p-value	.796	.245	.348	.079	.880	.044	**.414**	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Source: Field Survey (2017)

KEY
V1 = Automobile emission CO_2
V2 = Ambient air CO_2
V3 = Automobile emission CO
V4 = Ambient air CO
V5 = Automobile emission HC
V6 = Ambient air HC
V7 = Automobile emission NO
V8 = Ambient air NO

On the other hand, V3 and V4 variables (Automobile emission CO and Ambient air CO) reveal a very low negative coefficient value (r) of -0.086 and p-value of 0.341 probability levels, which is an indication that decrease in the concentration of CO pollutant from automobiles in the study area will impact positively in reducing the concentration of CO in the ambient air. This invariably means that to ensure CO pollutant safe air in the study area, efforts should be channelled towards regulating CO emission from automobiles.

Similarly, V5 and V6 variables (Automobile emission HC and Ambient air HC) also reveal a negative coefficient value (r) of -0.107 and p-value of 0.231 significancelevels, which means that there is a low negative correlation between automobile emission levels of HC and ambient air concentration of HC. In addition, V7 and V8 variables (Automobile emission NO and Ambient air NO) reveal a negative coefficient value (r) of -0.073 and p-value of 0.414 significant levels, which also means that there is a low negative correlation between automobile emission levels of NO and ambient air concentration of the same pollutant.

The result on negative correlations between automobile emission levels of CO, HC and NO and ambient air pollutant concentration of the same pollutants is an indication improvement in the emission levels of CO, HC and NO will guarantee safer CO, HC and NOon the air in the study area. This can only be achieved through improved traffic flow, regular engine maintenance among other emission factors. This statement is further justified with the submission by Campbell (2006) who noted in his study that by repairing the 10% worst emitters as identified by idle simpletesting from his study is expected to reduce on-road petrol fleet CO and HC emissions somewhere in the order of 10% and reduce NO emissions much lesser than that.

4.2 Automobile Emission Concentrations

Table 4.3shows that the average emission concentrations of CO and CO_2 are higher on Trucks and Omni-buses which accounted for a mean value of 575ppmand 585.7ppmvalues respectively, with an emission meandifferenceof 10.7ppm. Mini-buses and Motor-cycles have the least mean emission concentration of 1.9ppm and 2.0ppm respectively.

Trucks and Omni-buses (diesel engines) have higher mean emission concentration for CO_2which ranges from 15ppm and 14.2ppm respectively, compared with emission concentration of the same pollutant from motor-cycles and Tri-cycles which accounted for the least with mean

emission concentration of 3.4ppm and 2.9ppmrespectively. This finding is contrary to the observation by Wilson *et al* (2008) that diesel engines are generally more efficient than petrol engines (they have a higher compression ratio, and diesel fuel also contains more energy per unit volume), and they produce lower levels of CO and CO_2 emissions per kilometre travelled.

The possible reason for the finding can be adduced to inadequate maintenance of the heavy duty automobiles. Whereas, the lower emission of CO_2 from petrol engine automobiles as indicated in the study may be attributed to the presence of catalytic converter in most petrol vehicles which oxidizes the pollutant.

Tri-cycles have the highest mean concentration of HC emissions with 4808.5ppm, followed by Motor cycles with mean value of 3079.4ppm. On the other hand, Omni Buses with mean value of 418ppm recorded the lowest emission of HC. Moreso, the mean emission concentration of NO is higher on omni buses with 980.0ppm, followed by the emission concentration from Omni bus with mean value of 745.8ppm. Meanwhile, motorcycles accounted for the least with 15.0ppm on types of automobile emission concentration for nitrogen oxide. The cause of higher hydrocarbon emissions from both Tri-cycles and motor-cycles to the report by Faiz, Weaver and Walsh (1996) who submitted that compared with four-stroke spark-ignition engines, two strokes exhibit vastly higher hydrocarbon and particulate matter emissions, with the major sources of hydrocarbon emissions in two strokes being the loss of unburned air-fuel mixture via the exhaust during scavenging and emissions caused by misfire or partial combustion at light loads.

Table 4.3 Mean average of CO, CO_2 HC and NO Emissions by different Automobile Types

Automobile Type	Pollutants	N	Mean	Std. Deviation
Car	CO_2	140	9.674	4.3802
	CO	140	2.990	2.7438
	HC	140	434.664	594.1928
	NO	140	90.136	96.0327
Trucks	CO_2	2	15.410	.5657
	CO	2	575.200	105.7832
	HC	2	417.850	66.6802
	NO	2	980.010	14.1421
Mini Bus	CO_2	140	11.540	2.7896
	CO	140	1.878	2.2591
	HC	140	504.936	659.0654
	NO	140	165.349	146.4758
Omni bus	CO_2	12	14.208	3.8366
	CO	12	585.692	238.3553
	HC	12	507.000	248.8356
	NO	12	745.768	164.3273
Motorcycle	CO_2	14	3.368	1.3632
	CO	14	2.041	1.4983
	HC	14	3079E3	3270.5023
	NO	14	15.048	2.5969
Tri-cycle	CO_2	4	2.922	.5956
	CO	4	2.290	1.4333
	HC	4	4808E3	5026.2729
	NO	4	220.290	151.1661

Source: Field Survey (2017)

Also, the finding of higher emission of NO from Trucks and Omni-buses (Heavy duty vehicles) is not surprising, this is because, according to Guensler, Sperling, and Jovanis, (1991) heavy duty/diesel engines typically run at higher combustion chamber pressures and temperatures than lower/gasoline engines, with both conditions conducive for high NO emission levels.

4.3 Emission Differentials from Automobile Types

Table 4.4is a presentation of test for emission differentials of pollutants from various sampled automobiles using single time factor analysis of variance (ANOVA) at 0.05 statistically level of significance.The results show that emission concentration from the sampled automobiles differs significantly from different categories of automobiles. This is indicated where the mean differences in Carbon dioxide concentration between different types of automobiles (F21.692 at 0.000) is statistically significant.

Table 4.4 ANOVA Result of Emission Concentration Differentials from Automobiles

Variables		Sum of Squares	Df	Mean Square	F	Sig.
CO_2	Between Groups	1395.059	5	279.012	21.692	.000
	Within Groups	3935.992	306	12.863		
	Total	5331.051	311			
CO	Between Groups	4526188.087	5	905237.617	434.223	.000
	Within Groups	637927.195	306	2084.729		
	Total	5164115.281	311			
HC	Between Groups	1.616E8	5	3.232E7	30.429	.000
	Within Groups	3.250E8	306	1062023.871		
	Total	4.866E8	311			
NO	Between Groups	6443537.004	5	1288707.401	85.171	.000
	Within Groups	4630043.804	306	15130.862		
	Total	1.107E7	311			

Source: Field Survey (2017)

Also, the result of CO emission concentration from automobiles differs significantly by automobiles. This is shown where the mean difference in Carbon monoxide concentration between different automobiles reveals F434.223 at 0.000. The result for HC and NO emission concentration from different sampled automobiles showsF30.429 at 0.000 and F85.171 at 0.000

respectively are statistically significant. These results are clear indications that there are concentration variability in CO_2, CO, HC and NO pollutants emitted from different automobiles. This finding is however not surprising as this is due to various factors which include the automobile engine make ups (large, medium or small), fuel composition, and frequency of maintenance amongst others.

This finding can be justified with the study by Guensler, Sperling, and Jovanis (1991) which affirmed that high levels of NO emissions from heavy-duty vehicles are caused by the characteristics of diesel engines, that is, diesel engines operate at higher combustion chamber pressures and temperatures than gasoline engines, with both conditions conducive for high NO emission levels. This is in consonance with the submission by Conte (1990), that emissions of SO_2 are substantially higher for diesel than for gasoline engines because of the high sulphur content of diesel fuel, whereas, diesel fuel contains no lead, unlike the petrol engines therefore emissions of the regulated pollutants (carbon monoxide, hydrocarbons and nitrogen oxides) are lower than those from petroleum cars.

4.3.1 Comparison of mean concentration of nitric oxide emission from automobiles

Multiple comparisons of the mean concentrations ofNO from different automobiles were made between each other,to shed more light on the differential levels between them. Table 4.5 shows that emission of nitrogen oxide from cars differs statistically with trucks, mini-buses and Omni-buses (at 0.05 level), except for motorcycles and tricycles with p-values of .450 and .501. This can be likened to the use of petrol which is common in cars, motorcycles and tricycles, unlike trucks, omni-buses which use diesel to power their engines, hence the non-variation in the concentration of nitrogen oxide emissions.

Table 4.5 Multiple Comparison of Emission differentials of NO from Automobiles

Automobile Class		Mean Difference	Std. Error	Sig Level.
Car	Trucks	-889.8740*	87.5986	.000
	Mini Bus	-75.2135*	14.7022	.000
	Omni bus	-655.6323*	36.9998	.000
	Motorcycle	75.0881	34.4798	.450
	Tricycle	-130.1540	62.3762	.501
Trucks	Car	889.8740*	87.5986	.000
	Mini Bus	814.6605*	87.5986	.000
	Omni bus	234.2417	93.9486	.289
	Motorcycle	964.9621*	92.9850	.000
	Tricycle	759.7200*	106.5277	.000
Mini Bus	Car	75.2135*	14.7022	.000
	Truck	-814.6605*	87.5986	.000
	Omni bus	-580.4188*	36.9998	.000
	Motorcycle	150.3016*	34.4798	.002
	Tricycle	-54.9405	62.3762	.978
Omni bus	Car	655.6323*	36.9998	.000
	Truck	-234.2417	93.9486	.289
	Mini-bus	580.4188*	36.9998	.000
	Motorcycle	730.7205*	48.3909	.000
	Tricycle	525.4783*	71.0185	.000
Motorcycle	Car	-75.0881	34.4798	.450
	Truck	-964.9621*	92.9850	.000
	Mini-bus	-150.3016*	34.4798	.002
	Omni-bus	-730.7205*	48.3909	.000
	Tricycle	-205.2421	69.7387	.127
Tricycle	Car	130.1540	62.3762	.501
	Truck	-759.7200*	106.5277	.000
	Mini-bus	54.9405	62.3762	.978
	Omni-bus	-525.4783*	71.0185	.000
	Motorcycle	205.2421	69.7387	.127

*. The mean difference is significant at the 0.05 level.

Source: Field Survey (2017)

NO emission concentration from trucks on the other hand, differs significantly between different types of sampled automobiles at 0.05 significance levels, exceptfor Omni-bus. This finding is as expected because, both types of automobiles use diesel to power their engines as

well as operate on higher combustion chamber pressures and temperature compared to the other types of automobiles.

Surprisingly, Table 4.5 also reveals that NO emission concentration from mini-buses have strong statistical difference with emission from other types of sampled automobiles at 0.05 significance levels, except with tricycles with p-value of .978. This result may be relatable to the bad conditions of most commercially used automobiles in the study area, which are often times referred to as super emitters. This assertion is further supported by the submission of Oni and Okanlawon (2004) which described commercially used automobiles in Lagos State especially the buses as old and rickety.

4.3.2 Comparison of mean concentration of hydrocarbon emission from automobiles

Table 4.6 shows the mean concentration differentials of hydrocarbon emissions from different sampled automobiles in the study area. The result indicates that there exists strong statistical difference between hydrocarbon emissions in cars and motorcycles and tricycles at 0.05 significance level, whereas, there is no statistical difference in the emission of the same pollutant between cars and trucks, mini-bus and Omni-buses with p-vales of 1.000, .997 and 1.000.The similarity in the emission of HC pollutants between cars, motorcycles and tricycles is unexpected especially in cars. This is because HC emissions in two or three stroke engines are caused by misfire or partial combustion at light loads as submitted by Hesterberg, Lapin and Bunn, (2008). However, the reason for the similarity in the emission of hydrocarbon pollutant between cars, and that of motorcycles and tricycles can be likened to the usage of air conditions in cars which increases the engine loads, hence, makes it favourable for higher emission of hydrocarbon pollutants.

Table 4.6 Multiple Comparison of Emission differentials of HC from Automobiles

Automobile Types		Mean Difference	Std. Error	Sig Level
Car	Trucks	16.8137	733.8922	1.000
	Mini Bus	-70.2720	123.1737	.997
	Omni-bus	-72.3363	309.9804	1.000
	Motorcycle	-2644.7649*	288.8680	.000
	Tricycle	-4373.8363*	522.5819	.000
Trucks	Car	-16.8137	733.8922	1.000
	Mini Bus	-87.0857	733.8922	1.000
	Omni-bus	-89.1500	787.0921	1.000
	Motorcycle	-2661.5786*	779.0191	.042
	Tricycle	-4390.6500*	892.4785	.000
Mini Bus	Car	70.2720	123.1737	.997
	Trucks	87.0857	733.8922	1.000
	Omni-bus	-2.0643	309.9804	1.000
	Motorcycle	-2574.4929*	288.8680	.000
	Tricycle	-4303.5643*	522.5819	.000
Omni-bus	Car	72.3363	309.9804	1.000
	Trucks	89.1500	787.0921	1.000
	Mini Bus	2.0643	309.9804	1.000
	Motorcycle	-2572.4286*	405.4144	.000
	Tricycle	-4301.5000*	594.9857	.000
Motorcycle	Car	2644.7649*	288.8680	.000
	Trucks	2661.5786*	779.0191	.042
	Mini Bus	2574.4929*	288.8680	.000
	Omni-bus	2572.4286*	405.4144	.000
	Tricycle	-1729.0714	584.2643	.123
Tricycle	Car	4373.8363*	522.5819	.000
	Trucks	4390.6500*	892.4785	.000
	Mini Bus	4303.5643*	522.5819	.000
	Omni-bus	4301.5000*	594.9857	.000
	Motorcycle	1729.0714	584.2643	.123

*. The mean difference is significant at the 0.05 level.

Source: Field Survey (2017)

Further multiple comparisons of the difference in hydrocarbon pollutantsemission concentration between trucks and the other sampled types of automobiles also reveal that there exists strong statistical difference between the emission concentration of hydrocarbon pollutant

in trucks, motorcycles and tricycles at 0.05 significance levels. Conversely, the emission concentration of hydrocarbon pollutants in trucks does not differ statistically between cars, mini-buses and omni-buses which show p-vales of 1.000 each.

The comparison of tricycle emission concentration of hydrocarbon pollutant with other types of sampled automobiles in Table 4.6 also indicates that there exist strong statistical differences between tricycles and cars, trucks, mini-buses and omni-buses at 0.05 significance levels, except with motorcycles which show p-value of 0.123. This finding maybe linked to be as a result of partial combustion of petrol powered engines which is usually very common in both motorcycles and tricycles at light loads.

4.3.3 Comparison of mean concentration of CO emission from automobiles

Table 4.7 represents the result of analysis on a multiple comparison of emission concentration of carbon monoxide pollutant with other types of sampled automobiles in the study area. The result on the emission differentials of carbon monoxide between different categories of automobiles (cars, trucks and omni-buses) shows strong statistical difference at 0.05 significant levels, whereas, the emission concentrations from cars, mini-buses, motorcycles and tricycles do not differ statistically with p-values of 1.000 each for mini-buses, motorcycles and tricycles respectively. This result is expected beacuse omni-buses and trucks are powered with diesel, unlike cars. Hence, the emission differentials between cars, trucks and omni-buses are expected as the use of additives such as lubricants, antirust agents, antioxidants, pre-ignition preventers and anti-knock agents in petrol products as well as the addition of aromatic hydrocarbons in petrol to aid refining help to reduce carbon monoxide emission in petrol powered automobiles.

Table 4.7 Multiple Comparison of Emission differentials of CO from Automobiles

Automobile Types		Mean Difference	Std. Error	Sig Level
Car	Trucks	-572.2100*	32.5155	.000
	Mini Bus	1.1118	5.4573	1.000
	Omni-bus	-582.7017*	13.7338	.000
	Motorcycle	.9486	12.7984	1.000
	Tricycle	.7000	23.1533	1.000
Trucks	Car	572.2100*	32.5155	.000
	Mini Bus	573.3218*	32.5155	.000
	Omni-bus	-10.4917	34.8725	1.000
	Motorcycle	573.1586*	34.5148	.000
	Tricycle	572.9100*	39.5417	.000
Mini Bus	Car	-1.1118	5.4573	1.000
	Trucks	-573.3218*	32.5155	.000
	Omni-bus	-583.8135*	13.7338	.000
	Motorcycle	-.1632	12.7984	1.000
	Tricycle	-.4118	23.1533	1.000
Omni-bus	Car	582.7017*	13.7338	.000
	Trucks	10.4917	34.8725	1.000
	Mini Bus	583.8135*	13.7338	.000
	Motorcycle	583.6502*	17.9621	.000
	Tricycle	583.4017*	26.3611	.000
Motorcycle	Car	-.9486	12.7984	1.000
	Trucks	-573.1586*	34.5148	.000
	Mini Bus	.1632	12.7984	1.000
	Omni-bus	-583.6502*	17.9621	.000
	Tricycle	-.2486	25.8861	1.000
Tricycle	Car	-.7000	23.1533	1.000
	Trucks	-572.9100*	39.5417	.000
	Mini Bus	.4118	23.1533	1.000
	Omni-bus	-583.4017*	26.3611	.000
	Motorcycle	.2486	25.8861	1.000

*. The mean difference is significant at the 0.05 level.

Source: Field Survey (2017)

In addition, emission concentration of carbon monoxide from trucks differs statistically with cars, mini-bus, motorcycles and tricycles at 0.05 significant levels, whereas the emission concentration of the same pollutant (CO) from trucks does not differ with omni-buses, which

reveals a p-value of 1.000. This is as expected because both trucks and omni-buses are diesel powered with diesel fuel and due to the high sulphur content of diesel fuel CO, SO and PM emissions are higher compare to petrol powered vehicles (Conte, 1990).

4.3.4 Comparison of mean concentration of CO_2emission from automobiles

Table 4.8 reveals an analysis of differentials in emission concentration of carbon dioxide from different sampled automobiles. The comparison of carbon dioxide emission concentration differentials between cars and trucks shows that there is no statistical difference in the emission concentration of the pollutant (CO) both types of automobiles with p-value of 0.413. On the other hand, a comparison on car emission of carbon dioxide concentration with mini-buses, omni-buses, motorcycles and tricycles shows strong statistical differences at 0.05 significant levels.

This finding can be justified with the report from Guensler, Sperling, and Jovanis(1991); Enviropedia (2017) of a dramatic reduction of CO_2pollutant emission from petrol cars due to the introduction of catalytic converters, a product, which helps to reduce the emission of dangerous pollutants from exhaust pipes of petroleum powered vehicles, which are also mostly not being used with diesel engines because of particulates and concentrated sulphur gases in the exhaust, which could clog or deactivate the catalyst.

Table 4.8: Multiple Comparison of Emission differentials of CO_2 from Automobiles

Automobile Types		Mean Difference	Std. Error	Sig.
Car	Trucks	-5.7356	2.5541	.413
	Mini Bus	-1.8655*	.4287	.002
	Bus/Lorries	-4.5331*	1.0788	.004
	Motorbyke	6.3065*	1.0053	.000
	Keke	6.7519*	1.8187	.019
Trucks	Car	5.7356	2.5541	.413
	Mini Bus	3.8701	2.5541	.806
	Bus/Lorries	1.2025	2.7392	.999
	Motorbyke	12.0421*	2.7111	.002
	Keke	12.4875*	3.1060	.007
Mini Bus	Car	1.8655*	.4287	.002
	Trucks	-3.8701	2.5541	.806
	Bus/Lorries	-2.6676	1.0788	.298
	Motorbyke	8.1720*	1.0053	.000
	Keke	8.6174*	1.8187	.001
Bus/Lorries	Car	4.5331*	1.0788	.004
	Trucks	-1.2025	2.7392	.999
	Mini Bus	2.6676	1.0788	.298
	Motorbyke	10.8396*	1.4109	.000
	Keke	11.2850*	2.0706	.000
Motorbyke	Car	-6.3065*	1.0053	.000
	Trucks	-12.0421*	2.7111	.002
	Mini Bus	-8.1720*	1.0053	.000
	Bus/Lorries	-10.8396*	1.4109	.000
	Keke	.4454	2.0333	1.000
Keke	Car	-6.7519*	1.8187	.019
	Trucks	-12.4875*	3.1060	.007
	Mini Bus	-8.6174*	1.8187	.001
	Bus/Lorries	-11.2850*	2.0706	.000
	Motorbyke	-.4454	2.0333	1.000

*. The mean difference is significant at the 0.05 level.

Source: Field Survey (2017)

The result also shows the existence of strong statistical differences in the emission concentration of carbon dioxide between motorcycles and cars, trucks, mini-buses, omni-buses at

0.05 significant intervals, except between tricycles with p-value of 1.000. This finding can be attributed to loss from unburned air-fuel mixture into the exhaust during partial combustion at light loads in small engine automobiles such as tricycles and motorcycles.

4.3.5 Concentration of HC and NO by automobile models

Figure 4.1shows the distribution of automobile models and their average emission concentrations for HC and NO pollutants. From the presentations, it shows that the average emission concentration of hydrocarbon pollutants (HC) is higher on Jincheng model of tri-cycle with 9200ppm, followed by Nipon model of tricycle with 8781ppm. The least emission concentration of NOpollutant is found in Chevrolet car with 9.1ppm. This finding is in agreement with the submission in a study by Hesterberg, Lapin and Bunn (2008) where it was postulated that auto-rickshaws (Tricycles), 2-strokes (Motorcycles) and un-maintained vehicles are great contributors of HCs, non-methane HC, and carbonyl compounds as compared to 4-stroke engines.

