CHARACTERIZATION OF TRAFFIC-RELATED AIR POLLUTANTS AND ASSESSMENT OF RESPIRATORY CONDITIONS OF TRAFFIC WARDENS ACROSS TWO SELECTED LOCAL GOVERNMENT AREAS OF IBADAN, NIGERIA.

BY

JOHN OLUSEYE OLAMIJULO

B.Sc. MICROBIOLOGY (IBADAN)

MATRIC NUMBER: 122277

A DISSERTATION SUBMITTED TO THE UNIVERSITY OF IBADAN IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PUBLIC HEALTH (ENVIRONMENTAL HEALTH) DEGREE

DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES, FACULTY OF PUBLIC HEALTH, COLLEGE OF MEDICINE, UNIVERSITY OF IBADAN, IBADAN NIGERIA.

APRIL, 2013

CERTIFICATION

I certify that this research work was carried out by **John Oluseye, OLAMIJULO** of the Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan.

....

Supervisor

Godson R.E.E. Ana

B.Sc (PH), M.Eng (PH), MPH (Ib), PhD (Ib), FLEAD (UK), MRSPH (UK), MAPHA (USA)

Department of Environmental Health Sciences,

Faculty of Public Health,

College of Medicine,

University of Ibadan, Ibadan.

DEDICATION

This research work is dedicated to the Almighty God for his love and care despite my short coming, my beloved parents, Elder and Mrs. G.A. Olamijulo. Thanks for believing in me

AND

My Late brother Mr. Peter Opeyemi Olamijulo. May his gentle soul rest in perfect peace. Amen

ACKNOWLEGEMENTS

I give all thanks and adoration to the Most High God for his faithfulness and mercies that I enjoy every day. I express my profound gratitude to God for the gift of life and for the grace and strength he has given me to complete this work.

My Sincere thanks goes to my Supervisor and Mentor Dr. Godson R.E.E. Ana, for his wise counsel, motivation, exposure, constructive criticism and encouragement towards the completion of this work. I am eternally grateful sir.

My Special appreciation goes to my dear parents, Elder and Mrs. G.A Olamijulo. Thanks for your love, prayers, financial and moral support. Without your care I would not have been able to make it thus far. To my loving siblings – Mr. Abiola Olamijulo and Mrs. Modupe Ogundeyi am very grateful for your encouraging words and support.

I am grateful to Dr. E.O. Oloruntoba, Dr. O.T. Okareh, Mrs Adeola Osuntade (Department of Environmental Health Sciences), Dr. I.O. Fawole, Dr. I.O. Ajayi, Dr. A.A. Fatiregun, Dr. M.D. Dairo, Dr. O.B. Yusuf, Dr.B.O. Adedokun, Dr. A.S. Adebowale, Dr. A.F. Fagbamigbe, Mr. J.O. Akinyemi (Department of Epidemiology and Medical Statistics), Mr. B.A. Ushie (Institute of Child Health) for their lectures, advice and comments as well as my teachers at the earlier stages of my life.

I am immensely indebted to my Uncle CSP Titus Oluwafemi Olamijulo (Rtd) for his support, encouragement, prayers and wise counsel during the course of this work.

I appreciate all my senior colleagues Ukhun Anthony, Olowolade Tope (2007/2008), Jimoh Lawrence, Fakunle Adekunle, Yesufu luqman, Ogunwale Tayo (2008/2009), my colleagues Adegbola Paul, Bankole Mayowa, Dada Abiodun, Umar Zainab, Agboluaje Nafisat, Erhahon Osas, Ashaolu Ajibike and a host of others, thanks for the precious times we spent together. I appreciate all the words of encouragement from Alufa I., Idowu A., Adekunle S., Enest D., Osibote B., Gbenga, Adeolu, Olanrye Donald (2010/2011).

To my friends, Ojo Kolawole Henry (T2), Oluokun Adeniyi, Alao Mikaheel, I say thank you for your contribution and your words of comfort during the trying times.

ABSTRACT

Traffic-related emissions contribute immensely to ambient air pollution in urban areas and Traffic Wardens (TW) have been reported to be at high risk of respiratory problems. Although data on road traffic emissions are available in Nigeria, information on personal exposure of traffic wardens to particulate matter is lacking. This study was designed to characterize traffic emissions and compare lung function status of TW with Regular Policemen (RP) in two Local Government Areas (LGA) of Ibadan.

A comparative cross-sectional study was conducted involving all 122 TW (exposed group) in the study area and 125 RP (unexposed group). Ibadan North and Northeast LGAs were purposely selected based on high traffic density. Thirteen Study Locations (SL) were randomly chosen from eighteen identified SL in the two LGAs. Levels of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon (II) oxide (CO) emissions were measured using calibrated SO_2, NO_2 and CO metre respectively according to WHO guideline. Respirable Suspended Particulate Matter (RSPM) was measured using personal respirable dust sampler within 30cm range of the TW nasal region and values were compared with WHO guideline limit. Measurements were taken in the morning (6am - 8am), afternoon (12pm - 2pm) and evening (4pm - 6pm) for 12 weeks. Traffic density was estimated via manual counting using tally system. An interviewer-administered questionnaire was used to elicit information from the 247 respondents on work hours and respiratory problems. A calibrated spirometer was used to determine the Force Expiratory Volume in 1 second (FEV_1) in 61 of the 122(TW) and 63 of the 125RP. Data were analyzed using descriptive statistics, Chi-square and Pearson correlation tests at $p \leq 0.05$.

Mean gaseous emissions level were CO (38.6 ± 22.2ppm). SO_2 (1.0 ± 0.7ppm). NO_2 (0.2 ± 0.1ppm) and RSPM (28.1 ± 11.5μg/m^3). These values exceeded the WHO guideline limit for CO (10ppm). SO_2 (0.17ppm). NO_2 (0.17ppm) and RSPM (25μg/m^3). The peak CO emission level (165ppm) was recorded in the evening (4pm-6pm). Mean total traffic density at the SL was 3478 ± 1043.4/hr. Mean concentration of traffic emissions were elevated with increase in traffic density at SL. There was a significant positive correlation between SO_2 and traffic density (r= 0.48). Mean age of TW and RP were 37.7 ± 9.3 years and 37.0 ± 7.7 years respectively. Majority (54.9%) of the TW spend more than 8hours at road intersections. Reported respiratory problems

experienced included: breathing difficulty (TW: 66.4%; RP 6.4%), chest pain (TW: 72.1%: RP: 5.6%), sore throat (TW: 60.7%; RP: 14.4%) and catarrh (TW: 68.9%; RP: 41.6%). There was a significant difference between the observed FEV_1 among TW (2.2 ± 0.7l) and RP (3.4 ± 0.5l). A negative correlation was observed between RSPM and the actual FEV_1 of TW (r= -0.6).

Ambient air emissions at study locations exceeded the World Health Organization guideline limit for occupational exposures and respiratory problems were higher among traffic wardens. Routine air monitoring of motor ways and the use of personal protective equipment by traffic wardens while on duty is advocated.

Keywords: Air pollution, Lung function status, Traffic emission, Traffic wardens.

Word count: 495

TABLE OF CONTENT

CHAPTER TWO

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

GLOSSARY OF TERMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
AQI	Air Quality Index
BMI	Body Mass Index
CNS	Central Nervous System
COPD	Chronic Obstructive Pulmonary Disease
dB	Decibel
DALYs	Disability Adjusted Life Years
EPA	Environmental Protection Agency
FEPA	Federal Environmental Protection Agency
FEV_1	Forced Expiratory Volume in 1 second
FVC	Forced Vital Capacity
GHGs	Greenhouse Gases
GPS	Geographical Positioning System
LGAs	Local Government Areas
NAAQS	National Ambient Air Quality Standards
NEERI	National Environmental Engineering Research Institute
NESREA	National Environmental Standards Regulation and Enforcement Agency
NOAA	National Oceanic and Atmospheric Administration
NPC	National Population Commission

PAHs	Poly Aromatic Hydrocarbons
PEF	Peak Expiratory Flow
PFT	Pulmonary Function Test
PM	Particulate Matter
PPM	Parts per million
RP	Regular policemen
RSPM	Respirable Suspended Particulate Matter
SP	Sampling Point
TW	Traffic warden
UNEP	United Nations Environment Programme
UNFPA	United Nations Population Fund
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The World health organization (WHO, 1990) defines air pollution as limited to situation in which the ambient atmosphere contain materials in concentrations which are harmful to man and his environment. Air pollution causes some gases in the atmosphere to exist at higher than normal conditions and can be seriously harmful to human health. Examples of these include nitrogen oxides (NOx), sulphur oxides (SO_x), carbon monoxide (CO), particulate matter (PM), photochemical oxidants (e.g. ozone and lead (Pb), along with a variety of airborne heavy metals and volatile organic compounds (VOCs). Air pollutants arise from both man-made and natural processes (Kyle *et al.*, 2001).

Air pollution is the introduction into the air of any substance different from any of its natural constituents. It can occur as a result of natural conditions, such as ash from volcanic eruptions, sand storms or forest fires. Natural geomorphic terrain, such as low valleys surrounded by mountains, temperature and wind speed can also exacerbate already polluted surroundings in a region. More serious, however are the anthropogenic or human causes of air pollution that are directly linked to energy consumption, industrial emissions and vehicular exhausts in heavily congested urban areas. It is often a combination of both natural as well as human activities that lead to highly unhealthy conditions of air (Abatan, 2007).

An air pollutant is known as a substance in the air that can cause harm to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made (EPA, 2006). Pollutants can be classified as either primary or secondary. Usually, primary pollutants are substances directly emitted from a process, such as ash from a volcanic eruption, carbon dioxide from burning fossil fuels, the carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground level ozone — one of the many secondary pollutants that make up photochemical smog.

Air pollution and its public health impacts are drawing increasing concern from the environmental health research community, environmental regulatory agencies, industries, as well as the public. The quality of air, both indoors and outdoors, is closely related to morbidity and mortality from respiratory and cardiovascular diseases. (Xianglu *et al*., 2006). Common air pollutants that draw intense concerns include particulate matter (PM), ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), lead (Pb), volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs).(Xianglu *et al*., 2006).

In 1997, the US Environmental Protection Agency (USEPA) modified its National Ambient Air Quality Standards (NAAQS), in which the 24-h and annual average concentration limits for ambient $PM_{2.5}$ were 65 and 15 µg/m^3, respectively. Also included in the standards are CO, PM_{10}, SO_2, NO_2 and Ozone. Standards with different time durations are defined because of some pollutants, like Ozone and CO, short-term effect is a concern, while for lead and particulate matter, more attention is focused on its long-term effect. In addition, the time duration that is chosen depends on which durations are more associated with human health effects.

Table 1.1 NAAQS standards

Pollutants	Time duration	Values
CO (ppm)	1h	35
	8h	9
NO_2(ppb)	Annual	53
PM_{10} (µg/m^3)	24h	150
	Annual	50
$PM_{2.5}$ (µg/m^3)	24h	65
	Annual	15
O_3 (ppb)	1h	120
	8h	80
SO_2 (ppb)	24h	140
	Annual	30

Source: USEPA (1997)

In urban areas mobile or vehicular pollution is predominant and significantly contributes to air quality problems. Road traffic produces volatile organic compounds, suspended particulate matter (SPM), oxides of sulphur (SOx), oxides of nitrogen (NOx), and carbon monoxide (CO), which cause adverse health effects to the exposed population. The particles emitted from the vehicular exhaust of more than 10-micron size are held in upper respiratory tract and particles less than 10-micron size (PM10) accumulates in the lung and produces respiratory abnormalities (Ingle *et al.*, 2005).

Traffic-related emissions are a complex mix of pollutants consisting of nitrogen oxides (including nitrogen dioxide), particulate matter, carbon monoxide, sulphur dioxide, volatile organic compounds, ozone, and many other chemicals such as trace toxics and greenhouse gases. This concentration of pollutants varies both spatially (by location) and temporally (by time). A significant proportion of the population are exposed through occupations that lead to extended periods of time on or near roads and highways or close to traffic like asphalt workers (Randem *et al.*, 2004), traffic officers (de Paula *et al.*, 2005; Dragonieri *et al.* 2006; Tamura *et al.* 2003; Tomao *et al.*, 2002; Tomei *et al.*, 2001), street cleaners (Raachou-Nielsen *et al.* 1995), street vendors and tollbooth workers. Health impacts are greater for these groups who work close to traffic than for those that are not occupationally exposed.

Exposure to dust has long been associated with the prevalence of varying degrees of airway obstruction and respiratory symptoms in man (Noor *et al*, 2000). A high incidence of cough, chronic bronchitis, sneezing and eye irritation coupled with infection of the throat has also been reported. There are many health effects of air pollution including irritation of the eyes, nose, mouth and throat, chest pain, laboured breathing and increased susceptibility to lung infection. At very low levels, air pollution is a nuisance to healthy individuals and a burden to those with respiratory disease. (Mandryks *et al.*, 2000).

Respiratory problem from air pollution can be measured using lung function test also called pulmonary function tests (PFTs) which evaluates how well the lungs works. The normal value ranges for lung function tests is usually adjusted for age, height, sex and sometimes weight and race. Results are often expressed in terms of a percentage of the expected value. The test determine how much air the lungs can hold and how quickly air can move out in and out of the lungs, and how well the lungs put oxygen into and remove carbon dioxide from the blood. Lung function tests provide qualitative and quantitative evaluation of pulmonary function and are therefore of definitive value in the diagnosis and therapy of patients with cardiopulmonary disorders as well as those with obstructive and restrictive lung disease (Frampton *et. al.*, 2000).

1.2 Problems Statements

Air pollution continues to pose a significant threat to health of population worldwide. In many urban areas of Asia, Latin America and Africa, deteriorating air quality has been associated with rapidly rising population growth and increased use of motor vehicles, coupled with inadequately regulated emissions of air pollution from industrial plants and power generating facilities. Annually, air pollution accounts for an estimated 3 million deaths, which is 5% of the 55 million deaths that occur worldwide each year (Cacciola *et al.*, 2002).

According to the United States Environmental Protection Agency (USEPA), vehicular emissions account for 51% of carbon monoxide, 34% of nitrogen oxides and 10% of particulate matter released each year in the United States. The United Nations estimated that over 600 million people in urban areas worldwide were exposed to dangerous levels of traffic-generated air pollutants (Human exposure to these air pollutants is believed to have posed severe health problems especially in urban areas where pollution levels are on the increase. In accordance with World Bank report, the estimated annual damage of loss of life and diseases due to the air pollution is about $640 and $260 million respectively (Boudaghpour *et al.*, 2009).

In 2004, Toronto Public Health reported a study that estimated the burden of illness associated with ambient (outdoor) levels of air pollution in Toronto. The study showed that smog-related pollutants from all sources contributed to about 1,700 premature deaths and 6,000 hospitalizations each year in Toronto. The study indicated that these deaths would not have occurred when they did without chronic exposure to air pollution at the levels experienced in Toronto.

Outdoor PM air pollution is estimated to be responsible for about 3% of adult cardiopulmonary disease mortality; about 5% of trachea, bronchus, and lung cancer mortality; and about 1% of mortality in children from acute respiratory infection in urban areas worldwide. This amounts to about 0.80 million (1.2%) premature deaths and 6.4 million

(0.5%) lost life years. (Cohen *et al.*, 2004). These adverse outcomes from exposure to vehicular emissions range from acute symptoms like coughing and wheezing to more chronic conditions such as asthma and chronic obstructive pulmonary disease (COPD), which includes chronic bronchitis and emphysema.(Mckeown,2007).

A recent study conducted in Abuja, Nigeria by Moen in 2008 on the effect of vehicular emissions on the health of Traffic wardens showed that 16% of the traffic wardens had runny nose, 15% had chest pain, 26% had cough while 14% and 8% had eye irritation and sore throat respectively (Moen, 2008).

1.3 Rationale for the study

Ibadan Is the largest indigenous city in the whole of West Africa. There are eleven (11) Local Governments in Ibadan Metropolitan area consisting of five urban local governments in the city and six semi-urban local governments in the lesser outskirt of the metropolis (Areola, 1992). The city also links Lagos that is the major commercial nerve centre of the. This linkage has led to the introduction of motorized vehicles and trucks that emit pollutants and vehicle exhaust emissions which affects the air quality of the local government area.

Many studies have been carried out on the determination of the ambient concentration of air pollutants at major road intersections and they assessed its effect on the exposed population without a corresponding control group and majority were carried out in developed countries, indicative of a dearth of research on personal exposure of Traffic wardens to Particulate Matter (PM_{10}) in developing countries.

Traffic wardens have been reported to be at high risk of respiratory impairment due to their exposure to traffic-related air pollutants (Ingle, *et al.*, 2005) but no studies have been carried out on the assessment of pulmonary status of traffic wardens in Nigeria. An assessment of traffic-related air pollutants as well as the evaluation of the pulmonary status of traffic wardens would assist in the development of intervention studies in the future and also provide a database which would be useful for the government for policy formulation on traffic emissions. This is particularly important considering the fact that policy and practical measures can be used to reduce occupational exposure to traffic emissions.

1.4 Research Question

1. What is the perception of Traffic wardens and Regular policemen about air quality?

2. What is the ambient concentration of gases and particulate matter within the selected traffic routes in the two Local Government Areas?

3. What is the traffic density at the selected traffic routes in the two Local Government Areas?

4. What is the pulmonary function status of Traffic wardens and Regular policemen

1.5 Research Hypothesis

H_0: There is no significant association between the prevalence of respiratory symptoms and exposure to traffic related air pollutants among traffic wardens.

H_1: There is a significant association between the prevalence of respiratory symptoms and exposure to traffic related air pollutants among traffic wardens.

H_0: There is no significant difference in the mean force expiratory volume in 1second (FEV_1) of traffic wardens and regular police officers.

H_1: There is a significant difference in the mean force expiratory volume in 1second (FEV_1) of traffic wardens and regular police officers.

1.6 Objective of the Study

1.6.1 Broad Objective

The main objective is to Characterize traffic related air pollutants and to assess the respiratory health problems experienced by policemen in Ibadan North and Northeast Local Government Areas.

1.6.2 Specific Objectives

The specific objectives of this study were to:

1. describe the traffic routes.
2. determine the traffic density at selected traffic routes.
3. determine gaseous and particulate matter concentrations within the selected traffic routes in the Local Government areas.
4. document the Policemen's perception of air quality.
5. document the reported respiratory symptoms among Traffic wardens and Regular policemen.
6. determine the pulmonary function status of selected Traffic wardens and Regular policemen.
7. identify possible association between exposure variables and the lung function status of selected policemen.

CHAPTER TWO

LITERATURE REVIEW

2.1 Atmosphere

The Earth is surrounded by a blanket of air, which we call the atmosphere. It reaches near or over 600 kilometres (372 miles) from the surface of the Earth. This blanket of air is a layer of gases surrounding the planet Earth that is retained by Earth's gravity. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night (NOAA, 2010).

The atmosphere that originally surrounded the earth was probably much different from the air we breathe today. The earth's first atmosphere (some 4.6 billion years ago) was most likely hydrogen and helium- the two most abundant gases found in the universe- as well as hydrogen compounds, such as methane (CH_4) and ammonia (NH_3). (Ahrens, 2008).

Air is the name given to atmosphere used in breathing and photosynthesis. Dry air contains roughly (by volume) 78.09% nitrogen, 20.95% oxygen, 0.93% argon, 0.039% carbon dioxide, and small amounts of other gases. Air also contains a variable amount of water vapour, on average around 1%. While air content and atmospheric pressure varies at different layers, air suitable for the survival of terrestrial plants and terrestrial animals is currently known only to be found in Earth's troposphere and artificial atmospheres.

Oxygen (O_2), the second most abundant gas in today's atmosphere, probably began as an extremely slow increase in concentration as energetic rays from the sun split water vapour (H_2O) into hydrogen and oxygen. The hydrogen, been lighter, probably rose and escaped into space, while the oxygen remained in the atmosphere. (Ahrens, 2008).

2.2 Structure of the atmosphere

According to Ahrens, (2008), a vertical profile of the atmosphere reveals that it can be divided into series of layers. Each layer may be defined in a number of ways: by the manner in which the air temperature varies through it, by the gases that comprise it, or even by its electrical properties. These layers include:

- Troposphere; which is the lowest layer. It extends up to about 16 km in tropical regions (to a temperature of about -79°C, or about -110°F).
- Stratosphere: This is the layer that houses the ozone layer. It is located immediately above the troposphere. Temperatures gradually rise within the Stratosphere due to the effects of the ozone layer.
- Mesosphere: The mesosphere is immediately above the stratosphere and it extends an additional 53 miles into space. Temperatures fall once again, reaching a low of -93° Celsius. When meteors enter Earth's atmosphere, they usually burn in the mesosphere before reaching the layers below. In the North and South Pole, clouds can form in this layer, which is unique to those regions of the planet.
- Ionosphere: The ionosphere is not really a layer, but rather an electrified region within the upper atmosphere where fairly large concentrations of ions and free electrons exist. The lower region of the ionosphere is usually about 60Km above the earth's surface. From here (60Km), the ionosphere extends upward to the top of the atmosphere. Hence, the bulk of the ionosphere is in the thermosphere.
- Thermosphere: At an altitude of about 90Km, temperatures begin to rise. The layer that begins this altitude is the thermosphere, because of high temperatures reached in this layer (about 1200°C, or about 2200°F).
- Exosphere: This is the region beyond the thermosphere. It extends to about 9.600 Km the outer limit of the atmosphere (See Figure 2.1)

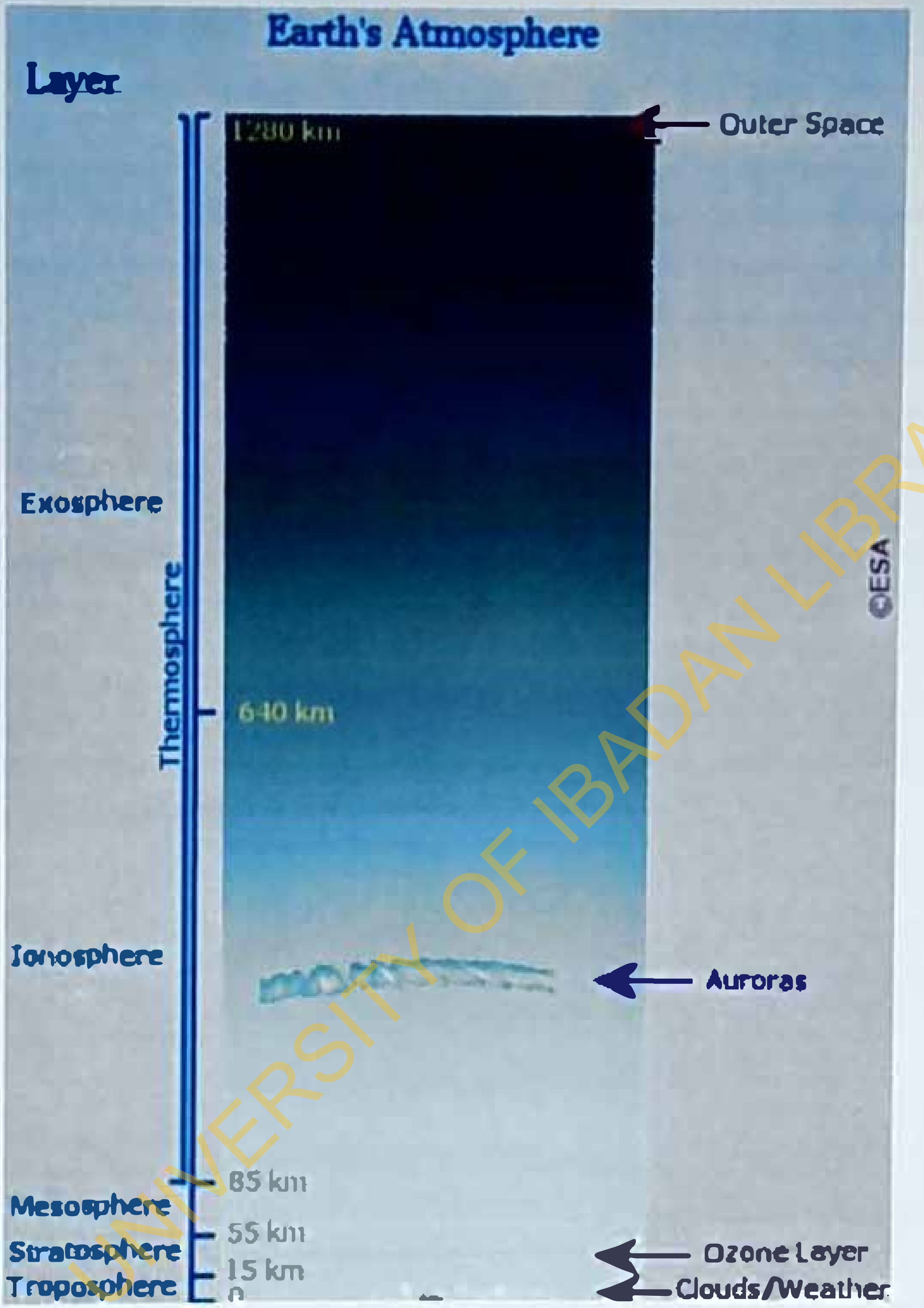


Fig 2.1: An illustration of the Earth's Atmosphere

Source: European Space Agency (2010)

2.3 Physical characteristics of air

2.3.1 Air Composition

The immediate environment of man comprises air on which depend all forms of life. Air is mainly composed of nitrogen, oxygen, and argon, which together constitute the major gases of the atmosphere. The remaining gases are often referred to as trace gases among which are the greenhouse gases such as water vapour, carbon dioxide, methane, nitrous oxide, and ozone. Apart from supplying life-giving oxygen, air and atmospheric conditions serve several functions. The human body is cooled by air contact; the special senses of hearing and smell function through air by dust, smoke, toxic gases and chemical vapours has resulted in sickness and death. Human beings need a continuous supply of air to exist. The requirement of air is relatively constant (about 10-20m^3), (Parks, 2006). The composition of air is given in Table 2.1.

Air is a mechanical mixture of gases and depending on location and time, it contains the molecules and particles of thousands of different materials usually separable into chemical materials and biological forks (Chanlett, 1993).

Table 2.1: Composition of Dry Atmosphere by volume

Gas	Volume
Nitrogen(N_2)	780,840 ppmv (78.084%)
Oxygen (O_2)	209,470 ppmv (20.946%)
Argon(Ar)	9,340 ppmv (0.9340%)
Carbon dioxide (CO_2)	390 ppmv (0.039%)
Neon(Ne)	18.18 ppmv (0.001818%)
Helium (He)	5.24 ppmv (0.000524%)
Methane (CH_4)	1.79 ppmv (0.000179%)
Krypton (Kr)	1.14 ppmv (0.000114%)
Hydrogen (H_2)	0.55 ppmv (0.000055%)
Nitrous oxide (N_2O)	0.3 ppmv (0.00003%)
Carbon monoxide (CO)	0.1 ppmv (0.00001%)
Xenon (Xe)	0.09 ppmv (9×10^{-6}%) (0.000009%)
Ozone (O_3)	0.0 to 0.07 ppmv (0 to 7×10^{-6}%)
Nitrogen dioxide (NO_2)	0.02 ppmv (2×10^{-6}%) (0.000002%)
Iodine (I_2)	0.01 ppmv (1×10^{-6}%) (0.000001%)
Ammonia (NH_3)	Trace
Not included in above dry atmosphere:	
Water vapour (H_2O)	~0.40% over full atmosphere, typically 1%-4% at surface

Source: NOAA Earth System Research Laboratory (2010).

2.3.2 Air Temperature

Air molecules are in constant motion. The speed of air molecules corresponds to their kinetic energy, which in turn corresponds to the amount of heat energy in the air. Air temperature is a measure of the average speed at which air molecules are moving; high speed corresponds to high temperature. The temperature of a substance is measured using a thermometer. (Ahrens, 2008).

2.3.3 Air Pressure

Air is held to the earth by gravity. The strong invisible force pulls the air downward, giving air molecules weight. The weights of the air molecules exert a force upon the earth and everything on it. The amount of force exerted on a unit surface area is called atmospheric pressure or air pressure. The air pressure at any level in the atmosphere can be expressed as the total weight of air above a unit surface area at that level in the atmosphere. The instrument used in measuring air pressure is called barometer. (Ahrens, 2008).

2.3.4 Wind

Wind is air in motion. It is caused by horizontal variations in air pressure. The greater the difference in air pressure between any two places at the same altitude, the stronger the wind will be. The wind direction is the direction from which the wind is blowing. Wind speed is the rate at which the air moves past a stationary object. Varieties of instrument are used in measuring wind. A wind vane measures wind direction while anemometers measures wind speed. (Ahrens, 2008).

2.3.5 Precipitation

Precipitation is any form of water (either liquid or solid) that falls from the atmosphere and reaches the ground, such as rain, snow or hail. Rain gauge is an instrument that measures rainfall. The standard rain gauge consists of a funnel-shaped collector that is attached to a long measuring tube. (Ahrens, 2008).

2.3.6 Humidity

Humidity refers to the air's water vapour content. The maximum amount of water vapour that the air can hold depends on the air temperature; warm air is capable of holding more water vapour than cold air. Relative humidity is the ratio of the amount of water vapour that the air could hold at that particular temperature. When the air is holding all the moisture possible at a particular temperature, the air is said to be saturated. Relative humidity and dew-point temperature (the temperature at which air is said would have been cooled for saturation to occur) are often obtained with a device called psychrometer. (Ahrens, 2008).

2.4 Air quality

Air quality is defined as a measure of the condition of air relative to the requirements of one or more biotic species and or to any human need or purpose. Air quality is therefore an indication of healthfulness of the air based on the quantity of polluting gases and particulates (liquid droplets or tiny solid particles are suspended in air) it contains. The Air Quality Index (AQI) (also known as the Air Pollution Index (API) or Pollutant Standard Index (PSI) is a number used by government agencies to characterize the quality of the air at a given location.(EPA, 2003). It is an index used for reporting daily air quality. It shows how clean or unhealthy the air is, and what associated health effect might be a concern.. The AQI is calculated for four major air pollutants regulated by the Clean Air Act: ground- level ozone, particle pollution, carbon monoxide, and sulphur dioxide. For each of these pollutants, EPA has established national air quality standards to protect public health. (EPA, 2009).

As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. The AQI includes sub-indices for ozone, particulate matter, carbon monoxide, sulphur dioxide and nitrogen dioxide, which relates ambient pollution concentrations to index values on a scale from 0 through 500. This represent a broad range of air quality from pristine air to air pollution levels that present imminent and substantial danger to the public (EPA, 2003).The purpose of the AQI is to help understand what local air quality means to health. To make it easier to understand, the AQI is divided into six levels of health concern:

Table 2.2: Air Quality Index

Air quality index(AQI) values	Levels of health concern	Colours
When the AQI is in this range:	.... air quality conditions are	... as symbolized by this colour
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for sensitive groups	Orange
151 to 200	[illegible]	Red
201 to 300	[illegible]	Purple
301 to 500	[illegible]	Maroon

Each category corresponds to a different level of health concern:

Good: When the AQI value is between 0 and 50. Air quality is satisfactory and poses little or no health risk.

Moderate: Whenthe AQI is between 51 and 100. Air quality is acceptable; however, pollution in this range may pose a moderate health concern for a very small number of individuals. People who are unusually sensitive to ozone or particle pollution may experience respiratory symptoms.

Unhealthy for Sensitive Groups: When AQI values are between 101 and 150, members of sensitive groups may experience health effects, but the general public is unlikely to be affected.

- **Ozone:** People with lung disease, children, older adults, and people who are active outdoors are considered sensitive and therefore at greater risk.
- **Particle pollution:** People with heart or lung disease, older adults, and children are considered sensitive and therefore at greater risk.

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

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

Hazardous: AQI values over 300 trigger health warnings of emergency conditions. The entire population is even more likely to be affected by serious health effects. (EPA, 2009).

2.5 Air pollution

Air pollution can be described as the presence of substances in air in sufficient concentration and for sufficient time, so as to be, or threaten to be injurious to human, plant or animal life, or to property, or which reasonably interferes with the comfortable enjoyment of life and property. (Abatan, 2007). It can also be defined as the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to organisms into the atmosphere.

It is the introduction into the air of any substance different from any of its natural constituents. It is usually from four main sources, namely, industrialisation, tobacco smoking, domestic cooking and vehicular or machinery fuel combustion (Tanimowo, 2000). Air pollution is either due to gases (carbon monoxide, nitrogen dioxide, sulphur dioxide, benzene and ozone) or particulates (dust). These, singly or in combination cause respiratory impairment if inhaled at adequate concentrations and over a long enough period of time (WHO, 1964; WHO, 1984).

Life on earth depends heavily, among many other things, on the resources provided by the atmosphere. Anthropogenic pollution of the air resources is causing a large variety of adverse impacts on the natural and built environments including biological, ecological, and architectural values. Especially effects on the health of human populations have received a lot of attention lately (Hänninen *et al.*, 2006).

Impurities from both natural and human sources are also present in the atmosphere. Wind picks up dust and soil from the earth's surface and carries it aloft; small saltwater drops from ocean waves are swept into air (upon evaporation, these drops leave microscopic salt particles suspended in the atmosphere); smoke from forest fires is often carried high above the earth; and volcanic spew many tons of fine ash particles and gases into the air. (Ahrens, 2008).

Urban air is polluted by a number of toxic or potentially carcinogenic compounds, mainly originating from the combustion of fossil fuels. In particular, the occurrence in urban air of significant amounts of organic carcinogens such as benzene and benzo (a) pyrene raises concerns about the possible long term effects in urban populations. (Tomei, *et al.*, 2001).

The problem of air pollution in urban areas is also aggravated by inadequate power supply for industrial, commercial and residential activities due to, which consumers have to use diesel-based captive power generation units emitting high levels NO_x and SO_x. In addition, non-point sources such as waste burning, construction activities, and roadside air borne dust due to vehicular movement also contribute to the total emission load.

Ambient pollution is further compounded by the rapid urbanization of many developing countries. The global urban population reached 50% in 2008 and is expected to increase to 60% by 2030. This increase will be particularly pronounced in developing countries, in which 80% of the urban population will be living in 2030 (UNFPA, 2007). Accompanying this rise in urban populations will be a fourfold increase in the number of motorized vehicles in cities by 2050, making transport-related pollution a hazard even in countries with overall low motorization rates (World Bank, 2004).

2.5.1 Brief history of air pollution

Air pollution first received recognition as an urban problem in England in the ninth century, when coal was discovered and complaints about foul air began to be heard. The possible menace to human health was recognized in the 17th century by John Evelyn, who dared to ascribe chronic respiratory ailments to the inhalation of coal smoke. (Miller, 1998). These classic episodes of severe air pollution are important because they caused so many deaths that they served as a "wake up call" to the public and to policy-makers which made them realize that air pollution was more than just a nuisance. They led to the first major legislation designed to reduce air pollution. After these incidents, there was little doubt that high levels of air pollution were associated with an increase in premature deaths.

During the London Smog of 1952, the smog was so thick that road, rail and air transport were brought almost to a standstill and a performance at the Sadler's Wells Theatre had to be suspended when fog in the auditorium made conditions intolerable for the audience and the performers. There was a cattle show going on at the time in Smithfield, and the press reported that the cattle were asphyxiated. The fog was so thick that in many parts of London it was impossible for pedestrians to find their way at night, even in familiar districts. It is said that people could not even see their own feet. This kind of dense fog in London came to be known as a "pea souper". It was very different from the clean white fog of the countryside because it contained noxious emissions from factory chimneys which had an unpleasant odour and was a dirty yellow or brown colour. It is not known how many people died as a direct result of the fog. Many who died already suffered from chronic respiratory or cardiovascular diseases. Without the fog, they might not have died when they did. In England, the Clean Air Act of 1956 banned emissions of black smoke and decreed that the residents of urban areas and operators of factories must convert to smokeless fuels. (Ware *et al.*, 1981).

2.5.2 Air pollution in Nigeria

Air pollution is considered a major problem in the major cities of the world. As this danger looms on the developed countries of the world, Africa can only be described as operational disaster areas. In Nigeria much attention is given to general industrial pollution and pollution from oil related industries, with little reference on damage of pollution caused by mobile transportation sources of air pollution (Faboya, 1997; Magbabeola, 2001).

The situation of increased pollution from mobile transportation source is on the increase in Nigeria as a result of per capita vehicle ownership, thus resulting to high congestion on major roads and increase in the concentration of pollutants in the air. This has consequently, increased health risk on human population (Abam *et al.*, 2009). Studies conducted in Kaduna and Abuja cities show higher values of CO_2 concentration in heavily congested areas: 1840ppm for Sambo Kaduna, 1780ppm for Stadium roundabout, Kaduna, and 1530ppm for A.Y.A, Abuja, 1160ppm for Asokoro Abuja (Akpan *et al.*, 1999).Similar work by Ndoke *et al.*, 2000, at Minna, a city in Nigeria shows the maximum value of 5,000ppm for CO_2 in congested areas, which was still lower than WHO stipulated maximum value of 20,000ppm. The maximum value for CO emission obtained was 15ppm which was still lower than the base line of 48ppm stipulated by W.H.O and 20ppm stipulated by Federal Environmental

Protection Agency of Nigeria (FEPA). The reason for this low emission concentration in Minna is due to low traffic and industrial activities in the city.

A study of the impacts of urban road transportation on the ambient air was conducted by Koku and Osuntogun, (1999) in three cities of Nigeria: Lagos, Ibadan and Ado – Ekiti all in South-west region of Nigeria. Air quality indicators namely CO, SO_2, NO_2, and total suspended particulates (TSP) were determined. The highest levels obtained for the air pollution indicators in Lagos were CO-233 ppm at Idumota, SO_2-2.9 ppm at Idumota, NO_2-1.5 ppm at Iyana–Ipaja and total particulates 852 cpm at Oshodi bustop. At Ibadan, the CO and SO_2 levels at 271 and 1.44 ppm were highest at Mokola round about while NO_2. at 1.0ppm was highest at Beere round about. In Ado - Ekiti the highest level obtained were CO-317 ppm at Oke Isha, NO_2 -0.6 ppm at Ijigbo Junction and SO_2-0.8 ppm at Old Garage Junction. The obtained results of CO, SO_2, NO_2, and particulate counts per minute were found by Koku, to be higher than FEPA limits. Limits set also by FEPA are CO-10 ppm, SO_2-0.01 ppm, NO_2-0.04-0.06 ppm. The noise level in all the locations were found to be higher than FEPA limit of 90dB and the WHO limit of 70 dB – 75 dB WHO, (2000). Conclusions of this investigation show a growing risk of traffic-related problems in Nigeria Cities and demand for serious air quality measures.

A comparative study of emission figures in Lagos and the Niger Delta (Oil producing region) area has been reported by Jerome (2000). Two major cities in the Niger Delta were considered, Port-Harcourt and Warri. The results obtained in Table 2.3 show that the concentrations of TSP (Total suspended particulates), NOx, SO_2, and CO in Lagos and Niger Delta were above FEPA recommended limit. Concentration of CO emissions for Lagos was quite high, being in the range of 10 – 250 ppm recorded higher than the ranges of 5.0 – 61.0 ppm and 1.0 – 52ppm recorded for oil communities in the Niger Delta. The TSP concentrations were also high for both cities when compared to WHO's guideline

However, the overall levels of vehicular related air pollution in Nigeria from all the studies conducted show an increasing trend with potential hazards to the population. It is not out of place to state that the concentration of these pollutants must have increased tremendously in the past ten years of democratic rule in Nigeria due to the influx of old and fairly used vehicles into the country following changes in government policy.

Kaduna state in Nigeria is an industrialized city considering the number of process industries cited there. The principal sources of emission in Kaduna state are refinery, transportation (combustion of fuel), incinerators, refuse, burning etc. The major pollutants are gases and particulate matters. Gases such as oxide of sulphur, nitrogen and carbon, ammonia and hydrocarbons predominate. Other pollutants are particulate matters such as smoke, dust, fog, mist etc (Perry, 1984).

Table 2.3: Ambient air pollutants in Lagos and Niger Delta Area

Lagos Area Pollutant	Niger Delta Area Oil Communities	Cities	Non-Traffic Urban zone	Traffic Zone	FEPA Standards
TSP μ/m^3	92.2-348.5	396.8-583.3	31.4-746.5	72-950	250
NOx(ppm)	22.0-295.0	35-370	81-81.5	34-131.6	40-60
SO_2(ppm)	7.0-97.0	16-300	0.5-43	20-250	100
CO(ppm)	5.0-61.0	1.0-52	0.5-3.9	10-250	10
CO/NOx	20	15-130	0.0-6.0	50-200	-

Source: Jerome, 2000

2.6 Sources of Air Pollution.

Sources of air pollution can be divided into two main groups namely; natural sources and anthropogenic sources. Natural sources of air pollution include;

- Dust from natural sources, usually large areas of land with little or no vegetation.
- Methane, emitted by the digestion of food by animals, for example cattle.
- Smoke and carbon monoxide from wildfires.
- Vegetation, in some regions, emits environmentally significant amounts of VOCs on warmer days. These VOCs react with primary anthropogenic pollutants specifically, NO_x, SO_2, and anthropogenic organic carbon compound to produce a seasonal haze of secondary pollutants.
- Volcanic activity, which produce sulphur, chlorine, and ash particulates. (Goldstien *et al*., 2009)

Anthropogenic sources include;

- Stationary Sources" including smoke stacks of power plants, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices

- "Mobile Sources" including motor vehicles, marine vessels, aircraft and the effect of sound etc.

- Chemicals, dust and controlled burn practices in agriculture and forestry management.

- Waste deposition in landfills, which generate methane. Methane is not toxic; however, it is highly flammable and may form explosive mixtures with air. Methane is also an asphyxiant and may displace oxygen in an enclosed space. Asphyxia or suffocation may result if the oxygen concentration is reduced to below 19.5% by displacement

- Military, such as nuclear weapons, toxic gases, germ warfare and rocketry

One criterion is whether the source is mobile or not. The former refers to traffic-related sources, including ground traffic (bus, private car, taxi, combi, motorcycle, etc.), underground traffic (metro or subway) and air traffic, and the latter is mainly industrial, commercial and personal emissions. (Xianglu *et al*., 2006).

2.6.1 Mobile sources

2.6.1.1 Automobiles

Across the entire globe, motor vehicle traffic has increased tremendously. In 1950, there were about 53 million cars on the world's roads. On the average, the fleet has grown by 9.5 million units per year over this period. Simultaneously, the truck and bus fleet has been growing by about 3.6 million vehicles per year (Motor Vehicle Manufacturers' Association, 1991). While the growth rate has slowed considerably in the industrialized countries, population growth and increased urbanization and industrialization are accelerating the use of motor vehicles elsewhere. If the approximately 120 million two-wheeled vehicles around the world are included (growing at about 4 million vehicles per year over the last decade), the global motor fleet is now about 715 million. (Schwela *et al*., 1997).

Vehicle emissions represent a serious environmental health problem, which is expected to increase in significance as vehicle ownership increases globally (Moen, 2008). In developing countries, motorization growth has been largely unchecked by environmental regulations, creating high levels of pollution (Han, 2006). Traffic contributes more to ambient pollution in developing countries, accounting for upwards of 40-80% of NO_2 and CO concentrations (Fu, 2001; Goyal, 2006; Abbaspour, 2004). This situation is alarming and is predicated on the poor economic disposition of developing countries. Poor vehicle maintenance culture and importation of old vehicles which culminate to an automobile fleet dominated by a class of vehicles known as "super emitters" with high emission of harmful pollutants, has raised high this figure of emission concentration. Furthermore, in developing countries the super emitters contribute about 50% of harmful emissions to the entire average emission (Brunekeef, 2005). In Mexico City for example these supper emitters is reported to be responsible for 90% of hydrocarbon and CO emissions and 80% of NOx emission accounting for 60% of the kilometres travelled in the country (UNEP, 1999).The increase of these traffic-related pollution is not based on the aforementioned factors only, but also on low quality fuel, poor traffic regulation and lack of air quality implementation force. These are clear indices to high levels of traffic-related pollution in developing countries.

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

Developing cities in Asia and Africa are at high risk to exposure of this traffic-related pollution. Research conducted in Ethiopia, Mozambique, Kenya and Republic of Benin, show that there is a high level of DNA damage in urban residents and higher prevalence of asthma in urban school children exposed to traffic pollution compared to rural children (Autrup, 2006). The African continent may be highly affected if priority is not given in understanding the scale of this problem and its control.

2.6.2 Stationary sources

Stationary sources are non-moving sources, fixed-site producers of pollution such as power plants, chemical plants, oil refineries, manufacturing facilities, and other industrial facilities. Air pollution from stationary sources is produced by two primary activities. These activities are stationary combustion of fuel such as coal and oil at power generating facilities, and the pollutant losses from industrial processes. Industrial processes include refineries, chemical manufacturing facilities, smelters e.t.c (USEPA, 2010).

Stationary sources have many possible emission points. An emission point is the specific place or piece of equipment from which a pollutant is emitted. Air pollutants can be emitted from smoke stacks, storage tanks, equipment leaks, process wastewater handling/treatment area, loading and unloading facilities, and process vents. A process vent is basically an opening where substances (mostly in gaseous form) are "vented" into the atmosphere. Common process vents in a chemical plant are distillation columns and oxidation vents. Emissions from storage tanks are due to pollutants that can leak through the roofs, and can leak through tank openings when liquids expand or cool because of outdoor temperature changes. Also, air pollutants can escape during the filling and emptying of a storage tank. Air pollution produced from wastewater occurs when wastewater containing volatile chemicals comes in contact with the air (USEPA, 2010).

Large, stationary sources of emissions that have specific locations and release pollutants in quantities above an emission threshold are known as point sources. Those facilities or activities whose individual emissions do not qualify them as point sources are called area sources. Area sources represent numerous facilities or activities that individually release small amounts of a given pollutant, but collectively can release significant amounts of a pollutant. For example; dry cleaners, vehicle refinishing and gasoline dispensing facilities, and residential heating will not typically qualify as point sources, but collectively the various emissions from these sources are classified as area sources. Stationary sources are also classified as major and minor sources. A major source is one that emits, or has the potential to emit, pollutants over a major source threshold. A minor source is any source which emits less pollutant than the major source threshold (USEPA, 2010).

