EVALUATION OF SOME GASEOUS AIR POLLUTANTS IN WARRI AND ITS ENVIRONS, IN DELTA STATE, NIGERIA.

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SUPERVISOR

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CERTIFICATION

This is to certify that this research work "Evaluation of Some Gaseous Air Pollutants in Warri and its Environs, in Delta State, Nigeria." was carried out by Oguname, Ufuoma Sebastian in the Department of Chemistry, Delta State University, Abraka.

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DR. O. O. Emoyan **Date**
Project Supervisor

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Head of Department

DEDICATION

This research work is dedicated to God Almighty for his grace; tender mercies and enablement which enabled me to finish this academic pursuit.

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My profound gratitude goes to God Almighty for being the essence of my academic provision and beyond. I ascribe all glory to Him.

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ABSTRACT

The concentration of air pollutants such as Carbon Monoxide $CO_{(g)}$, Carbon (IV) oxide $CO_{2(g)}$, Hydrogen sulphide $H_2S_{(g)}$, Nitrous oxide $NO_{(g)}$ and Methane $CH_{4(g)}$ were determined in selected sites in Warri and its environs Delta State Nigeria using aeroqual gas detector kit model American Standard for Testing Materials (ASTM) D3249-95 (2011).The sampled stations were; Deco junction, Airport junction, Petroleum Training Institute junction and Oviore junction respectively. Results showed that $CO_{(g)}$ ranged from 5.01 – 7.90µg/m³ in Deco junction 6.01 – 8.80µg/m³ in Airport junction, 7.01 – 8.20µg/m³ in Petroleum Training Institute junction and 3.20 – 4.60µg/m³ in Oviore junction (control); the mean concentration of $CO_{2(g)}$ ranged from 3.20 – 16.20µg/m³ in Deco junction, 11.00 – 15.90µg/m³ in Airport junction, 11.90 – 15.80µg/m^3 in Petroleum Training Institute junction and 6.50 – 8.80mg/m³ in Oviore junction; the mean concentration of $H_2S_{(g)}$ ranged from 0.13–1.60µg/m³ in Deco junction, 0.09 – 0.15µg/m³ in Airport junction, 0.01 – 0.19µg/m³ in Petroleum Training Institute junction and 0.01 – 0.40µg/m³ in Oviore junction; also the mean concentration of $NO_{(g)}$ ranged from 0.10 – 0.18µg/m³ in Deco junction, 0.02 – 0.90µg/m³ in Airport junction, 0.01–0.11µg/m³ in Petroleum Training Institute junction and 0.01 – 0.10µg/m³ and Oviore junction. The mean concentration of $CH_{4(g)}$ ranged from 3.20 – 5.20µg/m³ in Deco junction, 3.02 – 4.33µg/m³ in Airport junction, 4.09 – 4.69µg/m³ in Petroleum Training Institute junction and 0.00 – 0.09µg/m³ in Oviore junction. However, the concentrations of the pollutant $CO_{2(g)}$, $CO_{(g)}$ and $CH_{4(g)}$ were higher in Petroleum Training Institute junction when compared to the locations. $H_2S_{(g)}$ and $NO_{(g)}$ had higher concentration in Deco junction. However, on seasonal variation the concentration of pollutants were higher in dry season than wet season. Hence, the study showed that the concentration of $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $CH_{4(g)}$ and $NO_{(g)}$ measured in the various sites was below the Department of Petroleum Resources limits.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The atmosphere is a complex natural gaseous system that is essential to support life on planet earth. Air is the mixture of gases that fills the atmosphere, giving life to the plants and animals that makes the earth such a vibrant place (Woodford, 2010). The atmosphere of the earth is the layer of gases, commonly referred to as 'air' that surrounds the earth and is retained by gravity. It absorbs ultraviolet (UV) solar radiation, warming the surface through heat retention (green house effect), reducing extreme temperature between day and night (diurnal temperature variation).

