IMPACT OF VEHICULAR TRAFFIC EMISSIONS ON AMBIENT AIR QUALITY IN KADUNA METROPOLIS

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DECLARATION

I declare that the work entitled **"Impact of Vehicular Traffic Emissions on Ambient Air Quality in Kaduna Metropolis"** was carried out by me in the Department of Water Resources and Environmental Engineering under the supervision of Dr. D.B Adie and Dr. S.B. Igboro. The information derived from other literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree in any institution.

Anthony Abutu ATTAH	______________________	______________________
(M.Sc/Eng/00770/2010-2011)	**Signature**	**Date**

CERTIFICATION

This thesis titled **"IMPACT OF VEHICULAR TRAFFIC EMISSIONS ON AMBIENT AIR QUALITY IN KADUNA METROPOLIS"** by **ANTHONY ABUTU ATTAH**, has been read and approved as having met the regulation of governing senate for the award of Master Degree in the Department of Water Resources and Environmental Engineering, Faculty of Engineering, Ahmadu Bello University, Zaria.

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Prof. A.Z. Hassan **Dean, Postgraduate School**	____________________ **Signature**	____________________ **Date**

DEDICATION

This thesis is dedicated to Almighty God for His guidance and protection during the period of this study.

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My acknowledgement goes first and foremost to Almighty God who has been so faithful to me and who has sustained me with health throughout this academic pursuit.

To my immediate family, especially my parents, Dr. and Mrs. Simon Attah, for the necessary moral support they have always rendered as parents and for their part in seeing to my development to this stage in life.

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ABSTRACT

The study investigates the concentrations of CO, NO_2, SO_2, CO_2 and HC arising mainly from the activities of motor vehicles on the ambient air quality of selected sites in Kaduna metropolis. The sites are situated in the Central market area, the Stadium Roundabout, and Kawo area. Others include Bakin Ruwa Junction, Abuja Junction, Sabon Tasha and a control site at the Angwa Rimi G.R.A. Furthermore, sites situated about a distance of 100m from each of the traffic sites were investigated. The sampling was carried out over both the dry and wet season. Results from dry season survey indicate that the average CO concentrations at the Stadium Roundabout peaked at 29.04ppm. The site also recorded highest concentrations for NO_2, SO_2, CO_2 and HC at 0.042ppm, 0.040ppm, 370.92ppm and 0.030ppm respectively. In the wet season, the Stadium Roundabout recorded highest CO concentrations at 18.72ppm. NO_2 was highest at 0.03ppm in Sabon Tasha. Both Stadium Roundabout and Sabon Tasha area recorded highest SO_2 concentration at 0.032ppm. Sabon Tasha recorded highest concentrations for both CO_2 and HC at 370.92ppm and 0.028ppm respectively. Results from comparison of the average CO concentration with the National Ambient Air Quality Standard (NAAQS), showed that CO concentrations in virtually all sites exceeded the 10ppm for an averaging time of 1 hour in both seasons. The same was true for SO_2, which exceeded the 0.01ppm limit for an averaging time of 1 hour. NO_2 limit of 0.04ppm for a 1 hour averaging time was exceeded at Stadium Roundabout in the morning hour, Central Market area in the afternoon, and in the evening hours at Central Market, Stadium Roundabout and Bakin Ruwa all in the dry season. All sites were within limit in the wet season. Results from comparison of the pollutants concentration at the three classified locations i.e. at traffic points, 100 m away from traffic points and at a control location indicates that all pollutants concentration decreased with increased distance away from the traffic sites. The model developed is therefore useful for planning of residential and other facilities in Kaduna metropolis and beyond.

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LIST OF ABBREVIATIONS

AQI	Air Quality Index
CEC	Centre for Environmental Control
CNG	Compressed Natural Gas
CO	Carbon (II) Oxide
CO_2	Carbon (IV) Oxide
COMEAP	Committee of the Medical Effects of Air Pollution
ECMT	European Conference of |Ministers of transport
EPA	Environmental Protection Agency
FAQS	Federal Air Quality Standards
FEPA	Federal Environmental Protection Agency
GHGs	Green House Gases
GPRS	General Packet Radio Service
GPS	Global Positioning System
HC	Hydrocarbon
LPG	Liquefied Petroleum Gas
m	Metres
NAAQS	National Ambient Health Quality Standards
NO_2	Nitrogen (iv) Oxide
O_3	Ozone
OECD	Organisation for Economic Co-operation and Development
PM	Particulate Matter
ppm	Parts Per Million
SO_2	Sulphur (iv) oxide
TSP	Total Suspended Particles
UN	United Nations
UNFPA	United Nations Population Fund

USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organisation
WRI	World Resource Institute

CHAPTER ONE

INTRODUCTION

1.1 PREAMBLE

The air we breathe is a mixture of gases and particulate solid and liquid matter. Some of these substances come from natural sources while others are caused by human activities such as our use of motor vehicles, domestic activities, industries and businesses. Air pollution occurs when the air contains substances in quantities that could harm the comfort or health of humans and animals, damage plants and materials. These substances are called air pollutants and can be either particles, liquids or gaseous in nature (Alias *et al*., 2007). Keeping the air quality acceptable has become an important task for decision makers as well as for non-governmental organizations.

As many cities around the world become more congested, concerns increase over the level of urban air pollution being generated and in particular its impact on localized human health. The more this relationship is understood, the better chance there is of controlling and ultimately minimizing such effects. Urban air quality is an issue that is currently on top of air pollution agendas around the world (Colvile *et al*., 2001). Estimate worldwide show that nearly one billion people in urban environments are continuously being exposed to health hazards from air pollutants (Ahrens, 2003).

Air pollutants are airborne substances that occur in concentrations high enough to cause adverse effects on health, the environment and/or outdoor structures. Air pollutants can affect health in different ways and in varying degrees of severity ranging from minor irritation through serious illness, to premature death (Dickey, 2000).

Air pollutant emissions come from both natural (biogenic emissions) and anthropogenic sources. Although emissions from natural sources can be substantial, and are indeed the dominant source in non-urban areas, this study specifically investigates (anthropogenic) road traffic emissions in an urban area. The emission of air pollutants has led to several air quality issues such as photochemical smog, acid rain, visibility degradation and nuisance. Although major efforts have been made over the past decades to reduce air pollution and improve air quality, these issues have proven to be quite persistent and continue to exist, despite the implementation of several air quality strategies. A major factor in this is the strong and continued growth in road traffic.

Road transport emits air pollutants from the combustion of liquid or gaseous fossil fuels. Although thousands of air pollutants from road traffic can be identified, most of them can be classified in the following major groups according to their origins and formation processes:

a). Products of incomplete combustion, including carbon monoxide (CO), particulate matter (PM) and hydrocarbons (HCs):

b). Products of high-temperature combustion processes, including nitrogen oxides (NOx);

c). By-products of combustion due to impurities in the fuel, including heavy metals and sulphur oxides (SOx);

d). Non-combustion products, including evaporative emissions;

e). Secondary air pollutants such as photochemical oxidants, including tropospheric ozone (O_3) and peroxyacetyl nitrate (PAN); and

f). Greenhouse gases, including carbon dioxide (CO_2) and methane.

Around the world, and particularly for CO, NOx and HC, road traffic is the dominant, if not the most important, anthropogenic source of air pollution in urban areas (Fenger, 1999). This is not only because of the magnitude of its emissions, but also because pollutants are emitted in close proximity to human receptors, which enhances exposure levels.

With the emission concentration in traffic being some 10^4 – 10^5 times above typical ambient background and released only a few tens of centimeters above ground level, excellent dispersion is essential for dilution of the pollutants in the ambient air (Colls, 2002; Abhishek and Colls, 2010). Thus the meteorological conditions, in addition to concentration of activities, which generates emission, account for the spatial and temporal variations. The emission of vehicle pollutants into the atmosphere is an increasingly important health issue that affects nearly everyone (Rouphail *et al*, 2001).

The health challenges faced by road users, passers-by, residents and business operators in traffic flash points, having high concentration of vehicular traffic during some periods of the day are worrisome issues (Utang and Peterside, 2011). A comparison of the monitored and inventory emissions with acceptable standards (threshold) is useful in determining the extent of safety of road side business operators and hawkers in traffic intersection and congested traffic points.

Generally, exhaust gas emission concentrations vary, depending on the engine operating mode (idling, accelerating, cruising and decelerating) (Colls, 2002). Deceleration and idle are characteristics of peak traffic at road intersections, while high acceleration and cruise are common at off peaks. Thus a spatio-temporal variation in rate and type of air pollutant exists between and within peak and off peak periods of urban traffic (Utang and Peterside, 2011). Once these emissions are released into the atmosphere, dispersion processes transport and dilute these emissions. In addition to dispersion, pollutants can also undergo (chemical) transformation and deposition. Depending on the ground level location, these processes results in certain ambient concentration levels, which are referred to as immissions (Harssema, 1987), the extent of which is a function of meteorological conditions, topographical characteristics and distance between source and receptor.

The level of exposure to air pollutants depends on ambient concentration levels and where sensitive receptors (e.g. population) are situated in time and place. Health effects then depend on dose-effect relationships, which may be obtained from epidemiological of clinical studies. The magnitude of the effects subsequently determines the economic effects (cost) of air pollution.

1.2 STUDY AREA

Kaduna is the capital city of Kaduna state in the north western part of Nigeria. It is located at Latitude 10°20′N and Longitude 7°45′E and occupies a total land area of 1,190 sq. mi. (3,080km^2). It has an estimated population of 760,084 inhabitants according to the 2006 population and housing census (FGN, 2010). The city is transversed by the Kaduna River. It is also a trade centre and a major transport hub for the surrounding agricultural areas with its rail and road junction. Kaduna is also one of the industrial centers of Northern Nigeria where products like textiles, machinery, steel, aluminum, petroleum products, fertilizers and brewing are produced. The main highway through the city is called Ahmadu Bello Way along which there are quite a number of traffic intersections. There is also the ever busy Constitution road, Yakubu Gowon way and the Nnamdi Azikiwe by-pass; which all feed into the extended Ahmadu Bello way at one point or the other. The map of the study area is shown in Figure 1.1.

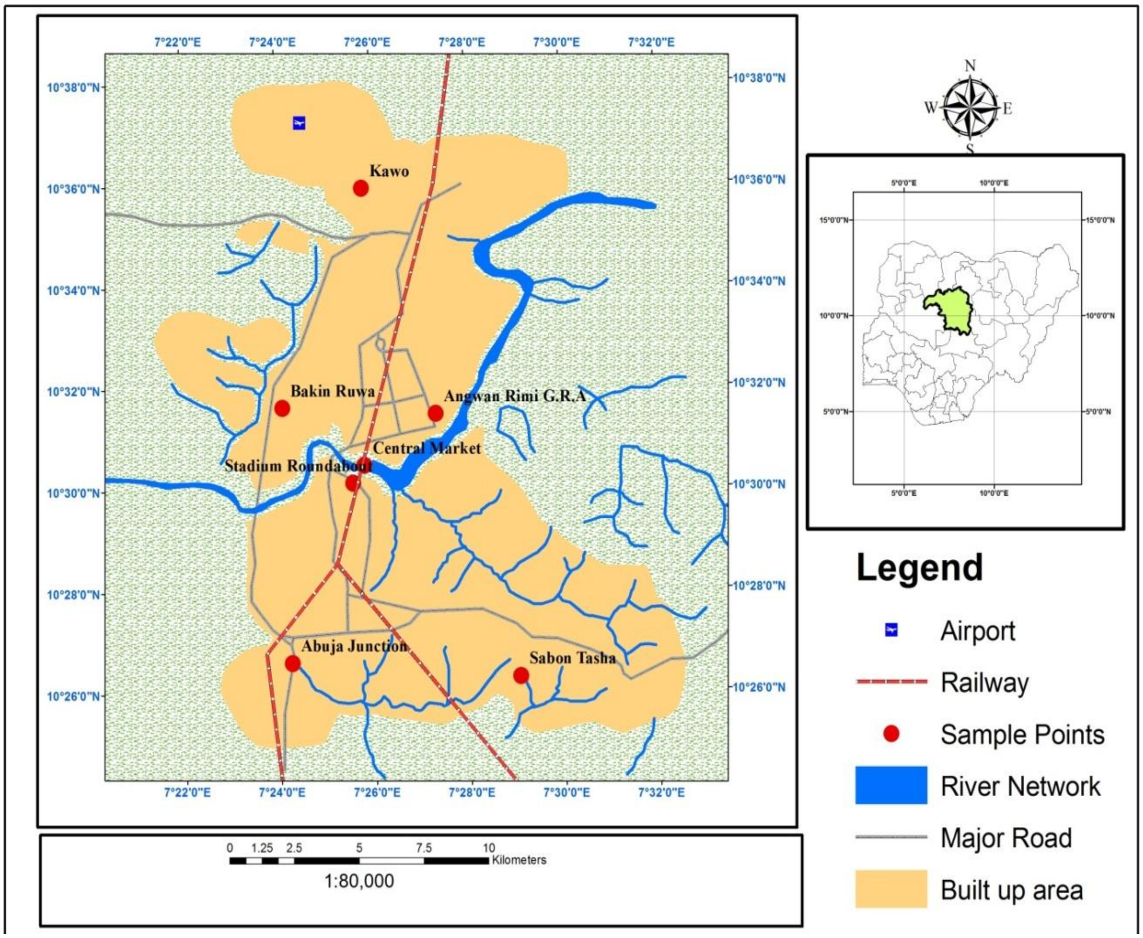

Figure 1.1: Map of study area

1.3 PROBLEM STATEMENT

The study is concerned with the two steps in the assessment of air quality impacts from road traffic, namely, traffic activity/performance and air pollutant emissions and in particular the role of congestion in the prediction of these emissions.

1.4 AIM AND OBJECTIVES

The research work is aimed at determining the impact of vehicular traffic emissions on ambient air quality in Kaduna metropolis.

The specific objectives of the study are thus:

1. To generate information through data collection on the spatial and temporal distribution of air quality in Kaduna metropolis
2. To identify ‘traffic hotspots’ in Kaduna metropolis through preliminary study of the sites
3. To compare monitored data at traffic spots with those from background (that is a distance of about 100 metres away from traffic)
4. To compare monitored air quality data obtained with Federal Air Quality Standards (FAQS)
5. To assess the ambient air quality using the Air Quality Index (AQI)

1.4 SCOPE

The extent of vehicular pollution of the ambient air in Nigeria is widespread and the effects are felt all around especially in the urban areas where traffic congestion has steadily been on the rise. The study focuses on six major locations in Kaduna metropolis with considerable level of traffic congestion. Residential areas were equally given consideration in this study with the realization that emissions are dispersed from regions of high concentrations to those of low concentrations.

1.5 JUSTIFICATION

Assessment of traffic performance and air pollutant emissions are essential for effective air quality management and policy making, which requires the identification, quantification, forecasting and control of all air pollutant emission sources. There are various purposes for which traffic emission information on links is required (Affum and Brown, 1999), for instance:

1. Evaluation of existing air quality control strategies (trend analysis, forecasting);
2. Assessment of effectiveness of alternative policy options (scenario testing);
3. Assessment of importance of road traffic to overall pollution (prioritization of sources);
4. Development (planning and design) of transport policies;
5. Identification of high-priority areas or locations with severe air pollution;
6. Forecasting of air pollution episodes; and
7. Assessment of urban air quality.

With Kaduna fast growing like other cities in Nigeria, this research work will go a long way in educating and enlightening the public, agencies of government and all stakeholders involved in the management and safeguarding of the environment on the need to do more to better the health and environment of its populace.

1.6 LIMITATIONS

Emissions travel and are dispersed in all directions from their original source. The non-availability of more than one air sampler for each of the gases was therefore one of the limitations to this study since it would have being more ideal to carry out the monitoring simultaneously in all four possible directions of travel of emission from the source.

The lack of stationary ambient air monitoring station in the state in general was equally a limiting factor in determining accurately whether or not weather conditions such as wind speed, wind direction as well as temperature did play a role in the quantity of emission recorded in space and time.

The lack of weather measuring instruments such as wind vane and wind anemometer was a huge limitation and the use of unconventional method of measuring and monitoring both the speed of the wind and its direction respectively had to be resorted to.

CHAPTER TWO

LITERATURE REVIEW

2.1 AIR POLLUTION

The atmosphere is one of our greatest resources. Ever since life began on earth, the atmosphere has been an important resource for chemical elements and a medium for the deposition of wastes. The movement of air across the earth's surface continually renews the air around us. Chemical pollutants can be thought of as compounds that are in the wrong place at the wrong time in the wrong concentrations (Mishra, 2008). Many industrial activities, and particularly energy generation, industrial production and vehicular traffic, have brought significant increase in the atmosphere contamination, in addition to the pollutants released from natural sources.

There are two main groups of air pollutants: primary and secondary. Primary pollutants are those that are emitted directly into the air, including particulates, sulphur dioxides, carbon monoxide, nitrogen dioxides and hydrocarbons. Secondary pollutants are those produced through reaction among primary pollutants and normal atmospheric compounds. Ozone is a secondary pollutant formed through photochemical reactions among primary pollutants and the natural atmospheric gases.

Unfortunately, pollutants are not evenly distributed. They are produced locally or regionally. It is useful to distinguish two major kinds of pollution sources – point and non-point sources. An example of a point source is a smokestack from a large power plant and an example of a non-point source is the exhaust from automobiles during rush hour in a city. The primary pollutants such as particulates, hydrocarbons, carbon monoxide, nitrogen oxides and sulphur oxides, account for more than 90 percent of air pollution problems in the developed countries (Mishra, 2008). An assessment of the potential for increased vehicular pollution requires some basic information relating to traffic volume and the intensity of pollutant emissions on road corridors. With respect to traffic volume, the critical factors will include population size, fuel consumption per capita and the proportion of the population that owns motor vehicles as well as annual average distances covered (Orubu, 2004).

2.2 GASES IN THE AIR

The atmosphere surrounding the earth is a mixture of gases. In some places, human activities have added other gases to the atmosphere, which are called pollutants. Most of these pollutant gases are produced by the burning of fuel in the combustion chamber of automobiles. The burning of fuels releases a large amount of carbon dioxide into the atmosphere. This is thought to cause global warming. Other pollutant gases which are released into the air when fuels are burned include carbon monoxide, sulphur dioxide and nitrogen dioxide. The incomplete combustion of fuels also releases small particles of solids, such as carbon into the air. This particles and gases released, inadvertently raises the concentration of these gases above what it should be in clean dry air. The rise in the concentration of these gases in the atmosphere play major roles in impacting on health of humans, animals, plants, structures and on the environment in totality. Carbon monoxide for instance, is toxic and can lead to death. Other pollutants are harmful to the environment, so cause harm to humans indirectly. For example, sulphur dioxide causes acid rain which can damage or kill trees and crops. The main gases in the atmosphere and their approximate percentages in dry air according to David and Frederikse, 1997 are as shown in Table 2.1.

Table 2.1: Composition of air in percent by volume at sea level at 15 ^{O}C and 101325 pa according to David and Frederikse, 1997.

Gases	Symbols	Percentage composition in air
Nitrogen	N_2	78.084% (780840ppm)
Oxygen	O_2	20.9476% (209476ppm)
Argon	Ar	0.934% (9340ppm)
Carbon Dioxide	CO_2	0.0314% (314ppm)
Neon	Ne	0.001818% (18.81ppm)
Methane	CH_4	0.0002% (2ppm)
Helium	He	0.000524% (5.24ppm)
Krypton	Kr	0.000114% (1.14ppm)
Hydrogen	H_2	0.00005% (0.5ppm)
Xenon	Xe	0.0000087% (0.087ppm)
Ozone	O_3	0.000007% (0.07ppm)
Nitrogen Dioxide	NO_2	0.000002% (0.02ppm)
Iodine	I_2	0.000001% (0.01ppm)
Carbon Monoxide	CO	Trace
Ammonia	NH_3	Trace

2.3 AIR QUALITY INDEX (AQI)

AQI is an index for reporting daily air quality in the United States (USEPA, 2003). It gives information on how clean or polluted the air is, and what associated health effects might be of concern for individuals. The AQI focuses on health effects individuals may experience within a few hours or days after breathing polluted air. The Environmental Protection Agency (EPA) of the U.S calculates the AQI for five major air pollutants regulated by the

Clean Air Act: ground level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulphur dioxide and nitrogen dioxide. For each of these, USEPA established national air quality standards to protect public health.

The AQI runs on a yardstick of 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 300 represents hazardous air quality (USEPA, 2003)

Table 2.2 shows the air quality index values and the levels of health concern according to USEPA (2003).

Table 2.2: Air quality index values and levels of health concerns

When the AQI is in this range:	air quality conditions are:
0 – 50	Good
51 – 100	Moderate
101 – 150	Unhealthy for sensitive group
151 – 200	Unhealthy
201 – 300	Very unhealthy
301 – 500	Hazardous

Each category corresponds to different level of health concern. The six levels of health concern according to USEPA and what they mean are:

“Good” The AQI is between 0 and 50. Air quality is considered satisfactory, and air pollution poses little or no risk.

“Moderate” The AQI is between 51 and 100. Air quality is acceptable, however, for some pollutants; there may be a moderate health concern for a small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.

“Unhealthy for sensitive groups” When AQI values are between 101 and 150, members of sensitive groups may experience health effects. This means they are likely to be affected at lower levels than the general public. For example, people with lung disease are at greater risk from exposure to particle pollution. The general public is more likely to be affected when the AQI is in this range.

“Unhealthy” Everyone may begin to experience health effects when AQI values are between 151 and 200. Members of sensitive groups may experience more serious health effects.

“Very unhealthy” AQI values between 201 and 300 trigger a health alert, meaning everyone may experience more serious health effects.

“Hazardous” AQI values over 300 trigger health warnings of emergency conditions. The entire population is more likely to be affected.

A summary of the interpretation of the AQI values according to USEPA (2003) are as presented in Table 2.3.

Table 2.3: Interpretations of the AQI values classification

Index Values	AQI Category	AQI Rating	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)
0 – 50	Good	A	0 – 4.4	0 – 0.053	0 – 0.035
51 – 100	Moderate	B	4.5 – 9.4	0.054 – 0.1	0.036– 0.075
101 – 150	Unhealthy for sensitive groups	C	9.5 – 12.4	0.101 – 0.36	0.076– 0.185
151 – 200	Unhealthy	D	12.5 – 15.4	0.361 – 0.64	0.186 – 0.304
201 – 300	Very unhealthy	E	15.5 – 30.4	0.65 – 1.24	0.305 – 0.604
301 – 500	Hazardous	F	30.5- 50.4	1.25 – 2.04	0.605 – 1.004

AQI values can vary from one season to another. In winter, for example, carbon monoxide may be high in some areas because the cold winter makes it difficult for car emissions control systems to operate effectively. In summer, ozone may be a significant air pollutant because it forms in the presence of heat and sunlight. Particle pollution can be elevated at any time of the year.

AQI values can also vary depending on the time of the day. For example, ozone levels often peak in the afternoon, while carbon monoxide is usually a problem during morning or evening rush hours. Particle pollution can be high at any time of the day (USEPA, 2003).

2.4 AIR POLLUTANTS AND THEIR EFFECTS

Air pollution is a basic problem in today's world. Exposure to ambient air pollution has been linked to a number of different health outcomes, starting from modest transient changes in the respiratory tract and impaired pulmonary function, continuing to restricted activity/reduced performance, emergency room visits and hospital admission and to mortality. There is also increasing evidence of adverse effects of air pollution not only on the respiratory system, but also on the cardiovascular system (WHO, 2004).

Physical damage functions relating health (mortality and morbidity) to air pollution levels have been estimated over a number of years in different countries. Although the net effect of pollutants on health is unclear, the Committee of the Medical Effects of Air Pollution (COMEAP), set up by the United Kingdom government has found the strongest link between health and pollution to be for particulates (PM_{10}), sulphur dioxide (SO_2) and Ozone (O_3) (Powe and Willisc, 2002).

Cars, trucks, motorcycles, scooters and buses emit significant quantities of carbon monoxide, hydrocarbons, nitrogen oxides and fine particles. Where leaded gasoline is used, vehicles are also a significant source of lead in urban air. The adverse health and environmental consequences resulting from these pollutants are summarized below:

(i) Particulate matter:

Particulate matter (PM) represent a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplet or solids) over a wide range of sizes.

Particle matter may be emitted directly into the atmosphere or may be formed by transformation of gaseous emissions such as sulphur dioxide, nitrogen oxides and volatile organic compounds (VOCs). Some particulate matter occurs naturally originating from volcanoes, dust storm, forest and grass land fires, and sea spray. Particulate matter is a core emission by automobile especially diesel engine vehicles.

Vehicular emission is connected to two types of particulate matter, the fine particulate matter ($PM_{2.5}$) and the coarse particular (PM_{10}). $PM_{2.5}$ consist of particles less than one-tenth the diameter of human hair and poses the most serious threat to human health (Ronni, 2012). The size of particle is directly linked to their potential for causing health problems. Particles that are ten micrometer (PM_{10}) in diameter generally pass through the nose into the lungs. Once inhaled these particles can affect the health and lungs and cause serious health effect. Particles less than 2.5 micrometers in diameter are termed "fine particle or $PM_{2.5}$ as mentioned before, they are so small that they can be inhaled deeper into the lungs than the PM_{10}, hence it causes more health problem than PM_{10} (Walsh, 2002).

