CONTRIBUTION OF MOTOR VEHICLE EMISSIONS TO AIR POLLUTION IN KADUNA METROPOLIS, NIGERIA

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ZARIA

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA IN PATIAL FULFILMENT FOR THE AWARD OF MASTER OF SCIENCE IN ENVIRONMENTAL MANAGEMENT

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JULY, 2014

DECLARATION

I solemnly declare that this thesis titled "Contribution of Motor Vehicle Emissions to Air Pollution in Kaduna Metropolis, Nigeria" is a record of my own research work under the supervision of Dr. I. A. Abdulhamed and Dr. I. J. Musa. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this research work has been submitted for the award of degree in any other university.

HENA, Musa Kulausa **Date**

CERTIFICATION

This thesis titled "Contribution of Motor Vehicle Emissions to Air Pollution in Kaduna Metropolis, Nigeria" meets the regulations governing the award of the degree of Master of Science "M.Sc. Environmental Management" of Ahmadu Bello University Zaria, and is approved for its contribution to knowledge and literary presentation.

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Dean, School of Postgraduate Studies

DEDICATION

This research work is dedicated to my beloved mother Mrs. Nancy K. Bukar ‘the best mother a child will always want’ and my dear wife Mrs. Murna M.K.H ‘the best woman a man will always love’ and those striving to restore balance between people and nature in the broad spectrum of human activities in relation to the environment wherever they are.

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ABSTRACT

This study was aimed at determine the contribution of motor vehicle emissions along some busy roads in Kaduna metropolis. The Crowcon Tetra III was used to measure the concentrations of air pollutants such as CO, NO_2, and SO_2. Also Vehicle count was conducted manually to determine the vehicle volumes at the sampling points. The results indicated that the concentrations of CO, NO_2, and SO_2.measured were ranged 29.1-37.0ppm, 0.03-0.05 and 0.0037-0.051 respectively. With few exceptions, at some sampling points were all above the National Environmental Standards and Regulatory Enforcement Agency (NESREA) recommended safe limits especially during the afternoon-evening periods. 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 concentrations at all sampling points. This implies that motor vehicle emissions in Kaduna metropolis is not within the safe limits, and that motor traffic-related pollution in Kaduna metropolis is a potential hazard to the environment and human health. It was recommended that, for the benefit of public health and sustainability of the natural functioning of ecosystems motorization growth should be largely checked by environmental regulations. Also construction of inner roads and bridges that would link Kaduna North and South can be valuable to reduce the number of vehicles on major roads, which in turn will help reduce the concentration of pollutants if there are no serious traffic holdups in a particular area at every point in time.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The term pollution refers to any change in the physical, chemical, or biological characteristics of the air, water, or soil that can affect the health, survival or activities of humans or other forms of life in an undesirable way (United State Environmental Protection Agency USEPA, 2001). 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). 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 involved 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 other living organisms such as food crops, or damage 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 (NO_x), carbon oxides (CO_x), sulphur oxide (SO_x), 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: These include volcanic eruption 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 (SO2), Nitrogen Dioxide (NO2) suspended particulate matter, Carbon Monoxide (CO), photochemical oxidants (OX), Non-Methane Hydrocarbon Species (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 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. 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 identified as one of the 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 emissions, but the two sources of air pollutants ubiquitous in most urban areas are transportation and fuel combustion by stationary sources, including industrial heating (WHO, 2000). However, motor vehicle emissions, seems to be the 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 NO_x, 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 produce more air pollution than any other single human activities.

This situation is therefore pathetic especially in developing countries 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). So also in this study area (Kaduna metropolis), some studies have revealed that air quality is been threatened due to emissions. And attempt has been made to measure some of the air pollutants (CO, SO_2, NO_2 and CO_2). Examples of these studies are: Abdulkareem and Kovo (2006), in their study carried out in Kaduna metropolis have attempted to measure the levels of CO, SO_2 and NO_2 in the air. Though their study is centered on emissions, but arising from process engineering and restricted to only Kaduna Refinery and Petrochemical Company (KRPC). Another study by Stanley, Mbamali and Dania (2011), have also attempted to measure same air pollutants (CO, SO_2 and NO_2) in Kaduna metropolis. However, their study focuses on those emissions arising from electric power generators which affect only indoor air quality. Also another study was conducted by Ndoke, Akpan and Kato (2006) in Abuja and Kaduna metropolis even though their study was on road traffic emissions but only one parameter carbon dioxide (CO_2) was measured. These provide a gap for structured study of this kind.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Air quality monitoring in most developing countries including Nigeria is not routinely conducted, and in some urban areas like Kaduna Metropolis 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 (Pope III, 2004).

Several 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 Yussuf, 2008). All these 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 are usually performed in urban areas, where automotive vehicles are the main source of air pollution. According to Oguntake, *et al,* (2008), the Human health problems due to air pollution arising from vehicular emissions in Abeokuta city, was approximately 56.4% of the total number of the sample suffered cough and breathing impairments (23.6%) among others.

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 city. The study suggested that the city is under threat of traffic related pollution and is possibly more susceptible given 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 reveal that with few exceptions at some sites emissions values of gases measured were above Air Quality Index recommended by USEPA (2001). It was concluded that air quality within Kano metropolis is potentially harmful to human health. Although, it is evident that several efforts have been made to measure emissions from vehicular traffic in some cities in Nigeria but after performing a literature search with keywords related to air pollution and vehicle traffic emissions in Kaduna Metropolis, and selected articles published between the years 2000 to 2013. It was noted that only few studies have attempted to measure vehicle traffic emissions in the metropolis. Some of these studies are (Ndoke, Akpan and Kato 2006), and (Vivan Dyaji, and Nwokedirioha 2013).

Therefore the dearth of information on these air quality parameters is a fundamental issue in Kaduna Metropolis. Alongside with high per capita ownership of 'tokunbo' vehicles, old dilapidated vehicles, high number of motor cycles in urban towns and state capital. Also high number of security check spots 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 this is another serious dimension of the problem.

Consequently, in order to achieve environmental sustainability with regards to the atmosphere, air quality monitoring should be a routine exercise.

1.3 RESEARCH QUESTIONS

i. What are the concentration levels of CO, NO_2 and SO_2, pollutants at the sampling points?

ii. How do they compare to the National Environmental Standards and Regulations Enforcement Agency (NESREA) and the World Health Organization (WHO) limits?

iii. What is the volume of vehicular movement along the sampling points in Kaduna metropolis?

1.4 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to determine the contribution of motor vehicle emissions to air pollution in Kaduna metropolis. The specific objectives are to:

i. measure and compare with NESREA standards the concentration levels of Carbon monoxide (CO), Nitrogen dioxides (NO_2) and Sulphur dioxides (SO_2), in the ambient air at five sampling points within Kaduna metropolis.

ii. measure and compare the concentration of the pollutants from each sampling points with the control station for any variable difference.

iii. compare the concentration of pollutants among the four sampling points for any variable difference.

iv. determine the relationship between traffic volume and concentration levels of CO, NO_2 and SO_2, at the sampling point.

1.5 RESEARCH HYPOTHESIS

H_o 1: there is no significant difference in the air quality within the city center and the control station.

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

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

1.6 RESEARCH JUSTIFICATION

Kaduna Metropolis in particular is experiencing an increase in per capita vehicle ownership (State Licensing Office, 2012), coupled with an increase in security check spots. 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 air.

The resultant effects of motor vehicle emissions 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 is a major culprit attributed to a global warming.

Therefore, for the benefit of public health and sustainability of the natural functioning of ecosystems it is necessary to carry out a study like this which aims to determine the contribution of motor vehicles emissions to air pollution particularly in the study area (Kaduna metropolis) where only few studies on air quality deterioration induced by motor vehicles are undertaken. Moreover air quality monitoring should be a routine activity.

1.7 SCOPE OF THE STUDY

The scope of this research is limited to some selected major motorways within Kaduna Metropolis which are Kawo, Central market, Stadium roundabout, and Sabo. These are roads purposively selected and with high concentration of motor vehicles, business/commuters and most vehicles engines are still running. And only CO, NO_2 and SO_2 pollutants was measured. Also at these points no meteorological parameters was given detailed consideration as the study entails direct measurement of pollutants within the ambient air along the selected motorways. However during data collections the wind flow is nearly static. Also traffic counts were carried out manually.

CHAPTER TWO

CONCEPTUAL AND THEORITICAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

This section deals with the various concepts and theoretical frameworks which were used to form based for this research work. Also relevant literatures were review which provides suitable information for this study.

2.2 CONCEPTUAL FRAMEWORK

2.2.1 Air Pollution

Air pollution is defined as the 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 other living organisms such as food crops, or damage the natural environment or built environment (Millicent, 2009). 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, the explosion of the human population and the introduction and use of vehicles, have caused an exponential growth in goods, services and unfortunately environmental pollution particularly, air pollution (USEPA, 1998).

Also according to the United States Environmental Protection Agency (EPA 2006), motor vehicles account for 51 percent of carbon monoxide (CO), 34 percent of nitrogen oxides (NO_2) and 10 percent of particulate matter (PM) released each year in the US. 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 emissions, 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.

2.2.2 Pollution and the Environment

Pollution can take any form; it depends on which area of the environment that has been polluted that will culminate into the type of pollution that it will be attributed to. Basically there are two major forms of pollution: local and global pollution (Obeka 2009). Local pollution has to do with the situation in the immediate environment, such as indiscriminate dumping and burning of refuse in and around homes and cities: clogging of drains and gutters all these can cause health hazard such as flooding, malaria, cholera, etc.

On the global level, discharging nutrients from industries, agriculture, residential runoff into lakes and costal oceans: nuclear testing and wars which produce excess radiation, excess emission of carbon dioxide and carbon monoxide fumes from industrial plants, motor vehicle, gas flaring, etc., has led to human health problems and harmful changes in the earth's climate such as global warming.

The concern about environmental pollution is growing worldwide especially in connection with the problems associated with it. It is well known that environmental problems are complex and difficult to understand. They are often hard to solve. The technical, social economic and political factors involving different interest groups all contribute to environmental problems.

