CHAPETER ONE

INTRODUCTION

1.1 Background Information

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 phenomenon, such as sand storm, ash from volcanic eruptions, or forest fires. Natural geomorphic terrain, such as low valleys surrounded by mountains, temperature and wind speed can also aggravate already polluted surrounding in a region. More importantly, however are the anthropogenic or human causes of air pollution that are directly linked to energy consumption, industrial emissions and vehicular emissions in heavily trafficked urban centres. It is often a combination of both natural and anthropogenic activities that lead to highly unhealthy conditions of air (Abatan, 2007).

The World Health Organization (2000) defines air pollution as limited to situation in which the ambient atmosphere have materials in levels which are injurious to man and his environment. Examples of air pollutants include nitrogen oxides (NOx), sulphur oxides (SOx), particulate matter (PM), carbon monoxide (COx), photochemical oxidants (e.g ozone and lead (Pb), along with a variety of air borne heavy metals and volatile organic compounds (VOCs). Air contaminants can come from both anthropogenic and natural processes (Kyles *et al*., 2001).

An air pollutant can be described as a substance in the air that can cause harm to humans and the environment. Pollutants can be in form of solid particles, liquid droplets or gases. In addition, they may be natural or man-made (McCladin and Heidel, 1997). Pollutants can be categorized as either primary or secondary. Usually, primary pollutants are substances directly emitted from process such as ash from a volcanic eruption, carbon dioxide from burning of fossil fuels, the carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide emitted from industries. Secondary pollutants are not emitted directly, rather they are produced in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground ozone; one of the key secondary pollutants that make up photochemical smog.

Air pollution and its attendant health effects are getting increasing attention from the environmental regulatory agencies, environmental health research communities, governments, industries, as well as the public. The quality of air, both indoors and ambient, is closely related to morbidity and mortality from cardiovascular and respiratory diseases (Xianglu *et al*., 2006). We are constantly exposed to particulate matter in our daily lives and traffic related emissions are a significant contributor to ambient pollution, especially in urban areas. Heavy metals pollution from automobiles has gained much attention in the recent past particularly in particulate matter (PM) concentrations because traffic related particulate matter is increasingly becoming an environmental stressor that is found everywhere (Kummer, et al., 2009). During the last 200 years, humans began to significantly alter the composition of the atmosphere through pollution. Although air is still made up mostly of oxygen and nitrogen gases, mankind, through its pollution activities, has increased the levels of many heavy metals and in some cases, released new gases into the atmosphere.

As many cities in the developing nations swell with people and automobiles, the numbers of cities with poor air quality continue to rise. Air quality monitoring in most developing countries is not routinely carried out, and in some urban centres such information does not even exist, though signs of deteriorating air quality and health problems related to ambient air pollution are visible (Carter, et al., 1997). The main sources for ambient PM concentrations at urban roadways are vehicle exhausts, emissions from tyre and brake wear, fluid leakage, corrosion of body parts and re–suspension. There is an urgent need to address the interwoven issues and common obstacles being experienced by these urban centres around the world and a need for a more complete understanding of the connection between air pollution and human health (WHO, 2000).

The environmental issues cause by urban air pollution, land degradation, and climate change are closely related problems sharing common causes and solutions. The fact that the air pollutants and greenhouse gases arise largely from combustion (fossil, bio-fuel, and biomass) and that particulate matter play important roles in air quality, climate change and ecosystem perturbation are illustrative examples (WHO, 2000). The quality of the environment is a matter of serious concern, especially today that the consequences of human intervention are already evident.

Although environment is extremely valuable for people and other organisms living in it, it is also endangered due to human activities that are continuously ruining it (Kummer *et al.,* 2009).

Ambient air pollution is the presence of one or more contaminants in the outdoor atmosphere or the combinations thereof in such quantities and of such duration over and above the natural physical diffusion, deposition, chemical elimination and biological purification functions as may be or may tend to be injurious to human, plant or animal life, or which may unreasonably interfere with the comfortable enjoyment of life or property or the conduct of business (Xie *et al*., 1998).Man's activities on the earth's surface have largely degraded the quality of the lower atmosphere. The growth and development of industries and urbanization have contributed immensely to ambient air pollution. Traffic-related emissions are a complex mix of pollutants that comprises of nitrogen oxides, particulate matter, carbon monoxide, sulphur dioxide, volatile organic compounds, ozone and many other chemicals such as heavy metals and greenhouse gases (Chellam et al., 2005). 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 and traffic officers (Shendell and Naeher, 2002) street cleaners (Raachou-Nielsen *et al*., 2010), street vendors and tollbooth workers.

Air can accept any kind of pollutants produced mainly from industries, but also naturally, domestic or traffic originated. Consequently, particulate matter containing heavy metals have been dispersed in the environment and could cause human health problems through the atmosphere. It has been shown that traffic related particulate matter cause a number of direct adverse effects other than respiratory related problems. These include cardiovascular, premature mortality, birth and developmental effects, cancers and reduced heart rate variability. Also, vegetation exposed to wet and dry deposition of particulates may be injured when particulates are combined with other pollutants. Coarse particles, such as dust, directly deposited on leaf surfaces can reduce gas exchange and photosynthesis, leading to reduced plant growth. Heavy metals that may be present in particulates, when deposited on soil, inhibit the process in soil that makes nutrients available to plants. This, combined with the effects of particulates on leaves, may contribute to reduction of plant growth and yields.

In addition, particulates contribute to the soiling and corrosion of buildings, materials, and paint, leading to increased cleaning and maintenance costs and to loss of utility. Particulate emissions have their greatest impact on terrestrial ecosystems in the vicinity of emissions sources (Smargiassi *et al*.,2005) . Ecological alterations may be the result of particulate emissions that include toxic elements. Furthermore, the presence of fine particulates may cause light scattering, or atmospheric haze, reducing visibility and adversely affecting transport safety, property values, and aesthetics. The indirect or secondary effects of heavy metals in particulate matter are often not easy to quantify and satisfactory assessment models are lacking (Smargiassi *et al*.,2005).

The respirable particulate matter (PM<10) are trapped in conducting airways and high ambient levels of PM are associated with a number of health effects mainly aggravated asthma, increasing respiratory symptoms like coughing and painful breathing, chronic bronchitis, eyes irritation as well as, premature deaths (USEPA,2009). PM_{10} levels have been reported to frequently exceed guideline limits from the European Union (EU), United States Environment Protection Agency (USEPA) and other international environmentally concerned agencies; in many European, North American, Asian and African urban areas (EEA,2007). At very low level, air pollution is a nuisance to healthy individuals and a burden to those with respiratory disease. (Mandryks *et al*.,2000). Those living very close to the highways are assumed to be at risk for adverse effects of heavy metals of traffic related particulate matter and this situation is further complicated by limited environmental air quality standards in Nigeria.

1.2 Problem Statement

Ambient air pollution continues to pose immense threat to the wellbeing of mankind worldwide. Urban air pollution is becoming one of the major areas of concern for both developed and developing world, deteriorating air quality has been associated with rapidly economic development and rising population growth and increased use of motor vehicles coupled with inadequately emission regulations. On global scale, more than 0.5 million deaths per year are due to exposure to ambient PM concentrations (WHO, 2000).

The continuing elevated levels of certain toxic pollutants in urban and industrial centers still remain a major public health problem in advanced countries, especially among young people, the elderly and other vulnerable portions of the population. For instance, in the United States, air pollution still account for approximately 60,000 deaths each year, caused majorly by gaseous and particulate emissions from motor vehicles and other fossil fuel burning sources (WHO, 2000). In advanced countries, much attention has been paid by regulatory agencies in recent years to minimize the concentration of fine particulate matter and photochemical oxidants in the atmosphere, which cause a number of serious acute and chronic respiratory diseases. Among the major sources of high levels of airborne fine particulate matter in advanced countries are diesel engine motor vehicles, electric-power generating plants and metals refining processes (WHO, 2000).

According to Wrobel *et al*., 2000, traffic–generated emissions are accounting for more than 50% of the total PM emissions in the urban areas. At present, over 600 million people living in urban areas worldwide are being exposed to dangerous levels of traffic–generated air pollutants (Cacciola *et al*., 2002). About 30% of the respiratory diseases are related to personal exposure to high level ambient PM concentrations (WHO, 2000b). According to (WHO, 2002a), outdoor air pollution contributes as much as 0.6 to 1.4% of the burden of disease in developing regions, and other types of pollution, such as lead in water and soil, may contribute 0.9%. 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 *and Jadidi*, 2009).

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 centres worldwide. This amounts to 0.80million (1.2%) premature deaths and 6.4million (0.5%) lost life years. (Cohen *et al*., 2004) The occurrence of toxic heavy metals in the respirable fraction of PM is assumed to contribute to substantial health effects (Wallenborn *and Schladweiler*,2009). Some of the particulate heavy metals are strong triggers for carcinogenesis, teratogenesis and mutagenesis (Ken *et al*., 2002), because heavy metals have a great ecological significance due to their toxicity and cumulative behavior. In developing countries the state of affairs is compounded by the

importation of old vehicles leading to an automobile fleet dominated by a class of automobiles known as "super emitters" which release higher concentrations of harmful pollutants in comparison to properly maintained vehicles or new ones (Bekele, 1997).

In highly congested Nigerian city centres, traffic is responsible for large portion of the particulate matter burden, which poses significant threat to human health and natural resources (World resources, 1996). Increase pollution from mobile transportation source is on the rise in per capital vehicle ownership, thus resulting in high congestion and serious air pollution on Nigerian city roads. Also a recent study conducted in Abuja, Nigeria by Enemari (2001) on the effect of vehicular emission on the health of Traffic warden showed that 16% of the traffic wardens had various health effects.

1.3 Rationale for the study

Ibadan is the third largest metropolitan area in Nigeria. 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. The five local government areas in the city include: Ibadan North, Ibadan Northeast, Ibadan Northwest, Ibadan southwest, and Ibadan southeast. Ibadan Northeast local government links Lagos that is the commercial hub of the nation to Ibadan municipality. The linkage has led to introduction of motorized vehicles and trucks that emit pollutants and vehicle exhaust emission which affects the air quality of the local government area. Idi-ape –Iwo road motorway is a major commercial and residential hub and has the highest population density in Ibadan Metropolis. Explosive population growth resulting from the great influx of people into the local government, combined with the increasing number of vehicles and increase commercial activities around this area has contributed immensely to aggravation of ambient air pollution in this area (Areola,1992).

In Nigeria, identified gap in knowledge of heavy metals characterization of traffic related particulate matter exist compared with varieties of studies carried out in the developed world. Much attention is placed on general industrial pollution and pollution in oil industries, with little reference on damage of pollution caused by mobile transportation sources of air pollution in Nigeria (Iyoha 2009, Magbagbeola, 2001).

Idi-Ape – Iwo road motorway being one of the major commercial hubs in Ibadan Metropolis, populations living, working and going to school along this traffic-way are exposed to high traffic-related particulate matter burden and subjected to an increased risk for a number of adverse health effects because they are directly and frequently exposed to toxic emissions from vehicles and trucks that commonly ply this route on a daily basis. The increasing volume of road traffic and congestion is a fundamental issue in this area. The degradation of air quality arising from these is another serious dimension of the problem. Locally, most studies on traffic related particulate matter have provided little information on the particle-bound heavy metals and most people do not know the hazards they are exposed to on daily basis because the awareness is also poor.

This study was intended to provide dataset on PM_{10}burden and heavy metals levels present in PM_{10}at 10 metres, 20 metres and 30 metres away from the motorway at selected sampling locations along this motorway. This study would assist in providing dataset for policies formulation that would help reduce traffic-related pollution on our motorways and its attendant effects and helps in future research. This is particularly essential considering the fact that change in policies and holistic measures are needed to reduce the traffic air pollution in our country.

1.4 Research question.

1) What is the traffic density at the selected motorway?

2) What is the ambient concentration of particulate matter within the selected sampling locations?
3) What is the ambient concentration of selected heavy metals at the selected sampling locations?
4) What are the other activities contributing to particulate matter pollution along this motorway?

1.5 Research hypothesis

Ho: There is no significant difference in PM_{10} concentration among the five locations.

Ho: The concentration of PM_{10} does not change between the morning and afternoon periods.

Ho: There is no significant difference in heavy metals concentration among the five locations

1.6 Objective of the Study

1.6.1 Broad objective

The broad objective of this study was to determine the heavy metal concentrations present in particulate matter PM_{10} emitted along Idi-Ape – Iwo road motorway

1.6.2 Specific objectives

The specific objectives of this study were to;

1) Determine the traffic density along the sampling points.
2) Determine the nature of activities that take place along the selected motorway.
3) Determine the outdoor PM_{10} burden of selected sampling points.
4) Determine the concentration of priority heavy metals viz: Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Nickel (Ni) and Zinc (Zn) from the selected sampling points.
5) Determine relationship between PM_{10} load and heavy metals concentration along this route.

CHAPTER TWO

LITERATURE REVIEW

2.1 Atmosphere

The atmosphere is made up of the mixture of gases surrounding any celestial object that has a gravitational field strong enough to prevent the gases from escaping; especially the gaseous envelope of Earth (Ahrens, 2008).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).

The principal constituents of the earth's atmosphere dry air contains roughly (by volume) are nitrogen (78 percent) and oxygen (21 percent). The atmospheric gases in the remaining 1 percent are argon (0.09 percent), carbon dioxide (0.03 percent), varying amounts of water vapour, and trace amount of hydrogen, ozone, methane, carbon monoxide, helium, neon, krypton, and xenon (Ahrens, 2008). Almost all the free oxygen in the air today is believed to have been formed by photosynthetic combination of carbon dioxide with water. About 570 million years ago, the oxygen content of the atmosphere and ocean became high enough to permit marine life capable of respiration. Later, some 400 million year ago, the atmosphere contained enough oxygen for the evolution of air-breathing land animal (Ahrens, 2008).

The water-vapour content of the air varies considerably, depending on the temperature and relative humidity. With 100 percent relative humidity, water-vapour content of air varies from 190 parts per million (ppm) at $-40^{O}C$ to 42,000 ppm to $30^{O}C$

2.2 Structure of the atmosphere

According to Ahrens, (2008) the atmosphere may be divided into several 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 $-79^{O}C$, or about $-110^{O}F$) and to about 9.7 km in temperate

latitudes (to a temperature of about -51^{o}C, or about -60^{o}F). The temperature as a rule decreases upward at the rate of 5.5^{o}C per 1,000 m (3^{o}F per 3,000ft). This is the layer in which most clouds occur.

- **Stratosphere**: This is the layer that houses the ozone layer. It is located immediately above the troposphere. In the lower stratosphere the temperature is practically constant or increases slightly with altitude, especially over tropical regions. Within the ozone layer the temperature rises more rapidly, and the temperature at the upper boundary of the *stratosphere,* almost 50 km above sea level, is about the same as the temperature at the surface of the Earth.
- **Mesosphere**: The mesosphere is immediately above the stratosphere and The layer from 50 to 90 km, called the mesosphere, is characterized by a marked decrease in temperature as the altitude increases reaching a low of -93^{0} 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 70 km above the earth's surface. From investigations of the propagation and reflection of the radio waves, it is known that beginning at an altitude of 70 km, ultraviolet radiation, X rays, and showers of electrons from the sun ionizes several layers of the atmosphere, causing them to conduct electricity; these layers reflect radio waves of certain frequencies back to Earth. From here (70 km), 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 90 km, temperatures begin to rise. The layer that begins the altitude is the thermosphere, because of high temperatures reached in this layer (about 1200^{0}C, or about 2200^{0}F).
- **Exosphere**: This is the region beyond the thermosphere. It extends to about 9,600 km the outer limit of the atmosphere (Ahrens, 2008).

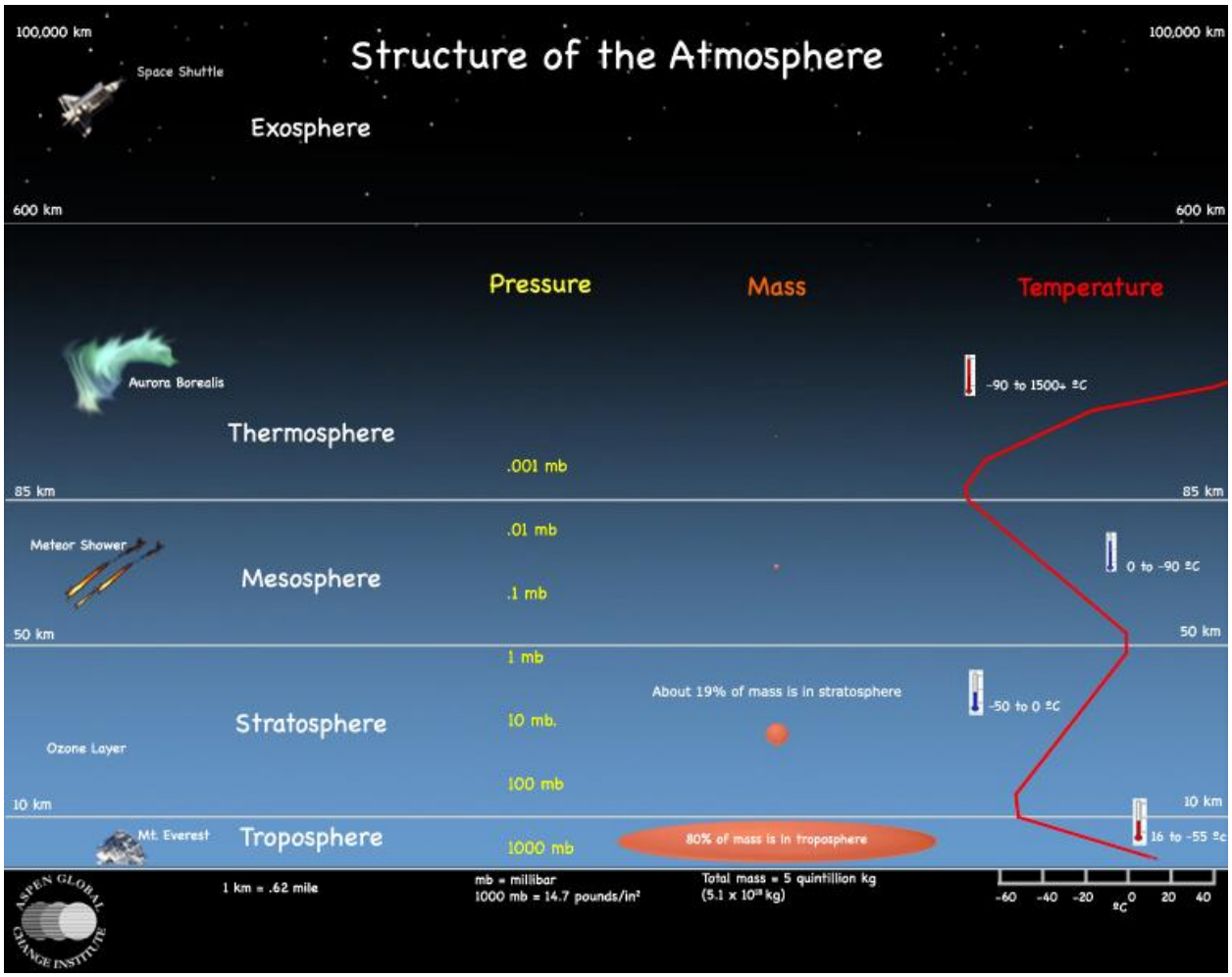

Fig 2.1: The diagram of the Earth's atmosphere

Source: Wikipedia, 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 a mixture of gases that surrounds the earth and makes our atmosphere. The composition of the air is given in Table 2.1

Apart from supplying the life-giving oxygen, air and atmosphere serve several functions. The human body is cooled by the air contact. Air is a mechanical mixture of gases and depending on locality and time contains the molecules and particles of thousands of differential materials usually separable into chemical materials and biological forms (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%)
Carbondioxide (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 Pressure

Air is held to the earth by gravity. This strong invisible force pulls the air downward, giving air molecules weight. The weight of the air molecules exerts a force upon the earth and everything on it. The amount of force exerted on a unit surface area (a surface that is one unit in length and one unit in width) 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. Higher in the atmosphere, there are fewer air molecules pressing down from above. Consequently, air pressure always decreases with increasing height above the ground. Because air can be compressed, the density of the air (the mass of the air molecules in a given volume) normally is greatest at the ground and decreases at higher altitudes. Barometers are the instrument used to measure air pressure.

2.3.3 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 speeds correspond to higher temperatures. The temperature of a substance is measured by a thermometer(Ahrens, 2008).

2.3.4 Wind

Wind is the 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. A north wind blows from the north and a south wind blows from south. The prevailing wind is the wind direction most often observed during a given time period. Wind speed is the rate at which the air moves pasts a stationary object. A variety of instruments are used in measuring wind. A wind vane measures wind direction while anemometers measure wind speed (Ahrens, 2008).

2.3.5 Humidity

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

2.3.6 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 gauges are instruments that measure rainfall. The standard rain gauge consists of a funnel-shaped collector that is attached to a long measuring tube (Ahrens, 2008).

2.4 Air quality

Air quality is defined as a measure of the condition of the air relative to the requirements of one or more biotic species and or to any human need or purpose (Janssen,2001). Air quality is therefore an indication of healthfulness of the air based on the quality of polluting gases and particulates (liquid droplets or tiny solid particles are suspended in air) it contains. Air is considered safe when it contains no harmful chemicals and only low levels of other chemicals that become harmful in higher concentrations to humans, other animals, plants or their ecosystems.

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. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. The U.S Environmental Protection Agency (EPA) developed the air quality index (AQI) to monitor and measure the air quality. The AQI is an index for forecasting daily air quality. The AQI includes sub-indices for Particulate

matter, ozone, carbon monoxide, nitrogen dioxide, sulphur dioxide, which relates ambient pollution concentration to index value on a scale from 0 through 500. This represents a broad range of air quality from pristine air to air pollution levels that present imminent and substantial danger to the public(USEPA, 2010b).

To measure the air quality, network of monitors record the concentrations of the major pollutants at more than one location across the U.S each day. These raw measurements are converted into AQI values using standard formulae developed by EPA. An AQI value is calculated for each of the individual pollutants in an area (ground level ozone, particulate matter, carbon monoxide, sulphur dioxide, and nitrogen dioxide). Like the weather, air quality can change from day to day or even hour to hour (USEPA,2010b).The EPA has revised the AQI with assigned colour and brief descriptors to categories of ambient concentrations of pollutants. The six categories now include: Good" (green), moderate (yellow), unhealthy (purple), unhealthy for the sensitive groups (Orange), Unhealthy (Red), very unhealthy" (hazardous (maroon). The pollutant with the highest AQI is used as the overall AQI reading for the day and it is listed as the principal pollutant (see table 1). Each category corresponds to a different level of health concern. The six level of health concern and what they mean according to USEPA Research Triangle Park, 2006 are;

1) **Good-**The AQI value for your community is between 0 and 50. Air quality is considered satisfactory, and air pollution poses little or no risk.
2) **Moderat**e-The AQI for the community is between 51 and 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.
3) **Unhealthy for Sensitive Groups**- When AQI values are between 101 and 150, members of sensitive groups may experience health effects. This means they are likely to be affected at lower levels than the general public. For example, people with lung disease are at a greater risk from exposure to particle pollution. The general public is not likely to be affected when the AQI is in this range.

4) 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.

5) Very Unhealthy- AQI values between 20 1and 300 trigger a health alert, meaning everyone may experience more serious health effects

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

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	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Each category corresponds to a different level of health concern:

Source: WHO (2000).

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, plants or animal life, or the property or which reasonably interferes with the comfortable enjoyment of life and property. On the other hand, it can be referred to as the discharge of harmful substances into the air to the extent that it can reduce visibility or produce undesirable odour (Abatan, 2007).It can also be defined as the introduction of chemicals, particulate matter, biological materials that cause harm or discomfort to organisms into the atmosphere.

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 leaves microscopic salt particles suspended in the atmosphere; smoke from forest fire is often carried high above earth; and volcanic spew many tons of fine ash particles and gases into the air(Ahrens,2008). Motorization, industrial processes (petroleum refineries, power generating stations, pulp and paper mills, ore smelters and incinerators) and the burning of fossil fuels release pollutants. In urban centres, cars, buses, trucks, motorcycles and airplanes, as well as industry and construction may cause air pollution (Parks, 2006).

Urban air is polluted by a number of toxic or potentially carcinogenic and mutagenic 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 population (Tomei *et al*., 2001). Ambient pollution is further compromised by the rapid urbanization of many developing countries. The global urban population climbed to 50% in 2008 and it is expected to rise to 60% by 2030. This rise would be particularly pronounced in developing nations, in which 80% of the urban population will be living in 2030 (UNEP, 1999). Accompanying this rise in urban population will be a fourfold increase in the number of motorized vehicles in the cities by 2050, making transport related pollution a hazard even in countries with overall low motorization rates

2.5.1 Brief history of air pollution

Human being probably first experienced harm from air pollution when fires were ignited in poorly ventilated caves. Since then man has gone on to pollute more of the earth's surface. Much of what is known of ancient civilizations comes from the wastes they left behind. Refuse such as animal skeletons and implements from stone-age cave dwellings in Europe, China, and the Middle East helps reveal hunting techniques, diets, clothing, tool usage and the use of fire for cooking. Prehistoric refuse heaps, or middens, discovered by archaeologists in coastal areas of North America revealed information about the shellfish diet and eating habit of Native Americans who lived more than 10,000 years ago (Chanlett,1993). Until recently, environmental pollution problems have been local and minor because of Earth's own ability to absorb and purify minor quantities of pollutants.

Development of new technologies by humans, the industrialization of society, the introduction of motorized vehicles, and the explosion of the population are factors contributing toward (and severity of air pollution (Schwela, 2000). Many historians speculate that the extensive use of lead plumbing for drinking water in Rome caused chronic lead poisoning in those who could afford such plumbing. The mining and smelting of ores that accompanied the transition from the Stone Age to the Metal Age resulted in piles of mining wastes that spread potentially harmful elements such as mercury, copper, lead, and nickel throughout the environment. Air pollution is not new. In medieval England, where burning coal was the primary method of heating, the black smoke from chimneys created problems. The king issued proclamations to regulate the use of coal, but this failed to solve the problem. Temperature inversion in London trapped fog laden with pollutants (created by burning coal) in which more than 4,000 deaths were attributed to this deadly 'black fog'.

Also, there was history of air pollution incidents in the United States. On October 27,1948, Donora, Pennsylvania was blanketed in fog, mainly due to weather conditions, which included a temperature inversion. During the four days of the episode, streetlights had to be turned on during the day, and 17 people died on the third day, mainly from respiratory ailments (Schwela, 2000).

In 1955, the visibility was drastically reduced by dense smog in Los Angeles. Air pollution was blamed for causing 2000 auto crashes in a single day. In 1966, New York had a three day temperature inversion over Thanksgiving weekend that was blamed for the death of 168 people. During the 20th century, pollution evolved from a mainly localized problem to one of global consequences in which pollutants not only persisted in the environment, but changed atmospheric and climatic conditions. In 1976, an explosion at a chemical factory in Seveso, Italy, released clouds of toxic dioxins into the area, exposing thousands of residents and killing thousands of animals that ate the exposed food. The world's worst industrial accident occurred in Bhopal, India, in 1948. A deadly gas leaked from an American chemical plant, killing more than 3800 people and injuring more than 200,000 (Afroz et al., 2003).

2.5.2 Air pollution in developed countries

According to a source air pollution from cars, trucks and other sources is killing more people globally than traffic crashes (WHO, 2001). More than 75% of all people in the developed countries now live in cities, which is a 60% increase since 1950. For developing countries this rate is even faster, with twice as many people now living in urban areas, as did 50 years ago. It does not matter where people live: New York, London, Toronto, Beijing Sydney, or hundreds of other cities, breathing dirty air has become a common fact of life. The haze of pollution is spread all over the place. The inmates are bustling through the polluted haze, hardly knowing anything about the poison they are inhaling (Islam, 2002). An estimated 2.7 to 3.0 million people every year (annually around 6% of all deaths) die due to air pollution according to Population Reports. The source also mentioned deaths caused by air pollution in Brazil, Sao Paulo, Mexico city and New York City. Researcher anticipated that adopting green gas mitigation methods, which are currently available, would save 64,000 lives in these cities during the next twenty years. This dangerous attack would also stop 65,000 cases of bronchitis and save about 37 million days of restricted or lost work (WHO, 2000).