(ii) Carbon monoxide:

Motor vehicles significantly contribute to ambient carbon monoxide (CO) concentrations. Although CO emissions from motor vehicles have declined through emission control technologies and regulations in many countries, motor vehicles remain the primary source of this pollutant in most locations. All motor vehicles emit CO, but the majority of CO emitted from this source occurs from light-duty, gasoline-powered vehicles. In addition to health concerns from CO exposures, CO may be a useful indicator of the transport and dispersion of inert, primary combustion emissions from traffic sources since CO does not react in the near-road environment (Baldauf *et al*., 2009).

(iii) Oxides of nitrogen

NOx represents the sum of the various nitrogen gases found in the air, of which Nitric oxide (NO) and Nitrogen dioxide (NO_2) are the dominant form. The emission sources are varied but tend to result from high temperature combustion of fuel for industrial activities and residential heating, and vehicle use.

Motor vehicles also significantly contribute to ambient nitrogen oxides (NOx) emissions in most countries. Although all motor vehicles emit NOx, the majority of on-road emissions occur from diesel vehicles. In terms of primary emissions, the majority of NOx exhaust is in the form of nitrogen oxide (NO). Nitrogen dioxide (NO_2), which is the focus of concern in terms of adverse health effects, quickly forms by a photochemical reaction in the ambient air in the presence of NO and ozone (O_3). However, primary NOx emissions from more technologically advanced heavy-duty diesel engines with after treatment devices may contain a much greater percentage of NO_2 in exhaust emissions. Thus, NO and NO_2 will be present in varying concentrations in the near-road microenvironment (Baldauf *et al*., 2009).

NOx causes severe respiratory problems, especially in children. When combined with water, it forms nitric acid and other toxic nitrates. NO_2 is a main component in the formation of ozone at ground level. The gas irritates the lungs and has been known to lower the immune system (Wai and Steven, 2007).

(iv) Sulfur dioxide

Although motor vehicles emit sulfur dioxide (SO_2) and other sulfur-containing compounds, traffic sources typically make only small contributions to ambient concentrations. In addition, the introduction of low-sulfur fuels in most countries should further reduce SO_2 emissions. Therefore, this pollutant is not commonly monitored in near-road applications. However, the monitoring of SO_2 may be useful near other types of transportation facilities, such as airports, railway yards, and seaports, as sources at these locations may still burn high sulfur fuels. In addition, it may be useful to measure this pollutant (or other sulfur-containing compounds) in specific situations to identify the influence of other sources at the monitoring site, such as power generation or ship emissions (Baldauf *et al*., 2009).

The gas irritates airways and eyes and is known to cause longer-term heart diseases, other cardiovascular ailments, and bronchitis. It also readily causes shortness of breath and coughing amongst asthma sufferers. SO_2 is also a major contributor to acid rain, which damages the environment and upsets the ecosystem (Wai and Steven, 2007).

(v) Ozone:

Ozone is not directly emitted from motor vehicles, and O_3 measurements are not typically collected for near road applications. However, the presence of elevated NO concentrations in the near-road microenvironment may lead to lower concentrations due to "ozone scavenging" as part of the formation of NO_2 from NO and O_3. Thus, O_3 measurements may be useful under select circumstances as support for health studies investigating the role of O_3 and other co-pollutants on adversely affecting public health given the potentially lower concentrations of this pollutant relative to other pollutants in this microenvironment (Baldauf *et al*., 2009).

(vi) Lead:

Before the introduction of unleaded gasoline in most countries of the world, motor vehicle lead (Pb) emissions were a major public health concern. While Pb is no longer added to gasoline in many countries, motor vehicle fuels still contain trace amounts of Pb from crude oil. Lead is also present in trace amounts in lubricating oil. Other sources that may contribute to ambient Pb concentrations in the near-road environment include brake wear, tire wear, and the degradation of wheel weights used for aftermarket tire balancing. Re-suspended road dust may also contain Pb from historically deposited industrial or mobile source emissions (Baldauf *et al*., 2009).

(vii) Hydrocarbon:

These are otherwise known as Volatile Organic Compounds (VOC). They are essentially fuel which was unburnt during combustion process or which has escaped into the atmosphere through fuel evaporation. Hydrocarbons can often be divided into separate categories of methane (CH_4) and non-methane (NMVOCs). Vehicles are also a major source of atmospheric hydrocarbons. Stationary sources of hydrocarbons include petrochemical manufacture, oil refining, incomplete incineration, paint manufacture and use, and dry cleaning (Mishra, 2008). Methane is a greenhouse gas and has prominent role in global warming even though majority of gaseous pollutants are inhaled and may affect respiratory system. They can also induce hematological (blood-related) problems (Baldauf *et al*., 2009).

(viii) Carbon dioxide:

Carbon dioxide, methane, and gas molecules that have similar structures may influence the global climate by internal molecular vibration and rotation which cause these molecules to absorb infrared radiation. When these gases form part of the atmosphere, they absorb some of the heat that the earth normally radiates into space (Pierce *et al*., 1998). Carbon dioxide is a "greenhouse gas" which is a major player in global warming.

2.5 GLOBAL WARMING

Global warming is acknowledged to be one of the most critical environmental problems facing human kind. The earth's atmosphere is composed of gases that form a protective blanket around the planets, maintaining equilibrium of heat reaching the earth from the sun and heat radiating from earth back into space. This insulating blanket keeps the temperature above the earth's surface at a comfortable level for human existence. The average global temperature is 15^{o}C above what it would be without the greenhouse gases (Murray 1992).

The primary greenhouse gases that occur naturally in the atmosphere are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) water vapour and ozone. Carbon dioxide is the least radiative of the gases, yet because it is the most prevalent and persists in the atmosphere for many years, it is considered to be the most important. Methane, in contrast, absorbs more heat but has a shorter atmospheric life. Climatologists have attempted to come up with a common unit of measurement with which to compare the radiative effects of the various gases. They have calculated the "global warming potentials" (GWPs) of each of the gases by assessing the combined effect of its absorption efficiency, indirect effects and atmospheric life time in order to have a single unit for assessing and comparing the collective effects of the greenhouse gases from various sources (Victor 1990).

An atmospheric monitoring station data analysis from the summit of Mauna Loa, Hawaii in 1956 for the International Geo physical year in 1957 confirmed scientists' concerns that atmospheric concentration of CO_2 and the greenhouse gases were steadily increasing (Boyle and Ardill 1989). Carbon dioxide concentration that were recorded to be 315 parts per million (ppm) in 1958, for example, had increased to 350ppm by 1988, an 11% increase (Gribbon, 1990). Human activities such as fossil, fuel combustion, industrial chemical production and deforestation have over the past century augmented the flows of natural greenhouse gases – carbon dioxide, nitrous oxide, methane and ozone – and have added new ones, the chlorofluorocarbons (CFCs), which are by the most potent. The total global warming potential increase resulting from human activities over the past one hundred years is equivalent to a 50% increase in atmospheric CO_2 concentrations (Jastrow, *et al.* 1990).

Due to the longevity of the Green House Gases (GHGs), ranging up to 200 years, the excess flows are increasing atmospheric GHG concentrations. In other words, the effect of CO_2 emissions being released today is virtually irreversible since the molecules will still have a radiative warming effect many years from now (Murray, 1992).

2.6 MOTOR VEHICLE EMISSIONS AND LOCAL AMBIENT AIR QUALITY

Human health is degraded by air pollution, and transportation contributes to air pollution. However, the interaction between transportation and human health costs is somewhat straightforward. Fossil fuel use in transportation produces "local" pollutant emissions – lead, Particulate Matter (PM), Nitrous Oxides (NOx), Sulphur Oxides (SOx), Volatile

Organic Compounds (VOCs), Carbon Monoxide (CO) and toxins – but the kinds of pollutants produced and in what proportions and concentrations varies significantly based on a number of factors, including the vehicle and fuel used and the driving conditions of a particular trip. These emissions are dispersed into the ambient air according to atmospheric conditions, which also influence the extent to which they react to form secondary pollutants. People may be exposed to these primary or secondary pollutants depending on what kinds of activities they engage in and where, and also where the highest concentrations of pollutants tend to be in a metropolitan area (Mishra, 2008).

The relative dose of the pollutants that individuals receive depends on their own physiological conditions during exposure, and responses to doses can vary from person to person. Many different pollutants are capable of causing damage to human health, but only some of these are regulated. These pollutants are sometimes called "criteria" pollutants in that monitored levels can constitute criteria that trigger regulatory responses. For many of these pollutant categories, certain variants of the pollutant species can be more damaging to human health than others hence the pollutant to be regulated more stringently becomes a debate. Table 2.4 shows the Nigerian National Ambient Air Quality approved Standards by the Federal Ministry of Environment according to Nwachukwu *et al*., (2012).

Table 2.4: Nigerian National Ambient Air Quality (NAAQ) Standards according to Nwachukwu *et al.*, (2012)

Pollutants	Averaging time	Limits
Particulates	1 hour	250µg/m^3
Sulphur dioxide (SO_2)	1 hour	0.01ppm
	24 hours	0.1 ppm
Nitrogen dioxide (NO_2)	1 hour	0.04 ppm
	24 hours	0.06 ppm
Carbon monoxide (CO)	1 hour	10ppm
	8 hours	20ppm
Hydrocarbon	3 hours	0.6ppm
Photochemical oxidants	1 hour	0.06ppm

2.6 VEHICULAR TRAFFIC EMISSIONS

Vehicles no doubt are important assets in the socio-economic development of a nation. They are used to transport goods, services and people from one place to another. The mode of transportation in Nigeria is largely by road, air, rail and water transport in the coastal areas. The fleet of road vehicles, no doubt has steadily increased in Nigeria, the implication of which is the increased fuel consumption.

With the rise in vehicle ownership, however, emissions from these vehicles remain a threat to the environment. Over 600 million people globally are exposed to hazardous level of traffic-generated pollutants (UN, 1998). Human exposure to these air pollutants due to traffic is believed to have constituted severe health problems especially in urban areas where pollution levels are on the increase. Worldwide, cars, trucks, buses, and other motor vehicles continue to play a dominant role in causing air pollution. They are major sources of volatile organic compounds (VOCs) and nitrogen oxides, the precursors to both tropospheric ozone and acid rain; carbon monoxide (CO); toxic air pollutants such as diesel particulate; and chlorofluorocarbons (CFCs).

In the European Union as a whole, on and off road vehicles is the largest source of CO, NOx and non-methane hydrocarbons (ECMT, 2000). Prior to the adoption of the Euro 3/4 requirements, forecasts indicated that vehicles would remain a major emissions source out to 2010. In densely populated urban areas, vehicles can be a major source of exposure to particulates as well. Currently, road vehicles account for 74% of nitrogen oxides and 94% of black smoke emissions in London. On their own, diesels account for 32% and 87% of total emissions (43% and 92% of vehicle emissions) for these two pollutants respectively (ECMT, 2000).

Motor vehicles are also major emissions sources in the United States and Japan. In the densely populated North-eastern United States where the air pollution problem is especially severe, the Environment Protection Agency (EPA) has projected that highway vehicles will account for approximately 38% of the total NOx inventory and 22% of the total VOC inventory in 2005, in spite of the introduction of tighter motor vehicle standards in the 1990 Clean Air Act (ECMT, 2000).

Pollution due to traffic constitute up to 90 – 95% of the ambient CO levels, 80 – 90% of NOx, hydrocarbon and particulate matter in the world, posing a serious threat to human health (Savile, 1993). Research conducted almost two decades ago has shown that transportation sources in the USA were responsible for 77% of CO levels, 80-90% of NOx, 36% of volatile organic compounds and 22% of particulate matter (USEPA, 1993).

Similarly, in UK the average concentration of NO_2 was found to increase by 35% from 1986 to 1991 due to increase in vehicular emission (CEC, 1992).

Motor vehicles produce more air pollution than any other single human activity (WRI, 1997). Nearly 50 % of global CO, hydrocarbons (HCs) and NO_2 emissions from fossil fuel combustion come from petrol and diesel engines. In city centres and congested streets, traffic can be responsible for 80-90 % of these pollutants and this situation is particularly severe in cities in developing countries (Whitelegg and Haq, 2003). Vehicle emissions mainly result from fuel combustion or evaporation. The most common types of transport fuels are gasoline (in leaded or unleaded form) for light-duty vehicles (such as cars) and diesel fuel for heavy-duty vehicles (such as buses and trucks). Other commercial fuels used in light-duty vehicles include alcohols (such as ethanol and methanol), gasoline-alcohol mixtures, compressed natural gas (CNG), and liquefied petroleum gas (LPG). For heavy-duty vehicles other commercially available fuels include gasoline, CNG, and LPG. Emissions from motor vehicles with spark ignition engines (for example, gasoline fueled vehicles) are from the exhaust, engine crankcase, and fuel system (carburetor, fuel line, and fuel tank). CO_2 and water vapor (H_2O), the main products of combustion, are emitted in vehicle exhaust (Onursal and Gautam, 1997).

The major pollutants emitted from gasoline fueled vehicles are CO, HCs, NOx, and lead (Pb) (only for leaded gasoline fuel), whereas the presence of sulfur compounds in diesel fuel results in sulphur dioxide (SO_2) and PM emissions from the exhaust of diesel-fueled vehicles. Metal sulfates and sulfuric acid in the form of PM constitute 1 to 3 % sulfur emissions from heavy-duty diesel-fueled vehicles and 3 to 5 % of sulfur emissions from light-duty diesel fueled vehicles. They also account for about 10 % of 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.

2.6.1 Vehicular Traffic Emission in Developing Countries

In most developing countries of the world vehicular growth has not been checked properly by environmental regulating authorities leading to increased levels of pollution. Traffic emissions contribute about 50 - 80% of NO_2 and CO concentration in developing countries (Fu, 2001; Goyal, 2006). This situation is alarming and is predicated on the poor economic disposition of developing countries. Poor vehicle maintenance culture and importation of old vehicles which culminate to an automobile fleet dominated by a class of vehicles known as ''super emitters'' with high emission of harmful pollutants, has raised this figure of emission concentration. Furthermore, in developing countries the super emitters contribute about 50% of harmful emissions to the entire average emission (Brunekreef, 2005).

In Mexico City for example these supper emitters is reported to be responsible for 90% of hydrocarbon and CO emissions and 80% of NOx emission accounting for 60% of the kilometers travelled in the country (OECD, 1999). The increase in this traffic-related pollution is not based on the aforementioned factors only, but also on low quality fuel, poor traffic regulation and lack of air quality implementation force. These are clear indices to high levels of traffic-related pollution in developing countries.

The UNFPA, (2008) reports show that the world urban population reached 50% in 2008 and is projected to increase to 60% by 2030. This increase will have a back effect in developing countries where 80% of the urban population will be living in 2030. The rise in urban population will have a geometrical effect in the increased number of motorized vehicles in cities by 2050, aggravating the hazard even in countries with overall low motorization rates (World Bank, 2004). Statistics in China show that the concentrations of particulate and other traffic-related Pollutants, in China cities are six times higher than WHO recommended baseline. The ratio of person to vehicle in China is 8 vehicles per 100 persons compared to 750 vehicles per 100 persons in the USA (Faiz and Sturm, 2000).

2.6.2 Vehicular Traffic Emissions in Nigerian Cities

In Nigeria much attention is given on general industrial pollution and pollution in oil industries, with little reference on damage of pollution caused by mobile transportation sources of air pollution (Faboye, 1997; Iyoha, 2000; Orubu et al, 2002; Magbabeola, 2001). In other studies, only casual references are made to the gravity of the problem of pollution from mobile transportation sources (World Bank, 1995; Garba and Garba, 2001). The situation of increased pollution from mobile transportation source is on the increase in per capital vehicle ownership, thus resulting to high congestion on Nigeria city road and increase in the concentration of pollutants in the air, consequently increasing health risk on human population.

Studies conducted in Kaduna and Abuja cities show higher values of CO_2 concentration in heavily congested areas: 1840ppm for Sabo Kaduna, 1780ppm for Stadium round-about, Kaduna, and 1530ppm for *A.Y.A*, Abuja, and 1160ppm for Asokoro Abuja, (Akpan and Ndoke, 1999).

A similar work by Ndoke and Jimoh (2000) at Minna, a city in Nigeria shows the maximum value of 5,000ppm for CO_2 in congested areas, which was still lower than WHO stipulated maximum value of 20,000ppm. The maximum value for CO emission obtained was 15ppm which is also still lower than the base line of 48ppm stipulated by WHO and 20ppm stipulated by Federal Environmental Protection Agency of Nigeria (FEPA, 1991). The reason for this low emission concentration in Minna is due to low traffic and industrial activities in the city.

A study of the impacts of urban road transportation on the ambient air was conducted by Koku and Osuntogun, (2007) in three cities of Nigeria: Lagos, Ibadan and Ado – Ekiti all in South-west region of Nigeria. Air quality indicators namely CO, SO_2, NO_2, and total suspended particulates (TSP) were determined. The highest levels obtained for the air pollution indicators in Lagos were CO-233ppm at Idumota, SO_2-2.9ppm at Idumota, and NO_2-1.5ppm at Iyana-Ipaja. At Ibadan, the CO and SO_2 levels at 271 and 1.44ppm were highest at Mokola round-about while NO_2 at 1.0ppm was highest at Bere round-about. In Ado-Ekiti the highest level obtained were CO-317ppm at Oke Isha, NO_2-0.6ppm at Ijigbo Junction and SO_2-0.8ppm at Old Garage Junction. The obtained results of CO, SO_2, NO_2, and particulate counts per minute were found by Koku and Osuntogun (2007), to be higher than FEPA limits. Limits set also by FEPA are CO-10ppm, SO_2-0.01ppm, NO_2-0.04 - 0.06ppm. Conclusions of this investigation show a growing risk of traffic-related problems in Nigeria cities and demand for serious air quality measures.

A comparative study of emission figures in Lagos and two Niger Delta (Oil producing region) cities of Port Harcourt and Warri reported by Jerome (2000) indicates that the concentrations of TSP (Total suspended particulates), NOx, SO_2, and CO in Lagos and Niger Delta were above FEPA recommended limit. Concentration of CO emissions for Lagos is quite high, being in the range of 10 – 250ppm, as against the ranges of 5.0 – 61.0ppm and 1.0 – 52ppm recorded for oil communities of Port Harcourt and Warri respectively in the Niger Delta.

Similarly, a survey conducted by Abam and Unachukwu (2009) in Calabar revealed a rise in the concentration of NO_2 and SO_2 especially at highly congested traffic points. When assessed using Air Quality Index, the concentration of SO_2 ranged between 0.04ppm to 0.15ppm (poor to very poor). Similarly, NO_2 ranged from poor to very poor at concentrations of between 0.02ppm – 0.09ppm. Concentrations of other pollutants (CO, PM_{10} and noise) were poor. The study concluded that transport-related pollution in Calabar is indeed significant with possible severe health consequences.

Utang and Peterside (2011), in a study which estimated the emissions of pollutants from vehicles within Port Harcourt city, averred that the concentrations of CO detected during peak periods of traffic was higher than the Federal Environmental Protection Agency limits and the recommended municipal (local) standard. Similarly the concentration of NOx was above local and international standards in all the locations during peak traffic periods.

Asheshi (2012) measuring traffic emissions (CO, NO_2 and particulate matter concentration) at three different sites in Lafia metropolis of Nasarawa state, reported that at high traffic level, the concentration of carbon monoxide reached as high as 12ppm.

A similar study on assessment of automobile induced pollution in an urban area" by Okonkwo et al. (2012) in Port Harcourt city, Rivers State focused on four pollutants: carbon monoxide, sulphur dioxide, nitrogen dioxide and hydrocarbon. Results indicated that the highest carbon monoxide concentration measured was 46ppm, SO_2 at 0.08ppm, NO_2 at 0.09ppm and HC at 0.61ppm.

All these evidences from works carried out by researchers and scholars tend to indicate that vehicular emissions in Nigerian cities are on the rise. A long term study is however required to authenticate this.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 MATERIALS

3.1.1: Equipment and Field Materials

The equipment used in obtaining data for this study was sourced from Kaduna Environmental Protection Authority (KEPA) in Kaduna. The equipment are as follows:

1. **Air samplers** (CROWNCON GASMAN TO MODEL CE89/336/EEC) for CO, NO_2, SO_2 and HC measurement: It is an automatic ambient air measuring instrument. It uses infrared sensing technology.

2. **CO_2 meter** (MODEL EE80): It works based on the principle of infrared sensing technology. It was equally used to measure temperature and relative humidity in the course of the survey. It measures carbon dioxide within the range of 0 - 4000ppm. It boasts of a resolution of 1ppm and an accuracy of +/- 40ppm. It measures temperature in the range of -20^{o}C to 60^{o}C and relative humidity range of 10 – 95%RH.

3. **Digital camera (**SAMSUNG 100): This was used to show pictorially the characteristics of the study sites.

4. **Global Positioning System (GPS) Receiver** (Garmin model 60 CSx): This was used to determine the exact coordinates of the sampling sites. The elevation of the sites above sea level was also determined with the aid of the GPS receiver.

Nokia N8 mobile handset with in-built GPRS was used to monitor the wind speed at the sites. The wind direction was determined by visual observation of the smoke particles released from the tailpipe of moving vehicles. The direction of the particles emitted determined the position assumed when taking emission readings.

3.2 Method

3.2.1 Domain of Inquiry and Definitions

In this project, the subjects that were studied specifically were the sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), hydrocarbon (HC) and carbon dioxide (CO_2) at ground level in relation to traffic. For this project, ground level was defined as five (5) feet above the ground at intersections within the city. The height of five feet was chosen because it best represents the height of breathing of people, whether standing or seating. Traffic "hot spots" are defined as intersections/roads with high vehicular levels. As part of the objective of the study to form a basis of comparison of traffic levels in the so-called "hot spots" and "background" (about 100 metres away from traffic), air quality measurements from "background" were equally carried out. Measurement at a "control site" was carried out. A control site in this context is an area adjudged free from significant impact of traffic/vehicular emission.

3.2.2 Spatial and Temporal Coverage

The areas in Kaduna metropolis on which the study focused include: Kawo, Central market, Stadium Junction, Sabon Tasha, Abuja Junction and Bakin-Ruwa Junction. From all these locations, "background" measurements were carried out. A Government Residential Area at Angwa Rimi G.R.A was selected as "control site". The collection of information was conducted in two phases. The first phase conducted in the dry season spanned from 15th December 2012 to 6th February 2013. The second phase on the other hand was conducted in the wet season between 17th June 2013 and 2nd July 2013. In both seasons, monitoring was conducted on a daily basis though not on consecutive days in the sites due to the long distance between the sites. For convenience, therefore, three sites were monitored daily in most cases and two sites on few occasions.

The time blocks chosen covered expected periods of high traffic ("rush hour" – 7:30am - 9:00am) as well as expected periods of low traffic (11:30am - 1:00pm) and again in the evening (3:45pm – 5:15pm). At least three measurements were carried out at each sampling site.

3.2.3 Determination of Traffic Levels

The number and types of vehicles that travelled through certain intersections in a given time period were counted. All types of vehicles were counted and recorded according to their traffic movement. The type of intersection determined the amount of persons conducting the traffic counts. For a four way intersection, four persons recorded the traffic flow. Each person was responsible for only one directional flow of traffic in order to reduce the probability of human error. The persons were positioned at the corners of the intersection and counted the traffic approaching from their left. All traffic counted was categorized by the type of vehicle. The categories were as follows:

i. Motorcycles/Tricycles
ii. Cars/Buses
iii. Trucks/Lorries

The traffic density was determined by directly observing and counting the vehicles during the morning (8:00am – 9:00am), afternoon (12:00pm – 1:00pm) and evening hours

(4:00pm – 5:00pm) for each day. This was done three times daily for all the sites and the average volume of traffic at each site per hour was calculated.

3.2.4 Determination of Correlation between Traffic Levels and Air Quality.

In order to establish an association or relationship between air pollution and traffic emissions, the collected data was analyzed extensively. There were three logical steps taken to ascertain this connection. First, traffic level information was analyzed. Second, air quality data was analyzed, and finally, pattern in the two sets of information were identified.

Once the traffic and air quality data were analyzed, the correlation between the two sets of information was identified. In order to establish a connection between traffic counts and air pollution, the relationship between high traffic and pollutants concentration was explored. Using the Statistical Package for Social Scientists (SPSS), the pollutants concentrations were graphed versus traffic counts in order to demonstrate a correlation between the two sets of data.

3.2.5 Relationship between Concentration of Emission at Source, Receptor and Distance from Emission Source.

The interrelationship between concentration at a sources location (C_S), concentration at a receptor location (C_R) and distance (D) from the source of the emission was established based on the fact that pollutant concentration will decrease with increasing distance from the source of the pollution. Concentration of pollutant emission at a receptor location is directly proportional to the concentration released at source and inversely proportional to the distance from the source.

$$C_R \; \alpha \; \frac{C_S}{D} \qquad 3.1$$

$$C_R = \frac{K * C_S}{D} \qquad 3.2$$

Where C_R is the concentration of pollutant at a receptor location (background) in ppm,

C_S is the pollutant concentration released from the source of the emission in ppm,

D is the reception distance from the emission source in metres,

K is a constant of proportionality.

