EVALUATION OF GREENHOUSE GASES LEVELS IN AMBIENT AIR AT SELECTED ROADS INTERSECTIONS IN KANO METROPOLIS, NIGERIA.

BY

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Declaration

I declare that the work in this Dissertation entitled ‘’Evaluation of Greenhouse Gases Levels in Ambient Air at Selected Roads Intersection in Kano Metropolis, Nigeria’’ has been carried out by me in the Department of Chemistry under the supervision of Prof. C.E. Gimba DR. S.E Abechi and DR. H. Omenesa. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

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Certification

This Dissertation entitled ‘’Evaluation of Greenhouse Gases Levels in Ambient Air at Selected Roads Intersection in Kano Metropolis, Nigeria’’ by Yusuf Riingim ADAMU, meets the regulations governing the award of the degree of Doctor of Philosophy in Analytical Chemistry of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literacy presentation.

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Dedication

To my dearest late parents; Khadija and Adamu, my beloved wife Hajiya Suwaiba Abdu and to our lovely children whom we pray fervently will grow up and stand firmly in search for knowledge.

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All thanks are to ALLAH (S.W.T.) who saw me through this work. I would like to express my sincere gratitude to my major supervisor, Professor C.E. Gimba for undertaking a very important task of correcting this research work. His versatile knowledge, experience and logical way of thinking have been of great value to me. His understanding, encouragement, advice and guidance provided to me have been a good basis to the completion of this thesis.

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Abstract

This research work monitored levels of greenhouse gases in ambient air of Kano metropolis. Carbon monoxide (CO), Hydrogen sulphide (H_2S), Nitrogen (IV) oxide (NO_2), Sulphur (IV) oxide (SO_2) and Methane (CH_4) are the priority greenhouse gas pollutants whose concentrations were monitored in the morning and evening every month for the period of one year covering the four seasons. The sampling frame consists of eleven major traffic points within urban Kano namely; Aminu Kano Teaching Hospital/Kwandila Housing Estate (LN1), Zoo road/Aliyu bn Abu Talib Mosue (LN2), Court/France roads (LN3), Igbo road/Sabon gari Market (LN4), Kofar Nasarawa (LN5), Rimi Market/Murtala Hospital (LN6), Dan - Agundi/B.U.K. (LN7), Kofar Mazugal/Abatoir (LN8), Airport/Zungeru roads (LN9), Sani Abaca/Murtala Mohd roads (LN10) and Environmental Pollution Control Laboratory/Wazobia Radio junction (LN11) which serve as control. An automatic monitoring systems with certificate number EX 93C 2069X and EX 93Y 2078X for 'TO' and 'FL' respectively was used to monitor the concentrations of these greenhouse gases. Traffic count was conducted to obtain the statistics of motorcycles, tricycles, cars and trucks movement in the various sampling traffic points. The results obtained show that the mean level of greenhouse gases in the morning (7:30 - 9:30 am) sampling hours were 5.75 ± 1.11, 1.39 ± 0.77, 0.20 ± 0.13, 0.09 ± 0.11, and 0.19 ± 1.38 ppm for CO, H_2S, NO_2, SO_2, and CH_4 respectively. For evening (4:30 - 5:30 pm) hours the mean levels of these gases were 15.64 ± 1.56, 3.22 ± 3.05, 2.42 ± 4.32, 0.14 ± 0.10, and 0.76 ± 0.53 ppm for CO, H_2S, NO_2, SO_2, and CH_4 respectively. The mean level of greenhouse gases in the evening is higher than the FEPA established guideline of 10, 0.06, 0.04 - 0.06, 0.06 and 0.06 ppm for CO, H_2S, NO_2, SO_2 and CH_4 respectively. The higher mean level of the

greenhouse gases in the evening at site 5, 5, 6, 6 and 7 can be attributed to the high traffic density at the sites. The four seasons monitoring results revealed that CO is far higher than all other gases across the sites. The next higher was hydrogen sulphide. The next higher to H_2S were NO_2, SO_2 and CH_4 during dry and (warm,cool) and wet and warm seasons. The mean levels of greenhouse gases were noticed to be very low both in the morning and evening during dry and hot and wet and warm seasons. This could be attributed to the shorter sunshine period and lower temperature which predetermined decomposition/burning of organic matters. Comparison of the Air Quality Index level (AQI) revealed that the values were in the range of CO moderate at roads junctions 1, 3, 4,6,8,9 and 10 to good at locations 2, 7 and 5 during both hours of sampling, NO_2 was very low at all road junctions except 11 which is very good whereas, H_2S and SO_2 values were very good in the morning. Statistic analysis of mean level of greenhouse gases across the eleven sampling locations has shown a normal distribution with remarkable variations and of significance difference at p □ 0.05. The correlation studies showed that there is high correlation of 0.909 between H_2S and CO and 0.864 between SO_2 and H_2S indicating that they could be from the same source. The research generally established that motor cars are the predominant source of these greenhouse gases emissions as shown by the significant correlation of 0.603, 0.677 and 0.689 for CO, H_2S and SO_2 respectively and volume of cars.

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Glossary of Common Terms Used

Anthropogenic: human source or human caused

Asphyxiate: interfere with the supply of oxygen to vital organs of the body.

Atmosphere: thin layer of gaseous envelop which is chemically active and rich in oxygen.

Climate: is a long term prevailing weather conditions at a particular place based upon record taken.

Climate change: A significant change in temperature, pressure, precipitation and wind Speed/direction for certain period of time.

Contaminant: A substance foreign to a natural system or present at unnatural concentrations in air, water, solid/food.

Greenhouse effect: is a progressing warming of the earth's surface to increase concentration of greenhouse gases.

Greenhouse gases: these are gaseous compounds found in the earth's atmosphere that trap heat and contribute to an increase in the temperature of the earth's surface and habitat.

Global warming: the heating of the earth and rise in temperature.

Latitude: is the distance from the equator measured in degree North or South of the equator.

Ozone layer: A layer of the atmosphere that shield living creature from harmful ultra-violet radiation.

Pollution (air): Anything causing or inducing objectionable conditions in the air and adversely affecting the man's live, properties and environment.

Sample location: the place where a sample is collected/taken and /or where measurements/tests are conducted.

Spatial: Varying over geographic area or space example lowland highland.

Stratosphere ozone: is part of an important naturally occurring shied around the earth.

Troposphere layer: is an atmospheric layer that harbours all living things and nearly all human activities taken place there.

Weather: is the state of atmosphere at a particular place and moment.

List of Abbreviations

AQI: Air Quality Index

FEPA: Federal Environmental Protection Agency

GHGs: Greenhouse Gases

G.P.S.: Global Positioning System

IPCC: International Panel on Climate Change

Km^2: square kilo meter

LGAs: Local Government Areas

LNs: Locations

NAPCA: National Air Pollution Control Administration

NASA: National Aeronautics and Space Administration

NDIR: Non- Dispersive Infrared Spectrometer

NDN: Niger Delta News

NEST: Nigerian Environmental Study/Action Team

NIOSH: National Institute for Occupational Safety and Health

NOUN: National Open University of Nigeria

OECD: Organization of Economics Co-operation and Development

PBL: Planetary Boundary Layer

$Pm_{10:}$ Particulate Matter of size 10

ppm: Part Per Million

Tg: Tetra gram

TSP: Total Suspended Particles

UN: United Nation

UNEPA: United Nation Environmental Protection Agency

UNFCC: United Nation Framework on Climate Change

UNHR: United Nations Habitat Report

USA: United State of America

U.S. EPA: United State Environmental Protection Agency

WHO: World Health Organization

WMO: World Metrological Organization

WRI: World Resources Institute

CHAPTER ONE

1.0 INTRODUCTION

1. 1 Atmosphere

Earth is the right planet of our solar system to life in being wrapped in a thin layer of gaseous envelope that is chemically active and rich in oxygen known as atmosphere. The earth's atmosphere acts as an insulating blanket, trapping sufficient solar energy to keep the global average temperature in pleasant range. The blanket is a collection of atmospheric gases called ''greenhouse gases''. Greenhouse gases are gaseous compound found in the earth's atmosphere that trap heat and contribute appreciably to the warming of the earth habitat. An increase in the concentration of greenhouse gases would result in the greater retention of infra-red radiation in the atmosphere and this give rise to the phenomenon known as greenhouse effect (Hill, 1992; NEST, 2001; Zumdahl, 2002).

The term greenhouse effect is a progressive warming up of earth's surface due to blanketing effect of man-made greenhouse gases in the atmosphere. It is a phenomenon whereby greenhouse gases create a condition in the troposphere causing a trapping of heat and leading to increased surface and lower tropospheric temperatures (Tawari and Abowei, 2012). Greenhouse effect means the excessive presence of those greenhouse gases that blocked in the infra-red radiation from the earth's surface to the atmosphere leading to an increase in temperature, which in turn would make life on earth difficult (Chitkara, 1982). Ultimately, more greenhouse gases means more infra-red radiation trapped and held which gradually increases the temperature of the earth's surface and the air in the lower atmosphere.

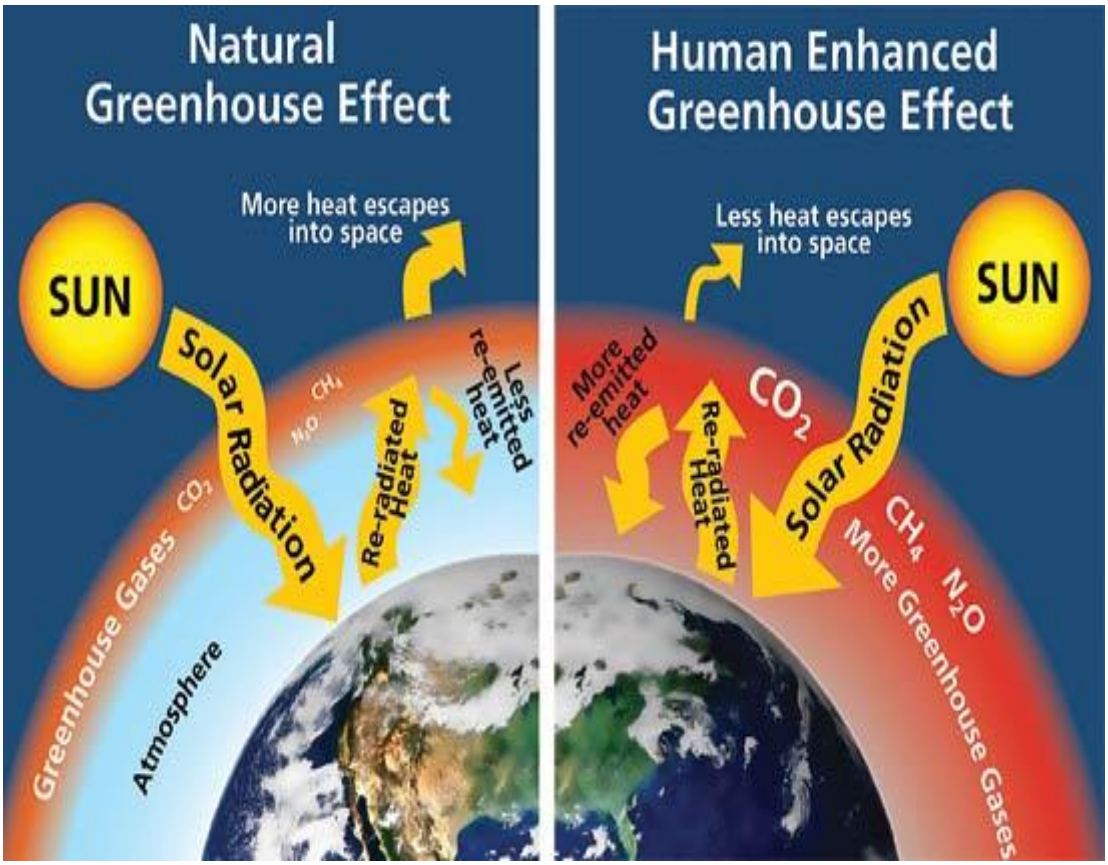


Figure 1.1: The Natural and Human Enhanced Greenhouse Effect.

Source; from Google image of greenhouse effect

About 30% of the sunlight that beams toward the earth is deflected by the outer atmosphere and scattered back into space. The rest reaches the planet's surface and is reflected upward again as a type of slow moving energy called infra-red radiation. Some amount of this infra-red radiation (heat) is absorbed by greenhouse gas which causes the weakly held molecules to vibrate and emit heat to another gas molecule which re-emitted heat in to the earth's surface. This emission - re-emission process has been sufficient to raise the average temperatures at the surface by about $33^{O}C$ ($59^{O}F$) above what it would otherwise have been. Without the natural greenhouse effect, life on this planet would probably not exist as the average temperatures of the earth would be chilly $-18^{O}C$, rather than the present $15^{O}C$ and water would have been present as ice. The natural greenhouse effect allowed liquid water to remain stable over most of the earth's surface, this provide the fundamental substrate for biological activity (Mintzer, 1993 and Pidwirny, 2006).

This greenhouse effect has been understood by scientists for about a century and technological advancements during this period have helped to increase studies on the phenomenon. Greenhouse effect was understood as natural process that aids in the heating of the earth's surface and atmosphere. Therefore, it is an essential environmental prerequisite for life as it keeps the earth's climate warm and habitable. Currently, the problem is understood as man-made activities that distort and accelerate the natural process by creating more greenhouse gases in the atmosphere than are necessary to warm the planet to an ideal temperature. It is as a result of the fact that carbon (IV) oxide is the single most important greenhouse gas accounting for about half of all current addition to the greenhouse effect. Other gases, such as methane,

nitrous oxide, chloroflouro carbons (CFCs), ozone also contribute to the greenhouse effect and certain traces of anthropogenic atmospheric gases, sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), hydrogen sulphide (H_2S) and ammonia (NH_3) although make up only a one percent of the total atmosphere, they are able to pchange the energy balance of the planet by helping in the decomposition or building of major greenhouse gases (Pidwirny, 2009).

According to British Broadcasting Corporation greenhouse effect refers to circumstance where the short wavelengths of visible light from the sun pass through a transparent medium and are absorbed, but the longer wavelengths of the infra-red re-radiation from the heated object are unable to pass through that medium. The trapping of the long wavelength radiation leads to more heating and higher resultant temperature. Broadly speaking greenhouse effect is used to describe the trapping of an excess heat by raising the concentration of greenhouse gases in the atmosphere. Water vapour provides the majority of the natural greenhouse effect with fewer contributions from carbon (IV) oxide, methane, nitrous oxide and ozone.

These gases form a blanket around the earth that lets the incoming sun rays to pass through but blocks the reflected heat rays from going out into the space. They keep the earth's surface and lower layers of the atmosphere warmer, and the upper layers cooler, than if the greenhouse gases are not there.

About 80-90% of the earth natural greenhouse effect is due to water vapour and clouds. Most of the rest is due to carbon (IV) oxide, methane and a few other minor gases. While the remaining gases in the atmosphere such as carbon (II) oxide, sulphur

(IV) oxide, nitrogen (IV) oxide, ammonia and hydrogen sulphide also absorb and emit a small amount of infra-red radiation, their radiative effect on temperature is so weak that they can be neglected, but however they help to build or in the decomposition of other greenhouse gases. Among the major greenhouse gases methane is much more potent than carbon (IV) oxide, there is far less of methane in the atmosphere and its concentration in the atmosphere is increased due to the presence of carbon monoxide that reacts with atmosphere hydroxyl radicals (OH^-) (Yusuf and Oyewunmi, 2008).

However, today the concentration of carbon (IV) oxide is increasing, due to the burning of fossil fuels and forest. Compared to a pre-industrial atmospheric concentration of 270 ppm, the average concentration has increased to close to 400 ppm in 2012. The causes of the man-made portion of the greenhouse effect, is believed to be responsible for the global warming of the last fifty years or more. Also the concentration of methane, although extremely small has also increased in recent decades contributing somewhat to the strengthening of greenhouse effect.

The mechanism of greenhouse effect involves energy from the sun passes through the atmosphere; a portion of the energy (about 26%) is reflected or scattered back to space by clouds and other atmospheric particles. About nineteen percent of the energy available is absorbed by clouds, greenhouse gases such as ozone and particles in the atmosphere. The remaining fifty five percent (55%) of the solar energy passing through the earth's atmosphere four percent is reflected from the surface back to space. On average about fifty one percent (51%) of the sun radiation reaches the surface. The energy is then used in a number of processes, including the heating of the ground

surface; the melting of ice and snow and the evaporation of water and plant photosynthesis.

The heating of the ground by sun energy causes the earth's surface to become a radiator of energy in the long wave band (infra-red radiation). This emission of the energy is generally directed to space. However, only a small portion of this energy actually makes it back to space. The majority of the outgoing infra-red radiations absorbed by greenhouse gases are used to warm the planet earth. Absorption infra-red radiation by the atmosphere causes global warming of the Earth's surface through the atmospheres trapping of outgoing infra-red radiation (Jessica and Stephen, 2007).

One of the first scientists to conceive the greenhouse effect were French Physicist and mathematician Jean Batise-Joseph Fourier who compared the effect with a horticultural hot house or greenhouse. The term has persisted to date, even though the greenhouse analogy is actually poor one. A greenhouse keeps plants warm by letting sunlight in while preventing out (0ghifo, 2011).

The greenhouse effect is important as it keep the Earth warm enough to sustain life. However, if it gets too warm, it could endanger all life on the planet Earth. Human activities, especially agriculture and industrial have increased the emission of greenhouse gapses and these gases led to the progressive depletion of ozone layer in the stratosphere (Olufemi and Samson, 2010). The ozone layer is the shield that absorbs about 90% of the harmful electromagnetic energy emitted by the sun on the earth. The abundance of greenhouse gases accentuates the effect globally, thus causing global warming.

During the last 150 years there has been a rise in greenhouse gases concentrations. This has been due largely to the rapid growth in population which increased the number of things like housing, clothes, and cars and air conditions resulting in vast stretches of deforestation and more industries. A large number of new cars rolling out on the road every year contribute to air pollution caused by burning petrol and diesel. Fossil fuels like petroleum and oil, wood and gas are being consumed heavily for industries and domestic purposes. Industries release a large amount of pollutants not only in the atmosphere, but also in rivers and oceans.

Major greenhouse gases such as carbon (IV) oxide (CO_2), methane (CH_4) water vapour and nitrous oxide (N_2O) occur naturally and from fuel combustion in the atmosphere while chloroflourocarbons (CFCs), hydroflourocarbons (HFCs) and perflourocarbons (PFCs) as well as sulphur hexafluoride (SF_6) are solely man-made (Kellog, 1996). Other gaseous compounds that are produced by the process of internal combustion engines that burn gasoline or other fossil fuels are carbon (II) oxide, hydrogen sulphide, nitrogen (IV) oxide and sulphur (IV) oxide have continue to pose significant threats to human health and gradual warming of the earth's surface. They caused indirect effects on global warming through the build up or decomposition of major greenhouse gases in the atmosphere which leading to increase in the earth's average temperature (Yusuuf and Oyewunmi, 2008: Wang, *et al.*, 2011). Though is insignificant but can cause changes in the air quality over a period and can be attributed to the human activities (Karen, 2008).

The Global warming and climate change have been described as the greatest threat facing humanity. The challenge before scientist is how to prevent the earth from global temperature rise on further emissions of greenhouse gases and high risen of temperature changes are likely to be so extreme thus, would be difficult to cope with would produced more instance and frequent extreme weather events, melting the ice in the atmosphere and thereby increasing the volume of water on the earth that may result into flood, sea level could raise as much as one meter and hurricane as seen in the United State of America (Karen, 2008). This was the basis for the creation of world bodies such as International Panel on Climate Change (IPCC) in 1988; by the United Nation Environmental Protection Agency (UNEPA) and World Metrological Organization (WMO) and the United Nation Framework Convention on Climate Change (UNFCC) which Nigeria has also signed in 1995 at Rio de-janeiro in Brazil (Madugu, 2009).

Climate change refers to as any significant change in measures of climate such as temperature, precipitation, or wind lasting for an extended period. It is a permanent departure of climate patterns from mean value of observed climate indices (Chikaire *et.al,* 2006). The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate which is attributable directly or indirectly to human activities that alter the composition of the global atmosphere and which are in addition to natural climate variability observed over a comparable time periods (Intergovernmental Panel on Climate Change [IPCC], 2001).

According to Odjugo (2011), climate changes are caused by both natural (biogeographically) process and human (anthropogenic) activities. He further identified

natural processes as (i) astronomical factors such as the eccentricity of earth's orbit, obliquity of ecliptic and orbital processions; and extraterrestrial; factors such as the quality of and quantity of solar radiation variations and volcanic eruptions. Li (2009) observed that up to 1950, natural factors particularly solar radiation variations and volcanic dust was the predominated factor of temperature change. However, recent studies have shown that the heightened incidence of climate change across the globe is as a result of aggressive and unsustainable human activities that are associated with population growth, urbanization, gas flaring, mechanized life styles which take place on domestic and industrial scale. The quantum energy consumed and harmful gases released from these activities have been identified as a major factor accelerating atmospheric global warming or climate in recent times (Guiness and Nagle, 2006: Bello *et.al,* 2008 and Iwejingi, 2013). The most important of activities that generate emission of greenhouse gases which alter the Earth's radiation balance are; burning of fossil fuels, deforestation, uncontrolled grazing, livestock migration and growing of population also posed threat to the environments (Bello *et.al,* 2008).

The IPCC (2007) asserted that global greenhouse gas released via human activities have increased by 70% from 1970 to 2004. Ozor (2009) defined climate change a change in climate over time, whether due to natural variability or as a result of human activity and is widely recognized as the most serious environmental threat facing our planet today. Ozor emphasized threat posed by climate change and called for the urgent need for countries to rise up to this clarion call of combating the negative effects of climate change.

Although the length of time it takes the changes to manifest matters, the level of deviation from the normal and its impacts on the ecology are most paramount. Climate change is the end product of a changing climate (Odjugo, 2011). Climate change is said to exist when the level of climatic deviation from the normal is very significant over a long period of time preferably thirty to thirty five years and such deviations have clear and permanent impacts on the ecosystem. Climate therefore refers to the characteristics condition of the atmosphere deduced from repeated observations and averaging the weather of a region over a long period of time, such as thirty years.

Many developing countries have experienced a progressive degradation in air quality as a consequence of rapid development over last three decades (Agrawal *et al.*, 2003). Nigeria as developing country in the world would not be exempted from the global effect, as Nigerians economy today heavily dependent on the oil sector, which account for around eighty percent (80%) of government revenues (Ekeme, 2007). This is particularly problematic because fossil fuels are the chief culprit implicated in the climate change phenomenon called global warming. Hence, Nigeria has begun to feel the effect of climate change as the frequency and intensity of extreme events like drought, sea level rises, prevalent infection of disease and flood have increased (Elisha, 2009: Bello *et al.*, 2012).

One of the anthropogenic sources of greenhouse gases are products of combustion and according to USEPA (2004) the major contributing sectors are ranked in the following order; industrial, transportation, residential, commercial and agriculture. Other human activities that contribute to greenhouse gas emission include change of land use, use of fertilizer, deforestation, industrialization, urbanization and

poor municipal solid waste management. However, in Nigeria as well as other developing countries in the world which are not yet fully industrialized, majority of the environmental effects result from vehicular emissions, burning of solid fuels, urbanization, deforestation and growing population. Vehicular emissions were the largest source of air pollutant and therefore a large contributor to global climate change (Barth and Boriboonsomsi, 2008). Motor vehicles produced more air pollution than any other human activity (WRI, 1997). In most developing countries of the world vehicular growth has not been checked properly by environmental regulating authorities leading to increase levels of pollution (Han and Naecher, 2006). Traffic emission contributes about 50 to 80% of nitrogen (IV) oxide and carbon (II) oxide concentration in developing countries (Fu, 2001: Goyal, 2006). This situation is alarming and is predicted 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 vehicle known as ‘‘super emitters’’ with high emission of harmful pollutants (Ibrahim, 2009).

Ambient pollution is further compounded by rapid urbanization of many developing countries. The global urban population reached 50% in 2008 and is expected to increase to 60% by 2030. This increase will be particularly pronounced in developing countries, in which 80% of the urban population will be living in 2030 (UNEPA, 2007). Accompanying this rise in urban population will be four times increase in the number of vehicles in cities by 2050, making transport- related pollutants a hazardous even with low vehicular movement rates (World Bank, 2004). Faize and Sturn (2000) stated that in Chinese cities, concentrations of particulates and other transport-related pollutants are up to six times higher than WHO- recommended

guidelines, even though China only has eight vehicles per 100 persons compared to 750 vehicles per 1000 persons in U.S.A.

Kano State is among the major cities in Nigeria, its metropolis developed over the years resulting in a steady progress in industrialization, urbanization and increase in population and high traffic density. Industrially, it is one of the most developed cities in Nigeria with many industries predominantly tannery, plastics and textile industries (Faboye, 1997). The presence of raw materials, availability of markets, transportation networks, capital and labour made Kano metropolis one of the major industrialized cities in Nigeria. The aforementioned factors resulted in a rapid population growth especially through migration (Malumfashi *et al.,* 2011). The growth in population and the collapse of public transport services has led to motorbike taxis being adopted as a mean of intercity and intracity transport, increased in economic activities leading to more automobiles, extensive urbanization and indiscriminate refuse disposal which decompose to a number of gases such as hydrogen sulphide and methane that have aggravated the problem of ambient air quality (Otti *et al.,* 2011; Okunola, *et al.,* 2012).

The air along the intersections of selected roads where majority of people reside along the busy roads every day either to do their work or sell their wares could hardly be regarded as clean due to pollutants emission from various activities along the roads intersection. Therefore, the ill-effects on health due to air pollution resulting from automobile exhaust emission must be very serious indeed (Ayodele and Bayero, 2009).

Much attention is given to general industrial pollution and pollution in gas flaring, with little reference given to damage caused by vehicular emission major sources of gases which are the causative agent of global warming. Koku and Osuntogun

(2007) studied three cities in south west region of Nigeria: Lagos, Ibadan and Ado-Ekiti which have significant air quality pollution. Air quality indicators CO, SO_2, NO_2 and total suspended particles (TSP) were determined. The results of CO, SO_2, NO_2 and particulate count per minute were higher than FEPA limits. Their conclusions showed a growing risk of traffic-related problems in these cities and hence recommended serious air quality measures.

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

Oguntoke and Yusuuf (2008) carried out a study on air pollution arising from vehicular emission and the associated human health problems in Abeokuta metropolis, Nigeria. Their assessment on the level of some selected air pollutants which are largely products of internal combustion engines namely CO, NO_2, SO_2, H_2S and CH_4 demonstrated that vehicular emissions contribute significantly to urban air quality.

Kumar *et al.,* (2011) in a study of ambient air quality status in Japur city (Raasthan, India), using AQI reported that the level of air pollutants in the cities vary with climatic conditions and are higher in winter season.

1. 2 Greenhouse gases inventory in Nigeria

Article 4 of the United Nation Framework Convention on Climate Change (UNFCC, 2005) requires each party to periodically report the emissions of greenhouse gases including CO_2, CH_4, N_2O and non-methane volatile organic compounds (NMVOC) in their National Communication. In fulfillment of the article, Nigeria's national communication based on emission per unit human population (based on gross population of 96.7 million for the year 1994) indicates gross per capita CO_2 emission of 0.5tC/cap. Per capita, non CO_2 greenhouse gas and precursor gases are between 2 to 4 orders of magnitude lower than CO_2 per capita emissions.

An overview of gross carbon emission by sources and removal by sinks indicates gas flaring, transportation, and electricity generation as the most significant energy consumption process leading to greenhouse gas emissions. Energy and land use change sectors were the main contributors to carbon (IV) oxide emissions, while energy, agriculture and solid waste are the main contributors to methane emissions.

The total methane emission in Nigeria is 5.9Tg methane (Sodangi *et al.*, 2011). The energy production and consumption sector with a total emission of 1.48Tg-CH_4 contributed 25% of gross national emissions with agriculture contributing the rest. Municipal solid waste and waste water treatment contributed 0.21 and 1.88Tg CH_4. These respectively represent 4 and 32% of gross national emissions. The gross emission of nitrous oxide (N_2O) was 11.95Gg N_2O. The energy sector petroleum refining, small combustion and transportation sub-sectors generated 7.47Gg N_2O representing 63% of gross national emissions for the year. This was closely followed by emissions from savannah burning (28%), field burning of agricultural waste (6%),

burning of solid waste (2%) and biomass burning from forest conversion (1%) (Nabegu, 2011).

The total CO_2 emission was 17.05Tg CO_2. Out of these, the energy sector generated 13.1Tg CO_2 with the following major energy sub-group emissions: transport 4.73Tg CO_2 or 28% of the gross national emissions; small combustion sources and gas flaring each representing about 25% of the gross national CO_2 emissions. The agricultural sector emitted 3.59Tg CO_2 or 28% of the gross national emissions for 1994, while the other energy sub-sectors, solid waste and land use change emitted 33.2Gg CO_2, 171Gg CO and 162Gg CO_2 (Nabegu, 2011).

The total generation of greenhouse gases based on the current data for Nigeria is low when compared to emissions from United State and other developed economies. However, Nigeria's gross emissions may approach those of these countries if its population continues to grow at the current rate of 3.5% per annum since per capita emissions is also likely to increase. The current population of Nigeria is estimated to 140 million representing 20% of the entire population of Africa. The United Nations population projected a population of 289 million for Nigeria by 2050. Apart from population growth, Nigeria has been experiencing urbanization over the last five decades. The proportion of the population living in the urban centers has risen from 15% in 1960 to 43.3% in 2000 and is projected to rise to 60% by 2015 (NPC, 2004). Furthermore, current economic growth of 7% per annum since 2005 has been projected to continue and would invariably fuel increase in the generation of solid waste and fossil fuel combustion (Nabegu, 2011).

1. 3 Statement of the Problem

Nigeria as a developing country in the world is experiencing an adverse global warming and climate change with negative impact on the welfare of its people; such as persistent droughts and flooding, and alteration of precipitate levels. Deforestation which is the common act in Nigeria result in the decay of a lot of plant matter, contributes to the greenhouse effect by releasing of carbon contained in cut trees and reduction in the ability to reduce carbon (IV) oxide from the atmosphere through photosynthesis which in turn affect crop's yield.

Kano state is one of the hottest states in Nigeria which made the inhabitant to be at risk of hot climatic condition, malaria, meningitis and many other diseases. Kano metropolitan is highly populated and is currently at the risk of global warming due to emission of gaseous pollutants on daily basis and from vehicular emission and other anthropogenic activities.

1. 4 Justification

Naturally, greenhouse gases in the atmosphere play a key role of regulating the temperature of the earth by trapping some of the heat radiating from the surface and transferred to the atmosphere. As a result of photosynthesis and other regulatory processes, the concentration of greenhouse gases present in the atmosphere is kept constant. However, today the various forms of anthropogenic activities have resulted into a considerable increase in the atmospheric concentration of greenhouse gases and consequently, accelerated the rate of climate change and global warming.

Most of the world has already being affected by climate change across all the continents and this has resulted in adverse impact on their development in such sectors as agriculture, water quality, increasing population and health (IPCC, 2001). Nigeria as pa developing nation is also experiencing an adverse climate conditions with negative impacts on the welfare due to rapid increase in population without considering the limited resources in the following ways.

(i) persistent droughts and flooding, off season rains and dry spell have sent growing seasons out of orbit, on a country dependent on a rain fed agriculture,

(ii) lakes drying up and a reduction in river flow in the arid and semi arid region due overexploitation of the natural resources without renewability (resource maitanance),

(iii) increasing carbon dioxide and carbon fluoro carbons level in the atmosphere due to human activities promote global warming and hinder the normal rainfall,

(iv) extinction of animal and plant species as the pace of change in habitat driven by global warming outstrips their ability to adjust,

(v) winds blowing at increasing intensity and frequency along the sahara and sub-saharan region in north-eastern parts Nigeria, thereby making agriculture to be difficult, and

(vi) Biodiversity change cause by excessive use of living things (plants and animals) by human activities due population increase.

1. 6 Aim and Objectives

The aim of the present study is to evaluate the present levels of greenhouse gases in the ambient air at intersections of selected roads in Kano metropolis, Nigeria.

The specific objectives are:

(i) Determining the levels of greenhouse gas (CO, H_2S, NO_2, SO_2 and CH_4) in the ambient air at the intersections of selected roads in Kano metropolis, Nigeria.

(ii) Comparing the concentration recorded with standard limits (WHO, FEPA and USEPA) to identify potential risks to human being and environment.

(iii) Establishing a relationship between pollutants and vehicular emissions.

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CHAPTER TWO

2.0 LITERATURE REVIEW:

2. 1 Urbanization and Population Growth in Developing Countries

Urbanization has been identified as one of the most powerful and visible anthropogenic force on earth (UNHR, 2011). According to Adeniji and Ogundiji (2009) it is a process and outcome of social changes, in-flow and concentration of people and activities in cities. The dynamics of the urbanization is driven by change in population, industrialization, consumption patterns, and migration (Dawson *et al.*, 2006). Urban areas account for less than 3% of the earth's land surface but over 50% of the world's population (UN, 2001). It is estimated that the total population in the cities in developing countries will double between 2000 and 2030 (UN, 2004). Dodman (2009) assert that in industrialized countries, the population of cities will increase by approximately 20%.

Due to technological development, urban centers have concentrated industries, transportation and other activities that release large quantities of greenhouse gases (UNHR, 2001). The increasing concentration of population and economic activities in urban areas demand that more vehicles be used for transportation. This has resulted in rapid rate of uncontrolled traffic related emissions of greenhouse gas pollutant which consequently, aggravated to global warming and vulnerability to climate change hazards.

In the cities of developing countries the environmental problems are much greater, because of the overwhelming scale and speed of urbanization (Atash, 2007).

The level of air pollutions are increasing rapidly in urban areas in many mega cities of the developing world (Agrawal, *et al.*, 2003). The increased risks were observed mainly for the population exposed to urban air which is affected predominantly by the traffic emission, emission from household heating and industries (Skarek *et al.*, 2007).

In Nigeria there has been rapid increase in population from 3,340,000 in 1950 to 38, 159,000 in 19990 and by 1995 there were about 40 million people living in Nigerian cities and towns and this population increase has led to the migration of individual from rural to the urban areas. Cities all over the world present opportunities and limitations. As in the case of Nigeria and many other developing countries, large population concentration and rapid growth of urban centers pose serious problem in the provision and management of services and the entire living environment (Ndoke and *et al.*, 2012). The various opportunities offered by cities are therefore accompanied by problem of congestion, environmental degradation, unemployment, poverty, violence and all sorts of environmental risks.

2. 2 Traffic Emission in Developing Countries

Traffic emission has remained a threat to environmental health problem which is increasing as vehicle ownership increases in the world. Over 600 million of 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 problem especially in urban areas where pollution levels are on the increase (Abam and Unachukwu, 2009). Motor vehicle emissions, is the dominant source of air pollution especially in areas with high traffic densities. Nearly 50% of global CO, hydrocarbon and NO_X emission from fossil fuel combustion come

from gasoline and diesel- powered engines (WRI, 1997). In most developing countries of the world vehicular growth has not been checked properly by environmental regulating authorities leading to increase levels of greenhouse gas pollutants. Furthermore, in developing countries the super emitters contribute about 50% of harmful emissions to the total emission (Brunekeef, 2005).

Fu (2006) reported that traffic emission in developing countries contribute about 50 to 80% of carbon (II) oxide and nitrogen (IV) oxide concentration. According to Ntziachristosa *et al.*, (2006) in Nigeria the amount of unburned hydrocarbons due to high incidence of gas flaring, high number of cars on roads and power generating set increases. In Mexico City for instance these super emitters is reported to be responsible for 90% of hydrocarbon and CO emission and 80% of NO_X emission accounting for 60% of the kilometer travelled in the country (OECD, 1999). The increase of 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.

Developing cities in Asia and Africa are at high risk to exposure of this traffic-related pollution. Research conducted in Ethiopia, Mozambique, Kenya and Republic of Benin, show that there is a high level of Dioxy Nuceic Acid (DNA) damage in urban residents and higher prevalence of asthma in urban school children exposed to traffic pollution compared to rural children (Autrup, 2006;Abam and Unachukwu, 2009).

2. 3 Traffic Emissions in Nigerian Cities

The greenhouse gas pollution from mobile transportation source is on increase in per capita vehicle ownership, hence 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. Small and Kazimi (1995) reported that motor vehicles emission account for 32 - 98% of national emission of CO, volatile organic compound and NOX. Furthermore, Cline (1991) stated that transportation account for an important fraction of greenhouse gases emission.

Studies conducted in Kaduna and Abuja cities show higher values of carbon (IV) oxide concentration in heavily congested areas; 1840 ppm for Sambo Kaduna, 1780 ppm for Stadium round-about, Kaduna and 1530 ppm for A.Y.A Abuja, 1160 ppm for Asokoro Abuja (Akpan and Ndoke, 1999). Similar work by Jimo and Ndoke (2000) at Minna, a city in Nigeria shows the maximum value of 5,000 ppm for CO_2 in congested areas, which was still lower than W.H.O., stipulated maximum value of 20,000 ppm. The maximum value for CO emission obtained was 15 ppm and still lower pthan the base line of 48 ppm stipulated by W.H.O. and 20 ppm stipulated by Federal Environmental Protection Agency of Nigeria (FEPA). The reason for this low emission concentration in Minna is attributed to low traffic and industrial activities in the city.