2.6.2.1 Thermal power plant

Coal based thermal power plants affect the air quality of the surrounding region more than natural plants. For example in India, around the coal based plants, the ambient sulphur dioxide concentration was in the range of 20-25 ug/m^3 in and around Ramagundam. In case of Chandrapur Super Thermal Power Station the concentration of SO_2 varied from 3.61-189 ug/m^3, NO_x varied from 8.89-26.55ug/m^3 and SPM from 52.6-193.2ug/m^3. The concentration of SO_2, NO_x and SPM varied from 3-37, 5-34, 65-482 ug/m^3, respectively in and around Gandhinagar Thermal Power Plant (GTPP.) Ambient NO_x concentration in case of natural gas based power plant was found to be in the range of 5-7 ug/m^3. From the epidemiological data of the area surrounding the Ramagundam coal based plant, it has been observed that around 6.5% of population living within a 2 km radius of the plant suffers from respiratory disorders, while the figure decreases to 3. 2% at a distance of 2.5 km and becomes negligible (0.91%) at over 5 km from the plant. Thus it can be inferred that people living within 5 km radius of coal based power plant suffer from respiratory ailments. (NEERI, 2006).

2.6.2.2 Industrial sources

2.6.2.2.1 Cement industries

Different greenhouse gases and solid particles derived from cement industries threaten air with the least supervision. As time passes, these gases and solid particles gradually condense in the environment and can be a potential risk for the atmosphere, inhabitants and animals. Suspended solid particles, carbon monoxide, carbon dioxide, different types of nitrogen oxides, sulphur oxides are the most common pollutants releasing from furnaces into atmosphere (Boudaghpour *et al.*, 2009).

2.6.2.2.2 Oil refineries

Air pollutants are emitted from a variety of sources throughout the oil and gas development process. Table 2.4 summarizes the major air pollutants released during oil and gas development and the major sources of emissions

Table 2.4: Major air pollutants released during oil and gas development

	Fugitive emissions	Dehydration	Vehicles	Flaring	Engines	Pits	Venting
Particulate matter		X	X		X		
Hydrogen Sulphide	X			X			X
Ozone	O	O	O		O		
Carbon Monoxide			X	X	X		
Nitrogen Oxides			X	X	X		
Sulphur dioxide			X	X	X		
VOCs	X	X		X	X	X	X
BTEX	X	X		X	X	X	X
PAHs				X			
Methane	X	X				X	X
Dust		X	X				

- 'X' means that a pollutant is emitted as a direct result of the particular activity
- 'O' means that the pollutant is generated in a secondary reaction associated with the particular oil and gas development activity.

Source: www.earthworksaction.org (2010)

2.7 Types of air pollution

Air pollution can be classified into two types namely:

- Indoor air pollution
- Outdoor air pollution

2.7.1 Indoor air pollution

Indoor air pollution can be traced to prehistoric times when humans first moved to temperate climates approximately 200,000 years ago. These cold climates necessitated the construction of shelters and the use of fire indoors for cooking, warmth and light. Ironically, fire, which allowed humans to enjoy the benefits of living indoors, resulted in exposure to high levels of pollution as evidenced by the soot found in prehistoric caves. (Albalak, 1997). It has been estimated that approximately half of the world's population, and up to 90% of rural households in developing countries, still rely on biomass fuels.

Lack of ventilation indoors concentrates air pollution where people often spend the majority of their time. Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain locations and trapped inside houses. Building materials including carpeting and plywood emit formaldehyde (H_2CO) gas. Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled. Intentional air pollution is introduced when air fresheners, incense, and other scented items are used in the home. Controlled wood fires in stoves and fireplaces can add significant amounts of smoke particulates into the air, inside and out (Duflo *et al.*, 2008).

The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to indoor air pollution (WHO, 2002).

2.7.2 Outdoor air pollution.

Power plants, factories and vehicles spew out harmful gases and small particles that can penetrate deep into children's lungs. In strong sunlight, oxides of nitrogen from vehicle exhaust fumes form ozone at ground level, which can trigger asthma attacks. Air pollution does not respect national borders. Heavy metals and persistent organic pollutants are carried by winds, contaminating water and soil far from their origin. In the late 1990s, forest fires, mainly in Indonesia, caused a haze of smoke to hang for months over neighbouring Southeast Asian countries. Schools and kindergartens were forced to close, while local hospitals reported large numbers of haze-related illnesses in young children. The Great London Smog of 1952 focused the world's attention on the problem of air pollution, and since then there has been a marked improvement in air quality in developed countries. Nevertheless, every year outdoor air pollution is responsible for the death of hundreds of children in Europe, and of more than 24 000 globally. Industrial growth and rapid urbanization aggravate the problem, with the pressure felt most acutely in the megacities of the developing world. Use of cleaner fuels and technologies, refined motor engines, and public transport are crucial in ensuring that children breathe clean air (Gordon *et al*., 2004).

Outdoor pollution primarily results from the combustion of fossil fuels by industrial plants and vehicles. This releases carbon monoxide, sulphur dioxide, particulate matter, nitrogen oxides, hydrocarbons and other pollutants. The characteristics of emissions and solid waste disposal may vary for each specific industry (e.g. smelting, paper production, refining and others) (WHO, 2008).

Air pollution levels are tightly linked to climate and topography. Air pollution episodes can be particularly troublesome if the affected city is located in a valley surrounded by mountains (this was the case in the Meuse Valley in Belgium and is the case in Mexico City, Mexico). Surfaces such as roads (gravel, dirt, asphalt) can generate air pollution when cars drive on them. The potential risk posed by outdoor air pollution varies by the concentration and composition of this mixture, which can vary by location, time of the day or year, and weather conditions (Etzel, 2003).

Table 2.5: Estimate for indoor and outdoor air pollution related diseases

Air pollution related diseases	Outdoor (%)	Indoor (%)	DALY's Attributed (OUT)	DALY's Attributed (IN)
Acute respiratory infections	0.1	0.9	1,856.46	16,708.14
Ischemic heart disease	0.6	0.4	142.02	94.68
Chronic Obstructive Pulmonary Disease	0.7	0.3	639.1	273.9
Asthma	0.5	0.5	178.25	178.25
Trachea, bronchus, lung cancer	0.7	0.3	39.375	16.875
Cerebrovascular disease	0.4	0.6	183.8	275.7
Tuberculosis	0.3	0.7	763.8	1,782.20
Trachoma	0.1	0.9	5.24	47.16
Cataract	0.1	0.9	16.22	145.98
			3,824.27	19,522.89

*DALYs: Disability Adjusted Life Years

(Source: WHO, 1999)

2.8 Outdoor Air Pollutants

Air pollution can be carried thousands of miles across borders and oceans or from one urban area to another. This phenomenon is common around the world and is referred to as "long range atmospheric transport" or "trans-boundary pollution (Amato *et al.*, 2005).

There are basically three types of air pollutants according to Omofonmwan and Osa-Edoh, (2008) namely:

- Physical
- Biological
- Chemical

The chemical air pollutants are further grouped into two namely:

a) Hazardous pollutants
b) Criteria pollutants

2.8.1 Hazardous pollutants

Polluted air contains one or more hazardous substance, pollutant or contaminant that creates a hazard to general health. Hazardous air pollutants, also known as air toxics are those pollutants that cause or may cause cancer or other serious health effects such as reproductive effects or birth defects. (USEPA, 2009).

Air toxics are substances that occur in the air in much smaller amounts than 'criteria' pollutants, but which are much more potent in terms of adverse impacts. In general, air toxics are of particular concern with chronic (long term) exposure, and are associated with serious health outcomes such as cancer and reproductive effects. (Mckeown, 2007).

While over 200 of these toxic chemicals have been detected in ambient air, it has been difficult to gauge the extent of potential health risks because very few communities monitor this kind of air pollution (USEPA, 2009). Examples of air toxics include chromium, benzene, polycyclic aromatic hydrocarbons (PAHs), 1, 3-butadiene, formaldehyde, acrolein etc The sources of hazardous pollutants originate mostly from man-made activities. This includes mobile sources (cars, buses and trucks) and stationary sources (factories, refineries, power plants etc) as well as indoor sources (USEPA, 2009).

2.8.2 Criteria pollutants

Criteria pollutants are commonly emitted from the combustion of fossil fuels, whether gasoline, diesel, propane, natural gas, oil, coal or wood. (Mckeown, 2007). Six pollutants are used to determine the air quality of an environment which is regulated by Environmental Protection Agency (EPA). The pollutants are:

- Particulate matter, fine $PM_{2.5}$ and coarse PM_{10}
- Sulphur dioxide
- Nitrogen dioxide
- Ozone
- Lead
- Carbon monoxide (Amato *et al.*, 2002; Kyle *et al.*, 2001)

2.8.2.1 PARTICULATE MATTER (PM)

Particle pollution is a mixture of microscopic solids and liquid droplets suspended in air. This pollution, also known as particulate matter, is made up of a number of components, including acids (such as nitrates and sulphates), organic chemicals, metals, soil or dust patticles, and allergens (such as fragments of pollen or mould spores) (EPA, 2003).

Airborne particulate matter represents a complex mixture of organic and inorganic substances. Mass and composition tend to divide particulate matter in two principal groups: coarse particles larger than 2.5 μm in aerodynamic diameter and fine particles smaller than 2.5μm. The smaller particles contain the secondarily formed aerosols (gas to particle conversion), combustion particles and re-condensed organic and metal vapours (WHO, 1987c).

It also refers to particles or droplets of various sizes, physical characteristics and chemical compositions present in the air. Previously, environmental epidemiologists had mainly focused on particulate matter with an aerodynamic diameter equal to or less than $10\mu g/m^3$ (PM_{10}). Increasing evidence links $PM_{2.5}$ to various respiratory and cardiac effects, more and more attention is paid to the exposure assessment of $PM_{2.5}$ and its cardiopulmonary impacts (Goldberg *et al*., 2001; Janssen *et al*., 2002; Magari *et al*., 2002).

Particle pollution (also known as "particulate matter") consists of a mixture of solids and liquid droplets. Some particles are emitted directly; others form when pollutants emitted by various sources react in the atmosphere. Particle pollution levels can be very unhealthy and even hazardous during events such as forest fires. Particle levels can be elevated indoors, especially when outdoor particle levels are high. Particles come in a wide range of sizes. Those less than 10 micrometres in diameter (smaller than the width of a single human hair) are so small that they can get into the lungs, where they can cause serious health problems.

- **Fine particles:** The smallest particles (those 2.5 micrometres or less in diameter) are called "fine particles". These particles are so small they can be detected only with an electron microscope. Major sources of fine particles include motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, some industrial processes, and other combustion processes. Ultrafine particles ($PM_{0.1}$) are a subset of inhalable $PM_{2.5}$ particles less than 0.1 µm in diameter. They are not specifically regulated but have a strong link to combustion and therefore are garnering special attention.

- **Coarse particles:** Particles between 2.5 and 10 micrometres in diameter are referred to as "coarse." Sources of coarse particles include crushing or grinding operations, and dust stirred up by vehicles travelling on roads (EPA, 2003).

PM can also be classified by its source:

- **Primary particles:** directly emitted from a natural or human source
- **Secondary particles:** produced when chemicals from natural and human sources react in the atmosphere often energized by sunlight (EPA, 2003).

Anthropogenic airborne particulate matter comes from a variety of sources, which include, but are not restricted to traffic, industries, commerce and domestic heating and cooking. Among them, traffic-related particulates have been under intensive scrutiny for at least two reasons. One is due to the evidence that particulates generated from combustion processes, especially diesel exhaust particulates (DEP), are more potent in posing adverse health effects than those from non-combustion process (Laden *et al.*, 2000; Janssen *et al.*, 2002). Another reason is that traffic-generated emissions were estimated to account for more than 50% of the total emissions of particulate matter in the urban areas in highly industrialized countries (Briggs *et al.*, 1997; Wrobel *et al.*, 2000).

In London, UK, more than 80% of particulate matter is from road traffic (Department for Transport, 2002). In Athens, Greece, the contribution of road traffic to total $PM_{2.5}$ emission is estimated to be 66.5% (Economopoulou and Economopoulos, 2002). In addition, many cities in the developing world are facing serious problems from traffic-related particulate emissions (Kulkarni and Patil, 1999; Yang, 2002; Shendell and Naeher, 2002; Wang *et al.*, 2003). In Malaysia, air pollutant emissions from traffic vehicles were estimated to account for 82% of the total emissions in 1996 (Afroz *et al.*, 2003).

Airborne particulate pollution is more serious in the developing world than in the developed countries, especially in those developing countries currently under rapid industrialization and changes in land use (Xinoglu *et al.*, 2005). Particles smaller than 10 micrometres in diameter can cause or aggravate a number of health problems and have been linked with illnesses and deaths from heart or lung disease. These effects have been associated with both short-term exposures (usually over 24 hours, but possibly as short as one hour) and long-term exposures (years) (EPA, 2003).

The biological effect of inhaled particles is determined by the physical and chemical properties of the particles, the sites of deposition, and the mechanisms by which the particle injure the lung. The deposition of particulate matter depends mainly on the breathing pattern and the particle size. Larger particles are mainly deposited in the extra thoracic part of the respiratory tract (between 10 and 100 μm) and most of the particles in the range of 5 to 10 μm are deposited in proximity to the fine airways with normal nasal breathing. With mouth breathing the proportion of tracheobronchial and pulmonary deposition increases. Because of their small size (fine particles), acid ambient aerosols tend to deposit in the distal lung airway and airspace. Some neutralization of the droplets can occur before deposition due to normal excretion of endogenous ammonia into the airways. Deposited free H^+ reacts with components of the mucus of the respiratory tract changing its viscosity; the non- reacting part diffuses into the tissues (WHO, 1987c). Current concepts of particle toxicity emphasize the role of particle acidity and the induction of inflammation at the sites of injury (Bascom *et al.*, 1995).

Various studies have been carried out on the characterization of particulate matter especially $PM_{2.5}$ since it is more related with traffic emissions than TSP or PM_{10}. A particulate characterization study was carried out in five Asian sites: Manila in the Philippines, Hong Kong, Cheju Island in Korea, Sado Island, Japan, and Hanoi in Vietnam in 2001. It was found that, except for the site in Japan, annual average $PM_{2.5}$ and PM_{10} concentrations were well above the USEPA annual standard of 15μg/m^3 for $PM_{2.5}$ in the four other sites (Cohen *et al.*, 2002). In addition, the chemical composition of the pollutant is also different in different regions under study. For instance, the contents of organic matter (45%) and elemental carbon (28%) in $PM_{2.5}$ were the highest in Manila monitoring site compared to those in the other four sites, which ranged from 7% to 8.8% for elemental carbon and 8% to 25% for organic matter. Though the pollutants monitored at the five sites were sampled using the same method during roughly the same period, their comparison may still differ from the different locations, since some locations (Cheju Island in Korea and Sado Island in Japan) were more remote than others.

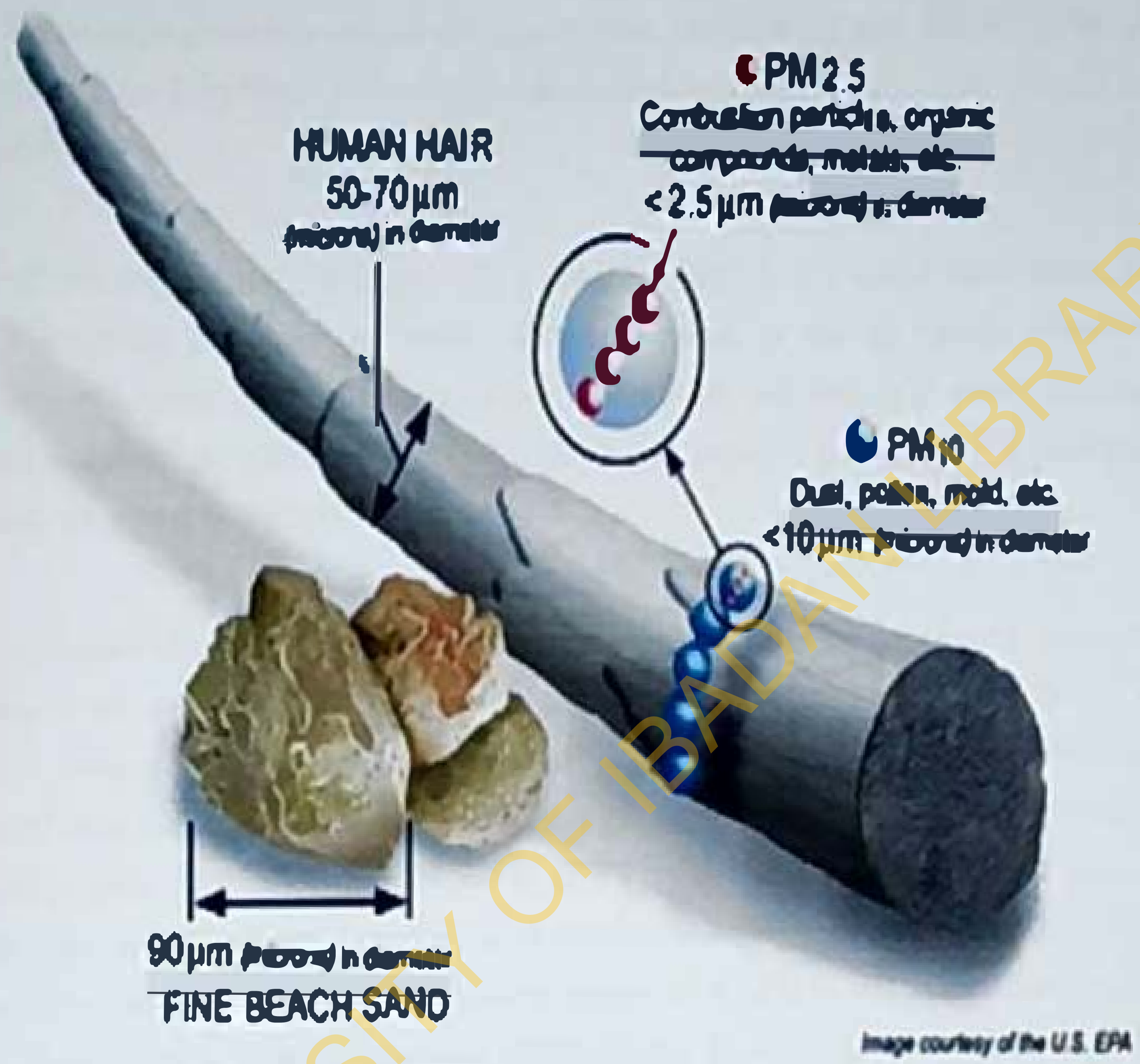


Fig 2.2: Comparison of particulate matter sizes

Source: Courtesy of US EPA office of Research and Development, 2003.

2.8.2.2 Sulphur dioxide (SO_2)

This is a chemical compound with the formula SO_2. It is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulphur compounds, their combustion generates sulphur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and which when absorbs moisture forms acid rain (USEPA, 2006).

Sulphur dioxide is a colourless gas with a pungent odour. It is a liquid when under pressure, and it dissolves in water very easily. Sulphur dioxide in the air results primarily from activities associated with the burning of fossil fuels (coal, oil) such as at power plants or from copper smelting. In nature, sulphur dioxide can be released to the air, for example, from volcanic eruptions (ATSDR, 1998).

It is produced when sulphur-containing fuels such as coal and oil are burned. Generally, the highest levels of sulphur dioxide are found near large industrial complexes. Major sources include power plants, refineries, and industrial boilers (USEPA, 2006). Sulphur dioxide when released into the atmosphere can also be converted to SO_3 which leads to production of sulphuric acid. When SO_3 is inhaled it is likely to be absorbed in moist passages of respiratory tract. When it is entrained in an aerosol, however, it may reach far deeper into the lungs. SO_2 can cause breathing problems in people with asthma, but at relatively high levels of exposure. There is some evidence that exposure to elevated SO_2 levels may increase hospital admissions and premature deaths. Sulphur dioxide can damage vegetation and cause corrosion. Airborne sulphates reduce visibility. It is also the cause of acid rain in some countries (Sheppard *et al.*, 1980).

SO_2 can react with other compounds in the atmosphere to form small particles. These particles penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease, such as emphysema and bronchitis, and can aggravate existing heart disease, leading to increased hospital admissions and premature death (USEPA, 2006).

2.8.2.3 Nitrogen dioxide (NO_2)

Nitrogen dioxide is one of the main traffic-related air pollutants and precursors forming photochemical smog (together with VOCs) and ground level ozone. The gas is reddish brown and highly reactive in ambient air. As one member of nitrogen oxides (NOx), it undergoes a complex chain of chemical and photochemical reactions with nitric oxide (NO), ozone, and other gases. Usually the NO_2 in the atmosphere comes from two sources, either directly from emission sources (primary pollutant) or from chemical reactions in the atmosphere (Xianglu *et al.*, 2006). NO_2 is a widespread contaminant of indoor as well as outdoor air, and indoor levels can exceed those found outdoors. Indoor levels of NO_2 are determined by the infiltration of NO_2 in outdoor air, by the presence and strength of indoor sources such as gas cooking stoves, kerosene space heaters, and by air exchange (Bascom *et al.*, 1995).

NO_2 shares the same seasonal pattern with several other air pollutants, its level is usually higher in the winter than in the summer. Many studies showed that NO_2 concentration decreased drastically with increasing distance downwind from traffic (Gilbert *et al.*, 2003; Singer *et al.*, 2004). In a Canadian study (Gilbert *et al.*, 2003), the authors found that wind and the logarithm of distance from a major highway under study may serve as surrogates for traffic NO_2 exposure, which needed further validation. In this Canadian study, the NO_2 levels ranged from 11.9 to 29.3 ppb. Investigation conducted at schools near Northern California freeways (Singer *et al.*, 2004) found highest NO_2 levels (24–30 ppb) in schools downwind and close to freeways. In addition to conditions of vehicles, fuel type plays an important role in traffic emissions. The increasing use of compressed natural gas (CNG) attributed to decreases of ambient air pollutants in Delhi, India. From 1995 to 2001, the annual average concentrations of suspended particulate matter, CO, and NOx decreased to 347 (from 405), 4197 (from 4681), and 34 (from 36) $\mu g/m^3$, respectively (Goyal and Sidhartha, 2003).

In developing countries, exposure studies on NO_2 usually indicate higher exposure levels than in the developed world. In Tartu, Estonia, ambient level of NO_2 increased by 50% to 100% in several monitoring stations, according to the yearly monitoring data from 1994 to 1999. This increase may have been mainly caused by increasing number of vehicles, poor maintenance of many of these vehicles and narrow streets in the city (Kimmel and Kaasik, 2003). At elevated levels, NOx can impair lung function, irritate respiratory system and at very high levels, make breathing difficult, especially for people who already suffer from asthma or bronchitis. Almost all NOx emissions are in the form of NO, which has no known adverse health effects in the concentrations found in atmosphere. (Lebowitz et al., 1985). NO can be oxidized to NO_2 in the atmosphere, which in turn give rise to secondary pollutants, which are injurious. NO_2 may also lead to formation of HNO_3, which is washed out of the atmosphere as acid rain.

2.8.2.4 Carbon monoxide (CO)

Carbon monoxide is an odourless, colourless gas. It forms when the carbon in fuels does not completely burn. Vehicle exhaust contributes roughly 75 percent of all carbon monoxide emissions nationwide, and up to 95 percent in cities. Other sources include fuel combustion in industrial processes and natural sources such as wildfires. Carbon monoxide levels typically are highest during cold weather, because cold temperatures make combustion less complete and cause inversions that trap pollutants close to the ground (EPA, 2009). Carbon monoxide is one of the most common and widely distributed air pollutants. It is a colourless, odourless and tasteless gas that is poorly soluble in water. Carbon monoxide has a slightly lower density than air. In the human body, it reacts readily with haemoglobin to form carboxyl-haemoglobin. Small amounts of carbon monoxide are also produced endogenously (Bascom et al., 1996). It is another important pollutant in traffic-related exposure studies and epidemiologic investigations. It results from incomplete combustion of natural gas, diesel or gasoline in traffic engines. High concentrations of CO generally occur in areas with heavy traffic intensity and congestion. Point sources of CO emissions also include industrial processes, non-transportation fuel combustion, and natural sources such as wild forest fires. Indoor sources include leaking gas stoves, heaters, generators, etc. CO is a colourless, odourless and tasteless gas (Xianglu, *et al*., 2006).

The annual global emissions of carbon monoxide into the atmosphere have been estimated to be as high as 2600 million tonnes, of which about 60% are from human activities and about 40% from natural processes. Anthropogenic emissions of carbon monoxide originate mainly from incomplete combustion of carbonaceous materials. The largest proportions of these emissions are produced as exhausts of internal combustion engines, especially by motor vehicles with petrol engines. Other common sources include various industrial processes, power plants using coal, and waste incinerators. Petroleum-derived emissions have greatly increased during the past few decades (EPA, 1991).

Table 2.6: Selected Traffic-related Air Pollutants and their known Health Effects.

Pollutant group (source)	Known health effects	Contributing or potentiating factors/agents	Populations especially vulnerable
Particulate matter (biomass and fossil fuel combustion in home heating, industry and motor vehicle engines.	Upper respiratory tract irritation and infection; exacerbation of and increased mortality from cardiorespiratory diseases.	Sulphur dioxide, sulphuric acid, cold, heat and humidity.	Elderly, people with respiratory and cardiovascular diseases; children with asthma
Sulphur dioxide and acid aerosols (fossil fuel and combustion; metal smelting and petrol-chemical industries; home heating/cooking with coal).	Throat irritation; exacerbation of cardiorespiratory diseases including asthma.	Exercise, particulates, asthma	People with respiratory diseases (e.g. children with asthma); elderly people with respiratory and cardiovascular diseases
Oxides of nitrogen (fuel combustion at high temperature (e.g. from vehicle engines, gas cooking and heating).	Eye irritation, upper respiratory tract infection (especially in children), exacerbation of asthma and irritation of the bronchi.	Exercise, respiratory tract infection, asthma.	People with respiratory diseases (e.g. children with asthma).
Carbon monoxide (biomass and fossil fuel combustion, cigarette smoke and vehicular exhaust).	Headache, nausea, dizziness, breathlessness, fatigue, visual disturbance, confusion, coma, death, low birth weight.	Coronary artery disease	People with ischemic heart disease.

Source: WHO Air Quality Guidelines, 2005.

2.8.2.5 Ground-level ozone (O_3)

Ground level ozone (O_3) is formed from NO_2 and Volatile Organic Compounds (VOCs). Ozone (O_3) is a key constituent of the troposphere (it is also an important constituent of certain regions of the stratosphere commonly known as the Ozone layer). Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and by night. At abnormally high concentrations brought about by human activities (largely the combustion of fossil fuel), it is a pollutant, and a constituent of smog).

Ozone is produced from the photochemical reactions of hydrocarbons and oxides of nitrogen which in urban atmospheres are primarily of motor vehicle origin (60 - 80 %). At levels of ozone of 200µg/m^3 and even lower, there is statistically evidence of decrements in lung function, airway inflammatory changes, and exacerbations of respiratory symptoms in healthy children and adults, and symptomatic and functional exacerbations of asthma (Schwela *et al.*, 1997).

It is a highly reactive gas that is a form of oxygen. It is the main component of air pollution known as smog. Ozone reacts chemically ('oxidizes') with internal body tissues that it comes in contact with, such as those in the lung. It also reacts with other materials such as rubber compounds, breaking them down. Ozone is formed by the action of sunlight on carbon-based chemicals known as hydrocarbons, acting in combination with a group of air pollutants called oxides of nitrogen. It is thus called photochemical pollution (Lipsett, 2001).

2.8.2.6 Lead

It is a metal found naturally in the environment as well as in manufactured products. The major sources of lead emissions have historically been motor vehicles (such as cars and trucks) and industrial sources. As a result of EPA's regulatory efforts to remove lead from motor vehicle gasoline, emissions of lead from the transportation sector dramatically declined by 95 percent between 1980 and 1999, and levels of lead in the air decreased by 94 percent between 1980 and 1999. Today, the highest levels of lead in air are usually found near lead smelters. The major sources of lead emissions to the air today are ore and metals processing and leaded aviation gasoline (USEPA, 2010).

In the past, automobile sources were the major contributor of lead emissions to the atmosphere. As a result of EPA'S regulatory efforts to reduce the content of lead in gasoline, the contribution from the transportation sector has declined over the past decade. Today, metals processing is the major source of lead emissions to the atmosphere. Lead is similarly dangerous as poisoning causes irreversible neurobehavioral consequences, such as decreased IQ and attention deficits, and death at high levels of poisoning (Schwela, 2000).

Most of the lead in ambient air is in fine particles (10 µm). For adults the retention rate of airborne particulate matter ranges from 20% and 60%. Young children inhale proportionately higher daily air volume per unit measure (weight, body area) than do adults. It was estimated that children have a lung deposition rate of lead that can be up to 2.7 times higher than that of adults on a unit body mass basis (Schwela, 1997).

2.8.3 Green House Gases (GHG)

Vehicles are a very large source of greenhouse gases (GHGs). Unlike criteria pollutants and air toxics which have direct adverse impacts on health, GHGs are of health concern because of secondary effects such as global warming and climate disruption. (Mckeown, 2007).

Table 2.7: Annual Emissions of Greenhouse Gases for the city of Toronto

Source of Emissions	Greenhouse gas emissions (eCO_2 tonnes/year)
Residential	5,997,042
Commercial & small industry	6,884,767
Large commercial & industry	2,002,172
Transportation	8,558,966
Waste transport to Michigan	35,507
Streetlights & traffic signals	29,203
Waste (methane from landfills)	942,550
Total	24,450,207

Source: Greenhouse Gases and Air Pollutants in the City of Toronto: Towards a Harmonized Strategy for Reducing Emissions. Prepared by ICF International in collaboration with Toronto Atmospheric Fund and Toronto Environment Office. Toronto June 2007

The transportation sector contributes about 35% of the total GHGs emitted as a result of activities in Toronto. Greenhouse gas emissions have continued to rise in the City during the period between 1990 and 2004. Over this period, greenhouse gas emissions have risen from 22.0 million tonnes to 24.4 million tonnes annually, with transportation emissions from the use of gas and diesel-powered vehicles continuing to be a major contributor (Mckeown, 2007). Based on recent research, Toronto Public Health has determined that on average (over the 46 year study period), about 120 people die prematurely from heat-related causes in Toronto. Furthermore, it is projected that global warming could result in a doubling of heat-related deaths by 2050, and a tripling by 2080 (Toronto Public Health, 2005).

2.9 Meteorological factors that affect air quality

Amongst all the meteorological variables, wind speed has been the most closely scrutinised with regard to exposure since it influences the dispersion and dilution of pollutants. Generally, both exposure (Kingham *et al.*, 1998; Alm *et al.*, 1999; Krausse and Mardaljevic, 2005) and ambient (Molnar *et al.*, 2002; Holmes *et al.*, 2005) studies have identified that an increase in wind speed results in a decrease in exposure concentrations to fine particulate matter and CO.

Ambient temperature and local meteorology influences the concentration and location of vehicle-emitted pollutants. For example, elevated sulphur dioxide levels are typically reported in the winter and elevated ground-ozone levels in the summer (Goldberg *et al.*, 2001). Cold weather can result in higher levels of pollutants in ambient air due to reduced atmospheric dispersion and degradation reactions.

Seasonal variations in ambient temperatures and traffic volumes affect total automotive emissions. Likewise, seasonal variations in wind speeds affect the dilution and dispersion of those emissions on roadways. Ott *et al.* (1994a) in northern California and Dor *et al.* (1995) in France, who both measured in-vehicle CO exposures for an entire year, reported that they were generally higher in fall/winter than in spring/summer. This result was attributed to colder winter temperatures which increase CO emissions per vehicle mile. Higher summer temperatures have the opposite effect. The genotoxic effects of $PM_{2.5}$ and PM_{10} have also been found to be greater in the winter months (Abou *et al.*, 2007). Dispersion of pollutants is also affected by other meteorological factors like humidity, wind speed and direction and general atmospheric turbulence.

Some studies have found wind direction to have a considerable impact on fine particulate matter and CO concentration levels. Lung *et al.*, (2005) measured ultrafine particle count pedestrian exposures levels during northerly prevailing winds to be higher on the south side compared to the north side of an intersection. This is the most likely due to the wind direction, road and building configuration causing recirculation of the wind in the street causing pollutants concentrations to be higher on one side of the street in comparison to the other. Kaur *et al.*, 2005a recorded different levels of ultrafine particle count exposures of pedestrians on the opposite sides of the road which are believed to be due to recirculation in the street canyon generated by the prevailing wind direction during sampling.

2.10 The Human Respiratory System

The health of our lungs and entire respiratory system is affected by the quality of the air we breathe. In addition to oxygen, this air contains other substances such as carbon monoxide, nitrogen dioxide e.t.c which can be harmful. Exposure to chemicals by inhalation can negatively affect our lungs and other organs in the body. The respiratory system is particularly sensitive to air pollutants because much of it is made up of exposed membrane. Lungs are anatomically structured to bring large quantities of air (on average, 400 million litres in a lifetime) into intimate contact with the blood system, to facilitate the delivery of oxygen (Health Canada, 2006).

Lung tissue cells can be injured directly by air pollutants such as ozone, metals and free radicals. Ozone can damage the alveoli – the individual air sacs in the lung where oxygen and carbon dioxide are exchanged. More specifically, airway tissues which are rich in bioactivation enzymes can transform organic pollutants into reactive metabolites and cause secondary lung injury. Lung tissue has an abundant blood supply that can carry toxic substances and their metabolites to distant organs. In response to toxic insult, lung cells also release a variety of potent chemical mediators that may critically affect the function of other organs such as those of the cardiovascular system. This response may also cause lung inflammation and impair lung function (Health Canada, 2006).

2.10.1 Structure and function

The human respiratory system is composed of the nasal passage, the pharynx, larynx, the trachea, bronchi and lungs. It is responsible for the process of respiration that is vital to the survival of living beings. Respiration is the process of obtaining and using oxygen, while eliminating carbon dioxide. It is the process by which human beings take in the oxygen from their environment and give out the carbon dioxide that is produced as a result of chemical reactions within the cells. The specialized system that brings about this critical process of respiration in human beings is known as the human respiratory system.

The human respiratory system is dominated by our lungs, which bring fresh oxygen (O_2) in our bodies while expelling carbon dioxide (CO_2). The oxygen travels from the lungs through the blood stream to the cells in all parts of the body. The cells use the oxygen as fuel and give off carbon dioxide as waste gas. The waste gas is carried by the bloodstream back to the lungs to be exhaled.

The lungs accomplish this vital process called gaseous exchange using an automatic and quickly adjusting control system. This gas exchange process occurs in conjunction with the central nervous system (CNS), the circulatory system and the musculature of the diaphragm and chest. The human lungs encounter approximately 7 litres of air per minute. Thus it is evident that lungs are a target for adverse effects of noxious gases due to air pollution. The airborne contaminants include: Nitrogen dioxide (NO_2), Carbon mono oxide (CO), Carbon dioxide CO_2), Ozone (O_3) Sulphur dioxide (SO_2), Hydrocarbons and Suspended particulate matters SPM). They are responsible for injury to airways and lung parenchyma and lead to bronchoconstriction, increased mucous secretion and increased alveolar swelling. Nitrous fumes may results acute pulmonary oedema. To protect it our body employs several defence mechanisms, e.g., increased mucous secretion. Inhalation of NO_2 and SO_2 causes bronchoconstriction, mucosal irritation and alveolar swelling leading to obstructive and restrictive disorders of lungs (Binawara *et al.*, 2010).

The respiratory system in human beings can be divided into the upper respiratory tract that consists of the nasal passages, pharynx and the larynx and the lower respiratory tract that is composed of the trachea, the primary bronchi and the lungs.

Nasal passages: Air entering from the nostrils is led to the nasal passages. The nasal cavity that is located behind the nose comprises the nasal passages that form an important part of the respiratory system in human beings. The nasal cavity is responsible for conditioning the air that is received by the nose. The process of conditioning involves warming or cooling the air received by the nose, removing dust particles from it and also moistening it, before it enters the pharynx.

Pharynx: It is located behind the nasal cavity and above the larynx. It is also a part of the digestive system of the human body. Food as well as air passes through the pharynx.
Larynx: It is associated with the production of sound. It consists of two pairs of membranes. Air causes the vocal cords to vibrate, thus producing sound. The larynx is situated in the neck of mammals and plays a vital role in the protection of the trachea.

Trachea: The term refers to the airway through which respiratory air travels. The rings of cartilage within its walls keep the trachea open.

Bronchi: The trachea divided into two main bronchi. The bronchi extend into the lungs spreading in a tree-like manner as bronchial tubes. The bronchial tubes subdivide and with each subdivision, their walls get thinner. This dividing of the bronchi into thin-walled tubes results in the formation of bronchioles. The bronchioles terminate in small air chambers, each of which contains cavities known as alveoli. Alveoli have thin walls, which form the respiratory surface. The exchange of gases between the blood and the air takes place through these walls.

Lungs: Lungs form the most vital component of the human respiratory system. They are located on the two sides of the heart. They are responsible for transporting oxygen from the atmosphere into blood and releasing carbon dioxide from blood to the atmosphere. Other functions of the lungs and the other parts of the respiratory system include the following;

2.10.1.1 Lung Defence Mechanisms

Airway epithelial cells can secrete a variety of molecules that aid in lung defence. Secretary immunoglobulins (IgA), collectins (including Surfactant A and D), defensins and other peptides and proteases, reactive oxygen species, and reactive nitrogen species are all generated by airway epithelial cells. These secretions can act directly as antimicrobials to help keep the airway free of infection. Airway epithelial cells also secrete a variety of chemokines and cytokines that recruit the traditional immune cells and others to site of infections

2.10.1.2 Metabolic & Endocrine Functions

In addition to their functions in gas exchange, the lungs have a number of metabolic functions. They manufacture surfactant for local use, as noted above. They also contain a fibrinolytic system that lyses clots in the pulmonary vessels. They release a variety of substances that enter the systemic arterial blood and they remove other substances from the systemic venous blood that reach them via the pulmonary artery. Prostaglandins are removed from the circulation, but they are also synthesized in the lungs and released into the blood when lung tissue is stretched. The lungs also activate one hormone; the physiologically inactive decapeptide angiotensin I is converted to the pressor, aldosterone-stimulating octapeptide angiotensin II in the pulmonary circulation. The reaction occurs in other tissues as well, but it is particularly prominent in the lungs. Large amounts of the angiotensin-converting enzyme responsible for this activation are located on the surface of the endothelial cells of the pulmonary capillaries. The converting enzyme also inactivates bradykinin. Circulation time through the pulmonary capillaries is less than 1 s, yet 70% of the angiotensin I reaching the lungs is converted to angiotensin II in a single trip through the capillaries. Four other peptidases have been identified on the surface of the pulmonary endothelial cells.

2.10.1.3 Vocalization

The movement of gas through the larynx, pharynx and mouth allows humans to speak, or phonate. Vocalization, or singing, in birds occurs via the syrinx, an organ located at the base of the trachea. The vibration of air flowing across the larynx (vocal chords), in humans, and the syrinx, in birds, results in sound. Because of this, gas movement is extremely vital for communication purposes (Wikipedia, 2010).

2.11 Human Cardiovascular System

The cardiovascular system has two major components: the heart and a network of blood vessels. The cardiovascular system supplies the tissues and cells of the body with nutrients, respiratory gases, hormones, and metabolites and removes the waste products of cellular metabolism as well as foreign matter. It is also responsible for maintaining the optimal internal homeostasis of the body and the critical regulation of body temperature and pH.

The inhalation of air pollutants eventually leads to their absorption into the bloodstream and transport to the heart. A wide spectrum of chemical and biological substances may interact directly with the cardiovascular system to cause structural changes, such as degenerative necrosis and inflammatory reactions. Some pollutants may also directly cause functional alterations that affect the rhythmicity and contractility of the heart. If severe enough, functional changes may lead to lethal arrhythmias without major evidence of structural damage to the myocardium. There also may be indirect actions secondary to changes in other organ systems, especially the central and autonomic nervous systems and selective actions of the endocrine system. Some cytokins released from other inflamed organs may also produce adverse cardiovascular effects, such as reducing the mechanical performance and metabolic efficiency of the heart and blood vessels (Health Canada, 2006).

Many chemical substances may cause the formation of reactive oxygen. This oxidative metabolism is considered to be critical to the preservation of cardiovascular function. For example, oxygen free radicals oxidize low-density lipoproteins, and this reaction is thought to be involved in the formation of the atherosclerotic plaques. Oxidized low-density lipoproteins can injure blood vessel cells and increase adherence and the migration of inflammatory cells to the injured area. The production of oxygen free radicals in heart tissues has been associated with arrhythmias, and heart cell death (Health Canada, 2006).

2.12 Fate of Air Pollutants in the Respiratory System

Air pollutants cause pathological damage in three different parts of the lung, namely, the major bronchi, the terminal bronchioles, and the alveoli (Tanlmowo, 2000).

Major bronchi: With acute exposure, there may be reversible bronchospasm with considerable individual variation. The longer term effects are more important and they result from particles with size 2.0-50.0μ and/or gas exposure, such as, sulphur dioxide, nitrogen dioxide and ozone. These effects consist of: (i) paralysis of cilia; (ii) hyper secretion of bronchial mucous glands; (iii) mucous gland hypertrophy and extension into smaller air ways.

Terminal bronchioles: Smaller particles (0.01-2.0μ) will penetrate and be deposited in this region, and there could be potentiation of effects if gases and particles are inhaled concurrently as in cigarette smoke. Most of the sulphur dioxide that is breathed in is stopped in the nose, and soluble gases such as oxides of nitrogen are similarly diminished if breathed in the gas form. Combined with particles, these gases get further down the lung and have greater effect in lower concentration There are also some experimental data and some human data indicating that acute exposure to high concentrations of oxides of nitrogen characteristically produces pulmonary oedema and fibrosing bronchiolitis rather than chronic bronchitis or bronch iectasis. These gas exposures produce the following effects in the terminal bronchioles: (i) loss of normal defences; (ii) adverse effect on surfactant, which has something to do with keeping these small airways patent; (ii) goblet cell metaplasia; (iv) inflammation and obliteration and; (v) premature closure of airways, which is what has been demonstrated with increased closing volume in cigarette smokers (Tanimowo. 2000).

Alveoli: Particles of range order 0.01-0.05μ are particularly likely to get to this region and in modern city air, there are plenty of particles in this size range. It is difficult to calculate how much of a gas such as ozone actually reaches the alveolar level because it is so reactive to surfaces, and it is possible that much of it has disappeared before reaching the alveolar wall. Some gases, such as, sulphur dioxide may be absorbed in the nose and later removed through the alveoli and then exert their effect not by having them delivered to the alveoli through the bronchial tree but by re-diffusion out from the blood into alveolar gas. If both particulate and gaseous pollution are present there is potentiation of effects, and the major consequences of each of these is an increase in cells and macrophages in the lung (Tanimowo. 2000). There is ample evidence that this is the primary response to most of these challenges, and an increased aggregation of macrophages and leucocytes occurs quite quickly in response to most of them (Tanimowo, 2000). The presence of these cells will enhance the release of proteolytic enzymes, causing alveolar destruction in individuals with inherited deficiency of serum anti- trypsin, with the subsequent possibility of developing emphysema.

from particles with size 2.0-50.0μ and/or gas exposure, such as, sulphur dioxide, nitrogen dioxide and ozone. These effects consist of: (i) paralysis of cilia; (ii) hyper secretion of bronchial mucous glands; (iii) mucous gland hypertrophy and extension into smaller air ways.

Terminal bronchioles: Smaller particles (0.01-2.0μ) will penetrate and be deposited in this region, and there could be potentiation of effects if gases and particles are inhaled concurrently as in cigarette smoke. Most of the sulphur dioxide that is breathed in is stopped in the nose, and soluble gases such as oxides of nitrogen are similarly diminished if breathed in the gas form. Combined with particles, these gases get further down the lung and have greater effect in lower concentration. There are also some experimental data and some human data indicating that acute exposure to high concentrations of oxides of nitrogen characteristically produces pulmonary oedema and fibrosing bronchiolitis rather than chronic bronchitis or bronchiectasis. These gas exposures produce the following effects in the terminal bronchioles: (i) loss of normal defences; (ii) adverse effect on surfactant, which has something to do with keeping these small airways patent; (ii) goblet cell metaplasia; (iv) inflammation and obliteration and; (v) premature closure of airways, which is what has been demonstrated with increased closing volume in cigarette smokers (Tanimowo, 2000).

Alveoli: Particles of range order 0.01-0.05μ are particularly likely to get to this region and in modern city air, there are plenty of particles in this size range. It is difficult to calculate how much of a gas such as ozone actually reaches the alveolar level because it is so reactive to surfaces, and it is possible that much of it has disappeared before reaching the alveolar wall. Some gases, such as, sulphur dioxide may be absorbed in the nose and later removed through the alveoli and then exert their effect not by having them delivered to the alveoli through the bronchial tree but by re-diffusion out from the blood into alveolar gas. If both particulate and gaseous pollution are present there is potentiation of effects, and the major consequences of each of these is an increase in cells and macrophages in the lung (Tanimowo, 2000). There is ample evidence that this is the primary response to most of these challenges, and an increased aggregation of macrophages and leucocytes occurs quite quickly in response to most of them (Tanimowo, 2000). The presence of these cells will enhance the release of proteolytic enzymes, causing alveolar destruction in individuals with inherited deficiency of serum anti- trypsin, with the subsequent possibility of developing emphysema.

2.13 Cardiovascular and Respiratory Effects of Air Pollutants

The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, the individual's health status and genetics. People who exercise outdoors, for example, on hot, smoggy days increase their exposure to pollutants in the air (Health Canada, 2006).

There is substantial evidence that supports an association between vehicle emissions and cardiovascular disease; particularly mortality from cardiovascular causes (Gehring *et al.* 2006; Pope *et al.*, 2004a; Miller *et al.*, 2007). Cardiovascular and stroke mortality rates have been associated with both ambient pollution at place of residence as well as residential proximity to traffic (Finkelstein et al. 2005). Several recent studies also consider nonfatal cardiovascular outcomes like acute myocardial infarction (AMI) and have found an association with exposure to vehicle emissions, particularly as a result of long-term exposure to $PM_{2.5}$ and/or close residential proximity to busy roads (Hoffmann *et al.*, 2006; Jerrett *et al.* 2005; Rosenlund *et al.*, 2006; Tonne *et al.*, 2007; Peters *et al.*, 2004).