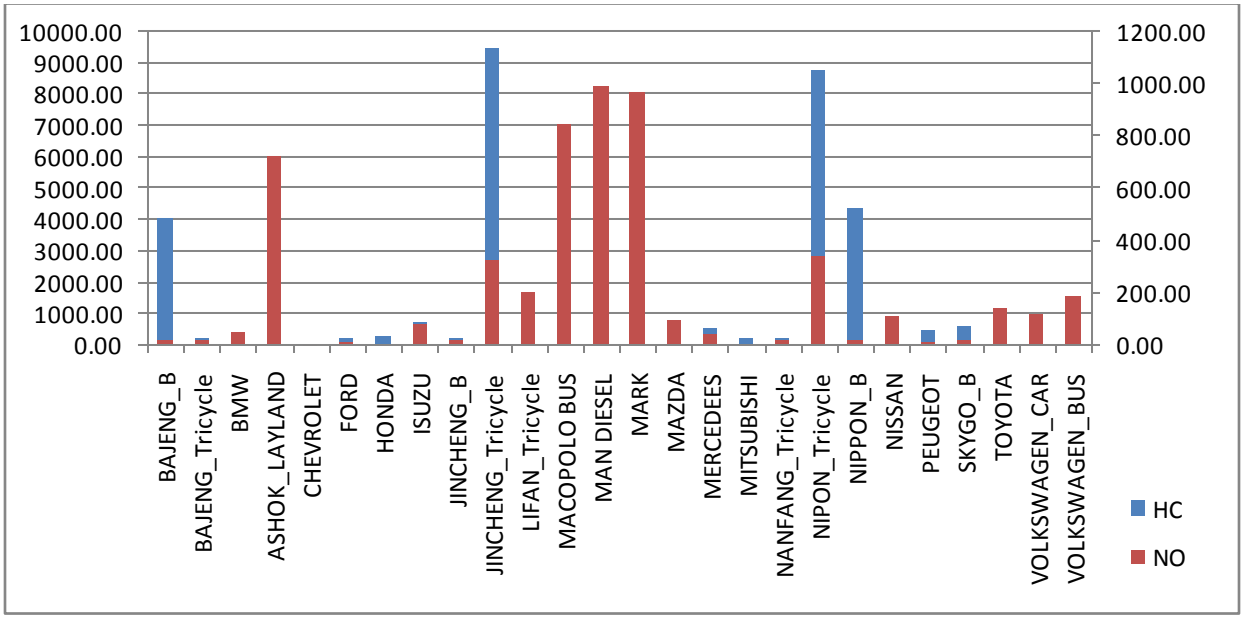


Figure 4.1: Emission Concentration of HC and NO Pollutants across Automobile Models

Source: Field Survey (2017)

On the other hand, Man Diesel truck, has the highest emission concentration of NO with an average concentration of 990.01ppm, followed by Mark trucks, Macopolo and Ashok Layland omni-buses with concentration values of 970.01ppm, 850.07ppm, 724.91ppm respectively. Also the least emission concentration of NO pollutant is recorded on Chevrolet and Mitsubishi cars with 1.54ppm and 4.79ppm respectively. This is finding is expected because diesel and large engine automobiles are known to emit mostly NO pollutants than petrol engines due to the engine and fuel characteristics of such automobiles.

4.3.6 Concentration of CO and CO_2 by automobile models

Figure 4.2 reveal that Man diesel T^m truck with 650ppm dominated other models of automobiles on the emission of carbon dioxide (CO) pollutant, followed by Macopolo $T^m$of omni-buses with 611.79ppm emission concentration for the same pollutant.

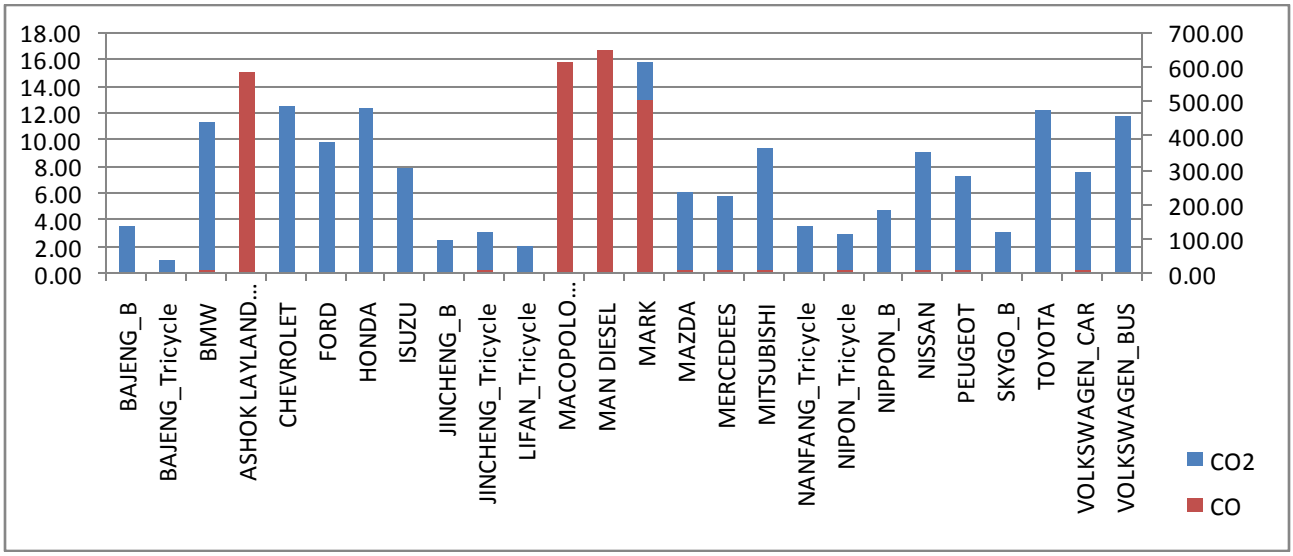


Figure 4.2: Average Concentration of CO and CO_2 on Different Automobile Models

Source: Field Survey (2017)

The study also reveals that Mark truck T^m has the highest emission concentration of Carbon dioxide with an average of 15.81ppm, followed closely by Ashok Layland T^m omni-bus

with an average concentration of 14.37ppm, whereas, Bajeng T[m]of tricycle recorded the least concentration of the same pollutant with an average concentration level of 1.02ppm.The dominance of CO and CO_2 emission concentrations from diesel engine automobiles can also be attributed to combination of factors which includes, fuel characteristics, engine design, air temperature, engine loads amongst others, which differs from petrol engines automobiles. This view is further elaborated in the submission by European Automobile Manufacturers Association/European Petroleum Industry Association (1995) that different fuel composition and characteristics play an important role in engine design and emissions performance, although the relationships among fuel properties, engine technologies and exhaust emissions are complex, but changes in one fuel characteristic may lower emissions of one certain pollutant and may increase those of another (for example, decreasing aromatics content in petrol lowers CO and HC emissions but increases NOx emissions).

4.4 Emission Levels and Automobile Fuel TypesUsage

Figure 4.3 shows the emission concentration from diesel and petrol engine automobiles. The presentation shows that petrol vehicles constitute the highest emitter of Hydrocarbon pollutants with an average estimated level of 997.92ppm, whereas, the concentration of Hydrocarbon emission from diesel engines constitute 779.23ppm.

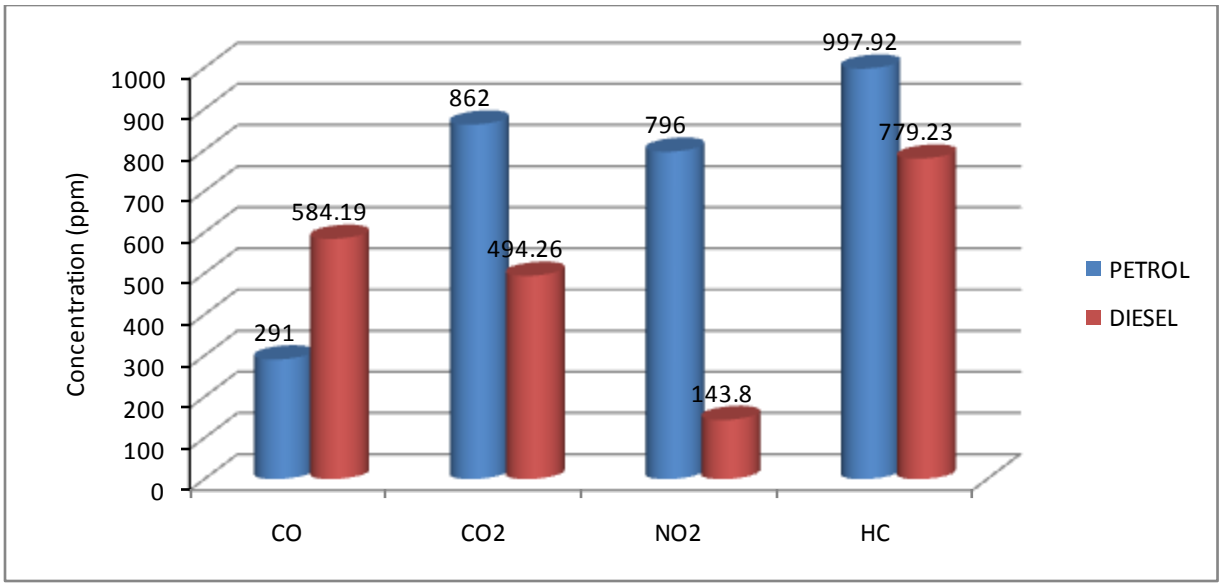


Figure 4.3: Emission Concentration Differentials of Petrol and Diesel Engines

Source: Field Survey, 2017

Also petrol engine automobiles have higher emission concentration of CO_2 and NO pollutants that ranges from 862ppm and 796ppm respectively, compared with diesel engines with a concentration of 494.3ppm and 143.8ppm respectively. On the contrary, the concentration of CO pollutant is higher on diesel engine automobiles which amounted for 584.19ppm, while the concentration from petrol engine is in the range of 291ppm. Thehigherconcentration of pollutants such as HC, CO_2 and NOfrom petrol engine automobiles may not be far-fetched, as it can be justified with the report by Enviropedia (2017) that diesel fuel contains no lead, hence the emissions of regulated pollutants (Hydrocarbons and Nitrogen oxides) are lower than those from petrol cars.

4.5 Automobile Emission and Regulation Standards

4.5.1 Truck emissions and regulation standards

Figure 4.4 shows the differentials in average concentration of heavy truck gaseous pollutant emission and LASEP/EURO III standards. The result shows that an average heavy

truck in the study area emits higher concentration of hydrocarbon pollutant than the set limits and less emission of CO and NO.

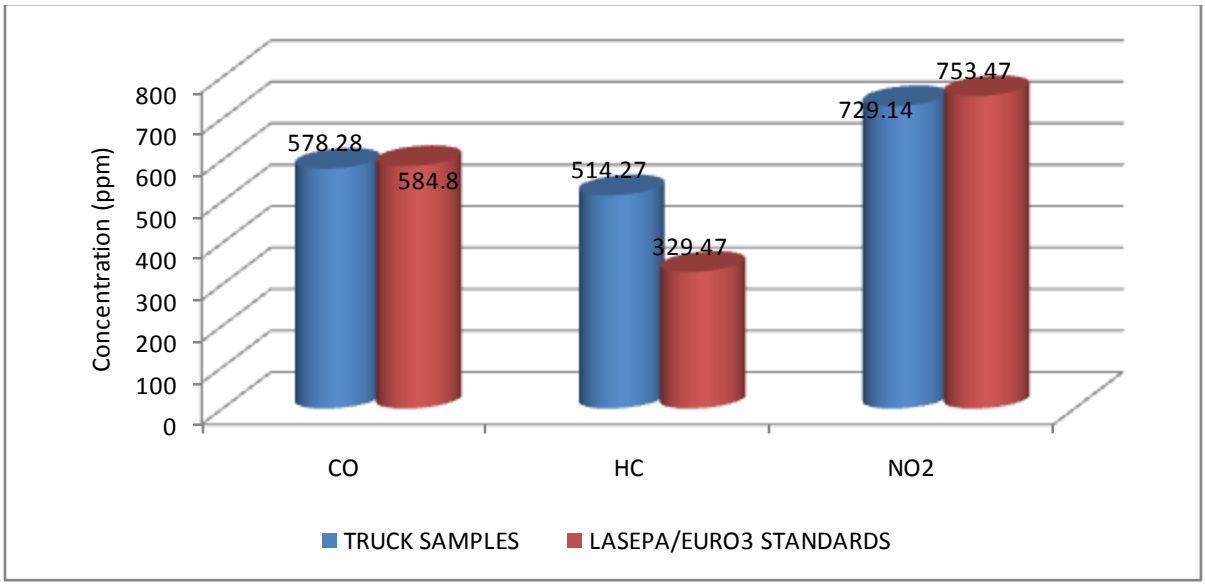


Figure 4.4: Heavy Truck Emission and LASEPA/EURO III Standards

Source: Field Survey (2017)

The Table shows that an average heavy duty truck in the study area emits lower concentration of CO and NO that are in the range of 578.28ppm and 729.14ppm respectively, compared to standards set by LASEPA and EURO III which are in the range of 584.8ppm and 753.47ppm respectively. On the other hand, hydrocarbon emission from an average heavy truck in the study area is in the range of 514.27ppm compared to set standard of 329.47ppm.

In a nutshell, the higher emission of hydrocarbon by an average heavy duty trucks in the study area can be attributed to the fact that they are mostly powered by diesel engines which usually run at higher combustion chamber pressures and temperatures and hence produces manly hydrocarbon pollutant.

4.5.2 Tricycle emissions and regulation standards

Figure 4.5 shows the concentration of different pollutants emitted from tricycles in the study area. The result shows that NO emission concentration from an average tricycle in the study area is in the range of 220.29ppm which is far above the set limit of 5.25ppm by LASEPA.

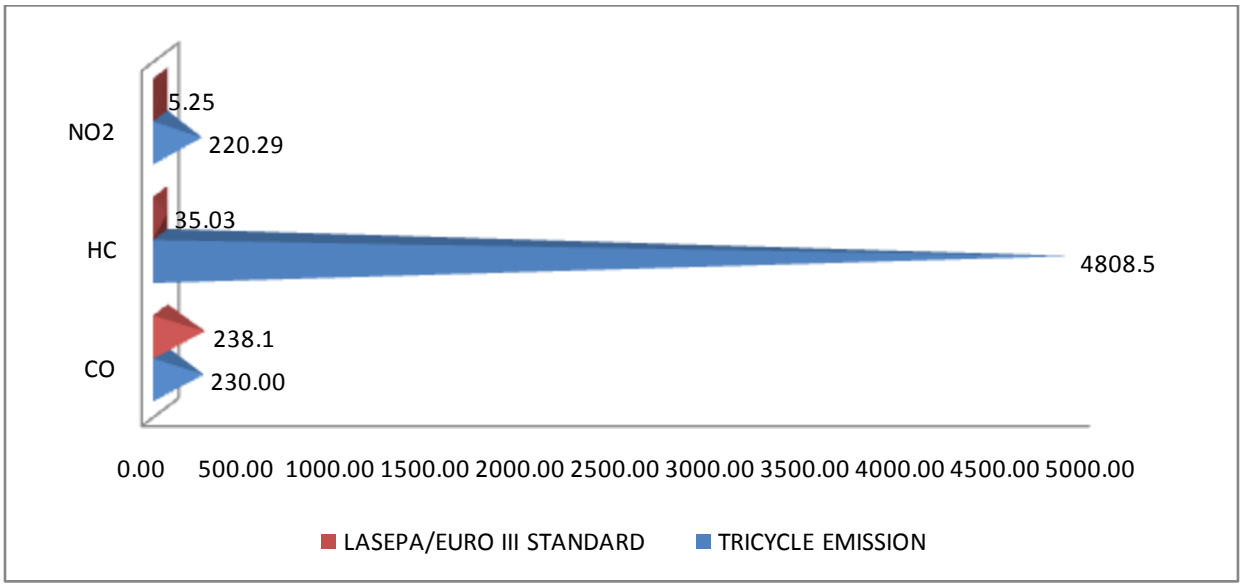


Figure 4.5: Tricycle Emission and LASEPA/EURO III Standards

Source: Field Survey (2017)

Additionally, the concentration of hydrocarbon (HC) emission from tricycles in the range of 4808.5ppm far exceeded the LASEPA set limit of 35.03ppm. While the concentration of carbon monoxide (CO) emission in the range of 238.1ppm is slightly below the 230.00ppm limit set by LASEPA.

4.5.3 Motor cycle emissions and regulation standards

Figure 4.6 shows that the concentration of NO and HC emission from motorcycles in the range of 150.50ppm and 3079.43ppm respectively far exceeded the LASEPA set limit of 5.25ppm and 35.03ppm respectively.

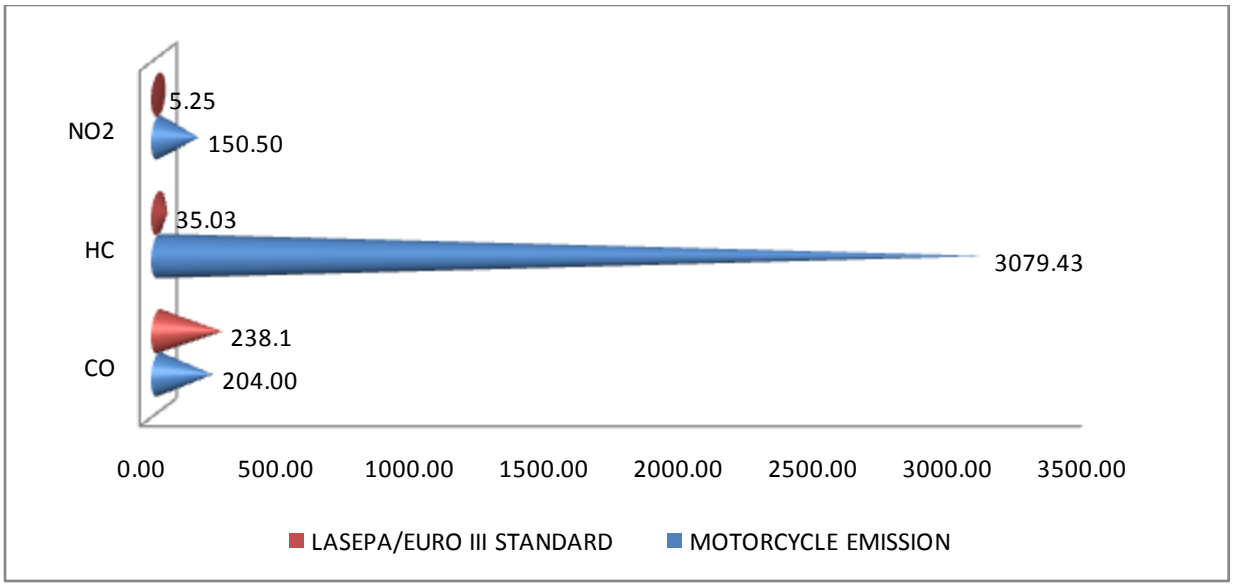


Figure 4.6: Motorcycle Emission and LASEPA/EURO III Standards

Source: Field Survey (2017)

Conversely, the concentration of CO emission from motorcycles is in the range of 204.00ppm which is found to be below the LASEPA set limit of 238.1ppm. This finding is similar to the study by WHO (2007) which reported of a growing trend in vehicular-derived air pollution in Lagos due to emission from 2-stroke engines motorcycles which have higher emissions of particulate matter and un-burnt hydrocarbons than other types of engines.

4.5.4 Mini bus emissions and regulation standards

Figure 4.7 shows that an average mini bus emits about 167.3ppm and 504.9ppm concentration of NO and HC respectively, which is higher than the LASEPA set limit of 6.3ppm and 43.8ppm for NO and HC respectively.

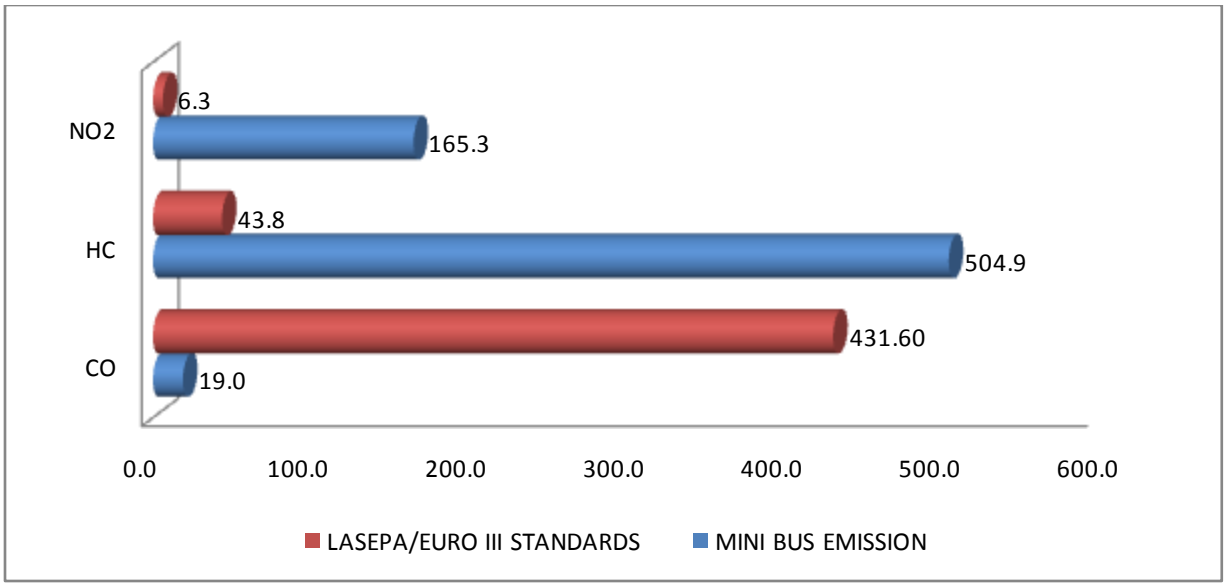


Figure 4.7: Mini Bus Emission and LASEPA/EURO III Standards

Source: Field Survey (2017)

Also, an average mini bus emits about 19.0ppm concentration of CO which is found to be below the LASEPA/EURO III set limit of 431.60ppm. The high concentration of NO and HC emission from mini buses above the set limits in the study can be likened to poorly maintained engine and physical conditions of most commercial buses (Danfo) commonly used in the study area which makes it possiblefor them to produce more harmful pollutants.

4.5.4 Omni bus emissions and regulation standards

Omni bus emission concentration results of gaseous pollutants and regulation standards are presented in Figure 4.8. The result reveals that omni buses emit slightly higher concentration of CO emission in the range of 585.7ppm than the LASEPA/EURO III set limit of 584.8ppm. Also there is higher emission of HC from omni bus which is found to be in the range of 507.0ppm, compared to the set standard of 329.5ppm.