Taking logarithm of both sides of the equation:

$$\text{Log } C_R = \text{Log k} + \text{Log } \frac{C_S}{D} \qquad 3.3$$

A plot therefore of Log C_R against Log $\frac{C_S}{D}$ produces a straight line graph whose slope gives the value of Log k. The antilog of which gives the value of the constant, k.

3.3 Characteristics of Study Sites

The sites selected for investigation are located in Kawo, Central Market area, Stadium Roundabout, Sabon Tasha and Bakin Ruwa all in Kaduna metropolis.

(a) Kawo

Kawo is located on latitude 10^o 30’ 55.8” N and longitude 07^o 25’ 49.1” E. It is at an elevation of 614m above sea level (a.s.l). It forms the entry and exit point into Kaduna city mostly for those coming from and going to the north-western part of the country. This points out the fact that vehicular movement in and around Kawo area is usually high. Kawo is notable for the presence of the “overhead” bridge which to a large extent has helped in solving the gridlock in the area. To a relatively large extent, it boasts of high commercial activities ranging from market to retail shops, motor parks and banks; the presence of military formations are not left out with the presence of army and police barracks. All these, no doubt, contribute to the problem of traffic congestion and hence possible air pollution. Plate 1 shows the site characteristics of Kawo at the entrance to Kaduna.

Plate 1: Site Characteristics of Kawo

(b) Central Market (Sheik Gumi Market)

The central market area is located on latitude 10^{o} 30' 28" N and longitude 07^{o} 25' 49" E. It is at an elevation of 606m above sea level. The central market area, no doubt, forms one of the busiest parts of Kaduna city. Located along the ever busy Ahmadu Bello way, and surrounded by other major roads like the Kano road, Ibrahim Taiwo road as well as other minor streets like the Lagos street which has its linkage with both Kano road and Ibrahim Taiwo road. There is also Benin street cutting through Ibrahim Taiwo road and Kano road and down towards Jos road and Katsina road. Some of these streets boast of presence of banks and high level commercial activities, hence vehicular movement in and around the areas are usually high. The presence of motor parks is not left out notable among them is the Sheik Gumi park. The area also boasts of residential settlements. Plate 2 shows the site characteristics of Central market area.

Plate 2: Site Characteristics of Central Market Area

(c) Stadium Roundabout

It is located at latitude 10^{o} 30’ 07” N and longitude 07^{o} 25’ 34.5” E and at an elevation of 587m above sea level. The area is characterized by the presence of quite a number of high rise buildings along the Ahmadu Bello way and the Constitution road. It also forms the intersection between the junction road, the constitution road and the Ahmadu Bello way.

The junction road takes traffic from the north and city centre to the south and vice versa. The constitution road forms a major link to most residential settlements around Angwa-

Rimi, Malali and most government establishments, as well as schools and other commercial outfits.

Therefore, vehicular movement from the city center to Kaduna South and vice versa, most often, converge traffic at the roundabout causing traffic “gridlock”. This problem has been reduced to some degree with the construction of a by-pass linking the areas around Malali and Angwa-Rimi to Tamazo in Kaduna South (around the refinery). Plate 3 shows the site characteristics around Stadium Roundabout.

Plate 3: Site Characteristics of Stadium Roundabout Area

(d) Sabon Tasha

Sabon Tasha is known for its high population density as well being the transit route to the only petroleum refinery in the northern part of Nigeria. So, it is normal to expect high movement of heavy-duty automobiles in and out of Kaduna in the area. Sabo is located at a latitude of 10^{o} 26’ 17” N and a longitude of 07^{o} 29’ 04” E and at an elevation of 582m above sea level.

The traffic level is also boasted by the presence of the Sabo market, the major market in the south of Kaduna city. And with the market and motor parks located some few metres away from the highway, one would expect some level of traffic gridlock in and around the area. Sabon Tasha is also characterized by the presence of schools, retail shops, banks and other commercial activities. Plate 4 shows the site characteristics of Sabon Tasha.

Plate 4: Site Characteristics of Sabon Tasha

(e) Abuja Junction

The Abuja junction is the main gateway into Kaduna city from the southern part of the Nigeria as well as the main exit from the city. It is located on latitude 10^{o} 26’ 35.0” N and longitude 07^{o} 24’ 15.1” E and at an elevation of 697m above sea level.

It is characterized by a well-constructed overhead bridge that has effectively diffused traffic from the city centre through the by-pass to Kawo and to the northern part of the country as well as to other parts of the city. The presence of the bridge no doubt has helped in keeping traffic at its lowest ebb. Though little commercial activities take place in the area, it boasts of a quarry sites some few meters away. Plate 5 shows the site characteristics of Abuja Junction.

Plate 5: Site Characteristics of Abuja Junction Area

(f) Bakin Ruwa

Bakin Ruwa is located on latitude 10^{o} 31' 36.8" N and longitude 07^{o} 24' 05.9" E and at an elevation of 600m above sea level. The area is located along the by-pass road. It is strategic in that it conveys vehicular traffic in and out of the city but away from the city centre. With heavy duty vehicular movement restricted through the city centre, the area has become an alternative transit route especially for those on transit to and from the north.

Bakin Ruwa is often characterized by high vehicular traffic since it forms the major outlet and exit for vehicles aside through the city centre. It links Kawo, Abuja junction, Sabon Tasha as well as the Rigasa road, another area of the metropolis with a high population. The presence of a market a few metres from the highway may equally be responsible for the high traffic occasionally experienced in the area. Also, with a lot of residential areas (Badiko, Nasarawa, Kurmin-Mashi, Tudun-Wada etc.) concentrated along the by-pass road, traffic to the area is usually on the high side. Schools and other retail outlets are not left out either. Plate 6 shows the site characteristics of Bakin Ruwa.

Plate 6: Site Characteristics of Bakin Ruwa Area

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

Tables 4.1 and 4.2 show the average traffic volume per hour in the monitored sites and the GPS values for the sites respectively.

Table 4.1 Average traffic volumes per hour in selected points in Kaduna metropolis

Sampling Site	Average traffic volume per hour			
	Motorcycles/ tricycles	Cars/buses	Trucks/ lorries	Total
Kawo	1032 ± 16	1126 ± 12	106 ± 2	2264 ± 30
Central Market	1206 ± 19	1612 ± 14	4 ± 1	2820 ± 34
Stadium Roundabout	1319 ± 20	1783 ± 18	9 ± 1	3111 ± 39
Sabon Tasha	1211 ± 18	1335 ± 13	103 ± 2	2649 ± 33
Abuja Junction	684 ± 8	1013 ± 10	116 ± 4	1813 ± 22
Bakin Ruwa	996 ± 10	1219 ± 12	68 ± 2	2283 ± 24

Table 4.2: Field location and GPS values

Location	GPS Values	Elevation Above Sea Level (Metre)
Kawo	10^{o} 30’ 55.8” N	614
	07^{o} 25’ 49.1” E	
Central Market	10^{o} 30’ 28” N	606
	07^{o} 25’ 49” E	
Stadium Roundabout	10^{o} 30’ 07” N	587
	07^{o} 25’ 34.5” E	
Sabon Tasha	10^{o} 26’ 17” N	582
	07^{o} 29’ 04” E	
Abuja Junction	10^{o} 26’ 35.0” N	697
	07^{o} 24’ 15.1” E	
Bakin Ruwa	10^{o} 31’ 36.8” N	600
	07^{o} 24’ 05.9” E	
G.R.A	10^{o} 31’ 28.4” N	604
	07^{o} 27’ 20.0” E	

For clarity on the data generated from the field survey as well as in the statistical analysis carried out on the data, the discussion will be done based on the following headings:

1. Comparison of pollutants concentration at all the sampled points and at the various times of the day.
2. Comparison of data with Federal Ministry of Environment Standards
3. Comparison of air quality data with air quality index of the United States.
4. Comparison of data at traffic points with those at background as well as at the control location.
5. Predictive modeling of pollutant concentration with increasing distance from source of emission.

4.2 COMPARISON OF POLLUTANTS CONCENTRATION AT SAMPLED POINTS FOR DRY AND WET SEASON

4.2.1 Dry Season

A summary of the average data obtained during the dry season for morning, afternoon and evening hours are presented in Tables 4.3- 4.5.

Table 4.3 Average concentration of pollutants during the morning hours in dry season

Location	Air Quality Parameter					Meteorology		
	Morning							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temperature (^oc)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	22.80	0.038	0.038	337.00	0.035	32.0	32.8	3
Central Market	23.73	0.036	0.038	336.33	0.025	29.1	39.8	4
Stadium Roundabout	29.67	0.041	0.041	353.67	0.037	28.4	29.8	3
Sabon Tasha	26.43	0.037	0.037	363.33	0.029	29.9	29.9	2
Abuja Junction	10.25	0.026	0.022	341.00	0.004	31.3	33.2	4
Bakin Ruwa	26.43	0.039	0.035	342.00	0.027	31.7	34.4	3

Table 4.4 Average concentration of pollutants during the afternoon hours in dry season

Location	Air Quality Parameter					Meteorology		
	Afternoon							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temperature (^oc)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	25.30	0.040	0.039	360.00	0.028	32.0	32.8	3
Central Market	27.53	0.041	0.039	365.67	0.026	29.1	39.8	4
Stadium Roundabout	25.77	0.038	0.038	399.10	0.012	28.4	29.8	3
Sabon Tasha	24.47	0.035	0.035	376.33	0.026	29.9	29.9	2
Abuja Junction	13.95	0.028	0.017	357.00	0.008	31.3	33.2	4
Bakin Ruwa	24.00	0.036	0.036	366.00	0.027	31.7	34.4	3

Table 4.5 Average concentration of pollutants during the evening hours in dry season

Location	Air Quality Parameter					Meteorology		
	Evening							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temperature (^oc)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	26.60	0.039	0.040	330.00	0.024	32.0	32.8	3
Central Market	29.50	0.044	0.040	349.67	0.033	29.1	39.8	4
Stadium Roundabout	31.67	0.047	0.042	360.00	0.042	28.4	29.8	3
Sabon Tasha	27.53	0.038	0.035	360.00	0.029	29.9	29.9	2
Abuja Junction	17.30	0.025	0.028	370.50	0.015	31.3	33.2	4

Bakin Ruwa	25.57	0.041	0.037	365.33	0.035	31.7	34.4	3

It is observed from the results in Tables 4.3 – 4.5 that the average concentration of CO at the traffic spots was highest at Stadium roundabout for both morning (Table 4.3) and evening (Table 4.5) hours (29.67 and 31.67ppm respectively) and least at Abuja junction during the same periods (10.25 and 17.30 ppm respectively). The same was the case for all other pollutants (NO_2, SO_2, and HC) for both morning and evening hours with highest concentrations recorded at Stadium roundabout and least at Abuja junction. The highest concentration recorded at Stadium roundabout in the morning hours is not unconnected with the fact that it coincides with when workers and traders usually go to work and business. With the roundabout forming the major intersection between the constitution road and junction road, vehicles are at "idle speed" because of the slow pace of traffic at which condition they tend to emit more pollutants. The same is true for the evening hours.

The Central Market area, however, experiences most traffic hence most emission in the afternoon as adjudged from results in Table 4.4. Business is usually at its peak at this time of the day and as such more vehicular movement is experienced in and around the area.

Bakin Ruwa and Sabo are areas that equally experience high traffic during the morning hours. Afternoon and the evening hours seem not to be left out as pollutants concentrations are equally high. These areas are known for their high residential provision for the populace in Kaduna metropolis. And with the field reading taken at the major intersection in Bakin Ruwa area, this would have accounted for the high concentration in the area.

On a general assessment of the average pollutants concentrations, Abuja junction and the Kawo areas experience the lowest pollution in the metropolis. While Central Market, Stadium roundabout, Sabo, and Bakin Ruwa experience the most traffic in descending order.

A careful assessment of the pollutant concentration recorded at various days of the week indicates that in as much as Saturday is a weekend and public civil servants are not expected to go to work, emission concentration was quite high. This was due to the fact that the Christmas season was at hand when this survey was carried out hence business activities had increased. Sunday, however recorded the least traffic and hence least pollutant concentration as seen in the table of results in the appendix. This was so because most places of work and businesses were usually closed.

4.2.2 Wet Season

A summary of results obtained during the wet season are presented in Tables 4.6 - 4.8.

Table 4.6: Average concentration of pollutants during the morning hours in wet season

Location	Air Quality Parameter					Meteorology		
	Morning							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oc)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	13.93	0.025	0.024	353.00	0.023	30,97	69.50	3
Central Market	14.33	0.025	0.026	350.67	0.024	28.23	70.87	3
Stadium Roundabout	19.90	0.030	0.033	361.67	0.024	29.10	72.30	3
Sabon Tasha	14.67	0.033	0.034	349.67	0.030	28.00	73.40	3

Abuja Junction	8.53	0.026	0.025	353.67	0.019	27.93	76.50	3
Bakin Ruwa	15.70	0.030	0.032	348.33	0.025	28.57	75.13	3

Table 4.7: Average concentration of pollutants during the afternoon hours in wet season

Location	Air Quality Parameter					Meteorology		
	Afternoon							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oc)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	16.10	0.028	0.029	333.33	0.024	33.97	55.40	3
Central Market	19.37	0.025	0.028	351.67	0.018	33.77	54.97	3
Stadium Roundabout	16.27	0.027	0.030	352.67	0.023	31.2	58.57	3
Sabon Tasha	11.50	0.027	0.027	351.67	0.020	33.10	56.13	3
Abuja Junction	6.73	0.020	0.021	342.33	0.014	33.50	61.07	3
Bakin Ruwa	11.97	0.029	0.027	338.33	0.024	33.90	58.27	3

Table 4.8: Average concentration of pollutants during the evening hours in wet season

Location	Air Quality Parameter					Meteorology		
	Evening							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oc)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	20.87	0.032	0.034	354.67	0.030	31.90	66.17	3
Central Market	21.27	0.032	0.034	360.00	0.028	30.73	65.03	3
Stadium Roundabout	20.00	0.031	0.034	354.67	0.025	30.47	66.33	3
Sabon Tasha	19.23	0.031	0.034	360.00	0.030	29.93	66.87	3

Abuja Junction	11.33	0.025	0.024	353	0.023	30.97	69.5	3
Bakin Ruwa	17.37	0.027	0.031	340.33	0.023	30.83	69.27	3

The results indicate that the CO concentrations recorded highest values at Stadium roundabout and at the Central Market areas. The highest concentration recorded during the morning hours was 21.0ppm at the Stadium Roundabout and 20.6ppm at the Central Market area. The Abuja Junction and Kawo areas recorded the least CO concentrations of 9.3ppm and 18.0ppm respectively during the morning hours.

A similar observation was noticed during the afternoon and evening hours where CO concentrations peaked at 22.4ppm and 25.0ppm for both afternoon and evening at the Central market area while the Stadium roundabout recorded concentrations of 21.3ppm and 24.6ppm in the afternoon and evening hours respectively. It is interesting to know that the peak values recorded for both the Central market and Stadium roundabout were recorded on a Saturday. This is connected with the fact that commercial and business activities normally reaches its peak in the afternoon, and with traders and buyers itching to return home after the day's business, traffic and hence pollutants concentration levels will rise. Besides, it is expected that government workers would take out the opportunity of a work-free day to do some buying and selling thereby adding up to the impact around those areas. Kawo equally recorded a high CO concentration of 22.0ppm in the evening.

Therefore, CO concentration is mostly highest during week days at Stadium roundabout in the morning hours but highest at Central market area in the afternoon and evening hours both during week days and on Saturdays.

Observation on the Nitrogen dioxide (NO_2) concentration indicate that even though formation of NO_2 take place at high temperature, it could not be clearly established whether a high temperature was actually responsible for the results obtained from field. Because, even where temperature was adjudged to be low, it was discovered that NO_2 concentrations were higher compared to when temperature was high. However, when the results were compared with David and Frederikse (1997), taken at 15^oC, it was observed that the results recorded on field were higher (between 0.03ppm and 0.04ppm) compared to David and Frederikse (1997) who recorded 0.02ppm at 15^oC.

A comparison of the general assessment of the air quality situation at the sites for both seasons indicates that the pollutants' concentration during the dry season was higher compared to the wet season concentration.

4.3 COMPARISON OF AIR QUALITY DATA (DRY AND WET SEASON) AT TRAFFIC SITES WITH NATIONAL / LOCAL STANDARDS.

4.3.1 Dry season

Results of the comparison of air quality data recorded at traffic sites with the national/local standards during the dry season are presented in Figures 4.1 – 4.5.

In order to come up with an affirmative conclusion as to the air quality status of Kaduna metropolis, descriptive statistics was used. The air quality data for Kaduna metropolis was compared with National Ambient Air Quality Standard (see Table 2.4) as shown in the Figures 4.1 – 4.5.

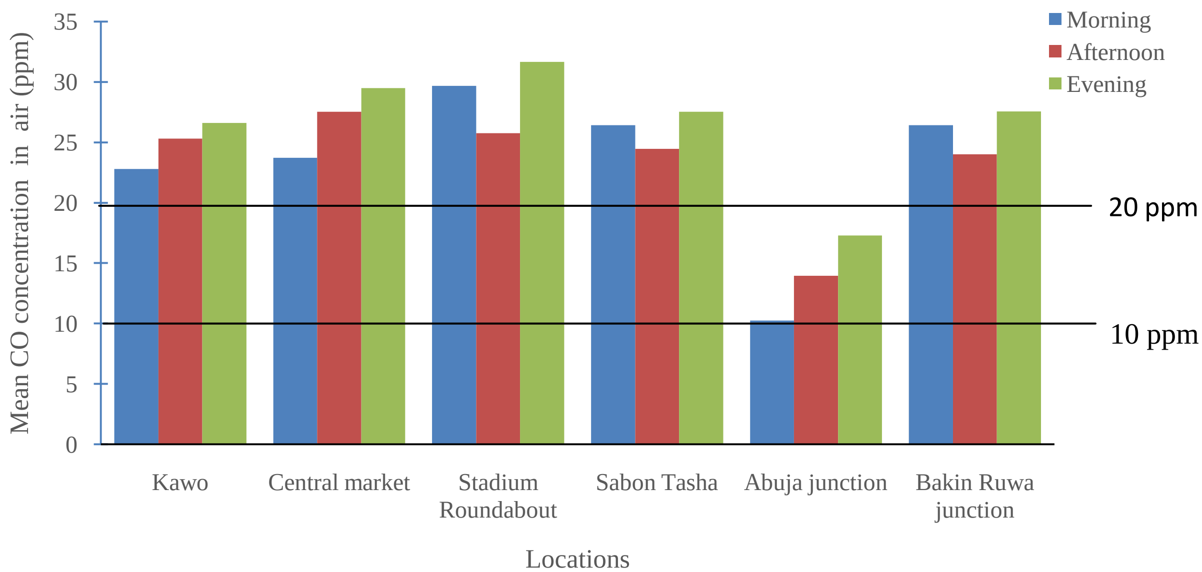

Figure 4.1: Mean CO concentration for morning, afternoon and evening hours during dry season

Figure 4.1 shows that the CO level in all the sites exceeds the 1 hour averaging time of 10ppm. This is more worrisome because it occurs all through the day. The same is observed for the 8 hours averaging time of 20ppm except for Abuja junction which still falls within the limit. The implication of this is that in as much as people subsist daily in these areas to carry out their business activities, they are constantly exposed to these concentrations of pollutants which are released at ground level (i.e. human breathing level) with their attendant health implication. The short-term limit of 10 ppm based on one hour average is meant to prevent the immediate health effects that may occur from exposure to CO for a short period of time (e.g. one hour). Though, even at 20 ppm, a short-term effect may not be felt but it is important to know that the effect of CO is not only related to the level and duration of exposure but also on an individual’s health status. An individual’s exposure to a CO level as recorded in the sites (above 20 ppm) is capable of causing headache, dizziness and exertion. It may even be severe in individuals with health conditions such as asthma.

Similarly, a comparison of the nitrogen dioxide (NO_2) concentration reveals that the 0.04 ppm limit for an averaging time of 1 hour is being exceeded in places like the Central Market area, Stadium Roundabout and Bakin Ruwa. Though, these occur at different hours of the day as can be seen in Figure 4.2, they tend to increase above the national standards. For the 24 hours averaging time, however, the six sites were well within the national/local limits.

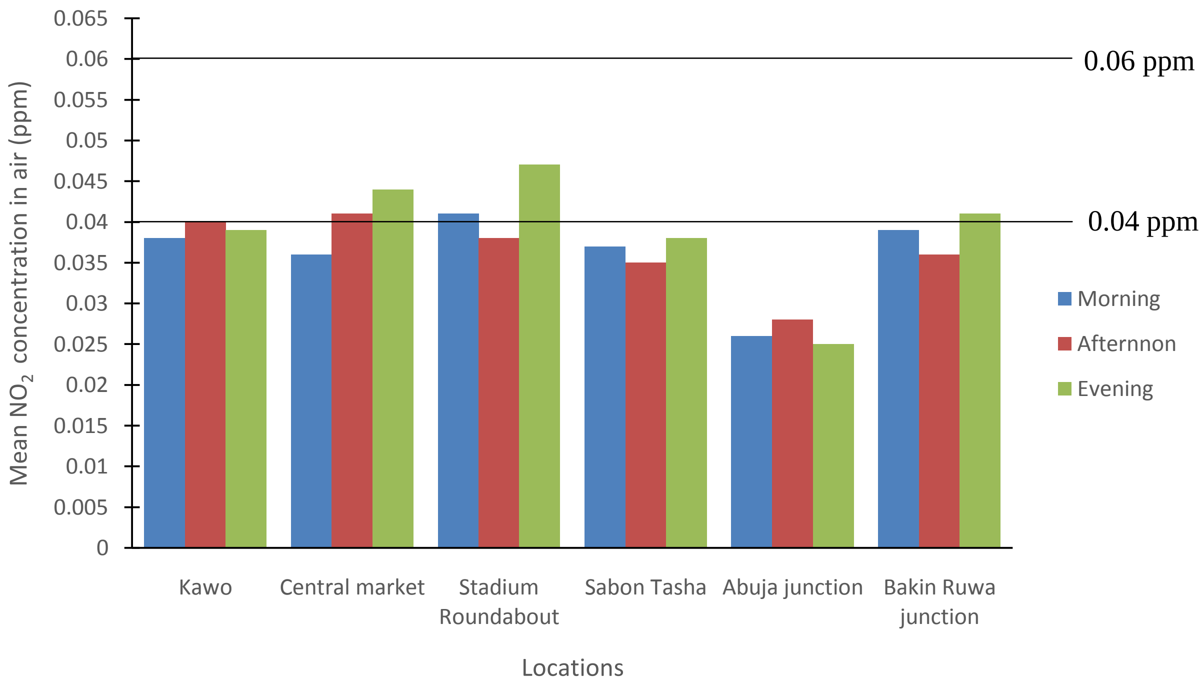

Figure 4.2: Mean NO_2 concentration for morning, afternoon and evening hours during dry season

Figure 4.3 shows the comparison in the case of SO_2. It is observed that the entire site surveyed, fell short of the 0.01 ppm for an averaging time of 1 hour. They were however, within the limits of 0.1 ppm for 24 hours duration.

