IMPACT OF VEHICULAR EMISSION TO AIR QUALITY IN THE FEDERAL CAPITAL TERRITORY (FCT) ABUJA, NIGERIA

BY

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PROFESSIONAL MASTER OF SCIENCE ENVIRONMENTAL RESOURCE MANAGEMENT (ERM)

OCTOBER, 2018

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, NASARAWA STATE UNIVERSITY KEFFI, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF PROFESSIONAL MASTER OF SCIENCE IN ENVIRONMENTAL RESOURCE MANAGEMENT (ERM)

DEPARTMENT OF GEOGRAPHY
FACULTY OF SOCIAL SCIENCE

NASARAWA STATE UNIVERSITY, KEFFI
NIGERIA

DECLARATION

I solemnly declare that this dissertation titled "Impact of Vehicular Emission to Air Quality in the Federal Capital Territory (FCT) Abuja, Nigeria" has been written by me and it is a report of my research work under the supervision of Professor Haruna K. Ayuba. It has not been presented in any previous application for the award of degree in any other university. All quotations are indicated and sources of information specifically acknowledged by means of references.

.....

UGWUANYA BONAVENTURE CHIGOZIEM **Date:**
NSU/PMS/ERM/0046/16/17

CERTIFICATION

This dissertation titled "Impact of Vehicular Emission to Air Quality in the Federal Capital Territory (FCT) Abuja, Nigeria" meets the regulations governing the award of Professional Master of Science in Environmental Resources Management (ERM) of the School of Post Graduate Studies, Nasarawa State University, Keffi, and is approved for its contribution to knowledge.

Professor Haruna K. Ayuba **Supervisor**	29/3/2019 **Date**
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Dean of Faculty	**Date**
External Examiner	**Date**
Dean, School of Postgraduate Studies	**Date**

DEDICATION

This Thesis is dedicated to the memories of my late Parents:

- Mr. Ignatius Uchegharam Ugwuanya – 1930 – 1996.
- Mrs. Angelina Nwanyinnaya Ugwuanya - 1936 – 2006.

And my Sisters

- Celestina Blessing Ngozi Ugwuanya - 1964 – 2014
- Jacinta Kelechi Ugwuanya - 1975 – 1ST Jan. 2018

ACKNOWLEDGEMENT

There are many people to thank, as no environmental pursuit is solitary. Along the way, I have been driven, inspired, and supported by all of the people who placed their confidence in me.

In particular, I give deep thanks to my wife, Mrs. Emmanuela Chetachukwu Ugwuanya, for her love and friendship, my little daughter, Chiziterem Gabriela Ugwuanya, my son Chukwuebuka Daniel Ugwuanya for teaching me to trust in God and my intuition, and my brothers, Rev. Fr. Valentine (USA), Edmund and Cajetan Ugwuanya and my two younger sisters, Mrs. Angela Nwokedi and Mrs. Emmanuela Ogechi Emeziem for their support.

I am also more grateful than I can express to:

Professor Haruna K. Ayuba, my supervisor for inspiring me to trust in the science of Environmental Resources Management.

My Lecturers at the Faculty of Social Science, Department of Geography, Nasarawa State University for impacting on me the knowledge.

My Colleagues in the 2016/2017 Professional Masters in Environmental Resource Management (ERM).

My Director General/Chief Executive Officer, Dr. Lawrence Chidi Anukam who encouraged me to aspire to greater heights, my Director, Mr. Simon Joshua Bagudu and other Directors at the National Environmental Standards and Regulations Enforcement Agency (NESREA) for all their support.

I also wish to thank my colleagues in the office for covering the office work while I was away. Lastly, I thank God for His mercies and benevolence throughout the programme at Nasarawa State University, Keffi.

ABSTRACT

This project report presents the results of the investigation of vehicular emission in selected roads leading into the Federal Capital Territory (FCT) Abuja. Three areas MP'A', MP'B', and MP'C' were considered with sampling points (SP1 – SP13) in each sampling location, observations were carried out at a safe distance away from the edge of the road in downwind direction, the Ground Positioning System (GPS) of the locations were taken. Priority parameters such as: Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO) was monitored. Noise level and Ambient Temperature were monitored as well as traffic count at the sampling points. The mean daily levels of pollutants SO_2, NO_2, CO, measured were found to be ranged between 1.3 - 1.65ppm, 0.12 - 0.14ppm and 1.71 - 10.57ppm for Keffi - Abuja road, Suleja - Kubwa road 1.22 - 1.75ppm, 0.11 - 0.14ppm, and 1.24 -3.13ppm, City Gate - Airport road 1.33 - 1.73ppm, 0.11 - 0.13ppm and 1.21 - 3.09ppm respectively. With the exception of Guzape road (the control station) mean pollutants levels was found to be ranged between 0.67 - 0.97ppm, 0.02-0.07ppm, and 1.00 - 1.04ppm for SO_2, NO_2, and CO respectively.

Average noise level measured was 70dB while Ambient temperature was 30°C. All the monitored air pollutants when compared with USEPA Air Quality Index (AQI) were in the range - SO_2 from very poor to poor, NOx- from very poor to poor, and CO from poor to moderate and moderate to poor in different locations. The overall comparison of data for different sections show that concentration of pollutants is higher than USEPA AQI and the National Standard at all the three areas MP'A', MP'B', and MP'C' due to volume of traffic. This shows that the air quality is very poor and it implies that motor vehicle emission in the FCT are not within the safe limits, and that motor traffic-related pollution in the FCT is a potential hazard to the environment and human health.

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CHAPTER ONE

1.1 BACKGROUND TO THE STUDY

On our planet, the air we breathe is one of the most important things around us. It is a vital natural resource on which all life depends. Clean air is something that we all need for good health and the well-being of humans, animals, and plants. Sadly, however, our atmosphere is being continuously polluted.

Many cities around the world, particularly in developing countries like Nigeria, are experiencing rapid growth. Yet, in the absence of adequate environmental policy and action, this growth is occurring at a considerable, and often increasing, economic and social cost. More people, more industry, and more motor vehicles cause ever-worsening air pollution which poses a serious environmental threat in many cities. The World Health Organization (WHO) and other international agencies have long identified urban air pollution as a critical public health problem.

Air pollution has been defined [World Bank, 1978] as the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odour, smoke, or vapour in such quantity, characteristics and duration as to make them actually or potentially injurious to human, plant or animal life, or property, or which unreasonably interferes with the comfortable enjoyment of life and property.

Also the World Health Organization (WHO) (2001) defines air pollution as the disequilibrium of air caused due to the introduction of foreign elements to human's natural and manmade sources to the air so that it becomes injurious to biological communities. In general air pollution involves an introduction of pollutants into the earth's atmosphere such as chemicals, particulate matter, or biological materials that cause discomfort, diseases, including burning eyes and nose, itchy irritated throat and

breathing problems, or death to humans, damage to other living organisms such as food crops, or damage to the natural environment or built environment.

Air pollution can be classified into natural air pollution which includes windblown dust, volcanic ash, and gases, smoke and trace gases from forest fires, and anthropogenic air pollution which includes products of combustion such as nitrogen oxides (NOx), carbon monoxides (CO), sulphur dioxide (SO_2), Volatile Organic Compounds VOCs (primarily hydro- carbons) etc.

Basically, air pollution can result from both natural and man- made (anthropogenic) *sources (Botkin and Keller 2000).*

i. Natural Sources: Natural sources of air pollution such as volcanic eruptions releasing poisonous gases, forest fire, natural organic and inorganic decays or vegetation decay, pollen scattering, deflation of sands and dust, sea salt particles being blown up from the surface of the sea by winds, extraterrestrial bodies, cosmic dust, and comets.

ii. Man-made (anthropogenic) sources: The major anthropogenic sources include but not limited to substances emitted due to the burning of fossil fuels in engines, gasses and particulate matter created in the production process (industrial and agricultural), suspended particulate matter and chemical substances created in the process of waste disposal and even war. Examples of air pollutants include sulphur dioxide (SO_2), Nitrogen dioxide (NO_2) Suspended Particulate Matter (SPM), Carbon Monoxide (CO), Photochemical Oxidants (O_X), Non-Methane Hydrocarbon (NMHC). etc.

The nature of air pollution is dependent on the source profile of the city, the presence of sunlight to promote production of secondary pollutants, such as ozone, through photochemical reactions, the altitude, which affects combustion processes and global air circulation patterns. Clean air is the basis of a healthy life. Air pollution causes

discomfort or harm to people and other living organisms. Therefore, air pollution must be controlled if air quality is going to be maintained. Poor or deteriorating air quality in many cities results from high levels of energy consumption by industry, transport and domestic use *(UNEP/WHO, 1992).*

Health and Environment Research Institute (2001) reported that some chemicals found in polluted air could cause cancer, birth defects, brain and nerve damage, and longtime injury to the lungs and breathing passage in certain circumstances. The concentrations of such chemicals beyond a limit, and an exposure over a certain period are extremely dangerous and can cause severe injury or even death. In support of this, it was stated that transportation accounts for an important fraction of green house gases (especially carbon monoxide) emission *(Cline, 1991).* Indeed, motor vehicle has been incriminated as one of the leading causes of air pollution in urban cities of the world, though China, United States of America (USA), Russia, Mexico and Japan are the world leaders in air pollution. The two main causes of air pollutants in urban cities are transportation and fuel combustion by stationary sources, including industrial heating (WHO 2000). However, motor vehicle emissions, seems to be the most dominant source of air pollutants especially in areas with high traffic densities and industrial activities *(Seinfeld, 1989).*

Also, USEPA (1994) identified automobile transport emissions as a key factor in the deterioration of the urban air environment, constituting up to 90% of urban air pollution. Similarly, *Saville (1993)* reported that pollution due to traffic alone is responsible for up to 90 – 95% of the ambient CO levels, 80 – 90% of NOx, and high levels of hydrocarbon and particulate matter in the world, posing a serious threat to human health. Another similar report by the World Resource Institute (1997) revealed that motor vehicle produces more air pollution than any other single human activities.

This situation is therefore pathetic especially in developing countries like Nigeria, where motorization growth has been largely unchecked by environmental regulation, thereby creating high levels of pollution *(Han and Nacher, 2006).* In a similar study on motor vehicular emission conducted in Kenya by *Odhiambo, Kinyua, Gatebe, and Awange, (2010)*, the research concluded that traffic and other related congestions is responsible for 80-90% of gaseous pollutants emitted into the atmosphere particularly in city centers of most developing countries. This could be interpreted to mean that air quality in most developing countries is associated with high level of risk and is also hazardous to human health.

In Nigeria also, study indicates that road traffic emissions are a major source of air pollution in urban areas with subsequent adverse human health effects *(Faize, 1993).*

1.2 STATEMENT OF THE PROBLEM

Air quality monitoring in most developing countries including Nigeria is not carried out on a regular basis, and in some urban areas just for academic exercise, only a few of such information exist, though signs of deteriorating air quality and health problems related to air pollution are visible. In recent years the public concern is being aroused due to the wide publicity on the damage to human health from the inhaling of gaseous pollutants and fine particulates. It has also been suggested that high incidence of respiratory health in urban areas may be associated with inhaling noxious gases and particulates in the air *(CA Pope III, 2004).*

Numerous epidemiological studies were carried out in related topics but in different areas *(Brunekreef, et al. 1997; Oguntoke, et al, 1998; Rouphail, Frey, Colyar, and Unal, 2001; Oguntoke and Yusuf, 2008).* Their findings found associations between exposure to atmospheric pollutants and adverse health effects, such as the increase in the number of

hospitalizations and mortality and decrease in life expectancy. These studies were performed in urban areas, where motor vehicles are the main source of transportation. According to *Oguntoke, et al, (2008),* he observed that Human health problems due to air pollution arising from vehicular emission in Abeokuta city, was approximately 56.4% of the total number of the sample that suffered cough and breathing impairments (23.6%) among others.

Likewise, *Utang and Peterside (2011),* assessed the level of some selected air pollutants which are largely products of internal combustion in motor vehicle engines namely: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and methane (CH_4) in four sampling points in Port Harcourt (Garden city). The study indicated that the city is under threat of traffic related pollution and is possibly more susceptible given the increasing population influx and vehicular traffic.

A recent research conducted by *Okunola, Uzairu, Gimba and Ndukwe (2012),* to assess the concentrations of CO, SO_2, NO_2, and H_2S, in Kano city, findings of the study revealed that with few exceptions at some sites emission values of gases measured were above Air Quality Index (threshold) recommended by USEPA (2001). It was concluded that air quality within Kano metropolis is potentially harmful to human health.

Therefore, the dearth of information on these air quality parameters is a fundamental issue in many urban Nigerian cities. Alongside with high per capita ownership of poorly maintained and high emitter ('tokunbo') vehicles, high number of motor cycles and tricycles in urban areas and state capitals. Also high number of security check points causes traffic holdups and slow flow of vehicles, leading to longer times spent in congestions and in turn, increasing fossil fuel burning and pollution as well as degradation of the air quality.

Consequently, in order to achieve environmental sustainability with regards to the atmosphere, air quality monitoring should be a routine exercise. Agencies of Government charged with the mandate of enforcing compliance with all environmental standards and regulations in the country should as a matter of national priority fast track the setting up of stationary and real time air quality monitoring equipment in major roads or in our cities.

1.3 RESEARCH QUESTIONS

i. What are the concentration levels of SO_2, NO_2, and CO, pollutants in the study area?

ii. How do these levels compare to the National Standards i.e. National Environmental (Air Quality Control) Regulations, 2014 and the USEPA Air Quality Index (AQI).

Iii. What is the relationship between volumes of vehicular movement along some of these locations into the Federal Capital Territory, Abuja with concentration level of the pollutants?

1.4 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to assess the impact of vehicular emission on air quality in the Federal Capital Territory, (FCT) Abuja, Nigeria.

The specific objectives are to:

i. conduct traffic survey on the sampling locations;

ii. determine the concentration of vehicular emission like Carbon Monoxide (CO), Sulphur Dioxides (SO_2), Nitrogen Dioxide (NO_2), in the study area;

iii. measure and compare the concentration of the pollutants from each sampling location with the control station for any possible difference;

iv. assess the relationship between traffic volume and concentration levels of the measured pollutants at the sampling locations.

1.5 STATEMENT OF THE HYPOTHESES

Ho 1: there is no significant difference in the air quality within the FCT and the control station.

Ho 2: there is no significant difference in the concentrations of pollutants among the sampling locations.

Ho 3: there is no significant relationship between traffic volume and air pollutants at the sampling locations.

1.6 JUSTIFICATION FOR THE STUDY

The Federal Capital Territory (FCT) is experiencing an increase in per capita vehicle ownership - 1.3 million vehicles (*Source: FRSC Vehicle registration records from 2006 to 2017 in FCT)*, coupled with an increase in security check points. This situation is leading to slow flow of traffic and longer times spent in congestions, which in turn increase burning of fossil fuel thereby polluting the ambient air.

The resultant effects of motor vehicle emission on human health cannot be overemphasized as several epidemiological studies have found an association between exposure to atmospheric pollutants and adverse health effects, such as the increase in the number of hospitalizations and mortality, and even decrease in life expectancy as highlighted by *Mateus, Andrea and Nelson (2011).*

Also to make the situation more complicated, air pollutants which include products of automotive engine combustion such as carbon monoxides (CO), nitrogen dioxides (NO_2), sulphur dioxide (SO_2) and other volatile organic compounds (VOCs) which are primarily hydro- carbons are an important fraction of green house gases (especially carbon) which

has high Global Warming Potential (GWP) is a major culprit attributed to global warming.