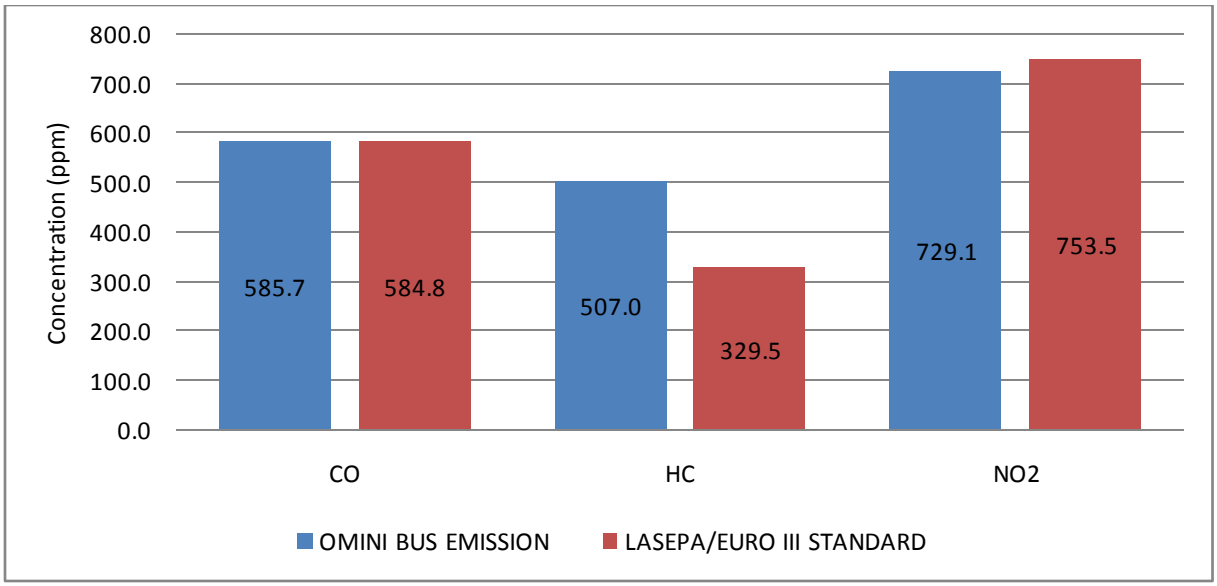


Figure 4.8: Omni Bus Emission and LASEPA/EURO III Standards

Source: Field Survey (2017)

Also, the emission level of NO from omni bus is found to be in the range of 729.1ppm, which is slightly below the regulated standard of 753.5ppm. The low emission of NO from omni bus can be attributed to the lower concentration of lead in the diesel products which helps to reduce NO emission.

4.5.5 Car/jeep/pickup vanemissions and regulation standards

Figure 4.9 indicates that an average car, Jeep and or Pick up Van in the study area emits about 90.1ppm and 434.7ppm concentration of NO and HC respectively. This emission concentration is found to be higher than the LASEPA set limit of 6.3ppm and 43.8ppm for the same pollutants.

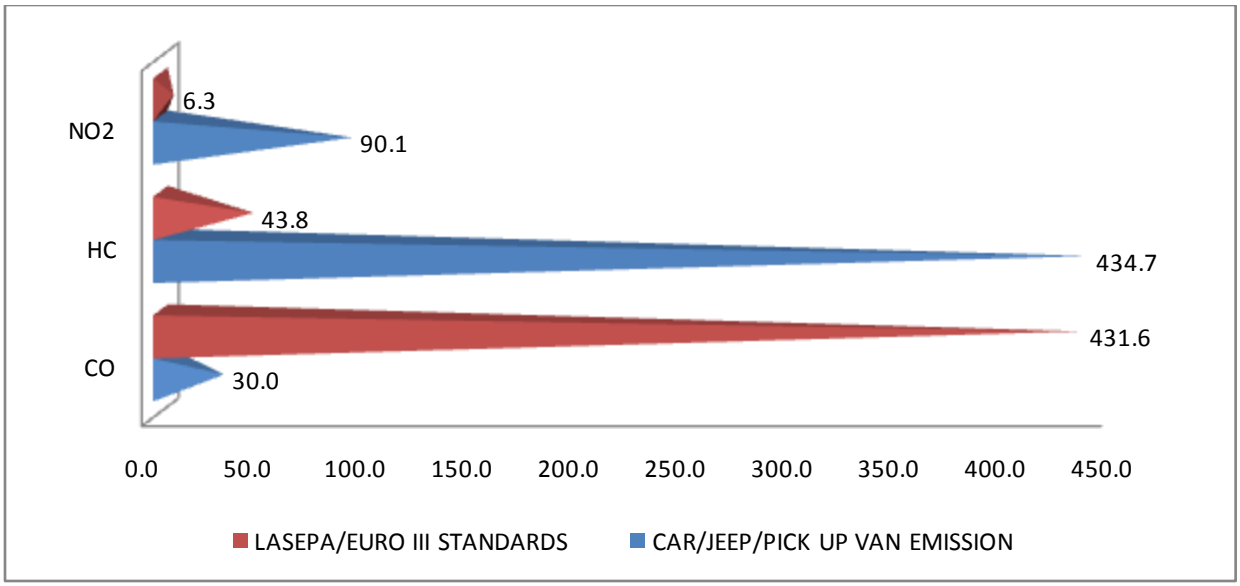


Figure 4.9: Car, Jeep and Pickup Van Emission and LASEPA/EURO III Standards

Source: Field Survey (2017)

The concentration of CO emission from car, jeep and pickup van in the study is found to be lower than the regulated limit of 431.6ppm. This is indicated where an average types of vehicles in the category emits about CO pollutant with 30.0ppm concentration level.

4.6 Ambient Air Quality along Heavy Traffic Corridors

4.6.1 Average ambient air quality on Monday at sampled locations

Table 4.9 shows the average quality of ambient air on the first day (Monday) for five selected gaseous and particulate matter (PM_{10} and $PM_{2.5}$) pollutants as well as temperature and humidity at the 6 sampled locations. The presentation shows that CO has its highest concentration at Ojota Corridor with about 17.1ppm, while the least concentration for the same pollutant is found at Ikorodu corridor(16.7ppm). The highest concentration of CO_2 is at Dopemu corridor (24ppm), followed by Ikeja Awolowo corridor (22.7ppm), while the least concentration is Ojota corridor (5.7ppm).

Table 4.9: Average Monday Ambient Air Quality and Metrological Indices

Sample Locations	CO (ppm)	CO2 (ppm)	HC (ppm)	SO_2 (ppm)	NO (ppm)	PM_{10} (ppm)	$PM_{2.5}$ (ppm)	RH (%)	^oC
Ojota corridor	17.1	5.7	31.3	0.00	0.4	256	123.3	66	32
Ikorodu corridor	16.7	8.3	25.3	0.00	0	147.7	65.3	65	33
Oshodi corridor	16.9	6.3	29	0.00	0	100	47.7	59	34
Ikeja Along corridor	16.9	8.7	27.3	0.00	0.1	219	105.3	57	33
Dopemu corridor	16.9	24	25.3	0.00	0	138.3	70.3	54	34
Ikj Awolowo corridor	17	22.7	27.7	0.00	0	126	67.3	38	34
Average Total	**16.9**	**12.6**	**27.7**	0.00	**0.1**	**164.5**	**79.9**	**57**	**33**

Source: Field Survey (2017)

In addition, the average air concentration of hydrocarbon (HC) pollutants across all the sampled locations is 27.7ppm, whereas, the concentration hydrocarbon at various sample locations shows that Ojota corridor recorded the highest concentration in the range of 31.3ppm, while Ikorodu corridor and Dopemu corridor both have least concentration of 25.3ppm each. The possible reason for higher concentration of HC at Ojota corridor is likely to be the higher volume of heavy duty vehicles which are found to have highest HC emission concentration among different types of automobiles sampled.

Also, no trace of SO_2 was detected at any of the sampled locations, whereas, NO in the range of 0.4ppm was found Ojota corridor, which is three times higher than the NESREA 1 hour permissible of 0.1ppm. The ambient air concentration of particulate matter PM_{10} pollutant is found to have the highest concentration at Ojota corridor, which is slightly higher than the NESREA limit of 250ppm daily. Value for $PM_{2.5}$ air concentration also shows that the average concentration across all the sample locations is 79.9ppm, with the highest daily average of 123.3ppm found at Ojota corridor. This air concentration result at Ojota corridor can be apportioned to be due to heavy influx of automobiles into the State from other states especially

during morning and evening peak hours when night and day time travellers would be arriving from weekend trips from outside the State.

4.6.2 Average ambient air quality on Tuesday at sampled locations

Table 4.10 shows the result of ambient air concentration at different sampled locations across the study area. From the presentation, it shows that the average daily air concentration of CO across all the sampled location is 16.8ppm, while the highest concentration of 17ppm each is found at both Dopemu corridor and Ikeja Awolowo corridor respectively. The average concentrations of CO at all the sampled location are found to be above the hourly limits of 10ppm, but lower than the daily limit of 20ppm set by NESREA.

Table 4.10: Average Tuesday Ambient Air Quality and Metrological Indices

Sample Locations	**CO (ppm)**	**CO2 (ppm)**	**HC (ppm)**	**SO_2 (ppm)**	**NO (ppm)**	**PM_{10} (ppm)**	**$PM_{2.5}$ (ppm)**	**RH (%)**	**^oC**
Ojota Corridor	16.9	28.3	32.3	0.01	0.5	179.3	81.7	68.3	34
Ikorodu Road	16.8	28.7	22	0.00	0.6	173.7	78.7	70.3	33
Oshodi Corridor	16.5	20.7	30.7	0.00	0.3	131.7	57	64.7	34
Ikeja Along Corridor	16.7	25.7	26	0.00	0.7	234.7	120.3	63.7	34
Dopemu Corridor	17	20.3	30	0.00	0	259.3	161.3	60.3	35
Awolowo Road Ikeja	17	26.3	25.7	0.00	0.4	194.7	101.3	70	34
Average Total	**16.8**	**25.0**	**27.8**	0.00	**0.4**	**195.6**	**100.1**	**66.2**	**34**

Source: Field Survey (2017)

Air concentration of carbon dioxide shows a daily range of 25.0ppm across all the sampled locations, while the highest concentration of 28.7ppm is obtained at Oshodi corridor and the least which is in the range of 20.3ppm is found at Dopemu corridor. The concentrations of both the average total across all the sampled locations and the individual locations are all below the USEPA permissible limit of 5000ppm.

Hydrocarbon air concentration across all the sampled locations is 27.8ppm, while concentration on Tuesday at sampled locations shows that Ojota corridor has the highest with 32.3ppm and the least concentration of 22ppm recorded at Ikorodu road. There is no trace of sulphur dioxide pollutant found at any sampled locations except at Ojota corridor which is 0.01ppm. The particulate matter with a diameter of PM_{10} and $PM_{2.5}$ highest values of 259.3ppm and 120.3ppm respectively is found at Ikeja along corridor, compared to the least values of 131.7ppm (PM_{10}) and 57ppm ($PM_{2.5}$) obtained at Oshodi corridor.

4.6.3 Average ambient air quality on Wednesday at sample locations

Table 4.11 shows a daily average of 16.5ppm concentration of ambient air CO across all the sampled locations on Wednesday, while the concentrations at different sampled locations shows that highest concentration of 16.7ppm each is obtained at both Oshodi corridor and Ikeja along corridor respectively. The highest concentration of carbon dioxide at the range of 40.7ppm is found at Ikorodu corridor, with the least concentrationof 29ppm found at Dopemu corridor.

Concentrations of hydrocarbon at different sampled locations shows that Ikorodu corridor has the highest concentration in the range of 38.7ppm, followed closely by Ojota corridor with 38ppm. Also, a daily range of 0.02 concentration of SO_2 pollutant is found atIkeja along corridor.

The SO_2 value obtained at the sampled location is found to be higher than the NESREA daily permissible ambient air standards of 0.1ppm. This concentration of SO_2 at Ikeja along can be attributed to high number of diesel engine or heavy duty vehicles which are usually known to emit higher SO_2 concentrations due to high sulphur contents in diesel fuel.

Table 4.11: Average Wednesday Ambient Air Quality and Metrological Indices

Sample Locations	CO (ppm)	CO2 (ppm)	HC (ppm)	SO_2 (ppm)	NO (ppm)	PM_{10} (ppm)	$PM_{2.5}$ (ppm)	RH (%)	^oC
Ojota Corridor	16.4	34.7	38	0.00	0.4	273	141.7	67.7	33
Ikorodu Road	16.5	40.7	38.7	0.00	1.2	231	119	66.7	32
Oshodi Corridor	16.7	26.7	27.7	0.00	0	149	79	65.7	32
Ikeja Along Corridor	16.7	35	32.3	0.02	0	243.7	107.7	67.3	32
Dopemu Corridor	16.3	29	35	0.00	0.4	224.7	93	67	34
Ikj Awolowo Corridor	16.3	39	30.7	0.00	0	226.3	124	65	33
Average Total	**16.5**	**34.2**	**33.7**	**0.00**	**0.3**	**224.6**	**110.7**	**66.6**	**33**

Source: Field Survey (2017)

The Wednesday's concentration of NO is found to have the highest daily average 0.4ppm each at both Ojota corridor and Dopemu corridor, while the daily average concentration across all the sampled locations is 0.3ppm. The PM_{10} and $PM_{2.5}$ pollutants are found at a daily average of 224.6ppm and 110.7ppm respectively. The highest concentration of 273ppm concentration of PM_{10} and 141.7ppm of $PM_{2.5}$ pollutants are found at Ojota corridor. The PM_{10} concentration found at Ojota is found to be higher than the FEPA/NESREA permissible limit of 250ppm daily set standard.

4.6.4 Average ambient air quality on Thursday at sample locations

Table 4.12 shows a daily average concentration of CO in the range of 18.3ppm across the sampled locations on Thursday, while the highest concentration at sampled location in the range of 20ppm is found at Ikeja corridor. Ojota corridor has the least concentration with 16.7ppm.

The highest concentration of CO_2 across sampled locations is found at Depemu corridor which records 41.7ppm, followed by Ikorodu road sampled location which recorded 40ppm. Hydrocarbon has its highest concentration 46.7ppm recorded at Ikorodu corridor, while the least concentration of 32.7ppm is found Ojota corridor. The highest concentration for NO is found at

Dopemu corridor in the range of 0.3ppm. This concentration according air quality index rating is considered good and safe for human survival.

Table 4.12: Average Thursday Ambient Air Quality and Metrological Indices

Sample Locations	CO (ppm)	CO2 (ppm)	HC (ppm)	SO_2 (ppm)	NO (ppm)	PM_{10} (ppm)	$PM_{2.5}$ (ppm)	RH (%)	^{o}C
Ojota Corridor	19	37.7	32.7	0.00	0	378	187	71.7	32
Ikorodu Road	16.8	40	46.7	0.00	0.1	486	236.3	75.3	32
Oshodi Corridor	16.9	37.7	32.7	0.00	0.2	736.3	157	67.7	32.3
Ikeja Along Corridor	20	32.3	36.3	0.02	0.2	213.7	144.7	64.7	33.3
Dopemu Corridor	19.7	41.7	41.3	0.00	0.3	213.3	93.7	75	32.7
Awolowo Road Ikeja	17.1	39.7	44.3	0.00	0	284.7	120	71.3	33.7
Average Total	**18.3**	**38.2**	**39.0**	**0.00**	**0.1**	**385.3**	**156.5**	**71.0**	**32.7**

Source: Field Survey (2017)

Particulate matter concentration (PM_{10}) at most locations are higher than the NESREA stipulated safety standard of 250ppm, with the concentration at Oshodi corridor in the range of 736.3ppm more than doubled the approved safety limits by NESREA. $PM_{2.5}$ pollutant has its highest concentration in comparison to other sampled locations at Ikorodu road with 236.3ppm, followed by Ojota corridor with 187ppm. This high concentration of CO_2 and HC at most sampled locations may be likened to be as a result of change in climatic parameters. This is so a closer look at climatic parameters (temperature and humidity) of Monday to Wednesday reveals a slight increase. In order word, high ambient temperature can also have a secondary influence on exhaust emissions because engine load is increased by the use of air conditioner.

4.6.5 Average ambient air quality on Friday at sample locations

Presentation in Table 4.13 shows that the concentrations of CO at all the sampled locations are within the safety limits of 20ppm as stipulated by NESREA, except for the concentration at Ikorodu corridor with 20.9ppm, which is as a result of lower traffic volume

compared to the other locations. Also, the concentrations of CO_2 are still within the safety limits at all the sampled locations, with the highest value in the range of 51ppm found at Ikeja along corridor and the least concentration in the range of 36.7ppm found at Ikorodu road.

The concentrations of hydrocarbon at all the sampled locations are more than twice above the NESREA recommended safety limits of 16ppm daily, with the highest concentration of 41.7ppm found at Awolowo road Ikeja. This needs to be monitored as human exposure to this pollutant at the recorded limit can result to acute respiratory damage, suffocation or death. The concentrations SO_2 at all the sampled locations are found to be within the safety limits of air quality index ratings of 0.1-0.4ppm, except for the concentration of 0.6ppm found at Awolowo road Ikeja which is above the safety limits.

Table 4.13: Average Friday Ambient Air Quality and Metrological Indices

Sample Locations	CO (ppm)	CO2 (ppm)	HC (ppm)	SO_2 (ppm)	NO (ppm)	PM_{10} (ppm)	$PM_{2.5}$ (ppm)	RH (%)	^0C
Ojota Corridor	16.7	45	36.3	0.00	0	355.7	157	74	33.3
Ikorodu Road	20.9	36.7	33.3	0.00	0	368	169	71.7	33
Oshodi Corridor	18	42.3	39.7	0.00	0	370.7	179.7	75	33
Ikeja Along Corridor	16.9	51	38.7	0.02	0	504	230	72	33
Dopemu Corridor	17	49	37	0.00	0.5	401	214.7	72.3	33.3
Awolowo Road Ikeja	17.1	38.7	41.7	0.06	0	366.3	146.3	73.3	33.7
Average Total	**17.8**	**43.8**	**37.8**	**0.01**	**0.0**	**394.3**	**182.8**	**73.1**	**33.2**

Source: Field Survey (2017)

Moreso, the ambient air concentrations of NO pollutant at all the sampled locations are found to be safe, except the concentration at Dopemu corridor in the range of 0.5ppm which is considered poor in the air quality index ratings. The ambient air concentrations of PM_{10} at all the sampled locations are found to be above the FEPA/NESREA safety limit of 250ppm. Meanwhile the concentration of $PM_{2.5}$ at all the sampled locations is high and above safety limits. This is considered to be dangerous for humans as exposure to such concentration of pollutant can trigger

asthmatic attack on asthmatic patients, clogging of breathing track, eye and nose irritation among other effects.

4.6.6 Average ambient air quality on Saturday at sample locations

Table 4.14 shows that the concentration of CO at all the sampled locations on Saturday are within the 24 hours safety limits of 20ppm, except for Dopemu corridor with a concentration in the range of 21.4ppm which is above FEPA/NESREA daily exposure set limits.

The concentration of CO_2 at all the sampled locations are found to be within the safety limits, while the ambient air concentration of Hydrocarbon at all the sampled locations are found to be within the safety limit of less than 16ppm set by NESREA, except the concentrations at both Oshodi corridor and Ikeja along corridor with 17.7ppm and 20.3ppm respectively which are found to be higher than the NESREA set limits.

Table 4.14: Average Saturday Ambient Air Quality and Metrological Indices

Sample Locations	CO (ppm)	CO2 (ppm)	HC (ppm)	SO_2 (ppm)	NO (ppm)	PM_{10} (ppm)	$PM_{2.5}$ (ppm)	RH (%)	^oC
Ojota Corridor	18.9	22.3	11.3	0.00	0.1	276.3	89.7	67	30.7
Ikorodu Road	19.6	11	7	0.00	0	282	90.7	67.7	31.3
Oshodi Corridor	19.3	13.7	17.7	0.00	0	288.7	79	58.7	32.7
Ikeja Along Corridor	18.9	41	20.3	0.01	0.1	249.7	71.3	64	32.7
Dopemu Corridor	21.4	44.3	4.3	0.02	0	239.7	64.3	57.3	32.3
Awolowo Road Ikeja	18.5	13	11.3	0.0	0	242.7	79.3	58	32.7
Average Total	**19.4**	**24.2**	**12.0**	**0.00**	**0.0**	**263.2**	**79.1**	**62.1**	**32.1**

Source: Field Survey (2017)

In addition, Table 4.8 shows that the concentration of SO_2 and NO pollutants in the ambient air across sampled locations are within the recommended safe limits by NESREA. Also the ambient air concentration of PM_{10} pollutant at Ojota Corridor, Ikorodu Road and Oshodi Corridor are found to be above the daily set limit of 250ppm, while the concentrations at Ikeja

along Corridor, Dopemu Corridor and Awolowo Road Ikeja are found to be within the safety limits.

4.6.7 Average ambient air quality on Sunday at sample locations

The result in Table 4.15 shows that the daily average value of CO across all the sampled locations is 16.9ppm. Meanwhile the daily concentration at sampled locations shows that the highest concentration of 17.2ppm is found at Ikorodu road and the least concentration of 16.6ppm is found at Ojota corridor.

The concentrations of CO_2 at all the sample locations on Sunday are insignificant with the highest concentrations of 0.01pp each recorded at both Ikeja Awolowo and Ojota corridors. The ambient air concentrations of hydrocarbon at all the sampled locations are all below the NERSEA set limit of 16ppm, except for the concentration at Awolowo road Ikeja with 16.3ppm. At Ojota and Ikeja along corridors, the concentrations of SO_2 are found to be in the range of 0.03ppm each and are within the safety limits according to the air quality index rating.

Table 4.15: Average Sunday Ambient Air Quality and Metrological Indices

Sample Locations	CO (ppm)	CO2 (ppm)	HC (ppm)	SO_2 (ppm)	NO (ppm)	PM_{10} (ppm)	$PM_{2.5}$ (ppm)	RH (%)	^oC
Ojota Corridor	16.6	0.1	9	0.03	0	167.7	79	65	33
Ikorodu Road	17.2	0	8.7	0.00	0	107.3	49.7	64.3	32.7
Oshodi Corridor	17.1	0	13.3	0.00	0	136	63.7	64	33.3
Ikeja Along Corridor	16.7	0	11	0.03	0	138.3	55.7	67.7	33
Dopemu Corridor	17	0	6	0.00	0	137.7	55.7	64.3	32.7
Awolowo Road Ikeja	17	0.01	16.3	0.00	0.02	111.7	48	54.7	34.7
Average Total	**16.9**	**0.0**	**10.7**	**0.01**	**0.0**	**133.1**	**58.6**	**62.6**	**33.2**

Source: Field Survey (2017)

Lastly, the ambient air concentration of PM_{10} and $PM_{2.5}$ at all the sampled locations are found to be within the safety limit set by NESREA, with the highest concentration of PM_{10} found

at Ojota corridor which recorded 167.7ppm. This result may be due to the low vehicular traffic on the roads compared to week days.

4.6.8 Weekly average ambient air quality at sampled locations

Table 4.16 shows the mean weekly concentration of ambient air at the sampled locations. The result of the combined ambient air concentrations across sampled locations shows that CO has its highest concentration at Ojota corridor (18.1ppm). This is however lower than the daily set limit of 20ppm by NESREA, but higher than 1 hourly regulated limit of 10ppm. This implies that the weekly concentration estimate of CO pollutants is within the safety limits, but hourly exposure should be avoided by the residents as such an exposure at the long run will result to negative health outcomes.