Short-term exposures have also been shown to be associated with ischemic effects (Lanki *et al.*, 2006a). A case-crossover study of 772 individuals in Boston found that elevated concentrations of $PM_{2.5}$ were associated with an increased risk of AMI within a few hours and one day following exposure (Peters *et al.*, 2001). Another study of 12,865 individuals in Utah found a similar effect for both AMI and unstable angina, and that this effect was worse for patients with underlying coronary artery diseases (Pope *et al.*, 2006). The specific toxicants most commonly associated with these effects are PMs, although there is also evidence of an adverse influence of CO (Lanki *et al.*, 2006b) and SO_2 (Fung *et al.*, 2005).

Increased levels of CO and NO_2 have also been implicated in increased incidence of emergency department visits for stroke (Villeneuve *et al.*, 2006). It has been suggested that it is the strong association between air pollution and ischemic heart disease that drives the cardiopulmonary association with air pollution (Jerrett *et al.*, 2005). Many plausible patho-physiological pathways linking PM exposure and cardiovascular disease have been suggested and include systemic inflammation, accelerated atherosclerosis, and altered cardiac autonomic function reflected by changes in heart rate variability and increases in blood pressure (Brook *et al.*, 2002; Brook *et al.*, 2003; Luttmann-Gibson *et al.*, 2006; Pope *et al.*, 2004a; Pope *et al.*, 2004b; Schwartz *et al.*, 2005; Urch *et al.*, 2005).

Respiratory disease encompasses pathological conditions affecting the organs and tissues that make gas exchange possible in higher organisms, and includes conditions of the upper respiratory tract, trachea, bronchi, bronchioles, alveoli, pleura and pleural cavity, and the nerves and muscles of breathing. It ranges from mild and self-limiting, such as the common cold, to life-threatening entities like bacterial pneumonia, pulmonary embolism, and lung cancer.

The health effects caused by air pollutants may range from subtle biochemical and physiological changes to difficulty in breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions. These effects can result in increased medication use, increased doctor or emergency room visits, more hospital admissions and even premature death (Health Canada, 2006).

It is clear that air pollution, infections and allergies can exacerbate heart and lung illnesses. An early diagnosis can lead to appropriate treatment and ensure a normal or close to normal quality of life. In many cases however, there is no cure and those affected may die prematurely. The following are the most prevalent diseases.

Minor Lung Illnesses: The common cold is the most familiar of these, with symptoms including sore throat, stuffy or runny nose, coughing and sometimes irritation of the eyes.

Lung Infections: croup, bronchitis, and pneumonia are caused by viruses or bacteria and are very common. Symptoms may include cough, fever, chills and shortness of breath.

Asthma: It is an increasingly common chronic disease among children and adults. It causes shortness of breath, coughing or wheezing or whistling in the chest. Asthma attacks can be triggered by a variety of factors including exercise, infection, pollen, allergies and stress. It can also be triggered by sensitivity to non-allergic types of pollutants present in the air such as smog.

Chronic Obstructive Pulmonary Disease (COPD): It is also known as chronic obstructive lung disease and encompasses two major disorders: emphysema and chronic bronchitis. Emphysema is a chronic disorder in which the walls and elasticity of the alveoli are damaged. Chronic bronchitis is characterized by inflammation of the cells lining the inside of bronchi, which increases the risk of infection and obstructs airflow in and out of the lung. Smoking is responsible for approximately 80% of COPD cases while other forms of air pollution may also influence the development of these diseases. Symptoms include cough, production of mucous and shortness of breath. It is important to note that no cure exists for people suffering from COPD although healthy lifestyle and appropriate medication can help (Health Canada, 2006).

Lung Cancer: It is the most common cause of death due to cancer in women and men. Cigarette smoke contains various carcinogens and is responsible for most cases of this often fatal disease. The symptoms of lung cancer begin silently and then progress to chronic cough, wheezing and chest pain. Air pollution has been linked somewhat weakly to lung cancer (Health Canada, 2006).

Coronary Artery Disease: It refers to the narrowing or blocking of the arteries or blood vessels that supply blood to the heart. This disease includes angina and heart attack which share similar symptoms of pain or pressure in the chest. Unlike angina, the symptoms caused by heart attack do not subside with rest and may cause permanent damage to the heart. Smoking, lack of exercise, excess weight, high cholesterol levels in the blood, family history and high blood pressure are some of the factors that may contribute to this disease (Health Canada, 2006).

Heart Failure: It is a condition in which the heart is unable to cope with its work load of pumping blood to the lungs and the rest of the body. The most common cause is severe coronary artery disease. The main symptoms are shortness of breath and swelling of the ankles and feet.

Heart-Rhythm Problems: They are irregular or abnormal rhythms of the heartbeat. In some cases heart-rhythm problems are caused by coronary artery disease. Symptoms of heart-rhythm problems influttering in the chest (palpitation) and feeling light-headed. Some heart-rhythm problems are life-threatening and need emergency treatment (Health Canada, 2006).

2.14 Population at risk of Respiratory symptoms

Although everyone is at risk from the health effects of air pollution, certain sub-populations are more susceptible. Individual reactions to air contaminants depend on several factors such as the type of pollutant, the degree of exposure and how much of the pollutant is present. Age and health are also important factors (Health Canada, 2006).

There are some populations which are particularly susceptible to the effects of traffic-related pollution. These include foetuses and children, the elderly, and those with pre-existing breathing and heart problems. However, healthy individuals are also at risk of these effects from both short-term exposures as well as chronic exposure over several years or a lifetime (Mckeown, 2007).

The human foetus is particularly susceptible to the effects of traffic-related pollution given physiological immaturity. A study of the genotoxic effects of exposure to PAHs in pregnant mothers in Manhattan, Poland, and China used personal air monitors to assess exposure to air pollution. This study reported that in utero exposure increases DNA damage and carcinogenic risk to the foetus (Perera *et al.*, 2005). Prenatal exposure to high levels of PAHs has been associated with decreased subsequent cognitive development at 3 years of age (Perera *et al.*, 2006). Foetal growth impairment has also been linked to in utero exposure to airborne PAHs, even at relatively low levels of exposure (Choi *et al.*, 2006).

Several studies suggest that the effect size from exposure to traffic-related pollution is greater among the elderly than other age groups (Goldberg *et al.*, 2001; Pope 2000; Zeka *et al.*, 2005). These individuals are also likely to have pre-existing illness and have been subject to a lifetime of exposure. Individuals with pre-existing illness are particularly vulnerable to the effects of traffic-related pollution, especially those with illnesses with systemic effects like diabetes and cancer. It has been reported that increased levels of CO exacerbate heart problems in individuals with both cardiac and other diseases (Burnett *et al.*, 1998b). Several studies support the suggestion that individuals with diabetes are particularly at risk of suffering from heart disease during periods when air pollution is high (Goldberg *et al.* 2006; O'Neill *et al.*, 2005; O'Neill *et al.*, 2007). This has been attributed to the effects of fine particles and elemental carbon as well as other components of the air pollution mixture.

A slightly higher risk of mortality associated with vehicle-related pollutants has been associated with low socioeconomic status (SES), a variable that is known to be correlated with health status. This effect may result from the fact that individuals of low SES may live in lower value dwellings that are in close proximity to major roads and therefore at a higher risk of exposure (Smargiassi *et al.*, 2006). Furthermore, vehicles may be newer and create less pollution in high SES neighbourhoods, with homes with better ventilation and insulation to offer protection against these effects (Ponce *et al.*, 2005).

2.15 Lung Capacity

Lung capacities refer to the volume of air associated with different phases of the respiratory cycle. The average total lung capacity of an adult human male is about 6 litres of air, but only a small amount of this capacity is used during normal breathing (Guyton *et al.*, 2005). Lung capacity is related to body size, and standing height is the most important correlating variable. In children and adolescents, lung growth appears to lag behind the increase in standing height during the growth spurt, and there is a shift in the relationship between lung volume and height during adolescence (Dockery, 2001). Height growth in young males between 12.5 and 18 years of age peaks 1 year before the growth rate of weight and Forced Vital Capacity (FVC), and 1.5 years before the growth rate of maximum flow at 50% FVC. In young females, growth rates of all spirometric indices decrease over the same age range. Using simple allometric relationships between stature and lung volumes, volume predictions are too high in the youngest age group and too low in the oldest adolescents.

Furthermore, for the same standing height, young males have greater lung function values than young females, and Caucasians have greater value than blacks. Lung function increases linearly with age until adolescent growth spurt at age 10 years in females and 12 years in males. The pulmonary function versus height relationship shifts with age during adolescence (Dockery, 2001).

Individuals who live at sea level will develop a slightly smaller lung capacity than those who spend their life at a high altitude. This is because the partial pressure of oxygen is lower at higher altitude which, as a result means that oxygen less readily diffuses into the bloodstream. In response to higher altitude, the body's diffusing capacity increases in order to process more air. When individuals living at or near sea level travels to locations at high altitudes (e.g., the Andes, Denver, Colorado, Tibet, the Himalayas, etc.) that person can develop a condition called altitude sickness because their lungs remove adequate amounts of carbon dioxide but they do not take in enough oxygen. (In normal individuals, carbon dioxide is the primary determinant of respiratory drive.) (Guyton *et al.*, 2005).

2.16 Pulmonary Function Test

Pulmonary Function Testing (PFT) is a complete evaluation of the respiratory system including patient history, physical examinations, chest x-ray examinations, arterial blood gas analysis, and tests of pulmonary function. The primary purpose of pulmonary function testing is to identify the severity of pulmonary impairment. There is evidence of considerable variations in pulmonary function in different ethnic groups and across generations (Ostrowski *et al.*, 2005).

Rapid lung growth begins in utero and continues until the late teens in girls and early 20s in boys. Lung function reaches a maximum by 18-20 years of age in females and 22-25 years in males. Some males may show a small increment in lung function into their mid-20's. Lung function varies widely among adults. The big difference in lung function in adults are due to attained lung function at maturity, which can differ by a factor of two for individuals of the same age, sex, height, weight and race (Dockery *et al.*, 2005). Thus, factors that can affect growth of lung function in childhood are important in determining the level of lung function in adulthood. Lung function test (LFTs) have evolved from tools for physiologic study to clinical tools widely used in assessing the respiratory status. In addition they have become a part of routine health examinations in respiratory, occupational, and sports medicine. However, the results of LFTs should be interpreted in relation to reference values, and in terms of whether or not they are considered to be within the normal ranges (Quanjer *et al.*, 1993).

Spirometry, the most frequently performed pulmonary function test (PFT) is the cornerstone of occupational respiratory evaluation programs. In the occupational health setting, spirometry plays a critical role in the primary, secondary, and tertiary prevention of workplace-related lung disease (ACOEM, 2000). It is used for both screening and clinical evaluations, spirometry tests are performed in a variety of venues ranging from small clinical practices to large testing facilities and multiple plant medical departments within an industry.

Spirometry is a physiological test that measures how an individual inhales or exhales volumes of air as a function of time. The primary signal measured in spirometry may be volume or flow. It is invaluable as a screening test of general respiratory health in the same way that blood pressure provides important information about general cardiovascular health. However, on its own, it does not lead clinicians directly to an aetiological diagnosis (Miller *et al.*, 2005).

The common lung function indicators measured with spirometry are:

2 **Forced Vital Capacity (FVC)**: This measures the amount of air an individual can exhale with force after inhaling as deeply as possible.

3 **Forced Expiratory Volume (FEV)**: This measures the amount of air an individual can exhale with force in one breathe. The amount of air exhaled may be measured at 1 second (FEV_1), 2 seconds (FEV_2) or 3 seconds (FEV_3), even up to 6 seconds (FEV_6). FEV1 divided by FVC can also be determined.

4 **Forced Expiratory Flow 25% to 75%.** This measures the air flow halfway through an exhale.

5 **Peak Expiratory Flow (PEF):** This measures how quickly an individual can exhale. It is usually measured at the same time as Forced Vital Capacity (FVC).

6 **Maximum Voluntary Ventilation (MVV)**: This measures the greatest amount of air an individual can breathe in and out during one minute.

7 **Slow Vital Capacity (SVC)**: This measures the amount of air an individual can slowly exhale after inhaling as deeply as possible.

8 **Total Lung Capacity (TLC):** This measures the amount of air in the lungs after inhaling as deeply as possible.

9 **Functional Residual Capacity (FRC):** This measures the amount of air in the lungs at the end of a normal exhaled breathe.

10 **Residual Volume (RV)**: This measure the amount of air in the lungs after an individual has exhaled completely. It can be done by breathing in helium or nitrogen gas and seeing how much is exhaled.

11 **Expiratory Reserve Volume (ERV)**: This measures the difference between the amount of air in the lungs after a normal exhale (FRC) and the amount after exhaling with force (RV).

The most important parameters of spirometry are the forced vital capacity (FVC), which is the volume delivered during an expiration made as forcefully and completely as possible starting from full inspiration, and the forced expiratory volume (FEV) in one second, which is the volume delivered in the first second of an FVC manoeuvre (Miller, 2005).

The spirometry maneuver may be divided into the following three steps (or phases), each of which requires a different type of effort: (1) "take a deep breath" (maximal inhalation); (2) "blast out your air" (maximal exhalation effort); and (3) "keep blowing until all your air is gone" (prolonged exhalation). Poor effort may occur during any (or all) of these steps and is usually due to suboptimal interaction between the technician and the subject. A sub-maximal inhalation falsely reduces the PEF, FEV_1, and FVC values. A sub-maximal inhalation falsely reduces the PEF values, variably affects the FEV_1 values, and may increase the FVC values. A premature termination of the exhalation falsely reduces only the FVC values provided the termination occurs after the first second. Quality assurance measurements are designed to detect all these faults and, thereby, to identify any poorly performed maneuver or test session that could result in false-positive or false-negative diagnosis in the clinical setting or in increased measurement noise/bias in epidemiologic and intervention studies (Enright *et al.*, 2000).

2.17 Effect of Air Pollutants on Lung Function Status

Occupational exposure to dust is a well-known phenomenon, especially in developing countries (Aigbedion *et al.*, 2007; Fatusi *et al.* 1996). Although sources of air pollutants include power plants, cement factories, refineries and petrochemical industries, the emission of particulates is quite high from quarries (Olusegun *et al.*, 2009). The health impacts of working in stone quarrying industry have been well documented (Oxman *et al.*, 1993), individuals working in dusty environment have been found to carry the risk of inhaling particulate materials (e.g., silica) that may lead to adverse respiratory effects, (Park, 2007) such as chronic bronchitis, emphysema, acute and chronic silicosis, lung cancer, lung function impairment e.t.c (Kasper, 2008). The occupationally related lung diseases are most likely due to the deposition of dust in the lung and are influenced by the type of dusts, the period of exposure, the concentration and the size of the airborne dust in the breathing zone (Mengesha, 1998).

Nwibo *et al.*, 2012 conducted a study on Pulmonary Problems among Quarry Workers of Stone Crushing Industrial Site in Umuoghara community in Ezza North Local Government Area of Ebonyi State, Nigeria. They found out that only 13.7% of the dust-exposed workers had their mean FEV_1 values between the ranges of 4.00-6.50L indicating that the lung function of majority of the respondents had been impaired. The significant decline in the mean FEV1 and FVC values and the negative correlation between duration of work and FEV_1 ($r = -0.198$, $p<0.05$) showed that the longer the respondent was exposed at work, the lower the values.

A study by Ingle *et al.*, 2005 in India indicated a lung function efficiency of the traffic policemen exposed to vehicular pollution. Similar observations were reported by Gupta *et al.*, 1988 in the rubber factory workers exposed to particulates prevailing at work place environment. The Forced Vital Capacity (FVC) was 82% of the expected in traffic policemen, while the control group shows 99% efficiency. Though the Forced Vital Capacity (FVC) of traffic policemen was less than the control group, it was not much affected like FEV_1 and PEFR. The Forced Expiratory Volume in one second (FEV_1) of traffic policemen was affected severely. It shows 0.81 L difference in the expected and observed FEV_1 of the subject. This confirms the definite acute effect on forced expiratory volume (FEV_1) in the traffic policemen. Sharma *et al.*, 2004 studied the effects of air pollution on the respiratory health of subjects who lived in three areas of Kanpur, India. They observed that subjects who resided at clean area performed at predicted values more often than did subjects who lived at more polluted area. Subjects who were more exposed to air pollution demonstrated a substantial average deficit in baseline FVC and FEV_1. Furthermore, a study by Forbes *et al.*, 2009 in England showed that adult FEV_1 was associated with average outdoor concentrations of PM10, NO_2 and SO_2 estimated for postcode sector of residence. The size of the effect on population mean FEV_1, expressed for an increase in pollutant level of 10 mg/m^3 was about 3% for PM_{10}, and 0.7% for NO_2 and SO_2. The associations were strongest in men, older adults and in ex-smokers, and were independent of active and passive smoking, social class, region and month of testing.

CHAPTER THREE

METHODOLOGY

3.1 Study Design

The study design was a descriptive cross-sectional survey with a comparative approach. Respondents which are police officers were categorized based on their exposure status;

- Traffic wardens (those exposed to vehicular emissions during the performance of their day to day activities).
- Regular Policemen (that are not exposed to vehicular emissions during the performance of their activities).

It involved collection of baseline data on perception of police officers about air quality and the health problems they are experiencing. An exposure assessment involving pulmonary function test of police officers was also carried out.

3.2 Study Area

The study was carried out in Ibadan North and Northeast Local Government Areas respectively. Ibadan is the capital city of Oyo State and the largest indigenous city in West Africa. It is located in the south-western region of Nigeria. It is 130Km inland from Lagos and is a prominent transit point between the coastal region and the areas to the north. It lies between latitude 7° and 9°30' east of prime meridian. Ibadan covers a land area of 12 kilometres radius. It has an altitude generally ranging from 152m to 213m with isolated ridges and peaks rising to 274m. Its population is estimated to be about 3.8million according to the National Population Commission's 2006 census estimates (NPC, 2006). The principal inhabitants of the city are the Yorubas (Brown, 2009).

3.2.1 Brief description of Ibadan North Local Government Area

Ibadan North Local Government was founded by the Federal Military Government of Nigeria on 27th of September 1991. The Local Government was carved out of the defunct Ibadan Municipal Government along with others. The components of the Local Government cover areas between Beere roundabout through Oke-Are to Mokola, Oke-itunu and Ijokodo. The other components are areas from Beere roundabout to Gate, Idi-ape to Bashorun and up to Lagos/Ibadan Express way, Secretariat, Bodija, University of Ibadan and Agbowo areas. The headquarters of the Local Government is Bodija. The Local Government headquarters is temporarily accommodated at Quarter 87 at Government Reserved Area in Agodi where the Secretariat is located. Ibadan North Local Government is bounded by other L.G.As including Akinyele, Ido, Ibadan Southwest, Ibadan Southeast and Lagelu L.G.A's. Ibadan North Local Government has a population of about 308,119 people, comprising 152,608 males and females (National Population Commission, 2006). Using a growth rate of 3.2% from 2006 census, the 2010 estimated population for the Local Government area is put at 347,998 people.

Table 3.1: Ibadan North Local Government Wards

S/NO	WARDS
1	Beere, Keninke, Agbadagbudu, Oke Are, Odo Oye
2	Odo Oole, Inalende, Oniyanrin and Oke Oloro
3	Adeoyo, Yemetu, Oke Aremo and Isale Alfa
4	Itutaba, Idi omo, Oje Igodun, Kube, Oke apon, Abenla, Aliwo/Total garden and NTA area
5	Bashorun, Oluwo Ashi, Akingbolu, Ikolaba and Gate
6	Sabo Area
7	Oke Itunu, Cocacola and Oremeji Areas
8	Sango, Ijokodo
9	Mokola, Ago tapa and premier Hotel Areas
10	Bodija, Secretariat, Awolowo, Obasa, Sanusi
11	Samonda, Polytechnic, University of Ibadan
12	Agbowo, Bodija market, Oju irin, Barika, Iso pako, Lagos/Ibadan Express Road

Source: Brown, 2009

3.2.2 Brief description of Ibadan Northeast Local Government Area

Ibadan Northeast Local Government has a land mass of about 18 km square. This feature makes it one of the smallest LGA's in Oyo State. The Local Government administrative headquarters is at Iwo road. Ibadan Northeast Local Government is approximately 120 km from Lagos by the most direct route and 440km from Abuja, Federal Capital Territory (FCT). It is bound by Zenith bank Plc and Oba Akinyele shopping complex in the west and east respectively. Ibadan Northeast Local Government has a population figure of 330,399 according to the final result of 2006 census released by the National Population Commission (NPC). There are 12 wards within the Local Government Area.

Fig 3.1 : Map of Oyo State showing the 33 Local Government Areas

Source: Town planning Department, Ibadan North Local Government Authority

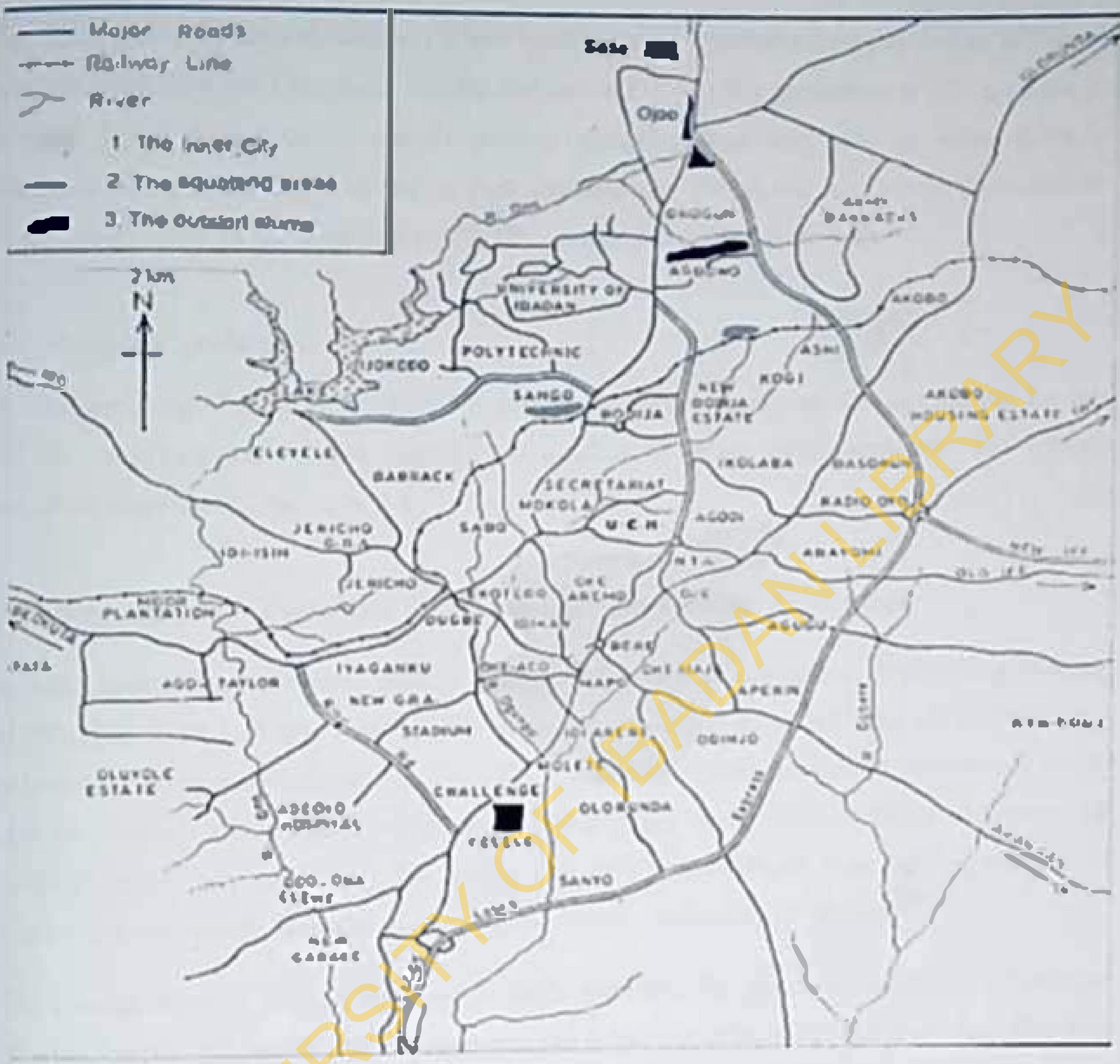


Fig 3.2: Map of Ibadan Metropolis
Source: Town planning Department, Ibadan North Local Government Authority

3.3 Description of sampling points

The list of major traffic intersections where traffic wardens perform their day to day activities was obtained from the Divisional Traffic Officers (DTO) in the respective police stations in the two Local Governments. Simple random sampling then was used to select thirteen intersections from the eighteen major road intersections within the two Local Government Areas which serve as the sampling point (SP) for the study. (See table 3.2)

3.4 Sampling procedure

A total sampling of all police officers in the two Local Governments was carried out for the survey. A systematic random sampling was used to select participants for the human exposure assessment (See table 3.3)

3.5 Determination of sampling coordinates and production of risk maps

A hand held battery-powered factory calibrated Garmin Geographical Positioning System (GPS) (See Plate 3.1) was used to determine the geographical coordinates of the locations selected for air quality assessment. The GPS is a satellite based navigation system that sends and receives the radio signal and provides information on location, velocity and time, 24 hours a day, in any weather in the world. The GPS was obtained from the Department of Environmental Health Sciences, College of Medicine, University of Ibadan.

The coordinates was entered into Google earth software. The mean concentration of sulphur dioxide, carbon monoxide and nitrogen dioxide at the sampling locations was classified into three categories according to the United States Environmental Protection Agency (USEPA) criteria for determining ambient air quality: For sulphur dioxide: low risk (0 – 0.03ppm), moderate risk (0.03 – 0.04ppm) and high risk (> 0.06ppm). for carbon monoxide: low risk (0 – 4.0ppm), moderate risk (4.1 – 6.0ppm) and high risk (>9.0ppm) while the risk level of nitrogen dioxide was classified as: low risk (0 – 0.03ppm), moderate risk (0.03 – 0.04ppm), and high risk (> 0.06ppm). A red place mark was used to represent areas with very high risk; a blue place-mark was used to represent areas with moderate risk while a green place-mark was used to represent areas with low risk

Plate 3.1: A GARMAIN GPS

Table 3.2: Description of Sampling Points

S/N	Sampling area	Sampling code	Description
1	Mokola	L1	Inalende junction, in front of Total filling station
2	Mokola	L2	In front of AP Petrol station
3	Sango	L3	Sango cemetery junction
4	Sango	L4	In front of Total Petrol station
5	University of Ibadan	L5	At the main entrance gate of the University opposite the road that enters Agbowo community.
6	Bodija	L6	Entrance to Bodija abbatoir in front of First Bank
7	Bodija	L7	Oju irin junction opposite Ola mummy food canteen
8	Osuntokun avenue	L8	In front of Zenith bank
9	Awolowo avenue	L9	Awolowo junction, in front of UBA Bank
10	Total Garden	L10	Total garden junction opposite Orita-mefa Baptist Church
11	Agodi gate	L11	Entrance of Agodi gate spare parts market
12	Idi ape	L12	Opposite Mr Biggs Restaurant
13	Oremeji	L13	Junction before Oremeji overhead bridge

Table 3.2: Description of Sampling Points

S/N	Sampling area	Sampling code	Description
1	Mokola	L1	Inalende junction, in front of Total filling station
2	Mokola	L2	In front of AP Petrol station
3	Sango	L3	Sango cemetery junction
4	Sango	L4	In front of Total Petrol station
5	University of Ibadan	L5	At the main entrance gate of the University opposite the road that enters Agbowo community.
6	Bodija	L6	Entrance to Bodija abbatoir in front of First Bank
7	Bodija	L7	Oju irin junction opposite Ola mummy food canteen
8	Osuntokun avenue	L8	In front of Zenith bank
9	Awolowo avenue	L9	Awolowo junction, in front of UBA Bank
10	Total Garden	L10	Total garden junction opposite Orita-mefa Baptist Church
11	Agodi gate	L11	Entrance of Agodi gate spare parts market
12	Idi ape	L12	Opposite Mr Biggs Restaurant
13	Oremeji	L13	Junction before Oremeji overhead bridge

3.6 Field sampling of air quality parameters

Gaseous and particulate matter sampling was carried out for a period of twelve weeks (June-August, 2011). The measurements were done twice within the working days of the week for each of the sampling points and one weekend. Sampling was carried out in the morning (6am-8am), afternoon (12pm-2pm) and evening (4pm-6pm). The purpose of this periodic determination of the air quality parameters was to identify peak periods for these parameters which are due to variation in the traffic density and also the location of the sampling points.

3.7 Study Population

The study population comprised police officers (traffic wardens and regular police officers) working in Ibadan North and Northeast Local Governments.

3.8 Eligibility criteria for study participants

3.8.1 Inclusion Criteria

The inclusion criteria for this study were that study participants:

- Must have been a Police officer for at least three years.
- Must have been working in the Local Government Areas for at least six month.

3.8.2 Exclusion Criteria

The following exclusion criteria were observed for the study:

- Policemen that were just transferred to the Local Government that have not spent up to six months were left out.
- New police recruits who have not spend up to three years in service were left out.

3.9 Sample Size Determination

Using the formula below, the required sample size was calculated as follows:

$$N = \frac{[(Z_{1-\alpha/2}\sqrt{P_o(1-P_o)} + Z_{1-\beta}\sqrt{P_1(1-P_1)})]^2}{(P_o-P_1)^2}$$

Where:

N = the desired sample size

$Z_{1-\alpha/2}$ = standard deviation at 5% level of significance = 1.96

$Z_{1-\beta}$ = standard deviation corresponding to 95% power = 1.28

P_1 = prevalence of cough among traffic wardens in Bangalore = 27%

P_2 = prevalence of cough among non-traffic police officers in Bangalore = 14.40%

$$N = \frac{[1.96\sqrt{0.27(1-0.27)} + 1.28\sqrt{0.144(1-0.144)}]^2}{(0.27-0.144)^2}$$

$$= \frac{[0.8702 + 0.4495]^2}{0.015876}$$

$$= \frac{[1.3197]^2}{0.015876}$$

= 109.69 (approx 110)

10% of 110, would be added to take care of attrition (no response)

N= 110 + 11 = 121

Since the study is a comparative cross sectional design, the sample size would be doubled in order to account for the comparative group and for better precision in the study.

Therfore N= 242

3.10 Air quality sampling

3.10.1 Particulate matter level determination

An Envirotech personal respirable dust sampler model APM 801 was used to determine traffic warden's exposure to total suspended particulate matter (see plate 3.2). The sampler is made up of a rotameter (pump unit) which houses a DC 6V rechargeable battery, a sampling head (which holds the filter paper) to be worn on the collar of the worker so that it could suck air from his breathing zone, a flexible tube (which connects the sampling head to the rotameter) and a side clamp (which allows the instrument to be worn on the belt of the worker).

The sampler was used to collect samples of air borne particles at different sampling points. The particles ($PM_{10\mu m}$) were collected by drawing air through a weighed high efficiency (small pore size) microfiber filter housed in a leak proof teflon filter holder fitted at the top of the sampling head at a known volumetric flow rate. The flexible tube was used to connect the sampling head to the pump unit and the pump was started and set at desired flow rate. The sampler was turned on and allowed to run for two minutes to ensure that there were no loose connections. The pump unit was then attached to the belt of traffic wardens through its clip. The flexible tube was passed through the traffic wardens shirt and the sampler head was clipped to the collar of their shirt so that it was close to their breathing zone (see plate 3.4).

The sampler was then switched on and allowed to run for two hours. The initial flow rate of the sampler was noted at the beginning of sampling. The final flow rate of the sampler was obtained just before the unit was switched off to obtain the average flow rate

Plate 3.2: Envirotech personal respirable dust sampler model APM801

Plate 3.3a: Filter paper before sampling

Plate 3.3b: Filter paper after sampling showing concentric ring of dust particles

The filter paper was carefully removed and placed in the desiccator to remove moisture. The filter paper was then reweighed to determine the net gain in the collected particulate matter. The result was expressed in micrograms per cubic meter ($\mu g/m^3$) of air sampled.

$$\text{PM Concentration (C)} = \frac{(W_1 - W_0) \times 10^6}{\frac{T(R_1+R_2)}{2}}$$

Where W_0 = Initial weight of filter paper before sampling (mg)

W_1 = Final weight of filter paper after sampling (mg)

R_1 = Initial flow rate before start of sampling

R_2 = Final flow rate just before the unit is turned off

T = Sampling time in minutes

Plate 3.4: Shows the sampling head attached to the shirt of a traffic warden

Plate 3.5: Sampler unit strapped to the belt of a traffic warden

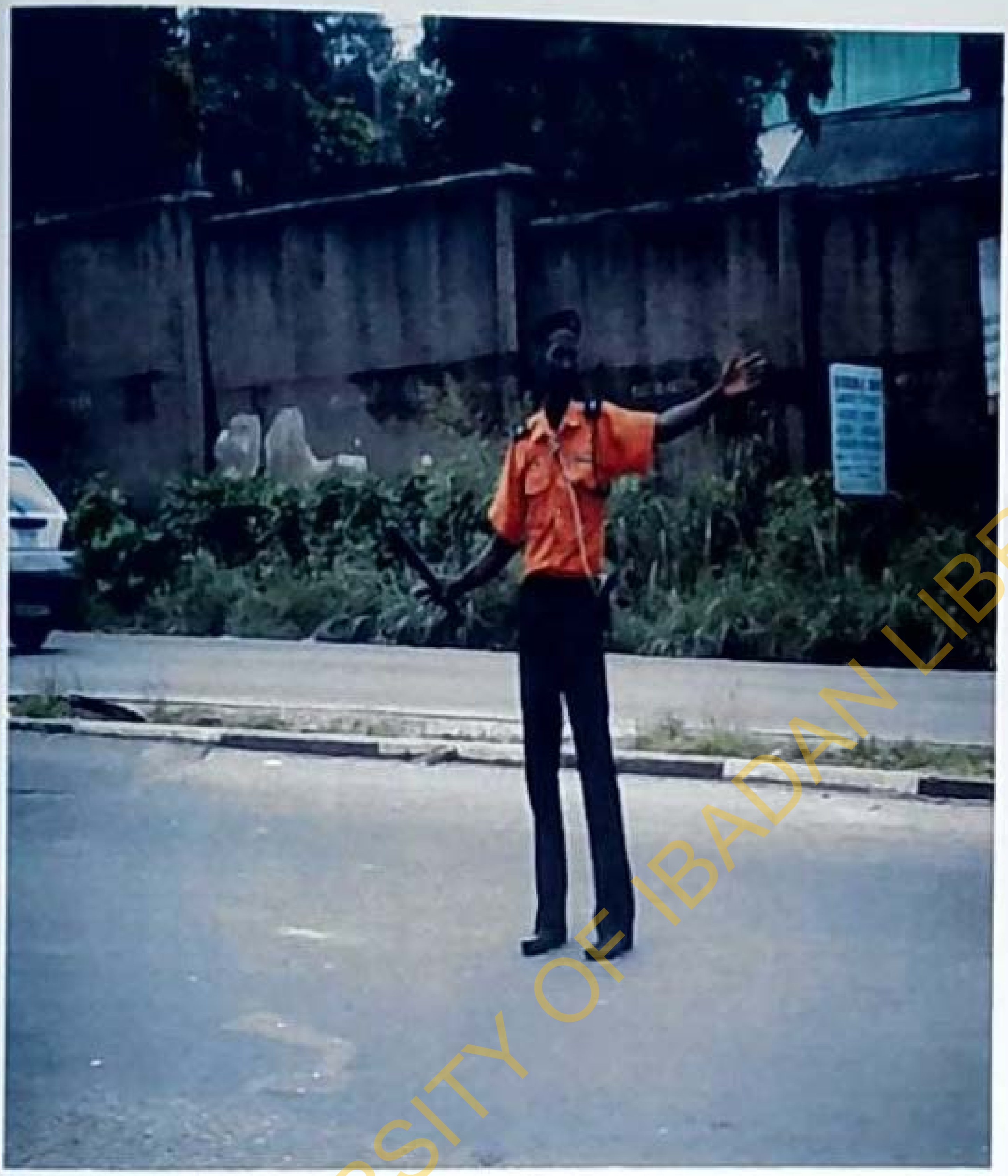


Plate 3.6: A traffic warden on duty with the personal respirable dust sampler

3.10.2 Gaseous emissions determination

Traffic related air pollutants levels comprising carbon monoxide (CO), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2) were determined using extech carbon monoxide monitor model CO10, environmental sensors sulphur dioxide monitor model Z-1300 and environmental sensors nitrogen dioxide monitor model Z-1400 respectively. Prior calibration of the monitors was done according to standard procedures. The gas monitors were hand held at the sampling locations and stretched at arm's length to determine the ambient levels of the pollutants. Measurements were taken at each sampling location and the means were computed.

Plate 3.7: Air samplers: nitrogen dioxide and sulphur dioxide monitors model Z-1400 and Z-1300 respectively.

Plate 3.8: Extech carbon monoxide monitor model CO10

3.10.3 On-site observations

An observational checklist was used to assess the following:

- Location of sampling point
- Nature of road
- Activities within and around the study site

3.10.3.1 Traffic density estimation

According to Abam *et al*., 2009, traffic density can be estimated through manual counting. Three research assistants were recruited to count the number of cars, buses, bikes and trucks that pass through the sampling points for a period of 10 minutes and this was used to estimate the hourly traffic density. This is then compared with the standard set by (Ozkurt *et al*., 2009). The traffic density is calculated as the number of vehicles or automobiles over the time as shown below:

$$Density_i = \frac{V_i}{T}$$

$Density_i$: Traffic density of vehicles type i

V_i: Number of vehicle type I that passed the road in time period T

T: Time period

The classification of traffic density is described below:

Category	Cars/minute	Cars/hour
High Traffic	>40	>1600
Medium Traffic	10 - 39	400 - 1600
Low Traffic	<10	<400

Source: Ozkurt *et al.*, 2009

3.11 Survey

3.11.1 Questionnaire Administration

A 46 item semi structured questionnaire was designed and used to elicit relevant information from police officers in the two Local Governments. This instrument has four major sections: Socio-demographic information, perception of respondents of air quality, household characteristics and health conditions. A pre-test was carried out among Federal Road Safety Corps (FRSC) in Ibadan and a reliability value of 0.7 was calculated which showed that the instrument was valid and reliable to elicit vital information from the respondents. Two research assistants were employed and trained on administration of questionnaires to the respondents. A total number of 247 questionnaires were administered to both Traffic wardens and Regular policemen.

3.11.1.1 Perception Scoring

- Point Scale: 8
- Maximum Score: 1 and Minimum Score: 0
- 50th percentile and Above = High Perception
- Below 50th Percentile = Low Perception

3.12 Human exposure assessment

3.12.1 Lung function test

3.12.2.1 Description of participants

Participants recruited were police officers that took part in the questionnaire survey. Those that show willingness to partake in the test and who also met the eligibility criteria for the test were chosen from those that participated in the survey. Systematic random sampling was used to select 124 police officers (61 traffic wardens and 63 regular policemen) representing 50% of the study population (See table 3.3 for details). The proportion used in this study is twice that used in a previous study carried out by Kogevinaset *et al.*, 1998.

3.12.2.2 Eligibility criteria for study participants for the lung function test

The major criteria for selection of study participants were as follows:

- Participants must not have a family history of respiratory symptom or disease from the response got from questionnaire.
- Participants must be a non-smoker.
- Participants must be willing to take part in the test.
- Participants must have been a police officer for at least 3 years.

The rationale behind the above eligibility criteria was to reduce the influence of confounders.

3.12.2.3 Materials for lung function test

Spirometer: A white digital spirometer was used by the selected participants to determine FEV_1 parameter used in assessing lung function.

Mouthpiece: 124 mouthpieces for the 124 participants were attached to the spirometer before usage to avoid mouth infectious disease.

Weighing scale: This instrument is used for measuring the weight of the lung function test participants to be able to determine the BMI.

Plate 3.9: A participant undergoing lung function test

Table 3.3: Proportional allocation of participants for spirometry

Local Government	Occupation	Number of participants	Proportional allocation (50%)	Participants for spirometry	Systematic sampling strategy
Ibadan North	TW	83	(50*153)/100 = 77	42	153/83 = 2
	RP	70		35	153/70 = 2
Total		153		77	
Ibadan Northeast	TW	39	(50*94)/100 = 47	19	94/39 = 2
	RP	55		28	94/55 = 2
Total		94		47	

Key

TW = Traffic wardens

RP = Regular police officer

Metre rule: The long metre rod was used to measure the height of the participants for both lung function and BMI estimations.

Lung function calculator: This is the instrument used in calculating the expected lung function value of people after inserting the age, sex and height of the participant. The programmed value on the calculator which is the expected lung function is the lung function value of a similar healthy black population.

3.12.2.4 Procedure used in the Lung function test

Lung function test was carried out through the use of Ferraris digital spirometer to determine the actual forced expiratory volume in one second (FEV_1). A disposable mouthpiece was inserted at the tip of the spirometer to prevent spread of mouth infection among the participants. The spirometer was calibrated to 0.00 before the participants were asked to Inhale air and later exhale air with force into the spirometer. This was used on an individual at three manoeuvres and the best i.e. the highest was recorded for each participant. The height and weight of the participants were measured using a meter rule and weighing scale respectively to calculate the Body Mass Index (BMI) and to be able to input their values into the lung function calculator in order to get the predicted FEV_1. The actual FEV_1 was compared with the predicted FEV_1 to reveal the variation between the values and percentage predicted FEV_1.

3.13 Data analysis

Questionnaires were serially numbered for control and recall purposes and data collected were checked for completeness and accuracy before it was then edited and coded manually. The data was imputed into the computer while analysis was carried out using SPSS software version 16. Descriptive statistics (proportions, means and standard deviations) was employed. Chi square was used to test for association between qualitative variables from the questionnaire survey. ANOVA was used to determine the difference in the mean levels of respirable suspended particulate matter (RSPM) and traffic related air pollutants at different sampling points and time as well as determining the variation between the observed values and the guideline limits. Spearman-Rank correlation test was used to establish relationship between the particulate burden and lung function status of traffic wardens as well as the relationship between the concentration of the traffic-related air pollutants and traffic density. All analysis was carried out at 5% level of significance.

3.14 Informed consent and Ethical Consideration

Ethical approval was obtained from the joint UI/UCH institutional review board (see appendix VI). Informed consent informing respondents' on their right to either to take part or not was done before any interaction with the respondent after having shown full understanding of the study. Confidentiality of information obtained from respondents was ensured. Identifiers were stripped from the respondents' responses and number codes used for respondent.

1. **Non-Maleficence:** This research did not in any way inflict harm on the participants and every participant was treated equally as much as possible.
2. **Confidentiality of Data:** Assurance of absolute confidentiality and all information provided by the research participant were kept secret, not to be used in a non-research purpose.
3. **Disclosure of Information:** All research participants were duly informed of all the process involved in the research before commencement of the project. No biological samples were collected.
4. **Beneficence to participants:** The participants of this study benefited from free pulmonary function test.
5. **Right to withdraw from study:** Research participants who wish to withdraw from the study were free to do so, at any point in time, without any fear.

CHAPTER FOUR

RESULTS

This chapter presents the results of the gaseous emissions and particulate matter monitoring across the selected sampling points. The results from the questionnaire survey which included information on socio-demographic characteristics, perception on air quality, household characteristics and health conditions of respondents from the two LGA's are also presented. Also included in this chapter are the results of the lung function tests carried out on a subset of the study population.

4.1 General description of sampling locations

Table 4.1 shows the onsite observations related to air quality in the selected sampling locations. Majority of the sampling locations were situated in areas with high commercial activity though there were no industries located in the study sites.

Activities around the study sites include bush burning, construction processes e.t.c There were also dumpsites and generators in some study sites. Due to the presence of a cemetery at location 3, the bushes in the cemetery were regularly cleared and burnt to beautify it and this accounted for generation of some air pollutants. Location 4 is situated around Sango market while locations 6 and 7 are sited within the popular Bodija market. Usually, large volume of waste is generated from markets and due to the inefficiency in the disposal of waste in this markets, large expanse of land develop into dumpsite. Burning of waste in this dumpsite also contributed to the poor air quality in these areas. Generator emission was also a major menace at location 5 because of its closeness to the main campus of the University of Ibadan. Due to the erratic supply of electricity in Nigeria, most commercial ventures around the University depend mainly on generators.

The dualization of the road along location 10 increased the level of particulate matter generated in this area coupled with the fact that it is the only location where the road around it is not tarred.

Table 4.1: General information about sampling locations

Indicators	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13
Location of sampling point													
Residential area	+	-	-	+	++	-	+	++	++	++	+	++	++
Commercial activities	+++	+++	++	+++	++	+++	+++	++	+++	++	+++	++	+++
Industrial activities	-	-	-	-	-	-	-	-	-	-	-	-	-
Nature of road network													
Paved roads	+++	+++	+++	+++	+++	+++	+++	+++	+++	-	+++	+++	+++
Unpaved (graded earth) roads	-	-	-	-	-	-	-	-	-	++	-	-	-
Activities within and around study location													
Bush burning	-	-	+	+	-	+	+	-	-	-	-	-	-
Dumpsite	-	-	-	-	-	-	+	-	-	-	-	-	-
Generator emissions	-	-	-	+	+++	+	+	++	+	-	++	-	-
Construction activities	-	-	-	-	-	-	-	-		++	++	-	-

Key: +++ highly present   ++ moderately present   + present   - absent

4.2 Trend of respirable particulate matter (PM_{10}) concentration at sampling locations

The trend of the particulate matter concentrations at the selected sampling locations is graphically shown in Figure 4.1. The values on the chart represent the concentrations measured in each location at three distinct periods (morning: 6a.m-8a.m, afternoon: 12p.m-2p.m and evening: 4p.m-6p.m). Concentration of PM_{10} peaked at location 10 (48.38 μg/m^3) during the evening period and this is higher than the WHO guideline limit while the least concentration was recorded at location 7 during the morning period. The highest concentration of PM_{10} in the morning was recorded at location 13 (16.13 μg/m^3) while the least concentration was recorded at location 2. PM_{10} concentration recorded at location 10 (48.39 μg/m^3) was about four folds higher than the concentration during the morning hours (10.75 μg/m^3).