The constituent of the atmosphere by volume contains dry air which is made up of different types of gases that is; 78.09%of Nitrogen, 20.95%of oxygen, 0.93% Argon, 0.039% Carbon dioxide and minute quantities of other gases. However, air also contains a variable amount of water vapour with an average around 1% of sea level and 0.4% over the entire atmosphere (Woodford, 2010). The three major constituents of air are nitrogen, oxygen and argon which are known as atmospheric gases while other gases such as; carbon dioxide, methane, nitrous oxide and ozone are known as trace gases. The composition of the atmosphere is considered vital for the existence of the ecosystems on the planet earth (Andersen *et al*., 2011).

Air pollution is a term that applies to any chemical, physical or biological agent that affects the natural characteristics of the atmosphere. Air pollution is perceived as the presence in the outdoor or indoor atmosphere of one or more gaseous or particulate contaminants in quantities, characteristics and of duration that is injurious

to human, plant or animal life or to property, or which unreasonably interferes with the comfortable enjoyment of life and property. Cole and Gray, (2015) asserted that air pollution is a physical, biological or chemical alteration to the air in the atmosphere which occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive. Air pollution poses a major threat to the health of individuals in many West African countries like Nigeria as well as other industrialized nations (WHO, 2014).Since Nigeria started exploration of its oil and gas, and other natural resources in 1970s, it has experienced an escalation in its population growth, urbanization, and industrialization together with great increase in motorization and energy use. The environment today has become contaminated, undesirable and harmful for mans habitation following the pollution of the air.

Air pollutant is a substance in the air that can have adverse effects on humans and the ecosystem. Indoor air pollutants and urban air quality are listed as two of the world's worst toxic pollution problems and around two million people die prematurely from the effects of polluted air every single year. The various forms of air pollutants in Nigeria include: aggravated bush burning, combustion, gas flaring, improper disposal of domestic and industrial wastes; pollution through oil spillage; car exhausts, unsanitary and unsafe housing. According to WHO, (2004) the sources of air pollutants are; traffic (especially diesel vehicles), industrial sectors (from brick making to oil and gas production), power plants, cooking and heating with solid fuels (e.g. coal, wood, crop waste), forest fires and open burning of municipal waste and

agricultural residues. Though, the levels of air pollutants can vary from country to country and from continent to continent (Bingheng and Haidong, 2008).

Causes of air pollution in Nigeria could be linked to high incidence of gas flares, that is, a situation where 53% of the gas produced are being flared (Okebukola, 2001); similarly, massive use of fuel wood for cooking by the people due to the nation's ailing economy, indiscriminate bush burning and other damaging forces have aspirated the problem of air pollution contemporarily. The most serious causes of air pollution in Nigeria environment are found in cities in Niger Delta following activities of exploitation and exploration of oil and gas. According to Opera, (2008) their surroundings have been adversely polluted.

During recent years, there has been a growing awareness about possible biological effects of deposition of various pollutants in the atmospheric environment (Abdulkareem and Odigure, 2001). The frequent pollution of the environment is one of the most critical ecological crises the world is subjected today. The environment (air, water, land, and soil) was in the past pure, virgin, undisturbed, uncontaminated and basically most hospitable for living organisms but the situation today is reverse. Due to this, "air pollution and population health" has become one of the most important environmental and public health issues (Bingheng and Haidong, 2008). It is against this backdrop that this study seeks to evaluate the pollution status in some selected sites in Warri and its environs in Delta State.

1.2 Statement of the Problem

The phenomenon of air pollution involves a sequence of events: the generation of pollutants at and their release from a source; their transport and transformation in and removal from the atmosphere; and their effects on human beings, materials, and ecosystems. Air pollution has been identified as one of the most critical environmental problems confronting the Niger Delta Region. Multiple factors especially lack of equipment, inadequate skilled personnel and poor policy frame work has militated against effective and qualitative air quality studies in the area. There is a clear indication that the effects of air pollution on our natural environment, health and life as a whole cannot be over-emphasized thus affecting the biodiversity and ecological resources which are the main sources of their income and the peoples' mode of survival.

1.3 Aim of Study

The aim of this study is to evaluate the concentrations of the pollutants $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ in Warri and its environs in Delta State, Nigeria during the dry season and wet season.

1.4 Specific Objectives

The objectives of this study are to;

i. determine the concentration of some gaseous pollutants ($CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$) concentration in wet and dry season in the study area.

ii. determine the seasonal variation in the concentration of the pollutants.

