Spatial Ambient Air Quality Analysis and Its Effects on the Traffic Police Officers within the Central Business District in Nairobi, Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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This thesis has been submitted for examination with our approval as university supervisors

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DEDICATION

This research work is dedicated to my beloved parents, wife and children

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LIST OF ABBREVATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AJRCCM	American Journal of Respiratory and Critical Care Medicine
AQM	Air Quality Management
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
CBD	Central Business District
CCTV	Closed Circuit Television
CL	Confidence Level
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COHb	Carboxyhemoglobin
COK	Constitution of Kenya
COPD	Chronic Obstructive Pulmonary Disease
DOSHS	Directorate of Occupational Safety and Health Services.
EMCA 1999	Environmental Management and Coordination Act, 1999
EPA	Environmental Protection Agency
Ft	Feet
GHG's	Green House Gases
GOK	Government of Kenya
ITROMID	Institute of Tropical Medicine and Infectious Diseases

JKUAT	Jomo Kenyatta University College oa Agriculture and Technology
KNBS	Kenya National Bureau of Statistics
KU	Kenyatta University
MENR	Ministry of Environment and Natural Resources
MOH	Ministry of Health
MSDS	Material Safety Data Sheet
N_2O	Dinitrogen Oxide
NCST	National Council for Science and Technology
NGO	Non-Governmental Organization
NIOSH	National Institute for Occupational Safety and Health
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NOx	The generic term for mono-nitrogen oxides
OCS	Officer Commanding Station
OEL – CL	Occupation Exposure Limit – Control Limit
OSHA	Occupational Health and Safety Administration
OSHA 2007	Occupational Safety and Health Act 2007,
R/RA	Researcher /Research Assistant
RL	Recommended Limit
ROK	Republic of Kenya
SAED	School of Agriculture and Enterprise Development
SEI	Stockholm Environmental Institute

SPSS	Statistical Package for Social Scientists
TPO	Traffic Police Officer
TWA	Time Weighted Average
UN	United Nation
UN – HABITAT	United Nations Human Settlements Programme
UNCHS	United Nation Centre for Human Settlement
UNDP	United Nation development Programme
UNEP	United Nation Environmental Programme
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds
WHO	World Health Organization
WSL	Warren Spring Laboratories

DEFINATION OF TERMS

Air pollution	A mixture of solid particles and gases in the air. Car emissions, chemicals from factories, dust, and pollen and mold spores may be suspended as particles.
Biological Monitoring	A planned programme of periodic collection and analysis of body fluid, tissues, excreta or exhaled air in order to detect and quantify the exposure to or absorption of any substance or organism by persons
Exposure	The amount of a workplace agent that has reached an individual worker (external dose) or has been absorbed into the individual worker (absorbed dose)
Medical Surveillance	A planned programme of periodic examination, which may include clinical examinations, biological monitoring or medical tests of persons employed by a designated health practitioner or by an occupational medical practitioner;
Risk	The probability of occurrence of an adverse effect from a substance on people or the environment combined with the magnitude of the consequence of that adverse effect;
Workplace	Includes any land, premises, location, vessel or thing, at, in, upon, or near which, a worker is, in the course of employment;

ABSTRACT

In Kenya, every person is entitled to a clean and healthy environment. Although clean air is a basic requirement for human health and well-being, air pollution continues to pose a significant threat to the health of people worldwide. In Kenya the traffic police officers (TPO's) spend most of their time on the road controlling traffic a condition that exposes them to automobile pollution.

This study investigated the levels of automobile emissions and determined the health effects of exposure to these toxins. Emissions of carbon monoxide (CO), carbon dioxide (CO_2) and oxides of nitrogen (NO_x) from vehicles were therefore sampled at ten selected sites in the Central Business District (CBD) in Nairobi. It was carried out through non-experimental cross sectional survey employing both qualitative and qualitative data collection method. The sampling were carried out in the morning (between 7.00 and 9.00 am), at noon (between 12.00 and 2.00 pm) and evening (between 5.00 and 7.00 pm).

A gas Aspiration pump AP-20 together with detector tubes were used to determine the levels of NOx, CO emissions while Testo 435 multifunction measuring instrument was used to determine CO_2 levels, wind velocity and temperature at ten purposely selected sites within the CBD.

The results showed that CO_2, CO and NO_x sampled had means of 634.80 parts per million (ppm), 12.74 ppm and 2.56 ppm respectively. These results demonstrated that CO_2 were far much below the Occupational Exposure Limits –Control Limit for the gas

while CO_2 and NO_x levels were found to be above the WHO thresh hold limits for the gases respectively. These findings suggest that the TPO's were at risk of being affected by the emissions with continued exposure. It is therefore recommended that measures be put in place to reduce both emissions levels and also period of exposure.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

In Kenya, every person is entitled to a clean and healthy environment and has a duty to safeguard and enhance it. The entitlement to a clean and healthy environment includes the access by persons in Kenya to the various public elements or segments of the environment for recreational, educational, health, spiritual and cultural purposes (GOK, 1999). World Health Organization contents that clean air is a basic requirement for human health and well-being even though air pollution continues to pose a significant threat to health worldwide. According to their assessment of the burden of disease due to air pollution, more than two million premature deaths each year can be attributed to the effects of urban outdoor and indoor air pollution caused by the burning of fuels (WHO, 2002). More than half of these disease burdens in particular respiratory complications are borne by the populations of developing countries Kenya included (WHO, 2002). Currently urban air pollution is increasingly being considered as a major public health problem (Brunekreef & Holgate, 2002; Salvi, Blomberg, Rudell, Sandstrom, Holgate & Frew, 1999; Schwartz, 1994; WHO, 2001).

It should be appreciated that the lung is a critical interface between the environment and the human body and an average person takes about 10 million breaths a year and toxic substances in air can easily reach the lung and other organs where they can produce harmful effects (WHO, 2004). Both indoor and outdoor air contains chemical and biological gases, droplets and particles some of which are harmful to health. Air pollution therefore, describes any harmful gases or particles in the ambient air brought about by product of combustion (Complete or incomplete) of petroleum products and industrial waste such as ground-level Ozone (O_3), particulate matter (PM), Sulphur dioxide (SO_2), Carbon Monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), Hydrogen Sulphide (H_2S), sulphates and nitrates. Examples of other air pollutants include toxic metals (lead, mercury, manganese, arsenic and nickel), benzene, formaldehyde, polychlorinated biphenyl (PCB), dioxins, and other chemicals. The presence or absence of these pollutants will determine the quality of air at any particular place and time. In Kenya, resent inventory studies have revealed significant levels of air pollutants with potential high toxicities to man (MENR/UNEP, 2005).

1.2 Upward increase of cancer and respiratory diseases

Recently, the Kenya Medical Research Institute (KEMRI) released shocking figures which indicated that cancer among the urban population in Kenya between the periods 2000 to 2002 was in an upward trend with cancer due to other causes leading in the various categories studied (Korir, Mutuma & Omach, 2008). Statistics in Kenya also indicate that about 50 Kenyans die daily from various forms of cancer and about 80,000 cases of cancer are diagnosed each year in the word (Olick, 2011). The Ministry of Health report also provides information that seems to confirm the same fact. The data indicate that malaria was the leading cause of morbidity followed closely by diseases of respiratory infections in the year 2005, 2006 and 2007 respectively. Both diseases have been cited as contributing to more than 50% of the burden of the disease in total outpatient cases (MOH, 2008). Both reports, however, failed to give the causal factors for cancer and respiratory ailments. This clearly gives a gloomy situation in Kenya. Worse still lack of adequate data and information on automobile air pollution in most Africa countries including Kenya has made it impossible to quantify the effects of automobile air pollution. However, the little information available on automobile air pollution in Nairobi suggests high pollution emissions (Gatebe, 1992; Gatebe, *et al.,* 1996; Karue, Kinyua & El-Busaidy, 1992).

1.3 Traffic Police Officers

The traffic police department is among other Kenya Police departments in the Kenya Police force that is charged with ensuring that drivers on the road comply with the traffic Act and related subsidiary legislations. A majority of the traffic police staff have to spend much of their time on the roads while on duty (Plate 1). In these circumstances therefore, they are exposed to particulate matter and exhaust gases emitted by the vehicles on the road. This situation is worsened during peak hours when the traffic is heavy and more pollutants are released into the ambient air. This may affect their health in a variety of ways including irritation of eyes, nose and throat. This scenario clearly points to the urgency needed in determining the effects of motor vehicle emissions on ambient air quality and its effects on the health of the public and in particular the traffic police officers who are always on the roads as they discharge their duties.

Plate 1.1: Traffic Police Officer controlling vehicles in the CBD

There is a special Vehicle Inspection Unit in the traffic department that is charged with conducting vehicle testing to determine engine combustion efficiency of vehicles. This is done on vehicles suspected to be emitting excessive smoke to the ambient air. There are only eight units within the country. Only Nairobi unit has equipment's that can do such tests but in most cases it is not able to cope with the volume of vehicles that may require such tests. There is also no legislation that requires that vehicles must undergo such tests on regular basis.

1.4 Registration of Motor Vehicles

Data available from Kenya National Bureau of Statistics indicate that a total of 52,817 vehicles were registered in 2006 and 85,324 were registered in 2007 while 121,831 were registered in 2008 (KNBS, 2009**)**. On the other hand domestic consumption of petroleum in the year 2006 was 3,038,2000 tons and 3,121,800 tons in 2007 while 3,133,200 tons was consumed in the year 2008 (KNBS, 2009).

All these figures indicate that there was a consistent increase in the number of vehicles registered coupled with an increase of consumption of petroleum products (KNBS, 2009). This data together with Session paper No 4 of 2004 (ROK, 2004), reveal that there has been a rapid growing number of second hand cars and a majority of them are expected to be used in Nairobi. These cars have been used elsewhere and their combustion efficiency has seriously been compromised leading to significant emission of harmful gases. This coupled with the poor road network, traffic congestion during peaks hours with impacts of fuel wastage all lead to increased air pollution (ROK, 2004).

1.5 Automobile emissions

Vehicular emissions have been found to be the dominant source of air pollution especially in areas with high traffic densities (Carl- Elis, 1993; Seinfeld, 1989). More specifically diesel exhaust was cited as a major contributor to combustion derived particulate matter air pollution.

Most of the vehicle population is in developed countries however, motor vehicle pollution in developing countries is rapidly worsening due to increasing vehicle fleet growth, increasing distances travelled, and high rates of emissions from the vehicle fleets. The causes of the high emissions rates include road congestion which increases emissions per kilometre travelled, poor fuel quality including high lead content, inadequate emissions controls, poor maintenance and high average age of the vehicle fleet (Faiz & de Larderer, 1993).

Similarly Mulaku and Kamau (2001) demonstrated that a similar situation and condition prevailed within Nairobi. It should be noted that an increase of the number of automobile within the CBD is a critical factor in air pollution and hence air quality. In most cases, air pollution increases in direct proportion with the increase of the number of vehicles (Odhiambo, Kinyua, Gatebe & Awange, 2010) in the absence of clear policies in the management of emissions from these motor vehicles. In developing countries and particular in Kenya, most vehicles are not fitted with exhaust filters and/or catalytic converters. Vehicle age and lack of regular maintenance, poor infrastructure and economic inability are factors that were found to agravate the air pollution situations in urban centres especially the CBD (Maina, Gatari, Bundi & Muturi, 2005).

Plate 1.2: A vehicles producing excessive smoke in the CBD in Nairobi

1.6 General Effects of Automobile emissions

In several human experimental studies, using a well validated exposure chamber setup, diesel exhaust has been linked to acute vascular dysfunction and increased thrombus formation. This serves as a plausible mechanistic link between the previously described association between particulate matter air pollution and increased cardiovascular morbidity and mortality (Christopher, Stacey, Jonathan, Lianne & Joel 2004; Michael & Konstantinos, 2008). United Nation Development Programme also reported that unsustainable pattern of consumption and production of energy sources by industry and transport were the leading sources of key outdoor air pollutants (UNDP, 2004).

1.7 Statement of the problem

The principle research problem addressed in this study was to determine spatial ambient air quality within Nairobi CBD and its effects on the health of the traffic police. It should be appreciated that in spite of the existence of various legal frame works in Kenya such as the Environmental Management Coordination Act, 1999, Occupational Safety and Health Act, 2007, the traffic Act Cap. 403, that safe guard against the pollution of the environment, particularly the pollution of ambient air little research work has been carried out in Kenya to determine the levels of automobile emissions and specifically to investigate their effects on the general public. Worse still is the fact that climate change and air pollution have not been adequately factored in the country's economy including development policies and plans (GOK, 2010a).

The effect of air pollution on the health of traffic police staff in Kenya has hardly been assessed. Moreover, in Kenya, there are no national programmes on air pollution measurements.

It should also be emphasized here that it is not only the traffic police who are exposed to automobile emissions but the general public who include municipal council staff, pedestrians and self-employed persons who have premises or reside near the roads/streets with heavy traffic are also exposed (Bruce & Gooch, 2007; Cohen & Haggins, 1995 and Odhiambo *et al.,* 2010).

Plate 1.3: TPO's and members of the public equally exposed to automobile emissions in the CBD

1.8 Research Hypothesis

1.8.1 Null Hypothesis

Automobile emissions in Nairobi CBD are within the WHO thresh hold and have no significant effect on the health of the traffic police.

1.9 Objectives

1.9.1 Main objective

To analyze spatial ambient air quality within the CBD in Nairobi and to determine its effects on the health of the traffic police officers.

1.9.2 Specific Objectives

i. To determine automobile Carbon Monoxide (CO) emissions levels in selected sites within the CBD in Nairobi,

ii. To determine automobile Carbon Dioxide (CO_2) emissions levels in selected sites within the CBD in Nairobi

iii. To determine automobile NO_x (Nitrogen Oxide + Nitrogen Dioxide) emission levels in selected sites within the CBD in Nairobi,

iv. To examine the effects of CO, CO_2 and NO_x on the health of the traffic police who operate within the CBD in Nairobi,

v. To suggest appropriate strategies and measures to mitigate or prevent the possible effects of air quality on the health of TPO's who operate within the CBD in Nairobi.

1.10 Significance of the Study

Most developing countries including Kenya have no adequate data on automobile air pollution (Odhiambo *et al.,* 2010) despite having legal frameworks on air pollution and fastest growing populations. Mulaku and Kariuki (2001) underscored the importance of pollution data as vital for an integrated air quality management. They argued that the data is useful for identifying sources of pollution and their general emission levels. The information helps in developing and implementing cost effective mitigation measures and monitoring regimes. It should be appreciated that the objective of air quality monitoring is to provide information necessary for research, policy development and planning and assist in decision making on the efficient management of the environment.

In Kenya, one major challenge for effective air quality management has been lack of data on air pollution and its effects on public health. This gives a false illusion that air pollution is not a serious problem. This is far from the truth and only contributes to the concealment of a very significant public problem. This is attested and confirmed by the few recent research studies that have been conducted coupled with the medical reports from the health institutions that indicate that air pollution continues to adversely affect human health and the environment particularly in urban centers (Gatebe, 1992; Gatebe *et al.,* 1996; Karue *et al*., 1992; Maina *et al*., 2005 & MOH, 2008). It is therefore, more than certain that should the ambient air quality continue to degenerate undeterred, the health effects and the disease burden among the public is likely to continue in an upward trend. In the long run, Kenya may not realize its vision 2030 on environment i.e. being a nation that has a clean, secure and sustainable environment and to lessen by half all environment-related diseases by 2030

(GOK, 2007b). This will no doubt have the effect of more funds being diverted for treatment of ailments at the expense of capital investment.

There is therefore need to analyze the quality of automobile emissions and assess its effects on the public in particular the traffic police on a continuous basis so as to develop and implement policies and institute preventive measures as a proactive strategy towards minimizing risks associated with air pollution as a way of achieving sustainable development in the country. The findings of this study are expected to lead to policy change in the management of automobile air pollution in Kenya and in particular they will raise concern on the health effects of automobile air pollutions to the public.

1.11 Sampling Sites

Air sampling was conducted at ten selected major sites within the CBD in Nairobi with relatively high traffic density. This included, Harambee SACCO roundabout (Junction of Moi Avenue and Hailse Salasei Avenue), University way roundabout (Junction of Uhuru Highway and University Way) , Globe Cinema roundabout (Junction of Kijabe, Kipande, Kirinyaga and Muranga roads), Kencom Bus Stage, Fire station roundabout (Junction of Tom Mboya Street and River Road), Nyayo House roundabout (Junction of Uhuru Highway and Kenyatta Avenue), Bomb Blast roundabout (Junction of Moi Avenue and Haile Selassie Avenue), Wakulima Market roundabout (Junction of Haile Selassie Avenue and Race course Road), junction of Tom Mboya and Ronald Ngala Street and junction of Muindi Bingu and Kenyatta Avenue.

1.12 Conceptual Frame Work of the study

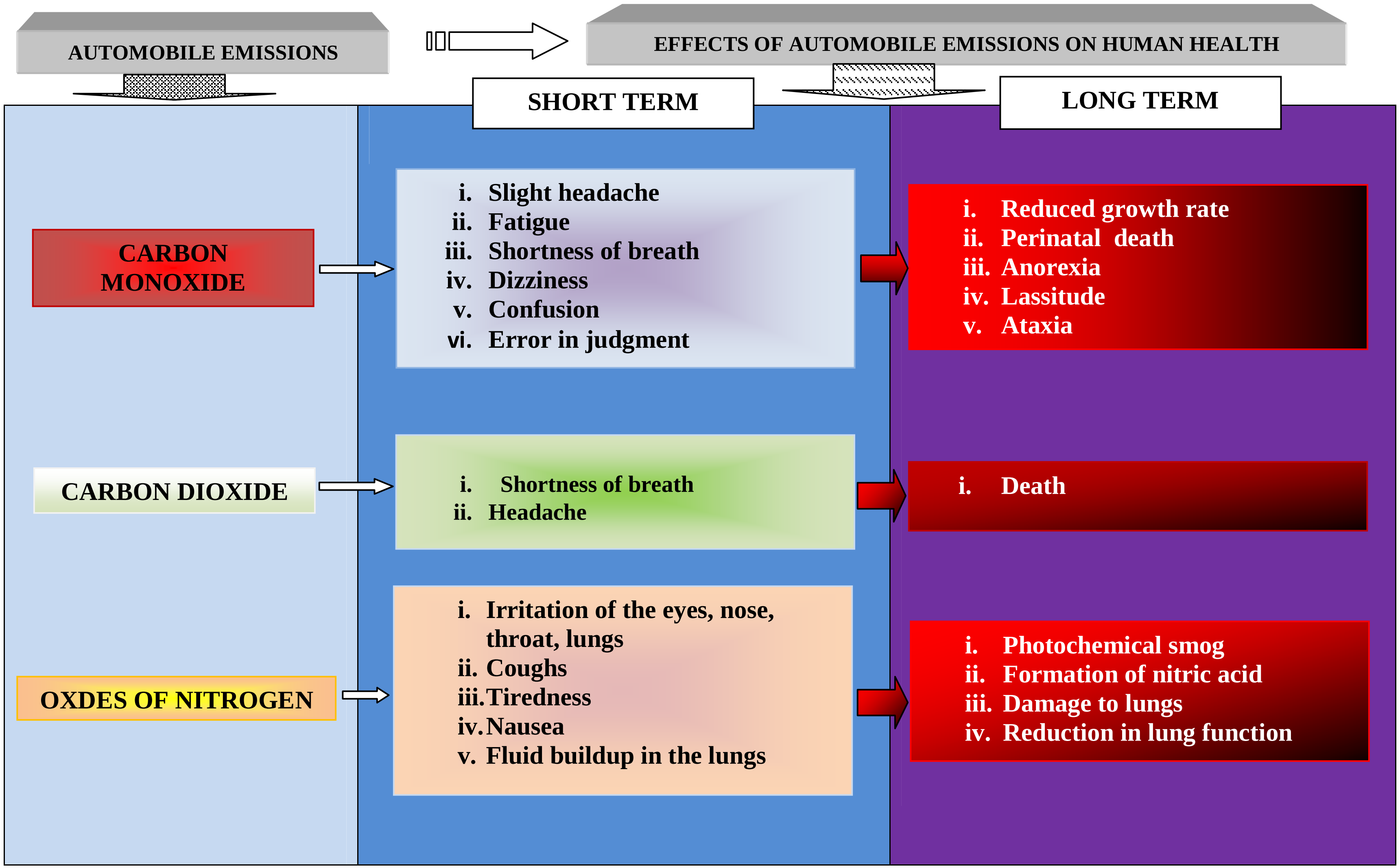

Figure. 1.1: The health effects of exposure to automobile emissions on human beings

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Air pollution is the introduction of chemicals, particulate matter or biological materials that cause harm or discomfort to humans or other living organisms or damages the natural environment (Mulaku & Kariuki, 2001). An air pollutant is therefore, a substance in the air that can cause harm to humans and the environment. A pollutant can be in the form of solid particles, liquid droplets, or gases.