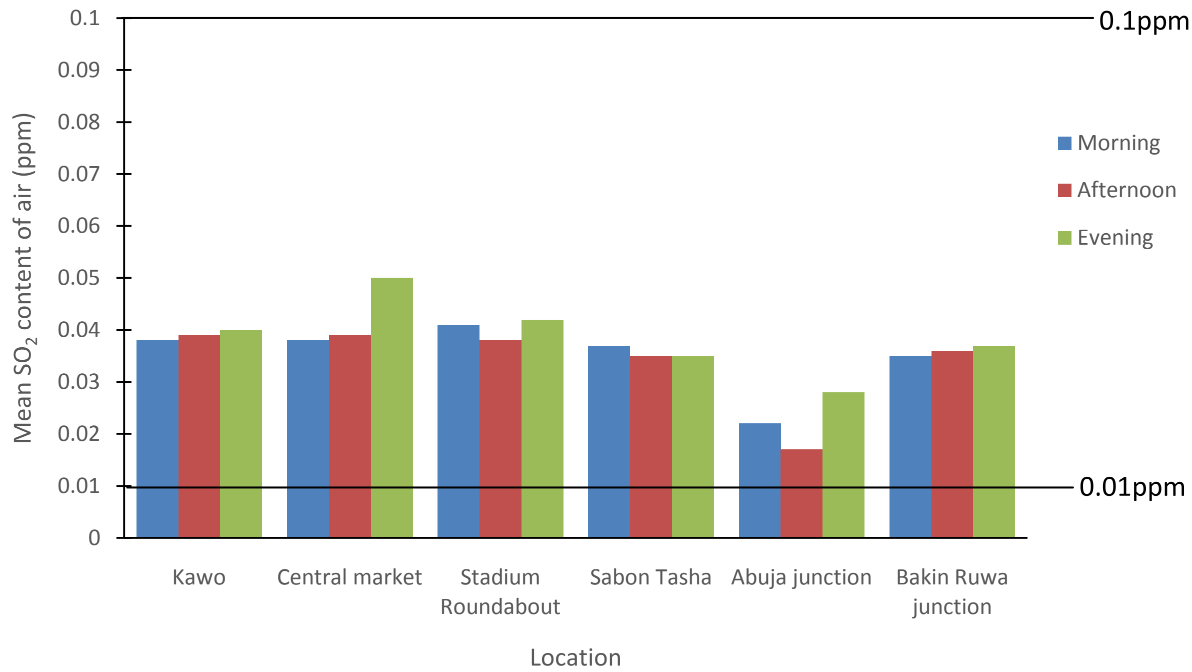

Figure 4.4: Mean SO_2 concentration for morning, afternoon and evening hours during dry season

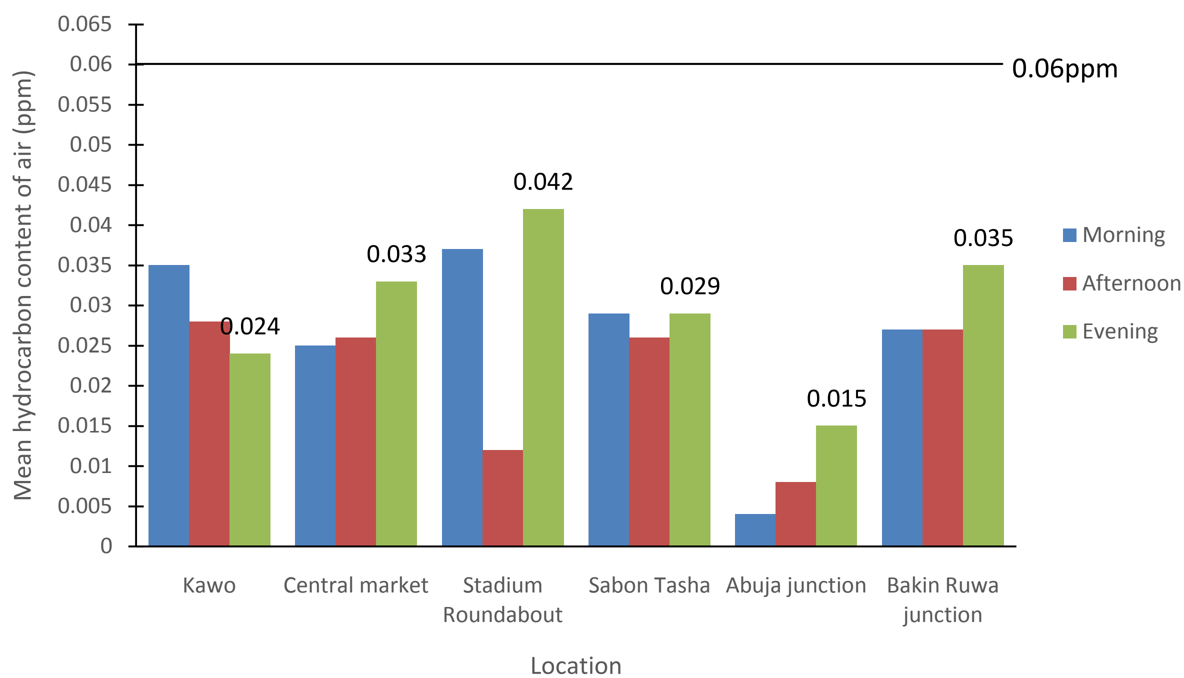

Figure 4.4: Mean HC concentration for morning, afternoon and evening hours during dry season

The sampled sites were all within set limits in terms of the concentration of HC. This is clearly seen in Figure 4.4. Except at crude oil drilling sites or in the event of an oil spill resulting from an accident, it may be difficult for HC concentration to attain the set limit of 0.6ppm.

Figure 4.5 shows the CO_2 level for the sampled sites. There is however no national ambient air quality standards for CO_2 concentration in the atmosphere, but literature survey show that the average concentration of CO_2 in ambient air stands at 314 ppm (David and Frederikse, 1997). This therefore implies that the average concentration of CO_2 in Kaduna metropolis is above the ambient standard presented by David and Frederikse, 1997.

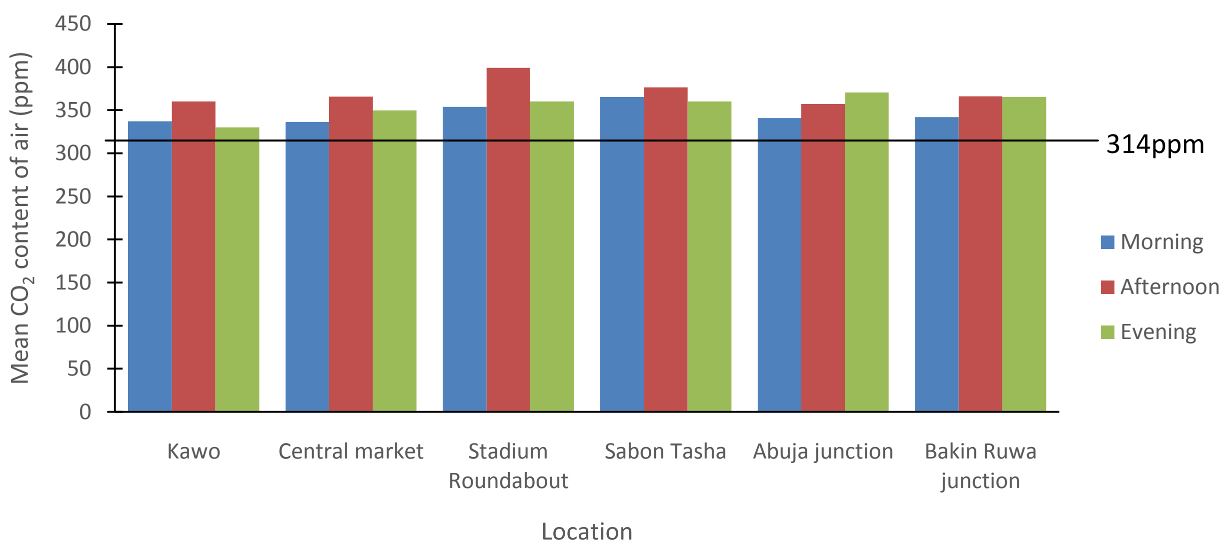

Figure 4.5: Mean CO_2 concentration for morning, afternoon and evening hours during dry season

4.3.2 Wet Season

The same comparison as was done in 4.3.1 was equally carried out for the wet season. The results are as presented in Figures 4.6 – 4.10. Similarly, as was observed during the dry season, CO concentration at all sampled sites were above the one hour averaging time of

10ppm apart from the morning and afternoon hours for Abuja junction which recorded 8.53ppm and 6.73ppm respectively. Unlike what was observed for the 24 hours averaging time for the dry season where CO concentrations were above the 20ppm standard, virtually all the sampled sites recorded concentrations less than 20ppm. This is clearly depicted in Figure 4.6.

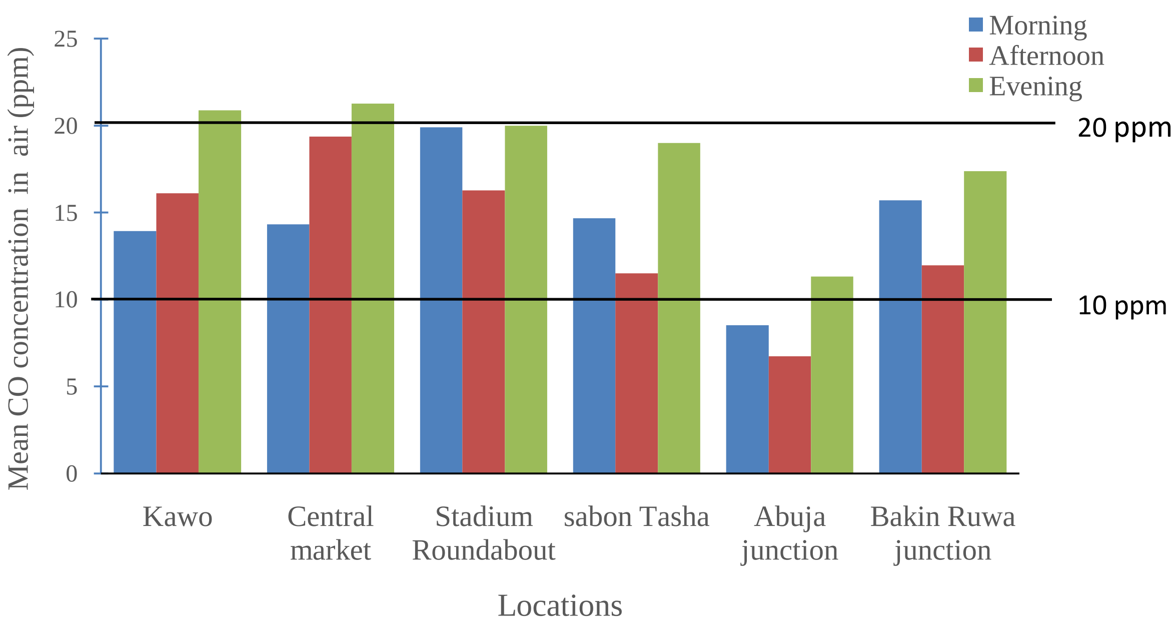

Figure 4.6: Mean CO concentration for morning, afternoon and evening hours during wet season.

Observations for the NO_2, during the dry season, indicate that all sampled sites met both the 0,04ppm and 0.06ppm level for 1 hour and 8 hours averaging time respectively. This is shown in Figure 4.7.

For the SO_2 concentration as shown in Figure 4.8, it is observed that at all the sampled sites, SO_2 concentrations were above the 0.01ppm for an averaging time of I hour but way below the 0.1ppm for an averaging time of 24 hours.

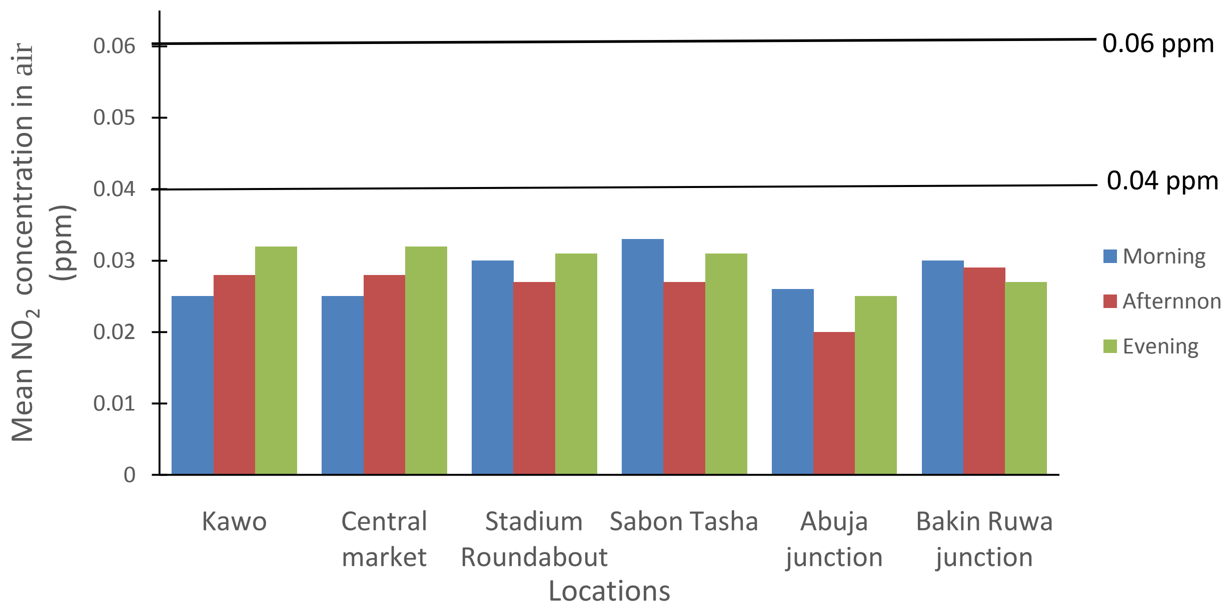

Figure 4.7: Mean NO_2 concentration for morning, afternoon and evening hours during wet season

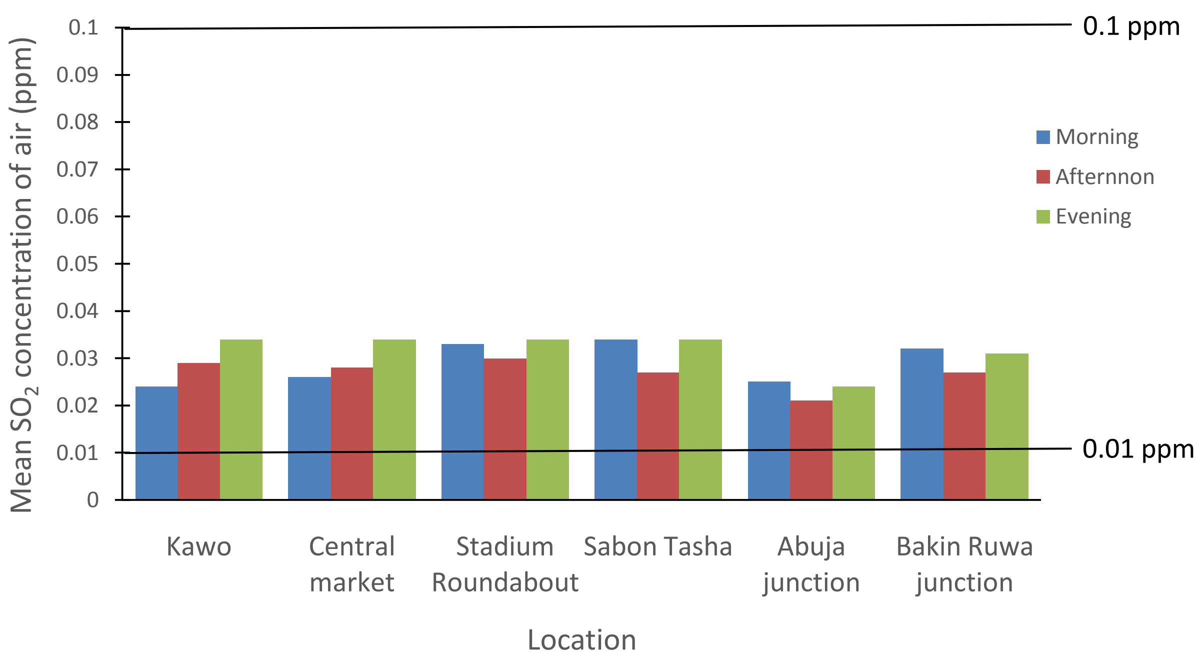

Figure 4.8: Mean SO_2 concentration for morning, afternoon and evening hours during wet season

The same manner it was observed for the HC concentration during the dry season, the concentration during the wet season was far below the national standard of 0.6 ppm. This is as shown in the Figure. 4.9.

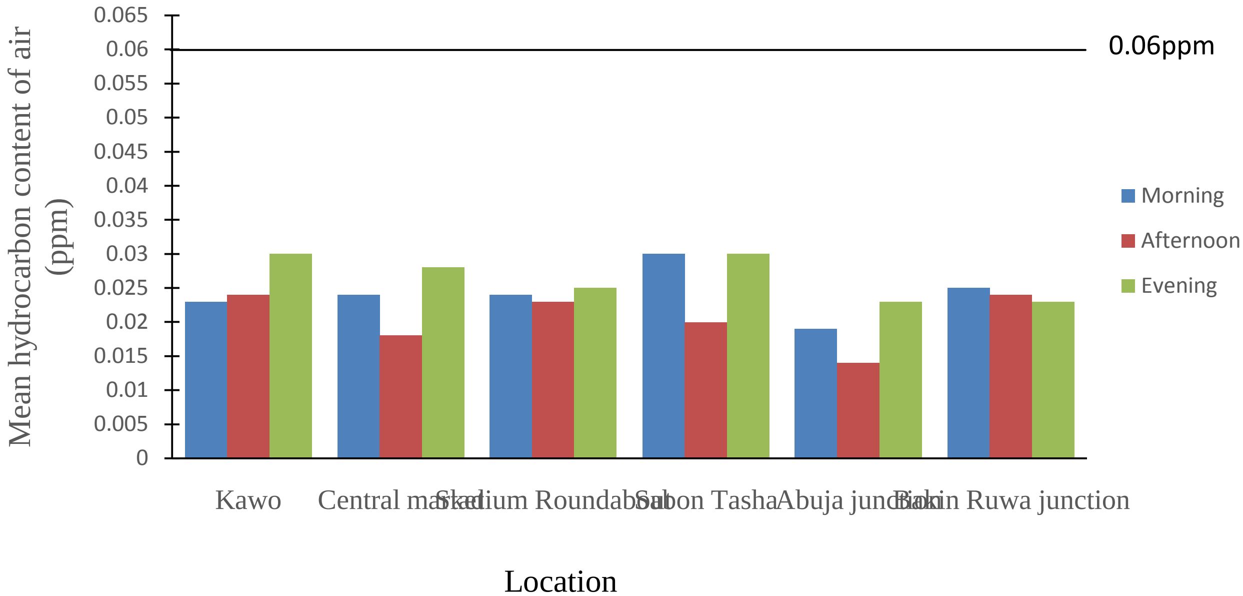

Figure 4.9: Mean HC concentrations for morning, afternoon and evening hours during wet season

Observations from the CO_2 concentrations at the sites during the wet season did not show much deviation from what was recorded during the dry season. It was observed that CO_2 concentration in Kaduna metropolis was high and above the normal ambient composition of 314ppm recorded at sea level at 15^0C and 101.3 KPa (David and Frederikse, 1997). The recorded values for the sampled sites are represented in Figure. 4.10.

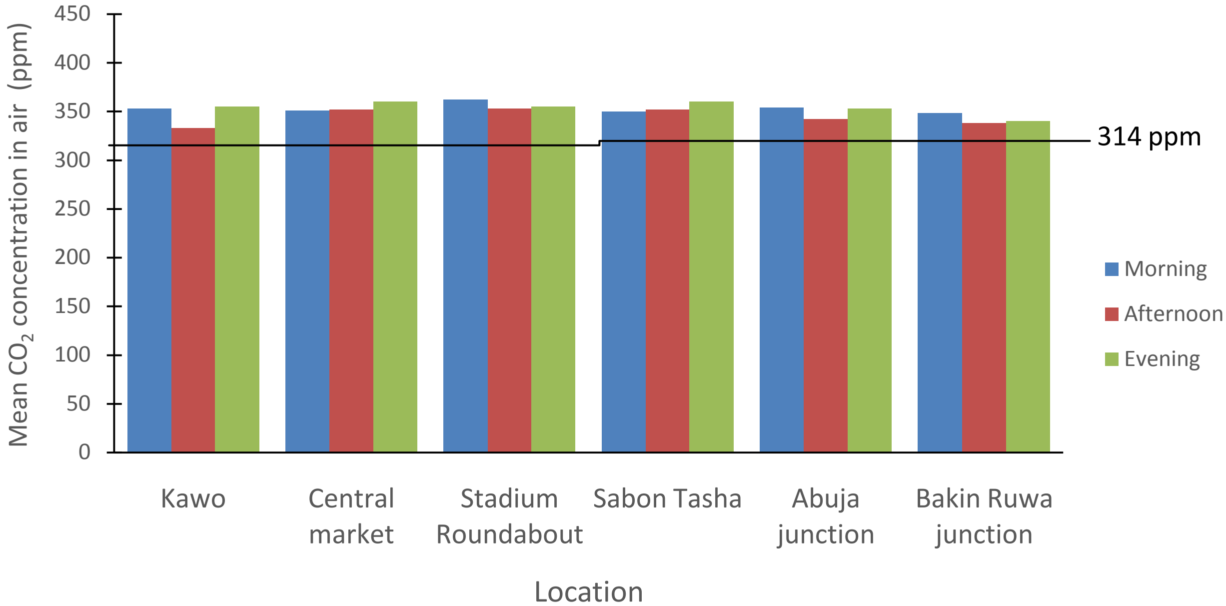

Figure 4.10: Mean CO_2 concentrations for morning, afternoon and evening hours during wet season

4.4 COMPARISON OF AIR QUALITY DATA (BOTH DRY AND WET SEASON) 100 METRES AWAY FROM TRAFFIC SITES WITH NATIONAL / LOCAL STANDARDS.

4.4.1 Dry Season

A comparison of data was carried out on pollutant concentrations recorded at 100 metres away from the traffic site during the dry season. Result however indicate that all other pollutant concentration apart from CO were within national standards.

CO concentration in Kawo was above the 1 hour limit during the afternoon hour. The Central market area, Stadium roundabout and Sabon Tasha recorded CO concentrations were above national standard in the morning, afternoon and evening hours, while Bakin Ruwa exceeded the limit in the afternoon and evening hours. Residences in Abuja junction area enjoy a relatively high air quality standard.

Observations however, show that some of the residents around the central market area and stadium roundabout use their residents for petty businesses and as such sound of generators were heard around the vicinities. This might have increased the level of the CO recorded in those areas. The increase may also not be unconnected with the fact that most of the residences are situated in between the ever busy streets in the central areas around central market and the stadium roundabout area. Their health is bound to deteriorate as long as they continue to reside in these ever busy areas except steps are taken by government to relocate them. Results from CO monitoring at the sites are shown in Figure 4.11

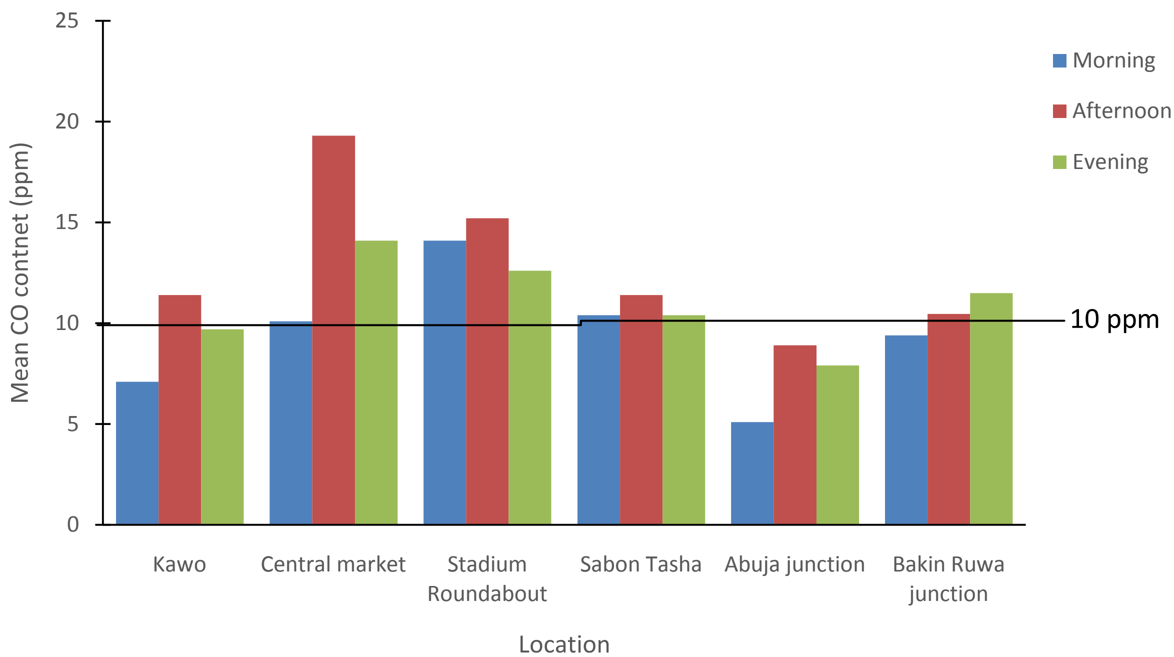

Figure 4.11: CO concentration 100 metres away from traffic for morning, afternoon and evening during dry season

Observation in the CO_2 concentration still indicates that its concentration is higher than the standard value of 314ppm recorded during the dry season as shown in Figure. 4.12.

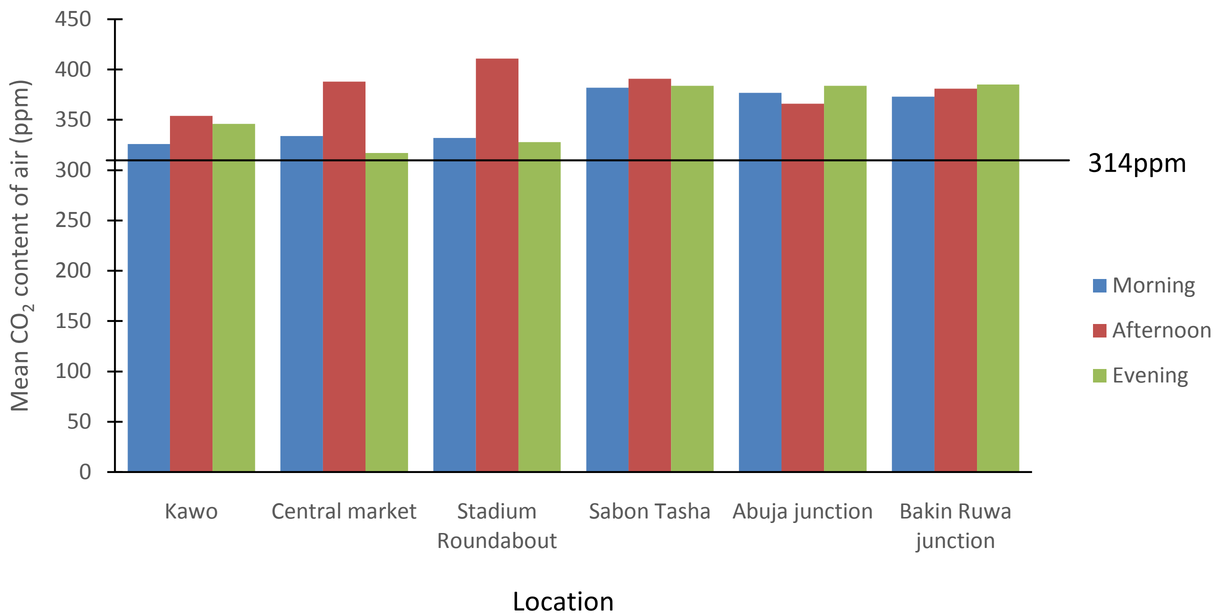

Figure 4.12: CO_2 concentration 100 meters away from traffic for morning, afternoon and evening for dry season

A general assessment therefore, of the air quality situation of residences 100 metres away from the source of traffic indicates that they fall within the national ambient air quality standards. However, with increasing population and economic growth, these concentrations are bound to rise and tend towards the standards. This is true especially for CO, where limits are already being exceeded in some times of the day.