Although argument about energy options, long term climate change impacts, and the ability to adapt to those impacts go on with the progress, there is small reservation that air pollution from current patterns of fossil-fuel use for electricity generation, transport, industry and housing are already killing millions throughout the humankind (Afroz et al., 2003). Research team

researched ozone, particulate, carbon dioxide and other pollutants from the combustion of fossil fuels, which create the so-called greenhouse gas, affect the climate in coming decades. These pollutants also cause premature death from asthma, heart disease and lung disorders (The Nation Health, 2001). In the past, air pollution research found that reducing emissions from older, coal-fired power plants in the United States would avoid 18700 deaths, 3 million lost days and 16 million restricted activity days each year. One research showed that reducing emission from nine older coal plants in the Midwest would prevent 300 deaths (yearly), 2000 respiratory and cardiac hospital admissions, 10,000 asthma attacks and 400,000 days of respiratory symptoms. In current research, investigator alleged reducing air pollutants could bring even more public health benefits that they did not chart (Afroz et al., 2003).

Another influential minor pollutant is acid rain, created when sulfur dioxide and oxides of nitrogen combine with water vapor and oxygen in the presence of sunlight to form a watery "soup" of sulfuric and nitric acids. They can fall as either wet (acid rain) or dry deposition. Other damaging pollutants comprise sulfur dioxide, suspended particulate matter (soot, ash, and smoke from fires), carbon monoxide from vehicle exhausts, and lead, mostly from the exhaust of vehicles that burn leaded gasoline (Afroz et al., 2003).

2.5.3 Air pollution in developing countries

“In many developing countries, atmospheric pollution is a serious hazard, responsible for at least 2 million deaths annually. Curbing outdoor and indoor air pollution would improve health substantially. Over 2.2 million Children die of respiratory infection associated with indoor air pollution a year in developing countries. In the developing countries, about 9 deaths in every 10 due to air pollution take place. Nearly in all the developing countries (About 2.5 billion people) suffer from high levels of indoor air pollution resulting from burning wood, animal dung, crop residues, and coal for cooking and heating are women and girls are the sufferers of indoor pollution, whose primary responsibility is cooking and looking after the house. In contrast, mostly in cities outdoor air pollution harms 1.1+ billion people (WHO, 2000).

Smelters, lead pots, and pipes are typically held accountable by the specialist for loss of intelligence among children and for brain damage and unusual behavior among grown persons.

Heavy metals released into the environment emerge from uncontrolled emissions by metal smelters and other industrial activities, unsafe disposal of industrial wastes and lead in water pipes, paint, and gasoline. These heavy metals are most dangerous to human health (lead, mercury, cadmium, arsenic, copper, zinc, and chromium). These metals are occurring naturally in the soil in trace amounts, which create several harms. When concentrated in particular areas, they present a serious danger. Arsenic and cadmium can be the source of cancer. Mercury can be the cause of mutations and genetic damage, and copper, lead, and mercury can be the cause of brain and bone damage (WHO, 2000).

Lead additives in gasoline cause well-known health problems. In Thailand, in 1990 a survey established that some 70,000 children in Bangkok risked losing more than four points of IQ because they were largely exposed to lead emissions from vehicles. In Latin America, some 15 million children (less than two years) are at risk of health troubles from lead pollution. In 1970 United States Leaded gasoline began to be phased out after clean Air Act. It was not up until eighties, the European Community followed suit. Elsewhere, such as Bangladesh, leaded gasoline continues to be used widely. As a result, high levels of pollution impair photosynthesis, air pollution is also reduces food production and timber harvests. In Germany, in a year 4.7 billion dollar (US$) is lost in agricultural production due to high amount of sulfur, nitrogen oxides, and ozone (WHO, 2000).

In developing countries, the World Health Organization estimates that annually about 700,000 deaths could be prevented if three major atmospheric pollutants carbon monoxide, suspended particulate matter, and lead were brought down to safer point. In 1995, in developing countries the health expenditure of urban air pollution was estimated almost US$100 billion a year. Around US$40 billion accounted for chronic bronchitis. Millions of people are at risk from air pollution in citieswhere pollution control is not stringent. Bangkok, Dhaka, Manila, Mexico City, and New Delhi, which are one of the densely populated and rapidly growing cities in the world, are often entombed with air pollution from trucks, taxi, and motorcars and from uncontrolled industrial discharge. In 1995, in Mexico City the standard ozone concentration was about 0.15 parts per million, ppm, which are 10 times the natural atmospheric concentration and also twice the maximum permitted in Japan and or the United States of America.

2.5.4 Air pollution in Nigeria

In Nigeria much attention is given to general industrial pollution and pollution in oil industries, with little reference to the damage caused by mobile transportation sources of ambient air pollution (Faboya, 1997; Magbagbeola, 2001).The situation of increased pollution from mobile transportation source is on the increase as the number of car owners increase, thus resulting in high congestion on Nigeria city road and increase in the concentration of pollutants in the air, consequently, increasing health risk on human population *(Abam and Unachukwu, 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 round-about, Kaduna, and 1530ppm for Aya, Abuja, 1160ppm for Asokoro Abuja (Akpan *and Ndoke,* 1999). Similar study by Ndoke and Jimoh, 2000, at Minna, a city in Nigeria shows the maximum value of 5,000ppm for CO_2 in congested areas, which was still lower than WHO stipulated maximum value of 20,000ppm.

The maximum value for CO emission obtained was 15ppm still lower than the guideline limit of 48ppm stipulated by WHO 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, (2007) in three cities of Nigeria: Lagos, Ibadan and Ado – Ekiti all in South-west region of Nigeria. Air quality indicators namely CO, SO_2, NO_2, and total suspended particulates (TSP) were determined. The highest levels obtained for the air pollution indicators in Lagos were CO-233 ppm at Idumota, SO_2-2.9 ppm at Idumota, NO_2-1.5 ppm at Iyana–Ipaja and total particulates 852ppm at Oshodi bustop. In Ibadan, the CO and SO_2 levels at 271 and 1.44 ppm were highest at Mokola round about while NO_2, at 1.0 ppm was highest at 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. Conclusions of this investigation show a growing risk of traffic-related problems in Nigerian 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 Jerome, (2000). The results obtained in Table 2.2, 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 is quite high, being in the range of 10 – 250 ppm recorded higher than the ranges of 5.0 – 61.0 ppm and 1.0 – 52 ppm recorded for oil communities in the Niger Delta. The TSP concentrations are also high for both cities when compared to WHO's guideline limit.

However, the overall levels of vehicular related air pollution in Nigeria from all the studies conducted show an increasing trend and thus possess a potential hazard 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 as a result of 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).

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;

(i) Dust from natural sources, usually large areas of land with little or no vegetation.

(ii) Methane, emitted by the digestion of food by animals, for example cattle.

(iii) Smoke and carbon monoxide from wildfires.

(iv) 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.

(v) Volcanic activity, which produce sulphur, chlorine, and ash particulates (Goldstien *et al*., 2009)

Anthropogenic sources include;

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

(ii) **Mobile Sources**- include 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 pollution

Rapid urbanization and industrialization led to increase in air pollution level of cities worldwide. The population of cities, motor vehicles, motor fuel consumption increases and finally air pollution level increased (Gee and Raper, 2004). Vehicle emissions represent a serious environmental health problem, which is expected to rise in significance as vehicle ownership increases globally (Enemari, 2001). In urban centers, the population is very large and the traffic volume is relatively high, so the exposure of people to the traffic related concentrations is significant. In most European cities urban air quality has become more and more affected by

traffic related pollutants in recent years. Vehicular traffic is known to be one of the major, if not the largest, sources of atmospheric particulate matter (PM) in the urban environment (Almeida *et al*., 2005; Viana *et al*., 2008; EEA, 2009; Gietl *et al*., 2010). Other studies also point to the traffic sector as a major contributor to diffuse metal emissions (EEA, 2004; Sorme *et al*.,2001).

Exposure to air pollution, especially traffic related particulate pollution, PM_{10} (particulate matter which passes through a size selective impactor inlet with a 50% efficiency cut-off at 10μm aerodynamic diameter) is now an almost inescapable part of an urban life throughout the world. Dust from paved and unpaved roads, construction and demolition, and bare ground sites are important contributors to PM_{10} (Chow and Watson, 2002). Traffic emissions are generally produced via the exhaust, by abrasion of vehicle parts and by re-suspension of material deposited on the roads. The emissions depend on number factors such as vehicle age, engine design and operating conditions, lubricant oil and fuel. Also diesel engines in developing countries are generally old, and exhaust emission controls are rare and most of particles emitted from diesel exhaust are in submicron size and diesel exhaust particle is a complex that has been linked to acute cardiopulmonary and vascular responses, chronic health effects, and lung cancer in a number of epidemiologic studies (Lim et al., 2010).

The presence of particulate matter below ten microns size (PM_{10}) is significant due to the associated respiratory health implications (Byrd *et al*., 2010) and other negative health effects. A recent study in Sweden, found that PM_{10} generated by erosion of road pavement by studded tyres provoked an inflammatory responses in cells as potent as the response caused by diesel particles (Luginaah *et al*., 2005). Transport Research Arena Europe 2010, Brussels reported that the emission factor for PM_{10} derived from the road simulator experiments corresponds well with those derived from ambient air measurements near busy streets. The main source to PM_{10} concentrations near busy streets has been found to be road surface wear (50% of the overall PM_{10} mass), and other local traffic sources (exhaust, brake and tyre wear) contribute another 20%.

Urban traffic related air pollution problems are further aggravated by meteorological and topographical factors that often accumulate pollutants in the city and prevent proper dispersion and dilution. Ambient particulate matters also have adverse impact on environment including change in cloud formation, scattering solar radiation and visibility impairment. Toxicological

studies show that the health effects of particles are dependent on their chemical composition (Mugica *et al*., 2002). Heavy metals have a great ecological significance due to their toxicity and cumulative behavior (Mesa *et al*., 1999).

High vehicle traffic was proven to be one of the important heavy metals emissions sources and Zinc, copper and lead are three of the most common heavy metals emitted by vehicle traffic, totaling at least 90% from the total emitted quantity. Also, vehicle traffic is responsible for the emission of some small quantities of other metals, like nickel and cadmium (EPA, 2003). Fine particles from traffic related emissions are also often enriched in potentially toxic heavy elements (Fernandez Espinosa *et al*., 2002), such as Chromium (Cr) from fuel combustion, Sb and Copper (Cu) from brake–lining materials and Zinc (Zn) from tire tread.

Exposure to heavy metals in road particulate matter can occur by means of ingestion, inhalation and dermal contact and when the concentrations of heavy elements in aerosols exceed critical thresholds, they may pose potential toxic effects on human health and ecosystem. Therefore, it is important to quantify heavy element concentrations near the highways, significant sources of air pollutant emissions. Heavy metals associated with air-borne particulate matter (PM) have different speciation or fractions that exhibit different bioavailability and potential risk to human beings. Shortness of breath, coughing, wheezing, septum, bronchitis, decreased pulmonary function, pneumonia, and other respiratory disorders have been observed from chronic exposure of chromium (Cr) (Mugica *et al*., 2002).

Atmospheric lead (Pb) can adversely affect nervous system, the hemo group syntheses and the vascular system, especially to children (Mugica *et al*., 2002). Cadmium (Cd) is a possible carcinogen and its chronic exposition to high concentrations can result in respiratory illness. Continuous and prolonged exposure to Nickel (Ni) may produce dermatitis and disorders to respiratory system. Manganese (Mn) is a neurotoxic element whose prolonged exposure leads to neurological disease called manganism. Zinc and iron deteriorates human metabolism. Iron is a potentially toxic element that acts as a catalyst in the development of the highly poisonous free oxygen radicals in living organisms. Endocrine system malfunction and immune system suppression may also occur (Ferreira-Baptista and Miguel, 2005).

These particles remain suspended in the air for a long time, and distribute or redistribute other pollutants absorbed with them, especially metals. Particulate matters may also account for climatic changes as they have the property of absorption of light energy. The movement and fate of PM depends on the physical nature of the PM and meteorological conditions of the surrounding areas (Fernandez *et al*., 2000). Since the metals are natural constituents of the earth's crust and are widely distributed in environmental matrices, the humans are easily exposed to them even at trace levels (AMAP, 1997) by either anthropogenic activities or by necessity. When these metals are concentrated in the environment, air, food and water, they affect the health of humans and animals (Abulude *et al*., 2003). Studies in Greek cities revealed that heavy metals represent an important fraction of the PM of the atmosphere with increased content in inhalable fraction. Indeed, several studies suggest an association between fine-particulate air pollution and the increase of the rate morbidity/mortality cases (Arden-Pope and Dockery, 2006).

Unlike the industrialized countries where much research has been done, little seems to have been done in developing countries, especially in Africa with regard to motor vehicle air pollution. The little information available on transport related pollution in Nairobi city indicates high pollutant emissions (Gatebe *et al*., 1996). In key urban centers, such as Lagos, heavy dependence on oil-dominated transportation is the major contributor to degraded air quality. Studies in Ethiopia, Mozambique, and Kenya found significantly higher prevalence of asthma in urban school children exposed to traffic pollution compared to rural children. Motor vehicles produce more air pollution than any other single human activity.

However, the overall levels of vehicular related air pollution in Nigeria from all the studies conducted show an increasing trend and thus possess a potential hazard to the population. In Nigeria, problem of pollution from vehicular emission is worsened by limited street space, traffic delays, poorly maintained vehicles and roads and lack of emission control and management programmes and high tailpipe emission and many homes and offices are also built so close to major high traffic areas that the occupants live their daily lives in traffic induced pollution conditions .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 which no longer meet environmental standards, especially tailpipe

emission in Europe and other blocks of developed nations into the country following changes in government policy. In Nigeria, air quality is further compromised by the lack of automotive emission standards (Faboya, 1997).

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 the pollutant losses from industrial processes. Industrial processes include refineries, chemical manufacturing facilities, and smelters (USEPA, 2010a). 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 smokestacks, 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, 2010a).

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, 2010a).

2.6.2.1 Thermal power plants

They are the major sources of NOx, SPM and SO_2. Depending upon the type of fuel used, emission of one or more of these pollutants may be environmentally significant. A large amount of suspended particulate matter as fly ash is produced from coal fired plants, particularly if the ash content of the coal is high and a fly ash removal unit, such as, an electrostatic precipitation (ESP) is not used. The flue gas from combustion of the fossil fuels is discharged to the air. This gas contains carbon dioxide, water vapour, mercury, traces of other metals. Fossil fueled power stations are major emitters of CO_2, a greenhouse gas (GHG) which according to a consensus opinion of scientific organizations is a contributor to global warming as it has been observed over the last 100 years (Nel, 2005).

2.6.2.2 Industrial source

2.6.2.2.1 Cement manufacture

Raw materials include lime, silica, iron and aluminum. Lime is gotten from calcium carbonate. Other raw materials are introduced as clay, sand, shale, and blast furnace slag. The process consists of mining, crushing, grinding and calcining in a long cylindrically shaped oven or kiln. Air pollutants can be generated at several processes listed above.

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 et al., 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, 2000).

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,

2000). 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 move on them. The potential risk posed by ambient air pollution varies by the concentration and composition of this mixture, which can vary by location, time of the day or year, and meteorological conditions (Etzel, 2003).

2.8 Outdoor air pollutants

Air pollutants can be carried hundreds or thousands of miles across borders and oceans or from one city centre to another. This process is known around the world and is referred to as 'long-range atmosphere transport" or trans-boundary pollution (Amato *et al*.2002)

There are basically three types of air pollutants viz:-

1) Physical
2) Biological
3) Chemical

The chemical air pollutants are further divided into two namely:-

a) Hazardous pollutants
b) Criteria pollutants

2.8.1 Hazardous pollutants

Polluted air contains one or more hazardous substance, pollutants or contaminant that creates a hazard to general health of humans and the environment. They are also known as toxic air pollutants or air toxics, are those pollutants that cause or may cause cancer or other grave health effects, such as birth defects, reproductive effects or adverse environmental or ecological effects. While over 200 of these toxic chemicals have been detected in ambient air, it has been very difficult to gauge the extent of potential health risks because so few communities monitor for this kind of pollution (USEPA, 2009).

EPA is required to control 187 hazardous pollutants. Examples of toxic air pollutants include benzene, which is found in gasoline; methyl chloride, which is used as solvent and paint stripper by a number of industries and perchloethlyene, which is emitted from some dry cleaning

facilities. Other hazardous pollutants include Asbestos, Aniline, Acrolein, Carbon tetrachloride, Formaldehyde, Hexane, Methanol, Naphthalene, Phenol, Quinoline, Vinyl acetate, and Xylene. Hazardous pollutants originate mostly from man-made activities. These include mobile sources (cars, trucks, and buses) and stationary sources (factories, refineries, power plants)(USEPA,2009)

2.8.2 Criteria Pollutants

Six pollutants are used to determine the air quality of an environment which is regulated by Environmental Protection Agency (EPA). These pollutants are:-

- Carbon Monoxide(CO)
- Lead(Pb)
- Nitrous oxide (NO_2)
- Ozone (O_3)
- Sulphur dioxide (SO_2)
- Particulate matter, fine $PM_{2.5}$ and coarse PM_{10}

(Amato et.al, 2002, Kyles *et al*, 2001)

2.8.2.1 Particulate matter

Airborne particulate matter is the generic term used for a type of air pollution that consist of complex and varying mixtures of particles suspended in the air we breathe. Particles are present everywhere, but high concentrations and specific types of particles have been found to present a serious danger to human health. Particulate matter is a combination of fine solids such as dirt, pollens, soil dust, moulds, ashes, and soot; and aerosols that are formed in the atmosphere from gaseous combustion by-products such as volatile organic compounds, sulphur dioxide and nitrogen oxides (EPA, 2003).

Perhaps no other pollutant is as complex as particulate matter. It's a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot or smoke, are large to be seen with the naked eye. Others are so small; they can only be detected using electron microscope. These tiny particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some of these particulate matters are emitted directly from a source, while others from complex chemical reactions in the atmosphere. Some are not stable, they can

change back and forth from gas to particle form. Particulate matter is made up of different chemical components, or species are carbon, nitrate and sulphate compounds, and crustal materials such as soil and ash. The different components that make up particulate matter pollution come from specific sources and are often formed in the atmosphere. Particulate matter pollution also varies by time of year and by location and is affected by several aspects of weather such as humidity, temperature, precipitation and wind (Janssen, 2001).

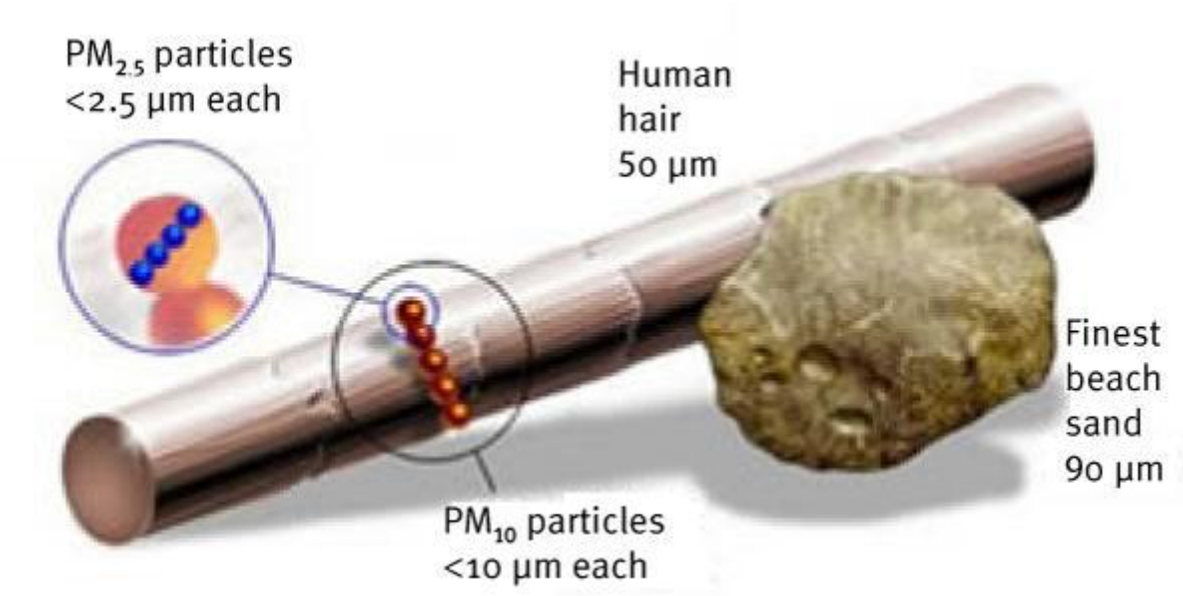

Fig 2.2: Different sizes of particulate matter

Source: USEPA, 2010

- **Fine particles**: The smallest particles (those 2.5 micrometers 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 0.1µm 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 micrometers 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 (Janssen, 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).

2.8.2.2 Carbon monoxide

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, 2003). 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 carboxy-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 (USEPA, 2010b).

2.8.2.3 Sulphur dioxide

It 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 thus acid rain (USEPA, 2010a). 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 (WHO, 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, 2010b). 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). SOx 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, 2010b).

2.8.2.4 Nitrogen dioxide

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*., 1996)

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) µg/m3, respectively (Goyal, 2006).

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.

2.8.2.5 Ground-level ozone

Ground level ozone (O_3) formed from NO_x and 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 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 200 µg/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, 2010a).

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).

2.8.3 Green House Gases

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 2.3: Annual Emissions of Greenhouse Gases for the city of Toronto

Source of Emission	**Greenhouse gas emissions (eCO2 tonnes/year)**
Residential	5,997,042
Commercial and small industry	6,884,767
Large commercial and industry	2,002,172
Transportation	8,558,966
Waste transport to Michigan	35,507
Streetlights and traffic signals	29,203
Waste (methane and landfills)	924,550
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

2.9 Types of particulates

2.9.1 Dust

Smoke is a mixture of very fine particles and the particles differ depending on what material the dust came from, how the dust was created, and what happened to the dust after it was released. Analysis of dust samples will provide information on the components of the dust. The fume and dust are included in chemical materials, given dust particle may be a complex conglomerate of minerals and absorbed gases and vapours.

2.9.2 Smoke

Smoke is composed of many tiny particles of carbon compounds from the burning of organic matter such as coal, dung or wood. It can also come from tobacco smoking. The smell of wood smoke evokes lovely memories for many people, but for other it has become danger signals (Wikipedia, 2010). Wood smoke largely from wood stoves has become a major part of air pollution in the United States

2.9.3 Soot

It is powder-like form of amorphous carbon resulting from the incomplete combustion of a hydrocarbon. The Thomas report uses carbon black as a surrogate for soot because human health effects data and established occupational exposure standards are available for carbon black, and because the United State Army Environmental Hygiene Agency (US AEHA) data from the Gulf War shows the soot to be well-combusted, carbon- based material similar in properties to commercial carbon black.

2.10 Physical characterization of particulate matter

Physical characterization of atmospheric particles includes determination of size, size distribution, shape, optical features, elemental, molecular and isotope structure. All these properties profoundly influence the behaviour of atmospheric particles, and their effects on health and environment. The effect of particle size is strongly dominant as it influences the aerodynamics, respirability, lifetime and removal from the atmosphere. The particle shape controls the toxicity and respirability. Characterization of particles and size distribution help in knowing the possible source. The atmospheric particles show evidence of the three major modes (Molnar et al, 2002). The first (nucleation mode) is attributable to the nucleation process and contains a very large number of particles of 10 nm in diameter.

The mass in this component is often a small fraction of the total aerosol mass concentration. In the second component, the accumulation mode, particles, roughly in the size range 0.05 to 2μmdiameters are long-lived in the atmosphere. They are important tracers for long range transport and efficient light-scatteres, so they are often dominant in optical effects such as visibility. The third peak to particles with diameters between 10 μm and 100 μm; they don't stay long in the atmosphere due to their sizes, very variable according to local conditions, and likely to travel distances typically of metres to hundreds of kilometers according to size and wind speed. They may contribute substantially to aerosol mass, although the number of such particles is often small.

Dusts are particulate formed by abrasion, cutting, and shattering. These actions result in sizes which remain airborne from a matter of a few second to many hours and result in an enormous aggregate surface area for the mass. The suspension in air and particle size determines the

likelihood of the dust particles being inhaled along with its penetration and retention in the respiratory system.

2.11 Sources of Particulate Matter

The ultrafine particles of size range less than 0.1mm are formed by nucleation that is condensation of low-vapour pressure substances formed by chemical reaction or by high-temperature vapourization in the atmosphere to form new particles (nuclei). They come mostly from anthropogenic source such as emission from diesel engines, automobile exhaust, wood smoke and generators. In close vicinity of the road, automobiles contribution to fine particle concentration was 68% (Wrobel, 2000). Particulate matter includes both "primary" PM, which is directly emitted into the air, and "secondary" PM, which forms indirectly from fuel combustion and other sources. Generally, coarse PM is made up of primary particles, while fine PM is dominated by secondary particles.

Biomass combustion is an important source of inhalable particulate matter smaller 10 microns (PM_{10}) in the ambient air. Since PM_{10} is regarded as one of the most relevant parameters in air pollution (Dockery and Pope, 1994). Coarse particles ranging from 1-200 mm are predominantly rock or soil material of natural sources spewed into the atmosphere by mechanical grinding or spraying. These particles can include wind- blown dust from agricultural processes, road dust, uncovered soil, unpaved roads or mining operations. Traffic produces road dust and air turbulence that can re-entrain road dust. Near the coast, evaporation of sea spray can produce copious particles.

In the urban atmosphere, dust arises due to agitation of soil through activities such as vehicular movement (Miranda et.al, 2000), construction and earth –moving. An estimated 80% of the coarse particle from traffic in the urban environment settles within 150m distance from the road. PM_{10} fraction that causes significant health impacts is dominated by particles from three sources (Harrison *and Yin* 2000) viz ;

(i) Primary fine particles from industrial and combustion sources, mostly road traffic.

(ii) Secondary aerosol, predominantly ammonium sulphate and ammonium nitrate formed through photochemical reactions.

(iii) Wind-blown soil and re-suspended street dust presently largely in coarse fraction (2.5-10mm). These particles make a significant contribution to the particle mass, with coarse particles showing seasonal variation from about 20% of the total PM_{10} mass in winter to 50% in summer, reflecting the impact of drier summer climate on the re- suspension process.

Re-suspension of paved-road dust found in urban atmosphere contributing up to 25-63% of the PM_{10} (Ferreira-Baptista and de Miguel, 2005). Primary PM consists of soot spewed from cars, trucks, heavy equipment, burning waste and forest fires and crustal materials from unpaved roads, stone crushing, construction sites and metallurgical processes while secondary PM forms in the atmosphere from gases. Sunlight and/or water vapour is needed for these reactions to take place.

Secondary PM include:-

- Carbon formed from reactive organic gas emission from cars, trucks, industrial complexes, and forest fires.
- Nitrate formed from nitrogen oxide emissions from power plants, cars and trucks.
- Sulfates formed from sulphur dioxide emission from industrial complexes and power plants.

2.12 Dispersion

Dispersion is the scattering of gases and particles in the atmosphere, so that they leave their source and become progressively less concentrated. There are a number of atmospheric processes which lead to dispersion of contaminants. Dispersion of the atmospheric particles in the air is affected by meteorological conditions (wind speed, wind direction and atmospheric stability), the emission height (e.g. ground level sources such as road traffic or high level sources such as tall chimneys), local and regional geographical features, the source (e.g. fixed point, such as a chimney, or a diffuse number of sources such as cars and solvents). Meteorological conditions can be described as either stable or unstable, where the stability is determined by wind (which stirs the air) and heating effects (which cause convection currents) (EEA, 2004).

Atmospheric stability affects pollution released from ground level and elevated sources differently. In unstable conditions, ground level pollution is readily dispersed thereby reducing

ground level concentrations. Elevated emissions, however, such as those released from a chimney, are returned more readily to ground level, leading to higher ground level concentrations. Stable conditions mean less atmospheric mixing and therefore higher concentrations around ground level sources, but better dispersal rates, and therefore lower ground level concentrations, for elevated plumes (EEA, 2007).

2.13 Meteorological factors that affect air quality

Amongst all the meteorological parameters, wind speed has been the most closely studied with regard to exposure since it influences the dispersion and dilution of pollutants. In all, both ambient; (Holmes *et al*., 2005) and exposure (Krausse and Mardaljevic, 2005) studies have identified that an increase in wind speed results in a decrease in exposure concentrations to fine particulate matter and CO. Wind speed was also said to be a significant determinant of ultrafine particle count and CO exposure levels shown in a multi-mode exposure study (Kaur et al, 2005). Interestingly, Almeida *et al*., (2005) found that while elevating wind speed decreased the finest PM fraction counts, it increased (windblown dust) the count of coarse PM.