The mean levels of PM_{10} measured at various sampling points are graphically represented in Figure 4.2. The values on the chart shows the mean particulate matter concentration of the locations at three different periods (morning: 6a.m-8a.m, afternoon: 12p.m-2p.m and evening: 4p.m-6p.m) in comparison with the World Health Organization guideline limit (WHO) for air quality (25μg/m^3). The mean particulate concentration in the morning, afternoon and evening were 10.12 ± 4.34μg/m^3, 23.80 ± 11.89μg/m^3 and 28.11 ± 11.45μg/m^3 respectively ($p < 0.05$) and they were higher than the World Health Organization guideline limit for air quality except during the morning and afternoon sampling hours.

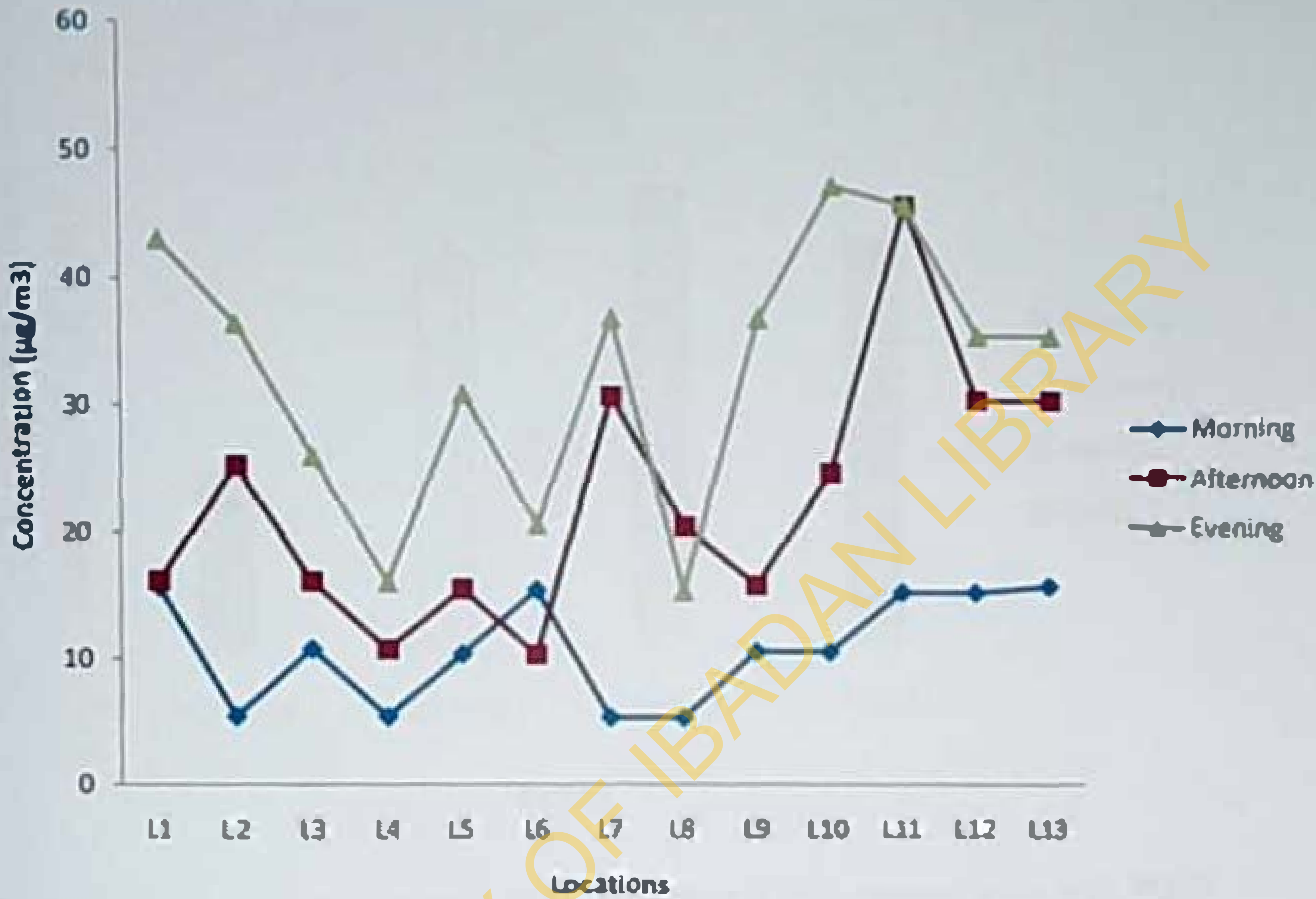


Figure 4.1: Trends in concentration of PM_{10} at the selected sampling locations

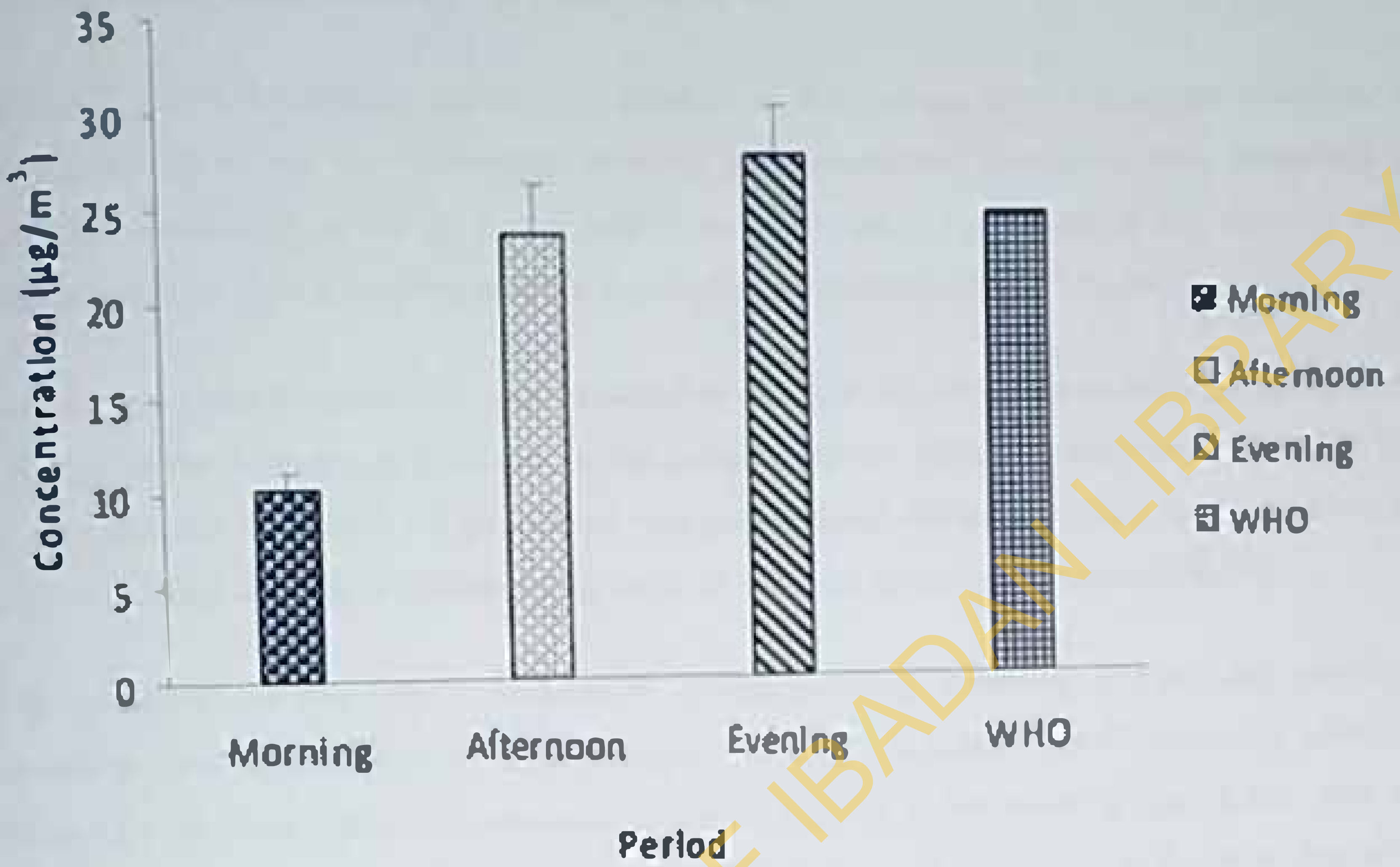


Figure 4.2: Comparison of mean particulate matter (PM_{10}) concentration with WHO guideline limit

4.3 Gaseous Emissions Concentration

4.3.1 Sulphur dioxide (SO_2) concentration

The weekly mean concentrations of gaseous emissions determined at the thirteen selected sampling locations are presented in Tables 4.2 to 4.4.

Table 4.2 shows the weekly mean concentration of SO_2 across the 13 sampling locations at various period of the day (morning, evening and afternoon). Levels of SO_2 measured at location 1 were high in the morning, afternoon and were at their peak in the evening with concentration as high as 1.24ppm. This was higher than standard of 0.17ppm.

The least concentration of SO_2 was recorded at location 10 with concentration ranging from 0.07ppm in the morning to 0.56ppm in the evening period. However they were all above the WHO guideline limit of 0.17ppm. There was a significant difference in the concentrations of SO_2 determined at each of the sampling point at different sampling periods ($p<0.05$).

SO_2 concentrations recorded at location 11 during morning, afternoon and evening sampling periods showed that location 11 had the highest levels of SO_2 in all the 13 sampling points in the two Local Governments. Concentrations were highest in the evening period and were all above the WHO guideline limit which is 0.17ppm (See Table 4.2). It was observed that most of the concentrations of SO_2 recorded during the evening period were two folds higher than the morning concentrations.

Figures 4.3 to 4.5 show the comparison of mean concentration of SO_2 at different periods in all the 13 sampling points in comparison with WHO guideline limit.

4.3 Gaseous Emissions Concentration

4.3.1 Sulphur dioxide (SO_2) concentration

The weekly mean concentrations of gaseous emissions determined at the thirteen selected sampling locations are presented in Tables 4.2 to 4.4.

Table 4.2 shows the weekly mean concentration of SO_2 across the 13 sampling locations at various period of the day (morning, evening and afternoon). Levels of SO_2 measured at location 1 were high in the morning, afternoon and were at their peak in the evening with concentration as high as 1.24ppm. This was higher than standard of 0.17ppm.

The least concentration of SO_2 was recorded at location 10 with concentration ranging from 0.07ppm in the morning to 0.56ppm in the evening period. However they were all above the WHO guideline limit of 0.17ppm. There was a significant difference in the concentrations of SO_2 determined at each of the sampling point at different sampling periods ($p<0.05$).

SO_2 concentrations recorded at location 11 during morning, afternoon and evening sampling periods showed that location 11 had the highest levels of SO_2 in all the 13 sampling points in the two Local Governments. Concentrations were highest in the evening period and were all above the WHO guideline limit which is 0.17ppm (See Table 4.2). It was observed that most of the concentrations of SO_2 recorded during the evening period were two folds higher than the morning concentrations.

Figures 4.3 to 4.5 show the comparison of mean concentration of SO_2 at different periods in all the 13 sampling points in comparison with WHO guideline limit.

Table 4.2: Weekly mean concentration of SO_2 across locations at different periods

Locations	6a.m - 8 a. m	12p.m - 2 p. m	4p.m - 6 p. m	P- value
L1	0.26±0.13	0.82±0.35	1.24±0.48	
L2	0.36±1.33	0.95±0.43	1.50±0.72	
L3	0.24±0.17	0.79±0.34	1.47±0.87	
L4	0.72±0.35	1.23±0.54	1.24±0.75	
L5	0.45±0.36	0.75±0.29	1.24±0.87	
L6	0.52±0.49	0.99±0.59	1.35±0.46	<0.05
L7	0.59±0.29	0.86±0.37	1.39±0.69	
L8	0.60±0.26	0.75±0.47	1.13±0.77	
L9	0.85±0.13	0.97±0.52	1.30±0.59	
L10	0.07±0.06	0.37±0.31	0.56±0.39	
L11	0.70±0.31	1.69±0.42	2.07±0.64	
L12	0.64±0.32	1.15±0.38	1.34±0.46	
L13	0.51±0.26	0.99±0.61	1.26±0.76	

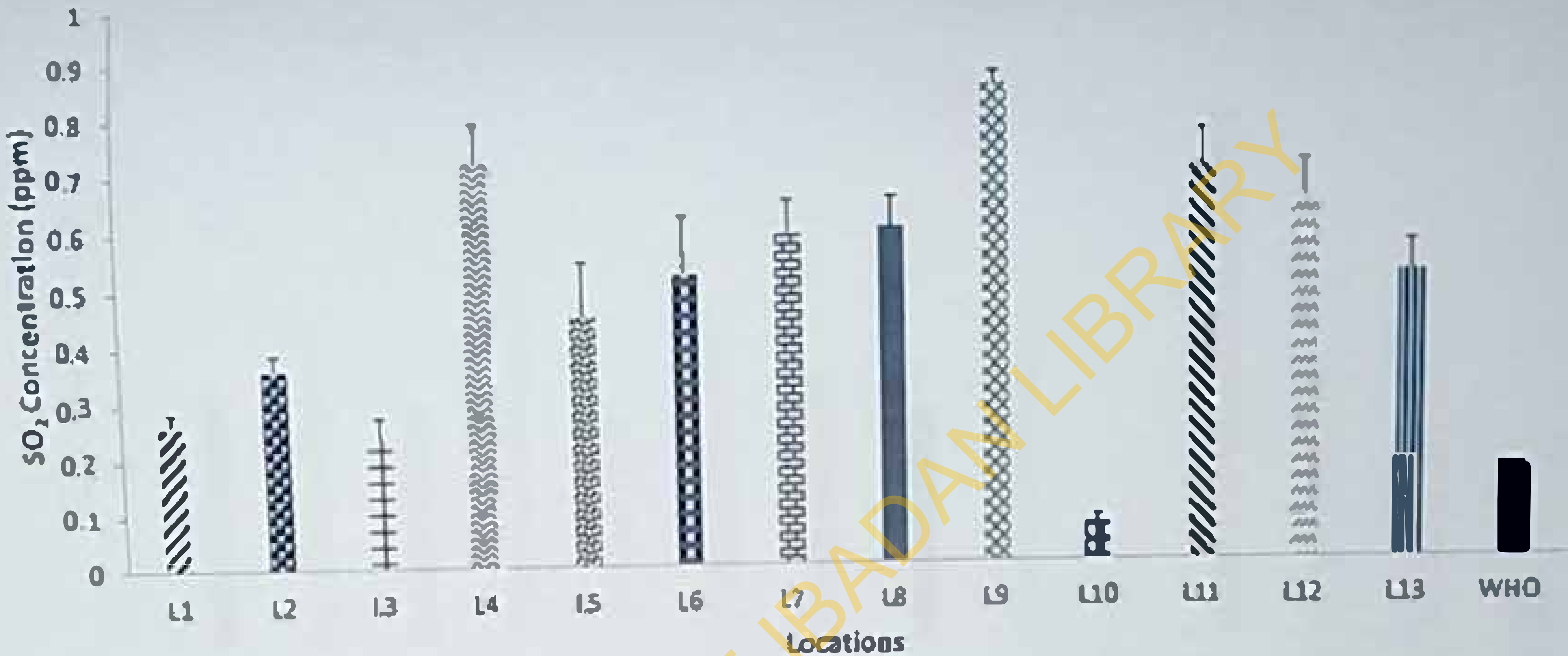


Figure 4.3: Comparison of weekly mean SO_2 concentration with WHO guideline limit for all the thirteen locations in the morning

*L1 Inalende junction L2 Mokola L3 sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Oshuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

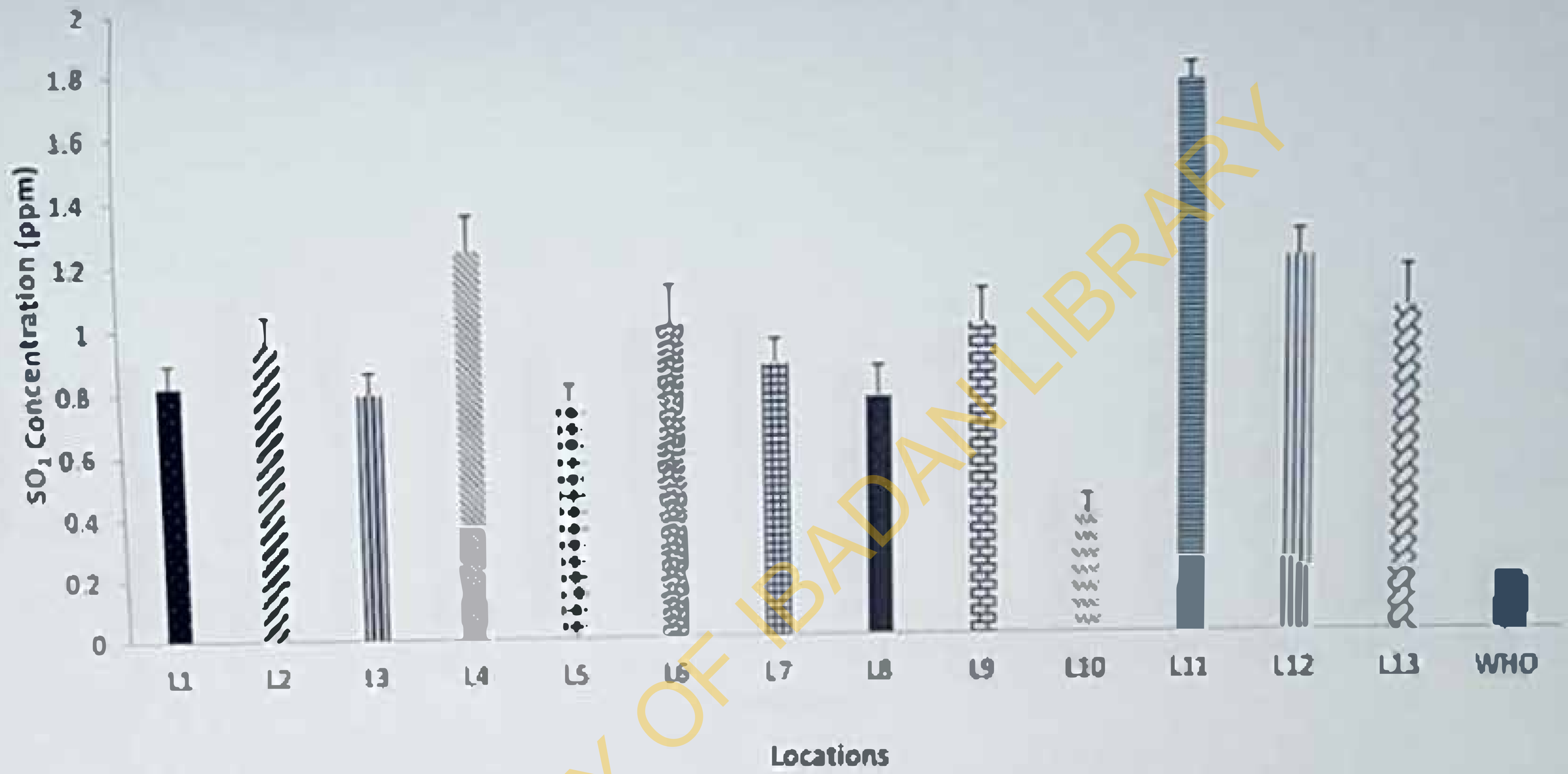


Figure 4.4: Comparison of weekly mean SO_2 concentration with WHO guideline limit for all the thirteen locations in the afternoon

*L1 Iwo road junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Onamtokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

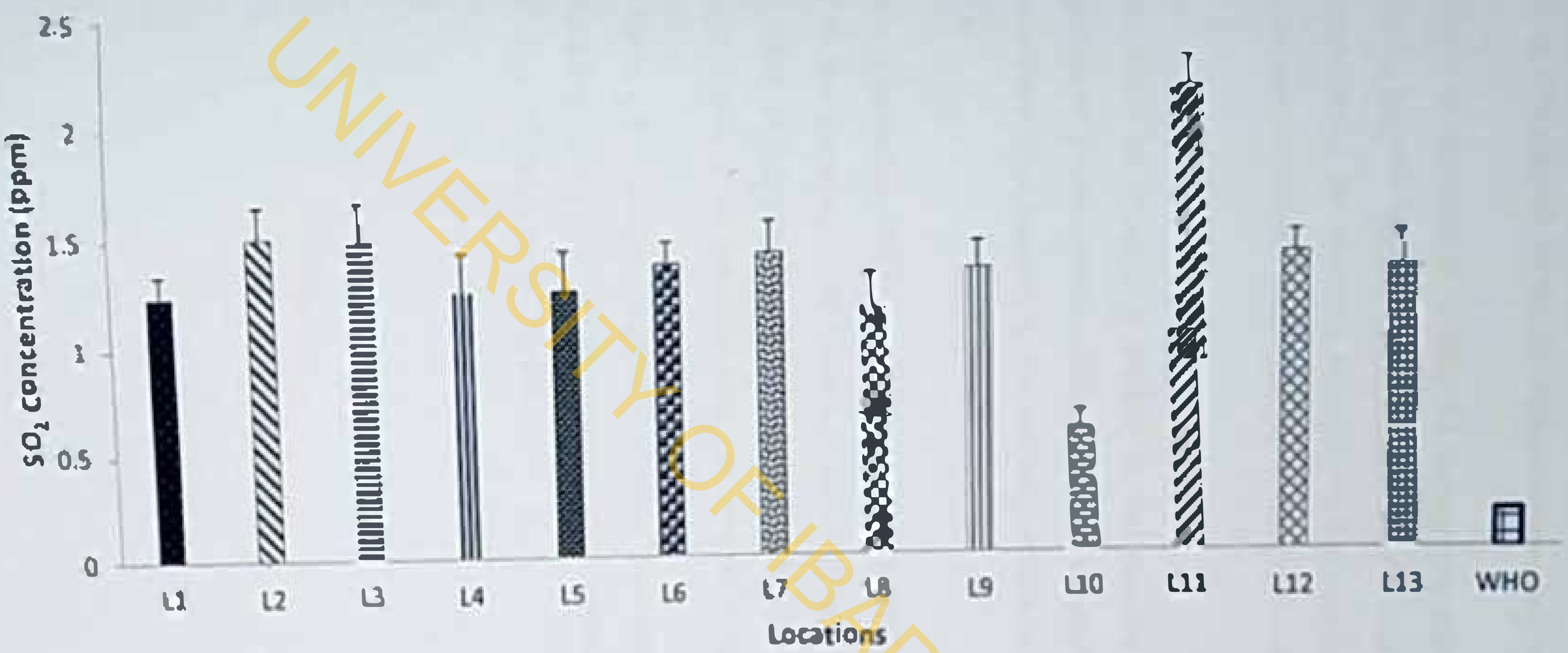


Figure 4.5: Comparison of weekly mean SO_2 concentration with WHO guideline limit for all the thirteen locations in the evening

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

4.3.2 Carbon (II) oxide concentration

Table 4.3 shows the weekly mean concentration of CO measured in all the 13 sampling locations at various periods of the day (morning, evening and afternoon).

CO concentrations recorded at location 11 during both afternoon and evening periods showed that location 11 had the highest concentration amongst all the 13 sampling points in the two LGA's except during the morning periods. All the evening concentrations were higher than the afternoon concentrations and these were all above 10ppm (WHO guideline limits) (See Table 4.3).

CO concentration at location 4 peaked in the evening period (61.63ppm) while in the morning period; CO concentration at location 4 was higher compared to location 11.
CO concentration was highest in the morning period at location 8 while it was lowest at location 10.

The least concentration of CO was recorded at location 10 with concentration ranging from 6.88ppm in the morning to 30.38ppm in the evening period and they were all above the guideline limit of 10ppm. There was a significant difference in the concentration of CO determined in each of the sampling points at different sampling period ($p<0.05$).

Figures 4.6 to 4.8 show the comparison of mean concentration of CO at different periods for the 13 sampling points with WHO guideline. CO concentrations at all sampling points were above WHO guideline limit of 10ppm.

Table 4.3: Weekly mean concentration of CO across locations at different periods

Locations	6a.m - 8 a. m	12p.m - 2 p. m	4p.m - 6 p. m	P- value
L1	11± 5.10	34.04±10.26	63.20±12.06	
L2	12.96±4.97	40.86±15.13	66.23±31.48	
L3	11.5±8.27	34.33±10.24	60.04±28.12	
L4	25.58±10.88	41.87±15.88	61.63±21.19	
L5	23.70±11.83	36.88±8.22	53.04±24.46	
L6	19.78±8.10	41.39±10.47	65.91.65±17	
L7	25.67±9.10	38.21±12.09	53.38±18.16	< 0.05
L8	31.67±10.06	40.67±9.17	50.04±8.36	
L9	26.29±6.92	36.13±8.12	46.46±10.82	
L10	6.88±2.27	21.04±8.89	30.38±8.09	
L11	22.54±6.35	50.38±19.53	66.20±21.23	
L12	24.68±8.04	41.15±13.01	60±28.83	
L13	28.20±11.70	43.42±21.99	55.04±21.69	

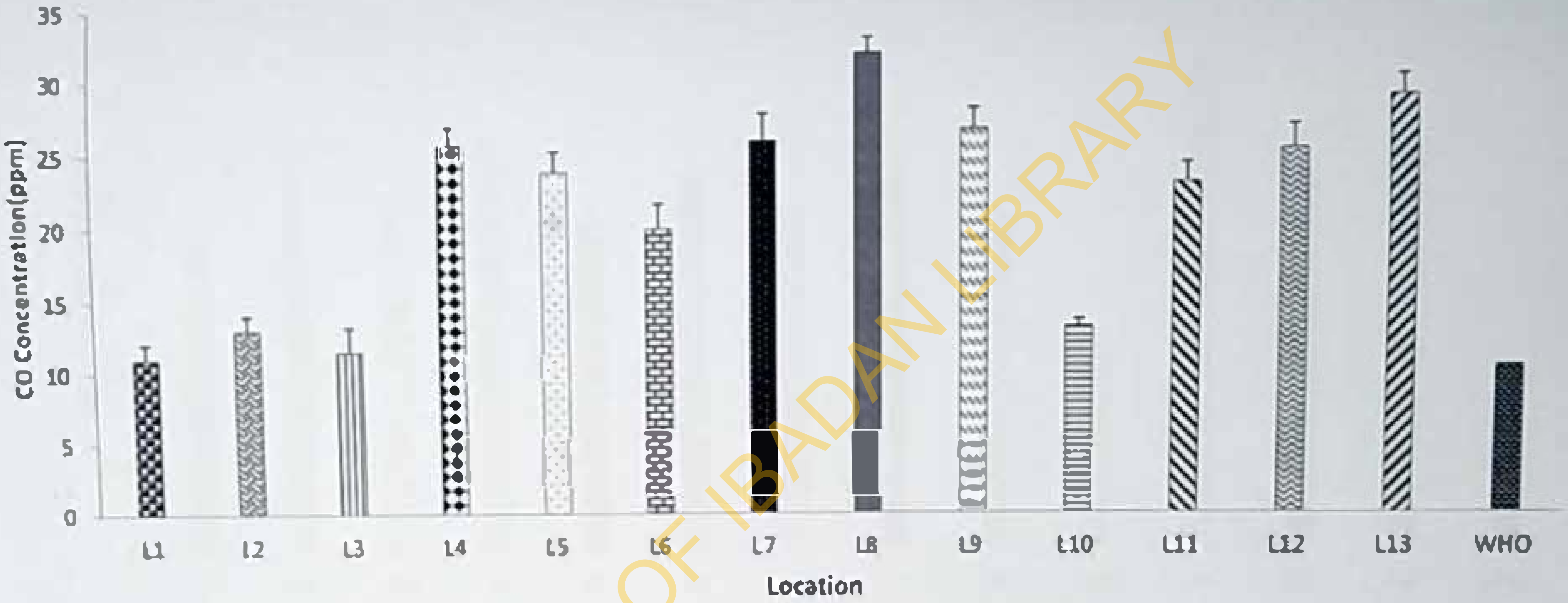


Figure 4.6: Comparison of weekly mean CO concentration with WHO guideline limit for all the thirteen locations in the morning
*L1 Iwakeside junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

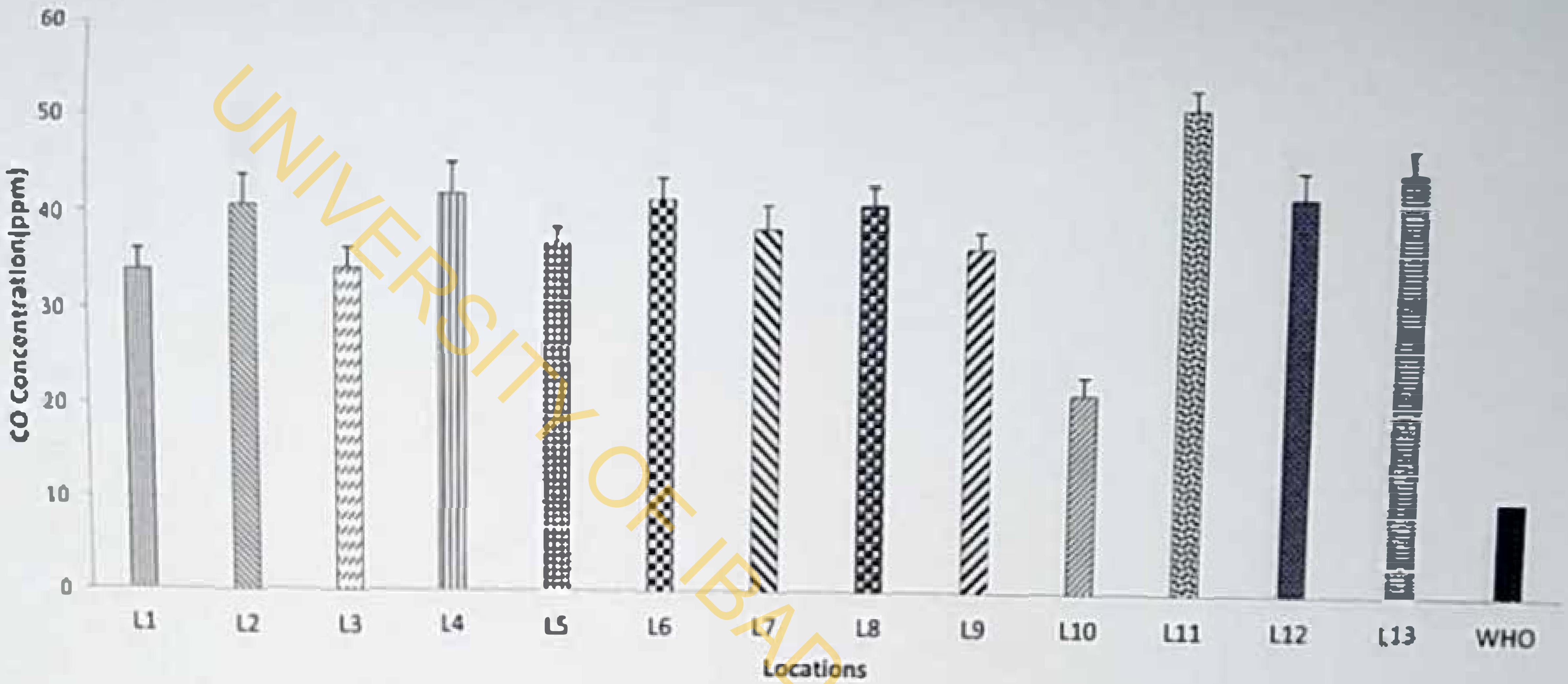


Figure 4.7: Comparison of weekly mean CO concentration with WHO guideline limit for all the thirteen locations in the afternoon

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

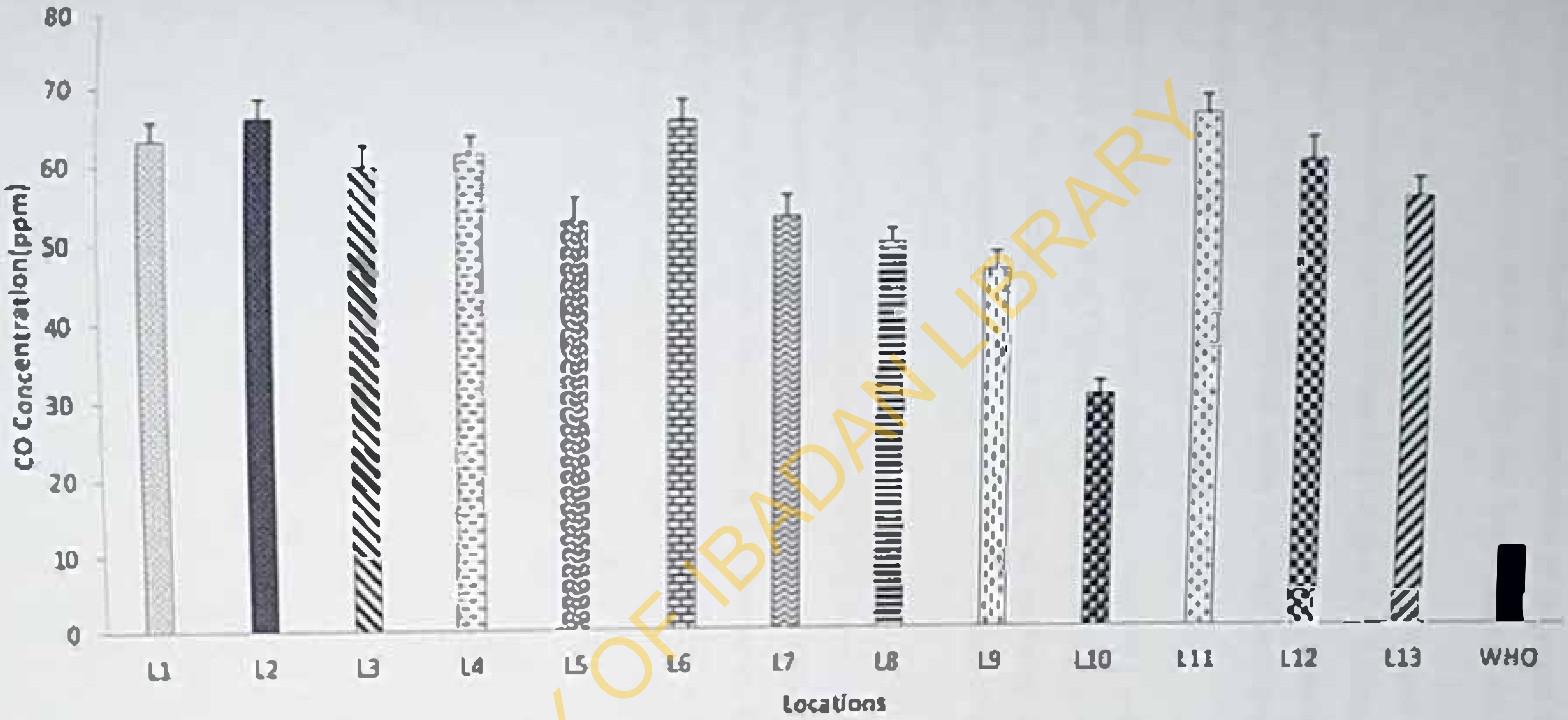


Figure 4.8: Comparison of weekly mean CO concentration with WHO guideline limit at all the thirteen locations in the evening

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

4.3.3 Nitrogen dioxide (NO_2) concentration

Table 4.4 shows the weekly mean concentration of Nitrogen dioxide measured in all the 13 sampling points at various periods of the day (morning, evening and afternoon).

Levels of NO_2 at location 1 were high in the morning and afternoon but peaked in the evening with concentrations of 0.04ppm, 0.12ppm and 0.20ppm respectively and they were all higher than the guideline limit of 0.17ppm except in the morning and afternoon hours. Concentrations of NO_2 in the morning hours in all the sampling locations were all below the guideline limit of 0.17ppm.

The least concentration of NO_2 was recorded at location 5 with concentration ranging from 0.04ppm in the morning to 0.12ppm in the evening period. Concentration of NO_2 during the afternoon and the evening hours were below the guideline limit. There was a significant difference in the concentrations of NO_2 determined in each of the sampling points at different sampling periods ($p<0.05$).

NO_2 concentrations during the morning and evening periods peaked at location 12 while NO_2 concentration peaked during the afternoon period at location 11. All evening concentrations were higher than the afternoon and morning concentrations (See Table 4.4). Figures 4.9 to 4.11 show the comparison of mean concentration of NO_2 at different periods in all the 13 locations with WHO guideline limit.

Table 4.4: Weekly mean concentration of NO_2 across locations at different periods

Locations	6a.m - 8 a.m	12p.m - 2p.m	4p.m - 6p.m	P- value
L1	0.04 ± 0.02	0.12 ± 0.10	0.20 ± 0.11	
L2	0.08 ± 0.07	0.11 ± 0.06	0.15 ± 0.08	
L3	0.05 ± 0.04	0.07 ± 0.05	0.13 ± 0.07	
L4	0.07 ± 0.06	0.12 ± 0.07	0.18 ± 0.10	
L5	0.05 ± 0.04	0.07 ± 0.05	0.12 ± 0.07	
L6	0.06 ± 0.05	0.07 ± 0.03	0.13 ± 0.06	
L7	0.07 ± 0.05	0.08 ± 0.06	0.15 ± 0.10	< 0.05
L8	0.08 ± 0.06	0.09 ± 0.05	0.14 ± 0.06	
L9	0.08 ± 0.06	0.10 ± 0.06	0.15 ± 0.07	
L10	0.05 ± 0.03	0.10 ± 0.05	0.14 ± 0.09	
L11	0.10 ±0.05	0.18 ± 0.11	0.22 ± 0.14	
L12	0.11 ± 0.07	0.15 ± 0.09	0.23 ± 0.15	
L13	0.06 ± 0.05	0.12 ± 0.07	0.16 ± 0.08	

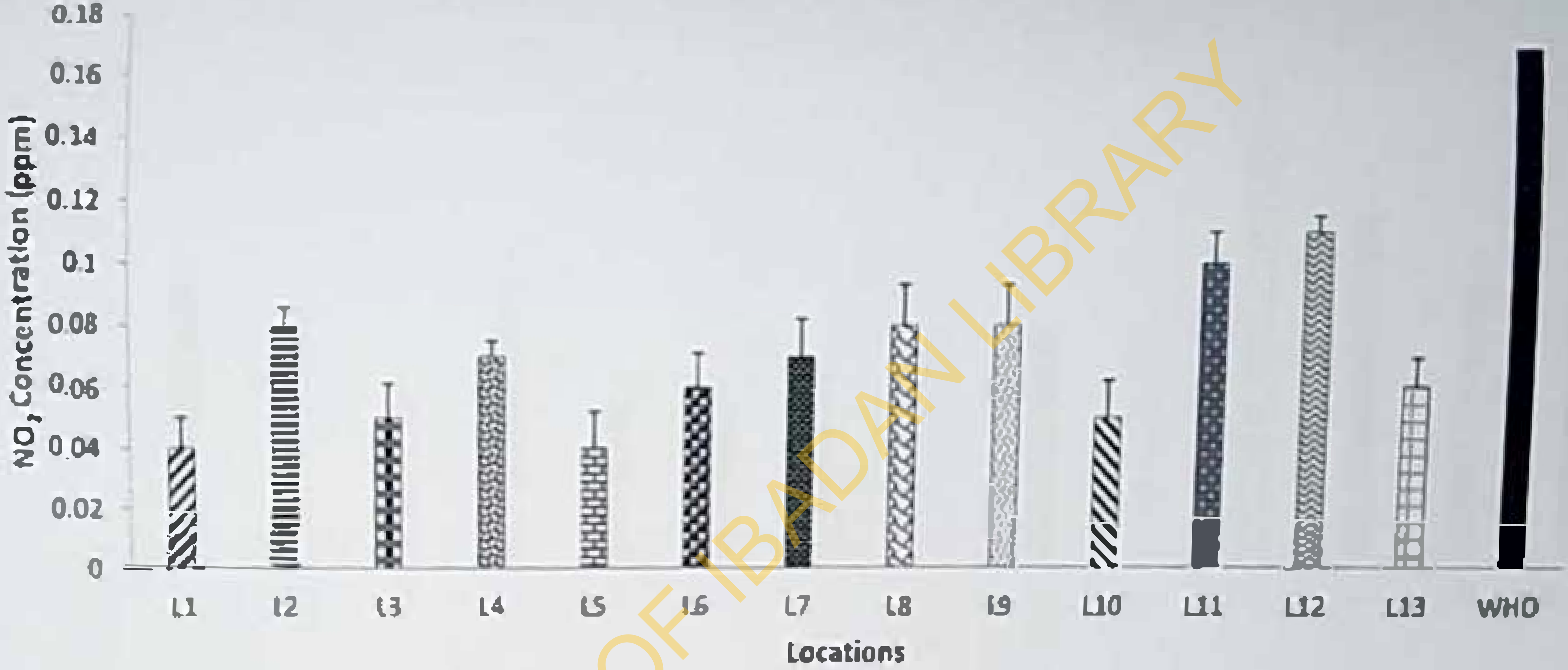


Figure 4.9: Comparison of weekly mean NO_2 concentration with WHO guideline limit for all the thirteen locations in the morning

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

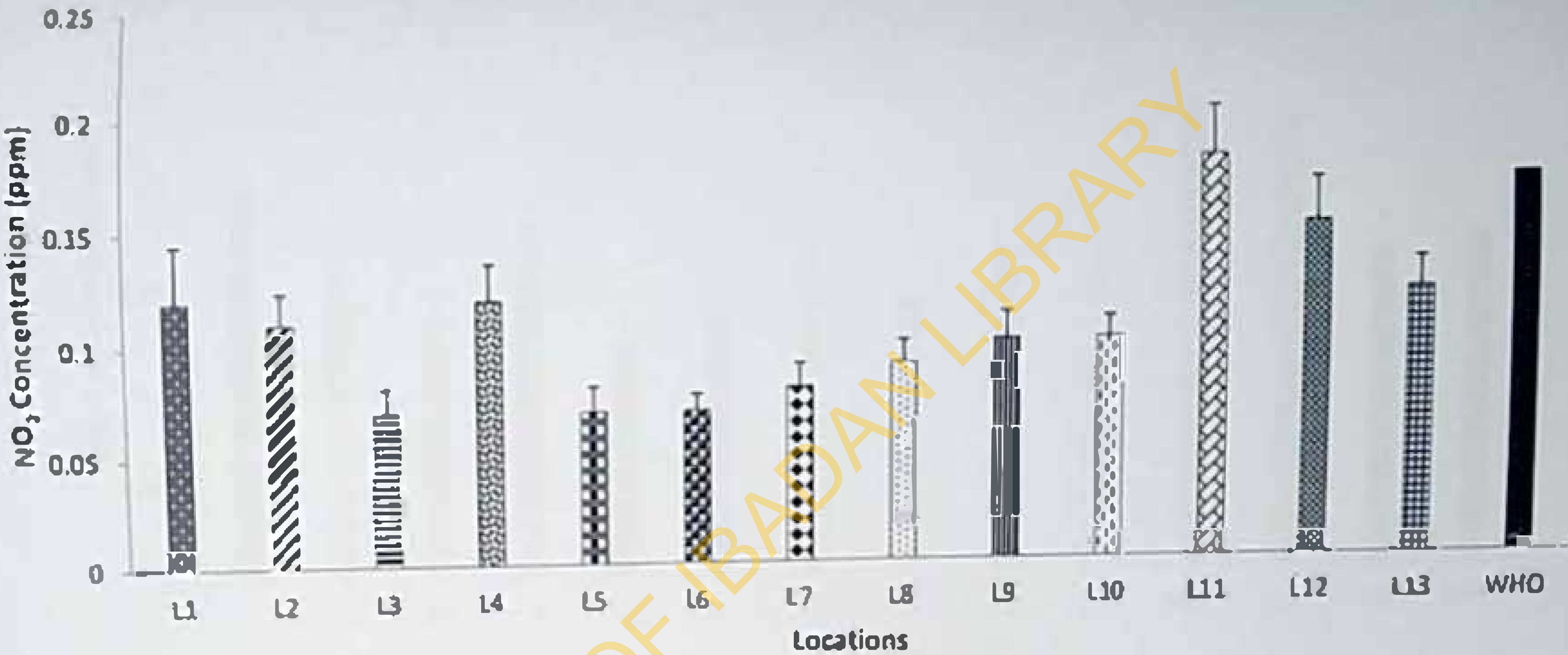


Figure 4.10: Comparison of weekly mean NO_2 concentration with WHO guideline limit for all the thirteen locations in the afternoon

*L1 Iwalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Oshuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

Figure 4.11: Comparison of weekly mean NO_2 concentration with WHO guideline limit for all the thirteen locations in the evening