2.2.3 Ways of Environmental Pollution

Obeka (2009) have identified some ways of environmental pollution as follows:

i. Rapid population growth i.e in 1950's the entire world population was about 2-5 billion by 2001 it became 6.5 billion, is expected by 2015 to be 15 billion, unless there is a high death rate. (Obeka 2009).
ii. Simplification and degradation of some part of planet earth.
iii. Poverty: which makes people to use non renewable resources and non sustainable for short term benefit and exposes the same people to higher environmental and health risk.

iv. Extensive use of relatively cheap and environmental damages i.e. fossil like fuel and coal.
v. Rapid and wasteful use of resources with little emphasis on pollution and waste management.
vi. Over exploitation and degradation of global common properties resources which are owned by none but available to everybody.
vii. Failure to encourage environmentally sustainable forms of economic activities and discourage environmental degradation.
viii. Urge to exploit nature for selfishness.

2.2.4 Pollution of the Atmosphere by Gases and Solid Substances

This is the most serious consequence to man and the ecosystem. The atmosphere is made dirty with poisonous substances which include: sulphur compounds as sulphur oxides, hydrogen sulphide tar, nitrogen compounds, ammonia, nitrogen dioxide, ozone carbon dioxide, hydrogen fluoride and chloride, aerosol, and radioactive gases. Some of these gases and particulates are naturally in the atmosphere at a varying quantity, (Osaga, 2001).

2.2.5 Vehicular Emissions and Air Quality

Air pollution due to vehicular emission remains a threat to the environment and health related problems which are expected to increase rapidly as per capita vehicle ownership increase around the world (WHO, 2000; Abam and Unachukwu, 2009). The most common types of vehicular fuels are the fossil fuel commonly known as petroleum and gasoline. Petroleum is commonly used in light duty vehicles while gasoline or diesel is commonly used in heavy duty vehicles. Both petroleum and diesel can be in leaded or unleaded form.

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, HC_s, NO_2, and lead (Pb) (only for leaded gasoline fuel), whereas the presence of sculpture compounds in diesel fuel results in sulphur dioxide (SO_2) and PM emissions from the exhaust diesel-fueled vehicles. Metal sulphates and sulphuric acid in the form of PM constitute 1 to 3 percent sulphur emissions from heavy-duty diesel-fueled vehicles and 3 to 5 percent of sulphur emissions from light-duty diesel fueled vehicles, they also account for about 10 percent of particular matter (PM) emissions from these vehicles (Faiz, *et al.* 1996). In addition, SO_2 may also be present in exhaust gases. The air conditioning system, tires, brakes, and other vehicle components also produce emissions.

Many studies such as (Oguntake *et al.*, 1998*;* Oguntoke and Yussuf, 2008; Erica, 2010; and Vivan, *et al.*, 2013), conducted in Abeoukuta, 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; Wargo *et 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; Wago *et al.,* 2006). Lead is similarly dangerous as poisoning causes irreversible neurobehavioural 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 emissions 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.

2.2.6 Air Quality and Other Related Air Pollutants

The present-day atmosphere is quite different from the natural atmosphere that existed before the Industrial Revolution in terms of chemical composition and if the natural atmosphere is considered to be "clean", then this means that clean air cannot be found anywhere in today's atmosphere (Ashton, 1948). Defining "air pollution" is not simple. One could claim that air pollution started when humans began burning fuels. In other words, all man-made (anthropogenic) emissions into the air can be called air pollution, because they alter the chemical composition of the natural atmosphere. So taking all of the above into account, we can define an "air pollutant" as any substance emitted into the air from an anthropogenic, biogenic, or geogenic source, that is either not part of the natural atmosphere or is present in higher concentrations than the natural atmosphere and may cause a short-term or long-term adverse effect (Delay and Zanetti, 2007).

2.2.7 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 high enough concentrations are the following:

1. Carbon compounds, such as CO, $CO_{2,}$ CH_4 and VOC_s
2. Nitrogen compounds, such as NO, N_2O, and NH_3
3. Sulphur compounds, such as H_2S and SO_2
4. Halogen compounds, such as chlorides and bromides
5. 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 high enough 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 VOC_s 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, sulphur dioxide, PM, carbon monoxide (CO), and lead (Pb). Four of these pollutants (CO, Pb, NO, and SO_2) are emitted directly from a variety of sources. Ozone is not directly emitted, but is formed when nitrogen oxides (NO_x) and VOC_s react in the presence of sunlight. PM is mostly directly emitted, but $PM_{2.5}$ particles can also be added as secondary pollutants (sulphates, nitrates, and organic particles) (USEPA, 2003; Delay and Zanetti, 2007). As listed above, there are 6 principal, 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 high concentrations 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 No_x and VOC_s. Automobiles are the largest source of VOC_s necessary for these reactions. Ozone concentrations tend to peak in the afternoon and can cause eye irritation, aggravation of respiratory diseases and damage to plants and animals.

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).

2.3 LITERATURE REVIEW

2.3.1 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; Bilkis *et 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. Also Finding 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 (Delfino *et al., 1998;* Yu *et al.,* 1990; Nordenhall *et 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.

2.3.2 Vehicular Emission in Developing Countries

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

In developed countries, these super emitters represent 10 percent of the vehicles on the road, yet generate 50 percent of emissions (Brunekreef, 2005). It is further compounded by the rapid urbanization of many developing countries because according to (UNFPA, 2007) the next few decades will see an unprecedented scale 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 Bankok, 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 Bankok area.

Khaled-Ahmad (2012) also conducted a statistical analysis of air pollution study in Brishbane, Australia; he concluded that the overall vehicular transportation pollution situation in his study is poor. His findings show and indicate 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 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.

2.3.3 Vehicle Emissions in Sub-Saharan Africa

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

Since SSA is in the early phases of economic development, air pollution is given low priority and there is little investment in understanding the scale of the problem or its control. Yet, that does not mean that air pollution is not a problem. In fact, there is reason to believe that exposure to transport-related pollutants in SSA cities may be considerably higher than in other parts of the world and, because of malnutrition and high prevalence of disease the populations may be more vulnerable. In Benin, there is data that exposure to traffic pollutants, specifically polycyclic aromatic hydrocarbons, has led to comparatively higher levels of DNA damage in urban residents (Autrup, 2006).

2.3.4 Vehicular Emission in Some Major Nigeria Cities

Several studies have been carried out by some scholars to measure the extent of vehicular emissions in some cities in Nigeria. For example, Ndoke *et al.* (2006) carried out a study to examine the quantity of carbon dioxide (CO_2) contributed by automobile emissions 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.

A similar study was conducted by Jerome (2000), on the impacts of urban road transportation on air pollution in two major cities of the Niger Delta namely, Port Harcourt and Warri the results of the findings indicated that the concentrations of TSP (Total Suspended Particulates), NO_x, SO2, and CO in the Niger Delta were above FEPA recommended limit.

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 FEPA limits. Conclusions of this investigation show a growing risk of traffic-related problems in these Nigerian cities and therefore recommended for serious air quality measures.

Moen (2008) carried out a study in which ambient hourly concentrations for CO, NO_2, and SO_2 at six major intersections in Abuja were monitored during morning, low-traffic hours and during afternoon, high-traffic hours. These concentrations served as a model of exposure for traffic wardens, a high exposure group. The result showed that vehicle emissions are having a negative impact on air quality, and that traffic wardens have a high prevalence of symptoms that are possibly related to and are exacerbated by exposure to vehicle emission. Clearly, air quality management should be a greater priority in Abuja and the effect of vehicle emissions on air quality and health should be studied further if public health is to be protected.

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

Okunola *et al.,* (2012) 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.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This section deals with the background of the study area and methodology. The study area is Kaduna Metropolis, Nigeria. Also highlighted 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

3.2 THE STUDY AREA

3.2.1 Location

Kaduna metropolis is located between latitudes $10^{o}26^{1}$ N and $10^{o}37^{1}$N and longitudes $7^{o}22^{1}$ E and $7^{o}31^{1}$E of the Greenwich meridian on the high plains of the north central highlands of Nigeria (Udo 1970). It covers more than 35 square kilometers, Kaduna metropolis is about 912 Km north of the Gulf of Guinea (Atlantic Ocean), about 930 Km from the Nigeria's northern border and 180 Km from the nation's capital city, Abuja. The River Kaduna from which the town derived its name tends to divide the town into two unequal parts. Kaduna metropolis cuts four local governments areas in the state thus: Kaduna North, Kaduna South as well as parts of Igabi and Chikun local government areas. (Akpu, 2012). The metropolis is indicated in figure 3.1.