Seasonal variations in ambient temperatures and traffic volumes influence total automotive emissions. Also, seasonal variations in wind speeds affect the dilution and dispersion of those emissions on roadways. Dor *et al*. (1995) in France and Ott *et al*. (1994) in northern California and, who both measured in-vehicle CO exposures for an entire year, reported that they were generally higher in fall/winter than in spring/summer. They attributed this result to colder winter temperatures which increase CO emissions per vehicle mile. Higher summer temperatures have the opposite effect.

Ambient temperature and local meteorology affect the concentration and location of vehicle-emitted pollutants. For example, elevated sulphur dioxide levels are typically reported during winter and elevated ground-ozone levels during 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. Dispersion of pollutants is also affected by other meteorological factors like humidity, wind speed and direction and general atmospheric turbulence. Some studies pointed out that wind direction does have considerable impact on fine particulate matter and other pollutants concentration levels. Measured fine particle count pedestrian exposure levels

during northerly prevailing winds to higher on the south side compared to the north side of an intersection. This may most likely be due to road and building configuration causing recirculation of the wind in the street causing pollutants to be higher on one side of the street in comparison to other (Lung *et al*., 2005).

2.14 Selected heavy metals that may be found in particulate matter.

Heavy metals are collection of metallic chemical elements that have relative high density that exceed 4.5 g/cm^3 and are toxic or poisonous at low concentrations, and they differ significantly in terms of toxicity, namely arsenic, cadmium, chromium, lead, nickel, copper, zinc, iron, mercury, and platinum. They are natural constituent of the Earth's crust. Heavy metals are stable and cannot be destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain. Heavy metals are dangerous because they tend to bioaccumulate.

However, human activities have seriously altered the biochemical and geochemical cycles and balance of some of these heavy metals. The main man-made origins of heavy metals are traffic, industrial point sources, e.g. mines, foundries and smelters, and diffuse sources such as combustion by-products e.t.c. . Relatively volatile heavy metals and those that become attached to airborne particles can be widely dispersed on very large scales. Lead, arsenic, mercury and cadmium are metals that occur naturally in soil, air, dust and water. Since theses compound do not have any smell, it is difficult to tell when they are present. In the environment, lead, mercury, cadmium and arsenic are usually found combined with other elements. The toxicity of these metals and their fate in the environment is determined by the complexes they form with these elements.

Lead is a high density element which is soft, flexible, and malleable poor metal. It is highly resistant to corrosion but does react with nitric acid, and with boiling sulphuric or hydrochloric acids. It does not occur naturally in the metallic state. Lead compounds have variety number of uses. Lead oxide is incorporated into glass to prevent the escape of radiation from cathode ray tubes especially from televisions and computer screen and for the manufacture of crystal glass.

The use of lead in paint has virtually disappeared, with lead carbonate and lead sulphate pigments no longer permitted in many countries around the world. Lead glazes are used for hygienic scratch-free surfaces on ceramics product it against degradation. It is found in the natural environment and it was added to various products in the past including paint and water pipes. Humans are usually exposed to lead occupationally and from environment as a result manufacturing, mining, and burning of fossil fuels. Lead was found in homes built before 1970 where lead- based paint was used. The primary routes of human exposure to lead are through inhalation of air and ingestion of water, food, soil and dust (Hong et.al, 2010).

The relative importance of any single source of exposure is difficult to predict and will vary with local geochemistry and geographic location. The amount of lead absorbed into the body is known to vary depending on the concentration and composition, i.e. particle size, chemical form of the lead inhaled or ingested. In addition, children are exposed to lead via polluted dust and soil contaminated by deposition from air and other sources. In the environment, lead is known to be toxic to animals, plants and microorganisms. Generally, effects are localized to contaminated areas. Lead concentrations in the ambient air were reviewed in 2008, and a limit value of 500ng/m^3 was specified based upon the WHO guideline limit. Important mechanisms underlying the toxic effects were the oxidative stress. It was reported that production of reactive oxygen species (ROS) exposed to lead alters the status of ROS or oxidative stress leading inflammatory reaction (Hong et al., 2010). Lead is therefore one of the metals responsible for the effect of particulate matter pollutants.

Zinc is an important element for cell differentiation and proliferation, and it also essential element in preventing free radicals formation (Stefanidou et.al, 2006). Excess zinc in the body can be harmful. Excessive presence of zinc in the body can suppress iron and copper absorption in attendant symptoms of anemia and neutropenia, as well as impaired immune function and adverse effects on the ratio of low-density-lipoprotein to high-density-lipoprotein (LDL/HDL) cholesterol have been reported.

Cadmium is typically a metal of the 20th century, even though large amounts of this by-product of zinc production have been emitted by non-ferrous smelters during the 19th century. Currently, cadmium is mainly used in rechargeable batteries and for the production of special alloys. Metal smelting operations and soldering may also emit cadmium into the air. Mining activities, and

industrial and hazardous wastes may contaminate groundwater with cadmium. Cadmium is a relatively rare metal, it does occur mostly in association with sulphide ores of other metals. Oral uptake of cadmium is the most important route of exposure; sufficient evidence is available to show that cadmium in ambient air constitutes a serious risk to human health and environment. Once absorbed, cadmium irreversibly accumulates in the human body, in particularly in kidneys and other vital organs such the lungs or the liver. In addition to its extraordinary cumulative properties, Cd is also a highly toxic metal that can disrupt a number of biological system.

2.15 Summary of Literature Review

The air that goes into our lungs contains several toxic pollutants, sulphur oxides (SOx), carbon oxides (COx), nitrogen oxides (NOx) and dust with a diameter of less than 2.5 or 10μm ($PM_{2.5}$ or PM_{10}). Each of these factors causes air flow limitation, and increase the prevalence of bronchial hyper-reactivity and airways infections. The influence of air pollution on our health has been well documented for a long time. In Nigeria, various researches have implicated a high level of ambient air pollution in most urban centres. Most air quality assessments in major cities in Nigeria revealed that the levels of volatile oxides of nitrogen, sulphur, carbon and total particulate matter exceed WHO permissible limits for urban centres.

According to the global estimate made by the United Nations Environment Programme, over 1 billion people breathe unhealthy air every day and according to Wrobel *et al*., 2000, traffic–generated emissions are accounting for more than 50% of the total PM emissions in the urban areas. At present, over 600 million people living in urban areas worldwide are being exposed to dangerous levels of traffic–generated air pollutants (Cacciola *et al*., 2002). This increases the number of hospital admissions and deaths worldwide, because health effects resulting from these especially cardiopulmonary related problems are enormous.

The occurrence of toxic heavy metals in the respirable fraction of PM is assumed to contribute to substantial health effects. Some of the particulate heavy metals are strong triggers for carcinogenesis, teratogenesis and mutagenesis because heavy metals have a great ecological significance due to their toxicity and cumulative behavior. This amounts to 0.80 million premature deaths and 6.4 million lost life years around the world. Most of the studies focused on the cardiopulmonary effects of these pollutants as well as other non-cardiopulmonary effects

such as eye irritation, bad smell e.t.c. The Nigerian Federal Environmental Protection Agency (FEPA) now under the auspices of National Environmental Standard and Regulations Enforcement Agency (NESREA) now has standard air quality guideline limit for occupational exposure over an eight hour period. Large number of researches carried out in Nigeria showed that the concentration of air pollutants were beyond these guideline limits.

Many recent studies have shown that, populations living, working, or going to school around major motorways are exposed to high particulate matter burden and subjected to an increased risk for a number of adverse health effects because they are directly and frequently exposed to toxic emissions from vehicles and trucks that commonly ply these routes. The degradation of air quality arising from these is another serious dimension of the problem. Locally, most studies on traffic-related particulate matter have provided little information on levels of heavy metals present in traffic-related particulate matter and most people do not know the hazards they are exposed to on daily basis due to limited information on levels of heavy metals from traffic activities.

CHAPTER THREE
METHODOLOGY

3.1 Study design

The study was a descriptive survey which involved environmental field sampling of ambient particulate matter (PM_{10}) and laboratory analysis of selected heavy metals. It also involved traffic density estimation which was done via manual counting and onsite observation of activities contributing to particulate matter burden in the area.

3.2 Study area

The study was carried out in Ibadan Northeast Local Government Area. Ibadan is the capital city of Oyo State. It is located in the south-western region of Nigeria. It lies between latitude 7° and 9°3°' east of prime meridian. It has an altitude generally ranging from 152 to 213m with isolated ridges and peaks rising to 274m. Its population is estimated to be about 3.8 million according to the National Population Commission's 2006 census estimates. The principal inhabitants of the city are the Yorubas (Brown, 2009).

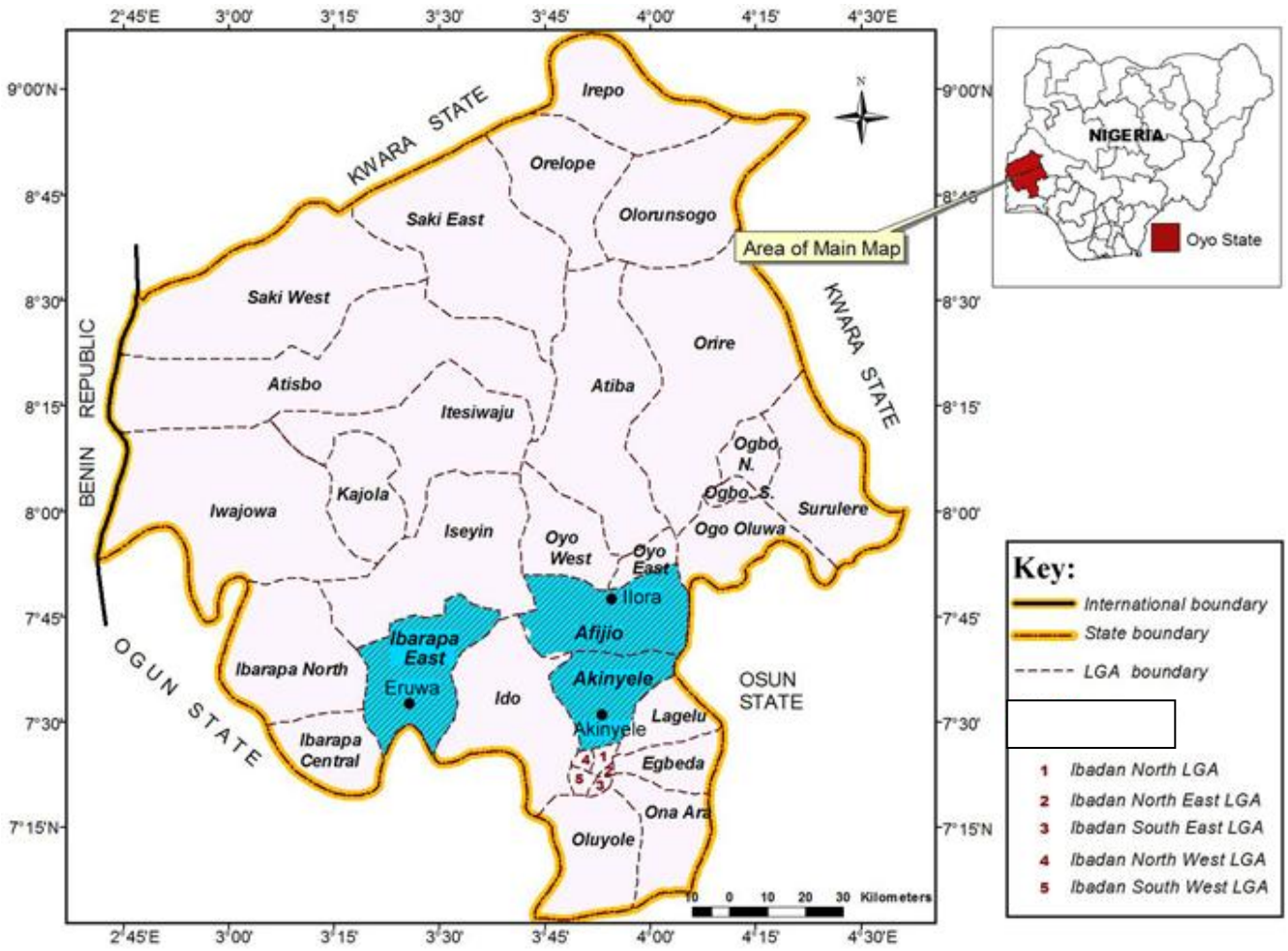

Fig 3.1Map of Nigeria showing the location of Oyo State

Source: www.emeraldinsight.com

3.2.1 Brief description of Ibadan Northeast Local Government Area.

The administrative headquarters is located at Iwo road. Ibadan Northeast Local Government is approximately 128 km from Lagos by most direct route and about 440 km from Abuja, the Federal Capital Territory (FCT) (Mabogunje, 2002). It is bound by Zenith Bank Plc and Akinyele shopping complex in the west and east respectively. It has a population figure of 330,399 according to the final result of 2006 census released by the National Population Commission (NPC, 2006). There are twelve wards within the Local Government Area.

3.3 Description of sampling points

Five sampling locations viz: Abayomi area (AA), Iyana-agbala (IA), Barracks Area (BA), Agbaakin Layout (AL) and Holiness Junction (HJ) were purposively selected along Idi-ape – Iwo road area. At each sampling location, PM_{10} was measured at 10 metres, 20 metres and 30 metres away from the main road (see Table 3.1)

3.4 Particulate matter (PM_{10}) sampling

Particulate matter sampling was carried out for a period of ten weeks (December 2011 -March, 2012). The measurements were done twice a week for each of the sampling points and the sampler was set up in the morning (7-10.30 am) and afternoon (1-4.30 pm). The reason for this periodic determination of particulate matter (PM_{10}) was to capture peak periods where dust or particulate matter is produced.

3.5 Determination of sampling coordinates

A hand held battery-powered factory calibrated Garmin Geographical Positioning System (GPS) was used to obtain the geographical coordinates of the sampling points selected for particulate matter determination and the results are presented as Latitudes, Longitude and elevation. The GPS is a satellite based navigation system that sends and receives the radio signals and provide information on location, velocity and time, 24 hours a day, in any weather in the world.

The mean concentration of PM_{10} and selected heavy metals at the sampling locations was classified in three categories according to the United States Environmental Protection Agency (USEPA) criteria for determining ambient air quality: For particulate matter (PM_{10}) : low risk (

0- 100 µg/m^3) , moderate risk: (101-200 µg/m^3) , high risk : (200-500 µg/m^3). 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.

Table 3.1: Description of sampling locations

S/N	Sampling location	Sampling code	Description
1	Abayomi Area	AA	Abayomi Junction, beside Ecobank, Iwo road
2	Iyana agbala	IA	Iyana-agbala bus-stop, close to Conoil filling station
3	Barracks Area	BA	Barracks bus-stop, infront of Olowotonfowosannu shopping complex
4	Agbaakin Layout	AL	Beside Airtel office
5	Holiness Junction	HJ	Holiness bus-stop, beside Sterling bank

3.6 Air quality sampling

3.6.1 Particulate matter (PM_{10}) level determination

Spectro fine particulate sampler model SLE-FPS105 made in India was used to collect particulate matter at all the sampling locations. At each sampling location, measurement was done at 10, 20 and 30 metres away from Idi-ape – Iwo road motorway into the community to determine how far particulate matter travels (see plate 3.1). Abayomi junction, Iyana-igbala junction, Barracks junction, Agbaakin layout and Holiness junction were the purposively selected locations along the traffic-way.

Ambient particulate matter was collected using Spectro fine particulate sampler, through an omni directional inlet designed to provide a clean aerodynamic cut-off for particles greater than 10 microns at a sampling rate of 1 m^3/hr unaffected by voltage fluctuation and filter choking was maintained by critical orifice at each site. Cellulose membrane filters were used as the sampling media (VWR, 1.0μm pore size, 47 mm diameter) and pre-field filters were conditioned in a room of constant relative humidity 50±5 % and temperature at 20 ± 1 °C respectively and were gravimetrically tared (USEPA—MethodIO-3.1 1999).

Plate 3.1 Typical Spectro fine particulate matter sampler

3.6.2 Principle and procedure of sampling

Ambient air entered the SLE-FPS105 through a size-selective inlet and through one or more filters. Conditioned filter papers were weighed before going to the field and the weights were recorded. Filter papers were brought to sampling site in separate clean polyethylene bag at each effective sampling day and conditioned clean filters were loaded to filter holder. After sampling each day, the loaded filters were returned to the laboratory and conditioned as before and then particle mass was gravimetrically determined by weighing filters after drying for 24 hours and placed in desiccators so that there would be no PM loss.

Standard operating procedure (SOP) for weighing filter paper was followed throughout the weighing process (Begum *et al*., 2004). Moisture content of a filter may affect its weight; therefore, filters were equilibrated in a conditioning environment for 24 hours before being weighed. During this equilibration period, the relative humidity and temperature would be kept typically around 50% relative humidity and 22°C respectively. Stainless steel tweezer was used for safe filter handling.

Plate 3.2 : Researcher conducting ambient air sampling

$$\frac{PM_{10}}{Vstd} = \frac{(Wf - Wi) \times 10^6}{}$$

where:

PM = mass concentration of particulate matter (PM_{10}, fine or coarse friction), µg/std m^3.

Wi= average initial weight of clean filter, g.

Wf= average final weight of exposed filter, g.

Vstd= air volume sampled, converted to standard conditions, std m^3 (Inorganic Compendium Method IO-2.4).

10^6=conversion of g to µg

3.7 Meteorological Data

The meteorological unit of the Ibadan Airport authority, Samonda was approached for the weekly weather conditions for Ibadan metropolis during the sampling period of this study. Parameters that were obtained included Temperature, Relative humidity, Rainfall, Wind speed and Wind direction.

3.8 On site observation

A well-structured observational checklist was used to assess the environmental characteristics of the selected sampling locations and the following was documented;

- Location of sampling point
- Nature of road
- Activities with and around the sampling locations

3.9 Traffic density determination

The traffic density along this motorway was captured through manual counting. Two research assistants were hired and properly trained to count the number of cars, buses, bikes and trucks that pass through the sampling points for a period of 10minutes and this was recorded on tally sheet while stopwatch was used to measure the desired count interval and this was used to estimate the hourly traffic density (Abam and *Unachukwu*, 2009). This was then compared with

stipulated guideline. The traffic density is calculated as the number of vehicles or automobiles over the time as shown below:

$$\text{Density i} = \frac{Vi}{T}$$

Density: Traffic density of vehicles type i

Vi: Number of vehicles type I that passed the road in time period T

T: Time period

Table 3.2 The classification of traffic is described below

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

Source: Ozkurt *and Camci*, 2009

3.10 Determination of heavy metals

After each filter paper was weighed and the particulate matter (PM_{10}) at each sampling locations determined, filter papers were cut into tiny fragments using stainless steel cutter (to avoid contamination) and this was done to increase the surface area of filter papers so as to speed up reaction and after which 50 ml mixture of concentrated hydrochloric acid and nitric acid collectively known as aqua regia in a 3:1 was added for digestion to take place to recover available metal present. The selection and preparation of filters, digestion and analysis of heavy metals were carried out based on the USEPA method IO-3.1 and IO-3.2(USEPA—Method IO-3.1 1999). According to these procedures, the inorganic elements collected on the filter papers were digested using a hot acid extraction procedure (USEPA—Method IO-3.1 1999).

3.10.1 Principle and procedure for acid digestion

- To determine the heavy metals content of PM_{10} from the filter papers, the weighed filter papers were divided into tiny fragments using a stainless cutter so as to avoid contamination.
- Weighed filter papers were split into tiny fragments to increase the surface area so as to speed up digestion (USEPA—Method IO-3.1 1999).
- According to these procedures, the inorganics collected on filters were digested by pressure disintegration in acid medium, 50 ml of hydrochloric and nitric acid mixture in 3:1i.e 37.5 ml of hydrochloric acid and 12.5 ml of nitric acid using a hot acid digestion procedure (USEPA—Method IO-3.1 1999).
- It was placed in a digestion vessel and mixed for 10 min in an ultrasonic system. The digestion vessel was then heated using heating mantle at $95^oC \pm 5^oC$ without boiling for dissolution of the PM and reflux for 15 minutes and it was covered with a watch-glass /vapor recovery device.
- Digestate was filtered through Whatman No.1 filter paper (or equivalent) and filtrate was collected in a 100-mL volumetric flask. The filter paper was then washed, while still in the funnel, with no more than 5 mL of hot (~95^oC) HCl, then with 20 mL of hot (~95^oC) deionized water. Washings were collected in the same 100-mL volumetric flask.
- Filter and residue from the funnel was removed, and placed back in the vessel. 5 mL of conc. HCl was added and the vessel was placed on the heating source, and heated at $95^oC \pm 5^oC$ until the filter paper dissolves. Digestion vessel was removed from the heating source, the cover and sides were rinsed for three times with de-ionized water. Filtrate was allowed to cool, then dilute to volume (25 ml).
- Precipitate formed on the bottom of the flask was washed with 10 ml of concentrated HCl to dissolve the precipitate.
- The heavy metal concentrations in each sample were determined by atomic absorption spectrometry according to standard analytical procedures (atomic absorption spectrophotometry is capable of quantitatively determining most metals at

levels that are required by federal, state, and local regulatory agencies; USEPA—Method IO-3.2 1999).

- Before analyzing the samples, the instrument was calibrated for As, Cr, Pb, Cd, Zn, Ni and Cu. As per the USEPA method stock solutions (of 1,000 ppm) was prepared and diluted to the range of working standards for individual metal just before their utilization. Using these working standards, the calibration graphs were prepared in the linear range of the optical density (0.04–0.8). The instrument was calibrated at three different levels (0.1, 10, and 100 ppm) for each metal. Exactly the same extraction and analysis procedure would be employed for PM_{10} filter papers in order to examine the background heavy metals content of blank filter paper.
- As suggested in the method and to verify reproducibility and low background metal concentrations of reagent and filters, 1% of the total number of samples were taken as blank and analyzed for presence of specific metals

3.11 Instrument calibration

The calibrations of the AAS for Chromium, Cadmium, Copper, Iron, Lead, Nickel and Zinc were carried out with certified reference standard solutions covering the desired concentration range of the analyte in the sample. The instrument was calibrated at three different levels (0.1, 10, and100 ppm) for the following metals: Cadmium, Chromium, Copper, Iron, Lead, Nickel and Zinc. Exactly the same extraction and analysis procedure was employed in order to examine the background heavy metal content of blank filter papers. As suggested in the method and to verify reproducibility and low background metal concentrations of reagent and filters, 1% of the total number of samples was taken as blank and analyzed for presence of specific metals. The concentration of heavy metals in air was expressed in mg/m^3. All the samples were run in triplicates.

3.12 Quality assurance /Quality Control procedure

The samples were handled and processed in a clean laboratory and articulate matter mass concentration was determined by weighting of the filters using a semi-micro balance (Sartorius, R 160P). Loaded and blank filters (stored in Petri dishes) were weighed after 48 hours conditioning in a desiccator, in the clean room at a relative humidity of 45-55% and a temperature of 20 ± 2 °C. Atomic Absorption Spectrophotometer (AAS) BUCK SCIENTIFIC (Model- 210VGP) was used. For calibration, standard solutions containing all heavy metals of interest were prepared using Merck certified atomic absorption stock standard solutions (Kyotani *and Iwatsuki,* 2002). Auto calibrateable transfer pipettes of 0.5–5 mL volume range from E. Merck(Germany) and volumetric flasks by Borosil glass works India Limited were used.

3.13 Statistical analysis and data management

Environmental assessment and results obtained from the laboratory were analyzed using SPSS software. Data analysis was done using descriptive statistics, ANOVA and spearman-rank correlation tests. Descriptive statistics with the use of means, standard deviations was employed to describe PM loads and heavy metals concentrations at each location, at different times of the day. ANOVA was used to determine the difference in the mean levels of PM loads and heavy metals concentrations at the different sampling locations as well as determine the variation between the observed values and WHO guideline limits. Spearman-rank correlation test was used to establish relationship between PM load and heavy metals concentration for the five sampling locations. All the statistics was done at 5% level of significance

CHAPTER FOUR
RESULTS

This chapter presents the results of the ambient air particulate matter sampling i.e. particulate matter concentration expressed in µg/m^3 and the results of the chemical analysis for heavy metals present in the particulate matter expressed in mg/$m^{3.}$ The results of onsite observation which included information on location of sampling points, road characteristics, traffic density, activities within and around sampling vicinity and effects of the particulate matter on surroundings are also presented.

4.1 General description of sampling locations

Table 4.1 shows the onsite observation related to air quality in the selected sampling locations. Majority of the sampling locations were situated in areas with high commercial activities though there were no major industries situated in these sampling locations. The results obtained from observational checklist showed that the sampling locations/sites were all located in residential areas and where high commercial activities also took place. There were small industries where metallurgical, spraying, and electroplating activities took place around study sites. Also, around the study sites, open refuse burning, high emissions from generators used by banks, small scale businesses and emission from heavy trucks were observed and all these contributed to the poor air quality in these areas.

At Holiness junction, Barracks area, Iyana-agbala and Abayomi area, large volume of waste was seen generated from these areas as a result high commercial activities and because of the inefficiency in the disposal of waste, open refuse burning was rampant in these sampling locations and this might have contributed also to the poor air quality at these sites. Banks and small scale businesses depend on electric generators to meet their power needs and in the process release large volume of pollutants in the atmosphere around these sampling locations.

Furthermore, at Iwo- road – Idi-ape which is another commercial hub in Ibadan Metropolis also witnessed large influx of large trucks that came to deliver goods to business owner and most of these trucks are old and diesel powered. During sampling, these trucks contributed large volume

of emissions at all the sites used in this study. High levels of PM_{10} observed at Holiness junction, Agbaakin layout and Barracks area might be due to the nature of the roads which were not tarred. Construction processes (roads at Abayomi Area and Agbaakin Layout were graded during sampling periods). Also, due to large commercial activities in all the sampling locations, heavy trucks were seeing delivering goods at shops around the study sites.

Table 4.1: General information about sampling locations

Indicators	AA	IA	BA	AL	HJ
Location of sampling point					
Residential area	+	+	+	+	+
Commercial area	+	+	+	+	+
Industrial activities	–	–	–	–	–
Nature of road network					
Paved roads	–	+++	–	–	–
Unpaved (graded earth) roads	+++	–	+++	+++	+++
Activities within and around study locations					
Refuse burning	++	++	++	++	+++
Emission from heavy truck	+++	++	++	+++	+++
Dumpsite	++	+	+	++	+
Generator emission	+++	++	+++	+	+++
Bush burning	–	–	–	–	–
Road construction	–	–	–	–	–

KEY: +++ highly present + + moderately present + present - absent

4.2 Pattern of Particulate matter (PM_{10}) concentrations at sampling locations

The pattern of the particulate matter concentrations at the selected sampling locations is graphically illustrated in Figure 4.1. The values on the chart represent the concentrations measured at two different periods (morning: 7-10.30 am, afternoon: 1-4.30 pm). Concentration of PM_{10} reached peak at Holiness junction (132.6 µg/m^3) during the afternoon period and this was higher than the WHO guideline limit while the least concentration was obtained at Barracks area (68.64 µg/m^3) during the morning period. The highest concentration of PM_{10}in the morning period was recorded at Holiness junction (110.5 µg/m^3). Most of these values were 4-6 times higher than WHO guideline limit.

The mean levels of PM_{10} recorded at different sampling locations are graphically represented in Figure 4.2. The values on the chart shows the mean particulate matter concentration of the location at two different periods (morning: 7am-10.30 am and afternoon: 1pm-4.30 pm) in comparison with the WHO guideline limit for air quality (20 µg/m^3). The mean particulate matter in the morning and afternoon were 94.4 µg/m^3 and 110.8 µg/m^3respectively giving an overall mean of 103.4 ± 36.8 µg/$m^3$with range of 42.7 to 192.8 µg/m^3 ($p< 0.05$). These values were 4–6 times above the daily PM_{10} air quality guideline (AQG) (20 µg/m^3) set by the World Health Organization (WHO, 2002).