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

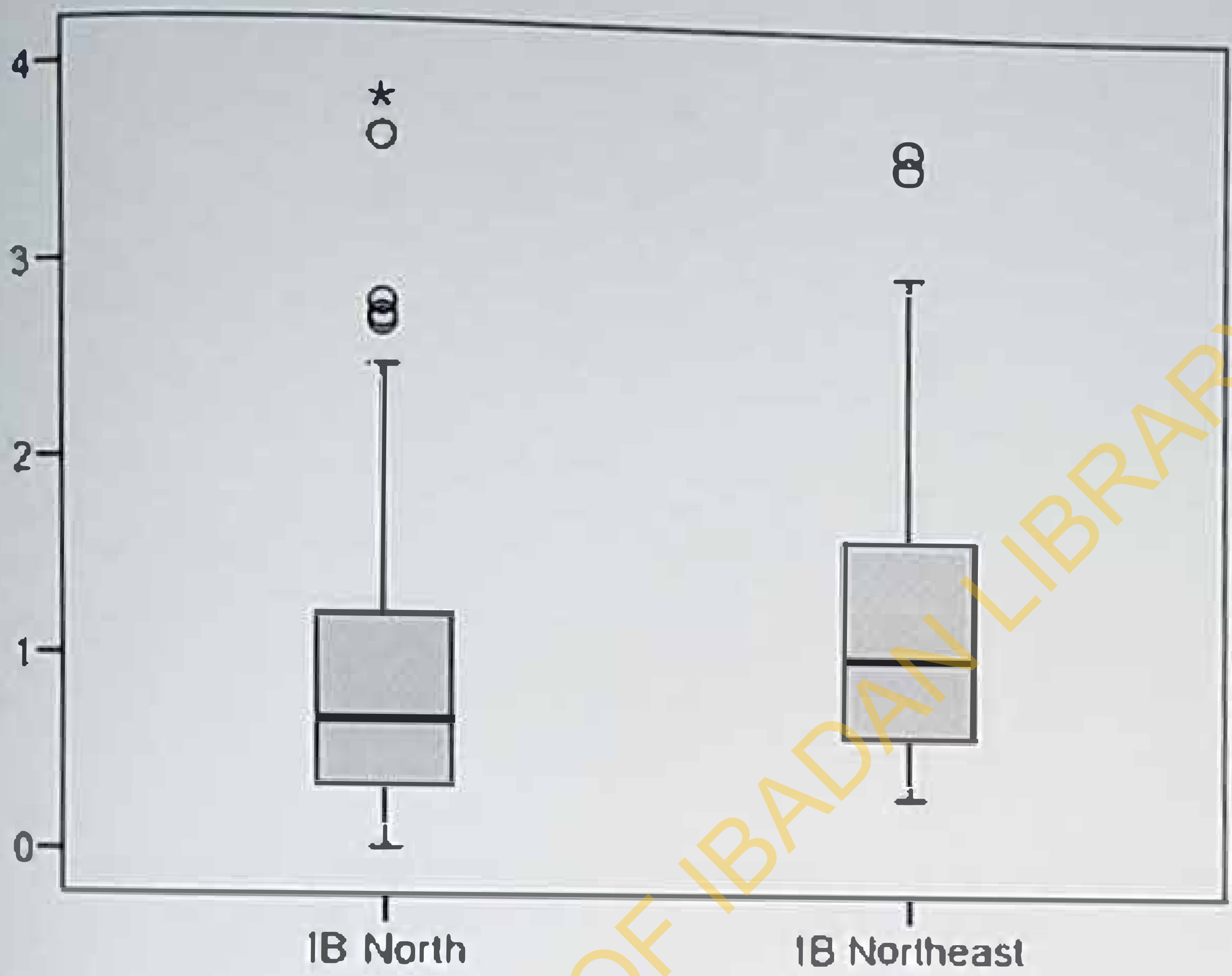


Figure 4.12: Concentration of SO_2 at the Local Government Areas

*IB North: Ibadan North Local Government Area IB Northeast: Ibadan Northeast Local Government Area

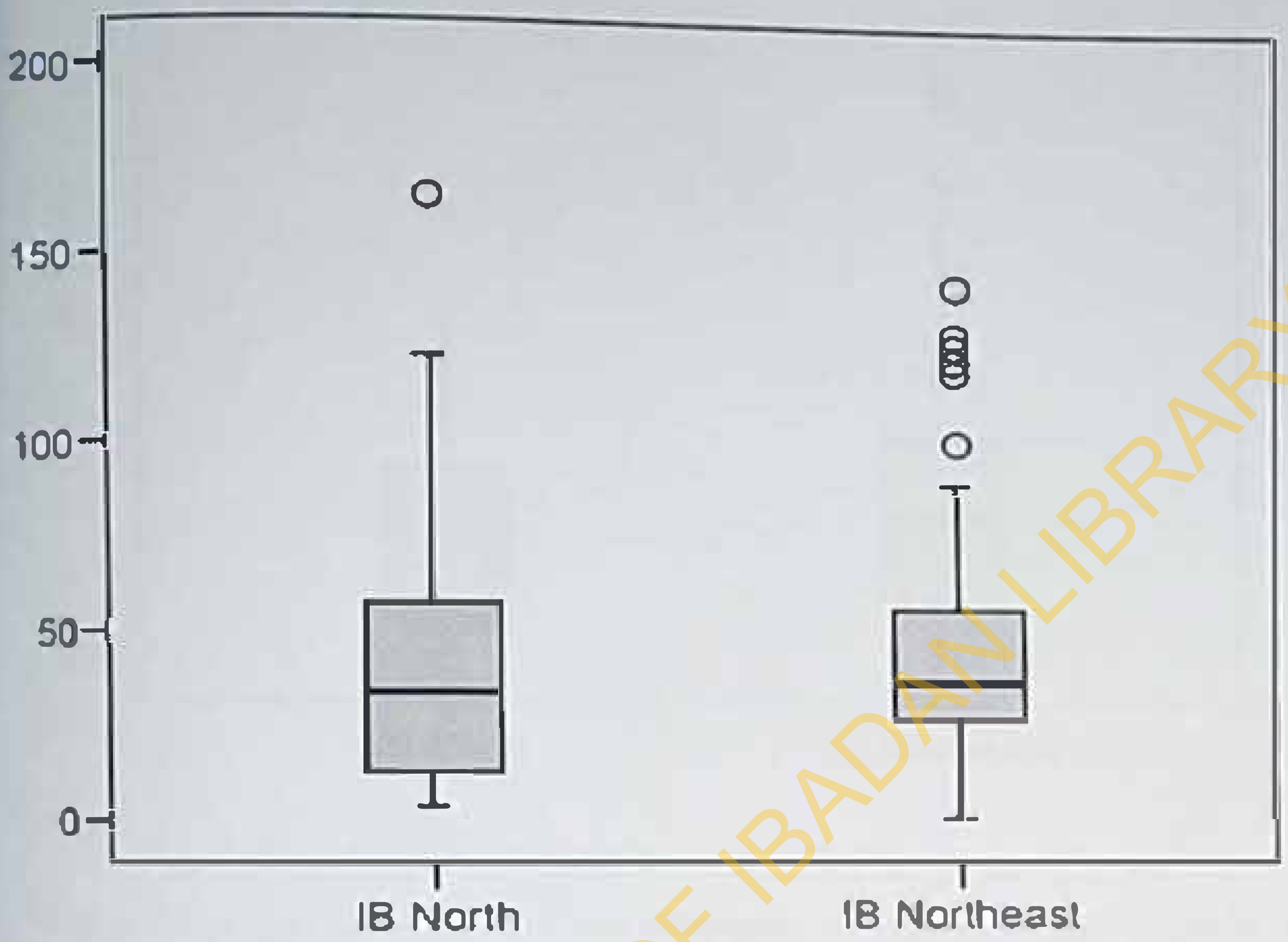


Figure 4.13: Concentration of CO at the Local Government Areas

*IB North: Ibadan North Local Government Area IB Northeast: Ibadan Northeast Local Government Area

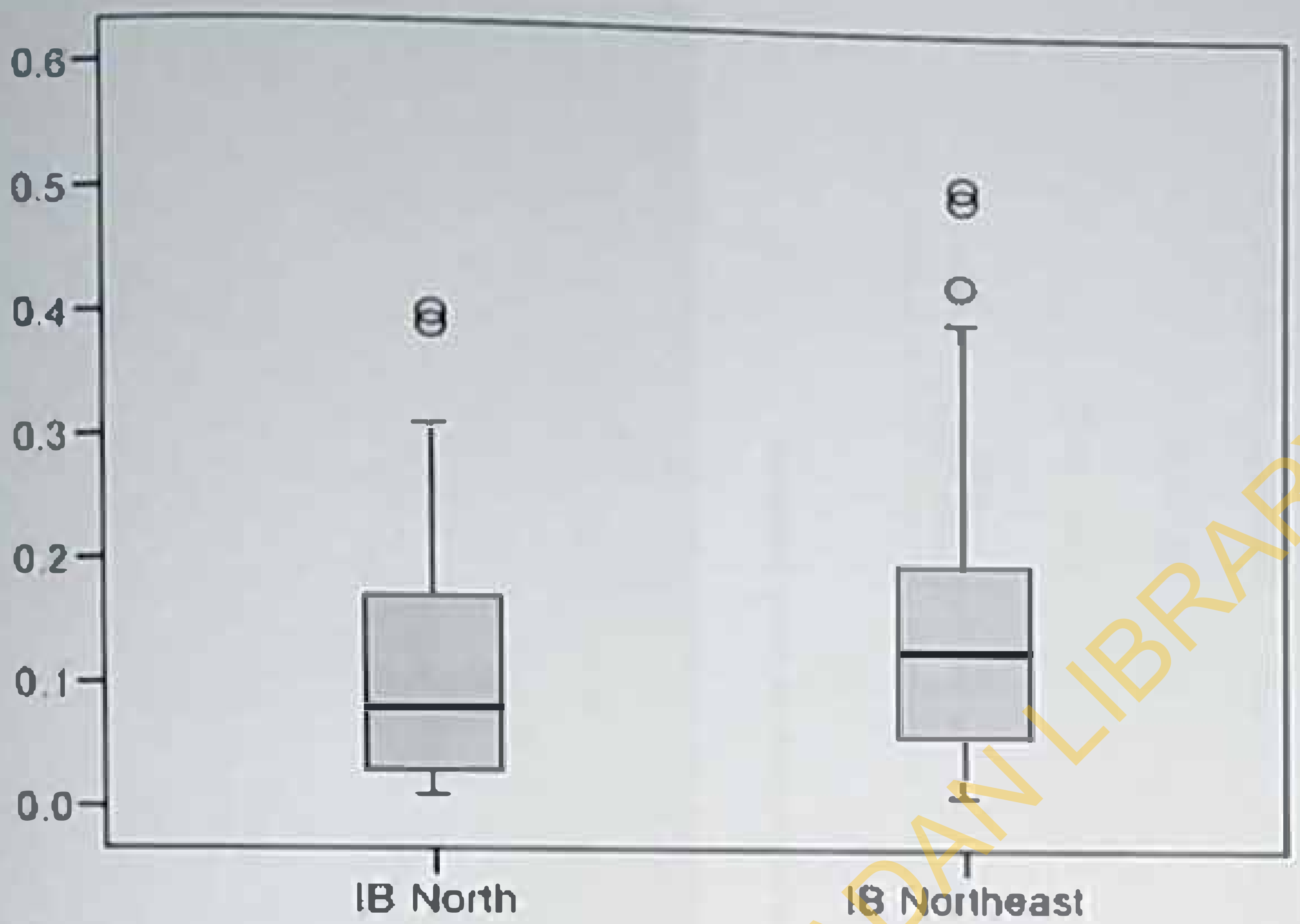


Figure 4.14: Concentration of NO_2 at the Local Government Areas

*IB North: Ibadan North Local Government Area IB Northeast: Ibadan Northeast Local Government Area

Plate 4.1: Risk map for mean concentration of sulphurdioxide at selected locations

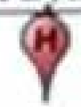
Key:

Risk Category	Risk Symbol	Range (ppm)
High Risk		>0.04
Moderate Risk		0.03 – 0.04
Low Risk		0 – 0.03

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

Plate 4.1: Risk map for mean concentration of sulphurdioxide at selected locations

Key:

Risk Category	Risk Symbol	Range (ppm)
High Risk		>0.04
Moderate Risk		0.03 – 0.04
Low Risk		0 – 0.03

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango Junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway Junction L8 Oseni-lakun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

Plate 4.2: Risk map for mean concentration of carbon (II) oxide at selected locations

Key:

Risk Category	Risk Symbol	Range (ppm)
High Risk		>9
Moderate Risk		4.1 – 6.0
Low Risk		0 – 4.0

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

Plate 4.3: Risk map for mean concentration of nitrogen dioxide measurable at selected locations

Key:

Risk Category	Risk Symbol	Range (ppm)
High Risk		>0.04
Moderate Risk		0.03 – 0.04
Low Risk		0 – 0.03

*L1 Iwalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Onireke avenue L9 [illegible] junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Orita

4.4 Traffic density estimation

A significant difference in the number of vehicles across the sampling period was observed for all the sampling locations. The weekly mean traffic count recorded in the morning (6am – 7am), afternoon (12pm – 1pm) and evening (4pm – 5pm) across all the 13 sampling points are presented in Table 4.5

Generally, location 12 had the highest traffic count/hr (270,136) while location 5 had the lowest traffic count/hr (197,382). Location 9 had the highest number of cars/hr (169, 394) while location 1 had the lowest number of cars/hr (80274). On the other hand, the highest number of buses/hr was recorded at location 4 (34, 564) while the lowest was recorded at location 12 (18,276).

Furthermore, location 4 had the highest number of trucks/hr (4578); total number of trucks at location 12 was 3436 while location 8 had the lowest number of truck/hr (2082). In addition the total number of bikes/hr (a combination of total number of motorcycles and tricycles) was on the high side in locations 1- 4 as well as locations 11-13. Location 11 had the highest number of bikes/hr (144,550) and this was higher than the corresponding number of cars/hr (57,170) at this location while the lowest number of bikes/hr was recorded at location 5 (45,552).

Table 4.5: Weekly mean traffic density for the sampling locations

Sampling locations	Cars			Buses			Trucks			Bikes		
	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening
L1	655	1390	1652	252	354	317	39	53	55	665	1718	2424
L2	1038	2118	2057	334	429	390	41	66	57	1007	1973	2461
L3	1021	1985	2139	313	339	426	46	39	48	831	1600	1801
L4	1180	1843	2246	454	643	516	49	79	63	1164	1753	1996
L5	1674	1742	1945	581	533	425	38	44	51	563	651	685
L6	1524	1781	2150	373	419	335	27	96	51	652	850	866
L7	2091	2237	2460	345	44	301	22	44	39	957	632	722
L8	1958	2183	2422	274	320	316	20	26	41	1004	900	1201
L9	2392	2209	2457	412	320	396	28	39	28	1010	916	965
L10	496	1470	1674	360	361	414	26	49	37	387	1150	1283
L11	555	943	885	343	478	423	26	37	48	1699	2121	2203
L12	1886	2023	2096	300	431	324	38	48	58	1161	2010	2038
L13	2003	1865	1864	231	323	282	29	451	43	1283	1908	1811

*Bikes: Motorcycles & Tricycles

*L1 Iwalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

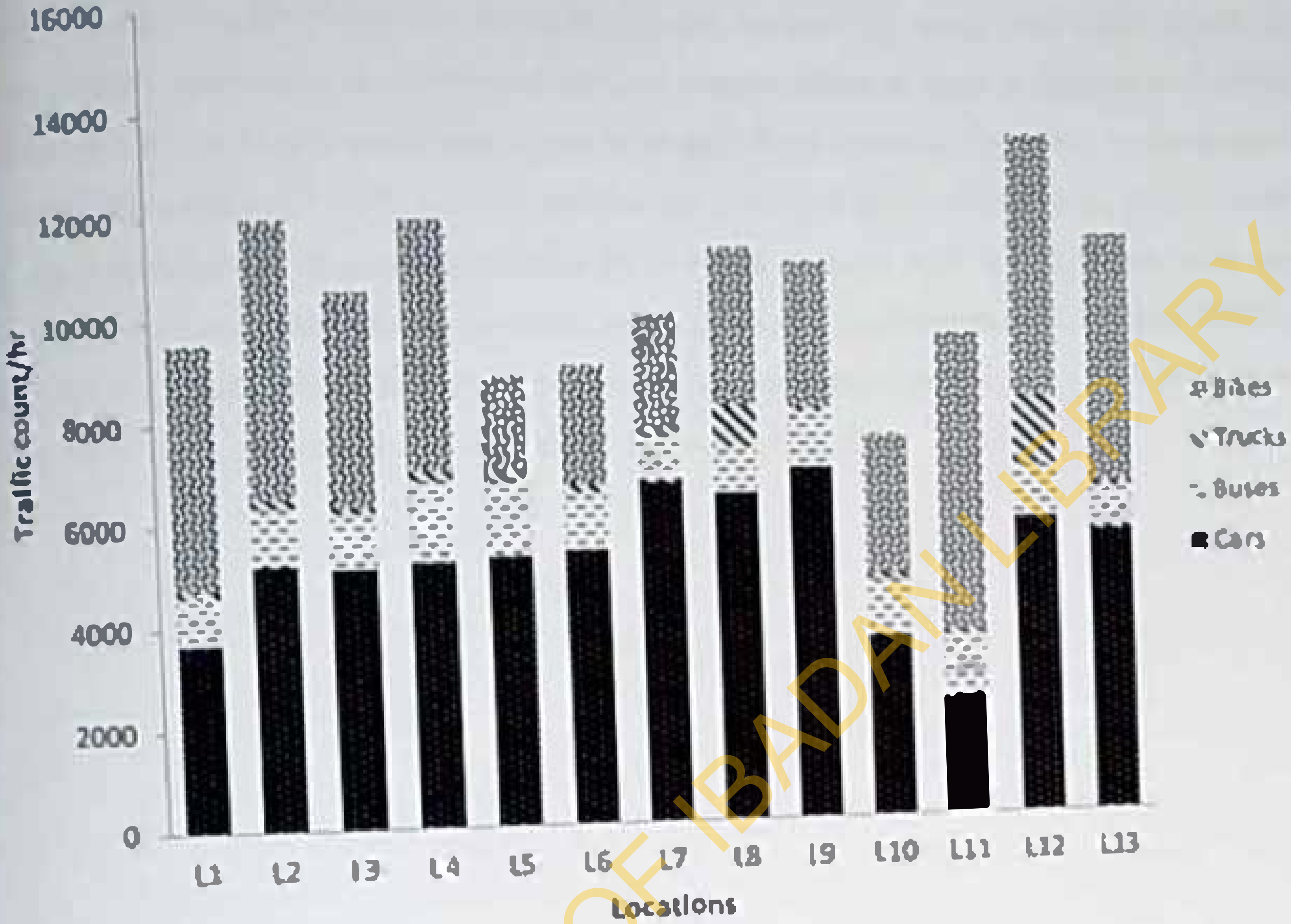


Figure 4.15: Weekly mean traffic count across sampling locations

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango Junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

4.5 Impact of traffic density on the concentration of traffic- related air pollutants

Figures 4.16 to 4.18 show the outcome of the Pearson correlation test between the concentrations of sulphur dioxide, nitrogen dioxide, carbon (II) oxide and traffic count. A strong positive correlation was observed between concentration of sulphur dioxide and traffic density (rs = 0.73). Traffic count was found to be positively correlated with the concentration of carbon (II) oxide (rs = 0.79) while a positive correlation also existed between traffic count and the concentration of nitrogen dioxide (rs = 0.60). Figures 4.16 to 4.17 also show the strength of the linear relationship between traffic count and concentration of sulphur dioxide (R^2 = 53.1%) traffic count and concentration of nitrogen dioxide (R^2 = 36.0%) as well as traffic count and concentration of carbon (II) oxide (R^2 = 61.8%).

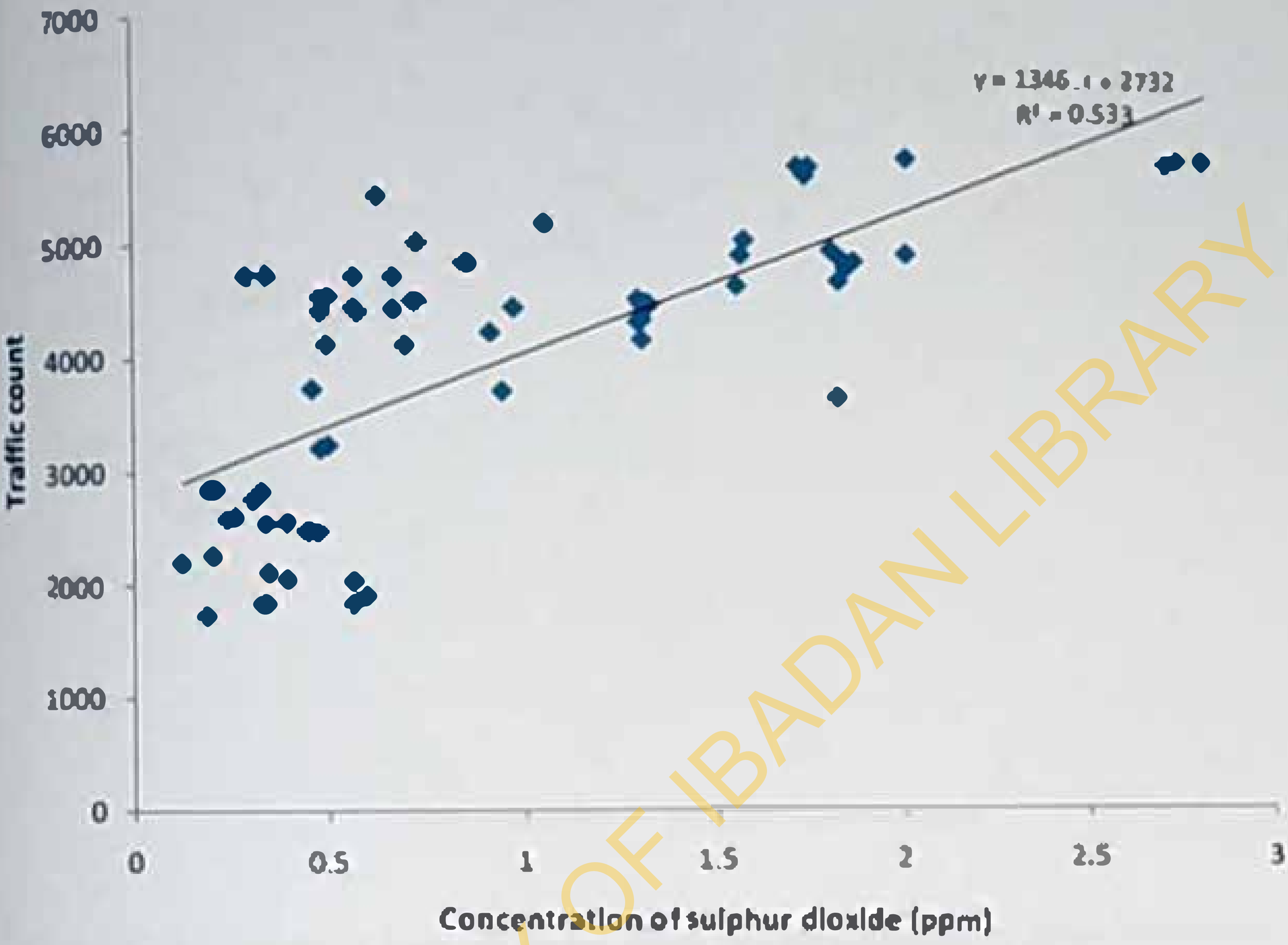


Figure 4.16: Relationship between traffic count and concentration of sulphur dioxide

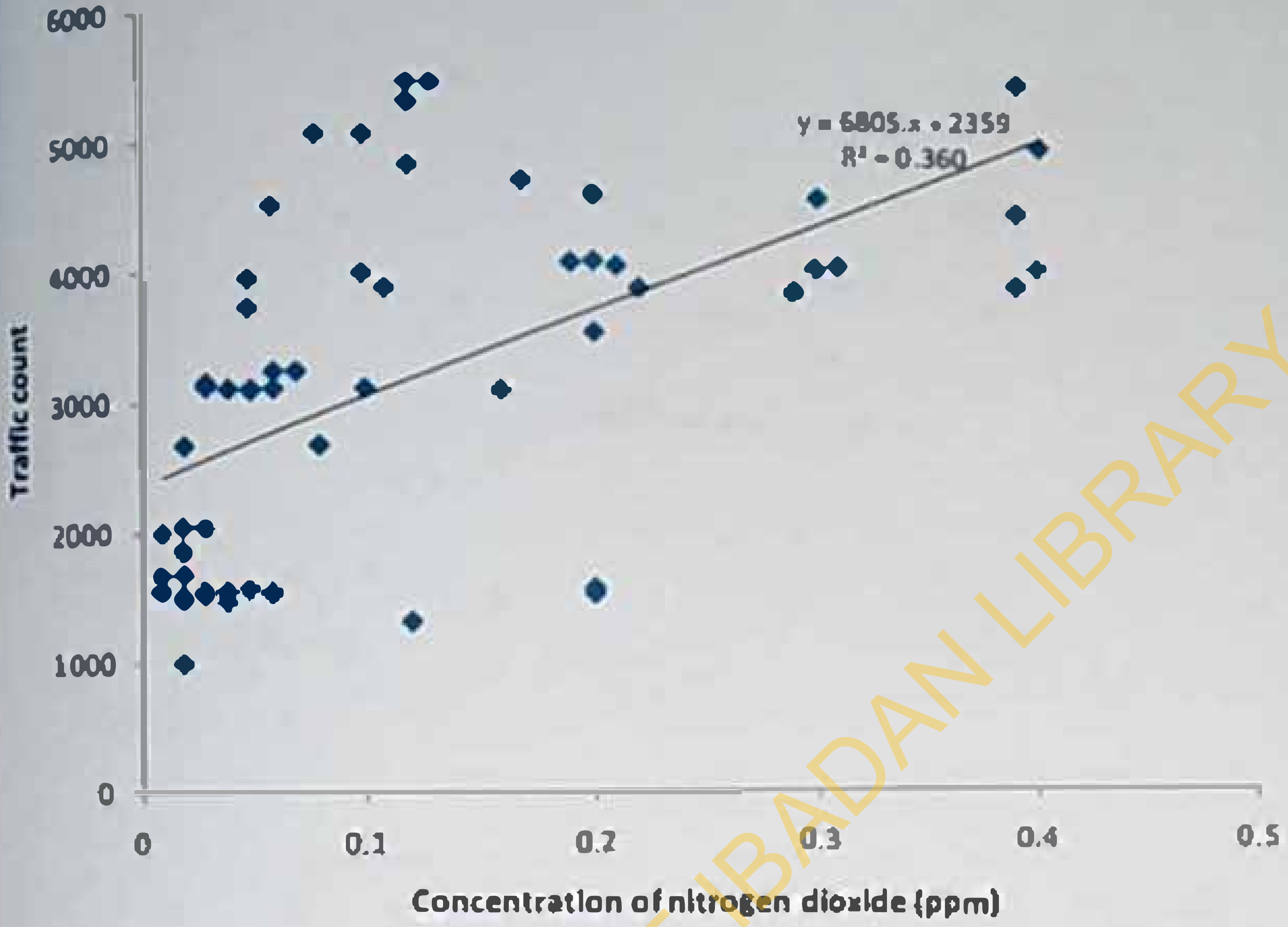


Figure 4.17: Relationship between traffic count and concentration of nitrogendioxide

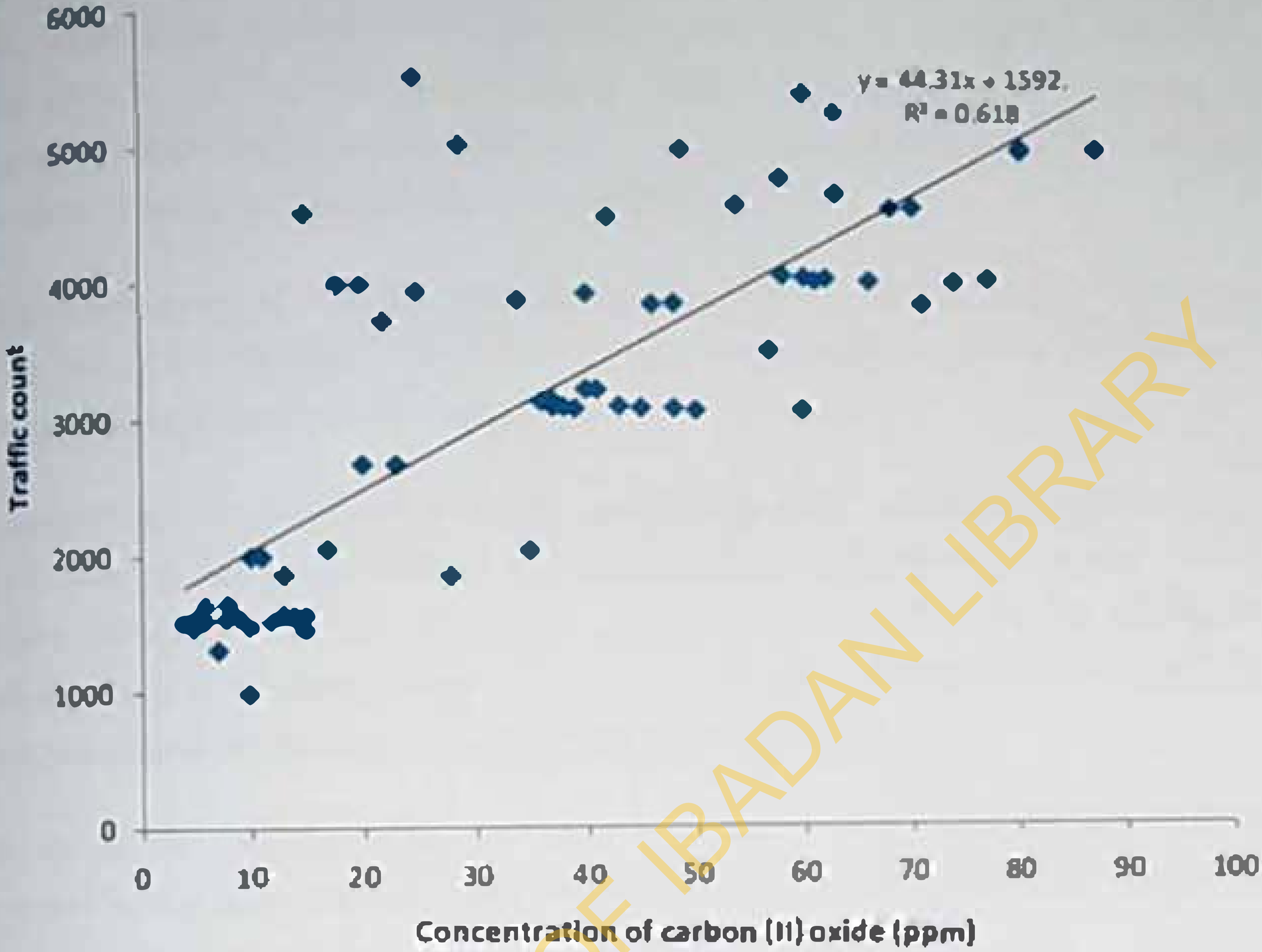


Figure 4.18: Relationship between traffic count and concentration of carbon (II) oxide

4.6 Socio – demographic characteristics of respondents

The Socio-demographic characteristics reported in Table 4.5 included sex, religion, ethnic group, marital status and educational status. Majority 87 (71.3%) of the Traffic wardens were males while 35 (28.7%) were females and the male to female ratio was 1:2. Among the Regular Policemen (RP), more than half of the respondents 83 (66.4%) were also males and the male to female ratio was also 1:2 (See Table 4.6).

A higher proportion 96 (78.7%) of Traffic wardens were married while 26 (21.3%) were single. Among the Regular Policemen, 95 (76.0%) were married while 29 (23.2%) and 1 (0.8%) were single and divorced respectively.

Majority 47 (38.5%) of the Traffic wardens and Regular Policemen (44.8%) were in the age group 30-39 yrs. Age group 20-29 yrs accounted for 21.3% of Traffic wardens and 19.2% of Regular policemen while 32 (26.2%) of Traffic wardens and 33 (26.4%) of Regular Policemen were in the 40-49 yrs age group. 13.9% of Traffic wardens and 9.6% of Regular Policemen were in the 50-59 yrs age group (See Figure 4.19).

Seventy two (59.0%) Traffic wardens were Christians while 50 (41.0%) were Muslims compared to Regular Policemen where 84 (67.2%) were Christians and 39 (31.2%) and 2 (1.6%) were Muslims and traditionalists respectively.

Majority of respondents combined (i.e. Traffic wardens and Regular Policemen were Yorubas). More than half 97 (79.5%) of the Traffic wardens were Yorubas. 5 (4.1%) were Hausas while 16 (13.1%), 3 (2.5%) and 1 (0.8%) were Ibos, Edos and Igbira respectively. A higher proportion 68 (54.4%) of the Regular Policemen were Yorubas. 14 (11.2%) were Hausas and 34 (27.2%) were Ibos. Other ethnic groups included Edo (2.4%), Efik (0.8%), Isoko (1.6%), Igala (1.6%) and Igbira (0.8%).

In terms of level of education, majority 80 (64.0%) of Regular Policemen had tertiary education while 44 (35.2%) and 1 (0.8%) had secondary and primary education respectively compared to Traffic wardens where more than half 75 (61.5%) had secondary education and 47 (38.5) had tertiary education.

Table 4.6: Socio-demographic characteristics of respondents

Variable	Options	Traffic wardens N (%)	Regular Policemen N (%)	P-value
Sex	Male	87 (71.3)	83(66.4)	
	Female	35 (28.7)	42(33.6)	0.41
Marital Status	Single	26 (21.3)	29 (23.2)	
	Married	96 (78.7)	95 (76.0)	0.57
	Divorced	0 (0.0)	1 (0.8)	
Religion	Christianity	72 (59.0)	84 (67.2)	
	Islam	50 (41.0)	39 (31.2)	0.12
	Traditional	0 (0.0)	2 (1.6)	
Ethnic group	Yoruba	97 (79.5)	68 (54.4)	
	Hausa	5 (4.1)	14 (11.2)	
	Igbo	16 (13.1)	34 (27.2)	
	Edo	3 (2.5)	3 (2.4)	0.04
	Efik	0 (0.0)	1 (0.8)	
	Isoko	0 (0.0)	2 (1.6)	
	Igala	0 (0.0)	2 (1.6)	
	Ebira	1 (0.8)	2 (0.8)	
Educational status	Primary	0 (0.0)	1 (0.8)	
	Secondary	75 (61.5)	44 (35.2)	0.00
	Tertiary	47 (38.5)	80 (64.0)	

*Mean age of Traffic wardens: 37.7 ± 9.3 years

*Mean age of Regular policemen: 37.0 ± 7.7 years

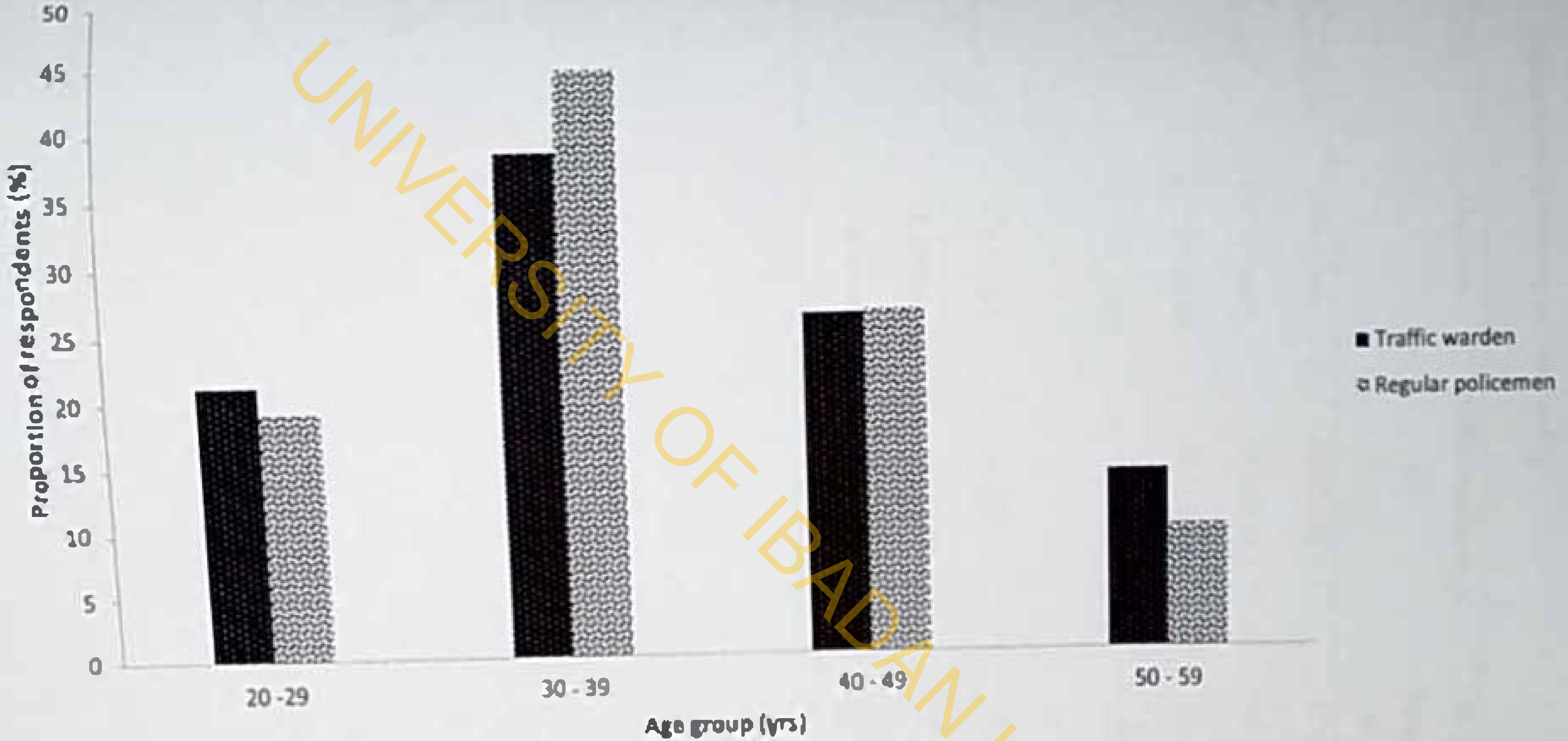


Figure 4.19: Age distribution of respondents

Table 4.7: Occupational history of respondents

Variable	Options	Traffic wardens N (%)	Regular Policemen N (%)	P-value
Years of service in the profession	0-9 years	66 (54.1)	61 (48.8)	0.078
	10-19 years	26 (21.3)	44 (35.2)	
	20 – 29 years	23 (18.9)	15 (12.0)	
	30 – 35 years	7 (5.7)	5 (4.0)	
Hours at work daily	< 8 hours	15 (12.3)	0 (0.00)	0.000
	8 hours	40 (32.8)	9 (7.2)	
	> 8 hours	67 (54.9)	116 (92.8)	

4.7 Occupational history of respondents

The results on occupational history as shown in Table 4.7 revealed that majority of respondents have been serving in their respective profession between 0 – 9 years. There was no significant difference (p >0.05) in the years of service of respondents as majority 66 (54.1%) of the Traffic wardens have been in the profession for about 9 years. 26 (21.3%) have served between 10 -19 years, 23 (18.9%) have served between 20 – 29 years while 7 (5.7%) have served for about 35 years. Similarly, a higher proportion 61 (48.8%) of the Regular Policemen have been in the profession for about 9 years. 44 (35.2) have served between 10 – 19 years, 23 (18.9%) have been in the profession between 20 – 29 years while 5 (4.0%) have served for about 35 years.

There was a significant difference (p <0.05) in the number of hours respondents work daily as majority 67 (54.9%) of the Traffic wardens work for more than 8 hours a day. 40 (32.8%) work for 8 hours while 5 (4.1%) work for less than 8 hours a day compared to their counterpart, the Regular policemen where a higher proportion 116 (92.8) work for more than 8 hours daily and 9 (7.2%) work for 8 hours.

A higher proportion 121 (99.2%) of the Traffic wardens do not use Personal Protective Equipment (PPE) while performing their duties on the road while only 1 (0.8%) use Personal Protective Equipment while working (See Figure 4.20).

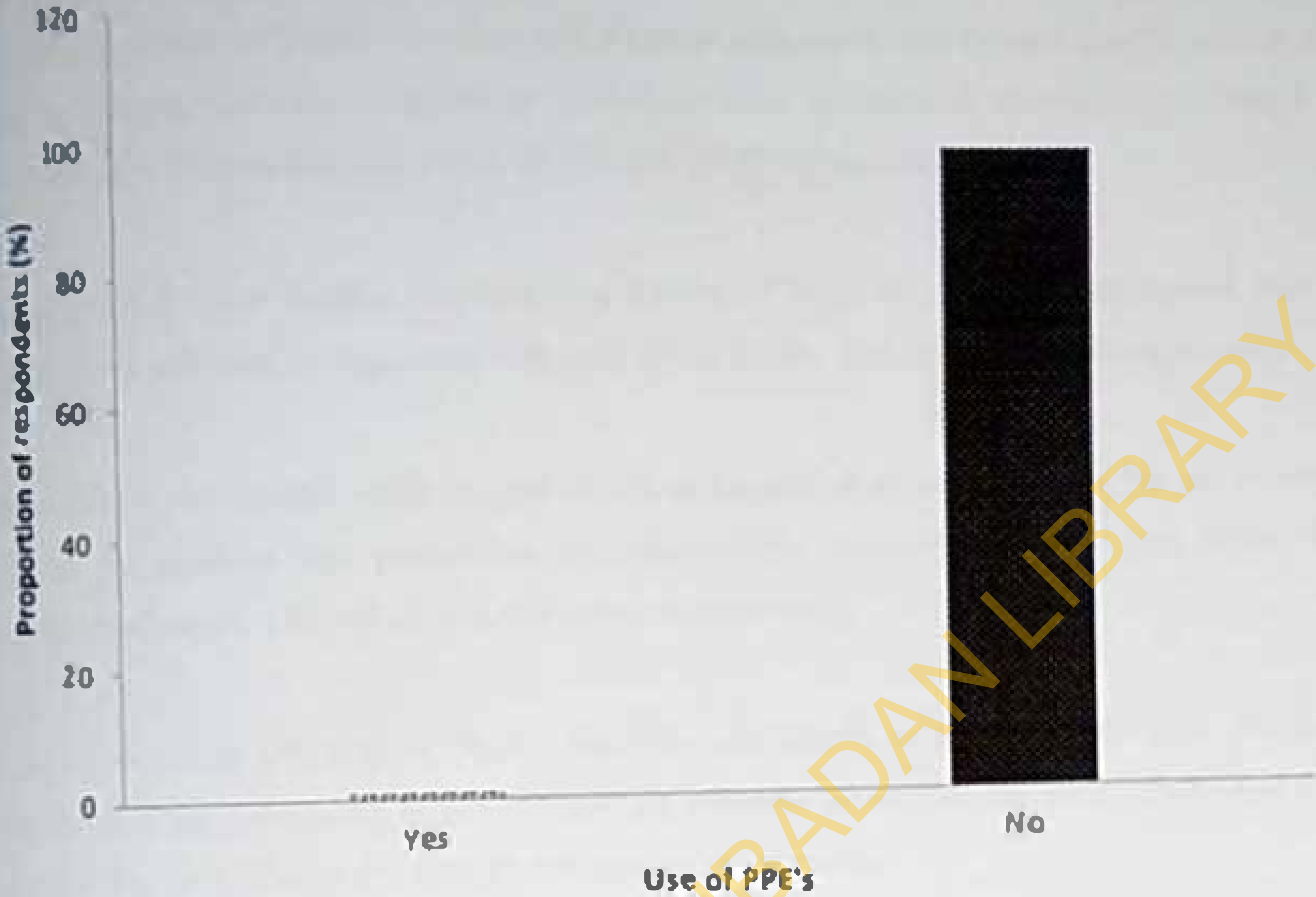


Figure 4.20: Use of Personal Protective Equipment by Traffic wardens

4.8 Respondents' perception of Air Quality

The results on the perception of respondents of air quality as presented in Table 4.8 revealed that the proportion of Traffic wardens and Regular policemen that agreed that the use of nose mask by people normally exposed to emissions from vehicles is necessary accounted for 73.0% and 69.2% respectively while 16.4% and 19.4% disagreed.

Majority (66.4%) of Traffic wardens and 64.8% of Regular policemen disagreed that air quality is not affected by high traffic density while 23.8% and 24.0% agreed respectively.

About (59.0%) of Traffic wardens and 70.4% of Regular policemen agreed that air quality is affected by gaseous and particulate emissions from industries. 14.8% and 6.4% were indifferent while 26.2% and 23.2% disagreed respectively.

A good proportion (50.8%) of Traffic wardens and 60.0% of Regular policemen disagreed with the fact that air quality is not affected by different seasons of the year. 16.4% and 8.8% were indifferent while 32.8% and 31.8% agreed respectively.

A sizeable proportion (57.4%) of Traffic wardens and 54.4% of Regular policemen disagreed with the fact that driving when air quality is bad cannot cause accident. 9.0% and 6.4% were indifferent while 33.6% and 39.2% agreed respectively.

Majority (67.2%) of Traffic wardens and 62.4% of Regular policemen agreed that enforcement of law by the Government can go a long way to ensure good air quality. 9.0% and 12.8% were indifferent while 23.8% and 24.8% disagreed respectively.