Therefore, for the benefit of public health and sustainability of the natural ecosystems, it becomes imperative to carry out a study like this which aims to assess the impact of vehicular emission to air pollution particularly in the study area (the Federal Capital Territory) where only few studies on air quality deterioration induced by motor vehicles are undertaken. Moreover, air quality monitoring should be a routine activity as the data and information gathered could be used in national planning, advising people with health challenges on air quality index as obtainable in some developed countries.

1.7 SCOPE OF THE STUDY

The scope of this research is limited to some selected major motorways leading into the FCT namely: Mararaba – Nyanya road on the eastern axis (MP'A'), Suleja- Kubwa road on the western axis (MP'B'), and City Gate – Airport road on the southern axis (MP'C'). These selected roads are associated with high concentration of motor vehicles, business/commuters and most vehicles engines are still running. Only few selected air pollutants were measured such as: SO_2, NO_2, and CO, Also at these locations no meteorological parameters were given detailed consideration as the study entails direct measurement of pollutants within the ambient air along the selected motorways. However, during data collections, the GPS of the locations, the noise levels, ambient temperature as well as traffic counts were carried out manually.

CHAPTER TWO

LITERATUREREVIEW

This section of the study deals with the various concepts of pollution and the theoretical frameworks which were used to form bases for this research work. Also relevant literatures were reviewed which provided suitable information for this study.

2.1 CONCEPTUAL FRAMEWORK

2.1.1 Air Pollution

Air pollution is a major issue of concern to the public and politicians, with the focus of attention being on poor air quality and way it affects the quality of life in urban areas. It is well recognized that road transport plays a significant part in air pollution in urban environments, and thus contributes to this public health issue.

Air pollution is defined as the contamination of air by discharge of harmful substances, which can cause health problems including burning eyes and nose, itchy irritated throat and breathing problems *(USEPA 1994).* It was also reported that some chemicals found in polluted air could cause cancer, birth defects, brain and nerve damage, and long-term injury to the lungs and breathing passages in certain circumstances. The concentrations of such chemicals beyond a limit, and an exposure over a certain period are extremely dangerous and can cause severe injury or even death. The atmosphere is a complex dynamic natural gaseous system that is essential to support life on planet earth. However, the pollution of the atmosphere due to combustion of fossil fuel by motor vehicles and many other sources, including the burning of coal and oil power plants, incinerators, home heating oil, and construction equipment has long been recognized as a threat to human health as well as the earth ecosystem.

The combustion of gas and diesel fuels produces greenhouse gasses that are contributing to local, regional and global climatic changes. In the past, pollution used to be regarded as a local problem, close to where the sources are located but however, the industrialization of society, human population explosion and the introduction and use of vehicles, has caused an exponential growth in goods, services and unfortunately environmental pollution particularly, air pollution *(USEPA 1998).*

According to the United States Environmental Protection Agency (USEPA 2006), motor vehicle account for 51 percent of Carbon monoxide (CO), 34% of Nitrogen dioxide (NO_2) and 10% Particulate matter (PM) released each year in the United States of America.

Similarly, the World Health Organization (2001), has identified motor vehicle as one of the major leading causes of air pollution in most urban cities of the world, though China, United States, Russia, Mexico, and Japan are the world leaders in air pollution emission, but the two sources of air pollutants ubiquitous in most urban areas are transportation and fuel combustion by stationary sources, including industrial heating. This is a clear indication that, motor vehicle emission is a major source of air pollution in both developed and developing countries. Therefore, if air quality is going to be maintained then vehicular emission must be checked.

2.1.2 Causes of Air Pollution

There are various locations, activities or factors which are responsible for releasing pollutants into the atmosphere. These sources can be classified into two major categories.

- **Anthropogenic (man-made)sources:**Human beings largely depend on their environment for survival and that is why it is highly encouraged that each one avoids activities that may cause pollution. Man-made sources of air pollution are:

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- **Stationary sources** include smoke stacks of power plants manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices. In developing and poor countries, traditional biomass burning is the major source of air pollutants; traditional biomass includes wood, crop waste and dung.
- **Mobile sources** include motor vehicles, marine vessels, and aircraft.
- **Controlled burn** practices in agriculture and forest management. Controlled or prescribed burning is a technique sometimes used in forest management, farming, grassland restoration or greenhouse gas abatement. Fire is a natural part of both forest and grassland ecology and controlled fire can be a tool for foresters. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest.
- **Mining:** when mining activities take place, heavy machinery causes a release of dust and other fumes into the atmosphere. This may result in toxicity of air within the region.
- **Agricultural activities:** human beings rely on agriculture for food. However, certain agricultural activities like spraying of chemicals to get rid of parasites may end up causing pollution to the air.
- **Poor waste disposal:** poor waste disposal is regarded as one of the major causes of pollution because it is widely practiced. Both industries and individual human beings contribute to this cause.
- **Industrial Emission:** in the process of creating products to be used for various issues, industries end up emitting large quantities of toxic wastes and fumes which end up causing pollution.
- **Fossil fuels:** petroleum and coal are among some of the leading causes of fossil fuel pollution.
- **Fumes** from paint, hair spray, varnish, aerosol sprays, and other solvents.

1. **Military resources,** such as nuclear weapons, toxic gases, germ warfare and rocketry.

b. Natural sources:

- **Dust** from natural sources, usually large areas of land with little or no vegetation.
- **Methane,** emitted by the digestion of food by animals, for example cattle.
- **Radon gas** from radioactive decay within the Earth's crust. Radon is a colorless, odorless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking.
- **Smoke** and carbon monoxide from wildfires.
- **Vegetation**, in some regions, emits environmentally significant amounts of Volatile organic compounds (VOCs) on warmer days. These VOCs react with primary anthropogenic pollutants—specifically, NO_x, SO_2, and anthropogenic organic carbon compounds — to produce a seasonal haze of secondary pollutants. Black gum, poplar, oak and willow are some examples of vegetation that can produce abundant VOCs. The VOC production from these species results in ozone levels up to eight times higher than the low-impact tree species.
- **Volcanic Activity:**Volcanic eruptions are a major source of natural air pollution. When an eruption occurs, it produces tremendous amounts of sulphur, chlorine, and ash products, which are released into the atmosphere and can be picked up by winds to be dispersed over large areas. Additionally, compounds like sulphur dioxide and volcanic ash have been known to have a natural cooling effect, due to their ability to reflect solar radiation.

2.1.3 Vehicular Emission and Air Quality

With a population of about 180 million people, Nigeriautilizes transportation systems, the majority of which includes cars, buses, trucks and motor cycles to move people, goods and services around. Increasing vehicle ownership, especially among the middle and upper classes, has meant more travels, making automobile, the fastest growing source of pollution.

A report from the National Bureau of Statistics for 2017 revealed that vehicle population in Nigeria is 11.46 million vehicles (1.3 million in the FCT alone) and over three million motorcycles plying our roads. These vehicles are concentrated in major urban centers, with Lagos alone accounting for up to 30%. The situation is compounded by poor urban transportation planning and the concomitant congestion, where people spend a lot of time in traffic jams. Worse still, majority of the vehicles on our roads are found to be usually second-hand vehicles with poor engine performance and heavy emission of air pollutants. The transportation system has been fingered as the highest cause of air pollution with its attendant ecological problems.

The most common types of fuel used in Nigeria are the fossil fuel commonly known as Premium Motor Spirit (PMS). Petrol is commonly used in light duty vehicles while gasoline (AGO) or diesel is mostly used in heavy duty vehicles.

CO_2 and water vapor (H_2O), the main products of incomplete combustion, are emitted in vehicle exhaust *(Onursal and Gautam, 1997).*

The major pollutants emitted from gasoline fueled vehicles are CO, HCs, NO_2, and lead (Pb) (only for leaded gasoline fuel), whereas the presence of sulphur compounds in diesel fuel results in Sulphur Dioxide (SO_2) and PM emissions from the exhaust of diesel-fueled vehicles. Metal sulphates and sulphuric acid in the form of PM constitute 1 to 3 percent

Sulphur emission from heavy-duty diesel-fueled vehicles and 3 to 5 percent of Sulphur emission from light-duty diesel fueled vehicles, they also account for about 10 percent of particular matter (PM) emission from these vehicles (Faiz, *et al.* 1996). In addition, SO_2may also be present in exhaust gases. The air conditioning system, tires, brakes, and other vehicle components also produce emission.

Many studies such as *(Oguntokeet al., 1998; Oguntoke and Yusuf, 2008; Erica, 2010; and Vivan, et al., 2013),* conducted in Abeokuta, Kaduna and Abuja respectively, have documented adverse health effects associated with high concentrations of transport-related pollutants. Nitrogen oxides and Sulphur oxides, for example are associated with immune system impairment, exacerbation of asthma and chronic respiratory diseases, reduced lung function, and cardiovascular diseases *(Schwela, 2000; Wargoet al., 2006).* Exposure to carbon-monoxide can result in fatigue, headaches, dizziness, loss of consciousness, and even death at very high concentrations *(Schwela, 2000).* Particulates are especially dangerous because they have been implicated in the development of lung cancer and higher rates of mortality *(Schwela, 2000;Wagoet al., 2006).* Lead is similarly dangerous as poisoning causes irreversible neuro behavioral consequences, such as decreased intelligence quotient (IQ) and attention deficits, and death at high levels of poisoning *(Schwela, 2000).*

A number of epidemiological studies have similarly linked exposure to vehicle emission over 10 years decreased lung function among tunnel officers *(Evans et al. 1988).* Atmospheric studies, particularly air pollutant measurements have been widely carried out on various air pollutants and greenhouse gasses and also relating their interactions to human and environmental health.

2.1.4 Classification of Air Pollutants and their Trends

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 higher concentrations are the following:

a. Carbon compounds, such as CO, CO_2, CH_4 and VOCs

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

c. Sulphur compounds, such as H_2S and SO_2

d. Halogen compounds, such as chlorides and bromides

e. Particulate Matter (PM or "aerosols"), either in solid or liquid form, which is usually categorized into these 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 higher concentrations 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_3.

iii. Sulpuric 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 VOCs in gas-to-particle reactions *(Delay and Zanetti, 2007).*

The United States Environmental Protection Agency (USEPA) has set National Air Quality Standards (NAAQS) for six principal air pollutants: Nitrogen Oxides (expressed as NO_2), Ozone (O_3), Sulphur Dioxide (SO_2), 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 (NOx) and VOCs react in the presence of sunlight. PM is mostly emitted, but $PM_{2.5}$ particles can also be added as secondary pollutants (Sulphates, Nitrates, and Organic particles) *(USEPA, 2003; Delay and Zanetti, 2007).* As listed above, there are 6 principals, or "criteria" pollutants regulated by the USEPA and most countries in the world:

i. Total Suspended Particulate Matter (TSPM), with additional subcategories of particles smaller than 10 μm in diameter (PM_{10}) and particles smaller than 2.5 μm 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.

ii. Sulphur Dioxide (SO_2). This compound is colorless, 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.

iii. 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. Large concentrations can reduce visibility and increase the risk of acute and chronic respiratory disease.

iv. Carbon monoxide (CO). This odorless, colorless gas is formed from the incomplete combustion of fuels. Thus, the largest source of CO today is motor vehicles. Inhalation of CO reduces the amount of oxygen in the bloodstream, and at higher concentration can lead to headaches, dizziness, unconsciousness and death.

v.Ozone (O_3) Tropospheric "low-level" ozone is a secondary pollutant formed when sunlight causes photochemical relations involving NOx and VOCs. Automobiles are the largest source of VOCs 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.

vi. Lead (Pb). The largest source of Pb in the atmosphere has been from 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 *(Daly and Zanetti, 2007).*

2.2 LITERATURE REVIEW

2.2.1 Vehicular Emission and Health Implication

Air pollution due to vehicular emission has become one of the serious environmental concerns in most urban areas especially in view of the adverse health effects that have been associated with ambient fine particles, gaseous pollutants and heavy metals *(Dockery et al., 2005: Dockery and Pope, 1997; Bilkiset al., 2009).* Due to enhanced human activities producing increased emissions, atmospheric pollution in urban areas has become a major issue in many developing countries all over 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 lower than WHO-recommended guidelines resulted in a significant increase in respiratory effects *(Raaschou, 1995).*

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. Findings reported by the Environmental and Human Health Effects Inc. *(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 asthmatics. Exhaust can adversely affect lung function *(D' Amato, 1999; interagency forum for child and family statistics, 2009; USEPA, 2012; Koren, 1995)* and may promote allergic reactions and airway construction *(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 asthmatics *(Delfinoet al., 1998; Yu et al., 1990; Nordenhallet al., 2001).* Asthmatic children are particularly sensitive to air pollution.

iii. Vehicles emit numerous carcinogenic chemicals. Diesel contains benzene, formaldehyde, and 1, 3-butadiene-all three are 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 subtitle 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 individual's health status and genetics.

2.2.2 Air Pollution in Developing Countries

Air pollution is an important public health problem in most cities of the developing world. Motorization growth has been largely unchecked by environmental regulations, thereby creating high levels of air pollution *(Han and Naeher, 2006).* Vehicular emissions contribute 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 of 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.

Pummakarnchana, et al., (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 has been

facing serious air; pollution problems. As seen in central Bangkok, black and white smoke from truck and public bus exhaust still occurs. This, they attributed to the rapid economic and industrial growth, combined with a lack of strict implementation of air quality and requires the pollution control department (PCD) to adapt or extend the current PCD's air quality monitoring systems and also facilitate the problem of analyzing and mentoring air pollution in Bangkok area.

Khaled-Ahmad (2012) also conducted a statistical analysis of air pollution study in Brisbane, Australia; he concluded that the overall vehicular transportation pollution situation in his study is poor. His findings showed and indicated 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 distribution of deaths from respiratory diseases, cardiovascular diseases and cardio-respiratory diseases.

In a similar study on Air Pollution from Motor Vehicles, Standards and Technologies for Controlling Emission by *Asif Faiz Christopher S. Weaver, Michael P. Walsh.* With contributions by *Surhid P. Gautam Lit-Mian Chan- November 1996,* concluded that common air pollutants in urban cities in developing countries with regards to vehicular emission include:

- Respirable particulate matter from smoky diesel vehicles, two-stroke motorcycles and 3-wheelers, burning of waste and firewood, entrained road dust, and stationary industrial sources.
- Lead aerosol from combustion of leaded gasoline.
- Carbon monoxide from gasoline vehicles and burning of waste and firewood.

- Photochemical smog (Ozone) produced by the reaction of Volatile Organic Compounds and Nitrogen Oxides in the presence of sunlight; motor vehicle emission is a major source of nitrogen oxides and volatile organic compounds.
- Sulfur oxides from combustion of sulfur-containing fuels and industrial processes.
- Secondary particulate matter formed in the atmosphere by reactions involving ozone, sulfur and nitrogen oxides and volatile organic compounds.
- Known or suspected carcinogens such as benzene, 1.3 butadiene, aldehydes, and polynuclear aromatic hydrocarbons from motor vehicle exhaust and other sources.

2.2.3 Vehicular Emission Studies in Some Nigeria Cities

Several studies on the extent of vehicular emission in some cities of Nigeria have been carried out by many scholars. For example, a study 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), NOx, SO_2, and CO in the Niger Delta were above National limits.

Koku and Osuntogun (2007) in three cities of Nigeria: Lagos, Ibadan and Ado Ekiti all in South-West region of Nigeria has significant on air quality. Air quality indicators namely CO, SO_2, NO_2, and total suspended particulates (TSP) were determined. The obtained results of CO, SO_2, NO_2 and particulate counts per minute were found by the study to be higher than National limits. Conclusions of their investigation showed a growing risk of traffic-related problems in these Nigerian cities and therefore recommended for serious air quality measures.