4.4.2 Wet Season

CO results obtained 100m away from the traffic site indicate that the a few sites recorded CO concentrations above the 10ppm for an averaging time of 1 hour at different times of the day. Sabo recorded 10.1ppm in the evening while Central Market area recorded CO concentrations of 11.33ppm in the afternoon and 13.40ppm in the evening. At all times of the day, other sites located 100m away from the traffic site were less than the national standards. However, with increasing population and traffic volume, the national standard of 10ppm may soon be surpassed especially around Bakin Ruwa, Sabo and Stadium roundabout. A representation of the situation is as shown in Figure 4.13.

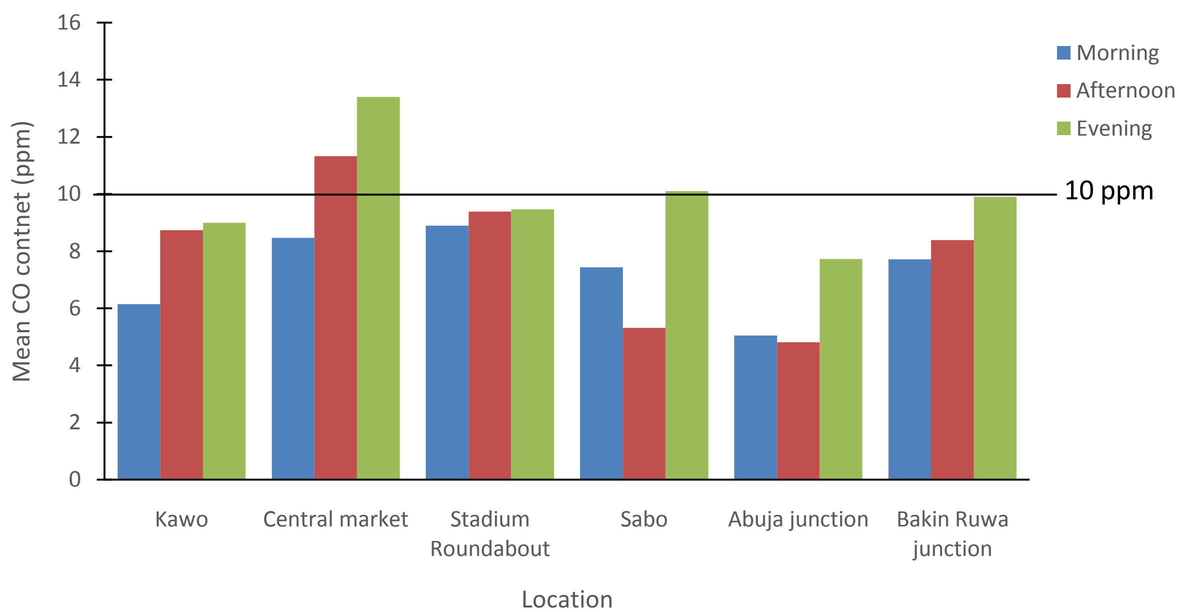

Figure 4.13: CO concentration 100 meters away from traffic for morning, afternoon and evening during wet season

For all sites monitored for NO_2, and HC emissions, the concentrations were quite below the national standards. However, SO_2 recorded concentrations above the set national standard of 0.01ppm for an averaging time of 1 hour.

CO_2 monitored at all sites show an elevation above normal ambient standard of 314 ppm recorded by David and Frederikse (1997). This is depicted in Figure 4.9.

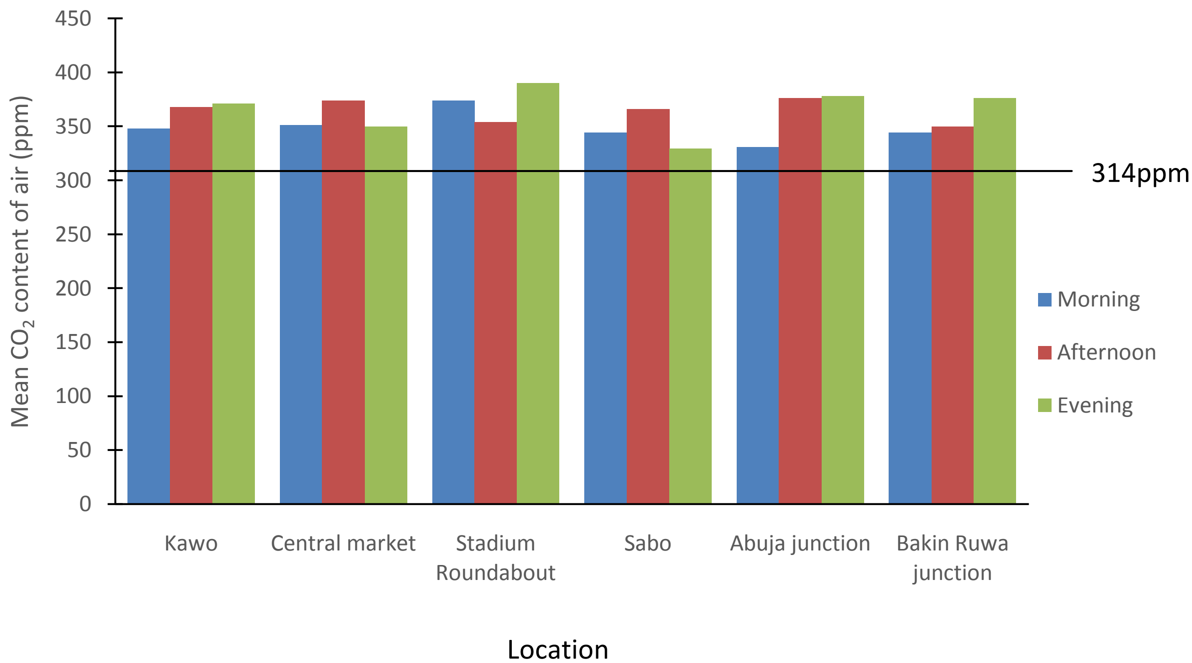

Figure 4.14: CO_2 concentration 100 meters away from traffic for morning, afternoon and evening during the wet season

4.5 COMPARISON OF AIR QUALITY DATA OF KADUNA METROPOLIS WITH AIR QUALITY INDEX (AQI) OF THE UNITED STATES

Air quality index is an index for reporting daily air quality in the United States. It gives information on how clean or polluted the air is and what associated health effects might be a concern for individuals. Harmonizing the air quality data for Kaduna metropolis during the "dry season" with the air quality index value (Tables 2.2 and 2.3) therefore indicate that CO concentration at all the sites which ranged between 24.9ppm and 29.04ppm (except for Abuja junction with 13.5ppm) falls within an index value of 201 and 300. The air quality status is therefore "very unhealthy" meaning that those residing in those areas are vulnerable to serious health effects. That of Abuja junction is adjudged as "unhealthy" as it falls between an index of 151-200. This means that individuals with sensitive health conditions are at risk.

NO_2 at all sites surveyed had concentrations of between 0.026ppm and 0.040ppm. On the AQI table therefore, it falls within an AQI range of 0 - 0.053. Therefore, the air quality status is adjudged "good", thus it poses little or no risk to health.

As for the SO_2 concentration, Abuja junction with a daily average concentration of 0.024ppm is adjudged "good" while for all the other locations are "moderate" as they all fall between 0.036 and 0.07 on the AQI chart. Health concern may only arise for a small group of individuals that are highly sensitive to this gas at that concentration. Table 4.9 summarizes the result of air quality status at the various sampled locations within Kaduna metropolis for the dry season.

Table 4.9: AQI result for sampled traffic sites in Kaduna metropolis for dry season

Sample Sites	Air Quality Status (CO)	Air Quality Status (NO_2)	Air Quality Status (SO_2)
Kawo	Very Unhealthy	Good	Moderate
Central Market	Very Unhealthy	Good	Moderate
Stadium Roundabout	Very Unhealthy	Good	Moderate
Sabon Tasha	Very Unhealthy	Good	Moderate
Abuja Junction	Unhealthy	Good	Good
Bakin Ruwa	Very Unhealthy	Good	Moderate

Similarly, relating the air quality data for Kaduna metropolis during the rainy season with the index (Tables 2.2 and 2.3) therefore indicate that CO concentration at most of the sites fall within the 12.5ppm - 30.4ppm. For the morning hours, only Abuja junction with CO concentration of 8.53ppm is adjudged "moderate" in terms of the air quality. Kawo, Central Market, and Sabo with CO concentrations of 13.93ppm, 14.33ppm and 14.67ppm respectively fall within an index value of 151–200 hence adjudged "unhealthy". Bakin Ruwa and Stadium Junction with a concentration of 15.70ppm and 19.90ppm respectively is "very unhealthy". The implication is that those living or subsisting in those areas are vulnerable to serious health risks. For the afternoon hours, Abuja junction is adjudged "moderate" with a CO concentration of 6.73ppm. Sabo and Bakin Ruwa with CO concentrations of 11.50ppm and 11.97ppm respectively is "unhealthy" while Kawo, Central Market and stadium with CO concentrations of 16.10ppm, 19.37ppm and 16.27ppm respectively are adjudged as "very unhealthy". For the evening hours, it is noticed that aside Abuja Junction whose AQI category is "unhealthy for sensitive group", all other sites are adjudged "very unhealthy" as they all fall within an index value of 201-300.

Similar analysis for NO_2 for morning, afternoon and evening hours indicate that the recorded concentrations fall within the range of 0-0.053ppm corresponding to an index value of 0-50. Therefore, the AQI status of all the sampled sites is adjudged "good".

Similarly for SO_2, at all durations, the air quality status of the study areas falls within an index value of 0-50. This implies that the air quality status is "good" for all sites visited. A summary of the air quality rating of all sites studied for the wet season is given in Table 4.10.

Table 4.10: AQI result for sampled Traffic Sites in Kaduna Metropolis for wet season

Sample Sites	Air Quality Status (CO)	Air Quality Status (NO_2)	Air Quality Status (SO_2)
Kawo	Very Unhealthy	Good	Good
Central Market	Very Unhealthy	Good	Good
Stadium Roundabout	Very Unhealthy	Good	Good
Sabon Tasha	Unhealthy	Good	Good
Abuja Junction	Moderate	Good	Good
Bakin Ruwa	Unhealthy	Good	Good

An overall comparison of the air quality for both seasons indicated that the air quality during the wet season was relatively better compared to the dry season. This was so because during the wet season, the atmosphere is bound to be humid and saturated with water vapour hence a considerable quantity of the pollutants would have been absorbed in the atmosphere unlike in the dry season where the atmosphere is dry and pollutants roam freely in the atmosphere.

4.6 COMPARISON OF AIR QUALITY DATA AT TRAFFIC POINT, 100 METRES AWAY FROM TRAFFIC SITES AND AT CONTROL LOCATION.

Figure 4.15 to Figure 4.19 shows a graphical comparison of the variation of traffic emissions at traffic points, a distance of 100 metres away from the traffic point and a control location almost entirely free of traffic. Data used for the graphical representation are from the average concentrations of the various pollutants at traffic sites and at a distance of 100m away from the traffic sites. The data can be found in Appendix 2.26 and 2.27 for both the dry and wet season respectively.

4.6.1 Dry Season

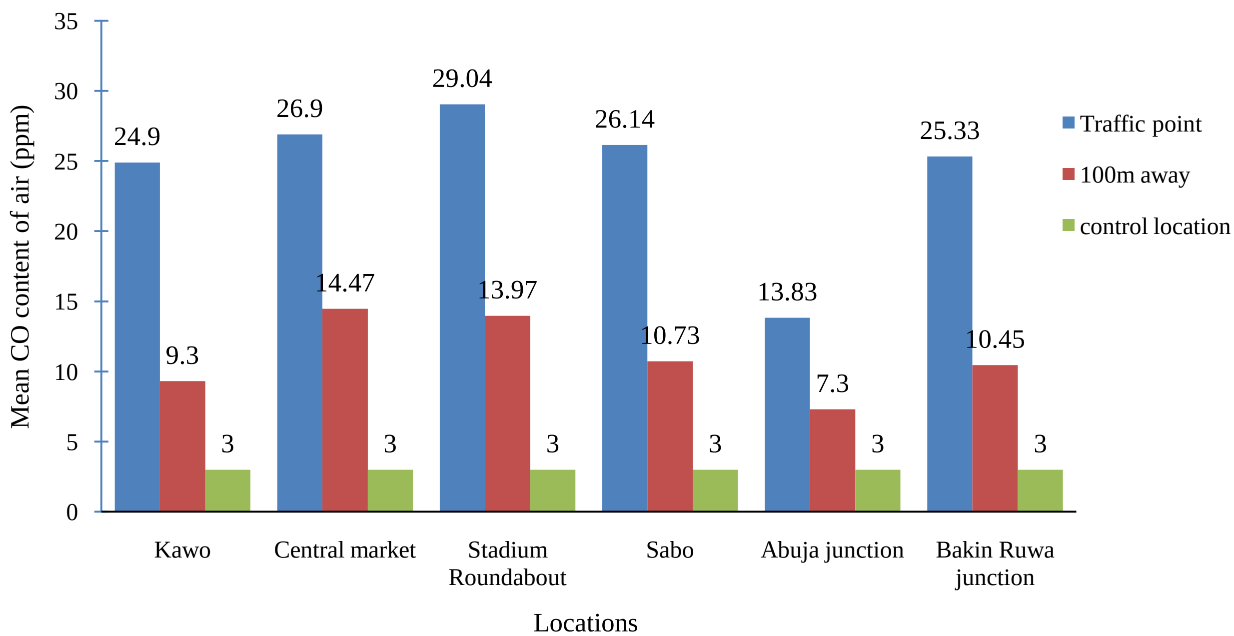

Figure 4.15: CO concentration at traffic point, 100m away from traffic and at control location during dry season

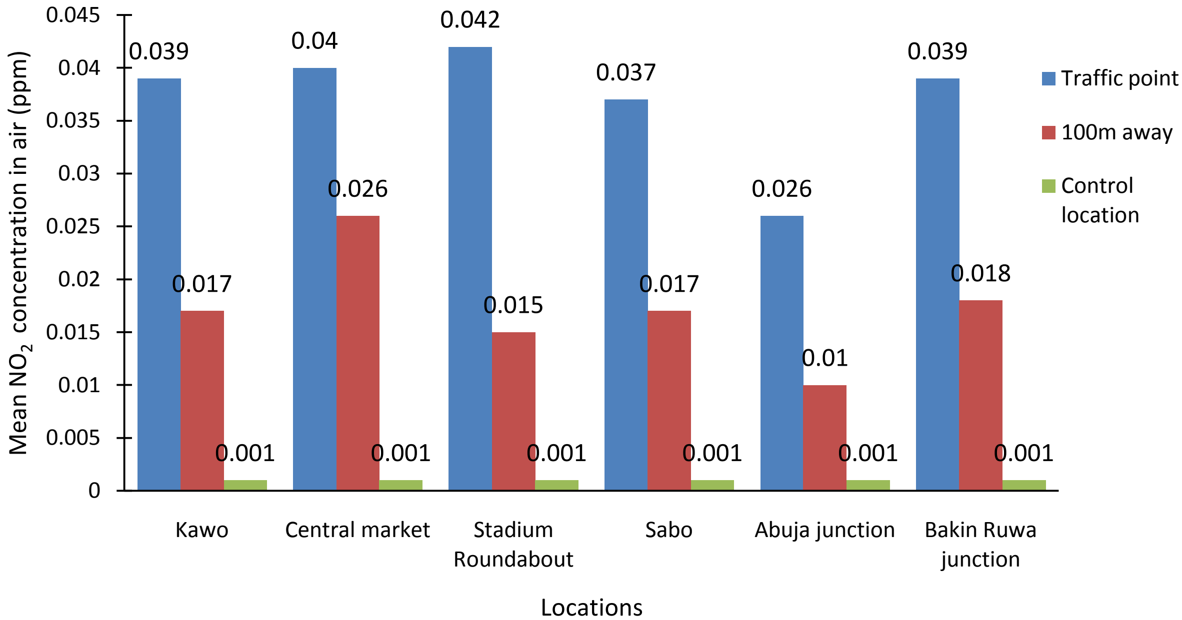

Figure 4.16: NO_2 concentration at traffic point, 100m away from traffic and at control location for dry season

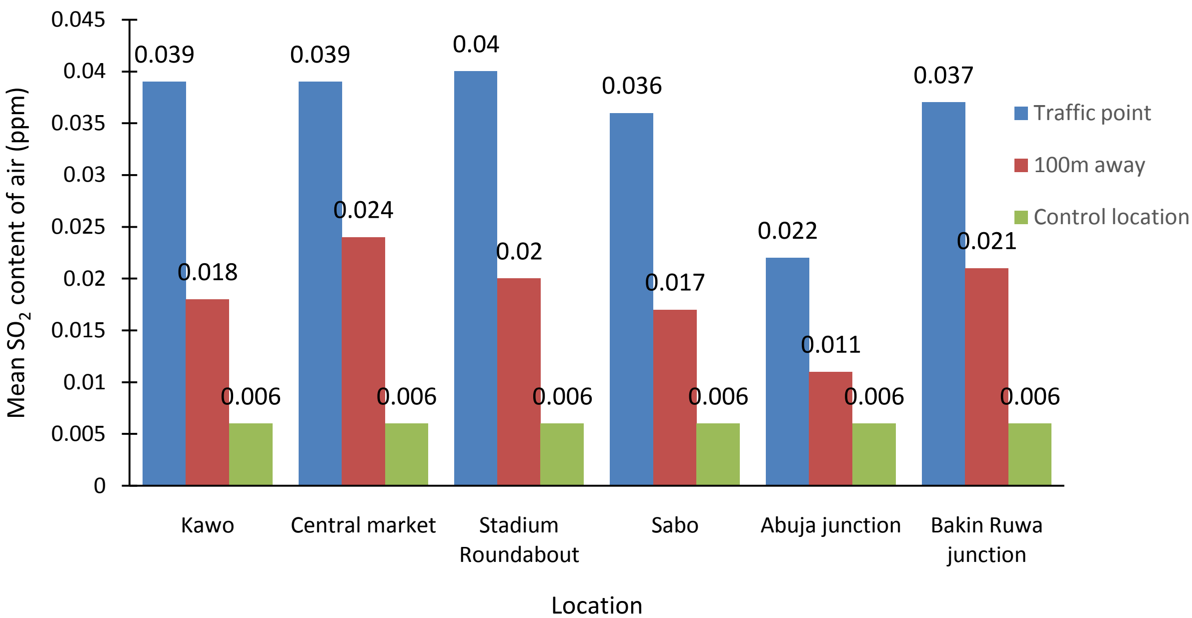

Figure 4.17: SO_2 concentration at traffic point, 100m away from traffic and at control location during dry season

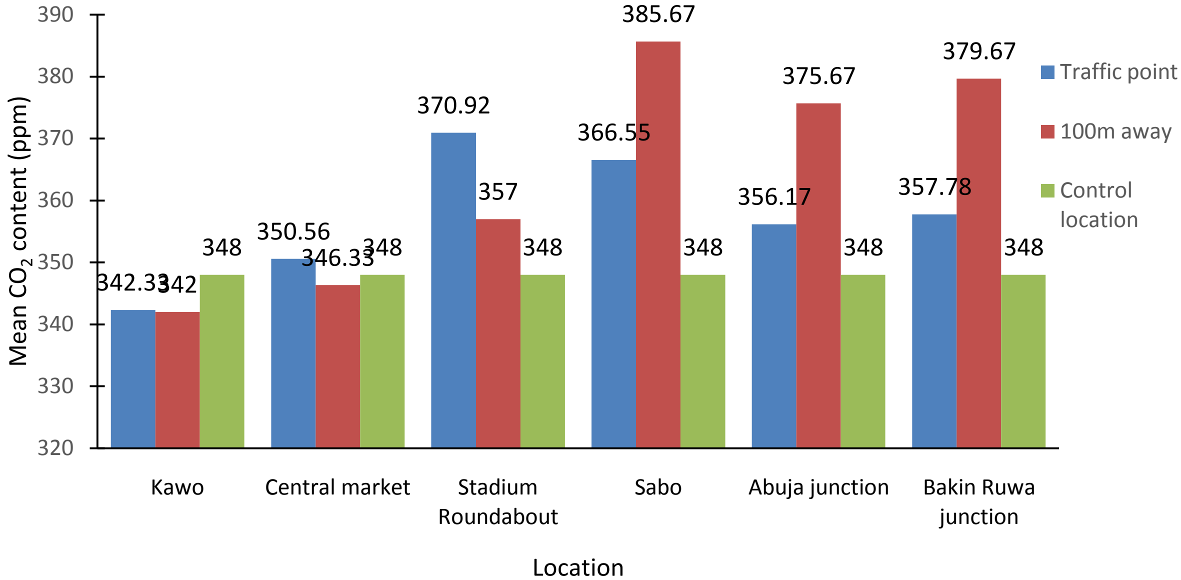

Figure 4.18: CO_2 concentration at traffic point, 100m away from traffic and at control location during dry season

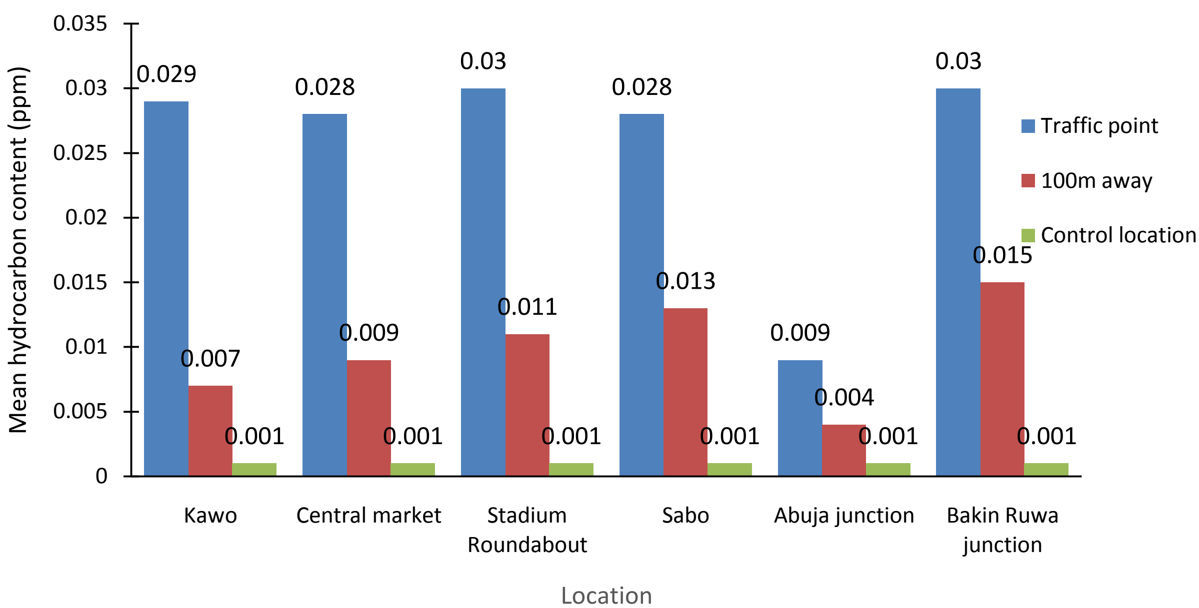

Figure 4.19: Hydrocarbon concentration at traffic point, 100m away from traffic and at control location for dry season.

It is obvious from the representation shown in Figures 4.15 - 4.19 that indeed, traffic pollutant concentrations are highest at traffic points, but reduces with distance away from traffic.

Results from comparison of the pollutants concentration at the three classified locations i.e. at traffic points, 100m away from traffic points and at a control location during the dry season as presented in Figures 4.15 – 4.19 indicated that CO concentration was reduced by 51.89% with a distance of about 100m away from Stadium Roundabout been the most polluted site on the average. Similarly, NO_2, SO_2 and HC concentrations were reduced by 64.29%, 50% and 63.33% respectively a distance of 100m all with reference to Stadium Roundabout.