Table 4.16: Weekly Average Concentrations of Ambient Air along Heavy Traffic Corridors

Sample Points	CO (ppm)	CO_2 (ppm)	HC (ppm)	SO_2 (ppm)	NO (ppm)	PM_{10} (ppm)	$PM_{2.5}$ (ppm)	RH (%)	^oC
Ojota Corridor	18.1	24.8	27.3	0.01	0.2	269.4	122.8	68.5	32.5
Ikorodu Corridor	17.8	23.6	26.0	0.00	0.3	256.5	115.5	64.2	32.4
Oshodi Corridor	17.3	21.0	27.2	0.00	0.1	273.2	94.7	65.0	33.1
Ikeja Along Corridor	17.6	27.7	27.4	0.01	0.1	257.6	119.3	65.1	33.1
Dopemu Corridor	17.9	29.8	25.6	0.00	0.1	230.6	107.6	64.4	33.3
Ikeja Awolowo Corridor	17.3	25.4	27.2	0.01	0.1	217.1	98.5	61.9	33.6

Source: Field Survey (2017)

Furthermore, the weekly estimate of CO_2 concentration has its highest record of 29.8ppm at Dopemu corridor, this is followed closely by the concentration at Ikeja corridor with 27.7ppm, whereas, the weekly estimate of HCconcentration across all the sampled points shows that its

highest record is found at Ikeja along corridor with 27.4ppm, followed closely by Ojota corridor with 27.3. By implication, it is worthy to note that both hourly, daily, weekly concentrations of CO_2 and HC are within the regulated limits and such considered safe for the environment and health of living organisms in the locations.

Furthermore, the weekly average concentration of SO_2 shows that the highest record is found at both Ojota and Ikeja Awolowo corridors with 0.01ppm each. Also, the highest concentration for NO is recorded at Ikorodu corridor with 0.3ppm, followed by Ojota with 0.2ppm. The high concentration of NO found at both Ojota and Ikorodu corridors compared to other locations is likely because of higher number of heavy duty vehicles that plies the road daily which are known to emit higher concentrations of NO compared to light duty vehicles. Therefore, it is evidently clear that the weekly concentrations of SO_2 and NO at all the sampled locations are within the air quality index category very good and moderately good respectively.

The weekly PM_{10} concentration shows that Oshodi corridor has the highest with 273.2ppm, followed by Ojota corridor with 269.4ppm. Ikorodu and Ikeja along corridors recorded 256.5ppm and 257.6ppm respectively. In addition, the $PM_{2.5}$ has its highest concentration at Ojota corridor with 122.8ppm, followed by Ikeja along corridor with 119.3ppm. From the result, it shows that the weekly average concentration of PM_{10} exceeded the set limit of 250ppm at all the sampled locations except Dopemu and Ikeja Awolowo corridors. By implication exposure to this pollutant at these locations should be avoided as it may result to many health effects such as immune system impairment, exacerbated asthma attacks, lungs cancer as well as environmental effects such as formation of smog, degrading of surface water quality among others.

4.6.9 Ambient air CO and CO_2average hourly concentrations at sampled locations

Figure 4.10 and 4.11 shows the ambient air average hourly concentration at various sampled road corridors. The red colours in figure 4.10 shows the concentration of CO above the NESREA safe limits of 10ppm hourly concentration. This means that the concentration of CO across all the sampled locations were found to be above the safety set limits.

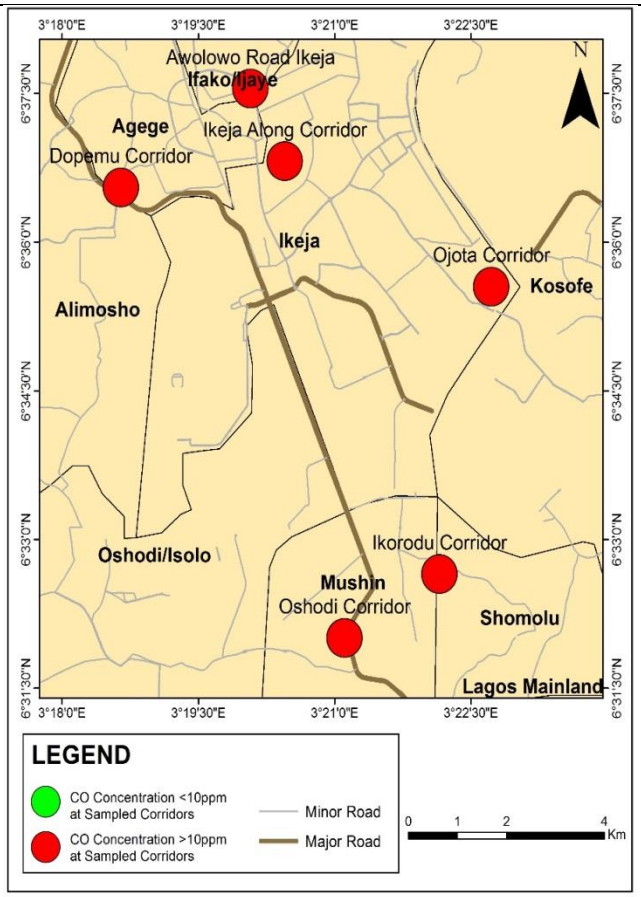


Figure 4.10: CO Concentrations at Sampled Locations

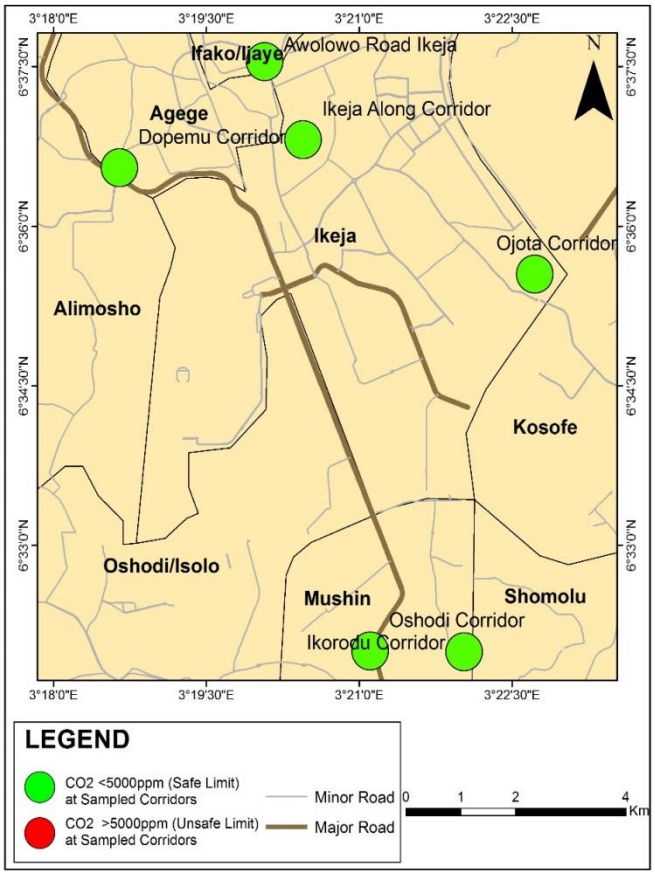


Figure 4.11: CO_2 Concentrations at Sampled Locations

Figure 4.10;11: Ambient Air CO and CO_2 Concentrations at Sampled Locations

Source: Field Survey (2017)

On the other hand, Figure 4.11 reveals the average hourly concentration of CO_2 across the sampled road corridors. It shows from the Figure that the CO_2 concentrations across all the sampled locations were found to be within the NESREA safety limit of less than 5000ppm.

4.6.10 Ambient air PM_{10} and $PM_{2.5}$concentrations at sampled locations

Figure 4.12 and 4.13 shows the ambient airhourly concentrations of PM_{10} and $PM_{2.5}$at sampled road corridors in the study area. The ambient air PM_{10}hourly concentration in Figure 4.12,indicated in green colour (Ikeja Awolowo and Dopemu corridors) shows that the concentration is within the NESREA safety limit of <250ppm, whereas, the concentrations at Ikeja Along, Ojota, Oshodi and ikorodu corridors (red colour) were found to be above the safety limit of >250ppm. This can be attributed to the high number of articulated vehicles that ply the road on daily basis compared to the other sampled corridors.

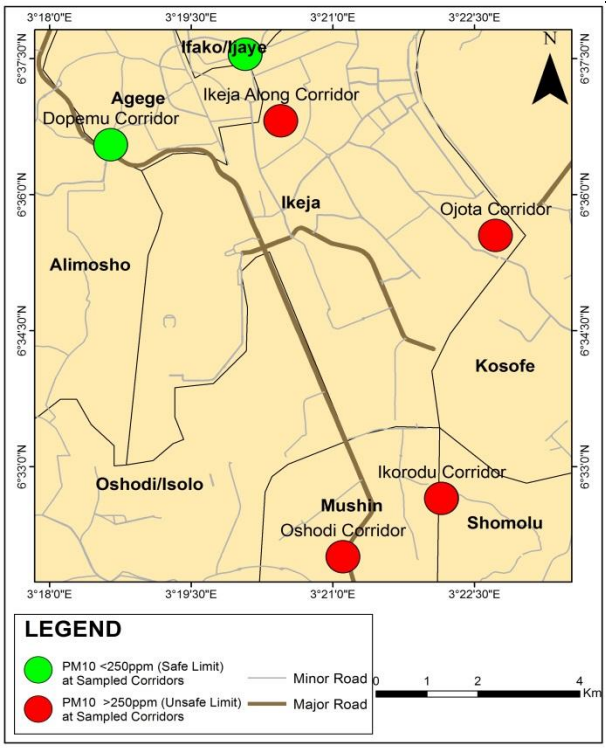


Figure 4.12: Ambient Air PM_{10} Concentrations at Sampled Locations

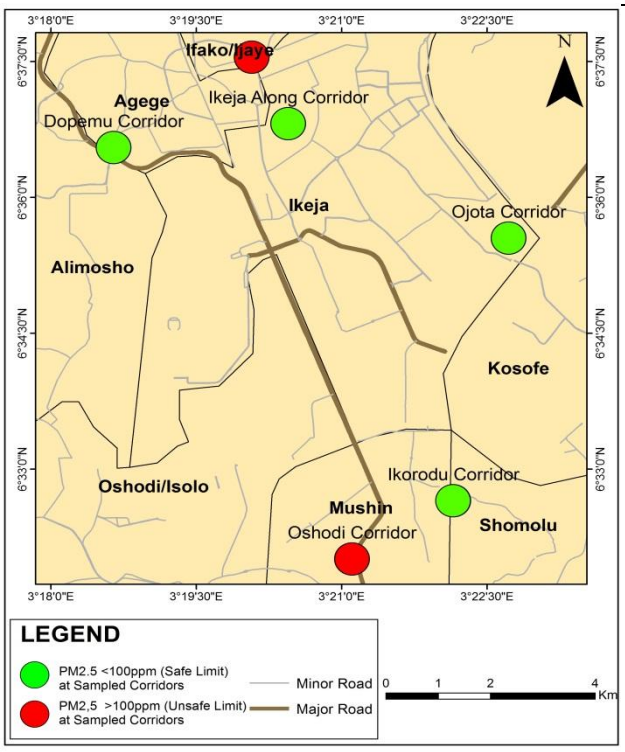


Figure 4.13: Ambient Air $PM_{2.5}$ Concentrations at Sampled Locations

Figure 4.12; 13: Ambient Air PM_{10} and $PM_{2.5}$Concentrations at Sampled Locations

Source: Field Survey (2017)

In addition, Figure 4.13 reveals theresult of ambient air $PM_{2.5}$hourly concentrations at various sampled road corridors. The result show that the ambient air $PM_{2.5}$hourly concentration at Ikeja Awolowo and Oshodi corridors were found to be less than 100ppm, while the concentrations across other corridors such as Ojota, Ikeja Along, Dopemu and Ikorodu corridors were found to be above >100ppm. The results in Figure 4.12 and 4.13 show that there are spatial dimensions to the concentration of PM_{10} and $PM_{2.5}$ in the air across sampled road corridors. This is as a result of variations in the emission factors such as number of automobiles, temperature and humidity of the sampled locations.

4.6.11 Ambient air NO and SO_2concentrations at sampled locations

Figure 4.14 and 4.15 shows the result of ambient air hourly concentration of NO and SO_2across the sampled road corridors in the study area. The result in Figure 4.14 show that the ambient air hourly concentration of NO across all the sampled road corridors were within the safety limits that ranges between 0.04ppm to 0.06ppm. On the other hand, the result of ambient air concentration of SO_2 across the sampled road corridors as presented in Figure 4.15 show that irrespective of road corridors, the concentration SO_2 is within the safety limit of 0.1ppm.

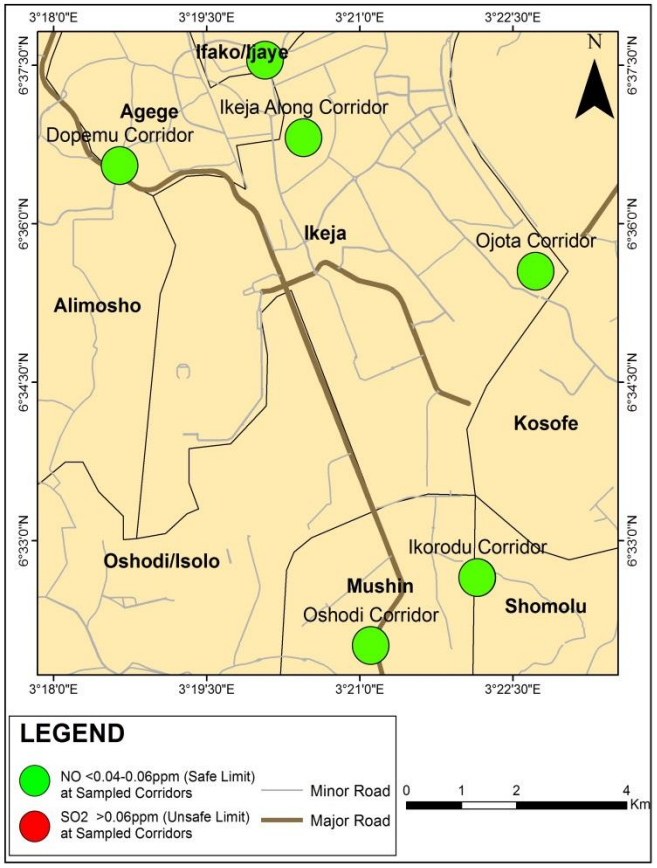


Figure 4.14: Ambient Air NO Concentrations at Sampled Locations

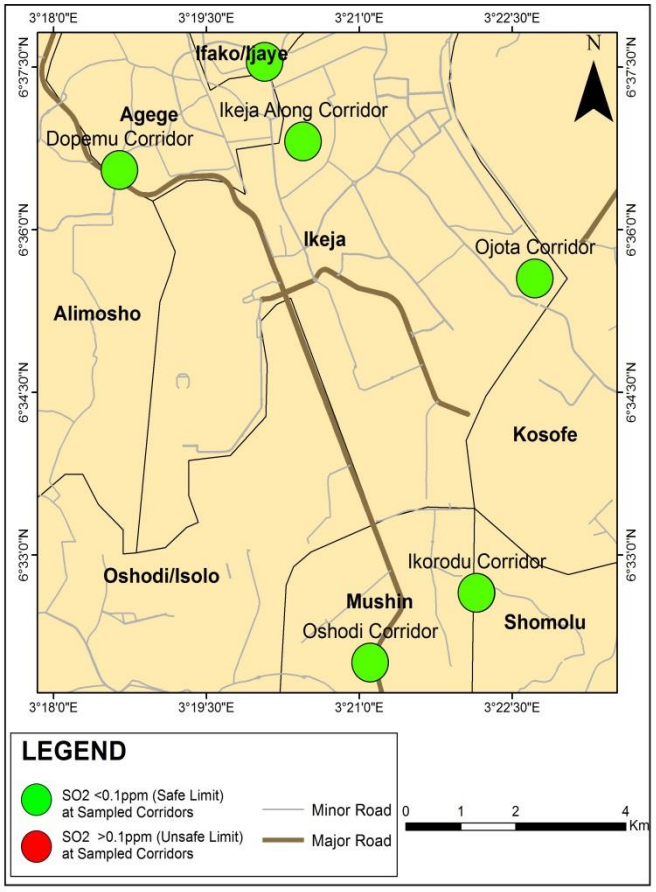


Figure 4.15: Ambient Air SO_2 Concentrations at Sampled Locations

Figure 4.14; 15: Ambient Air NOand SO_2Concentrations at Sampled Locations

Source: Field Survey (2017)

The finding on NO and SO_2hourly concentrations analysis being within the safety NESREA set limits is found to be contrary to the submission by Jerome (2000) report of higher ambient air concentrations of NO and SO_2 around traffic zones. These differences in the concentration of the pollutants can be due to the possibility of interferences from other emission sources (residential and industrial emission sources) in the process of data collections, which were purposively isolated in the process of data collection in this present study.

4.7: Test of Hypotheses

4.7.1. $Ho_{1:}$ There is no significant difference between automobile emission levels of CO, NOandHCpollutants and the recommended standards.

Table 4.17 shows the T-test result on differentials in automobile emission of CO, NO and HC pollutants from the recommended standards. The Table reveals the t-critical value of 0.188, with degree of freedom (df) 622 and P-value of 851. This implies that there is no significant difference between the automobile emission of CO and the LASEPA/Euro III recommended standard.

Table 4.17: T-Test of Differences in Automobile Emission and LASEPA/Euro III Standard

Variables		N	Mean	Std.D	Std. Error Mean	T-value	df	Sig.
CO	Emission	312	28.52	128.860	7.295	.188	622	.851
	LASEPA/EURO III	312	26.64	121.174	6.860			
HC	Emission	312	643.62	1250.800	70.813	8.287	622	.000
	LASEPA/EURO III	312	56.12	59.428	3.364			
NO	Emission	312	153.106	188.6965	10.6828	8.199	622	.000
	LASEPA/EURO III	312	39.771	154.9484	8.7722			

Source: Field Survey (2017)

Table 4.17 also reveals t-critical value of 8.29 and p-value of .000 for automobile emission of HC pollutant. This means that there is strong significant difference between automobile emission of hydrocarbon pollutant and the LASEPA/Euro III set standard. In addition, the automobile emission of NO shows t-value of 8.199 withdfvalue of 622 and p-value of .000, which implies that there is a strong statistical difference between automobile emission of NO and the regulatory standard in the study area. The explanation for the differentials in the sampled automobile emission of HC and NO with the regulatory set standards can be attributed

to poor vehicular maintenance habit of most divers especially the commercial driver, as well as the characteristics of fuel used to power the vehicles which may differ from the required standards.

4.7.2. Ho_2 There is no significant relationship between traffic volume and concentration of CO, CO_2, SO_2, NO, HC, PM_{10}, and $PM_{2.5}$ pollutants.

Table 4.18 shows the PearsonProduct Moment Correlation coefficient of relationship between ambient air concentrations of analysed gases and particulate matter pollutants, climatic variables and traffic volume. From the Table 4.18, CO_2, $PM_{2.5}$ and HC pollutants reveal the following P-values of 0.000, 0.001 and 0.000 at 0.01 significance levels respectively, which signifies that there is strong statistical relationship between the pollutants and traffic volume in the study area. This simple means that the concentrations of the pollutants are strongly dependent on traffic volume.

Table 4.18: Pearson Product Moment Correlation on Ambient Air Concentration and Traffic Volume

Variables	Coefficient (R)	P-value
CO	0.001	0.993
CO_2	.369**	0.000
HC	.317**	0.000
SO_2	-0.024	0.794
NO	0.154	0.084
PM_{10}	0.145	0.105
$PM_{2.5}$	0.288**	0.001
R/H	.083	.355
^oC	-109	.223

N=126
**. Correlation is significant at the 0.01 level (2-tailed).

Source: Field Survey (2017)

Furthermore, variables such as CO, NO and PM_{10} show no relationship with traffic volume. This is indicated where CO, NO and PM_{10} pollutants have p-values of 0.993, 0.084 and 0.105 in that order. This implies that there are no significant statistical relationships between the pollutants and traffic volume. Moreso, SO_2 pollutant shows p-value of 0.794, with a negative coefficient value of -0.024, which implies that there is no significant relationship between SO_2 pollutant and traffic volume, but there may be other sources contribution to the concentration of the pollutant.

The relative humidity and temperature concentrations at the sampled locations also shows p-value of .355 and .223 respectively, which implies that there is no significant relationships between the relative humidity and temperature with traffic volume in the study area. However, given the negative correlation coefficient value of relative humidity at -0.109, implies that at 10% reduction in traffic volume, the relative humidity will be positively affected. This means that the relative humidity of the study area is not directly generated by the automobile traffic volume, but may be mainly by other natural factors such as wind speed, direction, and prevalent air mass in the area. Therefore, the location of the study area along the tropical maritime air mass means that the percentage concentration of relative humidity is high across the seasons.

4.7.3. Ho_3 There is no significant difference in air quality around the sample points and the NESREA standards

Table 4.19 indicate a t-critical value of 48.243, df 250 and p-value of .000 on CO air concentration, which means that there is a strong significant difference between the ambient air concentration of CO and the NESREA set limit across the sampled locations in the study area. Ambient air concentration of CO_2 on the other hand shows a t-critical vale of -3022.238, df of 250 and p-value of .000. This can be interpreted to mean that there is a strong statistical

difference between ambient air concentration of CO_2 and the NESREA regulatory standard. Comparing the mean average concentration value of 25.39ppm with ambient air and 5000ppm of WHO standards, it is clear that the mean average ambient air is far below the WHO set limit. This can be likened to high number of petrol engine automobiles plying the sampled roads compared to diesel engines vehicles which are often times considered to emission mostly CO_2 pollutants due to high rate of diesel consumption per mileage of heavy duty vehicles as in Plate 1-8.

Table 4.19: T-Test of Differences in Sampled Air Quality and NESREA Standards

Variables		N	Mean	Std.D	Std. ErrorMn	T	Df	Sig.
CO	Air Qlty	126	17.547	1.7560	.1564	48.243	250	.000
	NESREA SD	126	10.000	.0000	.0000			
CO2	Air Qlty	126	25.385	18.4763	1.6460	-3022.238	250	.000
	WHO SD	126	5000.000	.0000	.0000			
HC	Air Qlty	126	26.786	15.2114	1.3551	7.959	250	.000
	NESREA SD	126	16.000	.0000	.0000			
SO2	Air Qlty	126	.007	.0216	.0019	-1.652	250	.100
	NESREA SD	126	.010	.0000	.0000			
NO	Air Qlty	126	.150	.3617	.0322	2.808	250	.005
	NESREA SD	126	.060	.0000	.0000			
PM10	Air Qlty	126	250.730	179.1268	15.9579	.046	250	.964
	NESREA SD	126	250.000	.0000	.0000			

Source: Field Survey (2017).