Ndokeet al. (2006) carried out a study to examine the quantity of carbon dioxide (CO_2) contributed by automobile emission to the environment in some areas of Kaduna and Abuja in Northern Nigeria. Five census stations were selected in each of the two towns. The study 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.

Moen in 2008 carried out a study in which he monitored the hourly concentrations of CO, NO_2, and SO_2 at six major intersections in Abuja Metropolis during morning - low-traffic hours and afternoon- high-traffic hours. This study served as a model of exposure for traffic wardens, a high exposure group. The result showed that vehicle emission 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 emission on air quality and health should be studied further if public health is to be protected.

F. I. Abam and G.O.Unachukwu in 2009 reported the results of the investigation of vehicular emission in selected areas in Calabar Nigeria. All the five monitored air pollutants when compared with Air Quality Index (AQI) CO, range from moderate to very 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.

Finally, Okunolaet al., in2012 conducted a research in Kano-Nigeria using the Crowcon gas sensor to collect emission values of various gases. They 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 is significant with potentially hazardous health consequences.

2.2.4 Impacts of Air Pollution on Environment and Human Health

2.2.4.1 Human Health Effects

Air pollution can harm us when it accumulates in the air in high enough concentrations. Millions of people live in areas where urban smog, particle pollution, and toxic pollutants pose serious health concerns. People exposed to high enough levels of certain air pollutants may experience:

- Irritation of the eyes, nose, and throat;
- Wheezing, coughing, chest tightness, and breathing difficulties;
- Worsening of existing lung and heart problems, such as asthma;
- Increased risk of heart attack;

Overall, sufficient and suggestive evidence for these health outcomes indicates that exposure to traffic-related pollution is likely to be a matter of concern regarding public health, and deserves public attention in light of the fact of the large numbers of people residing within 300m to 500m of major roads. Similarly, a recent WHO review of evidence on the health impacts of air pollution looked explicitly at the proximity to roads and health impacts *(WHO, 2013).* This study concluded that "adverse effects on health due to proximity to roads were observed after adjusting for socioeconomic statusand after adjusting for noise." The health impacts are related to a mixture ofpollutants at the roadside, including PM, NO_2, CO and polycyclic aromatichydrocarbons. However, the

evidence does not allow discernment of the directimpact of specific pollutants, although the association with direct tailpipe PM isincreasingly identified.

2.2.4.2 Environmental Effects

Along with harming human health, air pollution can cause a variety of environmental effects:

Acid Rain is precipitation containing harmful amounts of nitric and sulfuric acids. These acids are formed primarily by nitrogen oxides and sulfur oxides released into the atmosphere when fossil fuels are burned. These acids fall to the Earth either as wet precipitation (rain, snow, or fog) or dry precipitation (gas and particulates). Some are carried by the wind, sometimes hundreds of kilometers. In the environment, acid rain damages trees and causes soils and water bodies to acidify, making the water unsuitable for some fish and other wildlife. It also speeds the decay of buildings, statues, and sculptures that are part of our national heritage.

Eutrophication is a condition in a water body where high concentrations of nutrients (such as nitrogen) stimulate blooms of algae, which in turn can cause fish kills and loss of plant and animal diversity. Although eutrophication is a natural process in the aging of lakes and some estuaries, human activities can greatly accelerate eutrophication by increasing the rate at which nutrients enter aquatic ecosystems. Air emissions of nitrogen oxides from power plants, cars, trucks, and other sources contribute to the amount of nitrogen entering aquatic ecosystems.

Haze is caused when sunlight encounters tiny pollution particles in the air. Haze obscures the clarity, color, texture, and form of what we see. Some haze-causing pollutants (mostly fine particles) are directly emitted to the atmosphere by sources such as power plants, industrial facilities, trucks and automobiles, and construction activities.

Others are formed when gases emitted to the air (such as sulfur dioxide and nitrogen oxides) form particles as they are carried downwind.

Effects on Wildlife. Toxic pollutants in the air, or deposited on soils or surface waters, can impact wildlife in a number of ways. Like humans, animals can experience health problems if they are exposed to sufficient concentrations of air toxics over time. Studies show that air toxics are contributing to birth defects, reproductive failure, and disease in animals. Persistent toxic air pollutants (those that break down slowly in the environment) are of particular concern in aquatic ecosystems. These pollutants accumulate in sediments and may bio-magnify in tissues of animals at the top of the food chain to concentrations many times higher than in the water or air.

Ozone Depletion. Ozone is a gas that occurs both at ground-level and in the Earth's upper atmosphere, known as the stratosphere. At ground level, ozone is a pollutant that can harm human health. In the stratosphere, however, ozone forms a layer that protects life on earth from the sun's harmful ultraviolet (UV) rays. But this "good" ozone is gradually being destroyed by man-made chemicals referred to as Ozone-Depleting Substances (ODS), including chlorofluorocarbons, hydrochlorofluorocarbons, and halons. These substances were formerly used and sometimes still are used in coolants, foaming agents, fire extinguishers, solvents, pesticides, and aerosol propellants. Thinning of the protective ozone layer can cause increased amounts of Ultra Violet (UV) radiation to reach the Earth, which can lead to more cases of skin cancer, cataracts, and impaired immune systems. UV can also damage sensitive crops, such as soya beans, and reduce crop yields.

Crop and Forest Damage. Air pollution can damage crops and trees in a variety of ways. Ground-level ozone can lead to reductions in agricultural crop and commercial

forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests and other environmental stresses (such as harsh weather). As described above, crop and forest damage can also result from acid rain and from increased UV radiation caused by ozone depletion.

Global Climate Change. The Earth's atmosphere contains a delicate balance of naturally occurring gases that trap some of the sun's heat near the Earth's surface. This "greenhouse effect" keeps the Earth's temperature stable. Unfortunately, evidence is mounting that humans have disturbed this natural balance by producing large amounts of some of these greenhouse gases, including carbon dioxide and methane. As a result, the Earth's atmosphere appears to be trapping more of the sun's heat, causing the Earth's average temperature to rise - a phenomenon known as global warming. Many scientists believe that global warming could have significant impacts on human health, agriculture, water resources, forests, wildlife, and coastal areas.

CHAPTER THREE
STUDY AREA AND RESEARCH METHODOLOGY

This chapter deals with the background of the study area and the methodology employed in carrying out the research work. The study area is the Federal Capital Territory (FCT, Abuja). Also highlighted in this section are the major environmental features, as well as industrial and economic activities and other general land use and human settings that are of relevance to this type of study are considered here. The methodology adopted for this study is organized in three parts:

i. Types and Sources of data used for the study
ii. Methods of data collection
iii. Methods of data analyses

3.1 The Study Area:

3.1.1 Brief overview of Abuja (Federal Capital Territory)

The Federal Capital Territory (FCT) is the capital of Nigeria. The Federal Capital Territory is located in the geographical centre of the country and viewed as neutral both ethnically and religiously, it is where culture and religion meet. The vehicle license plate for the FCT reads "Centre of Unity" a constant reminder that Abuja was selected in the hope of creating a united central city."

The territory was formed in 1976 from parts of former Nasarawa, Niger, and Kogi States. It has a land area of 8,000 square kilometers, and it is bordered to the north by Kaduna State, to the east by Nassarawa State, to the south-west by Kogi State and to the west by Niger State.The Federal Capital Territory lies between latitudes 8.8556838'N and longitude: 7.179026, with an elevation of: 273m/896feet.

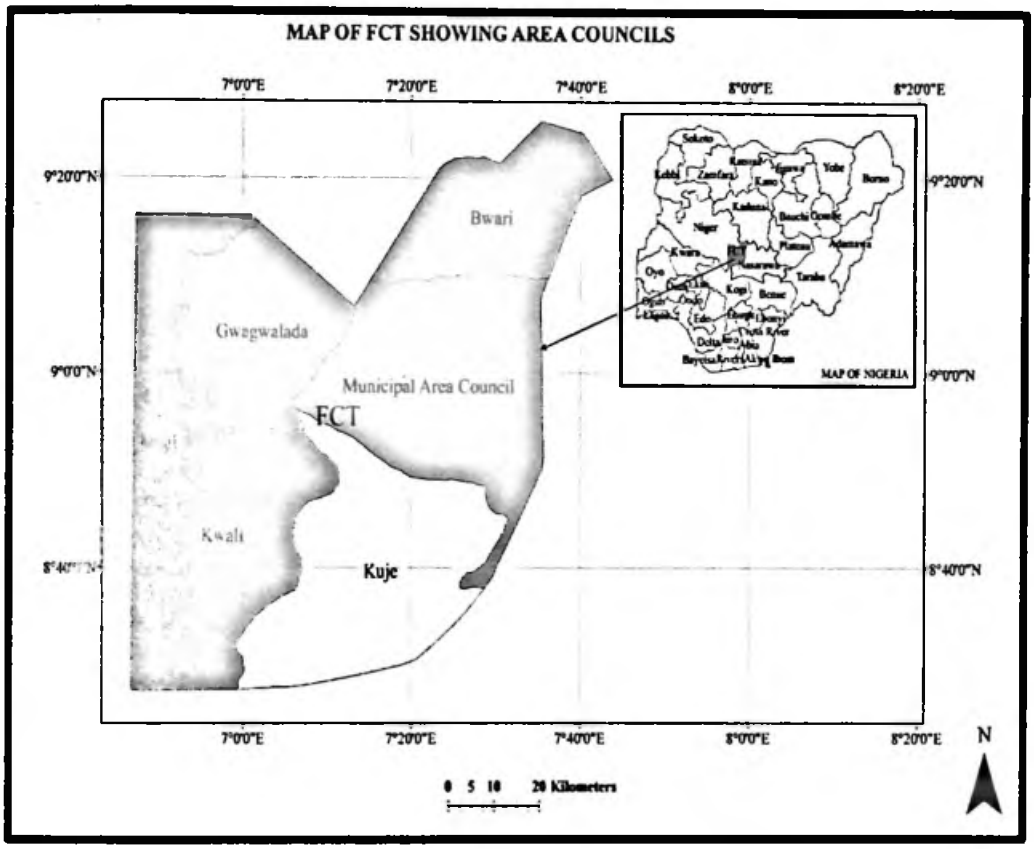


Plate 3.1.1: Map of the Federal Capital Territory (FCT) showing the Six Area Councils

The FCT's natural endowments such as; its rolling hills, isolated highlands and other endearing features make it a delight. The savannah grassland of the North and the Middle Belt, the richness of the tropical rain forests of the south and an equable climate all combined to make the FCT a soil-rich agricultural haven.

History

The land of Abuja was the southwestern part of the ancient kingdom of Zazzau (Zaria). The name "Abuja" was derived from Abu Ja, a brother to Muhammadu Makau, the last Hausa ruler of Zaria. Makau had left Zaria after being defeated by the Fulani and settled in the area now known as Abuja. In 1825 his brother Abu Ja succeeded him as the 62nd King of Zaria.

The full name of Abu Ja was Abubakar (shortened to "Abu") and the name Ja was given to him because he was light in complexion ("Ja" means red or fair in Hausa). Hence he became known as "Abu-Ja", "Abu the fair one" (other sources claim that the name "Ja" was derived from the last name of his father which was "Jatau"). Abu Ja built a new capital for his Kingdom and named it "Abuja" after himself.

People

The largest indigenous group in Abuja is the Gbabyi (also known as the Gwari). The next largest indigenous group is the Koro. Smaller indigenous groups also inhabit the area, such as the Gade, Egbura, Gwandara, Bassa and the Ganagana.

Local Government Areas

The FCT is divided into six area councils namely, Abuja Municipal, Gwagwalada, Abaji, Kuje, Bwari and Kwali.

3.1.2 Weather and Climate

Abuja under Koppen climate classification features a tropical wet and dry climate. The FCT experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season. In between the two, there is a brief interlude of harmattan occasioned by the northeast trade wind, with the main feature of dust haze, intensified coldness and dryness.

The rainy season begins from April and ends in October, when daytime temperatures reaches 28°C (82.4°F) to 30°C (86.0°F) and nighttime lows hover around 22°C (71.6 °F) to 23°C (73.4 °F). In the dry season, daytime temperatures can soar as high as 40 °C (104.0 °F) and nighttime temperatures can dip to 12 °C (53.6 °F). Even the chilliest nights can be followed by daytime temperatures well above 30 °C (86.0 °F).

The high altitudes and undulating terrain of the FCT act as a moderating influence on the weather of the territory.

3.1.3 Rainfall in the FCT reflects the territory's location on the windward side of the Jos Plateau and the zone of rising air masses. Due to the hilly and mountainous nature of Abuja city, Orographic activities bring heavy and frequent rainfall of about 1,500 mm (59.1 in) during the rainy season. Beginning in March to November, the rainy season peaks in September, during which abundant rainfall is received in the form of heavy downpours.

3.1.4 Vegetation

The FCT falls within the Guinean forest-savanna mosaic zone of the West African sub-region. Patches of rain forest, however, occur in the Gwagwa plains, especially in the rugged terrain to the southeastern parts of the territory, where a landscape of gullies and rough terrain is found.

3.1.5 Agriculture

Being centrally located, Abuja is blessed with a mix of agricultural produce such as tubers and root crops of the south (yams, cassava, maize and plantains) and grain (sorghum, guinea corn and rice) of the north.

3.1.6 Mineral Resources: The FCT has proven deposits of a wide range of mineral resources including marble, tin, mica, clay, iron ore, feldspar, gold, tantalite and talc.

3.1.7 Population: In the year 2016 the metropolitan area of Abuja is estimated at 6 Million persons.

3.1.8 Transportation and Road Network in the FCT

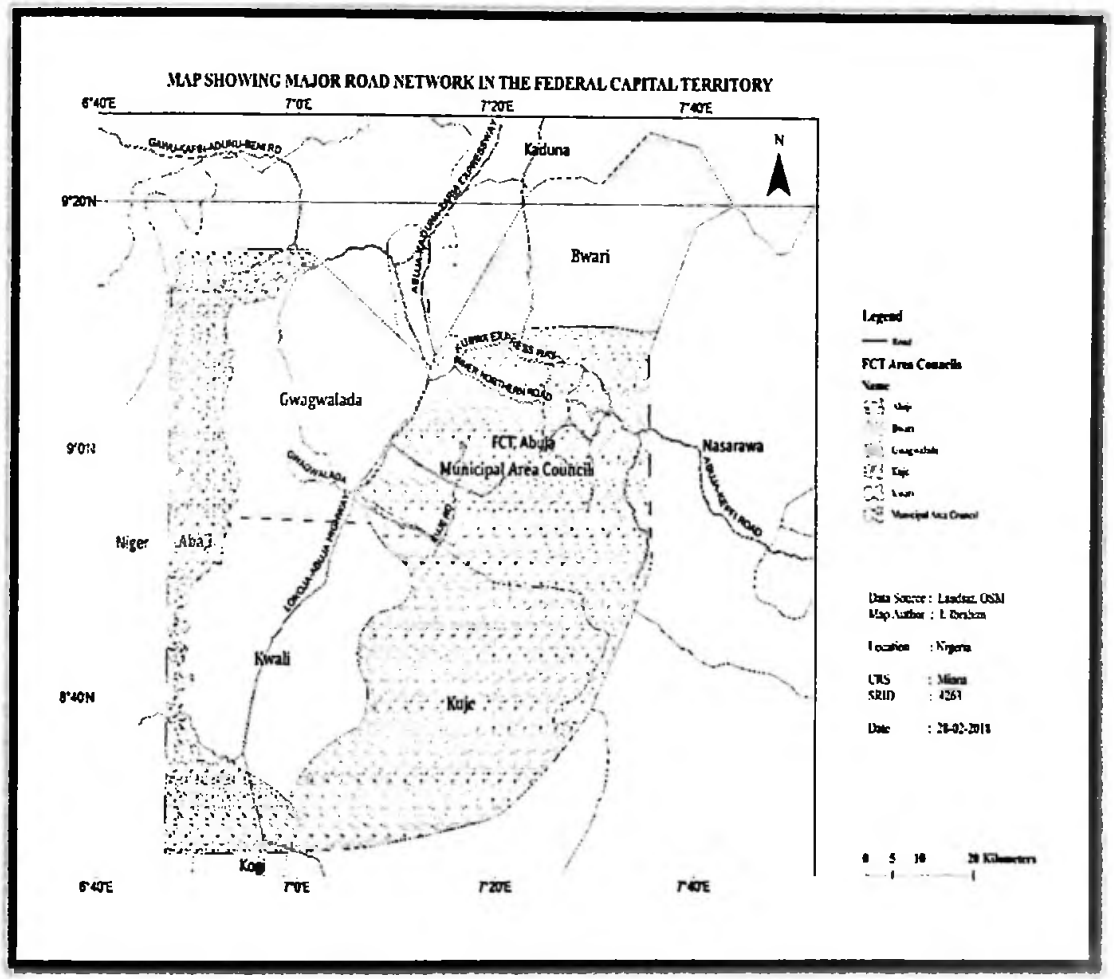


Plate 3.1.2: Map showing major road network in the Federal Capital Territory (FCT) Abuja.