1.5 Significance of the Study

The concentration of $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ in wet and dry seasons with respect to air pollution and their effect on ambient air, human and environment would provide a baseline data on the pollution status of the study area. Consequently, it is hoped that this study would provide a ready guide to policy makers and other stakeholders in Delta State to make informed decisions in relation to implementing action plans on air pollution geared towards the sustainable development of the region. Finally, the results obtained from this study could be adopted by the decision-makers and stakeholders in curbing the challenges posed by air pollutants.

1.6 Scope of the Study

The study is focused on evaluation of air pollutants such as $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ in wet and dry seasons in the study areas (Petroleum Training Institute junction, Deco junction, Airport junction and Oviore junction) within a period of 12months.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Air Pollution

Air pollution refers to the presence in the outdoor or indoor atmosphere of one or more gaseous or particulate contaminants in quantities, characteristics and of duration such as; to be injurious to human, plant or animal life or to property, or which unreasonably interferes with the comfortable enjoyment of life and property (Odigure, 1998). Admassu and Wubeshet (2006) affirmed that the concept 'Air pollution' may also be seen as any atmospheric condition in which certain substances are present in such concentrations that they can produce undesirable effects on man and his environment.

According to Mudakari, (2010), air pollution is defined as any abnormal increase or decrease in the concentration of the normal component of the atmosphere. On the other hand, it also refers to the discharge of harmful substances into the air to the extent that it can reduce visibility and produce undesirable odour (Aghil, 2011). Air pollution can also be the introduction of chemicals particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or cause damage to the natural environment. Ladan (2013) observed that it has been difficult to achieve cooperation for air pollution control in developing countries like Nigeria, whose chief concern is to provide such basic need as food, shelter and employment for her populace.

Kumar and Katoria (2013) argued that air pollution is foreign material present in the air which can be man made or occur naturally, and are concentrated where

people are concentrated. The author noted that this pollution is injurious to health and its prevention places an economic burden on the citizen. Air pollution is one of the most serious environmental problems in societies at all level of economic development. Godish, (2004) noted that air pollution can also affect the properties of materials, visibility and the quality of life in general. Industrial development has been associated with emission to air of large quantities of gaseous and particulate emissions from both industrial production and from burning fossil fuels for energy and transportation.

Anjaneyulu, (2005) opted that air pollution is generally perceived as the presence in the outdoor atmosphere of one or more contaminants such as fumes, dust, gases, mist, odour, smoke, smog or vapours in considerable quantities and duration of which is injurious to human, animal and plant life or which unreasonably interferes with the comfortable enjoyment of life and property. Air pollution is an environmental problem that is directly related to the number of individuals living in an area and the kinds of activities they engaged in. In a place where the population is low and their energy usage is also low, the impact of people in creating pollution is minimal. However where the population is high, the area urbanized and industrialized with high energy usage large quantities of pollutants are released into the environment.

Makinde, (2000) contended that air pollution are harmful solid, liquid or gaseous substances that are present in such concentrations in the environment which tend to be injurious to living organisms. They are also known as substances in the air that can cause harm to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may also be natural or man-

made. Similarly, anthropogenic $CO_{2(g)}$ emissions from combustion processes were considered safe because they are not toxic, but the long-term accumulation of $CO_{2(g)}$ in the atmosphere may lead to a climate change, which could then be harmful to humans and the ecosystem.

Odilara, et al., (2006) asserted that air pollution is a major problem arising mainly from industrialization. It has also been reported that when exposed to air pollutants, most plant experience physiological changes before exhibiting visible damage to leaves (Dohmen, et al., 1990). Urban air pollution has a significant impact on the chemistry of the atmosphere and thus potentially on regional and global climate. Already, air pollution is a major issue in an increasing number of megacities around the world, and new policies to address urban air pollution are likely to be enacted in many developing countries irrespective of the participation of these countries in any explicit future climate policies (Prinn, 2003).