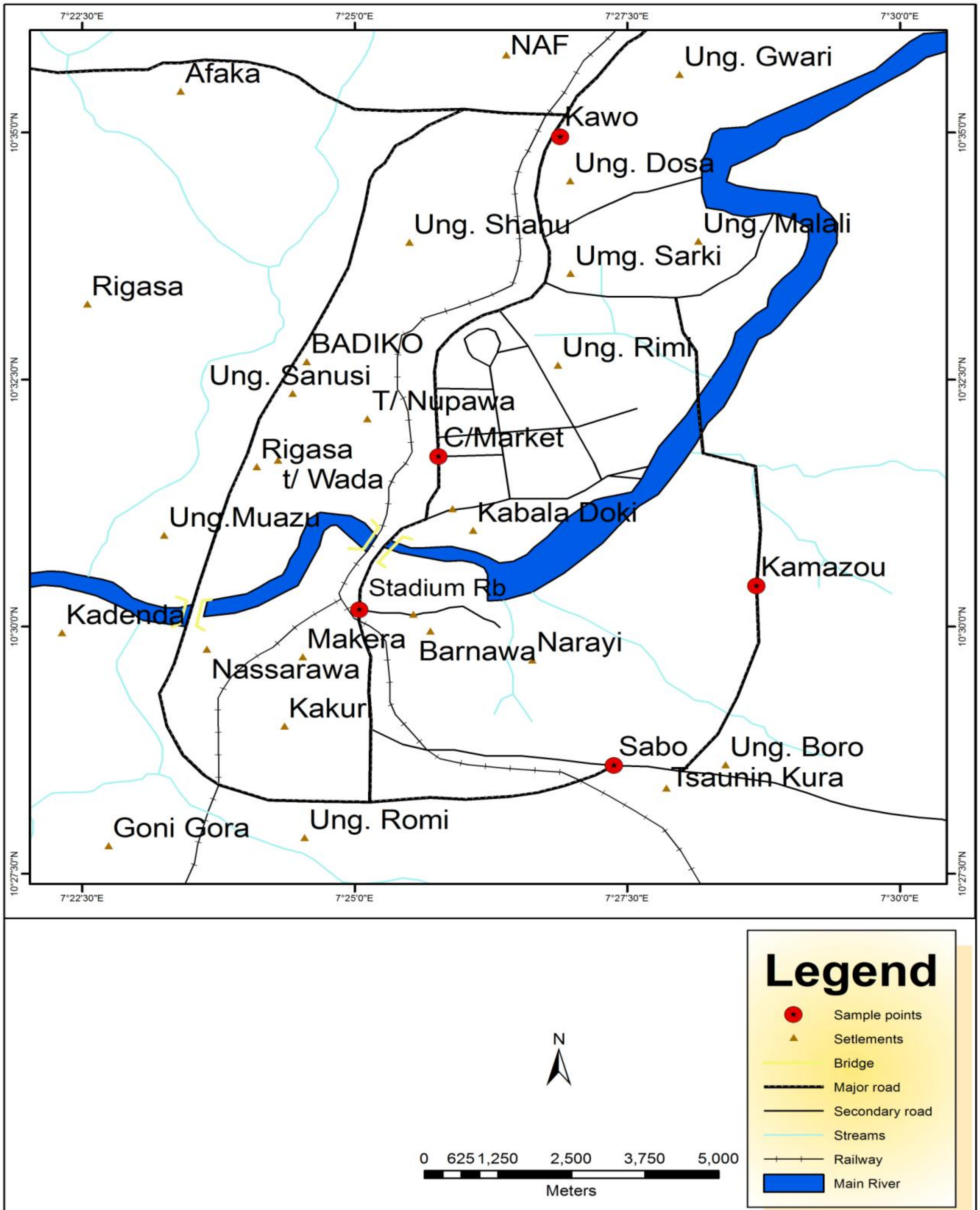


Figure 3.1 Map of Kaduna State showing Sample points
Source: Adopted and Modified from Administrative map of Kaduna State (2013)

3.2.2 Climate

The study area has a tropical continental climate (Aw) with distinct wet and dry seasons, reflecting the influences of tropical maritime air mass (mT) and tropical continental air mass (cT) which alternate over the country. When mT which originates over the Atlantic Ocean, prevails over the area, it brings in the rainy seasons. While cT originates from the Sahara Desert and it brings in the dry season with cold and dusty air that occasionally limits visibility and reduces solar radiation bringing in harmattan conditions in the areas (Iguisi, 1996). Kaduna metropolis experiences four distinct seasons:

a. Dry and cold season- from end of November to February
b. Dry and hot season- from March to beginning of May
c. Wet and warm season- from mid May to beginning of October
d. Dry and warm season- from mid October to mid-November

The city has mean monthly minimum and maximum temperatures of 15.9^{o}C and 35.35^{o}C respectively, with a range of about 19.45^o. The highest temperatures are recorded in March and April, and the lowest occurred in December and January. Average annual rainfall in the city is about 1530mm; it ranges from 0.00mm November and 825.0mm in August, which is the wettest month (Iguisi 1996).

3.2.3 Soils and Vegetation

The soils are typically red-brown to red-yellow tropical ferruginous soils derived from the regolith of the Basement complex. In some places these soils are covered by a layer of Aeolian drift materials. Soils in the upland are rich in red clay and sand but poor in organic matter. While soils within the flood plains are rich in kaolinitic clay and organic matter and are referred to as Fadama soils (Iguisi, 1996).

Kaduna metropolis is located within the Guinea savanna vegetation zone of Nigeria; therefore it has a savannah grassland type of vegetation. The natural vegetation of this zone consists of scattered trees interspersed with tall grasses. However human activities associated with urbanization have seriously modified to the extent that now, trees are most often found only as ornamental ones, comprising mostly of exotic species. Such as Eucalyptus and economic trees such guava, mango, sheer butter trees *(Viteletriaparadoxa), isoberliniadoka, Parkiabiglobosa, silk cotton tree (ceibapentadra)* and a variety of flowers with an average height of about 6m-10m. other less frequent shrub species are are *Dachrostachys specie, Termalina specie, Vitexpiliostima* etc. the area consists of vegetal cover made up of scattered trees predominantly grasses (Folorunsho, 2004; Usman, 2012).

3.2.4 Drainage, Relief and Geology

Kaduna metropolis is drained by Kaduna River which has its source from the Jos Plateau in Ganawuri hills, which is about 9000m above sea level. The river flows North West towards Kaduna metropolis, hence takes a south west direction and Mureji. The major tributaries of the river Kaduna are river Galma, Tubo Karamin-kogi. River Kaduna flows through various geological formations such as the younger granite on the Jos plateau and the basement complex underlying the Hausa plains of the northern Nigeria. (Folorunsho, 2004).

The general relief of the study area is undulating plains, with areas along the flood plains of the river being lower than those on the upland sections and occasional rock outcrops in some part of the city. Eastern part of the city which is mostly bounded by the River Kaduna has a mean elevation of about 550 m above mean sea level. The north-western part of the city is comparatively higher with a mean elevation of about 620 m amsl. The relief is to the largest extent controlled by the geology, that is, areas more resistant to denudation are higher than those that are susceptible, (Iguisi 1996). It is note-worthy that in parts of the city; there are outcrops of hard resistant of granitic rocks. This is as a result of weathering through the age of previously existing Pre-Cambrian rocks. These rocks have been exposed to agents of erosion through these ages and the erosive activities bring out crops of rocks forming inselbergs and some huge rocky land as that of Tudun Wada and Malali. (Lauretta, 2009).

The area is underlain by rock of basement complex consisting of biotite gneiss and older granites. These rocks have been subjected to weathering to produce fairy deep regolith which has been subjected to lateralization. There is also the occurrence of hardened literate and rocks of the basement complex of different locations within the metropolis and at the different section of the Kaduna River (Iguisi, 1996).

3.2.5 Population

The population of Kaduna has grown rapidly from 40,000 in 1952 to 149,000 in 1963 to an estimated 150,000 in 1965 and 500,000 in 1984 (DFD final research report, 2003). The 1991 census put the human population of Kaduna metropolis at 971,070 (NPC, 1991). Based on 2.7% growth rate, the population was estimated to have reach 1,448,129 in 2006. By 2009, at 3.0% growth rate, the population was estimated to have hit 1,582,409. The population was projected to reach 1,729,142 by 2012. This high growth rate can be attributed to natural increase and high rate of immigration (Akpu, 2012).

3.2.6 Settlement Pattern

Kaduna Metropolis is divided into two by river Kaduna. The northern part is made up of residential quarters mentioned here in decreasing order of population density; Hayin Banki, Badarawa, Malali, Unguwan Dosa, Unguwan Sarkin Musulmi, Unguwan Kanawa, Unguwan Shanu and Kurmin Mashi. These areas serve mixed residential and commercial purposes and are interspersed with Government Institutions and military establishments such as schools, hospitals, Nigerian Defense Academy and military Barracks. The central part of Kaduna metropolis is made up of Government Residential Area, polo grounds, race course, and the state house of assembly building (Lugard hall). The area has been designed with broad tree-lined avenues. The main axis avenue is known as Independence Way led south through an open area consisting of military parade grounds, golf course and other government establishments. (Usman, 2012).

The low density core is flanked to the west by high density commercial and residential areas along Ahmadu Bello Way, which is the principal commercial artery of

Kaduna Metropolis. This is where a regional and the largest market in the city, Abubakar Gumi Market is located. To the west of the Ahmadu Bello Way lies high density residential quarters such as Sabon Gari, Tudun Nupawa, Tudun Wada, Unguwan Sanusi and Badikko. The central part of Kaduna South constitutes the largest industrial area of the city known as Kakuri Industrial area or Kaduna South Industrial Area. This area is flanked to the west by medium density residential quarters such as Nasarawa and Tirkania. To the east is flanked by high density residential areas like Barnawa, Narayi, Unguwan Television, Sabon Yelwa, Unguwan Sunday/Ungwan Bako and Sabon Tasha. (Usman, 2012).

Military establishments are scattered all over the city. Right from the Lugard's plan of 1917 up to the late 1960s, they were the largest occupiers of land in Kaduna Metropolis (28.8%), followed by Low Density Housing (20.7%) (Maxlock and Partners 1967). Due to influx of people into the city coupled with rapid population increase characteristics of cities in developing countries, residential quarters (especially high density housing) have recently taken the lead,

3.2.7 Socio-Economic Activities

In terms of economic activities in northern Nigeria Kaduna is second only to Kano. It has many industrial manufacturing plants mostly located within the largest industrial area at Kakuri. Other small industrial areas include Unguwan Mu'azu industrial layout and Kawo Light Industrial Area. There is also the international trade fair center, where the Kaduna international trade fair takes place annually. Some of the industrial manufacturing plants found within Kaduna metropolis (especially in Kakuri area) include:

i. Federal Super Phosphate Fertilizer Company Limited
ii. Peugeot Automobile (Nigeria) Limited
iii. Arewa Textile Limited
iv. First Aluminum (Nigeria) Limited
v. Arewa Bottles
vi. Ballapur Glass Nigeria Limited
vii. NOCACO Limited
viii. Kaduna Textiles
ix. National Oil and Chemical Company Limited
x. Nigerian Breweries Limited
xi. Defense Industrial Company of Nigeria
xii. Kaduna Refinery and Petro-chemical Company Limited etc

The city is also a railway and road network hub connecting north and south of the country in addition to housing an international airport and important educational institutions such as the Kaduna Polytechnic, Kaduna State University and the Nigerian Defense Academy (The only military university in West Africa). Kaduna still plays an important role in the politics of northern Nigeria. Each of their northern states maintain a liaison office in Kaduna and governors of northern states holds there quarterly meetings in Kaduna to discuss matters of common interest affecting the north (Usman 2012).

3.3 METHODOLOGY

The materials and methods that were used for the purpose of this research are clearly explained in this section.