Motor Vehicles are very important assets for the socio-economic development of a nation. Vehicles transport goods, services and people from one place to another, and the mode of transportation in Nigeria is largely by road, air, rail and water transport in the coastal areas, with road transport being the most widely used. In the FCT the mode of transportation is by road, rail is still being developed.

The fleet of road vehicles in Nigeria and the Federal Capital Territory (FCT) has steadily increased from the 1950s to date. A study by *Obio and Adegbulugbe in 1997* indicated

that from 1950 to 1992, cars increased from 12,544 to 623,113, trucks 444 to 54,587, motorcycles 4,387 to 675,637 and that a total of 38451 vehicles in 1950 rose to 1,666,731 in 1992. Similarly, records available from the Federal Road Safety Corps (FRSC) indicates a total of 8,954 vehicles in 2006 rose to 66,978 in 2017 and motorcycles from 32,670 to 135,469. From the above data it is apparent that the average emission concentration from motor vehicles and motorcycles in the FCT is in the increase.

Table 3.1.8: VEHICLE REGISTRATION FROM 2006 TO 2017 IN FCT

YEAR	MOTOCYCLE	MOTORVEHICLES	TOTAL
2006	32,670	8,954	4124
2007	48,30	13,800	62,430
2008	73,938	45,721	119,659
2009	55,637	1,906	57,543
2010	41,325	12,455	53,780
2011	31,297	15,963	47,260
2012	41,414	25,631	67,045
2013	106,140	49,024	155,164
2014	126,987	122,346	249,333
2015	88,522	45,893	134,415
2016	107,345	85,369	192,714
2017	135,469	66,978	202,447
GRAND TOTAL	**889,374**	**494,040**	**1,383,414.**

Source: FRSC HQ Abuja.

Transport System: According to the Abuja Master Plan (1979) the provision of facilities to accommodate the daily functioning of the capital city include good road network, public transport and auxiliary facilities which will allow for proper traffic flow.

The planning, designing and construction of the different types of road environment and provision of road furniture will create room for effective traffic management.

The Abuja master plan therefore highlights the features of a good environment and furniture to include:

i. Road hierarchy clearly categorizes roads and marking indication at each junction;
ii. Land Use: Traffic and safety implication of all proposed road project should be thoroughly examined.
iii. Locating shops and school within walking distance to home will minimize travel by vehicles.
iv. Access control, direct access to building should be permitted in only exceptional circumstance.
v. Road furniture: - safety consideration should be carried out throughout the complete design and construction process.

Shuaibu 2010 is of the opinion that the adoption of metropolitan public transport concept which the plan now is being implemented will go a long way to decongest the FCT.

3.1.9 Socio-Economic Activities

As a new capital, Abuja has the advantage of being well-planned over many capital cities. Visitors arriving into Abuja will be greeted by wide, well-designed and maintained roads and clean streets. Abuja also has excellent access to the wider road network than the rest of the country. It is built on a pre-Cambrian basement (granite) rock complex of distinctive domes and hills, the most striking of which is called Aso Rock.

According to the United Nations (UN) Abuja is one of the fastest growing city in the world and the fastest growing city in African continent, it grew by 139.7% between the year 2000-2010.

Abuja is the headquarters of the Economic Community of West African States, or ECOWAS. It also has the regional headquarters of OPEC.

In terms of economic activities, the FCT is gradually becoming an economic hub. It has many companies, manufacturing plants mostly located within the largest industrial area at Idu. There is also the international trade fair center, where international trade fair and Carnivals takes place annually.

The FCT has railway and road networks connecting the northern and southern part of the country in addition to housing the Dr. NnamdiAzikiwe International Airport where both international and domestic flights arrive at and take off, as well as many important educational institutions such as University of Abuja, Abuja,Nigerian Turkish Nile University, Abuja, Baze University, Abuja, The African University of Science and Technology, Abuja and Veritas University, Abuja.

Each of the states in the Federation maintains a liaison office in Abuja. The FCT also plays host to majority of the Embassies and High Commissions of Foreign Countries that have bilateral relations with Nigeria.

3.2 METHODOLOGY

This section deals with the methods and materials used for the purpose of this research.

3.2.1 Types of Data

a. **Primary Data**

i. The concentration levels of some selected gaseous pollutants (SO_2, NO_2, and CO)from motor vehicles emissions passing at the sampling locations;

ii. Statistics of the motor vehicles passing at the sampling locations.

iii. Photographs of motor vehicles passing at the sampling locations were also taken to give a visual impression of the differences between the volumes of traffic at the locations entering into the city and at the control station for visual understanding of the circumstances found on ground during the exercise.

iv. The noise levels at the sampling locations were also measured, and

v. Ground Positioning System (GPS) of the sampling locations areas were taken.

b. **Secondary Data**

i. Literatures were read from published and unpublished journals, conference papers, research thesis, and other related documents or materials relevant to this type of study as well as related websites.

3.2.2 Sources of Data

i. Gaseous Pollutants and Emission Levels; Levels of the selected gaseous pollutants SO_2, NO_2, and CO. were obtained from field through the use of Mobile handheld air quality monitoring equipment - Gray Wolf Toxic Gas Analyzer (Model: TG-500)

ii. Motor Vehicle Count; Statistics of the motor vehicles passing at each location were obtained using manual count recordings.

iii. Photographs; the photographs of motor vehicles passing at the locations were taken at the field from a digital still camera.

iv. Noise levels, the Ground Positioning Systems (GPS) as well as the ambient temperature at the sampling locations were also measured.

3.3. Equipment Used for the Study



Plate 3:3.3Equipment used for the data collection (see names below)

3.3.1 Hardware

i. Computer Laptop (HP DV 6) for processing of acquired data.

ii. Gray Wolf Toxic Gas Analyzer (Model: TG-500) a portable multi-gas monitor for field detection and recordings of concentration levels of emitted gases (pollutants) CO, NO_2, NO, O_3, H_2S, SO_2 and ambient temperature.

iii. Digital still camera Sony lens Cyber-Shot for taken the photographs of traffic congestion and volume.

iv. Magellan Triton 300. Handheld GPS.

v. Noise Meter (Model: MT-901A)

3.3.2 Software

i. Microsoft Excel 2007 and Statistical Analysis Software SAS (Version 9) for statistical analysis.

3.3.3 Methods of Data Collection

3.3.3.1 Sampling Procedure

For the purpose of this research four measurement points (MPs) were mapped out namely points MPA, MPB, MPC and MPD. Measuring Points, A, B, C represents motorways entering into the Federal Capital Territory (FCT), with high traffic volume. While station D represents motorway which has very less traffic volume, this also served as control point/station. At stations 'A', 'B', 'C' air quality samples were measured at four (4) selected motorways around: Mararaba – Nyanya road on the eastern axis, Suleja- Kubwa road on the western axis and City Gate – Airport road on the southern axis respectively. These motorways were selected based on their potential high traffic.

i. The air pollutants were measured usingGray Wolf Toxic Gas Analyzer (Model: TG-500) a portable multi-gas monitor for field detection and recordings of concentration levels of emitted gases (pollutants) CO, NO_2, NO, H_2S and SO_2. It offers flexibility, assurance, and robustness. Intrinsically safe, it is a portable gas detector with embedded software designed that met the requirements of International Electro Technical Commission (IEC 61508-3) which is the international standard for electrical, electronic and programmable electronic safety related systems, guaranteeing reliable and dependable operation and certified by Lloyds Register.

ii. Motor traffic count was conducted manually to obtain the volume of traffic at the sampling points. Both in and out coming motor vehicles movement was counted. The counting was done within the space of 60 minutes so as to avoid repetition.

iii. The time frame for data collection from the three (3) measuring points including the control station was carried out concurrently in one month, five days per each measuring point, and three (3) times per day for this five (5) days of the week that is

from Monday to Friday which covered complete vehicles movement within the working week at the measuring points. These times are categorized as follows:

- 6.30 am – 9.30 am morning peak hours.
- 11.30 pm – 2.30pm off-peak hours
- 4.30 pm – 6.30 pm evening peak hours

3.3.4 Instruments Used and their Calibration status

3.3.4.1 Toxic Gas Analyzer TG - 501

Handheld Toxic Gas Analyzer TG -501, made by Gray Wolf Sensing Solution, was calibrated with appropriate kit and factory calibration data. The calibration kit contains a regulator, calibration hood with tubing and reference gas to calibrate CO_2, CO and other gases. For VOC calibration, the zero- reference gas used was Hydrocarbon-Free, with 0.0ppm concentration. The high point reference gas (for low range sensor), was Isobutylene between 5.0ppm and 10.0ppm. The calibration was done in the month of June, 2018.

3.3.4.2 Magellan GPS Map Triton

Magellan GPS Map Triton was calibrated using the manufacturer's standard and procedures coupled with appropriate geographic conditions and calibration data. To ensure accuracy, GPS Map Triton was laid on a flat, level surface and the calibration was done outdoor, away from object that influences magnet field like buildings, cars and overhead power lines. Calibration of the equipment was done in the month of June, 2018.

3.4 Method of Data Analysis

i. The concentration levels of the gaseous emissions SO_2, NO_2, and CO were compared with the National Environmental (Air Quality Control) Regulations,

2014 standards, which are: CO (10 - 20 ppm), NO_2 (0.04 - 0.06 ppm), and SO_2 (0.01 - 0.1 ppm) and the USEPA AQI Chart.

ii. Bar charts were designed to show the variation between the recorded emission levels.

iii. The total and mean emission levels of these gases for each day was calculated and also represented in a table. This was achieved by using the formula below:

TEL = ELS (M+A+E)

MEL = ELS (M+A+E) .....(1)

Where; TEL = Total Emission Level

ELS = Emission Levels

MEL = Mean Emission Level

M = Morning

A = Afternoon

E = Evening

iv. The concentration levels of the gaseous emissions recorded at the three sampled stations A, B and C, was compared by using Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT) to test for hypothesis Ho: 1, predicated based on the assumption that "there is no significant difference in the air quality within the FCT and the control station". This test was carried out at 0.05 level of significance. This helped to confirm if motor vehicles contribute to air pollution in the study area.

Analysis of variance (ANOVA) and DMRT (Duncan Multiple Range Test) were used to test for variation in the concentration of pollutants among the three sampling points also to test for hypothesis Ho: 2, that were predicated based on

the assumption that "there is no significant difference in the concentrations of pollutants among the three sampling points". This test was done at 0.05 level of significance. This also helped to confirm if there is any variation among the three sampling points with respect to their pollutants concentration.

vi. Linear Correlation 'r' was used to test the third null hypothesis Ho: 3, that was stated based on the assumption that "there is no significant relationship between volume of traffic and concentration of pollutants at the sampling points" This test was also done at 0.05 level of significance, this helped to confirm if there is any relationship between traffic volume and concentration levels of detected gaseous emissions (SO_2, NO_2 and CO) at the sampling points.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

This chapter presents the results which were discussed successively. First the Analysis of Traffic survey on sampling locations, followed by vehicular emission concentration, the comparisons of concentration of pollutants and the relationship between traffic volume and concentration of pollutants. The results were also discussed. The three hypothesis were also analyzed using Analyses of Variance (ANOVA) and Duncan Multiple Test Range (DMTR).

4.1 Analysis of Traffic Survey on Sampling Locations.

This project work is aimed at determining mainly the volume of traffic moving on the roads at a particular section during a particular time. The traffic survey was carried out for continuously five days from Monday to Friday for three different timings (Morning, afternoon and evening). The selected sites are located at almost ten (10) kilometers or less to the Federal Capital Territory (FCT) and it is congested during the morning hours of 7:30 – 9:30 a.m., when offices and commercial centers opened for business, non peak hours 11.30 – 2.30pm, and 4:30–7:00 p.m. in the evening when the offices and business centers have closed. Traffic volume and activity is high on the two-lane dual carriageway road. The survey was carried out by manual counting method.



Plate 4:1.1 The Researcher carrying out data collection in one of the Sampling Points.

4.2 Determination of Vehicular Emission Concentration in the Study Area:

For the purpose of this research three Measurement Points (MPs) were mapped out namely points MP'A', MP'B', MP'C' and MP'D'. Measuring Points, A, B, C represents motorways entering into the Federal Capital Territory (FCT), with high traffic volume. While station D represents motorway at the (FCT) which has very less traffic volume, this also served as control point/station. At stations 'A', 'B', 'C' air quality samples were measured at four (4) selected motorways as shown in table 4:2.1 below with their coordinates.

Table 4:2.1 Location of Areas/ Sampling Points.

S/N	Measurement Point	Sampling Point/ Coordinates	Section
1.	MP "A" Keffi – Abuja Road (eastern axis)	**SP1**: 9.02177 N 7.56833 E **SP2:** 9.02414 N 7.56136 E **SP3**: 9.02756 N 7.55144 E **SP4:** 9.04889 N 7.53379 E	(NNPC Filling Station near Nyanya Bridge Karu Bridge (Near Army Check Point). VIO Computerized Centre (Kugbo). Abacha Barracks (Near AYA Roundabout).
2.	MP "B" Airport Road - City Gate (southern axis)	**SP5**: 9.02757 N 7.55148 E **SP6**: 8.98406 N 7.38879 E **SP7:** 8.99583 N 7.40688 E **SP8:** 9.03374 N 7.44705 E	NNPC Filling Station (adjacent Obasanjo Space Center Lugbe). Karamajiji after Shoprite (adjacent International Cancer Center). Kuchingoro (adjacent National Army cemetery). City Gate (adjacent Army post).
3.	MP "C" Suleja – Kubwa Road (western axis).	**SP9**: 9.04888 N 7.53378 E **SP10**: 9.13787 N 7.35359 E **SP11**: 9.13787 N 7.35357 E **SP12:** 9.11865 N 7.40817 E	NIPCO Filling station adjacent Kubwa second gate. Kubwa 1st Gate, adj. NEMA Ambulance Bay. Gwarimpa main gate, near pedestrian flyover bridge. Katamkpe hill, adjacent SHEMA Petroleum.
4.	MP "D" Guzape Road Asokoro Abuja. CONTROL STATION.	**SP13**: 9.02953 N 7.53637 E	

4.3 Measurement and Comparison of Concentration of Pollutants in the Study Area:

The air pollutants were measured at each of the sampling points using the Gray Wolf Toxic Gas Analyzer (Model: TG-500) at a safe distance away from the road. Other parameters measured along with the pollutants were the coordinates (GPS) of the

locations the noise levels in decibels (dB), the total traffic count per hour passing the sampling location as well as the ambient temperature were all recorded.