2.2 Classifications of Air Pollution

Air pollution may be natural or man-made. Air pollution can also be classified as either primary or secondary. Primary pollutants are substances directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulfur dioxide released from factories. While on the other hand, secondary pollutants are not emitted directly. Rather, they are formed in the air when primary pollutants react or interact with each other or with the sun, for instance in the formation of ground level ozone - one of the many secondary pollutants that make up photochemical smog (GreenFacts, 2011).

2.3 The General Effects of Air Pollution

According to International Programme for Chemical Safety (WHO, 1999a), a link between air pollution and the increased prevalence of respiratory allergies such as asthma and rhinitis has been suspected for some time. There has also been consistent and overwhelming evidence that indicate that exposure to automobile emissions has devastating effects on people (Devlin, 2004; EPA, 2002; Finkelstein, Jerrett & Sears, 2004). For example, a 2004 study in Ontario Canada found increased risk of mortality from heart and lung disease in people living within 100 meters of a roadway. New York city studies demonstrated that diesel trucks create air toxics hot spots at crossings, urban areas, bus stops, and bus depots (Kinney, Aggarwal, Northridge, Janssen & Shepard, 2000; Lena, Ochieng, Carter, Holguín-Veras & Kinney,2002).

It is also worth appreciating that studies have also shown reasonably consistent and strong relationships between the indoor use of solid fuel and a number of diseases. These analyses estimate that indoor smoke from solid fuels causes about 35.7% of lower respiratory infections, 22.0% of chronic obstructive pulmonary diseases and 1.5% of trachea, bronchus and lung cancer. Indoor air pollution may also be associated with tuberculosis, cataracts and asthma (WHO, 2002).

Angle (1988) and Karol (1991) further demonstrated that a variety of indoor sources contributed significantly to indoor air burden and might play a role in the exacerbation of allergic diseases like asthma. Most common sources identified included respirable particles simply referred to as particulates from stove and tobacco smoke, combustion smoke from cookers, ovens and heaters; volatile organic compound (VOC) and other chemical paints, spray fabrics and combustion. Other sources include biological materials from animals such as mites, cats or from pollen, fungi and bacteria. Some pollutants may be both primary and secondary that is, they are both emitted directly and formed from other primary pollutants. Some of the pollutants are also greenhouse gases (GHG's) that trap heat from the sun.

Naturally occurring GHGs include water vapour, ozone (O_3), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These naturally occurring gases make life possible. A serious concern today however, is climate change which is as result of increased levels of some of these gases in the atmosphere due to anthropogenic activities. Higher concentrations of GHGs cause the Earth's average surface temperature to rise, leading to global warming (Pidwirny & Howard, 2008; Reay, 2008).

2.4 Environmental toxins

Studies in the field of occupational and environmental diseases have shown that currently, trends in research focus on the relation of low-dose exposures to human health, the influence of environmental toxins on both male and female reproductive functions and the potential health implications of subclinical indications of biological damage for example, genetic or chromosomal damage (Bell, 2006).

It is important to note here that the health effects of these pollutants in an individual is directly dependent on the exposure period, toxicity of the pollutant, one's susceptibility, age, the immune status of the individual and the target organ affected (Bell, 2006). Other factors according to Bell (2006) that affect pollutant concentration include reduced atmospheric mixing, which further is dependent on weather conditions such as temperature, wind speed, and the movement of high and low pressure systems and their interaction with the local topography, for instance, mountains, buildings and valleys. Ordinarily, temperature decreases with altitude. However, if a situation occurs where a colder layer of air settles under a warm layer, producing a temperature or thermal inversion, atmospheric mixing will be retarded leading to accumulation of pollutants near the ground. Under these circumstance inversions can become sustained under a stationary high-pressure system coupled with low wind speeds (Bell, 2006). Additionally, Katsouyanni (1997) demonstrated that urban air pollution may be a risk factor for lung cancer, with estimated relative risks in the order of up to about 1.5 in most situations.

Numerous studies have also found significant effects on reduction on sperm concentration, count, and morphology as a result of exposure to ambient air pollution (Craig *et al*., 2010). A study conducted by Cathryn, Melly, Murray, Brent, Robert & Schwartz (2006) in the US, further provided an association between long-term exposure to traffic air pollution and the risk of acute myocardial infarction. It is should be noted that that major pollutants are as a result of anthropogenic activities. The pollutants may include the following:

2.4.1 Carbon Monoxide (CO)

Carbon monoxide (CO) is a trace constituent of the troposphere, produced by both natural processes and human activities. Motor vehicle exhaust has been cited as the most important source for elevated carbon monoxide levels (WHO, 1999b). CO is a colorless, odorless gas. It is also produced by burning wood, paper or plastic products and from welding when Carbon Dioxide shielding gas is used. Workers can be exposed to carbon monoxide in any workplace where equipment's which uses petroleum products to power the machines are used. This results from partial combustion of carbon in the fuels (Lambert, Holderness & Thompson, 1976).

2.4.1.1 Chemical and Physical Properties

Carbon monoxide is a strong reducing agent and is extremely poisonous as it combines with the haemoglobin in red blood cells to essential sites in the body cells. It is also a neutral oxide; it is insoluble in water and does not react with either acids or alkalis under normal conditions (Lambert *et al.,* 1976). Carbon monoxide has the formula CO and molecular weight of 28.01 g/mole. It boils at -191.5 ^{0}C (at 21^{0}C) while its specific gravity (water = 1) is 0.79 at 0 ^{0}C. It has a vapor density of 0.97 and freezes at -205 ^{0}C (MSDS, 2010).

2.4.1.2 Occupational Exposure Limits

Legal Notice No. 60 of 2007 gives Occupational Exposure Limit – Control Limit (OEL – CL) for CO as: Long-term 8-TWA OEL-CL = 50 ppm (55 mg/ m^3) while short term OEL-CL = 300 ppm (330 mg/m^3) (GOK, 2006) while WHO gives a 8 hour TWA for CO as 9 ppm (10 mg/m^3) and 26 ppm (30 mg/ m^3) for 1 hour (WHO, 1999b)

2.4.1.3 Health effects of Carbon Monoxide

Routes of exposure to CO occur through the inhalation of the gas, contact of the eye or skin with the liquid CO. It is also an asphyxiant that combines with the haemoglobin of the blood which decreases the amount of oxygen delivered to the tissues resulting to tissue hypoxia. An earlier study conducted on animals revealed that carboxyhaemoglobin (COHb) level of 5% increases the degree of myocardial ischemia associated with acute myocardial infarction in dogs (ACGIH, 1991). Further, there is evidence that has been adduced by medical studies conducted by both Peters *et al*., (2004) and Tonne *et al.,* (2007) that have linked proximity to areas with heavy traffic to heart attacks (myocardial infarction).

According to Gosselin, Smith and Hodge (1984) exposure to CO also presents a special risk to the foetus and the elderly are more susceptible to its poisoning. Additionally, exposure to CO can also lead to cardiovascular effects. Studies have found out that exercise duration was significantly decreased by the onset of chest pain (angina) with patients with angina pectoris at post exposure carboxyhaemoglobin levels as low as 2.9% (Gosselin, Smith & Hodge, 1984). Acute pulmonary effects may also result from occupational or accidental exposure to the product of combustion and pyrolysis, particularly indoors that may lead to the detriment of lung function in the case where carboxyhaemoglobin levels are high (WHO, 1999b).

Additionally, Parmeggiani (1983) demonstrated that the appearance of symptoms on exposure to CO depends on the concentration of the gas in air (Table 2.1), exposure time, the degree of exertion and individual's susceptibility. With massive exposure unconsciousness may follow instantly with few or no pre-mounting signs and symptoms. There is evidence given by Parmeggiani (1983) that suggest that exposure to 10,000 – 40,000 ppm of CO will lead to instant death.

Table 2.1: Principle signs and symptoms with various concentrations of COHb

COHb Conc %	**Principle Signs and Symptoms**
0.3 - 0.7	No signs or symptoms. Normal endoglim levels
2.5 - 5.0	No signs or symptoms. Compulsory increase in blood to certain vital organs. Patients with severe cardiovascular disease may lack compulsory reserve. Chest pain or angina pectoris is provoked in patients by less exertion
5.0 - 10.0	Visual light threshold slightly increase
10.0 - 20.0	Tightness across the fore head. Slight headache. Visual evoked response abnormal. Possibly slight breathlessness on exertion. May be lethal to foetus and patients with severe heart disease.
20.0 - 30.0	Slight or moderate headache and throbbing in the temple. Flushing, nausea. Fine manual dexterity abnormal
30.0 - 40.0	Severe headache, vertigo, nausea and vomiting. Weakness, irritability and impaired judgment. Syncope on exertion
40.0 - 50.0	Seen as above but non severe with greater possibility of collapse and syncope
50.0 - 60.0	Possibility of come with intermittent convulsion and cheyne stokes respiration
60.0 - 70.0	Come with intermittent convulsions. Depressed respiration heart action. Possible death
70.0 - 80.0	Weak pulse and slow respiration, depression of respiratory construction leading to death

Source: Adapted from Parmeggiani (1983), Conc: concentration

Levels between 1,000 – 10,000 ppm may cause symptoms of headache, dizziness and nausea in 13 – 15 min and later unconsciousness and death if exposure continues for 10 – 45 min (Parmeggiani, 1983).

Below these levels the time before the onset of symptoms is longer. Levels of 500 ppm causes headache after 20 min while levels of 300 ppm cause headache after 50 min (Parmeggiani, 1983).

2.4.2 Carbon Dioxide

Carbon Dioxide (CO_2) is a colourless gas with a faint smell. It occurs in normal atmosphere in varying concentrations from 0.03 to 0.08%. It is sometimes found in spring water which is charged with the gas under pressure that is effervescence, evolved in large quantities from vents and fissures in the earth in volcanic regions and from product of foundries, burning of carbonaceous substances in excess of $O_{2,}$ synthetic ammonia production and limestone calcinations (Parmeggiani, 1983).

2.4.2.1 Chemical and Physical Properties

Carbon Dioxide has the formula CO_2 and molecular weight of 44. It melts at -56.6^{0}C (at 5.2 Atmosphere) and boils at 78.5^{0}C (at 760 mm Hg). It is denser than air and contains carbon and oxygen (MSDS, 2002).

2.4.2.2 Occupational Exposure Limits

Legal Notice No. 60 of 2007 gives Occupational Exposure Limit – Control Limit (OEL – CL) for CO_2 as: long-term (8-hour time weighted average) (TWA OEL-CL) = 5000 ppm (9000 mg/ m^3) while short term OEL-CL = 15000 ppm (27000 mg/ m^3) (GOK, 2006).

2.4.2.3 Health Effects of Carbon Dioxide

A concentration of 5% (50,000 ppm) may lead to shortness of breath and headache while at 10% may lead to unconsciousness in exposed person (Parmeggiani, 1983).

2.4.3 Oxides of Nitrogen

The generic term for mono-nitrogen oxides is NO_x. These oxides are normally produced during combustion, especially combustion at high temperatures. These nitrogen oxides are a mixture of gases that are composed of nitrogen and oxygen. There are three common oxides of nitrogen which include dinitrogen oxide formerly called nitrous oxide (N_2O), nitrogen oxide formerly called nitric oxide (NO) and nitrogen dioxide (NO_2). Nitric oxide and nitrogen dioxide are the most toxicologically significant oxides and both are non-flammable and colorless to brown at room temperature. Nitric oxide is a sharp sweet-smelling gas at room temperature, whereas nitrogen dioxide has a strong, harsh odor, becoming a reddish-brown gas above 21.1°C.

Nitrogen oxides are released to the air from the exhaust of motor vehicles, the burning of coal, oil, or natural gas and during processes such as arc welding, electroplating, engraving, and dynamite blasting. They are also produced commercially by reacting nitric acid with metals or cellulose. At ambient temperatures, the oxygen and nitrogen gases in air will not react with each other. However, in the internal combustion engine, combustion of a mixture of air and fuel produces combustion temperatures high enough to drive endothermic reactions between atmospheric nitrogen and oxygen in the flame, yielding various oxides of nitrogen.

In areas of high motor vehicle traffic, such as in large cities, the amount of nitrogen oxides emitted into the atmosphere can be quite significant. In the presence of excess oxygen, nitric oxide (NO) will be converted to nitrogen dioxide (NO_2), with the time required dependent on the concentration in air (Carl- Elis, 1993).

2.4.3.1 Dinitrogen Oxide (N_2O)

According to Lambert and others (1976), dinitrogen oxide (N_2O) gas may be prepared in the laboratory by heating any mixture of salts which by double decomposition will yield ammonium nitrate as indicated in the equation (1) and (2) below. For instance a mixture of potassium nitrate and ammonium sulphate finely ground and heated will produce the following reaction.

$$2KNO_{3(s)} + (NH_4)_2\,SO_{4(s)} \longrightarrow 2NH_4NO_{3(s)} + K_2SO_{4(s)} \quad \cdots\cdots\cdots \quad (1)$$

On heating, the ammonium nitrate melts and effervesces during which N_2O and steam is given off as shown in the equation below.

$$NH_4\,NO_{3\,(s)} \longrightarrow N_2O_{\,(g)} + 2H_2O_{\,(l)} \quad \cdots\cdots\cdots \quad (2)$$

2.4.3.1.1 Chemical and Physical Properties of Dinitrogen Oxide (N_2O)

Dinitrogen oxide is a colourless and has faint, rather sweet, sticky smell. It can produce insensibility for a short periods and normally is used as an anaesthetic for minor surgical operations for instance in dentistry. It has a density of 22 relative to that of hydrogen (Lambert *et al.,* 1976). Dinitrogen oxide has the formula N_2O and is relatively un-reactive being inert to the halogens. It has a relative molecular mass of 44 and relatively soluble in water (Lambert *et al.*, 1976). It oxidizes some low valance transition metal complexes and forms the complex:

$$[Ru\,(NH_3)_5N_2O]^{2+}$$

At elevated temperature it decomposes to nitrogen and oxygen. It also reacts with alkali, metals and many organic compounds (Cotton, 1986).

2.4.3.1.2 Occupational Exposure Limits of Dinitrogen Oxide

Legal Notice No. 60 of 2007 OEL – CL for N_2O as: long-term (8-hour time weighted average) (TWA OEL-CL) = 100 ppm (180mg/ m^3) while short term OEL-CL is not provided (GOK, 2006).

2.4.3.2 Nitrogen Oxide (NO)

Nitrogen oxide is always produced mixed with other oxide of nitrogen by the action of nitric acid on most metals e.g the action of moderately concentrated nitric acid on copper turnings as in the following equation.

$$3Cu_{(s)} + 8HNO_{3\,(aq)} \longrightarrow 3Cu\,(NO_3)_{2(aq)} + 4H_2O_{\,(l)} + 2NO_{\,(g)} \quad \text{.................. (1)}$$

However, Carl – Elis (1993) was able to show that in combustion processes at elevated temperatures nitrogen can be formed in the following reactions:

$$N_{2\,(g)} + O_{(g)} \longrightarrow NO_{(g)} + N_{(g)} \quad \text{.................. (2)}$$

$$N_{(g)} + O_{2\,(g)} \longrightarrow NO_{(g)} + O_{(g)} \quad \text{.................. (3)}$$

2.4.3.2.1 Chemical and Physical Properties of Nitrogen Oxide (NO)

It is a colourless almost insoluble in water. Its density relative to that of hydrogen is 15 and therefore slightly denser than air (14.4). In the lungs it reacts with oxygen to produce poisonous Nitrogen Dioxide (Lambert *et al.,* 1976).

Nitrogen oxide has the formula NO and reacts with ferrous ions, chlorine and bromine to form the nitrocy/halides XNO. It is oxidized to nitric acid by very strong oxidizing agents. NO is thermodynamically unstable at 25^0C and 1 atmosphere. At higher pressures it readily decomposes in the range 30 - 50^0C (Cotton, 1986).

2.4.3.2.2 Occupational Exposure Limits of Nitrogen Oxide (NO)

Legal Notice No. 60 of 2007 gives OEL – CL for NO as: long-term (8-hour time weighted average) (TWA OEL-CL) = 25 ppm (30 mg/ m^3) while short term OEL-CL = 35 ppm (45 mg/ m^3) (GOK, 2006).

2.4.3.3 Nitrogen Dioxide (NO_2)

Nitrogen dioxide is given off together with oxygen when nitrates of heavy metals are heated as shown in the following equation involving lead (II) nitrate.

$$2Pb\ (NO_3)_{2(s)} \longrightarrow 2PbO_{(s)} + 4NO_{2\ (g)} + O_{2\ (g)}$$

The lead (II) nitrate decrepitates and melts on heating. It effervesces giving brown gas Nitrogen Dioxide and oxygen.

2.4.3.3.1 Chemical and Physical Properties of Nitrogen Dioxide (NO_2)

It is usually seen as a reddish-brown gas and its boiling point (22^oC) is above the atmospheric temperature. It has a pungent, irritating smell and is a dangerous gas on its account of its tendency to set up septic pneumonia if inhaled. On heating NO_2 dissociates and at any temperature between 22^oC and 150^oC contains dinitrogen tetra oxide (N_2O_4) and nitrogen oxide (NO) molecules, the proportion of the latter increasing as the temperature rises to 150^oC.

$$\underset{\text{Light Yellow}}{N_2O_{4\,(g)}} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \underset{\text{Dark Brown}}{NO_{2\,(g)}}$$

Nitrogen oxides are used in the production of nitric acid, lacquers, dyes and other chemicals. Nitrogen oxides are also used in rocket fuels, nitration of organic chemicals and the manufacture of explosives (Lambert *et al.*, 1976).

Nitrogen dioxide has the formula NO_2. In the solid state the oxide is wholly dinitrogen tetra oxide (N_2O_4). In liquid, partial disassociation occurs and it is pale yellow at freezing point (-11.2^0C) and contains 0.01% NO_2 which increase to 0.1% with a deep red brown liquid at the boiling point 21.15^0C. In the vapour form at 100^0C, the decomposition is 90% N_2O_4, 10% N_2O and the dissociation is complete at 140^0C. NO_2 reacts with water to forms nitric acid which later decomposes on warming (Cotton, 1986).

$$2\,NO_2 + H_2O \longrightarrow HNO_3 + HNO_2 \quad \text{.......................} \quad (1)$$

On warming the reaction is as follows:

$$3HNO_2 \longrightarrow HNO_3 + 2NO_2 + H_2O \quad \text{...} (2)$$

Thermal decomposition begins at 150^0C and finishes at 600^0C.

2.4.3.3.2 Occupational Exposure Limits of Nitrogen Dioxide (NO_2)

Legal Notice No. 60 of 2007 gives Occupational Exposure Limit – Control Limit (OEL – CL) for NO_2 as: long-term (8-hour time weighted average) (TWA OEL-CL) = 3 ppm (5 mg/ m^3) while short term OEL-CL = 5 ppm (9 mg/ m^3) (GOK, 2006). WHO provide long term exposure limits for NO_2 as 0.072 ppm (120 μg/m^3) for an 8 hour TWA, 0.024 ppm (40 μg/m^3) for annual mean and 0.12 ppm (200 μg/m^3) 1-hour mean for short term exposure (WHO, 2000).

2.4.3.4 The Effects of Nitrogen Oxides in the atmosphere

Nitrogen oxides are broken down rapidly in the atmosphere by reacting with other substances commonly found in the air such as VOC and water vapour. The reaction of nitrogen dioxide with chemicals produced by sunlight leads to the formation of nitric acid, which is a major constituent of acid rain. Nitrogen dioxide also reacts with other VOC's in the presence of sunlight to form ozone (O_3) and photochemical smog conditions in the air we breathe. The general population is primarily exposed to nitrogen oxides by breathing in air. People who live near combustion sources such as coal burning power plants or areas with heavy motor vehicle use may be exposed to higher levels of nitrogen oxides (EPA, 1999 and Marika, 1993).

2.4.3.5 Health effect of Oxides of Nitrogen

Marika (1993) noted that there were various health risks posed by exposure to nitrogen oxides. These risks are determined by the personal exposure of individuals, long term average concentration levels, diurnal variations, short term peak exposures, activity patterns and finally personal and home characteristics of individuals.

Low levels of nitrogen oxides in the air can also irritates the eyes, nose, throat, and lungs, possibly leading to cough and shortness of breath, tiredness, and nausea. Exposure to low levels can also result in fluid build-up in the lungs one or two days after exposure. Breathing high levels of nitrogen oxides can also cause rapid burning, spasms, and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of body tissues, a build-up of fluid in the lungs and even death. Exposure to high concentrations of nitrogen oxide gases or nitrogen dioxide liquid through contact on the skin or eye would result to serious burns (Marika, 1993).