3.3.1 Types of Data

3.3.1.1 Primary Data

i. The concentration levels of some selected gaseous pollutants (CO, NO_2 and SO_2) emissions from motor vehicles movement at sampling points.

ii. Statistics of the motor vehicles movement at each sampling points.

iii. The photographs of motor vehicles movement at sampling points were taken so as to give a visual impression and understanding of the differences between the volume of traffic at sampling points within the city and control the station for visual understanding of the circumstances found on ground during the field survey.

3.3.1.2 Secondary Data

i. Literatures: was reviewed 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.

3.3.2 Sources of Data

i. Gaseous Pollutants and Emissions Levels; Levels of the selected gaseous pollutants CO, NO_2 and SO_2 were obtained from field recordings by the use of Crowcon (Tetra 3) with a model number IECEx BAS 05.0059.

ii. Motor Vehicle Count; Statistics of the motor vehicles movement at each sampling points was obtained from field using manual counting and recordings.

iii. Photographs; The photographs of motor vehicles movement at sampling points were obtained from field survey by the use of digital still camera Sony lens Cyber-Shot 12.1 Mega Pixels.

3.3.3 Equipment Used for the Study

3.3.3.1 Hardware

i. Computer Laptop (HP DV 6) for processing of acquired data.
ii. Crowcon (Tetra 3) a portable multi-gas monitor for field detection and recordings of concentration levels of emitted gases (pollutants) CO, NO_2, and SO_2.
iii. Digital still camera Sony lens Cyber-Shot for taken the photographs of traffic congestion and volume.
iv. Motor cycle for easy maneuver through traffic congestion.

3.3.3.2 Software

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

3.3.4 Methods of Data Collection

3.3.4.1 Sampling Procedure

i. Based on this research two sampling stations was mapped out namely station A and B. The station A represented motorways within the city center (urban core), with high traffic volume. While station B represented motorways at out sketch of the city which has very less traffic volume this also served as control point/station. At station ‘A’ air samples were measured at four (4) selected motorways around: Kawo area, Central market (Kasuwa), Sabo and Stadium roundabout. These motorways were selected based on their potential high traffic and urban Land Use Classification, where Kawo and Sabo falls within Local Climatic Zone (LCZ) class 4, Central market area and stadium roundabout are within LCZ class 2 (Oke and Stewart 2009).

ii. The air pollutants were measured by Crowcon (Tetra 3) with a model number IECEx BAS 05.0059, a unique and portable multi-gas monitor for detection of Carbon monoxide (CO), Nitrogen dioxides (NO_2), and Sulphur dioxides (SO_2), and flammable gases. It offers flexibility, assurance, and robustness. Intrinsically safe, it is a portable gas detector with embedded software designed that met the requirements of International Electrotechnical 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. This unique instrument was rented from the Kaduna Environmental Protection Authority (KEPA).

iii. 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 45 minutes so as to avoid repetition (Jaro, 2010).

iv. The time frame for data collection from the five (5) sampling points including the control station was carried out concurrently in one month, one week per each sampling point, and three (3) time periods for duration of seven (7) days of a week that is from Monday to Sunday which covered complete vehicles movement within the week at the sampling points. These times are categorized as follows:

- 7.30 am – 9.30 am morning peak hours
- 12.30 pm – 2.30pm off-peak hours
- 4.30 pm – 6.30 pm evening peak hours

3.3.5 Instrument Calibration Methods

3.3.5.1 Gas Test

Tetra 3 unit was switched on and was allowed time to boot. It takes about ten (10) minutes to complete the booting this was done to ensure normal operation. The flow plate was then clipped unto the front of the unit and the hose was attached from the trigger regulator. The outlet hose was then attached to the ‘vent gas away’ and the magnet was swipe over the bubble label on the front of the unit, near the main button. Then Tetra 3 begins the Gas Test and show 'GAS TEST' on the display. A countdown progress bar also appears at the bottom of the display. The Trigger regulator was then used to apply gas to the Tetra 3 whilst the progress bar is still counting down. It takes about thirty to forty-five (30-45) seconds to complete the progress bar. The instrument was then disconnected from the test gas and the unit returns to its normal mode. The unit compares what it measures from the bottle with the standard gas values it knows should be in the bottle.

3.3.5.2 Laboratory Calibration Test

Tetra 3 calibration was performed at the Kaduna Environmental Protection Authority (KEPA) laboratory, using the Portables PC software which was supplied with an auto zero function on start-up. This function was configured to operate automatic, on user confirmation. Then a test gas of known composition was applied, to verify sensors response and alarm function, this process was repeated three consecutive times to ensure accuracy and eliminate errors before the instrument was taken to the field for field calibration test as required before data collection.

3.3.5.3 Field Calibration Test

On arrival to the field the Tetra 3 unit was first of all set at Zero for 15 minutes before commencing the gas test, for this was the recommended time set by the manufacturer's instructions. Tetra 3 unit was then switched on to ensure normal operation. Then **t**he flow plate was clip unto the front of the unit and the hose was attached from the trigger regulator. The outlet hose was then attached to the 'vent gas away' and the magnet was swipe over the bubble label on the front of the unit, near the main button. Then Tetra 3 begins the Gas Test and show 'GAS TEST' on the display. A countdown progress bar also appears at the bottom of the display. An alternate screen massage also beeps up from the display and button was pressed within 10 seconds to confirm Calibration. Automatic, Tetra 3 begin to display a progress bar at the bottom of the screen, the names of the gas sensors fitted appear in reverse image with a cross beside each. The Trigger regulator was then used to apply gas to the Tetra 3 whilst the progress bar is still counting down. As gas flows Tetra 3 allows the sensors to respond and then adjust the value for each gas channel to match the stored calibration gas value within each sensor i-module. Confirmation massage beeps up on the display reading 'calibration successful' which means that all channels calibrate successfully within the allowed time.

3.3.6 Method of Data Analysis

i. The concentration levels of the gaseous emissions (CO, NO_2, and SO_2) were measured with Crowcon (Tetra 3) digital multi-gas remote monitor and were compared with the safe limits set by NESREA 2009 standards, which are: CO (10-20 ppm), NO_2 (0.04-0.06 ppm), and SO_2 (0.01-0.1 ppm).

ii. Bar charts were designed to show the variation between the recorded emission levels and the NESREA 2009 safe limits.

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:

$$TE_L = EL_S\,(M+N+E)$$

$$ME_L = \frac{EL_S\,(M+N+E)}{3}$$

Where; TE_L = Total Emission Level

EL_S = Emission Levels

ME_L = Mean Emission Level

M = Morning

N = Noon

E = Evening

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

v. Analysis of variance (ANOVA) and DMRT (Duncan Multiple Range Test) was used to test for variation in the concentration of pollutants among the four sampling points also to test for hypothesis H_o: 2, that were predicated based on the assumption that "there is no significant difference in the concentrations of pollutants among the four sampling points". This test was done at 0.05 level of significance. This also helps to confirm if there is any variation among the four sampling points with respect to their pollutants concentration.

vi. Linear Correlation 'r' was used to test the third null hypothesis H_o: 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 help to confirm if there is any relationship between traffic volume and concentration levels of detected gaseous emissions (CO_2, NO_2 and SO_2) at the sampling points.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results which were discussed sequentially. First, concentration and variation of pollutants (CO, NO_2 and SO_2), measured across sampling points, and then followed by correlations among pollutants concentrations and traffic volume across sampling points. The results were also discussed and for statistical method, comprehensive statistical software (SPSS Version 20) and Microsoft Excel 2007 were used. The entire three hypotheses were also analyzed and tested using Statistical Analysis Software (SAS Version 9), in particular ANOVA and Duncan Multiple Test Range (DMTR).

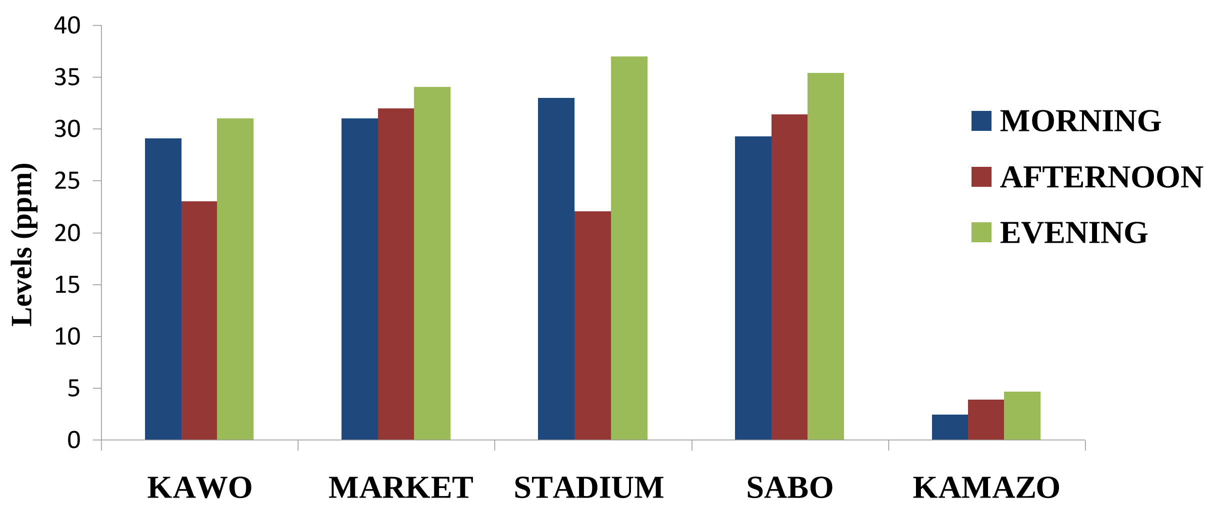
4.2 AIR POLLUTION LEVELS IN KADUNA MTROPOLIS

Table 4.1: Average Traffic Volume per Week and Emission Estimates at Five Sampling Points

				Average Pollutants Concentration per week								
Sampling Points	**Average Traffic Volume Per Week**			**CO**			**NO_2**			**SO_2**		
	M	**A**	**E**	**M**	**A**	**E**	**M**	**A**	**E**	**M**	**A**	**E**
Kawo	3236	2217	4996	29.1	23.0	31.0	0.004	0.003	0.042	0.090	0.037	0.040
Market	3994	3364	6346	31.0	32.0	34.0	0.042	0.040	0.050	0.410	0.040	0.050
Stadium	5199	2997	8257	33.0	22.0	37.0	0.050	0.040	0.050	0.420	0.043	0.050
Sabo	4077	5224	7431	29.3	31.4	35.4	0.040	0.044	0.050	0.420	0.050	0.050
Kamazo	350	149	405	3.84	2.42	4.00	0.005	0.003	0.008	0.003	0.002	0.005

Key: M-morning A-afternoon E-Evening. Source: Author's Fieldwork, 2013.