The average concentration of pollutants for the vehicles surveyed during the three different timing for morning peak hours, non-peak hours and evening peak hours is shown in Table: 4.3.1.

Table 4.3.1 Average Concentrations of Pollutants on the Measurement Points into the FCT.

	Average Pollutants Concentration per Week											
Sampling Point	**Average Traffic Count Vol. Per Week**			**SO_2**			**NO_2**			**CO**		
MP	M	A	E	M	A	E	M	A	E	M	A	E
MPA	5,861	3,414	5,119	1.32	1.42	1.52	0.10	0.11	0.11	6.67	6.24	6.92
MPB	5,741	4,154	5,696	1.72	1.44	1.36	0.07	0.10	0.13	2.65	2.04	1.48
MPC	4,848	3,156	4,301	1.42	1.60	1.50	0.27	0.14	0.14	2.60	1.48	2.84
MPD	131	99	113	0.93	0.91	0.94	0.05	0.05	0.04	1.03	1.00	1.00

Key: **Source**: Researcher's Field report, 2018.

M= morning, A= afternoon, E= evening

Table 4.3.1 shows the average traffic volume for the five (5) days and emission estimates at the measurement points. The result shows that the average levels of the pollutants measured were found to be ranged between 1.32 – 1.72ppm, 0.07 – 0.27ppm and 1.48 – 6.92ppm for SO_2, NO_2 and CO respectively. With the exception of Guzape (the control) pollutants level was found to be ranged between 0.91 – 0.94 ppm, 0.04 – 0.05ppm and 1.00 – 1.03ppm for SO_2, NO_2 and CO respectively.

Air Pollution Levels in the Measurement Points (MP's)

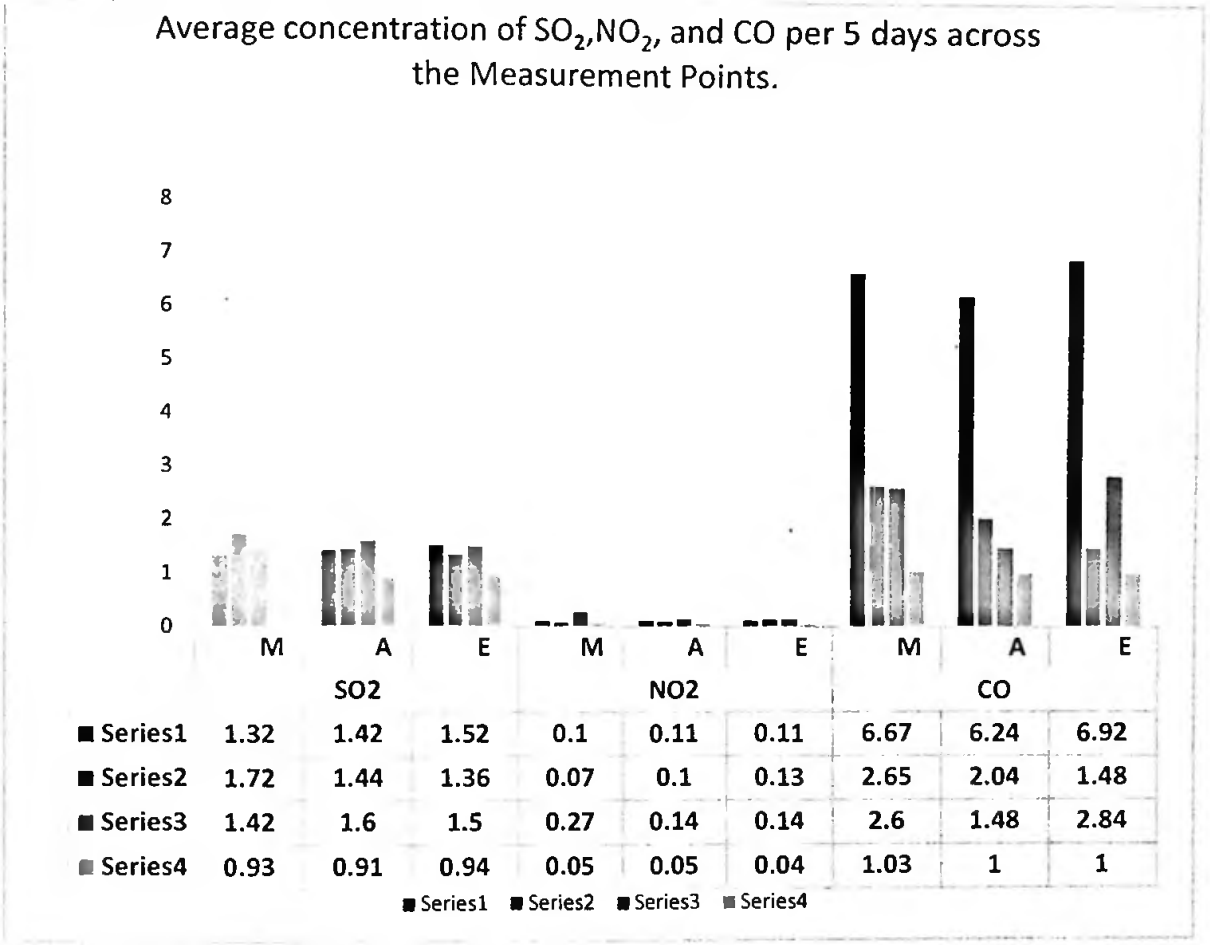


Fig. 4.3.1 Average concentrations of SO_2, NO_2, and CO per 5 days across the (MP's)

KEY: **Source**: Researcher's Field report, 2018.

Series 1, 2 3 4: MP's A, B, C and D respectively (combined in one plot)

"A" Keffi – Abuja Road (eastern axis)

"B" Airport Road - City Gate (southern axis)

"C" Suleja – Kubwa Road (western axis).

"D" Guzape Road Asokoro Abuja.

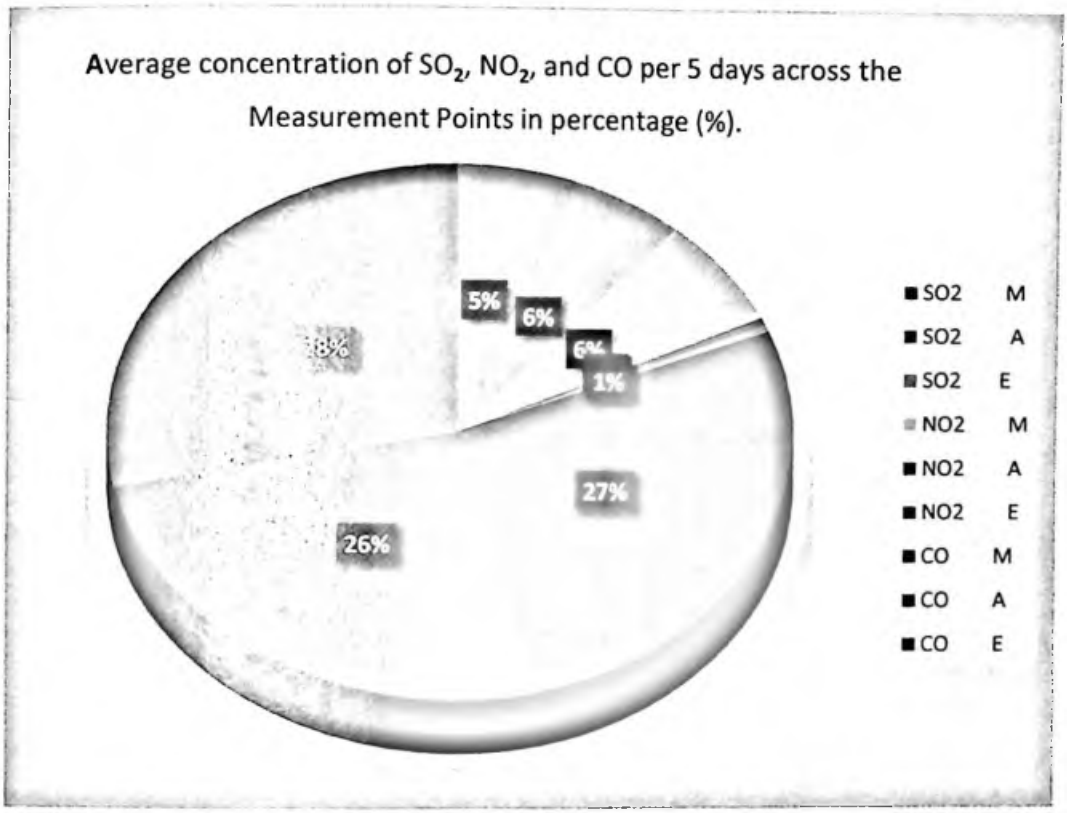


Fig. 4.3.1 Air Pollution Levels in the Measurement Points in percentage (%)

Table: 4:3.2. Air Quality Index (AQI) for Priority Pollutants

AQI	AQI Rating	PM_{10} u g/m^3	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)
Very good (0 – 15)	A	0 - 15	0 - 2	0 – 0.02	0 - 0.02
Good (16 – 31)	B	51 - 75	2.1 – 4.0	0.02 -0.03	0.02 -0.03
Moderate (32 – 49)	C	76 - 100	4.1 – 6.0	0.03 – 0.04	0.03 – 0.04
Poor (50 – 90)	D	101 - 150	6.1 – 9.0	0.04 – 0.06	0.04 – 0.06
Very Poor (100 or over)	E	>150	>9.0	>0.06	>O.O6

Source:USEPA 2000.

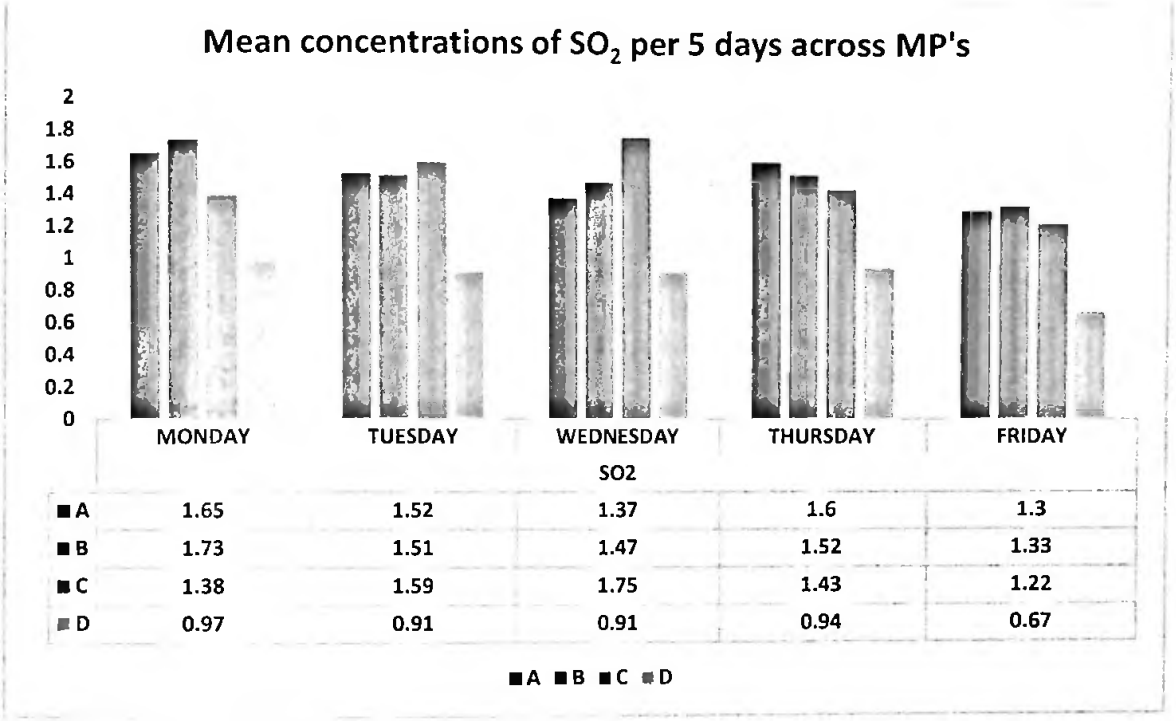


Fig. 4.3.2(a)Mean Sulphur Dioxide levels (SO_2) levels per 5 days across the Measurement Points

Source: Researcher's Field report, 2018.

Key:
Blue = MPA,
Orange = MPB
Ash = MPC and
Yellow = MPD for control.

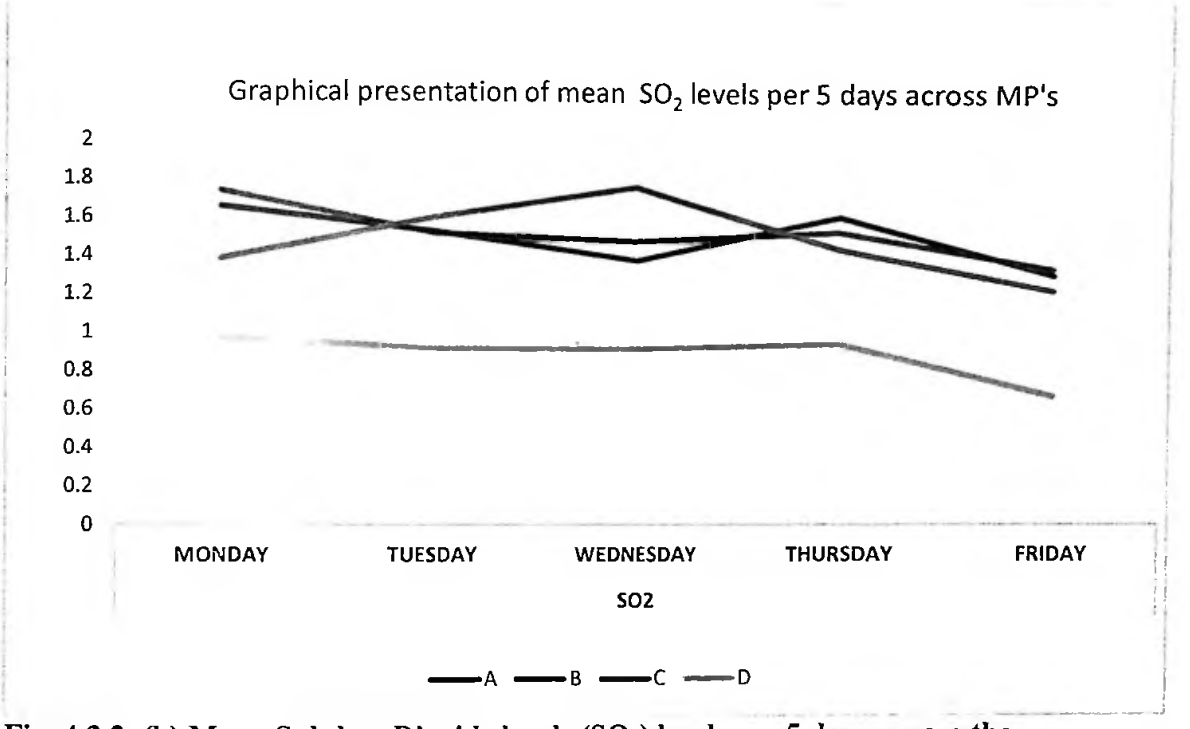


Fig. 4.3.2. (b) Mean Sulphur Dioxide levels (SO_2) levels per 5 days across the Measurement Points. **Source**: ResearcheR's Field report, 2018.