It is also worth mentioning here that NO_x is an important constituent of photochemical smog. According to Parmeggiani (1983), photochemical pollution results from a complex interaction in the presence of strong sunlight between VOC and NO_x leading to the formation of ozone and many organic compounds which are peroxyacetylnitrate (PAN) that are irritant to the eyes. According to Carl –Elis (1993) gasoline engines are the main sources of hydrocarbons and NO_x precursors. NO is oxidized normally in many ways including the following reactions:

$$2NO + O_2 \longrightarrow 2NO_2 \quad \text{...} (1)$$

$$NO + O_3 \longrightarrow NO_2 + O_2 \quad \text{(2)}$$

$$HO_2 + NO \longrightarrow NO_2 + OH \quad \text{(3)}$$

$$RO_2 + NO \longrightarrow RO + NO_2 \quad \text{(4)}$$

R is a part of an organic compound; OH, HO_2 and RO being reactive radicals.

Carl – Elis (1993) emphasizes that the three last equations happens very fast and equations 2 and 3 are the most important in the formation of NO_2 in ambient air. According to him, NO_2 plays an important role in the formation of photochemical smog in a process called photolysis during which NO_2 is converted to NO and atomic oxygen as shown in equation 5.

$$NO_2 + h\nu \longrightarrow O + NO \quad \text{(5)}$$

$$O + O_2 \longrightarrow O_3 \quad \text{(6)}$$

Equation 4 leads to the formation of more NO_2 and in this way more ozone. Additionally, volatile organic compound contributes to the formation of photochemical smog after they have been converted to peroxy radicals (RO_2). Smog is also formed when there is a failure in the scavenging mechanism during episodes of anticyclones weather conditions. During these episodes the cold air lies under the warm air with the resultant cessation of the upward current. A lid is therefore formed and the pollutants emitted accumulate in still air. Such weather conditions normally accompany fog and a mixture of fog, smoke and irritant gases is termed as smog.

There is evidence to indicate that children and people with lung diseases such as asthma, and people who work or exercise outside are susceptible to adverse effects of smog such as damage to lung tissue and reduction in lung function (Gauderman, *et al.,* 2000; Gauderman, *et al.,* 2002 and Peters, *et al.,* 1999).

2.5 Some Research Study conducted on Automobile Air Pollution

A preliminary study conducted in Sao Paulo, Brazil, showed that a 75 $\mu g/m^3$ increase in NO_2 was related to a 30% increase in mortality for respiratory illness among children less than five years old (Saldiva, *et al.,* 1995). Moreover, stronger associations were observed during the winter months, when NO_2 levels ranged from 40-160 $\mu g/m^3$ (mean 90 $\mu g/m^3$). The correlation coefficient between pollutants and illness was 0.44. The highest indicated effect of NO_2 was observed with a two-day lag. A survey of respiratory symptoms as a function of distance from roads with heavy traffic showed that the prevalence rate of respiratory symptoms, such as chronic cough and wheezing, was higher in residents nearer roads (Nitta, Sato, Nakai, Maeda, Aoki & Ono, 1993; Ono, Murakami, Nitta, Nakai, Maeda, 1990).

It has also been reported that an interaction between air pollution, especially NO_2, and high temperature, may synergistically increase lung cancer mortality rates, since regional differences in age-adjusted lung cancer rates were explained by an interaction between NO_2 and temperature (Choi & Shinozaki, 1997). In Australia Morgan, Corbett and Wlodarczyk (1998) examined the effects of outdoor air pollutants on daily hospital admissions in Sydney, Australia. A time-series analysis of counts of daily hospital admissions and outdoor air pollutants (1990-1994) showed that an increase in the daily maximum 1-hour concentration of NO_2 from the 10^{th} to the 90^{th} percentile was associated with an increase of 5.29% (95% CI: 1.07% to 9.68%) in childhood asthma admissions and 4.60% (95% CI: -

0.17% to 9.61%) in COPD admissions. While in China, Chinese middle-school students residing in a relatively low-pollution district of Shenyang, and undergraduate students studying at a relatively low-pollution district of Beijing, had average blood COHb concentrations of 0.8 % and 0.5 % respectively. And finally in Africa, there is little data about health effects associated with exposure to specific air pollutants. However, numerous studies in South Africa have indicated associations between a variety of respiratory symptoms and air pollution in urban, industrial and informal settlement areas. For example, high prevalence rates for respiratory illness were found in a residential suburb within an industrial area, relative to a suburb further away. Similarly, when compared with areas using cleaner fuel, raised levels of respiratory effects have been identified in informal settlements, where coal and wood were commonly used for domestic purposes (Opperman, Nel, Bekker, Booysens & Terblanche, 1993; Terblanche, Opperman, Nel, Reinach, Tosen & Cadman, 1992; Terblanche, Opperman, Nel & Pols, 1993).

In India, a study conducted by Sharat, Shallu, Avnish & Kamal (2011) on non-smokers traffic policemen in Patiala also revealed that the adverse health effects of automobile pollution to exposed policemen was significant and they therefore concluded that the effects were probably due to the prolonged exposure to vehicular pollution which causes airway obstruction by inducing chronic airway irritation and increased mucus production.

2.6 Air Pollution Management

Poor air quality is emerging as a major health and environmental problem in Sub-Saharan African cities. Preliminary studies in some of the larger cities in the region show that pollution levels are comparable to some of the worst polluted cities in the World. However, by initiating air quality management measures at an early stage of development, countries can avoid the severity of air pollution impacts and their related costs. This statement was underlined by the 200 participants at the regional workshop on, 'Better Air Quality in Sub-Saharan African cities' held from 25-28 July 2006 at UNEP Headquarters in Nairobi, Kenya (UN – HABITAT, 2006). The conference delegates noted that apart from lack of adequate legal and regulatory frameworks to address air pollution, the region also lacked the capacity to assess, monitor pollution levels and impacts (UN – HABITAT, 2006). Air pollution is also not prioritized as a key input to the region's development goals. It is against this background that the conference resolved to mainstream better air quality into poverty reduction and growth strategies. Some of the key areas highlighted at the conference that would need to be addressed in the preparation of an air quality management strategy for the region include cleaner fuels and vehicles, mass transport and town planning, solid waste and plastic waste management, industrial and mining pollution (UN – HABITAT, 2006).

2.6.1 Air Pollution Capabilities

Mulaku and Kamau (2001) in their research, 'Mapping and Analysis of Air Pollution in Nairobi, Kenya', suggested that effective management of air quality in cities requires an effective monitoring capability for documenting and managing air quality. It then follows that with such a capability the magnitude and sources of air pollution problems will be measured, cost -effective and targeted responses made possible and the success and otherwise mitigation measures gauged (UN, 2006). This fact received international recognition in 1992 when the United Nations Conference on Environment and

Development (UNCTED) made specific recommendations in its Agenda 21 with regards to addressing air pollution in cities (UN, 1992a). One key recommendation in the conference was the establishment of appropriate air quality management capabilities in large cities and the establishment of adequate environmental monitoring capabilities or surveillance of environmental quality and the health status of population. Mulaku and Kariuki (2001) further suggested that every major city should have an air quality management capability.

According to UNEP/WHO (1996), air quality management is defined as the capability to generate and utilize appropriate air quality information within a coherent administrative and legislative framework to enable the rational management of air quality. This involves monitoring air quality, compiling pollutant emissions inventory, use of models to predict air quality trends, setting and enforcing air quality standards and finally putting in place relevant legislative and administrative frameworks for the management of air quality.

Furthermore, it is important to carry out health impact assessment of the pollutants on the exposed people as this will allow one to quantify the effects of exposure to environmental hazards. This plays a central role in assessing the potential effects on health of different policies and measures, thereby providing a basis for decision-making (WHO, 2004).

In should be noted that most developed countries have put in place such capabilities by legislating laws for air quality management. Presently most developed countries and a few developing countries such as Brazil, India, Mexico and Egypt have established such capabilities in their major cities (CAIP, 2001; NAPS, 2001; USEPA, 1993; WSL, 1994). However, most developing countries, Kenya included, have no such air quality management capabilities despite having the fastest growing urban populations (Mulaku and Kamau, 2001). Some of the reasons for this include lack of expertise to formulate air pollution management policies, low budget allocation priority given to air pollution management when compared with other social and environmental problems, inadequate political will and inadequate legislative and administrative frameworks in which responsibility for air quality is divided between a number of government ministries and the local administrations, thus complicating policy making.

2.6.2 Capacity Building and Awareness Creation

Climate knowledge and indeed air pollution is the foundation for the development of an effective response to the climate change challenges. It is on this background that governments should develop the knowledge and practical skills of its people to foresee and identify environmental health hazards and the capacity to reduce the risks. Basic capacity requirements must include knowledge about environmental health problems and awareness on the part of leaders, citizens and specialists in combating pollution (UN, 1992b).

Moreover, the UN systems play a central role in this area by bringing together global resources for observation and analysis of climate change trends. It is committed to reinforcing its efforts to provide sound and unbiased scientific information and climate services to enable evidence-based policy and decision making at all levels (UN, 2008). It is against this background that governments should take the initiative to raise awareness among its subjects on the effects of air pollution. Building up the individual and collective capacity of countries to monitor climate variability and change enhance climate science and services and utilizing climate predictions is crucial for effective adaptation and mitigation strategies. Such capacity also enables timely planning to reduce the impact of increasing natural disasters, enhance food security and manage climate risks in all socioeconomic sectors (UN, 2008).

Governments in particular Kenya can partner with the UN and other organizations e.g NGO's in their endeavors to manage the city air quality. UN-HABITAT has made tremendous progress in the management of air quality in cities. As one of their initiative, they have launched the interactive Urban Air Quality Management Tool book CD-ROM at a training session during the recent World Urban Forum III that was held in Vancouver in June 2006. This tool is adapted to the needs of cities in developing countries and will help urban practitioners gather data, assess the health impacts of air pollution in their cities and devise ways to address these problems (UN-HABITAT, 2006).

Additionally Partnership for Clean Fuels and Vehicles (PCFV) was formed in 2002 as a result of the discussions at the World Summit on Sustainable Development in Johannesburg (UN, 2006). The Partnership addresses urban air quality through the use of clean fuels, namely the use of unleaded gasoline and low Sulphur fuels, and clean vehicle options, focusing on the implementation of clean fuels and vehicles policies in the developing World (UN, 2006). The Clearing House for the PCFV is situated at UNEP headquarters in Nairobi, Kenya. The partners play a role often specified by their geographic proximity interest in certain regions, sectoral expertise and financial capacities. With partner activities identified for the African, Asia/Pacific, Latin America/Caribbean and Central/Eastern Europe regions, the partnership has truly become a global one (UN, 2006).

2.6.3 Government Interventions

Air pollution varies from country to country and the problems associated with it are complex and varied. However, in Kenya road transport sector is by far the main drivers of air pollution especially in the CBD. Other problems associated with road transport include acute traffic congestion, loss of time and increased fuel consumption. The prevalence of old vehicles with poor fuel efficiencies within the city makes the already bad situation even worse. Tackling transport emissions is difficult as it requires major transport and planning policies (SEI, 2009). This therefore calls for government intervention. Some of the interventions the government can put in place include; ensuring efficient transport system, developing policies to address vehicle demand, improving the efficiency of the road vehicle fleet and introducing efficient public transport systems. Implementing such measures could sometimes prove to be challenging but are essential to ensure effective and efficient transport systems. Reduction of air pollution will also require sustained policy action and commitment by governments and other partners. Key elements will be the creation or strengthening of national institutions to implement and evaluate risk reduction programmes and more effective engagement of sectors such as transport, education and finance to capitalize on the potential for greatly reducing population exposures (Alan, David, Margaret & Erica, 2002).

2.6.3.1 Challenges in Managing Air Pollution by Government of Kenya

First and foremost the ambiguous and weak laws remain by far the main challenge faced by Kenya Government in managing air quality. For instance, two sections in the traffic Act Cap. 403 directly address air pollution. Thus section 55 requires vehicle parts and equipment to be maintained at all time in a condition that the driving of the vehicle is not likely to be a danger to the other users of the road while section 58 gives the offense of driving such a vehicle in contravention of section 55 (GOK, 1993). Rule 27(1) under section 119 of the same Act also requires vehicle owners to ensure that their vehicles are so constructed, maintained and used that no smoke or visible vapour is emitted from them. These sections are ambiguous as they fail to provide the standards for the maintenance and emissions from the vehicles. The procedure for determining the degree of the emissions from vehicles is also not provided. It is worth noting that in Kenya issues of climate change and specifically air pollution have not been adequately factored in the country's economy including development policies and plans (GOK, 2010a). Similar challenges are also faced in various legislations that deal with air pollution.

Secondly the available laws are rarely enforced, perhaps due to their weaknesses. However, lack of capacity to enforce them appears to be the main reason. Under the Occupational Safety regulation it is a requirement for employers to provide a safe and healthy work environment to their workers apart from carrying out regular medical examination of their employees. The type of medical examination will depend on the type of hazard to which the employees are exposed (GOK, 2007a). The Act farther requires the employers to cause a risk assessment of the work environment and on the basis of the finding of the risk assessment institute preventive measures. Hardly are these provisions enforced by the Directorate of Occupational Safety and Health in the Ministry of Labour and Human Resource Development. The department is ill funded and poorly staffed.

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Plate 2.1: A vehicle producing excessive smoke from its exhaust while passing a traffic officer at a road block. Weak legislations have made enforcement of pollution laws impossible

2.6.4 Installation of Catalytic Converters

Automotive emissions are controlled in three ways; one is to promote more complete combustion so that there are less by products. The second is to re-introduce excessive hydrocarbons back into the engine for combustion and the third is to provide an additional area for oxidation or combustion to occur. This additional area is called a catalytic converter. The catalytic converter looks like a muffler and is normally located in the exhaust system ahead of the muffler. The catalytic converter is a device placed in the exhaust pipe, which converts hydrocarbons, carbon monoxide, and NO_x into less harmful gases by using a combination of platinum, palladium and rhodium as catalysts. Inside the converter are pellets or a honeycomb made of platinum or palladium. The platinum or palladiums are used as a catalyst (a catalyst is a substance used to speed up a chemical process). As hydrocarbons or carbon monoxide in the exhaust are passed over the catalyst, it is chemically oxidized or converted to Carbon Dioxide and water. As the converter works to clean the exhaust, it develops heat. The dirtier the exhaust, the harder the converter works and the more heat that is developed. In some cases the converter can be seen to glow from excessive heat. If the converter works this hard to clean a dirty exhaust it will destroy itself. Also leaded fuel will put a coating on the platinum or palladium and render the converter ineffective. This is why, in the U.S.A all fuels designed for automobile engines are now unleaded.

2.6.5 Research

Even though the evidence on the relationship between exposure to different air pollutants and health effects has increased considerably over the past few years, there are still large uncertainties and important gaps in knowledge. These gaps can be reduced only by targeted scientific research. This fact received international attention during the United Nations Conference on Environment & Development held at Rio de Janerio, Brazil, from 3 to 14 June 1992 (UN, 1992b). During the conference it was recommended to governments to (i) develop appropriate pollution control technology on the basis of risk assessment and epidemiological research (ii) develop and carry out interdisciplinary research on the combined health effects of exposure to multiple environmental hazards (iii) develop and carry out interdisciplinary research on epidemiological investigations of long-term exposures to low levels of pollutants and the use of biological markers capable of estimating human exposures, adverse effects and susceptibility to environmental agents and finally (iv) develop pollution control capacities in large cities with emphasis on enforcement programmes and using monitoring networks (UN, 1992b).

Areas in which such research is urgently needed therefore, include exposure assessment, dosimetry, toxicity of different components, biological mechanisms of effects, susceptible groups and individual susceptibility (taking into account gene–environment interactions), effects of mixtures versus single substances, and effects of long-term exposure to air pollution (UN, 1992b).

2.6.6 Air Quality Guideline

The WHO Air quality guidelines represent the most widely agreed and up-to-date assessment of health effects of air pollution, recommending targets for air quality at which the health risks are significantly reduced. In the recent years, WHO has investigated and reviewed the effects of different environmental hazards on human health. The European Centre for Environment and Health of WHO's Regional Office for Europe have in particular investigated the health effects of ambient air pollution. The Regional Office published Air quality guidelines for Europe in 1987 (WHO, 1987) and an updated second edition in 2000 (WHO, 2000). The aim of these guidelines were to provide a basis for protecting public health from adverse effects of air pollutants and for eliminating, or reducing to a minimum, those contaminants of air that are known or likely to be hazardous to human health and wellbeing.

Additionally WHO Air Quality Guidelines (AQGs) are intended for worldwide use but have been developed to support actions for healthy air quality in different contexts, acknowledging the need of each country to set up their own air quality standards to protect the public health of their citizens based on local circumstances. They inform policy-makers and provide appropriate targets for a broad range of policy options for air quality management in different parts of the world. Consequently, by reducing air pollution levels, WHO helps countries reduce the global burden of disease from respiratory infections, heart disease, and lung cancer (WHO, 2004).

The systematic review clearly demonstrated the need to set up a more comprehensive monitoring and surveillance programme for air pollution and health in different European cities. Air pollutants to be monitored include coarse PM, $PM_{2.5}$, PM_{10}, ultrafine particles, chemical composition of PM including elemental and organic carbon, and gases such as ozone, nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) (WHO, 2004). The value of black smoke and ultrafine particles as indicators of traffic-related air pollution should also be evaluated.

Furthermore, periodic surveillance of health effects requires better standardization of routinely collected health outcome data. The systematic review also showed that there needs to be a system for maintaining the literature database and for developing the science of meta-analysis for the purpose of monitoring research findings, summarizing the literature for health effects, and health impact assessment. The European Community and national institutions are invited to make appropriate funding available to facilitate the corresponding studies, such as through the forthcoming 7th Framework Programme of the European Community for research, technological development and demonstration activities (WHO, 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Study Design

The study was conducted through non-experimental cross sectional study employing both qualitative and quantitative data collection methods. The sample included traffic police officers who normally control traffic in Nairobi CBD. This design is appropriate and convenient to the researcher’s since the study is limited by time and funds available and according to the argument advanced by Kombo and Tromp (2006), the study design is also both simple and flexible.

3.1.2 Study site

The study was conducted in Nairobi the Capital City of Kenya. Nairobi is situated at an elevation of about 1660 m (about 5450 ft) above sea level in the highlands of the Southern part of the country and 90 miles or 138 Km South of the equator. The City has a population of approximately 3 to 4 million people (CBS, 2009). Nairobi is Kenya's principal economic, administrative and cultural center and is one of the largest and fastest growing cities in Africa that is associated with a vibrant economy that have opportunities for investments and development. The city has some high-rise buildings and lots of bustle especially in the CBD (Plate 3.1 and Fig. 3.1). However, the study was concentrated within the CBD in ten purposively selected sites as shown in Fig. 3.1, 3.2 and 3.3.