Table 4.1., shows the average traffic volume per week and emission estimates at the five sampling points. The result shows that the levels of pollutants CO, NO_2, and SO_2 measured were found to be ranged between 29.1-37.0ppm, 0.03-0.05ppm and 0.0037-0.051ppm for Kawo, Central market, Stadium roundabout and Sabo respectively. With exception, at Kamazo new road (the control station) pollutants levels was found to be ranged between 4.0-3.8ppm, 0.008-0.005ppm, and 0.005-0.003ppm for CO, NO_2, and SO_2 respectively.



Figures 4.1: Mean carbon monoxide (CO) levels across periods at five sampling points. Source: Author's Analysis, 2013.

Figure 4.1 shows the mean carbon monoxide (CO) levels across periods at sampling points. The result indicated that the highest levels of pollutants are at evening peak hours between 4.30 pm – 5.30 pm around stadium roundabout with levels of CO 37.0ppm; 35.4ppm Sabo; 34.0ppm Market; 31.0ppm Kawo; and 4.6ppm Kamazo.

Similarly, the CO level during morning hours at Kawo was 29.1ppm; 31.0 Market; 33.0ppm Stadium; 29.3ppm Sabo; and 2.42ppm Kamazo. During afternoon hours CO levels is 23.0ppm Kawo; 32.0ppm Market; 22.0ppm Stadium; 31.4ppm Sabo; and 3.8ppm Kamazo.

Table 4.2: Mean Carbon monoxide (CO) levels **per day across sampling points**

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Kawo	27.8	27.5	27.6	27.7	28.5	27.4	27.8
Market	32.1	30.9	31.6	31.6	32.6	31.8	33.1
Stadium	30.2	30.6	30.4	29.6	30.3	31.4	30.4
Sabo	31.9	31.2	32.2	32.0	33.1	32.7	30.8
Kamazo	2.4	2.2	2.6	2.1	2.5	2.3	2.0

Source: Author's Analysis, 2013.

The results for CO from table 4.2 ranged from 27.4-28.5ppm for Kawo sampling point; 31.0-33.0ppm for Central Market sampling point; 30.0-31.5ppm for Stadium Roundabout sampling point: and 31.3-33.1ppm for Sabo sampling point, also 2.0-26ppm for Kamazo new road which serves as the control point.

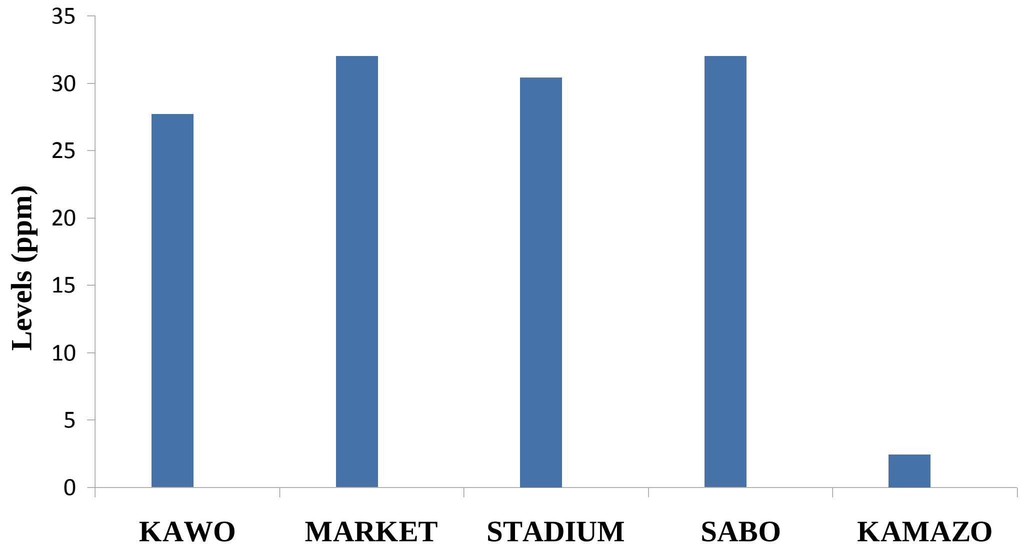


Figure 4.2: Mean Variation of Carbon monoxide (CO) levels per week across five sampling points. Source: Author's Analysis, 2013.

Figure 4.2 above shows the weekly mean Variation of Carbon monoxide (CO) concentrations per week across sampling points, for Kawo is 27.7ppm; 32.0ppm Market; 30.0ppm Stadium; 32.0ppm Sabo and Kamazo is 2.4ppm.

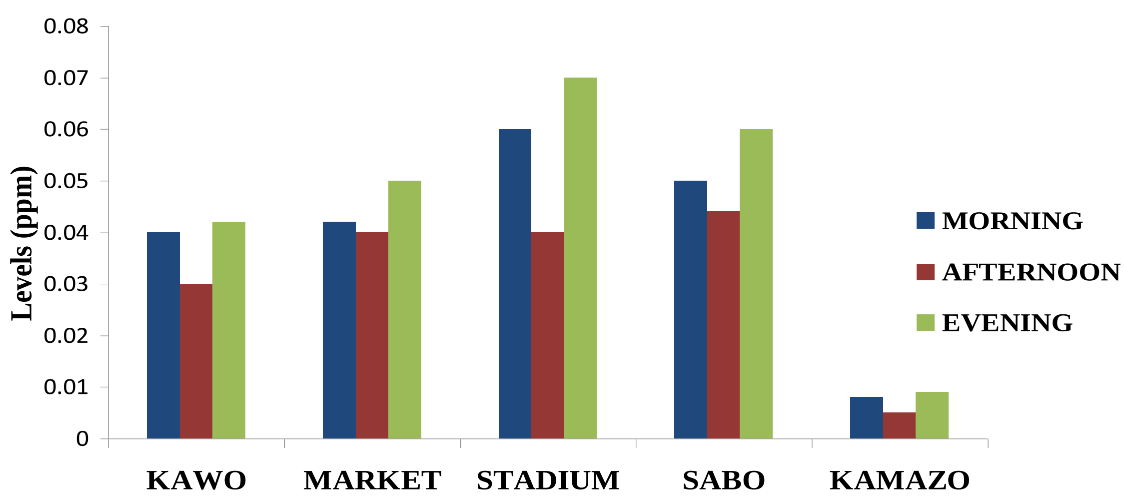


Figure 4.3: Mean Nitrogen oxide (NO_2) levels across periods at five sampling points. Source: Author's Analysis, 2013.

Figure 4.3 shows the mean Nitrogen oxide (NO_2) levels across periods at five sampling points. The result indicated that the highest NO_2 levels is at evening peak hours between 4.30 pm – 5.30 pm around stadium roundabout with levels of NO_2 0.07ppm; 0.06ppm Sabo; 0.05ppm Market; 0.042ppm Kawo; and 0.009ppm Kamazo.

The NO_2 level during morning hours at Kawo is 0.04ppm; 0.042 Market; 0.06ppm Stadium; 0.05ppm Sabo; and 0.008ppm Kamazo. During afternoon hours NO_2 levels is 0.03ppm Kawo; 0.04ppm Market; 0.04ppm Stadium; 0.044ppm Sabo; and 0.005ppm Kamazo.

Table 4.3: Mean Nitrogen oxide (NO_2) concentrations per day across sampling points

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Kawo	0.039	0.040	0.035	0.037	0.040	0.04	0.039
Market	0.043	0.043	0.042	0.038	0.040	0.040	0.044
Stadium	0.045	0.043	0.044	0.042	0.046	0.048	0.046
Sabo	0.042	0.044	0.044	0.045	0.046	0.044	0.043
Kamazo	0.002	0.001	O.006	0.004	0.007	0.005	0.003

Source: Author's Analysis, 2013.

The results for NO_2 levels per day as presented in table 4.3 ranged from 0.035-0.040ppm for Kawo sampling point; 0.038-0.044ppm for Central Market sampling point; 0.042-0.048ppm for Stadium Roundabout sampling point: and 0.042-0.046ppm for Sabo sampling point, also 0.001-0.007ppm for Kamazo new road which serves as a control point.

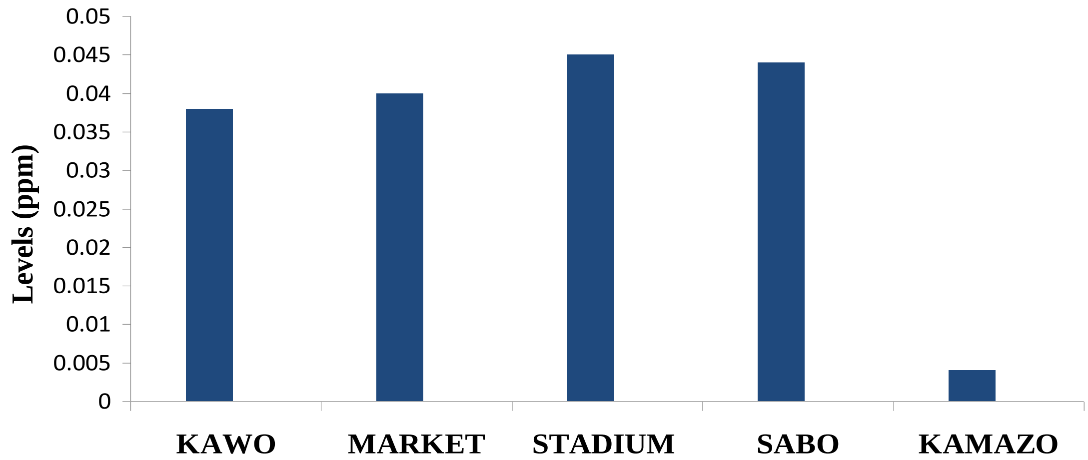


Figure 4.4: Mean Variation in Nitrogen oxide (NO_2) Levels per week Across five sampling points Source: Author's Analysis, 2013.