4.6.2: Wet Season

Similarly, for the wet season, when the pollutants concentrations from the traffic point, a distance of 100 metres and at the control location were considered for comparison, it was obvious that the pollutants concentrations recorded at the traffic points were highest, those at a distance of 100 metres away from the traffic point were lower while those recorded from the control location were way less compared to the first two locations. A graphical representation of the comparative result is shown in Figures 4.20 – 4.24.

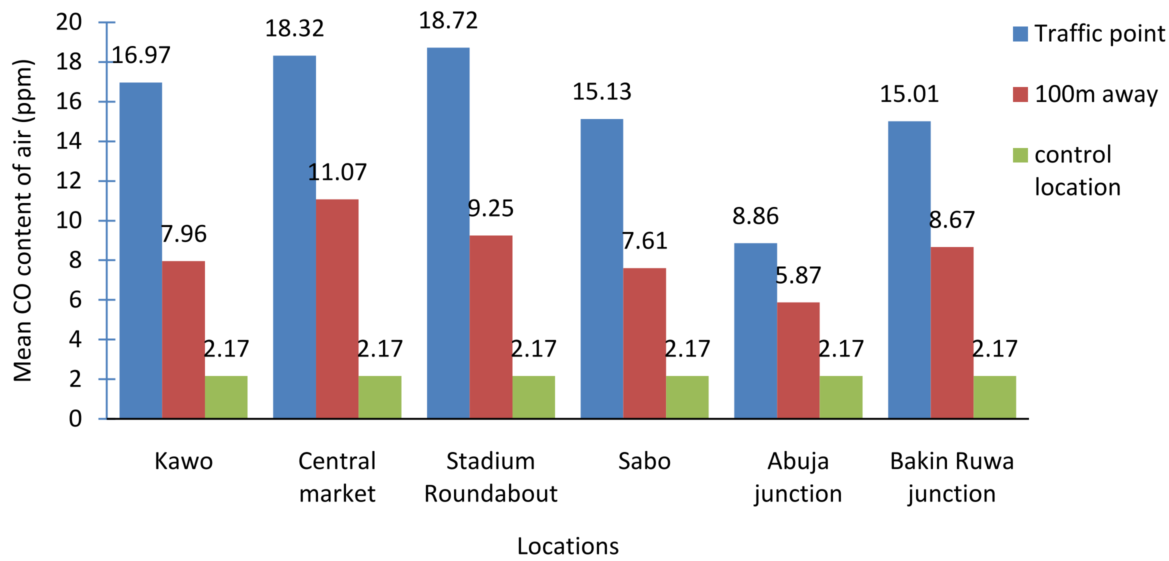

Figure 4.20: CO concentration at traffic point, 100m away from traffic and at control location during wet season

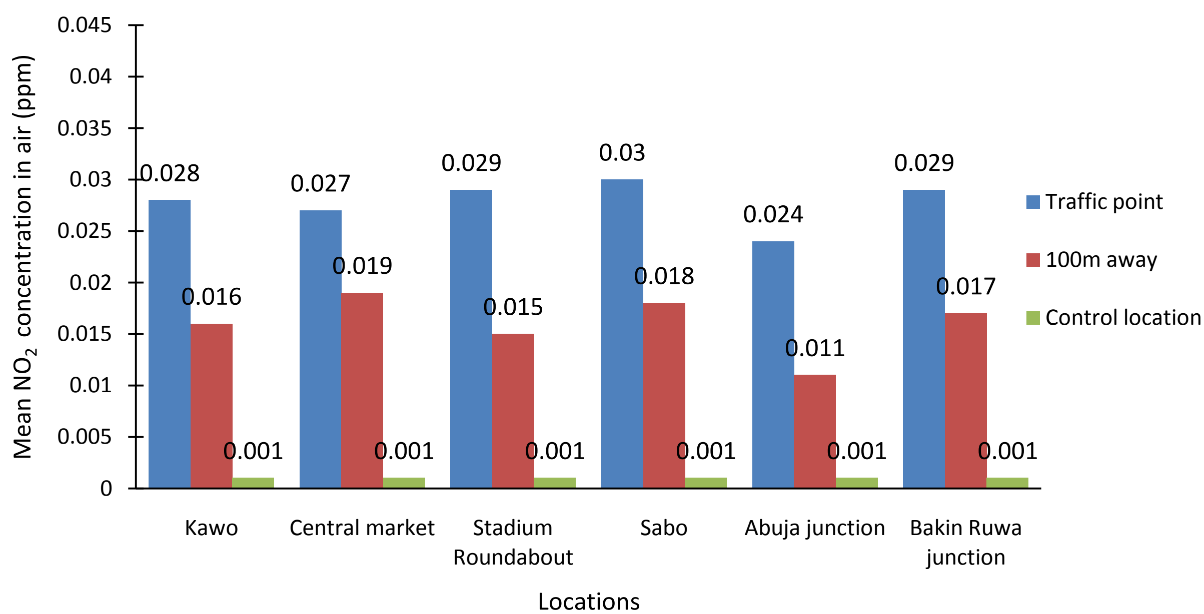

Figure 4.21: NO_2 concentration at traffic point, 100m away from traffic and at control location during wet season

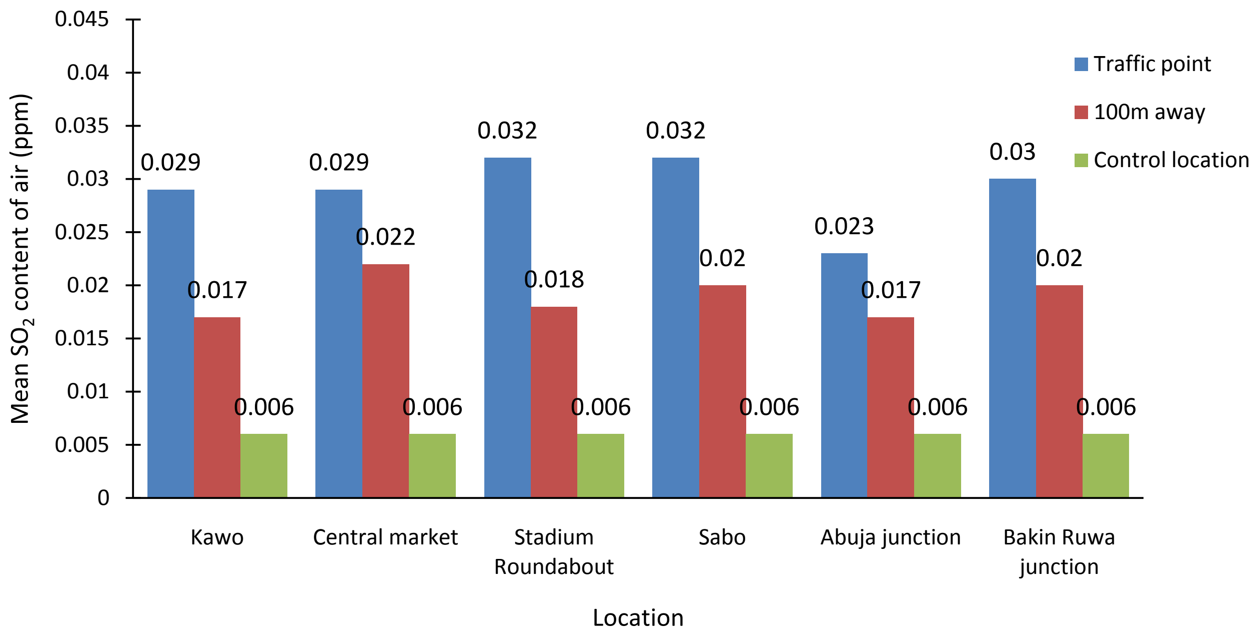

Fig 4.22: SO_2 concentration at traffic point, 100m away from traffic and at control location during wet season

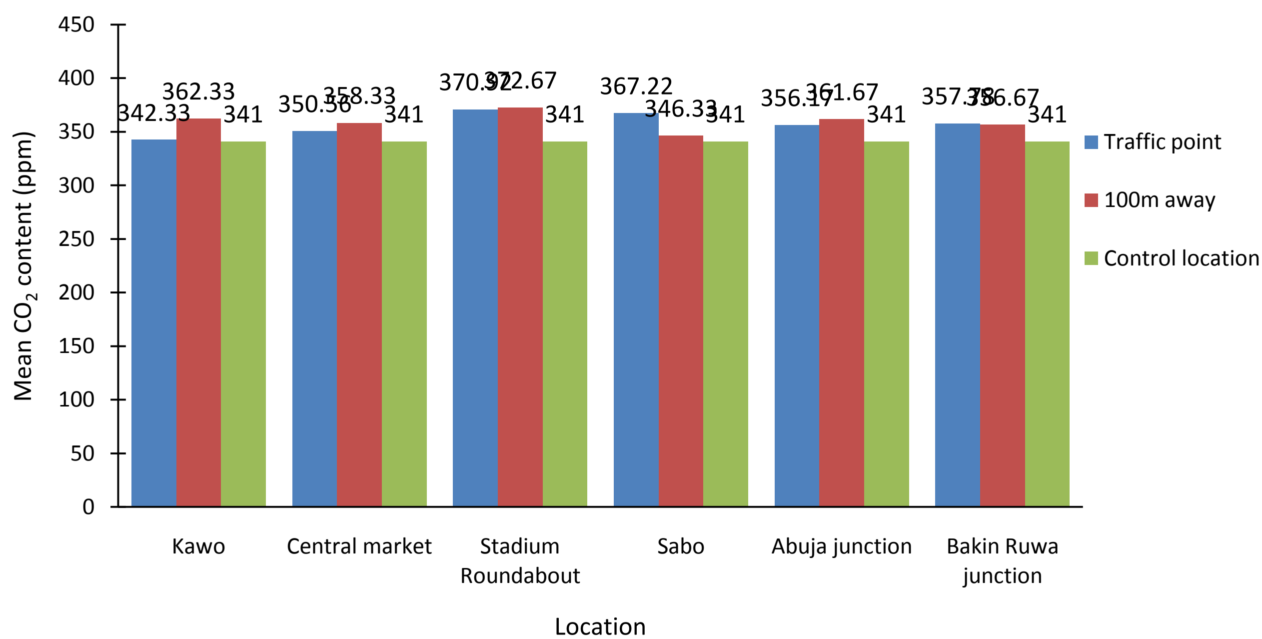

Figure 4.23: CO_2 concentration at traffic point, 100m away from traffic and at control location during wet season

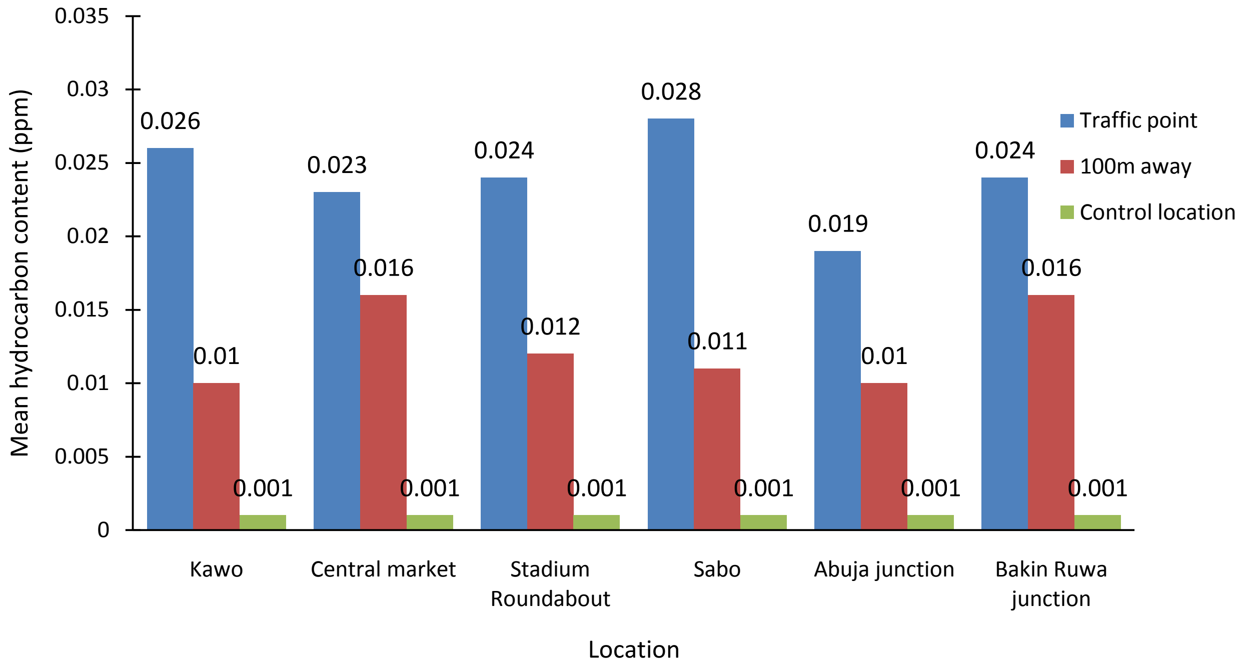

Figure 4.24: HC concentration at traffic point, 100m away from traffic and at control location during wet season

In the wet season, however, reduction of CO a distance of 100m with reference to Stadium Roundabout was by 45.25%; NO_2 a distance of 100m away from Sabon Tasha was reduced by 40%; SO_2 experienced a reduction of 37.5% with reference to Sabon Tasha and HC a reduction of 60.71% with reference to Sabon Tasha being the most polluted site on the average.

The fact that vehicular emission concentrations tend to decrease with increase in distance from the emission source, can pave the way for the representation of the air dispersion model developed to show the interaction/relationship between emission concentration at a source location and what the concentration will be at a receptor location.

4.7: AIR QUALITY PREDICTIVE MODEL SHOWING VARIATION OF EMISSION WITH INCREASING DISTANCE AWAY FROM SOURCE.

Appendix 2.30, 2.31, 2.32 and 2.33 are the results obtained from the mathematical model used for the prediction of CO, NO_2, SO_2, and HC emissions concentration with increase in distance from the source. CO_2 was left out for prediction because the concentration of CO_2 at the sites, where independent on the traffic activities as areas with little or no traffic recorded even higher CO_2 concentrations.

The slope of the plot of log C_R against log $\frac{C_S}{D}$ gives 0.9474 as depicted in the graph. Therefore, k = antilog (0.9474) which give 8.8587. The tables used for the plot are presented in Appendix 2.28, and 2.29, they are borne out of Appendix 2.26 and 2.27. The value of k can therefore be directly slotted into the equation $C_R = \frac{K*C_S}{D}$ for the prediction of the concentrations of any of the pollutants at some distance away from the source of the emission.

Values obtained from the predictions are presented in Appendix 2.30, 2.31, 2.32 and 2.33.The site in Kawo (dry season) was selected as sampled site for the prediction. No specific reason was considered for its choice as any other site and season can equally be selected for prediction employing the same equation.

The model is based on the law of dispersion which states that there is a trend in the reduction of pollutant concentration with increase in distance. The model has its application in the prediction of air pollutant dispersion in air pollution control and the safe distance for human habitation from traffic locations and industrial areas.

It is seen in Figure 4.25 that with increase in distance from the traffic area, the pollutant concentration was decreasing. As observed at a distance of about 3m from the emission source, the pollutant (CO) concentration was highest at 22.8ppm. At 100m away from the source is decreased to 2.0198ppm; it decreased steadily to 0.2020ppm at a distance of 1000m away from the source.

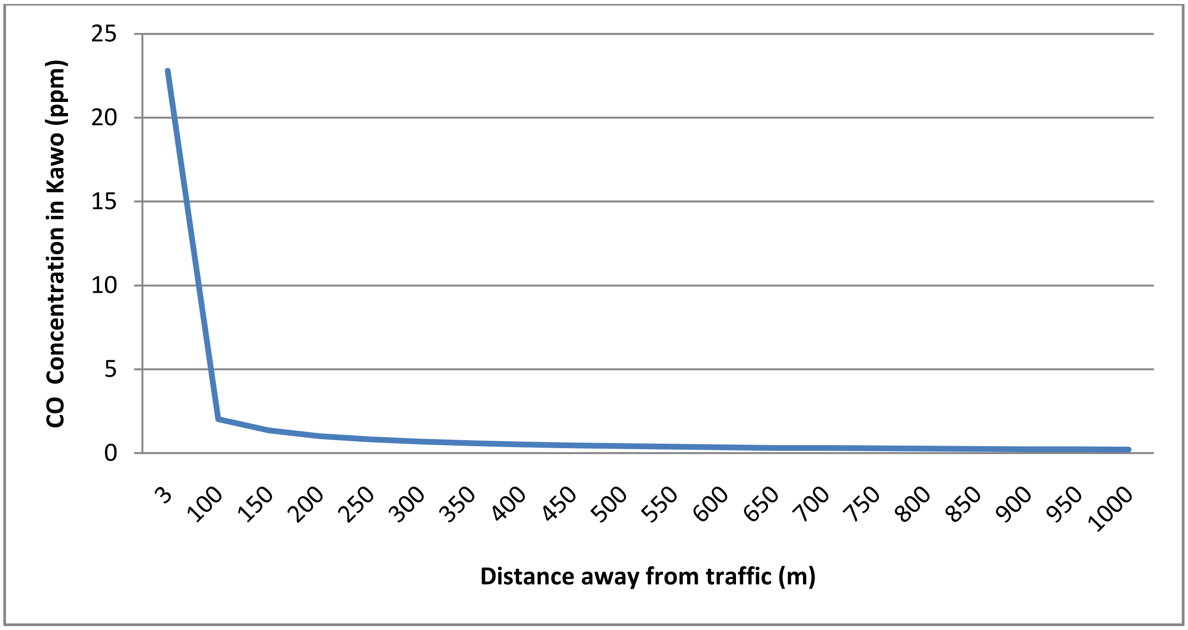

Figure 4.25: Modeled graph of CO concentration (Kawo) at source and further distances away from traffic.

Similarly, It is observed from Figure 4.26 that NO_2 concentration decreased with further distance from the traffic area. At a distance of about 3m from the emission source, the pollutant (NO_2) concentration was highest at 0.038ppm. At 100m away from the source is decreased to 0.00673ppm; it decreased steadily to 0.00034ppm at a distance of 1000m away from the source.

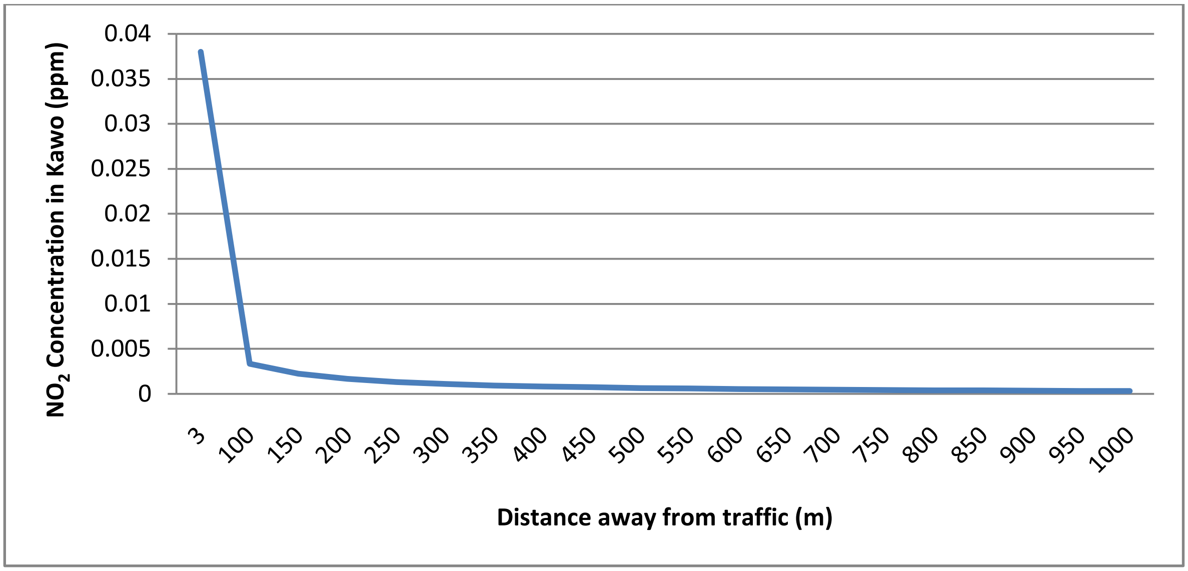

Figure 4.26: Modeled graph of NO_2 concentration (Kawo) at source and further distances away from traffic.

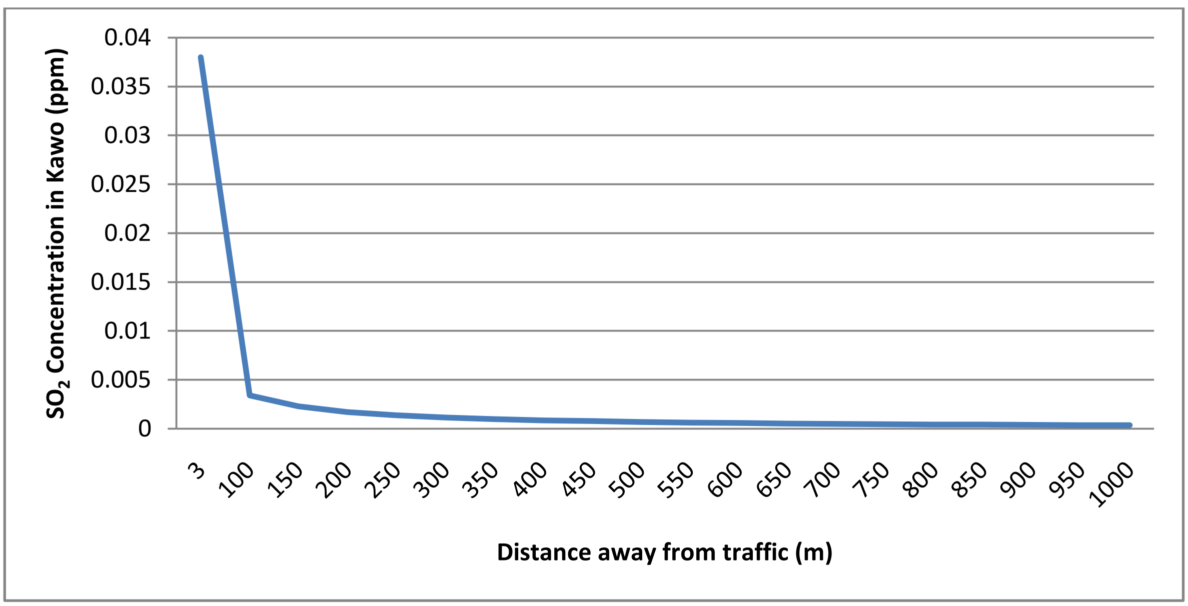

Figure 4.27: Modeled graph of SO_2 concentration (Kawo) at source and further distances away from traffic.

It is observed from the Figure 4.27 that SO_2 concentration decreased with further distance from the traffic area. At a distance of about 3m from the emission source, the pollutant

(SO_2) concentration was highest at 0.038ppm. At 100m away from the source is decreased to 0.00673ppm; it decreased steadily to 0.00034ppm at a distance of 1000m away from the source.

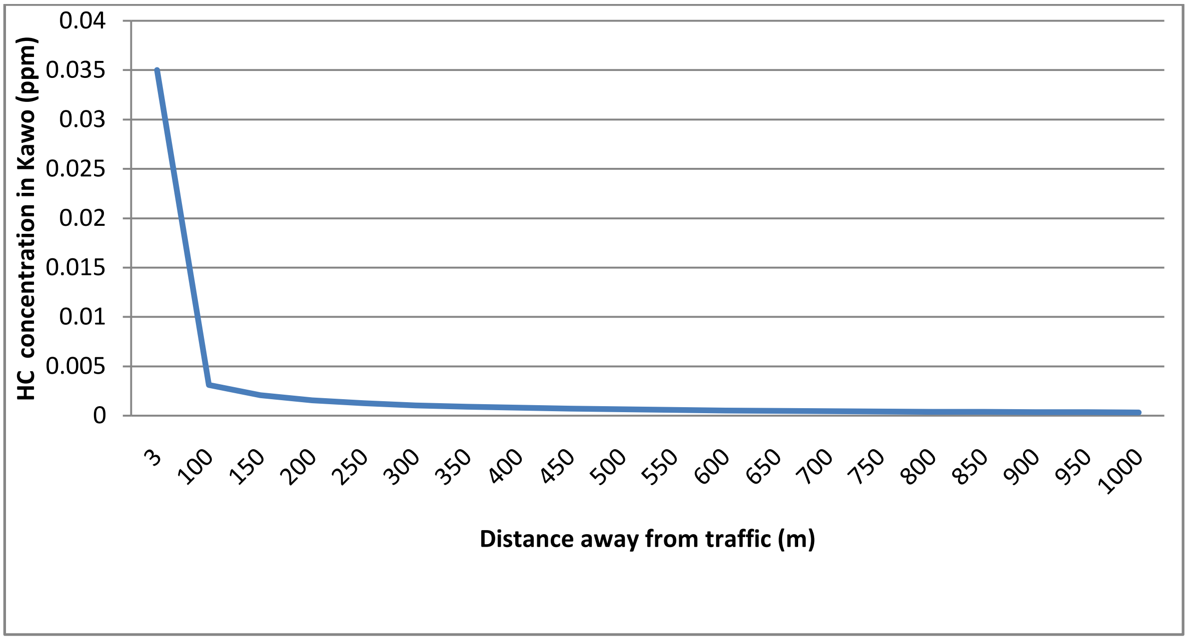

Figure 4.28: Modeled graph of HC concentration (Kawo) at source and further distances away from traffic.