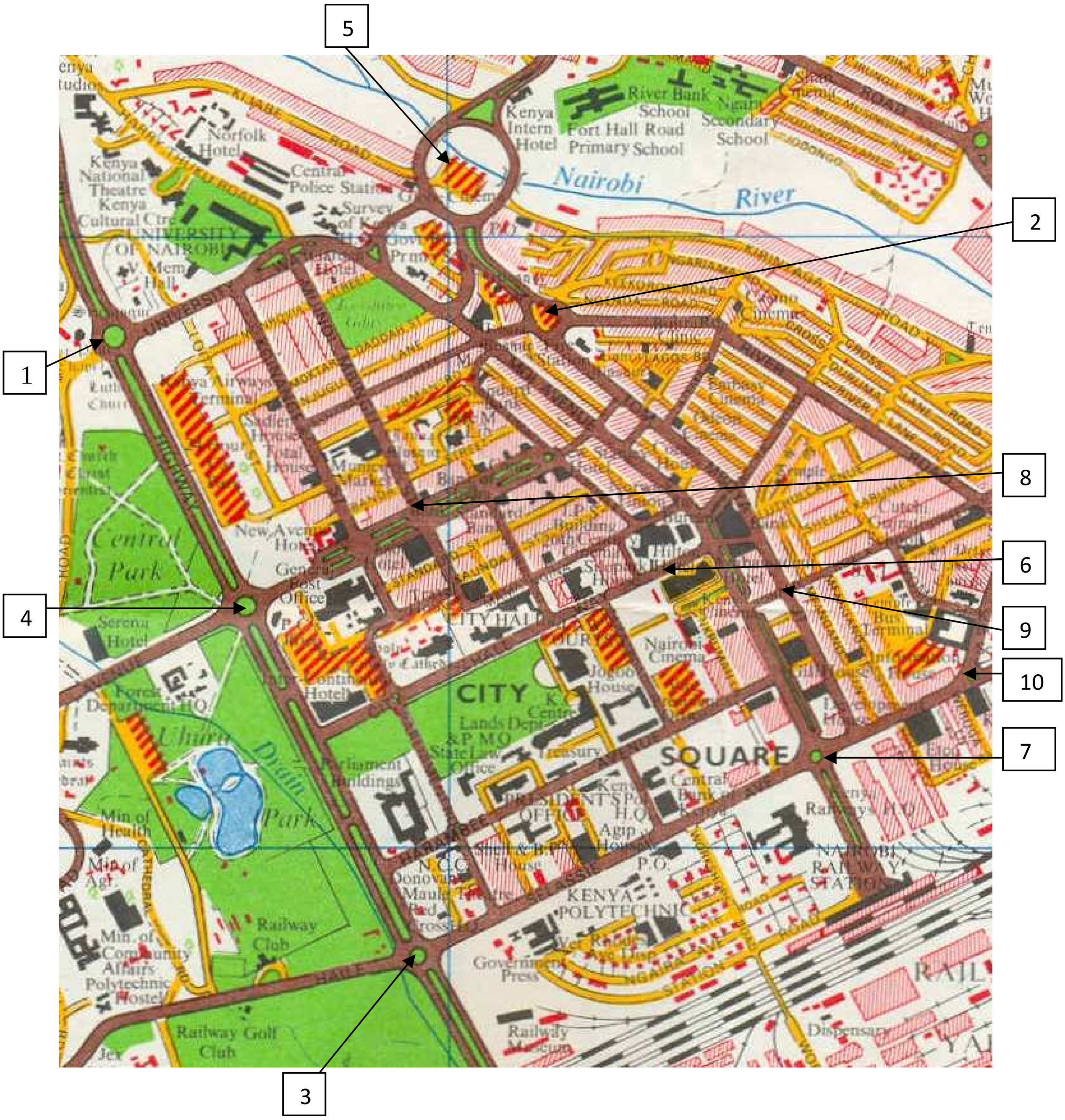


Figure. 3.1: Map showing air sampling points

Table 3.1: Air Sampling Site Notations

	Name of air sampling site	**Notation**
1.	UNIVERSITY WAY ROUND ABOUT………………………..	UWR
2.	FIRE STATION ROUND ABOUT……………………………..	FSR
3.	HARAMBEE SACCO ROUND ABOUT………………………	HSR
4.	NYAYO HOUSE ROUND ABOUT……………………………	NHR
5.	GLOBE CINEMA ROUND ABOUT…………………….…….	GCR
6.	KENCOM BUS STAGE……………………………………...	KBS
7.	BOMB BLAST ROUND ABOUT……………………………...	BBR
8.	JUNCTION OF MUHINDI BINGU & KENYATTA AVENUE	JMK
9.	JUNCTION OF TOM MBOYA AND RONALD NGALA STREET……………………………………………………….	JTR
10.	WAKULIMA MARKET ROUND ABOUT…………………..…	WMR

Plate 3.1: Section of Nairobi CBD

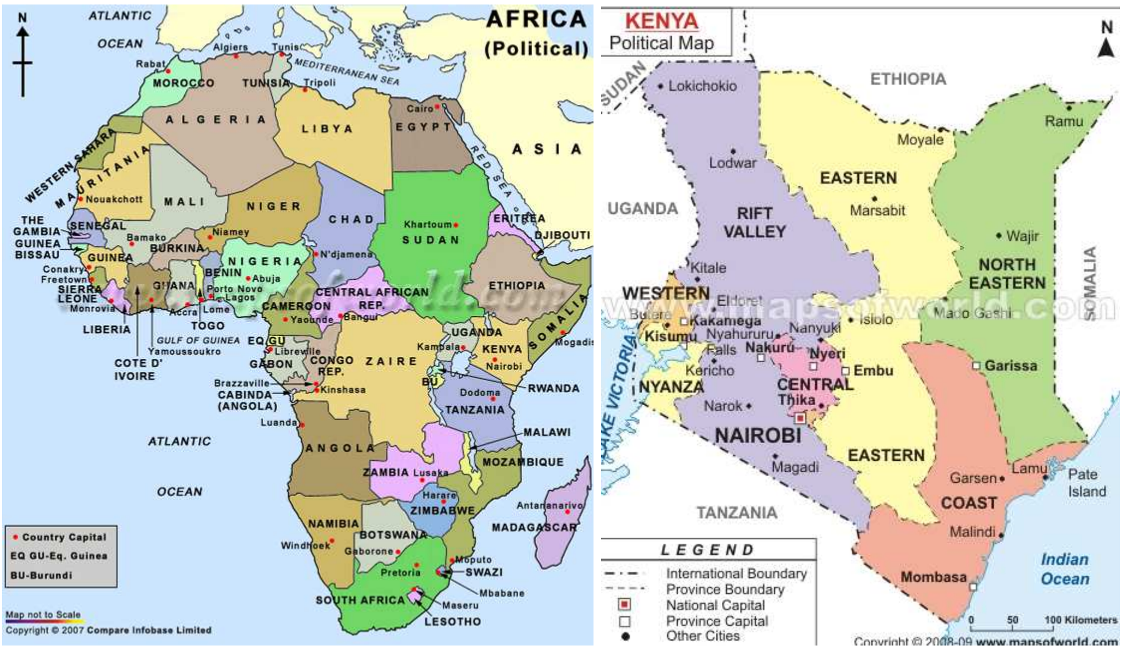


Figure. 3.2: Africa and Kenya map

Figure. 3.3: Map showing the City of Nairobi

3.2 Population and Sampling Techniques

3.2.1 Target Population

The study population (a total of 174 TPO's) was drawn from the traffic department based at Central Police Station and Nairobi Area Police Station who normally operate within the city of Nairobi CBD. These police stations have been purposively selected since most of the traffic police officers controlling vehicles in Nairobi CBD roads with high vehicle density are drawn from these stations.

3.2.2 Sampling Techniques

3.2.2.1 Sample Frame

Table 3.2: Sample Frame

	Population		
	Male	**Female**	**Sub Total**
Central Police Station	27	11	38
Nairobi Area Police Station	117	19	136
Grant Total	**144**	**30**	**N =174**

3.2.2.2 Sample size determination

The sample size was determined by the use of the formula:

$$n = \frac{Z^2 . p . q . N}{(N-1) . e^2 + Z^2 . p . q}$$

(Adopted from Kothari, 2004)

Where "n" represents the sample size and "N" is the size of population, "e" is the acceptable error (The precision) and it shall be taken to be equal to 0.05, "Z" is the statistical constant representing 95% Confidence level (Z = 1.96 as per table of area under normal curve for given confidence level), "p" is the sample proportion (the possibility of success) that is found to have been affected by exposure to automobile emissions.

"q" is the sample proportion (the possibility of failures) that is found not to have been affected by exposure to automobile emissions. "p" and "q" each will be taken to equal to

0.5 where q = 1 - p . This formula was chosen by the researcher's since it is envisaged that information on the exposure assessment to automobile emissions and its effects on the traffic police in Nairobi may not be available. It was considered appropriate since Cooper and Schindler (2008) suggested that when no further information on proportion data is available or no pilot study has been done to generate the variance estimate for the calculation of the sample size then "p" can be assumed to be equal to 0.5. Thus using the formula when N= 176 then n= 120

3.2.2.3 Inclusion Criteria

All police officers from the traffic department based at Central Police Station and Nairobi Area Police Stations and who had worked at these stations for at least three months were eligible to take part in the study. This study therefore employed both stratified and convenience sampling procedures. The first procedure ensured that the total participants selected from each stratum is in proportion to the total number of that stratum to the population as shown in the formula below i.e the number of each stratum is a simple fraction (or percentage) of the total population. This ensures that each sub-group characteristic are taken into account, thus raising the validity of the study (Oso & Onen, 2005). The various police stations therefore constitute the strata and the variance in the sexes, life style (smoking/non-smoking habits, nature of residential places, type of fuels used at home, age, health status etc) of the sample units represented the different characteristics in the sample.

Sub-group Sample Size (n_i) = $\frac{\text{Total sub group population (stratum) size} * n,}{\text{The total population}}$

For i = 1, 2, …..k

Where "n" is the sample size and "k" is the total number of strata and

$$n = n_1 + n_2 + n_3 + \ldots\ldots + n_k$$

Table 3.3: Determination of sample size

Strata	Population			Determined Sample		
	Sub Total	F	M	F	M	Sub Total
Central Police Station	38	11	27	7	19	n_1 =26
Nairobi Area Police Station	136	19	117	13	81	n_2=94
Grant Total	**N =174**	**30**	**144**	**20**	**100**	**n=120**

The study achieved a 97.5% (117) response.

3.2.2.4 Exclusion Criteria

All the other police officers from the other departments based at Central Police Station and Nairobi Area Police Station were excluded from the study.

3.3 Data Collection Procedures and Instrumentation

3.3.1 Instrumentation

The gas levels were determined by use of active method. A gas aspiration pump AP-20 together with detector/dragger tubes (*Appendix iv*) were used to determine the levels of various pollutants (NO_x and CO) while Testo 435 multifunction measuring instrument was used to determine CO_2 levels, wind velocity and temperature (*Appendix v*). The instruments were held at one meter from the ground. The researchers also used structured and semi structured questionnaires (*Appendix viii and ix*), interviews, observations at the sites and document analysis as the main tools for collecting data. Structured and semi structured questionnaires enabled the researcher's to balance between quality and quantity on data collection (Oso & Onen, 2005).

3.3.2 Research Procedure

The researchers first obtained permission from relevant authorities to conduct the study (*Appendix i, ii* and *iii*). The questionnaires were first pre- tested to determine their content validity by being given to a panel of experts. The experts in the research area assessed the relevance of each question item to study objectives and rated each item on a scale of 1 - 4 such that: "1" represented that the question item was "Not Relevant" (NR), "2" is "Somewhat Relevant" (SWR), "3" is "Quite Relevant" (QR) and "4" is "Very Relevant' (VR). All items rated "3" or "4" were regarded as relevant while all those rated "1" or "2" were considered as irrelevant. The ratings of all the experts were pooled and validity of the questionnaire was determined through content validity ratio (CVR) on the basis of the items rated "3" and "4" using the formula:

$$CVR = \frac{n_{3/4} - N/2}{N/2}$$

(Adopted from Oso & Onen, 2005)

Where "$n_{3/4}$" is the number of experts indicating an item as quite relevant and very relevant. "N" is the total number of experts asked to judge the items.

CVR was then converted to content validity index (CVI) by obtaining the average of CVR.

Table 3.4: Determination of Content Validity

		Expert II	
		NR/SWR	**QR/VR**
Expert I	**NR/SWR**	1	2
	QR/VR	10	33
Totals		**11**	**35**

A Content Validity Index of 0.717 was therefore achieved and any CVI with a value of at least 0.70 is accepted as valid (Oso & Onen, 2005). The questionnaire was amended to include the expert's comments and view's before it was administered to the TPO's who happened to be available. The subjects were scored until the required sample size was attained. Two research assistant's help was sought to administer the questionnaires. Observations were also made at the collection sites and recorded. During the study the subjects were assured of confidentiality during the collection of data. Both qualitative and quantitative data was collected between December 2009 and September 2011. Air sampling for CO, CO_2 and NO_x were carried out during periods of high traffic density during the week in the morning (7.00 – 9.00 am), noon (12.00 -2.00 pm) and evening (5.00 – 7.00 pm) at ten purposively selected sites within the CBD (Fig.3.1). Several readings were taken both during the wet season and dry seasons.

3.3.3 Data Analysis Methods

Descriptive and inferential analysis was used to analyze the data. Data was also represented in form of bar graphs, percentages and frequency tables. Computer software Statistical Package for Social Scientists (SPSS) software was used to assist in data analysis. Inferential results are reported at $\alpha = 0.05$ level of significance.

3.4 Limitations

Ideally, this study ought to have been conducted in all major urban centers in Kenya with all air pollution parameters examined e.g suspended particulate matter, xylene, polycyclic aromatic hydrocarbons and noise levels. Conducting medical surveillance and biological monitoring on the subjects would also have provided vital information to confirm the link between an individual's exposure to a specific pollutant and its effect on the subject. But time and financial constraints with regard to the cost of the equipment's to be used for sampling dictated that only a few air pollution parameters are determined at purposively selected sites. Biological monitoring of the participants was also not conducted because of the high expenses for the examinations together with the bureaucracy involved in seeking for approval from the ethic department in the government.

3.5 Ethical Considerations

The participants were not subjected to any risks for volunteering to take part in the study. They were informed of the purpose of the study, the expected duration, the benefits of the study to them and they were also assured of their privacy and confidentiality. The participants were also reminded that they were at liberty to ignore items in the questionnaire that they did not wish to respond to or to withdraw from the study at any time they so wished.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Introduction

This study investigated spatial ambient air quality analysis and its effects on the health of the TPO's within the CBD in Nairobi. The first three objectives of this study were to determine CO, CO_2 and NO_x automobile emission levels within the CBD. To achieve these objectives air sampling was carried out by use of active method technique at ten purposively selected sites within the CBD. Data collected are presented in the sub sections below.

4.2 Automotive Emission levels for CO, CO_2 and NO_x

The results of the CO, CO_2 and NO_x emission levels are presented in Table 4.1. The results in the table show that CO_2 had the highest concentration as compared with the other gases with a mean value of 634.80 ± 47.61 ppm. The highest value of CO_2 was found at JTR sample site with a mean value of 675.25 ± 43.03 ppm while the lowest value was found at sample site BBR with a mean value of 605.50 ± 42.51 ppm. This was followed by CO with a mean value of 12.74 ± 1.14 ppm and the sample site with the highest concentration of CO was KBS with a mean value of 13.63±0.94 ppm while the lowest value of CO was found at sample site UWR with a mean value of 12.26 ± 1.42 ppm. Finally NO_x had very low mean values as compared with both CO and CO_2.

Table 4.1: Automotive emission levels for CO, CO_2 and NO_x , temperature and wind velocity within the CBD, Nairobi

Sampling Point	**CO_2 (ppm) n=100**	**CO (ppm) n=100**	**NO_x (ppm) n=100**	**Temp (^oC), n=100**	**Wind Vel. (m/s) n=100**
UWR	622.25±13.11	12.26±1.42	2.44±0.27	26.90±1.63	1.65±0.20
FSR	660.00±40.55	12.56±1.29	2.56±0.41	27.90±1.70	1.60±0.22
HSR	627.00±50.94	12.56±1.29	2.50±0.46	28.20±1.77	1.46±0.09
NHR	613.50±58.88	12.44±1.12	2.62±0.12	25.60±1.67	1.68±0.46
GCR	655.50±27.57	13.60±1.20	3.02±0.46	28.40±2.24	1.59±0.19
KBS	646.25±29.81	13.63±0.94	3.02±0.60	26.90±2.24	1.29±0.16
BBR	605.50±42.51	12.35±0.71	2.47±0.51	27.80±1.63	1.94±0.21
JMK	614.50±29.39	12.38±1.07	1.52±0.16	27.70±1.86	1.73±0.16
JTR	675.25±43.03	12.56±0.99	2.47±0.18	31.80±0.40	1.58±0.26
WMR	628.25±74.35	13.05±0.37	3.02±0.23	25.30±1.25	1.61±0.33
Mean (Comb)	**634.80**±47.61	**12.74**±1.14	**2.56**±0.55	**27.65**±2.34	**1.61**±0.28

Values are presented as mean ± Satandard deviation, Temp: Temperature, Vel: Velocity, Comb: combined

4.2.1 Test of Hypothesis

The null and alternative hypotheses were considered for the air sampled by applying '*t*'-test at 5% significant level. The results are presented in Table 4.2.

Table 4.2: Summary of the analyses of the hypotheses for automobile emissions

	Pollutant	Mean (ppm)	Null Hypothesis	Alternative Hypothesis	α =0.05
1.	CO	**12.74**	$H_o : \mu = 9$ ppm	$H_a : \mu > 9$ ppm	*P= 0.0026*
2.	NO_X	**2.56**	$H_o : \mu = 0.072$ ppm	$H_a : \mu > 0.072$ ppm	*P= 0.3788*

WHO thresh hold values have been used as test values for CO and NOx .

The results in table 4.1 demonstrated that the emission levels for CO_2 were found to be far much below the thresh hold levels given by Legal Notice No. 60 of 2007. Since CO_2 is normally emitted in any combustion process involving petroleum products, then it follows that CO_2 was quickly diluted by air once emitted into the atmosphere. Additionally the results in table 4.2 show a statistically significant difference between the sample means and the population means for CO and NO_x. Thus the null hypothesis is rejected and the alternative hypothesis is therefore accepted for CO and NO_x that the automobile emission levels were above the WHO thresh hold values for the two gases (CO and NO_x). These results suggest that the traffic police were at risk of being affected by the emissions with continued exposure. The recommended WHO thresh hold values for CO is given as 9 ppm for 8 hours TWA while for NO_x it is given as 0.072 ppm (120 µg/m^3) for 8 hrs TWA and 0.024 ppm (40 µg/m^3) for annual mean and finally 0.12 ppm (200 µg/m^3) 1-hour mean for a short term exposure (WHO, 2000).

These findings are consistent with the findings of Atimtay, Emri, Bagci and Demir (2000); Jinsart, Tamura, Loetkamonwit, Thnondh, Karita and Yano (2002) and Volpino *et al.*, (2004). Atimtay *et al.*, (2000) had reported in his study in Ankara the capital city of Turkey that the traffic policemen were the population group under risk due to their inhalation of CO rich air while on duty at the crowded cross-sections of the city. Jinsart *et al.*, (2002), reported in Bangkok, Thailand that traffic police who were exposed to high levels of automobile derived particulate air pollution showed higher prevalence of respiratory disorders. And finally Volpino *et al.*, (2004), also reported in Rome, Italy that chronic occupational exposure to urban pollutants of traffic police personnel reduces resistance to physical effort and increased risk of cardiovascular and respiratory changes including slight hypoxemia. The results also agrees with the findings of Bell (2006), Marika (1993) and Parmeggiani (1983) who asserted that any health effects of any pollutant are dependent on its toxicity.

Additionally, Devlin (2004), EPA (2002), Finkelstein and others (2004) and WHO (1999a) also demonstrated that exposure to automobile pollution has devastating effects on people's health. Several epidemiological studies have also shown an association between air pollution and adverse health outcomes (Schwartz, 1994). This study also revealed that the probable cause for the high concentrations of the pollutants within the CBD were the high number of second hand vehicles plying the CBD with a majority of them having been used elsewhere hence their combustion efficiency have seriously been compromised leading to excessive emission of pollutants (Carl- Elis, 1993; Maina *et al.*, 2005). Lack of regular maintenance and tune up of the vehicles especially by public transport vehicles owners, traffic congestion, lower wind speed within the CBD and lack of fitting catalytic converters on the vehicles were other probable factors that made the already bad situation worse (Bell, 2006; Maina *et al.*, 2005).

4.2.2 Determination of Pearson's Coefficient of Correlation

Bivariate analyses were conducted on the parameters of air sampled by determining Pearson's Coefficient of Correlation. The results were further tested applying '*t*' test to determine the significance of correlation obtained. It was assumed that the samples were drawn from a population with zero correlation coefficient.

Thus: H_o: $\rho = 0$ and H_a: $\rho \neq 0$

Table 4.3: Summary of Pearson's Coefficient of Correlation between CO_2, CO and NOx with temperature and wind velocity

Sample (n=100)	**(Temperature)**			**(Wind velocity)**		
	ρ_{xy}	ρ^2_{xy}	$\alpha = 0.05$	ρ_{xy}	ρ^2_{xy}	$\alpha = 0.05$
CO_2	0.511	0.261	p = 0.046	-0.745	0.555	p = 0.118
CO	-0.123	0.015	p = 0.804	-0.767	0.558	p = 0.055
NO_x	-0.210	0.044	p = 0.573	-0.480	0.230	p = 0.195

The results in table 4.3 show a fairly moderate degree of positive correlation between CO_2 with temperature (ρ_{xy} = 0.511) while a weak negative correlation between CO (ρ_{xy} = -0.123) and NO_x (ρ_{xy} = -0.210) with temperature respectively was observed. This perhaps shows the important role played by NO_x in the formation of O_3 at elevated temperatures. This agrees with the results obtained by Odhiambo and others (2010) who in their study demonstrated that there existed a positive correlation between O_3 with temperature (ρ_{xy} = 0.66) with a diurnal cycle for O_3 and NO_x being observed in the mid-day and most parts of the afternoon. They were able to demonstrate that O_3 increased with a decrease in the concentration of NO. They also observed high correlation between NO and vehicle density (ρ_{xy} = 0.94) and concluded that motor vehicle exhaust contributed to high proportions of NO.

The positive correlation between CO_2 with temperature and the negative correlation between CO with temperature suggests that temperate also plays a critical role in the combustion process. The amount of CO produced is therefore a good indicator of the combustion efficiency of the engine since in any combustion process involving petroleum product, CO_2 and water must be produced as by products. It should be mentioned here that the more CO_2 and the less CO is produced in any combustion process suggest improved combustion efficiency. However, only 26.0%, 1.0% and 4.0% of these variations in CO_2, CO and NO_x respectively were accounted for by the linear relationship with temperature.