Key:
Blue = MPA,
Orange = MPB
Ash = MPC and
Yellow = MPD for control.

Figures 4.3.2 (a and b) Shows the mean SO_2 levels across periods at sampling points. The result illustrated that the highest SO_2 level is at the evening peak hours between 4.30 pm – 5.30 pm around kubwa – Suleja road with level of SO_2 1.75ppm; 1.73ppm at Airport – City gate road; and 1.65ppm at Keffi – Abuja (Mararaba- Nyanya); and 0.97ppm Guzape road.

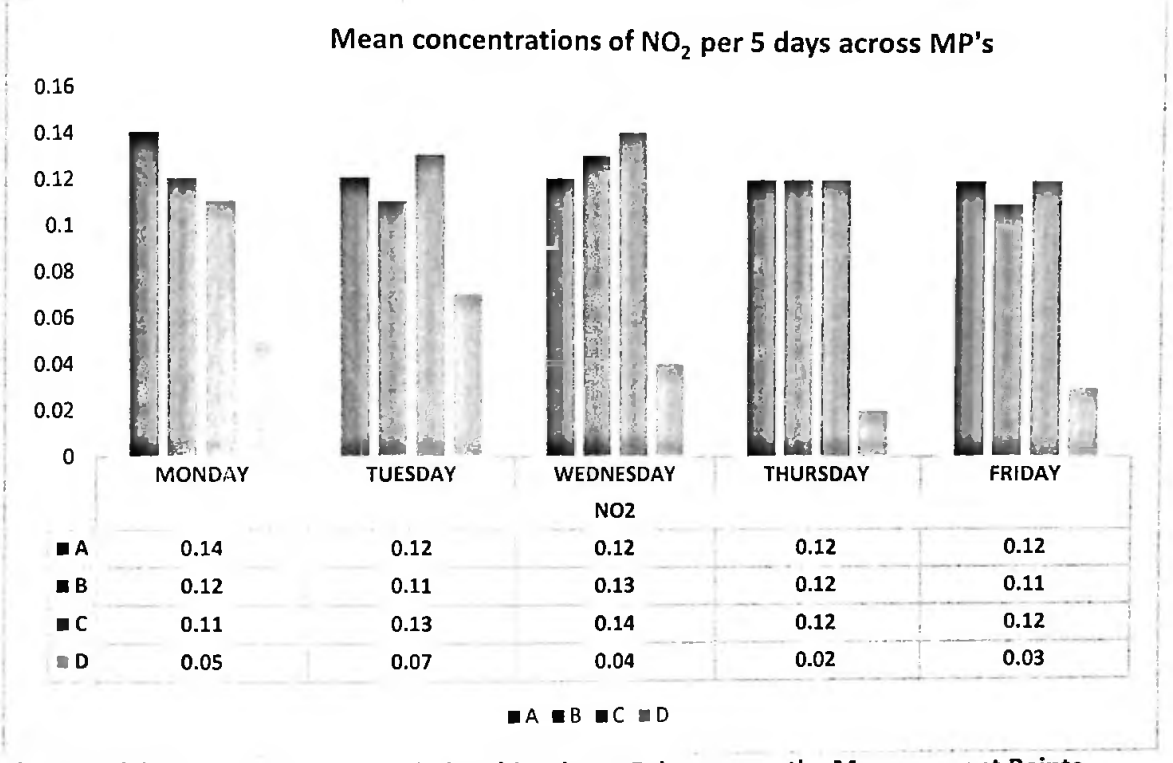


Fig. 4.3.3 (a) Mean Nitrogen Dioxide (NO_2) levels per 5 days across the Measurement Points

Source: **Researcher**'s Field report, 2018.

Key:
Blue = MPA,
Orange = MPB
Ash = MPC and
Yellow = MPD for control.

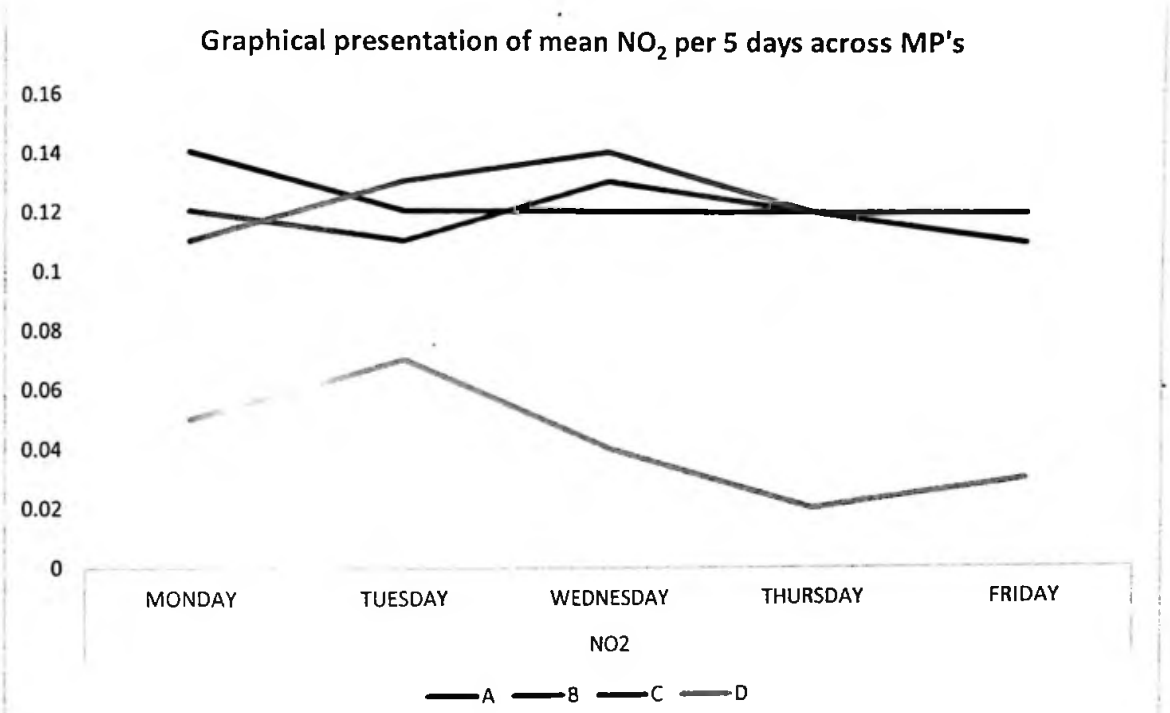


Fig. 4.3.3 (b) Mean Nitrogen Dioxide levels (NO_2) levels per 5 days across the Measurement Points

KEY:

Blue = MPA,
Orange = MPB
Ash = MPC and
Yellow = MPD for control.

Source: Researcher's Field report, 2018.

The results of the mean NO_2 levels per 5 days as presented in table 4.3.3 (a) ranged from 0.12- 0.14ppm for Keffi – Abuja road sampling point; 0.11 -0.13ppm for Airport - City gate road sampling point; 0.11 - 0.14ppm for Suleja – Kubwa road sampling point, and 0.02-0.07ppm for Guzape road which serves as a control point

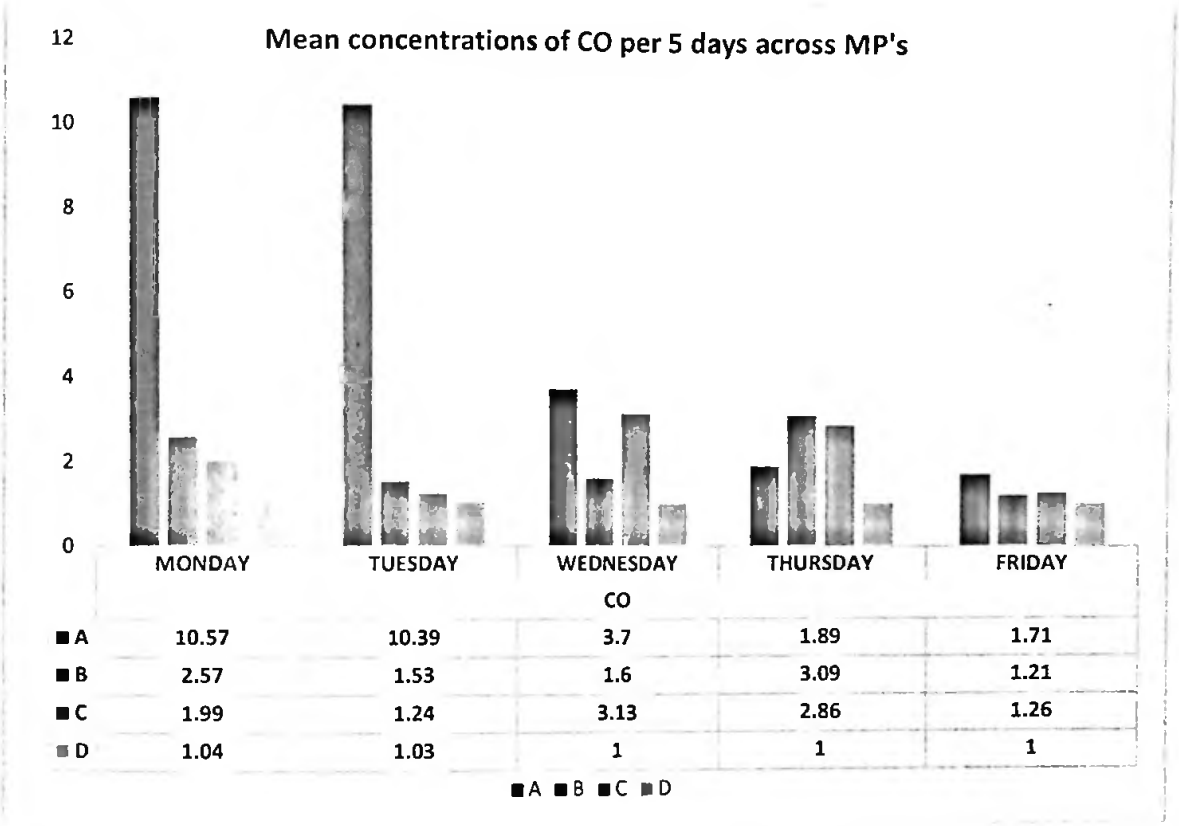


Fig. 4.3.4 (a) Mean Carbon Monoxide (CO) levels per 5 days across the Measurement Points

KEY:

Blue = MPA,

Orange = MPB

Ash = MPC and

Yellow = MPD for control.

Source: Researcher's Field report, 2018.

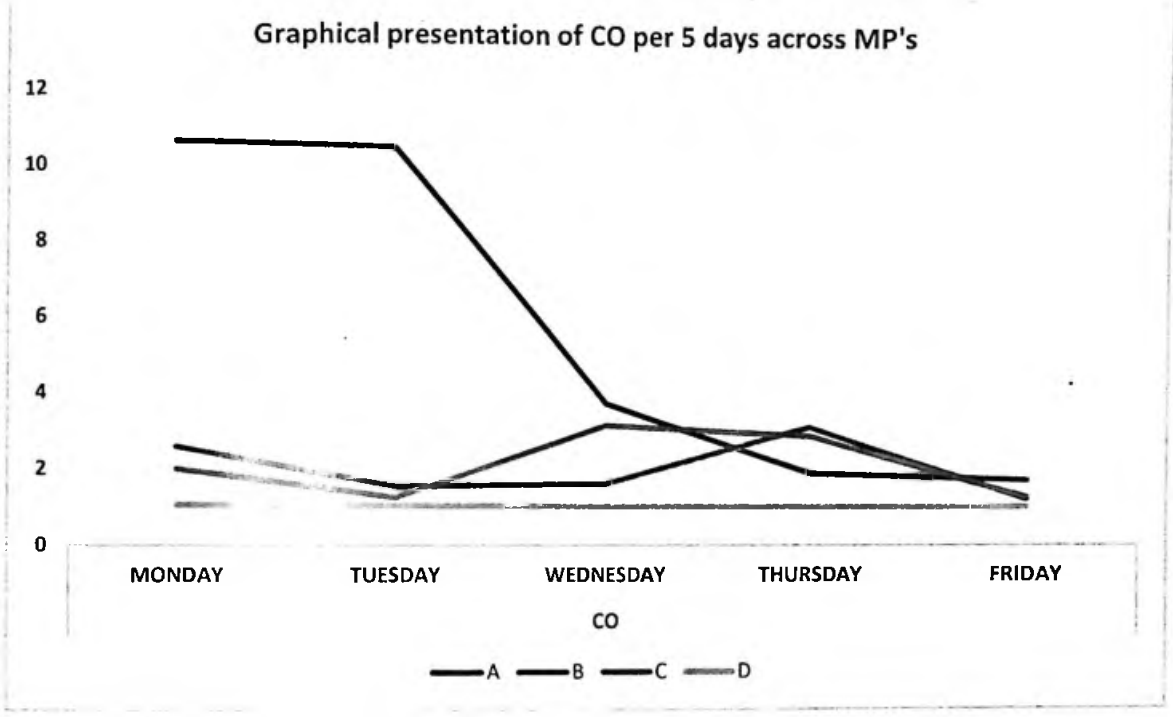


Fig. 4.3.4 (b) Mean Carbon Monoxide (CO) levels per 5 days across the Measurement Points. **Source:** Researcher's Field report, 2018.

Key: Blue= MPA, Orange=MPB, Ash= MPC and Yellow= MPD

The results for CO levels per day as presented in table 4.3.4 (a) ranged from 1.71 – 10.57ppm for Keffi – Abuja road sampling point; 1.21 – 3.09ppm for Airport –City Gate road sampling point; 1.24 – 3.13ppm for Suleja – Kubwa road sampling point: and 1.00 - 1.04ppm for Guzape road which serves as a control point.

4.4 Relationship between Traffic Volume and Concentration of measured Pollutants

Table 4.4.1 Correlation among Pollutants concentrations and traffic volume.

Parameters	Traffic	CO	NO_2	SO_2
Traffic	1			
SO_2	0.879	0.899	0.924	1
NO_2	0.840	0.858	1	
CO	0.979	1		

**correlation is significant at the 0.01 level (2-tailed)

Table 4.4.1 shows the degree of relationship between concentrations of pollutants measured and traffic volume across the sampling points. This was investigated using Bivariate Pearson's correlation (r), the correlation coefficient between traffic and concentrations of pollutant was found to be r = 0.879; r = 0.840; r = 0.979 for SO_2, NO_2, and CO, respectively. The result indicated that all variables (SO_2, NO_2, and CO) had a very strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels. According to Sharma *et al.* (2009), the significantly positive correlation indicates that the emissions sources are similar and that could be vehicles exhausts generated by the traffic volume. Also, it could be argued that the very strong relationship between traffic volume and pollutants may be because most commercial vehicles (busses, taxies, and motorcycles) plying the road were old and poorly maintained. Therefore, they emitted high amount of pollutants into the environment.