Figure 4.4 above shows the weekly mean Variation of NO_2 levels per week across sampling points, for Kawo is 0.038ppm; 0.04ppm Market; 0.045ppm Stadium; 0.044ppm Sabo and Kamazo is 0.004ppm.

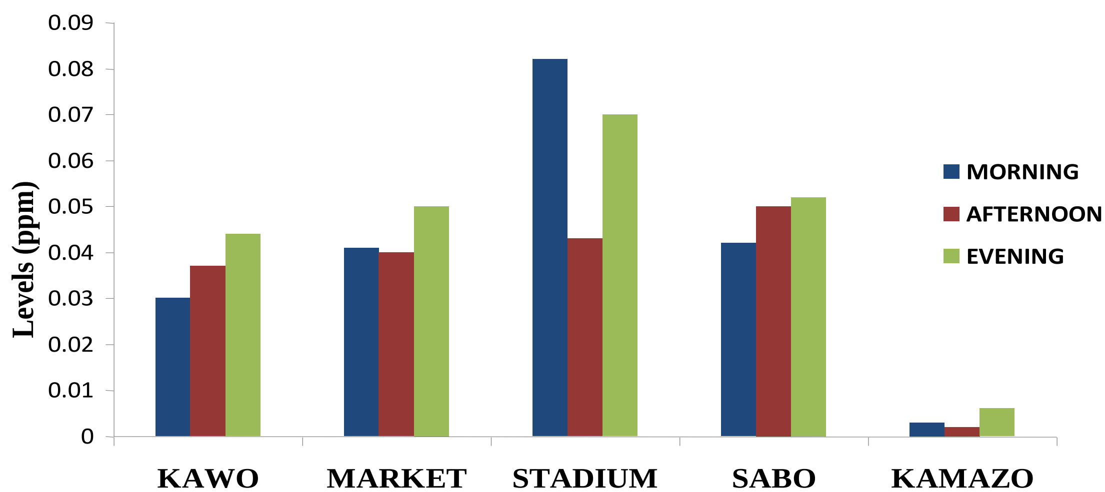


Figure 4.5: Mean Sulphur oxide (SO_2) levels across periods at five sampling points. Source: Author's Analysis, 2013.

Figure 4.5 shows the mean SO_2 level across periods at sampling points. The result illustrated that the highest SO_2 level is at evening peak hours between 4.30 pm – 5.30 pm around stadium roundabout with level of SO_2 0.07ppm; 0.052ppm Sabo; 0.05ppm Market; 0.044ppm Kawo; and 0.006ppm Kamazo.

The NO_2 level during morning hours at Kawo is 0.03ppm; 0.041Market; 0.082ppm Stadium; 0.042ppm Sabo; and 0.003ppm Kamazo. During afternoon hours NO_2 level is 0.037ppm Kawo; 0.04ppm Market; 0.043ppm Stadium; 0.05ppm Sabo; and 0.002ppm Kamazo.

Table 4.4: Mean Sulphur oxide (SO_2) levels per day across five sampling Points

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Kawo	0.040	0.043	0.037	0.041	0.040	0.043	0.040
Market	0.042	0.042	0.044	0.041	0.042	0.044	0.041
Stadium	0.045	0.050	0.044	0.043	0.044	0.043	0.045
Sabo	0.044	0.044	0.047	0.045	0.047	0.045	0.044
Kamazo	0.003	0.001	0.002	0.006	0.004	0.003	0.002

Source: Author's Analysis, 2013.

The results for SO_2 levels per day as presented in table 4.4 ranged from 0.037-0.043ppm for Kawo sampling point; 0.041-0.044ppm for Central Market sampling point; 0.043-0.050ppm for Stadium Roundabout sampling point: and 0.044-0.047ppm for Sabo sampling point, also 0.001-0.006ppm for Kamazo new road which serves as a control point.

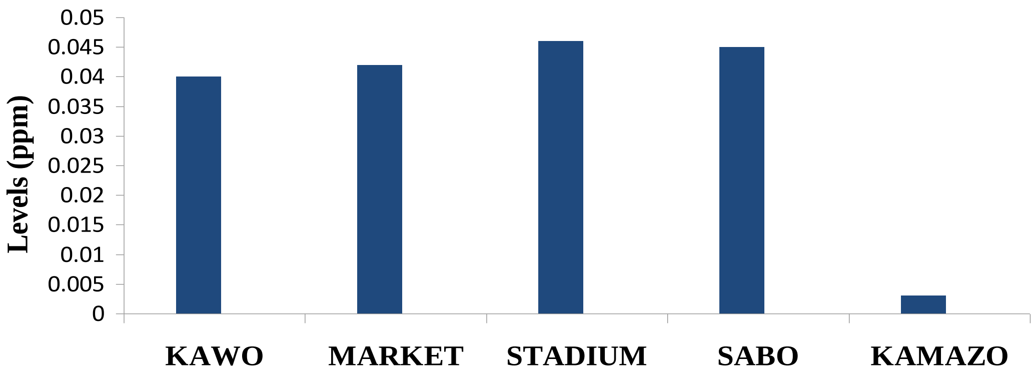


Figure 4.6: Mean Variation in Sulphur oxide (SO_2) levels per week across five sampling points. Source: Author's Analysis, 2013.

Figure 4.6 above shows the weekly mean variation of SO_2 levels per week across sampling points, for Kawo is 0.040ppm; 0.043ppm Market; 0.046ppm Stadium; 0.045ppm Sabo and Kamazo is 0.003ppm.

Table 4.5: Correlations among pollutants concentrations and traffic volume

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

****. Correlation is significant at the 0.01 level (2-tailed).** **Source: Author's Analysis, 2013.**

Table 4.5 shows the degree of relationship between pollutants concentrations and traffic volume across the sampling points. This was investigated using Bivariate Pearson's correlation (r), the correlation coefficient between traffic and pollutant concentrations was found to be r = 0.979; r = 0.840; r = 0.879 for CO, NO2, and SO2 respectively. The result indicated that all variables (CO, NO_2, and SO_2) 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 motor vehicles (busses, taxies, and motorcycles) were old and dilapidated, and poorly maintained poor standard. Therefore they emitted high amount of pollutants. See plate I - XII.

Plate I: Traffic Congestions and Emissions around Market @ 9:00am, 12/10/2013

Plate II: Vehicle Emissions around Stadium Sampling Point @ 6:00pm, 6/10/2013

Plate III: Motorcycle Congestions opposite Stadium Round-about Filling Station@ 5:00am, 12/10/2013

Plate IV: Vehicle omissions opposite central market sampling point @ 12:00noon, 3/10/2013

Plate V: Vehicle Emissions around Stadium Round about @ 6:30pm, 16/10/2013

Plate VI: Vehicle Emissions around Market Sampling Point @ 5:30pm, 23/10/2013

Plate VII: Vehicle Emissions around Kawo Sampling Point @ 4:30pm, 26/10/2013

Plate VIII: Vehicle Emissions around Sabo Sampling Point@ 2:30pm, 7/10/2013

Plate IX: Vehicle Emissions around Stadium Round about @ 9:30pm, 11/10/2013

Plate X: Vehicle Pollutant Emission around Kawo Sampling Point@ 4:30pm, 13/10/2013

Plate XI: Very less or no Traffic congestion at Kamazo (control station) @ 8:30pm, 30/10/2013

Plate XII: Very less or no Traffic congestion at Kamazo (control station) @ 1:30pm, 30/10/2013

4.3 DISCUSSION

From the results obtained, the concentrations of pollutants (CO, NO2 and SO2) 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 pollutants gases was lower during morning period. However this variation may be attributed to the following reasons; first the relationship between traffic volumes and pollutants concentrations as revealed in the result obtained in correlation table 4.4 where traffic volume affects pollutants concentrations.

The second reasons may also be attributed to the dynamics of the atmospheric boundary layer and associated convective turbulence which extensively mixed and redistributed pollutant gases to a greater vertical extent. And when the sunset is high air mixed layers tends to deforms. Also as night keeps on advancing, so also the boundary layer keeps becoming stratified until it finally resulted in the formation of a nocturnal inversion and a shallow stable boundary layer near the surface and residual layer overhead. As this process continues with night proceedings, the nocturnal inversion gains height and inhibits vertical transport of aerosols and gases (Coyle et al., 2002).

From figure 4.1, the levels of CO recorded were high at all the sampling points with exemption of the control station. The highest levels of CO recorded were around Stadium sampling point with levels value up to CO 37.5ppm. This concentration value when compared with other concentration values reported in literature was found to be very high. For example, in Athens, Greece the average range of atmospheric concentration of urban air pollutants was 1.6 - 3.8ppm, as reported by (Kalabokas *et al*., 1999). This value is also higher than range of 0.7 - 1.9ppm in Jahara, Kuwait (Ettouney *et al*., 2010) and higher than the range of 4.25 - 14.33ppm in Kano, Nigera (Okunola *et al.*, 2012). However, in this study the concentration values were lower than range of 233 - 317ppm reported in three cities of Nigeria: Lagos, Ibadan and Ado - Ekiti (Koku and Osuntogun, 1999). Comparing the concentration values of CO at the five (5) sampling points, the highest value was seen at the sampling point near Stadium roundabout due to traffic holdups that takes hours to resolve as people journeys from activities to residence causing high traffic congestion by cars, taxies intra-city commercial buses, trucks and commercial motorcycles congestions as well as burning of old tiers around this area.

Also this site is located in between Kaduna North and South bridged. It also serves as the only major road that links the two parts of the metropolis (Kaduna North and South). This situation is very complicated just adjacent to this roundabout and at the sharp bend on each of the opposite lane was two big petrol filling stations facing one another each with a nearby bus-stop for most intra-city buses, taxies and commercial motorcycles thereby experiencing flux of traffic, especially during the afternoon-evening hours.

Generally at all the five sampling points the CO variation across the periods revealed that air quality is poor (greater than 20ppm for NESREA safe limit) at all sampling points with exemption of the control station. Generally, condition of the air during afternoon - evening hours indicate poor air quality. This further indicates that the environment around these sampling points is exposed to CO. And it was said 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).