A study of the impact 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 particulate (TSP) were determined. The highest levels obtained for the air pollution indicators in Lagos were CO-233 ppm at Idumota, SO_2-

2.9 ppm at Idumota, NO_2-1.5 ppm at Iyana-Ipaja and total particulates 852 ppm at Oshodi bus stop. At Ibadan, the CO and SO_2 levels at 271 and 1.44 ppm were highest at Mokola round about while NO_2, at 1.0 ppm was highest at Bere round about. In Ado-Ekiti the highest level obtained were CO-317 ppm at Oke Isha, NO_2 -0.6 ppm at Ijigbo junction and SO_2-0.8 ppm at Old Garage junction. The results of CO, SO_2 NO_2 and particulate counts per minute were found to be higher than FEPA limits. Limits set by FEPA are CO-10 ppm, SO_2-0.01 ppm, and NO_2-0.04-0.06 ppm. In conclusion the investigation showed a growing risk of traffic-related problems in Nigeria cities and demanded for serious air quality measures.

A comparative study of emission figures in Lagos and Oil producing region (Niger Delta) has been reported by Jarome (2000). Two major cities in the Niger Delta were considered, Port Hacourt and Warri. The results obtained show that the concentrations of total suspended particulates (TSP), NO_X, 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 10-250 ppm higher than the ranges of 5.0-61.0 ppm and 1.0-52 ppm recorded for oil communities in the Niger Delta. The TSP concentrations are also high for both cities when compared to W. H. O.'s standard.

Abam and Unachukwu (2009) reported the result of the investigation of vehicular emission in three selected areas with nine sampling points in Calabar, Nigeria. The priority parameters monitored were CO, NO_2, SO_2, PM_{10} and noise. Others monitored include ambient temperature, wind direction, wind velocity and traffic count. The emission concentrations of CO, SO_2, NO_2, PM_{10} and noise level was found to be highest where traffic intersections and traffic count is high. All the five

monitored air pollutants when compared with Air Quality Index level (AQI) were in the range of poor to moderate for CO at different locations, very poor to poor for SO_2 and NO_2, PM_{10} and noise level was poor at all locations. However, the overall levels of vehicular related air pollution in Nigeria from all studies conducted show an increasing trend and thus posses a potential hazard to the population. Thus, it is worthy to state that the concentration of these pollutants must have increased tremendously in the past fifteen years of democratic rule in Nigeria due to the influx of old and fairly used vehicles into the country following changes in government policy.

Bada and Akande (2010) investigated effect of vehicular emission on greenhouse gases concentrations along selected roads of different traffic densities in Abeokuta, Ogun State, Nigeria. Nine roads which comprised highway, commercial and residential were selected and greenhouse gases were determined from both sides of the roads by using gas sampler placed 1, 5 and 10 meter away from the roads at different road segments (up/downhill, bend and flat surface). The concentrations of greenhouse gases obtained were $CO_2 > CO > NO_X > NO > SO_2 > CH_4$ and decreased significantly ($p < 0.05$) as distance increased from the road and highway. The highest traffic density had the highest concentration of NO, NO_X, CO, CO_2, SO_2 and CH_4 with 1.51 ppm, 2.22 ppm, 22.15 ppm, 15.33 ppm, 1.43 ppm and 0.85 ppm respectively followed by commercial and residential areas. They concluded that the concentrations of greenhouse gases decreased with increased horizontal distance away from the road edge and the extent of greenhouse gases pollution was positively related to traffic volume.

Utang and Peterside (2011) in their study estimated the emission of pollutants from vehicle during traffic peak period within parts of the city of Port-Hacourt in Nigeria. It estimated air pollutants CO, NO_X, SO_X and hydrocarbon in four sampling points. The level of variation in concentration of emission between locations was determined at all times and locations, while the concentration of CO detected was higher than the FEFA limits at certain location, levels of hydrocarbon detected varied in space and time and NO_X was generally above the local and international standards in all the locations during peak traffic period. In their conclusion, they stated that although the study did not cover the whole city of Port-Hacourt, finding from the four sampling points suggest that the city is under the threat of traffic related pollution and possibly more susceptible giving increasing population influx and vehicle traffic.

Okunola *et al.,* (2012) conducted a research in Kano, Nigeria using Crowcon gas sensor to collect emission levels of various gases. They concluded that the concentrations of CO, H_2S, NO_2 and SO_2 measured, with few exceptions, at some sites were above the AQI stipulated by USEPA especially during dry seasons. This implies that traffic emission within Kano is not within the safe limits. The results revealed that transport-related pollution in Kano metropolis is significant with potentially hazardous health consequences'. Asheshi (2012) measured the concentration of CO, NO_2 and PM in Lafia metropolis at three different sample sites during phases of traffic that is heavy, normal and light for three consecutive days (morning, afternoon and evening). The results obtained were found to be higher than the standard value given by Nigerian Ambient Air Quality Standard (NAAQS). This shows that concentrations of the pollutants are high in metropolis, implying that population along the sample sites are more expose to these toxic gases. Ojo and Awokola (2012) reported the result of their

investigation of air pollution from automobiles at intersections on some selected major roads in Ogbomoso, South Western Nigeria. The results of SO_2, NO_X, CO were in the range of 0.02-0.09 ppm, 0.09-0.039 ppm, and 1.79-51.38 ppm respectively. The concentration of the air pollutants SO_2, NO_X and CO were obtained highest at intersection with traffic congestion and traffic intersection, where long waiting time for vehicles was observed. They concluded that all the three monitored air pollutants when compared with AQI level were in the range of SO2-very poor to good, NO_X from good to very good, CO- very good to moderate and moderate to to poor indifferent locations. Hence, it has become quite important to understand the role of mobile source emissions on air quality through well- designed studies. ,

Ola *e.t al.* (2013) studied the level of toxic gases CO, H_2S and Particle matter to index pollution in Jos metropolis, Nigeria. The study was conducted using crowcon detection instruments and concluded that 'there is gross atmospheric pollution along the main streets in Jos due to vehicular traffic. CO levels particularly points to the fact that many vehicles on Nigeria roads are not road worthy due to lack of proper optimal tuning for combustion efficiency.

Greenhouse gas emission due to traffic is a product of urbanization and technological development, and other factors of population density and industrialization (Olade, 1987). It constitute up to 90-95% of the ambient CO levels, 80-90% of NO_X, hydrocarbon and particulate matter in the world, posing a serious threat to human health (Savile, 1993). Cities in the world are facing many problems related to traffic emissions. The USA is responsible for 77% of CO levels, 80-90% of NO_X, 36% of volatile organic compounds and 22% of particulate matter (USEPA, 1993). Similarly,

the average concentration of NO_2 was found to increase by 35% in United Kingdom (UK) from 1986 to 1991 due to increase in vehicular emission (Seneca and Tausing 1994: Faucet and Sevingny, 1998). This is a clear indication that vehicle emission is a major source of ambient air pollution and must be controlled if accepted air quality is to be assured. In addition, there is numerous health problems associated with high concentration of these pollutants. For example CO and NO_2 are responsible for immune system impairment, exacerbation of asthma and chronic respiratory diseases: reduce lung function and cardiovascular disease (Schwela, 2010).

Research conducted in 1994 under Federal Ministry of Environment revealed that Nigeria's transport sector along accounted 41% of CO_2, 83% of CO, 59% of NO_2 and 98% of SO_2 in air. Mansouri and Ebrahimpour (2011) stated that the increasing development of human activities has giving rise to a significant increase in atmospheric pollutions.

Akanni (2010) carried out research on spartial-seasonal analyses of traffic related pollutant concentration in Lagos metropolis and observed that the monitored pollutant values for wet season recorded are relatively lower in many cases than that recorded for the dry season monitoring and attributed this observation to lower air temperature witnessed during wet season (25 to 28.8^0C) and high wind speed (3 to 9 m/minute).

Oguntoke *et al.*, (2010) stated that utilization of fuel wood as a source of energy would produce gases that apart from affecting human health negatively, their release into the environment is capable of adding to the concentration of greenhouse gases in the atmosphere.

Bada and Akande (2010) opined that the extent of greenhouse gases pollution was positively related to traffic volume and their concentration decreased with increased horizontal distance away from the road edge. Also road segments affected the level of greenhouse gases in the atmosphere surrounding the road. Up/down hill had the highest concentrations followed by the flat surface. According to Aderogba (2011) there is a positive correlation between growth and development of railway locomotives, marine activities, vehicular movement and air travel in the metropolis with the estimated greenhouse gases emitted. Taylor and Nakai (2012) reported that the existing anthropogenic activities that peak in dry season were highly responsible for different in seasonal variation of greenhouse gas pollutants.

The largest contributing sources of greenhouse gases in urban areas are believed to come from burning of fossil fuels, industrial processes and transportation. Whereas, in the rural areas are from farming, deforestation and fuel wood burning for cooking. The series of health impacts of high concentration of these gases which include slight feel of stress and discomforts to ailment such as asthma and cancer, birth defects and genetic mutations as well as premature deaths are identified and assessed by Okonkwo *et al.,* (2012); Erica (2000); Schwela (2000); Taninmowo, (2000); Oguntuke *et al.,* (2010) Musa and Abdullahi, (2012) and Alabi, 2012).

The ambient air quality of an area affects the Chemistry of the atmosphere and the general wellness of the environment including humans. Air quality reports in most advanced countries are therefore presented regularly to assist the public in the management of their environment and health. Many industrialized countries have air quality standards and guidelines to regulate emission of greenhouse pollutants into the

environment. The pollutants that are emitted are either gases or particulate matter such as smoke, aerosol, fume, soot and mist. These chemical discharged into the atmosphere undergo chemical change and are referred to as indirect effect greenhouse gases. The effect of these pollutants is upon the climate, environment, people, buildings, and structures (USEPA, 1993, FGN, 1988 and Adelagun *et al.,* 2012).

The environmental effects of elevated smog, acid rains and ultraviolet radiation are indentified as the effects that have high implications on climate change through ozone layer depletion including absorption and reflection of incoming short-wave radiation from the sun and long wave radiation from the surface of the earth and the atmosphere (Bond, 1972 and Efe, 2008).

The increase in concentrations of greenhouse gases is believed to occur since the beginning of industrial revolutions. Burning of fossil fuels, deforestation, livestock rearing, agriculture and waste dumping have contributed to increase in the amount of anthropogenic primary greenhouse gases (Pidwirny, 2006). Hensen *et al.,* (1999) reported that atmospheric concentration of both natural and man-made gases have been rising over last few century due to human activities. Although these concentrations are lower, but are important because apart from absorption of infra-red radiation they contribute to the formation of other greenhouse gases such as carbon (IV) oxide. Indeed a recent study by Ahuaja, (2004) and Lashof, (2005) shows that trace gases are responsible for 43% of the increase in radiative forcing from 1980 to 1990.

Parida, et al., (2005) are of the opinion that the global increase in temperature and change of other climatic variables such as rainfall and evaporation are as a result of greenhouse gas emission. Ademola (2012) opined that rising the concentrations of

greenhouse gases that absorb infra-red light generally produce an increase in the average temperature of the earth which also leads to global warming and climate change causing shortage of food, water and lead to increase rate of diseases, depletion of the rain forest, flooding and desertification as well as extreme weather conditions.

Moreover, the increase in the earth's temperature is attributed to the following factors; firstly, the increase in anthropogenic activities as a result of increase in urbanization and industrial activities worldwide. Secondly, and the most important factor is the increase in the generation of greenhouse gases by vehicular transportation. According to Augustine (2012) the high levels of temperature may be associated with global warming caused by the accumulation of greenhouse gases in the atmosphere. He empirically stated that CO_2 emission from power plants, gas flaring from the oil and gas sector, exhaust pipes of cars and stationary industrial sources account for more than 60% of global greenhouse gas emissions.

Intergovernmental Panel on Climate Change (IPCC, 2007); reported that most of the observed temperature increase since the middle of twenty first century was caused by increasing concentration of greenhouse gases resulting from fuel burning and deforestation. It also conclude that variation in natural phenomenon such as solar radiation and volcanism produced most of the warming from pre- industrial times to 1950 and has a small cooling effect afterward.

The fourth IPCC assessment report indicates that the global surface temperature will probably rise a further 1.1 to 6.4^{o}C during the twenty first century. Based on estimate made by NASA's Goddard Institute for Space Studies; 2005 was the warmest

year exceeding the previous record set in 1998 by few degrees. This is in accordance with conclusion made by World Meteorological Organization and Climatic Research.

2. 4 Sources of Greenhouse gas pollutants

2.4.1 Anthropogenic (human activity) sources

United Nations Framework Convention on Climate Change (UNFCCC, 1991) reported that consumption of fossil fuels to provide electricity, heat and steam to industrial, commercial and residential sectors and to fuel transport sector constitutes 73 percent. The combustion of fuels produced oxides of carbon, nitrogen and sulphur. Beside the extractive processes of fossil energy is another dangerous endeavor to human societies especially through the burning of natural gas that is linked with crude oil when it is pumped up from the ground to the surface of the earth (NDN, 2004) reported that Nigeria flares more gas than any other country in the world and furthermore explained that, approximately 75% of total gas production in Nigeria is flared and about 95% of the associated gas produced as by-product of crude oil extraction also flared. Therefore, gas flaring in Nigeria contributes a measurable percentage of the world's total emission of greenhouse gases.

Secondly, land-use change such as deforestation, which releases the oxides of carbon, nitrogen and sulphur that are stored in forest organic matter and soils, makes up 22%, cement manufacturing process result in the emission of carbon (IV) oxide and carbon monoxide that covered two percent (Mohammed *et al.*, 2012). Agricultural activities principally contribute to the emissions of hydrogen sulphide, methane from

rice cultivation and livestock, nitrous oxide from fertilizer applications and carbon (IV) oxide from vehicles and equipment used, landfills and sewage disposal also emit methane, hydrogen sulphide and ammonia to the atmosphere and finally, stationary and mobile sources such as mobile vehicles, ship and airplanes.

2.4. 2 Natural sources

These are carbon and sulphur oxides that are released during volcanic eruption. Others are hydrogen sulphide, and hydrochloric acid (HCl), hydrofluoric acid (HF), carbon (II) oxide (CO), halocarbon and some metal halide are released into the atmosphere in smaller traces. These gases released may also lead to acid rain, forest fire that spread very rapidly and release pollutant gases like carbon monoxide, sulphur dioxide, nitrogen dioxide and ozone into the atmosphere, methane emission from farm animals like cattle into the atmosphere during the end stage of their digestive cycles. Methane gas affects the ozone layer in the atmosphere since it is a very potent greenhouse gas and it is also highly inflammable when it combines with other element in the air. Moreover, methane leads to asphyxiation if someone is trapped in a closed room with the presence of methane gas in the air

2. 5 Direct Effect Greenhouse gases

2.5. 1 Water vapor (H_2O)

The most abundant natural greenhouse gas is water vapor, which reaches

the atmosphere through evaporation from oceans, lakes and rivers, and causes about 36 to 70 percent of the greenhouse effect on the earth. The amount of water vapor in the

atmosphere is not directly affected by human activities. Pure water is colorless, odorless and tasteless and so common. Most of the plants and animals bodies contain more than 60% water by volume. Thus, without water, life and indeed civilization would not be possible on earth (Odjugo, 2011).

Water is the only substance that exists naturally on earth in all three physical states of matter (solid, liquid and gas) (Akani *et al.,* 2009). Energy from the sun is absorbed by liquid water in oceans, lakes and rivers and thereby causes some of it to evaporate and enter the atmosphere as an invisible gas (water vapor). As the water vapor rises in the atmosphere it cools and condenses into tiny liquid droplets that scatter light and become visible as clouds. Under certain conditions these droplets further combine and become precipitate as drops of liquid. Hence, returning to the earth's surface and the cycle continue.

Water in all three states makes a large contribution to the earth's climate. Water is the most abundant of the atmospheric constituents containing three atoms, two atoms of hydrogen and one atom of oxygen. Consequently, water vapor is the most abundant natural greenhouse gas that traps energy radiated from the surface of the earth and helps to keep the earth warm enough to sustain the complex life that has evolved in the environment and it is responsible for more than half the earth's greenhouse warming. However, regarding the extent of its contribution to global warming, water vapor is not an issue, because unlike other greenhouse gases, its concentration is dependent on the atmospheric temperature rather than emission from the earth's surface.

As the temperature rises, more water is evaporated from ground storage (rivers, ocean, reservoir and soil). Because the air is warmer the absolute humidity leads to more water vapor in the atmosphere. As a greenhouse gas water is able to absorb more thermal infra-red energy radiated from the earth, thus further warming the atmosphere. The warmer atmosphere can hold more water vapor and an increase in the atmospheric water vapor will condense into clouds, which reflect a good deal of the incoming solar radiation more effectively, thus prevent the radiation from reaching the surface and warm it. The reflectivity of cloud has a cooling effect on the earth.

2.5.2 Carbon (IV) oxide (CO_2)

Carbon (IV) oxide is an integral component of earth's atmosphere and plays a vital role in habitability of the plants. It is an essential ingredient in the photosynthesis process in addition to being a greenhouse gas. The impact of carbon (IV) oxide on the climate and atmosphere has been well documented. Joseph Fourier (1827) proposed that atmospheric gases play a central role in trapping heat. Arrhenius was the first scientist to speculate the impact that varying level of carbon (IV) oxide has on the changing earth's surface temperature due to the absorption of infra-red radiation (Wijinsma, 2009). Rise of global carbon (IV) oxide in 2011 by 2 ppm have increase global temperature by 0.5^0C (Okonkwo *et al.*, 2012). Guy and Levine (2011); Joseph et-al (2011); Shu et-al (2010) and Anomohanran (2011) have stated that carbon dioxide emission is known to contribute significantly to global warming which account for rising global temperatures and eventually cause sea level to rise.

Carbon (IV) oxide is a colorless, odorless and unreactive gas produced naturally when dead animals and plants decay, respiration in animals, oxidation of carbon

monoxide, combustion of organic materials and out gassing from oceans. Human economic activities also, are adding carbon (IV) oxide into the atmosphere mostly by burning of fossil fuels such as oil, wood, solid waste and coal, as well as several activities which produce carbon (IV) oxide (IPCC, 1996 and Pitt, 2000).

The carbon (IV) oxide molecules (O = C = O) contains two double bonds, has linear shape and vibrated when they absorb infra-red radiation. Eventually, the vibrating molecules emit the radiation again and this is absorbed by another greenhouse gas molecule. It is this absorption-emission-absorption that keeps the heat near the surface from the cold space. At concentration 2500 to 5000 ppm carbon (IV) oxide can cause headache. At extremely high level of 100,000 ppm people loss consciousness in ten minutes and at 200,000ppm carbon (IV) oxide can lead to death (Ndoke *et al.,* 2011).

Carbon (IV) oxide is obviously the most important contributor to man-made greenhouse gas, because it contributes 76.7% of all man-made greenhouse gas emission and its annual emission grew by about 80% from 1970 to 2004 (Odjugo, 2011). Ten years after the adoption of Kyoto Protocol (1997-2007). Earth's atmospheric carbon (IV) oxide increased by 5.85% or 19 ppm which is 35% more than the increase in the last ten years before the treaty. According to USEPA (2004) 41% of the carbon (IV) oxide emissions in the United State of America come from the generation of electricity, a process that mainly uses coal. The second largest producer is the transportation sector, including cars, trucks and airplanes which account for about 33%. The industrial sector including petroleum refining, chemical and food production is the third largest producer of carbon (IV) oxide.

Naturally, there is exchange of carbon (IV) oxide between the atmosphere and life through the processes of photosynthesis and respiration. Plant directly uses carbon (IV) oxide in the process of Photosynthesis, where the gas carbon (IV) oxide from the atmosphere is utilizes to produce glucose and oxygen with the help of sunlight which provides the energy required and water. Plants use the glucose to fuel their growth and animals' breath in the oxygen, consume plant matter and exhale carbon (IV) oxide. In respiration, oxygen is combined with glucose to chemically release energy for metabolism to produce water and carbon (IV) oxide (NOUN, 2010).

$6CO_2 + 6H_2O + \text{ENERGY} \rightarrow C_6H_{12}O_6 + 6O_2$ ---------- (i)

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{ENERGY}$ ---------- (ii)

Thus, the most common natural source is respiration. Carbon (IV) oxide emission due to human activities is cause by transportation, industry and power plants. Transportation however, contributes to greater percentage of carbon (IV) oxide emissions as a result of the combustion of fossil fuels. Another source is fire used for firewood, cooking, and bush burning and refuse disposal.

Nkangolo *et al.,* 2008 stated that carbon dioxide emissions produced in our daily lives through burning of fossil fuels to meet essential needs such as electricity, heating and transportation and have been identified to be a major component of greenhouse gas emission. Additionally, Augustin (2012) opined that carbon (IV) oxide emission from power plants, gas flaring from the oil and gas sector, exhaust pipes of cars and other stationary industrial sources account for more than 60% of global greenhouse gas emissions.

The atmospheric Carbon (IV) oxide is removing by sink process; on land by trees is the process of photosynthesis. However, their efficiency today is being reduced due to deforestation practices, thereby causing greater amount of carbon (IV) oxide to be absorbed by the atmosphere (Peter *et al.*, 2011). In Nigeria deforestation is a major contributor to carbon dioxide greenhouse gas accumulation. Few trees mean less carbon dioxide uptake for organic energy and oxygen production (DeLacy, 2006).

Also, atmospheric carbon (IV) oxide is constantly scavenged and dissolved in the oceans. The other reservoir is geological, formed by conversion of decomposing plants and animals into hydrocarbons. Human activity is now altering carbon-cycle and an essential gas may come to be viewed as a potentially harmful pollutant (David, 1982). Carbon (IV) oxide is a prominent gas that contributes to the greenhouse effect known significantly as global warming which consequently account for rising global climate change and eventually cause sea level to rise (Anomohanran, 2011). As mentioned by Petty (2004) despite the carbon dioxide small concentration in the atmosphere, it is an important component of Earth's atmosphere that absorbs and emits infra-red radiation strongly and slowly re-emitting the infra-red at the same wavelength. Thus, help to retain certain amount of the infra-red radiation that is radiated by earth, thereby playing a role in greenhouse effect.

Keeling (1958) measured the atmospheric carbon (IV) oxide in the university of Californian San Diego, U.S.A. He introduced a new technique for the accurate measurement of atmospheric carbon (IV) oxide and used cryogenic condensation of air samples followed by non diffusive infra-red (NDIR) spectroscopic analysis against a reference gas using monometric activity. Latter many researchers such as Malgwi *et al.*,

(2002); DeLacy (2006); Malygin and Ponomareva (2007); Galadima and Garba (2008); Abdulkarim *et al.,* (2010); Sauvei *et al.,* (2011) reported the ambient atmosphere concentration of carbon (IV) oxide by bubbling air through alkaline sodium hydroxide solution.

Malgwi *et al.,* (2002) reported the atmospheric pollution concentration of indoor-Air pollutants carbon (IV) oxide from fuel combustion. His finding indicated that the estimated annual emission is 110000ppm which is about 350 times the CO_2 content (325ppm) of the atmosphere. Spector and Dodge (1996) used the colorimetric method for the determination of traces of CO_2 in air. The barium oxide hydrate method of simple chemical determination was used by Malygin and Ponomareva, (2007).

2.5.3 Methane (CH_4)

Methane is a colorless, non toxic gas when inhaled but can produce suffocation by reducing the concentration of oxygen inhaled. It has a sweet smell and oily type odor and is synthesized commercially by distillation of bituminous coal and heating a mixture of carbon and hydrogen.

$$C + 2H_2 \rightarrow CH_4$$

In the laboratory methane can be produced by heating sodium acetate with sodium hydroxide and by the reaction of carbide with water.

$$Na + NaOH \rightarrow Na + CH_4$$

$$Al_4C_3 + 6H_2O \rightarrow 3CH_4 + 2H_2O$$

Its chemical formula contains one atom of carbon and four atoms of hydrogen. Methane is lighter than air, at normal temperatures and pressures it will condense to a liquid at – 164^0C and will become solid at -183^0C. Methane is chemically reduced state and will readily oxidized (burn as fuel), giving off heat and producing carbon (IV) oxide and water by the following reactions (Yusuf and Oyewunmi, 2008);

$$CH_4\,(g) \quad + \quad 2O_2\,(g) \quad \rightarrow \quad 2CO_2\,(g) \quad + \quad H_2O\,(l)$$

The primary methane gas hazards are its flammability, explosive potential and the possibility of asphyxiation. Asphyxiation can be caused by breathing air with high concentration of methane, because the high concentration of methane can reduce the oxygen level below that which is needed for life (Stonesypher, 2010).

Secondly, methane is the second biggest contributor to global warming. Methane is emitted from a variety of natural and human influenced sources such as land fill, natural gas and petroleum systems, coal mining, stationary and mobile combustion, waste water treatment, certain industrial processes and the most is associated with animal agriculture. However, according to recent estimates, the waste sector contributes about one-fifth of global anthropogenic methane emissions (Nabegu, 2011). It is the primary constituent of natural gas and important source of energy constitutes 0.00018 percent of the atmospheric air component much less than carbon (IV) oxide and its molecules trap twenty one times more infra-red energy than carbon (IV) oxide molecules in their respective life times in the atmosphere. This is because it has a relatively shorter life span in the atmosphere (Ayodele and Emmanuel, 2007 and Gworgwor *et al.,* 2006).

Preston and Leng (1989) reported that though methane is responsible for 18% of the current global warming trend it is accumulating at fast rate and is apparently responsible for some depletion of the protective ozone layer. Leng (1993) similarly reported that methane concentration on the atmosphere is rising rapidly and that it contributes about 19% of the overall warming, and that it is one of the atmospheric gas that cause serious problem.

Methane's chemical life span in the atmosphere is approximately 12 years compared to 100 years for carbon (IV) oxide and its relatively short atmospheric lifetime, coupled with its biodegrading to carbon (IV) oxide in about five years contribute to its significant as a greenhouse gas for mitigating global warming. (Dictris, 2005; Ayodele and Emmanuel, 2007).

Methane is a principal component of natural gas, wetlands and rice paddy, and stomach of ruminant animals. It is formed and released to the atmosphere by biological process occurring in anaerobic environments. Once in the atmosphere, methane absorbs terrestrial infra-red radiation that would otherwise escape to space. This property can contribute to the warming of the atmosphere which is the reason that methane is a greenhouse gas (Chitkara, 1982: Ayodele and Emmanuel, 2007). Methane is also stored in clathrates, which are depositions of ice and changes in ocean temperature and currents cause a sudden release of methane from the clathrates. Scientists believe that past releases of methane from clathrates caused warming trends in the earth's history (Asher, 2002).

Methane is a natural gas and it is widely used around the world as a fuel. The largest uses of natural gas as a fuel are for space heating, water heating and the

generation of electricity. Natural gas typically contains about 87 to 96% methane by volume; with most of the remainder being ethane. Methane in natural gas is formed from anaerobic decomposition of organic (plant and/or animal) matter that was trapped underground long in the past. It remains there until trapped and extracted (Bengtson, 2010).

The methane containing gas produced by anaerobic decomposition of waste organic matter is referred to as biogas and the process is called methane digester. Biogas is less concentrated fuel than natural gas and it typically contains about 50 to 75% methane, with most of the remainder being carbon (IV) oxide, along with small to trace amount of nitrogen, oxygen, water vapor, hydrogen sulphide and various organic compounds.

Methane chemical characteristics and interactions in the atmosphere makes it a greenhouse gas that remain in the atmosphere for a considerable length of time and its relatively short atmospheric lifespan, coupled with its potency as a greenhouse gas makes it a candidate for mitigating global warming (Houghton *et al.*, 1992, EPA, 2005 and Ayodele and Emmanuel, 2007). Once methane is emitted, it is removed from the atmosphere by a variety of processes. The balance between its emissions and removal processes ultimately determine its atmospheric concentrations, and how long methane emissions remain in the atmosphere. The dominant sink of atmospheric methane is oxidation by chemical reaction with hydroxyl radicals (OH^-). Methane reacts with hydroxyl radical to produce methyl (CH_3) radical and water in the troposphere layer of the atmosphere.

$$CH_4 + OH \rightarrow CH_3^{\bullet} + H_2O$$

However, stratospheric oxidation plays a minor role in removing methane from the atmosphere. Similar to troposphere oxidation, minor amounts of methane are destroyed by reacting with OH in the stratosphere. These two OH reactions account for 90% of methane removals. In addition to methane reaction with OH, there are two other known sinks; microbial uptake of methane in soil and methane's reaction with chlorine (Cl) atoms in the marine boundary layer. It is estimated that these sinks contribute 7% and less than 2% of total methane removal respectively (IPCC, 2001).

The natural concentrations of methane in the atmosphere range from 1.2 to 1.5 ppm on a worldwide basis (NAPCA, 1970). Enhalt and Schmidt (1978); Heldt and Enhalt (1980) and Ayodele and Emmanuel (2007) reported that Methane is the only hydrocarbon found naturally with background concentration in the atmosphere of 1.3 to 1.4 ppm. Other hydrocarbons in airs are derived from a variety of sources such as oil and petroleum refineries and storage deports (Leggett *et al.,* 1972 and Ayodele and Emmanuel, 2007).

The level of methane in atmosphere falls from 1990 to 2004 perhaps due to drought in wetland areas, as well as better management of landfills, gas wells and oil wells. In 2007 methane levels began climbing, which may be due to the thawing of the arctic tundra. A positive feedback loop may occur if the thawing of the Arctic tundra causes a rapid release of methane and this would in turn accelerate global warming (Ayodele and Abubakar, 2001).

However, the contribution of methane to the greenhouse effect will not be overstated as it is an important component of greenhouse gases in the atmosphere and is mostly associated with animal agriculture. Methane effect is four to six times

that of carbon (IV) oxide and contributes about one-third to a half of that of carbon (IV) oxide to climate change. (Leng, 1993; Moss *et al.,* 2000 and Gworgwor *et al.,* 2006).

The presence of methane in the atmosphere has been known since the 1940's when Migeotte in 1948 observed strong absorption bands in the infra-red region of the ultra violet radiation spectrum which were attributed to the presence of atmospheric methane. An increase up to 18ppm per volume per year between the periods 1980 to 1990 was observed (Rodhe, 1990). The current global average atmospheric concentration of methane is 1720ppm more than double its pre-industrial value of 700ppm (Bolle *et al.,* 1986 and Gworgwor *et al.,* 2006).

The rising concentration of methane is attributed to the increasing population and currently about 70% of methane production arises from anthropogenic sources and the remainder from natural sources. Agriculture is considered to be responsible for about two-third of the anthropogenic source and biological anaerobic generation is the major natural source of methane (Gworgwor *et al.,* 2006).

Different methods have been employed to determine the concentration of methane in air. Ayodele and Emmanuel (2007) use an automatic Crowcon Gasman in determining methane in Kano atmosphere. Yusuf and Oyewunmi (2008) utilized IPCC (1996) Tier 1 methodology to carry out the qualitative assessment of methane generation potential from municipal solid wastes.

2.5.4 Nitrous oxide (N_2O)

Nitrous oxide also known as laughing gas, nitrogen (I) oxide or dinitrogen oxide occur naturally and also as a result of man's activities in environmental conditions. It is a colorless, compressed liquefied gas with characteristic odor, heavier than air, sweet smelling gas, slightly soluble in water and may accumulate in ceiling space causing deficiency of oxygen and although non-flammable it will support combustion. When inhaled it has an anesthetic (sedative) and analgesic (pain reliever) effects; hence the name 'laughing gas'.

Chemically, nitrous oxide reacts violently with sulphurous anhydride, amorphous boron, ethers aluminum, hydrazine, phenyl-lithium and tungsten carbide, causing fire and explosion hazard. The gas is a strong oxidant above $300^{O}C$ temperature and may form explosive mixtures with ammonia, carbon monoxide, hydrogen sulphide, oil, grease and fuels. The liquid may cause effect on the central nervous system resulting in lowering of consciousness and prolong exposure of the liquid may affect the bone marrow, the peripheral nervous system and the human reproductive.

The anesthetic and analgesic properties of nitrous oxide have been used in medicine and dentistry since the late 19^{th} century, where it was also used as a recreational drug. Presently, nitrous oxide is abundantly used in the dairy industry as a mixing and foaming agent, in motor sports to speed engine and by deep sea divers to avoid nitrogen narcosis.

Nitrous oxide is released naturally from a wide variety of biological sources in soil and water bodies as part of microbial processes of nitrification and denitrification. The two major man-made sources are from agriculture (application of fertilizers to soils and subsequent leaching to water bodies) and the manufacture of nitric and adipic acids and nylon. It is also released from power stations and road transport (particularly since the introduction of catalyst converter). Nitrous oxide also is emitted during combustion of fossil fuels and solid waste (IPCC, 2001). Aubrey and Robert (1958) confirmed that poorly aerated soils which are approaching saturation with moisture rapidly released large amount of their available nitrogen as nitrous oxide. A sampling from a variety of combustion systems reveals that N_2O emissions are usually low from the combustion of coal, very low in a laboratory gas fired fiber burner, and domestic oil combustor whereas emission from combustion of straw or wood were slightly higher (Hulgaard and Dam-Johansen, 2006).

Nitrous oxide has been proposed to be formed by the reaction of molecular nitrogen with ozone in the ozonosphere and at ground level by the following reactions;

$$N_2 + O + M \rightarrow N_2O + M$$

Where M is a third body, and

$$N_2 + O_3 \rightarrow N_2O + O_2$$

Where O_3 is activated ozone molecule.

The increased use of fertilizers is causing an increase in the quantities of nitrous oxide being produced by micro-organisms. As nitrous oxide is a very stable compound, it passes up through the troposphere and finally enters the stratosphere. In the

stratosphere, it is broken down under the influence of ultra-violet radiation into a mixture of about 90% nitrogen and 5% nitrogen monoxide (NO). The nitrogen monoxide generated interacts with and destroy ozone in the stratosphere allowing more ultra violet radiation to penetrate the atmosphere and reach the earth, leading to skin damage and cancer and detrimental effects on crops and vegetation (Narayanan, 2009).

$$2N_2O \rightarrow \underset{(95\%)}{N_2} + 2NO$$

$$NO + O_3 \rightarrow NO_2 + O_2$$

$$NO_2 + O \rightarrow \underset{(5\%)}{NO} + O$$

The effect of increased nitrous oxide concentrations may be mitigated by increases in methane which is capable of increasing or preserving ozone concentration by reacting with chlorine in the stratosphere (NOUN, 2010).

Nitrous oxide does not have a local environmental impact. However, on a global scale it does contribute to global warming and is the third most important greenhouse gas on molecular basis, it has a high global warming potential of about 310 times than carbon (IV) oxide and also damage the ozone layer thus reducing the protection offered from harmful ultra-violet sun rays (Listowki *et al.,* 2011).

However, at normal environmental concentrations nitrous oxide is not harmful to human's health. But inhalation of higher concentrations in an enclosed space could exclude oxygen causing dizziness, nausea and eventually unconsciousness. Also the

part its play in depletion of ozone means that human may be exposed to excessive ultra-violet sun rays which might consequently cause skin cancers.

Nitrous oxide is another powerful greenhouse gas listed in the Kyoto Protocol, a large quantity of nitrous oxide compounds emitted into the atmosphere by human activities is through the mobile and stationary burning of fossil fuels and the use of nitrogen fertilizer in agriculture for soil management that enters the oceans and may lead to the removal of some carbon (IV) oxide from the atmosphere (Robert, 2008).

However, some of the nitrogen deposited in the ocean is re-processed to form another nitrogen compound called nitrous oxide, which is then released back in to the atmosphere from the ocean. Nitrous oxide is a powerful greenhouse gas due to its long atmospheric life time (approximately 120 years) and has more heat trapping effect than carbon (IV) oxide.

Action is being taken to reduce industrial emission of nitrous oxide but measures to limit or reduce agricultural emissions are more difficult. The relative importance of nitrous oxide in the Kyoto Protocol list of greenhouse gases increase because complete mitigation measures for nitrous oxide are difficult, expansion of land area devoted to crops production to feed the increasing population and to accommodate the current development of biofuels likely to lead to an increase in nitrogen fertilizer use.

2.5.5 Halogenated gases (examples, hydrogen chlorocarbons (HClCs), perfluoro carbon (PFCs) and SF6)

These are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. They are major greenhouse gases and the subject of the Kyoto protocol which come into force in 2005. The most common of these gases are chloroflouro carbons which also deplete the ozone layer. These gases were popularly found in cooling and refrigeneration processes like air conditioning, aluminium manufacturing and also used as a gassy 'fizz' for many plastic foams and as propellant in spray cans for deodorants, insecticides and paints. They are extreme powerful and can trap twenty two thousands (22,000) times more heat than carbon (IV) oxide (CO_2) and accounted for about two percent (2%) of greenhouse gases in 2001(Karen, 2008).

Chloroflouro carbons (Freon) are non poisonous, non flammable and do not corrode metals. They diffuse into the stratosphere, where they are broken down by ultra-violet radiation. Chlorine atom formed in this process break down the ozone that protects the earth from harmful radiation.

(i) $CF_2Cl_2 + \text{ultra-violet light} \rightarrow CF_2Cl + Cl\cdot$

(ii) $Cl\cdot + O_3 \rightarrow ClO\cdot + O_2$

(iii) $ClO\cdot + O \rightarrow Cl\cdot + 2O_2$

The last step (iii) results in the formation of another chlorine atom that reacts with another molecule of ozone. The second and third steps are repeated many times; thus, the decomposition of one molecule of halogenated hydrocarbon can result in the destruction of many molecules of ozone (O_3).