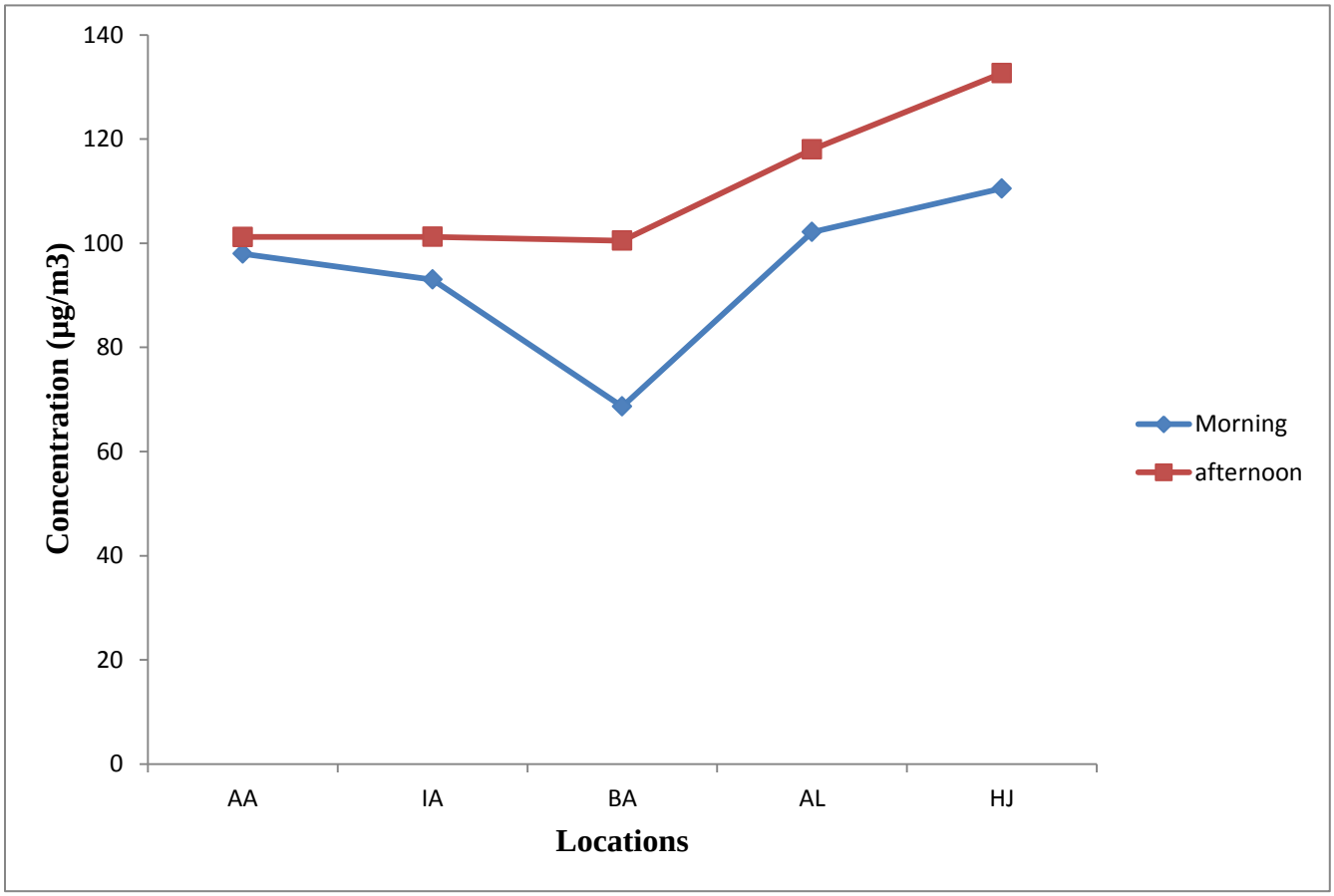

Figure 4.1: Morning and afternoon concentrations of PM_{10} at the selected sampling locations for the whole study period

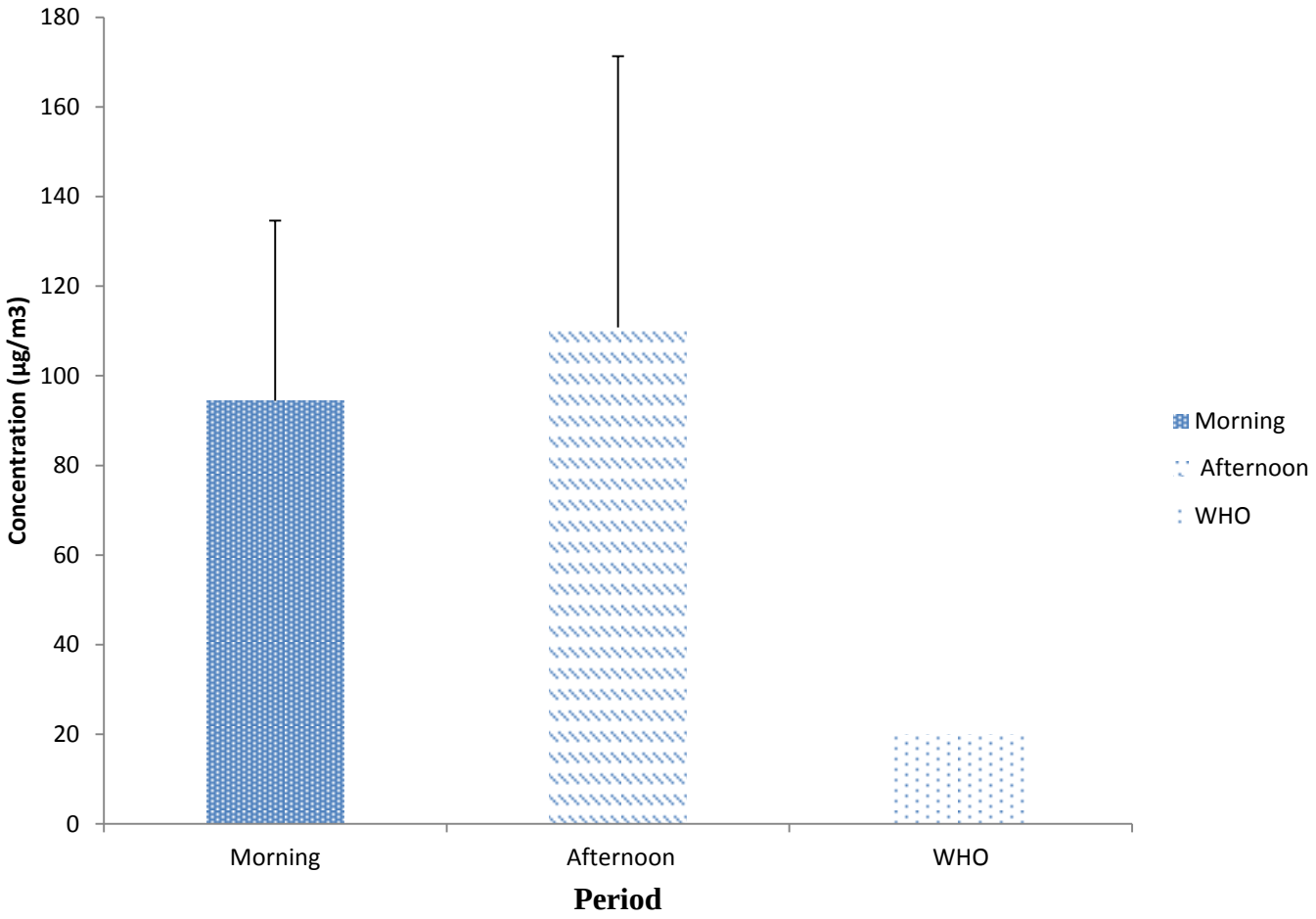

Figure 4.2: Comparison of mean particulate matter (PM_{10}) concentration with WHO guideline limit

4.3 PM_{10} concentrations

4.3.1 PM_{10} concentration at Abayomi Area

The particulate matter (PM_{10}) concentration recorded at the two different times (7-10.30 am and 1-4.30 pm) across the three distances sampled at Abayomi area showed higher concentrations in the afternoon with no significant difference. There was a significant change between morning and afternoon concentration at AA at 10 metres but not at 20 metres and 30 metres.

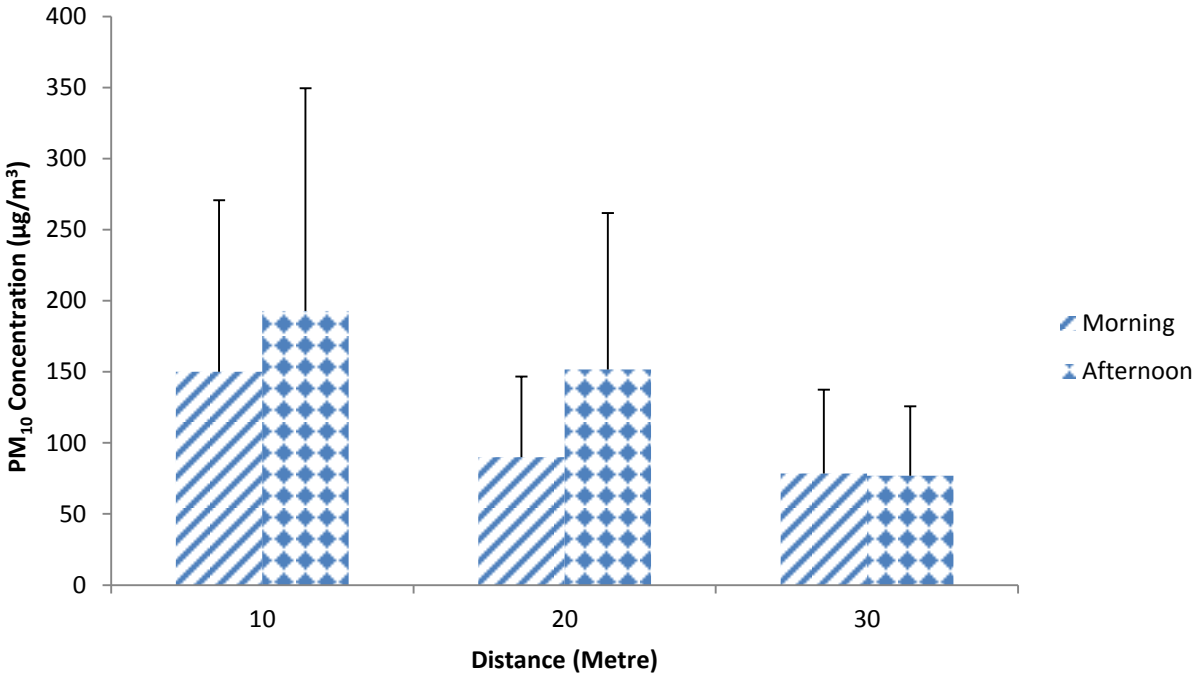

Fig 4.3: Concentration of PM_{10} at Abayomi area during morning and afternoon period

4.3.2 PM_{10} concentration at Iyana-Agbala

The particulate matter concentration (PM_{10}) at Iyana-Agbala was highest at 10 metres in the morning and afternoon with concentration of 114.3 µg/m^3 and 137.5 µg/m^3 respectively. The concentrations in the morning and afternoon at 30metres were slightly above the guideline limit of 20 µg/m^3.

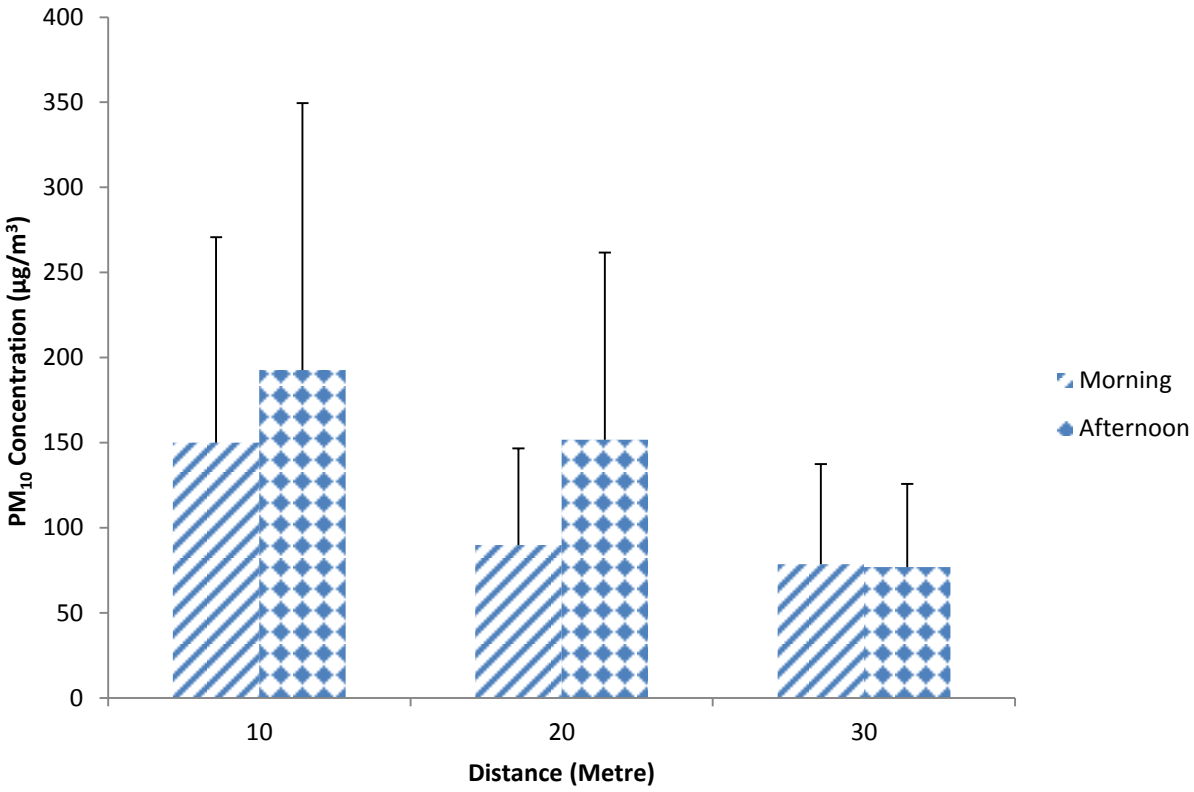

Fig 4.4: Concentration of PM_{10} at Iyana-agbala during morning and afternoon periods

4.3.3 PM_{10} concentration at Barracks area

The particulate matter concentration (PM_{10}) in the morning recorded at Barracks Area at 30 metres was lower than the standard limit value. However, the particulate matter concentration (PM_{10}) at 10 metres and 20 metres were above the guideline limit. When all the concentrations during afternoon periods at all distances were compared with the WHO guideline value, it was observed that they were all significantly higher than 20 µg/m^3 ($p < 0.05$).

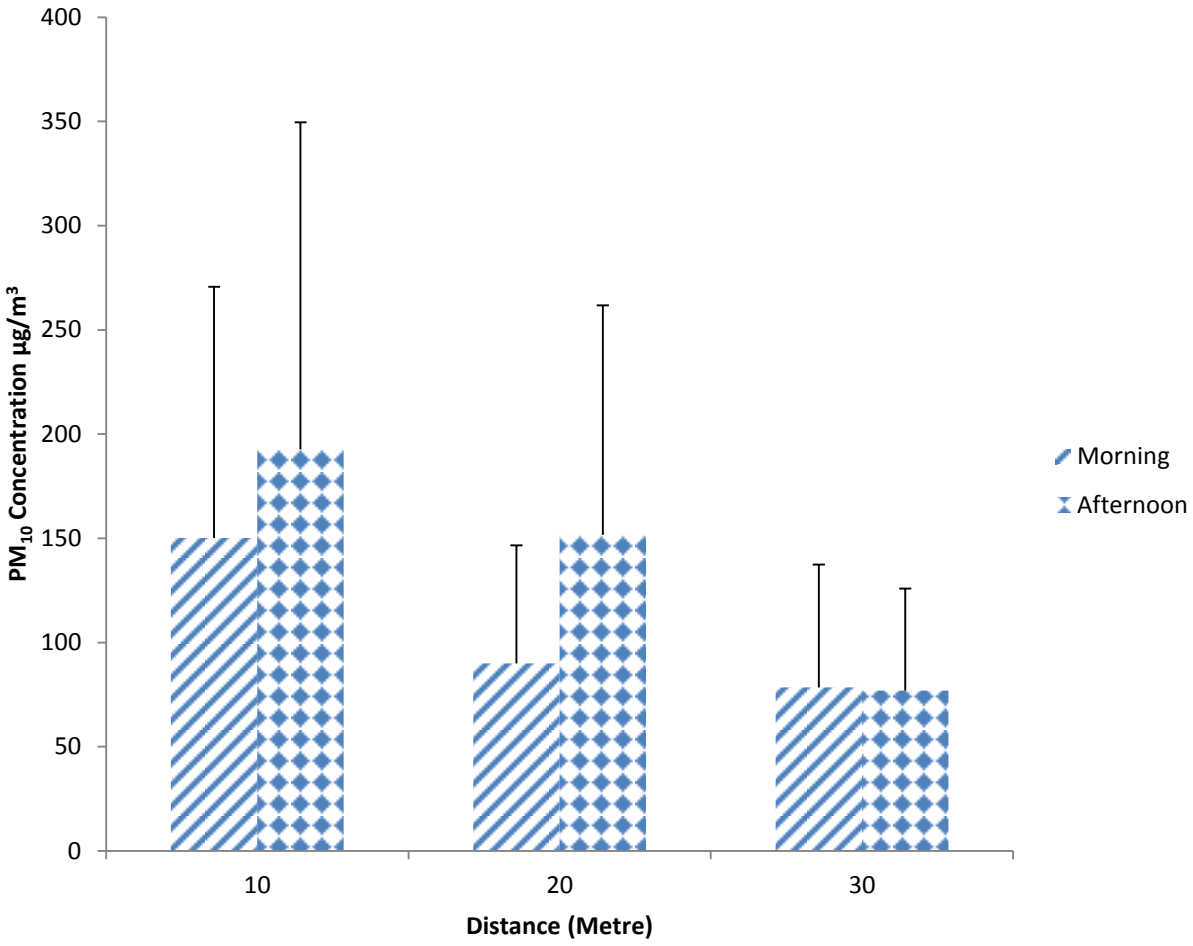

Fig 4.5: Concentration of PM_{10} at Barracks area during morning and afternoon periods

4.3.4 PM_{10} concentration at Agbaakin layout

The particulate matter concentrations (PM_{10}) obtained both in the morning and afternoon at Agbaakin-layout across all distances were found to be above WHO guideline limit. It was observed that the highest particulate matter concentrations (PM_{10}) were recorded at 10 metres both in the morning and afternoon period with PM_{10} values of 144.9 µg/m^3 and 165.7 µg/m^3 respectively.

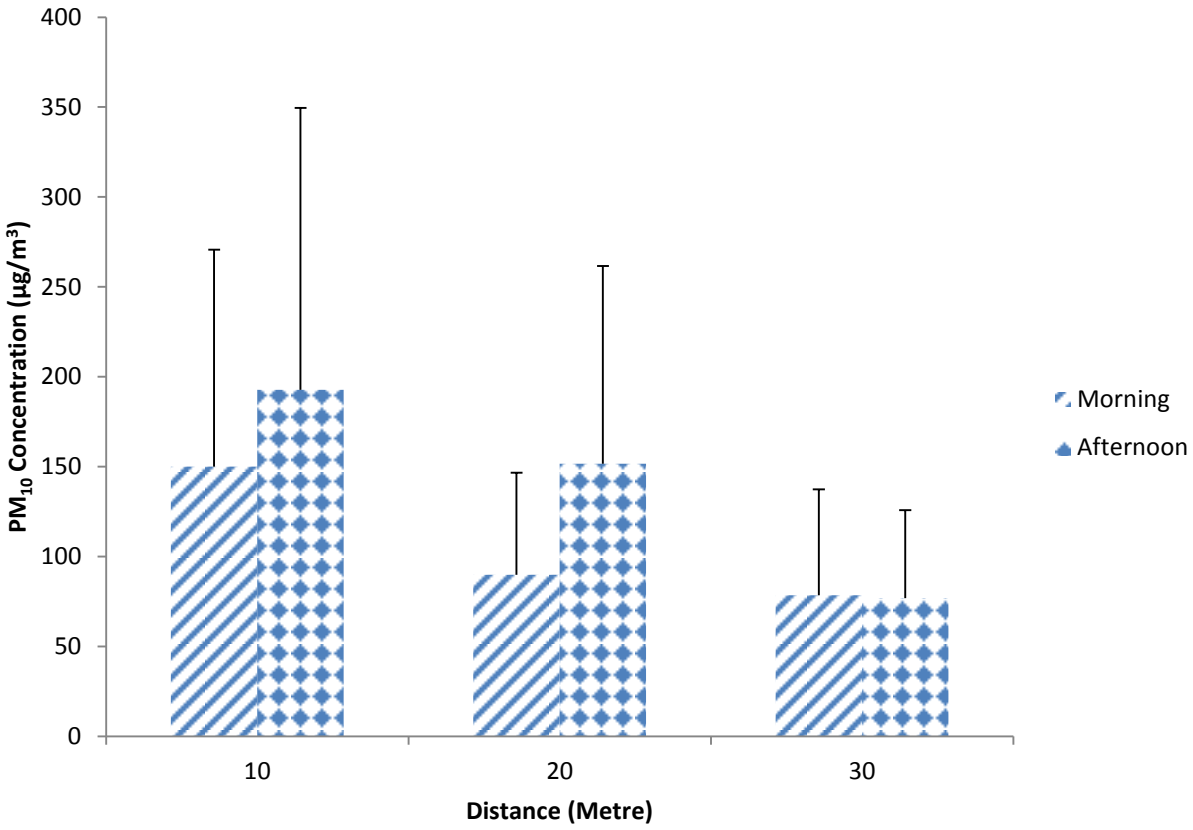

Fig 4.6: Concentration of PM_{10} at Agbaakin layout during morning and afternoon periods

4.3.5 PM_{10} concentration at Holiness junction

The particulate matter recorded at Holiness junction during both morning and afternoon periods showed that the highest particulate matter concentrations (PM_{10}) at 10 metres and had the highest particulate concentration at all the three distances across the five study locations with concentrations of 166.6 µg/m^3 and 192.8 µg/m^3 respectively. At all distances, both morning and afternoon particulate matter concentrations (PM_{10}) values at Holiness junction were all above standard limit of 20 µg/m^3

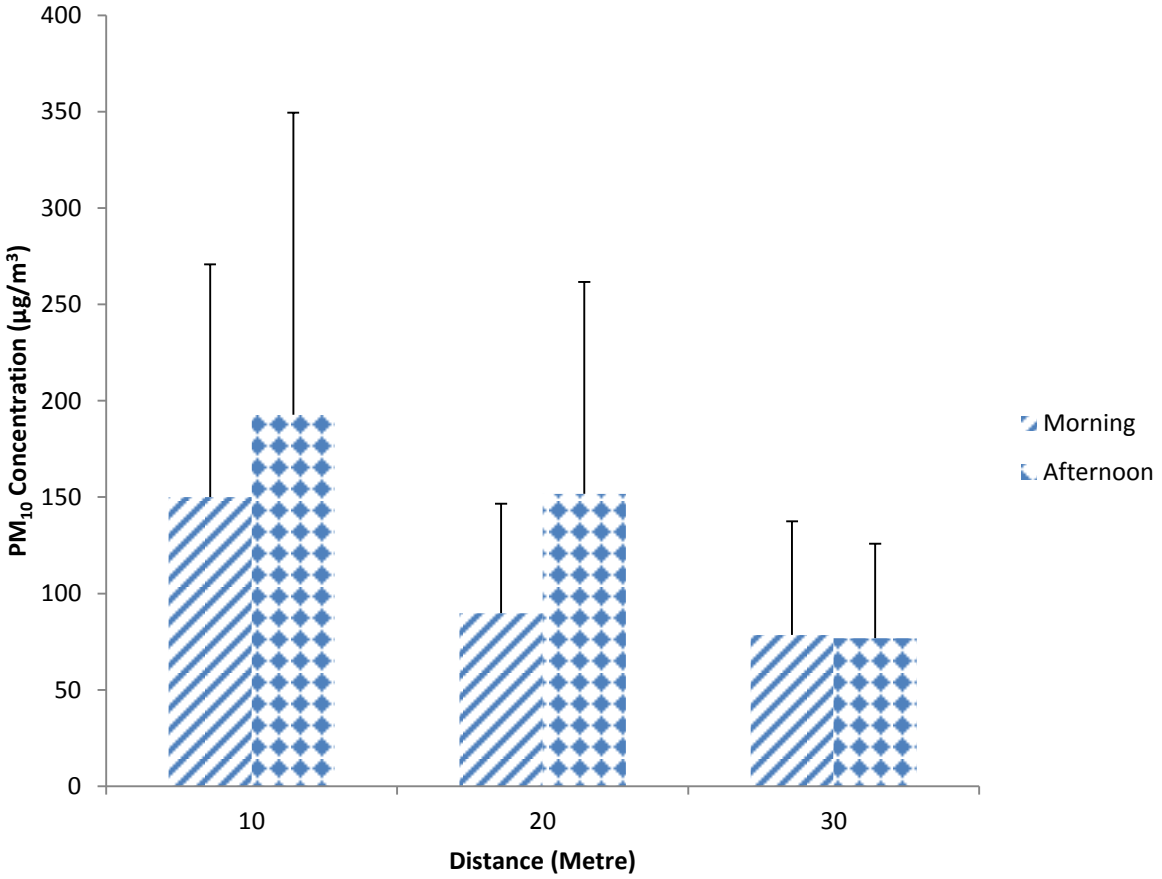

Fig 4.7: Concentration of PM_{10} at Holiness junction during morning and afternoon periods

The result of the mean concentration illustrated in Fig. 4.1 at each sampling points showed that the mean particulate matter concentrations PM_{10} in the morning and afternoon at all the sampling locations were; 97.9±32.7 µg/m^3 and 101.18 ± 47.9 µg/m^3 and (AA), 93.0±46.5 µg/m^3 and 101.2±33.7 µg/m^3 (IA), 68.7±21.9 µg/m^3 and 100.5±33.1 µg/m^3 (BA), 102.1±34.1 µg/m^3 and 118.1± 56.1 µg/m^3 (AL), 110.5±37.5 µg/m^3 and 132.6±41.4 µg/m^3 respectively.

Table4.2: PM_{10} ($\mu g/m^3$) at all the sampling locations

Locations	Period	10	20	30	Mean of each period in $\mu g/m^3$	Average concentration(Morning and Afternoon in $\mu g/m^3$	WHO guideline
Abayomi area	Morning	108.9	97.5	53.7	97.9±32.7	99.6± 37.1	20
	Afternoon	114.3	101	87.6	101.2±50.6		
Iyana-Agbala	Morning	114.3	108.4	56.39	93.0±46.5	97.1±42.1	20
	Afternoon	137.7	107.6	58.6	101.2±33		
Barrack area	Morning	103.2	60.1	42.7	68.6±22.9	84.6±21.1	20
	Afternoon	129.4	111.7	60.5	100.5±33.5		
Agbaakin layout	Morning	144.9	105.7	55.8	102.1±34.1	110.1±48.4	20
	Afternoon	165.7	98.81	89.8	118 ±56.1		
Holiness junction	Morning	166.6	89.8	76.1	110.5±32.8	121.6±59.8	20
	Afternoon	192.8	130.3	74.8	132.7±41.2		

All the mean particulate matter concentrations in the afternoon periods were higher than their corresponding morning particulate matter concentrations in all the five sampling points ($p>0.05$). Similarly, all concentrations recorded both in the morning and afternoon periods at all the points were significantly higher than WHO guideline limit of 20 $\mu g/m^3$. The PM_{10} concentrations observed in the morning and afternoon hours at the distance nearest to the main motorway i.e. 10metres at all the sampling points as shown in Table 4.3 were 108.9 $\mu g/m^3$ and 158.9 $\mu g/m^3$ (Abayomi area), 114.3 $\mu g/m^3$ and 137.5$\mu g/m^3$ (Iyana-Agbala), 103.2 $\mu g/m^3$ and 129.4 $\mu g/m^3$ (Barracks area), 144.9 $\mu g/m^3$ and 165.7$\mu g/m^3$ (Agbaakin layout), and 166.6 $\mu g/m^3$ and 192.8 $\mu g/m^3$ (Holiness junction). The average PM_{10} concentrations in the morning and afternoon periods for the total period of sampling at the study site were 94.4 ± 44.6 $\mu g/m^3$ and 110.7 ± 47.5 $\mu g/m^3$ which were also significantly higher than guideline limit of 20$\mu g/m^{3.}$

4.4 Traffic density

A significant difference in the number of vehicles across the sampling periods was observed for all the sampling location. The mean traffic count was recorded in the morning (7 – 10.30 am) and afternoon (1 – 4.30 pm) across the five (5) sampling points. In all, Holiness junction had the highest traffic count/hr (24,786) while Abayomi area had the lowest traffic count/hr (17,043). The highest number of Bikes/hr (a combination of total number of motorcycles and tricycles) was recorded at Holiness junction (5,686) while the lowest was recorded at location Iyana-agbala (4,708). Also, the highest number of cars/hr was recorded at holiness junction (14,596) while the lowest was recorded at Iyana-agbala (12,011).