2.2 Sources of Air Pollution

Basically, air pollution can result from both natural and man-made (anthropogenic) sources. This includes the following;

1. **Natural Sources:** These include volcanic eruption releasing poisonous gases, forest fire, natural organic and inorganic decays or vegetation decay, pollen scattering, deflation of sands and dust, sea salt particles being blown up from the surface of the sea by winds, extraterrestrial bodies, cosmic dust, and comets (Godish, 2004).
2. **Man made (anthropogenic) sources:** The major anthropogenic sources include substances emitted due to the burning of fossil fuels in engines, gasses and

particulate matter created in the production process (industrial and agricultural), suspended particulate matter and chemical substances created in the process of waste disposal and even war (Heinsohn and kabel, 1999). Some of these anthropogenic sources includes;

a. **Increase in human population and activities:** An increase in population leads to the emission of green house gases and global warming. This in turn cause rise in sea level; and prospects of reduced food production. An increase in population also contributes to loss of forest and loss in wildlife species (Colbeck and Nasir, 2010).
b. **Industrial and human development activities**: Gaseous air pollutants from the sources include nitric acid, gaseous nitric acid, and hydrogen chloride. Consequently, other offensive odorous substances like ammonia, hydrogen sulphide, methyl sulphide, trimethylamine, dimethyl sulphide, aldehyde, and styrene are also considered to be gaseous air pollutants. In addition to suspended particulate matter, dust fall is also considered to be particulate air pollutant (Colbeck and Nasir, 2010)
c. **Burning:** The conventional sources of energy are wood, coal and fossil fuel. A large percentage of the energy we use in our homes and factories is generated from these sources (Colbeck and Nasir, 2010)
d. **Deforestation:** Indiscriminate cutting of plants, trees and clearing of the jungles and forests i.e. deforestation by man for his own needs has disturbed the balance of carbon dioxide and oxygen in nature (WHO, 2000)

e. **Automobile exhausts:** are responsible for a high percentage of total air pollution. Automobiles release huge amount of poisonous gases such as carbon monoxide, leaded gas and particulate lead as a result of incomplete combustion of petrol and diesel which react in the presence of other gases to form smog in the atmosphere which are toxic to nature. Examples of air pollutants include Sulphur Dioxide ($SO_{2(g)}$), Nitrogen Dioxide ($NO_{2(g)}$) suspended particulate matter, Carbon Monoxide ($CO_{(g)}$), photochemical oxidants (OX), Non-Methane Hydrocarbon Species (NMHC).

2.3 Classifications of Air Pollutants

Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made (Anderson, 2005). Pollutants can be classified as primary or secondary. According to Olobaniyi and Efe (2007) usually, primary pollutants are directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulfur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground level ozone-one of the many secondary pollutants that make up photochemical smog. Some pollutants may be both primary and secondary: that is, they are both emitted directly and formed from other primary pollutants.

Akpoborie et al., (2000) and Daly et al., (2007) classified air pollutants into four distinct categories. These are criteria, toxic, radioactive and indoor pollutants. These are discussed below;

1. **Criteria Pollutants:** There are basically six (6) principal, or "criteria" pollutants regulated by the US-EPA and most countries in the world:

a. **Total suspended particulate matter (TSP):** with additional subcategories of particles smaller then 10μm in diameter (PM10), and particles smaller than 2.5μm in diameter (PM2.5); PM can exist in solid or liquid form, and includes smoke, dust, aerosols, metallic oxides, and pollen. Sources of PM include combustion, factories, construction, demolition, agricultural activities, motor vehicles, and wood burning. Inhalation of enough PM over time increases the risk of chronic respiratory disease (Akpoborie et al., 2000).

b. **Sulfur dioxide ($SO_{2(g)}$):** This compound is colorless, but has a suffocating, pungent odor. The primary source of SO_2 is the combustion of sulfur-containing fuels (e.g., oil and coal). Exposure to SO_2 can cause the irritation of lung tissues and can damage health and materials (Daly et al., 2007).

c. **Nitrogen oxides ($NO_{(g)}$ and $NO_{2(g)}$):** $NO_{2(g)}$ is a reddish-brown gas with a sharp odour. The primary source of this gas is vehicle traffic, and it plays a role in the formation of tropospheric ozone. Large concentrations can reduce visibility and increase the risk of acute and chronic respiratory disease (Daly et al., 2007).

d. **Carbon monoxide ($CO_{(g)}$):** This odorless, colorless gas is formed from the incomplete combustion of fuels. Thus, the largest source of $CO_{(g)}$ today is motor vehicles. Inhalation of $CO_{(g)}$ reduces the amount of oxygen in the bloodstream, and high concentrations can lead to headaches, dizziness, unconsciousness, and death (Daly et al., 2007).