The ambient air concentrations of HC and NOare found to be statistically different from the NESREA set limit. This is evident by the t-critical value of 7.959,df 250 and p-value of .000 for HC and t-critical value of 2.808, df 250 and p-value of .005 for NO. It is clear that the ambient air concentration of CO, HC and NO at the sampled locations are above the NESREAset

limits. This finding concurs with the report by Jerome (2000) which reported high ambient air concentration of CO and NO at traffic points Lagos State compared to NESREA limits.

Moreso, the T-test result on ambient air concentration of SO_2 and PM_{10} shows a t-critical value of -1.652, df 250 and .100 and a p-vlaue of .046, df 250 and p-value of .964 respectively. This indicates that there are no statistical differences between the ambient air concentration of SO_2 and PM_{10} with the NESREA set limits at the sampled locations.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter is focused on the summary of the study, conclusion, recommendations based on the results of the findings are presented as well as the recommendations for future studies.

5.2 Summary of Findings

This research study analysed the automobile emission levels and air quality in Lagos State, Nigeria. In order to conduct a comprehensive assessment, the research was divided into two sections: (a) study of vehicular exhaust emissions and, (b) air quality along purposively selected heavy traffic corridors.

Automobile emission study analysed the emission concentration of the different pollutants from six different categories/types of automobiles (Table 3.1). The air quality study centered on the analysis of different pollutants found in the air along the selected traffic corridors. The research also employed the use of comprehensive experimental data collection and multiple statistical tools to study the interconnectivities between the different sampled air and automobile emission pollutants as well as analyse the emission differentials of petrol and diesel powered automobiles.

An all-encompassing emission testing protocol used for characterizing emission concentrations from different types of automobiles, and over 312 different automobiles were tested in engine idling mode. The findings from the study are divided into two (2) groups.

A. The general findings made from the study includes the following;

1) Automobile emission constitutes aair pollution along the heavy traffic corridors in the study area, with most of the automobiles emitting pollutants above the set limits.
2) Pollutants such as CO, CO_2, HC and NOwere detected in the air along all the traffic locations as well as from all the sampled automobiles at varying concentrations levels.
3) Correlation analysis revealed the existence of statistical relationship between CO_2 emission from automobile and ambient air quality in the study area, whereas, CO, HC and NO emissions from automobiles showed no significant statistical relationship with ambient air quality.
4) On the emission concentration differentials across various types of automobiles, it was found that the emission concentrations of CO and CO_2 are higher on Trucks and Omni-buses with 585.7ppm and 575ppm respectively, while tricycles and motor-cycles have the least emission concentration of the same pollutants at 1.9ppm and 2.0ppm respectively.
5) Concentration of hydrocarbon emission is higher on Tricycles with 4808.5ppm, followed by motor cycles with an average of 3079.4ppm, than on omni buses which recorded the lowest average emission of 418ppm.
6) Nitric oxide emission concentration is higher on omni buses with 980ppm, followed by Trucks with an average value of 745.8ppm, whereas motorcycles accounted for the least with 15.0ppm.
7) Analysis of variance result showed that there are concentration variability in CO_2, CO, HC and NO pollutants emitted from different automobiles, with emission of nitrogen oxide from cars varying statistically with trucks, mini-buses and Omni-buses at 0.05 significant levels, except for motorcycles and tricycles with p-values of 0.450 and 0.501.

8) Further comparison on emission differentials between types of sampled automobiles showed that there exists strong statistical difference in hydrocarbon emissions between cars, motorcycles and tricycles at 0.05 significant levels. On the contrary, there is no statistical difference in the emission of the same pollutant between cars, trucks, mini-buses and omni-buses with p-vales of 1.000, .997 and 1.000. The emission of carbon dioxide from car shows strong statistical differences with mini-buses, omni-buses, motorcycles and tricycles differences at 0.05 significant levels.

9) Analysis of emission variations across different models of automobiles showed that the concentration of NO pollutant is higher in Jincheng model of tri-cycles with 9200ppm, followed by Nipon model of tricycle with 8781ppm, with the least emission concentration found in Chevrolet car with 9.1ppm.

10) Man diesel model of truck, has the highest emission concentration of NO with an average concentration of 990.01ppm, followed by Mark model of trucks with 970.01ppm, while Chevrolet model of car recorded the least with 1.54ppm.

11) On CO emission concentration by models of automobiles, it showed that Man diesel T^m truck with 650ppm dominated in the emission of carbon dioxide (CO) pollutant, followed by Macopolo T^m of omni-buses with 611.79ppm. Mark T^m truck has the highest emission concentration of Carbon monoxide with mean of 15.81ppm, followed closely by Ashok Layland T^m omni-bus with mean concentration of 14.37ppm, whereas, Bajeng T^m of tricycle recorded the least concentration with 1.02ppm.

12) Analyses of emission concentration from diesel and petrol engine automobiles shows that petrol vehicles constitute the highest emitter of Hydrocarbon pollutant with an average

estimated concentration of 997.92ppm, whereas, the concentration of Hydrocarbon emission from diesel engines accounts for 779.23ppm.

13) Also, petrol engine automobiles have higher emission concentration of CO_2 and NO pollutants that ranges from 862ppm and 796ppm respectively, compared with diesel engines with a concentration of 494.3ppm and 143.8ppm respectively. On the contrary, the concentration of CO_2 pollutant is higher on diesel engine automobiles which amounted for 584.19ppm, while petrol engines recorded 291ppm.

14) In terms of the daily average quality of ambient air, it was found that CO has its highest concentration of 19.4ppm across all the sampled days on Saturday, while the least concentration of 16.5ppm was recorded on Wednesday.

15) The highest concentration of CO_2 (43.8) was recorded on Friday, while the least concentration was recorded on Sunday. The highest concentration of hydrocarbon (39.0ppm) was detected on Thursday, while the least recorded concentration of 10.7ppm was found on Sunday.

16) The highest concentration of SO_2 was detected on Friday and Sunday at 0.01ppm each respectively, while the NO highest concentration of 0.4ppm was detected on Tuesday.

17) Air concentrations of particulate matter pollutant (PM10 and PM2.5) have their highest concentrations detected on Friday at 394.3ppm and 182.8ppm respectively. These particles at these levels of concentrations pose the highest risk to humans as they can travel deep inside the human lungs and can cause cancer, eye irritation among other health challenges.

18) Relative humidity and temperature across the sample collection days was at its peak on Friday with 73.1% and 33.2^{o}C. This may have played some contributory roles to the high

concentration of particulate matter detected on the same day as compared to the rest of the days.

19) In relation to weekly average of ambient air pollutant concentrations across sampled locations, it was found that that CO has its highest concentration at Ojota corridor (18.1ppm), which is still within the safety limit set by NESREA.

20) The weekly estimate of CO_2 concentration in the air has its highest record of 29.8ppm at Dopemu corridor, while the weekly estimate of HC concentration across all the sampled points shows that its highest record was found at Ikeja along corridor with 27.4ppm, followed closely by Ojota corridor with 27.3ppm.

21) In addition, the weekly PM_{10} concentration result shows that the weekly average concentration of PM_{10} exceeded the set limit of 250ppm at all the sampled locations except Dopemu and Ikeja Awolowo corridors, which by implication constitute great concern for human health and the environment.

22) A comparison of emission concentration across automobile types with the set standards shows that an average heavy truck in the study area emits higher concentration of hydrocarbon pollutant than the set limits and less emission of CO and NO pollutants.

23) NO emission concentration from an average Tricycle in the study area is in the range of 220.29ppm which is far above the set limit of 5.25ppm by LASEPA.

24) The concentration of hydrocarbon (HC) emission from Tricycles with 4808.5ppm far exceeded the LASEPA set limit of 35.03ppm.

25) Emission concentration of NO and HC emission from Motorcycles far exceeded the LASEPA set limits.

26) An average mini bus emits higher concentration of NO and HC than the LASEPA set limit, while the concentration of CO is found to be below the LASEPA/EURO III set limit.

27) Omni buses emit slightly higher concentration of CO and HC pollutants of 585.7ppm and 584.8ppm respectively compared to the LASEPA/EURO III set limit.

28) An average car in the study area emits higher concentration of NO and HC of 90.1ppm and 434.7ppm, compared to the LASEPA set limit of 6.3ppm and 43.8ppm respectively.

29) Result of T-test analysis on differentials in automobile emission of CO, NO and HC pollutants from the recommended standards show that there is no significant difference between the automobile emission of CO and the LASEPA/Euro III recommended standard. While the analysis of the differentials in emission of HC and NO shows existence of strong statistical differences with the set standards.

30) Pearson correlation analysis on the relationship between ambient air concentrations of analysed gases and particulate matter pollutants, climatic variables and traffic volume indicate the existence of strong statistical relationships between CO_2, $PM_{2.5}$ and HC pollutants and traffic volume in the study area. On the other hand, variables such as CO, NO and PM_{10} show no relationship with traffic volume.

31) Lastly, the hypothesis test on the differences between the ambient air concentration of CO, CO_2, SO_2, NO and PM_{10} pollutants and FEPA set limits shows that the air concentration of CO, CO_2, HC and NO have strong statistical differences with the FEPA set limits, while SO_2 and PM_{10} pollutants shows no differences with the regulated standards.

B. The major findings from the study include;

i. There is no difference between the pollutants found in the air along the traffic corridors with those emitted from the sampled automobiles. Hence automobile emission has mega effects on air quality along the heavy traffic corridors.

ii. There is a strong difference in the emission concentration from different types of automobiles, with the strongest difference found in CO with 434ppm and NO with 85ppm, while the least difference of 21.692ppm is found in CO_2 pollutants.

iii. Amongst all the models of automobiles sampled, Jincheng model of tricycle has the highest emission concentration of 9200ppm for HC, with the least concentration of 9.1ppm of the same pollutant is found on Chevrolet model of car.

iv. Man diesel model of truck has the highest emission concentration of CO with 650ppm, followed by Macopolo omnini bus with 611ppm, while Mark model of truck recorded the highest concentration of CO_2 with 15.81ppm and the least concentration of the same pollutant of 1.02ppm was recorded by Bajeng model of tricycle.

v. Petrol powered automobiles have the highest emission concentration HC, NO and CO_2 with 997.92ppm, 796ppm and 862ppm respectively, than diesel powered automobiles with 779.23ppm, 143.8ppm and 494.26ppm. Whereas diesel automobiles have the highest emission levels of CO pollutants with 584.19ppm compared to petrol automobiles with 291ppm.

vi. The mean average weekly concentration of CO along the heavy traffic corridors is below the daily safety limits, but higher than 1 hourly limits of 10ppm, which means daily exposure of individuals along these corridors should be avoided to mitigate negative health outcomes.

vii. The weekly average concentration of PM_{10}pollutants exceeded the set limit of 250ppm at all the sampled locations except Dopemu and Ikeja Awolowo corridors. By implication exposure to this pollutant at these locations should be avoided as it may result to many health effects such as immune system impairment, exacerbated asthma attacks, lungs cancer as well as environmental effects such as formation of smog, degrading of surface water quality among others.

viii. Heavy truck emission of NO and CO with 729.14ppm and 578.28ppm respectively, were slightly below the set standards of LASEPA/EURO III, while HC concentration of 514.27ppm is above the set limit of 329.47ppm.

ix. Emission concentration of tricycles on HC and NO with 4808.5ppm and 220.29ppm exceeded the regulatory limits of 35.03ppm and 5.25ppm set by LASEPA/EURO III, while CO emission concentration of 238.1ppm is below the set limit of 230.00ppm.

x. Motorcycle emission concentration of NO and HC with 150.50ppm and 3079.43ppm far exceeded the LASEPA/EURO III set limits of 5.25ppm and 35.03ppm, while the concentration of CO with 204.00ppm is below the set limit.

xi. Mini-bus emission concentration of NO and HC with 165.3ppm and 504.9ppm is higher than the set limits of 6.3ppm and 43.8ppm, while the CO concentration of 19.0ppm is far below the set limit of 431.60ppm by LASEPA and EURO III.

xii. Omni-bus automobile type has higher emission concentration of CO and HC with 585.7ppm and 507.0ppm than the set limits by LASEPA/EURO III, while the NO concentration with 729.1ppm is below the regulated limits of 753.5ppm.

xiii. Cars have higher emission concentration of NO and HC with 90.1ppm and 434.7ppm than the set limits of 6.3ppm and 43.8ppm respectively. It also recorded lower

emission concentration of CO with 30.0ppm compared to the regulatory set limits of 431.6ppm of LASEPA/EURO III.

5.3 Conclusion

The management and control of vehicular emission/ambient air quality should be seen in the interest of humanity in general and not only the motorists/operators, this is because the effect does not discriminate. It has been established from the study that the emissions levels and ambient air concentrations at sampled locations are mostly above their set limits by various regulatory agencies. This implies automobile emissions undoubtedly contribute to global anthropogenic pollutant emission through road transportation. Therefore, by taking deliberate steps now such as inclusion of emission tests as part of vehicular road worthiness criteria to reduce harmful vehicle emissions, Lagos State can improve its own air quality while leading the way for the adoption of nationwide standards of automobile emission framework which is yet to be developed. It is however, against this backdrop that no effort should be spared to be taken to begin, sustain and accelerate the move towards ensuring holistic implementation and enforcements of emission control standards which is citizen oriented and in tune with the socio-economic realities of the country at large as this will go a long way in ensuring total compliance across board.

5.4 Recommendations

Findings made in the study, have shown that emission of gaseous and particulate matter pollutants from automobiles constitute a serious threat to the air quality. This is so as most types of automobiles sampled emit these dangerous pollutants at concentrations above the set limits Therefore, to ensure improved air quality, safety of the environment by drastically reducing

emission rate and concentration of emission of the dangerous pollutants from automobiles at various heavy traffic roads in the study area, the following recommendations are advanced:

i. There is the need to adopt sustainable auto-specific emission control measures with focus on the control of specific dangerous pollutants such as Hydrocarbon, Carbon dioxide and Nitrogen dioxide which are mostly emitted by Trucks, Tricycles and motor-cycles at high concentrations.

ii. The use of tricycles should be completely banned across every parts of the State as they constitute mage threat to air pollution. This is because the concentration of pollutants they emits was more than 100% the set limits across all the analysed pollutants. However, effort should be made to provide alternative means of livelihood (provision of subsidised smaller shuttle buses) to the affected citizens who depend on the use of tricycle transport services as means of income to mitigate the effects. Alternatively, stricter emission laws should be imposed on tricycle uses as this will make it possible for users to comply to emission standards.

iii. Government should formulate a policy that bans the use of old and poorly maintained mini-buses otherwise known as Danfo for commercial purposes. This can also be replaced with better and environment friendly types of buses or cars.

iv. There is need to position VIOs at strategic positions across the State (entry and exit points) to impound every old and poorly maintained looking heavy duty vehicles.

v. The use of diesel engine automobiles should be encouraged as they have lower emission of dangerous gaseous pollutants such as contribute HC, CO_2 and NO. This can be achieved through a scheduled tax rate reduction on the importation of diesel fuels automobile engines and or by lowering the price of diesel compared to petrol as this will

help to disincentive the purchase of petrol engine automobiles in the short term. As well as adopt sustainable emission control technologies aimed at reducing the higher emission of CO pollutants from most diesel engine automobiles.

vi. There is need for the environmental protection agency (LASEPA) to periodically monitor and report the ambient air quality at heavy traffic locations/interceptions where high concentrations of the pollutants are reported to inform people about the dangers of exposure to pollutants as this will help to minimise the exposure of citizens to the pollutants.

vii. There is the need for collaboration between importers and automobile dealers across the country on ensuring that all automobiles (New or second new) are subjected to and passed all emission tests before they are imported or sold to the end user.

viii. More importantly, there is the need to develop a holistic automobile emission regulation framework that is generally acceptable nationally which is based on the socio-economic realities of the country. This is expected to ensure compliance by all operators irrespective of social-status and or class of automobiles.

ix. There is need to formulate automobile inspection and maintenance system for all vehicles operating in the State. This could be done through the forming of partnership with FRSC/VIS and LASTMA, LASEPA and police to inspect, coordinate and enforce compliance by automobile operators/owners to the set standards. This could however help to reduce pollution loads generated by vehicles through proper periodical inspections and maintenance of vehicles.

x. Finally, given the fact that on average, most of the sampled automobile types failed to comply with all the pollutants analysed especially going by the set standard used in the

study, it is recommended that the LASEPA (EURO III) emission standard should be reviewed to EURO II standard so as to make compliance possible at early stage and can gradually be reviewed upwards when total compliance is achieved. This will go a long way in reducing the burden on the failed emission automobile owners being force to forfeit or buy new vehicles when impounded.

5.5 Suggestions for Further Studies

i. A more comprehensive exhaust particulate emission analysis needs to be studied to understand their dynamics of sources, dispersion and size specification from different vehicular types.

ii. Examine the seasonal variation of ambient air concentrations across heavy traffic locations to help understand the possible differences in ambient air concentrations across seasons.

iii. There is the need to conduct a study that will analyse more pollutants emitted from automobiles as this will help shed light on the contribution of automobiles to emission of other pollutants not considered in this present study.

iv. Analyse the effects of different vehicular characteristics like fuel types, engine size, frequency of maintenance and vehicle operationconditions on the vehicular emissions.

REFERENCES

Abam F.I. and Unachukwu, G.O., (2009). Vehicular Emissions and Air Quality Standards in Nigeria. *European Journal of Scientific Research*. 34 (4), 550- 560.

ACEA/EUROPIA (European Automobile Manufacturers Association/European Petroleum Industry Association) (1995). *European Programme on Emissions, Fuels, and Engine Technologies Report*, Brussels, Germany.

Achi P. B. U., (2000). *An update on the Nigerian environment*. *3rd International Conference on Quality, Reliability, and Maintenance* (QRM 2000) Ed. McNulty GJ Oxford Univ England Consortium Int Activ; Inst Mech Engineers.

Adegoroye, A. (1994). *The challenges of environmental enforcement in Africa: The Nigerian Experience*. The Third International Conference on Environmental Enforcement held in Oaxaca, México, April 25-28, 1994.

Aduagba, O.N., Amine, J. D. and Oseni, M.I. (2013). Investigating Emission Values of a Passenger Vehicle in the Idle Mode and Comparison with Regulated Values. *American Journal of Engineering Research* (AJER) pp-13-19.

Aeroqual Ltd (2015). *Compact of Air Quality Monitoring Station*. Auckland, New Zealand. Aeroqual.

African Development Bank/United Nations Economic Commission, (2003). *For Africa: "Review of the Implementation Status of the Trans African Highways and the Missing Links, Description of Corridors.* African Development Bank.

Autrup, S. E., (2006). Survey of air pollution in Cotonou, Benin – air monitoring and biomarkers. *Science of Total Environment*.358 (1-1), 85-96.

Awange, J. (2010). Motor vehicles Air Pollution in Nairobi, Kenya. *Research Journal of Environmental and Earth Science, 2(4)*, 178-187.

Barth, M. and Boriboonsomsin, K. (2008). Real-World CO_2 Impacts of Traffic Congestion. Transport Research Record. *Journal of the Transportation Research Board*, No. 2058, Transportation Research Board, National academy of science.

Baumbach, G., Vogt, U., Hein, K.R.G., Oluwole, A.F., Ogunsola, O.J., Olaniyi, H.B., and. Akeredolu, F.A., (1995). Air pollution in a large tropical city with a high traffic density - results of measurements in Lagos, Nigeria. *The Science of the Total Environment*, 169, 25-31.

Bilkis, .B., Tazmin, A., Rbbani, K.A., Swapan, K.B. and Nasiruddin, M. (2009). Investigation of Sources of Particulate Matter from the Tajgon Industrial Area, Dhaka. *Journal of Bangladesh Academy of Sciences*, 33(1): 71-85

Botkin, B.D and Keller, E.A (2000), *Environmental Science: Earth as a living* (2nd edition). New York. John Wiley and Sons Ltd.

Bond, M and Rayner, S. (2005). Republic of South Africa: Recently Gazetted and Imminent Vehicle Emission Legislation: GRPE June 2005.SA Representatives at 50th GRPE Agenda Item 8.

Brook R.D., Rajagopalan S., Pope C.A., Brook J.R., Bhatnagar A., Diez-Roux A.V. et al. (2010). Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *Circulation* 121(21): 2331-2378.

Brunekreef, B. (2005). Out of Africa. *Occupation and Environmental Medicine*. Vol: 62:351-352.

Bull, K.R., (1991). The critical loads/levels approach to gaseous emission control, *Environmental Pollution*, 69,105-123.

Bureau of the Census. (1990). Truck Inventory and Use Survey. 1987 Census of Transportation, TC87-T-52. U.S. Department of Commerce, Aug., 166 pg. Cambridge Systematics, Inc. with Hague Consulting Group. 1991. *Making the Land Use Transportation Air Quality Connection*: Vol. I: Modeling Practices.

C.E.P.A. (1999). *Clean Air Act--Compilation of Regulations and Guidelines, Ottawa, Environment Canada (Report EPS1-AP-78-2).* Ottawa: Environment Canada.

CAI-Asia (2010). *Air Quality in Asia: Status and Trends*, 2010 Edition. Clean Air Initiative for Asian Cities (CAIAsia) Center, Philippines, 25 Pages. http://cleanairasia.o rg/wp-content/uploads/portal/files/documents/AQ_in_A sia.pdf.

Chelani, A.B. (2013). Study of extreme CO, NO and O3 concentrations at a traffic site in Delhi: Statistical persistence analysis and source identification. *Aerosol Air Qual. Res*. 13: 377–384.

Chinadaily (2004). China to adopt auto emission standard equal to Euro III in 2008. Chinadaily.com.cn. 2004-07-07. Retrieved 2011-02-02.

Chokor, B. A. (1993). Government policy and environmental-protection in the developing world: the example of Nigeria. *Environmental Management*. 17 (1) 15-30.

Collinsdictionary, (2016). Definition of air quality. Retrieved on 16/04/2017. https://www.collinsdictionary.com/dictionary/english/air-quality

Colls, J. (2002). *Air Pollution.* London: Spon press. pp. 591.

Commission of the European Community (CEC) (1992). *The state of the environment in the European Community, Overview*. Vol. 3. Commission of the Communities, Brussels and Belgium.