The above results also demonstrated a fairly high degree of negative correlation between CO_2 (ρ_{xy} = -0.745) and CO (ρ_{xy} = -0.767) with wind velocity while a moderate negative correlation between NO_x (ρ_{xy} = -0.480) with wind velocity was observed. Fifty five point five percent, 55.8% and 23.0% of these variations in CO_2, CO and NO_x respectively were accounted for by the linear relationship with wind velocity.

The p - values further suggested that the correlation coefficient of all the parameters sampled with temperature were not significant while on the other hand the p - values for the association of the parameters with wind suggested that the correlation coefficient were significant except for NO_x. The results also revealed that the highest concentrations of the pollutants were obtained when the wind speeds were lower. These results are comparable with the results that were obtained by Odhiambo and others (2010), in their research where they demonstrated that higher O_3 concentrations were observed during lower wind speeds. This provided evidence that wind plays a crucial role in the dilution of the pollutants once emitted from the source and therefore at lower wind speeds dilution of the pollutants is retarded as the transportation of pollutants away from the point of emission is reduced. However, other probable factors that affects wind velocity include the development of high rise structures within the CBD and pressure differences prevailing at any one time (Bell, 2006). This condition significantly reduces wind speed that now impedes air circulation which finally leads to the accumulation of toxins once emitted.

4.3 Analysis of questionnaire responses

The traffic police officers were asked to react to given statements on a questionnaire. Their response to the questionnaire items are presented below.

4.3.1 Sex, Age, Marital Status, Number of Children and Smoking Habits

Table 4.4: Sex of the TPO’s

Sex	Frequency	Percent
Male	100	85.5 %
Female	17	14.5 %
Total	**117**	**100 %**

Table 4.4 show that 100 (85.5 %) of the officers who took part in the study were male while only 17 (14.5 %) were female. These results revealed that deployment of officers in the traffic department in Nairobi is still in breach of part II, section 27 subsection 3 as read together with subsection 8 of the constitution of Kenya which states that women and men have the right to equal treatments including the right to equal opportunities in political, economic, cultural and social spheres and that not more than two-thirds of the members of elective or appointive bodies shall be of the same gender (GOK, 2010b).

Table 4.5: Age of the TPO’s

Age Bracket	Frequency	Percent
18 - 25 years	9	7.7 %
26 - 35 years	71	60.7 %
36 - 45 years	35	29.9 %
46 years and above	2	1.7 %
Total	**117**	**100 %**

The age of the officers studied are shown in table 4.5. The results show that a greater majority of those exposed 90.6 % (106) were in the age bracket between 26 and 45 years. This ordinarily represents the most product group in any society. The results therefore suggest that exposure of this group to pollutants and subsequent effects on their health will have a significant negative impact on the effectiveness and efficiency of the traffic department.

Table 4.6: Marital Status

Marital Status	**Frequency**	**Percent**
Married	101	86.3 %
Not Married	16	13.7 %
Total	**117**	**100 %**

Table 4.7: Number of Children in each family of TPO's

No. of Children	**Frequency**	**Percent**
No Children	5	4.3 %
1 - 3 Children	96	82.1 %
4 - 6 Children	16	13.7 %
Total	**117**	**100.0 %**

The marital status and number of children's the TPO's have in their families are shown in table 4.6 and 4.7. The results from the tables show that 86.3 % (101) TPO's were married while 82.1 % (96) had between 1- 3 children. Only 13.7 % (16) of the officers interviewed had between 4 - 6 children. From the results a significant number of the TPO's 95.8% (112) studied had sired children this therefore suggest that exposure to the pollutants had not significantly affected their fertility contrary to expectation and as was argued by Craig and others (2010) in their study that exposure to air pollution have effects on sperm concentration, count and morphology. However, it must be emphasized that the risks of the effects of exposure to automobile air pollution to the TPO's taking place in future still existed.

Table 4.8: Smoking Habits of the TPO's

Smoking Habit	Frequency	Percent
Smokes	9	7.7 %
Do Not Smoke	108	92.3 %
Total	**117**	**100 %**

The results in table 4.8 show that 92.3 % (108) of the TPO's were nonsmokers while only 7.7 % (9) were smokers. This suggest that smoking as a confounding factor in this study did not significantly affect the outcome of the study and any health effects was to a great extent attributed to automobile air pollution and not to smoking. These results agrees with the 2012 World Health Statistic that indicated that current daily tobacco smoking in Kenya is estimated at 9.3% (Gathura, 2012). These results also compares well with the findings of Sharat *et al.*, (2011), who had observed from his study that there was a significant decline in various parameters examined such as forced vital capacity (FVC), forced expiratory volume in one second (FEV), and peak expiratory flow rate (PEFR) on the exposed nonsmoking TPO's when compared with the controls. It was also observed that in traffic policemen with >8 years of exposure, the values of FVC (2.7 L), FEV (1.8 L), and PEFR (7.5 L/s) were significantly lower than those obtained in traffic policemen with <8 years of exposure, in whom the values were 2.9 L, 2.3 L, and 7.7 L/s for FVC, FEV and PEFR respectively. He therefore came to the conclusion that the respiratory effects of air pollution among nonsmoking traffic policemen of Patiala, India was majorly due to vehicular exhausts.

4.3.2 Place of Residence and Energy Used for either Cooking or Lighting

a) Place of Residence

Table 4.9 show the place of residence for the TPO's. From the table, 48.8% (57) of the TPO's resided in or close to the CBD i.e Kamkunji and Central Police staff quarters, 22.3 % (26) resided close to the CBD i.e in Pangani, Umoja and Eastleigh Estates, 3.4% (4) resided in an Industrial set up, 1.8% (2) officers resided in areas referred to as informal settlements i.e Mathare and Baba Dogo. 23.7% (28) of the TPO's resided in other places away from the CBD. These results show that the officers besides being exposed to pollutants during working hour a significant number of them 48.8% (57) still resided in areas that are suspected to be polluted with automobile emissions i.e staying in/or close to the CBD. This therefore suggested that a significant number of the officers were still exposed after work. These results are consistent with the findings of a study carried out by Kinney and others (2000) in Ontario Canada, which demonstrated that there was an increased risk of mortality from heart and lung diseases in people living within 100 meters of a roadway.

Table 4.9: Place of Residence of the TPO’s

Place of Residence	Frequency	Percent
Langata	7	6.0%
Pangani	18	15.4%
Kamkunji	32	27.4%
Umoja	3	2.6%
Kasarani	10	8.5%
Central Police Station	25	21.4%
Embakasi, Utawala, Quarry, Industrial Area,	4	3.4%
Baba Dogo	1	0.9%
Esatleigh	5	4.3%
Mathare	1	0.9%
Ngong	2	1.7%
Others	9	7.7%
Total	**117**	**100%**

b) Energy Used for either Cooking or Lighting

The TPO’s were also asked to state the form of energy they used for cooking and lighting most of the time and their responses are shown in Table 4.10.

Table 4.10: Frequency distribution table for the forms of energy used for Lighting/Cooking at home by the TPO's

Form of energy	**Cooking**		**Lighting**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Paraffin	33	28.2%	3	2.6%
Firewood	3	2.6%	0	0.0%
Gas	53	45.3%	2	1.7%
Electricity	17	14.5%	112	95.7%
Charcoal	11	9.4%	0	0.0%
Totals	**117**	**100.0**%	**117**	**100.0**%

The results show that 95.7% (112) of the TPO's prefered to use electrity as the main form of enegy for lighting while a small percentage of 2.6% and 1.7% prefered to use paraffin and gas respectively. However, when it came to cooking, there is a shift from the use of electricity as the prefered form of energy. The results show that 45.3% (53) of the TPO's prefered gas, followed by 28.2% (33) who prefered paraffin while 14.4% (17) prefered electricity as the form of energy for cooking. Only a few 9.4% (11) and 2.6% (3) of the TPO's prefered charcoal and firewood respectively as the form of energy for cooking.

There are three major findings from the results. First the results show that electricity is easily accessible in the city suggesting wide spread connectivity. Second, the TPO's preffered to use electricity as the main form of energy for lighting while gas was preffered as the form of energy for cooking. This could be attributed to the high electricity bills making the officers to prefer other forms of energy for cooking. And finally, the results suggests that indoor air pollution exposure may not play a significant role in affecting the health of the TPO's since a majority of the TPO's used form of energy that is clean burning.

4.3.3 Period of Exposure

a) Year of Employment in the Police Force

The year in which the officers were employed in the police force is shown in Fig. 4.1.

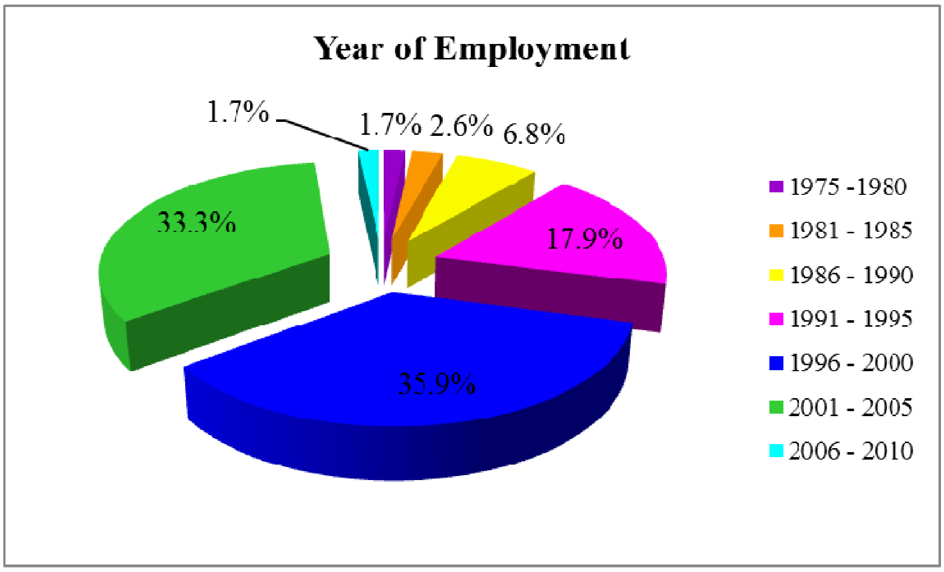
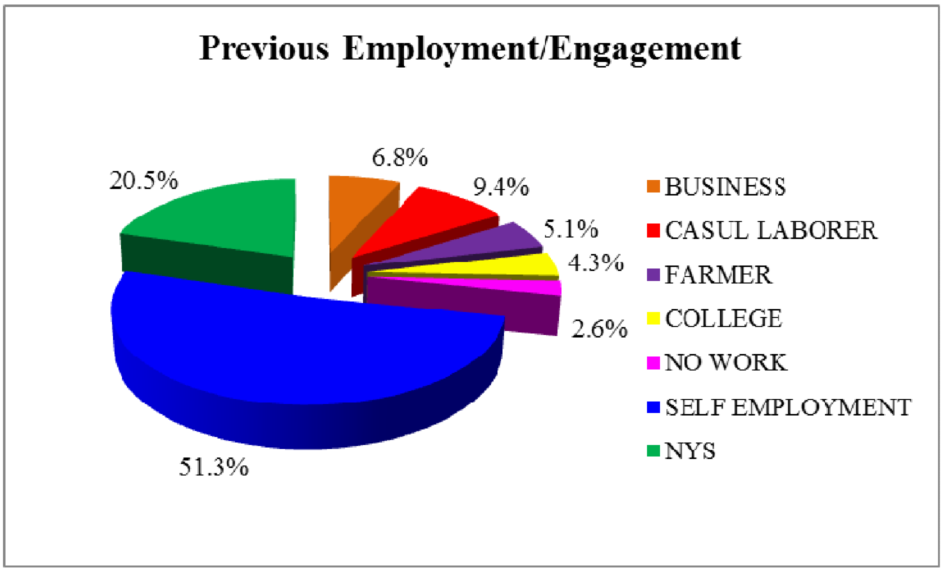


Figure. 4.1: Year of Employment of the TPO's in the police force

The result shows that 35.9% (42) of the TPO's were employed in the police force between the years 1996 and 2000; followed by 33.3% (39) TPO's who were employed between the years 2001 and 2005. Only 8 (6.8%) were employed between the year 1986 and 1990 while 2.6% (3) were employed between the years 1981 and 1985. And finally 1.7% (2) of the TPO's each were employed between the years 1975 - 1980 and 2006 - 2010 respectively. The results indicate that the longest serving officer studied had worked for at least 36 years while a significant number of the officers studied had worked in the police force for at least 15 years since employment.

b) Previous Employment

The nature of the TPO's previous engagement before employment in the police force is presented in Fig. 4.2



NYS-Naional Youth Service

Figure. 4.2: TPO's pevious employment before employement in the police force

The results in Fig. 4.2 show that 51.3% of the officers were self-employed, 20.5% were in the National Youth Service (NYS), 9.4% were casual laborer's, 6.8% had engaged in business, 5.1% were farmers while 4.3% and 2.6% were in college and had no work respectively before being employed in the police force. These results indicate that the TPO's were not engaged in any hazardous activities prior to being employed in the police force.

c) Period Worked in Nairobi CBD as TPO

Table 4.11: Frequency distribution table showing period worked in Nairobi as TPO

Period worked in Nairobi CBD	Frequency	Percent %
Less than one year	19	16.2%
Between 1 & 2 Years	47	40.2%
Between 2 & 3 Years	21	17.9%
Over 3 Years	30	25.7%
Total	**117**	**100%**

The results in table 4.11 show that 68.1% (68) the TPO's had worked in Nairobi CBD as TPO's for between one and three years while 25.7% (30) had worked for more than three years while only 16.2 % (19) officer had worked for less than one year in the CBD as TPO's. The average year worked in Nairobi CBD by the traffic officers was 2.5 years.

d) Period Spent at the sample sites by TPO's while discharging their duties

Fig. 4.3 show the period spent at the sample sites by TPO's while discharging their duties. The results above show that 84.62% (99) TPO's studied spent the mandatory eight hours or more at the sample sites while only 11.96% (18) spent 8 hours or less while discharging their duties. The average hours spent at the sample site was 10 hours. Ideally there are two shifts of eight hours each for the traffic police officers who work in the CBD. The morning shift starts at 6.00am and end at 2.00 pm while the afternoon shift commences at 2.00 pm and ends at 10.00 pm. Each shift is eight hours. However, when an officer falls sick or has to leave because of other reasons, his or her duties must be taken over by other officers.

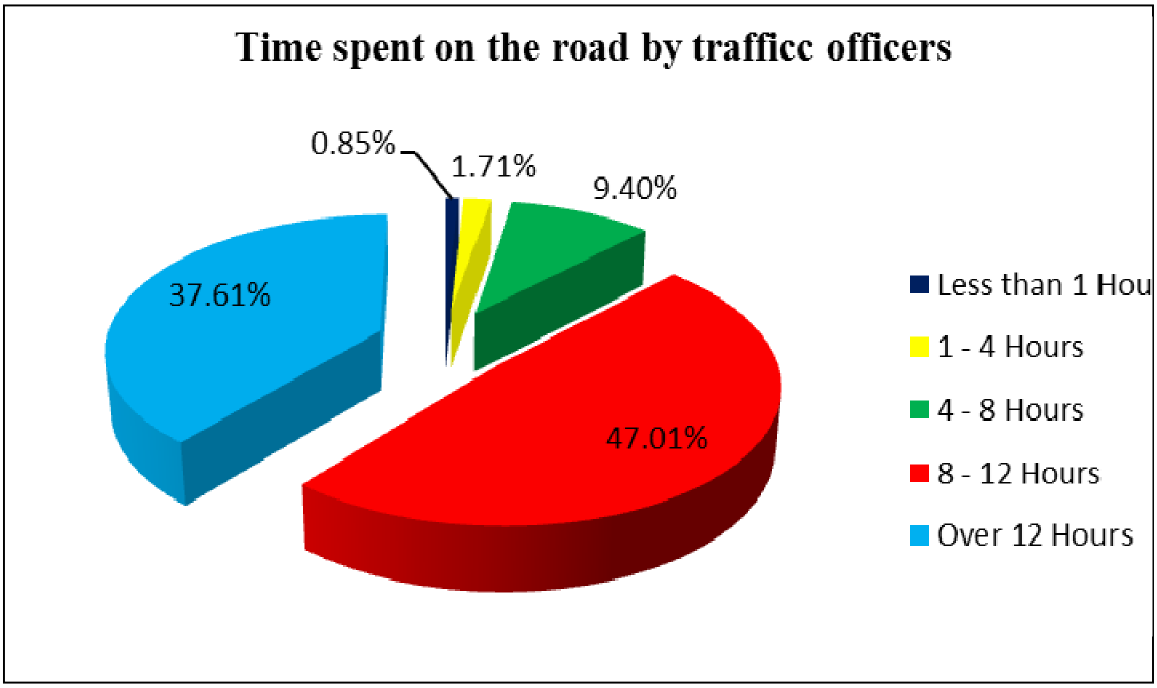


Figure. 4.3: Period spent at the sample sites by TPO's

But because of the limited number of officers, at times one repeats a shift. This fact was illustrated when a many of TPO's interviewed stated that they spent more than twelve hours on the road while discharging their duties in the CBD. Other factors that require traffic officers to spend more time on the road included increased human traffic and non-operational traffic lights within the CBD. The officers have to be physically present to control the traffic both humans and vehicles in the CBD. It is also worth mentioning that a few of the operational traffic lights in the CBD are rarely followed by road users.

The above results further suggest that although the average period worked in Nairobi CBD by the TPO's was 2.5 years, 25.7% (30) of the officers had worked in the CBD for more than three years and a significant percentage 84.62% (99) of the TPO's were exposed for long periods on daily basis. This coupled with the high concentrations levels of the pollutants as already discussed above predisposes the TPO's to the effects of automobile air pollution. This therefore provides credible evidence that suggest that the TOP's were at risk of being affected by the pollutants with continued exposure.

These results compares well and could be corroborated with other studies previously carried out and reported elsewhere in other parts of the world (Peters *et al.,* 1999; Zemp *et al.*, 1999; Nanda Kumar *et al.,* 2009; Gauderman *et al.,* 2000; WHO, 2002; Finkelstein *et al.,* 2004; Bell, 2006 and Michael and Konstantinos, 2008). Nanda Kumar *et al.,* (2009), in their study among 80 TPO's in Tirupati, India observed that there was a significant statistical correlation between period of exposure and an increase in admission rate for respiratory disorders. They observed that traffic police personnel who were occupationally exposed for longer period in their life reported to have more number of admissions than traffic police with less exposure periods. They further observed that there were 58 reports for respiratory disorders among 15 traffic police personnel who were occupationally exposed for five years while there were 37 admission reports among 5 traffic police who were exposed for 6 years. The percentages of admission into hospital as outpatients from 1 to 4 year period of exposure ranged from 0.36% to 34.66% whereas for traffic police who were exposed for 5 years and 6 years the % admission was 20.93 and 13.35% respectively. The admission rate for 1 year was low and then showed a steep and gradual increase from 20 to 404 from 1st year to 4th year of service. Zemp *et al.*, (1999), also reported in Basel, Switzerland that there existed an association between long-term exposure to ambient air pollution and respiratory symptoms. Similar trends were observed by the investigator where there was more number of admissions among the traffic police personnel who were exposed for 6 years. Bell (2006), Finkelstein and others (2004), Peters others (1999), WHO (2002), Michael and Konstantinos (2008) and Gauderman and others (2000) all argued and demonstrated that the health effects of any pollutant is dependent on the period of exposure and the target organ affected.

4.3.4 Traffic Density in the CBD in Nairobi

a) Period of the Day when Traffic Density is relatively high in the CBD in Nairobi

Those studied were also asked to state when traffic density is relatively high within the CBD. The results are presented in Fig. 4.4a, 4.4b and 4.4c below.