Although halogenated hydrocarbons are greenhouse gases, they are regulated by the Montreal protocol, which was motivated by CF_2Cl_2 contribution to ozone depletion rather than by their contribution to global warming. It is the same greenhouse gases that threaten the public health and welfare of the American people (U.S.EPA, 2009).

2. 6 Indirect Effect Greenhouse gases

These are gaseous compounds that have an indirect effect on global warming because they contribute to the build-up or decomposition of other greenhouse gases in the atmosphere.

2.6.1 Carbon (II) oxide also called carbon monoxide (CO)

Carbon (II) oxide unlike many toxic gases is a colorless, odorless, low reactivity and low water solubility. It is non- irritating to the victim when breathed but highly poisonous gas emitted into the atmosphere as product of incomplete combustion of wood, coal, tobacco, car emission, gas water heater, leaking chimney and furnaces, generator and other gasoline powered equipment; it is produced when there is not enough oxygen to form carbon (IV) oxide that is when operating in a closed space (Victor, 2011; Musa and Mohammed, 2012).

Carbon monoxide is the next abundant atmospheric pollutants emitted into the troposphere from natural origin due to photochemical reactions in the troposphere that generate about ($5 * 10^{12}$ kg per year), other natural sources of carbon monoxide include volcanoes, forest fires while anthropogenic sources are road vehicles, non-road equipment, fuel combustion and industrial processes. These are quite small in comparism with natural sources (WHO, 1999). At the earth surface, carbon (II) oxide is

produced in all form of burning of biotic material at inadequate oxygen level. In the atmosphere, natural production to the extent of 50% of the total atmospheric carbon (II) oxide load is by the interaction of solar radiation with methane. (Ayodele *et al.*, 2007). When the materials mentioned are burned in an atmosphere of restricted oxygen, carbon monoxide is generated along with carbon dioxide, which is in the main product.

$$2C + O_2 \rightarrow 2CO \text{ (incomplete combustion).}$$

$$C + O_2 \rightarrow CO_2 \text{ (complete combustion).}$$

In urban areas, developing towns and cities great deal of carbon monoxide (90%) comes from motor vehicle exhaust, rest percent from fuel consuming industries and domestic fire. In rural areas biomass burning in conjunction with agriculture practices is a major contributor (Omotosho *et al.,* 2014). Carbon monoxide is the most abundance constituent of road traffic emissions that has a long residence time (about 3 years) in the atmosphere and reacts with other chemicals, giving rise to secondary air pollutants (Narayanan, 2009).

In areas away from major sources, the atmospheric level of carbon monoxide is fairly constant which meant that significant natural sinks exist to remove the vast excess of gas. The natural sinks and their importance are the oxidation to carbon dioxide in the troposphere by hydroxyl radicals, the atmospheric oxidation or the absorption by soil microbes, the ocean, or plant and animals (Ochigbo, 2011).

In most part of developing countries wood, stubble, trunk and grass are used daily as source of energy for cooking. They are burnt in open fire or inefficient stoves in poorly ventilated kitchen. The resultant toxicity of carbon monoxide gas lies in its

unusual ability to bind very strongly to hemoglobin (Stanley, 1993 and Hamid *et al.*, 2010). It is a powerful asphyxiating gas, interfering with normal function of hemoglobin. Hemoglobin's oxygen-binding capacity is decrease in the presence of carbon monoxide because both gases compete for the same binding sites on hemoglobin, carbon monoxide binding preferentially in place of oxygen (Hamid *et al.*, 2010). When hemoglobin combines with carbon monoxide it forms a very bright red compound called carboxyl hemoglobin, which may cause the skin of carbon monoxide poisoning victims to appear pink in death, instead of white or blue (Guyton, 2005).

Annually, a large number of individual die as a result of exposure to very high concentration of CO levels, far above the ambient levels. In Flanders, for example between 1987 and 1988 about 100 people died, mostly as a result of accidental exposure (Magnus, 1995 and Musa and Mohammed, 2012). CO is one of the most common air pollutants, for which many countries have set air quality limit values. CO is brought into the atmosphere by two different mechanisms; emission of CO and chemical formation from other pollutants (EU, 1999 and Musa and Mohammed, 2012).

Musa and Mohammed, (2012) cited that burning of forest, savannah and agricultural waste accounts for half the global CO emissions. The chemical formation of CO is due to the oxidation of hydrocarbon and this adds 600-1600 Mega tones to the atmosphere. Two third of it stem from methane and one third result from natural sources, including that derived from hydrocarbon oxidation.

The health effects associated with exposure to carbon monoxide at low concentration include fatigue and chest pain in people with heart disease (WHO, 2004). At high concentration, impaired vision and coordination, headaches, permanent damage

to central nervous system, dizziness, confusion, nausea and death may occur. At a moderate concentration, impaired vision and reduced brain function may result. During pregnancy it results to low birth weight and parental mortality (Ayodele *et al.,* 2007).

Carbon (II) oxide levels in busy city streets are higher than carbon (II) oxide near highways since the amount of carbon (II) oxide emitted per kilometer strongly decreases with vehicle in city street is less; carbon (II) oxide levels are usually highest in winter, because cold engines emit much more carbon (II) oxide than hot engines and also the atmosphere is more stable than in summer (Musa and Mohammed, 2012).

Carbon (II) oxide in the atmosphere plays an important role in global region and atmospheric chemistry by affecting the concentration of OH^- radical and the cycle of troposphic ozone. Carbon (II) oxide is considered as an indirect greenhouse gas due to its close coupling with atmospheric methane, a strong greenhouse gas (Pickering and Owen, 1994 and Gomati *et al.,* 2010).

$$CO + OH \rightarrow CO_2 + H$$

$$CO_2 + H + M \rightarrow HOO + M$$

The OH is regenerated from HOO (hydroperoxyl) by the equations below;

$$HOO + NO \rightarrow OH + NO_2$$

$$HOO + HOO \rightarrow H_2O_2 + O_2$$

The H_2O_2 formed undergoes photochemical reaction to regenerate hydroxyl ion (OH^-).

The atmospheric concentrations of carbon monoxide vary widely around the world and throughout the year, ranging from as low as 30 ppb up to around 200 ppb.

Concentrations increased during twenties century, but dropped slightly in the 1990s due to the wide use of catalytic convertors, with their lower carbon monoxide emissions in cars. Carbon monoxide concentration in the atmosphere is determined by electrochemical and non dispersive infra-red (NDIR) spectrometer methods. However, NDIR is a versatile continuous monitoring technique. Gas chromatography analyzers based on the reduction to methane are the most sensitive but they are unsuitable for continuous monitoring.

2.6.2 Nitrogen (IV) oxide gas or also nitrogen dioxide (NO_2)

Nitrogen (IV) oxide is one of the oxides of nitrogen (NO_x) which is produced from high temperature combustion vehicle exhaust systems, power generating system and some chemical manufacturing processes. NO_2 is a pungent, irritating gas, which absorbs in green region of light and displays a reddish brown haze dome above or plume downwind of cities. Like ozone, it can be formed by photochemical action and so is present in photochemical smog (Howell, 1997; Speeding, 1997 and Adelagun *et al.*, 2012). Vehicle exhaust arises mainly from inefficient combustion of hydrocarbon fuels. Hydrocarbon gases easily unite with oxides of nitrogen oxide (NOX) through photochemical reactions in sunlight to produce smog.

Photochemical smog is a reddish-brown haze that has been observed by many urban areas. It is formed from the reaction of NO_2 with hydrocarbons in the presence of sunlight to form a secondary class of pollutants, the photochemical oxidants among them ozone and eye-stinging peroxyacetyl nitrate (Swersen, 2000 and Koku and Osuntogun, 2007). The formation of ozone occurs when the atomic oxygen formed in the process reacts with molecular oxygen. Ozone is not emitted as such from a source

and is considered a greenhouse gas. Therefore, the sequence of reactions below is showing how nitrogen dioxide gas leading to photochemical smog is formed.

$NO_2 \rightarrow NO + O$

$O + O_2 \rightarrow O_3$

$O_3 + NO \rightarrow NO_2 + O_2$

$O + HC \rightarrow HCO.$

$HCO^* + O_3 \rightarrow HCO_3 + O$

$HCO_3 + HC \rightarrow$ Aldehydes, ketone

$HCO_3. + NO \rightarrow HCO_2 + NO_2$

$HCO_3. + O_2 \rightarrow O_2 + HCO_2.$

$HCO_2. + NO_2 \rightarrow H_3 - C - C(=O) - O - NO_3$

(Peroxyacetyl nitrates)

In the sequence, ozone in turn reacts with hydrocarbons to form a series of compounds, which include aldehydes, ketones, organic acids and epoxy compounds (Hamid *et al.,* 2010).

Nitrogen oxide combines with other organic substance in the atmosphere to create ozone, with devastating effect on climatic stability. Nitrogen (IV) oxide is an indirect greenhouse gas that has positive radiative forcing effects on climate. Nitrogen

dioxide also can cause a variety of health impacts such as eye irritation, pulmonary edema, an accumulation of excessive fluid into the lungs that provide an ideal culture medium for microbial growth and exacerbate asthma and increase susceptibility to infection. Additionally nitrogen oxides react with hydroxyl radicals to form nitric acid, which easily converted in to aerosols and finally leading to acid rain (Narayanan, 2009). Nitrogen dioxide emission from aircraft is also likely to decrease methane concentrations, due to its oxidation reaction with hydroxyl radicals in the atmosphere thus having a negative radiative forcing effect (IPCC, 1999).

$$HO + NO_2 + (M) \rightarrow HONO_2 + (M)$$

2.6.3 Sulphur (IV) oxide gas or sulphur dioxide (SO_2)

Sulphur (IV) oxide is a chemical compound with the formula SO_2. It is not terribly toxic to most people. Low level in the atmosphere does have some health effects. Sulphur (IV) oxide pollution is known primarily to inhibit respiration especially to an asthmatics people, reproductive disorder and inhibit photosynthesis in lower and higher plants. Also reproductive disorders, respiratory and cardiac problems in human have been related to sulphur (IV) oxide pollution (AbdulRahim, *et al.,* 2006). Atmospheric sulphur (IV) oxide is harmful to plants; high levels exposure of gas kills leaf tissue and chronic exposure of plants causes' chlorosis, a bleaching or yellowing of the green portion of the leaf (EPA, 2007).

Sulphur dioxide is a colorless and pungent irritating smell gas that is released by the combustion of sulphur containing fossil fuels, volcanoes and various industrial processes of smelting of sulphide-containing ores such as FeS_2, PbS, ZnS, NiS, CuS

and HgS, manufacture of elemental sulphur and sulphuric acid, conversion of wood pulp to paper, decay of organic wastes and incineration of refuse. It is estimated that 50% annual global emission of sulphur is from coal burning and 25 to 30% from oil burning and the remaining includes volcanoes and forest fires. The contribution from automobile is small (Narayanan, 2009).

Sulphur (IV) oxide emissions influence the level of acidification of soils and fresh water ecosystem (Staldard *et al.,* 1999; Scchopp *et al.,* 2003) and have impact on human health (WHO, 2006). Emission and successful deposition of sulphur have caused material, soil and forest damage (Nelleman and Goul Thomsen, 2001) and surface water acidification. WHO (2000) reported that in dry unpolluted atmospheric conditions, it is estimated that the sulphur (IV) oxide concentration for urban areas showed annual mean ranging from 0,0072 to 0.022 ppm and daily mean rarely exceeding 0.045 ppm.

Sulphur dioxide is not a 'greenhouse gas' but its presence in the atmosphere may influence climate. Sulphur dioxide reacts with a variety of photochemically produced oxidants to form sulphate aerosols. The concentrations of these particulates are increasing due to the burning of sulphur containing fossil fuels, the anthropogenic sulphur dioxide emissions world-wide amount to 70-80 million tons per year (Abdurrahman *et al.,* 2011). The natural emissions have been estimated to be 18-70 million tons per year. However, more than 80% of anthropogenic sulphur dioxide arises from fuel combustion with three quarter of this from coal. The global sulphur cycle involves primarily hydrogen sulphide, sulphur dioxide and sulphate (SO_4) which is the highest source of sulphur entering the atmosphere. The hydrogen sulphide is rapidly

converted into the sulphur dioxide by the following process reaction (Abdurrahman *et al.,* 2011).

$$H_2S + 3O_2 \rightarrow 3SO_2 + 2H_2O$$

Sulphur dioxide produces during fuel combustion is oxidized in the atmospheric air by photolytic and catalytic process involving hydroxyl radical (OH), O_3, H_2O_2, NO_x and O_2 (reactions with O_2 are catalyzed by iron and manganese in the cloud droplets) given rise to the formation of photochemical smog. Under normal conditions of the atmosphere, sulphur dioxide reacts with water vapor, at pH of less than five and in the presence of hydrogen peroxide (H_2O_2) oxidant to produce droplets of sulphuric acid aerosol which give rise to the so called 'acid rain' causing adverse impacts on forest, vegetation, fresh waters and soil, killing insects and aquatic life form as well as causing damage to building and human health (Narayanan, 2009).

$$SO_2\,(g) + OH^- \rightarrow HOSO_2$$

$$HOSO_2 + O_2 \rightarrow HO_2 + SO_3$$

$$SO_3\,(g) + H_2O\,(l) \rightarrow H_2SO_4\,(l)$$

$$SO_2 + H_2O_2 \rightarrow H_2SO_4$$

Human exposure to sulphur (IV) oxide cause irritation of eye, throat and respiratory tract by damaging the mucus lining of the respiratory tract, and leading to bronchitis. Textiles have in some cases not only faded or weakened but dissolved (Ayodele and Abubakar, 2008). Sulphur (IV) oxide reacting with ozone and nitrogen dioxide it is responsible for cardiovascular diseases (Narayanan, 2009).

Sulphur dioxide also contributes to the formation of sulphate aerosols has both a positive and negative radiative forcing (climate warming and cooling). This is because of the ozone depletion during photochemical oxidation process, the process also used OH radical thereby reducing the methane sink and increase its atmospheric concentration. Ecosystems are sinking for about 30% of sulphur dioxide emission and for sulphur aerosols. Dimethyl sulphide emitted by marine phytoplankton when they die or are eaten, contributes to cloud formation (El-Gammal *et al.,* 2011).

Different methods have been employed to determine the concentration of sulphur oxides in the atmosphere; McDermott *et al.,* (1979) collected and determined sulphur dioxide by permeation of the gas through a membrane in catalytic oxidizing solution, which stabilizes the sulphur dioxide as sulphate, which is then analyzed turbidmetrically by precipitation. Liu *et al.,* (1997) employed gas permeation continuous flow coulometric analysis for determining high sulphur dioxide. Neves *et al.,* (1994) determined sulphur dioxide in air on the basis of the catalyzed autoxidation of cobalt (II) in azide medium. Ayodele and Mohammed (2001) reported the ambient concentration of sulphur dioxide over Kano Municipality as in the range of 14 to 22μg/m^3 with coefficient of variation of 12.74% by bubbling air through dilute H_2O_2 solution.

Riordan and Adeeb (2004) carried a study on SO_2 concentration level in four sample points (Chrities Beach, Elizabeth, Northfield and Kensington) all within Adelaide metropolis. Their findings show that SO_2 concentration level did not exceed the 0.08 ppm one standard stimulated by the NEPA measure. Therefore the concentration level is not likely to have an adverse impact on either human health or

vegetation in the metropolitan Adelaide region. Barman *et al.,* (2008) conducted a study on the ambient air quality of the city Luck now, India during Diwali festival. Result show varied concentration of PM10 (particulate matter of size 10), SO_2 and NO_2 for observation taken at four representative locations day and night time for pre Diwali (day before Diwali) and Diwali day. On Diwali day, 24 hours average concentration of SO_2 was found to be 0.05 ppm and this concentration was found to be 1.95 and 6.59 times higher when compared with the representative concentration of pre Diwali and normal day. On Diwali night (24 hours) mean level of SO_2 was 0. 074 ppm that was 2.82 times higher than the day time concentration.

AbdurRahim *et al.,* (2006) reported that the ambient concentrations of sulphur (IV) oxide in the city of Ilorin, were found to vary significantly with traffic density and human activities. There was a significant difference (p= 0.05) between the sulphur (IV) oxide concentration at two sites (high and low traffic sites). However, there was no significance difference (p = 0.05) between high traffic/medium population density and medium traffic/high population areas. Aliyu *et al.,* (2013) in their study on appraisal of sulphur contaminants from transportation in urban Zaria, Nigeria, use Crowcon gas instrument to collect and analyze sulphuric gas samples from the densely populated areas of urban Zaria. The result showed varying concentration of SO_2 and H_2S. The high concentrations of these pollutants detected was attributed to increased population growth, increased production of gaseous waste and increased of vehicular movement.

2.6.4 Hydrogen sulphide (H_2S)

Hydrogen sulphide also referred to as dihydrogen sulphide, swamp gas, sewer gas and sour gas, is a highly flammable and colorless gas with a rotten eggs smell,

produced by decomposing organic matter. It is naturally found in hot springs, natural gas, volcanic gases and human and animal waste. Aside from these sources, hydrogen sulphide is emitted from other industrial activities such as paper mill, sugar beet, wood pulp processing, petroleum refinery, tanneries, waste treatment plants, sewer systems, asphalt plants, slaughter houses and mining operation.

The formation of hydrogen sulphide from massive volcanic eruption emitted carbon (IV) oxide and methane into the atmosphere, which warm the ocean, lowering their capacity to absorb oxygen that would otherwise oxidize hydrogen sulphide. The increase level of hydrogen sulphide could have killed oxygen generating plants as well as depleting the ozone layer causing further environmental stress. This effect has been detected in the Dead Sea and in the Atlantic Ocean of the coast of Namibia.

Other sources of hydrogen sulphide are microbial decay of organic matter and reduction of sulphate ion (SO_4^{2-}) as represented below;

$$SO_4^{2-} + (CH_2O) + 2H+ \rightarrow H_2S + 2CO_2 + 2H_2O$$

Because of high concentration of sulphate ion in sea water, bacterially mediated formation of hydrogen sulphide causes pollution problem in some coastal areas and is a major source of atmospheric sulphur (Mahan, 1979).

Hydrogen sulphide is soluble in water and can cause dangerous form of pollutant to both air and water. Its pollution can lead to hazardous disturbances in the physical and chemical composition of bodies of waters. It enters the environment from both natural and human processes; almost all hydrogen sulphide is releases to air where it exists in the gaseous phase. In the air it travels long distances until it finds a source of

ignition and then burn given off with poisonous and corrosive sulphur dioxide gas. The sulphur dioxide formed reacts with other oxidation chemicals and contribute to the formation of sulphate (SO_4) aerosol with negative radiative forcing effect (climate cooling) (Dora, 2004).

$$H_2S + O_2 \rightarrow 2SO_2 + 2H_2O$$

Hydrogen sulphide has a strong and offensive odor that is detectable at low concentration below 8μg/m^3 at a concentration of 50—150μg/m^3. It has a deceptive sweet smell, above this range; it deadens the sense of smell (Victor, 2011). Hydrogen sulphide is readily absorbed in the lungs, increasing breathing problem and other respiratory issues. Short exposure to high concentration may cause eye irritation, conjunctivitis with ocular pain and photophobia progressing to keratoconjunctivitis vessiculation and of the corneal epithelium, sore throat and cough, nausea, shortness of breath, and fluid in the lungs. On long term, it may result to fatigue, loss of appetite, headache, irritability, poor memory, dizziness and miscarriages in woman (Oguntoke and Yussuf , 2008).

Different methods have been employed for the determination of hydrogen sulphide gas in the environment. A sensitive spectrophotometric method has been use for the determination in the environmental sample after its fixation as zinc sulphide. The suitability of this method for monitoring hydrogen sulphide in atmosphere air in the vicinity of possible sources such as a sewage treatment plant and in waste water has been evaluated (Ochigbo, 2011). Colourimetric, ion- selective, iodometric and lead acetate methods has been developed by Narayanan (2009). Determination of worker exposure for up to 8 hour period for several inorganic air-borne contaminants in the

range of their threshold limit values. Pandurangappa and Balasubraalial (1996), employed extractive spectrophotometric method in the determination of trace amount of hydrogen sulphide after fixing the gas triethanolamine (TEA)-zinc acetate sodium hydroxide solution.

2. 7 EFFECTS OF GREENHOUSE GAS EMISSIONS

Greenhouse gases can affect the environment and health by the following;

2.7.1 Greenhouse effect (GHE)

One of the most important facts about greenhouse effect is as of today, there is an enormous change in the global temperatures which have risen by 0.5^0C since the middle of the last century, increased rapidly in 1980s and it is predicted that there could be further rise to 1.5^0C and 4.5^0C by the year 2100 (Waugh, 1995). The drastic change in temperature will cause in the water levels rising around the globe and consequently many islands are in fear of being drowned. Disappearance of rain forests cannot be replaced with new tree transplantation.

Impact of greenhouse effect on earth includes changes in global climate and spatial distribution of temperature, precipitation, cloud and air currents as well as shift in the vegetation belts, melting of ice caps; rise in sea level (Ayres and Walter, 1991 and IPCC, 1996).

2.7.2 Global warming

Global warming is when the Earth heat up (the temperature rises). It occurs, when greenhouse gases trap heat and light from sun in the Earth's atmosphere which

increases the temperature; this hurt many people, animals and plants (Barry *et al.*, 2010). It is caused by increasing concentrations of greenhouse gases, which result from human activity primarily burning of fossil fuels for transportation and energy production, and deforestation. Global warming disrupts millions of lives daily in the forms of destructive of weather patterns, massive fire, severe hurricane, melting of ice and consequently leads to the loss of habitat and livelihoods (Mintzer, 1993: James and Dugle, 2011).

These have brought a great concern over global warming prospect; the scientific community has recently united to express its confidence in the theory of greenhouse effect and evidence that the warming is already taking place is hard to refute. Some skeptics remain, however and their views have been given considerable publicity by interests that would prefer to ignore the warming and take no measure to regulate their activities. Daily trust (2011) comment that, today global warming is a general increase in world temperature caused by high amount of Carbon (IV) oxide around the earth has been described as the greatest threat facing humanity'.

It is generated by human influences on naturally occurring phenomenon called greenhouse gas effect (Ofoh, 2009). A body of scientist known as IPCC in 2007 stated that; 'certainly global warming is a reality and human kind is largely to blame'.

According to Erokoro (2006), the consequent of global warming, as it was predicted by the latest scientific assessment is raised at the face of 1.4 to 5.8 percent by 2010. He added that the consequence of global warming is raised in sea levels due to thermal expansion that occur as water is heated. The study carried out by United Nation Environmental Program (UNEP) revealed that about fifty percent of the world

population lives by the coastal areas and stand directly or indirectly affected by such changes. Other consequences of global warming include change in weather patterns, desertification, flooding, erosion disasters and human health problem, decline in overall biodiversity, and implications for agricultural and food security.

Global warming causes unpredictable and extreme weather events impact and an increasingly affect crop growth, availability of soil water, forest fires, soil erosion, drought, floods, sea level rise with prevalent infection of diseases and pest (Adejuwon, 2004). These environmental problems results to low and unpredicted crop yields, which invariably makes farmer more vulnerable, especially in Africa.

2.7.3 Acid Rain

The concept of acid rain was first referred to by Robert Augus in 1872 during industrial revolution era to means any acidic precipitation such as rain and fog or deposition that occur downwind of areas where major emission of oxides of sulphur, carbon and nitrogen from human activities takes place (Oden, 1976 and Efe, 2011).

It is evident that gaseous emission of sulphur (IV) oxide (SO_2), carbon (IV) oxide (CO_2), nitrogen oxide (NOx) and ammonia (NH_3) from burning fossil fuels, and other anthropogenic activities form the major sources of acid deposition in the region. Once the oxides are airborne, these pollutants can travel for several kilometers and this long atmospheric lifetime enables their oxidation into acidic species (Pickering and Owen, 1995). Subsequent deposition of acids onto land, leads to widespread soil and surface water acidification. Through infiltration processes, acid rain can also leach various heavy metals from the soil into subsurface water, which impacts on aquatic life.

Acid rain also affects flora and fauna on land as well as causing damage to sculpture and buildings (Ife, 2011).

Similarly, Efe (2011) reported from works that acid rain effects on fish in North America that could have been caused by poor water quality. In 1959 the Norwegian biologist Alf Dannevig suggested that long range transported sulphur pollution could cause acidification and kill fish in Norwegian bodies of water.

Oden (1976) described the possible effects of acid deposition on soils and water in Norway, and opined that increasing number of lakes and streams were reported to be acidic in the 1960s, and there was concern about possible effects on forests. In Nigeria, acid rain has been observed in Warri, the rural areas of Delta State and the Niger Delta region by Efe (2005). Efe, (2006) opined that gas flaring, waste incineration, bush burning, flumes from fairly used cars and other anthropogenic activities are the major causes of acid rain Nigeria.

More so, the increased atmospheric concentration of carbon (IV) oxide in recent years has also resulted in increased carbonic acid, which has been linked to the occurrence of acid rain in Nigeria (Efe, 2011). However, many studies carried out on acid rain in Nigeria have been confined to Niger Delta region and neglected other parts of Nigeria (Onianwa *et al.,* 2002). This is attributed to the gas flares in Niger Delta region. In recent times, the need for extension is advocated. In 1995, Shell Petroleum Development Company argued that acid rain is not restricted to the vicinity of the gas flares. Acids result from natural causes, such as volcanoes, vegetations and lightening.

2.7.4 Climate change

Climate change is one of the environmental life-threatening to economic development and sustainability of man-kind worldwide. Both natural climatic cycle and human activities have contributed to an increase in the accumulation of heat-trapping greenhouse' gases in the atmosphere thereby contributing to increase in temperature in the global climate (global warming) (UNFCCC, 2007; Bello *et al.*, 2012).

Climate change also could result in change in cloud cover, rainfall patterns, wind speeds and storms. IPCC (2001) defined climate change as a change of climate which is attributable directly or indirectly to human activities that alter the composition of the global atmosphere and which are in addition to natural climate variability observed over a comparable of time period.

Ayoade (2004) stated that climate change is more than the average weather conditions over a given area. It includes considerations of departure from average, extreme conditions and the probabilities of frequencies of occurrences of given weather conditions. Thus, climate is a generalization of events whereas weather deals with specific. Weather describes conditions such as air, pressure wind temperature and amount of moisture in the air whereas climate determines the type of plants or animals that can survive, and it influence how people live.

According to Odjugo (2001), climate change is caused by both natural process and human (anthropogenic) activities. He identified natural processes as the eccentricity of earth's orbit, obliquity of ecliptic and orbital procession, the quality and quantity of solar radiation variation and volcanic eruptions.

Li (2009) observed that up to 1950, natural processes particularly solar radiation variations and volcanic dust was the predominated factor of temperature change. However, recent studies have shown the incidence of climate change across the globe is as a result of aggressive and unsustainable human activities which take place on domestic and industrial scale. The harmful gases released from these activities have been identified as a major factor responsible for global warming. The IPCC (2007) asserted that global greenhouse gas release via human activities have increased by 70% from 1970 to 2004.

Cities consume as much as 80% energy production worldwide and account for a roughly equal share of global greenhouse gas emissions (World Bank Report, 2010). The report added that as development proceeds greenhouse gas emissions are driven less by industrial activities and more by the energy services required for lightening, heating and cooling. Climatologists predicted that climate change will have both positive and negative effects, but that the negative effects will exceed with greater rate of climate change. The effect of climate change according to IPCC (2001; Iwejingi, 2013) will manifest as more hot days and heat waves, fewer cold and cold waves, a change in global precipitation events, and the destruction of ecosystems, entire species and biodiversity. The United Kingdom (U.K) Government's Chief Scientist (2004) said that "climate change is the most severe problem we are facing today, more serious even than the threat of terrorism". The growing problem of climate change impacts is global and the developing countries, especially Africa will be mostly affected. This is because, Africa economy is predominantly agrarian rain fed, fundamentally dependant on the vagaries of weather, due to inability to cope as a result of poverty and low technological development.

Climate change is thought to be the culprit responsible for some of the environmental problems the world over, most prominent of which are severe flooding in part of Asia and America; droughts in parts of Africa and the global food crises which give rise to civil unrests in many part of the world (Nnaji, 2011). There is evidence in Nigeria today that climate change is already happening and it is due to human activities that give rise to emission of greenhouse gases. Climate models suggest that in the future this country is likely to experience higher temperatures changes in seasonal precipitation and a shift to more extreme rainfall events, rising sea levels and more frequent storms. Climate change is prevalent everywhere in Nigeria from the north where it has aggravated desert encroachment on the savannah belt, to the south where it has endangered ocean surge in coastal areas, erosion in many other parts. These changes could have significant impacts on a range of socio-economic and environmental processes that are affected by the weather and consequently resulted in loss of lives and damage to properties (Ahmed, 2012).

The IPCC (2001) revealed that the average surface temperature increased by about $0.6^{o}C$ over the 20^{th} century, that it was 66-90% confidence that most of the observed warming over the second half of the century was due to increase in greenhouse gas concentrations, and projected that temperature would increase from 1990-2100 by 1.4 to $5.8^{o}C$. It also stated that global mean sea level is projected to rise by 0.09 to 0.88 meters between 1990-2100, due primarily to thermal expansion and loss of mass from glaciers and ice caps. Odjugo (2011) revealed that in Nigeria temperature has increased by 1.78% within two climatic periods studied (that is 1901-1938 and 1911-2008), while rain fall has decreased by 91mm within the same period. He further stated that although there is general decrease in rainfall amount in Nigerian coastal

areas like Warri, Port-Hacourt, Calabar and Uyo among others have experienced slightly increasing rainfall in recent years. This significant change in temperature and rainfall overtime in Nigeria is a concrete evidence that climate is changing in Nigeria.

Nigeria like other countries in the world is now experiencing an adverse climate and temperature conditions with negative impacts on the welfare and live of the people by; severely disrupting the forest and water resource there by leaving them at risk. Scientific studies show that biological productivity in Nigeria will decrease in the event of global warming with an additional consequent of severe fuel wood shortages. Climate change could also affect agriculture in several ways such as crop growth, availability of water, temperature, climate variability, soil fertility and erosion, pest disease and sea level rise (Aja, 2010). Ayuba *et al.,* (2007) examine climate change impacts on six-arid range lands of north-eastern Nigeria. The result reveals declining forage, species composition, increased bare surfaces and increased shrub encroachment which are indication of combined effects of grazing fire, drought, and desertification and climate variability. Ekande *et al.,* (2007), examines the potential climate change impacts on the coastal cities of Lagos and Port-Harcourt using Models for Assessing Greenhouse Gas Induced Climate Change and Geographic Information System (GIS) interpolation techniques. The results confirm that sea level rise may occur with consequence of submerging all coastal cities of Niger Delta area and a large part of Lagos, the impact of climate change may be felt also by a wide spectrum of socio-economic variables like human health, energy, industry and other service sectors (Ekande et al, 2007). Barau (2007), appraise climate change risk in Kano State. The study found out that climate change constitutes multiple threats to Kano State in

agricultural system, the riverside and dam neighboring communities, the health sector, transportation sector and urban habitats among others.

Climate change has a lot of implications for public health. Awosika *et al.,* (1992) estimated that for one metrer rise in sea level, 3.7 million people will be displaced from the coastal regions of Nigeria; drought in hinterlands will lead to unhealthy sanitary conditions. Also application of fertilizer may take advantage of the potential for enhanced crop growth that can result from increased in atmospheric CO_2. This can pose a risk, for additional use of chemicals may impact water quality with consequent health (Rsenzweig *et al.,* 2002).

Emission of greenhouse gases mostly pollutes the quality of air which leads to global warming that determined the occurrence and localization of pest and diseases. In general pest and diseases vectors do better when the temperature is high. Global warming is therefore likely to extend the range of distribution of certain pest and diseases of pole wards (Adejawon, 2004). Clean air is prerequisite for sound and healthy living. Air pollution usually results indifferent cases of premature death especially among children and aged people. According to Mohammed *et al.,* (2012) several healths related problems was said to have been orchestrated by global climate change. An infectious disease like malaria has been reported (Anomohanran, 2011). Indoor air pollution has been another rampant situation among the developing country due to excessive combustion of solid biomass resources for energy consumption. Indoor air pollution from solid fuel is the cause of very severe health problem (Mohammed *et al.,* 2012). Diseases like eyes cataracts, tuberculosis, asthma attacks and lower birth weight are caused by indoor air pollution. Majority of illness related to

cardiovascular and acute lower respiratory infections are elicited by indoor air pollution.

2. 8 Solid Waste and Environment

Massive exploration of the earth crust has provided endless resources which are constantly being transformed into products that are discarded as waste after serving purpose. However, man cannot return these waste products to their crude state in the earth crust; hence the easiest route of escape is to release these materials to the atmosphere in gaseous forms. The accumulation of these gases in the atmosphere has upset a balance nature of the atmosphere. Thus increases the threat of climate change and global warming.

Recent events in major cities of world have shown that the problem of waste have become a ‘monster’ that has aborted most efforts made by international, federal governments, and state city authorities. It has been established that the process of waste management contributes to increasing generation of greenhouse gases that causes climate change and ozone layer depletion. Adejori and Olorunnimbe (2012) observed that waste generation is increasing at geometrical rate due to urbanization and industrialization and thus necessitates the release of greenhouse gases into the atmosphere. This is more common in developing countries such as Nigeria, and many mega cities in the world like Kano.

However, the volume of waste generated does not actually constitute major environmental problems, but the inability of governments, individuals and waste disposal agencies to keep up with the task of proper and efficient management of waste,

constitute to burden of environmental management (Nabegu, 2011). The volume of waste generated in any city is often reflection of the intensity of human activities such as population, urbanization and social development resources exploration and unchecked technological advances (Adesina 1993).

Urbanization and human economic activities has in the last 100 years, contributed to an increase in the concentration of greenhouse gases in the atmosphere leading to the enhanced greenhouse effect which in turn resulted in climate change, which is the most important and dangerous and certainly the most complex environment issue to date (IPCC, 1996; Hamilton, 1999). More so as the effect of change combine with overpopulation and weather crises, climate disruption will affect more people than does war (Ahmed, 2012).

Greenhouse gas pollutants emission is often caused by open burning at dumps and foul odour and windblown litters are common. Carbon (IV) oxide and methane are important greenhouse gases, are by product of the burning and decomposition of organic waste in landfill sites. In addition, waste dump may also be source of airborne bacterial spore and aerosols such as ammonia, hydrogen sulphide and sulphur oxides.

United State Environmental Protection Agency (USEPA) (2009) reported that 42% of total greenhouse gas emissions in the United State are associated with the management of waste materials. A simple analysis reveals that activities associated with waste and waste management contribute to a total of 57% of methane emission compared with 26% contributed by energy production sector.

Waste management option such as landfill, composting, incineration/mass burns and anaerobic digestion/ Biogas plants collectively emit substantial amount of greenhouse gases. Nnaji (2011) in his paper on 'Climate Change and waste management: A balanced Assessment' stated that the role of waste management in climate change is significant and concluded that greenhouse gas emission can be reduced through a thoroughly formulated waste management strategy.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3. 1 Materials

The sample used in this research was ambient air collected twice (morning and evening) each month for twelve (12) months (from September 2012 to August 2013). .

3. 2 The Study Area

Kano metropolis is located at the central western part of Kano State on latitude 12^{O} 25 to 12^{O} 40 north of equator and between longitude 8^{O}31 north to 8^{O} 45 east at an approximate altitude of 499 meter above sea level. It lies in the northern central boundary of Nigeria and is about 840 Km away from the Sahara desert and 1,140 Km from Atlantic Ocean (Okunola *et.al,* 2012). The city has for centuries been the most important commercial and industrial nerve centre of northern Nigeria attracting millions from all parts of the country and beyond with large urban areas that covers 137 square km and comprises six Local Government Areas (LGAs); Kano Municipal, Fagge, Dala, Gwale, Tarauni and Nasarawa. Immigration and natural growth rate of 3% is expected to continue to increase the population and traffic volume in the next years to come. With a population presently estimated at 3.5 million, Kano metropolis is among the fastest growing cities in Nigeria. With a population density of about 100 inhabitants per km^2 within the Kano closed-settled zone compared to the national average of 267 inhabitants per km^2. It is also one of the most crowded (Nabegu, 2011). With, the city experiencing erratic power supply with total dependent on alternative source of energy generator for commercial and business activities. These figures

indicate that greenhouse gases emission from internal combustion engines that burn gasoline or other fossil fuels is likely to be significant in Kano metropolis.

The principal inhabitants of Kano State are the Hausa people. As in most part of Nigeria, the city also is the capital of the Kano Emirate, home of an international Airport and about 75% of the working population engaged directly and indirectly to agriculture as the main source of economy.

3. 3 Climatic conditions

Kano State features savanna vegetation and hot, semi-arid climate. It receives an average precipitation of about 690 millimeter (27.2 inches) annually, which usually last for 3 to 5 months, the bulk of which fall from June to September and the average temperature ranges from 25 to 35^{O}C. The climate feature by the study area is the tropical wet and dry and these give rise to four seasons which are not equal in length of time; (i) a dry and cool which last from middle November to the end of February and is mark by cool and dry weather plus dusty haze, (ii) a dry and hot season which is a transition period between harmattan and rain seasons, last from March to middle of May and characterized by warmer temperatures which could go up to 40^{O}C; (iii) a wet and warm season, from mid-may to September is the proper wet season during which heat and high humidity causes the organic refuse wastes to decompose quickly leading to the release of greenhouse gas pollutants like methane, hydrogen sulphide and ammonia; (iv) a dry and warm season, which is the hottest season, lasting from October to mid-November and marked by high humidity and temperature (Barkindo, 1989).