Conte, F. (1990). Trucking in the '90s: Emissions. *Owner Operator*. Sept., pp. 58–65.

Dasgupta, S., (2001). Environmental Regulation and development: A Cross-country empirical analysis. *Oxford Development Studies*. 29 (2): 27-30

Delay, A., and Zannetti, P. (2007). An *Introduction to Air Pollution – Definitions, Classifications, and History. Chapter 1 of AMBIENT AIR POLLUTION*. Published by The Arab School for Science and Technology (ASST). Retrieved June 2, 2013, from: http://www.envirocomp.org/books/chapters/1aap.pdf

Department of Environmental Conservation (DEC) (2016). *Controlling Air Pollution from Motor Vehicles.* Department of Environmental Conservation and Motor Vehicles, NYC.

DieselNet, (2017). Engine and emission technology. https://www.dieselnet.com. Retrieved on 9 April, 2017.

Dor, F. (1995). Exposure of city residents to carbon monoxide and monocyclic aromatic hydrocarbon during commuting trips in Paris metropolitan area. *Journal of Air and Waste Management Association (45)*, 103-110.

Driverside, (2017). Glossary of Auto Terms. Driverside Incs. Retrieved on 16/04/2017. https://www.driverside.com/car-dictionary/emissions-5-94

Economic Intelligence Unit, (2013). The Socio-economic Costs of Traffic Congestion in Lagos. Ministry of Economic Planning Lagos State.

Edesess, M. (2011). *Roadside Air Pollution in Hong Kong: Why is It Still so Bad*? School of Energy and Environment, City University of Hong Kong.

EEA (2013). Air Quality in Europe 2013. EEA Technical Reports 9/2013, *European Environment Agency*, Copenhagen.

Enviropedia, (2017). Motor Vehicle Emission Controls: Fuel Types. Retrieved on 4/19/2017 http://www.air-quality.org.uk/26.php

European Commission (1991/2015). 91/441/EEC Council Directive 91/441/EEC of 26 June 1991 amending Directive 70/220/EEC on the approximation of the laws of the Member States relating to measures to be taken against air pollution by emissions from motor vehicles". Eur-lex.europa.eu. Retrieved 2016-02-02.

European Commission (2015). Comparison of real-world off-cycle NOX emissions control in Euro IV, V, and VI," The International Council on Clean Transportation, March 2015,

http://www.theicct.org/sites/default/files/publications/ICCT_Briefing_EuroIV-V-VI-NOx_Mar2015.pdf.

European Parliament and Commission (2002). Directive 2002/51/EC of the European Parliament and of the Council of 19 July 2002 on the reduction of the level of pollutant emissions from two- and three-wheel motor vehicles and amending Directive 97/24/EC. Eur-lex.europa.eu. Retrieved 2016-02-02

European Parliament and Commission (2007). "Regulation (EC) No 715/2007". Retrieved 2016-10-29. Regulation (EC) No. 715/2007 of the European Parliament and of the Council, Official Journal of the European Union, L 171/1, June 29, 2007, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:171:0001:0016: EN:PDF.

European technology emission standards (ETES) (2013). How to check your vehicle. Plymouth City Council. Retrieved 18 February 2017.

European Union (2002/2013). The Clean Air Policy Package, European Commission. http://ec.europa.eu/environment/air/ clean_air_policy.htm.

European Union (2015). Welcomes Member States Agreement on Robust Testing of Air Pollution Emissions by cars. Retrieved 2016-10-30

Evans, R.G., Webb, K., Homan, S. and Ayres, S.M. (1988). Cross-sectional and Longitudinal changes in Pulmonary Function Associated with Automobile Pollution Among Bridge and Tunnel Officers, *Am J. and Med.* 14:25-36

Faiz, A., Weaver, S.W. and Walsh, M.P. (1996). *Air Pollution from Motor Vehicle: Standards and Technologies for Controlling Emissions.* Washington, D.C: The World Bank.

Faulkner, M. and Russell, P. (2010). Review of Local Air Quality Management. A Report to DEFRA and the Devolved Administrations, http://www.scotland.gov.uk/ Resource/Doc/211199/0096175.

Federal Environmental Protection Agency, (FEPA) (1991). Guidelines and Standards for Environmental Protection Control in Nigeria. In Ajayi, A.B and Dosunmu, O.O (2002). *Environmental Hazards of Importing Used Vehicles into Nigeria*. Proceedings of International Symposium on Environment Pollution Control and Waste Management (EPCOWM). (7-10) January, 2002, Tunis, Tunisia. Pp. 521-532.

FHWA. (1992). *Transportation and Air Quality: Searching for Solutions: A Policy Discussion Series.* No. 5, FHWA-PL-92-029. U.S. Department of Transportation, Aug., 30 pp.

Frey, C.H. and Zheng J. (2002). Probabilistic Analysis of Driving Cycle- Based Highway Vehicle Emission Factors. *Environmental Science Technology*, 36(23) 5184-5191.

Fu and Chen, Y. (2015). Air Pollution Dynamics and Modelling *Encyclopedia of Life Support Systems* (EOLSS).

Fu, L. (2001). Assessment of Vehicle Pollution in China. *Journal of the air and waste management*:51(5):658-68.

Gbadamosi, K. T. and Ibrahim S. A. (2013). *Land Use Conversion and Traffic Situation in Lagos, Nigeria: An Impact Assessment of Victoria Island*. Selected Proceedings from World Conference on Transport Research in Rio, Brazil.

Gleick, P.H. (2001). *The World Water 2000-2001*. Washington, DC.: Island Press. World Health Organisation . (2000). *Global Water Supply and Sanitation Assessment*. Geneva. WHO.

Gokhale, S. and Khare, M. (2007). A Theoretical Framework for the Episodic-Urban Air Quality Management Plan (e- UAQMP). *Atmos. Environ*. 41: 7887–7894.

Gorham, R., (2002). *Air Pollution from Ground Transportation an Assessment of Causes, Strategies and Tactics, and Proposed Actions for the International Community*. Division for Sustainable Development Department of Economic and Social Affairs United Nations.

Goyal, S. (2006). Understanding urban vehicular pollution problem vis-a-vis ambient air quality case study of megacity (Delhi, India). *Journal of Environmental monitoring and assessment*, 119:557-569.

Guensler, R., D. Sperling, and P. Jovanis. (1991). Uncertainty in the Emission Inventory for Heavy-Duty Diesel-Powered Trucks. UCD-ITS-RR-91-02. Institute of Transportation Studies, University of California, Davis, June, 146 pp

Guidotii,T.L,. (1995). Ambient air quality and human health: Current concepts, Part 1. *Canadian Respiratory Journal* Vol 2(4):211- 222.

Gulia, S., Nagendra, S.M.S., Khare, M. and Khanna, I. (2015). Urban air quality management: A review. *Atmospheric Pollution Resources*. 6: 286–304.

Guttikunda, S.K. and Gurjar, B.R. (2012). Role of meteorology in seasonality of air pollution in megacity Delhi, India. *Environ. Monit. Assess*. 184: 3199–3211.

Han, X. and Naeher, L. (2006). A Review of Traffic-related Air Pollution Exposure Assessment Studies in the Developing World. *Environment International*. Vol. 32(1): 106-120

Hisashi, Y., Sugawara, K., Sudos, S., Aoki, I. and Nakasawa, T. (2009). Temporal and Spatial variation of Carbon Monoxide over the wester part of the pacific ocean. *journal of Geopysics Res., 114: Dos8305*, 17.

Horowitz, J.L., (1982). *Air Quality Analysis for Urban Transportation Planning*. MIT Press, Cambridge Massachusetts.

Hsu, A. and Zomer, A. (2014). An interactive air-pollution map. http://www.epi.yale.edu/the-metric/interactive-airpollution-map, Last Access: 15 July 15, 2014.

IEA (International Energy Agency) (2006). *Substitute Fuels for Road Transport: A Technology Assessment*. Organization for Economic Cooperation and Development, Paris.

IEA (International Energy Agency) (2012). *Substitute Fuelsfor Road Transport: A Technology Assessment*. Paris. Organization for Economic Cooperation and Development.

IEA. (2010). Enabling low-carbon end-use. Retrieved September 13, 2014, from International Energy Agency: http://www.iea.org/media/etp/FactsheetETP2012EndUseSector.pdf

International Council on Clean Transportation, (2014). EU CO2 standards for passenger cars and light-commercial vehicles. https://en.wikipedia.org/wiki/Emission_standard Accessed on 19 February 2017.

IPCC. (2001). *Climate Change 2001*: TheScientific Basis. Contribution of Working GroupI to the Third Assessment Report of theIntergovernmental Panel on Climate Change. University Press,Cambridge, United Kingdom and New York, USA, 881 pg.

Ismaila, A.O., Bolaji, B. O., Adetunji, .O. R, Adekunle, N. O.,. Yusuf, T. A. and . Sanusi, H. O., (2013). Vehicular Emission of Petrol and Diesel Engines. *International Journal of Engineering*. Pp. 1584-2673.

Itai, M. (2006). NEPAD Promoting Better Transport Networks. *Africa Renewal*, Vol. 20 (3)

Itua, E.O., (2010). Vehicular Emission (Air Quality) Monitoring Study in Lagos, Nigeria. Ikeja, Lagos. *Lagos Council of the Waste Management Society of Nigeria (WAMASON)*.

Iyoha, M.A., (2009). The Environmental effects of oil industry activities on the Nigerian Economy: A theoretical Analysis: Paper presented at National Conference on the management of Nigeria's petroleum Resources, Department of Economics, Delta State University Nigeria, 2009

Jeremiah, K., (2016, July, 22). Vehicle emission: Failure of roadworthiness scheme. Guardian Newspapers. Retrieved on 30/04/2017: Lagos Vehicle emission_ Failure of roadworthiness scheme_ — Features — The Guardian Nigeria.html

Jerome, A. (2000). Use of Economic instruments for Environmental Management in Nigeria. Paper presented at workshop on Environmental Management in Nigeria and Administration (NCEMA) in Abuja on July, 2000.

Karlson H.L., (2004). Ammonia, Nitrous Oxide and Hydrogen Cyanide Emissions from Fire Passenger Vehicles. *Science of Total Environment*, 334/335,125-132.

Kean, A.J., R.A. Harley, D. Littlejohn, and G.R. Kendall. (2000). On-road measurement of ammonia and other motor vehicle exhaust emissions. *Environmental Science and Technology,* vol. 34, No. 17, 1

Kelly, F.J., and Fussel, J.C., (2012). Size, Source and Chemical Composition as Determinants of Toxicity Atttributable to Ambient Air Particulate Matter. *Atmospheric Environment*, 60, 504-526.

Khaled-Ahmad, A.A. (2010). GIS-Based Mapping and Statistical Analysis of Air Pollution and Mortality in Brisbane, Australia. Unpublished M.Sc Dissertation, School of Built Environment and Engineering Research, Queensland University of Technology, Australia

Koku, C. A., and Osuntogun, B. A. (1999). Environmental Impacts of Road Transportation in South-western State of Nigeria. *Journal of Applied Science, 7*(6), 2536-2360.

Kumar, P., Khare, M., Harrison, R.M., Bloss, W.J., Lewis, A., Coe, H. and Morawska, L. (2015). New Directions: Air pollution challenges for developing megacities like Delhi. *Atmos. Environ.* 122: 657–661.

Lagos Area Metropolitan Transit Authority, (2016). www.lamata-ng.com. Retrieved February 19 2017.

Lagos Bureau of Statistics (LBS), (2013). *Annual Abstract of Statistics*, Alausa, Ikeja, Lagos.

Lagos Business School (LBS) (2014). *Monthly Economic News and Views*. Ikeja-Lagos, Financial Derivative Company Limited.

Lagos State Government (2010). Digest of Statistics 2010. Lagos State. Retrieved 4 April 2015.

Lagos Urban Transport Project (LUTP) (2002). *Inventory of Urban Development Infrastructure*.Lagos State Government, Lagos.

LAMATA (2012). LAMATA Ferry Services. Retrieved 19 January 2017

LAMATA, (2012). Lagos Metropolitan Area Transport Authority Rail Services. Retrieved 14 April 2016.

Legge AH, English M, Guidotti TL, Sandhu H. A,. (1992). Vision of Clean Air. *J Air Waste Management Association* Vol. 42:888-9 I.

Lvovsky, K., (2000). Environmental costs of fossil fuels: a rapid assessment method with application to six cities. *Environment Department Paper* 78. Washington, DC, World Bank.

Magbagbeola, N. O., (2001). The use of Economic Instruments for Industrial pollution Abatement in Nigeria: Application to the Lagos Lagoon. Selected paper, *Annual Conferences of the Nigerian Economic Society*. Port- Harcourt, Nigeria.

Mark, J. (2001). Strong Radiative heating due to the mixing state of black carbon in atmospheric aerosols. *In nature*. Vol: 409.

Mechelec Consortium (1996). Lagos Urban Transport Project Volume 2: Environmental Impact Assessment. Ikeja, Lagos State Ministry of Public Transportation.

Ministry of Economic Budget and planning (2013). Working Paper Series No. 2: *The Socio-economic Costs of Traffic Congestion in Lagos*. Economic Intelligence Unit, Ministry of Economic Planning and Budget, Ikeja, Lagos.

Moen, E. (2008). Vehicle Emissions and Health Impacts in Abuja, Nigeria an Unpublished Thesis submitted in partial fulfillment of the Bachelor of Science degree in Environmental Science, with Honors distinction. Retrieved January 05, 201, from: http://envstudies.brown.edu/.theses/archive20072008/ericaoenthesis.pdf/

Motor Vehicle Administration Agency and Lagos Bureau of statistics (2013). *Motor Vehicle Statistics*. Lagos State Government.

Moussiopoulos, N., Kalognomou, E.A., Douros, I., Samaras, Z., Gionnouli, M. and Mellios, G. (2005). Air pollution level at hotspot areas of selected European cities. Proceeding of 10th conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes held in Sissi, *Crete*, pp. 283–287.

Musa, K.H., (2014). *Contribution of Motor Vehicle Emissions to Air Pollution in Kaduna Metropolis, Nigeria*. Unpublished M.Sc dissertation submitted to the Department of Geography, Ahmadu Bello University Zaria, Kaduna State, Nigeria.

National automotive Council (NAC) (2014). *New Auto Industry Policy Seeks to Revive Local Production*. Abuja, Economic Intelligent Unit Limited.

National Bureau of Statistics, (2015). Lagos State Information. NBS publication. Retrieved January, 2017.

National Population Commission (NPC) (2009). *The Nigeria Population Census 2006 Figures* .Federal Republic of Nigeria.

National Research Council (2010). *Ocean Acidification*: A National Strategy to Meet the Challenges of a Changing Ocean. Washington DC, The National Academic Press.

Ndoke, P.N. and Jimoh O.D (2000). Impact of Traffic Emission on Air Quality in Developing City of Nigeria. *Leonardo Electronic Journal of Practices and Technologies*. 6 (9): 88-92

Ndoke, P.N., Akpan. U.G. and Kato, M.E. (2006). Contributions of Vehicular Traffic to Carbon Dioxide Emissions in Kaduna and ABja, Northern Nigeria. *Leonardo Electronic Journal of Practices and Technologies*. Pp.81-90

NESREA. (2009). Corporate Strategic Plan 2009-2012: *Building Capacity, Enforcing Compliance*. A publication of National Environmental Standards and Regulations Enforcement Agency. 2009. Online. http://www.nesrea.org/forms/NESREA%20CSP.pdf [Accessed on 10/02/16]

Nizich, S.V., T.C. McMullen, and D.C. Misenheimer. (1994). *National Air Pollutant Emissions Trends, 1900–1993*. EPA-454/R-94-027. Office of Air Quality Planning and Standards, Research Triangle Park, N.C., Oct., 314 pp

Nordenhall, C. Pourazar, J. Ledin, M.C, Levin, J.O. Sandstrom, T. and Adelroth, E. (2001) Diesel Exhaust Enhances Airway Responsiveness in Asthmatic Subjects. *European Respiratory Journal* 17:909-915

Odhiambo, G.O. Kinyua., A.M. Gatebe, C.K. and Awange, J. (2010). Motor Vehicles Air Pollution in Nairobi, Kenya. *Research Journal of Environmental and Earth Sciences*, 2(4): 178-187

Ogunba, O.A. (2004). EIA systems in Nigeria: evolution, current practice and shortcomings. *Environmental Impact Assessment Review*. 24, 643–660.

Okunola, O.J., Uzairu, A., Gimba, C.E. and Kagbu, J.A. (2012). Assessment of Gaseous Pollutant along High Traffic Roads in Kano, Nigeria. *International Journal of Environment and Sustainability*. 1(1): 157-1590

Omidvarborna, A. (2014). Characterization of Particulate Matter Emitted from Transit Buses Fueled with B20 in Idle Modes. *Journal of Environmental Chemical Engineering*. 2 (4): 2335–2342. doi:10.1016/j.jece.2014.09.020.

Oni, S.I., and Okanlawon, R.K., (2004). Challenges and Prospects of Urban Mas Transit in Lagos, Nigeria. Paper Presented at the National Conference on Transport Professionalism in Nigeria 21st Century. 24-26th November at Olabisi Onabanjo University Ayo-Iwoye.

Oni, S. I. (2004). Urbanization and Transportation Development in Metropolitan Lagos',in Adejugbe M. O.A (ed.) *Industrialization, Urbanization and Development in Nigeria 1950 – 1999*. Lagos, Concept Publications Limited.

Onursal, B. and Gautam, S.P. (1997).*Vehicle Air Pollution: Experiences from seven Latin American Urban Centre*. Technical Paper No. 373. Washington D.C: World Bank

Pant, P. and Harrison, R.M. (2013). Estimation of the contribution of road traffic emissions to particulate matter concentrations from field measurements: A review. *Atmos. Environ*. 77: 78–97.

Pant, P., Shukla, A., Kohl, S.D., Chow, J.C., Watson, J.G. and Harrison, R.M. (2015). Characterization of ambient PM2.5 at a pollution hotspot in New Delhi, India and inference of sources. *Atmos. Environ*. 109: 178–189.

Parrish, D.D., Singh, H.B., Molina, L. and Madronich, S. (2011). Air quality progress in North American megacities: A review. *Atmos. Environ*. 45: 7015–7025.

Perry, A. (2011). Intelligent Cities: Making Over Lagos. Time Lists. Retrieved 20 June 2016.

Piers, F., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood J., *et al* (2007). *Changes in Atmospheric Constituents and Radioactive Forcing*. Contribution of Working Group I to the Fourth Assessment report of the Intergovernmental Panel on Climate Change in Climate Change 2007: *The physical Science Basis.* Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. PP. 129-234.

Prockop, L.D. and Chichkova, R.I. (2007). Carbon Monoxide Intoxication: An Update review. *Journal of the Neurological Sciences.* 262 (1-2): 122-130.

Pummakarnchana, ., Tripathi N, and Dutta J. (2005). Air Pollution Monitoring and GIS Modeling: A New Use of Nanotechnology Based Solid State Gas Sensors. Science and Technology of Advanced Materials 6 (2005) 251-255 Retrieved July 23, 2012from: http://faculty.mu.edu.sa/public/uploads/1338152569.2953air-24.pdf/

Quality of Urban Air Review Group,(QUARG) (1993). *Diesel Vehicle Emissions and Urban Air Quality, Second report*. Quality of Urban Air Review Group.

Ravindra, K. E., Wauters, E., Tyagi, S. K., Mor, S., and Grieken, R. V. (2015). A ssessment of air quality after implementation of CNG as fuel in public transport in Delhi, India. Environmental Monitoring and Assessment.

Riedl, M. and Sanchez, D. (2005). Biology of Diesel Exhaust Effects on Respiratory Function. *Journal Allergy Clin Immunol*:115(2):221-228.

Hassan, S.M and Okobia, L.E., (2008). Survey of Ambient Air Quality in Some Parts of The Federal Capital Territory, Abuja, Nigeria. *Abuja Journal of Geography and Development*, Vol. 2.

Saville, S. B., (1993). Automotive options and quality Management in developing Countries *Industrial Environment*. 16(1-2); 20, 32.

Schwela, D. (2000). Air Pollution and Health in Urban Areas. *Reviews on Environmental Health*. 15(12): 13-24.

Singh, S. K. (2006). Future Mobility in India: Implications for energy demand and CO_2 emission. *Transport Policy , 13*, 398–412

Sprawl, J. (2001). *Measuring Vehicular Contribution to Smog*. Freetown, Sierra Club.

Stam, R., (2005). Ambient Air Pollution and Pregnancy Outcomes: A review of the Literature. *Environmental Health Perspectives*. 113(4): 375-38

Taiwo, K., (2005). The Case of Lagos: Air Quality Improvement Project. A Seminar paper presented at Lagos Metropolitan Area Transport Authority *(LAMATA*), Lagos, Nigeria in August 2005.

The Federal Government Printer. (2007). *National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, 2007*. Federal Republic of Nigeria Official Gazette 94(92)

Tiwari, S., Chate, D.M., Pragya, P., Ali, K. and Bisht, D.S. (2012). Variations in mass of the PM10, PM2.5 and PM1 during the monsoon and the winter at New Delhi. *Aerosol and Air Qual. Res.* 12: 20–29.

U.S. Global Change Research Program (USGCRP). (2005). Our Changing planet: The U.S. Climate Change Science Program for Fiscal Year 2006. Washington D.C.: U.S. Global Change Research Program. http:// http://library.globalchange.gov/products/annualreports/our-changing-planet-the-u-s-climate-change-science-program-for-fy-2006-cd (Accessed on November 1, 2015).

UNFPA (2007). State of World Population 2007: Unleashing the Potential of Urban Growth., United Nations Fund for Population Activities (INFPA) Online Report, Retrieved May 13, 2012, from: http://www.unfpa.org/swp/2007/english/introduction.html

United Nation Conference on Trade and Development (UNCTAD) (2012). *Trade and Development*. United Nation, Geneva, Switerland.

USEPA (1994). *National Air Quality and Emission Trends Report*. United State Environmental Protection Agency. Washington DC, USA.

USEPA (2012a). *Environmental Fact Sheet: Air Toxics Motor Vehicles.* Retrieved from http://www.epa.gov/otaq/f02004.pdf. Accessed on 8-11-2015

USEPA (2012b). *Our Nation's Air Status and Trends through 2010*. U.S. Environment Protection Agency. EPA-454/R-12-001.

USEPA. (2003). *National air quality and emissions trends report*. New York: 2003 special studies edition. EPA/454/R-03/005.

USEPA. (1993). Guide to Environmental Issues, Doc. No 520/B-94-01. United States Environmental Protection Agency, Washington, DC, USA.