On the other hand, Holiness junction had the highest number of trucks/hr (530); total number of trucks at Agbaakin layout and Abayomi area were 445 and 368 respectively while Barracks area had the lowest number of truck/hr (359). Furthermore, the highest number of buses/hr was also recorded at Holiness junction (4,248); total number of buses at Barracks area and Agbaakin layout were 3663 and 3186 respectively while the lowest was recorded Iyana-agbala (2,962).

Table 4.3: Traffic density

Location	Buses	Cars	Motorcycles	Trucks	Total
LC1 10M (Morning)	616	2380	708	46	3750
LC1 20M (Morning)	476	2000	900	40	3424
LC1 30M (Morning)	228	1924	812	128	3092
LC1 10M (Afternoon)	800	2256	844	60	3960
LC1 20M (Afternoon)	728	2248	780	44	3800
LC1 30M (Afternoon)	492	1227	668	50	2437
LC2 10M (Morning)	536	2424	796	78	3834
LC2 20M (Morning)	524	1856	536	138	3210
LC2 30M (Morning)	436	1207	920	36	2599
LC2 10M (Afternoon)	620	2916	812	32	3598
LC2 20M (Afternoon)	460	2292	812	32	3598
LC2 30M (Afternoon)	386	1316	792	92	2584
LC3 10M (Morning)	360	2500	1228	61	4111
LC3 20M (Morning)	412	1876	728	6	3324
LC3 30M (Morning)	783	1368	821	92	3064
LC3 10M (Afternoon)	972	2056	972	963	4920
LC3 20M (Afternoon)	636	2572	721	76	4026
LC3 30M (Afternoon)	500	1772	592	28	2892
LC4 10M (Morning)	536	2700	1196	73	4534
LC4 20M (Morning)	676	2300	1156	88	4220
LC4 30M (Morning)	128	1004	384	74	2310
LC4 10M (Afternoon)	614	2500	892	84	4090
LC4 20M (Afternoon)	716	2010	1000	84	3790
LC4 30M (Afternoon)	516	2148	792	42	3498
LC5 10M (Morning)	768	2900	780	152	4600
LC5 20M (Morning)	708	2316	954	128	3830
LC5 30M (Morning)	536	1932	712	42	3222
LC 5 10M (Afternoon)	876	2536	1576	108	5102
LC5 20M (Afternoon)	876	2740	1028	72	4712
LC5 30M (Afternoon)	484	2172	636	28	3320

Keys: LC1 = Abayomi area, LC2= Iyana-agbala, LC3= Barracks area, LC4=Agbaakin layout, LC5= Holiness Junction

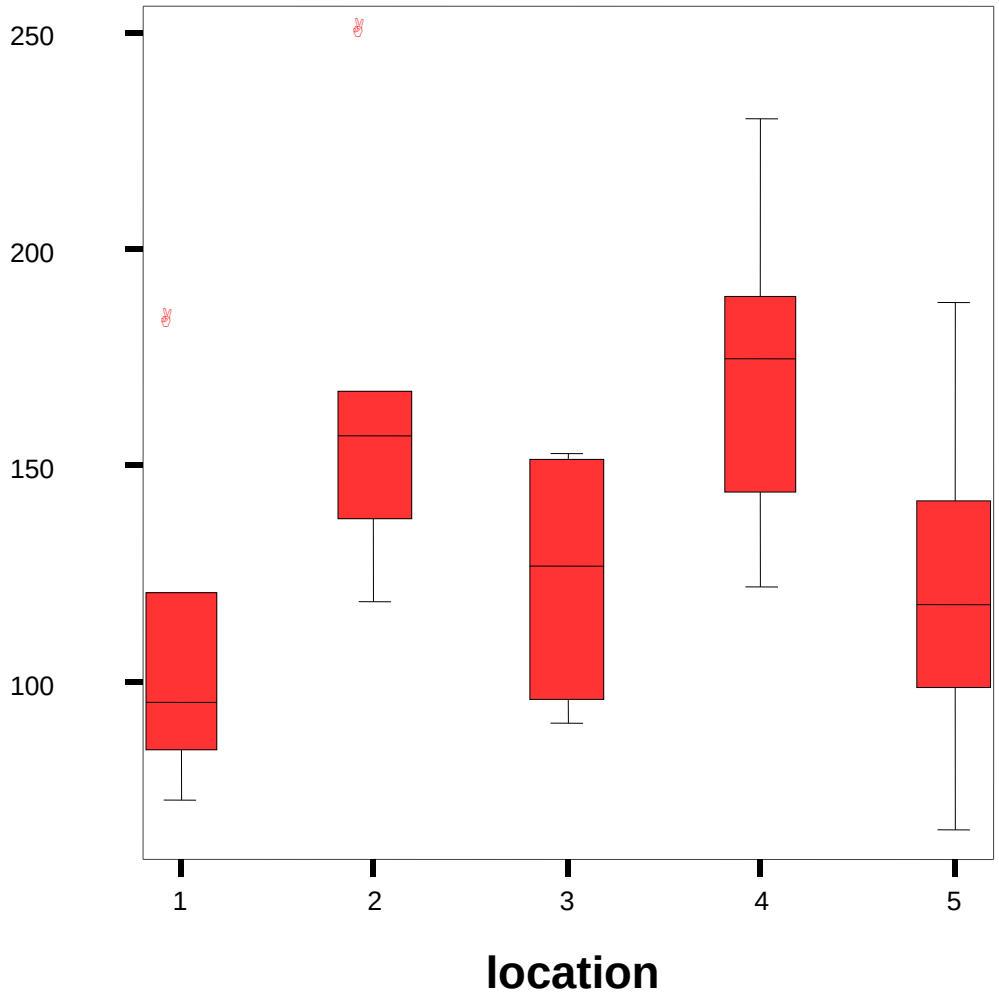

Fig 4.8: Concentration of Cadmium (mg/m^3) at the sampling locations

Key:1= Abayomi area, 2=Iyana Agbala, 3= Barracks Area, 4= Agbaakin Layout, 5= Holiness Junction

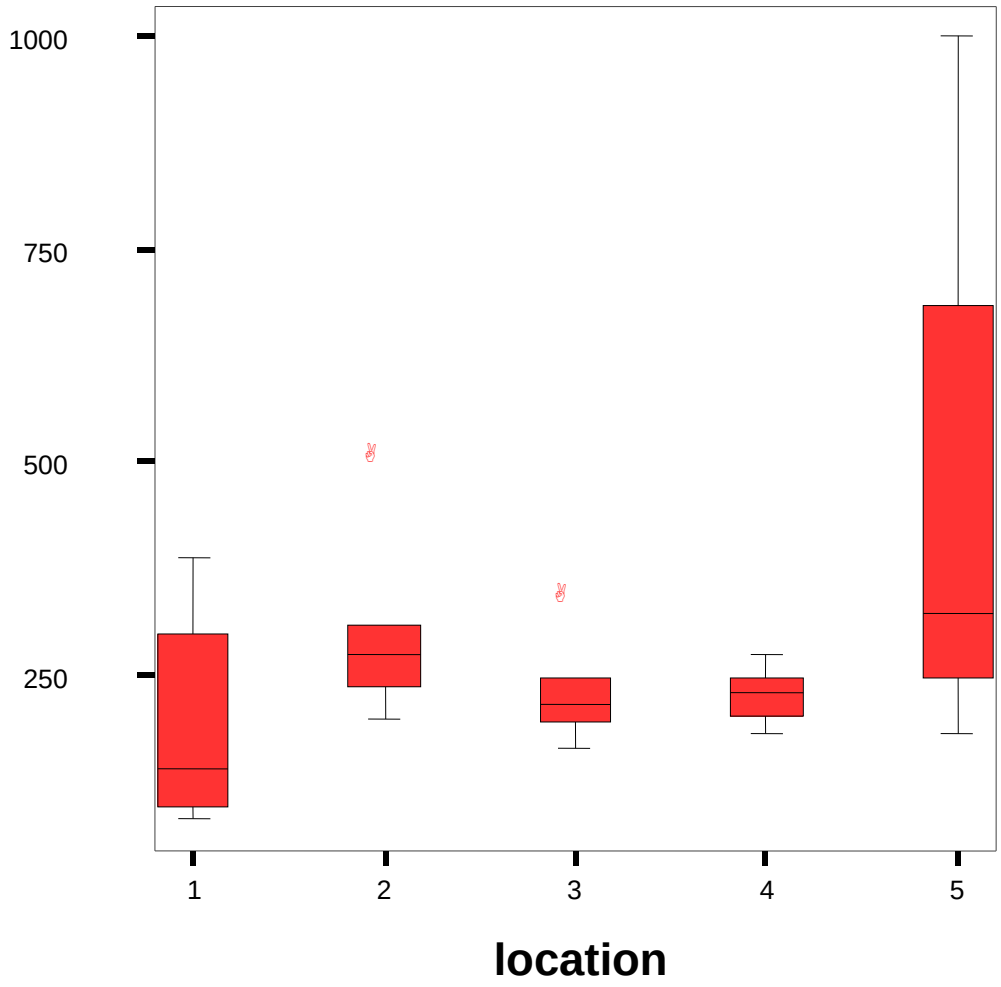

Fig 4.9: Concentration of Lead (mg/m^3) at the sampling locations

Key:1= Abayomi area, 2=Iyana Agbala, 3= Barracks Area, 4= Agbaakin Layout, 5= Holiness Junction

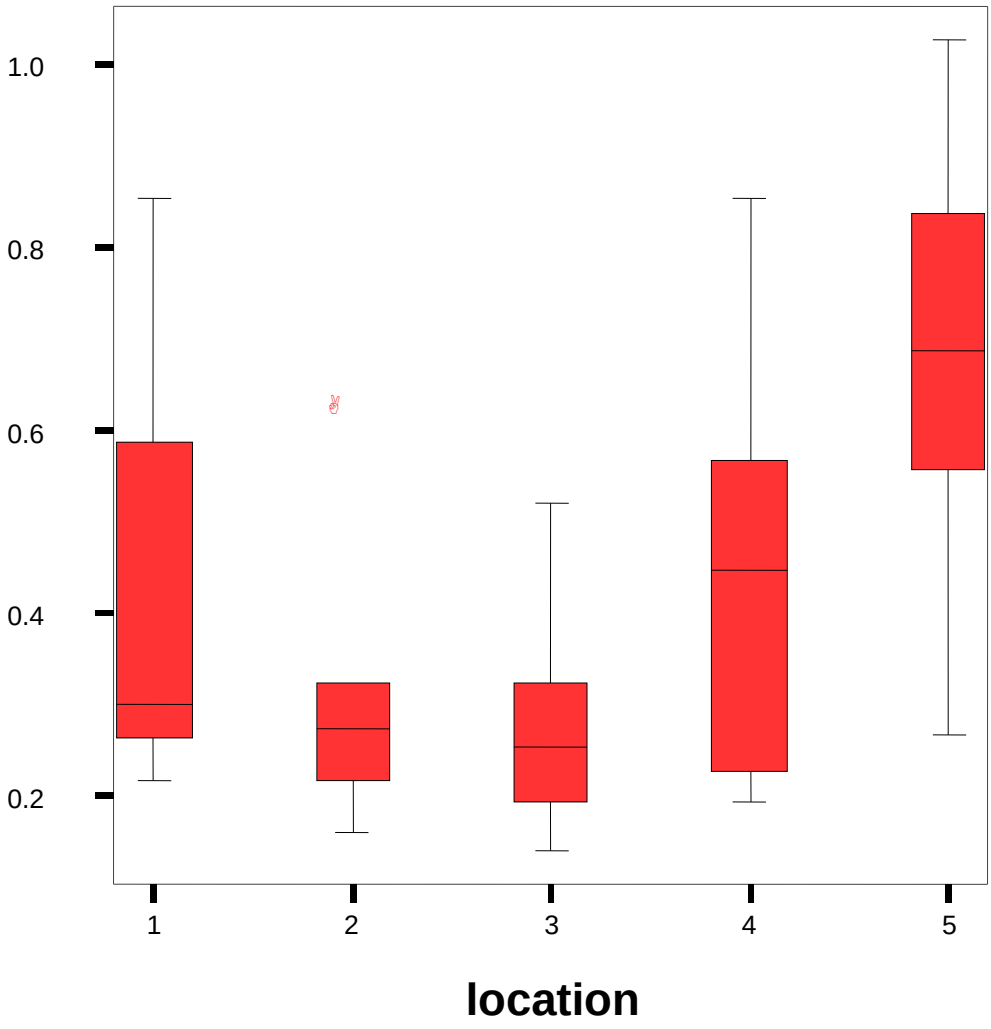

Fig 4.10: Concentration of Zinc (mg/m^3) at the sampling locations

Key:1= Abayomi area, 2=Iyana Agbala, 3= Barracks Area, 4= Agbaakin Layout, 5= Holiness Junction

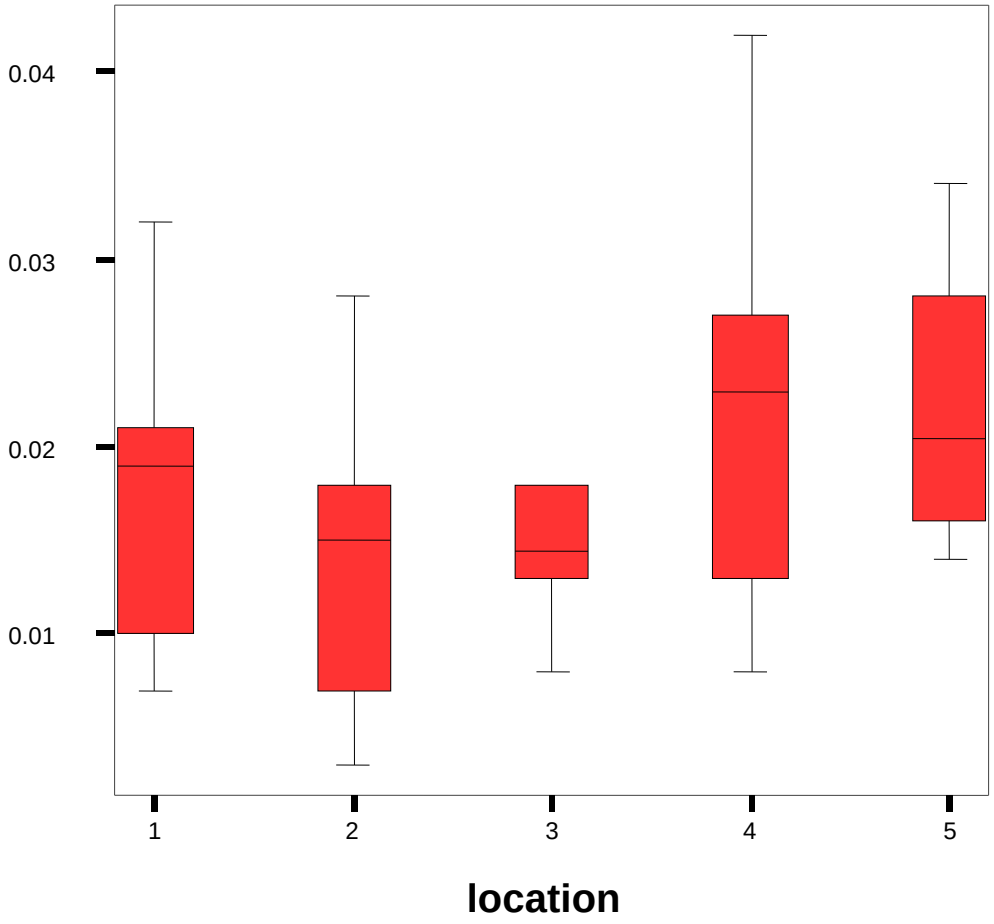

Fig 4.11: Concentration of Chromium (mg/m^3) at the sampling locations

Key:1= Abayomi area, 2=Iyana Agbala, 3= Barracks Area, 4= Agbaakin Layout, 5= Holiness Junction

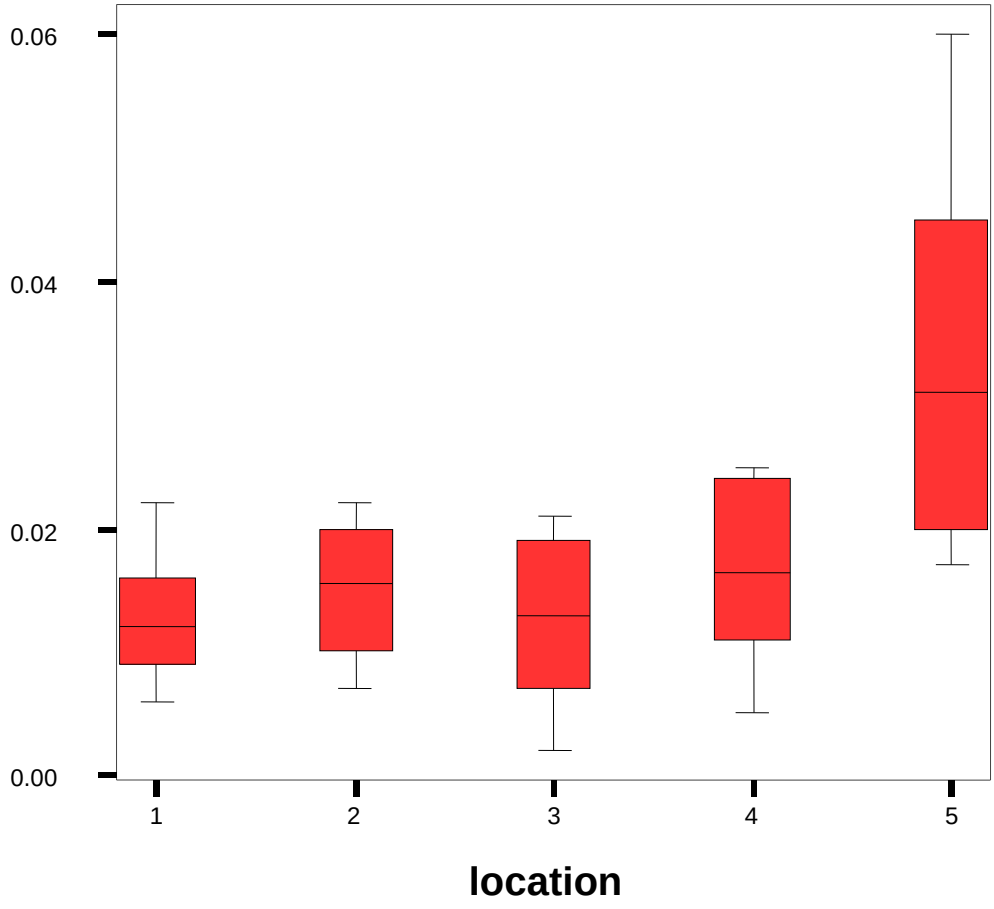

Fig 4.12: Concentration of Copper (mg/m^3) at the sampling locations

Key:1= Abayomi area, 2=Iyana Agbala, 3= Barracks Area, 4= Agbaakin Layout, 5= Holiness Junction

4.5 Influence of traffic density on the concentration of traffic-related heavy metals

Pearson correlation test was carried between the concentration of Copper, Zinc, Lead, Cadmium, Chromium, Iron and traffic density. A positive strong correlation was recorded between concentration of Copper and traffic density (rs = 0.92). Traffic density was observed to correlate positively with the concentration of Zinc (rs =0.89) and positive correlation was also found between concentration of Chromium and traffic density (rs =0.48). Lead concentration was also correlated positively with traffic density while a positive correlation also existed between traffic density and concentration of Cadmium (rs=0.44). A weak positive correlation existed between concentration of Iron and traffic density (rs=0.38). Figure 4.6 To 4.11 show the strength of the linear relationship between traffic density and copper concentration (R^2= 62.1%), traffic density and cadmium concentration (R^2= 25.4%), traffic density and lead concentration (R^2= 43.5%), traffic density and Chromium concentration (R^2=38.1%), traffic density and Iron concentration (R^2=38.1%) as well as traffic density and Zinc concentration (R^2=37.3%).