3. 4 Sampling Locations

A multistage sampling procedure was employed to select the study sites. Firstly, five (5) local governments were selected from the eight (8) local government areas in Kano metropolitan. The aim is to target local governments that have the following characteristics/features; low and high population density, and low and high traffic volume. The local governments were Fagge, Municipal, Tarauni, Nassarawa and Dala. Secondly, eleven (11) sampling point junctions were randomly selected two from each of the five sampled local government areas for air quality monitoring. The sample frame consisting of ten (10) high traffic density, commercial activities were found along these roads and high population areas which are selected by simple sampling technique.

3.5 Theoretical frame work

Kano metropolis is Nigerian's most bestowed region in term of human population and industries after Lagos. The operation of these industries and varying of other human activities, including fossil and wood fuel combustions, refuse burning and traffic emission, releases variety of substances like volatile organics, oxides of carbon, sulphur, nitrogen, particulate matters and other pollutants at level that might exceed the national and international guidelines.

Apart from compromising the quality of the atmosphere, most of these pollutants are observed to cause local and regional effects such as formation of acid rain, water pollution, and impact on plants and animals, effect on building structure and recently global warming and climate change.

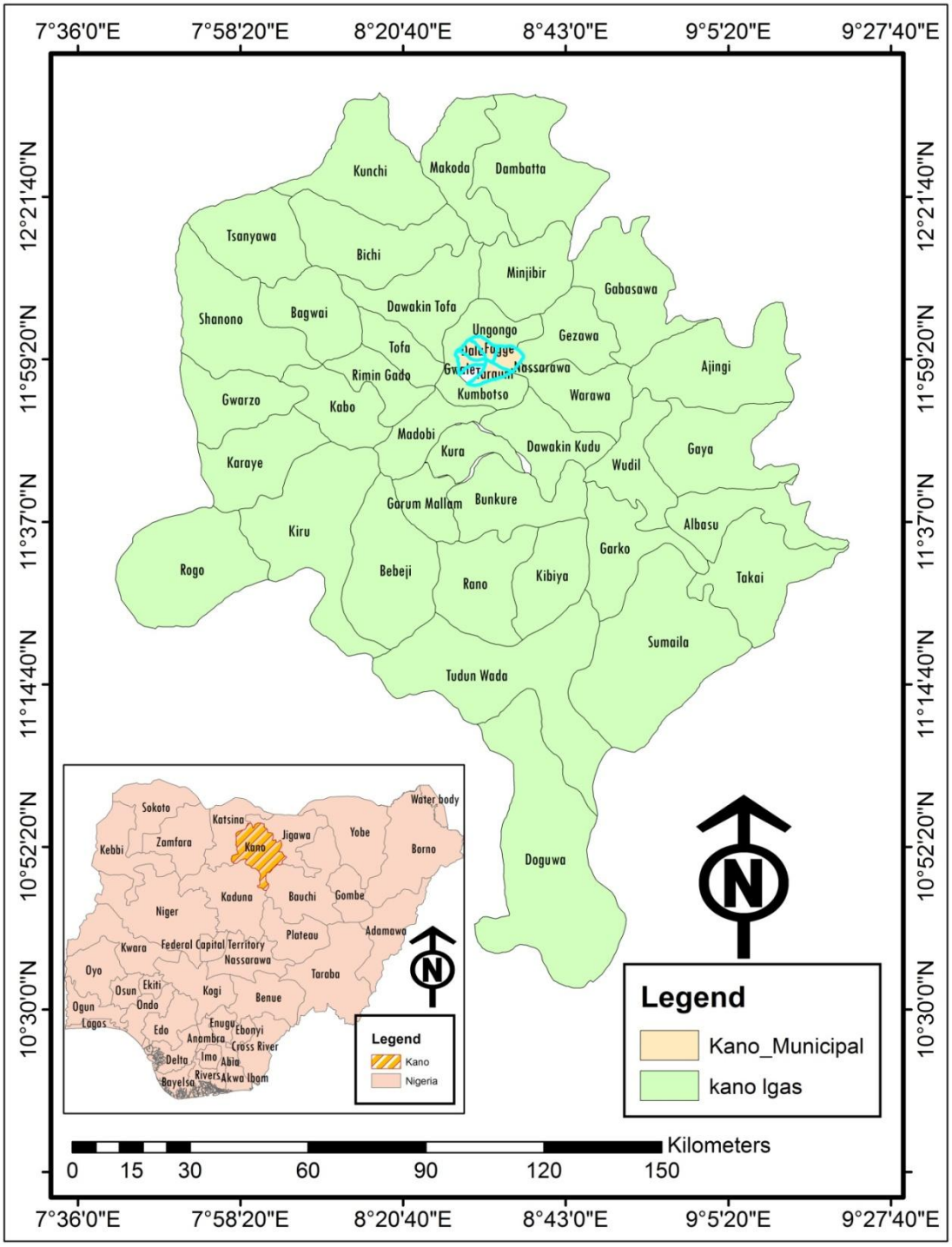


Figure 3.1: Map of Kano metropolis showing sampling Local Government Areas.

Table 3.1: Characteristic Features of the Study Locations

S/No	Sampling routes	Code for sampling point location	sampling location temperature range (^{0}C)	Coordinate of sampling points	General characteristics
1	Aminu Kano teaching hospital/kwandila housing estate	LN 1	27.6 to 33.5	N11,96821 E008,55053	Near filling station, local motor park, 3Km from main motor park, commercial vehicles and truck used to pass through the location
2	Zoo road/ Aliyu Ibn AbuTalib Mosque	LN 2	28 to 34.1	N11,97815 E008,53862	Refuse waste dump, many commercial vehicle especially taxicab.
3	Court/France roads	LN 3	29.3 to 33.6	N12,01436 E008,53446	Many commercial motorcycle, tricycle and commercial activities using generators, heavy traffic
4	Igbo road/ Sabon-gari market	LN 4	28.8 to 32.8	N12,01445 E008,53137	Heavy traffic, heavy people into and out of market
5	Kofar Nasarawa	LN 5	30 to 33.8	N11,99062 E008,53137	Heavy traffic, local food market, huge waste dump, mechanic garage, many vehicles
6	Rimi market/ Murtala hospital	LN 6	28.5 to 33.5	N11,99770 E00852134	Local market, high traffic, government building, illegal sidewalk market, many commercial vehicle
7	Dan-Agundi/B.U.K. road	LN 7	28.6 to 34.4	N11,98127 E008,52328	High traffic, many commercial vehicles,
8	Kofar mazugal/Abbatoir	LN 8	30 to 34.1	N12,01523 E008,51801	High traffic, commercial activities and grave yard, mechanic garage
9	Airport/Zungeru roads	LN 9	31.3 to 33.6	N12,02734 E008,54070	Large ditches and gutter, decomposed plants, food and dead animals
10	Sani Abaca/Murtala Mohd roads	LN 10	28.3 to 31.5	N12.00938 E008,54282	High traffic, many business activities, banks, many commercial activities
11		LN 11			Few vehicles, low traffic, less refuse waste

The sampling point junctions include: Aminu Kano Teaching Hospital/Kwandila Housing Estate (LN1). Zoo Road/ Aliyu bn Abu-Talib Mosque (LN2), Court Road/France Road (LN3), Igbo and Sabon gari Market (LN4), Kofar Nasarawa (LN5), Rimi market/Murtala Hospital (LN6), Dan-Agudi/ BUK (LN7), Kofar Mazugal/Abayoir (LN8), Airport/Zungeru Roads (LN9), Sani Abaca/Murtala Mohammed Roads (LN10) and a place in the farm center at the end road of Environmental Pollution Laboratory (LN11) was used to serve as control.

3. 6 Equipment

(i) Automatics gas sensors (EEx ias IIC T3/T4) ‘’TO’’ and ‘’FL’’ manufactured by Crown Detection Instrument Ltd.

(ii) Spss version 20.0

(iii) micro excel software ‘98’ window

3. 7 Data Collection

The concentration of greenhouse pollutants (CO, H_2S, NO_2, SO_2 and CH_4) were determined in-situ from eleven sampling locations (LN1 to LN11) around the five Local Government Areas of Kano metropolis. Three readings during morning from (7:30-9:30 am) and evening (4:30-5:30 pm) were taken twice every month from September 2012 to August 2013 for each of the five pollutant gases using an automatic gas sensors (EEx ia IIC T3/T4 and Ex ias IIC T3/T4 with certificate number Ex 93C 2069 X and Ex 93Y 2078 X for ‘’TO’’ and ‘’FL’’ respectively) manufactured by

Crown Detection Instrument Ltd. The analyzer unit was placed in normal air; the switch was turned to the GAS position. The green LED and the sound was operated once every three seconds. The LCD display showed “000”. If not, remove the black cover below the display is removed and adjusted to zero presets.

3. 8 Instrumentation

3.8.1 Crowncon-Gasman

The Gasman equipment manufactured by crowcon is an intrinsically safe personal gas detector, designed to warn the user of dangerous conditions in the immediate vicinity. The equipment was supplied by the Ministry of Environment and Pollution Control Laboratory, Kano State. The nugged design allows the instrument to be used in almost any application and the enclosure (except for sensor and sounder housings) was designed to IP65. There were three versions of the Gasman, powered by DC batteries and each suitable for specific applications. Gasman “FL” ‘’OX’’ and “TO”. However, Gasman ‘’FL’’ and ‘’TO’’ detection instruments were used for this research work (Figure 3.1). The Gasman ‘FL’ was designed to monitor the presence of flammable gases while the Gasman ‘TO’ was designed to monitor the presence of specific toxic gases and are certified to EEx ias IIC T3/T4 and EEx ia IIC T3/T4 with certificate number Ex 93Y 2078 X and Ex 93C 2069 X respectively. Temperature classification T3 applies if the unit is fitted with Crowcon rechargeable battery pack (Part number CO 1408), while the T4 applies if the unit is fitted with disposable battery.

3.8.2 Calibration

The span of Gasman “TO” and “FL” versions was adjusted by using gas of known concentration and reliable delivery systems to the sensor. The calibration gas test kits, comprising gas mixtures, both in disposable cylinders regulator and tube with calibration adaptors were used. The calibration adaptor was fitted into the top of the sensor housing and the gas cylinder valve was opened. The gas flow rate was set to the sensor to 0.5l/min and the reading on the display was allowed to stabilize. The CAL preset was adjusted so that the display indicated the concentration shown on the cylinder. Once adjustment was completed, the cylinder valve was closed and the adaptor disconnected. The control knob was carefully turned to achieve the required gas flow shown on the flow indicator. The control valve was completely closed and carefully turned to achieve the required gas flow shown on the gas flow indicator.

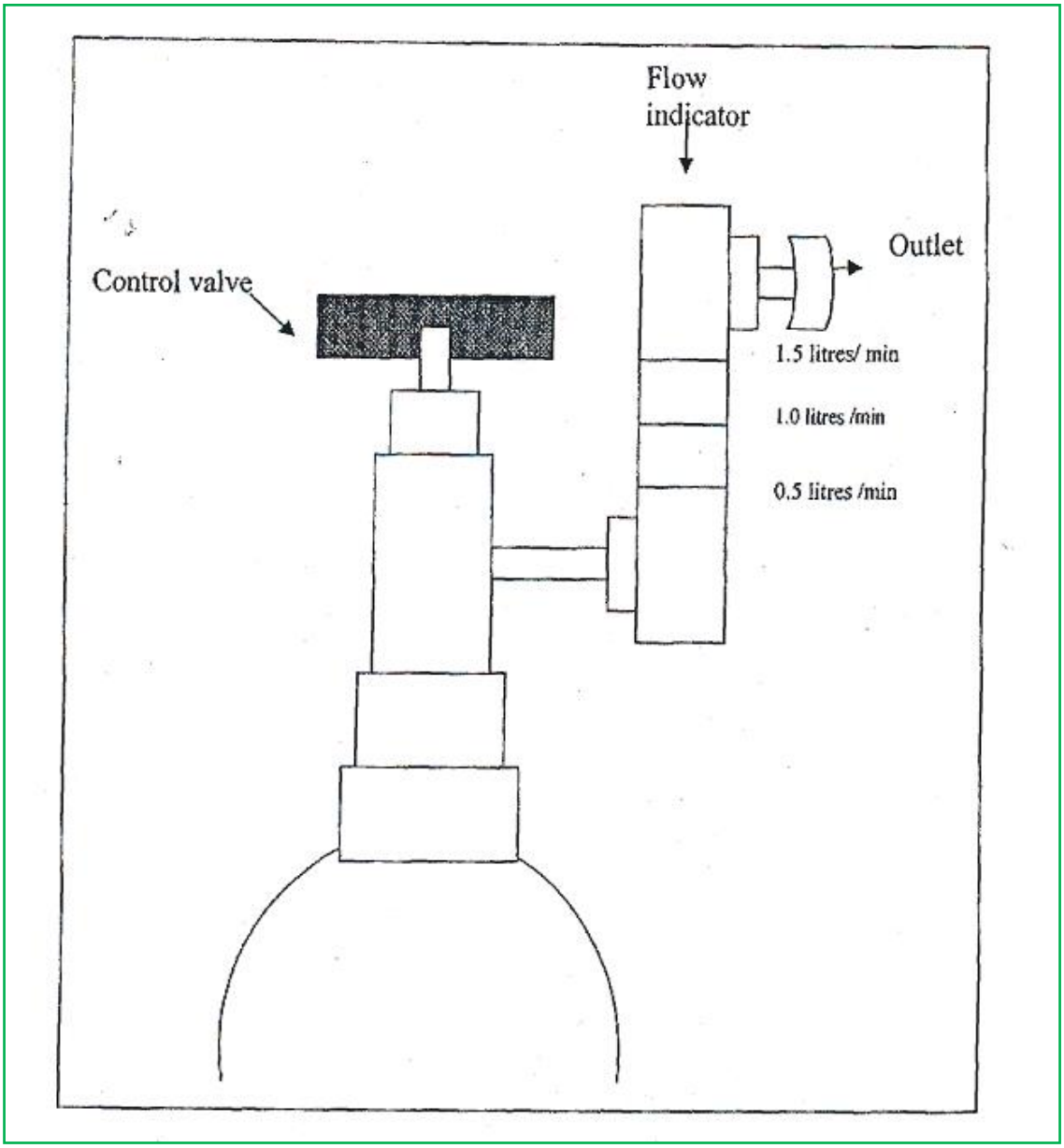


Figure: 3.2: Schematic Diagram of the Automatic Sampler

3.8.3 Operation

The unit was tested in air first and the switch was turned to the GAS position. The green LED and the sounder (if factory set) was operated once every three seconds. The LCD display showed '000' for "TO" and "FL" versions. If not the back cover below the display was removed and adjustment made to ZERO presets and replaced the cover back. An alarm condition was indicated by means of the flashing red LED and sounder and was automatically reset after the gas concentration had passed out of alarm range. The switch was turned to the TEST position. The audible alarm and red LED operated in intermittent mode and the LCD display showed a value between 30 and up to170. The battery was full capacity if the valve was between 30 and 170. If the valve shown was below 40, the battery pack was recharged or the dry cells replaced.

3. 9 Method

The levels of methane (CH_4), carbon (II) oxide (CO), sulphur (IV) oxide (SO_2), nitrogen (IV) oxide (NO_2) and hydrogen sulphide (H_2S) were detected at properly defined position of the selected locations. The ambient temperature around the location was measured and the co-ordinate of the sample point within the period of monitoring was recorded using Global Positioning System. The concentration of these gases were measured in part per million (ppm) using an automatic hand held personal gas sensor of model number EEx ias IIC T3/T4 and EEx ia IIC T3/T4 with certificate number Ex 93Y 2078 X and Ex 93C 2069 X respectively) manufactured by Crown Detection instruments Ltd England that employs a catalytic beard sensor for methane gas and electrochemical sensors for the gas measurements. During the gas measurements the hand held equipment were held at about 1.5 meter above the ground level and the

readings were recorded within ten seconds. All analyses were calibrated for zero and span before and after reading. Two sets of readings were recorded morning and evening in each month for the period of twelve lunar months. The temperatures of the atmosphere were also recoded.

3. 10 Statistical Analysis

The raw data obtained was analyzed using the basic descriptive statistics tools (mean and standard deviation). The mean values obtained were presented both on histograms and tables, further analysis was carried out to obtained the useful information of the closeness of the data to each other. Student t-test and analysis of variance (ANOVA) analyses have been applied for comparing the mean levels of pollutant gases obtained at different periods and seasons (morning and evening) across locations and at different sampling sites respectively. Pearson's correlation was used to determine the relationship between pollutant gases and traffic volume data. Statistical analyses were performed using the statistical software micro excel and SPSS version 20.0.

CHAPTER FOUR

4.0 RESULTS

4. 1 Greenhouse gases levels of the eleven sampling sites

Figure 4.1 shows the distribution of carbon (II) oxide across the sample sites. The level of carbon (II) oxide was generally higher in the evening then in the morning period across the sites. Similar results are obtained for hydrogen sulphide nitrogen (IV) oxide and sulphur (IV) oxide across the sites as shown in Figure 4.2, 4.3, 4.4. It is significant to note that the level of CO, H_2S and NO_2 and SO_2 were highest at either site 5 or site 6. Figure 4.5, however, show higher level of methane at site 4 in the morning then in the evening. All the other pollutants were higher in the evening then in the morning. Figure 4.6 shows the comparative result for all pollutant gases across the eleven (11) sites. The levels of carbon (II) oxide were far higher than all the other gases across the sites. The next higher gas was hydrogen sulphide.

Figure 4.7 shows the variation in the traffic volume across the sites of studies. The volume of motorcycle was highest only at sites 1, 2, 5,6,7,8 and 9. Figure 4.8-4.11 shows the variation of carbon (II) oxide during the four seasons of the year. While figure 4.12-4.15 shows the seasonal variation of hydrogen sulphide. The seasonal variation of nitrogen (IV) oxide, sulphur (IV) oxide and methane are depicted in Figure 4.16-4.19, 4.20-4.23 and 4.24-4.27 respectively. Figures 4.16 and 4.18, however, show equal levels of NO_2 at sites 10 and 2 during dry and warm, and dry and hot seasons respectively, Figure 4.23, show higher level of SO_2 at site 5 in the morning than in the evening and in Figure 4.26 no level of methane gas was detected in the evening. The

average variations in the level of pollutant gases across the studied sites are shown in figure 4.28 – 4.31.

Figure 4.28 shows the comparative study for all pollutant gases across the sites during dry and warm season. The level of carbon (II) oxide was far higher than all the other gases across the sites. The next higher gas was H_2S. Similar results are obtained during dry and cool, dry and hot and wet warm seasons as shown in figure 4.29, 4.30 and 4.31. However, comparative study for all pollutant gases across the sites during the four seasons. It is important to note that the levels of CO, H_2S and NO_2 were highest during dry and warm whereas, that of SO_2 and CH_4 were highest during dry and cool and wet and warm seasons respectively.

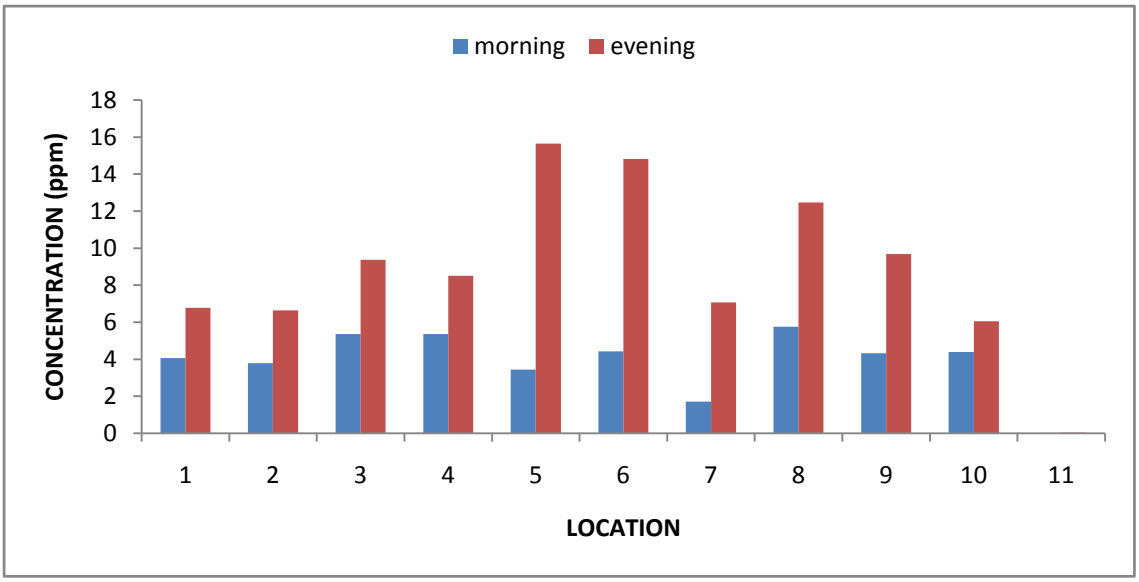


Figure 4.1: Variations in the levels of CO among sampling sites in Kano metropolis.

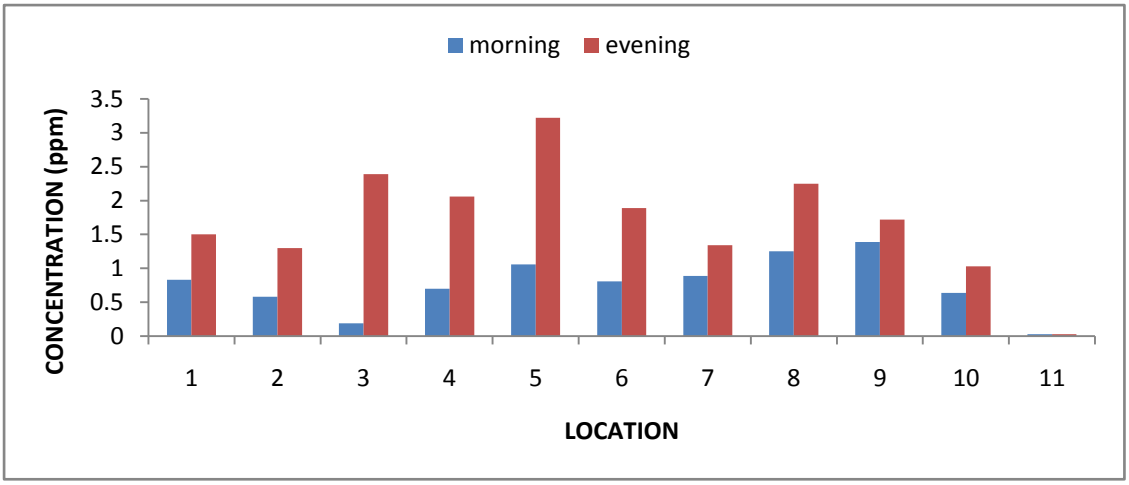


Figure 4.2: Variations in the levels of H_2S among sampling sites in Kano metropolis.

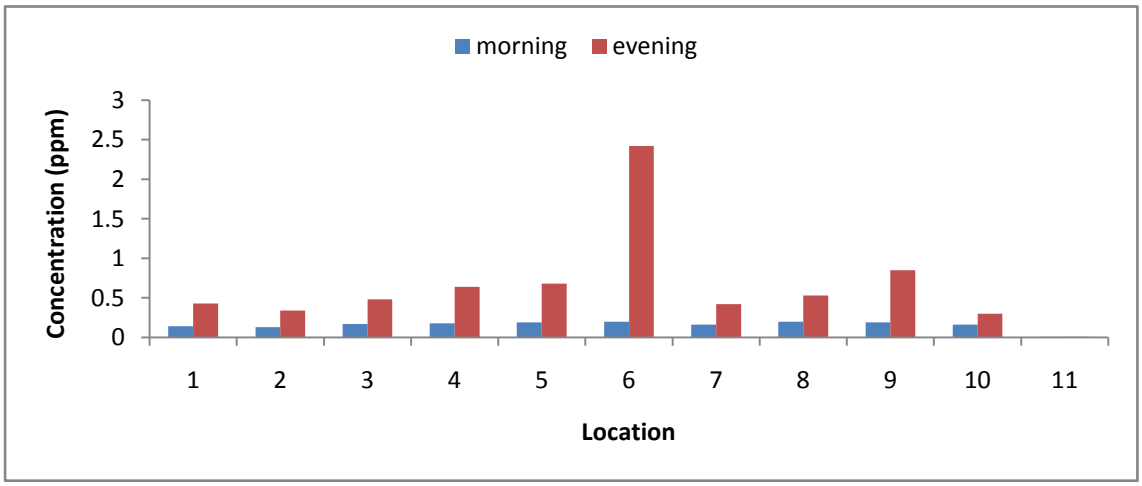


Figure 4.3: Variations in the levels of NO_2 among sampling sites in Kano metropolis.

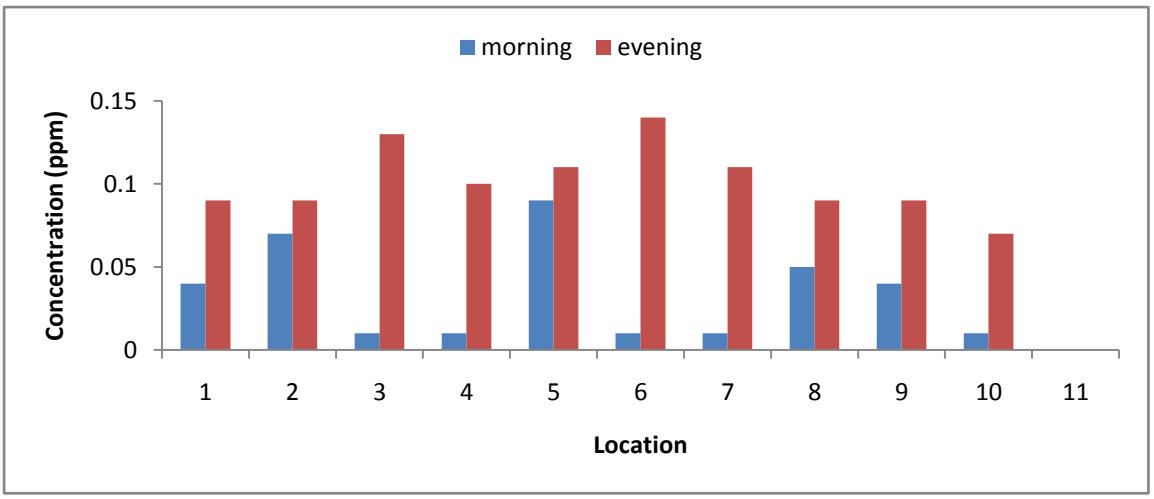


Figure 4.4: Variations in the levels of SO_2 among sampling sites in Kano metropolis.

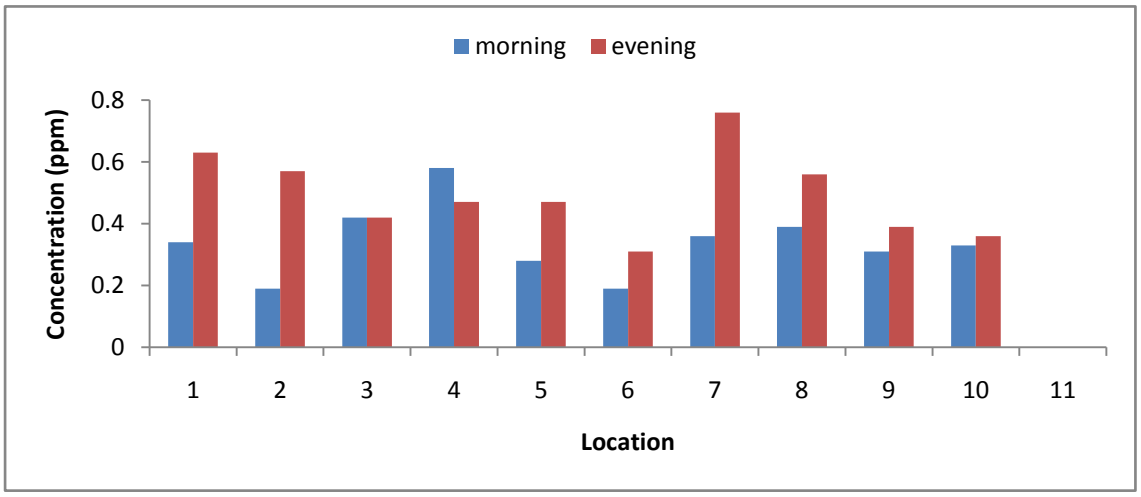


Figure 4.5: Variations in the levels of CH_4 among sampling sites in Kano metropolis.

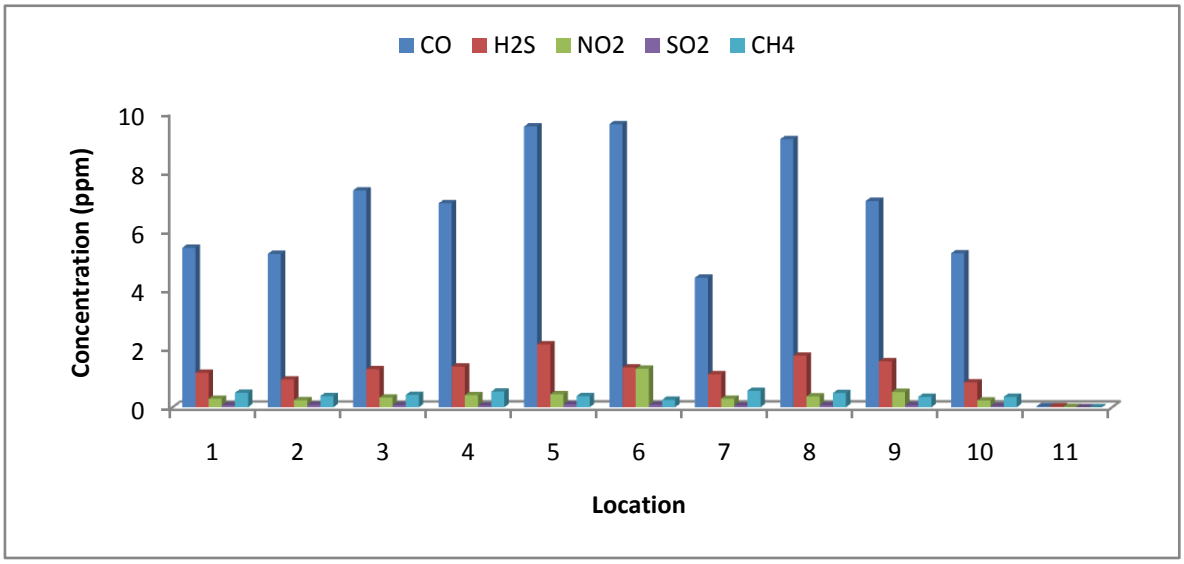


Figure 4.6: Variation in the levels of pollutant gases among sampling sites in Kano metropolis.

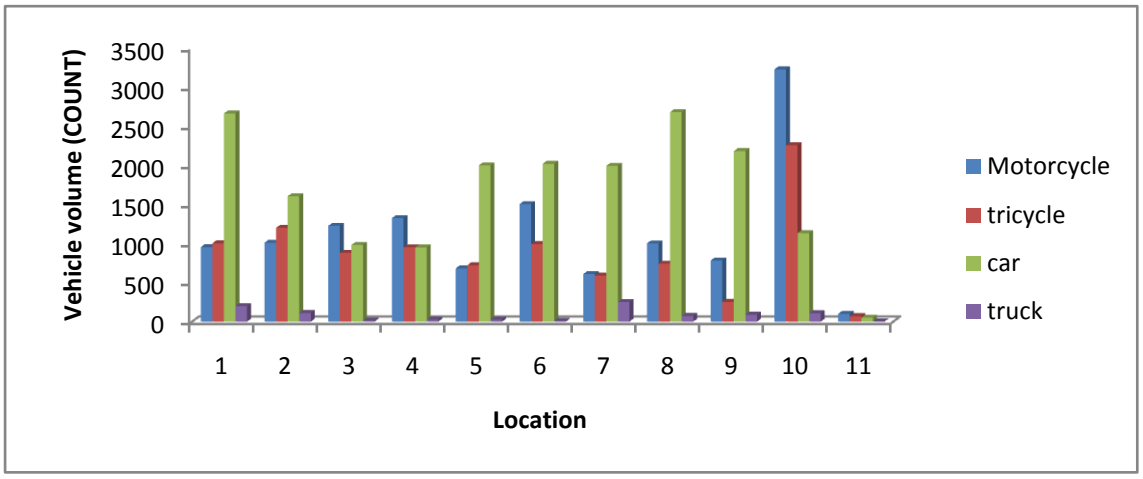


Figure 4.7: Variation in the Volume of traffic among sampling sites in Kano metropolis.

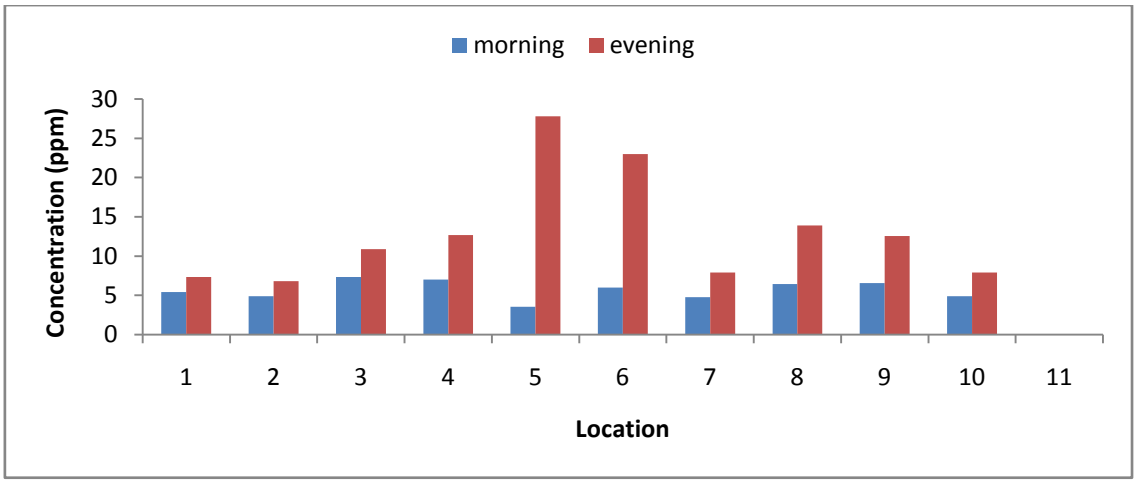


Figure4.8: Variations in the levels of CO among sampling sites in Kano metropolis during dry and warm season.

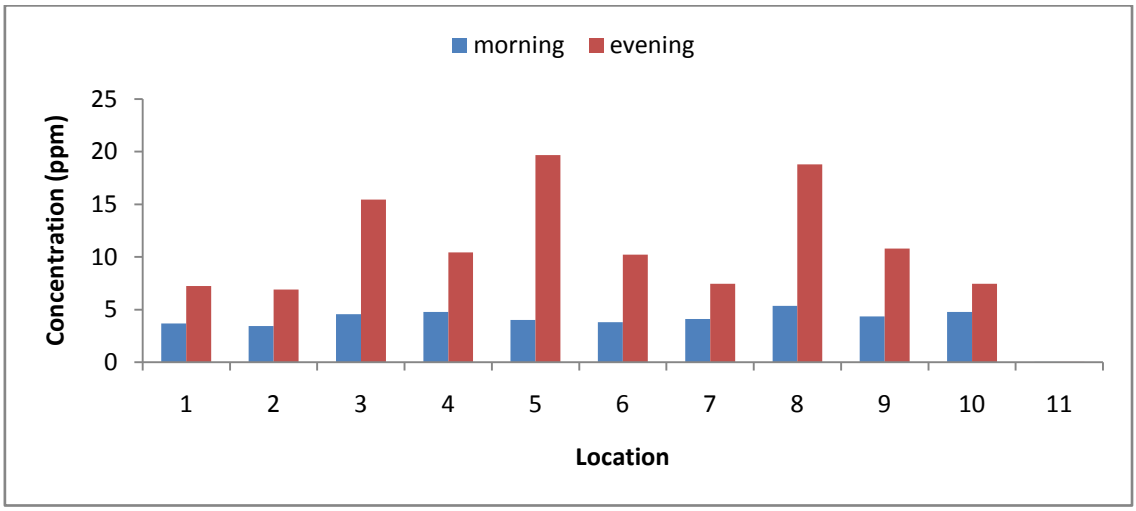


Figure 4.9: Variations in the levels of CO among sampling sites in Kano metropolis during dry and cool season.