Table 4.8: Perception of respondents about air quality

Variable	Options	Traffic wardens N (%)	Regular policemen N (%)
The use of nose mask by people occasionally exposed to emissions from vehicles is necessary	Agree	89 (73.0)	171 (69.2)
	Indifferent	13 (10.7)	28 (11.3)
	Disagree	20 (16.4)	48 (19.4)
Air quality is not affected by high traffic density	Agree	29 (23.8)	30 (24.0)
	Indifferent	12 (9.8)	14 (11.2)
	Disagree	81 (66.4)	81 (64.8)
Gaseous emissions from vehicles do not cause poor air quality	Agree	39 (32.0)	34 (27.2)
	Indifferent	19 (15.6)	10 (8.0)
	Disagree	64 (52.5)	81 (64.8)
Air quality is affected by gaseous and particulate emissions from industries	Agree	72 (59.0)	88 (70.4)
	Indifferent	18 (14.8)	8 (6.4)
	Disagree	32 (26.2)	29 (23.2)
Air quality is not affected by different seasons of the year	Agree	40 (32.8)	39 (31.2)
	Indifferent	20 (16.4)	11 (8.8)
	Disagree	62 (50.8)	75 (60.0)
Driving when air quality is bad cannot cause accident	Agree	41 (33.6)	49 (39.2)
	Indifferent	11 (9.0)	8 (6.4)
	Disagree	70 (57.4)	68 (54.4)
Enforcement of law by the Government can go a long way to ensure good air quality	Agree	82 (67.2)	78 (62.4)
	Indifferent	11 (9.0)	16 (12.8)
	Disagree	29 (23.8)	31 (24.8)
Continuous inhalation of vehicular emissions does not really affect one's health	Agree	40 (32.8)	50 (40.0)
	Indifferent	14 (11.5)	9 (7.2)
	Disagree	68 (55.7)	66 (52.8)

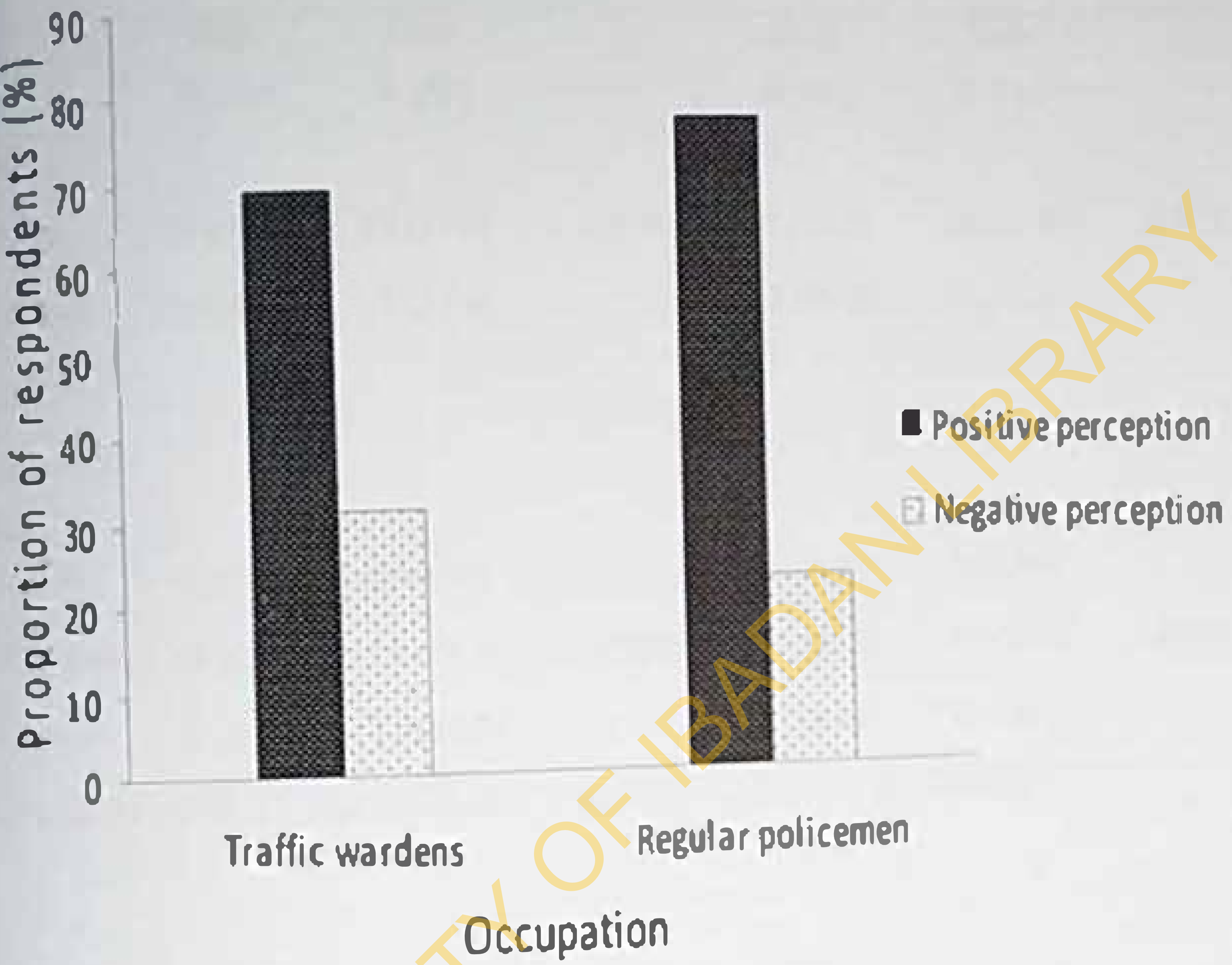


Figure 4.21: Perception of respondents of air quality

Table 4.9: Variations in perception of respondents about air quality

Variable	Traffic wardens (Perception grade)		P-value	Regular policemen (Perception grade)		P-value
	High N (%)	Low N (%)		High N (%)	Low N (%)	
Sex						
Male	60 (69.0)	27 (31.0)	0.564	65 (78.3)	18 (21.7)	0.822
Female	24 (68.6)	11 (31.4)		32 (76.2)	10 (23.8)	
Educational Status						
Primary	0 (0.00)	0 (0.00)		1 (100)	0 (0.00)	
Secondary	50 (66.7)	25 (33.3)	0.325	29 (65.9)	15 (34.1)	0.064
Tertiary	34 (72.3)	13 (27.7)		67 (83.8)	13 (16.3)	

*50th percentile and above = High perception   below 50th Percentile = Low perception

4.9 Respondents' Household Characteristics

Table 4.10 illustrates the household characteristics of respondents. Majority 61 (50.0%) of the Traffic wardens rate their residential areas being fair in terms of air quality, 45 (36.8%) were of the opinion that the air quality of their area was good, 8 (6.6%) reported excellent, likewise 8 (6.6%) reported that theirs was poor while a higher proportion 74 (59.2%) of the Regular policemen rate their residential area as being good in terms of air quality, 26 (20.8%) excellent, 24 (19.2%) fair and 1 (0.8%) poor.

More than half 78 (63.9%) of the Traffic wardens reside in areas where access roads are not tarred while 44 (36.1%) reside in areas with tarred roads as compared to their counterpart, the Regular policemen where majority 67 (53.6%) reside in areas with tarred access roads while 58 (46.4%) inhabit areas without tarred access roads.

Majority 89 (73.0%) of the Traffic wardens reside in areas where there are no industries while 33 (27.0) reside in industrialized areas. A higher proportion 109 (87.2%) of the Regular policemen on the other hand live in areas where there are no industries while 16 (12.8%) reside in areas where there are industries.

The proportion of Traffic wardens that made use of mechanical ventilation (fans and air conditioner) respectively were 122 (100.0%) and 1 (0.8%) while 121 (99.2%) depended on natural ventilation through opening of windows. On the other hand, among the Regular policemen, 113 (90.4%) and 23 (18.4%) made use of mechanical ventilation (fans and air conditioner) respectively while 113 (90.4%) depended on natural ventilation through opening of windows.

A higher proportion 89 (93.7%) of the Traffic wardens use kerosene stove for cooking while 9 (9.5%), 11 (11.6%), 22 (23.2%) and 9 (9.5%) use gas, charcoal, electricity and fire wood as sources of energy for cooking at home. On the other hand, majority 81 (98.8%) and 49 (59.8%) of the Regular policemen use kerosene stove and electric cooker respectively to cook at home while 18 (22.0%), 17 (20.7%) and 2 (2.4%) use gas, charcoal and fire wood as sources of energy for cooking.

Table 4.10: Household characteristics of respondents

Variable	Options	Traffic wardens N (%)	Regular policemen N (%)	P-value
Rating of residential area in terms of air quality*	Excellent	8 (6.6)	26 (20.8)	0.00
	Good	45 (36.8)	74 (59.2)	
	Fair	61 (50.0)	24 (19.2)	
	Poor	8 (6.6)	1 (0.8)	
Tarred road within residential area	Yes	44 (36.1)	67 (53.6)	0.04
	No	78 (63.9)	58 (46.4)	
Presence of industry within residence	Yes	33 (27.0)	16 (12.8)	0.04
	No	89 (73.0)	109 (87.2)	
*Means of ventilation in respondents' houses				
Fans	Yes	122 (100.0)	113 (90.4)	0.00
	No	0 (0.0)	12 (9.6)	
Air conditioner	Yes	1 (0.8)	23 (18.4)	0.00
	No	121 (99.2)	102 (81.6)	
Opening of windows	Yes	121 (992)	113 (90.4)	0.02
	No	1 (0.8)	12 (9.6)	
*Mode of cooking				
Gas cooker	Yes	9 (9.5)	18 (22.0)	0.18
	No	86(90.5)	64 (78.0)	
Charcoal	Yes	11 (11.6)	17 (20.7)	0.73
	No	84 (88.4)	65 (79.3)	
Electric cooker	Yes	22 (23.2)	49 (59.8)	0.00
	No	73 (76.8)	33 (40.2)	
Kerosene stove	Yes	89 (93.7)	81 (98.8)	0.86
	No	6 (6.3)	1 (1.2)	
Fire wood	Yes	9 (9.5)	2 (2.4)	0.49
	No	86 (90.5)	80 (97.6)	

*Multiple responses

4.10 Health conditions

There was a significant difference in the respondents' perception of their current state of health ($p < 0.05$) as majority 71 (58.2%) of the traffic wardens claimed that their current state of health was good, 43 (35.2%) reported that their state of health was excellent, 8 (6.6%) claimed that their current state of health was fair while more than half 74 (59.2%) of the Regular policemen claimed that their current state of health was excellent, 47 (37.6%) reported that health status was good while 4 (3.2%) reported that their state of health was fair (see Table 4.11).

4.10.1 Respiratory symptoms reported by respondents

Table 4.12 shows the respiratory symptoms suffered by respondents in six months preceding this study. Among the Traffic wardens, 59 (48.4%) had cough, 81 (66.4%) had breathing difficulty, 88 (72.1%) suffered from chest pains while 74 (60.7%) and 84 (68.9) suffered from catarrh and sore throat respectively. On the other hand, the proportion of Regular policemen that suffered from cough, breathing difficulty, chest pains, sore throat and catarrh were 22 (7.6%), 8 (6.4%), (5.6%), 18 (14.4%) and 52 (41.7) respectively.

4.10.2 Non-respiratory symptoms reported by respondents

Table 4.13 shows the non-respiratory symptoms experienced by respondents in six months preceding this study. The proportion of Traffic wardens that reported body weakness, itching eyes and light-headedness were 93 (76.2%), 81 (66.4%) and 98 (80.3%) respectively while among the Regular policemen, the proportion that suffered from itching eyes, body weakness and light-headedness were 16 (12.8%), 57 (45.6%) and 14 (11.2%) respectively

Table 4.11: Respondents' perception of current health status

Variable	Option	Traffic wardens N (%)	Regular policemen N (%)	P-value
State of health	Excellent	43 (35.2)	74 (59.2)	
	Good	71 (58.2)	47 (37.6)	0.01
	Fair	8 (6.6)	4(3.2)	
	Poor	0 (0.0)	0 (0.0)	

Table 4.12: Respiratory symptoms reported by respondents in six (6) months preceding the study

Variable	Option	Traffic wardens N (%)	Regular policemen N (%)	P-value
Cough	Yes	59 (48.4)	22 (17.6)	0.00
	No	63 (51.6)	103 (82.4)	
Breathing difficulty	Yes	81 (66.4)	8 (6.4)	0.00
	No	41 (33.6)	117 (93.6)	
Chest pain	Yes	88 (72.1)	7 (5.6)	0.00
	No	34 (27.9)	118 (94.4)	
Sore throat	Yes	74 (60.7)	18 (14.4)	0.00
	No	48 (39.3)	107 (85.6)	
Catarrh	Yes	84 (68.9)	52 (41.6)	0.00
	No	38 (31.1)	73 (58.4)	

Table 4.13: Non-respiratory symptoms reported by respondents in six (6) months preceding the study

Variable	Option	Traffic wardens N (%)	Regular policemen N (%)	P-value
Body weakness	Yes	93 (76.2)	57 (45.6)	0.00
	No	29 (23.8)	68 (54.4)	
Itching eyes	Yes	81 (66.4)	16 (12.8)	0.00
	No	41 (33.6)	109 (87.2)	
Light-headedness	Yes	98 (80.3)	14 (11.2)	0.00
	No	24 (19.7)	111 (88.8)	

4.10.3 Respondents' perception in relation to occupationally induced health effect

Table 4.14 shows the result of respondents' perception to occupationally induced health effects. Majority 109 (93.2%) of the Traffic wardens reported that the health symptoms they experienced worsen while at work. 7 (6.0%) reported that there was no change while 1 (0.8%) reported that there was improvement. On the other hand, a higher proportion 109 (87.2%) said that their condition did not change while at work ($p < 0.05$).

A higher proportion 84 (71.2%) of the Traffic wardens claim that the symptoms they experience become more frequent and severe in the late afternoon during high traffic. 25 (21.2%) reported that the symptoms they experience become frequent and severe during low traffic. 8 (6.8%) experience severe symptoms in the morning during high traffic while 1 (0.8%) experience no change with time of the day and traffic.

4.10.4 Treatment practices by respondents

There was a significant difference ($p < 0.05$) in the management of air pollution related symptoms by respondents as majority 70 (56.0%) of the Regular policemen claimed they managed their air pollution related symptoms by visiting clinics, those that patronize local chemists were 43 (34.4%). 12 (9.6%) practiced self-medication while a good proportion 42 (34.4%) of the Traffic wardens patronized local chemist. 42 (34.4%) visit clinics and 31 (25.4%) and 7 (5.8%) practiced self-medication and traditional therapy respectively (see Table 4.14).

Table 4.14: Respondents' perception in relation to occupationally induced health effects

Variable	Option	Traffic wardens N (%)	Regular policemen N (%)	P-value
How does your symptoms change while at work	Improve	1 (0.8)	16 (12.8)	0.00
	No change	7 (6.0)	109 (87.2)	
	Get worse	109 (93.2)	0 (0.0)	
How does your symptoms change with time of the day and traffic	More frequent and severe in the morning during high traffic	8 (6.8)	0 (0.0)	
	More frequent and severe during low traffic	25 (21.2)	0 (0.0)	0.00
	More frequent and severe in the late afternoon during high traffic	84 (71.2)	0 (0.0)	

Table 4.15: Management of air pollution related symptoms

Variable	Option	Traffic wardens N (%)	Regular policemen N (%)	P-value
Management of respiratory symptoms	Self-medication	31 (25.4)	12 (9.6)	0.00
	Local chemist	42 (34.4)	43 (34.4)	
	Visit clinics	42 (34.4)	70 (56.0)	
	Traditional therapy	7 (5.8)	0 (0.0)	

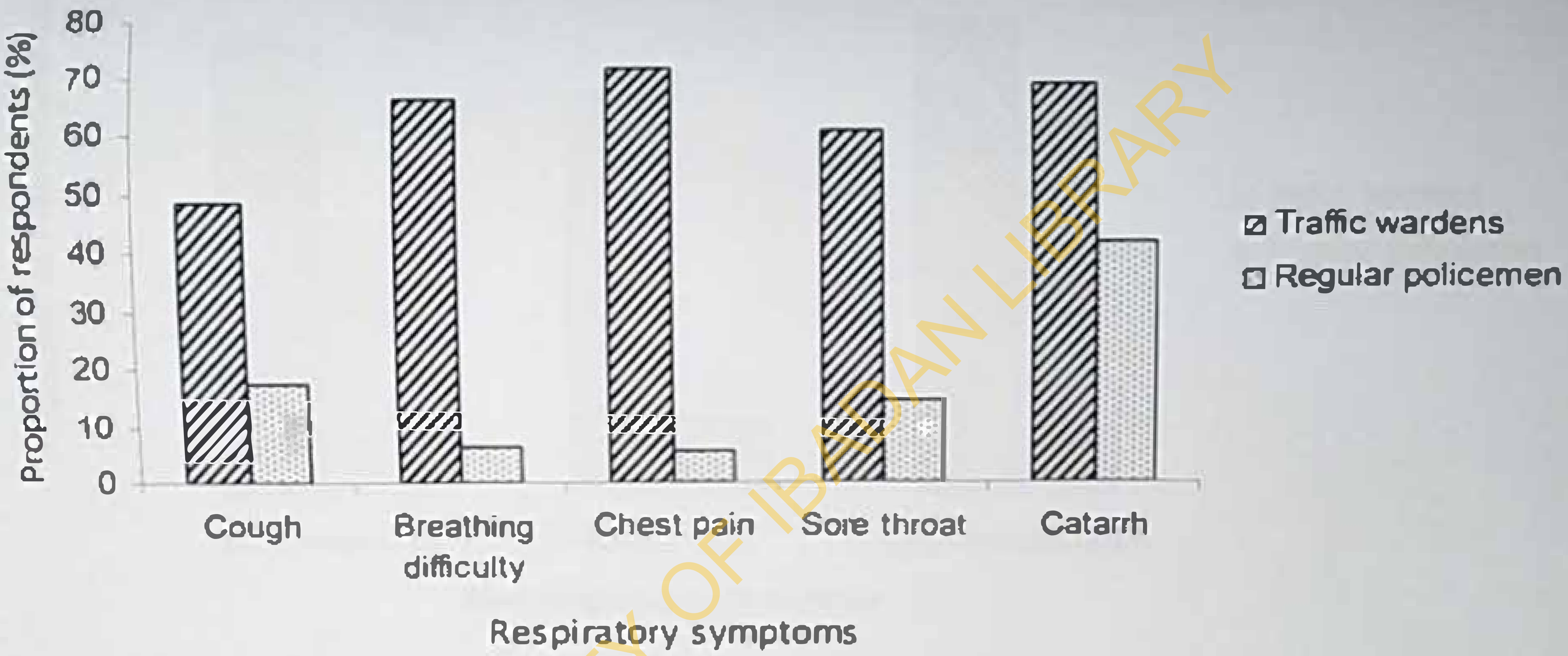


Figure 4.22: Respiratory symptoms experienced by Traffic wardens in comparison with Regular policemen

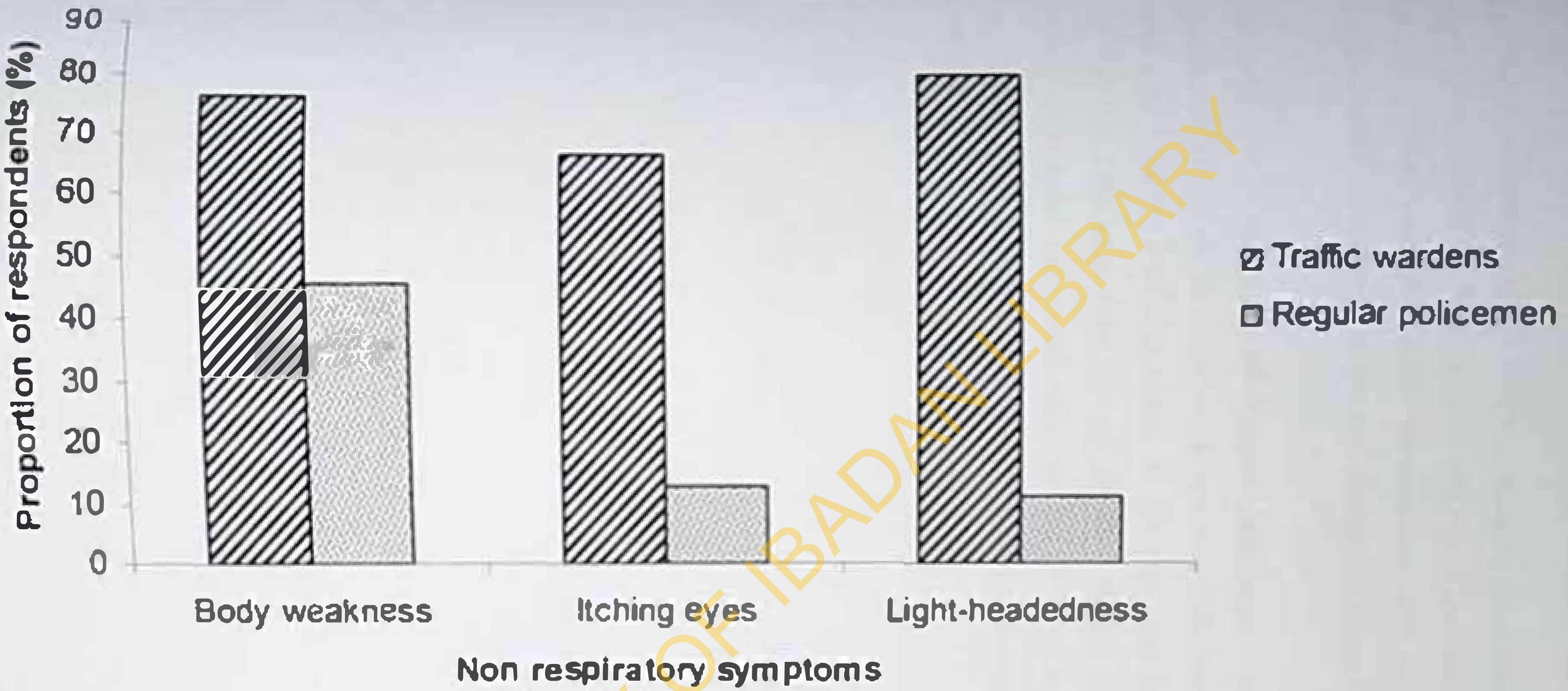


Figure 4.23: Non-respiratory symptoms experienced by Traffic wardens in comparison with Regular policemen

4.11 Socio-demographic characteristics of participants for lung function test

A total of 124 respondents (50% of the total study population) who consented to take part in the study were enrolled for lung function test out of the total population of 248 that took part in the survey. Sixty one (61) Traffic wardens and sixty three (63) Regular policemen were randomly selected from Ibadan North and Ibadan Northeast Local Government Areas.

A total number of 96 males and 28 females participated in the lung function test. Age group of participants as shown in Table 4.16 revealed that majority 29 (47.5%) of the traffic wardens were from 20 – 29 age group, 22 (36.1%) were from 30 – 39 age group while 5 (8.2%) and 5 (8.2%) were from age groups 40 – 49 and 50 -59 respectively. Likewise 29 (46.0%) of the Regular policemen were from the 20 – 29 age group, 25 (39.7%) were from 30 -39 age group while 5 (7.9%) and 4 (6.3%) were from age groups 40 – 49 and 50 – 59 respectively.

Table 4.16: Socio-demographic characteristics of participants for lung function test

Variable	Option	Traffic wardens N (%)	Regular policemen N (%)	P-value
Sex	Male	46 (75.4)	50 (79.4)	0.378
	Female	15 (24.6)	13 (20.6)	
Age group	20 – 29	29 (47.5)	29 (46.0)	0.721
	30 – 39	22 (36.1)	25 (39.7)	
	40 – 49	5 (8.2)	5 (7.9)	
	50 - 59	5 (8.2)	4 (6.3)	

4.12 Anthropometric characteristics of the participants

The results of anthropometric characteristics of participants as illustrated in Table 4.17 showed that the mean age of Traffic wardens that took part in the lung function test was 32.84 ± 8.28years while that of Regular policemen was 33.89 ± 7.52years. The age of Traffic wardens and Regular policemen ranged from 23yrs – 58yrs and 25yrs – 56yrs respectively with no significant difference. The mean height of Traffic wardens was 1.72 ± 0.05m with a range of 1.62m – 1.84m while the mean height of Regular policemen was 1.74± 0.05m and it ranged from 1.60 m – 1.84m. The mean weight of Traffic wardens that took part in the lung function test were 67.95 ± 10.73kg while the mean weight of Regular policemen was 73.06± 13.27kg. The weights of Traffic wardens and Regular policemen ranged from 48kg – 100kg and 52kg – 112kg respectively. In addition, the mean Body Mass Index (BMI) of Traffic wardens was 22.84 ± 3.47 kg/m^2 while the mean BMI of Regular policemen was 24.01 ± 3.82 kg/m^2 with no significant difference. A weak and significant positive correlation was established between age and BMI ($r = 0.192$, $p < 0.05$). There was a weak positive correlation between BMI and actual FEV_1 (Force Expiratory Volume in one seconds) though significant ($r = 0.272$, $p < 0.05$).

4.13 Lung function status of respondents

The values of the lung function indices appeared lower among the Traffic wardens compared to the Regular policemen. The expected FEV_1 is the expected or predicted value of a normal and healthy individual. This was got from the lung function calculator after the height, age and gender of the participants have been imputed into the calculator. The actual or observed FEV_1 is the value got from the digital spirometer used on the participants after three manoeuvres. The best of the three manoeuvres was taken as the FEV_1 actual. The FEV_1 actual is then compared with the FEV_1 predicted to determine the extent or magnitude of deviation from the FEV_1 predicted which is the normal FEV_1 value of a healthy individual. The mean observed or actual FEV_1 in litres of the Traffic wardens and Regular policemen were 2.21 ± 0.71 and 3.07 ± 0.55 respectively ($p < 0.05$) indicating higher vulnerability among the Traffic wardens while the predicted or expected FEV_1 (Litres) were 4.01 ± 0.57 and 3.95 ± 0.67 respectively with no significant difference. The mean percentage predicted FEV_1 which is calculated as FEV_1 actual/ FEV_1 expected * 100% of Traffic wardens and Regular policemen were 55.46 and 78.40 respectively ($p< 0.05$).

4.14 Impact of exposure to particles on lung function status

Figure 4.26 shows the outcome of the Spearman correlation test between the concentration of particulate matter and the actual Forced Expiratory Volume in 1 second (FEV_1) of the traffic wardens that took part in the lung function test. A significant negative correlation was observed between the particulate burden and their FEV_1 ($r = -0.20$, $p < 0.05$). This implies that the observed FEV_1 of the Traffic wardens decreases with increase in the concentration of PM_{10}. Similarly, Figure 4.26 also shows the strength of the linear relationship between the particulate burden and the actual FEV_1 of the traffic wardens ($R^2 = 34.9\%$). Figure 4.27 shows the outcome of the Spearman correlation test between the concentration of particulate matter and the actual Forced Expiratory Volume in 1 second (FEV_1) of the Regular policemen. A positive correlation was observed between the particulate burden and their FEV_1 ($r = 0.04$, $p > 0.05$).

Table 4.17: Comparison of anthropometric characteristics with lung function parameters among participants

Anthropometric characteristics	Traffic wardens	Regular policemen	P-value
AGE			
Mean ± SD (yrs)	32.84 ± 8.28	33.89 ± 7.52	0.460
Range (yrs)	23 – 58	25 - 56	
SEX			
Male N (%)	46 (47.9)	50 (52.1)	0.378
Female N (%)	15 (53.6)	13 (46.4)	
HEIGHT			
Mean ± SD (m)	1.72 ± 0.05	1.74 ± 0.05	0.083
Range (m)	1.62 – 1.84	1.60 – 1.84	
WEIGHT			
Mean ± SD (kg)	67.95 ± 10.73	73.06 ± 13.27	0.020
Range (kg)	48 – 100	52 - 112	
BMI			
Mean ± SD (kg/m^2)	22.84 ± 3.47	24.01 ± 3.82	0.076
Range (kg/m^2)	16.6 – 33.0	17.3 – 35.8	
Spirometry			
FEV_1 actual			
Mean ± SD (litre)	2.21 ± 0.71	3.07 ± 0.55	0.000
Range (litre)	0.88 – 3.97	2.15 – 4.57	
FEV_1 expected			
Mean ± SD (litre)	4.01 ± 0.57	3.95 ± 0.67	0.647
Range (litre)	2.07 – 4.96	2.07 – 4.80	
% Predicted FEV_1			
Mean ± SD (%)	55.46 ± 18.17	78.40 ± 16.18	0.000
Range (%)	23 – 112	49 - 133	

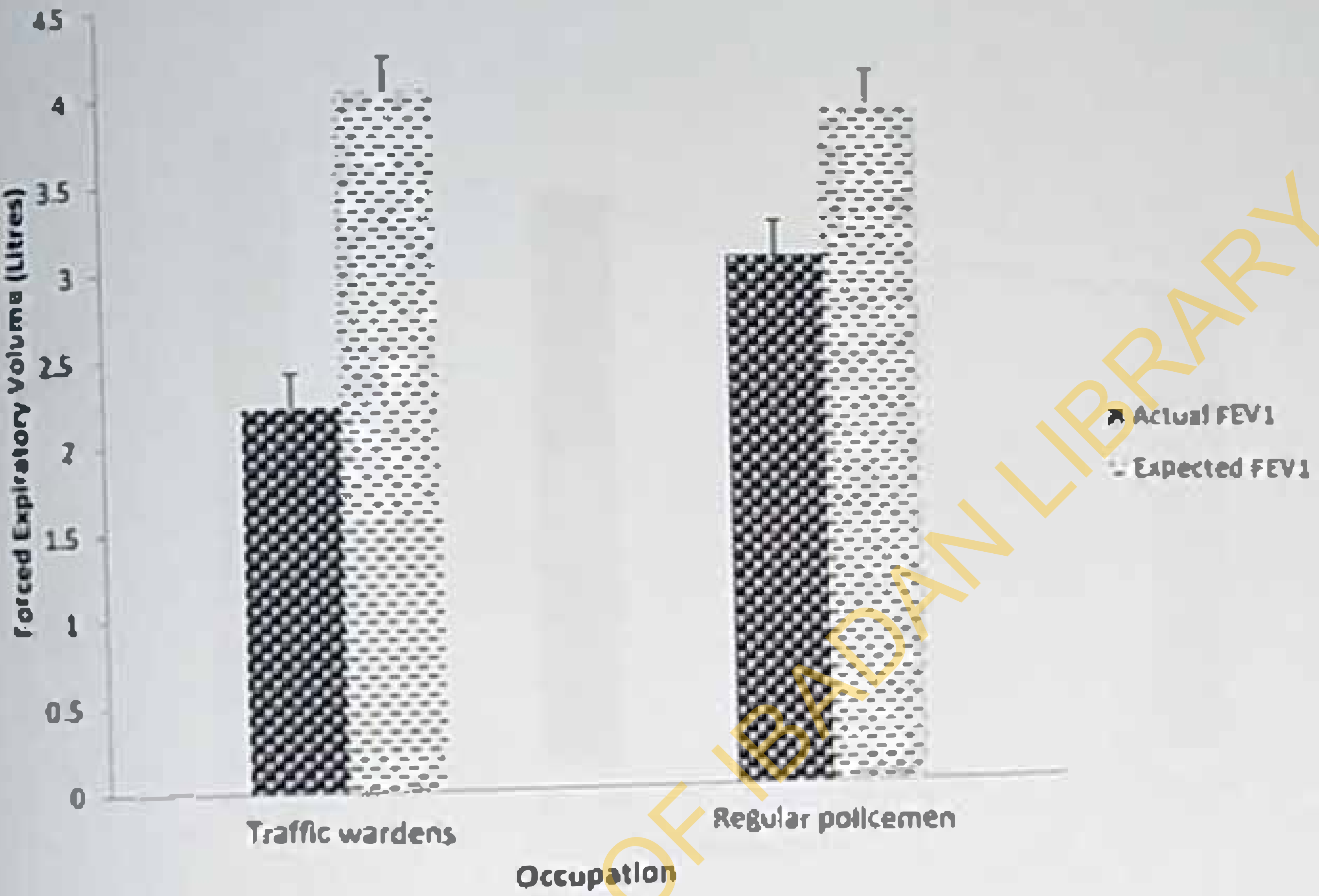


Figure 4.2.1: Comparison of mean actual FEV_1 with mean expected FEV_1 of Traffic wardens and Regular policemen.

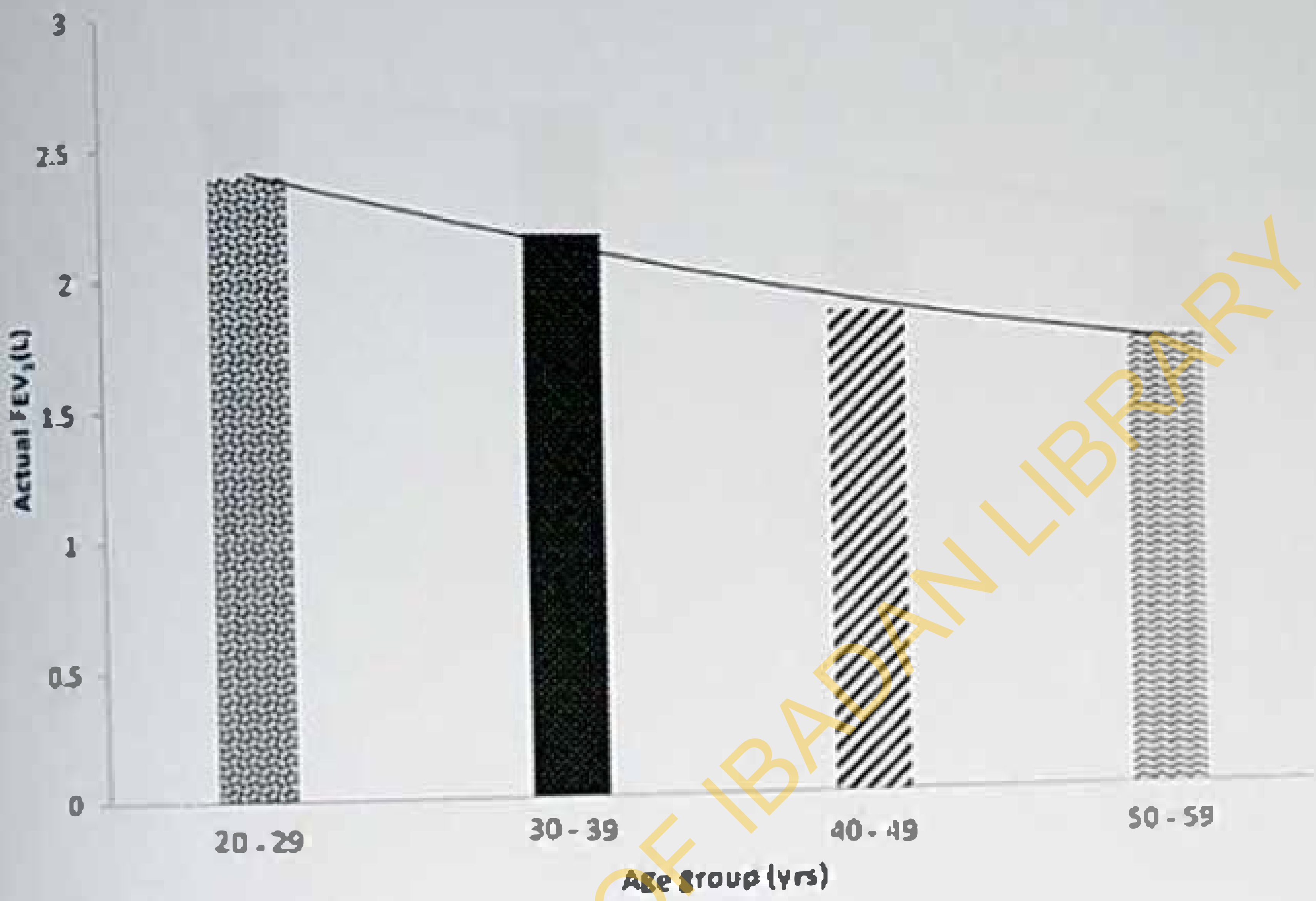


Figure 4.25: Trend in the actual FEV_1 of Traffic wardens across the different age groups

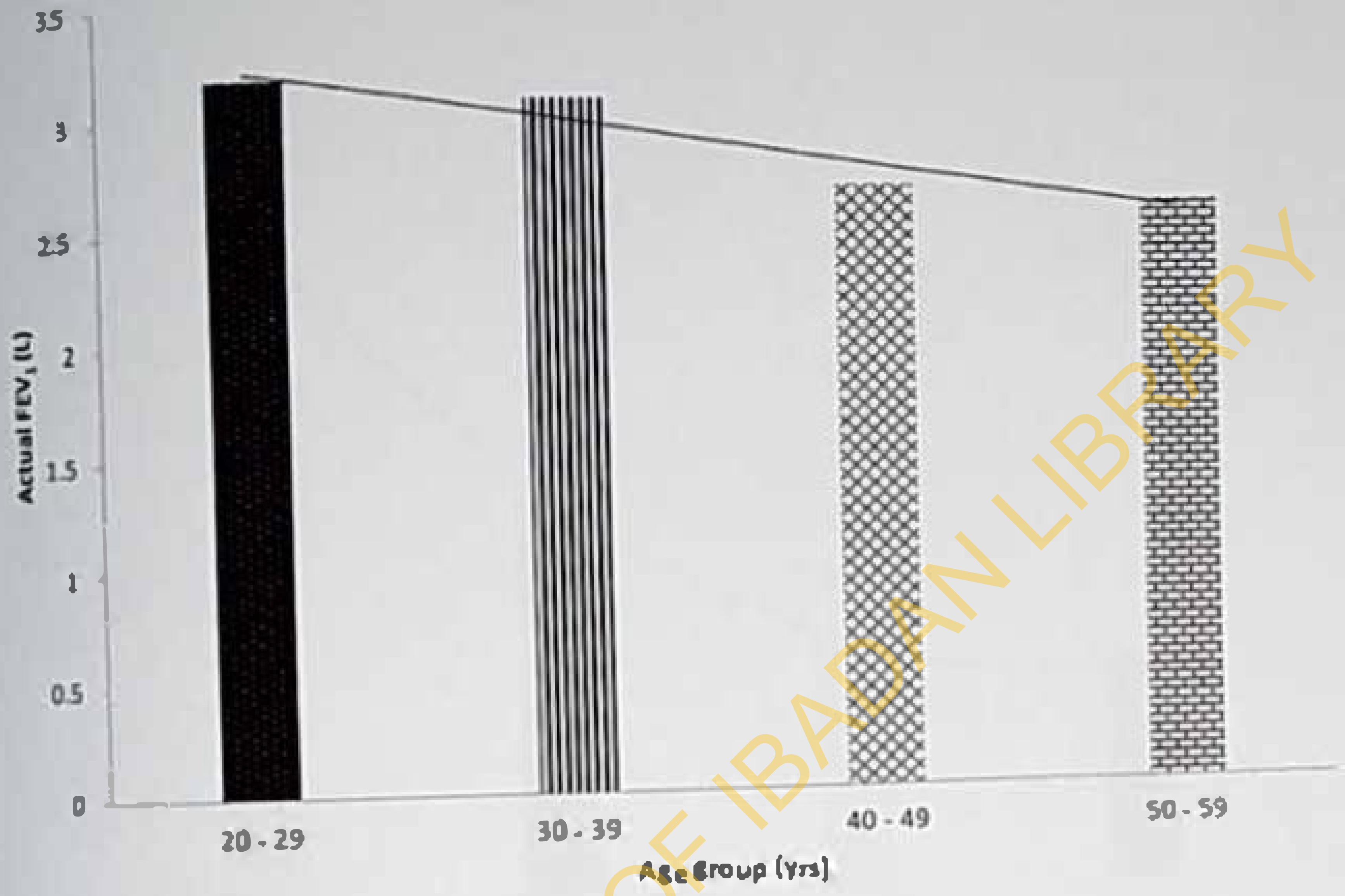


Figure 4.26: Trend in the actual FEV_1 of Regular policemen across the different age groups

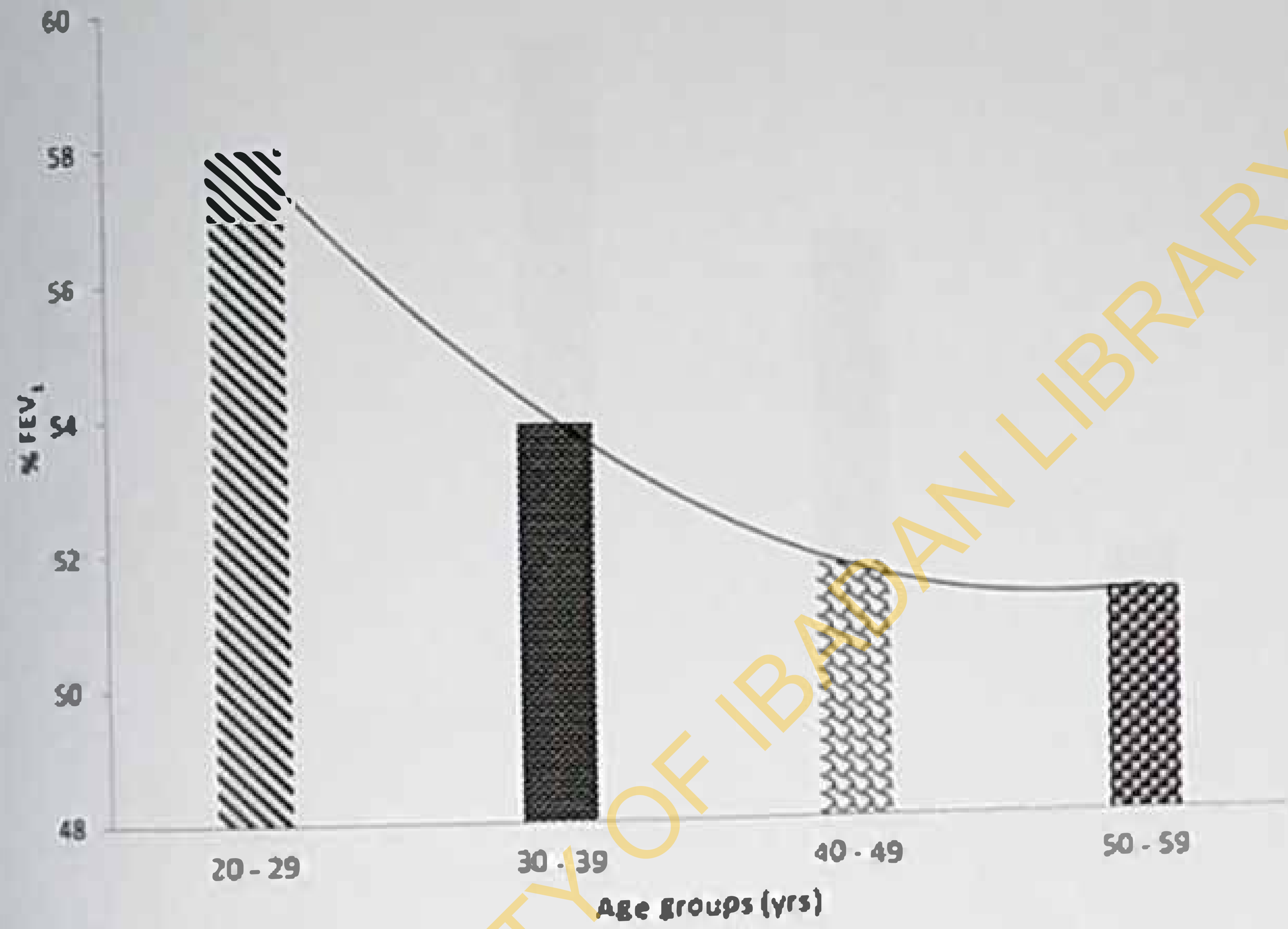


Figure 4.27: Trend in the % FEV_1 of Traffic wardens across the different age groups

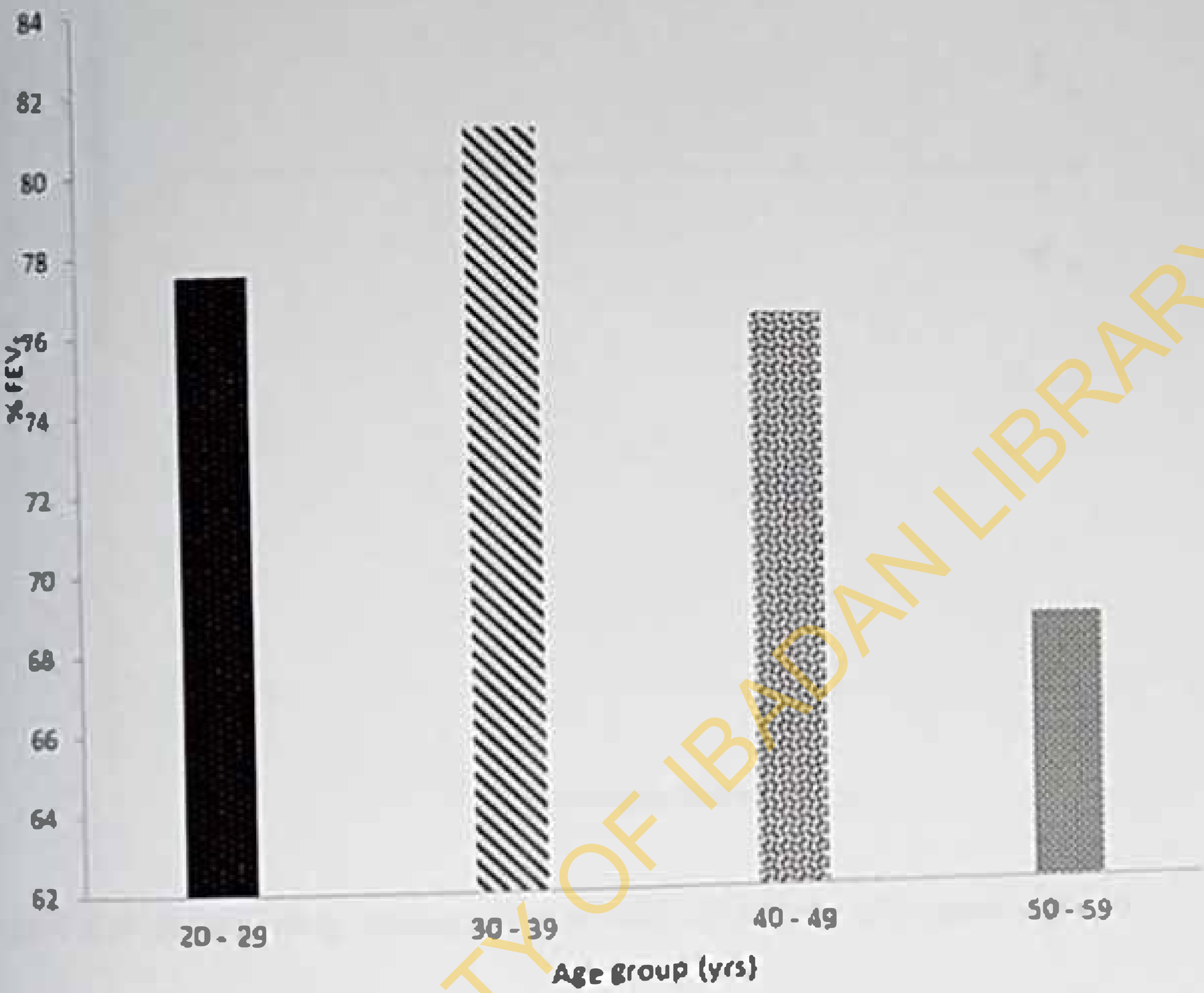


Figure 4.28: Trend in the % FEV_1 of Regular policemen across the different age groups