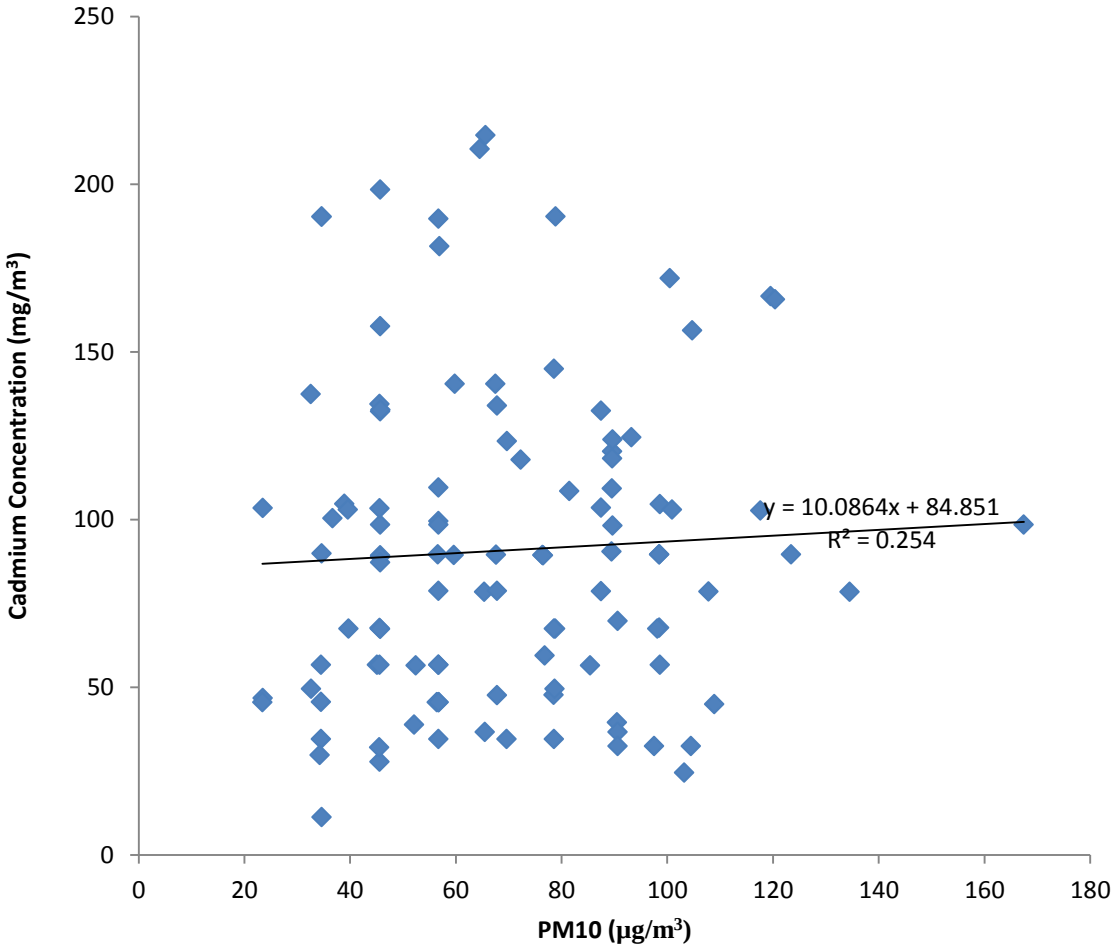

Fig 4.13: Relationship between PM_{10} and concentration of Cadmium

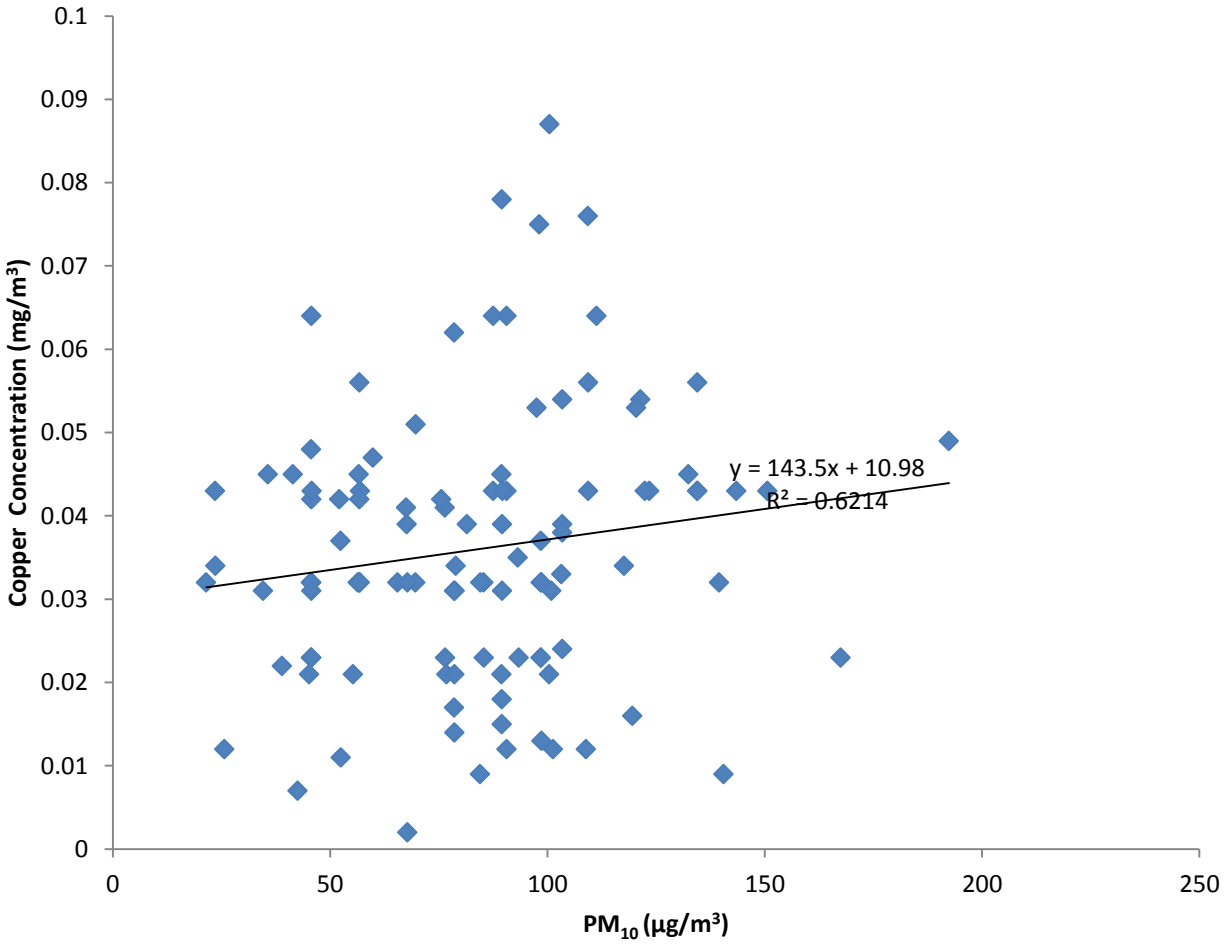

Fig 4.14: Relationship between PM_{10} and concentration of Copper

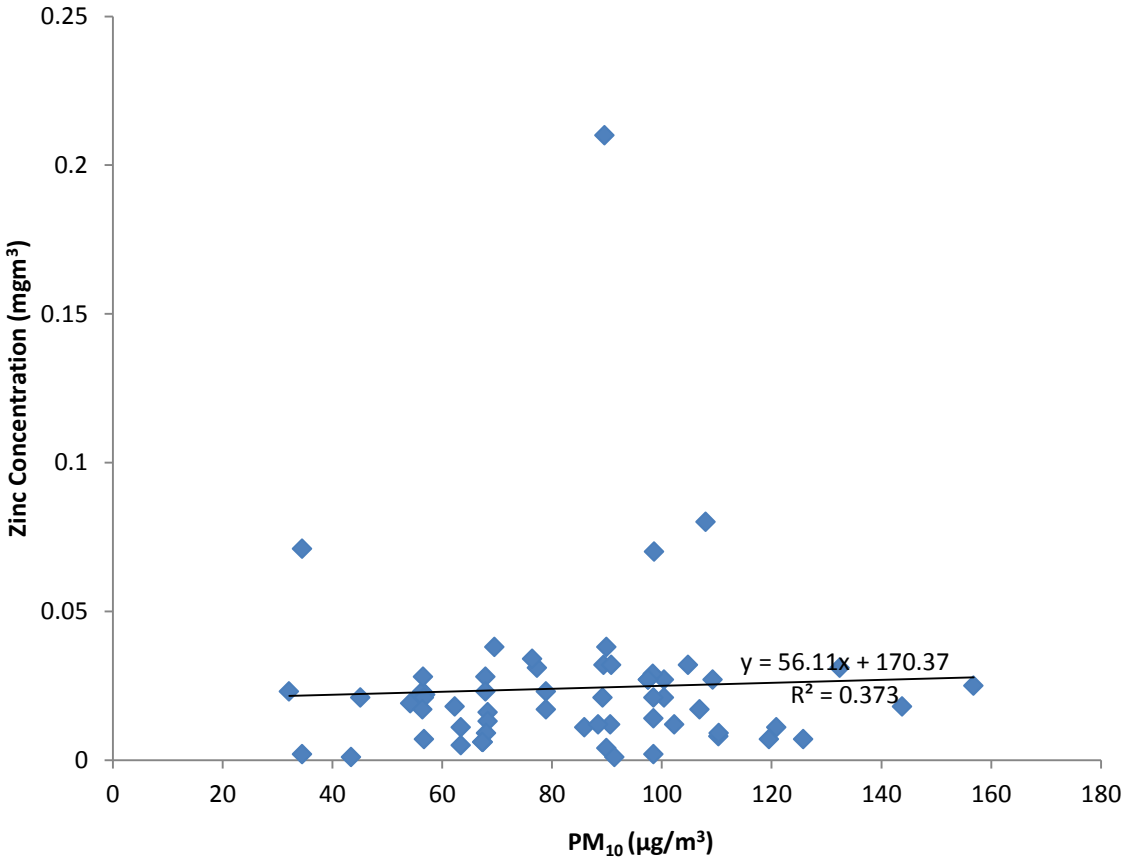

Fig 4.15: Relationship between PM_{10} and concentration of Zinc

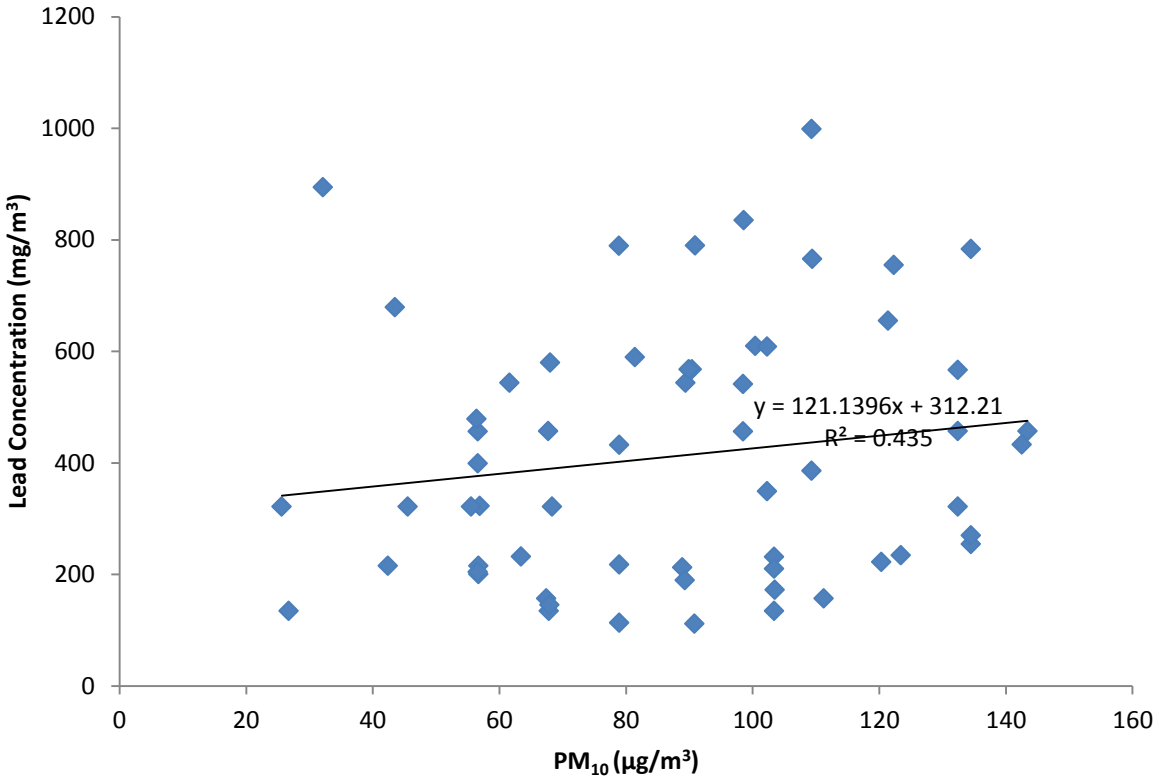

Fig 4.16: Relationship between PM_{10} and concentration of Lead

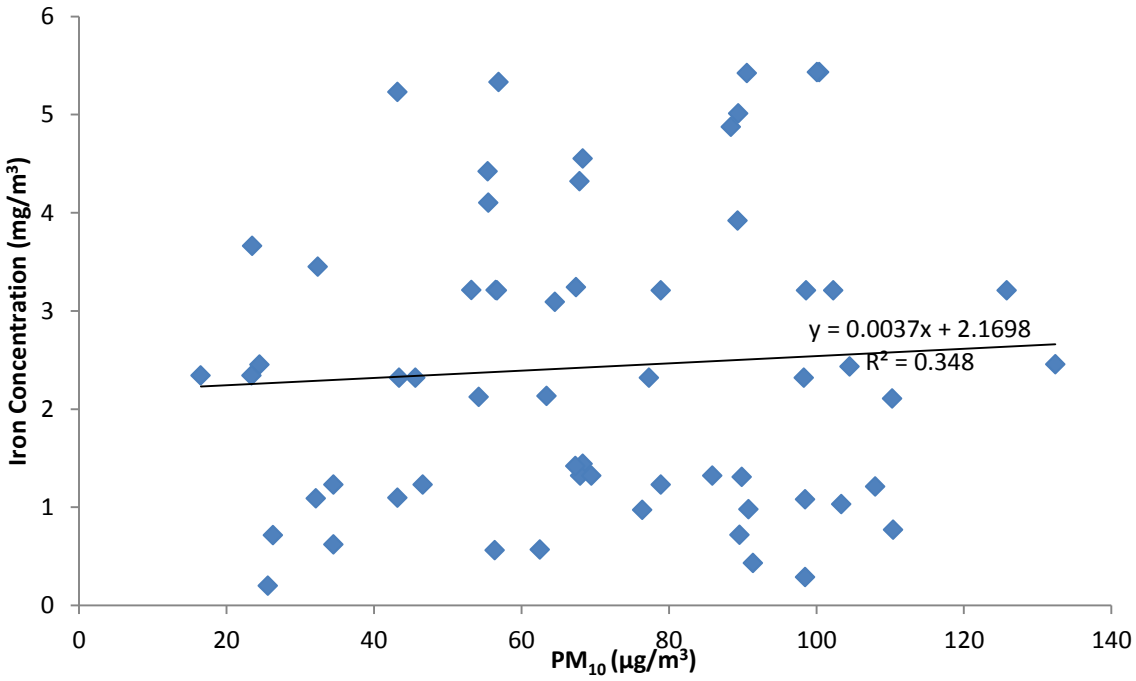

Fig 4.17: Relationship between PM_{10} and concentration of Iron

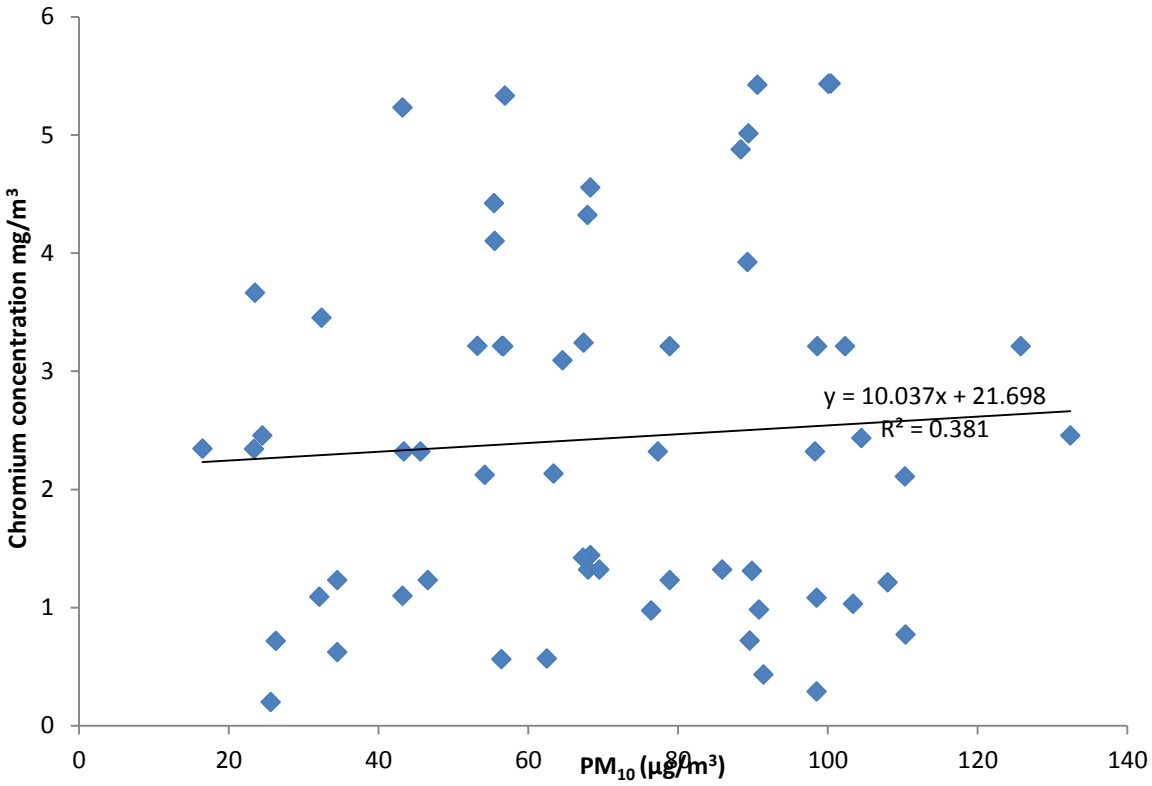

Fig 4.18: Relationship between PM_{10} and concentration of Chromium

4.6 Concentrations of particle-bound Heavy metals

The heavy metal (cadmium, chromium, copper, iron, lead, nickel and zinc) concentrations were determined using Atomic Absorption Spectrophotometer (AAS) for PM_{10} along Iwo road – Idi-ape motorway, Ibadan during the period of December 2011 and March 2012. The range of concentrations of heavy metals adsorbed on the particulate matter in all the five sampling locations along this motorway was compared with blank.

The association between heavy metals and ambient PM_{10} in all the sampling locations are given in Table 4.5. On the average, total heavy metal concentrations were above the concentration on the blank filter papers. Lead was the most abundant heavy metal in all the samples analyzed in all locations with relatively high concentrations in the range of several mg/m^3 while Cadmium was second most abundant heavy metal with concentrations also in the range of several mg/m^3. Chromium was the least abundant heavy metal in all the locations.

Table 4.4: Spearman correlation for Particulate matter and heavy metals at Abayomi area

	PM	Fe	Cu	Zn	Cr	Cd	Pb
PM Correlationn coefficient Sig.(2-tailed|)	1.000						
Fe Correlationn coefficient Sig.(2-tailed|)	0.943 0.005	1.000					
Cu Correlationn coefficient Sig.(2-tailed|)	0.667 0.148	0.493 0.321	1.000				
Zn Correlationn coefficient Sig.(2-tailed|)	0.943 0.005	0.600 0.208	0.754 0.084	1.000			
Cr Correlationn coefficient Sig.(2-tailed|)	0.771 0.072	0.829 0.042	0.986 0.000	0.829 0.042	1.000		
Cd Correlationn coefficient Sig.(2-tailed|)	0.834 0.005	0.600 0.208	0.986 0.000	0.829 0.042	0.943 0.005	1.000	
Pb Correlationn coefficient Sig.(2-tailed|)	0.829 0.042	0.714 0.111	0.899 0.015	0.771 0.072	0.986 0.000	0.9343 0.005	1.000

Table 4.5: Spearman correlation for Particulate matter and heavy metals at Iyana Agbala

	PM	Fe	Cu	Zn	Cr	Cd	Pb
PM Correlationn coefficient Sig.(2-tailed|)	1.000						
Fe Correlationn coefficient Sig.(2-tailed|)	0.714 0.111	1.000					
Cu Correlationn coefficient Sig.(2-tailed|)	0.886 0.001	0.771 0.072	1.000				
Zn Correlationn coefficient Sig.(2-tailed|)	0.914 0.002	1.000	0.771 0.042	1.000			
Cr Correlationn coefficient Sig.(2-tailed|)	0.638 0.173	0.986 0.000	0.667 0.148	0.829 0.042	1.000		
Cd Correlationn coefficient Sig.(2-tailed|)	0.429 0.397	0.919 0.003	0.257 0.623	0.829 0.787	0.058 0.913	1.000	
Pb Correlationn coefficient Sig.(2-tailed|)	1.000	0.714 0.111	0.886 0.019	0.714 0.111	0.986 0.000	0.943 0.005	1.000

Table 4.6: Spearman correlation for Particulate matter and heavy metals at Barracks Area

	PM	Fe	Cu	Zn	Cr	Cd	Pb
PM Correlationn coefficient	1.000						
Sig.(2-tailed|)							
Fe Correlationn coefficient	0.943	1.000					
Sig.(2-tailed|)	0.000						
Cu Correlationn coefficient	0.371	0.543	1.000				
Sig.(2-tailed|)	0.468	0.266					
Zn Correlationn coefficient	0.257	0.429	0.943	1.000			
Sig.(2-tailed|)	0.623	0.397	0.005				
Cr Correlationn coefficient	0.971	0.883	0.441	0.353	1.000		
Sig.(2-tailed|)	0.001	0.004	0.381	0.492			
Cd Correlationn coefficient	0.886	0.771	0.883	0.971	0.058	1.000	
Sig.(2-tailed|)	0.003	0.072	0.004	0.001	0.913		
Pb Correlationn coefficient	0.600	0.486	0.029	0.143	0.986	0.943	1.000
Sig.(2-tailed|)	0.208	0.329	0.957	0.787	0.111	0.005	

Table 4.7: Spearman correlation for Particulate matter and heavy metals at Agbaakin Layout

	PM	Fe	Cu	Zn	Cr	Cd	Pb
PM Correlationn coefficient	1.000						
Sig.(2-tailed|)							
Fe Correlationn coefficient	0.839	1.000					
Sig.(2-tailed|)	0.002						
Cu Correlationn coefficient	0.899	0.638	1.000				
Sig.(2-tailed|)	0.003	0.173					
Zn Correlationn coefficient	0.486	0.086	0.696	1.000			
Sig.(2-tailed|)	0.329	0.872	0.125				
Cr Correlationn coefficient	0.714	0.371	0.928	0.829	1.000		
Sig.(2-tailed|)	0.111	0.468	0.000	0.042			
Cd Correlationn coefficient	0.659	0.371	0.667	0.829	0.600	1.000	
Sig.(2-tailed|)	0.156	0.468	0.148	0.042	0.208		
Pb Correlationn coefficient	0.771	0.943	0.551	0.257	0.143	0.143	1.000
Sig.(2-tailed|)	0.072	0.005	0.257	0.623	0.787	0.787	

Table 4.8: Spearman correlation for Particulate matter and heavy metals at Holiness Junction

	PM	Fe	Cu	Zn	Cr	Cd	Pb
PM Correlationn coefficient Sig.(2-tailed|)	1.000						
Fe Correlationn coefficient Sig.(2-tailed|)	0.829 0.042	1.000					
Cu Correlationn coefficient Sig.(2-tailed|)	0.899 0.015	0.638 0.173	1.000				
Zn Correlationn coefficient Sig.(2-tailed|)	0.486 0.329	0.086 0.872	0.696 0.125	1.000			
Cr Correlationn coefficient Sig.(2-tailed|)	0.714 0.111	0.371 0.468	0.938 0.004	0.829 0.042	1.000		
Cd Correlationn coefficient Sig.(2-tailed|)	0.659 0.156	0.371 0.468	0.667 0.148	0.829 0.042	0.600 0.208	1.000	
Pb Correlationn coefficient Sig.(2-tailed|)	0.771 0.072	0.943 0.005	0.551 0.257	0.143 0.787	0.257 0.623	0.143 0.787	1.000

4.6.1 Relationship between particulate matter and heavy metals at Abayomi Area

Table 4.4 shows the outcome of Spearman's correlation (rs) test between particulate matter and concentration of heavy metals such as Lead, Cadmium, Chromium, Iron, Zinc, and Copper. Particulate matter was strongly correlated with Fe (rs=0.943, Zn (rs=0.943), Pb (rs =0.829), Cd (rs = 0.843). The concentrations of Cu (rs =0.667) and Cr (rs= 0.771) were also found to be positively correlated with particulate matter. A strong correlation was observed between Pb and Cr ratio (rs =0.986) while a weak correlation (rs= 0.493) existed between Cu and Fe ratio.

4.6.2 Relationship between particulate matter and heavy metals at Iyana Agbala

Table 4.5 shows the outcome of Spearman's correlation (rs) test between particulate matter and concentration of heavy metals such as Lead, Cadmium, Chromium, Iron, Zinc, and Copper at Iyana Agbala. Particulate matter was strongly correlated with Fe (rs=0.714), Zn (rs=0.914), Cu (rs =0.886), Cr (rs = 0.638). The concentrations of Cd (rs =0.429) was found to be weakly correlated with particulate matter. A strong correlation was observed between Cd and the Zn ratio (rs =0.829) while a weak correlation (rs= 0.257) existed between Cu and the Cd ratio.

4.6.3 Relationship between particulate matter and heavy metals at Barracks Area

Table 4.6 shows the outcome of Spearman's correlation (rs) test between particulate matter and concentration of heavy metals such as Lead, Cadmium, Chromium, Iron, Zinc, and Copper at Barracks Area. Particulate matter was strongly correlated with Cd (rs=0.886), Pb (rs=0.600), Fe (rs =0.934), and Cr (rs = 0.971). The concentrations of Zn (rs =0.257) was found to be weakly correlated with particulate matter. A strong correlation was observed between Cu and the Zn ratio (rs =0.943) while a weak correlation (rs= 0.353) existed between Zn and the Cr ratio

4.6.4 Relationship between particulate matter and heavy metals at Agbaakin Layout

Table 4.7 shows the outcome of Spearman's correlation (rs) test between particulate matter and concentration of heavy metals such as Lead, Cadmium, Chromium, Iron, Zinc, and Copper at Barracks Area. Particulate matter was strongly correlated with Pb (rs=0.771), Fe (rs=0.839), Cr (rs =0.714), and Cu (rs = 0.899). The concentrations of Zn (rs =0.486) was found to be weakly

correlated with particulate matter. A strong correlation was observed between Cu and the Zn ratio (rs =0.943) while a weak correlation (rs= 0.143) existed between Pb and the Cd ratio

4.6.5 Relationship between particulate matter and heavy metals at Agbaakin Layout

Table 4.8 shows the outcome of Spearman's correlation (rs) test between particulate matter and concentration of heavy metals such as Lead, Cadmium, Chromium, Iron, Zinc, and Copper at Holiness Junction. Particulate matter was strongly correlated with Cu (rs=0.899), Pb (rs=0.771), Fe (rs =0.829), and Cr (rs = 0.714). The concentrations of Zn (rs =0.486) was found to be weakly correlated with particulate matter. A strong correlation was observed between Fe and the Pb ratio (rs =0.943) while a weak correlation (rs= 0.371) existed between Fe and the Cr ratio

4.7.1 Cadmium

The average concentration of cadmium (Cd) across the five sampling locations was 108.1 mg/m^3 (AA), 164.3 mg/m^3 (IA), 124.1 mg/m^3 (BA), 172.5 mg/m^3(AL) and 121.6 mg/m^3 (HJ) while the blank was 4.2 mg/m^3.The concentrations of cadmium (Cd) recorded at 10, 20 and 30 metres in all sampling locations in the afternoon periods were higher than the morning periods except at Iyana Agbala where the concentration recorded in the morning at 10m (248.8 mg/m^3) was greater than afternoon period (137.4 mg/m^3).The concentration of cadmium was found to reduce with distance further away from traffic (from 10 metres to 30 meters in the community along the motorway) by 16.4% at Holiness junction and by 13.8%, 15.6%, 9.6% and 6.8% at, Iyana-agbala, Agbaakin layout, Barracks area and Abayomi area respectively.

Figure 4.8 show descriptive statistics for Cadmium across all the sampling locations. The overall mean for Cd was 138.12 while overall median was 137.20. Also Cd recorded overall minimum and maximum of 65.78 and 248.79 respectively. The 25^{th} and 75^{th} for Cd were 97.92 and 166.81 respectively.

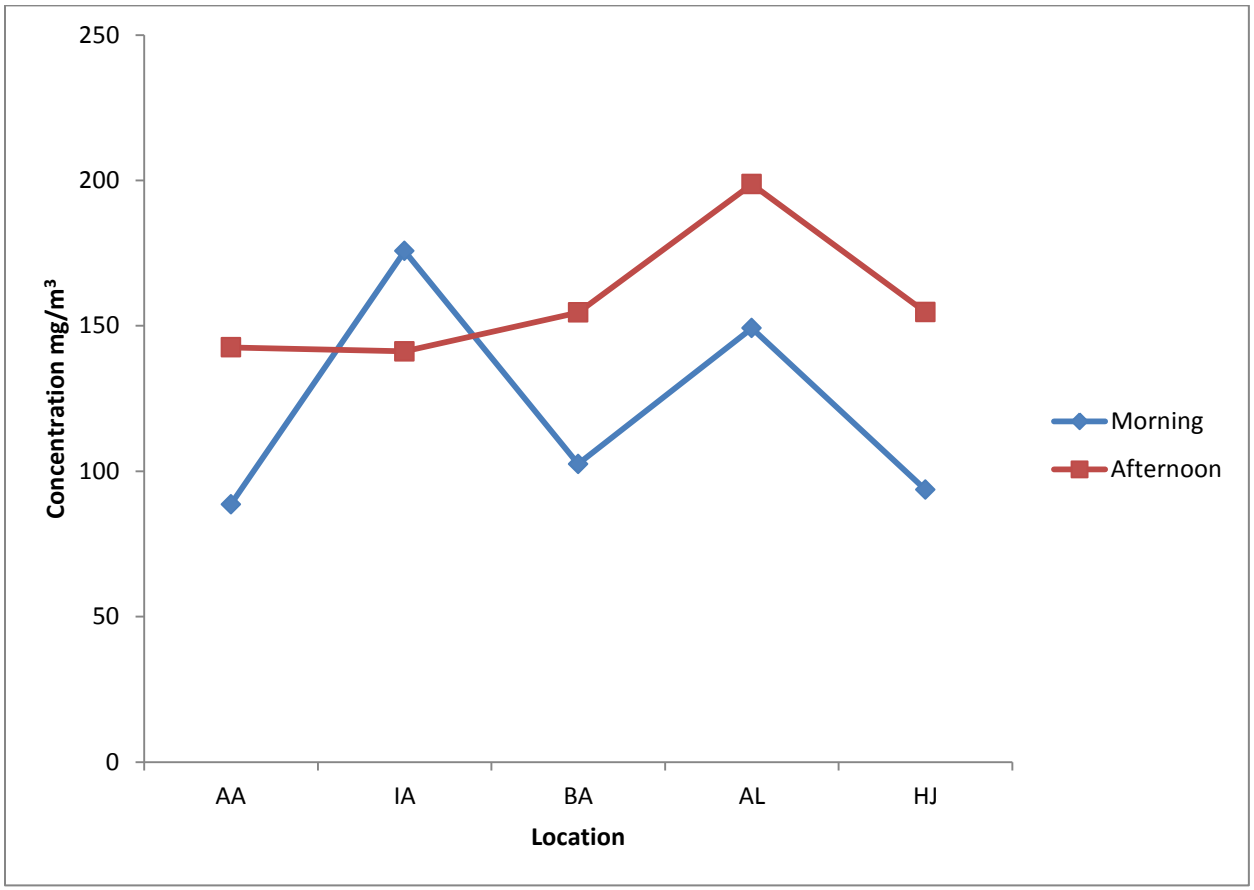

Fig 4.19: Mean concentrations of Cd across the five locations during morning and afternoon periods

4.7.2 Lead

Lead (Pb) recorded the highest average heavy metal concentration across the five sampling locations as follows 189.0 mg/m^3 (AA), 296.6 mg/m^3 (IA), 226.2 mg/m^3 (BA), 225.4 mg/m^3 (AL) and 457.9 mg/m^3 (HJ) while the blank was 19.8 mg/m^3. Concentrations of Lead (Pb) obtained at 10, 20 and 30metres during afternoon periods were higher than concentrations obtained in the morning periods across the sampling locations and highest concentration (998.6 mg/m^3) was recorded at Holiness junction during afternoon period at 10metres. Lead levels were found to reduce with distance further away from traffic at Holiness junction by 29.7% and the levels at Agbaakin layout, Barracks area, Iyana-agbala and Abayomi area reduced by 17.2%, 14.4%, 8.5% and 10.5% respectively. All these values were several folds higher than the guideline limit for Pb (0.0005mg/m^3) set by WHO for urban centres.

Figure 4.9 show descriptive statistics for Lead across all the sampling locations and Lead had overall mean of 279.03 while overall median was 240.39. Also Pb recorded overall minimum and maximum of 79.81 and 998.64 respectively. The overall 25^{th} and 75^{th} for Pb were 189.22 and 299.11 respectively.