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 was still during the evening hours at all 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. However NO_2 concentration is still within the safe limits set by NESREA (2009) for NO_2 which is 0.04 - 0.06ppm.

Throughout all the sampling points, highest levels of SO_2 recorded were still during the evening hours, 0.07ppm Stadium; 0.052ppm Sabo; 0.05ppm Market; 0.044ppm Kawo; and 0.006ppm Kamazo. It could be said that positive significant correlation at 0.01 confidence levels (0.899) between traffic volume and SO2 during this period could be responsible. However, the concentration of SO_2 is lower than ranges of 3.21 - 5.18ppm, 7.4 – l5.5ppm, 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, but was within the range of 0.03 - 0.09ppm reported in Kano metropolis, Nigeria (Okunola *et al.*, 2012).

4.4 HYPOTHESIS TEST

4.4.1 Hypothesis H_o 1

H_o 1: there is no significant difference in the air quality within the city center and control station.

Table 4.6: ANOVA test for CO concentration across sampling points

Source	Df	Sum of Squares	Mean Square	P value
Stations	4	4545.378286	1136.344	< 0.0001
Error	30	9.751429	0.325048	
Total	34			

Source: Author's Analysis, 2013.

On the ANOVA table 4.6 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.

Table 4.7: Duncan Multiple Range Test (DMRT) for CO levels across five sampling points

Stations	Means
Sabo	31.9857^{a}
Market	31.9571^{a}
Stadium	30.4143^{b}
Kawo	27.7571^{c}
Kamazo	2.3000^{d}

KEY: *Means with the same letter are not significantly different.*
Source: Author's Analysis, 2013.

The summarized result as presented on table 4.7 illustrated that the means ($\overline{X}$) concentration of CO in Sabo and Market sampled points are ranked with same letter 'a' (31.9857^{a}; 31.9571^{a}) this could be interpreted to mean that, the CO concentrations at Sabo and Market are not significantly different but performs significantly different when compared with Stadium 30.4143^{b} and Kawo 27.7571^{c} as well as the control station 2.3000^{d} (Kamazo). Therefore in the case of CO concentrations, there is a significant difference in the air quality within the city center and control station. Thus, the null hypothesis (H_o1) was rejected.

Table 4.8: ANOVA test for NO_2 levels across five sampling points

Source	Df	Sum of Squares	Mean Square	P value
Stations	4	0.00849486	0.00212371	< 0.0001
Error	30	0.00012943	0.00000431	
Total	34			

Source: Author's Analysis, 2013.

The ANOVA table 4.8 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 4.8.

Table 4.9: Duncan Multiple Range Test (DMRT) for NO_2 levels across five sampling points

Stations	Means
Stadium	0.044857[a]
Sabo	0.044000[a]
Market	0.042857[a]
Kawo	0.038571[b]
Kamazo	0.004000[c]

KEY: *Means with the same letter are not significantly different.*
Source: Author's Analysis, 2013.

The summarized result as presented on table 4.9 illustrated that the means $\overline{X}$ levels of NO_2 in Stadium, Sabo and Market sampled points are ranked with the same letter 'a' (0.044857[a]; 0.044000[a]; and 0.042857[a]) which mean that, the NO_2 levels at Stadium, Sabo and Market are not significantly different but perform significantly different when compared with Kawo 0.38571[b] and the control station 2.3000[c] (Kamazo). Therefore in the case of NO_2 levels, there is a significant difference in the air quality within the city center and control station. Thus, the null hypothesis (H_o1) was rejected.

Table 4.10: ANOVA test for SO_2 levels across five sampling points

Source	Df	Sum of Squares	Mean Square	P value
Stations	4	0.00913686	0.00228421	< 0.0001
Error	30	0.00008743	0.00000291	
Total	34			

Source: Author's Analysis, 2013.

On the ANOVA table 4.10 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 4.11 below:

Table 4.11: Duncan Multiple Range Test (DMRT) for SO_2 levels across five sampling points

Stations	Means
Sabo	0.0451429^{a}
Stadium	0.0447143^{a}
Market	0.0422857^{b}
Kawo	0.0405714^{b}
Kamazo	0.003000^{c}

KEY: *Means with the same letter are not significantly different.*
Source: Author's Analysis, 2013.

The summarized result as presented on table 4.10 illustrated that the means ($\bar{X}$) levels of SO_2 in Sabo and Stadium sampled points are ranked with the same letter 'a' (0.0451429^{a}; and 0.0447143^{a}) this mean that the SO_2 levels at Sabo and Stadium are not significantly different. Similarly, the means $\bar{X}$ levels of SO_2 in Market and Kawo sampled points are ranked with the same letter 'b' (0.0422857^{b}; and 0.0405714^{b}) this also mean the SO_2 levels at Market and Kawo are not significantly different but when compared Sabo and Stadium performs significantly different with Market and Kawo as well as with the control station 0.003000[c] (Kamazo). Therefore in the case of SO_2 concentrations, there is a significant difference in the air quality within the city center and control station. Thus, the null hypothesis (H_o 1) is also rejected.

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

4.4.2 Hypothesis H_o 2

On the null hypothesis (H_o 2) that there is no significant difference in the levels of pollutants in air among the four sampling points, the test results are presented in table 4.12

Table 4.12: Mean variations in levels of CO, NO_2 and SO_2 among the four sampling point from DMRT ranking.

Stations	CO Means	NO_2 Means	SO_2 Means
Sabo	31.9857[a]	0.044857[a]	0.0451429[a]
Stadium	31.9571[a]	0.044000[a]	0.0447143[a]
Market	30.4143[b]	0.042857[a]	0.0422857[b]
Kawo	27.7571[c]	0.038571[b]	0.0405714[b]

KEY: Means with the same letter are not significantly different.
Source: Author's Analysis, 2013.

The results as shown in table 4.11 indicate that the mean levels for CO at Sabo and Stadium did not vary hence they are ranked the same with letter 'a' (31.9857[a]; 31.9571[a]) however it varies significantly when compared with Market and Kawo (30.4143[b] ; 27.7571[c]) with Kawo being the least in CO levels among the four sampling points. The mean variations in NO_2 levels among Sabo, Stadium, and Market sampling points are not significantly different since the test result shows the same ranked with letter ‘a’ (0.044857^{a}; 0.044000^{a}; 0.042857^{a}) but vary with that of Kawo (0.038571^{b}) when compared. In terms of SO_2 levels in Sabo and Stadium sampling points do not performs significantly different hence the outcome results are ranked the same with letter ‘a’ (0.0451429^{a}; 0.0447143^{a}), similarly, SO_2 levels in Market and Kawo do not performs significantly different hence they are also ranked with the same letter ‘b’ (0.0422857^{b}; 0.0405714^{b}). But when compared Sabo and Stadium performs significantly different with Market and Kawo sampling point. Therefore, based on this proof the null hypothesis (H_o 2) is rejected since the test performs at least a significant difference in the levels of pollutants among the four sampling points.

4.4.3 Hypothesis H_o 3

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

In order to test for H_o 3, the average traffic volume and emissions estimates at five sampling locations were conducted and presented on table 4.1. 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 table 4.13 – table 4.17.

Table 4.13: Correlation coefficients for relationship between traffic and Pollutants (CO, NO_2, and SO_2) levels at Kawo sample point

Parameters	Traffic	CO	NO_2	SO_2
Traffic	1			
CO	0.997*	1		
NO_2	0. 720	0.667	1	
SO_2	0.902	0.868	0.949	1

*** Correlation is significant at the 0.05 level (2-tailed).**
Source: Author's Analysis, 2013.

The correlation coefficient between traffic and pollutant concentrations at Kawo sample point as presented on table 4.13 was found to be r = 0.997; r = 0.720; r = 0.902 for CO, NO2, and SO2 respectively. The result indicated that all variables (CO, NO_2, and SO_2) had a strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels.

Table 4.14: Correlation coefficients for relationship between traffic and Pollutants (CO, NO_2, and SO_2) levels at Market sample point

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

**** Correlation is significant at the 0.01 level (2-tailed).**
Source: Author's Analysis, 2013.

The correlation coefficient between traffic and pollutant concentrations at Market sample point as presented on table 4.14 was found to be r = 0.990; r = 0.952; r = 0.991 for CO, NO_2, and SO_2 respectively. The result indicated that all variables (CO, NO_2, and

SO_2) had a very strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels.

Table 4.15: Correlation coefficients for relationship between traffic and Pollutants (CO, NO_2, and SO_2) levels at Stadium sample point

Parameters	Traffic	CO	NO_2	SO_2
Traffic	1			
CO	0.966	1		
NO_2	0.966	1.000^{**}	1	
SO_2	0.937	0.815	0.815	1

****Correlation is significant at the 0.01 level (2-tailed).**
Source: Author's Analysis, 2013.

The correlation coefficient between traffic and pollutant concentrations at Stadium sample point as presented on table 4.15 was found to be r = 0.996; r = 0.966; r = 0.937 for CO, NO_2, and SO_2 respectively. The result indicated that all variables (CO, NO_2, and SO_2) had a very strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels.

Table 4.16: Correlation coefficients for relationship between traffic and pollutants (CO, NO_2, and SO_2) levels at Sabo sample point

Parameters	Traffic	CO	NO_2	SO_2
Traffic	1			
CO	0.998^{*}	1		
NO_2	0.764	0.803	1	
SO_2	1.000^{**}	0.998^{*}	0.762	1

***Correlation is significant at the 0.05 level (2-tailed).**
****Correlation is significant at the 0.01 level (2-tailed).**
Source: Author's Analysis, 2013.

The correlation coefficient between traffic and pollutant concentrations at Sabo sample point as presented on table 4.13.3 was found to be r = 0.998; r = 0.764; r = 1.000 for CO, NO2, and SO2 respectively. The result indicated that all variables (CO, NO_2, and

SO_2) had a very strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels.