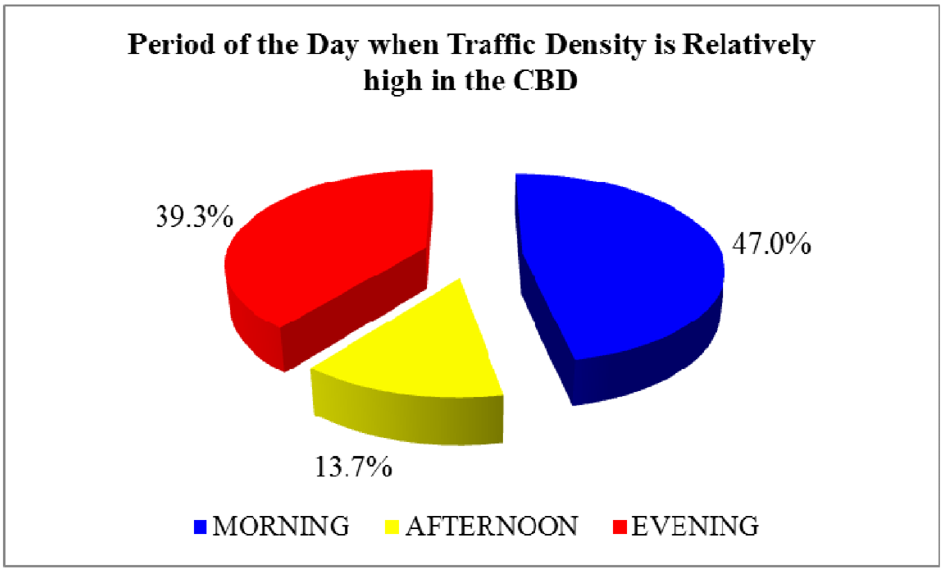


Figure. 4.4a: Period of the day when traffic density is high in the CBD

The results in Fig. 4.4a show that 47.0% (55) of the TPO's reported that the traffic density was relatively high in the morning followed by 39.3% (46) who said that it was high in the evening while 13.7% (16) of the TPO's felt that traffic was high during the afternoon. The relatively high traffic densities reported in the morning and evening could be attributed to the morning and evening rush hours.These results are comparable with the findings of Odhiambo and others (2010) who demonstrated in their study that the highest concentrations of NO_x were obtained in the morning and evening rush hours. They further concluded that motor vehicles were probably the main source of the gaseous pollutants as there existed a high positive correlation between NO and motor vehicle density.

b) Day of the week when Traffic Density is high in the CBD in Nairobi

The TPO's responses on the day of the week with the highest traffic density are shown in Fig. 4.4b below.

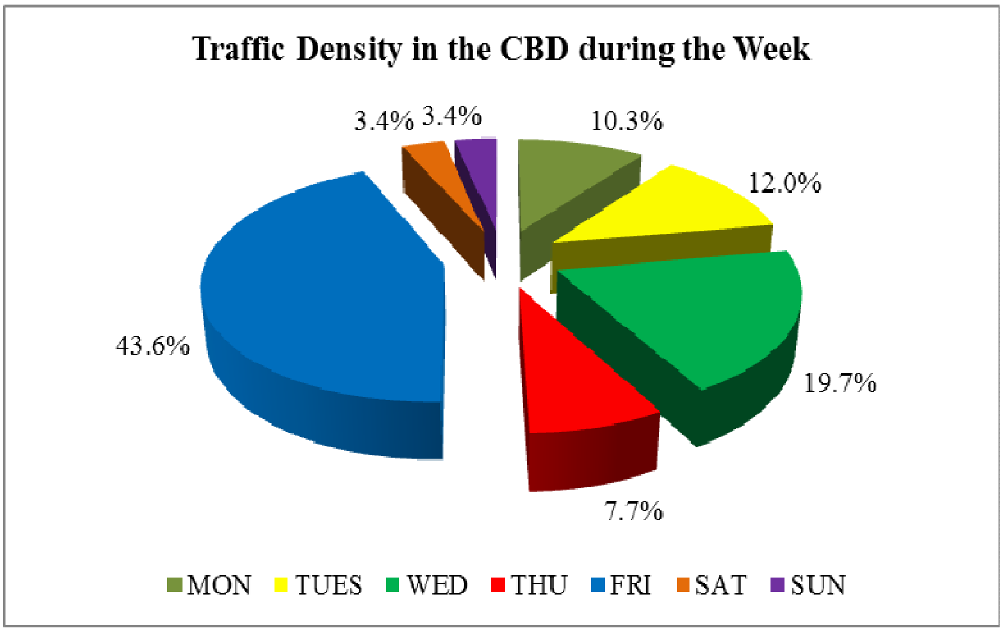


Figure. 4.4b: Day of the week when traffic density is high in the CBD

The results above show that 43.6% (51) of the TPO's reported that traffic density was high in the CBD on Friday, 19.7% (23) indicated that it was high on Wednesday while 12.0%

(14) were of the opinion that it was high on Tuesday. Ten point three percent (12), 7.7% (9) and 3.4% (4) each of the TPO's reported that the traffic densities were high in the CBD on Monday, Thursday, Saturday and Sunday respectively. This could be due to the fact that Nairobi is a commercial city where people come to transact business during the week and return back to their rural homes at the end of the week. Monday therefore represent when they come to the city for business while Friday represent when a majority of them travel back to their homes.

c) Period of the Month when Traffic Density is high in the CBD in Nairobi

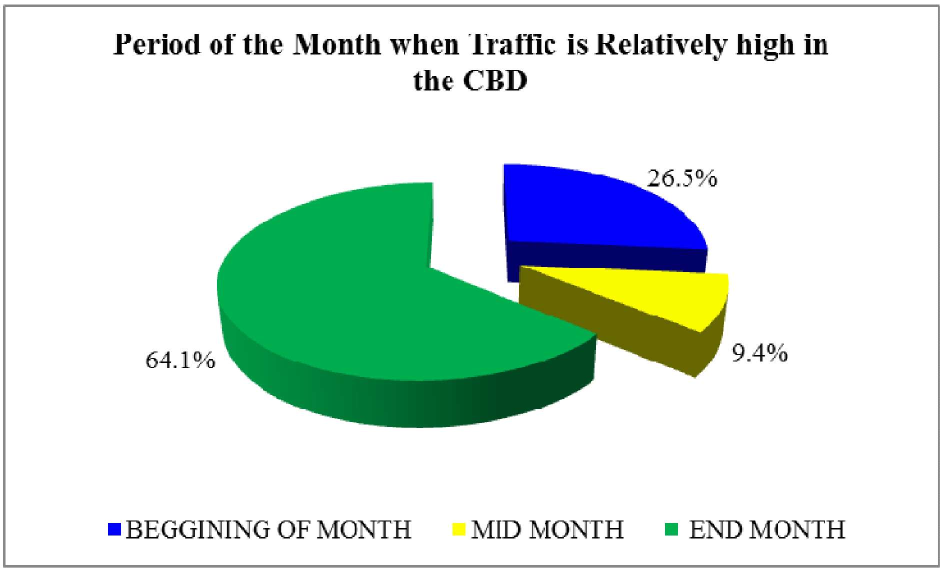


Figure 4.4c: Period of the month when traffic density is high in the CBD

From Fig. 4.4c above, 64.1% (75) of the TPO's interviewd felt that traffic density was relatively high in the CBD at the end of the month followed by 26.5% (31) who said that it was high at the begging of the month while 9.4% (11) felt that traffic density was relatively high during mid month. The explanation that perhaps could be given for the high densities at the end month and beggining periods of the month is that these represent the time when most people have receicved their salaries or still have money and therefore are able to fuel their vehicles. This suggest that traffic congestion in the CBD at the end or begining of the month is contributed to a great extent by personnal cars since public transport vehicles are always on the road as transportation is their core business.

4.3.5 Effects of Automobile Pollution on the Health of the TPO's

The TPO's interviewed were asked to react to a number of statements related to how they feel once exposed to the automobile air pollution gases. A summated scale was used to assess the interviewees opinion on the questionaire items. This consisted of a number of statments which express either a favourable or unfavourable attitude towards a given object/feeling to which the interviewee is asked to react. They were therefore to agree or disagree to the given statements. A five point likert scale was used and their responses were scored and recorded. A score of 40 to 65 showed favorable response and a score of 39 showed a neutral response while a score of less than 39 showed a unfavourable response. The results are presented in table 4.12 below.

a) Effects of exposures to Automobile emmissions in the CBD

Table 4.12: Effects of exposure automobile exposure to automobile polution on the TPO's

Effects of exposure to automobile emission	Favourable response	Neutral response	Unfavourable response	Total
Frequency	103	12	2	**117**
Percent	88.0%	10.3%	1.7%	**100.0%**

The results in table 4.12 show that 103 (88%) of the TPO's reported to have been affected by the pollutants in their work environment after exposure. This was followed by 12 (10%) of the TPO's who reported a neutral position while only 2 (2%) TPO's reported that they were not affected. The two included the TPO's in the two station who exercised supervisiory duties and spend most of their time in the office. The officers mainly compained of sneezing, flu, irritation of the throat, nose, eyes and lungs. These results are comparable to the fndings of Proietti and others (2005), who demonstrated from their study in Catania, Italy that a truly exposed traffic police officers assigned to direct traffic suffered a greater prevalence of symptoms (Cough, wheeze and dyspnoea) and positive reaction to skin allergy tests compared with the truly non-exposed group i.e. Traffic police officers working in administrative offices.

b) Day of the Week when Effects of exposure to Automobile emissions were most felt

The TPO's were asked to state on which day or days of the week they were most affected by the air pollution in their work environment. Their responses are presented in Fig. 4.5 below.

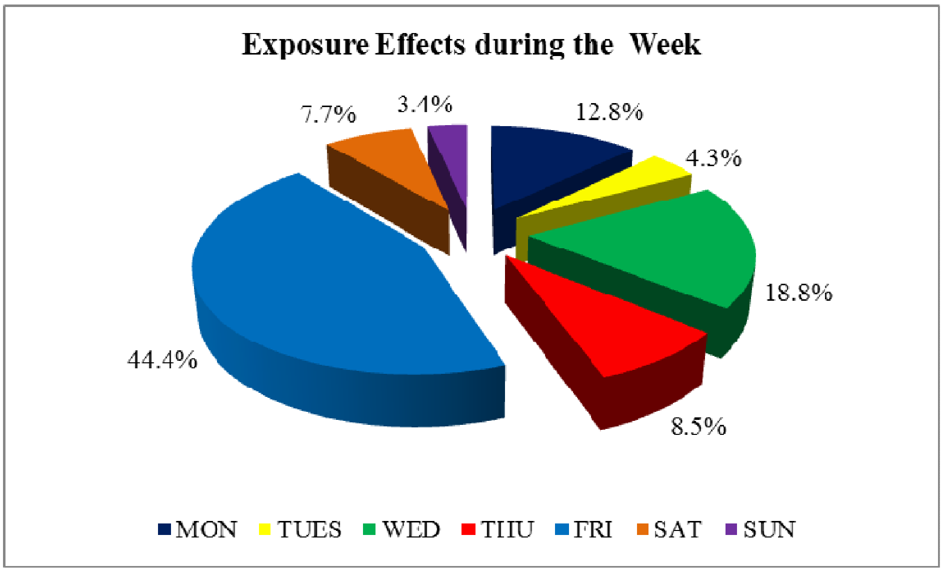


Figure. 4.5: Day of the week when TPO's are most affected after exposure to automobile pollution in their work environment

The results in Fig. 4.5 show that 44.4% (52) of the TPO's reported that the effects of exposure to automobile emission were felt most on Friday, followed by 18.8% (22) and 12.8% (15) who stated that it was felt on Wednesday and Monday respectivley. These results show that the effects were felt most as the days progressed from Monday through out the week.

c) The association between Traffic Density and Exposure Symptoms

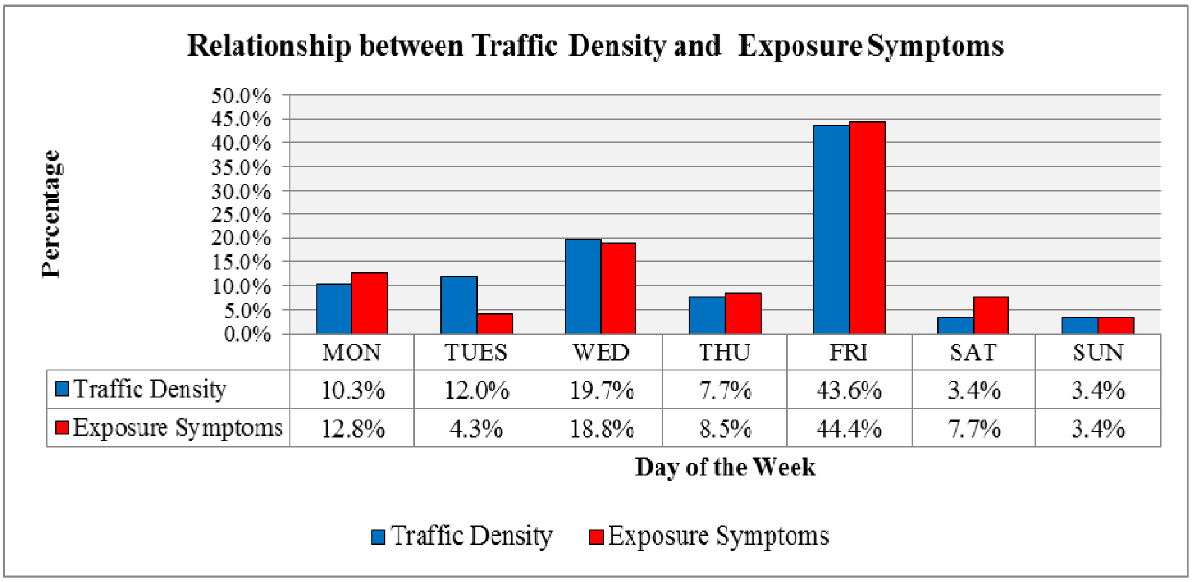


Figure. 4.6: Relationship between Traffic Density and Exposure Symptoms

From Fig.4.6, it is observed that there was some relationship and consistency observed between the day when the effects were most felt and the day when traffic density was reported to be high in the CBD. This is most likely due to the cumulative effects of the pollutants on their host as days progressed on and the concentration of the pollutants on these days. These results agrees with the findings of Bell, (2006) who reported in his study that the health effects of the pollutants in an individual is directly dependent on the exposure period and toxicity of the pollutant.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This study investigated automobile emissions and their effects on the traffic police within the CBD in Nairobi. This was in relation to the fact that little research work has been carried out in Kenya to determine the levels of automobile emissions and specifically to investigate their effects on the TPO's. The study specifically sought to determine CO, CO_2 and NO_x automobile emission levels within the CBD and their effects on the health of the TPO's who are normally stationed in the CBD to discharge their duties. The study also sought to suggest appropriate strategies and measures to mitigate or prevent any effects arising from air quality within the CBD in Nairobi.

5.2 Conclusions

In view of the findings in this study we wish therefore to conclude as follows:

i. Automobile emissions levels sampled for CO_2 had a mean of 634.80 ± 47.61 ppm. This was far much below the recommended OEL -CL values for the gas based on objective one.

ii. Automobile emissions levels sampled for CO had a mean of 12.74 ± 1.14 ppm. This was above the WHO thresh hold values for the gas based on objective two.

iii. Automobile emissions levels sampled for NO_x had a mean of 2.56 ± 0.55 ppm. This was also above the WHO thresh hold values for the gas based on objective three.

iv. The TPO's who were exposed to these pollutants were at risk of being affected by the pollutants with continued exposure or are already affected since a significant number of them 88% (103) reported to have been affected by the pollutants in their work environment based on objective four.

5.3 Recommendations

We have argued that the TPO's and indeed the public are at risk of being affected by exposure to automobile pollution as a result of high concentrations levels of the automobile emissions. This condition is further worsened by the suppressed wind velocity within the CBD. We have also argued that the TPO's spend more time at the ample sites while discharging their duties. It is against these back ground that the recommendations below are made. Despite its limitations, this study ought to have been conducted in all major towns with major pollutants analyzed e.g VOC, PAH, particulate matter etc. Conducting medical surveillance and biological monitoring on the subjects would also have provided vital information to confirm the link between an individual's exposure to a specific pollutant and its effect on the host. Basing generalization on the findings of this study, the researcher's recommends the following:

I. Primary Preventive Measures

a) It is imperative that appropriate air quality management capabilities be establish in major towns through harmonization of transport activities, emissions data tracking and reporting to monitor the state of ambient air. This will involve:

   i. Monitoring of air quality at designated air quality monitoring centers,

ii. Compiling pollutant emissions inventory for reference and forecasting,

b) It is important to establish and enforce air quality standards that are in line with WHO air quality guidelines including introduction of a legislation that imposes additional tax on vehicles that have attained a certain age or mileage so as to discourage old vehicles from the roads. Additionally there is need to establish mandatory automobile emissions testing programs for all vehicles to monitor vehicular emissions through formulation and enforcement of legislations for such programmes. It must also be mandatory under the law for vehicles that have attained a certain age or mileage to be fitted with catalytic convertors,

c) There is need to establish as a priority automobile air pollution policies that aim at reducing the exposure of the general population and a reduction in the overall health burden caused by automobile air pollution,

d) There is need for the government to prioritize automobile air pollution and allocate adequate funds to automobile air pollution activities including research programmes,

e) Air pollution should also be adequately factored in the country's economy including development policies and plans,

II. Secondary Preventive Measures

a) There is need to reduce the period of exposure of the traffic police officers to the emissions by :

   i. Establishing and implementing a system of rotation of duties for the officer's e.g alteration of field work with office work,

ii. Reducing the number of officers exposed at any given time by ensuring that the traffic lights within the city are always operational and are followed by the motorists. This can be achieved through the installation of closed circuit television (CCTV) cameras to monitor movement of vehicles from a central command location. It is also recommended that austerity measures be taken against all vehicle owners found to be in breach of traffic regulations. The few officers to be stationed on the roads will only have the task of apprehending offenders and respond to traffic emergencies and not to control traffic,

iii. Exposure can also be reduced by providing the TPO's with suitable personal protective devices such as masks and plain glasses to prevent lung and eye irritations. They should also be trained on their use, the type of air pollutions and associated health hazards and preventive measures required,

b) It is important to assess the potential effects on the health of automobile pollution by carrying out health impact assessment of the pollutants on the exposed people especially the traffic police officers e.g conducting regular medical surveillance and biological monitoring on those exposed to detect any departure of health as a result of exposure to the pollutants,

c) The government should as apriority improve on public transport system through the improvement of railway transport. Public awareness on the need to use carpool or public transport instead of the use of personal cars should . This will significantly reduce the number of vehicles within the CBD. The fewer the number of vehicles in the CBD the fewer the pollutants emitted to the air. It is also important to create public awareness on the benefits of practicing good vehicle maintenance which include regular tune-ups. They should be made to understand that this will prolong the efficiency of the engine and its emission control systems.

d) Improve on atmospheric missing through proper planning of the city to enhance wind velocity within the CBD.

REFERRENCES

ACGIH. (1991). Documentation of the threshold limit values and biological exposure indices (6th edition.). Cincinnati, OH: American Conference of Governmental Industrial Hygienists. pp 935.

Alan, A.; David, S.; Margaret, D. S. and Erica, W. (2002). Identifying and Managing Adverse Environmental Health Effects: 2. Outdoor air pollution. *Canadian Medical Association Journal • APR. 30, 2002; 166 (9): 1161-1167*

Angle, C. R. (1988). Indoor Air Pollutants. pp 35, 239- 280.

Atimtay, A. T.; Emri, S.; Bagci, T. and Demir, A. U. (2000). Urban CO exposure and its health effects on traffic policemen in Ankara. *Environmental Research. 82(3): 222-30.*

Bell, N. (2006). Air Pollution. Microsoft Corporation, 2006.

Brauer, M.; Hoek, G. and Van Vliet , P. (2002). Air Pollution from Traffic and the development of Respiratory Infections and Asthmatic and Allergic Symptoms in Children. *American Journal of Respiratory and Critical Care Medicine, Vol.166 , pp. 1092-1098.*

Bruce, L. H. and Gooch, J. (2007). Clean Air Task Force Report 2007 – 1. A Multi City Investigation Exposure to Diesel Exhaust in Multi commuting modes: Columbus, Austin TX, Boston MA, New York City.

Brunekreef, B. and Holgate, S. T. (2002). Air Pollution and Health. Lancet. 360(9341): 1233 – 1242

CAIP. (2001). *Website of the Cairo Air Improvement Project* (http://caip.chamonics.net)

Carl-Elis, B. (1993). Health Risk Evaluation of Nitrogen Oxides: *Scandinavian Journal of Work Environment & Health, Vol. 19, September 1993. pp 9-71.*

Cathryn, T.; Melly, S.; Murray, M.; Brent, C.; Robert, G. and Schwartz. J. (2006). A Case–Control Analysis of Exposure to Traffic and Acute Myocardial Infarction. *Environ Health Perspective. 2007 January; 115(1): 53–57.* http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1797833/ . Retrieved on 2/12/2011

CBS. (2009). Kenya population census. Ministry of Planning and National Development. Nairobi Kenya. Retrieved from: http://www.cbs.go.ke. (Retrieved on 2/06/2011)

Choi, K.S.; Inoue, S. and Shinozaki, R. (1997). Air pollution, temperature and regional differences in lung cancer mortality in Japan. Archives of Environmental Health.52: 160-168.

Christopher, H. G.; Stacey, A. N.; Jonathan, S. S.; Lianne, S. and Joel, D. K. (2004). "Effect of Ambient Air Pollution on Pulmonary Exacerbations and Lung Function in Cystic Fibrosis". *American Journal of Respiratory and Critical Care Medicine 169 (7): 816–821. doi:10.1164/rccm.200306-779OC. PMID 14718248.*

Cohen, A. J. and Higgins, M. W. P. (1995). Health effects of diesel exhaust, epidemiology in diesel exhaust: A critical analysis of emissions, exposure and health effects. Health Effects Institute, Cambridge MA. April 1995. pp 251-292.