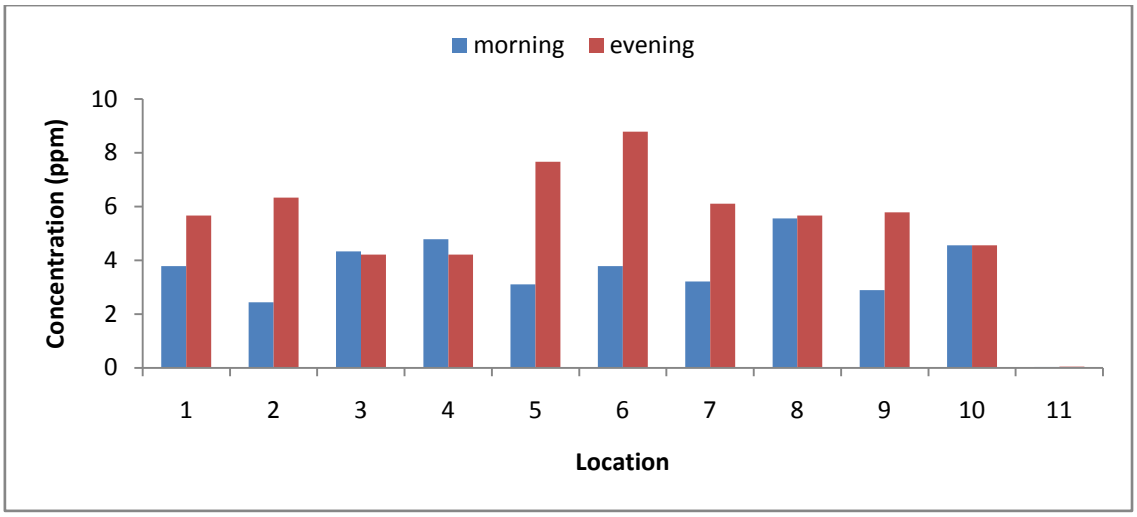


Figure 4.10: Variation in the levels of CO among sampling sites in Kano metropolis during the dry and hot season.

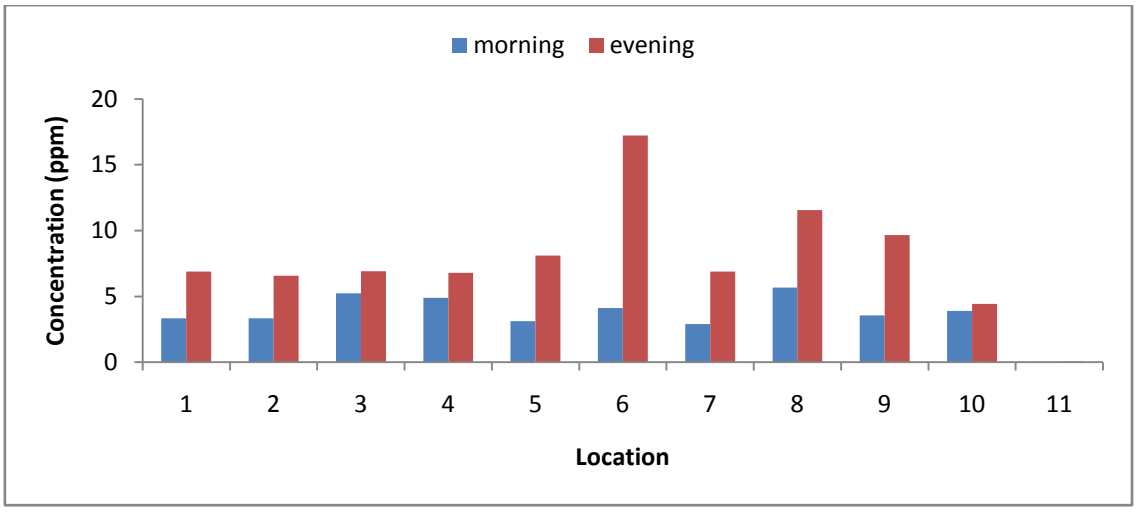


Figure 4.11: Variations in the levels of CO among sampling sites in Kano metropolis during wet and warm season.

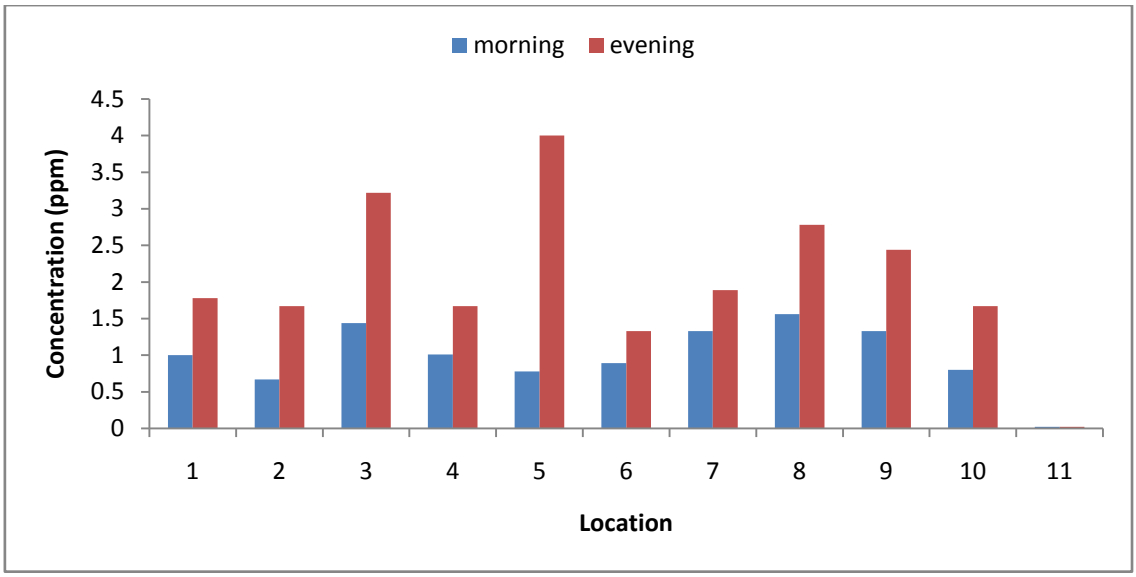


Figure 4.12: Variations in the levels of H_2S among sampling sites in Kano metropolis during dry and warm season.

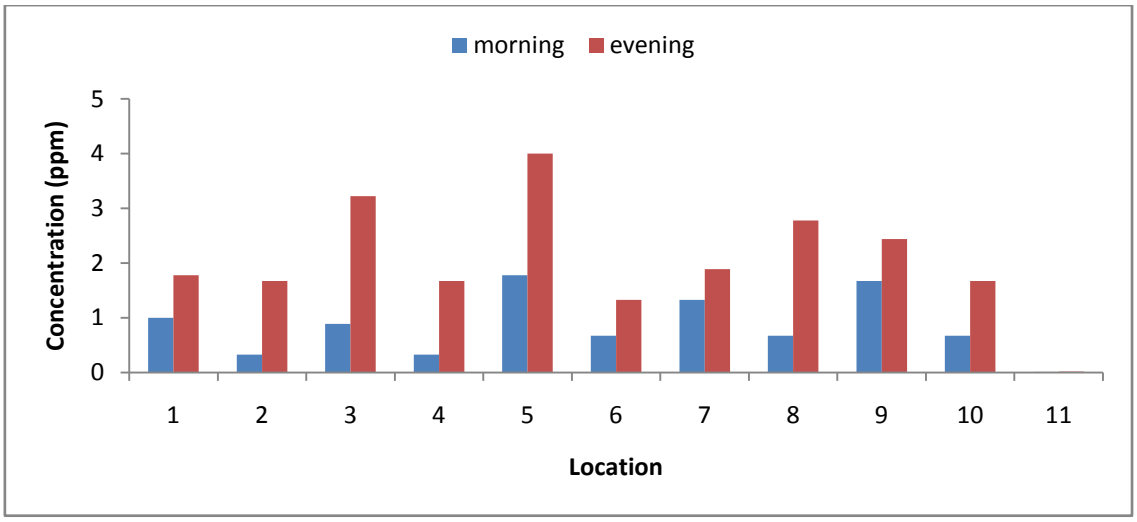


Figure 4.13: Variations in the levels of H_2S among sampling sites in Kano metropolis during dry and cool season.

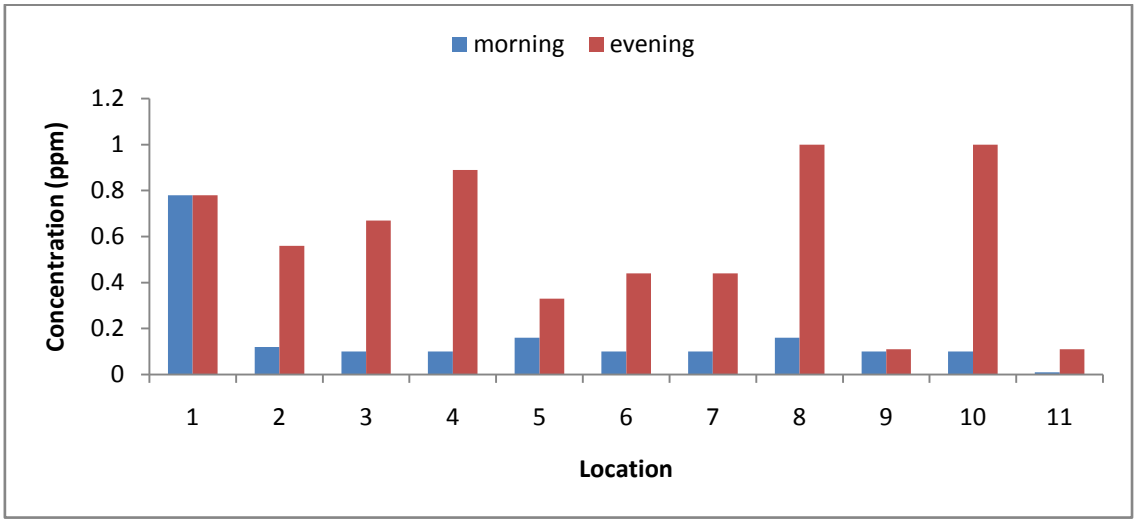


Figure 4.14: Variation in the levels of H_2S among sampling sites in Kano metropolis during dry and hot season.

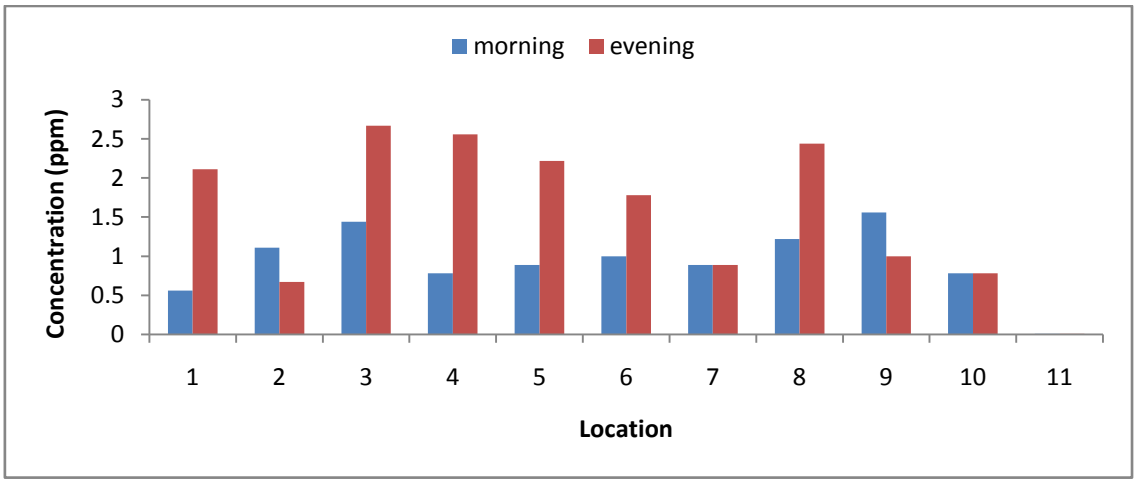


Figure 4.15: Variations in the levels of H_2S among sampling sites in Kano metropolis during wet and warm season.

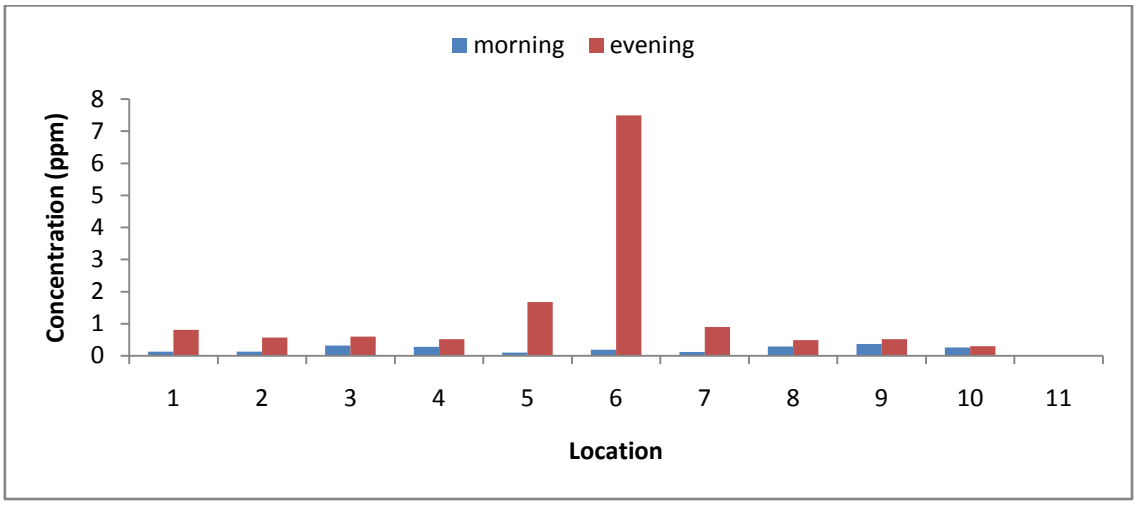


Figure 4.16: Variations in the levels of NO_2 among sampling sites in Kano metropolis during dry and warm season.

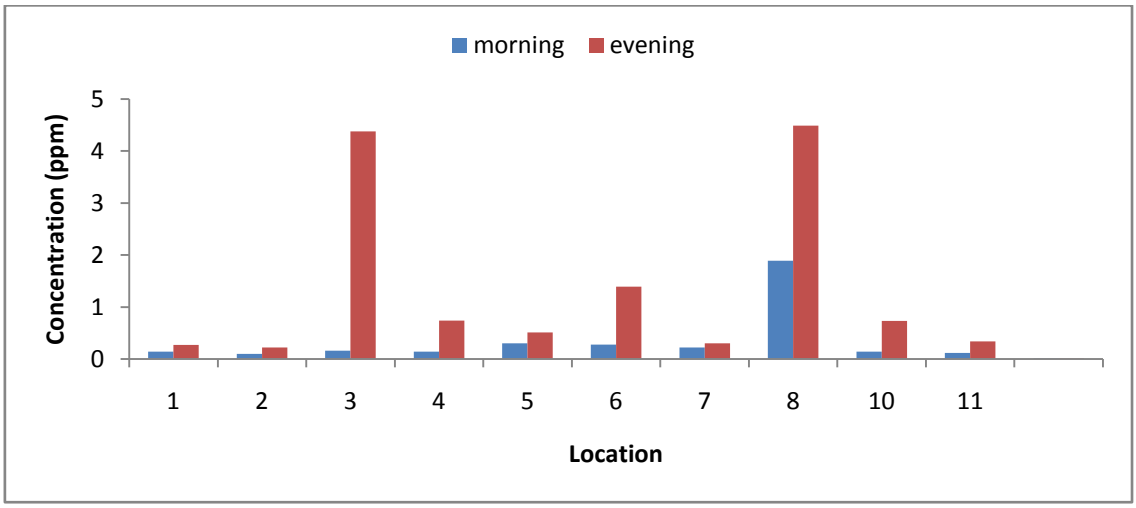


Figure 4.17: Variations in the levels of NO_2 among sampling sites in Kano metropolis during dry and cool season.

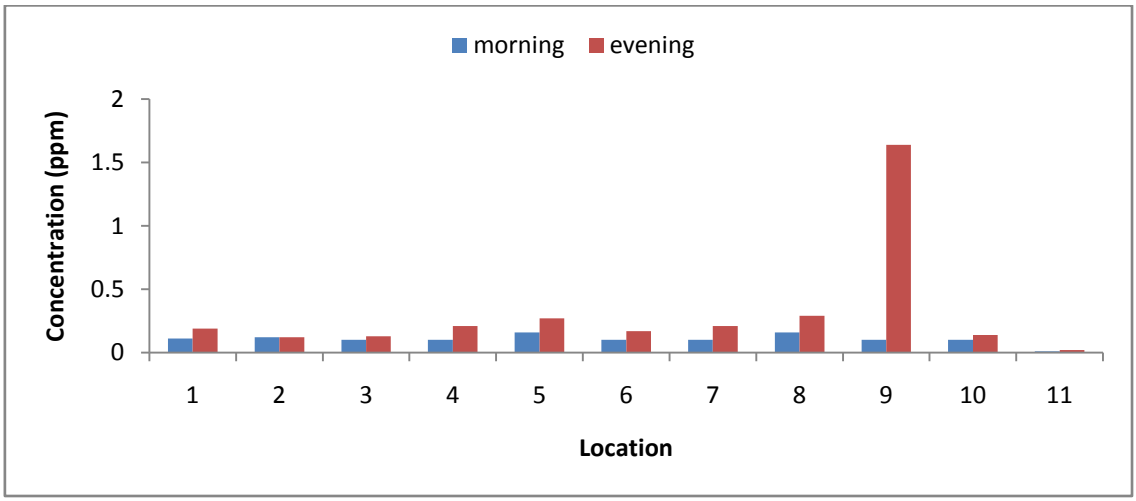


Figure 4.18: Variations in the levels of NO_2 among sampling sites in Kano metropolis during dry and hot season

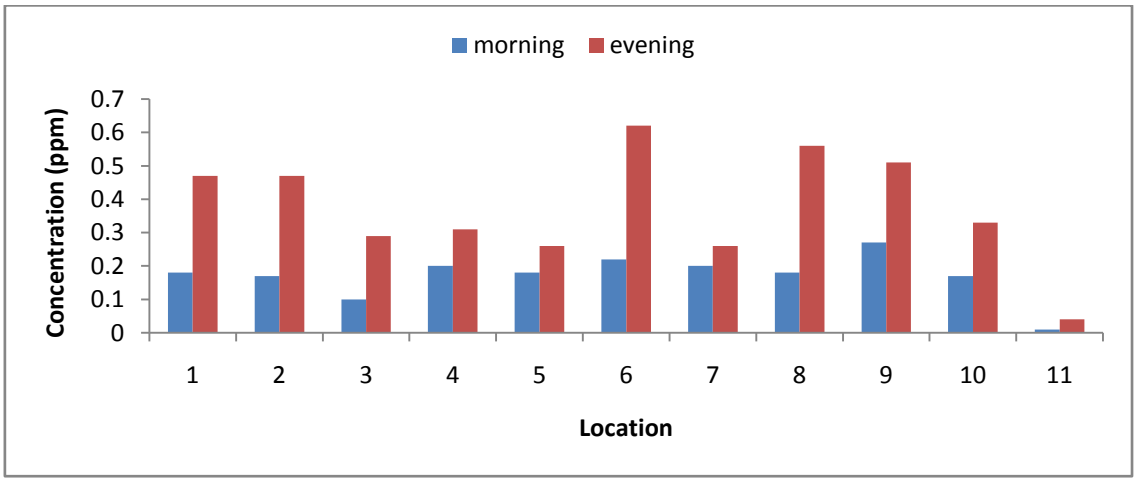


Figure4.19: Variations in the levels of NO_2 among sampling sites in Kano metropolis during wet and warm season.

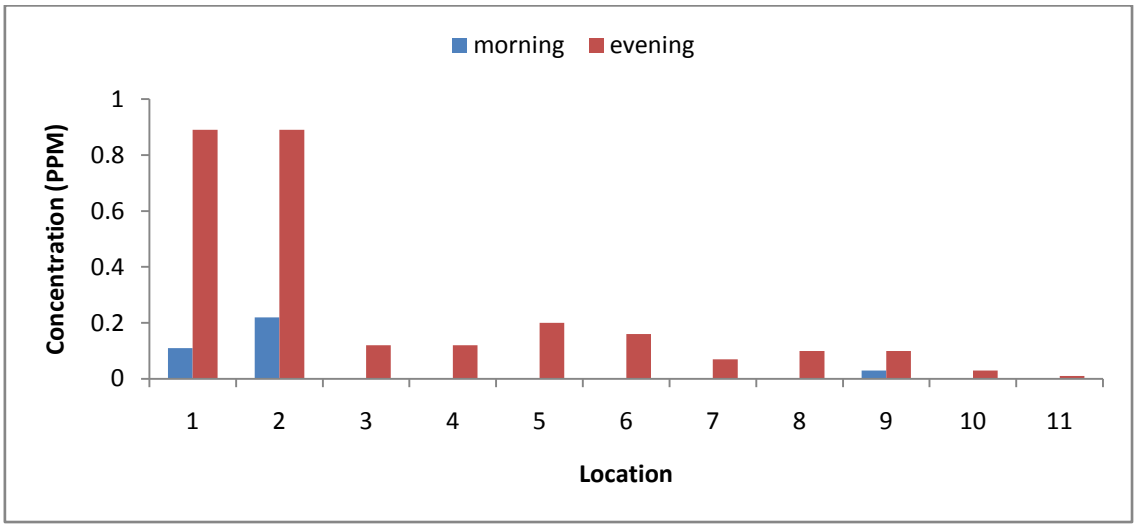


Figure 4.20: Variations in the levels of SO_2 among sampling sites in Kano metropolis during dry and warm season.

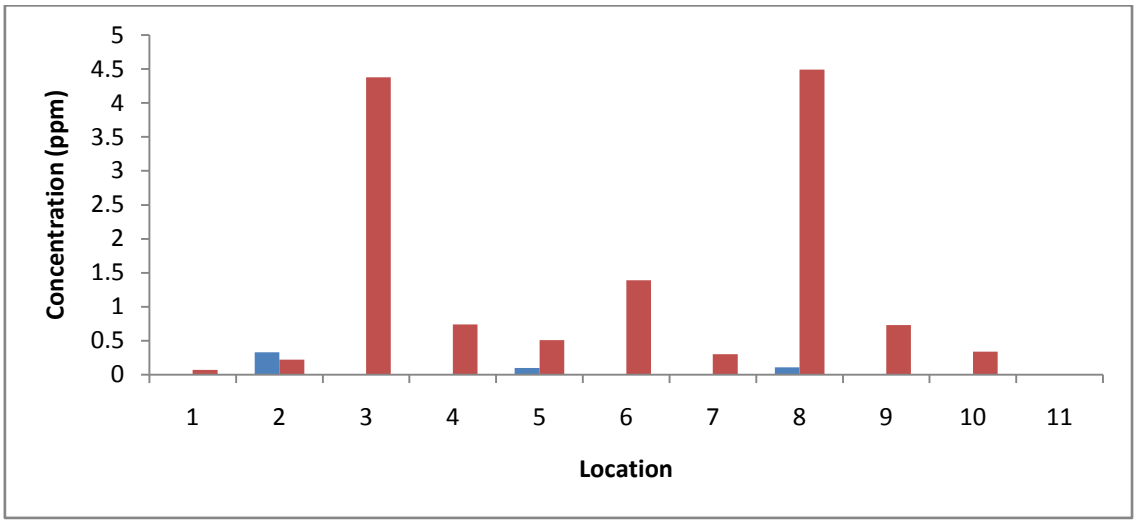


Figure 4.21: Variations in the levels of SO_2 among sampling sites in Kano metropolis during dry and cool season

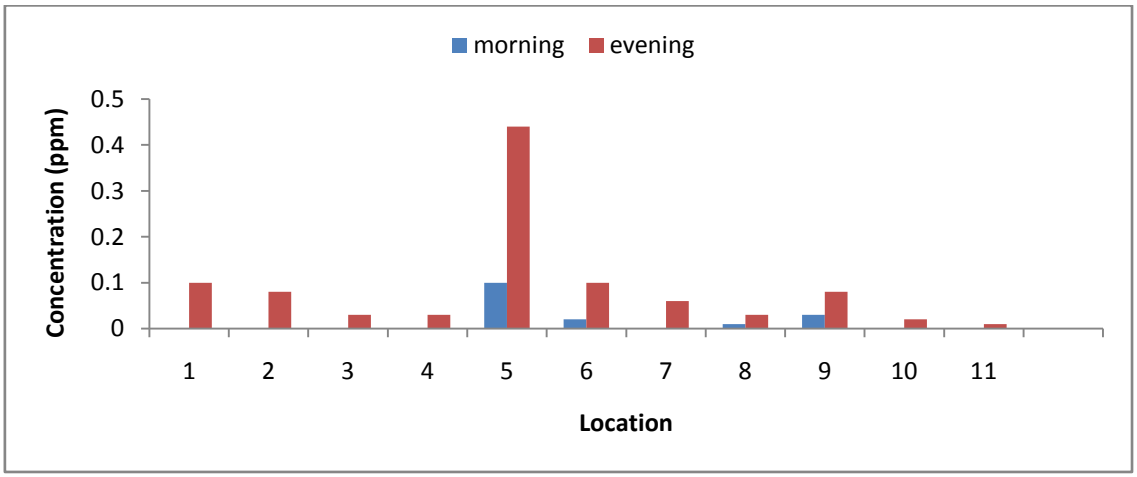


Figure 4.22: Variations in the levels of SO_2 among sampling sites in Kano metropolis during dry and hot season.

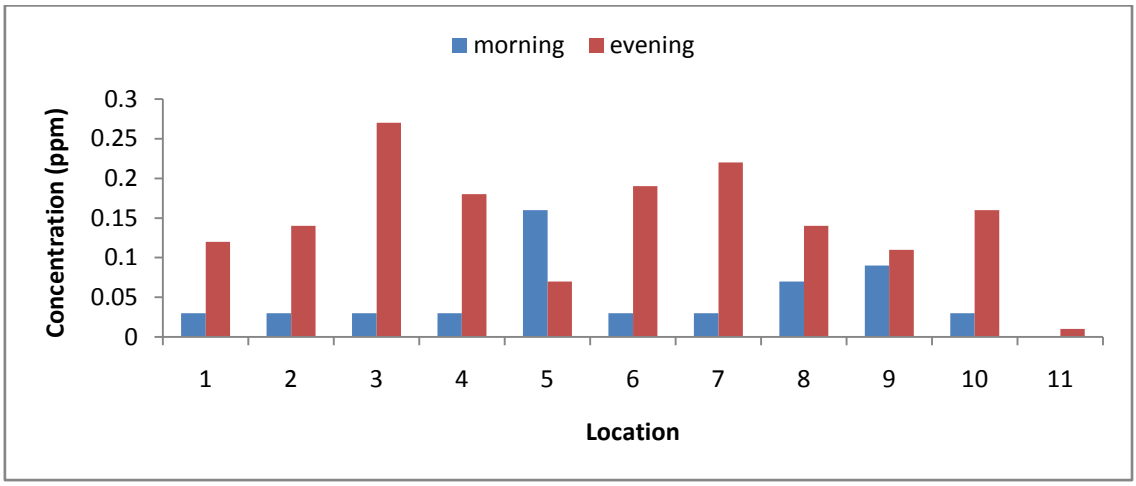


Figure 4.23: Variation in the levels of SO_2 among sampling sites in Kano metropolis during wet and warm season.

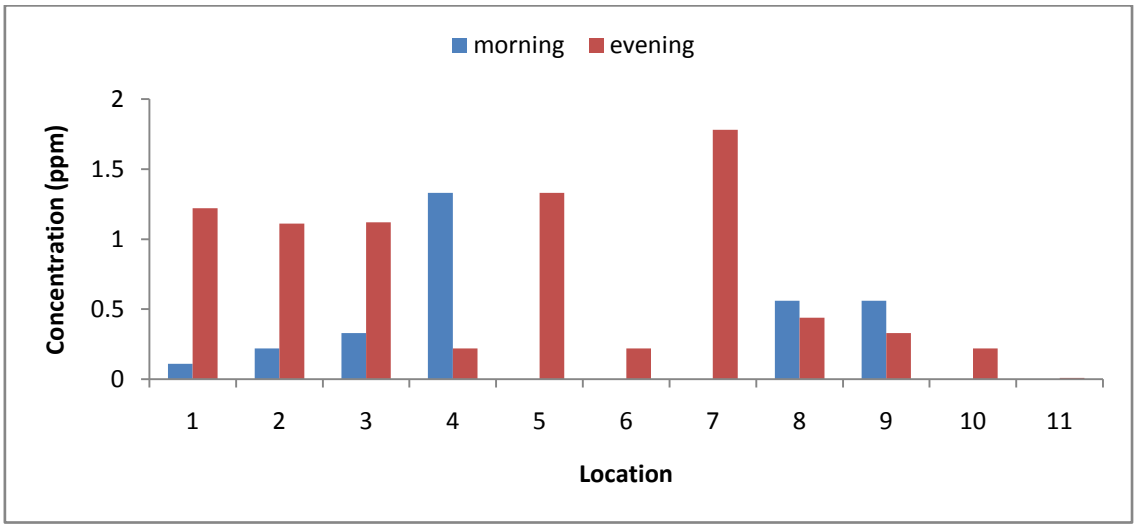


Figure 4.24: Variations in the levels of CH_4 among sampling sites in Kano metropolis during dry and warm season.

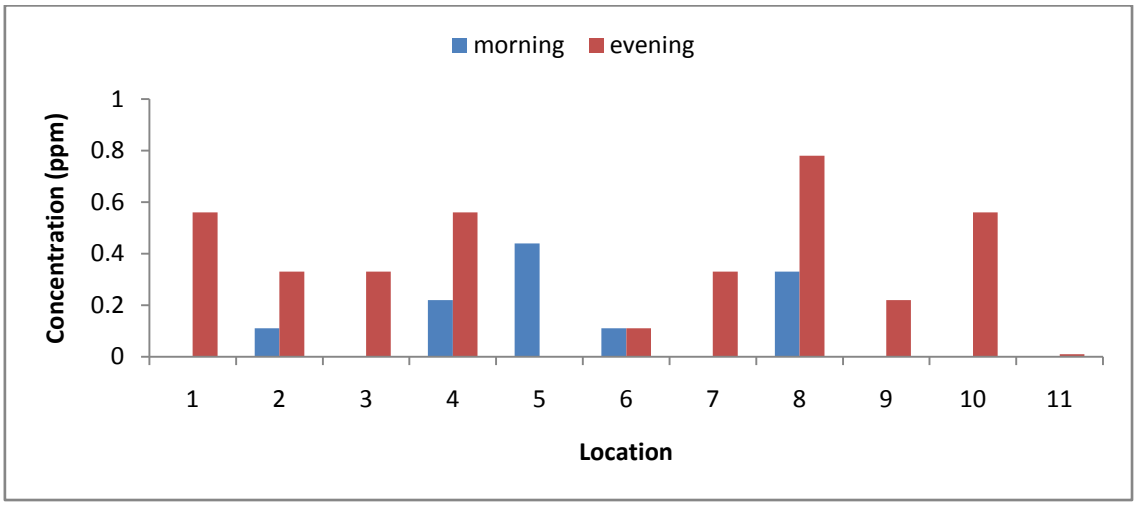


Figure 4.25: Variations in the levels of CH_4 among sampling sites in Kano metropolis during dry and cool season.

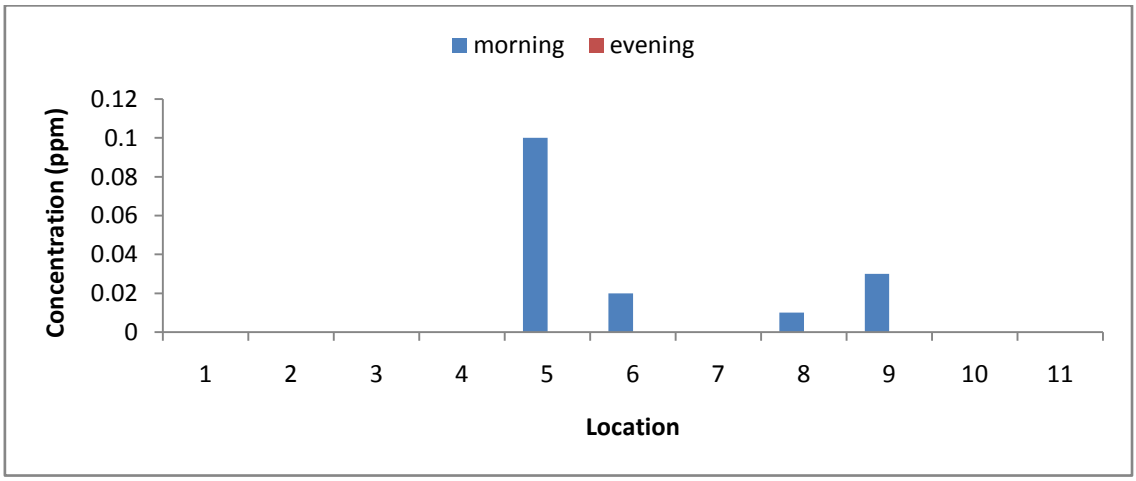


Figure 4.26: Variations in the levels of CH_4 among sampling sites in Kano metropolis during dry and hot season.

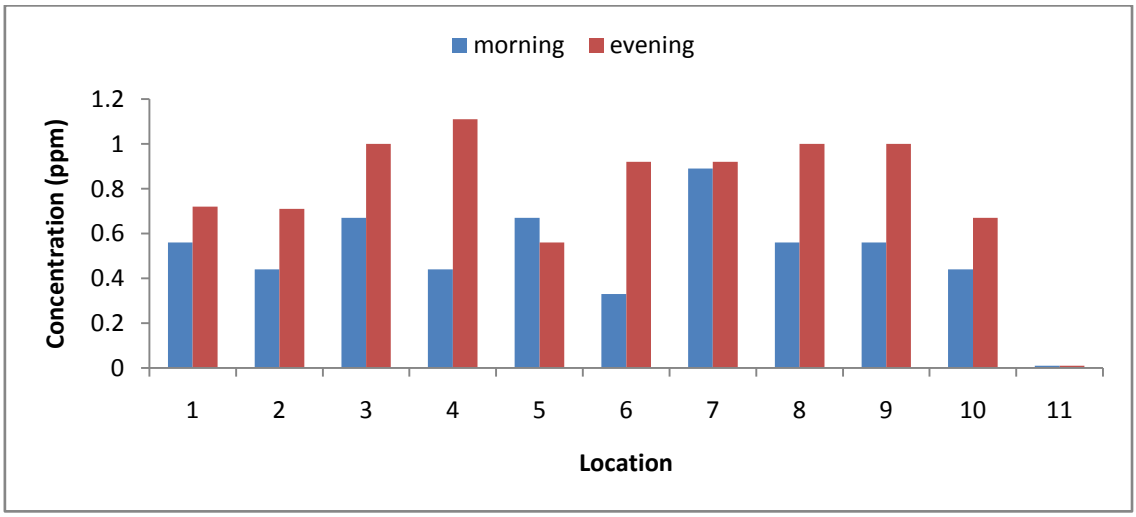


Figure 4.27: Variations in the levels of CH_4 among sampling sites in Kano metropolis during wet and warm season.

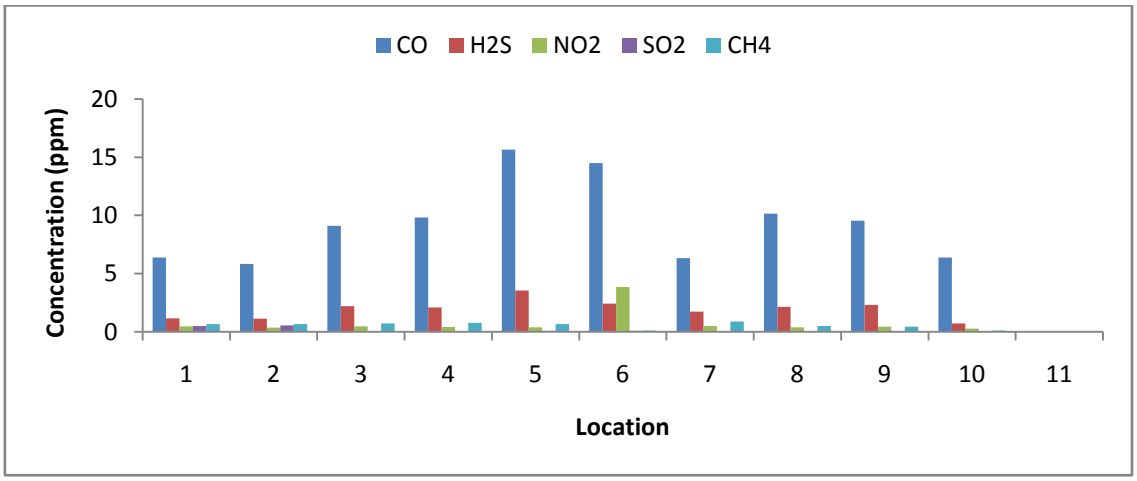


Figure 4.28: Variations in the levels of pollutant gases among sampling sites in Kano metropolis during dry and warm season

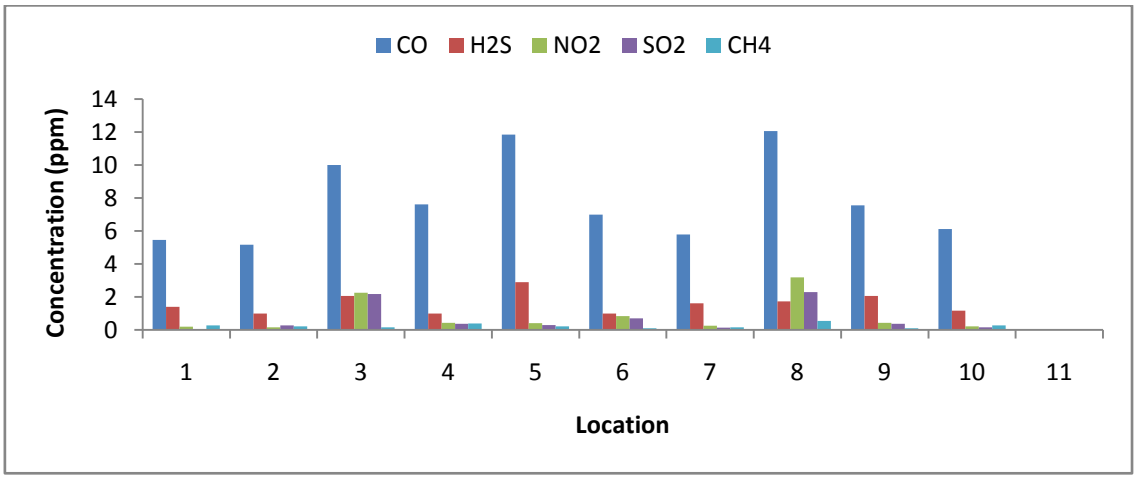


Figure 4.29: Variations in the levels of pollutant gases among sampling sites in Kano metropolis during dry and cool season.