Table 4.4.2 Average Traffic Count, Noise level and Ambient Temperature per 5 days across the Measurement Points

Sampling Point	Average Traffic Count			Sound level (dB)			Ambient Temp (°C)		
SP	M	A	E	M	A	E	M	A	E
1	6510	4312	5402	70	66	61	29	34	30
2	5420	3315	5389	67	60	72	30	31	28
3	6352	2906	5372	69	65	70	30	32	29
4	5163	3123	4313	67	63	69	29	33	31
5	6018	3350	5885	66	68	69	26	34	31
6	5255	4813	6130	69	69	68	26	30	33
7	5046	4215	4895	69	69	68	29	39	31
8	6645	4237	5875	78	62	70	27	29	28
9	4260	3415	3280	64	65	70	30	33	29
10	5160	3160	4832	68	68	69	30	35	31
11	5350	3020	4980	71	70	68	30	31	30
12	4620	3030	4112	72	73	71	29	31	30
13	131	99	113	53	62	63	26	28	29



Plate 4:4.1 Traffic at Nyanya Bridge along Keffi – Abuja Road at morning peak (7:30 - 9:30 a.m)



Plate 4:4.2 Traffic at Karu Bridge along Keffi – Abuja Road at morning peak (7:30 - 9:30 a.m)

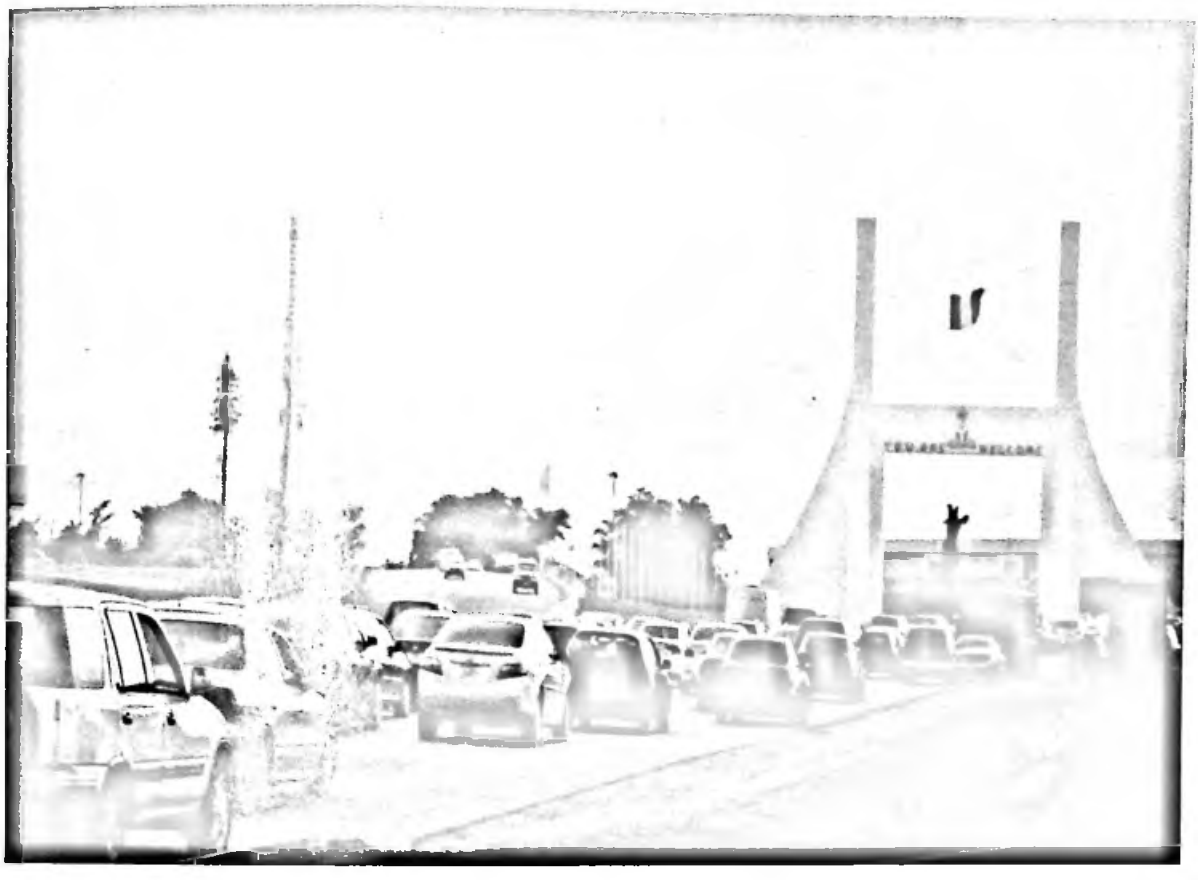


Plate 4.4.3 Traffic at Airport Road – City Gate during the morning peak (7:30 – 9:30 a.m)



Plate 4:4.4 Traffic at Airport Road – City Gate



Plate 4.4.5 Traffic along Kubwa – Suleja Road during the morning peak (7:30 9:30am)



Plate 4.4.6 Traffic along Guzape Road Abuja (Control station) during morning peak

4.5 DISCUSSION OF FINDINGS

From the results obtained, the concentrations of pollutants (SO_2, NO_2 and CO) were higher in the evening periods and relatively lower during morning periods. This result also, concord with the findings of the research conducted by Ragini*et al.* (2009), and Okunola*et al.* (2012), who reported that concentration of pollutant gases was lower during morning period. However, this variation may be attributed to the relationship between traffic volumes and pollutants concentrations as revealed in the result obtained in correlation table 4.4.1 where traffic volume affects pollutants concentrations.

From figure 4:3.2 (a and b) the result illustrated that the highest SO_2 level is at the evening peak hours between 4.30 pm – 5.30 pm around kubwa – Suleja road with level of SO_2 1.75ppm; 1.73ppm at Airport – City gate road; and 1.65ppm at Keffi – Abuja (Mararaba- Nyanya); and 0.97ppm Guzape road.

It could be said that positive significant correlation at 0.01 confidence levels (0.879) between traffic volume and SO_2 during this period could be responsible. However, the concentration of SO_2 is lower than ranges of 3.21 - 5.18ppm, 7.4 – 15.5ppm, and 16 - 64ppm as reported in similar studies conducted by Ayodele and Abubakar (2010), Ettouney*et al.* (2010), and Kalabokas*et al.* (1999), in Lagos, Port-Harcourt and Greece respectively.

Comparing the results obtained from the research with the National and USEPA standards shows that the air quality in the major roads leading into the FCT are grossly very poor (E). This could be attested to the high Sulphur content in the fuel used in the country - Sulphur content of 1,000ppm for Petrol, 3,000ppm for Diesel (*source NNPC submission to the Sub- Committee on desulphurization of fuel in Nigeria) unpublished.*

The NO_2, concentration recorded was relatively moderate at all sampling points with exemption of the control station. However, the highest levels of NO_2 recorded were during the afternoon and evening hours at two sampling points. When the levels of NO_2 were compared with values reported in literature, periodic mean of NO_2 was found very low than 35 - 108ppm reported in Athens, Greece Kalabokas*et al.*, (1999), but similar with the report of Okafor *et al.*, (2009) where concentration of NO_2 in Calabar metropolis, Nigeria which was found to be range 0.20 - 0.521ppm. It also agrees with the lower range of report by (Okunola*et al.*, 2012) for Kano metropolis, Nigeria. But relatively lower than the upper limit which range 0.14 - 1.09ppm.

Comparing the results obtained from the research with the National and USEPA standards shows that they are above the permissible limits in the National standard and the USEPA standard (0 – 0.06ppm) showing that the **Air Quality Index (AQI)** is very poor.

The results for CO levels per day as presented in table 4:3.4 (a) ranged from 1.71 – 10.57ppm for Keffi – Abuja road sampling point; 1.21 – 3.09ppm for Airport –City Gate road sampling point; and 1.24 – 3.13ppm for Suleja – Kubwa road sampling point: and 1.00 -1.04ppm for Guzape road which serves as a control point.

Generally, condition of the air during morning, afternoon and evening hours indicate poor air quality. This further indicates that the environment around these sampling points is exposed to CO. And it was mentioned that exposure to CO is associated with potential health risk because it reduces the oxygen carrying capacity of blood, which in turn impairs oxygen release into tissue and adversely affects sensitive organs such as the brain and heart (Bascom *et al.*, 1996)

Comparing the mean values of CO at the three sampling points as shown in table 4.3.4 (a) above with the values contained in the National Standard and that of USEPA (AQI) which for CO is 0 - ≤ 9.0ppm, the highest value is seen along Keffi – Abuja road sampling point due to congestion and traffic intersections where long waiting time for vehicles is observed. In terms of AQI the CO is very poor E, (10.57 ≥ 9.0) while the other sampling points are good B, (1.21 – 3.70ppm) and the control station very good A, (1.0 – 1.04).

4.6 TEST OFHYPOTHESES

4.6.1 Hypothesis Ho 1

Ho 1: there is no significant difference in the air quality within the Federal Capital Territory (FCT) and control station.

Table 4.6.1 ANOVA Test for SO_2 levels across the Sampling Points

Source	Df	Sum of Squares	Mean Squares	P value
Stations	3	0.00685265	0.00228422	< 0.0001
Error	25	0.00007286	0.000002914	
Total	28			

On the ANOVA table 4.6.1 the probability value (p **value**) of SO_2 levels across all sampling points performs at 0.01 and 0.05 confidence level is less than < 0.0001. This result indicated that there is significant difference among the sampling points. Therefore, in order to determine which of the sampling points performs significantly different when compared with the control station, the Duncan Multiple Range Test (DMRT) was performed. And the summarized result was presented on table 4.6.2 below:

Table 4.6.2 DMRT for SO_2 levels across the Sampling Points

Stations	Means
MP'A'	1.420000
MP'B'	1.506667[a]
MP'C'	1.506667[a]
MP'D'	0.926667

The summarized result as presented on table 4.6.2 illustrated that the mean (X) levels of SO_2 in MP'B' and MP'C' sampled points are ranked with the same letter 'a' (1.506667a; and 1.506667a) this means that the SO_2 levels at Airport road and Suleja- Kubwa road are not significantly different. The SO_2 level at MP'A' 1.420000 is not significantly different when compared with MP'B' and MP'C' as well as with the control station 0.926667(Guzape). Therefore, in the case of SO_2 concentrations, there is a significant difference in the air quality within the FCT and the control station. Thus, the null hypothesis (Ho 1) is rejected.

Table 4.6.3 ANOVA Test for NO_2 levels across the Sampling Points

Source	Df	Sum of Squares	Mean Squares	P value
Stations	3	0.00637115	0.002112372	< 0.0001
Error	25	0.000107858	0.000004314	
Total	28			

The ANOVA table 4.6.3 indicated that the p **value** of NO_2 levels across all the sampling point performs at 0.01 and 0.05 confidence level is less than < 0.0001. This result shows that there is a significant difference among the sampling points. Therefore, in order to determine which of the sampling points performs significantly different when compared with the control station, the Duncan Multiple Range Test (DMRT) was performed. And the summarized result was presented on table 4.6.4 below:

Table 4.6.4 DMRT for NO_2 levels across the Sampling Points

Stations	Means
MP'A'	0.106667
MP'B'	0.100000
MP'C'	0.183333
MP'D'	0.046667

The summarized result as presented on table 4.6.4 illustrated that the mean (X) levels of NO_2 in MP'A', MP'B' and MP'C' are ranked 0.106667, 0.100000 and 0.183333 respectively which means that, the NO_2 levels at Keffi – Abuja road, Airport – City Gate road and Suleja –Kubwa road are not significantly different but perform significantly different when compared with the control station MP'D' 0.046667(Guzape). Therefore, in the case of NO_2 levels, there is a significant difference in the air quality within the FCT and control station. Thus, the null hypothesis (Ho1) was rejected.

Table 4.6.5 ANOVA Test for CO levels across the Sampling Points

Source	Df	Sum of Squares	Mean Squares	P value
Stations	3	3409.034	1136.345	< 0.0001
Error	25	7.313572	0.292543	
Total	28			

On the ANOVA table 4.6.5 the probability value (p **value**) of CO levels across all sampling points performs at 0.01 and 0.05 confidence level is less than < 0.0001. This result indicated that there is significant difference among the sampling points. Therefore, in order to determine which of the sampling points performs significantly different when compared with the control station, the Duncan Multiple Range Test (DMRT) was performed. And the summarized result was presented on table 4.6.6 below:

Table 4.6.6 DMRT for CO levels across the Sampling Points

Stations	Means
MP'A'	6.610000
MP'B'	2.060000
MP'C'	2.310000
MP'D'	1.010000

The summarized result as presented on table 4.6.6 illustrated that the mean (X) concentration of CO in MP'A', MP'B' and MP'C' are ranked 6.610000, 2.060000 and 2.310000 respectively, this could be interpreted to mean that, the CO concentrations at Kefi – Abuja road, Airport – City Gate road and Suleja –Kubwa road are not significantly different but perform significantly different when compared with the control station MP'D' 1.010000(Guzape). Therefore, in the case of CO levels, there is a significant difference in the air quality within the FCT and the control station. Thus, the null hypothesis (Ho1) is also rejected.

Therefore, based on the ANOVA and DMRT tests performed, it is evident that the levels of pollutants in the atmosphere within the FCT vary significantly with that of control station. For this proof the null hypothesis (Ho 1) is rejected thus the alternative hypothesis is accepted.

4.7.1 Hypothesis Ho 2

On the null hypothesis (Ho 2) that there is no significant difference in the levels of pollutants in air among the three sampling points, the test results are presented in table 4.7.1

Table 4.7.1: Mean variations in levels of SO_2, NO_2 and CO, for the three sampling point from DMRT ranking.

Stations	SO_2 Means	NO_2 Means	CO Means
MP'A'	1.420000	0.106667	6.610000
MP'B'	1.506667[a]	0.100000	2.060000
MP'C'	1.506667[a]	0.183333	2.310000

KEY: means with the same letter are not significantly different.

Source: Researcher 's Field report, 2018.

The results as shown in table 4.7.1 indicate that the mean levels for SO_2 at MP'B' and MP'C' did not vary hence they are ranked the same with letter 'a' (1.506667**a**; 1.506667**a**) however it varies significantly when compared with MP'A' (1.420000) with the least in SO_2 levels among the three sampling points.

The mean variations in NO_2 levels among MP'A', and MP'B' sampling points are not significantly different since the test result shows close ranking (0.106667; 0.100000) but vary with that of MP'C' (0.183333) when compared.

In terms of CO levels, MP'A' sampling point have a value of (6.610000), and this do perform significantly different when compared with MP'B' and MP'C' sampling points. Therefore, based on this proof the null hypothesis (Ho 2) is rejected since the test performs at least a significant difference in the levels of pollutants among the three sampling points.

4.7.2 Hypothesis Ho 3

Ho 3: there is no significant relationship between traffic volume and air pollutant at the sampling points:

In order to test for Ho 3, the average traffic volume and emission estimates at four sampling locations were conducted and presented on table 4.3.1. Pearson correlation

analysis was also carried out to see if there is relationship between the pollutants levels and the traffic volume. Results show that there is strong correlation between these parameters at 0.01 and 0.05 significant levels as presented in tables 4.7.2 – table 4.7.5

Table 4.7.2 - Correlation Coefficient for relationship between Pollutants (SO_2, NO_2 and CO) at MP'A' (Keffi – Abuja) Road.

Parameters	Traffic	CO	NO_2	SO_2
Traffic	1			
SO_2	0.937	0.815	0.815	1
NO_2	0.966	1.000**	1	
CO	0.966	1		

Correlation is significant at the 0.01 level (2-tailed). **Source: Researcher 'sField report, 2018.

The correlation coefficient between traffic and pollutant concentration at Keffi- Abuja road sampling points as presented on table 4.7.2 was found to be r = 0.937; r = 0.966; and r = 0.966 for SO_2, NO_2 and CO respectively. The result indicated that all variables (SO_2, NO_2 and CO) have a very strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels.