Cooper, D. R. and Schindler, P. S. (2008). Business Research Methods (9^{th} Edition) 2008. Tata McGraw – Hill Publishing Company Limited, New Delhi. pp 402 - 427

Cotton, F. A. (1986). Advanced Inorganic Chemistry (3rd Edition).Wesley Eastern Limited. pp 339 – 366.

Craig, H.; Thomas J. L.; Jason D. S.; Andrew, O.; Susan, J.; Lillian, S. and Sally, D. P.(2010). The Effect of Ambient Air Pollution on Sperm Quality. *Environmental Health PerspectivesVol. 118, No. 2 (Feb.; 2010), pp. 203-209.*

Devlin, R. (2004). Particulate Matter Exposure in Cars Is Associated with Cardiovascular Effects in Healthy Young Men. *American Journal of Respiratory and Critical Care Medicine Vol. 169. pp. 934-940,*

EPA. (1999). Analysis of the Impacts of Control Programs on Motor Vehicle Toxics Emissions and Exposure in Urban Areas and Nationwide: Volume 1, EPA420-R-99-029, November 1999, Table 10-2.

EPA. (2002). Health Assessment Document for Diesel Exhaust: Office of Research and Development, Sept. 2002. pp 2-20.

Faiz, A. and de Larderel, J. A. (1993). Automotive air pollution in developing countries: Outlook and Control Strategies. *The Science of the Total Environment/134: 325-334*.

Finkelstein, M.; Jerrett, M. and Sears, M. (2004). Traffic air pollution and mortality rate advancement periods. *American Journal of Epidemiology. Vol. 160. pp. 173-177*

Galcano, C. M. and Kariuki, L. W. (2001). Mapping and Analysis of Air Pollution in Nairobi, Kenya. *International Conference on Spatial Information for Sustainable Development Nairobi, Kenya , 2–5 October 2001*

Gatari, M. J. Maina, D. M.; Bundi, P. and Muturi, H. (2006). Poster "Impact of Road Transport on Air Quality in Kenya; Roadside Survey in the cities of Mombasa and Nairobi". International Aerosol Conference, St. Paul Minnesota, USA, 10-15 September 2006. *Poster presentation, Joint CACP-IGAC-WMO Conference, Cape Town, South Africa, 17 -23 September 2006*

Gatebe, C. K. (1992). Estimation of Carbon Monoxide, Hydrocarbons and Oxides of Nitrogen from motor vehicles in Nairobi. M.Sc. Thesis. University of Nairobi.

Gatebe, C. K.; Kinyua, A. M.; Mangala, M.J.; Kwach, R.; Njau, L. N.; Mukolwe, E. A. and Maina, D. M. (1996). Determination of Suspended Particulate Matter of major significance to Human Health using nuclear techniques in Kenya. *Journal of Radioanalytical and Nuclear Chemistry; 203(1): 125 – 134.*

Gathura, G. (2012). Men pay price for risky life styles. *Daily Nation, Friday 18th May 2012. pp10.*

Gauderman, W. J.; McConnell, R.; Gilliland, F.; London, S.; Thomas, D. and Avon, E. (2000). Association between air pollution and lung function growth in Southern California children. *American journal of respiratory and critical care medicine 2000; 162;4: 1383–1390*

Gauderman, W. J.; McConnell, R.; Gilliland, F.; London, S.; Thomas, D.; and Avon, E. (2002). Association between air pollution and lung function growth in Southern California children. Results from a second cohort. *American journal of respiratory and critical care medicine, 166: pp 76–84.*

GOK. (1993). The Traffic Act. Cap 403. Government Printer.

GOK. (1999). Environmental Management and Coordination Act 1999. Government Printer.

GOK. (2007). The Factories and Other places of Work (Hazardous Substances) Rules 2007. Legal Notice No. 60 of 2007. Government Printer.

GOK. (2007a). The Occupational Safety and Health Act 2007. Government Printer.

GOK. (2007b). Kenya Vision 2030: The Popular Version. Government Printer.

GOK. (2010a). National Climate Change Response Strategy. Government Printer.

GOK. (2010b). The Constitution of Kenya. Government Printer.

Gosselin, R. E.; Smith, R. P. and Hodge, H. C. (1984). Clinical Toxicology of Commercial Products. (5th edition.). Baltimore, MD: Williams and Wilkins.

GreenFacts. (2011). Facts on Health and the Environment. Retrieved from: http://www.greenfacts.org/glossary/pqrs/primary-pollutant-secondary-pollutant.htm). Retrieved on 2/12/2011

Hoek, G.; Brunekreef, B.; Goldbohm, S.; Fischer, P. and Van den Brandt, P. (2002). Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. The Lancet vol. 360. December 19, 2002. pp 1203-1209.

Jinsart, W.; Tamura, K.; Loetkamonwit, S.; Thnondh, S.; Karita, K. and Yano, E. (2002). Road side particulate air pollution in Bangkok. *Journal of Air Waste Management Association. 52(9): 1102-10.*

Karol, M. H. (1991). Allergic Reaction to Indoor air Pollutants: Environmental Health Perspective. pp 95, Karue, J.; Kinyua, A. M. and El-Busaidy, A. H. S. (1992). Measured Components in Total Particulate Matter in a Kenyan Area. *Atmospheric Environment. Part B, Urban Atmosphere. 26(4):505 – 511.*

Katsouyanni, K. and Pershagen, G. (1997). Ambient Air Pollution Exposure and Cancer. *Cancer Causes & Control,* Vol. 8, No. 3, The Harvard-Teikyo Program Special Issue (May,1997), pp. 284-291, Published by Springer (http://www.jstor.org/stable/3552691)

Kinney, P.; Aggarwal, M.; Northridge, M.; Janssen, N. and Shepard, P. (2000). Airborne Concentrations of PM2.5 and Diesel Exhaust Particles on Harlem Sidewalks: A Community-Based Pilot Study. *Environmental Health Perspectives, vol. 108, No.3: 1009-1015*

KNBS. (2009). Kenya Facts and Figures 2009. Government printing Press. pp 46, 67.

Kombo, D.K. and Tromp, L.A. (2006). Proposal and Thesis Writing: An Introduction. Pauline Publication in Africa. pp 74,

Korir, A.; Mutuma, G. and Omach, J. (2008). Cancer in Urban Population of Kenya, 2000 -2002. Nairobi Cancer Registry. Kenya Medical Research Institute report on cancer.

Kothari, C. R. (2004). Research Methodology: Methods and Techniques (2nd Edition.). New Age International Publishers. New Delhi. pp152 -180.

Lambert, J.; Holderness, A. and Thompson, J. J. (1976). A new Certificate Chemistry. Heinemann Education Books Ltd. pp 308 - 323, 423 - 443.

Lena, S.; Ochieng, V.; Carter, M.; Holguín-Veras, J. and Kinney, P. (2002) Elemental Carbon and PM2.5 Levels in an Urban Community Heavily Impacted by Truck Traffic. *Environmental Health Perspectives, vol. 110,No.10:1009-1015*

Lin, S.; Munsie, J.; Hwang, S.; Fitzgerald, E. and Cayo, M. (2002) Childhood Asthma Hospitalization and Residential Exposure to State Route Traffic. Environmental Research Section A 88, pp. 73-81.

Maina, D.M.; Gatari, M. J.; Bundi, P. and Muturi, H. (2005). Impact of Road Transport on Air Quality in Kenya. Roadside Survey in the Cities of Mombasa and Nairobi. Unpublished.

Marika, B. (1993). Evaluation of Nitrogen Oxides: *Scandinavian Journal of Work, Environment and Health. Health, 1993, Vol. 19, supplement 2. pp14 – 19,*

MENR/UNEP. (2005). Kenya National Inventory of Persistent Organic Pollutants Under the Stockholm Convection. Final Report, March. Ministry of Environment and Natural Resources/UNDP. pp 148

Michael, K. and Konstantinos, H. (2008). "Short-Term Effects of Air Pollution Levels on Pulmonary Function of Young Adults". *The Internet Journal of Pulmonary Medicine 9 (2). pp 7.*

MOH. (2008). Annual Health Sector Status Report 2005 -2007. pp 37

Morgan, G.; Corbett, S. and Wlodarczyk, J. (1998). Air pollution and hospital admissions in Sydney, Australia 1990 to 1994, *American Journal of Public Health 88: 1762-1766.*

MSDS. (2002). Carbon Dioxide AIRGAS INC: Retrieved from: http://cnl.colorado.edu/cnl/images/MSDS/airgas%20co2.pdf . Retrieved on 01/05/2012

MSDS. (2010). Carbon Monoxide, AIRGAS INC. http://www.airgas.com/documents/pdf/001014.pdf. Retrieved on 16/07/2011.

Mulaku, G. C. and Kariuki, L. W. (2001). Mapping and Analysis of Air Pollution in Nairobi, Kenya, *International Conference on Spatial Information for Sustainable Development Nairobi, Kenya, 2–5 October 2001*

Nakai, S.; Nitta, H. and Maeda, K. (1995). Respiratory health associated with exposure to automobile exhaust. II. Personal NO2 exposure levels according to distance from the roadside, *Journal of Exposure Analysis and Environmental Epidemiology 5: 125-136.*

Nanda Kumar, N. V.; Sreedhar, B.P. and Nagarjuna, A. (2009). Health Hazards of Traffic Police Occupationally Exposed to Automobile Exhaust Pollutants in Tirupati Pilgrim Town. *The Ecoscan 3 (1 & 2): 189 - 197. An Internationally Quarterly Journal of Environmental Sciences*

NAPS. (2001). *Website of the Canadian National Air Pollution Surveillance Network* (www.etcentre.org)

Nitta, H.; Sato, T.; Nakai, S.; Maeda, K.; Aoki, S. and Ono, M. (1993). Respiratory health associated with exposure to automobile exhaust. I. Results of cross-sectional studies in 1979 1982, and 1983, *Archives of Environmental Health 48: 53-58.*

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

Olick, F. (2011). Slow Progress in halting disease claim many lives. *The Standard, Tuesday 8th November 2011.*

Ono, M.; Murakami, M.; Nitta, H.; Nakai, S. and Maeda, K. (1990). Epidemiological studies of air pollution and health effects in area near roadways with heavy traffic in Tokyo, *Japanese Journal of Public Health 37: 321-332.*

Opperman, L.; Nel, C. M.; Bekker, P. J.; Booysens, U. and Terblanche, A. P. S. (1993). Total suspended particulate levels and prevalence's of upper respiratory illnesses in the Vaal Triangle, South Africa. *Presentation at the 86th Annual Meeting & Exhibition of the Air & Waste Management Association, June 13-18, Denver, Colorado, USA.*

Oso, W.Y. and Onen, D. (2005). A General Guide to Writing Research Proposal and Report: A Handbook for Beginning Researchers. Options Press and Publishers. pp 39.

Parmeggiani, L. (1983). Encyclopedia of Occupational Health and Safety (3rd revised edition.). Vol. 1, Geneva, Switzerland: International Labour Organization. pp 95-97, 392 – 398

Peters, A.; Von Klot, S.; Heier, A.; Trentinaglia, I.; Hormann, A.; Wichmann, E. and Lowel, H. (2004). Exposure to traffic and the onset of myocardial infarction. *New England Journal of Medicine, Vol. 351, No. 17, October 15, 2004. pp 1721 -1730*

Peters, J. M.; Edward, A.; Gauderman, W. J.; William, S. L, William, N.; Stephanie, J. L.; Helene, M.; Edward, R.; Hita, V.; Henry, G Jr. and Duncan, C. T. (1999). A study of 12 Southern California communities with differing levels and types of air pollution. II Effects on pulmonary function. *AJRCCM, 1999; 159: 768–775.*

Pidwirny, M. and Howard, H. (2008). Greenhouse effect. Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). <http://www.eoearth.org/article/Greenhouse_effect>

Pope, C. A 3rd. (2004). Air pollution and health – good and news: (Editorial). *New England Journal of Medicine, Sep 9; 351: 1132 – 1134.*

Proietti, L.; Mastruzzo, C.; Palermo, F.; Vancheri, C.; Lisitano, N. and Crimi, N. (2005). Prevalence of respiratory symptoms, reduction in lung function and allergic sensitization in a group of traffic police officers exposed to urban pollution. *Med Lav. 96(1): 24-32.*

Reay, D. (2008). National Oceanic and Atmospheric Administration. Greenhouse gas. Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). <http://www.eoearth.org/article/Greenhouse_gas>

ROK. (2004). National Energy Policy, Session Paper No 4 of 2004.

Saldiva, P. H. N.; Pope, C. A III.; Schwartz, J.; Dockery, D. W.; Lichtenfelds, A. J.; Salge, J. M.; Barone, Y. and Bohm, G. M. (1995). Air pollution and mortality in elderly people: a time series study in Sao Paulo, Brazil. *Archives of Environmental Health 50: 159-164.*

Salvi, S.; Blomberg, A.; Rudell, B.; Kelly, F.; Sandstrom, T.; Holgate, S. T. and Frew, A. (1999). Acute inflammatory response in the airways and peripheral blood after short term exposure to diesel exhaust in healthy human volunteers. *American Journal of Respiratory and Critical Care Medicine, 1999; 159: 702 – 709.*

Schwartz, J. (1994). Air Pollution and mortality: Review and meta- analysis. *Environmental Research, 1994; 64: 36-52.*

SEI. (2009). Economics of Climate Change Kenya. Stockholm Environmental Institute, Project Report – 2009. pp 55. http://www.sei-international.org/mediamanager/documents/Publications/Climate-mitigation-adaptation/kenya-climatechange.pdf . Retrieved on 12/12/2011

Seinfeld, H. J. (1989). Air Pollution, Physical and Chemical Fundamentals. Mc Graw – Hill, New York.

Sharat, G.; Shallu, M.; Avnish, K. and Kamal, D. S. (2011). Respiratory effects of air pollutants among nonsmoking traffic policemen of Patiala, India. *Lung India, Vol. 28, No. 4, October-December, 2011, pp. 253-257*

Terblanche, A. P. S.; Opperman, L.; Nel, C. M. E.; Reinach, S. G.; Tosen, G. and Cadman, A. (1992). Preliminary results of exposure measurements and health effects of the Vaal Triangle Air Pollution Health Study. *South African Medical Journal 8: 550-556.*

Terblanche, A. P. S.; Opperman. L.; Nel. R. and Pols. A. (1993). Prevalence of respiratory illnesses in different regions of South Africa. *Clean Air Journal 8: 18-20.*

Tonne, C.; Melly, S.; Mittleman, M.; Coull, B.; Goldberg, R. and Schwartz, J. (2007). A Case- Control Analysis of exposure to Traffic and Acute Myocardial Infarction. *Environmental Health Perspective, 115(1):53-7, January 2007.*

UN. (1992a). Agenda 21: Rio Declaration, Rio de Janeiro: *Final text of the agreement negotiated by governments of the United Nations Conference on Environment and Development.*

UN. (1992b). United Nations Conference on Environment and Development Rio de Janerio, Brazil, 3 to 14 June 1992.

UN. (2006). United Nations Department of Economic and Social Affairs. *Commission on Sustainable Development Fourteenth Session 1-12 May 2006. New York.*

UN. (2008). Acting on Climate Change: The UN System Delivering As One. United Nations Headquarters, New York in November 2008.

UNCHS. (1996). An Urbanizing World: Global Report on Human Settlements, 1996, Oxford University Press, 599 pp.

UNEP. (2004). Sustainable Consumption and Production Activities in Africa. Regional Status Report (2002 - 2004)

UNEP/WHO. (1992). Urban Air Pollution in Megacities of the World, Blackwell, Oxford.

UN-HABITAT. (2006). Urban Environment. Steering Sustainable Urbanization in Africa. September 2006 (UN-HABITAT's Regional Office for Africa publications).

USEPA. (1993). National Air Quality and Emissions Trends Report, U. S. Environmental Protection Agency.

Volpino, P.; Tomei, F.; La valle, C.; Tomao, E.; Rosati, M. V.; Ciarrocca, M.; De Sio, S.; Congemi, B.; Vigliarole, R. and Fedele, F. (2004). Respiratory and cardiovascular function at rest and during exercise testing in a healthy working population: effects of outdoor traffic air pollution. *Occupational Medicine (London). 54(7): 475-482*.

WHO. (1987). Air quality guidelines for Europe. Copenhagen, WHO Regional Office for Europe, 1987 (WHO Regional Publications, European Series, No. 23)

WHO. (1999a). International Programme on Chemical Safety. Environmental Health Criteria 212 Principles and Methods for Assessing Allergic Hyper sensitization Associated with exposure to Chemicals. Geneva.

WHO. (1999b). International Programme on Chemical Safety: Environmental Health Criteria 213, Carbon Monoxide (2nd Edition.). Geneva. pp 19, 266 – 273. http://www.who.int/ipcs/publications/ehc/en/ehc_213_part_1.pdf

WHO. (2000). Air quality guidelines for Europe, 2nd ed. Copenhagen, WHO Regional Office for Europe, 2000 (WHO Regional Publications, European Series, No. 91), pp 33.

WHO. (2001). World Health Organization Strategy on Air Quality and Health Occupational and Environmental Protection of Human Environment. World Health Organization, Geneva.

WHO. (2002). World health report: Reducing risks, promoting healthy life. Geneva.

WHO. (2003). Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide. Report on a WHO Working Group Bonn, Germany 13–15 January 2003

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

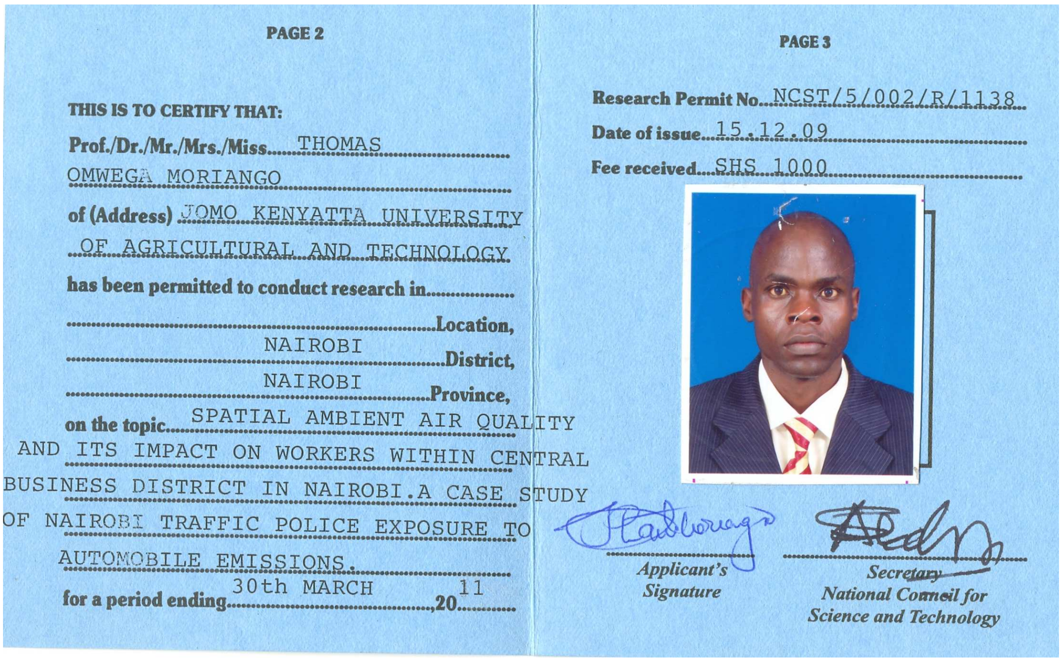
WHO. (2005). WHO Air quality guidelines for particulate matter, ozone, Nitrogen Dioxide and sulfur dioxide: Global Update 2005 (Document ref No. WHO/SDE/PHE/OEH/06.02**)**

WSL. (1994). Air Pollution in the UK 1992/93, Air Monitoring Group, Warren Spring Laboratories, Stevenage.