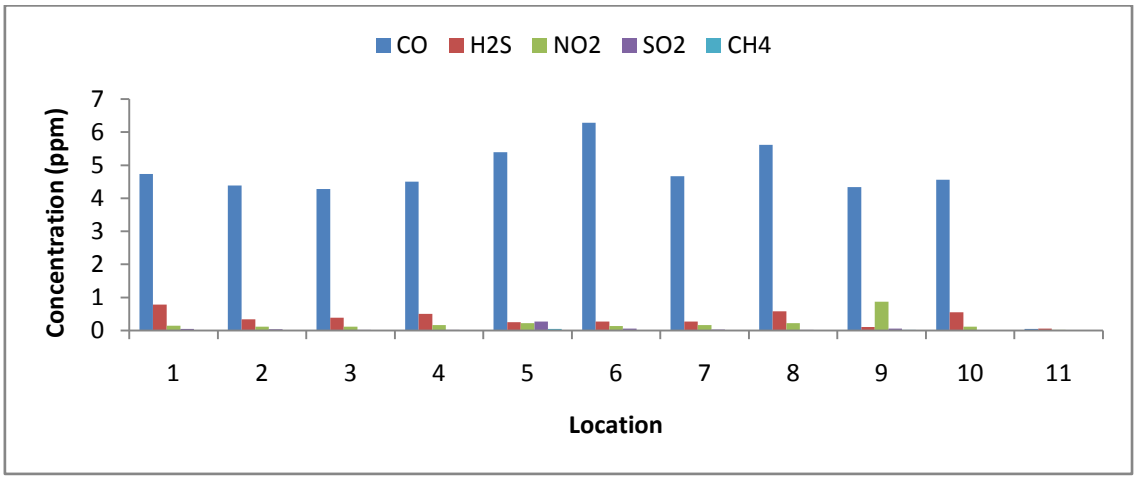


Figure 4.30: Variations in the levels of pollutant gases among sampling sites in Kano metropolis during dry and hot season

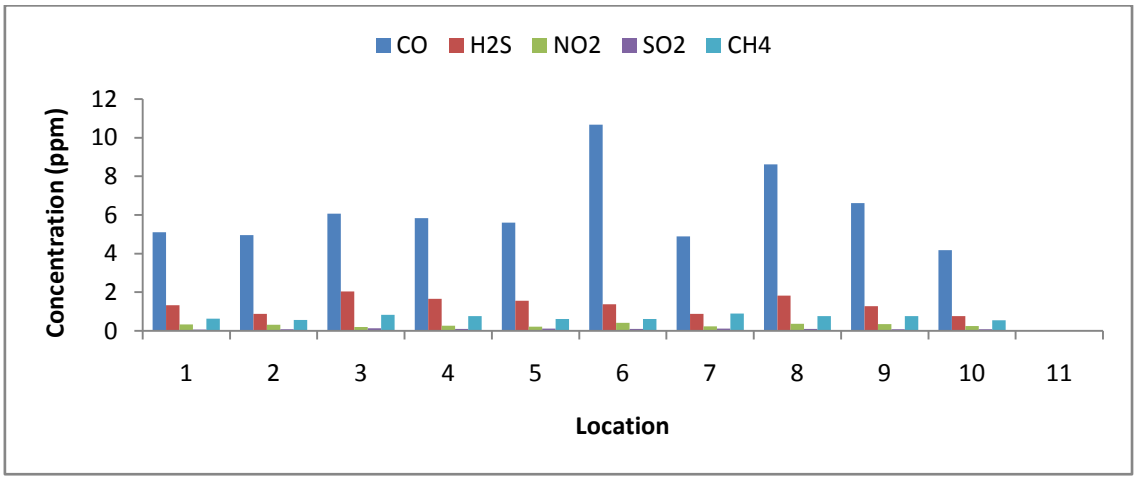


Figure 4.31: Variation in the levels of pollutant gases among sites in Kano metropolis during wet and warm season.

Table 4.1: t-test analysis result of pollutant gases across periods at all locations.

Gases	Degree of (df)	Hyphothesis (H_O)	t-test	t-critical	Level of significant	Pearson's correlation
CO	10	Null	-4.2815	2.2281	□ 0.05	0.6019
H_2S	10	Null	-4.5640	2.2281	□ 0.05	0.7562
NO_2	10	Null	-2.6938	2.2281	□ 0.05	0.5329
SO_2	10	Null	-5.0072	2.2281	□ 0.05	0.1844
CH_4	10	Null	-2.8619	2.2281	□ 0.05	0.5879

Table 4.2: One-way ANOVA of pollutant gases in all locations.

Location	Gases				
	CO (ppm)	H_2S (ppm)	NO_2(ppm)	SO_2 (ppm)	CH_4 (ppm)
1	5.42 ±1.92	1.17 ±0.47	0.29 ±0.21^{a}	0.07 ±0.04^{a}	0.49 ±0.21
2	5.21 ±2.02^{b}	0.94 ±0.51	0.24 ±0.15^{b}	0.08 ±0.01^{b}	0.38 ±0.27^{a}
3	7.37 ±2.64	1.29 ±1.56	0.33 ±0.22	0.07 ±0.09^{ac}	0.42 ±0.00
4	6.93 ±2.22	1.38 ±0.96	0.41 ±0.33	0.06 ±0.06^{d}	0.53 ±0.08
5	9.54±8.63	2.14 ±1.53	0.44 ±0.35	0.10 ±0.01	0.38 ±0.13^{a}
6	9.62 ±7.35	1.35 ±0.76	1.31 ±1.57	0.08 ±0.09^{b}	0.25 ±0.08
7	4.40 ±3.79	1.12 ±0.32	0.29 ±0.18^{a}	0.06 ±0.07	0.56 ±0.28
8	9.11 ±4.75	1.75 ±0.71	0.37 ±0.23^{b}	0.07±0.03^{ade}	0.48 ±0.12
9	7.01 ±3.79	1.56 ±0.23	0.52 ±0.47	0.07 ±0.04^{ace}	0.35±0.07^{b}
10	5.23 ±1.18^{b}	0.84 ±0.28	0.23 ±0.10	0.04 ±0.04	0.35 ±0.02^{b}
11	0.03 ±0.01	0.03 ±0.00	0.01 ±0.00	0.00 ±0.00	0.00 ±0.00

Where superscripts **a, b, c, d** and **e** indicate that no significant difference was seen in a gas pollutant found in different locations.

Table 4.3: Correlation analyses of Average pollutant gases emission across the sites, during the period of sampling with average traffic volume in those areas.

	CO	H_2S	NO_2	SO_2	CH_4	Motorcycle	Tricycle	Cars	Truck
CO	1								
H_2S	0.909**	1							
NO_2	0.675**	0.429*	1						
SO_2	0.847**	0.864**	0.507**	1					
CH_4	0.449**	0.585**	-0.01	0.571**	1				
Motorcycle	0.221	0.002	0.161	0.023	0.161	1			
Tricycle	0.176	-0.010	0.040	0.129	0.260	0.929**	1		
Cars	0.603**	0.677**	0.374*	0.689**	0.560**	0.051	0.011	1	
Truck	-0.238	-0.055	-0.268	0.069	0.546**	0.004	0.146	0.490**	1

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

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

Table 4.4: ANOVA: variations in the levels of pollutant gases emission across the sites, during the four seasons

4.4.1 Dry and Warm season

	Gases				
Site	CO	H_2S	NO_2	SO_2	CH_4
1	6.39 ±1.34[a]	1.17 ±0.23[a]	0.47 ±0.48[a]	0.50 ±0.55	0.67 ±0.79[a]
2	5.84 ±1.34	1.14 ±0.66[a]	0.35 ±0.31[b]	0.56 ±0.47	0.67 ±0.63[a]
3	9.11 ±2.52	2.22 ±1.10	0.46 ±0.20[a]	0.06 ±0.09[a]	0.73 ±0.56
4	9.84 ±4.01	2.12 ±1.56[b]	0.40 ±0.17	0.06 ±0.09[a]	0.78 ±0.79
5	15.67±17.13	3.56 ±3.94	0.89 ±1.12	0.10 ±0.14	0.67 ±0.94
6	14.50±12.02	2.45 ±2.20	3.84 ±5.16	0.08 ±0.11	0.11 ±0.16
7	6.34 ±2.20	1.74 ±0.57	0.51 ±0.55	0.04 ±0.05	0.89 ±1.26
8	10.17 ±5.27	2.17 ±0.86[b]	0.39 ±0.14[b]	0.05 ±0.07	0.50 ±0.09
9	9.56 ±4.24	2.33 ±1.41	0.45 ±0.11[a]	0.07 ±0.05	0.45 ±0.16
10	6.39 ±2.12[a]	0.74 ±0.09	0.28 ±0.28	0.02 ±0.02	0.11 ±0.16
11	0.02 ±0.01	0.002 ±0.01	0.00 ±0.00	0.01 ±0.01	0.01 ±0.01

Where the superscripts **a and b**, indicates that no significant difference was seen in a gas pollutant in different sites.

4.4.2 Dry and cool season

	Gases				
Site	CO	H_2S	NO_2	SO_2	CH_4
1	5.45 ±1.34[a]	1.39 ±0.55	0.21 ±0.92[a]	0.04 ±0.05	0.28 ±0.40[b]
2	5.17 ±1.34	1.00 ±0.95[a]	0.16 ±0.85	0.28 ±0.08	0.22 ±0.16[b]
3	10.00±2.52	2.06 ±1.65	2.27 ±2.98	2.19 ±3.10.	0.17 ±0.23[c]
4	7.61 ±4.01	1.00 ±0.95[a]	0.44 ±0.42[b]	0.37 ±0.52	0.39 ±0.24
5	11.84±17.13	2.89 ±1.57	0.41 ±0.15	0.31 ±0.29	0.22 ±0.31[b]
6	7.00 ±12.02	1.00 ±0.47[a]	0.84 ±0.79	0.70 ±0.98	0.11 ±0.00[d]
7	5.78 ±2.20	1.61 ±0.40	0.26 ±0.06[c]	0.15 ±0.21	0.17 ±0.23[c]
8	12.06±5.27	1.72 ±1.49	3.19 ±1.84	2.30 ±3.10	0.56 ±0.32
9	7.56 ±4.24	2.05 ±0.54	0.44 ±0.42[b]	0.37 ±0.52	0.11 ±0.16[d]
10	6.11 ±2.12[a]	1.17 ±0.71	0.23±0.16[ac]	0.17 ±0.24	0.28 ±0.40[a]
11	0.02 ±0.01	0.02 ±0.01	0.01 ±0.00	0.01 ±0.01	0.01 ±0.01

Where the superscripts **a, b, c and d** indicates that no significant difference was seen in a gas pollutant in different sites.

4.4.3 Dry and hot season

	Gases				
Site	CO	H_2S	NO_2	SO_2	CH_4
1	4.73 ±1.34[a]	0.78 ±0.00	0.15 ±0.06[a]	0.05 ±0.07	0.00 ±0.00[a]
2	4.39 ±2.75[b]	0.34 ±0.31[a]	0.12 ±0.00	0.04 ±0.06	0.00 ±0.00[a]
3	4.28±0.08[bc]	0.39 ±0.40[a]	0.12 ±0.02	0.02 ±0.02[a]	0.00 ±0.00[a]
4	4.50 ±0.40[d]	0.50 ±0.56[b]	0.16±0.08[ab]	0.02 ±0.02[a]	0.00 ±0.00[a]
5	5.39 ±3.22	0.25±0.12[c]	0.22 ±0.08	0.27 ±0.24	0.05 ±0.07
6	6.28 ±3.54	0.27 ±0.24[c]	0.14 ±0.05[a]	0.06 ±0.06	0.01 ±0.01[b]
7	4.67 ±2.04[a]	0.27 ±0.24[c]	0.16±0.08[ab]	0.03 ±0.04	0.00 ±0.00[a]
8	5.62 ±0.08	0.58 ±0.59	0.22 ±0.09	0.02 ±0.01	0.01 ±0.01[b]
9	4.34±2.04[bc]	0.11 ±0.01	0.87 ±1.09	0.06 ±0.04	0.02 ±0.02
10	4.56 ±0.00[d]	0.55 ±0.64[b]	0.12 ±0.03	0.01 ±0.01[b]	0.00 ±0.00[b]
11	0.05 ±0.01	0.06 ±0.07	0.02 ±0.01	0.01 ±0.01[b]	0.00 ±0.00[b]

Where the superscripts **a, b, c and** d, indicates that no significant difference was seen in a gas pollutant in different sites.

4.4.4 Wet and warm season

	Gases				
Site	CO	H_2S	NO_2	SO_2	CH_4
1	5.11 ±2.52	1.34 ±1.10[b]	0.33 ±0.21[a]	0.08 ±0.06	0.64 ±0.11[a]
2	4.95 ±2.28	0.89 ±0.31[b]	0.32 ±0.21[a]	0.09 ±0.08	0.58 ±0.19
3	6.07 ±1.20	2.05 ±0.87	0.20 ±0.13	0.15 ±0.17	0.84 ±0.23
4	5.84 ±1.34	1.67 ±1.26	0.26 ±0.07[b]	0.11 ±0.11[a]	0.78 ±0.47[b]
5	5.61 ±3.54	1.56 ±0.94	0.22 ±0.06	0.12 ±0.06	0.62 ±0.08
6	10.67 ±9.27	1.39 ±0.55[a]	0.42 ±0.28	0.11 ±0.11[a]	0.63 ±0.42[b]
7	4.89 ± 2.83	0.89 ±0.00[b]	0.23 ±0.04	0.13 ±0.13	0.91±0.02
8	8.62 ± 4.17	1.83 ±0.86	0.37 ±0.27	0.11 ±0.05[a]	0.78 ±0.31[b]
9	6.62 ±4.32	1.28 ±0.40	0.34 ±0.24[a]	0.10 ±0.01[b]	0.78 ±0.31[b]
10	4.17 ±0.39	0.78 ±0.00	0.25 ±0.11[b]	0.10 ±0.09[b]	0.56 ±0.06
11	0.04 ±0.01	0.01 ±0.00	0.03 ±0.02	0.01 ±0.01	0.01 ±0.00

Where the superscripts **a and b**, indicates that no significant difference was seen in a gas pollutant in different sites.

CHAPTER FIVE

5. 0 DISCUSSION

5. 1 General Discussion

The gaseous pollutant namely carbon monoxide (CO), hydrogen sulphide (H_2S), nitrogen (IV) oxide (NO_2), sulphur (IV) oxide (SO_2) and methane (CH_4) were dispersed throughout the atmosphere at all sampling point locations. The concentration of these pollutants especially CO, NO_2, SO_2 and methane are maximal in some sampling points with respect to time (7:30-9:30 am and 4:30-5:30 pm) of sampling and low in some. This was similar to report by Regini *et al.*. (2009), where concentrations of NO_2 and SO_2 were maximal in the afternoon and minimal in the morning times. This is suggesting that pollutants were predominantly from vehicular emission. The concentrations of these gases in Kano metropolis were below minimum permissible limit given by Federal Environmental Protection Agency (FEPA, 1991). Limits set by FEPA are CO- 10 ppm, SO_2- 0.01 ppm, NO_2- 0.04 - 0.06 ppm, H_2S- 0.006 ppm and CH_4- 0.06 ppm. However, information on their spatial distribution is of importance as their presence varied significantly ($p < 0.05$) across the sampling time and seasons with sampling locations.

The result obtained from this study when compared with United State Environmental Protection Agency (USEPA) standard for determining ambient air quality (Appendix D), it was noted that the Air Quality Index (AQI) rating in the range 0 - 15 is categories as ‘A (very good), while AQI in the range 16 - 31 is B’ (good), AQI

in the range 32 - 49 is ‘C’ (moderate), AQI rating in the range 50 - 99 is D’ (poor) and AQI rating in the range 100 or >100 is ‘E’ (very poor.).

The results for the variation in the levels of pollutants (CO, H_2S, NO_2, SO_2, and CH_4) across the sites, during the period of sampling, average pollutant gases emission and volume and composition of vehicular movement for one of the years are shown in the Figures 4.1 to 4.7. The results showed that CO, H_2S, NO_2, SO_2 and CH_4 were generally detected at all sampling locations except sulphur (IV) oxide (SO_2) and methane (CH_4) which were not found at site eleven used as control site.

5. 2 Morning (7:30-9:30 am) and Evening (4:30 – 5:30 pm) Sampling periods

Result obtained during morning (7:30 – 9:30 am) sampling period was indicated in Figure 4.1-4.5. It showed that the concentration of carbon (II) oxide and nitrogen (IV) oxide ranged from 0.02 – 5.75 ppm and 0.01 – 0.20 ppm respectively with the highest concentration at Kofar Mazugal/Abatoir (site 8). The concentration of hydrogen sulphide ranged from 0.03 – 1.39 with highest values at Airport/Zungeru roads (site 9) while sulphur (IV) oxide levels ranged from 0.00 -- 0.09 ppm with highest concentration observed at Kofar Nasarawa (site 5). Methane ranged from 0.00 – 0.58 ppm in concentration with highest at Igbo road-Sabon-gari market (site 4).

The result of the evening (4:30 – 5:30 pm) sampling hour is shown in Table 1b. It indicates that the concentrations of carbon (II) oxide, nitrogen (IV) oxide and sulphur (IV) oxide ranged from 0.03 – 13.81, 0.01 – 0.14 and 0.00 – 0.17 ppm respectively with the highest concentration observed at Rimi-market/Murtala hospital junction (site 6). However, hydrogen sulphide ranged from 0.03 – 3.22 ppm with highest concentrations

at Kofar Nasarawa (site 5) and methane (CH_4) ranged from 0.00 – 0.88 ppm with highest at Aminu Kano Teaching hospital/Kwandila Housing Estate (site 1).

5. 2.1 Carbon (II) oxide (CO)

Figure 4.1 shows the variation in the levels of CO across the sites, during the period of sampling recorded. Highest concentration of the gas were observed across sampling locations except at site 11 which is a control, having the highest concentration in the evening site 5 (15.68 ppm) and site 6 (14.81 ppm). This could be attributed to other sources of pollution at these sampling locations apart from vehicular emission. This could be burning of wood for cooking, burning of dump refuse and expired vehicle tires at Rimi Market/Murtala Hospital and Kofar Nasarawa sampling locations. The atmospheric CO along the corridors of these sampling locations when compared with the values reported in literature was found to be higher than average range of 1.6 to 3.8 ppm atmospheric concentration of urban air pollution in Athens, as reported by Kalabokas *et al.,* (1999). It is also higher than the range of 0.7 to 1.9 ppm in Jahara, Kuwait observed by Ettouney *et al.,* (2010). However, the values in this study were lower than a range of 233 to 317 ppm reported in three cities of Nigeria: Lagos, Ibadan and Ado-Ekiti (Koku and Osuntogun, 1999). It is also lower than the range of 60 to 110 ppm in Jos metropolis as reported by Ola *et al.,* (2013) and also lower than the range of 16.5 to 25 ppm in Zaria, Nigeria reported by Aliyu *et al.,* (2014). Comparing the mean concentration values of CO across periods at the eleven sampling locations, the highest value was recorded at Kofar Nasarawa (site 5) in the evening period due to traffic congestion, commercial congestion and refuse burning. The site is located in between a local food market congested with people who cause traffic congestion and slow

movement of vehicle. It is also few meters away from refuse dump and serve as temporary bus stop for most intra-city buses, taxies and motorcycles thereby experiencing flux of traffic, especially during evening hours. This indicated that Kofar Nasarawa dwellers and trade hawkers were generally exposed to the higher levels of carbon monoxide which is above the World Health Organization (WHO) permitted value of less than 9 ppm over 8 hour period. CO reduces the oxygen carrying capacity of blood, which as a result impairs with oxygen release into tissue and adversely affects sensitive organs such as the brain and heart (Bascom *et al.*, 1996). The atmosphere also is exposed to scavenging process of hydroxyl radical, thereby increasing the greenhouse gas methane concentration which consequently caused global warming. Carbon monoxide results from incomplete combustion of diesel or gasoline in traffic engines, non-transportation fuel combustion like private generator plants for electric supply as a substitute for the inconsistent Power Holding Company of Nigeria (PHCN) supply for commercial activities and some indoor source such as a leaking gas stove (Han and Nacher, 2006).

5.2.2 Hydrogen sulphide (H_2S)

The levels of H_2S recorded was higher at Air port/Zungeru roads site and lower at court/France site sampling location with values of 1.39 and 0.19 ppm in the morning (7:30 to 9:30 am) respectively Figure 4.2. Whereas, in the evening Kofar Nasarawa (site 5), has the highest concentration of value 3.22 ppm and Sani Abaca/Murtala Mohammed roads junction (site 10) has low of value 2.25 ppm during evening (4:30 to 5:30 pm) sampling hour. When the levels of H_2S were compared with the values in the literature, the concentration of H_2S was found

lower than the value recorded at some quarters in Kano metropolis; Brigade, Dorayi and Kofar Mata with value 2.93, 2.71 and 1.72 ppm respectively at morning sampling time and higher at evening sampling time as reported by Ayodele and Abubakar (2008) and little lower than the range of 1.0 to 3.6 ppm reported for Jos metropolis, Nigeria by Ola *et al.,* (2013). Hydrogen sulphide in this study is found to be higher than the range of 0.167 to 0.267 ppm reported for Abeokuta metropolis, Nigeria by Oguntoke and Yusuf (2008). Comparative study of the mean concentration of hydrogen sulphide across periods at eleven sampling locations showed that the highest level of H_2S was recorded at Kofar Nasarawa (site 5) during evening hours. This could be due to the fact hydrogen sulphide is pungent smelling gas emitted during the decay of organic matter. This could also be the source of bad odor at this location as observed during sample collection. The decay of food stuff, waste and refuse dump in this location could be responsible for high hydrogen sulphide emission in this location. The higher hydrogen sulphide concentration at Airport/Zungeru roads junction (site 9) sampling site was attributed to the near ghetto nature of these areas, decay of waste matter in dirty gutters, heaps of refuse, sewers, plants and animal waste by microbial activities (Ayodele and Bernarde, 2006).

Hydrogen sulphide is a hazardous gas and exposure to it can cause sudden death in work place (NIOSH, 1995). The mortality in its acute intoxication has been reported to be 6% (WHO, 1981). Acute and chronic lung function responses to H2S exposure has been investigated in a variety of studies (Abbey *et al.,* 1991, 1993; Lippman, 1989).

5.2.3 Nitrogen (IV) oxide (NO_2)

The concentration of nitrogen (IV) oxide across sampling sites is as indicated in Figure 4.3. NO_2 level is high at all locations, and similar at all locations with value approximated to 0.2 ppm except Aminu Kano Teaching Hospital/Kwandila Housing Estate junction (site 1) during morning period of sampling and Rimi market/ Murtala hospital junction (site 6) with values of 2.42 ppm recorded during evening. This is an indication that at these locations there were increases in emission due to high volume of motorcycle and car movement. When the levels of NO_2 were compared with available values reported in the literature, periodic mean of NO_2 was found lower than 35 to 108 ppm reported in Athens by Kalabokas *et al.,* (1999), higher than 0.20 to 0.52 ppm reported for Calabar metropolis, Nigeria by Okafor *et al.,* (2009) and 0.14 to 1.09 ppm as reported for Kano metropolis, Nigeria (Okunola, *et al.,* 2012). It is quite higher than the standard value limit set by FEPA, 1991 for NO_2 which is 0.06 ppm. This is mostly due to high traffic density and stationary fuel combustion process emissions from running of generators (Etiuma *et al.,* 2006) which are very common within the Kano metropolis due to erratic power supply. Nitrogen (IV) oxide is a recognized greenhouse gas pollutant because of its role in forming brown haze and photochemical reaction with ozone and organic compounds to form photochemical smogs such as peroxy acetyl nitrate (PAN).

5.2.4 Sulphur (IV) oxide (SO_2)

Variation in the levels of SO_2 across the sites, during the period was high as shown in Figure 4.4 with highest level above the standard of 0.06 ppm FEPA limit recorded at Kofar Nasarawa (0.09 ppm) in the morning, Court/France Roads (0.13

ppm) and Rimi Market/Murtala Hospital (0.14 ppm) junctions in the evening time. This could be attributed to the combustion of sulphur containing fuels vehicles and generators plant along the roads and burning wood and refuse waste as energy source. Wood fuels are the problem whose gravity is increasing in large towns in the developed and developing countries are variously documented (Ayodele and Abubakar, 2009). Comparism of the mean concentration of Sulphur (IV) oxide across periods along sampling locations indicated that the highest level was observed in the evening period of sample collection at Rimi market/Murtala Hospital (site 6). The literature the concentration of SO_2 was found to be lower than range of 3.21 to 5.18 ppm, 7.4 to 15.5 ppm and 16 to 64 ppm reported by Ayodele and Abubakar (2008), Ettouney *et al.*, (2010) and Kalabokas *et al.*, (1999) respectively. In term of ambient air quality standard at all locations the emission concentrations were within average value for 24 hours limit of 0.14 ppm given by United State Environmental Protection Agency (USEPA, 2009). Sulphur (IV) oxide is an indirect greenhouse gas pollutant that causes global cooling of the earth's surface. It is a recognized greenhouse gas pollutant because of it role in forming cold time smog (Hermann, 1991). It is an acidic, irritant gas which in high concentrations can cause constriction of the airways such as nose, throat and lung (Wolf *et al.*, 1975; Ayodele and Abubakar, 2008). People with asthma residing or carrying business at this location are more susceptible to the adverse effects of the gas as high concentration may result in the failure of lung function and may lead to tight chest, coughing, wheezing and phlegm at high level.

5.2.5 Methane (CH_4)

From the results obtained for Methane in Figure 4.5, it can be seen that the concentrations were high at all sampling sites. The highest levels were in the Igbo/Sabon gari market with value 0.58 ppm and DanAgundi/BUK road junction with 0.76 ppm in the morning and evening periods respectively. This could be attributed to the high vehicular volume traffic jam and increased burning of wood and grasses for domestic cooking by the residents. Among the sampling locations analyzed DanAgundi/BUK was highest in the evening with concentration of 0.76 ppm. This could be due to the passage of heavy duty vehicles whose engine is diesel powered, sulphur contain fuel combustion from stationary sources generator plants and vehicle engines. This could also be from anaerobic decay of plants and burning of dump refuse and vehicle tyires as the location is near to the dumping pitch for the residence.

The mean methane levels across sites were illustrated in Figure 4.5. It showed that high concentration was recorded in all locations during both periods except at site 11 which served as control. The highest and lowest morning concentrations were observed at locations 4 and 2 and 6 with values of 0.58 and 0.19 ppm respectively. In the evening sampling hours the concentration was higher at location 7 and lower at location 6 with values of 0.76 and 0.31 respectively. Comparison of the periodic concentration showed highest methane level at Dan Agundi/BUK road (site 7) and lowest at Rimi market/Murtala hospital in the evening period. This is attributed to the passage of heavy trucks as the road has linked to industrial areas like Challawa and Sharada industrial estates. The heavy vehicle use to transport raw materials and convey worker consumed ethanol in addition that burned to emit methane as exhaust gas.

Moreover when the level of methane was compared with available values reported in the literature, the time mean concentrations of methane were found to be lower than the value 0.60 ppm during morning period and higher than the range 0.53 to 0.58 ppm in the evening reported by Okonkwo *et al.,* (2012) for Port-Hacourt city of River State, Nigeria.

The average variations in the levels of pollutant gases emission in the sites, during the period of sampling was shown in Figure 4.6. It showed carbon (II) oxide concentration was higher at all sites with the following order 6 > 5 > 8 > 3 > 9 > 4 > 1> 10 > 2 > 7 > 11, H_2S has the following order 5 > 8 > 9 > 4 > 6 > 3 > 1 > 7 > 2 > 10 > 11, NO_2 has 6 > 9 > 5 > 4 > 8 > 3 > 1 > 7 > 2 > 10 > 11, SO2 has 5 > 2, 6 > 1, 3, 8, 9 > 4 > 7 > 10 > 11 and CH4 has 7 > 4 > 1 > 8 > 3 > 2 and 5 > 8 and 9 > 6 > 11. Generally, Figure 4.1 to 4.6 showed that the highest levels of the monitored greenhouse gas pollutants (CO, H_2S, NO_2, SO_2, and CH_4) were observed during evening (4:30 to 5:30) sampling hours at all sampling sites except for methane at Igbo/Sabongari Market junction (site 4) and Zugeru/Airport Roads (site 9) sampling points. This could be attributed to other sources of pollution along locations at this sampling period apart from high traffic. This could be from stationary source such as burning of dump refuse, fire woods for cooking, gasoline to generate electricity and vehicle.

The results obtained for volume and composition of vehicular movements within the various sampling sites were indicated in Figure 4.7. It showed that the volume of car is more than that of motorcycles, trucks and tricycles at all locations except at Sani Abaca/Murtala Mohammed (location 10). The high volume of motocycle observed at location 10 is not surprise as the location is a major junction which links

Sabongari and singer markets. It is also the centre of commercial activity of the state with many branches of banks, filing stations and food hawker along the roads and therefore has the highest motorcycles roaming. The location is also closer to railway.

5. 3 Statistical Analysis

Paired two samples for the comparism in the levels of pollutant gases across the sites, during the morning and evening sampling period using t-test is indicated in Table 4.1. The p-value of pollutant gases (CO, H_2S, NO_2, SO_2 and CH_4) for the eleven locations was found to be significant at $p < 0.05$. P-value less than 0.05 signified 95% difference in the levels of pollutants gases across the sites, during the period of sampling. The degree of association of pollutant gases was also revealed by Pearson's correlation which indicated that the pollutants CO, H_2S, NO_2 and CH_4 were strongly correlated at 0.05 significant level with positive values 0.6019, 0.7562, 0.5329 and 0.5879 respectively while SO_2 was weakly correlated as the value 0.1844 is less than one. The positive significant correlation values of pollutant gases indicated that the emission sources were somewhat similar that is vehicular exhaust generated by traffic density, traffic congestion and jam which often frequent in the evening has affect the concentrations of pollutants (Okunola *et al.,* 2012).

Table 4.2 was the statistical analyses of the mean pollutant gases along locations using one-way ANOVA for comparing the mean-values of pollutant gases obtained during the period per locations. The p-value for pollutant gases emission across the period of sampling per sites is significant at $p < 0.05$. From Table 4.2, it is observed that the concentration of carbon (II) oxide found at all locations is

significantly different at p □ 0.05 (except at locations 2 and 10), for H_2S is significant at

all locations, and NO_2 is also significant (except at 1. 2, 7 and 8), SO_2 are not significant at $p < 0.05$, CH_4 are significant (except at 2, 5, 9 and 10). However, similarity exists between the level of pollutant gas CO at locations 2 and 10 and that of NO_2 at locations 2 and 8, and that of SO_2 at locations 2 and 6, and CH_4 at locations 9 and 10. Also between NO_2 and SO_2 levels similarity exists at locations 1 and 2, and H_2S has no similarity at all locations with other five detected pollutant gases. For NO_2, similarity exists at locations 1, 7 and 8 with SO_2 at locations 1, 2. 3, 6, 8 and 9, at locations 1, 2, 7 and 8 with CH_4 at locations 2, 5, 9 and 10 and at locations 1, 2, 7 and 8. For SO_2 similarity exists at locations 1, 2, 3, 6, 8 and 9 and CH_4 at locations 2, 5, 9 and 10, at locations 1, 2, 3, 6, 8 and 9. When variations in the levels of gases across the locations were compared it indicated the following order: CO > H_2S > NO_2 > CH_4 > SO_2, 5 > 6 > 8 > 9 > 3 > 4 > 1 > 2 > 10 > 7 > 11. It could be seen that CO is the highest pollutant gas emitted at Kofar Nasarawa (site 5) sampling point per period. P-value at less than (< 0.05) signifies 95% difference in the levels across the sites, during the period of sampling.

The degree of association between pollutant gases and vehicles volume was investigated with Pearson's correlation across the sites, during the period of sampling (Table 4.3). From the correlation, It can be observed that there is a significant correlation at $p < 0.01$ between CO, and H_2S, NO_2, SO_2, CH_4, and cars, between H_2S and SO_2, CH_4 and cars, between NO_2 and SO_2, between SO_2 and CH_4 and volume of cars, between CH_4 and cars, between motorcycle and tricycle, and between cars and

trucks. There is significant correlation at $p < 0.05$ level between H_2S and NO_2, between NO_2 and cars, between SO_2 and cars. The significant correlation between pollutant gases and motor cars suggests their main source as being motor cars emission.

Moreover, correlation between pollutants gases NO_2 with CH_4 was observed to be very poor. This indicated that the source of emission of these gases is not similar. NO_2 pollutant emission source is combustion of engine under high temperature while methane source of emission is combustion/decomposition of organic matter. When CO and CH_4 correlated, it was observed to be weak. This is due to various sources CO is mainly from motor vehicle while methane from burning or decomposition of organic matters. This could be attributed to the fact the engine combustion of fuel is not perfect, thus, the vehicle used along the roads are long mileage and the catalytic conversion process of the engine is not working efficiently. The strong correlation between methane with trucks suggested source is trucks. This could be attributed to heavy trucks uses ethanol as fuel which burnt and produced energy methane gas.

From Table 4.3, it was also discovered that the correlation between the detected pollutant gases with motorcyclist and tricycles is not perfect and less than 30%. This suggests that the main source of the pollutant gases under study is not motorcycles and tricycle emission. This is not mysterious with the implementation of the law by the present administration that ban the use of motorcyclists for commercial in Kano metropolis which is among the major air pollutants emitter in Kano going by their numerical size and manner of operations. In order to minimize the effect of refuse waste disposal on greenhouse gas pollutants emission, the present government of Kano

state has embarked on evacuation of refuse in Kano metropolis by setting central collecting point at indifferent parts of the state to avoid indiscriminate refuse disposal.

5. 4 The levels of pollutant gases across the sites, during the four seasons

5.4. 1 Carbon (II) oxide (CO)

Figure 4.8-4.11 shows the variation in the levels of CO across the sites during the four seasons of sampling recorded. Highest concentration of the gas were observed across the sampling locations except at site 11 which is a control, the highest concentration was generally obtained in the evening at site 5 (27.78 ppm) and 6 (23.00 ppm) during dry and warm, site 5 (19.67 ppm) and 8 (18.78 ppm) during dry and cool, site 6 (8.78 ppm) and 5 (7.67 ppm) during dry and hot and site 6 (17.22 ppm) and 8 (11.56 ppm) during wet and warm.

Figure 4.10 however, show high level of CO at site 4 (4.78) in the morning than in the evening and equal levels at site 10 (4.56 ppm) in both periods during dry and hot season. This could be due to the reduce mixing of pollutant CO in the atmosphere because of the stronger and more frequent temperature inversions. As result pollutants can be trapped in a shallow layer at ground level and concentrated. Other factors such as motor vehicles, morning starts during dry and cool season lead to longer periods of incomplete combustion and longer warm-up time for catalytic converters which generate more CO and domestic heating using wood is more common in dry and cool season. Generally, concentrations of pollutants were highest in the evening periods.

This could be attributed to the high burning of refuse waste and wood as cooking fuel, incomplete combustion in automobile engines, high traffic density and congestion as people are rushing to reach their homes and most of the commercial activity such as selling of 'acra' and some indoor sources such as a leaking gas stove occur in the evening hours at this junction. The atmospheric concentration of CO along corridors of

selected roads when compared with values reported in literature was found to be higher than 1.6 to 3.8 ppm an average range of atmospheric concentration of urban Athens, Greece by Kalabokas, *et al.,* (1999), the values reported of 0.7 to 1.9 ppm in Jahara, Kuwait (Ettouney *et al.,* 2010) and also, the values reported of 5.42 to 7.04, 5.08 to 5.60, 4.92 to 7.21, 4.25 to 8.28, 6.50 to 14.33, 4.25 to 7.39, 5.42 to 8.17 5.75 to 8.71, 6.33 to 8.93 , 5,50 to 8.53 and 0.00 to 0.01 ppm in ten sampling sites along high traffic roads in Kano, Nigeria (Okunola *et al.,* 2023). However, the values of in this study were lower than range 233 to 317 ppm reported in three cities of Nigeria: Lagos, Ibadan and Ado-Ekiti by Koku and Osuntogun (1999).