Vasarevicius, S. (2011). *Classification of the Main Pollutants: Emissions Sources*. PlasTEP trainings course and Summer school 2011 Warsaw / Szczecin.

Villand, A. (2010). *Aerosols: Tiny Particles, big Impact*. Earth Observatory.

Walker, M. (2012). Vehicle emissions and global warming. Celsias, (online) http://www.celsias.com/article/vehicle-emissions-and-global-warming/ (Accessed on December 19, 2011).

Wang, Q., Zhuang, G., Huang, K., Liu, T., Lin, Y., Deng, C., Fu, Q., Fu, J.S., Chen, J., Zhang, W. and Yiming, M. (2016). Evolution of particulate sulfate and nitrate along the Asian

dust pathway: Secondary transformation and primary pollutants via long-range transport. *Atmospheric Resource*, 169: 86–95.

Wangwongwatana, S., (2018) Thailand: Implementing vehicle emission standards and equivalent fuel quality, and Roadmap to Euro 6/VI Paper presentation at United Nations Conference Centre Bangkok, Thailand on *Cleaner Fuels and Vehicles in Asia: Implementing the Global Sulfur Strategy* in 20 March 2018

Wargo, J., Wargo, L., Alderman N. and Brown, D.R. (2006). The Harmful Effects of Vehicle Exhaust. A Case for Policy Change. *Environmental and Human Health Inc*. Retrieved May 05, 2012 from http://www.epa.gov/otaq/f02004.pdf

Weaver, C.S., and R.F. Klausmeier. (1988). *Heavy-Duty Diesel Vehicle Inspection and Maintenance Study*. Final Report, Volume II: Quantifying the Problem. Radian Corporation, Sacramento, Calif., May 16

World Bank (2009). Logistic Performance Index of Africa's Transport Infrastructure. Washington DC, World Bank.

World Population Review (WPR) (2015) 2015 World Population Review. Retrieved at worldpopulationreview.com/world-cities/lagos-population/

Xinhua, H., (2004). China to adopt auto emission standard equal to Euro III in 2008. Chinadaily 2004-07-07 16:13. http://www.chinadaily.com.cn/english/doc/2004 07/07/content_346332.htm

Yahya, A.A., (2013). Evaluation of the Ambient Air Quality and Hazardsbfrom Vehicular Emission in Urban Zaria, Niegeria Using Geo-Information Technology. *Unpublished Msc Dissertation Submitted to the Department of Geography, Ahmadu Bello University Zaria, Nigeria*.

Yamene, T. (1976). *An Introductory Analysis*. 2rd Edition New York: Harper and Row Publishers.

Yang, K.D. (2000). Childhood Asthma: Aspects of Global Environment, Genetics and Management. *Changeng Yi Xue Za Zhi*: 23(11): 641-661

Yang, Z., (2018). China: Case of China in Implementing China 4/IV and Designing China 6/VI standards. Paper presentation at United Nations Conference Centre Bangkok, Thailand on *Cleaner Fuels and Vehicles in Asia: Implementing the Global Sulfur Strategy* in 20 March 2018

Zhang, H., Wang, S., Hao, J., Wang, X., Wang, S., Chai, F. and Li, M. (2012). Air pollution and control action in Beijing. *J. Cleaner Prod*. 112: 1519–1527.

APPENDIXES

Appendix 1: Ambient Air Quality Data Sheet (Monday to Sunday)

Monday										
Location	**Time**	**Coordinate**	**COppm**	**CO2ppm**	**HCppm**	**NOppm**	**PM10ppm**	**PM2.5ppm**	**RH%**	**^{o}C**
Ojota Corridor	1	06,35,33.0N,003,22,43.6E	17.7	3	40	1	360	164	73	31
Ikorodu Corridor	1	06,32.00.4N,003,22,01.9E	16.8	1	26	0.01	178	81	70	32
Oshodi Corridor	1	06,32,00.4N, 003,21,06.6E	16.8	2	41	0	102	51	62	35
Ikeja Along Corridor	1	06,36, 48.9N,003,20,27.1E	16.97	5	19	0	233	111	59	35
Dopemu Corridor	1	06,36, 33.0N,003,18,34.4E	16.75	55	36	0.1	153	81	56	36
Awolowo Road Ikeja	1	06 36 33.0N 003 18 34E	16.7	45	34	0	162	86	56	37
Ojota Corridor	2	06,35,33.0N,003,22,43.6E	16.55	2	11	0.09	98	46	51	34
Ikorodu Corridor	2	06,32.00.4N,003,22,01.9E	16.15	1	15	0.05	89	35	54	35
Oshodi Corridor	2	06,32,00.4N, 003,21,06.6E	16.65	1	9	0	78	37	53	36
Ikeja Along Corridor	2	06,36, 48.9N,003,20,27.1E	16.79	1	12	0.09	91	34	52	36
Dopemu Corridor	2	06,36, 33.0N,003,18,34.4E	16.84	0	8	0	112	51	51	35
Awolowo Road Ikeja	2	06 36 33.0N 003 18 34E	17.1	1	10	0	64	32	3	35
Ojota Corridor	3	06,35,33.0N,003,22,43.6E	17.09	12	43	0.07	310	160	73	31
Ikorodu	3	06,32.00.4N,003,22,01.9E	17.03	23	35	0.01	176	80	70	31

Corridor										
Oshodi Corridor	3	06,32,00.4N, 003,21,06.6E	17.16	16	37	0	120	55	62	32
Ikeja Along Corridor	3	06,36, 48.9N,003,20,27.1E	16.977	20	51	0.06	333	171	59	29
Dopemu Corridor	3	06,36, 33.0N,003,18,34.4E	17.01	17	32	0	150	79	56	30
Awolowo Road Ikeja	3	06 36 33.0N 003 18 34E	17.13	22	39	0.1	152	84	56	31

Tuesday

Location	**Time**	**Coordinate**	**COppm**	**CO2ppm**	**HCppm**	**NOppm**	**PM10ppm**	**PM2.5ppm**	**RH%**	**^{o}C**
Ojota Corridor	1	06,35,33.0N,003,22,43.6E	17.03	33	50	0.7	319	152	75	33
Ikorodu Corridor	1	06,32.00.4N,003,22,01.9E	16.64	30	27	1	354	154	73	33
Oshodi Corridor	1	06,32,00.4N, 003,21,06.6E	16.01	29	30	0	140	61	64	34
Ikeja Along Corridor	1	06,36, 48.9N,003,20,27.1E	17.03	32	31	2	207	109	60	35
Dopemu Corridor	1	06,36, 33.0N,003,18,34.4E	17.03	24	21	0.09	394	188	55	36
Awolowo Road Ikeja	1	06 36 33.0N 003 18 34E	16.85	28	25	0	311	176	58	35
Ojota Corridor	2	06,35,33.0N,003,22,43.6E	16.6	21	18	0.7	141	54	52	37
Ikorodu Corridor	2	06,32.00.4N,003,22,01.9E	16.68	19	20	0	100	50	58	34
Oshodi Corridor	2	06,32,00.4N, 003,21,06.6E	16.19	23	21	1	156	65	53	35
Ikeja Along Corridor	2	06,36, 48.9N,003,20,27.1E	16.01	15	17	0	300	158	57	36
Dopemu	2	06,36,	17.02	9	15	0.02	148	178	58	35

Corridor		33.0N,003,18,34.4E								
Awolowo Road Ikeja	2	06 36 33.0N 003 18 34E	17.15	15	5	0	118	54	57	35
Ojota Corridor	3	06,35,33.0N,003,22,43.6E	17.1	31	29	0	78	39	78	31
Ikorodu Corridor	3	06,32.00.4N,003,22,01.9E	17.01	37	19	0.9	67	32	80	31
Oshodi Corridor	3	06,32,00.4N, 003,21,06.6E	17.15	10	41	0	99	45	77	32
Ikeja Along Corridor	3	06,36, 48.9N,003,20,27.1E	17.07	30	30	0.12	197	94	74	31
Dopemu Corridor	3	06,36, 33.0N,003,18,34.4E	17.08	28	54	0	236	118	68	33
Awolowo Road Ikeja	3	06 36 33.0N 003 18 34E	17.09	36	47	1.1	155	74	95	32
Wednesday										
Ojota Corridor	1	06,35,33.0N,003,22,43.6E	17.1	55	42	0.4	208	104	81	31
Ikorodu Corridor	1	06,32.00.4N,003,22,01.9E	17.02	55	39	2	237	125	78	31
Oshodi Corridor	1	06,32,00.4N, 003,21,06.6E	17.13	30	27	0.03	73	32	78	32
Ikeja Along Corridor	1	06,36, 48.9N,003,20,27.1E	17.14	48	31	0	170	64	75	32
Dopemu Corridor	1	06,36, 33.0N,003,18,34.4E	16.79	30	33	0.01	176	58	73	33
Awolowo Road Ikeja	1	06 36 33.0N 003 18 34E	16.8	30	36	0	76	39	72	32
Ojota Corridor	2	06,35,33.0N,003,22,43.6E	15.11	20	32	0.8	221	119	71	36
Ikorodu Corridor	2	06,32.00.4N,003,22,01.9E	15.59	27	30	1	167	76	65	35
Oshodi Corridor	2	06,32,00.4N, 003,21,06.6E	16.01	15	14	0	73	35	61	34
Ikeja Along	2	06,36,	16.04	17	26	0.03	198	61	68	34

Corridor		48.9N,003,20,27.1E								
Dopemu Corridor	2	06,36, 33.0N,003,18,34.4E	15.01	19	29	1.1	156	54	61	36
Awolowo Road Ikeja	2	06 36 33.0N 003 18 34E	15.01	23	15	0	201	102	60	35
Ojota Corridor	3	06,35,33.0N,003,22,43.6E	17.05	29	40	0.1	390	202	51	32
Ikorodu Corridor	3	06,32.00.4N,003,22,01.9E	17	40	47	0.7	289	156	57	31
Oshodi Corridor	3	06,32,00.4N, 003,21,06.6E	17.02	35	42	0	301	170	58	31
Ikeja Along Corridor	3	06,36, 48.9N,003,20,27.1E	17.03	40	40	0.01	363	198	59	31
Dopemu Corridor	3	06,36, 33.0N,003,18,34.4E	17.01	38	43	0	342	167	67	32
Awolowo Road Ikeja	3	06 36 33.0N 003 18 34E	17.08	64	41	0.01	402	231	63	33
Thursday										
Ojota Corridor	1	06,35,33.0N,003,22,43.6E	23	50	41	0.07	501	217	71	31
Ikorodu Corridor	1	06,32.00.4N,003,22,01.9E	17.01	45	39	0.06	736	320	63	31
Oshodi Corridor	1	06,32,00.4N, 003,21,06.6E	17.09	55	40	0.01	1399	69	60	31
Ikeja Along Corridor	1	06,36, 48.9N,003,20,27.1E	17.07	42	50	0.5	138	68	59	32
Dopemu Corridor	1	06,36, 33.0N,003,18,34.4E	22	39	35	0	135	59	82	31
Awolowo Road Ikeja	1	06 36 33.0N 003 18 34E	21	33	30	0	274	160	85	31
Ojota Corridor	2	06,35,33.0N,003,22,43.6E	16.89	30	34	0	236	187	78	34
Ikorodu Corridor	2	06,32.00.4N,003,22,01.9E	16.16	35	50	0.06	301	200	98	35
Oshodi Corridor	2	06,32,00.4N, 003,21,06.6E	16.5	9	17	0.7	308	203	76	35

Ikeja Along Corridor	2	06,36, 48.9N,003,20,27.1E	23	11	19	0	254	254	70	36
Dopemu Corridor	2	06,36, 33.0N,003,18,34.4E	18.98	23	51	0.9	298	124	79	35
Awolowo Road Ikeja	2	06 36 33.0N 003 18 34E	16.76	33	29	0	407	177	71	34
Ojota Corridor	3	06,35,33.0N,003,22,43.6E	17.05	33	23	0.07	397	157	66	31
Ikorodu Corridor	3	06,32.00.4N,003,22,01.9E	17.1	40	51	0.06	421	189	65	30
Oshodi Corridor	3	06,32,00.4N, 003,21,06.6E	17.17	49	41	0	502	199	67	31
Ikeja Along Corridor	3	06,36, 48.9N,003,20,27.1E	20	44	40	0.01	249	112	65	32
Dopemu Corridor	3	06,36, 33.0N,003,18,34.4E	18.23	63	38	0.02	207	98	64	32
Awolowo Road Ikeja	3	06 36 33.0N 003 18 34E	17.33	48	53	0	75	33	65	32
Friday										
Ojota Corridor	1	06,35,33.0N,003,22,43.6E	16.96	46	46	0.07	365	166	73	33
Ikorodu Corridor	1	06,32.00.4N,003,22,01.9E	23.81	31	41	0.03	489	233	73	32
Oshodi Corridor	1	06,32,00.4N, 003,21,06.6E	16.98	40	39	0	702	311	73	32
Ikeja Along Corridor	1	06,36, 48.9N,003,20,27.1E	17.3	50	45	0.01	662	301	73	32
Dopemu Corridor	1	06,36, 33.0N,003,18,34.4E	18.11	48	47	0	501	298	73	32
Awolowo Road Ikeja	1	06 36 33.0N 003 18 34E	17.09	41	49	0.05	481	209	73	32
Ojota Corridor	2	06,35,33.0N,003,22,43.6E	16	30	20	0.02	102	74	78	36
Ikorodu Corridor	2	06,32.00.4N,003,22,01.9E	16.01	29	18	0.01	94	57	73	37
Oshodi Corridor	2	06,32,00.4N,	16.1	40	29	0	160	77	80	36

		003,21,06.6E								
Ikeja Along Corridor	2	06,36, 48.9N,003,20,27.1E	16.09	47	27	0.08	150	91	73	36
Dopemu Corridor	2	06,36, 33.0N,003,18,34.4E	16	39	30	0.01	201	101	74	36
Awolowo Road Ikeja	2	06 36 33.0N 003 18 34E	17.01	30	31	0	298	118	76	37
Ojota Corridor	3	06,35,33.0N,003,22,43.6E	17.23	59	43	0	600	231	71	31
Ikorodu Corridor	3	06,32.00.4N,003,22,01.9E	23	50	41	0	521	217	69	30
Oshodi Corridor	3	06,32,00.4N, 003,21,06.6E	21	47	51	0.01	250	151	72	31
Ikeja Along Corridor	3	06,36, 48.9N,003,20,27.1E	17.21	56	44	0	700	298	70	31
Dopemu Corridor	3	06,36, 33.0N,003,18,34.4E	17.01	60	34	0.05	501	245	70	32
Awolowo Road Ikeja	3	06 36 33.0N 003 18 34E	17.31	45	45	0.02	320	112	71	32
6th Day Saturday										
Ojota Corridor	1	06,35,33.0N,003,22,43.6E	17.01	23	11	0.01	177	77	79	27
Ikorodu Corridor	1	06,32.00.4N,003,22,01.9E	17.02	3	0	0	345	81	81	27
Oshodi Corridor	1	06,32,00.4N, 003,21,06.6E	16.84	24	0	0.05	404	65	65	32
Ikeja Along Corridor	1	06,36, 48.9N,003,20,27.1E	20.09	45	52	0	303	64	64	32
Dopemu Corridor	1	06,36, 33.0N,003,18,34.4E	21	45	2	0.06	376	58	58	33
Awolowo Road Ikeja	1	06 36 33.0N 003 18 34E	16.5	5	3	0	259	57	57	34
Ojota Corridor	2	06,35,33.0N,003,22,43.6E	19.55	32	9	0.08	380	100	66	34
Ikorodu Corridor	2	06,32.00.4N,003,22,01.9E	22	21	21	0.06	201	89	62	34

Oshodi Corridor	2	06,32,00.4N, 003,21,06.6E	21.01	11	34	0.03	187	77	60	34
Ikeja Along Corridor	2	06,36, 48.9N,003,20,27.1E	18.67	39	8	0.01	187	60	70	34
Dopemu Corridor	2	06,36, 33.0N,003,18,34.4E	20.09	42	2	0	143	57	64	34
Awolowo Road Ikeja	2	06 36 33.0N 003 18 34E	18.01	17	16	0.06	168	71	60	33
Ojota Road	3	06,35,33.0N,003,22,43.6E	20.03	12	14	0.07	272	92	56	31
Ojota Corridor	3	06,32.00.4N,003,22,01.9E	19.9	9	0	0.04	300	102	60	33
Ikorodu Corridor	3	06,32,00.4N, 003,21,06.6E	20.01	6	19	0.05	275	95	51	32
Oshodi Corridor	3	06,36, 48.9N,003,20,27.1E	17.98	39	1	0.01	259	90	58	32
Ikeja Along Corridor	3	06,36, 33.0N,003,18,34.4E	23	46	9	0.01	200	78	50	30
Dopemu Corridor	3	06 36 33.0N 003 18 34E	21	17	15	0.03	301	110	57	31
Sunday										
Ojota Corridor	1	06,35,33.0N,003,22,43.6E	15.9	0.3	12	0	136	62	89	29
Ikorodu Corridor	1	06,32.00.4N,003,22,01.9E	16.98	0.02	9	0	129	68	87	31
Oshodi Corridor	1	06,32,00.4N, 003,21,06.6E	16.95	0	6	0	88	44	81	32
Ikeja Along Corridor	1	06,36, 48.9N,003,20,27.1E	17.14	0.02	18	0	75	36	78	30
Dopemu Corridor	1	06,36, 33.0N,003,18,34.4E	17.2	0	2	0	150	52	72	31
Awolowo Road Ikeja	1	06 36 33.0N 003 18 34E	16.92	0.01	16	0.02	156	71	72	33
Ojota Corridor	2	06,35,33.0N,003,22,43.6E	16.98	0.01	3	0	97	40	54	36

Ikorodu Corridor	2	06,32.00.4N,003,22,01.9E	17.98	0	8	0	130	51	655	33
Oshodi Corridor	2	06,32,00.4N, 003,21,06.6E	17.14	0	14	0	120	47	61	34
Ikeja Along Corridor	2	06,36, 48.9N,003,20,27.1E	16.92	0	0	0.01	171	54	58	35
Dopemu Corridor	2	06,36, 33.0N,003,18,34.4E	16.89	0.01	9	0	145	56	63	34
Awolowo Road Ikeja	2	06 36 33.0N 003 18 34E	16.9	0.02	16	0	109	41	32	37
Ojota Corridor	3	06,35,33.0N,003,22,43.6E	16.98	0.01	12	0.01	270	135	52	34
Ikorodu Corridor	3	06,32.00.4N,003,22,01.9E	16.64	0	9	0	63	30	51	34
Oshodi Corridor	3	06,32,00.4N, 003,21,06.6E	17.09	0.01	20	0.04	200	100	50	34
Ikeja Along Corridor	3	06,36, 48.9N,003,20,27.1E	16.16	0.04	15	0.04	169	77	67	34
Dopemu Corridor	3	06,36, 33.0N,003,18,34.4E	16.96	0.05	7	0	118	59	58	33
Awolowo Road Ikeja	3	06 36 33.0N 003 18 34E	17.07	0.01	17	0.05	70	32	60	34

Appendix 2: Cars, Jeeps and Mini Bus Emission Data Sheet

MAKE	MODEL	FUEL	COppm	HCppm	CO_2ppm	NOppm
NISSAN	MAXIMA	PETROL	0.00	11	15.20	7.50
NISSAN	DATSUN	PETROL	0.49	133	9.80	6.66
NISSAN	PRIMERA SLX 2.0	PETROL	0.11	331	9.50	7.19
NISSAN	PATHFINDER	PETROL	0.00	7	0.00	20.57
NISSAN	SUNNY 1.6 SLX	PETROL	1.02	430	5.70	131.00
NISSAN	SUNNY (1.6)	PETROL	1.01	230	3.60	122.00
NISSAN	SUNNY	PETROL	3.14	363	10.70	277.00
NISSAN	SUNNY	PETROL	8.09	1117	4.40	110.00
NISSAN	SUNNY (1.6)	PETROL	3.15	2670	5.90	98.00
NISSAN	SUNNY 4X4	PETROL	7.98	420	8.00	102.00
NISSAN	SLX	PETROL	6.07	1706	6.20	100.00
NISSAN	140Y	PETROL	1.07	173	12.20	243.00
NISSAN	SUNNY 120Y	PETROL	4.43	297	4.50	212.00
NISSAN	SUNNY 120Y	PETROL	1.44	959	6.10	171.00
NISSAN	SUNNY	PETROL	6.04	354	9.60	115.00
NISSAN	PATHFINDER	PETROL	0.00	56	10.90	9.80
NISSAN	SUNNY	PETROL	1.02	1023	12.05	109.00
NISSAN	SENTRA	PETROL	0.02	28	14.50	97.00
NISSAN	SUNNY	PETROL	3.14	363	10.70	76.00
NISSAN	SUNNY	PETROL	8.09	1117	4.40	123.00
NISSAN	SUNNY (1.6)	PETROL	8.90	1901	5.90	190.00
NISSAN	SUNNY 4X4	PETROL	7.98	420	8.00	130.00
NISSAN	SLX	PETROL	7.90	981	6.20	107.00
NISSAN	140Y	PETROL	1.07	173	15.00	243.00
NISSAN	SUNNY 120Y	PETROL	3.45	321	12.00	123.00
NISSAN	PRIMERA SLX 2.0	PETROL	4.23	213	9.00	187.00
NISSAN	PATHFINDER	PETROL	4.12	275	14.00	104.00
NISSAN	PRIMERA SLX 2.0	PETROL	7.34	340	8.90	106.00

NISSAN	PATHFINDER	PETROL	5.78	1908	7.80	130.00
NISSAN	PATHFINDER	PETROL	0.34	15	13.00	7.90
NISSAN	PATROL SGL 4X4	PETROL	0.42	54	13.50	0.63
NISSAN	PATROL SGL 4X4	PETROL	1.20	84	13.70	0.42
NISSAN	CIVILLIAN	PETROL	3.44	157	6.70	7.41
NISSAN	PRIMERA SLX 2.0	PETROL	7.34	340	8.90	106.00
PEUGEOT	406	PETROL	1.90	120	15.00	119.00
PEUGEOT	504/2000	PETROL	2.86	472	9.30	5.28
PEUGEOT	907	PETROL	5.67	240	9.10	2.44
PEUGEOT	407	PETROL	1.33	181	12.30	1.98
PEUGEOT	2000	PETROL	0.43	182	13.00	1.99
PEUGEOT	2000	PETROL	8.58	2019	5.90	4.19
PEUGEOT	2000	PETROL	5.63	224	9.00	2.55
PEUGEOT	504/2000	PETROL	9.51	444	7.50	0.84
PEUGEOT	407 GL	PETROL	5.68	2220	5.80	6.34
PEUGEOT	307	PETROL	4.71	326	8.20	8.70
PEUGEOT	406	PETROL	8.00	342	1	6.01
PEUGEOT	306	PETROL	7.91	421	2	4.80
PEUGEOT	407	PETROL	2.90	187	2	6.07
PEUGEOT	PRESTIGE	PETROL	2.12	142	1	5.01
TOYOTA	LANDCRUISER V8	PETROL	0.01	23	14.10	0.39
TOYOTA	LANDCRUISER V8	PETROL	0.13	81	10.20	9.70
TOYOTA	RAV 4	PETROL	0.23	120	12.90	2.57
TOYOTA	LANDCRUISER V8	PETROL	0.01	23	14.10	0.39
TOYOTA	LANDCRUISER V8	PETROL	0.13	91	12.09	7.90
TOYOTA	RAV 4	PETROL	0.23	100	12.90	2.57
TOYOTA	LANDCRUISER V8	PETROL	0.01	23	14.10	0.39
TOYOTA	LANDCRUISER V8	PETROL	0.13	87	13.20	2.10