Zemp, E.; Elsasser, S.; Schindler, C.; Kunzli, N.; Perruchoud, A. P.; Domenighetti, G.; Medici, T.; Ackermann – Liebrich, U.; Levenberger, P.; Monn, C.; Bolognini, G.; Bongard, J. P.; Brondli, O.; Karrer, W.; Keller, R.; Schoni, M. H.; Tshopp, J. M.; Villinger, B. and Zellweger, J. P. (1999). Long term ambient air pollution and respiratory symptoms in adults (SAPALDIA Study)". The SAPALDIA team. *American Journal of Respiratory and Critical Care Medicine. 159(1): 1257-66.*

APPENDICES

Appendix (i): *Research Clearance Permit*



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THIS IS TO CERTIFY THAT:

Prof./Dr./Mr./Mrs./Miss. THOMAS OMWEGA MORIANGO

of (Address) JOMO KENYATTA UNIVERSITY OF AGRICULTURAL AND TECHNOLOGY

has been permitted to conduct research in .... Location,

NAIROBI District,

NAIROBI Province,

on the topic SPATIAL AMBIENT AIR QUALITY AND ITS IMPACT ON WORKERS WITHIN CENTRAL BUSINESS DISTRICT IN NAIROBI.A CASE STUDY OF NAIROBI TRAFFIC POLICE EXPOSURE TO AUTOMOBILE EMISSIONS.

for a period ending 30th MARCH, 2011

PAGE 3

Research Permit No. NCST/5/002/R/1138

Date of issue 15.12.09

Fee received SHS 1000

Applicant's Signature

Secretary
National Council for Science and Technology

Appendix (ii): *Letter of Authority from National Council for Science and Technology*

REPUBLIC OF KENYA

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Telegrams: "SCIENCETECH", Nairobi
Telephone: 254-020-241349, 2213102
254-020-310571, 2213123.
Fax: 254-020-2213215, 318245, 318249
When replying please quote

P.O. Box 30623-00100
NAIROBI-KENYA
Website: www.ncst.go.ke

Our Ref: **NCST/RR1/12/1/SS/76/5**

Date: **2nd March, 2010**

Mr. Thomas Omwega Moriango
JKUAT
NAIROBI

Dear Sir,

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Spatial ambient air quality and its impact on workers within the Central Business District in Nairobi: A case study of Nairobi Traffic Police exposure to Automobile Emissions"*** I am pleased to inform you that you have been authorized to undertake research in **Nairobi Central Business District** for a period ending ***31st March 2011.***

You are advised to report the **Provincial Commissioner Nairobi, the Town Clerk Nairobi and the Traffic Commandant Nairobi Area** before embarking on the research project.

On completion of the research, you are expected to submit two copies of the research report/thesis to our office.

P. N. NYAKUNDI
FOR: SECRETARY/CEO

Copy to:
The Provincial Commissioner
Nairobi Province

Appendix (iii): Letter of Authority from the Commissioner of Police

OFFICE OF THE PRESIDENT

Telegrams: "VIGILANCE", Nairobi
Telephone: Nairobi 341411/17
When replying please quote
C/PUB/5/29/XIV/284
Ref. No. ....
and date

POLICE HEADQUARTERS
P.O. Box 30083–00100
NAIROBI
8th December, 2009

Mr. Thomas Moriango Omwega
P.O. Box 30177 – 00100
NAIROBI

Dear Mr. Omwega,

RE: RESEARCH PROJECT

We acknowledge receipt with thanks your letter dated 24th November, 2009 on the above subject.

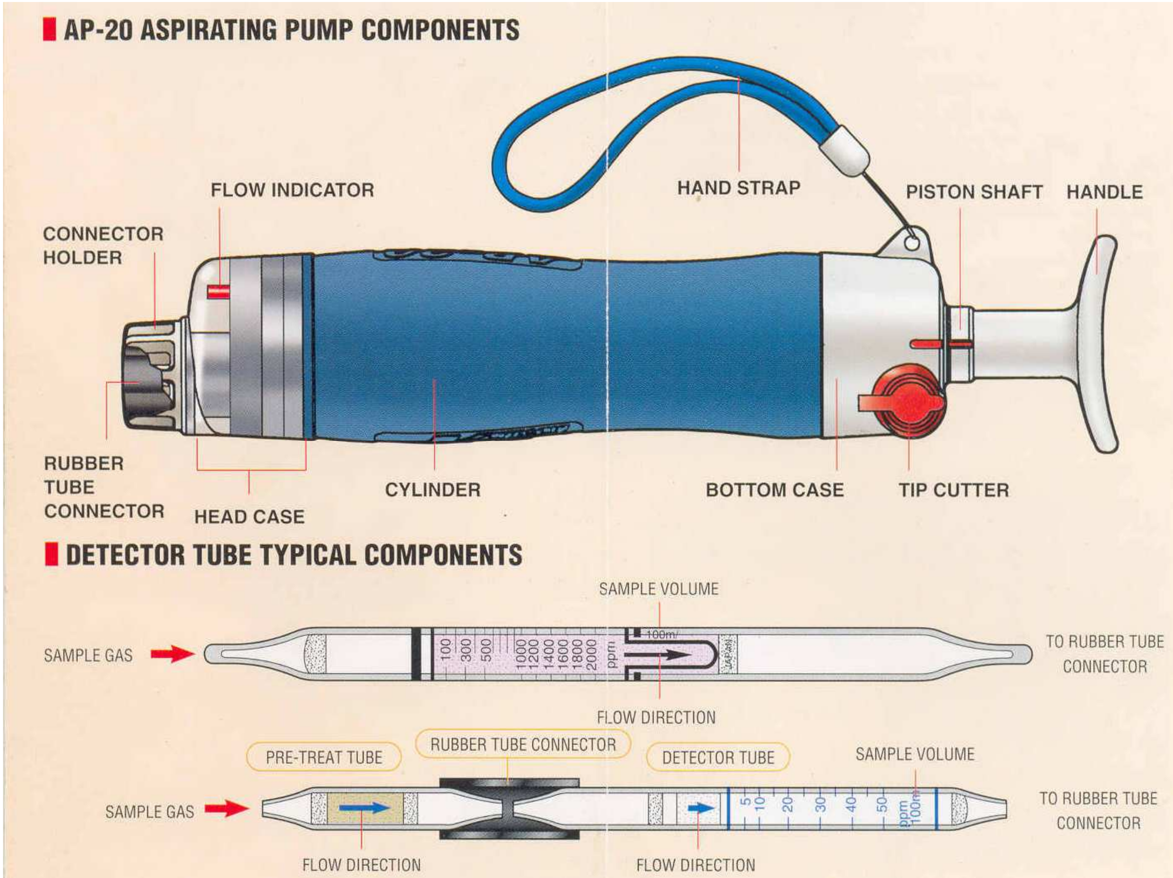
We are pleased to inform you that the Commissioner of Police has approved your request. It is however recommended that you approach individual police officers in the Traffic Department for your research study.

Yours sincerely,

Kiraithe E.K.
FOR: COMMISSIONER OF POLICE

c.c. The Commandant
Traffic Department
NAIROBI

Appendix (iv): *Gas aspiration pump AP – 20 and Detector tube*



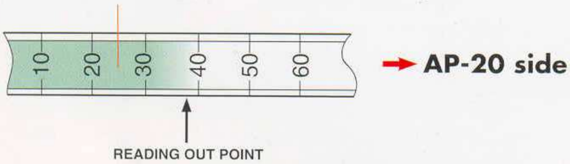
Appendix (v): *Instructions on how to read gas concentrations from Detector tube*

HOW TO READ THE GAS CONCENTRATION FROM GAS DETECTOR TUBE

[Direct reading type] Read the concentration of gas at the maximum end of the stain against the printed scale on the detector tube.

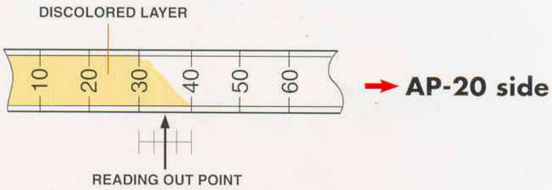
1. In case of faint discoloration

Read the concentration of gas at the maximum end of the stain.



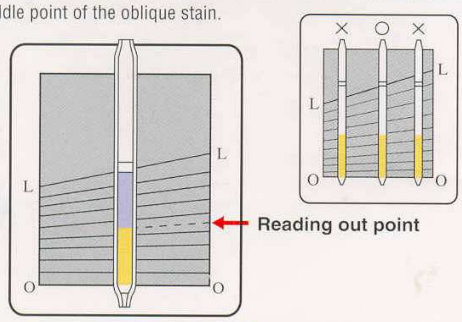
2. In case that the end of the stain is slanted.

Read out the numerical value at the middle of the oblique layer.



[Concentration chart type]

Align the zero end of the detecting reagent (inlet side of the tube) with the **0 - 0** line on the concentration chart. Align the other end of the same layer (exit side or pump side of the tube) with the **L - L** line respectively. Read the gas concentration at the maximum end of the stain against the scale on the card. If the end is slanted, read at the middle point of the oblique stain.



TEMPERATURE CORRECTION PROCEDURE

The temperature of concern is that of the detector tube (usually the temperature of the sample gas).

1. IN CASE OF USE OF CORRECTION TABLE

[EX.1] **When the tube reading is 550 ppm at 25 degrees C, the true concentration** is found by interpolating between the concentrations listed for 20 and 30 degrees C. In this example, the corrected value is 560 ppm.

Temperature correction (At 20°C)					
Scale reading (ppm)	True concentration of carbon monoxide (ppm)				
	0°C	10°C	20°C	30°C	40°C
1,000	870	930	1,000	1,030	1,060
900	780	840	900	930	960
800	690	750	800	830	850
700	610	660	700	720	740
600	520	560	600	620	640
500	430	470	500	520	540
400	350	370	400	410	430
300	260	280	300	310	320
200	180	190	200	210	220
100	90	100	100	100	110

Scale readings °C	20°C	25°C	30°C
600	600	(6[illegible]0)	620
550a	a(550)	5[illegible]0	(570)
500	500	(5[illegible]0)	520
(450)	(450)	(457.5)	(465)
400	400	(405)	410

2. IN CASE OF USE OF CORRECTION COEFFICIENT

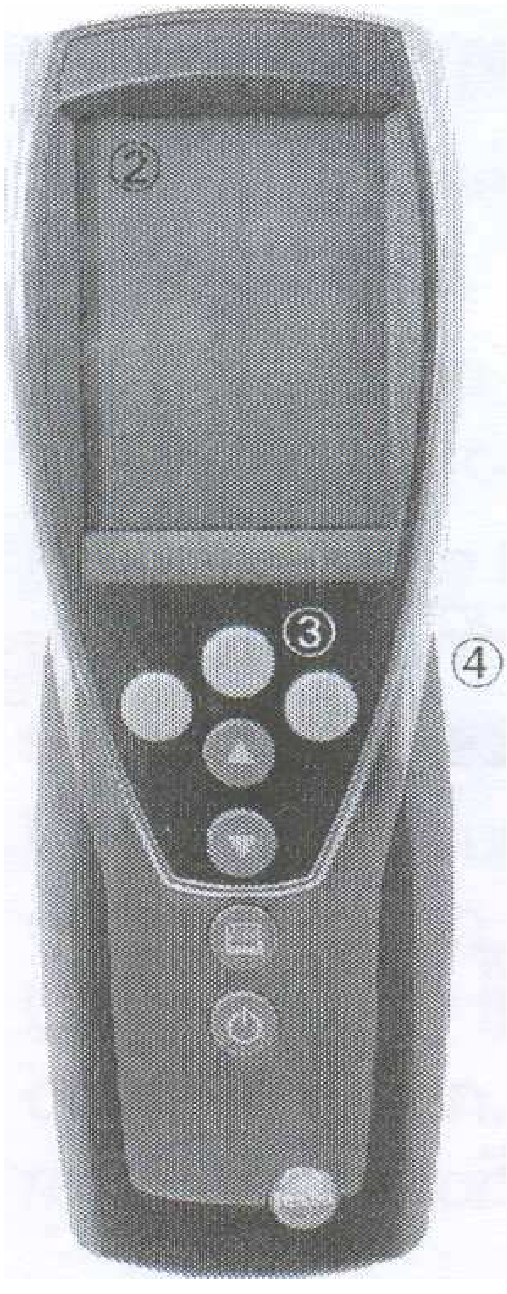
[EX.2] **When the detector tube reading is 0.4 mg/ℓ** at 23 degrees C, the true concentration of water vapour is 0.36 mg/ℓ by the following calculation. 0.4 mg/ℓ ×0.90 ≒ 0.36 mg/ ℓ

Temperature Correction Table

Temp.(°C)	0	1	2	3	4	5	6	7	8	9
0	1.85	1.81	1.77	1.72	1.68	1.63	1.59	1.54	1.49	1.45
10	1.40	1.36	1.31	1.27	1.23	1.19	1.15	1.11	1.07	1.03
20	1.00	0.96	0.93	0.90	0.87	0.84	0.84	0.78	0.76	0.73
30	0.71	0.68	0.66	0.64	0.62	0.60	0.58	0.56	0.55	0.53
40	0.51	—	—	—	—	—	—	—	—	—

Temp.(°C)	0	1	2	3	4
0	1.85	1.81	1.77	1.72	1.68
10	1.40	1.36	1.31	1.27	1.23
20	1.00	0.96	0.93	0.90	0.87
30	0.71	0.68	0.66	0.64	0.62

Appendix (vi): Testo 435 multifunctional measuring instrument



Appendix (vii): *Letter of Introduction and consent*

Dear Sir/Madam,

My name is Thomas Moriango Omwega. I am a student at Jomo Kenyatta University of Agriculture and Technology, Institute for Energy and Environmental Technology. I am carrying out a study on traffic police exposure to automobile emissions in Nairobi. I would very much appreciate your participation in this study by filling in the questionnaire or giving an in-depth interview to myself or one of the Research Assistants. Whatever information you provide relating to the study will be kept strictly confidential and will not be shown to other persons. You have the right to withdraw from the study at any time if you so wish. There are no risks associated with participating in the study and any benefits are indirect as the study may lead to policy changes that will greatly improve your work environment.

If you have any questions regarding the study you can reach the Principal Investigator on mobile number 0725112239.

Thank you.

Omwega

Appendix (viii): *Data capture form No 1: TPO Questionnaire*

Instructions

I. ***Please do not write your name on the questionnaire***

II. ***Give your responses by writing in the spaces provided or by showing with a √ or X in the boxes provided***

A. Biodata

1. Sex: Male ☐ Female ☐
2. How old are you?

   18 -25 yrs ☐ 26 -35 yrs ☐ 36-45 yrs ☐ 46 and above yrs ☐
3. Marital status: Married ☐ Not married ☐
4. If married, how many children do you have?

   1 – 3 children ☐ 4 – 6 children ☐ 7 – 9 children ☐ 10 and above children ☐
5. Do you smoke? Yes ☐ No ☐
6. Where do you stay? ……………………………………………….
7. Which form of energy do you use as fuel for cooking at your residence?

   Paraffin ☐ Firewood ☐ Gas ☐ Electricity ☐ Charcoal ☐ Any other……….
8. Which form of energy to you use for lighting at your residence?

   Paraffin ☐ Electricity ☐ Solar ☐ Gas ☐ Any other………………………

B. Work Experience

9. Had you worked elsewhere before you joined the police force? Yes ☐ No ☐

10. If the answer to **'9'** above is yes, briefly describe the nature of your previous work.

…………………………………………………………………………………………

…………………………………………………………………………………………

11. When were you employed in the police force? ……………………………………….

12. Which is your current department in the police force? ………..……………………

13. Which is your current station? ……………………………………..

14. If your current department is the Traffic department, for how long have you worked in Nairobi as a traffic officer?

    Less than 1 year ☐ 1 - 2 years ☐ 2- 3 years ☐ Over 3 years ☐

15. Where do you normally go to discharge your duties in most days of the week as a traffic officer in Nairobi...........…………………………………………………..…

16. Briefly describe your work schedule in Nairobi on any given day of the week ………

    ………………………………………………………………………………………

    …………………………………………………………………………………………

17. Approximately how long do you spend on each day on the roads in Nairobi while discharging your duties?

    Less than 1hour ☐ 1– 4 hours ☐ 4 – 8 Hours ☐ 8- 12 hours ☐ Over 12 Hours ☐

C. Information on Traffic

18. In your opinion on which days of the week do you consider as peak days for traffic in the city?

    Monday ☐ Tuesday ☐ Wednesday ☐ Thursday ☐

    Friday ☐ Saturday ☐ Sunday ☐

19. Show in the boxes with a **√ or X** in your opinion between which hours of the day you consider as peak hours for traffic in the city?

Peak hours						
Morning			**Afternoon**		***Evening***	
7.00 To 9.00	*9.00 to 11.00*	*11.00 to 1.00*	*1.00 To 3.00*	*3.00 To 5.00*	*5.00 To 7.00*	*7.00 and beyond*

20. In your opinion on which part of the month (**Beginning, mid or end month**) do you consider as the peak period of the month for traffic in the city?

Peak periods		
Beginning	**Mid-Month**	***End month***

21. Had you worked elsewhere as a traffic officer before being deployed to Nairobi?
22. If the answer to the above is yes, in which towns were you deployed? ……………………………………………………………………………………………..…

D. Personal Assessment

23. **Exposure to some pollutants may cause a number of effects on the body. Indicate your honest responses to the statements below by showing with a √ or X your most appropriate responses**.

Key	SA	A	NO	D	SD
	Strongly Agree	***Agree***	***Neither Agree Nor Disagree***	***Disagree***	***Strongly Disagree***

Statement	Response				
	SA	**A**	**NO**	**D**	**SD**
i. In the course of my duties I normally experience dizziness after some time during peak hours					
ii. I also experience shortness of breath					
iii. This is followed by a feeling of fatigue and state of confusion					
iv. I have sometimes made wrong judgments in the course of my duties due to these effects					
v. During peak hours I also experienced the following					
a) Irritation of the eyes,					
b) Irritation of the nose,					
c) Irritation of the throat,					
d) Irritation of the lungs					
e) Coughs					
f) Tiredness					
g) Nausea (e.g vomiting, sickness, unsettled stomach)					
h) Fluid buildup in the lungs e.g wheezing, panting, breathless					
i) Sneezing and flue					

24. Indicate in this chart by showing with a **√ or X** in the boxes on which days of the week you experience any of the following listed effects ***(Otherwise leave the boxes blank).***

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
i. Feeling of dizziness							
ii. Experiencing shortness of breath							
iii. Feeling of fatigue							
iv. Irritation of the eyes							
v. Irritation of the nose							
vi. Irritation of the throat							
vii. Irritation of the lungs							
viii. Coughs							
ix. Tiredness							
x. Nausea (e.g vomiting, sickness, unsettled stomach)							
xi. Fluid buildup in the lungs e.g wheezing, panting, breathless							
xii. Sneezing and flue							

E. RECOMENATIONS

25. In your opinion give recommendation on what can be done to solve the problems mentioned in **23** and **24** ?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Appendix (ix): *Data capture form No 2: General Observations Questionnaire*

Name (R/RA)…..……………Sample point:…… Date:……………… Time:……………

1. What observations can you notice on the general environment?

   Haze ☐ Misty ☐ Dusty ☐ Smoky ☐

2. What is the number of vehicles that can be noted on the road?

   Negligible ☐ Small ☐ Many ☐ Very many ☐

   Negligible: < 15 vehicles **Small:** 15 – 30 vehicles **Many:** 30– 60 vehicles

   Very many: Over 60 vehicles

3. What is the number of pedestrian seen passing by the highway

   Negligible ☐ Small ☐ Many ☐ Very many ☐

   Negligible: < 5 people **Small:** 5 – 10 people **Many:** 10–20 people

   Very many: Over 20 people

4. Comment on the flow of traffic on the road

   Very Slow ☐ Slow ☐ Moving fast ☐ Moving very ☐

5. What is the number of traffic officer present on the road?

   0 ☐ 1 to 3 ☐ 4 to 6 ☐ 7 and above ☐

6. Are the traffic lights operational?

   Yes ☐ No ☐

7. Are the traffic lights being obeyed by the drivers?

   Yes ☐ No ☐

8. What is the general weather condition?

   Dry and Hot ☐ Humid ☐ Drizzling ☐ Raining ☐

Appendix (x): *Data capture form No 3: Sample determination*

	NAME OF POLICE STATION	**WORK FORCE**	**SAMPLE**
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
GRAND TOTAL(Population)			
SUB TOTALS(Sample)			

Appendix (xi): *Data capture form No 4: Carbon Dioxide, Carbon Monoxide, Temperature and Wind velocity*

Name of R/RA……………………………………………… Date:……………… Site:…………… …….

DATE	TIME	COLLECTION POINT	***Carbon Dioxide (ppm)***			***Carbon Monoxide(ppm)***			***Temperature °C***			***Velocity m/s***		
			1ST reading	**2ND reading**	**3RD reading**	**1ST reading**	**2ND reading**	**3RD reading**	**1ST reading**	**2ND reading**	**3RD reading**	**1ST reading**	**2ND reading**	**3RD reading**

Appendix (xii): *Data capture form No 5: NO_{x}, Temperature and Wind Velocity*

Name of R/RA……………………………………………… Date:……………… Site:…………… …….

DATE	**TIME**	**COLLECTION POINT**	***Nitrogen Oxide (ppm)***			***Nitrogen Dioxide (ppm)***			***Temperature ^{o}C***			***Velocity m/s***		
			1^{ST} reading	**2^{ND} reading**	**3^{RD} reading**	**1^{ST} reading**	**2^{ND} reading**	**3^{RD} reading**	**1^{ST} reading**	**2^{ND} reading**	**3^{RD} reading**	**1^{ST} reading**	**2^{ND} reading**	**3^{RD} reading**