In term of Air Quality Index (AQI), the CO variation across seasons revealed that in dry and warm season air quality index is poor at Court- France roads junction, moderate at Kofar Mazugal during dry and cool, dry and hot and wet and warm seasons in the morning sampling period. Whereas, in the evening hours the air quality index is very poor at Kofar Nasarawa and Rimi-market/Murtala Hospital sampling locations in dry and warm and wet and warm seasons and poor at the same junctions in dry and cool and dry and hot seasons. Generally, the atmospheric condition of the air during morning – evening sample collection indicates poor – very poor air quality index. This showed that high volume of motor vehicles and motorcycles movement along these

junctions were responsible for carbon monoxide emission which has an indirect effect on global warming through oxidation to carbon dioxide and increasing the quantity of methane gas by scavenging the hydroxyl radicals (OH^-) in the earth's atmosphere (Ayodele and Emmanuel, 2007). In addition, CO reduces the oxygen carrying capacity of blood residents along these junctions, which consequently impairs oxygen release into tissue and adversely affects sensitive organs such as heart and brain (Bascon *et al.,*

1999 in Okunola *et al.,* 2012). Carbon monoxide pollutant result from incomplete combustion of diesel or gasoline fuel in automobile traffic engines, non- transportation combustion, bush burning and leakage from indoor gas stove (Han and Naecher, 2006).

5.4.2 Hydrogen sulphide (H_2S)

Similar result is obtained for H_2S across the sites, during the four seasons of sampling recorded as indicated in Figure 4.12-4.15. The levels of H_2S were generally higher in the evening than in the morning period across the sites with the highest at site 5 (6.33 and 4.00 ppm) during dry and warm and dry and cool seasons respectively, site 8 (1.00 ppm) during dry and hot and site 3 (2.67 ppm) and 4 (2.56 ppm) during wet and warm season. Figure 4.14, however, show equal levels of H_2S at site 1 (0.78 ppm) and site 7 (0.89 ppm) and 10 (0.78 ppm) in the evening and morning during dry and hot and wet and warm seasons respectively, Figure 4.15 show higher level of H_2S at site 2 (1.11 ppm) and 9 (1.56 ppm) in the morning than in the evening during wet and warm season. This could be attributed to seasonal and sources variation. The highest level of hydrogen sulphide was observed at Kofar Nasarawa in dry and warm and dry and cool seasons during the two sampling periods. Hydrogen sulphide is greenhouse gas emitted as a result of the decay of organic matter; this produced bad odour to this location as

noticed during sampling. Moreover, decay of food stuff, waste and refuse generated within the location and left uncollected for a long time on the street could be responsible for high hydrogen sulphide emission. When compared with the literature available the hydrogen sulphide level in this study is higher than the range 0.265 to 0.167 ppm reported for Abeokuta metropolis, Nigeria (Oguntoke and Yusuf, 2008) and

also higher than the range 3.60 to 1.00 ppm reported for Jos metropolis, Nigeria by Ola *et al.*, (2013).

In terms of AQI, Hydrogen sulphide variation across season revealed that the air quality is very good at all sampling locations across seasons during morning hour of sampling. In evening sampling it is poor to moderate at Kofar Nasarawa sampling location in dry and warm and in dry and cool seasons respectively, very good at Kofar Mazugal/Abatoir and Sani Abaca/Murtala Mohammed Roads junctions in dry and hot season and good at Court – France roads junction in wet and warm season. Generally conditions of the air during morning – evening sampling hours indicate very well to poor air quality. This shows that residents along Kofar Nasarawa are exposed to bad smell and warmer atmosphere in the evening during dry and warm season due to H_2S high level.

5.4.3 Nitrogen (IV) oxide (NO_2)

Result obtained for NO_2 across the sites, during the four seasons of sampling recorded is indicated in Figure 4.16-4.19. The levels of NO_2 were generally higher in the evening than in the morning period across the sites. The highest concentration was

generally obtained in the evening at site 6 (7.49 ppm) during dry and warm, site 3 (4.88 ppm) and 8 (4.49 ppm) during dry and cool, site 9 (1.64 ppm) during dry and hot and site 6 (0.62 ppm) during wet and warm seasons. This could be due to higher emission from automobiles exhaust.

Figure 4.14 however, show equal levels of NO_2 at site 2 (0.12 ppm) during dry and hot season. When the levels of nitrogen (IV) oxide were compared with the reported literatures, seasonal levels of NO_2 was found lower than 35 to 108 ppm reported in Athens by Kalabokas *et al.,* (1999), fall within 0.52 to 0.20 ppm reported for Calabar metropolis, Nigeria by Okafor *et al.*, (2009) and higher than 0.14 to 1.09 ppm as reported for Kano metropolis, Nigeria by Okunola *et al.,* (2012).

Comparative study of the concentrations of NO_2 across the locations, during the four seasons showed that the highest level of NO_2 was recorded at site 6 during dry and warm season. This could be due to the fact nitrogen (IV) oxide is emitted from fuel combustion process. Site 6 was characterized with high movement of vehicles and traffic density during this season. The value obtained from this site is higher than the standard value limit set by FEFA, 1991 which is 0.06 ppm. The AQI, at all studied locations are very poor. This is most likely due to high traffic density and stationary fuel combustion process emissions from running generators (Etiuma *et al.,* 2006) which is very common in the metropolis due erratic power supply. It can be deduced from the results that the distribution pattern of this NO_2 shows a decrease in concentration from

dry and cool to dry and warm seasons in the morning to wet and warm in evening period across the locations. This could be attributed to reduce mixing in the atmosphere because NO_2 is mainly produced by motor vehicles, cold starts in dry and cool lead to longer warm-up time for catalytic converters which generate more NO_2 and rain attenuation because of solubility of NO_2.

5.4.4 Sulphur (IV) oxide (SO_2)

Result obtained for SO_2 across the sites, during the four seasons of sampling was recorded in Figure 4.20-4.23. The levels of SO_2 were generally higher in the evening than in the morning period across the sites. The highest concentration was generally obtained in the evening at sites 1 (0.11 ppm) and 2 (0.22 ppm) during dry and warm, sites 3 (4.38 ppm) and 8 (4.49 ppm) during dry and cool, site 5 (0.44 ppm) during dry and hot and sites 3 (0.27 ppm) and 7 (0.22 ppm) during wet and warm seasons. Figure 4.21 and 4.23, however, show the higher levels of SO_2 at sites 2 (0.33 ppm) and 5 (0.16 ppm) in the morning than in the evening during dry and cool and wet and warm seasons respectively.

Sulphur (IV) oxide in this study is found to be lower than the value given in the literature 3.21 to 5.18 ppm reported by Ayodele and Abubakar (2008) and 16 to 64 ppm by Kalabokas *et al.,* (1999). Comparative study of the concentrations of SO_2 across the locations, during the four seasons showed that the highest level of SO_2 was recorded at sites 3 and 8 during dry and cool season. This could be due to the fact sulphur (IV)

oxide is emitted from fuel and refuses combustion process. Sites 3 and 8 were characterized with high rate of fuel and wood combustion to generate heat during this dry and cool season. The values obtained from these sites are above average value for 24 hours limit of 0.14 ppm given by United State Environmental Protection Agency.

Comparative study of the recorded data with the AQI values, indicates the air quality for SO_2 was observed to be in the category of very poor at all locations with exception of control site.

5.4.5 Methane (CH_4)

Figure 4.24-4.27 show the result obtained for CH_4 across the sites during the four seasons. The levels of CH_4 were generally higher in the evening than in the morning period across the sites. The highest concentration was generally obtained in the evening at site 7 (1.78 ppm) during dry and warm, site 8 (0.78 ppm) during dry and cool and site 4 (1.11 ppm) during wet warm. Figure 4.26, however, show the higher levels of CH_4 at sites 5 (0.1 ppm), 6 (0.02 ppm), 8 (0.01 ppm) and 9 (0.03 ppm) during dry and hot season in the morning. Methane in this study is found to be lower than the value given in the literature 3.21 to 5.18 ppm reported by Ayodele and Abubakar (2008) and 16 to 64 ppm by Kalabokas *et al.,* (1999). Comparative study of the concentrations of CH_4 across the locations, during the four seasons showed that the highest level of CH_4 was recorded at sites 7 during dry and warm season. This is attributed to the passage of heavy trucks as the road linked to industrial areas like Challawa and Sharada industrial estates. The heavy vehicle use to transport raw materials and convey worker consumed ethanol in addition that burned to emit methane as exhaust gas. Moreover when the level of methane was compared with available

values reported in the literature, the time mean concentrations of methane were found to be lower than the value 0.60 ppm during morning period and higher than the range 0.53 to 0.58 ppm in the evening reported by Okonkwo *et al.,* (2012) for Port-Hacourt city of River State, Nigeria. This could be due to the fact methane oxide is emitted from fuel and refuses combustion process. Site 7 was characterized with high rate of passage of heavy trucks that use ethanol as fuel. Also, burning and decomposition of dump refuse contribute to the emission of methane gas. The variation in levels across the sites, during the four seasons could be attributed to the seasonal temperature, wind

speed and source. Compared with available literature, it could be seen that this values are lower than 4.300 to 0.861 ppm reported for Calabar metropolis, Nigeria by Okafor et al. (2009).

The average variations in the levels of pollutant gases across the sites, during the four seasons of sampling were shown in Figure 4.28-4.31. The highest concentration for CO, H_2S, NO_2, and CH_4 was generally obtained during dry and warm season. SO_2, however, was observed to be of highest concentration during dry and cool season.

From the result of Figure 4.28, it could be observed for CO, the seasonal variation in the levels ranged from 4.73 – 6.39 ppm for location 1, 4.39 – 5.84 ppm for location 2, 4.28 – 10.00 ppm for location 3, 4.50 – 9.84 ppm for location 4, 5.39 – 15.67 ppm for location 5, 6.28 – 14.50 ppm for location 6, 4.67 – 6.34 ppm for location 7, 5.62 – 12.06 ppm for location 8, 4.34 – 9.56 ppm for location 9, 4.17 – 6.39 ppm for location 10 and 0.02 – 0.05 ppm for control location. Highest concentration of CO was

noticed at all locations (except 3, 8, and 11) during the dry and warm season with the highest concentration at Kofar Nasarawa (location 5).

Seasonal variation in the levels of H_2S showed ranges from 0.78 – 1.39 ppm for location 1, 0.34 – 1.14 ppm for location 2, 0.39 – 2.22 ppm for location 3, 0.50 – 2.12 ppm for location 4, 0.25 – 3.56 ppm for location 5, 0.27 – 2.45 ppm for location 6, 0.27 - 1.74 ppm for location 7, 0.58 – 2.17 ppm for location 8, 0.11 – 2.33 ppm for location 9, 0.55 – 1.17 ppm for location 10 and 0.01 – 0.06 for control location 11. Similar to CO highest concentration of H_2S was obtained during the dry and warm season at location 5. Also, the average seasonal variation across the locations showed that highest

concentrations were in dry and cool season for location 1 and 10 and dry and hot season for control location. The result of NO_2 revealed seasonal average ranges between: 0.15 – 0.47 ppm for location 1, 0.12 – 0.35 ppm for location 2, 0.12 – 2.27 ppm for location 3, 0.16 – 0.44 ppm for location 4, 0.22 – 0.89 ppm for location 5, 0.14 – 3.84 ppm for location 6, 0.16 – 0.51 for location 7, 0.22 – 3.19 ppm for location 8, 0.34 – 0.87 ppm for location 9, 0.12 – 0.28 ppm for location 10 and 0.00 – 0.03 ppm for control location. Similar to CO and H_2S highest concentration of NO_2 were observed in dry and warm season. However, contrary to CO and H_2S the concentration of NO_2 was observed at location 6. For SO_2, seasonal average ranged between 0.04 – 0.50 ppm for location 1, 0.004 – 0.56 ppm for location 2, 0.002 – 2.19 ppm for location 3, 0.02 – 0.37 ppm for location 4, 0.10 – 0.31 ppm for location 5, 0.06 – 0.70 ppm for location 6, 0.03 – 0.15 ppm for location 7, 0.02 – 2.30 ppm for location 8, 0.06 – 0.037 for location 9, 0.01 – 0.17 ppm for location 10 and similar for control. Compared to CO, H_2S and NO_2 for SO_2 majority of the locations have their highest concentrations in dry

and cool season (except location 1 and 2 which have in dry and warm season) with most at location 8. The seasonal average of CH_4 showed range from: 0.00 – 0.67 ppm for location 1, 0.00 – 0.67 ppm for location 2, 0.00 – 0.84 ppm for location 3, 0.00 – 0.78 ppm for location 4, 0.05 – 0.67 ppm for location 5, 0.01 – 0.63 ppm for location 6, 0.00 – 0.91 ppm for location 7, 0.01 – 0.78 ppm for location 8, 0.02 – 0.78 ppm for location 9, 0.00 – 0.56 ppm for location 10 and 0.00 – 0.01 ppm for control location. Compared to CO, H_2S, NO_2 and SO_2 for CH_4 majority of the locations have their highest concentrations in wet and warm season. The highest concentration of CH_4 was observed at location 7.

However, from the meteorological data it is shows that wet season are characterized with frequent rain and the average temperature ranged from 27 to 35^{O}C. This measured low emission level pollutants CO, H_2S, SO_2, and NO_2 during the sampling season except methane. This could be attributed to their solubility in rain water to form acidic or basic compound that are also detrimental to plant and animal health and material structure of the environment. Among these pollutants SO_2 has the lowest level. This is due to shorter sunshine time and lower temperature which is the precursor of organic matter decomposition. This is in accord with the available literature (Ayodele and Abba, 2010). More so, studies have reported the association of increase CO and NO_2 concentrations with global warming. The main source of CO and NO_2 emission in urban areas is traffic from vehicular transportation. Thus, the main force to decrease global warming must be focused on improving public transportation and traffic congestion at roads intersections (Aliyu *et al.,* 2013). Gobo *et al.,* (2012)

also reported that motor vehicles are major sources of air pollution in urban settlements and accounting for approximately 48% CO, 32% NO_2 and 59% volatile organic compounds in this amount have adverse effect on the environment and human health. This may also be observed in the study area which has high volume of motor cars roaming along the roads and of these cars are either outdated or lack efficient converter installed, they move regularly emitting pollutant gases to the environment depending on the seasons.

The commercial activities along the study locations also contributed to the indiscriminate disposal and burning of solid waste that adds significantly to the levels of pollutant gases emission which under dry and warm condition undergo incomplete combustion or decompose to emit greenhouse gases CO,H_2S and SO_2.

Tables 4.4 compare the levels of pollutant gases (CO, H_2S, NO_2, SO_2, and CH_4) across the sites, during the four seasons. The p-value for CO across season locations is significant at $p < 0.05$ at all sites except 1 and 10. The order of significance across the sites is 5 > 6 > 8 > 3 > 9 > 4 > 7 > 1 > 10 2 > 11. The seasonal significant is almost noticed in all sites across the four seasons except dry and hot season at $p < 0.05$, where 7 of 11 sites were not significant. The order of significance across seasons is dry and warm > dry and cool > wet and warm > dry and hot. p-value for H_2S at all sites was significant at $p < 0.05$. The level was similar at all sites except at Kofar Nasarawa. The order of significance is 5 > 3 > 8 > 9 > 4 > 6 > 1 > 7 > 2 > 10 > 11. Seasonal similarity is noted during all seasons except during dry and hot seasons at $p < 0.05$. The order of significance is dry and warm > dry and cool > wet and warm > dry and hot. P-value for NO_2 across seasons at all sites was not significant at $p > 0.05$. The mean-value is

similar at all locations and across seasons at $p > 0.05$ with highest at Rimi market /Murtala Hospital (location 6) and dry and cool season. The order of significance is 6 > 8 > 3 > 9 > 5 > 4 >7 > 1 > 2 > 10 > 11 and dry and cool > dry and warm > wet and warm > dry and hot respectively. p-value for SO_2 across seasons at all locations was significant at $p < 0.05$.The mean-values are similar at $p > 0.05$ at all locations with highest at Kofar mazugal/Abatoir junction (location 8) and across seasons except dry and cool. The order of significance is 8 > 3 > 2 > 6 > 5 > 1 > 9 > 4 > 7 >10 > 11 and dry and cool > dry and warm > wet and warm > dry and hot respectively. p-value for CH_4 across seasons at all sampling locations was significant at $p < 0.05$. The mean values was observed similar at all locations with highest at Dan Agundi/BUK junction and across season wet and warm and dry and warm seasons are similar in the ranking order; 7 > 4 > 8 > 3 > 1 > 5 > 2 > 9 > 10 > 6 > 11 and wet and warm > dry and warm >

dry and cool > dry and hot. Finally, p-value for CH_4 was significant at > 0.05 across seasons at all locations. The mean-value is similar at all locations and across seasons at $p > 0.05$ with highest value at Kofar Nasarawa sampling location and during dry and warm season in the following ranks; 5 > 6 > 9 > 2 > 8 > 7 >1 > 11 > 10 > 4 > 3. P-value less than 0.05 ($p < 0.05$) signifies 95% difference in their mean values across the seasons at sampling locations.

CHAPTER SIX

6.0 SMMARY, CONCLUSIONS AND RECOMMENDATIONS.

6.1 Summary

The whole of this study evaluated greenhouse gas in the ambient air at intersections of selected roads in Kano metropolis, Nigeria. The earth's atmosphere acts as an insulating blanket and consists of a collection of greenhouse gases that trap heat and contribute to the warming of the earth habitat. An increase in the concentration of the greenhouse gases as a result of human activities lead to greater retention of infra-red radiation in the atmosphere given rise to a phenomenon known as greenhouse effect. Greenhouse effect is progressive warming up of the earth's surface due to blanket effect of greenhouse gases in the atmosphere. Global warming and climate change

result from an increase in world temperature has been described as greatest threat facing humanity. Nigeria being a developing country is experiencing an adverse effect of global warming with negative impact on the welfare of its people such as drought and flooding. Kano is one of the hottest states in Nigeria which made the inhabitant to be at risk of hot climatic condition and many diseases such as malaria. The high population of Kano metropolis is current at the risk of global warming due to daily vehicular emission. The objective of the present study was achieved through the determination of the levels of greenhouse gases in the ambient air at the intersections of selected roads in Kano metropolis. Nigeria.

Urbanization is considered as one of the most visible anthropogenic forces on earth. It is defined as a process and outcome of social changes, inflow and

concentration of people and activities in cities. The driving force of the urbanization is industrialization, migration and consumption pattern. The concentration of people has increase vehicle ownership which increase traffic emission. Human exposure to vehicle emission constituted severe health problem. In Nigeria motor vehicle emission is increasing per capita hence, is the dominant source of air pollution especially in cities with high traffic densities.

The data were collected from the five selected Local Government Areas of Kano metropolis. Three readings were taken morning and twice every month covering the four seasons of the year using automatic gas sensors that are manufactured by Crown Detection Instrument Ltd. The data collected from the eleven sampling locations during the field work was presented in form of bar charts and tables and it was realized that the mean level of the greenhouse gases in the evening were higher than the FEPA

established standard limits. This can be attributed to the high traffic density at intersections. The statistical analysis using correlation shows that emission from motor cycle, tricycle are negligible compared with that of cars that bears positive correlation with greenhouse gas emission.

6.2 Conclusions

Based on the monitoring done for one year, covering the four seasons and the data generated. The following conclusions were drawn.

(i) the results obtained show that the mean levels of greenhouse gases measured in the evening is higher than the FEPA established standard limits of 10, 0.06, 0.04-0.06, 0.06 ppm and 0.06 ppm for CO, H_2S, NO_2, SO_2 and CH_4 respectively. The high levels of these gases can be attributed to the high traffic density at intersections.

(ii) the study shows the significant correlation between motor cars and greenhouse gases emission of 0.603, 0.677 and 0.689 for CO, H_2S and SO_2 respectively and volume of cars established that motor cars are the predominant source of these greenhouse gases emissions.

(iii) the air quality situation in Kano metropolis exhibits a dangerous picture. The public could be contacted with diseases such as malaria conjunctivitis and meningitis due to hot climates brought by increase in concentration of greenhouse gases. Therefore, the need for continuous monitoring to provide a picture of the damage

humans are doing to the environment, and to enable pollution problems to be discovered and dealt with.

6.3 Recommendations

The following recommendations also are important for further research:

(i) consider more elaborate time frame and traffic flow, include meteorological factors such as wind which time and security do not allowed this research work to consider.

(ii) investigate the concentrations of other gases such as carbon (IV) oxide, hydrogen cyanide, sulphur hexafluoride and halogen in the ambient air of Kano metropolis, Nigeria.

(iii) monitoring should be extended to other Local Government Areas due to urbanization accompanying the rise in population that increase in the number of vehicles making transport-related pollutants more hazardous.

For the abatement of ambient air quality in Kano in particular and Nigeria in general the following should be considered;

(i) the construction of modern roundabouts and overhead bridges can be valuable. This improve traffic flow as well as cut down vehicular emissions and fuel consumption by reducing the vehicle idle time at intersections and thereby creating a positive impact on the environment.

(ii) establishment of strong public enlightenment program on air quality.

(iii) government should provide mass transit transportation such as big buses and train to reduce the number of vehicles on the road.

(iv) enforcement of law barning old second hand cars over twenty years and the reduction in the use of motorcycles.

(v) the government should urgently establish and equipped air pollution monitoring centers and network them.

(vi) barn on the installation of two strokes motor engines and motor cycle not having emission reduction technology.

(vii) legislation to barn rampant bush burning and cutting of trees should be stopped.

(viii) frequent seminars and conferences on global greenhouse gas emission effects

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APPENDICES

APPENDIX A: Raw data obtained from the field of studies
Location 1

	POLLUTANTS PARAMETERS									
	MORNING (7:30 --- 9:30 am)					EVENING (4:30-- 5:30 pm)				
Month	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)
	7	1	0.1	1	1	9	1	0.5	0	0
Sept.	5	2	0.1	0	0	9	2	0.6	0.1	1
	6	1	0.1	0	0	8	1	0.7	0.1	1
	5	1	0.1	0	0	4	2	0.2	0.1	1
Oct.	5	0	0.2	0	0	4	3	0.3	0.1	1
	5	1	0.3	0	0	7	1	0.1	0.1	2
	6	1	0.1	0	0	9	1	4	0.1	1
Nov.	5	1	0.1	0	0	8	1	0.5	0.1	3
	5	1	0.1	0	0	8	0	0.4	0.1	1
	4	1	0.2	0	0	9	1	0.4	0.1	1
Dec.	4	0	0.1	0	0	8	1	0.4	0.1	3
	5	2	0.2	0	0	8	1	0.5	0.1	1

	6	1	0.1	0	0	10	3	0.1	0.1	0
Jan	5	1	0.2	0	0	9	2	0.2	0.1	0
	5	1	0.2	0	0	6	4	0.2	0.1	0
	2	1	0.1	0	0	6	1	0.2	0	0
Feb.	1	1	0.1	0	0	5	2	0.2	0	0
	1	1	0.1	0	0	4	1	0.2	0	0
	4	0	0.1	0	1	6	1	0.2	0.1	0
March	5	1	0.1	0	1	5	0	0.2	0.1	0
	3	0	0.2	0	1	6	1	0.2	0.1	0
	4	1	0.1	0	1	6	1	0.2	0.1	0
April	4	1	0.1	0	1	5	0	0.2	0.1	0
	3	1	0.1	0	1	6	1	0.1	0.1	0
	4	1	0.1	0	0.1	5	1	0.2	0.1	0
May	4	1	0.1	0	0.1	6	1	0.1	0.1	0
	3	1	0.1	0	0	6	1	0.2	0.1	0
	4	1	0.1	0	0	6	4	0.4	0.3	1
June	3	0	0.1	0	0	6	2	0.5	0.1	1
	4	1	0.1	0	0	6	4	0.5	0.1	1
	4	0	0.5	0.1	1	5	1	0.4	0.1	1
July	1	1	0.3	0.1	1	5	1	0.5	0.1	1
	4	1	0.1	0.1	2	5	1	0.5	0.1	1
	3	0	0.2	0	1	9	2	0.5	0.1	0.1
August	4	0	0.1	0	0	10	3	0.5	0.1	0.1
	3	1	0.1	0	0	10	1	0.4	0.1	0.3

Location 2

	POLLUTANTS PARAMETERS									
	MORNING (7:30 --- 9:30 am)					EVENING (4:30-- 5:30 pm)				
Month	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)

	6	1	0.1	2	2	9	3	0.6	0	0
Sept.	4	1	0.1	0	0	10	2	0.8	0.1	1
	4	1	0.1	0	0	10	3	0.9	0.1	2
	4	1	0.3	0	0	8	3	0.1	0.1	1
oct.	6	1	0.1	0	0	4	1	0.2	0.1	1
	6	1	0.2	0	0	6	1	0.1	0.1	1
	5	0	0.1	0	0	3	0.2	2	0.1	1
Nov.	5	0	0.1	0	0	4	0.3	0.3	0.1	2
	4	0	0.1	0	0	7	1	0.1	0.1	1
	5	0	0.1	0	1	4	2	0.2	0.1	1
Dec.	5	1	0.1	0	0	4	3	0.3	0.1	2
	4	0	0.1	0	0	7	1	0.1	0.1	1
	5	0	0.1	0	0	11	3	0.4	0	0
Jan	5	0	0.1	0	0	11	2	0.3	0	0
	4	0	0.1	0	0	9	2	0.3	0	0
	1	0	0.1	0.1	0	5	0	0.1	0	0
Feb.	1	1	0.1	0.1	0	6	1	0.1	0	0
	1	1	0.1	0.1	0	5	1	0.2	0.1	0
	4	0	0.2	0	0	6	1	0.1	0.1	0
March	3	0	0.1	0	0	5	1	0.1	0.1	0
	4	1	0.1	0	0	7	0	0.1	0.1	0
	4	0	0.2	0	0	6	1	0.1	0.1	0
April	1	0	0.1	0	0	6	1	0.1	0	0
	4	1	0.1	0	0	7	0	0.2	0	0
	4	0	0.1	0	0	7	1	0.1	0.1	0
May	3	0	0.1	0	0	7	0	0.1	0.1	0
	4	0	0.1	0	0	6	0	0.2	0.1	0
	4	1	0.1	0	0	6	0	0.6	0.1	1
June	4	1	0.1	0	0	6	1	0.7	0.1	1
	4	1	0.1	0	0	7	0	0.4	0.5	1
	4	1	0.3	0.1	1	5	0	0.6	0.1	1
July	2	1	0.1	0.1	1	6	0	0.7	0.1	1
	3	1	0.2	0.1	1	5	0	0.4	0.1	1
	3	1	0.3	0	0	5	3	0.3	0.1	0.1
August	4	2	0.2	0	1	9	1	0.2	0.1	0.1
	2	1	0.1	0	0	10	1	0.3	0.1	0.2

Location 3

Pollutant Parameters										
	Morning (7:30 --- 9:30 am)					Evening (4:30-- 5:30 pm)				
Month	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)	CO **(**ppm**)**	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)

	8	2	0.3	0	0	10	4	0.7	0.1	0
Sept	8	3	0.4	0	0	15	5	0.8	0.1	0
	8	3	0.4	0	0	15	5	0.8	0.3	0
	8	1	0.2	0	1	9	1	0.8	0.1	0.1
Oct.	7	1	0.2	0	1	10	1	0.8	0.1	1
	6	1	0.2	0	1	10	1	0.8	0.1	0
	7	1	1	0	0	10	4	0.3	0.1	0
Nov.	7	0	0.1	0	0	9	4	0.3	0.1	0
	7	1	0.1	0	0	10	2	0.1	0.1	0
	7	1	0.1	0	0	17	6	0.6	0.1	1
Dec.	7	1	0.1	0	0	16	5	0.7	0.1	1
	7	1	0.1	0	0	16	5	0.8	0.1	1
	4	2	0.2	0	0	20	3	1.1	0.1	0
Jan.	5	2	0.3	0	0	24	1	1.1	0.1	0
	3	1	0.3	0	0	22	1	1.4	0.1	0
	4	0	0.1	0	0	8	3	0.5	0.1	0
Feb	3	0	0.1	0	0	8	3	0.5	0.1	1
	1	0	0.1	0	0	8	2	0.3	0.1	1
	4	1	0.1	0	1	5	1	0.2	0	0
March	4	1	0.1	0	1	4	0	0.1	0	0
	4	1	0.1	0	1	5	0	0.1	0	0
	4	1	0.1	0	1	5	1	0.2	0	0
April	5	1	0.1	0	1	4	1	0.1	0	0
	5	1	0.1	0	1	3	1	0.1	0	0
	4	1	0.1	0	0	5	0	0.2	0.1	0
May	4	1	0.1	0	0	4	1	0.1	0.1	0
	5	1	0.1	0	0	3	1	1.1	0.1	0
	5	2	0.1	0.1	1	6	1	0.2	0.2	1
June	5	2	0.1	0.1	2	5	1	0.1	0.2	1
	4	3	0.1	0.1	1	4	1	0.9	0.2	1
	4	1	0.1	0	0	5	1	0.2	0.5	1
July	4	1	0.1	0	1	5	1	0.3	0.6	1
	4	1	0.1	0	1	5	1	0.3	0.3	1
	7	1	0.1	0	0	0.3	7	0.1	0.2	1
Aug.	7	1	0.1	0	0	15	6	0.3	0.1	1
	7	1	0.1	0	0	17	5	0.2	0.1	1

Location 4

Pollutant parameters	
Morning (7:30 – 9:30 am)	Evening (4:30 – 5:30 pm)

Month	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)
	7	2	0.2	0	1	13	6	0.6	0.1	1
Sept	7	1	0.3	0	1	13	5	0.8	0.1	0
	8	1	0.3	0	0	12	6	0.5	0.3	1
	7	1	0.1	0	8	12	1	0.6	0.1	0
Oct.	7	1	0.1	0	0	13	1	0.7	0.1	0
	7	1	0.1	0	0	14	1	8	0.1	0
	6	1	1	0	1	14	3	0.3	0.1	0
Nov.	7	0.1	0.1	0	1	11	2	0.3	0.1	0
	7	1	0.3	0	0	12	4	0.1	0.1	0
	6	1	0.1	0	1	4	1	0.9	0.1	1
Dec.	7	1	0.3	0	1	15	2	0.8	0.1	2
	7	1	0.3	0	0	13	3	1	0.1	1
	5	0	0.1	0	0	15	3	0.9	0.1	0
Jan	5	0	0.1	0	0	14	2	0.9	0.1	0
	4	0	0.1	0	0	14	2	1	0.1	0
	3	0	0.1	0	0	6	1	0.3	0	1
Feb.	3	0	0.1	0	0	7	0	0.4	0	0
	3	0	0.1	0	0	5	1	0.5	0	0
	5	0	0.1	0	0	5	1	0.2	0	0
March	4	1	0.1	0	0	3	0	0.1	0	0
	5	1	0.1	0	0	4	1	0.1	0	0
	5	0	0.1	0	0	5	1	0.2	0	0
April	4	1	0.1	0	0	3	1	0.1	0	0
	6	1	0.1	0	0	4	1	0.1	0	0
	5	0	0.1	0	1	6	1	0.1	0.1	0
May	4	1	0.1	0	1	5	1	0.1	0.1	0
	5	1	0.1	0	1	3	1	0.9	0.1	0
	4	1	0.2	0.1	1	7	1	0.2	0.1	1
June	5	1	0.2	0.1	2	6	1	0.1	0.1	1
	5	1	0.1	0.1	1	4	1	0.2	0.1	1
	3	0	0.2	0	0	5	1	0.4	0.3	1
July	4	0	0.2	0	0	6	1	0.5	0.4	1
	5	1	0.1	0	0	5	1	0.3	0.3	1
	5	1	0.2	0	0	8	8	0.5	0.1	1
August	6	1	0.3	0	0	9	5	0.3	0.1	2
	7	1	0.3	0	0	11	4	0.3	0.1	1

Location 5

Pollutant parameters										
	Morning (7:30 – 9:30 am)					Evening (4:30 – 5:30 pm)				
Month	CO	H_2S	NO_2	SO_2	CH_4	CO	H_2S	NO_2	SO_2	CH_4

	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
	5	1	0.1	0	0	12	5	0.3	0.1	2
Sept	3	1	0.2	0	0	15	6	0.6	1	1
	5	1	0.1	0	0	13	6	0.5	0.1	1
	4	1	0.1	0	0	35	8	1	0.1	2
Oct.	3	0	0.1	0	0	37	6	1.3	0.1	1
	3	0	0.1	0	0	33	6	1.2	0.1	1
	5	1	0.1	0	0	35	8	10	0.1	2
Nov.	2	1	0	0	0	37	6	0.13	0.1	1
	2	1	0.1	0	0	33	6	0.12	0.1	1
	4	1	0.6	0.1	0	35	8	1	1	0
Dec.	5	0	0.5	0.1	0	37	6	1.3	0	0
	3	0	0.2	0.1	0	33	6	1.2	0	0
	5	3	0.5	0.1	2	13	2	0.3	0	0
Jan	2	2	0.1	0.1	1	10	1	0.2	0	0
	5	4	0.3	0.1	1	11	1	0.1	0	0
	4	2	0.2	0.1	0	10	4	0.1	0	0
Feb.	5	2	0.1	0.1	0	12	3	0.2	0	0
	3	2	0.2	0.1	0	10	5	0.2	0.1	0
	3	0	0.2	0.1	0	6	0	0.3	0	0
March	2	1	0.1	0.1	0	8	1	0.3	0	0
	4	1	0.1	0.1	0	9	1	0.2	0.1	0
	3	0	0.2	0.1	0	6	0	0.3	0	0
April	1	1	0.1	0.1	0	8	0	0.3	0	0
	4	1	0.1	0.1	0	9	0	0.2	0	0
	4	1	0.1	0.1	0	6	1	0.3	0.1	0
May	4	1	0.1	0.1	0	9	0	0.3	0.1	0
	3	1	0.5	0.1	0	8	0	0.2	0.1	0
	4	1	0.1	0.3	0	8	0	0.3	0.1	0
June	4	1	0.1	0.6	0	8	0	0.6	0.1	0
	3	1	0.1	0.2	0	8	0	0.2	0.1	0
	3	0	0.1	0.1	2	5	0	0.1	0	1
July	2	1	0.1	0.1	1	6	0	0.1	0	2
	2	1	0.1	0.1	0	8	0	0.1	0	2
	3	1	0.5	0	1	11	8	0.6	0.1	0
August	4	1	0.4	0	1	10	6	0.2	0.1	0
	3	1	0.1	0	1	9	6	0.1	0.1	0

Location 6

Pollutant parameters										
	Morning (7:30 – 9:30 am)					Evening (4:30 – 5:30 pm)				
Month	CO	H_2S	NO_2	SO_2	CH_4	CO	H_2S	NO_2	SO_2	CH_4
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)

	7	1	0.2	0	0	35	8	14	0.2	0
Sept	7	1	0.1	0	0	40	7	15	0.3	0
	7	1	0.1	0	0	56	7	16	0.3	1
	7	2	0.2	0	0	11	5	0.2	0.1	0
Oct.	6	2	0.2	0	0	15	1	5	0.1	0
	6	1	0.5	0	0	12	1	6	0.1	1
	5	0	0.1	0	0	11	5	0.2	0.1	0
Nov.	5	0	0.2	0	0	15	1	5	0.1	0
	4	0	0.1	0	0	12	1	6	0.1	0
	7	1	0.5	0	1	11	5	0.2	0.1	0
Dec.	5	2	0.4	0	0	15	1	6	0.1	0
	5	2	0.5	0	0	12	1	5	0.1	1
	5	0	0.2	0	0	12	1	0.2	0.1	0
Jan	5	0	0.3	0	0	14	1	0.3	0.1	0
	5	0	0.3	0	0	12	0	0.4	0.1	0
	1	1	0.1	0	0	5	2	0.1	0.1	0
Feb.	0	0	0.1	0	0	5	0	0.2	0.1	0
	1	0	0.1	0	0	6	1	0.1	0.1	0
	4	1	0.1	0	0	7	1	0.3	0.1	0
March	4	0	0.1	0	1	9	1	0.1	0.1	0
	4	0	0.1	0.1	1	10	1	0.1	0.1	0
	4	1	0.1	0	0	7	0	0.3	0.1	0
April	4	0	0.1	0.1	1	9	0	0.1	0.1	0
	4	0	0.1	0	0	10	0	0.1	0.1	0
	3	0	0.1	0	0	7	0	0.3	0.1	0
May	3	1	0.1	0	0	10	1	0.1	0.1	0
	4	1	0.3	0	0	10	0	0.1	0.1	0
	4	1	0.1	0	0	9	3	0.6	0.6	3
June	4	0	0.1	0	0	9	2	0.6	0.2	1
	4	1	0.2	0	0	10	3	0.7	0.3	1
	5	1	0.1	0.1	1	6	0	0.6	0.1	1
July	5	0	0.2	0.1	1	9	0	0.6	0.1	1
	4	0	0.2	0.1	1	8	0	0.7	0.1	1
	3	3	0.3	0	0	35	5	0.6	0.1	0.1
August	4	2	0.4	0	0	37	1	0.9	0.1	0.1
	4	2	0.4	0	0	32	2	0.3	0.1	0.1

Location 7

Pollutant parameters										
	Morning (7:30 – 9:30 am)					Evening (4:30 – 5:30 pm)				
Month	CO	H_2S	NO_2	SO_2	CH_4	CO	H_2S	NO_2	SO_2	CH_4