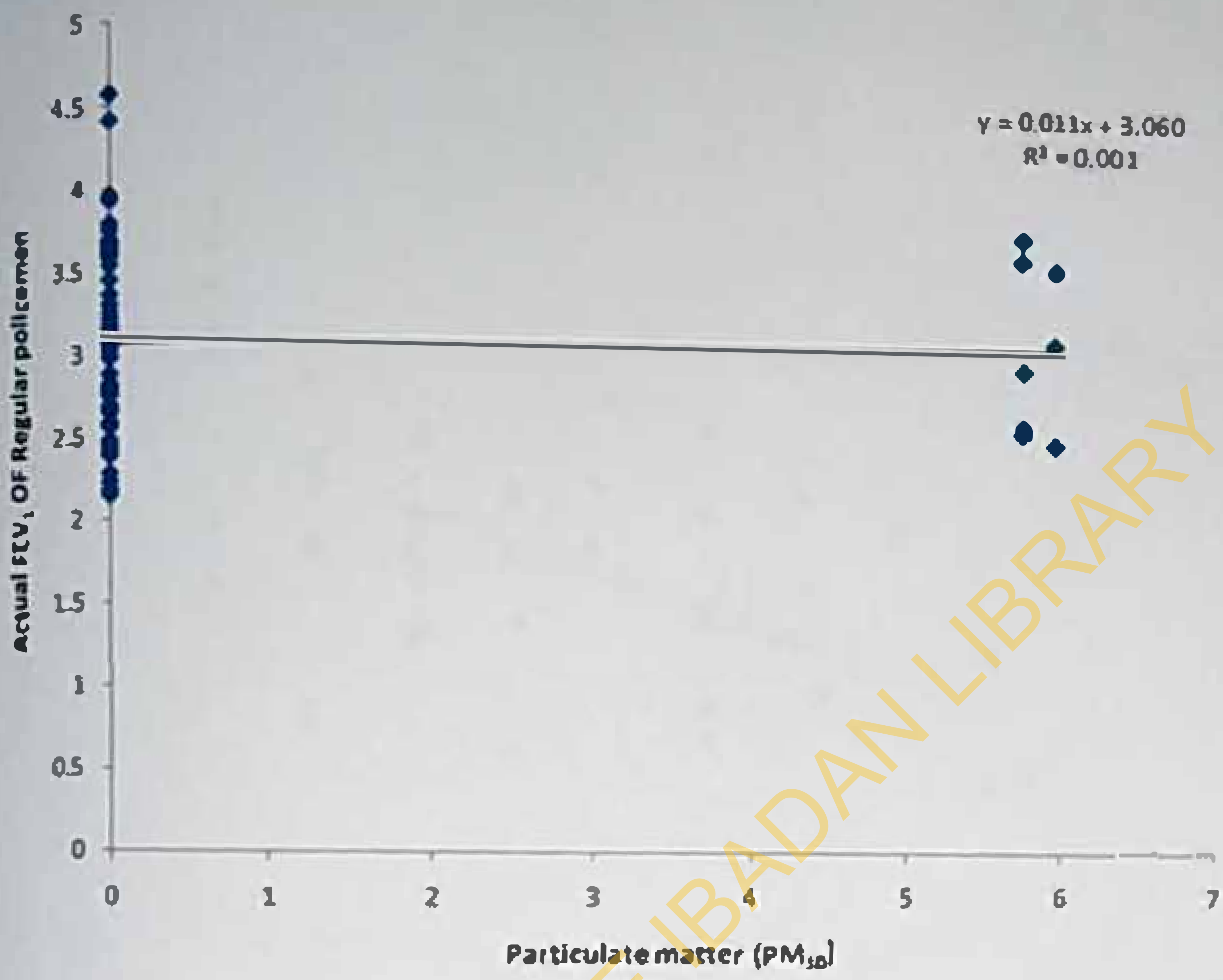


Figure 4.30: Relationship between actual FEV_1 of Regular policemen and PM_{10} burden

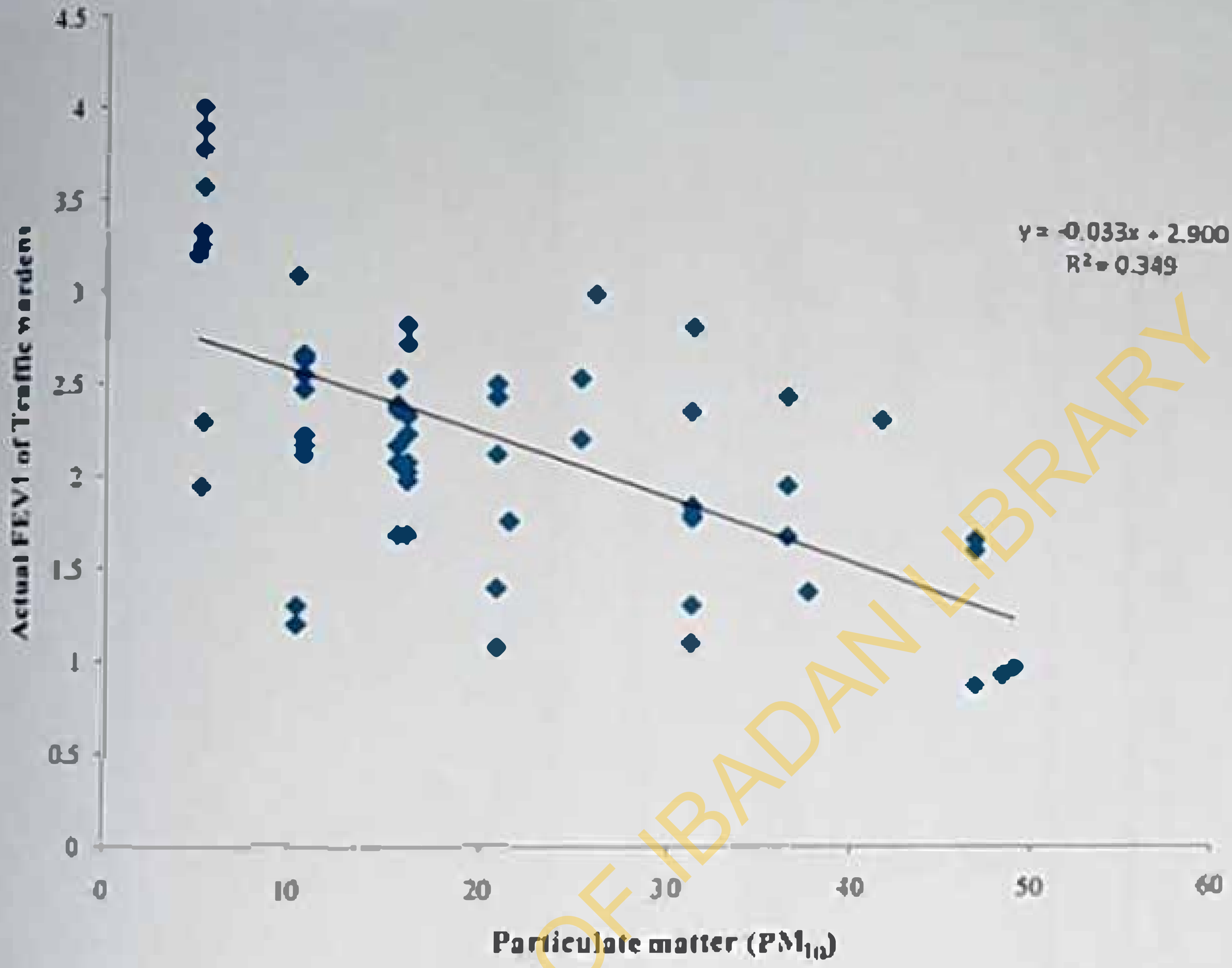


Figure 4.29: Relationship between actual FEV_1 of Traffic wardens and PM_{10} burden

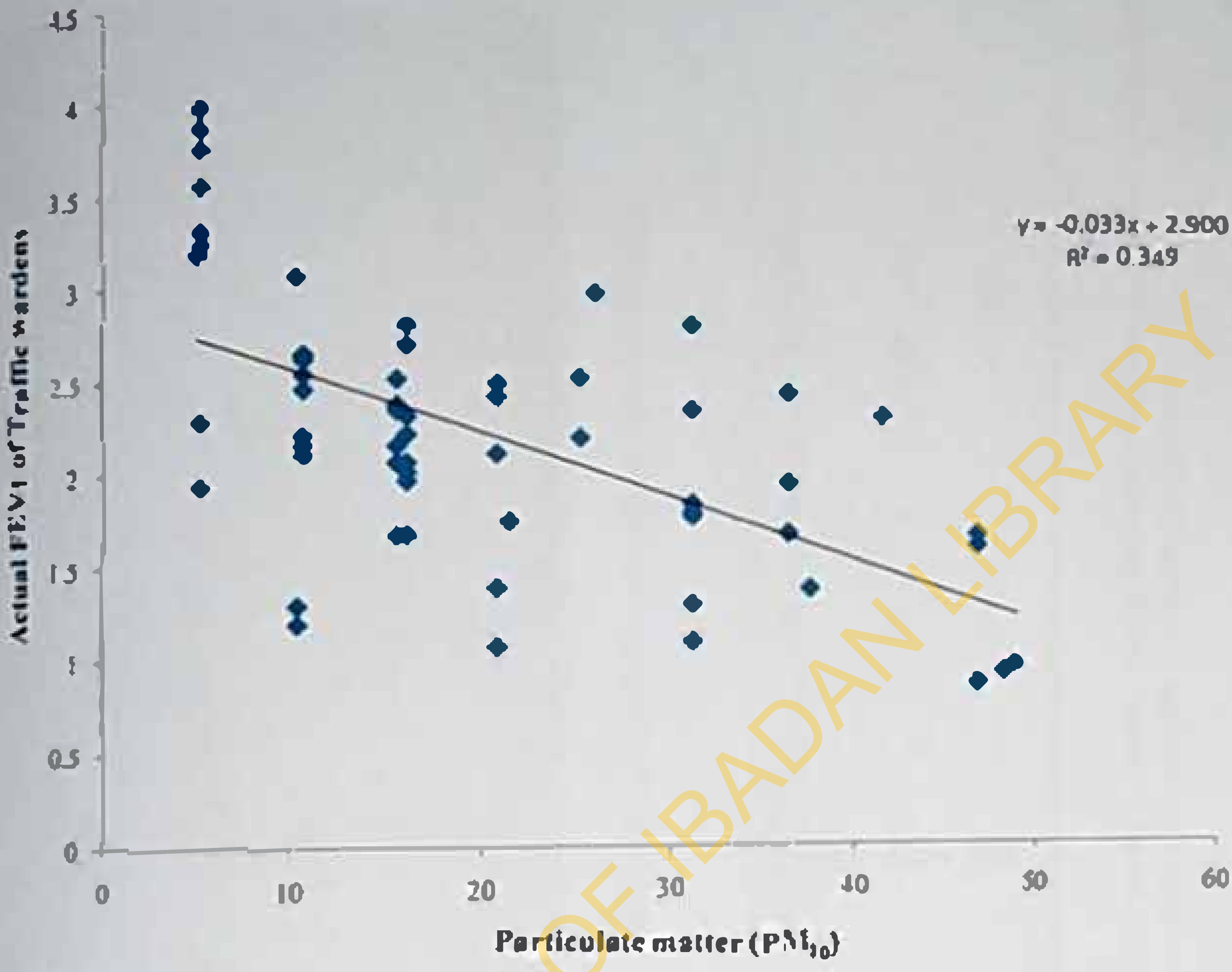


Figure 4.29: Relationship between actual FEV_1 of Traffic wardens and PM_{10} burden

Plate 4.3: Risk map for mean concentration of nitrogen dioxide monoxide at selected locations

Key:

Risk Category	Risk Symbol	Range (ppm)
High Risk		>0.04
Moderate Risk		0.03 – 0.04
Low Risk		0 – 0.03

*L1 Inalende junction L2 Mokola L3 Sango cemetery L4 Sango junction L5 University of Ibadan main gate L6 Bodija L7 Bodija railway junction L8 Osuntokun avenue L9 Awolowo junction L10 Total garden L11 Agodi gate L12 Idi ape L13 Oremeji

CHAPTER FIVE

DISCUSSION

This chapter presents the implications of the results obtained from the socio-demographic characteristics, perception of respondents of air quality, household characteristics of respondents and their reported health conditions. The results of the gaseous emissions as well as the particulate concentration are equally discussed. The health risk in terms of lung function status and other respiratory symptoms of study participants are also presented.

5.1 Nature of traffic route

Ibadan had been the centre of administration of the old Western Region, Nigeria since the days of the British colonial rule and parts of the city's ancient protective walls still stand till today. Until recently, Ibadan was little more than an overgrown rural town with narrow winding pot-hole infested roads serving as major roads.

Majority of the selected road intersections which served as sampling locations for this study were dual carriage roads and were usually characterized by heavy traffic. A high proportion of the selected roads network major areas within Ibadan metropolis viz the premier University (University of Ibadan), the state Secretariat, commercial banks and the popular Bodija market just to mention a few areas. This has led to major traffic congestion on these roads.

5.2 Traffic Density

Road traffic is a major factor in ambient air pollution in industrialised countries contributing pollutants including fine particulate matter, carbon monoxide and oxides of nitrogen. Traffic emissions result in small scale spatial variations and higher concentrations within short distances from major roads (Smargiassi *et al.*, 2005).

The weekly mean traffic count at study location showed that location 12 had the highest traffic count/hr. This is as a result of its proximity to the popular spare-parts market at Agodi gate and also due to the presence of banks in the area. This is consistent with the findings of a study carried out by Abam *et al.*, 2009 in Calabar, Cross-River state who reported that the high traffic volume in one of its study site was as a result of its closeness to a popular market in the town. Concentration of nitrogen dioxide, sulphur dioxide and carbon monoxide in almost all the study locations were above the WHO guideline limit and this can be attributed to the high traffic volume at these study locations. A study conducted by by Fu, 2001; Abdulgapour, 2004 and Goyal in 2006 revealed that traffic contributes more to ambient pollution in developing countries, accounting for 80% of nitrogen dioxide and carbon monoxide concentrations.

Furthermore, recent Government policies in Nigeria have increased the importation of old vehicles by 30% with the extension of the age of used motor vehicles from 10 years to 15 years from the year of manufacture (www.nigerianeliteforum.com). This coupled with poor vehicle maintenance culture in Nigeria has resulted in automobile highly dominated by old vehicles that produce high emissions of harmful air pollutants. This is in line with the findings of a study carried out in Mexico City in 1999 by United Nations Environmental Programme (UNEP). They reported that old vehicles are responsible for 90% of hydrocarbons and carbon monoxide emissions as well as 80% of nitrogen dioxide emissions in the country.

5.3 Gaseous emissions

Carbon monoxide (CO) is an important air pollutant which results from incomplete combustion of natural gas, diesel or gasoline in traffic engines. High concentrations of CO generally occur in areas with heavy traffic intensity and congestion. It is a colourless, odourless and tasteless gas and unlike nitrogen dioxide, CO is comparatively stable in the air (Gangla *et al.*, 2006). Carbon monoxide concentration in air is of primary importance because of its high toxicity, inducing human health impacts even at lower concentrations. Carbon monoxide impacts on health by reducing the oxygen carrying capacity of the blood. This occurs because CO binds more readily to haemoglobin than oxygen and results in the formation of carboxyhaemoglobin (COHb), which leaves less haemoglobin available for transferring oxygen around the body (Fisher *et al.*, 2002). This and other respiratory problems associated with CO explain the primary importance of its toxic effects at the different study locations.

The weekly mean concentration of carbon monoxide recorded between the hours of 6a.m – 8a.m in all the sampling locations were all above the World Health Organization (WHO) limit (10ppm) except at location 10 which had concentration of 6.88 ± 2.27ppm. Carbon monoxide concentration recorded in all locations between the hours of 12p.m – 2p.m (afternoon) were all above the WHO guideline limit and it peaked at location 11 (50.38 ± 19.53ppm). This was five-fold higher than the WHO guideline. Also, between the hours of 4p.m - 6p.m (evening), carbon monoxide concentrations in all the study locations were above the WHO guideline limit and peaked at location 2 (66.23 ± 31.48ppm).This was six fold higher than the WHO guideline limit. This finding was consistent with a study on the impacts of urban road transportation on the ambient air conducted by Koku and Osuntogun (1999) in three cities of Nigeria: Lagos, Ibadan and Ado-Ekiti all in South-west region of Nigeria. They recorded the highest concentration of carbon monoxide (271ppm) at mokola round about which is location 2 of this study. The high level of carbon monoxide in all study locations was as a result of the high traffic density at these locations. This is in agreement with the findings of the study by Xianglu, (2006) who reported that high concentrations of CO generally occur in areas with heavy traffic intensity and congestion.

The weekly mean concentration of sulphur dioxide (SO_2) recorded in all study locations between the hours of 6a.m – 8a.m (morning) were all above the WHO guideline limit of 0.17ppm except at location 10 where concentration was 0.07ppm. Concentration of SO_2 peaked at location 9 (0.85 ± 0.13) and this was 5 times higher than the WHO guideline limit. SO_2 concentration recorded in all study locations between the hours of 12p.m -2p.m (afternoon) and 4p.m – 6p.m (evening) were all above the WHO guideline limit with concentrations at some locations as high as 2.07 ± 0.64ppm which is 12 fold higher than the WHO guideline limit. This is consistent with a study conducted by Koku and Osuntogun (1999) in three cities of Nigeria: Lagos, Ibadan and Ado-Ekiti. They recorded the highest concentration of NO_2 (1.44ppm) in Ibadan at mokola round about.

Studies have shown that sulphur exercises its irritant effects by stimulating nerves in the lining of the nose, throat and the lung's airways. This causes reflex actions such as cough, irritation, and a feeling of chest tightness, which may lead to narrowing of the airways. This latter effect is particularly likely to occur in people suffering from asthma and chronic lung disease, whose airways are often easily inflamed and easily irritated (Gauderman *et al.*, 2000). These findings explain why there was a higher burden of respiratory symptoms among the Traffic wardens as compared to the Regular policemen.

The weekly mean concentration of Nitrogen dioxide (NO_2) recorded in all study locations between the hours of (6a.m – 8a.m) were all below the WHO guideline limit (0.17ppm). Furthermore, concentration of NO_2 recorded in all the study locations between the hours of (12p.m – 2p.m) were all below WHO guideline limit except at location 11 where NO_2 concentration was 0.18ppm. On the other hand, concentration of NO_2 recorded in all the study locations between the hours of (4p.m – 6p.m) were lower than the WHO guideline limit except at locations 1,4, 11 and 12.

Recent studies by Garcia-Aymerich *et al.*, 2000 have linked ambient NO_2 exposure with increased mortality, increased respiratory impairment, and increase in cardiac arrhythmias as well as increased intrauterine mortality. This therefore suggest that nitrogen dioxide has a negative effect on the respiratory functions and suggest reasons why there was a lower lung function among traffic wardens who are exposed to higher levels of this pollutant.

5.4 Particulate matter

Studies have shown that fine particles result from fuel combustion (from motor vehicles, power generation and industrial facilities), residential fireplaces and wood stoves. Fine particles can be formed in the atmosphere from gases such as sulphur dioxide, nitrogen dioxide and volatile organic compounds. Coarse particles are generally emitted from sources such as vehicles travelling on unpaved roads, materials handling and crushing and grinding operations (EPA, 2005). With exception of natural events such as volcanic eruptions and windstorms, the highest particulate matter concentrations occur on busy roadways with levels decreasing as the distance from the roadway increases (Municipality of Anchorage, 2005). Breathing fine particles can also adversely affect individuals with heart disease, emphysema and chronic bronchitis by causing additional medical treatment. Inhaling fine particulate matter has been attributed to increased hospital admissions, emergency room visits and premature death among sensitive populations.

The mean concentration of particulate matter recorded between the hours of (12p.m – 2p.m) (afternoon) at the study locations were higher than their respective morning and evening concentrations measured between the hours of (8a.m – 10a.m) and (4p.m – 6p.m) respectively. This is consistent with a study by Seaton *et al.*, (1995) that reported that particulate matter concentration increased progressively from the morning hours, reaching their peak during the midday hours. The mean concentration of particulate (PM_{10}) at the various study locations recorded between the hours of (4p.m – 6p.m) were all above the WHO guideline limit (25μg/m^3).

Meteorology often affects the particulate concentration level due to the differences in temperature, windspeed, rainfall and relative humidity. The temperature and humidity might also have affected the concentrations of particulate matter in the morning since the temperature is normally low in the morning and this makes the environment moist and may further trap dust particles in the air thereby reducing the particulate concentrations in the morning. However, in the afternoon, the temperature is higher and this may dry up the moist particles fast thus making them more active to be dispersed into the atmosphere thereby increasing the particulate concentrations during the afternoon period. This meteorological condition had implications on the particulate kinetic properties and this might also be responsible for higher concentrations of particulates in the afternoon than in the morning periods (Chan, 2002).

5.5 Socio-demographic characteristics of respondents

A study by Moen (2008) in Abuja, Federal Capital Territory (FCT) of Nigeria showed that the mean age of Traffic wardens was 31 ± 6 years with majority (58%) being males. The findings of this study revealed that, the mean age of Traffic wardens and Regular policemen were 37.7 ± 9.3 years and 37.0 ± 7.7 years respectively. Their age ranged from 22.0 – 59.0 years and 26.0 – 56.0 years respectively. The reason the mean age was relatively young was based on the fact that majority of the population were less than forty years. There were more males than female participants among the Traffic wardens and Regular policemen. This can be attributed to the sensitivity and the risk associated with the profession. The respondents were mainly Christians and majority belonged to the Yoruba ethnic group, which is expected in a study carried out in Yoruba land. More than half of the respondents were married. A higher proportion of the Traffic wardens had secondary education as the highest level of education they have attained and this can be attributed to the fact that the Senior Secondary School Certificate Examination (S.S.C.E) is the basic requirement for their recruitment. On the other hand, majority of the Regular policemen had undergone tertiary education. This is due to the basic requirement for their employment which is an Ordinary National Diploma (OND).

5.6 Respondents perception of air quality

Majority of the Traffic wardens and Regular policemen had a good perception of air quality and the risks associated with exposure to traffic related air pollutants. Majority of the respondents believed that lung function impairment can result from exposure to high levels of traffic related air pollutants. However, Regular policemen who are not exposed to these pollutants while carrying out their daily activities had a better understanding of this risk when compared with the Traffic wardens. This may be due to their high level of education.

5.7 Practice of respondents in relation to air quality

Poor practices like smoking or non-usage of Personal Protective Equipment (PPE) while working in high emissions area can go a long way in compromising the quality of air and health of respondents (Breton *et al.*, 2009). Though Traffic wardens had a good perception of air quality and the risks associated with exposure to traffic related air pollutants, this did not reflect in their practice because majority do not use personal protective equipment.

5.8 Perceived environmental characteristics

Studies have shown that Traffic wardens belong to the lower class of the society which is related to their educational status. This and other factors may affect the choices of the area in which they reside. A recent review of health, wealth and air pollution by O'Neill *et al.* (2003) suggests that socioeconomic status and its relationship to poor health may be partially explained by related exposure differentials. Possible explanations for the different distributions of air pollution by socioeconomic status include: housing-market dynamics, racism and class bias in land-use decisions (O'Neill *et al.*, 2003). If proximity to areas of dense traffic depresses property values, the lower prices for dwellings are likely to attract people of lower socioeconomic status, who often have higher personal exposures. This effect is in addition to the likely impact of socioeconomic status on the mode of transportation that people use.

A slightly higher risk of mortality associated with vehicle-related pollutants has been associated with low socioeconomic status (SES), a variable that is known to be correlated with health status. This effect may result from the fact that individuals of low SES may live in lower value dwellings that are in close proximity to major roads and therefore at a higher risk of exposure (Smargiassi *et al.*, 2006). Furthermore, vehicles may be newer and create less pollution in high SES neighbourhoods, with homes with better ventilation and insulation to offer protection against these effects (Ponce *et al.*, 2005).

The respondents commented on how polluted their residential environment were in terms of air quality. Majority (59.2%) of the Regular policemen reported that the air quality of their area was good while a good proportion (50.0%) of the Traffic wardens said that the air quality of their area was fair. This could be as a result of the nature of the activities around their residence coupled with the fact that majority of the roads in their area are not tarred.

Ventilation according to Etzel, (2003) has been considered related to air pollution since pollutants such as particulate matter may be brought into indoor environment from outdoor air by natural and mechanical ventilation. A higher proportion of the respondents (Traffic wardens and Regular policemen) made use of mechanical means of ventilation in their various homes. In addition, majority of the respondents also utilise the natural means of ventilation viz opening of windows. Inadequate ventilation can increase indoor pollutants' levels. Adequate ventilation would ideally bring enough outdoor air to help in the reduction of indoor pollutants especially where outdoor air is compromised or highly polluted. In many cases, outdoor pollution has a significant contribution to the indoor levels.

5.9 Self-reported health symptoms

5.9.1 Respiratory symptoms

Numerous studies have found an association with vehicle emissions and a diversity of respiratory symptoms and diseases. These adverse outcomes range from acute symptoms like coughing and wheezing to more chronic conditions such as asthma and chronic obstructive pulmonary disease (COPD), which includes chronic bronchitis and emphysema. Exposure to fine PM and ozone have been associated with these conditions. Studies have produced varying results on the relationship between NO_2 exposure and respiratory health (Mc keown, 2007).

A significant proportion of the population are exposed through occupations that lead to extended periods of time on or near roads and highways or close to traffic like asphalt workers (Randem *et al*., 2004), traffic officers (de Paula *et al*., 2005; Dragonieri *et al*., 2006; Tamura *et al*., 2003; Tomao *et al*., 2002; Tomei *et al*., 2001), street cleaners (Raachou-Nielsen *et al*., 1995), street vendors, and tollbooth workers. Health impacts are greater for these groups who work close to traffic than for those that are not occupationally exposed

The proportion of respondents that reported respiratory symptoms in six months preceding the study were higher among the Traffic wardens than the Regular policemen with significant differences. A comparison of respiratory symptoms observed among the control and test subjects in the study by Nku *et al*., (2005) showed that a significantly higher prevalence of respiratory symptoms among the experimental group and their control group. While in this study a comparison of the respiratory symptoms among the Traffic wardens (exposed group) and the Regular policemen (Unexposed group) indicated that breathing difficulty topped the list of the respiratory symptoms (66.4% vs. 6.4%) $P< 0.05$, cough (48.4% vs. 17.6%) $P< 0.05$, chest pain (72.1% vs. 5.6%) $P< 0.05$, sore throat (60.7% vs. 14.4%) $P< 0.05$, Catarrh (68.9% vs. 41.6%) $P< 0.05$. This is in conformity with a study carried out by Mc keown (2007) which showed that Exposure to vehicle-related pollutants is associated with excess overall mortality as well as with diverse health effects.

A study by Ingle *et al*., (2005) in India also showed that respiratory symptoms were associated with exposure to traffic related air pollutants. Significant differences were observed in respiratory symptoms between the Traffic wardens than their corresponding control group. This corroborates the findings of this study where significant differences were observed in the respiratory symptoms experienced by the Traffic wardens and the Regular policemen. Another study by Urom *et al*., (2004) compared the respiratory symptoms observed among the dust-exposed and control groups and reported that the incidence of unproductive (dry) cough, chest pain, catarrh were also significantly higher in the dust-exposed group than in controls ($p<0.05$).

5.9.2 Non respiratory symptoms

A comparison of the non-respiratory symptoms among Traffic wardens and Regular policemen in this study showed that body weakness topped the list (76.2% vs. 45.6%), itching eye irritation (66.4% vs. 12.8%) and light-headedness (80.3% vs. 11.2%). This is consistent with the study carried by Urom *et al.*, (2004) in Calabar, South-south Nigeria in which the burden of non-respiratory symptoms was found to be significantly higher in the dust-exposed group than in their controls.

5.10 Anthropometric factors and lung function status of study participants

Numerous studies have shown that anthropometric parameters have significant relationship with lung function indices (Aderele and Oluwole, 1983). There was no significant difference in the anthropometric characteristics of the Traffic wardens and Regular policemen. This is to ensure that there were no confounders in the study. It has been established from various studies that anthropometric parameters, viz; age, sex, height and weight are factors that account for variations in FVC, FEV_1 and PEFR (Aderele and Oluwole, 1983; Jaja and Fagbenro, 1995).

There was a weak positive correlation between the BMI (Body Mass Index) and FEV_1 actual (lung function status of respondents) ($r=0.272$, $p<0.05$). This suggests that as BMI increases, FEV_1 also increases. This is in conformity with a study by Thyagarajan *et al.*, (2008) in United States where participants with baseline BMI $< 21.3 kg/m^2$ experienced 10 year increases of 71ml in Forced Vital Capacity (FVC) and 60ml in FEV_1. In contrast, participants with baseline BMI $\geq 26.4 kg/m^2$ experienced 10 year decreases of 185 ml in FVC and 64 ml in FEV_1. FEV_1/FVC increased with increasing BMI. Weight gain was also associated with lung function. This can also further be explained by the mean age of participants (33.3 ± 7.9 years) which is relatively young. A study conducted by Thyagarajan *et al.*, (2008) among young adults in United States revealed that an increase in the BMI of thin respondents was associated with increasing then stable lung function through age 38. The finding of this study is in contrast with the finding of the study carried out by Santana et al., (2001) in the United States. They found out that lung function is decreased by excess body fatness after adjusting for other factors such as age, height, race, sex, asthma and smoking status in populations that are risk factors for reduced lung function.

5.11 Lung function and traffic-related air pollutants

There was a significant difference in the mean observed Forced Expiratory Volume in one second (FEV_1) between Traffic warden and Regular policemen. This was consistent with a study by conducted by Ingle *et al.*, (2005) in India. They found out that the FEV_1 of Traffic policemen were severely affected when compared to the controls. They recorded a 0.8litres difference in the expected and observed FEV_1 of the traffic policemen. This is an indication of the definite acute effect on their FEV_1. Another study carried out by Pravati, *et al.*, (2010) in Pondicherry India indicated a decrease in the FEV_1 of Traffic policemen compared to the general policemen.

Chronic exposure to traffic-related air pollutants may be a factor that contributes to lung function impairment. Brauer *et al.*, (2001) reported an association between lung function and personal exposure to particulate matter in a panel of subjects with COPD in Vancouver, BC. Although not significant, decrement of 3% and 1% in FEV_1 were associated with PM_{10} or $PM_{<2.5\mu m}$ in diameter respectively. Also in a study in Finland, Penttinen *et al.*, (2001) reported that both the concentration and the size of particles (0.1 to 1 μm) were determinants of associations between particulate matter and decreased lung function. This is in line with the findings of this study where correlation test between particulate concentration and lung function status of respondents showed a significant negative correlation which means as particulate load increased, lung function decreased and vice-versa.

5.12 Public Health Importance of Traffic exposure assessments in Nigeria

Findings from this study have public health importance and suggest the need for multiple interventions directed at tackling exposure to traffic-related air pollutants in Nigeria. Some of these strategies have been used in developed countries to abate the nuisance associated with traffic emissions. Studies carried out both in the developing and developed countries have shown that traffic wardens are at high risk of respiratory impairment. Concentration of traffic-related air pollutants at the selected road intersections exceeded the WHO guideline limit for occupational exposures and the burden of respiratory problems was higher among the traffic wardens. Hence pro-active steps must be taken to combat this menace. Effective control measures are based on the understanding of the problem which exists and on the available regulations. Routine air monitoring of our motorways should be carried out at major road intersections within the country to ensure compliance with stipulated guideline limit and to issue abatement notice where necessary.

Though majority of the traffic wardens had a good perception of air quality, this did not reflect in their practice. Majority of the traffic wardens do not use Personal Protective Equipment (PPE) while on duty. Government should enact laws that would enforce the usage of personal protective equipment by traffic wardens while on duty.

Studies have shown that old vehicles are responsible for 90% of hydrocarbons and carbon monoxide emissions as well as 80% of nitrogen dioxide emissions. Hence, Government policies aimed at reducing the rate of importation of old vehicles in to Nigeria should be enacted. Likewise, the age of imported used vehicles s used motor vehicles from 15 years to 8 years from the year of manufacture.

CHAPTER SIX

CONCLUSIONS AND RECOMENDATIONS

6.1 Conclusions

This study assessed the level of gaseous emissions and particulate burden generated by vehicular movement on selected traffic routes in Ibadan and the pulmonary function of Policemen in the selected Local Government Areas. The burden of the pollutants was determined through the estimation of particulate level and concentrations of selected traffic related gaseous emissions.

There was a variation in the level of particulate matter and gaseous emissions recorded across the different sampling locations. The study revealed that the high traffic density at the various study locations contributed to the high level of traffic-related air pollutants recorded at these locations.

The study also revealed that the mean particulate concentrations observed between the hours of 4p.m – 6p.m (evening) at the different locations were above the World Health Organization (WHO) guideline limit. Mean particulate matter concentrations determined between the hours of 6a.m – 8a.m and 12p.m – 2p.m were below WHO guideline limit. On the other hand, the levels of various traffic-related air pollutants at the different study locations were higher than the WHO guideline limit and this posed serious health risks to the traffic wardens.

A higher proportion of the Traffic wardens and Regular policemen had a good perception of the risk associated poor air quality and exposure to different traffic-related air pollutants but this did not affect their practice while working. Majority of the Traffic wardens do not use Personal Protective Equipment (PPE) while controlling traffic at the various road intersections.

This study also revealed that majority of the Traffic wardens reside in areas where the air quality is compromised compared to the Regular policemen. This may be attributed to their low socio-economic status and this increased their risk of exposure to various air pollutants.

Majority of the Traffic wardens complained more about respiratory symptoms than the Regular policemen. The apparent lowering of all respiratory function indices among the Traffic wardens compared to the Regular policemen suggests the possibility of serious lung function impairment due to chronic exposure to higher levels of traffic-related air pollutants.

The respiratory and non-respiratory symptoms reported by respondents in this study were significant and a higher proportion of the Traffic wardens experienced this symptoms compared to the Regular policemen. The findings of this study also showed a significant reduction in the mean lung function values of Traffic wardens compared to Regular policemen though it was not possible to determine all the various lung function parameters.

A decline in the lung function status of majority of the Traffic wardens and a high concentration of traffic-related air pollutants were recorded at the various study locations which was higher than the WHO guideline limit. Although the relatively higher levels of these pollutants might be a contributing factor, there may be other underlying factors. Therefore, there is need to institute a longitudinal study to establish true causality in relation.

6.2 Recommendations

6.2.1 Individuals

1. There is need to introduce and enforce safety measures such as the wearing of nose masks amongst Traffic wardens that work in areas with high traffic density.
2. The number of shifts at work should be increased thereby reducing the number of hours of exposure of Traffic wardens to these pollutants.
3. Traffic wardens should visit the hospitals for regular checkups and should desist from self-medication or use of traditional therapy.
4. There is need for adequate health education, awareness and advocacy in order to change the health seeking behaviour and practice about air quality of Traffic wardens.

6.2.2 Government

1. There is need for government to formulate specific policies aimed at improving traffic flow at major traffic routes.
2. The implementation of various traffic emission control and management programmes on air quality in Nigeria should be done.
3. There should be periodic monitoring of ambient air quality in the various municipalities as it is done in developed countries.
4. There in need for regular and periodic assessment of the lung functions status of Traffic wardens.
5. Relevant government regulations bodies and organizations such as NESREA should enact various environmental protection laws where there are none, enforce the existing ones and review the out-dated laws on air quality.
6. Government should reduce the age of used vehicles that are imported form developed countries from 15 years to 5 years from the year of manufacture.

6.2.3 Future outlook

1. An extended or longitudinal study spanning different seasons should be carried out to enable the comparison of the variation in the concentrations of the trafficrelated air pollutants and the associated health risks.
2. Other lung function parameters e.g Forced Vital Capacity (FVC) and Forced Expiratory Flow Rate (FEFR) should be determined.
3. Studies aimed at assessing the levels of some biological markers of air pollutants in the blood and urine of the respondents should be carried out.
4. There is need to characterize the filter paper obtained from the personal particulate matter sampling for heavy metals, moulds, PAH's e.t.c

REFERENCES

Abami, F.I., and Unachukwu, G.O. (2009). Vehicular emissions and air quality standards in Nigeria". *European Journal of Scientific Research*. ISSN 1450-216X Vol.34 No.4, pp.550-560. http://www.eurojournals.com/ejsr.htm

Abatan, A.A. (2007). Effect of air pollution on the socio-economic development in Nigeria. Nigerian Meteorological Agency, Abuja.http://ihy2007. Org/img/IHY_Nigeria_Abatan.doc

Abbaspour, M. and Soltaninejad, A. (2004). Design of an environmental assessment model on the effect of vehicle emission. *International Journal of Environmental Science Technology*: 1(1): 27-38.

Abou Chakra, O.R., Joyeux, M., Nerriere, E., Strub, M., Zmirou-Navier, D. (2007). Genotoxicity of organic extracts of urban airborne particulate matter: an assessment within a personal exposure study. *Chemosphere*; 66:1375-1381.

Adenole, W.I and Oluwole, O. (1983). Peak expiratory flow rate in healthy school children. *Nigerian Journal of Paediatrics*. Vol. 10 pp 45-55

Afroz, R., Hassan, M.N., Ibrahim, N.A. (2003). Review of air pollution and health impacts in Malaysia. *Environ Res*; 92:71–7.

Agency for Toxic Substances and Disease Registry (ATSDR) (1998). Toxicological profile for sulphur dioxide. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Ahrens, C. Donald (2008). 'Meterology. 'Microsoft Student 2008[DVD]. Redmond, WA: Microsoft Corporation, 2007.

Aigbedion, I., Iyayi, S.E. (2007) Environmental effect of mineral exploitation in Nigeria. *Int J Phys Sci* ;2: 33-8.

Akpan, U.G., Ndoke, P. N. (1999). Contribution of vehicular traffic emission to CO_2 emission in Kaduna and Abuja. Federal University of Technology Minna Nigeria.

Albalak, R., Frisancho, A.R., Keeler, G.J. (1997). Domestic biomass fuel combustion and chronic bronchitis in low rural Bolivian villages. *Journal of Thorax*; 54 (11): 1004-1008.

Alm, S., Jantunen, M.J. and Vartiainen, M., (1999). Urban commuter exposure to particle matter and carbon monoxide inside an automobile. *Journal of Exposure Analysis and Environmental Epidemiology*. Vol. 9, Pp 237.

Amato, G.D, G. Liccardi, D' Amato, M. and Cazzola, M. (2002). Outdoor air pollution, climatic changes and allergic bronchial asthma. *European Respiratory Journal*; Vol 2 Pp 763-776

American College of Occupational and Environmental Medicine (ACOEM) 2000. ACOEM position statement. Spirometry in the occupational setting. *J Occup Environ Med*. 42 (3): 228-45.

Areola O. (1992). The Spatial growth of Ibadan city and its impact on the rural hintherland. In: Ibadan region. Rex Charles and Conne publications, Ibadan Pp 98 – 106.

Avogbe, S. E. (2006). Survey of air pollution in Cotonou, Benin – air monitoring and biomarkers. *Science of Total Environment*.358 (1-3), 85-96.

Bascom, R., Bromberg, P.A., Costa, D.A., Devlin, R., Dockery, D.W., Frampton, M.W., Lambert, W., Samet, J.M., Speizer, F.E., Utell., (1996) (A committee of the environmental and occupational health assembly of the American Thoracic Society). 1995 *State of the art review*: Health effects of outdoor air pollution, *American Journal of Respiratory and Critical Care Medicine* 153: 3-150.

Bharat Thyagarajan, David R Jacobs, Jr, George G Apostol, Lewis J Smith, Robert Jensen, Robert O Crapo, R Graham Barr, Cora E Lewis and O Dale Williams (2008). Longitudinal association of body mass index with lung function: The CARDIA Study. *Respir Res*; 9(1): 31.

Boudaghpour Siamak and Alireza Jadidi. (2009). Investigation of the effect of outlet pollutants of cement production industries around Tehran and approaches to control and eliminate pollutants. *International Journal of Physical Sciences* Vol. 4, Pp 486-495.

Brauer. M., Ebelt, S.T., Fisher, T.V. (2001). Exposure of chronic obstructive pulmonary disease patients to paricles and respiratory and cardiovascular health effects. *Journal pf Exposure Analytical Environmental Epidemiology*. Vol. 11 Pp 490-500.

Breton. C.V., Vora, H., Salam, M.T., Islam, T., Wenten, M., Gauderman, W.J., Van Den Berg, D., Berhane, K., Peters, J.M., Gilliland, F.D. (2009). Variation in the GST mu locus and tobacco smoke exposure as determinants of childhood lung function. *Am J. Respir. Crit Care Med*. 179: 601-607.

Briggs. D.J., Collins, S., Elliott, P., Ficher, P., Kingham, S., Lebret E. (1997). Mapping urban air pollution using GIS: a regression-based approach. *Int J Geogr Inf Sci*. 11:699–718.

Brook, R.D., Brook, J.R., Rajagopalan, S. (2003). Air pollution: the "heart" of the problem. *Curr Hypertens Rep*; 5:3239.

Brown, G.E. (2009). Determination of Noise Levels, Perception and Auditory Effect among Students of Selected Secondary Schools in Ibadan, Nigeria. MPH Dissertation. Department of Epidemiology, Medical Statistics and Environmental Health. University of Ibadan. Pp 44–48.

Brunekreef, B. (2005). Out of Africa. *Occupation and Environmental Medicine*. 62:351-

352.

Burnett, R.T., Cakmak, S., Raizenne, M.E., Steib, D., Vincent, R., Krewski, D. (1998b). The association between ambient carbon monoxide levels and daily mortality in Toronto, Canada. *J Air Waste Manag Assoc*; 48:689-700.

Cacciola R.R., Sarva, M., Polosa, R. (2002). Adverse respiratory effects and allergic susceptibility in relation to particulate air pollution: flirting with disaster. Allergy; 57: 281–6.

Chan, A.T. (2002). Indoor-outdoor relationships of particulate matter and nitrogen oxides under different outdoor meterological conditions. Atmospheric Environment. Vol. 36(9), Pp 1543-1551.

Chanlett, E.T. (1993). Air pollution. Textbook on environmental engineering, Environmental Protection McGraw-Hill Kogakusha Ltd Pp 196-274.

Choi, H., Jedrychowski, W., Spengler, J., Camann, D.E., Whyatt, R.M., Rauh, V. (2006). International studies of prenatal exposure to polycyclic aromatic hydrocarbons and fetal growth. *Environ Health Perspect*; 114:1744-1750.

Cohen, D.D., Garton, D., Stelcer, E., Wang, T., Poon, S., Kim, J. (2002). Characterisation of $PM_{2.5}$ and PM_{10} Fine Particle Pollution in Several Asian Regions. 16th Int Clean Air Conf Christchurch, NZ, 18–22.

Cohen, A.J., Anderson, H.R., Ostro, B., Pandey, K.D., Krzyzanowski, M., Kuenzi N., Gutschimdt, K., Pope, C.A., Romieu, I., Samet, J.M., Smith, K. (2004). Mortality impacts of urban air pollution. In: Ezzati M, Lopez A.D, Rodgers A, Murray C.J.L, eds. *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors*. Geneva, World Health Organization, Vol. 2.

Department for Transport (UK). Sources of Particulate Matter in Urban Areas: TRAMAQ Project UG 250 September 2002.

De Paula Santos, U., Braga, A., Giorgi, D., Pereira, L., Grupi, C., Lin, C. (2005). Effects of air pollution on blood pressure and heart rate variability: a panel study of vehicular traffic controllers in the city of Sao Paulo, Brazil. *Eur Heart J*; 26:193-200.

Dockery, D.W. (2001). Epidemiologic evidence of cardiovascular effects of particulate air pollution. *Environment Health perspective*. Vol. 109 Pp 483-486

Dor, F., Le Moullec, Y., Festy B. (1995). Exposure of city residents to carbon monoxide and monocyclic aromatic hydrocarbons during commuting trips in the Paris metropolitan area. *Journal of the Air and Waste Management Association* 45, 103-110.

Dragonieri, S., Musti, M., Izzo, C., Esposito, L.M., Barbaro, M., Resta, O. (2006). Sputum induced cellularity in a group of traffic policemen. *Sci Total Environ*; 367:433-436.

Duflo, E., Greenstone, M., and Hanna, R. (2008) "Indoor air pollution, health and economic wellbeing"."S.A.P.I.EN.S."Sapiens.revues.org http://sapiens.revues.org/index130.html. Retrieved 2010-08-29.

Economopoulou, A.A., Economopoulos, A.P. (2002). Air pollution in Athens Basin and health risk assessment. *Environ Monit Assess*. 80: 277– 299.

EPA, (2003).Air quality. Retrieved 3rd March 2012 from http://en.wikipedia.org/wiki/Air_quality.

EPA, (2003). Particulate Matter (PM) Research. Retrieved 22nd February, 2012 from http://en.wikipedia.org/wiki/particulatematter/cleanairresearchprogram.

EPA (2006):"Air Pollutants".http://www.epa.gov/ebtpages/air air pollutants. html, Retrieved 2010-08-29.

EPA. (2009). Air Quality Index (AQI) - A Guide to Air Quality and Your Health. Retrieved March 10th 2012 from http://en.wikipedia.org/wiki/Air_quality

Erica Moen (2008). Vehicle Emissions and Health Impacts in Abuja, Nigeria. http://www.who.int/entity/quantifying_ehimpacts/countryprofilesebd.xls. Retrieved 2010-08-29.

Enright, P., Linn, William; Avol, Edward; Margolis, Helene; Gong, Henry Jr. and Peters John. (2000). Quality of spirometry test performance in children and adolescents. *American Journal of chest physician*. Vol. 118 Pp 665-671

Etzel, R.A. (2003). How environmental exposures influences the development and exacerbation of asthma. *Paediatrics*, July 1, 112 (1), Pp 233-239.

Faboya, O.O. (1997). "Industrial pollution and waste management" pp 26-35 in Akinjide Osuntokun (ed), Dimensions of Environmental problems in Nigeria. Ibadan Davidson press.

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

Fatusi, A., Erhabor, G. (1996). Occupational health status of sawmill workers in Nigeria. *J Roy Soc Health*: 116:232-6.

Fisher, G.W., Rolfe, K.A., Kjellstrom, T., Woodward, A., Hales, S., Sturman, A.P., Kingham, S., Peterson, J., Shrestha, R., King, D. (2002). Health effects due to motor vehicle air pollution in New Zealand. Report for the Ministry of Transport, Wellington.

Forbes, L.J.L., Kapetanakis, V., Rudnicka, A.R., Cook, D.G., Bush, T., Stedman, J.R., Whincup, P.H., Strachan, D.P., Anderson, H.R. (2009). Chronic exposure to outdoor air pollution and lung function in adults. *Thorax*; 64: 657-663.