It is observed from the Figure 4.28 that HC concentration decreased with further distance from the traffic area. At a distance of about 3m from the emission source, the pollutant (HC) concentration was highest at 0.035ppm. This is so because emission released at ground levels are usually highest at distances closer to the source of the emissions. At 100m away from the source is decreased to 0.00620ppm; it decreased steadily to 0.00031ppm at a distance of 1000m away from the source.

The mathematical model developed is therefore useful in the planning of residential and other facilities within Kaduna metropolis and beyond.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Air is no doubt one of the most important requirements needed to sustain a healthy life. Hence the need for access to clean air cannot be over-emphasized. From the reported study, air quality in Kaduna metropolis, varied in space and time. Though areas around the Central Market and the Stadium Junction experienced high traffic congestion and low air quality in most times of the day, the air quality was relatively improved on Sunday mornings due to low vehicular traffic.

Study from the monitoring and from preliminary investigation of the sites indicated that the Stadium Junction areas and the Central Market areas were most traffic-congested hence experienced high pollutants' concentrations. Areas around Sabon Tasha, Bakin Ruwa and Kawo were minimal both in terms of traffic and air quality when compared to Stadium Junction and Central Market areas. Abuja junction area had high air quality and very low traffic due to the low level of commercial activities in the area. The well-constructed bridge equally accounts for the low level of traffic in the area.

A comparison of the monitored air quality at the selected traffic spots and those monitored at background (100 meters away from traffic site) showed a reduction in the concentration of the pollutants' with increased distance. However, because some residences were situated close to areas around the Central Market and Stadium Junction, background concentrations in those areas were high when compared to other background locations.

When compared with National Ambient Air Quality Standards, CO concentration exceeded both the 1 hour limit of 10ppm and the 8 hours limit of 20ppm in all the sites during the dry season except for Abuja junction where only the 1 hour limit was exceeded. In the wet season most sites exceeded the 10ppm limit, most however were within the 8 hour limit of 20ppm. For sulphur dioxide (SO_2), both seasons experienced concentrations beyond the 1 hour standard of 0.01ppm. Only a few sites were above the 1 hour limit of 0.04ppm for nitrogen dioxide in the dry season. Hydrocarbon concentrations in both seasons were within the 0.6ppm limits. Carbon dioxide (CO_2) in both seasons was above the 314ppm obtainable in pure air.

An assessment of the carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) quality in the ambient air of Kaduna metropolis using the Air Quality Index of the United States indicated a better air quality in the wet season as compared to the dry season. While all sites (except Abuja junction – unhealthy), were adjudged “very unhealthy” in terms of CO concentration during the wet season, only Kawo, Central Market and Stadium Roundabout were adjudged “very unhealthy” in the wet season. Abuja Junction was “moderate” while Sabon Tasha and Bakin Ruwa were adjudged “unhealthy”. NO_2 quality was “good” in both seasons. On the other hand, SO_2 quality in the dry season was “moderate” in all sites (except Abuja Junction which was “good”) but “good” in all sites in the wet season.

5.2 RECOMMENDATIONS

In order to mitigate the problems/challenges posed by vehicular traffic emissions in Kaduna metropolis, the following strategies have been recommended:

1. **Funding of research by government**

The amount of pollutants released from vehicle exhausts system during combustion is dependent on how efficient an engine functions among other things. The ability to continue to increase fuel efficiency in a gas-powered car is likely limited by the cost of developing new technologies and the weight associated with necessary performance and safety materials. Government can therefore assist in the development of these new technologies that will enhance engine efficiency and reduce fuel consumption through the funding of research. Research into the use of alternative source of fuel/energy can be encouraged as well. Advanced materials are essential for boosting the fuel economy of modern automobiles while maintaining safety and performance. Because it takes less energy to accelerate a lighter object than a heavier one, lightweight materials offer great potential for increasing fuel economy improvement. Replacing cast iron and traditional steel components with lightweight materials such as high-strength steel, magnesium alloys, aluminum alloys, carbon fiber, and polymer composites can directly reduce the weight of a vehicle's body and chassis by up to 50 percent and therefore reduce a vehicle's fuel consumption.

2. **Improvement in public transport operation**

Motorized transport is one of the major sources of air pollution particularly in Kaduna City due to traffic congestion since vehicles release more pollutants when idling than when speeding; and inefficient motor vehicles especially second-hand vehicles which not only pose mechanical problems but also environmental problems. In this regards, there is a need to not only promote public transportation with larger capacity of passengers but also to improve public transportation system. This will reduce greenhouse gas emission by providing a convenient option to reduce unnecessary driving, lowering emissions per passenger kilometer travelled and supporting more compact urban design and reducing the need for travelling long distances.

3. **Land use planning**

A community that is designed to encourage transit ridership, walking or cycling has a huge potential for greenhouse gas emissions reductions. Such designs will encourage the use of non-motorized means of transportation and even walking, thereby reducing the use of motorized means, hence reducing emissions.

4. **Pricing mechanism**

Road pricing mechanism forms another mitigating measure aimed at reducing emission from vehicles. In this system, direct charges are levied for the use of roads, including road tolls, distance or time based fees, fuel sources or more polluting vehicles. These charges may be used primarily for revenue generation, usually for road infrastructure financing or as a transportation demand management tool to reduce peak hour travel and the associated traffic congestion or other social and environmentally negative externalities associated with road travel such as air pollution, greenhouse gas emissions, visual intrusion, noise and road accidents

5. **Promoting public awareness and education.**

Awareness creation efforts on the health impact of vehicular emission through key stakeholders (policy and decision makers, journalists, industrialists) as well as mainstreaming air quality management in school curricula can be encouraged. This will go a long way in discouraging people to situate businesses and residences along traffic corridors.

6. **Emission tests and standards**

Emissions from vehicular traffic can be mitigated if emission standards are set and enforced by the relevant agents of government. Such measure will require all vehicles to pass an emission test to be deemed fit to ply the road. This will encourage vehicle owners to carry out regular maintenance checks on their vehicles.

7. Urban Planning

The vulnerability of cities to vehicular pollution in most cities is closely linked to the type and characteristics of the built-up environment. The pattern of distribution of economic activities plays a significant role the presence of these pollutants in the environment. Kaduna metropolis for instance has these pollutants concentration more in the centre of the metropolis – Central Market area and the Stadium Roundabout areas. The decentralization of facilities such as markets churches and mosques, stadium and industries is a mitigating measure that can reduce the concentration of these pollutants at the city centres. The nature of the built roads is equally key. Overhead bridges, by-passes among others can help in the diversion of traffic.

8. **Vehicle Age**

Legislation on the age of vehicles imported into the country is can go a long way in mitigating vehicular emission. The older a vehicle is the more the tendency to emit more pollutants. This is even more problematic in Nigeria due to the low level of maintenance on vehicles.

REFERENCES

Abam, F.I. and Unachukwu, G.O. (2009). Vehicular emission and air quality standards in Nigeria. European journal of scientific research 34(4):550-560.

Abhishek, T. and Colls, J. (2010). Air pollution Measurement, Modeling and Mitigation, London, Routledge.

Affum, J.K. and Brown, A.L. (1999). Estimating urban air pollution levels from road traffic in TRAEMS, Journal of Eastern Asia Society for Transportation Studies, 3(1):139 – 150.

Ahrens, C.D. (2003) Meteorology Today - An Introduction to Weather, Climate and the Environment, 7th edition, Thomson Brooks/Cole.

Akpan, U.G. and Ndoke, P. N. (1999). Contribution of vehicular traffic emission to CO_2 emission in Kaduna and Abuja, Nigeria. Leonardo Electronic Journal of Practices and Technologies. p. 81-90.

Alias, M., Hamzah, Z. and Kenn, L.S. (2007). PM_{10} and total suspended particulates (TSP) measurement in various power stations. Malaysian Journal of Analytical Sciences, 11(1):255 – 261.

Asheshi, O.O. (2012). Measurement of Traffic Emission in Lafia Metropolis. Journal of Science and Multidisciplinary Research. 4:34-44.

Baldauf, R., Watkins, N., Heist D., Bailey, C., Rowley, P. and Shores, R. (2009). Near-road air quality monitoring: factors affecting network design and interpretation of data. Air quality, atmosphere and health. 2:1-9. Doi 10. 1007/s 11869 – 009 – 0028 – 0.

Boyle, S. and Ardill, J. (1989). The Greenhouse Effect. London, U.K.: New English Library Paperbacks.

Brunekreef, B. (2005). Out of Africa, Occupation and Environmental Medicine.62:351-352. BMJ publishing group.

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

Colls J. (2002). Air pollution; London, Spon Press.

Colvile, R.N., Hutchinson, E.J., Mindell, J.S. & Warren, R.F. (2001) The transport sector as a source of pollution, Atmospheric environment, vol. 35, pp. 1537 – 1565

David, R.L. and Frederikse, H.P.R. (1997). Handbook of Chemistry and Physics. 28^{th} Edition.

Dickey, J.H. (2000) Selected topics related to occupational exposures - part vii: air pollution: overview of sources and health, DM Disease - Mouth, vol. 46, No. 9, pp.556 – 589.

ECMT (2000). CO_2 emission from transport organisation for economic cooperation and development.

Faboye, O.O. (1997). Industrial pollution and waste management. PP 26-35 in Akinjide Osuntogun (ed.). Dimensions of Environmental Problems in Nigeria, Ibadan Davidson press limited, Nigeria.

Faiz, A. and Sturm, P. (2000). New directions: air pollution and road traffic in developing countries. 34(27):4745-4746.

Faiz, A., Weaver, S.W., and Walsh, M.P., (1996) Air pollution from motor vehicles: Standards and Technologies for Controlling Emissions. Washington DC: The World Bank

Fenger, J. (1999). Urban Air Quality, Atmospheric Environment, Vol. 33, PP. 4877- 4900

FEPA (1991). Guidelines and standards for environmental pollution control in Nigeria. Federal Environmental Protection Agency press, Lagos.

FGN (2010). 2006 Population and Housing Census Official Gazette, 94(4) of January 19, 2007. www.catalog.ihsn.org/index.php/catalog/48521**,** Retrieved 8th December, 2014.

Fu, L. (2001). Assessment of Vehicle Pollution in China. Journal of the Air and Waste Management: 51(5):658 – 668.

Garba, A.G. and Garba, P.K. (2001). Market Failure and Air Pollution in Nigeria: A theoretical investigation of two cases, selected papers, Annual Conference of Nigerian Economic Society, held in Port-Harcourt.

Gribbon, J. (1990). Hot house earth, New York N.Y. Grove Weidenfeld Ltd.

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

Harssema, H. (1987). Modeling and Measurement of Air Quality (in Dutch: Berekenem en Metem Van de Lutchtkwaliteit), Wageningen Agricultural University, Wageningen, The Netherlands, Report No. R-200.

Iyoha, M.A. (2009). The environmental effects of oil industry activities on the Nigerian economy: A Theoretical Analysis. Paper presented at the National conference on the Management of Nigeria's Petroleum Resources organized by the Department of Economics, Delta State University.

Jastrow, R., Nierenberg, W., and Seitz, F. (1990). Scientific Perspectives on the Greenhouse Problem. Ottawa, Illinois: The Marshall Press, Jameson Books inc.

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

Koku, C.A. and Osuntogun, B.A. (2007). Environmental Impacts of Road Transportation in Southwestern States of Nigeria. Journal of Applied Sciences 7(16):2536-2360.

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

Mishra, P.C. (2008). Fundamentals or Air and Water Pollution, New Delhi: APH publishers limited. P. 7-17.

Ndoke P. N. and Jimoh D.O. (2000). Impact of Traffic Emission on Air Quality in a Developing City of Nigeria. Unpublished paper presented at the Department of Civil Engineering, Federal University of Technology Minna, Nigeria.

Murray, J.C (1992). Global Warming: Policy analysis and proposal for a Carbon sink silviculture program. A Research project submitted in partial fulfillment of the requirements for the degree of Master of Business Administration, Simon Fraser University.

Nwachukwu, A.N., Chukwuocha, E.O. and Igbudu, O. (2012). A survey on the effects of air pollution on diseases of the people of Rivers State, Nigeria. African Journal of Environmental Science and Technology Vol. 6(10):371-379.

OECD (1999). Older Gasoline Vehicles. UNEP. www.clearairnet.org/cai/1403/articles-56396_Entire.pdf . Retrieved 28th May, 2014.

Okonkwo, S.I., Okpala, K.O. and Opara, M.F. (2012) Assessment of automobile Induced Pollution in an Urban Area (A Case Study of Port Harcourt City, Rivers State, Nigeria). 2012 International Conference on Environmental, Biomedical and Biotechnology. IPCBEE Vol. 41. IACSIT press, Singapore.

Onursal, B., and Gautam, S.P. (1997) Vehicle Air Pollution Experiences From Seven Latin American Urban Centres. Technical Paper No. 373. Washington DC: World Bank

Orubu, C.O. (2004). Using transportation control measures and economic instruments to reduce air pollution due to automobile emissions. Journal of Social Science. 8(3):227 – 236.

Orubu, C.O., Fajingbesi, A., Odusola, A. and Magbagbeola, N.O. (2002). Environmental Regulations in the Nigerian Petroleum Industry: Compliance and Implication for Sustainable Development". Research Report, Ibadan, NCEMA/ACBF Collaborative Programme.

Pierre J., Ruth, F., Weiner, P. and Vesilind, A. (1998). Environmental Pollution and Control 4th edition Butterworth Heinemann pp. 245 – 260.

Powe, A., and Willisc, G. (2002). Mortality and morbidity benefits of air pollution absorption by woodland, Social and Environmental Benefits of Forestry, phase 2.

Ronni, E.R., (2012). The effect of vehicular emission on human health. www.yale.edu/ynhti/nationalcurriculum/unit/2008/7/08.07. Retrieved May 6, 2012.

Rouphail, N.M., Frey, H.C., Colyar, J.D. and Unal, A (2001). Vehicle emissions and traffic measures: Exploratory analysis of field observation at signalized arterials. Paper presented at the 80th Annual Meeting of the Transportation Research Board.

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

UNFPA (2008). State of World Population 2008: Unleashing the potential of urban growth. www.unfpa.org/swp/2008/english/introduction.html. Retrieved 12th June, 2014.

United Nations Environment Programme and the United Nations Development Programme. Oxford University Press, New York, NY, USA.

UN (1998). Prospect of World Urbanization (Population Study No. 112) New York.

USEPA (2003). Guideline for Reporting Daily Air Quality. Air Quality Index (AQI), EPA-454/k-03-002, Office of Air Quality Planning and Standards: Research Triangle Park, NC.

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

Utang, P.B., and Peterside, K.S. (2011). Spatio-temporal variations in urban vehicular. Ethiopian Journal of Environmental Studies and Management, 4(2).

Victor, D.G. (1990). Calculating Greenhouse Budgets. Nature volume 347 (October 4).

Wai, C.S. and Steven, L. (2007). Air Pollution: Business risk or competitive advantage. P.285

Walsh, M.P. (2000). Transportation and the Environment in China. China Environment Series, no.3

Whitelegg, J. and Haq, G. (2003). The global transport problem: Some issues but a different place, in John Whitelegg and Gary Haq (Ed), World Transport, Policy and Practice. London: Earthscan publications limited.

WHO (2004). Health Aspects of Air Pollution: Results from the WHO project. "Systematic Review of Health Aspects of Air Pollution in Europe".

World Bank (1995). Defining Environmental Development Strategy for the-Niger Delta. DRAFT REPORT on Niger Delta Wetlands Volume II. World Bank, Washington DC. May 25th.

World Bank (2004). World Bank East Asia and the Pacific Urban Business Directions. World Bank, East Asia Department, Washington, DC.

WRI (1998). Environmental changes and human health. A Guide to the Global Environment. A joint publication of the World Resources Institute (WRI), the United Nations Environment Programme (UNEP), the United Nation Development Programme (UNDP) and the World Bank. Oxford University Press, New York, NY and Oxford.

APPENDIX 1

APPENDIX 1.1 TO 1.26 SHOW AIR QUALITY DATA DURING DRY SEASON IN KADUNA METROPOLIS

Appendix 1.1: Air Quality Data for Kawo (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	22.3	0.037	0.039	326	0.030	32.0	32.8	3
Sunday 16th Dec. 2012	9.1	0.019	0.021	298	0.012	28.8	26.2	4
Wednesday 19th Dec. 2012	23.3	0.038	0.036	348	0.040	26.4	36.8	4

Appendix 1.2: Air Quality Data for Kawo (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	22.5	0.040	0.042	323	0.021	32.0	38.1	3
Sunday 16th Dec. 2012	10.2	0.028	0.024	324	0.020	38.1	21.6	3
Wednesday 19th Dec. 2012	28.1	0.040	0.036	397	0.035	32.4	28.0	2

Appendix 1.3: Air Quality Data for Kawo (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	25.8	0.043	0.044	301	0.015	29.8	39.3	4
Sunday 16th Dec. 2012	18.2	0.020	0.023	343	0.019	30.4	21.6	4
Wednesday 19th Dec. 2012	27.4	0.035	0.035	359	0.033	30.8	29.6	3

Appendix 1.4: Air Quality Data for Central Market (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	23.6	0.034	0.035	341	0.018	29.1	39.8	4
Sunday 16th Dec. 2012	6.3	0.016	0.020	341	0.022	27.2	29.2	4
Wednesday 19th Dec. 2012	28.3	0.031	0.036	307	0.020	29.1	32.0	3
Monday 4th Feb. 2013	29.3	0.043	0.042	361	0.036	23.1	32.4	4

Appendix 1.5: Air Quality Data for Central Market (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	26.7	0.046	0.042	301	0.002	39.0	20.2	3
Sunday 16th Dec. 2012	11.0	0.026	0.025	333	0.002	39.1	20.2	3
Wednesday 19th Dec. 2012	30.1	0.045	0.043	402	0.040	33.6	27.8	3
Monday 4th Feb. 2013	25.8	0.031	0.031	394	0.037	35.1	20.4	3

Appendix 1.6: Air Quality Data for Central Market (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	28.9	0.047	0.046	327	0.030	31.0	35.2	3
Sunday 16th Dec. 2012	21.1	0.026	0.027	322	0.022	31.3	20.2	3
Wednesday 19th Dec. 2012	31.5	0.046	0.042	327	0.038	30.0	30.4	4
Monday 4th Feb. 2013	28.1	0.040	0.031	395	0.030	32.1	29.4	3

Appendix 1.7: Air Quality Data for Stadium Roundabout (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	22.3	0.041	0.038	333	0.040	28.4	29.8	3
Sunday 16th Dec. 2012	7.0	0.022	0.020	301	0.011	32.0	28.8	5
Wednesday 19th Dec. 2012	33.4	0.042	0.043	329	0.040	28.3	30.3	4
Monday 4th Feb. 2013	33.3	0.041	0.041	399	0.030	24.0	32.6	4

Appendix 1.8: Air Quality Data for Stadium Roundabout (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	24.1	0.043	0.040	313	0.003	36.4	21.3	3
Sunday 16th Dec. 2012	12.1	0.031	0.028	348	0.002	37.2	20.6	4
Wednesday 19th Dec. 2012	31.3	0.044	0.045	493	0.002	31.5	25.5	4
Monday 4th Feb. 2013	21.9	0.026	0.028	391	0.032	34.5	21.2	3

Appendix 1.9: Air Quality Data for Stadium Roundabout (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	28.6	0.046	0.043	346	0.040	32.0	34.8	4
Sunday 16th Dec. 2012	23.3	0.033	0.029	341	0.030	31.4	20.6	3
Wednesday 19th Dec. 2012	33.5	0.048	0.042	330	0.050	30.1	33.8	4
Monday 4th Feb. 2013	32.9	0.046	0.041	404	0.037	33.0	28.3	3

Appendix 1.10: Air Quality Data for Sabon Tasha (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	27.3	0.043	0.044	316	0.030	29.9	29.9	2
Sunday 16th Dec. 2012	8.0	0.021	0.020	338	0.023	28.1	29.0	4
Wednesday 30th Jan. 2013	28.4	0.037	0.038	401	0.029	27.4	34.2	3
Thursday 6th Feb. 2013	23.6	0.031	0.028	379	0.029	29.1	34.1	4

Appendix 1.11: Air Quality Data for Sabon Tasha (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	25.3	0.044	0.041	353	0.022	36.2	22.1	3
Sunday 16th Dec. 2012	10.4	0.029	0.027	336	0.019	39.0	20.5	3
Wednesday 30th Jan. 2013	23.2	0.029	0.032	386	0.024	34.2	20.4	2
Thursday 6th Feb. 2013	24.9	0.033	0.032	390	0.033	33.7	23.0	3

Appendix 1.12: Air Quality Data for Sabo Tasha (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	27.1	0.042	0.039	334	0.024	31.3	26.1	3
Sunday 16th Dec. 2012	22.4	0.028	0.026	335	0.024	32.0	20.5	4
Wednesday 30th Jan. 2013	28.5	0.039	0.033	374	0.029	30.1	25.1	3
Thursday 6th Feb. 2013	27.0	0.032	0.030	372	0.033	30.4	29.4	3

Appendix 1.13: Air Quality Data for Abuja Junction (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	13.2	0.032	0.020	315	0.002	31.3	33.2	4
Sunday 16th Dec. 2012	4.3	0.007	0.011	307	0.003	27.3	28.0	5
Tuesday 29th Jan. 2013	7.3	0.020	0.024	367	0.005	29.6	34.7	4

Appendix 1.14: Air Quality Data for Abuja Junction (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	15.3	0.032	0.020	348	0.003	35.8	21.4	4
Sunday 16th Dec. 2012	6.3	0.011	0.013	342	0.010	38.7	22.0	3
Tuesday 29th Jan. 2013	12.6	0.024	0.014	366	0.012	34.6	31.3	3

Appendix 1.15: Air Quality Data for Abuja Junction (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	20.3	0.021	0.030	365	0.019	30.7	35.3	4
Sunday 16th Dec. 2012	8.3	0.015	0.017	318	0.014	29.8	22.0	4
Tuesday 29th Jan. 2013	14.3	0.028	0.025	376	0.010	29.4	31.1	3

Appendix 1.16: Air Quality Data for Bakin Ruwa Junction (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	25.3	0.044	0.044	259	0.019	31.7	34.4	3
Sunday 16th Dec. 2012	6.7	0.017	0.021	322	0.020	29.1	28.3	4
Tuesday 29th Jan. 2013	28.2	0.042	0.035	384	0.032	27.8	35.8	4
Thursday 6th Feb. 2013	25.8	0.031	0.027	383	0.030	29.0	33.7	3

Appendix 1.17: Air Quality Data for Bakin Ruwa Junction (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	27.1	0.047	0.044	307	0.020	33.6	27.9	2
Sunday 16th Dec. 2012	11.5	0.030	0.028	355	0.022	38.4	21.1	3
Tuesday 29th Jan. 2013	23.8	0.038	0.039	397	0.034	33.4	21.3	2
Thursday 6th Feb. 2013	21.1	0.024	0.025	394	0.026	34.7	21.3	3

Appendix 1.18: Air Quality Data for Bakin Ruwa Junction (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Saturday 15th Dec. 2012	24.4	0.044	0.040	325	0.041	31.1	35.0	3
Sunday 16th Dec. 2012	20.5	0.026	0.029	356	0.020	30.6	21.1	3
Tuesday 29th Jan. 2013	29.4	0.043	0.041	399	0.036	31.2	28.6	3
Thursday 6th Feb. 2013	28.9	0.037	0.030	372	0.029	30.4	29.4	3

Appendix 1.19: Concentration of Pollutants 100 meters Away From Traffic Spots.

Location	Air Quality Parameter Morning					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	7.1	0.014	0.016	326	0.002	26.4	36.1	4
Central Market	10.1	0.021	0.023	334	0.010	30.3	31.6	3
Stadium Roundabout	14.1	0.016	0.021	332	0.004	29.0	31.3	3
Sabon Tasha	10.4	0.016	0.013	382	0.013	28.2	33.9	3
Abuja Junction	5.1	0.009	0.018	377	0.015	29.0	36.1	4
Bakin Ruwa	9.4	0.017	0.019	373	0.011	29.4	36.0	4

Appendix 1.20: Concentration of Pollutants 100 meters Away From Traffic Spots.