	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
	5	1	1	0	0	10	4	0.4	0.1	1
Sept	5	1	0.2	0	0	11	5	6	0.1	1
	5	1	0.2	0	0	12	5	0.6	0.1	1
	5	1	0.1	0	0	6	1	0.3	0	9
Oct.	6	2	0.1	0	0	7	1	0.03	0	1
	5	1	0.1	0	0	7	1	0.34	0	0
	4	2	0.1	0	0	8	0.3	0.1	0.1	1
Nov.	5	1	0.1	0	0	4	1	0.2	0.1	1
	3	2	0.1	0	0	6	1	0.1	0.1	1
	6	1	0.2	0	0	8	3	0.1	0.1	1
Dec.	6	1	0.5	0	0	4	1	0.2	0.1	1
	5	1	0.2	0	0	6	1	0.1	0.1	1
	4	2	0.2	0	0	10	3	0.8	0.1	0
Jan	5	1	0.3	0	0	9	1	0.8	0.1	0
	3	2	0.3	0	0	10	1	0.3	0.1	0
	3	2	0.1	0	0	8	2	0.1	0.1	0
Feb.	2	1	0.1	0	0	5	3	0.1	0.1	0
	3	1	0.1	0	0	7	2	0.2	0.1	0
	4	0	0.1	0	1	6	1	0.3	0.1	0
March	5	0	0.1	0	1	6	1	0.2	0	0
	4	0	0.1	0	1	6	1	0.1	0	0
	1	0	0.1	0	1	6	0	0.1	0.1	0
April	5	0	0.1	0	1	6	0	0.3	0	0
	1	0	0.1	0	0	6	0	0.2	0	0
	2	0	0.1	0	0	6	1	0.2	0.1	0
May	4	0	0.1	0	0	6	0	0.33	0.1	0
	2	0	0.1	0	0	7	0	0.2	0.1	0
	3	0	0.1	0	0	7	0	0.1	0.6	3
June	3	0	0.2	0	0	7	0	0.3	0.3	1
	3	0	0.1	0	0	8	1	0.3	0.5	1
	3	2	0.1	0.1	2	6	1	0.1	0.1	1
July	4	3	0.1	0.1	2	5	1	0.3	0.1	1
	5	0	0.2	0.1	2	6	0	0.3	0.1	1
	2	1	0.1	0	1	9	3	0.6	0.1	0.1
August	1	0	0.4	0	1	8	1	0.1	0.1	0.1
	2	2	0.5	0	0	6	1	0.2	0.1	0.1

Location 8

Pollutant parameters	
Morning (7:30 – 9:30 am)	Evening (4:30 – 5:30 pm)

Month	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)
	7	3	0.5	0	1	15	3	0.5	0.1	1
Sept	7	2	0.6	0	1	17	3	0.5	0.1	0
	7	3	0.6	0	0	18	5	0.6	0.1	1
	6	1	0.1	0	0	14	1	0.8	0.1	1
Oct.	5	1	0.1	0	0	15	1	0.8	0.1	1
	5	1	0.1	0	0	12	1	0.8	0.1	0
	8	1	0.2	0	1	13	3	0.2	0.1	0
Nov.	7	1	0.2	0	1	10	5	0.1	0.1	0
	6	1	0.2	0	1	11	3	0.1	0.1	0
	8	1	0.2	0	1	18	1	0.6	0.1	2
Dec.	7	1	0.2	0	1	21	4	0.7	0.1	1
	6	1	0.2	0	1	22	2	0.8	0.1	1
	5	0	0.2	1	0	25	2	1.2	0.1	0
Jan	5	0	0.3	0	0	27	1	1.2	0.1	0
	4	0	0.3	0	0	30	1	1.3	0.1	0
	5	1	0.1	0	0	9	5	0.4	0.1	1
Feb.	4	1	0.1	0	0	8	4	0.5	0.1	1
	4	1	0.1	0	0	9	5	0.4	0.1	1
	5	1	0.1	0	0	4	1	0.2	0	0
March	6	2	0.1	0.1	0	6	1	0.2	0	0
	6	2	0.1	0	1	8	1	0.1	0	0
	5	1	0.2	0	0	4	1	0.2	0	0
April	6	2	0.2	0	0	5	1	0.2	0	0
	6	2	0.2	0	0	7	1	0.1	0	0
	6	1	0.1	0	0	5	1	0.3	0.1	0
May	5	2	0.2	0	0	5	1	0.2	0.1	0
	5	1	0.2	0	0	7	1	1.1	0.1	0
	5	1	0.1	0.1	2	6	1	0.4	0.1	1
June	5	1	0.2	0.1	1	5	1	0.1	0.1	1
	5	3	0.2	0.1	2	7	1	0.8	0.2	1
	5	1	0.1	0	0	7	1	0.4	0.3	1
July	5	1	0.2	0	0	7	0	0.5	0.2	1
	5	1	0.2	0	0	6	0	0.6	0.1	1
	8	1	0.2	0.1	0	21	7	0.5	0.1	1
August	7	1	0.2	0.1	0	20	6	0.9	0.1	1
	6	1	0.2	0.1	0	25	5	0.8	0.1	1

Location 9

Pollutant parameters	
Morning (7:30 – 9:30 am)	Evening (4:30 – 5:30 pm)

Month	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)
	5	2	0.5	0	0	13	3	0.3	0.1	0
Sept.	6	2	0.6	0	0	12	6	0.7	0.1	0
	6	2	0.6	0	0	12	2	0.8	0.1	0
	9	1	0.4	0.1	1	13	2	0.7	0.1	1
Oct.	8	1	0.4	0.1	3	16	4	0.9	0.1	1
	9	1	0.5	0.1	1	12	5	0.7	0.1	1
	6	1	0.1	0	0	12	3	0.3	0.1	0
Nov.	5	1	0.1	0	0	12	2	0.1	0.1	0
	5	1	0.1	0	0	11	3	0.2	0.1	0
	6	1	0.1	0	0	11	4	0.9	0.1	0
Dec.	5	1	0.1	0	0	9	5	0.8	0.1	0
	5	1	0.1	0	0	11	8	0.7	0.1	1
	5	3	0.1	0	0	16	1	1.1	0.1	0
Jan	3	2	0.1	0	0	15	1	1.3	0.1	0
	2	4	0	0	0	17	0	1.4	0.1	0
	5	1	0.2	0	0	6	1	0.1	0.1	0
Feb.	4	1	0.2	0	0	7	1	0.2	0.1	0
	4	1	0.4	0	0	5	1	0.1	0	1
	3	1	0.1	0	0	4	1	0.1	0	0
March	3	1	0.1	0	0	7	0	0.2	0.1	0
	3	1	0.1	0.1	0	8	0	0.1	0.1	0
	3	1	0.1	0	0	4	0	0.1	0	0
April	3	1	0.1	0.1	0	7	0	0.2	0.1	0
	3	1	0.1	0.1	1	5	0	0.1	0.1	0
	3	1	0.1	0	0	4	0	3	0.1	0
May	3	1	0.1	0	0	5	0	5	0.1	0
	2	1	0.1	0	0	8	0	6	0.1	0
	4	2	0.3	0.2	1	5	1	0.5	0.1	1
June	2	3	0.1	0.1	1	5	0	0.6	0.1	1
	4	3	0.2	0.2	2	8	0	0.7	0.1	1
	1	1	0.3	0	1	6	0	0.4	0.1	1
July	2	1	0.1	0	0	7	0	0.3	0.2	1
	2	1	0.2	0	0	7	0	0.3	0.1	1
	6	1	0.1	0.1	0	18	1	0.4	0.1	1
August	6	1	0.1	0.1	0	19	3	0.6	0.1	1
	5	1	0.1	0.1	0	12	4	0.8	0.1	1

Location 10

Pollutant parameters	
Morning (7:30 – 9:30 am)	Evening (4:30 – 5:30 pm)

Month	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)
	5	1	0.2	0	0	1	1	0.2	0.1	1
Sept	6	1	0.2	0	0	10	1	0.4	0.1	1
	5	1	0.2	0	0	10	1	0.4	0.1	0
	4	1	0.2	0	0	8	0	0.3	0	0
Oct.	5	1	0.1	0	0	7	0	0.5	0	0
	5	1	0.1	0	0	8	0	0.4	0	0
	4	1	1	0	0	10	1	0.2	0	0
Nov.	5	0.1	0.1	0	0	9	1	0.2	0	0
	5	0.1	0.2	0	0	8	1	0.1	0	0
	4	1	0.2	0	0	8	1	0.3	0.1	1
Dec.	5	1	0.1	0	0	9	1	0.2	0.1	3
	5	1	0.1	0	0	8	1	0.1	0.1	1
	6	1	0.1	0	0	10	3	0.5	0.1	0
Jan	5	1	0.2	0	0	9	2	0.7	0.1	0
	6	1	0.2	0	0	10	4	0.8	0.1	0
	3	0	0.1	0	0	5	1	0.2	0	0
Feb.	2	0	0.1	0	0	3	1	0.1	0	0
	2	0	0.1	0	0	5	1	0.2	0	0
	5	0	0.1	0	1	5	1	0.1	0	0
March	4	1	0.1	0	1	4	1	0.2	0	0
	4	0	0.1	0	1	5	1	0.2	0	0
	5	0	0.1	0	1	5	1	0.1	0	0
April	4	1	0.1	0	1	3	1	0.2	0	0
	5	0	0.1	0	1	5	1	0.2	0	0
	4	0	0.1	0	1	5	1	0.1	0.1	0
May	5	1	0.1	0	0	4	1	0.1	0.1	0
	5	0	0.1	0	1	4	1	0.7	0.1	0
	3	1	0.1	0.1	0	5	1	0.1	0.1	1
June	4	2	0.2	0.1	1	5	1	0.2	0.1	1
	4	1	0.2	0.1	1	5	1	0.5	0.1	1
	4	0	0.1	0	0	4	1	0.5	0.2	0
July	3	0	0.2	0	1	3	1	0.3	0.4	0
	4	0	0.2	0	1	4	2	0.2	0.2	0
	5	1	0.2	0	0	6	0	0.7	0.1	1
August	4	1	0.1	0	0	4	0	0.3	0.1	1
	4	1	0.2	0	0	4	0	0.2	0.1	1

Location 11

Pollutant parameters										
	Morning (7:30 – 9:30 am)					Evening (4:30 – 5:30 pm)				
Month	CO	H_2S	NO_2	SO_2	CH_4	CO	H_2S	NO_2	SO_2	CH_4

	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
	0	0	0	0	0	0	0	0.2	0.1	0.1
Sept	0	0	0	0	0	0	0	0	0.1	0.1
	0	0	0	0	0	0	0	0	0.1	0
	0	0	0.2	0	0	0	0	0.1	0	0
Oct.	0	0	0.1	0	0	0	0	0	0	0
	0	0	0.1	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0.2	0	0
Nov.	0	0.1	0.1	0	0	0	0	0.2	0	0
	0	0.1	0	0	0	0	0	0.1	0	0
	0	0	0	0	0	0	0	0	0.1	0
Dec.	0	0	0.1	0	0	0	0	0.2	0	0.1
	0	0	0	0	0	0	0	0.1	0.1	1
	0	0	0.1	0	0	0	0	0	0	0
Jan	0	0	0	0	0	0	0.2	0	0.1	0
	0	0	0	0	0	0	0.1	0	0.1	0
	0	0	0	0	0	0	0	0	0	0
Feb.	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0.1	0	0
March	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0.1	0	0	0
	0	0	0	0	0	0	0.1	0.1	0.1	0
May	0	0.1	0.1	0	0	0	0	0.1	0.1	0
	0	0	0.1	0	1	0	0	0	0.1	0
	0	0	0	0.1	0	0	0	0.1	0.1	1
June	0	0	0	0.1	0	0	0	0	0.1	1
	0	0	0.	0.1	0	00	0	0	0.1	1
	0	0	0.1	0	0	0	0	0	0.2	0
July	0	0	0	0	0	0	0	0	0.4	0
	0	0	0	0	0	0	0	0.2	0.2	0
	0	0	0	0	0	0	0	0.1	0.1	1
August	0	0	0.1	0	0	0	0	0.1	0.1	1
	0	0	0	0	0	0	0.1	0	0.1	1

APPENDIX B

Table 1: Variations in the levels of pollutant gases among sampling sites during

periods.

1.1 Morning (7:30 to 9:30 am)

Site	Gases				
	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)
1	4.06 ±1.39	0.83 ±0.51	0.14 ±0.08	0.04 ±0.17	0.34 ±0.53
2	3.78 ±1.36	0.58 ±0.55	0.13 ±0.06	0.07 ±0.33	0.19 ±0.47
3	5.36 ±1.76	0.19 ±0.75	0.17 ±0.17	0.01 ±0.03	0.42 ±0.55
4	5.36 ±1.42	0.70 ±0.52	0.18 ±0.16	0.01 ±0.03	0.58 ±1.38
5	3.44 ±1.08	1.06 ±0.83	0.19 ±0.15	0.09 ±0.11	0.28 ±0.57
6	4.42 ±1.63	0.81 ±0.89	0.20 ±0.13	0.01 ±0.04	0.19 ±0.40
7	1.72 ±1.47	0.89 ±0.86	0.16 ±0.11	0.01 ±0.03	0.36 ±0.64
8	5.75 ±1.11	1.25 ±0.73	0.20 ±0.13	0.05 ±0.17	0.39 ±0.60
9	4.33 ±1.94	1.39 ±0.77	0.19 ±0.16	0.04 ±0.60	0.31 ±0.67
10	4.39 ±0.97	0.64 ±0.54	0.16 ±0.15	0.01 ±0.03	0.33 ±0.48
11	0.02 ±0.00	0.03 ±0.19	0.01 ±0.03	0.00 ±0.00	0.00 ±0.00

1.2 Evening (4:30 to 5:30 pm)

	Gases

Site	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)	CH_4 (ppm)
1	6.78 ±1.85	1.50 ±1.06	0.43 ±0.63	0.09 ±0.05	0.63 ±0.79
2	6.64 ±2.09	1.30 ±1.05	0.34 ±0.36	0.09 ±0.08	0.57 ±0.64
3	9.37 ±5.95	2.39 ±2.00	0.48 ±0.37	0.13 ±0.13	0.42 ±0.50
4	8.50 ±4.18	2.06 ±1.91	0.64 ±1.30	0.10 ±0.09	0.47 ±0.61
5	15.64 ±11.56	3.22 ±3.05	0.68 ±1.64	0.11 ±0.22	0.47 ±0.74
6	14.81 ±11.81	1.89 ±2.25	2.42 ±4.32	0.14 ±0.10	0.31 ±0.63
7	7.08 ±1.86	1.34 ±1.35	0.42 ±0.98	0.11 ±0.12	0.76 ±0.55
8	12.47 ±7.44	2.25 ±1.87	0.53 ±0.34	0.09 ±0.58	0.56 ±0.56
9	9.69 ±4.33	1.72 ±2.05	0.85 ±1,27	0.09 ±0.03	0.39 ±0.49
10	6.06 ±2.50	1.03 ±0.77	0.30 ±0.20	0.07 ±0.08	0.36 ±0.64
11	0.03 ±0.19	0.03 ±0.19	0.01 ±0.03	0.00 ±0.00	0.00 ±0.00

Table 2: Variations of pollutant gases emission among sampling sites.

Site	Gases				
	CO (ppm)	H_2S (ppm)	NO_2(ppm)	SO_2 (ppm)	CH_4 (ppm)
1	5.42 ±1.92	1.17 ±0.47	0.29 ±0.21	0.07 ±0.04	0.49 ±0.21
2	5.21 ±2.02	0.94 ±0.51	0.24 ±0.15	0.08 ±0.01	0.38 ±0.27
3	7.37 ±2.64	1.29 ±1.56	0.33 ±0.22	0.07 ±0.09	0.42 ±0.00
4	6.93 ±2.22	1.38 ±0.96	0.41 ±0.33	0.06 ±0.06	0.53 ±0.08
5	9.54±8.63	2.14 ±1.53	0.44 ±0.35	0.10 ±0.01	0.38 ±0.13
6	9.62 ±7.35	1.35 ±0.76	1.31 ±1.57	0.08 ±0.09	0.25 ±0.08
7	4.40 ±3.79	1.12 ±0.32	0.29 ±0.18	0.06 ±0.07	0.56 ±0.28
8	9.11 ±4.75	1.75 ±0.71	0.37 ±0.23	0.07 ±0.03	0.48 ±0.12
9	7.01 ±3.79	1.56 ±0.23	0.52 ±0.47	0.07 ±0.04	0.35 ±0.07
10	5.23 ±1.18	0.84 ±0.28	0.23 ±0.10	0.04 ±0,04	0.35 ±0.02
11	0.03 ±0.01	0.03 ±0.00	0.01 ±0.00	0.00 ±0.00	0.00 ±0.00

Table 3: Variations in traffic volume and composition among sampling sites.

Site	Vehicle types			
	Motorcycle	Tricycle	Cars / Buses	Truck
1	953	1002	2664	198
2	1010	1200	1605	111
3	1225	880	981	14
4	1325	951	949	25
5	681	721	2000	26
6	1503	992	2019	11
7	608	589	1994	251
8	1001	741	2681	74
9	782	252	2183	89
10	3228	2257	1132	108
11	100	70	50	4

Table 4: Variations in the levels of pollutant gases among sampling sites during the four seasons .

4.1 Carbon (II) oxide

Site	7:30 — 9:30 am (morning)				4:30 – 5:30 pm (evening)			
	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm
1	5.44	3.67	3.78	3.33	7.33	7.22	5.67	6.89
2	4.89	3.44	2.44	3.33	6.78	6.89	6.33	6.56
3	7.33	4.56	4.33	5.22	10.89	15.44	4.22	6.92
4	7.00	4.78	4.78	4.89	12.67	10.44	4.22	6.78
5	3.56	4.00	3.11	3.11	27.78	19.67	7.67	8.11
6	6.00	3.78	3.78	4.11	23.00	10.22	8.78	17.22
7	4.78	4.11	3.22	2.89	7.89	7.44	6.11	6.89
8	6.44	5.33	5.56	5.67	13.89	18.78	5.67	11.56
9	6.56	4.33	2.89	3.56	12.56	10.78	5.78	9.67
10	4.89	4.78	4.56	3.89	7.89	7.44	4.56	4.44
11	0.01	0.02	0.04	0.03	0.03	0.02	0.05	0.04

4.2 Hydrogen sulphide

Site	7:30 – 9:30 am (morning)				4:30 – 5:30 pm (evening)			
	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm
1	1.00	1.00	0.78	0.56	1.33	1.78	0.78	2.11
2	0.67	0.33	0.12	1.11	1.61	1.67	0.56	0.67
3	1.44	0.89	0.10	1.44	3.00	3.22	0.67	2.67
4	1.01	0.33	0.10	0.78	3.22	1.67	0.89	2.56
5	0.78	1.78	0.16	0.89	6.33	4.00	0.33	2.22
6	0.89	0.67	0.10	1.00	4.00	1.33	0.44	1.78
7	1.33	1.33	0.10	0.89	2.14	1.89	0.44	0.89
8	1.56	0.67	0.16	1.22	2.78	2.78	1.00	2.44
9	1.33	1.67	0.10	1.56	3.33	2.44	0.11	1.00
10	0.80	0.67	0.10	0.78	0.67	1.67	1.00	0.78
11	0.02	0.01	0.01	0.01	0.01	0.02	0.11	0.01

4.3 Nitrogen (IV) oxide

Site	7:30 – 9:30 am (morning)				4:30 – 5:30 pm (evening)			
	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm
1	0.13	0.14	0.11	0.18	0.81	0.27	0.19	0.47
2	0.13	0.10	0.12	0.17	0.57	0.22	0.12	0.47
3	0.32	0.16	0.10	0.10	0.60	4.38	0.13	0.29
4	0.28	0.14	0.10	0.20	0.52	0.74	0.21	0.31
5	0.10	0.30	0.16	0.18	1.68	0.51	0.27	0.26
6	0.19	0.28	0.10	0.22	7.49	1.39	0.17	0.62
7	0.12	0.22	0.10	0.20	0.90	0.30	0.21	0.26
8	0.29	1.89	0.16	0.18	0.49	4.49	0.29	0.56
9	0.37	0.14	0.10	0.27	0.52	0.73	1.64	0.51
10	0.26	0.12	0.10	0.17	0.30	0.34	0.14	0.33
11	0.00	0.01	0.01	0.01	0.00	0.01	0.02	0.04

4.4 Sulphur (IV) oxide

Site	7:30 – 9:30 am (morning)				4:30 – 5:30 pm (evening)			
	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm
1	0.11	0.00	0.00	0.03	0.89	0.07	0.10	0.12
2	0.22	0.33	0.00	0.03	0.89	0.22	0.08	0.14
3	0.00	0.00	0.00	0.03	0.12	4.38	0.03	0.27
4	0.00	0.00	0.00	0.03	0.12	0.74	0.03	0.18
5	0.00	0.10	0.10	0.16	0.20	0.51	0.44	0.07
6	0.00	0.00	0.02	0.03	0.16	1.39	0.10	0.19
7	0.00	0.00	0.00	0.03	0.07	0.30	0.06	0.22
8	0.00	0.11	0.01	0.07	0.10	4.49	0.03	0.14
9	0.03	0.00	0.03	0.09	0.10	0.73	0.08	0.11
10	0.00	0.00	0.00	0.03	0.03	0.34	0.02	0.16
11	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01

4.5 Methane

Site	7:30 – 9:30 am (morning)				4:30 – 5:30 pm (evening)			
	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm	Dry/ warm	Dry/ cool	Dry/ hot	Wet/ warm
1	0.11	0.00	0.00	0.56	1.22	0.56	0.00	0.72
2	0.22	0.11	0.00	0.44	1.11	0.33	0.00	0.71
3	0.33	0.00	0.00	0.67	1.12	0.33	0.00	1.00
4	1.33	0.22	0.00	0.44	0.22	0.56	0.00	1.11
5	0.00	0.44	0.1	0.67	1.33	0.00	0.00	0.56
6	0.00	0.11	0.02	0.33	0.22	0.11	0.00	0.92
7	0.00	0.00	0.00	0.89	1.78	0.33	0.00	0.92
8	0.56	0.33	0.01	0.56	0.44	0.78	0.00	1.00
9	0.56	0.00	0.03	0.56	0.33	0.22	0.00	1.00
10	0.00	0.00	0.00	0.44	0.22	0.56	0.00	0.67
11	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01

Table 5: Variations in the levels of pollutant gases among sampling sites during the four seasons.

5.1 Dry and warm

Gases	Site										
	1	2	3	4	5	6	7	8	9	10	11
CO	6.39	5.84	9.11	9.84	15.67	14.50	6.34	10.17	9.56	6.39	0.02
	±1.34	±1.34	±2.52	±4.01	±17.13	±12.02	±2.20	±5.27	±4.24	±2.12	±0.01
H_2S	1.17	1.14	2.22	2.12	3.56	2.45	1.74	2.17	2.33	0.74	0.02
	±0.23	±0.66	±1.10	±1.56	±3.94	±2.20	±0.57	±0.86	±1.41	±0.09	±0.01
NO_2	0.47	0.35	0.46	0.40	0.89	3.84	0.51	0.39	0.45	0.28	0.00
	±0.48	±0.31	±0.20	±0.17	±1.12	±5.16	±0.55	±0.14	±0.11	±0.28	±0.00
SO_2	0.50	0.56	0.06	0.06	0.10	0.08	0.04	0.05	0.07	0.02	0.01
	±0.55	±0.47	±0.09	±0.09	±0.14	±0.11	±0.05	±0.07	±0.05	±0.02	±0.01
CH_4	0.67	0.67	0.73	0.78	0.67	0.11	0.89	0.50	0.45	0.11	0.01
	±0.79	±0.63	±0.56	±0.79	±0.94	±0.16	±1.26	±0.09	±0.16	±0.16	±0.01

5.2 Dry and cool

Gases	Site										
	1	2	3	4	5	6	7	8	9	10	11
CO	5.45	5.17	10.00	7.61	11.84	7.00	5.78	12.06	7.56	6.11	0.02
	±2.51	±2.44	±7.69	±4.00	±11.08	±4.55	±2.36	±9.51	±4.58	±1.88	±0.00
H_2S	1.39	1.00	2.06	1.00	2.89	1.00	1.61	1.72	2.05	1.17	0.02
	±0.55	±0.95	±1.65	±0.95	±1.57	±0.47	±0.40	±1.49	±0.54	±0.71	±0.01
NO_2	0.21	0.16	2.27	0.44	0.41	0.84	0.26	3.19	0.44	0.23	0.01
	±0.92	±0.85	±2.98	±0.42	±0.15	±0.79	±0.06	±1.84	±0.42	±0.16	±0.00
SO_2	0.04	0.28	2.19	0.37	0.31	0.70	0.15	2.30	0.37	0.17	0.01
	±0.05	±0.08	±3.10	±0.52	±0.29	±0.98	±0.21	±3.10	±0.52	±0.24	±0.01
CH_4	0.28	0.22	0.17	0.39	0.22	0.11	0.17	0.56	0.11	0.28	0.01
	±0.40	±0.16	±0.23	±0.24	±0.31	±0.00	±0.23	±0.32	±0.16	±0.40	±0.01

5.3 Dry and hot

Gases	Site										
	1	2	3	4	5	6	7	8	9	10	11
CO	4.73	4.39	4.28	4.50	5.39	6.28	4.67	5.62	4.34	4.56	0.05
	±1.34	±2.75	±0.08	±0.40	±3.22	±3.54	±2.04	±0.08	±2.04	±0.00	±0.01
H_2S	0.78	0.34	0.39	0.50	0.25	0.27	0.27	0.58	0.11	0.55	0.06
	±0.00	±0.31	±0.40	±0.56	±0.12	±0.24	±0.24	±0.59	±0.01	±0.64	±0.07
NO_2	0.15	0.12	0.12	0.16	0.22	0.14	0.16	0.22	0.87	0.12	0.02
	±0.06	±0.00	±0.02	±0.08	±0.08	±0.05	±0.08	±0.09	±1.09	±0.03	±0.01
SO_2	0.05	0.04	0.02	0.02	0.27	0.06	0.03	0.02	0.06	0.01	0.01
	±0.07	±0.06	±0.02	±0.02	±0.24	±0.06	±0.04	±0.01	±0.04	±0.01	±0.01
CH_4	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.01	0.02	0.00	0.00
	±0.00	±0.00	±0.00	±0.00	±0.07	±0.01	±0.00	±0.01	±0.02	±0.00	±0.00

5.4 Wet and warm

Gases	Site										
	1	2	3	4	5	6	7	8	9	10	11
CO	5.1± 2.52	4.95 ±2.28	6.07 ±1.20	5.84 ±1.34	5.61 ±3.54	10.67 ±9.27	4.89 ±2.83	8.62 ±4.17	6.62 ±4.32	4.17 ±0.39	0.04 ±0.01
H_2S	1.3± 1.10	0.89 ±0.31	2.05 ±0.87	1.67 ±1.26	1.56 ±0.94	1.39 ±0.55	0.89 ±0.00	1.83 ±0.86	1.28 ±0.40	0.78 ±0.00	0.01 ±0.00
NO_2	0.3± 0.21	0.32 ±0.21	0.20 ±0.13	0.26 ±0.07	0.22 ±0.06	0.42 ±0.28	0.23 ±0.04	0.37 ±0.27	0.34 ±0.24	0.25 ±0.11	0.03 ±0.02
SO_2	0.0± 0.06	0.09 ±0.08	0.15 ±0.17	0.11 ±0.11	0.12 ±0.06	0.11 ±0.11	0.13 ±0.13	0.11 ±0.05	0.10 ±0.01	0.10 ±0.09	0.01 ±0.01
CH_4	0.6± 0.11	0.58 ±0.19	0.84 ±0.23	0.78 ±0.47	0.62 ±0.08	0.63 ±0.42	0.91 ±0.02	0.78 ±0.31	0.78 ±0.31	0.56 ±0.16	0.01 ±0.00

APPENDIX C

Table 6: Standard permissible limit value of pollutant gases given by WHO and FEPA

POLLUTANT GASES	WHO	FEPA
Carbon (II) oxide	30.00 ppm (1 hour) 9.00 ppm (8 hours)	10 ppm (24 hours)
Hydrogen sulphide	7.00 ppm (1 hour) 8.00 ppm (30 minutes)	0.06 ppm (24)
Sulphur (IV) oxide	0.50 ppm (1 hour) 0.11 ppm (24 hours)	0.06 ppm (24 hours)
Nitrogen (IV) oxide	0.06 ppm	0.04-0.06 ppm (24 hours)
Methane	0.06 ppm	0.06 ppm (24 hours)

APPENDIX D:

Table 7: Air Quality Index (AQI) rating (USEPA)

AQI Category	AQI Rating	CO (ppm)	H_2S (ppm)	NO_2 (ppm)	SO_2 (ppm)
Very good (0-15)	A	0-2	0-2.0	0-0.02	0-0.02
Good (16-31)	B	2.1-4.0	2.1-3.0	0.02-0.03	0.02-0.04
Moderate (32-49)	C	4.1-6.0	3.1-5.0	0.03-0.04	0.04-0.06
Poor (50-99)	D	6.1-9.0	5.1-7.0	0.04-0.06	0.06-0.08
Very poor (100 to above)	E	> 9.0	> 7.0	> 0.06	> 0.10

APPENDIX E:

Table 8: Summary of the AQI Rating for the priority pollutant gases along sampling sites.

Sites	AQI (CO)	AQI (H_2S)	AQI (NO_2)	AQI (SO_2)
1	C (D)	A (A)	E (E)	B (E)
2	B (D)	A (A)	E (E)	D (D)
3	C (E)	A (B)	E (E)	A (E)
4	C (D)	A (B)	E (E)	A (E)
5	B (E)	A (C)	E (E)	E (E)
6	C (E)	A (A)	E (E)	A (E)
7	B (D)	A (A)	E (E)	A (E)
8	C (E)	A (B)	E (E)	C (E)
9	C (E)	A (A)	E (E)	B (E)
10	C (D)	A (A)	E (E)	A (D)
11	A (A)	A (A)	A (A)	A (A)

(X) Represent Evening AQI

APPENDIX F

Table 9: ANOVA of Variations in the levels of pollutant gases along the sampling sites during the four seasons.

9.1 Carbon (II) oxide

	Season			
\Sites	Dry and warm	Dry and cool	Dry and hot	Wet and warm
1	6.39 ±1.34[a]	5.45 ±2.51	4.73 ±1.34[a]	5.11 ±2.52
2	5.84 ±1.34	5.17 ±2.44	4.39 ±2.75[b]	4.95 ±2.28
3	9.11 ±2.52	10.00 ±7.69	4.28 ±0.08[bc]	6.07 ±1.20
4	9.84 ±4.01	7.61 ±4.00	4.50 ±0.40[d]	5.84 ±1.34
5	15.67 ±17.13	11.84 ±11.08	5.39 ±3.22	5.61 ±3.54
6	14.50 ±12.02	7.00 ±4.55	6.28 ±3.54	10.67 ±9.27
7	6.34 ±2.20	5.78 ±2.36	4.67 ±2.04[a]	4.89 ±2.83
8	10.17 ±5.27	12.06 ±9.51	5.62 ±.08	8.62 ±4.17
9	9.56 ±4.24	7.56 ±4.58	4.34 ±2.04[bc]	6.62 ±4.32
10	6.39 ±2.12[a]	6.11 ±1.88	4.56 ±0.00[d]	4.17 ±0.39
11	0.02 ±0.01	0.02 ±0.00	0.05 ±0.01	0.04

9.2 Hydrogen sulphide

	Season

Sites	Dry and warm	Dry and cool	Dry and hot	Wet and warm
1	1.17 ±0.23[a]	1.39 ±0.55	0.78 ±0.00	1.34 ±1.10[a]
2	1.14 ±0.66[a]	1.00 ±0.95[a]	0.34 ±0.31[a]	0.89 ±0.31[b]
3	2.22 ±1.10	2.06 ±1.65	0.39 ±0.40[a]	2.05 ±0.87
4	2.12 ±1.56[b]	1.00 ±0.95[a]	0.50 ±0.56[b]	1.67 ±1.26
5	3.56 ±3.94	2.89 ±1.57	0.25 ±0.12[c]	1.56 ±0.94
6	2.45 ±2.20	1.00 ±0.47[a]	0.27 ±0.24[c]	1.39 ±0.55[a]
7	1.74 ±0.57	1.61 ±0.40	0.27 ±0.24[c]	0.89 ±0.00[b]
8	2.17 ±0.86[b]	1.72 ±1.49	0.58 ±0.59	1.83 ±0.86
9	2.33 ±1.41	2.05 ±0.54	0.11 ±0.01	1.28 ±0.40
10	0.74 ±0.09	1.17 ±0.71	0.55 ±0.64[b]	0.78 ±0.00
11	0.02 ±0.01	0.02 ±0.01	0.06 ±0.07	0.01 ±0.00

9.3 Nitrogen (IV) oxide

	Season

site	Dry and warm	Dry and cool	Dry and hot	Wet and warm
1	0.47 ±0.48[a]	0.21 ±0.92[a]	0.15 ±0.06[a]	0.33 ±0.21[a]
2	0.35 ±0.31[b]	0.16 ±0.85	0.12 ±0.00	0.32 ±0.21[a]
3	0.46 ±0.20[a]	2.27 ±2.98	0.12 ±0.02	0.20 ±0.13
4	0.40 ±0.17	0.44 ±0.42[b]	0.16 ±0.08[ab]	0.26 ±0.07[b]
5	0.89 ±1.12	0.41 ±0.15	0.22 ±0.08	0.22 ±0.06
6	3.84 ±5.16	0.84 ±0.79	0.14 ±0.05[a]	0.42 ±0.28
7	0.51 ±0.55	0.26 ±0.06[c]	0.16 ±0.08[ab]	0.23 ±0.04
8	0.39 ±0.14[b]	3.19 ±1.84	0.22 ±0.09	0.37 ±0.27
9	0.45 ±0.11[a]	0.44 ±0.42[b]	0.87 ±1.09	0.34 ±0.24[a]
10	0.28 ±0.28	0.23 ±0.16[ac]	0.12 ±0.03	0.25 ±0.11[b]
11	0.00 ±0.00	0.01 ±0.00	0.02 ±0.01	0.03 ±0.02

9.4 Sulphur (IV) oxide

	Season			
Site	Dry and warm	Dry and cool	Dry and hot	Wet and warm
1	0.50 ±0.55	0.04 ±0.05	0.05 ±0.07	0.08 ±0.06
2	0.56 ±0.47	0.28 ±0.08	0.04 ±0.06	0.09 ±0.08
3	0.06 ±0.09[a]	2.19 ±3.10	0.02 ±0.02[a]	0.15 ±0.17
4	0.06 ±0.09[a]	0.37 ±0.52	0.02 ±0.02[a]	0.11 ±0.11[a]
5	0.10 ±0.14	0.31 ±0.29	0.27 ±0.24	0.12 ±0.06
6	0.08 ±0.11	0.70 ±0.98	0.06 ±0.06	0.11 ±0.11[a]
7	0.04 ±0.05	0.15 ±0.21	0.03 ±0.04	0.13 ±0.13
8	0.05 ±0.07	2.30 ±3.10	0.02 ±0.01	0.11 ±0.05[a]
9	0.07 ±0.05	0.37 ±0.52	0.06 ±0.04	0.10 ±0.01[b]
10	0.02 ±0.02	0.17 ±0.24	0.01 ±0.01[b]	0.10 ±0.09[b]
11	0.01 ±0.01	0.01 ±0.01	0.01 ±0.01[b]	0.01 ±0.01

9.5 Methane

	Season			
Site	Dry and warm	Dry and cool	Dry and hot	Wet and warm
1	0.67 ±0.79[a]	0.28 ±0.40[a]	0.00 ±0.00[a]	0.64 ±0.11[a]
2	0.67 ±0.63[a]	0.22 ±0.16[b]	0.00 ±0.00[a]	0.58 ±0.19
3	0.73 ±0.56	0.17 ±0.23[c]	0.00 ±0.00[a]	0.84 ±0.23
4	0.78 ±0.79	0.39 ±0.24	0.00 ±0.00[a]	0.78 ±0.47[b]
5	0.67 ±0.94	0.22 ±0.31[b]	0.05 ±0.07	0.62 ±0.08
6	0.11 ±0.16	0.11 ±0.00[d]	0.01 ±0.01[b]	0.63 ±0.42[a]
7	0.89 ±1.26	0.17 ±0.23[c]	0.00 ±0.00[a]	0.91 ±0.02
8	0.50 ±0.09	0.56 ±0.32	0.01 ±0.01[b]	0.78 ±0.31[b]
9	0.45 ±0.16	0.11 ±0.16[d]	0.02 ±0.02	0.78 ±0.31[b]
10	0.11 ±0.16	0.28 ±0.40[a]	0.00 ±0.00[b]	0.56 ±0.16
11	0.01 ±0.01	0.01 ±0.01	0.00 ±0.00[b]	0.01 ±0.00

Table 10: One ANOVA Sample Test

	Test Value = 0					
	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
CO	13.547	32	.000	6.35533	5.3998	7.3109
H_2S	13.528	32	.000	1.23533	1.0493	1.4213
NO_2	7.300	32	.000	.40545	.2923	.5186
SO_2	15.100	32	.000	.06559	.0567	.0744
CH_4	14.622	32	.000	.38294	.3296	.4363
			.	.	.	