Frampton, M.W., Morrow, P.E., Gibb, F.R., Speers, D.M., Utell, M.J. (1991). Effects of nitrogen dioxide exposure on pulmonary function and airway reactivity in normal humans. *Am Rev Respir Dis* 143: 522 - 527

Fu, L. (2001). Assessment of vehicle pollution in China. *Journal of the Air and Waste Management Association*. 51(5): 658-68.

Fung, K.Y., Luginaah, I., Gorey, K.M., Webster, G. (2005). Air pollution and daily hospital admissions for cardiovascular diseases in Windsor Ontario. *Can J Public Health*; 96: 29-33.

Garcia-Aymerich, J., Tobias, A., Anto, J.M., Sunyer, J. (2000). Air pollution and mortality in a cohort of patients with chronic obstructive pulmonary disease: a time series analysis. *J Epidemiol Community Health* 54: 73-74.

Gauderman, V.J., McConnell, R., Gilliland, F. (2000). Association between air pollution and lung function growth in South Carlifonia children. *American Journal of Respiratory Critical care medicine*; Vol. 162 Pp 383-390.

Gehring, U., Heinrich, J., Kramer, U., Grote, V., Hochadel, M., Sugiri, D. (2006). Long-term exposure to ambient atir pollution and cardiopulmonary mortality in women. *Epidemiology*; 17: 545-551.

Gilbert, N.L., Woodhouse, S., Stieb, D.M., Brook, J.R. (2003). Ambient nitrogen dioxide and distance from a major highway. *Sci Total Environ*; 312:43– 6.

Gordon, B., Mackay, R., Rehfuess, E. (2004). World: The atlas of children's health and the environment. Geneva: World Health Organization. http://www.who.int/ceh/publications/atlas/en/index.html.

Goldberg, M.S., Burnett, R.T., Bailar, J.C., Brook, J., Bonvalot, Y., Tamblyn, R. (2001). The association between daily mortality and ambient air particle pollution in Montreal, Quebec 2 Cause-specific mortality. *Environ Res*, Sect A: 86:26 – 36.

Goldberg, M.S., Burnett, R.T., Brook, J., Bailar, III J.C. Valois, M., Vincent, R. (2001). Associations between daily cause-specific mortality and concentrations of ground-level ozone in Montreal, Quebec. *Am J Epidemiol*; 154:817-826.

Goldberg, M.S., Burnett, R.T., Yale, J., Valois, M., Brook, J.R. (2006). Associations between ambient air pollution and daily mortality among persons with diabetes and cardiovascular disease. *Environ Res*; 100:255-267.

Goldstein, Allen H., Charles, D. Koven, Colette L. Heald, Inez Y. Fung (2009). "Biogenic carbon and anthropogenic pollutants combine to form a cooling haze over the southeastern United States". Proceedings of the National Academy of Sciences. http://www.pnas.org/content/106/22/8835.full. Retrieved 2010-12-05.

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

Goyal, P., Sidhartha (2003). Present scenario of air quality in Delhi: a case study of CNG implementation". *Atmos Environ*; 37: 5423–31.

Gupta P, Makhijani SD, Meenakshi C (1988) Pulmonary function tests on rubber factory workers exposed to polynuclear aromatic hydrocarbons. *Indian Journal of Physiol*, 52, 71–5.

Guyton and Hall. (2005). Textbook of Medical Physiology (11ed). Philadelphia: Saunders. Pp 130. ISBN 81-8147-920-3.

Gwilliam, K. Urban transport in developing countries. *Transp Rev* 2003; 23 Johnson, D.L., S.H. Ambrose, T.J. Bassett, M.L. Bowen, D.E. Crummey, J.S. Isaacson, D.N. Johnson, P. Lamb, M. Saul, and A.E. Winter-Nelson. 1997. Meanings of environmental terms. *Journal of Environmental Quality* 26: 581-589. (2):197–216.

Han, X., Naeher, L. (2006). A review of traffic-related air pollution exposure assessment studies in the developing world. *Environment International*. 32(1): 106-120.

Health Canada. (2006). Health effects of air pollution. Environment and workplace Health journal. www.hc-sc.gc.ca/ewh.semt/air. Pp 1-7. Assessed on November 20th 2011.

Hoffmann, B., Moebus, S., Stang, A., Beck, E., Dragano, N., Mohlenkamp, S. (2006). Residence close to high traffic and prevalence of coronary heart disease. *Eur Heart J*; 27:2696-2702.

Holmes, N.S., Morawska, L., Mengersen, K. and Jayaratne, E.R. (2005). Spatial distribution of submicometre particles and CO in an urban microscale environment. *Atmosphere Environment* Vol. 39 Issue 22. Pp 397.

Ingle, S.T., Bhushan, G., Pachpande, Nilesh D. Wagh, Vijaybhai S. Patel and Sanjay B. Attarde. (2005). Exposure to vehicular pollution and respiratory impairment of Traffic policemen in Jalgon city, India. *Journal of Industrial Health*; 43: 656-662.

Isija, S.I. and Fagbenro, A.O. (1995). Expiratory flow rate in Nigerian school children. *African Journal of Medical Science*. Vol. 24 Pp 379-384

Janssen, N.A.H., Schwartz, J., Zanobetti, A., Suh, H.H. (2002). Air conditioning and source-specific particles as modifiers of the effect of PM10 on hospital admissions for heart and lung disease. *Environ Health Perspect*; 110:43–9.

Jerrett, M., Burnett, R.T., Ma, R., Pope III, C.A., Krewski, D., Newbold, K.B. (2005). Spatial analysis of air pollution and mortality in Los Angeles. *Epidemiology*; 16: 727-736.

Jerome, A. (2000). Use of Economic instruments for Environmental Management in Nigeria. Paper presented at Workshop on Environment and Sustainable Development. Ibadan. National Centre for Economic Management and Administration (NCEMA)

Jerrett, M., Burnett, R.T., Ma, R., Pope III, C.A., Krewski, D., Newbold, K.B. (2005). Spatial analysis of air pollution and mortality in Los Angeles. *Epidemiology*; 16:727-736.

Kasper, D.L., Braunwald, E., Fauci, A.S. (2008) Environmental lung diseases. In: Harrison's principles of Internal Medicine. 16th ed. New York: McGraw-Hill; 1521-7.

Kaur, S., Nieuwenhuijsen, M., Colvile, R. (2005b). Personal exposure of street canyon intersection users to PM2.5, ultrafine particle counts and carbon monoxide in Central London, *UK. Atmos Environ*; 39:3629-3641.

Kimmel, V., Kaasik, M. (2003). Assessment of urban air quality in south Estonia by simple measures. *Environ Model Assess*; 8:47–53.

Kingham, S., Meaton, J., Sheard, A. And Lawrenson, O. (1998). Assessment of exposure to traffic-related fumes during journey to work, *Transportation Research Part D: Transport and Environment* Vol. 3 Issue 4, Pp 271.

Kogevinas, M., Anto, J.M., Tobias, A., Alonso, J., Soriano, J., Almar, E., Muniozguren, N., Payo, F., Pereira, A., Sunyer, J. (1998). Respiratory symptoms, lung function and use of health service among unemployed young adults in Spain. *European Respiratory Journal*, Vol. 3 Issue 4, Pp 271.

Koku, C.A., Osuntogun, B.A. (2007). Environmental-impacts of Road Transportation in South-western States of Nigeria. *Journal of Applied Sciences* 7 (16): 2536-2360.

Krausse, B. and Mardaljevic, J. (2005). Patterns of drivers' exposure to particulate matter. In: K. Williams, Editor, *Spatial Planning, Urban Form and Sustainable Transport*, *Ashgate*, Aldershot. U.K.

Kulkarni, M.M., Patil, R.S. (1999). Monitoring of daily integrated exposure of outdoor workers to respirable particulate matter in an urban region of India. *Environ Monit Assess*; 56:129–46.

Kyle, A.D., Wright, C.C., Cadwell, J.C., Buffler, P.A., Woodruff, T.J. (2001). Evaluating the health significance of hazardous air pollutants using monitoring data. *Pub Med Public health Report*; Vol. 116 Issue 1 pp 32–44.

Laden, F., Neas, L.M., Dockery, D.W., and Schwartz J. (2000). Association of fine particulate matter from different sources with daily mortality in six US cities. *Environ Health Perspect*; 108:941– 7.

Lanki, T., de Hartog, J.J., Heinrich, J., Hoek, G., Janssen, N.A.H., Peters, A. (2006a). Can we identify sources of fine particles responsible for exercise-induced ischemia on days with elevated air pollution? The ULTRA study. *Environ Health Perspect* ; 114: 655-660.

Lanki, T., Pekkanen, J., Aalto, P., Elosua, R., Berglind, N., D'Ippoliti, D. (2006b). Associations of traffic related air pollutants with hospitalization for first acute myocardial infarction: the HEAPSS study. *Occup Environ Med*; 63:844-851.

Lebowitz, M.D., Holberg, C.J., Boyer, B., Hayes, C. (1985). Respiratory symptoms and peak flow associated with indoor and outdoor air pollutants in the southwest. *Journal of Air Pollution Control Association* Vol.35 Pp 1154-1158.

Lipsett, M.J. (2001). Oxides of nitrogen and sulphur. In: Sullivan, J.B, Krieger, G.R, eds. Clinical Environmental Health and Toxic Exposures. 2nd ed. Philadelphia, Pa: Lippincott Williams & Wilkins; Pp 818-832.

Lung, S.C., Kao, H.Y., Peng, C.W. (2005). Pedestrians' exposure concentrations of $PM_{2.5}$, Ultrafine particles and particulate polycyclic aromatic hydrocarbons in Taiwan at intersections with different surroundings. Unpublished manuscript.

Luttmann-Gibson, H., Suh, H., Coull, B., Dockery, D., Sarnat, S., Schwartz, J. (2006). Short-term effects of air pollution on heart rate variability in senior adults in Steubenville, Ohio. *JOEM*; 48:780-788.

Magari, S.R., Schwartz, J., Williams, P.L., Hauser, R., Smith, T.J., Christiani, D.C. (2002). The association between personal measurements of environmental exposure to particulates and heart rate variability. *Epidemiology*; 13: 305 – 10.

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

Mandryks, J., Alwrs, K. U., Hocking, A.D. (2000). Effect of personal exposure on pulmonary function and work related symptoms among sawmill workers. *Annals of occupational Hygiene* Vol 44 Pp 281- 289.

Mckeown, D. (2007). Toronto Public Health. Air Pollution Burden of Illness from Traffic in Toronto – Problems and Solutions. Retrieved 3rd December, 2010 from http://www.toronto.ca/health/hphe

Mengesha, Y.A., Bekele, A. (1998). Relative chronic effects of occupational dust on respiratory indices and health of workers in three Ethiopian factories. *Am J Ind Med*; 34:373-80

Microsoft Encarta (2007). 1993-2006 Microsoft Corporation. All rights reserved. 742 Current sciences, Vol 87, no. 6, 25 September 2004..

Miller, G.T. (1998). living in the environment: An introduction to environmental science. Wadsworth publishers.

Miller, M.R., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, R., Coates, A., Crapo, R., Enright, P., van der Grinten, C.P.M., Gustafsson, P., Jensen, R., Johnson, D.C., MacIntyre, N., McKay, R., Navajas, D., Pedersen, O.F., Pellegrino, R., Viegi, G., and Wanger, J. (2005). Series "ATS/ERS Task force: Standardization of lung function testing". *Eur Respir J*; 26: 319–338.

Miller, K.A., Siscovick, D.S., Sheppard, L., Shepherd, K., Sullivan, J.H., Anderson, G.L. (2007). Long-term exposure to air pollution and incidence of cardiovascular events in women. *NEJM*; 356(5):447–458.

Molnar, P., Janhall, S. and Hallquist, M., (2002). Roadside measurements of fine and ultrafine particles at a major road north of Gothenburg. *Atmospheric Environment* Vol. Issue 25, Pp 4115.

Motor Vehicle Manufacturers' Association, Inc., World Motor vehicles data, 1991 edition (1992)

National Population Commission (2006). The breakdown of the National and State Provisional Population Totals 2006 Census. Federal Republic of Nigeria Official Gazette. No.24, Vol.94. Published by the Federal Government Printer, Lagos, Nigeria.

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

NEERI, (National Environmental Engineering Research Institute), 2006. Summary report of the study on post clearance environmental impacts and cost-benefit analysis of power generation in India.

Nku. C.O., Peters, E.J., Eshiet, A.I., Oku, O., Osim, E.E. (2005). Effect of exposure to dust on lung function, oxygen saturation and symptoms among female street sweepers in Calabar. *Nigerian Journal of Physiology Sciences*. Vol. 24 Pp 30-39

NOOA, (2010). Source for figures. Methane, IPCC TAR. Retrieved 18th January, 2011 from http://en.wikipedia.org/wiki/Atmosphere_of_Earth

Noor, H., Yap, C.L., Zolkepli, O., Faridah, M. (2000). Effect of exposure to dust on lung function of clement Factory Workers. *Medicine Journal of Malaysia*. Vol. 55 Pp 51-57.

Nwibo, A.N., Ugwuja, E.I., Nwambeke, N.O., Emelumadu, O.F., Ogboonaya, L.U. (2012). Pulmonary Problems among Quarry Workers of Stone Crushing Industrial Site at Umuoghara, Ebonyi State, Nigeria. *IJEOM*. Vol 3, No 4, Pp 178 - 185

Olusegun, O., Adeniyi, A., Adeola, G.T. (2009). Impact of Granite Quarrying on the Health of Workers and Nearby Residents in Abeokuta Ogun State, Nigeria. *Ethiopian Journal of Environmental Studies and Management*.

Omofonmwan, S.I. and Osa-Edoh, G.I. (2008). The Challenges of Environmental Problems in Nigeria. *Journal of Human Ecology*. Vol 23 Issue 1 Pp 53-57.

O'Neill, M.S. (2003). Health, wealth, and air pollution: advancing theory and methods. *Environmental Health Perspectives*, 111:1861–1870.

O'Neill M.S., Veves. A., Zanobetti, J.A., Samat, J.A., Gold, D.R., Economides, P.A. (2005). Diabetes enhances vulnerability to particulate air pollution-associated impairment in vascular reactivity and endothelial function. *Circulation*; 111:2913-2920.

O'Neill M.S., Veves, A., Samat, J.A., Zanobetti, A., Gold, D.R., Economides P.A. (2007). Air pollution and inflammation in type 2 diabetes: a mechanism for susceptibility. *Occup Environ Med*; 64(6):373-379.

Ostrowski, S., Gorzywa, A., Mieczkowska, J., Rychlik, M., Lachowska, P., Lopatynski, J. (2005). Pulmonary functions between 40 and 80 years of age. *Journal of Physiology and Pharmacology* Vol. 4 Pp 127-133.

Ott, W., Switzer, P., Willits, N. (1994a). Carbon monoxide exposures inside an automobile travelling on an urban arterial highway. *Journal of the Air and Waste Management Association* 44, 1010-1018.

Otto Hänninen., Matti Jantunen. (2006). The European commission expolis programme: updating policy indicators for urban air pollution. Scientific symposium on air pollution and human exposure complexity. Abstract book edited by Angelo Carere, Valentina Minardi and Alessandro di Domenico.

Oxman A.D., Muir D.C.F., Shannon H.S.)1993) Occupational dust exposure and chronic obstructive pulmonary disease. A systematic review. *Am Rev Respir Dis*;148 :38-48.

Ozkurt, C., Camci, F. (2009). Automatic traffic density estimation and vehicle classification for traffic surveillance systems using neural networks. *Mathematical and Computational Applications*, 14(3): 187 - 196

Paramesh H. (2002). Proceedings of the 6th national symposium on environment in India Assessed on 22nd of March, 2011.

Parks, K. (2006). Textbook of Preventive and Social Medicine, 16th eds. M/s Banarsidas Bhanot; India, Pp 544-548.

Park, K. (2007). Occupational health In: Park's textbook of preventive and social medicine. 18th ed. Jabalpur: M/s Banarsidas Bhanot.; 608-10.

Penttinen, P., Timonen, K.L., Tittanen, P. (2001). Number concentration and size of particles in urban air: effects on spirometric lung function in adult asthmatic subjects. Environ Health Perspective: Vol. 109 Pp 319-323.

Peters, A., von Klot, S., Heier, M., Trentinaglia, I., Hormann, A., Wichmann, H. (2004). Exposure to traffic and the onset of myocardial infarction. *NEJM*; 351(17):1721-30.

Perera, F.P., Tang, D., Whyatt, R., Lederman, S.A., Jedrychowski, W. (2005). DNA damage from polycyclic aromatic hydrocarbons measured by bezo[a]pyrene DNA adducts in mothers and newborns from Northern Manhattan, the World Trade Center Area, Poland, and China. *Cancer Epidemiol Biomark*; 14:709-714.

Perera, F.P., Rauh, V., Whyatt R.M., Tsai, W., Tang, D., Diaz, D. (2006). Effect of prenatal exposure to airborne polycyclic aromatic hydrocarbons on neurodevelopment in the first 3 years of life among inner-city children. *Environ Health Perspect*; 114:1287-1292.

Ponce, N.A., Hoggatt, K.J., Wilhelm, M., Ritz, B. (2005). Preterm birth: the interaction of traffic-related air pollution with economic hardship in Los Angeles neighborhoods. *Am J Epidemiol*; 162:140-148.

Pope, C.A III. (2000). Epidemiology of fine particulate air pollution and human health: biologic mechanisms and who's at risk? *Environ Health Perspect*; 108:713-723.

Pope C.A. III., Burnett, R.T., Thurston, G.D., Thun, M.J., Calle, E.E., Krewski, D. (2004). Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. Circulation; 109:71-77.

Pope C.A III, Hansen, M.L., Long, R.W., Nielsen, K.R., Eatough, N.L., Wilson, W.E. (2004b). Ambient particulate air pollution, heart rate variability, and blood markers of inflammation in a panel of elderly subjects. *Environ Health Perspect*; 112:339-345.

Pravati Pal, John Robert A.T. K., Dutta and G. K. Pal (2010). Pulmonary function test in Traffic police personnel in Pondicherry. *Indian J. Physiol Pharmacol*; 54(4): 329-336

Quanjer, P.H., Tammeling, G.J., Coles, J.E. (1993). Lung volumes and forced ventilatory flows: report of working party, standardization of lung function tests. *European Respiratory Journal* Vol. 6 Issue 16 Pp 5–40.

Raaschou-Nielsen O., Nielson, M.L., Gehl, J. (1995). Traffic-related air pollution: exposure and health effects in Copenhagen street cleaners and cemetery workers. *Arch Environ Health*; 50(3):207-213.

Randem, B.G., Ulvestad, B., Burstyn, I., Kongerud, J. (2004). Respiratory symptoms and airflow limitation in asphalt workers. *Occup Environ Med*; 61:367-369.

Rosenlund, M., Berglind, N., Pershagen, G., Hallqvist, Jonson, T., Bellander, T. (2006). Long-term exposure to urban air pollution and myocardial infarction. *Epidemiology*; 17:383-390.

Santana H, Zoico, E., Turcato, E., Tosoni, P., Bissoli, L., Olivieri, M., Bosello, O., Zamboni, M. (2001). Relation between body composition, fat distribution, and lung function in elderly men; *Am J Clin Nutr*. 4, Vol. 73. United States Pp. 827–831

Schwartz, J., Litonjua, A., Suh, H., Verrier, M., Zanobetti, A., Syring, M. (2005). Traffic related pollution and heart rate variability in a panel of elderly subjects. *Thorax*; 60:455-461.

Schwela, D. (2000). Air pollution and health in urban area. *Reviews on Environmental Health*. 15(1-2):13–42

Schwela, D., Olivier, Z., Schwela, P. (1997). Motor vehicle air pollution public health impact and control measures. World Health Organization. Division of Operational support in environmental health, Geneva, Switzerland.

Seaton, A., MacNee, W., Donaldson, K., Godden, D. (1995). Particulate air pollution and acute health effects. Lancet 345 pp 176-178.

Singer, B.C., Hodgson, A.T., Hotchi, T., Kim, J.J. (2004). Passive measurement of nitrogen oxides to assess traffic-related pollutant exposure for the East Bay Children's Respiratory Health Study. *Atmos Environ*; 38:393– 403.

Sharma, M., Kumar, V.N., Katiyar, S.K., Sharma, R., Shukla, B.P., Sengupta, B. (2004) Effects of particulate air pollution on the respiratory health of subjects who live in three areas in Kanpur, India. *Arch Environ Health*; 59: 348–358.

Shendell, D.G., Naeher, L.P. (2002). A pilot study to assess ground-level ambient air concentrations of fine particles and carbon monoxide in urban Guatemala. *Environ Int*; 28:375– 82.

Sheppard, D., Wong, S.C., Uehara, C.D., Nadel, J.A., Boushey, H.A. (1980). Lower threshold and greater bronchomotor responsiveness of asthmatic subjects to Sulphur dioxide. *Am Rev Respir Dis*; Vol 12 Issue 2 Pp 873-878

Smargiassi, A., Baldwin, M., Pilger, C., et al. (2005). Small-scale spatial variability of particle concentrations and traffic levels in Montreal: a pilot study. *Sci Total Environ*; 338: 243–51.

Smargiassi, A., Berrada, K., Fortier, I., Kosatsky, T. (2006). Traffic intensity, dwelling value, and hospital admissions for respiratory disease among the elderly in Montreal (Canada): a case-control analysis. *J Epidemiol Community Health*; 60:507-512.

Tamura, K., Jinsart, W., Yano, E., Karita, K., Boudoung, D. (2003). Particulate air pollution and chronic respiratory symptoms among traffic policemen in Bangkok. *Arch Environ Health*; 58:201-207.

Taiwomowo, M.O. (2000). "Air pollution and respiratory health in Africa: A review. *East African Medical Journal* Vol. 77 No. 2.

Tomei, F., Ghittori, S., Imbriani, M., Pavanello, S., Carere, A., Marcon, F., Martini, A., Baccolo, T.P., Tomao, E., Zijno, A., Crebilli, R. (2001) Environmental and biological monitoring of traffic wardens from the city of Rome. *Occup Med*; 51:198-203.

USEPA. (2009). Pollutants and sources technology transfer network air toxics. http://www.epa.gov/glo/airpollution/sourcestechnology/transfernetwork. html.

USEPA. (2010). Sources of Pollutants in the Ambient Air - Stationary Sources. http://en.wikipedia.org/wiki/Stationary sources of air pollution.

USEPA. (2010). Lead in Air. Retrieved 3rd March, 2011 from http://www.epa.gov/air/lead

Verma, D.K., Tombe, K.D. (2002). Benzene in gasoline and crude oil: occupational and environmental implications. *AIHA J*; 63: 225– 30.

Villeneuve P.J., Chen, L., Stieb, D., Rowe, B.H. (2006). Associations between outdoor air pollution and emergency department visits for stroke in Edmonton. *Canada Eur J Epidemiol*; 21:689-700.

Wang, G., Wang, H., Yu, Y., Gao, S., Feng, J., Gao, S. (2003). Chemical characterization of water-soluble components of PM10 and PM25 atmospheric aerosols in five locations of Nanjing, China". *Atmos Environ*; 37: 2893–902.

Ware, J.H. (1981). Assessment of the health effects of atmospheric sulphur oxides and particulates matter: evidence from observational studies. *Environ Health Perspect*. 41: 255.

World Bank. "World Bank East Asia and the Pacific Urban Business Directions". 2001. Washington, DC: World Bank, East Asia Department.

World Health Organisation. (1964). WHO Expert Committee on Atmospheric Pollutants. Wld Hlth *Org. Tech. Rep. Ser.*, No.271.S

World Health Organisation. (1984). Recommended health-based occupational exposure limits for respiratory irritants. World Health Organisation. Tech. Rep. Ser. No.707.

World Health Organization. (1987c) Sulphur dioxide and particulate matter, in: Air Quality Guidelines for Europe, pp. 338-360, WHO Regional Office for Europe. WHO Regional Publications, European Series No. 23. Copenhagen.

World Health Organization (1990). The impact of Development Policies on Health. Pp 21–40. In: *A Review of the Life Nature*. A. Dianna and D. Cooper (Eds). WHO

World Health Organization, (2005). Air quality guidelines for Europe. WHO Regional Office for Europe, Copenhagen.

Wikipedia (2010). http://en.Wikipedia.org/Wiki/Human respiratory system/functions. Assessed November 20th, 2011.

World Health Organization. (2002). A physically active life through everyday transport with a special focus on children and older people and examples and approaches from Europe. A. Davis, ed. World Health Organization Regional Office for Europe.

Wrobel, A., Rokita, E., Maenhaut, W. (2000). Transport of traffic-related aerosols in urban areas. *Sci Total Environ*; 257:199– 211.

www.earthworks.com/oilandrefineries sources.htm. Oil and Gas Air Pollution. Assessed December 3rd, 2011.

www.nigerianelitesforum.com/ng/transportation/8190-policy-reversal-used-vehicle-importation-rises-by-30-a.html. Retrieved February 23rd, 2012.

www.NASA.com. Official website of the National Aeronautics and Space Agency. Illustration of the earth's atmosphere. Assessed November 20th, 2011.

Xiangglu, Han., Luke, P., Naeher. (2006). A review of traffic-related air pollution exposure assessment studies in the developing world. *Journal of Environment International* 32: 106 – 120

Yang, K. L. (2002). Spatial and seasonal variation of PM10 mass concentrations in Taiwan. *Atmos Environ*; 36:3403– 11.

Zeka, A., Zanobetti, A., Schwartz, J. (2005). Short term effects of particulate matter on cause specific mortality: effects of lags and modification by city characteristics. *Occup Environ Med*; 62:718-725.

APPENDIX I

GEOGRAPHICAL COORDINATES OF SELECTED SAMPLING LOCATIONS

Location	Latitude	Longitude	Elevation
L1	N07° 24.020'	E003° 53.387'	195m
L2	N 07° 24.044'	E 003° 53.409'	200m
L3	N 07° 25.157'	E 003° 53.774'	190m
L4	N 07° 25.394'	E 003° 53.908'	215m
L5	N 07° 26.461'	E 003° 54.400'	230m
L6	N 07° 25.022'	E 003° 54.704'	237m
L7	N 07° 25.850'	E 003° 54.769'	231m
L8	N 07° 25.044'	E 003° 54.591'	214m
L9	N 07° 25.022'	E 003° 54.661'	205m
L10	N 07° 23.908'	E 003° 54.542'	178m
L11	N 07° 23.721'	E 003° 55.136'	246m
L12	N 07° 24.171'	E 003° 55.541'	252m
L13	N 07° 22.842'	E 003° 56.035'	220m

APPENDIX II

QUESTIONNAIRE

DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES, COLLEGE OF MEDICINE, UNIVERSITY OF IBADAN.

QUESTIONNAIRE ON ASSESSMENT OF RESPIRATORY CONDITIONS OF TRAFFIC WARDENS IN IBADAN.

Dear Respondents,

I am a postgraduate student of the Department of Environmental Health Sciences, College of Medicine, University of Ibadan currently working on "Characterization of traffic related air pollutants and assessment of respiratory conditions of Traffic wardens in Ibadan". Please be informed that participation is voluntary. I wish to inform you that there are no right and wrong answers to the questions. Please be rest assured that all information provided by you would be used for research purposes only and strict confidentiality would be ensured. Please try and give honest responses to the questions as much as possible. I hereby solicit for your cooperation.

Thanks for your cooperation.

Olamijulo J.O

FOR OFFICE USE ONLY

SERIAL NUMBER……….

INSTRUCTION: PLEASE TICK (√) OR FILL ANSWERS WHERE APPROPRIATE.

SECTION A: SOCIO – DEMOGRAPHIC INFORMATION

1. Age of respondent (as at last birthday)……………………………
2. Sex: 1. Male [ ] 2. Female [ ]
3. Marital status 1. Single [ ] 2. Married [ ] 3. Divorced [ ] 4. Separated [ ] 5. Cohabiting [ ] 6. Widowed [ ]
4. Religion 1. Christianity [ ] 2. Islam [ ] 3. Traditional [ ] 4. Others (specify)
5. Ethnic group 1. Yoruba [ ] 2. Hausa [ ] 3. Ibo [ ] 4. Others [specify]………
6. Educational Status 1. Primary [ ] 2. Secondary [ ] 3. Tertiary [ ]

SECTION B: OCCUPATIONAL HISTORY

7. How long have you been on this profession? ....
8. How long have you been working in this Local Government? ....
9. How many hours in a day are you at work? ....
10. In the past 6 months have you been on the road controlling traffic? 1. Yes [ ] 2. No [ ]. If No, go to question 15
11. Do you use Personal Protective Equipment (PPE) while working? 1. Yes [ ] 2. [ ]
12. If yes to 11 above, how often do you use it? 1. Every time [ ] 2. Sometime [ ] 3. Once in a while [ ] 4. Never [ ]
13. What type(s) do you use? ....
14. When do you use it? 1. While on duty [ ] 2. While off duty [ ] 3. Every time [ ]

SECTION C: PERCEPTION OF AIR QUALITY

15 **The following are some issues about air quality; please tick the word that best suites your option for each statement.**

A – Agree (3)   I – Indifferent (2)   D – Disagree (1)

S/N	Statement	Agree	Indifferent	Disagree
a	The use of nose mask by people normally exposed to emissions from vehicles is necessary			
b	Air quality is not affected by high traffic density			
c	Gaseous emissions from vehicles do not cause poor air quality			
d	Air quality is affected by gaseous and particulate emissions from industries			
e	Air quality is not affected by different seasons of the year			
f	Driving when the air quality is bad cannot cause accident			
g	Enforcement of law by the Government can go a long way to ensure good air quality.			
h	Continuous inhalation of vehicular emissions does not really affect one's health.			

SECTION D: HOUSEHOLD CHARACTERISTICS

16. How long you rate your residential area in terms of air quality? 1. Excellent [ ] 2. Good [ ] 3. Fair [ ] 4. Poor [ ]

17. Is the road within your residential area tarred? 1. Yes [ ] 2. No [ ]

18. Is your residence located close to an industry? 1. Yes [ ] 2. No [ ]

19. What is the means of ventilation in your house? 1. Yes [ ] 2. No [ ]

	Yes	No
Fans		
Air conditioning		
Opening of windows		

20. Does your household have a personal generator? 1. Yes [ ] 2. No [ ]

21. If "Yes" to 20 above how many hours a day does it run? ....

22. If "No" to 20 above, does your neighbor has a personal generator? 1. Yes [ ] 2. No [ ]

23. Do you cook at home 1. Yes [ ] 2.No [ ]

24. If "Yes" to 23 above, what do you use to cook at home?

	Yes	No
Gas cooker		
Charcoal		
Electric cooker		
Kerosene stove		
Firewood		

25. Is your residence located close to any dumpsite? 1. Yes [ ] 2. No [ ]

26. How many rooms do your family members occupy in your house? ....

27. .How many people stay in your room? ....

SECTION E: HEALTH HISTORY AND CONDITIONS

28. How do you rate your current state of health? 1. Excellent [ ] 2. Good [ ] 3. Fair [ ] 4. Poor [ ]

29. If poor from question 28 above, what are the factors which may be responsible for your poor state of health? ....

30. Have you ever smoked? 1. Yes [ ] 2. No [ ]

31. Do you still smoke? 1. Yes [ ] 2. No [ ]

32. Do you drink alcohol? 1. Yes [ ] 2. No [ ]

33. Which of the following symptoms have you had in the past 6 months?

Symptoms	Yes (Y)	No (N)
Coughing (dry or wet)		
Shortness of breath		
Body weakness/fatigue		
Itching/irritated eyes		
Chest pain		
Sore throat		
Running nose/sneezing		
Light headedness/fainting		
Other allergies (specify)		

34. Have you visited the hospital for any of the above symptoms? 1. Yes [ ] 2. No [ ]

35. If "Yes" to question 34 above, how, many days at the hospital? ....

36. Have you missed work because of any of the above symptoms/conditions? 1. Yes [ ] 2. No [ ]

37. How do your symptoms change while at work? 1. Improve [ ] 2. No change [ ] 3. Get worse [ ]

38. If they "get worse" do they improve 1-2 hours after leaving work? 1. Yes [ ] 2. No [ ]

39. If "No" to question to question 35 above do they improve overnight or over the weekend? 1. Yes [ ] 2. No [ ]

40. How do your symptoms and conditions change with time of the day and traffic?
1. More frequent and severe in the morning during high traffic [ ] 2. More frequent and severe in the morning during low traffic [ ] 3. More frequent and severe in the late afternoon during high traffic [ ] 4. No change with time of day and traffic

41. Which of the following ailments are you on treatment for and for how long?

Ailment	Yes (Y)	No (N)	Duration in Years
Asthma			
Tuberculosis			
Chronic Bronchitis			
Pneumonia			
Lung cancer			
Other diseases			

42. Which of the following named ailment have you been admitted for in the past 6 months?...

43. How do you manage air pollution related respiratory diseases? 1. Self medication [ ] 2. Local chemists [ ] 3. Visit clinics [ ] 4. Traditional therapy [ ] 5. Don't Know [ ]

44. What is you reason for using any of the health management facilities?.......................................

45. Have you undergone a lung function test? 1. Yes [ ] 2. No [ ]

46. Would you like to undergo a free lung function test? 1. Yes [ ] 2. No [ ]

Observational checklist for Characterization of traffic related air pollutants in two selected Local Government Area of Ibadan.

Sampling point……………………………

LOCATION OF SAMPLING POINTS

Indicators observed	Highly present	Moderately present	Present	Absent
Commercial activity				
Industrial activity				
Residential area				

NATURE OF ROAD

Indicators observed	Highly present	Moderately present	Present	Absent
Tarred roads				
Graded roads				

ACTIVITIES WITHIN AND AROUND SAMPLING POINT

Indicators observed	Highly present	Moderately present	Present	Absent
Bush burning				
Dumpsite				
Generator emission				
Construction activity				

Key: +++ highly present   ++ moderately present   + present   - absent

APPENDIX III

RECORD SHEET FOR AIR QUALITY ASSESSMENT

Week……………………

PARAMETERS	L1	L2	L3	L4	L5
SO_2 6a.m-8a.m 12p.m-2p.m (ppm) 4p.m-6p.m					
CO 6a.m-8a.m 12p.m-2p.m (ppm) 4p.m-6p.m					
NO_2 6a.m-8a.m 12p.m-2p.m (ppm) 4p.m-6p.m					

APPENDIX IV

LUNG FUNCTION TEST RESULT SHEET

Date of Spirometry...

S/N	Sex	Age	Weight (Kg)	Height (m)	Actual FEV_1 (Litres)	PEF (Litres/mins)	Expected FEV_1 (Litres)	% Predicted FEV_1

SPIROMETRY DATA FOR RECRUITED PARTICIPANTS

OCCUPATION	FEV_1 ACTUAL	FEV_1 EXPECTED	PEF	% Predicted FEV_1
TW	2.49	3.70	280.0	67.0
TW	2.20	3.27	260.0	67.0
TW	3.97	3.70	312.0	107.0
TW	0.94	3.45	202.0	27.0
TW	1.10	3.38	162.0	32.0
TW	1.29	4.08	239.0	31.0
TW	2.37	3.68	371.0	64.0
TW	0.98	3.59	162.0	27.0
TW	3.18	3.94	401.0	80.0
TW	2.53	4.48	340.0	56.0
TW	1.63	4.71	182.0	34.0
TW	1.31	4.29	202.0	30.0
TW	1.80	3.06	171.0	58.0
TW	2.21	4.66	192.0	47.0
TW	0.88	3.73	162.0	23.0
TW	2.34	2.07	327.0	112.0
TW	2.11	4.16	156.0	50.0
TW	1.67	4.45	187.0	37.0
TW	2.80	4.44	209.0	63.0
TW	2.11	4.29	487.0	49.0
TW	3.23	4.16	367.0	77.0
TW	2.46	3.94	133.0	62.0
TW	2.99	3.95	312.0	75.0
TW	2.31	1.96	276.0	46.0
TW	2.82	4.56	291.0	61.0
TW	3.06	4.31	440.0	70.0
TW	1.75	4.73	234.0	37.0
TW	2.63	4.76	401.0	55.0
TW	2.42	4.51	405.0	53.0
TW	1.97	4.41	159.0	44.0
TW	2.20	4.08	197.0	53.0
TW	2.51	4.34	291.0	57.0
TW	1.69	4.08	291.0	41.0
TW	2.06	3.12	223.0	66.0
TW	1.69	3.62	291.0	58.0
TW	2.34	3.19	239.0	73.0
TW	1.78	3.67	347.0	48.0
TW	1.07	3.54	156.0	30.0
TW	1.39	3.07	247.0	45.0
TW	2.36	3.42	306.0	68.0
TW	2.64	4.71	317.0	56.0

OCCUPATION	FEV_1 ACTUAL	FEV_1 EXPECTED	PEF	% Predicted FEV_1
TW	1.96	4.31	162.0	45.0
TW	1.67	4.11	197.0	47.0
TW	1.93	4.06	218.0	47.0
TW	1.19	4.23	239.0	28.0
TW	2.06	4.14	208.0	49.0
TW	2.15	4.29	202.0	50.0
TW	2.28	4.52	205.0	50.0
TW	2.53	4.55	218.0	55.0
TW	2.61	4.37	301.0	59.0
TW	1.85	4.25	202.0	43.0
TW	1.39	3.07	247.0	45.0
TW	2.7	3.78	368.0	72.0
TW	3.3	4.43	317.0	74.0
TW	3.54	4.41	312.0	80.0
TW	3.75	4.58	340.0	81.0
TW	2.45	4.63	363.0	52.0
TW	3.86	4.58	394.0	84.0
TW	2.15	3.34	286.0	64.0
TW	2.01	3.3	289.0	59.0
TW	2.1	3.3	270.0	63.0
RP	3.66	4.4	517.0	81.0
RP	3.45	4.5	563.0	75.0
RP	2.48	3.2	162.0	86.0
RP	2.75	4.2	296.0	64.0
RP	3.61	4.2	501.0	85.0
RP	3.96	4.3	462.0	91.0
RP	3.67	4.1	497.0	87.0
RP	3.75	4.5	340.0	81.0
RP	2.65	4.6	275.0	57.0
RP	3.68	4.6	505.0	82.0
RP	3.3	4.4	317.0	73.0
RP	3.08	4.5	283.0	68.0
RP	2.98	4.6	291.0	63.0
RP	3.69	4.5	491.0	80.0
RP	3.59	4.4	517.0	81.0
RP	3.63	4.5	512.0	80.0
RP	3.21	4.0	439.0	80.0
RP	3.8	4.8	394.0	80.0
RP	3.93	4.2	518.0	92.0
RP	3.67	4.5	471.0	80.0
RP	3.15	4.0	482.0	78.0
RP	4.57	4.4	428	80
RP	4.41	4.2	448.0	102.0
RP	2.18	3.9	428.0	80.0
RP	2.99	3.7	418.0	79.0
RP	2.69	3.1	286.0	84.0

RP	2.46	2.9	223.0	83.0
RP	2.82	3.4	307.0	82.0
RP	2.4	2.9	239.0	80.0
RP	2.78	3.3	317.0	83.0
RP	2.59	3.1	387.0	82.0
RP	2.43	4.2	234.0	57.0
RP	2.28	3.6	249.0	63.0
RP	2.57	3.1	256.0	80.0
RP	2.39	2.9	247.0	81.0
RP	2.81	3.4	433.0	80.0
RP	3.16	3.9	456.0	80.0
RP	3.36	4.0	372.0	82.0
RP	2.75	4.1	371.0	66.0
RP	2.99	3.7	368.0	79.0
RP	2.88	4.13	417.0	69.0
RP	3.25	4.25	502.0	76.0
RP	2.76	3.42	346.0	80.0
RP	3.61	4.06	375.0	89.0
RP	2.53	4.55	275.0	55.0
RP	3.03	4.51	301.0	68.0
RP	2.76	2.07	301.0	133.0
RP	2.77	2.07	362.0	133.0
RP	3.69	2.07	452.0	129.0
RP	3.09	4.74	286.0	65.0
RP	3.54	4.3	312.0	80.0
RP	2.75	3.79	240.0	72.0
RP	2.56	4.42	249.0	57.0
RP	3.06	4.53	402.0	67.0
RP	2.23	4.48	382.0	49.0
RP	3.79	4.52	334.0	83.0
RP	2.8	4.38	306.0	63.0
RP	2.68	4.25	347.0	63.0
RP	3.17	4.22	420.0	75.0
RP	2.64	4.51	319.0	58.0
RP	2.6	3.29	320.0	79.0
RP	2.15	3.34	286.0	64.0
RP	2.67	4.29	343.0	62.0

Key

Traffic wardens – TW Regular policemen - RP

APPENDIX V

INFORMED CONSENT FORM

IRB Research approval number

This approval will elapse on ...../..../.....

Title of research: Characterization of traffic related air pollutants and assessment of respiratory conditions of traffic wardens in two selected Local Government Areas of Ibadan.

Purpose of research: To characterize traffic related air pollutants and assess the associated respiratory symptoms of traffic wardens in Ibadan.

Procedure of the research, what shall be required of each participants and appropriate total number of participants that would be involved in the research:

This research would be divided into two phases. In the first phase, air quality monitoring would be carried out at major road intersections within the Local Government and every research participants (traffic and non-traffic police officers) would be expected to complete a questionnaire and there would be about 252 participants. In the second phase about 50% of the participants would be enrolled. This phase involves an exposure attachment (determination of the amount of particulate matter inhaled by the traffic wardens) and a lung function test to determine the efficiency of their lungs. Phase II participants would be selected on certain exclusion and inclusion criteria.

Expected duration: The research is expected to take about 5 months

Risk: There are no risks involved for taking part in this study as every precaution has been taken to prevent this.

Cost to participants: Participation in this study will not cost you anything.

Benefits: Free lung function test will be carried out on participants. This will help you to know how efficient your lungs are.

Confidentiality: All information collected in this study would be given code numbers and no names will be collected.

Voluntariness: Participation in this study is entirely voluntary. You will not be paid any fees for participation in this research. At any time if you decide to pull out of this research you may do so without any consequence. Please note that some of the information that has been obtained about you before you choose to withdraw may have been modified or used in reports and publications. These cannot be removed anymore. However the researcher promises to make good effort to comply with your wishes as much as possible.

Treatment in case of injury: There is no expected injury in the course of this project.

After the research: The researcher will inform you of the outcome of the research through a news bulletin. During the course of the research, you will be informed about any information that may affect your continued participation or your health.

If this research leads to any benefits, the researcher will jointly own it. There is no plan to contact any participants now or in the future about any such benefits.

Conflict of interest: This research work is strictly for academic purposes, self-funded and there is no conflict of interest.

Statement of person obtaining informed consent: I have fully explained this research to .... and have given sufficient information, including risks and benefits, to make an informed decision.

Date: .... Signature...

Name: ....

Statement of the person giving informed consent:

I have read the description of the research. I understand that my participation is voluntary. I know enough about the purpose, methods, risks and benefit of the research study to judge that I want to take part in it. I understand that I may freely stop being part of this study at any time. I have read a copy of the consent from and additional sheet to keep for myself.

Date: .... Signature: ....

Name...

Detailed contact information including contact address, telephone, e-mail and any other contact information of researcher(s), institutional HRES and Head of Institution:

This research has been approved by the Health Research Ethics Committee of the University of Ibadan and University College Hospital and the Chairman of this committee can be contacted at BIODE building, Room T10, 2nd floor, Institute for Advanced Medical Research and Training (IMRAT), College of Medicine, University College Hospital. Email: uiuchirc@yahoo.com. If you have any question about your participation in this research you can contact the Principal Investigator, Olamijulo J.O at the Department of Environmental Health Sciences, College of Medicine, University of Ibadan. His phone number and email address are 07039394368 and johnette07@yahoo.com respectively. You can also contact the Head of Department of EHS, College of Medicine, University of Ibadan.

APPENDIX VI

ETHICAL APPROVAL

INSTITUTE FOR ADVANCED MEDICAL RESEARCH AND TRAINING (IMRAT)

COLLEGE OF MEDICINE, UNIVERSITY OF IBADAN, IBADAN, NIGERIA.

E-Mail - imratcomui@yahoo.com

UI/UCH EC Registration Number: NHREC/05/01/2008a

NOTICE OF FULL APPROVAL AFTER FULL COMMITTEE REVIEW

Re: Characterization of Outdoor Air Pollutants and Assessment of Respiratory Condition of Traffic Wardens in Ibadan North East Local Government

UI/UCH Ethics Committee assigned number: UI/EC/11/0036

Name of Principal Investigator:	Olaseye J. Olamijulo
Address of Principal Investigator:	Department of EMSEH College of Medicine University of Ibadan Ibadan

Date of receipt of valid application: 23/02/2011

Date of meeting when final determination on ethical approval was made: N/A

This is to inform you that the research described in the submitted protocol, the consent forms, and other participant information materials have been reviewed and given full approval by the UI/UCH Ethics Committee.

This approval dates from 14/06/2011 to 13/06/2012. If there is delay in starting the research, please inform the UI/UCH Ethics Committee so that the dates of approval can be adjusted accordingly. Note that no participant accrual or activity related to this research may be conducted outside of these dates. All informed consent forms used in this study must carry the UI/UCH EC assigned number and duration of UI/UCH EC approval of the study. It is expected that you submit your annual report as well as an annual request for the project renewal to the UI/UCH EC early in order to obtain renewal of your approval to avoid disruption of your research.

The National Code for Health Research Ethics requires you to comply with all institutional guidelines, rules and regulations and with the tenets of the Code including ensuring that all adverse events are reported promptly to the UI/UCH EC. No changes are permitted in the research without prior approval by the UI/UCH EC except in circumstances outlined in the Code. The UI/UCH EC reserves the right to conduct compliance visit to your research site without previous notification.

UI/UCH EC

14 JUN 2011

Dr. A. I. Olagbaju
Chairman, Medical Advisory Committee
University College Hospital, Ibadan, Nigeria
Vice Chairman, UI/UCH Ethics Committee
E-mail: uiuchirc@yahoo.com

Research Units: • Genetics & Bioethics • Malaria • Environmental Sciences • Epidemiology Research & Service • HIV/AIDS • Behavioural & Social Sciences • Pharmaceutical Sciences • Cancer Research & Services