Table 4.17: Correlation coefficients for relationship between traffic and Pollutants (CO, NO_2, and SO_2) levels at Kamazo sample point

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

*** Correlation is significant at the 0.05 level (2-tailed).**
Source: Author's Analysis, 2013.

The correlation coefficient between traffic and pollutant concentrations at Kamazo sample point as presented on table 4.16 was found to be r = 0.711; r = 0.884; r = 0.999 for CO, NO2, and SO2 respectively. The result indicated that all variables (CO, NO_2, and SO_2) had a strong positive correlation with the traffic volume at 0.01 and 0.05 significant levels.

Following the tests results as shown in table 4.13 - table 4.17 indicate a corroborated this hypothesis, particularly as the parameters, are significantly correlated and influenced by traffic volume. This also proof that there is a significant relationship between traffic volume and air pollutant at the sampling point. Therefore the null hypothesis (H_o 3) is rejected hence the alternative hypothesis is accepted since the traffic volume has a significant effect on pollutants levels at all the five sampling points.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In this chapter, summary, conclusion and recommendations are presented with an optimum view that if the recommendations are considered and implemented the menace of motor vehicles emissions (pollution) in the study area can be manage in a sustainable manner and transportations will therefore enhance development without destroying the environment.

5.2 SUMMARY OF MAJOR FINDINGS

i. The levels of pollutants CO, NO_2, and SO_2 measured were found to be ranged between 29.1-37.0ppm, 0.03-0.05ppm and 0.0037-0.051ppm for Kawo, Central market, Stadium roundabout and Sabo respectively. With exception, at Kamazo new road (the control station) pollutants levels was found to be ranged between 4.0-3.8ppm, 0.008-0.005ppm, and 0.005-0.003ppm for CO, NO_2, and SO_2 respectively.

ii. The highest level of pollutants recorded was at Stadium roundabout during the afternoon-evening periods and were found to be 37ppm, 0.05ppm and 0.05ppm for CO, NO_2, and SO_2 respectively. And were all above the National Environmental Standards and Regulatory Enforcement Agency (NESREA) recommended safe limits.

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 Kaduna metropolis is not within the safe limits, and that motor traffic-related pollution in Kaduna metropolis is a potential hazard to the environment and human health.

5.3 CONCLUSION

The overall situation regarding motor vehicle emissions in Kaduna metropolis is poor with a potential human health effect. The results revealed that motor vehicle emissions in Kaduna metropolis especially the urban core include pollutants like CO, NO_2, and SO_2. The levels of the CO measured at all the sampling points with exemption of the control station were above the NESREA standard limit. Therefore, in this aspect air quality is poor and hazardous for health.

As for SO_2 measured, at most of the sampling points were relatively above the NESREA lower limit but still does not exceeded the upper safe limit. Therefore in this aspect air quality is relatively safe. But as for NO_2 it was within the NESREA safe limit only at few sampling point where it relatively exceeded the NEREA lower safe limit but still did not exceeded the upper safe limit. Therefore the concentration level of NO_2 at this aspect is safe. This implies that motor vehicle emissions within Kaduna metropolis are not within the safe limits. Hence, the results revealed that transport-related pollution in Kaduna metropolis is significant with potentially hazardous health consequences.

Finally, this study also revealed that gaseous pollutants in the air, such as CO, NO_2 and SO_2 directly or indirectly threaten the environment and life of inhabitants of

Kaduna metropolis and that motor vehicles emission and other related activities carried out along these roads remain the dominant sources of these pollutants.

5.4 RECOMMENDATIONS

i. 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 emissions and protect health. This can be achieved through reduction of sulfur and carbon content in fuel, mandated emission control technology, and increased taxes to incentivize individuals to purchase cleaner vehicles and fuels. Of course, these may be beyond the financial means for many in Kaduna and Nigeria at large and the economics and feasibility of any suggested policy recommendations need to be fully understood.

ii. Construction of inner roads and bridges that would link Kaduna North and South can be valuable to reduce the number of vehicles on major roads, which in turn will help reduce the levels of pollutants if there are no serious traffic holdups in a particular area at every point in time.

iii. Finally, motorization growth should be largely checked by environmental regulations therefore, NESREA should reviews its air quality standard limit because looking at other air quality index of developed countries revealed a high variation, also air quality database within the country need to be developed urgently and made readily available and accessible to all stakeholders.

iv. Future Research: In order to improve on a study of this type more elaborates field survey should be carried out and more time frames is required to study the traffic flow beheaviour within the metropolis for such would provide more primary data and lots of details that would be useful for this type of studies. Also meteorological parameters such as wind factors, temperature and relative humidity should be given consideration because they affect atmospheric air boundary layers, and also influence the dynamics of the atmosphere and associated convective turbulence which extensively redistribute pollutants gases to a greater vertical extent. This can be achieved by combining both field survey (primary data) and secondary data which will provide a number of datasets for the study where temporal analysis can be perform so as to detect changes over a longer period so that a trend can be obtained. These suggestions are very important but require more time frame, better funds, and general understanding of the behavior of traffic flow, emissions trends and dispersion process. Therefore all stakeholders should be involved to facilitate this action especially the environmental regulatory agencies such as NESREA and the Federal Ministry of Environment. Also considering the state of this country Nigeria, being a developing nation it is important to carefully plan the use of transportation infrastructures especially traffic management alongside with environmental regulations with stiff rules and penalties for road vehicle polluters.

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Appendix 1: Pollutants Concentrations across Periods at Kawo Sampling Point

	KAWO											
	MORNING				AFTERNOON				EVENING			
Day	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**
Monday	28.4	0.041	0.038	3011	23.8	0.037	0.039	2071	31.1	0.043	0.044	4892
Tuesday	93.3	0.043	0.004	3187	22.8	0.036	0.042	2124	30.5	0.039	0.046	5011
Wednesday	27.8	0.033	0.036	3092	25.4	0.03	0.032	2044	29.6	0.04	0.042	4664
Thursday	29.2	22.6	31.3	3222	24.2	0.032	0.041	2018	31.9	0.37	0.44	4893
Friday	30.1	0.035	0.043	3420	23.6	0.036	0.041	2411	32.4	0.039	0.045	5511
Saturday	28.9	0.04	0.043	3511	22.4	0.033	0.044	2522	30.8	0.043	0.04	5518
Sunday	31	0.04	0.033	3212	20.7	0.04	0.043	2331	31.8	0.044	0.048	4886

Appendix 2: Pollutants Concentrations across Periods at Market Sampling Point

MARKET												
	MORNING				AFTERNOON				EVENING			
Day	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**
Monday	31.1	0.044	0.044	4111	29.4	0.04	0.039	3433	34.2	0.046	0.047	6778
Tuesday	31.1	0.042	0.044	3666	29.3	0.04	0.041	3201	34.1	0.047	0.048	6022
Wednesday	30.2	0.044	0.041	3997	29.5	0.041	0.039	3111	33.4	0.046	0.047	6195
Thursday	30.3	0.04	0.041	4001	30.2	0.032	0.038	3171	33.9	0.042	0.043	6002
Friday	31	0.044	0.042	4112	32.6	0.033	0.04	3662	34.2	0.044	0.045	6331
Saturday	30.8	0.039	0.044	4081	31.3	0.036	0.04	3881	33.3	0.04	0.049	7002
Sunday	31.9	0.044	0.042	3992	34.4	0.049	0.038	3089	34.4	0.049	0.044	6111

Appendix 3: Pollutants Concentrations across Periods at Stadium Sampling Point

	STADIUM											
	MORNING				AFTERNOON				EVENING			
Day	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**
Monday	33.1	0.047	0.044	5112	20.8	0.042	0.044	2889	36.8	0.046	0.048	8111
Tuesday	33.2	0.043	0.042	5201	23	0.042	0.04	2942	35.8	0.047	0.046	8246
Wednesday	32.2	0.042	0.044	5038	22.4	0.041	0.039	3002	36.6	0.048	0.049	8641
Thursday	32.4	0.04	0.043	5002	21.1	0.044	0.041	3012	35.2	0.044	0.045	8077
Friday	33.1	0.04	0.043	5482	21.8	0.04	0.041	3112	36.1	0.044	0.045	8886
Saturday	35.2	0.046	0.052	5677	22	0.043	0.044	3311	37.1	0.055	0.052	9021
Sunday	31.5	0.045	0.041	4886	22.6	0.042	0.043	2711	37.2	0.051	0.051	6822

Appendix 4: Pollutants Concentrations across Periods at Sabo Sampling Point

	SABO											
	MORNING				AFTERNOON				EVENING			
Day	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**
Monday	31.1	0.04	0.041	4002	31.2	0.042	0.044	5111	35.4	0.044	0.046	6886
Tuesday	30.8	0.041	0.04	4212	30.5	0.043	0.044	5313	34.6	0.048	0.047	7411
Wednesday	29.5	0.042	0.042	4422	31.1	0.044	0.046	5418	36.1	0.048	0.049	7768
Thursday	29.2	0.04	0.043	4161	31.4	0.045	0.047	5008	35.2	0.049	0.048	7611
Friday	30.8	0.042	0.044	4141	32.1	0.046	0.048	5313	36.4	0.051	0.049	7222
Saturday	28.8	0.041	0.042	4222	32.6	0.043	0.046	5633	36.8	0.049	0.048	8011
Sunday	29.1	0.04	0.041	3382	30.8	0.043	0.044	4778	33.1	0.045	0.046	7111

Appendix 5: Pollutants Concentrations across Periods at Kamazo (control station) Sampling Point

	KAMAZO											
	MORNING				AFTERNOON				EVENING			
Day	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**	**CO**	**NO2**	**SO2**	**Traffic**
Monday	2.32	0.002	0.003	422	1	0.001	0.002	168	4.1	0.009	0.006	501
Tuesday	2.1	0.002	0.004	388	0.99	0.001	0.002	152	3.2	0.007	0.005	408
Wednesday	2.1	0.003	0.002	366	0.89	0.003	0.001	144	3.2	0.008	0.007	411
Thursday	1.99	0.004	0.003	311	0.75	0.002	0.003	122	3.18	0.005	0.006	401
Friday	2	0.004	0.003	352	1	0.001	0.003	196	2.52	0.006	0.008	468
Saturday	2.12	0.005	0.004	398	0.56	0.003	0.001	127	3.62	0.008	0.005	367
Sunday	1.23	0.003	0.002	212	0.65	0.001	0.001	132	2	0.004	0.003	277