Table 4.7.3 Correlation Coefficient for relationship between Pollutants (SO_2, NO_2 and CO) at MP'B' (Airport – City Gate).

Parameters	Traffic	CO	NO_2	SO_2
Traffic	1			
SO_2	0.991	1.000	0.984	1
NO_2	0.952	0.986	1	
CO	0.990	1		

**correlation is significant at the 0.05 level (2-tailed)

The correlation coefficient between traffic and pollutant concentrations at Airport – City Gate road sample point as presented on table 4.7.3 was found to be r = 0.991; r = 0.952; r = 0.990 for SO_2, NO_2, and CO respectively. The result indicated that all variables (SO_2,

NO_2, and CO) had a strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels.

Table 4.7.4 - Correlation Coefficient for relationship between Pollutants (SO_2, NO_2 and CO) at MP'C' (Suleja – Kubwa).

Parameters	Traffic	CO	NO_2	SO_2
Traffic	1			
SO_2	1.000	0.998	0.762	1
NO_2	0.764	0.803	1	
CO	0.998	1		

*Correlation is significant at the 0.05 level (2-tailed).
Correlation is significant at the 0.01 level (2-tailed). **Source: Researcher 'sField report, 2018.

The correlation coefficient between traffic and pollutant concentrations at MP'C' (Suleja –Kubwa) sample point as presented on table 4.7.4 was found to be r = 1.000; r = 0.764; r 0.998 for SO_2, NO_2, and CO respectively. The result indicated that all variables (SO_2, NO_2, and CO) had a very strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels.

4.7.5 - Correlation Coefficient for relationship between Pollutants (SO_2, NO_2 and CO) at MP'D' (Guzape).

Parameters	Traffic	CO	NO_2	SO_2
Traffic	1			
SO_2	0.999	0.747	0.908	1
NO_2	0.884	0.957	1	
CO	0.711	1		

The correlation coefficient between traffic and pollutant concentrations at Guzape sample point as presented on table 4.7.5 was found to be r = 0.999; r = 0.884; r = 0.711 for SO_2, NO_2, and CO respectively. The result indicated that all variables (SO_2, NO_2, and CO) had a strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels.

traffic volume. This also proved that there is a significant relationship between traffic volume and air pollutant at the sampling points. Therefore, the null hypothesis (Ho 3) is rejected hence the alternative hypothesis is accepted since the traffic volume has a significant effect on pollutants levels at all the four sampling points.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter, summary, conclusion and recommendations are presented with most favorable views that if the recommendations proffered are considered and implemented by both the government and the general public, the menace of motor vehicle emission (pollution) in the Federal Capital Territory and most Urban Cites in Nigeria can be managed in a sustainable manner and transportations will therefore enhance sustainable development without destroying the environment.

5.1 SUMMARY OF MAJOR FINDINGS

i. The mean daily levels of pollutants SO_2, NO_2, CO, measured were found to be ranged between 1.3 - 1.65ppm, 0.12 -0.14ppm and 1.71 - 10.57ppm for Keffi - Abuja road, Suleja-Kubwa road 1.22-1.75ppm, 0.11-0.14ppm, and 1.24-3.13ppm, City Gate-Airport road 1.33-1.73ppm, 0.11-0.13ppm and 1.21-3.09ppm respectively. With the exception of Guzape road (the control station) mean pollutants levels was found to be ranged between 0.67 -0.97ppm, 0.02-0.07ppm, and 1.00- 1.04ppm for SO_2, NO_2, and CO respectively.

ii. The highest level of Carbon Monoxide (CO) pollutant recorded was at Keffi – Abuja road with a value of 10.57ppm, for SO_2 value recorded on this road was 1.66ppm and NO_2 value of 0.14ppm. At Suleja – Kubwa road CO level was 3.13ppm, for SO_2 value recorded was 1.75ppm and NO_2 value of 0.14. Measured value of CO at City Gate – Airport road was 3.09ppm, NO_2 value was 0.13ppm and SO_2 value of 1.73ppm. All the values of CO from Airport road - City Gate, Suleja-Kubwa road are below the National Environmental (Air Quality Control) Regulations, 2014 while Keffi- Abuja road is above the National Standard and

USEPA Air Quality Index values. All the other parameters are above the two (2) standards signifying very poor air quality.

iii. Also the level of pollutants across all the sampling points increases with traffic volume. The study therefore established strong statistical evidence that traffic volume affects the pollutants levels at all sampling points. This implies that motor vehicle emissions in the FCT are not within the safe limits, and that motor traffic-related pollution in the FCT is a potential hazard to the environment and human health.

5.2 CONCLUSION

The overall situation regarding motor vehicle emission in the FCT is very poor with a potential human health effect. The results revealed that motor vehicle emission in the FCT especially the urban core include pollutants like SO_2, NO_2, and CO. The levels of CO from City Gate –Airport road, Suleja-Kubwa road are below the lower limit of the National Environmental (Air Quality Control) Regulations, 2014 except Keffi- Abuja road which is higher than USEPA values. Comparing the whole values with USEPA standards ranges from very good, good and very poor respectively for the routes.

SO_2 valuesmeasured at most of the sampling points were relatively above the National Standards and the USEPA AQI. Therefore, in this aspect air quality is relatively very poor. As for NO_2 it was above the safe limits of the National Standard as well as the USEPA AQI. Therefore, the concentration level of NO_2 at these sampling points are very poor and hazardous for health.

Finally, this project study reveals that gaseous pollutants in the air, such as SO_2, NO_2 and CO directly or indirectly threaten the environment and life of Nationals living in the

FCT and that Vehicular emission and other related activities still remain the primary source of these pollutants.

5.3 RECOMMENDATIONS

Based on the pollution levels and health implications detailed in this study, it is important to initiate a monitoring program and to develop policies to reduce emission and protect health. This can be achieved through improved fuel quality and reduction of Sulphur content in fuel, mandate annual emission testing of vehicles, improve traffic flow and control which requires good city road network, proper implementation and enforcement of the existing legislative framework to regulate and control vehicular emission in Nigeria, programmes to reduce idling period for vehicles in highways and street.

i. Measures recommended for Government to reduce Vehicular emissions in the Country.

(a) **Stringent Emission levels/standards:** The Government of Nigeria has been instrumental in laying down norms to control vehicular emission. Nigerian emission standards for vehicles are given in (appendix A).

(b) **Cleaner Fuel Quality**: To adhere to the stringent emission norms, it is imperative that both fuel specification and engine technologies go hand in hand. Fuel quality specifications have been laid down by the Nigerian Industrial Standards (NIS) for gasoline and diesel for the period 2017-2021 and beyond 2021 for the country.

Given the increased usage of Petrol and diesel in our country, it becomes necessary to reduce its sulphur content, which for petrol is proposed from present 1000ppm –

150ppm, Diesel from 3,000ppm – 50ppm, and Kero

For Petrol, lead has been phased out in the entire country.

(c)Introduction of Alternate Fuel: The use of alternative fuels (such as Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG) should be promoted in Nigeria both for energy security and emission reduction.

(d Inspection and Maintenance (I&M): The first and most important step towards

emission control for the large in-use fleet of vehicles is the formulation of an inspection and maintenance system. It is possible to reduce 30-40% pollution loads generated by vehicles through proper periodical inspections and maintenance of vehicles. I&M measures for in-use vehicles are an essential complement to emission standards for new vehicles. In Nigeria the existing mechanism of I&M is inadequate. Thus, there is a great need to establish effective periodic I&M programmes.

Other Measures recommended:

- Ban on commercial vehicles, which are more than 15 years old.
- Replacement of all pre-1990 autos and taxis with new vehicles, which use clean fuels.
- Annual Vehicle Emission testing as a start for all vehicles should be made mandatory.
- Improve Traffic management/flow of traffic on the roads, reducing emission per vehicle kilometer traveled and enhancing urban mobility.
- Availability of improved and efficient Public/Mass Transit buses and trains.

- Government to introduce incentives to encourage hybrid/electric vehicles (e.g. lower import duties for eco-friendly vehicles) and encourage public participation in building electric recharge stations;
- Plant more trees to serve as carbon sinks.
- Air quality monitoring stations established along major roads and inside the city for realTime data collection; etc.

ii. Citizen Participation to reduce vehicular emission

For making Nigeria a cleaner and healthier environment to live, it is the responsibility of every citizen of the country, irrespective of age or socio economic status, to render their efforts and:

- Adopt and popularize car-pooling.
- Use Public transport where available.
- Maintain your vehicle properly including regular servicing,
- Buy a more energy efficient car, one that produces fewer emission or runs using an alternative fuel,
- Use hybrid vehicles,
- Use bicycle or walk where possible;
- Use 4-stroke engines that are environment friendly than 2-stroke engines;
- Maintain recommended tire pressure.
- Do not idle your car;
- Avoid speed;
- Clean fuel filters, air filters and oil filters regularly.
- Opt for newer car when possible, older used cars release more pollutants into the air;

- Awareness campaigns to help build pub[illegible]

from the school level.

5.4 Limitations of the Study: The study was carried out for the purpose of the dissertation and had the following limitations;

i. The data needed for the analysis were not available in any of the MDAs and was generated by the researcher from field work;

ii. The relevant air quality monitoring equipment are not easy to acquire or obtained as only few Firms are into environmental and air quality monitoring.

iii. The project was carried out during one season of the year i.e. Dry season. There is need to replicate the work during the Rainy season and Harmattan period to cover the three seasons for a balanced judgment.

iv. The study had the challenge of obtaining the accurate numbering of vehicles passing the sampling points from both lanesat the same time.

NATIONAL ENVIRONMENTAL (CONTROL OF VEHICULAR EMISSIONS FROM PETROL AND DIESEL ENGINES) REGULATIONS, S.I. NO. 20 OF 2011.EMISSION STANDARDS FOR CATEGORIES OF VEHICLES.

SCHEDULE I *Regulation* 3, 3(2), 5(1), 8(1)

EMISSION STANDARD OF POLLUTANTS FOR PETROL ENGINE

The emission of the gaseous pollutant of Carbon Monoxide and the combination of Hydrocarbons and Nitrogen Oxides shall not exceed the following standards:

Reference Mass (rm)(kg)	*Mass of CO (g/km)*	*HC (g/km)*	*NOx (g/km)*	*Combined Emission Mass of Hydrocarbons and Nitrogen Oxides(HC + NOx) (g/km)*
(Class I) **rm< 1305kg**	2.2	-	-	0.5
(Class II) **1305 <rm< =1760**	4.0	-	-	0.6
(Class III) **1760<rm**	5.0	-	-	0.7

Source: National Automotive Council (NAC)

SCHEDULE II *Regulation* 3(6)

EMISSION STANDARD OF POLLUTANTS FOR NEW MODELS OF PETROL ENGINES ON OR AFTER 1ST JANUARY, 2015

1. For a petrol engine with a Gross Vehicle Weight (GVW) of more than 2500kg, the exhaust emission of the gaseous pollutant of Carbon Monoxide and the combination of Hydrocarbons and Nitrogen Oxides shall not exceed the following standards:

Reference Mass (rm)(kg)	*Mass of Carbon Monoxide (g/km)*	*HC (g/km)*	*NOx (g/km)*	*Combined Emission Mass of Hydrocarbons and Nitrogen Oxides(g/km)*
(Class I) **rm< 1305kg**	2.3	0.20	0.15	-
(Class II) **1305 <rm<=1760**	4.17	0.25	0.18	-
(Class III) **1760<rm**	5.22	0.29	0.21	-

Source: National Automotive Council (NAC).

SCHEDULE III *Regulation 6(1)*

EMISSION STANDARDS FOR PETROL ENGINE IN USE

	Carbon Monoxide (%)	*Hydrocarbons (parts per million) (ppm)*
Existing model	4.5	800
New model	3.5	600

SCHEDULE VII *Regulations* 17(1) *and* 19(1)

EMISSION STANDARD OF POLLUTANTS FOR DIESEL ENGINE

1. Diesel Sulphur limits and vehicle Emission Standards.

	Heavy Duty			*Light Duty*	
Year	Vehicle	Max. Fuel Sulphur Level (ppm)	Year	Standards	Max. Fuel Sulphur Level (ppm)
2011	rm>1760	1,500	2011	rm<1305	500
2015	rm>1760	500	2015	rm<1305	350

2. In addition to paragraph 1, for a heavy-duty diesel engine for a vehicle with a Gross Vehicle Weight ("GVW") of over 3.5 tonnes, the exhaust emission of the gaseous pollutant of Carbon Monoxide ("CO"), Hydrocarbon ("HC") and Nitrogen Oxides ("NO ") shall not exceed the following standards:

Mass of Carbon Monoxide (CO) Grammes per kWh	*Mass of Hydrocarbons (HC) Grammes per kWh*	*Mass of Nitrogen Oxides Grammes per kWh*	*PM Grammes per kWh*
4.0	1. 1	7.0	0.15

3. For a diesel engine with a Gross Vehicle Weight of not exceeding 3.5 tonnes, in addition to paragraph 1, the emission of the gaseous pollutant of Carbon Monoxide and the combination of Hydrocarbons and Nitrogen Oxides shall not exceed the following standards:

Reference Mass (rm) (kg)	*CO (g/km)*	*PM (g/km)*	*Combined Emission of Hydrocarbons and Nitrogen Oxides (HC + NOX) (g/km)*
(Class I) **< 1305**	1.0	0.08	0.7
(Class II) **1305 <rm<17 60**	1.25	0.12	1.0
(Class III) 1760<rm	1.5	0.17	1.2

4. For a diesel engine with gross vehicle weight of not exceeding 2,500kg, the emission of the gaseous pollutant of Carbon Monoxide, the combination of Hydrocarbons and Nitrogen Oxides and participate matter shall not exceed the following standards :

Mass of Carbon Monoxide (CO) Grammes per kWh	*Mass of Hydrocarbons (HC)Grammes per kWh*	*Mass of Nitrogen Oxides Grammes per kWh*	*PM Grammes per kWh*
1.0	0. 7	-	0.08

Source: National Automotive Council (NAC).

SCHEDULE VIII *Regulation* 17 (2)

EMISSION STANDARD OF POLLUTANTS FOR NEW MODELS OF DIESEL ENGINES ON OR AFTER 1ST JANUARY, 2015

1. For a diesel engine having a total mass exceeding 3.5 tonnes, the emission of gaseous pollutants of Carbon Monoxide, Hydrocarbons, Oxides of Nitrogen and Particulates must not exceed the following standards:

Mass of Carbon Monoxide(CO) Grammes per kWH	*1. Mass of Hydrocarbons(HC) Grammes per kWH*	*Mass of Oxides of Nitrogen(NOx) Grammes per k WH*	*Mass of Particulates(PM) Grammes per kWH*
2.1	0.66		

2. For a diesel engine having a total mass not exceeding 3.5 tonnes, the emission of gaseous pollutants of Carbon Monoxide, the combination of Hydrocarbons and Oxides of Nitrogen and Particulates shall not exceed the following standards:

Reference Mass (rm) (kg)	*CO (g/km)*	*PM (g/km)*	*NOX (g/km)*	*Combined Emission of Hydrocarbons and Nitrogen Oxides (HC + NOX) (g/km)*
(Class I) **< 1305**	0.64	0.05	0.5	0.56
(Class II) **<1305 <rm<=1760**	0.80	0.07	0.65	0.72
(Class III) **1760<rm**	0.95	0.10	0.78	0.86

3. Heavy Duty (HD) Diesel Engines.

	4.0	0.25	7.0 HC = 1.1	-

4. Large Goods Vehicles

	4.0	0.15	1.1 HC = 7.0	-

Source: National Automotive Council (NAC).

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