TOYOTA	RAV 4	PETROL	0.23	130	11.70	6.90
TOYOTA	4RUNNER	PETROL	3.99	582	15.04	131.00
TOYOTA	CAMRY	PETROL	2.65	412	14.00	277.00
TOYOTA	CAMRY	PETROL	5.66	327	19.00	210.00
TOYOTA	4RUNNER	PETROL	1.84	480	9.00	15.00
TOYOTA	4RUNNER	PETROL	0.48	459	10.89	79.00
TOYOTA	CAMRY	PETROL	0.21	321	12.09	301
TOYOTA	CAMRY	PETROL	0.78	238	16.00	123
TOYOTA	CAMRY	PETROL	4.36	451	12.00	289
TOYOTA	LE	PETROL	2.03	312	17.09	211
TOYOTA	CARINA II	PETROL	0.99	219	7.90	109
TOYOTA	PICNIC	PETROL	1.95	111	8.01	120
TOYOTA	INFINITI	PETROL	3.2	113	10.09	210
TOYOTA	SIENNA	PETROL	0.05	123	9.01	127
TOYOTA	VENZA	PETROL	0.08	582	15.04	131.00
TOYOTA	AVALON	PETROL	1.83	412	14.00	277.00
TOYOTA	CARINA III	PETROL	2.13	582	15.04	131.00
TOYOTA	HIGHLANDER (SPORT)	PETROL	6.75	412	14.00	277.00
TOYOTA	HIGHLANDER	PETROL	1.41	327	19.00	210.00
TOYOTA	VENZA	PETROL	1.35	480	9.00	15.00
TOYOTA	HIGHLANDER	PETROL	5.02	459	10.89	79.00
TOYOTA	HIGHLANDER	PETROL	1.29	321	12.09	301
TOYOTA	HIGHLANDER	PETROL	1.65	213	9.01	89.90
TOYOTA	HIGHLANDER	PETROL	0.14	200	19.01	134.00
TOYOTA	CAMRY	PETROL	10.35	97	16.00	241.00
TOYOTA	CAMRY	PETROL	0.04	327	19.00	198.00
TOYOTA	4RUNNER	PETROL	0.96	480	9.00	17.00
TOYOTA	RAV 4	PETROL	0.42	472	3.00	131.00
TOYOTA	LANDCRUISER V8	PETROL	1.20	240	13.02	277.00
TOYOTA	CAMRY	PETROL	0.01	181	9.07	210.00

TOYOTA	PREVIA	PETROL	0.13	182	7.10	15.00
TOYOTA	RAV 4	PETROL	0.23	120	14.00	79.00
TOYOTA	VENZA	PETROL	3.44	150	12.89	301
TOYOTA	CAMRY	PETROL	0.75	312	10.08	123
TOYOTA	SIENNA	PETROL	1.13	132	11.20	289
TOYOTA	AVALON	PETROL	1.76	1201	7.91	321
TOYOTA	4RUNNER	PETROL	1.18	112	8.17	432
ISUZU	TROOPER	PETROL	0.05	860	9.80	6.17
ISUZU	MIDI	PETROL	0.37	747	9.80	115.00
ISUZU		PETROL	1.49	485	7.90	178.00
ISUZU	E2000	PETROL	2.67	1086	3.80	13.20
MAZDA	E2000	PETROL	2.33	312	11.40	215.00
MAZDA		PETROL	8.57	1324	2.60	17.08
MAZDA		PETROL	7.90	712	4.12	48.01
BMW	318i	PETROL	3.39	1020	11.00	7.00
BMW	6 SERIES	PETROL	4.61	90.01	8.01	6
BMW	3 SERIES	PETROL	4.23	180	13.20	1.63
B.M.W	3187	PETROL	5.91	332	5.70	8.34
B.M.W	4SERIES	PETROL	1.09	75.91	8.07	1.2
B.M.W	6 SERIES	PETROL	4.8	200	12.09	89.09
B.M.W	6 SERIES	PETROL	2.1	106	16.8	139
B.M.W	4 SERIES	PETROL	3.18	101	15.65	140
CHEVROLET	AVEOLT	PETROL	0.17	86	13.30	1.87
CHEVROLET	AVEOLT	PETROL	0.28	100	14.00	0.79
CHEVROLET		PETROL	6.64	91	9.99	1.95
MERCEDEES		PETROL	6.80	412	2.32	210

MERCEDEES	C230	PETROL	5.12	310	1.98	38.09
MERCEDEES	230	PETROL	5.11	287	12.30	10.57
MERCEDEES	C200 KOMPRESSOR	PETROL	1.09	98	11.11	91.6
MERCEDEES		PETROL	3.56	521	2.9	14.06
MERCEDEES	C230	PETROL	4.14	290	1.98	38
M/BENZ	230	PETROL	4.48	325	3.70	10.57
MERCEDEES	C200 KOMPRESSOR	PETROL	5.04	34	10.01	111.01
MERCEDEES	C350 KOMPRESSOR	PETROL	6.09	23	8.01	17.42
MERCEDEES	4MATIC	PETROL	0.01	9	1.7	1.2
MERCEDEES	ML	PETROL	2.3	213	15.02	15.76
MERCEDEES	ML	PETROL	4.11	290	2.9	14.67
MERCEDEES	C230	PETROL	5.12	300	2.04	45.12
M/BENZ	230	PETROL	4.48	325	3.70	10.57
M/BENZ	230	PETROL	4.22	254	9.70	3.67
M/BENZ	230	PETROL	2.58	5020	2.40	14.42
M/BENZ	230	PETROL	1.54	888	7.10	8.67
VOLKSWAGEN	VENTO	PETROL	2.65	534	3.70	132.00
VOLKSWAGEN	SHARON	PETROL	1.09	288	3.15	98.09
VOLKSWAGEN	TOUAREG	PETROL	1.65	178	9.01	32.10
VOLKSWAGEN	GOLF	PETROL	8.00	625	10.01	150.02
VOLKSWAGEN	JETTA	PETROL	6.87	372	8.00	121.02
VOLKSWAGEN	GOLF 2.5	PETROL	7.91	318	12.09	148.98
FORD	SCORPIO 2.4 GL	PETROL	0.19	236	9.80	6.91
HONDA	ACCORD	PETROL	1.20	656	12.80	1.05
HONDA	ACCORD	PETROL	0.32	182	12.80	2.62
HONDA	CRV 4WD	PETROL	1.12	324	15.09	1.23
HONDA	ACCORD	PETROL	0.42	93	12.20	3.50
HONDA	CIVIC	PETROL	2.01	230	9.08	7.7

VOLKSWAGEN	Mini Bus	PETROL	1.15	262	10.5	120.5
VOLKSWAGEN	Mini Bus	PETROL	0.51	442	11.5	96.5
VOLKSWAGEN	Mini Bus	PETROL	4.01	3090	13.5	113
VOLKSWAGEN	Mini Bus	PETROL	0.99	479	11	289
VOLKSWAGEN	Mini Bus	PETROL	1.06	424	11	120.5
VOLKSWAGEN	Mini Bus	PETROL	0.56	66	13.5	325
VOLKSWAGEN	Mini Bus	PETROL	0.77	99	14	122.5
VOLKSWAGEN	Mini Bus	PETROL	0.81	484	14	19
VOLKSWAGEN	Mini Bus	PETROL	0.34	133	13.5	247
VOLKSWAGEN	Mini Bus	PETROL	2.07	189	14	54.5
VOLKSWAGEN	Mini Bus	PETROL	6.4	106	13	96
VOLKSWAGEN	Mini Bus	PETROL	9.49	332	10	159
VOLKSWAGEN	Mini Bus	PETROL	0.71	396	8	79.5
VOLKSWAGEN	Mini Bus	PETROL	0.96	185	12.5	323
VOLKSWAGEN	Mini Bus	PETROL	1.45	535	13	172.5
VOLKSWAGEN	Mini Bus	PETROL	1.57	408	13	222.5
VOLKSWAGEN	Mini Bus	PETROL	0.48	272	13.5	147.5
VOLKSWAGEN	Mini Bus	PETROL	0.9	378	14.5	298.5
VOLKSWAGEN	Mini Bus	PETROL	0.44	689	13	133.5
VOLKSWAGEN	Mini Bus	PETROL	1.03	550	14.5	218.5
VOLKSWAGEN	Mini Bus	PETROL	0.49	296	12.5	376
VOLKSWAGEN	Mini Bus	PETROL	0.35	406	14	214.5
VOLKSWAGEN	Mini Bus	PETROL	0.73	250	3.5	104
VOLKSWAGEN	Mini Bus	PETROL	0	568	11	173.5
VOLKSWAGEN	Mini Bus	PETROL	0.6	254	0	164.5
VOLKSWAGEN	Mini Bus	PETROL	0.75	180	14	105.5
VOLKSWAGEN	Mini Bus	PETROL	1.18	504	9	75
VOLKSWAGEN	Mini Bus	PETROL	4.49	330	13.5	114
VOLKSWAGEN	Mini Bus	PETROL	0.02	3348	12	62.5

VOLKSWAGEN	Mini Bus	PETROL	6.13	646	14.5	98.5
VOLKSWAGEN	Mini Bus	PETROL	0.77	318	7	100.5
VOLKSWAGEN	Mini Bus	PETROL	1.12	54	14	113
VOLKSWAGEN	Mini Bus	PETROL	0.6	226	13	55
VOLKSWAGEN	Mini Bus	PETROL	0.88	36	14	40
VOLKSWAGEN	Mini Bus	PETROL	0.71	390	12	40.5
VOLKSWAGEN	Mini Bus	PETROL	7.6	146	12	218.5
VOLKSWAGEN	Mini Bus	PETROL	2.86	1148	5.5	107
VOLKSWAGEN	Mini Bus	PETROL	2.01	256	11.5	322
VOLKSWAGEN	Mini Bus	PETROL	1.38	246	12.5	188
VOLKSWAGEN	Mini Bus	PETROL	0.11	583	8.5	477.5
VOLKSWAGEN	Mini Bus	PETROL	7.55	114	12.5	196
VOLKSWAGEN	Mini Bus	PETROL	1.24	603	10.5	169.5
VOLKSWAGEN	Mini Bus	PETROL	0.62	520	13	132
VOLKSWAGEN	Mini Bus	PETROL	2.04	236	4.5	333
VOLKSWAGEN	Mini Bus	PETROL	1.04	299	10	152.5
VOLKSWAGEN	Mini Bus	PETROL	0.5	218	14	404.5
VOLKSWAGEN	Mini Bus	PETROL	0.39	228	12	184
VOLKSWAGEN	Mini Bus	PETROL	1.14	613	11.5	52.5
VOLKSWAGEN	Mini Bus	PETROL	2.51	380	7	76
VOLKSWAGEN	Mini Bus	PETROL	0.38	1031	12.5	74
VOLKSWAGEN	Mini Bus	PETROL	0.09	433	14	444
VOLKSWAGEN	Mini Bus	PETROL	0.03	126	12.5	79
VOLKSWAGEN	Mini Bus	PETROL	9.98	308	14	69
VOLKSWAGEN	Mini Bus	PETROL	5.55	419	13.5	380.5
VOLKSWAGEN	Mini Bus	PETROL	1.05	478	12.5	134
VOLKSWAGEN	Mini Bus	PETROL	0.82	533	8	158
VOLKSWAGEN	Mini Bus	PETROL	1.59	266	12	62
VOLKSWAGEN	Mini Bus	PETROL	0.02	554	11.5	73
VOLKSWAGEN	Mini Bus	PETROL	9.75	704	10.5	37

VOLKSWAGEN	Mini Bus	PETROL	0.89	419	12.5	122.5
VOLKSWAGEN	Mini Bus	PETROL	0.95	642	13.5	139.5
VOLKSWAGEN	Mini Bus	PETROL	4.22	195	13.5	181.5
VOLKSWAGEN	Mini Bus	PETROL	4.23	574	12.5	376.5
VOLKSWAGEN	Mini Bus	PETROL	0.49	634	14	81
VOLKSWAGEN	Mini Bus	PETROL	6.1	514	8.5	130.5
VOLKSWAGEN	Mini Bus	PETROL	1.23	84	12	177
VOLKSWAGEN	Mini Bus	PETROL	0.14	367	13	87.5
VOLKSWAGEN	Mini Bus	PETROL	0.45	663	8	160.5
VOLKSWAGEN	Mini Bus	PETROL	1.16	233	12	110
VOLKSWAGEN	Mini Bus	PETROL	2.43	422	11.5	83
VOLKSWAGEN	Mini Bus	PETROL	0.05	572	10.5	209.5
VOLKSWAGEN	Mini Bus	PETROL	1.69	2334	12.5	94.5
VOLKSWAGEN	Mini Bus	PETROL	0.62	280	13.5	109
VOLKSWAGEN	Mini Bus	PETROL	2.18	5084	13.5	261
VOLKSWAGEN	Mini Bus	PETROL	0.64	327	12.5	468.5
VOLKSWAGEN	Mini Bus	PETROL	5.72	80	14	85.5
VOLKSWAGEN	Mini Bus	PETROL	0.19	148	8.5	507
VOLKSWAGEN	Mini Bus	PETROL	1.31	536	12	184.5
VOLKSWAGEN	Mini Bus	PETROL	0.56	334	13	233.5
VOLKSWAGEN	Mini Bus	PETROL	9.41	815	12.5	139
VOLKSWAGEN	Mini Bus	PETROL	0.68	440	12	430
VOLKSWAGEN	Mini Bus	PETROL	0.32	1208	13	134
VOLKSWAGEN	Mini Bus	PETROL	0.84	606	7.5	193.5
VOLKSWAGEN	Mini Bus	PETROL	0.81	264	13	142.5
VOLKSWAGEN	Mini Bus	PETROL	0.53	230	13	127.5
VOLKSWAGEN	Mini Bus	PETROL	0.69	406	13.5	724
VOLKSWAGEN	Mini Bus	PETROL	0.57	202	6	432.5
VOLKSWAGEN	Mini Bus	PETROL	0.38	266	6	282.5
VOLKSWAGEN	Mini Bus	PETROL	1.54	344	13	453.5

VOLKSWAGEN	Mini Bus	PETROL	0.38	1024	7	135.5
VOLKSWAGEN	Mini Bus	PETROL	6.05	1994	13.5	220
VOLKSWAGEN	Mini Bus	PETROL	0.36	726	14	80.5
VOLKSWAGEN	Mini Bus	PETROL	4.07	624	14	161
VOLKSWAGEN	Mini Bus	PETROL	0	544	14	367
VOLKSWAGEN	Mini Bus	PETROL	0.04	515	8.5	142.5
VOLKSWAGEN	Mini Bus	PETROL	1.1	267	13	255
VOLKSWAGEN	Mini Bus	PETROL	0.93	582	2	123.5
VOLKSWAGEN	Mini Bus	PETROL	0.45	220	13.5	439
VOLKSWAGEN	Mini Bus	PETROL	1.32	588	13.5	87
VOLKSWAGEN	Mini Bus	PETROL	1.4	310	14	181
VOLKSWAGEN	Mini Bus	PETROL	0.96	165	14	554
VOLKSWAGEN	Mini Bus	PETROL	1.27	322	13	48
VOLKSWAGEN	Mini Bus	PETROL	0.02	0	11	121.5
VOLKSWAGEN	Mini Bus	PETROL	3.35	406	14	0
VOLKSWAGEN	Mini Bus	PETROL	0.42	202	13.5	189.5
VOLKSWAGEN	Mini Bus	PETROL	1.25	504	13	135.5
VOLKSWAGEN	Mini Bus	PETROL	2.74	570	15	143
VOLKSWAGEN	Mini Bus	PETROL	0.84	196	14	124.5
VOLKSWAGEN	Mini Bus	PETROL	0.78	3653	14	137
VOLKSWAGEN	Mini Bus	PETROL	0.21	226	10.5	130.5
VOLKSWAGEN	Mini Bus	PETROL	0.96	234	12.5	428
VOLKSWAGEN	Mini Bus	PETROL	3.94	168	10	62.5
VOLKSWAGEN	Mini Bus	PETROL	1.38	292	11.5	32
VOLKSWAGEN	Mini Bus	PETROL	0.11	326	13	162.5
VOLKSWAGEN	Mini Bus	PETROL	3.65	908	13	80
VOLKSWAGEN	Mini Bus	PETROL	1.13	1151	13.5	86
VOLKSWAGEN	Mini Bus	PETROL	0.25	332	13	164.5
VOLKSWAGEN	Mini Bus	PETROL	0.69	430	13	113.5
VOLKSWAGEN	Mini Bus	PETROL	0.21	120	12.5	896

VOLKSWAGEN	Mini Bus	PETROL	0.3	624	12	17.5
VOLKSWAGEN	Mini Bus	PETROL	0.49	532	13.5	71.5
VOLKSWAGEN	Mini Bus	PETROL	0.98	412	13	123.5
VOLKSWAGEN	Mini Bus	PETROL	1.09	454	6.5	195
VOLKSWAGEN	Mini Bus	PETROL	0.41	192	12.5	119
VOLKSWAGEN	Mini Bus	PETROL	3.7	304	13.5	29.5
VOLKSWAGEN	Mini Bus	PETROL	1	350	14	146.5
MITSUBISHI	L 300	PETROL	2.67	111	8.10	6.08
MITSUBISHI	L 300	PETROL	2.33	453	10.90	3.31
MITSUBISHI	L 300	PETROL	0.05	82	11.10	5.30
MITSUBISHI	GLX	PETROL	0.37	87	12.80	2.80
MITSUBISHI	L 300	PETROL	1.49	157	10.10	13.02
MITSUBISHI	L 300	PETROL	2.67	111	8.10	6.08
MITSUBISHI	L 300	PETROL	2.33	453	10.90	3.31
MITSUBISHI	L 300	PETROL	8.57	295	8.30	0.44
MITSUBISHI	GLX / L 300	PETROL	6.64	335	9.30	0.99
MITSUBISHI	L 300	PETROL	3.67	227	7.50	6.66
MITSUBISHI	L 300	PETROL	3.39	127	9.20	4.59
MITSUBISHI	L 300	PETROL	4.61	340	11.50	0.55
MITSUBUSHI	L300	PETROL	4.23	243	4.80	9.08
TOYOTA	HAICE	PETROL	5.91	213	4.98	3.72

Appendix 3: Tricycle Emission Data Sheet

MAKER	MODEL	FUEL TYPE	COppm	HCppm	CO_2ppm	NOppm
JINCHENG		PETROL	3.51	9520	3.10	325.02
LIFAN	PETROL	PETROL	1.84	696	2.09	200.00
NANFANG	PETROL	PETROL	0.46	237	3.50	14.35
NIPON	PETROL	PETROL	3.35	8781	3.00	341.79

Appendix 4: Motor Cycle Emission Data Sheet

NAME	MODEL	FUEL TYPE	COppm	HCppm	CO_2ppm	NOppm
NIPPON	SUPRA	PETROL	0.19	4420	4.80	13.26
BAJENG	SUPRA	PETROL	4.36	7421	3.60	11.25
SKYGO	CD 125	PETROL	0.92	1028	3.00	15.68
SKYGO	CG 125	PETROL	1.31	288	3.20	14.38
JINCHENG	CG 125	PETROL	2.93	282	2.50	15.04
BAJENG	SUPRA	PETROL	3.51	6520	4.00	19.02
BAJENG	SUPRA	PETROL	1.84	696	3.09	15.90
BAJENG	SUPRA	PETROL	0.46	237	2.03	12.02
BAJENG	SUPRA	PETROL	3.35	8781	4.98	16.16
BAJENG	SUPRA	PETROL	0.23	5420	3.98	13.02
BAJENG	SUPRA	PETROL	4.36	6422	4.90	15.77
BAJENG	SUPRA	PETROL	1.98	9029	5.00	20.01
BAJENG	SUPRA	PETROL	1.08	290	1.05	12.07
BAJENG	SUPRA	PETROL	2.45	273	1.02	17.09

Appendix 5: Omni Bus Emission Data Sheet

MODEL	FUEL TYPE	COppm	HCppm	CO_2ppm	NOppm
BRT	Diesel	452	433.1	13.09	783.42
MACOPOLO BUS	Diesel	800.9	500.9	12.77	891.01
MACOPOLO BUS	Diesel	422.6	521	14	809.12
BRT	Diesel	454.6	454.7	12.09	900.06
BRT	Diesel	1000.1	990.2	16.08	790
BRT	Diesel	448.5	429	14.15	608.05
BRT	Diesel	687	500.1	20.01	300.37
BRT	Diesel	400.5	325	10.22	698.05
BRT	Diesel	1040	1001	22.87	800.81
BRT	Diesel	458.5	454	9.56	698.08
BRT	Diesel	354.6	300.1	13.34	791.23
BRT	Diesel	509	174.9	12.31	879.02

Appendix 5: Trucks Emission Data Sheet

MAKER	MODEL	FUEL TYPE	COppm	HCppm	CO_2ppm	NOppm
MARK	TRUCK	Diesel	500.4	465	15.81	970.01
MAN DIESEL	TRUCK	Diesel	650	370.7	15.01	990.01



Plate 5: Afternoon Offpeak Traffic at Dopemu Corridor



Plate 6: Evening Peak Traffic at Dopemu Corridor



Plate 7: Evening Peak Traffic at Ikorodu Road



Plate 8: Morning Peak Tricycle Traffic at Awolowo Road Ikeja



Plate 9: Morning Peak Traffic at Ikeja along Corridor (Researcher taking ambient/traffic count)



Plate 10: Afternoon Offpeak period of Traffic at Ojota Corridor (Researcher taking ambient/traffic count



Plate 11: Emission Testing a KIA and Toyota Camry Cars