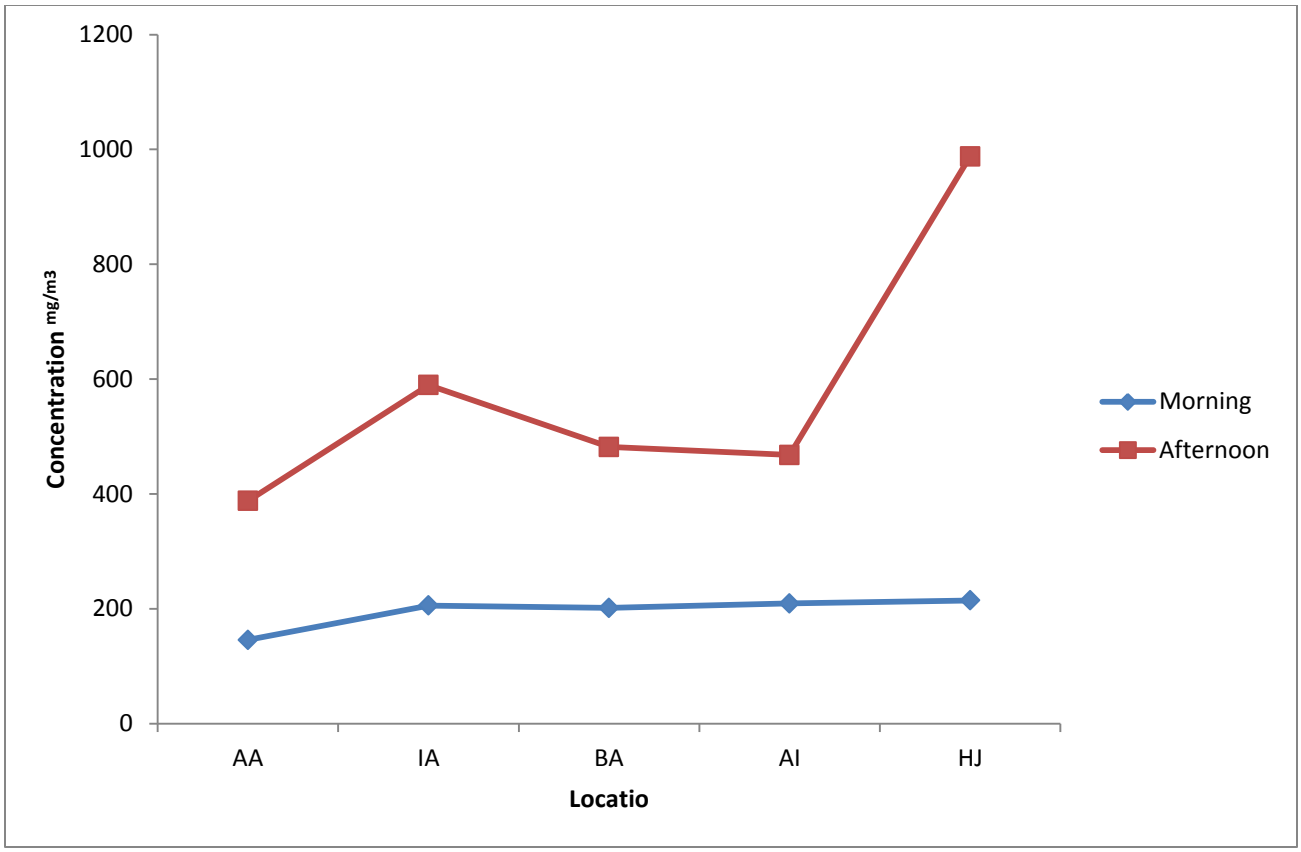

Fig 4.20: Mean concentrations of Lead across the five locations during morning and afternoon period

4.7.3 Zinc

Zinc also recorded an average concentration of 0.42 mg/m^3 (AA), 0.31 mg/m^3 (IA), 0.28 mg/m^3 (BA), 0.45 mg/m^3 (AL) and 0.68 mg/m^3 (HJ) and the blank was 0.0135 mg/m^3.Zinc (Zn) concentrations recorded at 10, 20 and 30 metres during afternoon periods were also slightly above concentrations recorded during morning periods except at Holiness junction at 20metres where morning concentration (0.802 mg/m^3) was slightly above the afternoon concentration (0.556 mg/m^3). Zinc level decreased with distance further away from traffic by 2.4% at Agbaakin layout and 3.4%, 1.09%, 2.45% and 7.5% at Holiness junction, Barracks area, Iyana-agbala and Abayomi area respectively. All these values were 7-17 times above the WHO guideline limit for Zn (0.04mg/m^3).

Figure 4.10 show descriptive statistics for Zinc across all the sampling locations and zinc had overall mean of 0.438 while overall median was 0.319. Also Zn recorded overall minimum and maximum of 0.138 and 1.029 respectively. The overall 25^{th} and 75^{th} for Zn were 0.225 and 0.573 respectively.

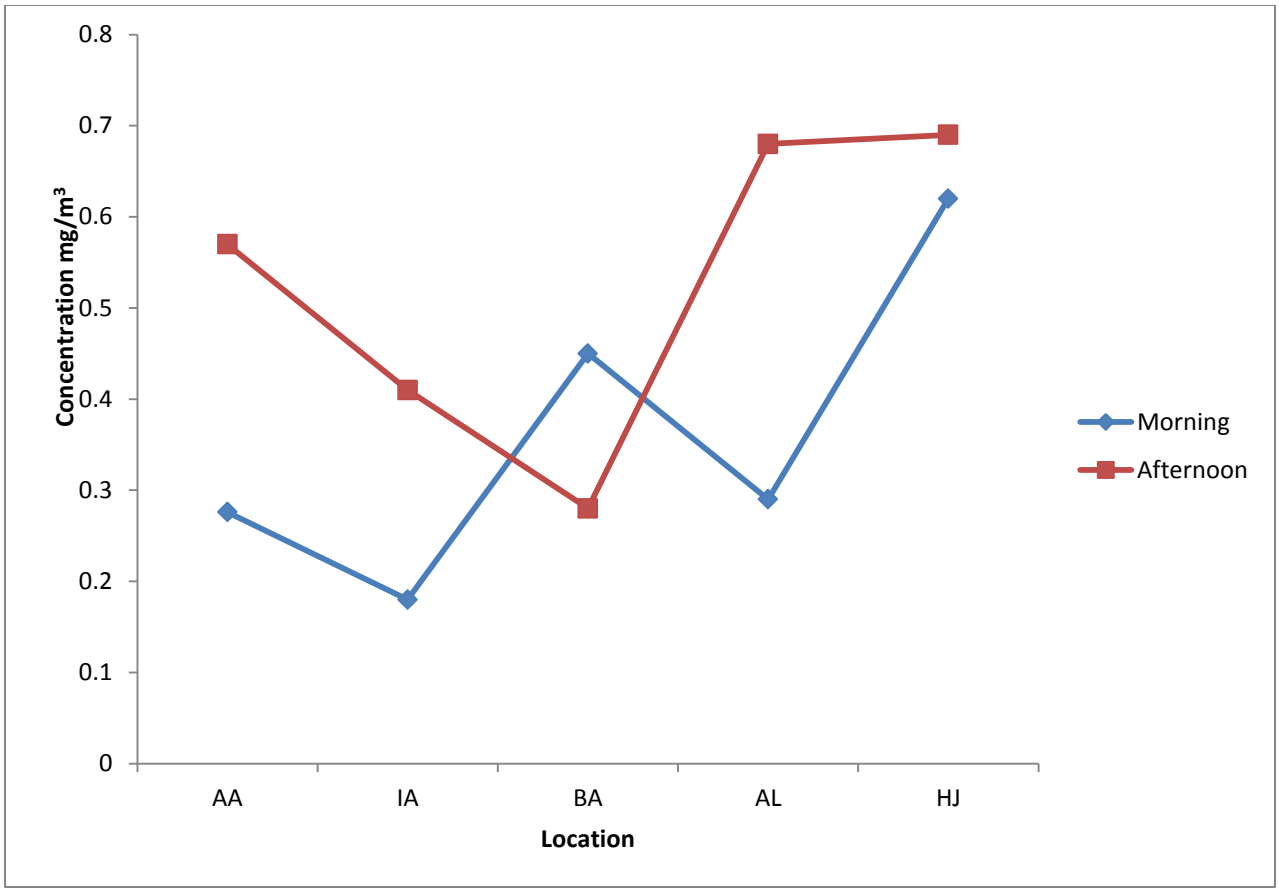

Fig 4.21: Mean concentrations of Zinc across the five locations during morning and afternoon period.

4.7.4 Iron

The concentrations of Iron (Fe) across the five locations were as follows: (1.69, 1.53, 1.44, 5.65 and 0.69 mg/m^3 and the blank was below detection limit). Iron (Fe) concentrations recorded at 10, 20 and 30 metres during afternoon periods across all sampling locations were also relatively higher than morning periods except at Agbaakin layout where morning concentrations at 10 and 20 metres (8.954 mg/m^3 and 5.563 mg/m^3 respectively) were slightly higher than corresponding afternoon concentrations (5.341 mg/m^3 and 5.038 mg/m^3 respectively). Iron concentration decreased with distance further away from traffic by 12.4% at Agbakin layout, 4.56% at Abayomi area, 3.9% at Holiness junction, 7.91% at Barracks area and 9.21% at Iyana-agabala respectively. All these values were several times above WHO guideline limit for Fe (0.01 mg/m^3).

Iron had overall mean of 2.202 while overall median was 0.821. Also Fe recorded overall minimum and maximum of 0.333 and 8.954 respectively. The overall 25^{th} and 75^{th} for Fe were 0.689 and 4.513 respectively.

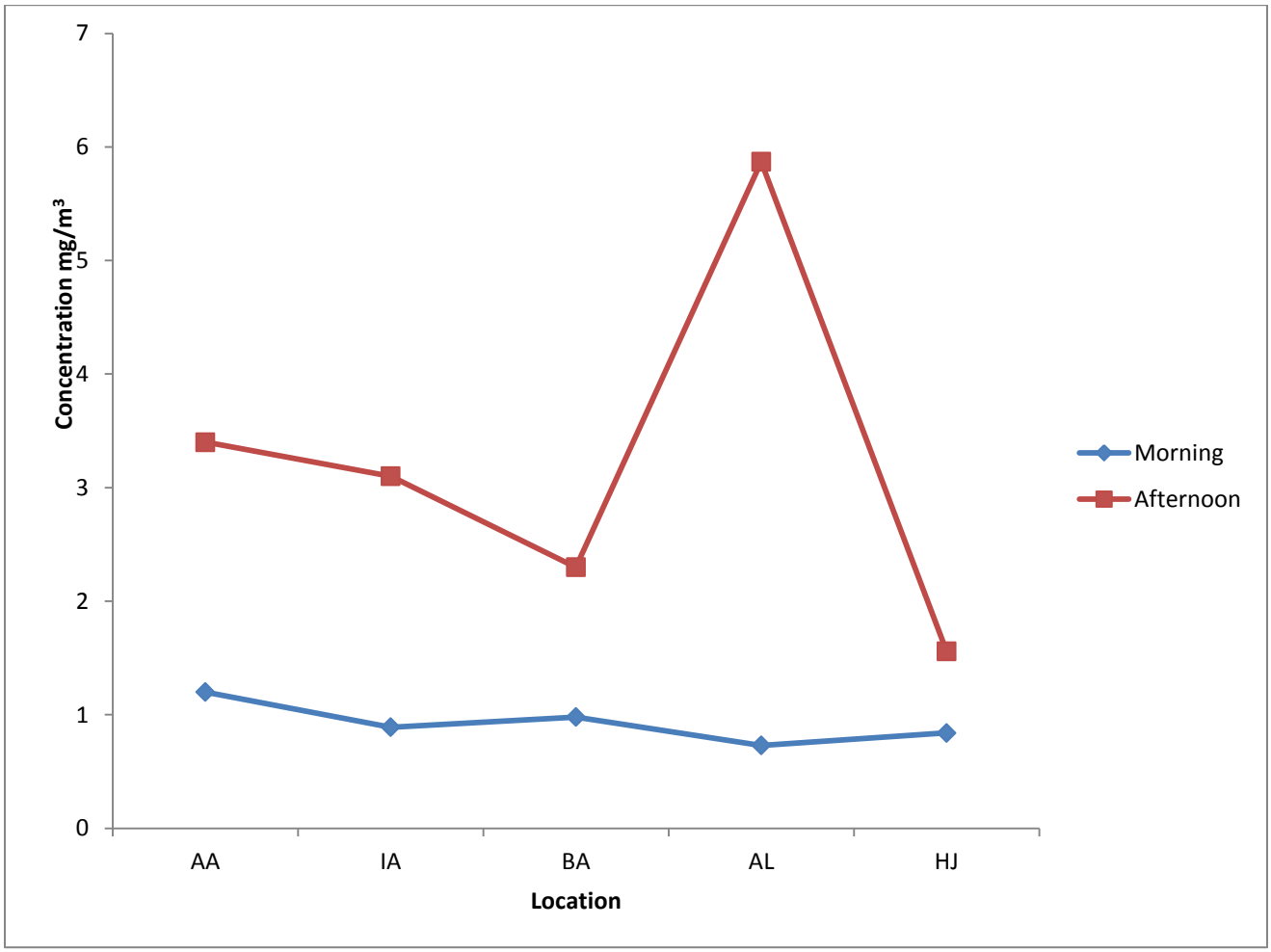

Fig 4.22: Mean concentrations of Iron across the five locations during morning and afternoon period

4.7.5 Chromium

Chromium recorded an average concentration of 0.013 mg/m^3 (AA), 0.015 mg/m^3 (IA), 0.012 mg/m^3 (BA), 0.016 mg/m^3 (AL) and0.034 mg/m^3 (HJ) and the blank was below detectable limit. Chromium (Cr) concentrations recorded at 10, 20 and 30metres throughout the sampling locations during afternoon periods were higher than the corresponding concentrations in the morning periods and the concentration decreased from the main road to the 30 metres point and highest concentration was recorded at 10metre both in the morning and afternoon periods.

Figure 4.11 show descriptive statistics for Chromium across all the sampling locations. Cr had overall mean of 0.019 while overall median was 0.017. Also Cr recorded overall minimum and maximum of 0.003 and 0.042 respectively. The overall 25^{th} and 75^{th} for Cd were 0.013 and 0.018 respectively.

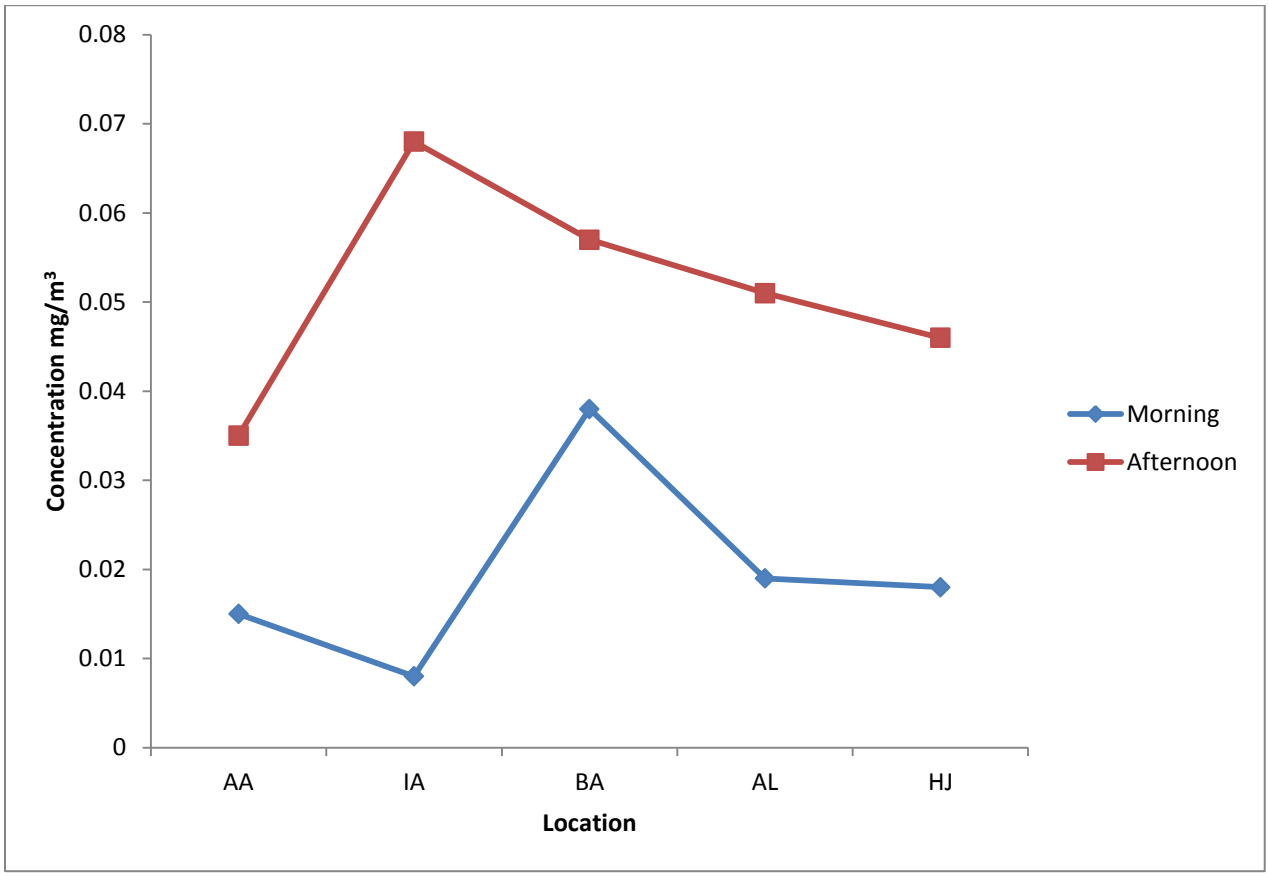

Fig 4.23: Mean concentrations of Chromium across the five locations during morning and afternoon periods

4.7.6 Copper

The mean of copper (Cu) was 0.013 mg/m^3 (AA), 0.015 mg/m^3 (IA), 0.012 mg/m^3 (BA), 0.016 mg/m^3 (AL) , 0.034 mg/m^3(HJ) and blank was 0.001 mg/m^3 respectively. Copper (Cu) concentrations obtained at 10, 20 and 30 metres across sampling locations in the afternoon periods were also higher than concentrations obtained in the morning periods. These values were 3.4times above WHO guideline limit for Cu (0.01 mg/m^3).

Figure 4.12 show descriptive statistics for Copper across all the sampling locations and Cu had overall mean of 0.018 while overall median was 0.017. Also Cu recorded overall minimum and maximum of 0.002 and 0.06 respectively. The overall 25^{th} and 75^{th} for Cd were 0.009 and 0.022 respectively.

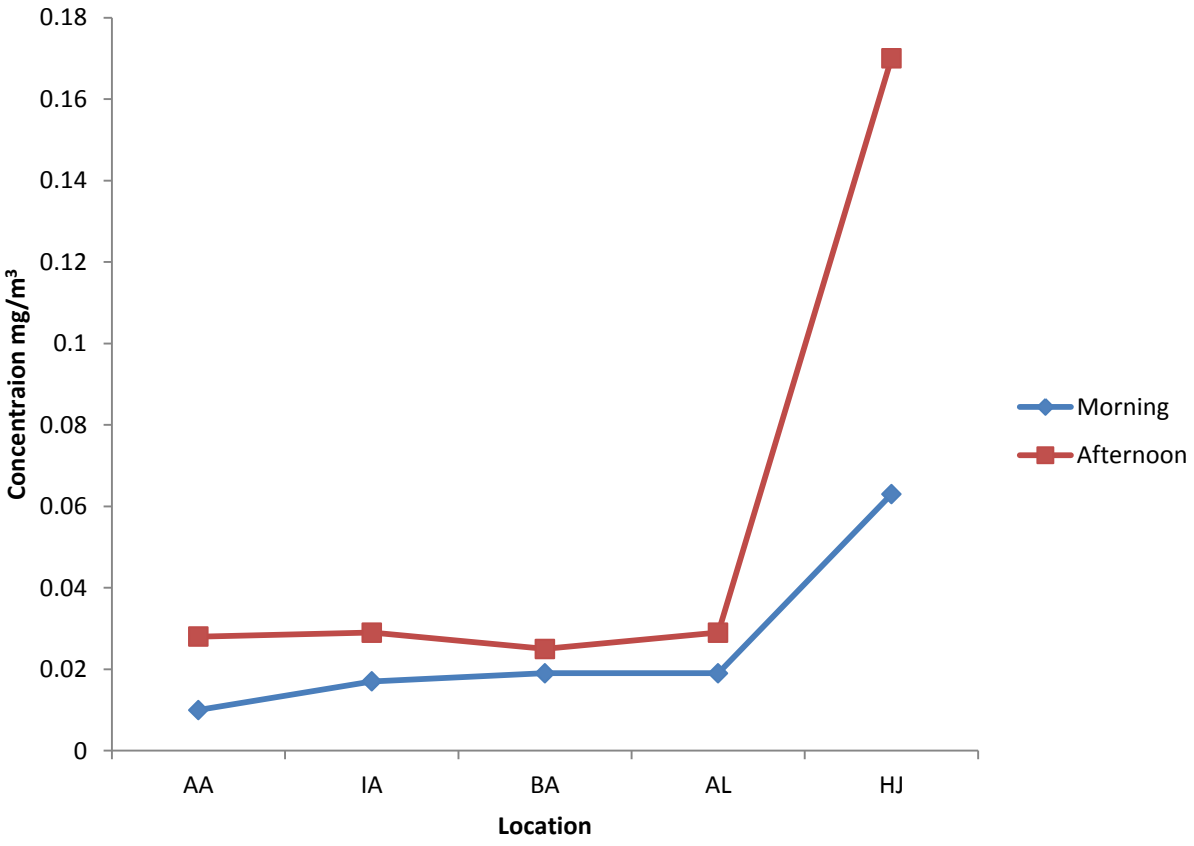

Fig 4.24: Mean concentrations of Cu across the five locations during morning and afternoon periods

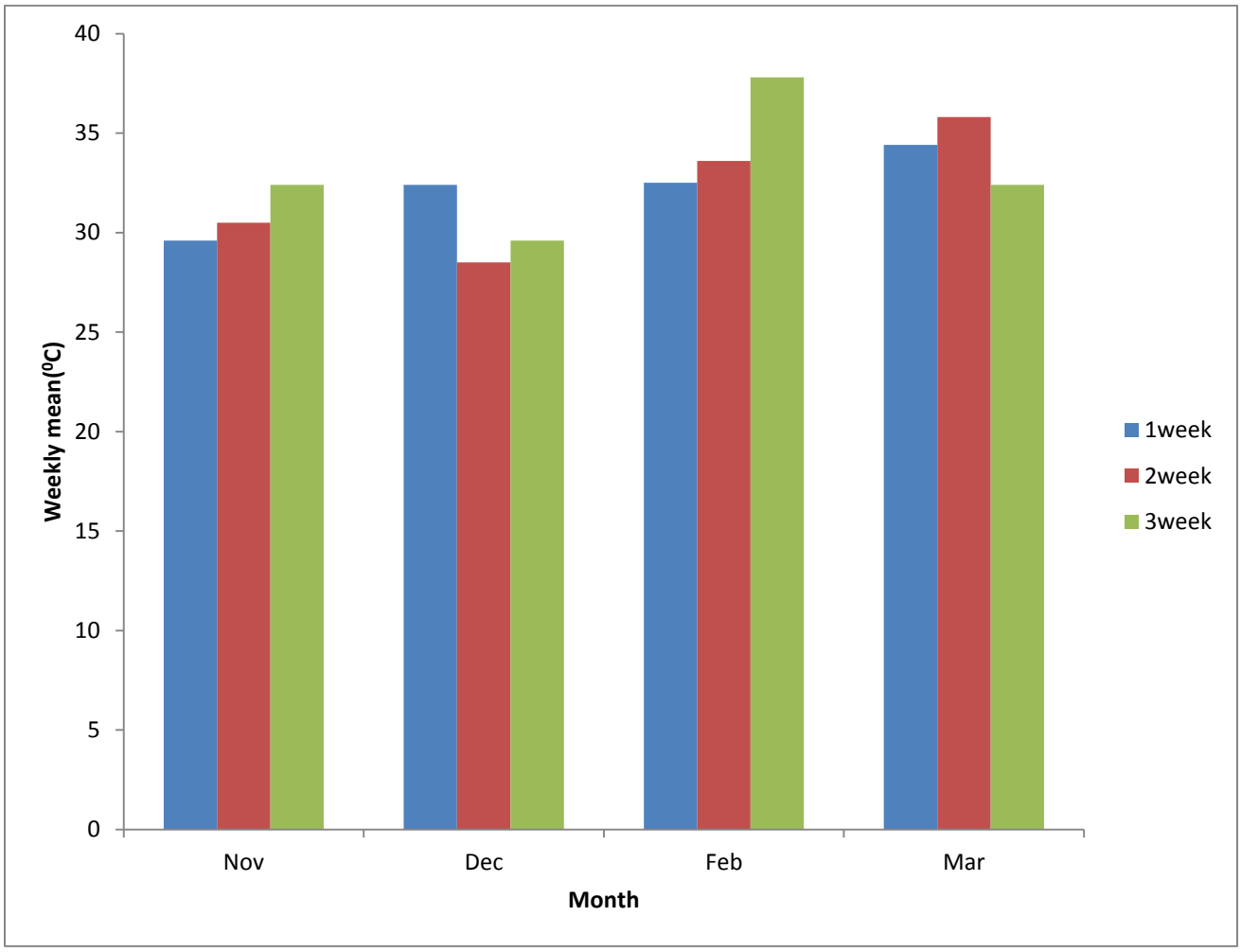

Fig 4.25: Mean temperature during the period of study

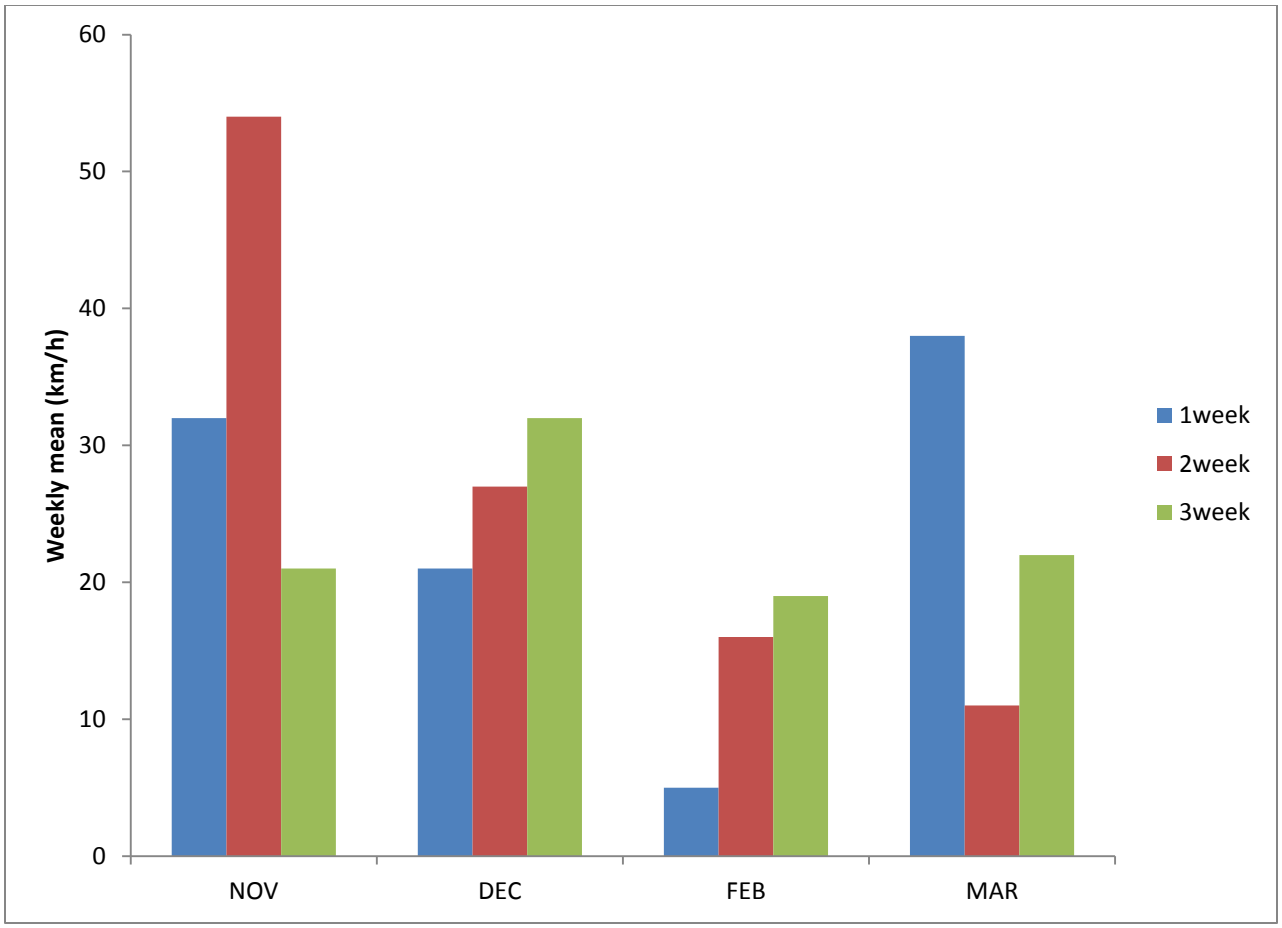

Fig 4.26: Mean wind speed during the study period

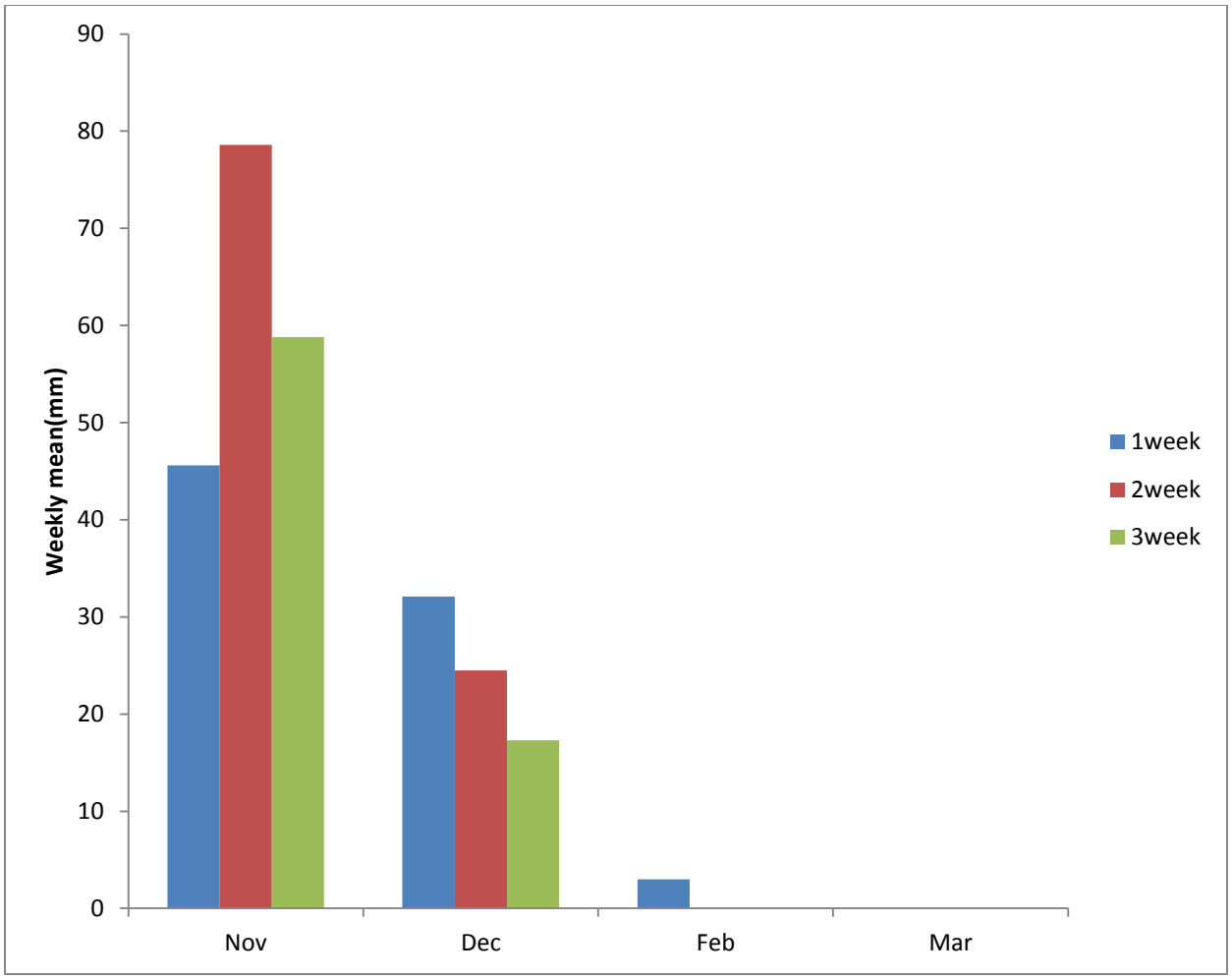

Fig: 4.27Mean rainfall for the period of the study

CHAPTER FIVE

DISCUSSION

This chapter presents the implications of the result obtained for particulate matter (PM_{10}) and heavy metals concentrations monitoring across the various sampling point. The implications of traffic density and activities around the sampling sites are equally discussed.