Location	Air Quality Parameter Afternoon					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	11.4	0.018	0.020	354	0.003	31.6	27.4	3
Central Market	19.3	0.022	0.027	388	0.004	32.4	28.2	3
Stadium Roundabout	15.2	0.011	0.019	411	0.013	31.3	26.1	3
Sabon Tasha	11.4	0.014	0.019	391	0.013	35.0	20.6	2
Abuja Junction	8.9	0.010	0.014	366	0.012	34.6	31.3	3
Bakin Ruwa	10.46	0.018	0.021	381	0.013	35.0	20.7	2

Appendix 1.21: Concentration of Pollutants 100 meters Away From Traffic Spots

Location	Air Quality Parameter Evening					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	9.7	0.020	0.018	346	0.017	29.6	30.1	4
Central Market	14.1	0.026	0.023	317	0.013	30.0	31.2	4
Stadium Roundabout	12.6	0.017	0.021	328	0.015	29.5	32.3	4
Sabon Tasha	10.4	0.021	0.018	384	0.014	31.4	26.3	3
Abuja Junction	7.9	0.011	0.002	384	0.016	28.7	30.6	3
Bakin Ruwa	11.5	0.019	0.024	385	0.020	30.7	31.1	2

Appendix 1.22: Air Quality Data of Control Site at Angwa Rimi G.R.A

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Wednesday 19th Dec. 2012	4.0	0.001	0.011	340	0.001	28.6	32.7	4
Tuesday 5th Feb. 2013	2.0	0.000	0.001	355	0.001	27.0	34.0	3
Average	3.0	0.001	0.006	348	0.001	27.8	33.4	4

APPENDIX II SHOWS AIR QUALITY DATA DURING THE WET SEASON IN KADUNA METROPOLIS

Appendix 2.1: Air Quality Data for Sabon Tasha (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Monday 17th June, 2013	11.0	0.037	0.038	331	0.030	28.1	72.3	3
Thursday 20th June, 2013	15.0	0.031	0.034	356	0.030	27.5	73.7	3
Sunday 23rd June, 2013	4.7	0.011	0.016	368	0.005	27.92	72.83	2
Monday 24th June. 2013	18.0	0.030	0.032	362	0.030	28.4	34.2	3

Appendix 2.2: Air Quality Data for Sabon Tasha (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Monday 17th June, 2013	8.0	0.023	0.031	337	0.020	36.1	51.2	3
Thursday 20th June, 2013	10.1	0.028	0.022	374	0.020	31.7	54.4	3
Sunday 23rd June, 2013	6.1	0.013	0.017	371	0.008	29.9	52.0	2
Monday 24th June. 2013	16.4	0.029	0.027	344	0.020	31.5	62.8	3

Appendix 2.3: Air Quality Data for Sabon Tasha (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Monday 17th June, 2013	19.8	0.033	0.036	343	0.030	29.4	68.4	3
Thursday 20th June, 2013	18.4	0.032	0.035	381	0.029	30.2	69.4	3
Sunday 23rd June, 2013	7.8	0.016	0.020	349	0.006	29.5	62.4	2
Monday 24th June. 2013	19.5	0.029	0.031	356	0.032	30.2	62.8	3

Appendix 2.4: Air Quality Data for Central Market (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Tuesday 18th June, 2013	9.0	0.027	0.029	353	0.030	31.2	63.2	3
Saturday 22nd June, 2013	13.4	0.022	0.023	348	0.023	26.4	74.3	3
Sunday 23rd June, 2013	8.2	0.019	0.024	366	0.011	27.9	75.3	2
Thursday 27th June, 2013	20.6	0.025	0.027	351	0.019	27.1	75.1	3

Appendix 2.5: Air Quality Data for Central Market (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Tuesday 18th June, 2013	17.0	0.025	0.027	345	0.020	36.7	52.6	3
Saturday 22nd June, 2013	22.4	0.028	0.030	362	0.026	33.6	51.3	3
Sunday 23rd June, 2013	10.1	0.013	0.017	362	0.013	30.1	60.4	2
Thursday 27th June, 2013	18.7	0.022	0.027	348	0.009	31.0	61.0	3

Appendix 2.6: Air Quality Data for Central Market (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Tuesday 18th June, 2013	17.0	0.039	0.041	356	0.030	32.0	65.2	3
Saturday 22nd June, 2013	25.0	0.030	0.032	357	0.029	29.8	63.0	3
Sunday 23rd June, 2013	13.4	0.019	0.019	350	0.010	28.4	74.7	2
Thursday 27th June, 2013	21.8	0.028	0.030	367	0.024	30.4	66.9	3

Appendix 2.7: Air Quality Data for Stadium Roundabout (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Tuesday 18th June, 2013	21.0	0.035	0.037	347	0.030	31.7	68.9	3
Saturday 22nd June, 2013	19.2	0.026	0.030	373	0.021	28.6	72.4	3
Sunday 23rd June, 2013	5.1	0.012	0.018	328	0.006	28.4	70.1	2
Thursday 27th June, 2013	19.5	0.029	0.031	365	0.022	27.0	75.6	3

Appendix 2.8: Air Quality Data for Stadium Roundabout (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Tuesday 18th June, 2013	11	0.033	0.035	341	0.030	30.8	63.8	3
Saturday 22nd June, 2013	21.3	0.021	0.026	369	0.019	32.4	52.9	3
Sunday 23rd June, 2013	8.4	0.017	0.021	321	0.009	31.3	51.4	2
Thursday 27th June, 2013	16.5	0.027	0.029	348	0.020	30.4	59.0	3

Appendix 2.9: Air Quality Data for Stadium Roundabout (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Tuesday 18th June, 2013	15.1	0.037	0.039	342	0.030	31.4	66.6	3
Saturday 22nd June, 2013	24.6	0.026	0.028	381	0.020	30.5	66.2	3
Sunday 23rd June, 2013	12.6	0.018	0.023	346	0.011	30.8	57.2	2
Thursday 27th June, 2013	22.1	0.031	0.034	341	0.026	29.5	66.2	3

Appendix 2.10: Air Quality Data for Bakin Ruwa Junction (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Monday 17th June, 2013	13.0	0.029	0.031	340	0.025	29.3	71.2	3
Thursday 20th June, 2013	15.0	0.030	0.032	351	0.024	28.4	77.4	3
Sunday 23rd June, 2013	6.0	0.014	0.015	376	0.006	28.8	71.5	2
Monday 24th June, 2013	19.1	0.031	0.034	354	0.027	28.0	76.8	3

Appendix 2.11: Air Quality Data for Bakin Ruwa Junction (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Monday 17th June, 2013	11.0	0.033	0.027	326	0.030	36.2	53.4	3
Thursday 20th June, 2013	8.4	0.028	0.022	350	0.024	33.4	60.0	3
Sunday 23rd June, 2013	6.4	0.018	0.018	384	0.013	30.6	51.6	2
Monday 24th June, 2013	16.5	0.027	0.031	339	0.019	32.1	61.4	3

Appendix 2.12: Air Quality Data for Bakin Ruwa Junction (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Monday 17th June, 2013	22.0	0.032	0.037	340	0.020	31.3	67.6	3
Thursday 20th June, 2013	9.9	0.020	0.022	347	0.019	30.6	73.3	3
Sunday 23rd June, 2013	7.8	0.012	0.014	356	0.010	29.3	60.4	2
Monday 24th June, 2013	20.2	0.029	0.033	334	0.029	30.6	66.9	3

Appendix 2.13: Air Quality Data for Abuja Junction (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Monday 17th June, 2013	9.0	0.031	0.033	329	0.020	28.7	72.9	3
Thursday 20th June, 2013	7.3	0.024	0.021	350	0.019	27.3	79.3	3
Sunday 23rd June, 2013	3.1	0.009	0.020	313	0.007	29.2	69.3	2
Monday 24th June, 2013	9.3	0.023	0.020	382	0.019	27.8	77.3	3

Appendix 2.14: Air Quality Data for Abuja Junction (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Monday 17th June, 2013	7.1	0.021	0.024	298	0.015	36.6	54.5	3
Thursday 20th June, 2013	6.4	0.018	0.020	347	0.012	31.5	68.8	3
Sunday 23rd June, 2013	4.6	0.013	0.020	321	0.010	30.9	50.2	2
Monday 24th June, 2013	6.7	0.020	0.018	382	0.014	32.4	59.9	3

Appendix 2.15: Air Quality Data for Abuja Junction (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Monday 17th June, 2013	14.2	0.032	0.031	351	0.026	30.1	70.6	3
Thursday 20th June, 2013	10.3	0.022	0.021	331	0.020	31.5	68.8	3
Sunday 23rd June, 2013	8.1	0.014	0.018	319	0.009	30.4	56.7	2
Monday 24th June, 2013	9.5	0.021	0.021	377	0.022	31.3	69.1	3

Appendix 2.16: Air Quality Data Kawo (Morning hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Tuesday 18th June, 2013	13.0	0.021	0.024	334	0.020	28.0	75.9	3
Saturday 22nd June, 2013	10.4	0.021	0.020	341	0.020	27.4	75.4	3
Sunday 23rd June, 2013	7.3	0.012	0.013	361	0.011	27.4	76.4	2
Thursday 27th June, 2013	18.4	0.029	0.031	347	0.029	29.4	68.2	3

Appendix 2.17: Air Quality Data for Kawo (Afternoon hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Tuesday 18th June, 2013	11.0	0.031	0.029	313	0.020	37.0	55.6	3
Saturday 22$^{nd\ J}$une, 2013	21.9	0.028	0.030	353	0.032	34.1	50.3	3
Sunday 23rd June, 2013	9.5	0.021	0.022	348	0.012	33.2	56.3	2
Thursday 27th June, 2013	15.4	0.024	0.028	334	0.020	30.8	60.3	3

Appendix 2.18: Air Quality Data for Kawo (Evening hours)

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Tuesday 18th June, 2013	21.1	0.035	0.039	342	0.030	31.6	64.5	3
Saturday 22$^{nd\ J}$une, 2013	22.0	0.031	0.030	361	0.032	34.1	66.2	3
Sunday 23rd June, 2013	12.6	0.025	0.024	351	0.016	31.4	59.7	2
Thursday 27th June, 2013	19.5	0.031	0.032	361	0.029	30.0	67.8	3

Appendix 2.19: Average Concentration of pollutants in Kaduna Metropolis for Rainy Season

Location	Air Quality Parameter Morning					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	13.93	0.025	0.024	353.00	0.023	30,97	69.50	3
Central Market	14.33	0.025	0.026	350.67	0.024	28.23	70.87	3
Stadium Roundabout	19.90	0.030	0.033	361.67	0.024	29.10	72.30	3
Sabon Tasha	14.67	0.033	0.034	349.67	0.030	28.00	73.40	3
Abuja Junction	8.53	0.026	0.025	353.67	0.019	27.93	76.50	3
Bakin Ruwa	15.70	0.030	0.032	348.33	0.025	28.57	75.13	3

Appendix 2.20: Average Concentration of Pollutants in Kaduna Metropolis for Rainy Season

Location	Air Quality Parameter Afternoon					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	16.10	0.028	0.029	333.33	0.024	33.97	55.40	3
Central Market	19.37	0.025	0.028	351.67	0.018	33.77	54.97	3
Stadium Roundabout	16.27	0.027	0.030	352.67	0.023	31.2	58.57	3
Sabon Tasha	11.50	0.027	0.027	351.67	0.020	33.10	56.13	3
Abuja Junction	6.73	0.020	0.021	342.33	0.014	33.50	61.07	3
Bakin Ruwa	11.97	0.029	0.027	338.33	0.024	33.90	58.27	3

Appendix 2.21: Average Concentration of Pollutants in Kaduna Metropolis for Rainy Season

Location	Air Quality Parameter Evening					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	20.87	0.032	0.034	354.67	0.030	31.90	66.17	3
Central Market	21.27	0.032	0.034	360.00	0.028	30.73	65.03	3
Stadium Roundabout	20.00	0.031	0.034	354.67	0.025	30.47	66.33	3
Sabon Tasha	19.23	0.031	0.034	360.00	0.030	29.93	66.87	3
Abuja Junction	11.33	0.025	0.024	353	0.023	30.97	69.5	3
Bakin Ruwa	17.37	0.027	0.031	340.33	0.023	30.83	69.27	3

Appendix 2.22: Concentration of Pollutants 100 meters Away From Traffic Spots.

Location	Air Quality Parameter Morning					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	6.14	0.014	0.015	348.00	0.011	27.30	75.4	3
Central Market	8.47	0.016	0.019	351.00	0.015	26.93	74.3	3
Stadium Roundabout	8.89	0.011	0.014	374	0.011	28.00	71.90	3
Sabon Tasha	7.43	0.019	0.021	344.00	0.013	27.65	74.80	3
Abuja Junction	5.05	0.007	0.018	331.00	0.010	27.10	78.90	3

Bakin Ruwa	7.71	0.019	0.020	344.00	0.016	28.70	76.90	3

Appendix 2.23: Concentration of Pollutants 100 meters Away From Traffic Spots.

Location	Air Quality Parameter					Meteorology		
	Afternoon							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	8.74	0.016	0.017	368	0.010	34.4	49.70	3
Central Market	11.33	0.018	0.023	374	0.014	34.10	52.00	3
Stadium Roundabout	9.39	0.014	0.020	354	0.014	31.9	50.4	3
Sabon Tasha	5.31	0.016	0.018	366	0.011	30.90	55.80	3
Abuja Junction	4.81	0.010	0.013	376	0.009	34.00	61.70	3
Bakin Ruwa	8.39	0.012	0.018	350	0.013	33.40	60.00	3

Appendix 2.24: Concentration of Pollutants 100 meters Away From Traffic Spots

Location	Air Quality Parameter					Meteorology		
	Evening							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Kawo	8.99	0.017	0.018	371	0.010	30.4	62.30	3
Central Market	13.40	0.024	0.024	350	0.018	28.40	71.30	3
Stadium Roundabout	9.46	0.014	0.020	390	0.011	30.4	67.7	3
Sabon Tasha	10.1	0.019	0.020	329	0.010	30.10	65.70	3
Abuja Junction	7.73	0.015	0.019	378	0.010	31.60	67.40	3

Bakin Ruwa	9.90	0.020	0.022	376	0.018	30.6	73.30	3

Appendix 2.25: Air Quality Data of Control Site at Angwan Rimi G.R.A

Day/Date	Air Quality Parameter					Meteorology		
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temp. (^oC)	Relative Humidity (%)	Wind Speed (m/s)
Wednesday 19th June 2013	2.00	0.001	0.010	336	0.001	29.70	71.23	3
Tuesday 2nd July 2013	2.33	0.001	0.002	346	0.001	29.67	64.87	3
Average	2.17	0.001	0.006	341	0.001	29.69	68.05	3

Appendix 2.26: Average concentration of pollutants at traffic sites and their corresponding average concentration 100m away from traffic sites for dry season

Pollutants	Sites	Kawo	Central Market	Stadium Round-about	Sabon Tasha	Abuja Junction	Bakin Ruwa
CO	Traffic site	24.9	26.9	29.04	26.14	13.83	25.33
	100m away	9.3	14.4	13.97	10.97	7.3	10.45
NO_2	Traffic site	0.039	0.040	0.042	0.037	0.026	0.039
	100m away	0.017	0.026	0.015	0.017	0.010	0.018
SO_2	Traffic site	0.039	0.039	0.040	0.040	0.022	0.037
	100m away	0.018	0.024	0.020	0.017	0.011	0.021
HC	Traffic site	0.029	0.028	0.030	0.028	0.009	0.030
	100m away	0.007	0.009	0.011	0.013	0.004	0.015

Appendix 2.27: Average concentration of pollutants at traffic sites and their corresponding average concentration 100m away from traffic sites for wet season

Pollutants	Sites	Kawo	Central Market	Stadium Round-about	Sabon Tasha	Abuja Junction	Bakin Ruwa
CO	Traffic site	16.97	18.32	18.72	15.13	8.86	15.01
	100m away	7.96	11.07	9.25	7.61	5.87	8.67
NO_2	Traffic site	0.028	0.027	0.029	0.030	0.024	0.029
	100m away	0.016	0.019	0.015	0.018	0.011	0.017
SO_2	Traffic site	0.029	0.029	0.032	0.032	0.023	0.030
	100m away	0.017	0.022	0.018	0.020	0.017	0.020
HC	Traffic site	0.026	0.023	0.024	0.028	0.019	0.024
	100m away	0.007	0.009	0.011	0.013	0.004	0.015

Appendix 2.28: Logarithm table of concentration of pollutants of traffic source, receptor location and distance from traffic for dry season

Pollutants	C_R (ppm)	C_S (ppm)	D (m)	$\frac{C_S}{D}$	Log C_R	Log $\frac{C_S}{D}$
CO	9.3	24.9	100	0.249	0.9685	-0.6038
	14.47	26.9	100	0.269	0.9503	-0.5702
	13.97	29.04	100	0.2904	0.5988	-0.5370
	10.73	26.14	100	0.2614	1.0306	-0.5827
	7.30	13.83	100	0.1383	0.0863	-0.8592
	10.45	25.33	100	0.2533	1.0191	-0.5964
NO_2	0.017	0.039	100	0.00039	-1.7696	-3.4089
	0.026	0.040	100	0.00040	-1.5850	-3.3979
	0.015	0.042	100	0.00042	-1.8239	-3.3768
	0.017	0.037	100	0.00037	-1.7696	-3.4318
	0.010	0.026	100	0.00026	-2.0000	-3.5850
	0.018	0.039	100	0.00039	-1.7447	-3.4089
SO_2	0.018	0.039	100	0.00039	-1.7447	-3.4089
	0.024	0.039	100	0.00039	-1.6198	-3.3979
	0.020	0.040	100	0.00040	-1.6990	-3.3768
	0.017	0.036	100	0.00036	-1.7696	-3.4318
	0.011	0.022	100	0.00022	-1.9586	-3.5850
	0.021	0.037	100	0.00037	-1.6778	-3.3418
HC	0.007	0.029	100	0.00029	-2.1549	-3.5376
	0.009	0.028	100	0.00028	-2.0458	-3.5528
	0.011	0.030	100	0.00030	-1.9586	-3.5229
	0.013	0.028	100	0.00028	-1.8861	-3.5528
	0.004	0.009	100	0.00009	-2.3979	-4.0458

0.015	0.030	100	0.00030	-1.8239	-3.5229

Appendix 2.29: Logarithm table of concentration of pollutants of traffic source, receptor location and distance from traffic for wet season

Pollutants	C_R (ppm)	C_S (ppm)	D (m)	$\frac{C_S}{D}$	Log C_R	Log $\frac{C_S}{D}$
CO	9.3	24.9	100	0.249	0.9685	-0.6038
	14.47	26.9	100	0.269	0.9503	-0.5702
	13.97	29.04	100	0.2904	0.5988	-0.5370
	10.73	26.14	100	0.2614	1.0306	-0.5827
	7.30	13.83	100	0.1383	0.0863	-0.8592
	10.45	25.33	100	0.2533	1.0191	-0.5964
NO_2	0.017	0.039	100	0.00039	-1.7696	-3.4089
	0.026	0.040	100	0.00040	-1.5850	-3.3979
	0.015	0.042	100	0.00042	-1.8239	-3.3768
	0.017	0.037	100	0.00037	-1.7696	-3.4318
	0.010	0.026	100	0.00026	-2.0000	-3.5850
	0.018	0.039	100	0.00039	-1.7447	-3.4089
SO_2	0.018	0.039	100	0.00039	-1.7447	-3.4089
	0.024	0.039	100	0.00039	-1.6198	-3.3979
	0.020	0.040	100	0.00040	-1.6990	-3.3768
	0.017	0.036	100	0.00036	-1.7696	-3.4318
	0.011	0.022	100	0.00022	-1.9586	-3.5850
	0.021	0.037	100	0.00037	-1.6778	-3.3418
HC	0.010	0.026	100	0.00026	-2.0000	-3.5850
	0.016	0.023	100	0.00023	-1.7959	-3.6383
	0.012	0.024	100	0.00024	-1.9208	-3.6198
	0.011	0.028	100	0.00028	-1.9586	-3.5528
	0.010	0.019	100	0.00019	-2.0000	-3.7212
	0.016	0.024	100	0.00024	-1.7959	-3.6198

Appendix 2.30: Data from mathematical model for predicting CO concentration

Concentration of CO at source, C_S (ppm)	K = constant of proportionality	Distance from source, D (metres)	Concentration of CO at receptor, C_R (ppm)
22.80	8.8587	3	22.80
22.80	8.8587	100	2.0198
22.80	8.8587	150	1.3465
22.80	8.8587	200	1.0099
22.80	8.8587	250	0.8079
22.80	8.8587	300	0.6733
22.80	8.8587	350	0.5771
22.80	8.8587	400	0.5049
22.80	8.8587	450	0.4488
22.80	8.8587	500	0.4040
22.80	8.8587	550	0.3672
22.80	8.8587	600	0.3366
22.80	8.8587	650	0.3017
22.80	8.8587	700	0.2885
22.80	8.8587	750	0.2693
22.80	8.8587	800	0.2525
22.80	8.8587	850	0.2376
22.80	8.8587	900	0.2244
22.80	8.8587	950	0.2126
22.80	8.8587	1000	0.2020

Appendix 2.31: Data from mathematical model for predicting NO_2 concentration

Concentration of NO_2 at source, C_S (ppm)	K = constant of proportionality	Distance from source, D (metres)	Concentration of NO_2 at receptor, C_R (ppm)
0.038	8.8587	3	0.038
0.038	8.8587	100	0.00337
0.038	8.8587	150	0.00227
0.038	8.8587	200	0.00168
0.038	8.8587	250	0.00135
0.038	8.8587	300	0.00112
0.038	8.8587	350	0.00096
0.038	8.8587	400	0.00084
0.038	8.8587	450	0.00075
0.038	8.8587	500	0.00067
0.038	8.8587	550	0.00061
0.038	8.8587	600	0.00056
0.038	8.8587	650	0.00052
0.038	8.8587	700	0.00048
0.038	8.8587	750	0.00045
0.038	8.8587	800	0.00042
0.038	8.8587	850	0.00040
0.038	8.8587	900	0.00037
0.038	8.8587	950	0.00035
0.038	8.8587	1000	0.00034

Appendix 2.32: Data from mathematical model for predicting SO_2 concentration

Concentration of NO_2 at source, C_S (ppm)	K = constant of proportionality	Distance from source, D (metres)	Concentration of SO_2 at receptor, C_R (ppm)
0.038	8.8587	3	0.038
0.038	8.8587	100	0.00337
0.038	8.8587	150	0.00227
0.038	8.8587	200	0.00168
0.038	8.8587	250	0.00135
0.038	8.8587	300	0.00112
0.038	8.8587	350	0.00096
0.038	8.8587	400	0.00084
0.038	8.8587	450	0.00075
0.038	8.8587	500	0.00067
0.038	8.8587	550	0.00061
0.038	8.8587	600	0.00056
0.038	8.8587	650	0.00052
0.038	8.8587	700	0.00048
0.038	8.8587	750	0.00045
0.038	8.8587	800	0.00042
0.038	8.8587	850	0.00040
0.038	8.8587	900	0.00037
0.038	8.8587	950	0.00035
0.038	8.8587	1000	0.00034

Appendix 2.33: Data from mathematical model for predicting HC concentration

Concentration of NO_2 at source, C_S (ppm)	K = constant of proportionality	Distance from source, D (metres)	Concentration of HC at receptor, C_R (ppm)
0.035	8.8587	3	0.035
0.035	8.8587	100	0.00310
0.035	8.8587	150	0.00207
0.035	8.8587	200	0.00155
0.035	8.8587	250	0.00124
0.035	8.8587	300	0.00103
0.035	8.8587	350	0.00089
0.035	8.8587	400	0.00078
0.035	8.8587	450	0.00069
0.035	8.8587	500	0.00062
0.035	8.8587	550	0.00056
0.035	8.8587	600	0.00052
0.035	8.8587	650	0.00048
0.035	8.8587	700	0.00044
0.035	8.8587	750	0.00041
0.035	8.8587	800	0.00039
0.035	8.8587	850	0.00036
0.035	8.8587	900	0.00034
0.035	8.8587	950	0.00030
0.035	8.8587	1000	0.00031

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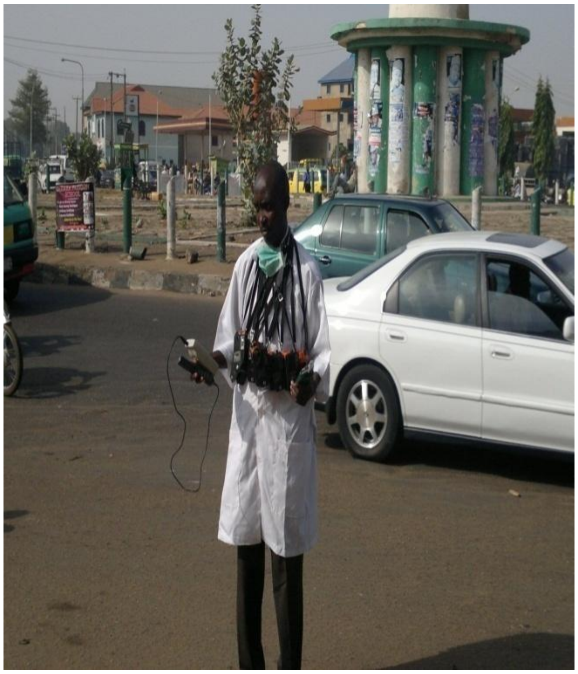

KEPA official on site around Stadium Roundabout

I and KEPA official on site in Kawo

Traffic activity in around the Stadium Roundabout

I and the KEPA official in Central Market area

I and KEPA official on site in Central Market area

Traffic activity in Sabon Tasha

Traffic activity in Bakin Ruwa area

Traffic activity around the Stadium Roundabout

DEVELOPMENT MAP OF KADUNA METROPOLIS