5.1 Particulate matter (PM_{10}) concentrations

Populations found along heavily trafficked major urban motorways are exposed to various pollutants and have been reported to be at higher risk of various health effects than people living in the rural areas (EPA, 2003). With the exception of natural events such as windstorms and volcanic eruptions, the highest PM_{10} mass concentrations occur near busy roadways with concentrations reducing as the distance from the roadways increases (Hitchins et al., 2000)).This is in agreement with particulate matter concentrations obtained at Abayomi area, Iyana-agbala, Barracks area, Agbaakin layout and Holiness junction all of which are impacted by high traffic emission near a busy motorway.

All these sampling points recorded higher concentrations of PM_{10} in the afternoon periods that reduced with distance away from traffic. A study conducted in Amsterdam showed that ambient concentrations of the pollutants such as PM_{10} and NO_2 were 15-22% higher at homes located in heavily trafficked streets compared to low traffic homes (Fischer *et al*., 2001). All particulate matter concentrations obtained in the afternoon periods (1-4.30 pm) were slightly above their corresponding morning (7-10.30 am) readings and higher than the WHO guideline limit of 20 $\mu g/m^3$. This is in accordance with a study that said that particulate matter concentrations increased drastically from morning periods, reaching their peak during the afternoon hours when the dispersion rate is expected to be very good.

In this study, all the PM_{10} concentrations obtained in afternoon periods were higher than the corresponding morning concentrations and greater also than the WHO guideline limit of 20 ug/m^3. The higher concentration of particulates in the afternoon may be attributed to higher traffic density and more activities carried out in the afternoon. A lot of people do move around in

the afternoon and evening hours than morning hours and their various daily activities may contribute to release of gases and particulates into the atmosphere at various concentrations, thus contributing to higher particulate matter burden in the afternoon than morning periods.

Meteorological factors namely wind speed and direction, temperature and rainfall often affect the particulate matter concentrations due to differences in these factors. Temperature and relative humidity might also have affected the concentrations of PM in the morning since the temperature is normally low and cold in the morning which make environment moist and may further trap dust particles in the air thereby reducing the particulate matter concentrations in the morning. According to Yang (2002), the most important factors driving the dispersion of traffic-generated emissions are wind speed and wind direction. This "vehicle-induced turbulence" can extend tens of meters from the road (Kalthoff *et al*.,2005). However in the afternoon, the temperature is higher generally and this may dry up the moist particles fast thereby making them more active to be dispersed into the atmosphere thus increasing the particulate matter concentrations in the afternoon hours than in the morning periods. There was little variation in the concentrations of particulate matter obtained and this maybe because the sampling periods were done in one season (dry season between December 2011 and March 2012). Traffic activity parameters that can affect particulate matter concentrations for near-road monitoring assessments include the number of vehicles, the fleet mix, and vehicle speeds. Each of these parameters has an effect on the concentration and characteristics of near-road pollutants. Traffic volume provides information on the overall source input. The fleet mix indicates the role of vehicle type on near-road air quality; for example, emissions can be quite different for locations where light-duty passenger vehicles primarily burn gasoline than where heavy-duty trucks primarily burn diesel.

The mean concentrations of particulate matter (PM_{10}) at all five sampling locations were significantly higher than the daily WHO guideline limit average of 20 ug/m^3. These values are higher than those obtained in most cities in developed countries, but compares closely with those obtained by other researchers in large cities in the developing countries with less strict pollution control measures (UNEP, 1999). There was positive correlation (r = 0.64) between traffic density and particulate matter (PM_{10}), the correlation is however not very strong and this indicates that other sources, such as re-suspended dust particles, emission from generators near the sampling

locations and emission from waste incinerators close to study areas did contribute to the particulate concentration. Spatial variations of PM_{10} were not statistically significant ($F = 1.807$, $p = 0.533$), which probably suggests that the study sites were impacted by similar sources.

The daily mean particulate matter (PM_{10}) levels measured at various sampling locations during the current study were found to be significantly higher than WHO and USEPA guideline limits (WHO, 2000). The overall daily mean level in particulate matter (PM_{10}) exhibited a mean concentration of 103.4 $\mu g/m^3$, showing predominantly a random distribution. The overall daily mean level in the particulate matter (PM_{10}) in this study was significantly higher than those reported from Yokohama (Khan *et al*., 2010), Delft (Wang *et al*., 2001), Tito Scalo (Ragosta *et al*., 2002), and Santa Cruz (Quiterio *et al*., 2004) while, the present levels were substantially lower than those reported from Lahore (Harrison *et al*., 2000), Faisalabad (Qadir and Zaidi, 2006), Delhi (Shridhar *et al*., 2010), Beijing (Wang *et al*., 2001), Bilbao (Aranguiz *et al*., 2002) and from Islamabad (Shah et al., 2008). However, the levels reported from Mumbai (Tripathi *et al*., 2004), Athens (Valavanidis *et al*., 2006), Pristina (Samara and Voutsa 2005) and Rio de Janerio (Quiterio *et al*., 2004) were almost comparable with the levels measured in this study

5.2 Effects of traffic density

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

The mean traffic count at sampling locations revealed that Holiness junction had the highest traffic count/hr (24,786). Concentrations of PM_{10} and heavy metals in all the sampling locations were several folds more than the WHO guideline limit for urban centres andthis could be attributed to the high traffic volume at these study locations and other activities as well along this motorway. Studies conducted by Abbaspour and Soltaninejad 2004 and Goyal, 2006 revealed that traffic contributes more to ambient pollution in developing countries, accounting for 80% of nitrogen dioxide and carbon monoxide and particulate matter concentrations.

In recent times, Nigeria has witnessed influx of importation of old vehicles by 30 % due to Government policies which increased the age of imported old vehicles (known as "Tokunbo" locally) from 10 years to 15 years from the year of manufacture(www.nigerianeliteforum.com)and are known as super-emitters of various pollutants. This coupled with poor vehicle maintenance culture in Nigeria as resulted in an automobile fleet which are 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, 1999).

5.3 Influence of meteorology on particle-bound heavy metals distribution

The dry season is generally characterized by a high degree of crustal re-suspension (of coarser particles) that leads to higher levels of PM_{10} and crustal metals. Dust storms are common in Nigeria during harmattan season that carry large amounts of suspended particulate matter from Sahara Desert. Mean temperature and wind speed were positively correlated with the crustal metal Fe ($r = 0.89$) which is because high solar radiation during dry season induces atmospheric convection favoring crustal re-suspension and strong winds favor atmospheric dust transport and this is in accordance with a study by Querol *et al*., 2002. High levels of Pb, Cd, Cu and Zn, along with considerable contributions from Cr and these heavy metals are believed to originate from automobile emissions together.

5.4 Heavy metals concentrations

Among the heavy metals in particulate matter sampled, major contribution was recorded for Pb and Cd. Overall, the decreasing trend of daily average heavy metals concentrations in the particulates revealed the following order: Pb> Cd > Fe > Zn > Cu> Cr. Comparison was made between the heavy metals concentrations observed in this study and those reported from other parts of the world (Singh *et al*., 2002; Shridhar *et al*., 2010). It is evident that concentrations of heavy metals along Iwo road – Idi-ape motorway are often greater than their European or US counterparts.

5.3.1 Copper

The overall daily mean value of Cu (0.91 mg/m^3) was significantly higher than those observed at sites with less traffic impacts regions in the United States, such as at Rutgers Garden in New Brunswick in central New Jersey (0.00077 mg/m^3) and at Sandy Hook on the New Jersey coast (0.00047 mg/m^3) (Gao *et al*., 2002) and one rural site in New York (Yang 2002).This suggests that traffic emissions could be a significant contributor to atmospheric Cu along this motorway. The average concentration of Cu, a typical metal from brake–lining materials, was highest at 10metres (0.034 mg/m^3) at Holiness junction, with a range 0.017 mg/m^3 to 0.060 mg/ m^3 and the concentrations reduced at other distances away from traffic.

A fairly good correlation was found between Cu and Zn at Holiness junction (R = 0.731); as Cu and Zn could be co–products in brake processes (Pakkanen *et al*., 2001; Weckwerth, 2001). High concentrations of Cu observed at this location could be an indicator of the extensive use of brakes in the vehicles as it is very close to a major intersection and also as by- products of lubricating oil in vehicles (Iijima *et al*., 2007). Presence of atmospheric Cu along Iwo- road – Idi-ape was also be attributed to intensive traffics along this route and the high emissions from old rickety vehicles.

5.3.2 Lead

Lead had overall average concentration of 161.1 mg/m^3 and it was significantly higher than the concentrations observed near motorways in Cincinnati (Martuzevicius *et al*., 2004). Highest concentration of Pb (998.6 mg/m^3) was obtained at 10metres at Holiness junction during afternoon period which was higher than the average lead concentration (0.096 mg/m^3) in highly polluted city of Dhaka in PM_{10}, value reported by Salam *et al*., 2003. A positive correlation (r=0.65) was found between Pb and traffic density which implies it could be as a result of tailpipe emission due to high traffic density. This is a clear indication that the leaded premium motor spirit (gasoline) is probably still in use in Nigeria (Oluyemi *et al*., 2001). This was asserted by Odukoya *et al*., 2000 that high levels of Pb are still released or re-suspended by vehicle traffic.

Also, the increased level of lead concentration at Holiness Junction and other sites was probably due to high number of motorcycles (locally called ‘Okada” and ‘Keke-Napep’) plying this

motorway. Motorcycles are two stroke engines and they are known to emit more pollutants due to incomplete combustion than cars and buses (Kumar et al., 2001). This is also in line with the WHO study in 2007 which indicated a growing trend in vehicular-derived air pollution in Lagos due to traffic volume comprising of 2-stroke engines motorcycles (which have higher emissions of particulate matter and un-burnt hydrocarbons and heavy metals than other types of engines).

Holiness junction was characterized by high vehicular traffic activities and good positive correlation (r= 0.65) was found between Lead (Pb) and traffic density, however, the correlation is not very strong which suggests that vehicular traffic contribute minimally to the high level of Pb and that other sources contributed immensely to the high levels of lead (Pb) at this site. Uncontrolled open incineration of waste was a common practice observed at this sampling point and at other sampling points as well and activity that involves the burning of energy such as petroleum derivatives such as plastics tends to release lead into the atmosphere and this is consistent with the study by M. Ragosta *et al*., 2002.This was a common feature at all the sampling points along this motorway which may explain why the levels of Pb were high and significantly above the guideline limit for lead set by WHO. Also, Idi ape- Iwo road area is a major banking hub in Ibadan metropolis and these banks rely heavily on petrol and diesel fuelled generators for electricity supply for their operations and in the process they burn a lot of fossil fuels, thereby contributing to emissions of Pb and other heavy metals as supported by studies carried out by Weckwerth, 2001.

Road paints might have contributed to high level of Pb along this motorway and similar view was shared by (Camatini M. *et al*,2001). Also, emissions from road or windblown dust, brickfields or other industries may also have significant contribution to the lead pollution around the study locations along Idi-ape – Iwo road motorway and similar finding was reported in Dhaka city by Samal *et al*., 2003. Being a commercial area, Iwo road- Idi-ape motorway does witness influx of heavy trucks that come to deliver goods on a regular basis and these vehicles use diesel engines which are known to emit more heavy metals such as Pb, Cu and Mn and this is in line with the study in the Balkans, where Rajsic *et al*., 2008 indicated that Pb and Cu are related to heavy trucks with diesel engines. Influx of heavy trucks/vehicles could also explain the high levels of atmospheric Pb in these sampling points.

5.3.3 Cadmium

The mean concentration of 52.5 mg/m^3that was recorded for Cd was found to be significantly higher than the concentrations observed near motorways in Cincinnati (Martuzevicius *et al*., 2004). The overall mean Cd concentration in the PM_{10} estimated in the present study was also found to be higher than the reported level Bursa (Samura *et al*., 2003).A positive correlation (r= 0.44) was found between Cd and traffic density. Most of the commercial buses and cars that ply this route are old and not road worthy. Scerbo *et al*. 2001 mentioned that Cd in the atmosphere can be traced to Di-methyl cadmium used in the production of tetraethyl lead and it is emitted by old vehicles that do not meet environmental standards. Weak correlation found between Cd and traffic density and this connotes that atmospheric Cd was also introduced from other sources along this motorway. According to Sharma *et al*.,2007 and Baez *et al*., 2007, Cd emission is attributed to disposal of batteries, as well as burning of tyre containing Cd pigments and this is in accordance with what was observed during the sampling periods. When mean concentration of cadmium in this study was compared with WHO guideline limit for cadmium, it was found to be several folds higher than the WHO guideline limit.

In most of the sampling points, burning of household wastes, burning of paint based materials, and incineration of municipal waste materials were the norm especially at Iyana-agbala, Holiness Junction and Abayomi area, tyres and plastic products were burnt freely all which could be a source of atmospheric Cd and it was captured in the observational checklist during sampling periods. This assertion was also supported by Olowoyo and van Heerlen (2010) that Cd in the atmosphere could be traced to urban metal smelting companies, burning of household wastes and paint based materials. There are many local restaurants close to all the sampling points and they burnt a lot of biomass/coal for cooking and the emission from burning of biomass and cigarette smoking could also have contributed to cadmium emission at most of the sampling points. This is consistent with what was reported by Azad and Kitada, 1998. There are numerous automobile mechanic workshops situated all over this area and they indiscriminately dispose their waste engine oils and some burnt these oils.

5.3.4 Zinc

The overall average concentration for Zn in this study was 0.52 mg/m^3 and this was found to be comparable with those reported from Athens, Greece 0.35 mg/m^3 (Valavanidis *et al*., 2006) ¸ Lahore, India 0.27 mg/m^3 (Harrison *and Yin*, 2000), and Delhi, India 0.46 mg/m^3 (Shridhar *et al*., 2010) but these values were above the guideline limit for Zn (0.04 mg/m^3) set by WHO. Similarly, this value was also found be higher than those reported from Bilbao, Spain 0.0027 mg/m^3 (Aranguiz *et al*., 2002), Ponzone, Italy 0.0098 mg/m^3 (Rizzio *et al*., 1999) and Paris, France 0.0046 mg/m^3 (Ayrault *et al*., 2010).

A good positive correlation (r=0.78) was found between Cu and Zn. This indicates that traffic emissions could be a significant contributor to atmospheric Cu along this motorway (Cadle *et al*., 1999). This is consistent with a study carried out by Sternbeck *et al*., 2002; Singh *et al*., 2002; Adachi and Tainosho, 2004) that zinc emission in the ambient air near high–traffic zones is associated with corrosion of metallic part of vehicles, re-entrained dust from roads, tyres rubber abrasion and tear and wear of engine parts and this was also reported by Houthuijs *et al*., 2001. Atmospheric Zn pollution along Iwo-road –Idi-ape may also be attributed to the high volume of diesel (Cadle *et al*., 1999) and two-stroke engine vehicles (Begum *et al*., 2004). In agreement with these results, Sillanpaa *et al*. 2005) found in ambient PM_{10} in Barcelona relatively high Cu and Zn ratios to particulate organic matter when compared with other European cities (urban background stations).

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5.3.5 Chromium

The overall average levels of Cr (0.19 mg/m^3) in the atmospheric PM along this motorway were higher compared with most of the cities in Asia and Europe. The value for average Cr level in Pristina, Kosovo was 0.0011 mg/m^3 (Samara and Voutsa, 2005), 0.005 mg/m^3 were reported in Mumbai, India (Tripathi *et al*., 2004) and 0.0054 mg/m^3 in Pavia, Italy (Rizzio *et al*., 1999). Also, the concentration of Cr in this study was found to be higher than the guideline limit for Cr (0.005 mg/m^3) set by WHO. A positive correlation (r=0.46) was obtained when traffic density was correlated with chromium. This correlation being weak one indicates that atmospheric Cr along this motorway emanated from other sources as well aside vehicular emissions.

Cr emission has significant contributions from crude–oil combustion and metallurgical units housed in the industrial areas (Querol *et al*., 2004). This is in accordance with what was observed at all the sampling sites; there are many mechanic workshops, small industries where electroplating works take place. Atmospheric Cr might have come from these places in great amount because they carry out their works without proper regulations. Also, other contributors include open waste incinerators (Chandler, 1996), which was visible during sampling periods at most of the sampling sites. Geogenic dust and construction debris wind- blown from far distances away from the sampling sites might have contributed to Cr concentration along this motorway and this was in accordance with a study by Chandler, 1996.

5.3.6 Iron

Fe had an overall mean concentration of 2.54 mg/m^3 and these levels were found to be comparable with those reported from Santa cruz, Brazil 3. 89 mg/m^3 (Quiterio *et al*., 2004), Bursa, Turkey 4.14 mg/m^3 (Samura *et al*., 2003), Athens, Greece 1.02 mg/m^3 (Valavanidis *et al*., 2006) and Dhaka, Bangladesh 2.50 mg/m^3 (Salam *et al*., 2003) but higher than those reported from Faisalabad 0.045 mg/m^3,(Qadir and Zaidi, 2006), Paris 0.048 mg/m^3 (Ayrault *et al*., 2010), Debrecen 0.058 mg/m^3 (Borbely–Kiss *et al*., 1999), Ispra 0.014 mg/m^3 (Rizzio *et al*., 1999), and Tito Scalo 0.052 mg/m^3 (Ragosta *et al*., 2002).A weak correlation (r=0.38) was obtained between Fe and traffic density which implies that vehicular emission contributed minimally to the atmospheric Fe pollution along this motorway. Atmospheric Fe in this study might have come from the windblown mineral dust being mainly of natural origin such as crustal weathering. This is in agreement with what was reported by (Borbely–Kiss *et al*., 1999; Pakkanen *et al*., 2001; Hao *et al*., 2007; Shah and Shaheen, 2008) in their studies.

5.5 Inter-locational variations of heavy metal concentrations

Inter- sampling location variations were significant for all heavy metals except Pb (F=2.1, p= 0.09 and Cu (F=0.18, p=0.95). Absence of significant spatial variations in Pb and Cu concentrations probably indicates ubiquitous traffic sources near the sampling sites. Concentration of all heavy metals was higher ($p< 0.05$) than WHO permissible limits for urban centres. Proximity of all the sampling locations to generator emission, uncontrolled open waste incinerators and emissions from small scale industries could be the reasons for higher heavy metal concentrations.

Being a residential area as well, domestic emissions (in the form of charcoal, biomass and low–grade coal combustion) could also be significant. Overall, it was observed that the differences in metal concentrations between the five investigated sampling locations, although statistically significant in most cases, were not extremely high. This is expected to some extent because all five sampling locations were typically residential in nature with similar land–use patterns and were possibly impacted by similar sources. Concentrations of traffic tracers (Cu, Zn and Cr) were on an average 5–19% higher during afternoon periods than morning periods but the differences were not statistically significant (p>0.05). This possibly suggests that traffic volumes were not significantly different at the sampling locations between afternoon periods and morning periods.

5.6 Variation in concentration gradients of heavy metals along classified traffic routes

The ambient concentrations of traffic related heavy metals at a specific location could be affected by the distance away from the vehicle emission source. The decreasing concentration gradients of certain components in aerosols were reported in previous studies Zhu *et al*. (2002a; 2004) found that the concentrations of black carbon decreased away from highways within a distance of 150 metres in Los Angeles, and aerosol mass concentrations were also found to be decreasing away from highways in Australia (Hitchins *et al*., 2000) and in the Netherlands (Janssen, 2001).In addition, particles may undergo certain processes in the air such as coagulation; these processes may also result in increased concentration of these elements with distance. On the other hand, temporal concentration variations of air pollutants were also observed. Zhu *et al*. (2004) reported higher concentrations of ultrafine particles and black carbon in summer during the daytime, while temporal variations of heavy metals concentrations were also found to be a function of the prevailing meteorological conditions including their upwind sources (Singh *et al*., 2002).

All the selected heavy metals in this present study showed a strong linear relationship between the concentrations and the distance away from the motorway. There were decreasing concentration gradients from 10, 20 and 30metres both during the morning and afternoon periods at all the sampling points. Spatial variations in heavy metals concentrations were found to reduce with distance away from traffic by 18.7% for this present study.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study assessed the levels of particulate matter and heavy metals concentrations of seven (7) selected heavy metals stratified at 10, 20 and 30metres away from the Iwo-road – Idi-ape motorway. Five sampling locations viz: Abayomi Area, Iyana- agbala, Barracks Area, Agbaakin layout, and Holiness junction were selected along the motorway. Traffic density was estimated using standard methods and activities that may contribute to particulate matter loads along this motorway were captured using well- structured observational checklist. PM_{10} and heavy metals levels at selected locations were 6-8times above the WHO guideline limit for urban centres. Holiness junction had the highest concentration of PM_{10} which was greater than the WHO guideline limit of 20 $\mu g/m^3$ by factor of 8 and Pb, Cd and Cu also recorded the highest concentrations at this sampling point which were higher than the WHO guideline limit for the metals by several factors.

The PM_{10} levels in selected locations increased during afternoon period and the same was observed for most of the heavy metals except for Cd and Fe that reached a peak during morning period. There was positive correlation (r=0.59) between traffic density and particulate matter (PM_{10}) in this study but the correlation was weak. This may be due to soil entrainment by wind and contributions from nearby generator emissions, uncontrolled open waste incinerators, industrial sources and similar sources. The average concentration of all the heavy metals was very much higher than the WHO guideline limits by several factors. Emissions from large number of two stroke wheeler engines (locally called okada and Keke-Napep) and old vehicles plying this motorway which do not meet environmental standards might have contributed also to high levels of these heavy metals in this area.

The heavy metal concentration variations along this motorway were affected by the high traffic volume, emissions from open waste incinerations, burning of biomass/coal by local restaurants, soil derived dusts, emission from electric generators fuelled by petrol and diesel by numerous banks and small business outlets along this motorway and wind speeds and directions; according to meteorological data obtained from Nigerian meteorological agency Samonda Ibadan, wind

direction observed was predominately North-east during this study which might have brought particulate matter from industrial areas of city to this study location and this is in accordance with what was reported by Allen *et al*., 2000 that particles have relatively longer residence times in the air, and are deposited more slowly, they can be transported over longer distances. There is need to initiate holistic longitudinal study to establish true relation between vehicular pollution and heavy metals concentrations found on our traffic-way.

6.2 Recommendations

1) There is need for periodic monitoring of ambient air quality along Idi ape – Iwo road and other major motorways in the country as it is being done in advanced countries to ascertain the levels of PM coming from traffic-related activities.

2) Residential and community facilities should be sited away from transportation-related emission areas to avoid the harmful effects of traffic related particulate matter.

3) There is need to integrate environmental and health considerations in urban planning, including locating offices and commercial space in area convenient for general populace in order to reduce the need for motorized transport.

4) Vehicle owner should be encouraged to adopt better technology such as use of scrubbers and catalyst converters so as to reduce emissions from their exhausts.

5) There is need for relevant organization such as NESREA to come up with guideline limits for heavy metals in air particulate in Nigeria.

6) Discrete initiatives to replace old and small vehicles and introduce new big capacity vehicles should be in place. Less the number of vehicles, less the level of traffic pollution.

6.2.2 Future outlook

1) Results from this research can be used to support further studies on traffic-related heavy metals and it can also help guide policy formulation in this part of the world.

2) More research is needed to eliminate the influence of possible co-founders i.e we need to distinguish between particulate matter coming from traffic related activities and those from other sources.

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APPENDIX 1

Observation checklist for levels of heavy metals in traffic-related particulate matter along Iwo road- Idi ape, Ibadan

Sampling point……..

LOCATION OF SAMPLING POINT

Indicator observed	**Highly Present**	**Moderately Present**	**Present**	**Absent**
Commercial activity				
Industrial activity				
Residential area				

ROAD CHARACTERISTICS

Indicator observed	**Highly Present**	**Moderately Present**	**Present**	**Absent**
Tarred roads				
Untarred roads				

ACTIVITIES WITHIN AND AROUND STUDY VICINITY

Indicator observed	**Highly Present**	**Moderately Present**	**Present**	**Absent**
Generator emission				
Burning of refuse				
Bush burning				
Emission from heavy truck				
Dumpsite				
Road construction				

Key: Highly present +++ Moderately present ++ Present + Absent -

APPENDIX 2

Table 4.2: Description of Sampling location using GPS

LOCATION	Longitude	Latitude	Elevation
Abayomi area			
10M	N O7^0 .24.179’	E003^0.56.404’	231m
20M	N O7^0 .24.181’	E003^0.56.401’	230m
30M	N O7^0 . 24.185	E003^0.56.400’	234m
Agbaakin layout			
10M	N O7^0 .24.226’	E003^0.55.955’	250m
20M	N O7^0 .24.217 ‘	E003^0.55.957’	251m
30M	N O7^0 .24.218’	E003^0.55.958’	253m
Barracks Area			
10M	N O7^0 .24.204’	E003^0.56.106’	243m
20M	N O7^0 .24.199’	E003^0.56.099’	244m
30M	N O7^0 .24.194’	E003^0.56.103’	245m
Holiness Area			
10M	N O7^0 24.231’	E003^0.55.703’	236m
20M	N O7^0 .24.238’	E003^0.55.706’	245m
30M	N O7^0 .24.244	E003^0.55.708’	241m
IyanaAgbala			
10M	N O7^0 .24.194’	E003^0.56.187’	236m

20M	N O7^{0} .24.192’	E003^{0}.56.193’	234m
30M	N O7^{0} .24.189’	E003^{0}.56.196	231m