e. **Ozone (O_3):** Tropospheric ("low-level") ozone is a secondary pollutant formed when sunlight causes photochemical reactions involving NOX and VOCs. Automobiles are the largest source of volatile organic compounds necessary for these reactions. Ozone concentrations tend to peak in the afternoon, and can cause eye irritation, aggravation of respiratory diseases, and damage to plants and animals(Daly et al., 2007)

f. **Lead (Pb):** The largest source of Pb in the atmosphere has been from leaded gasoline combustion, but with the gradual elimination worldwide of lead in gasoline, air Pb levels have decreased considerably. Other airborne sources include combustion of solid waste, coal, and oils, emissions from iron and steel production and lead smelters, and tobacco smoke. Exposure to Pb can affect the blood, kidneys, and nervous, immune, cardiovascular, and reproductive systems (Akpoborie et al., 2000).

2. Toxic Pollutants: Hazardous air pollutants (HAPS) also called toxic air pollutants or air toxics are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects. Examples of toxic air pollutants include benzene, which is found in gasoline; perchlorethlyene, which is emitted from some dry cleaning facilities; and methylene chloride, which is used as a solvent and paint stripper by a number of industries (Fuggle, 2004).

3. Radioactive Pollutants: Radioactivity is an air pollutant that is both geogenic and anthropogenic. Geogenic radioactivity results from the presence of radionuclides, which originate either from radioactive minerals in the earth's

crust or from the interaction of cosmic radiation with atmospheric gases. Anthropogenic radioactive emissions originate from nuclear reactors, the atomic energy industry (mining and processing of reactor fuel), nuclear weapon explosions, and plants that reprocess spent reactor fuel. Since coal contains small quantities of uranium and thorium, these radioactive elements can be emitted into the atmosphere from coal-fired power plants and other sources (Magbagbeola, 2002).

4. **Indoor Pollutants:** When a building is not properly ventilated, pollutants can accumulate and reach concentrations greater than those typically found outside. This problem has received media attention as "Sick Building Syndrome". Environmental tobacco smoke (ETS) is one of the main contributors to indoor pollution, as are $CO_{(g)}$, $NO_{(g)}$, and $SO_{2(g)}$, which can be emitted from furnaces and stoves. Cleaning or remodeling a house is an activity that can contribute to elevated concentrations of harmful chemicals such as volatile organic compounds emitted from household cleaners, paint, and varnishes. Also, when bacteria die, they release endotoxins into the air, which can cause adverse health effects. So ventilation is important when cooking, cleaning, and disinfecting in a building. A geogenic source of indoor air pollution is radon (Akpoborie et al., 2000).

2.4 Effects of Air Pollution

Different effects of air pollution on man and his environment will be discussed; air pollution affects our health, causing one health problem or the other. It also affects vegetation and impairs visibility into the distance. Air pollution is a serious issue

because when the air we breathe carries pollutants, it can affect us in many ways. A variety of diseases have been linked to exposure to air pollution including asthma, lung cancer and heart disease. Although everyone can be affected by this type of pollution, young children and elderly people are at an especially high risk. Air pollution can also damage materials, agriculture, and is a component of climate change (Encyclopaedia of Earth, 2015). The effects of air pollution are as follows:

1. Effects of Air Pollution on weather, climate and atmospheric processes

In general, air pollution is responsible for two (2) main global problems; contamination of the upper atmosphere and alteration of weather and climate. Some of the specific effects of pollution on the atmosphere are highlighted below:

a. Pollution affect local weather condition, as in the well the creation of a phenomenon known as "Heat Island" around cities. This is caused when heat emissions from many anthropogenic sources add to the warming of the built environment. This warming effect that results from this phenomenon could affect, significantly, the comfort and the life ability of the urban people (Samuels, 2004).

b. According to modern environmentalists, increasing particulate matter pollution may reduce the amount of sunlight reaching the surface of the earth thereby lowering solar radiation energy at the earth's surface (Makinde, 2000).

c. The distribution and abundance of particulate matters is responsible for local rainfall patterns and hence there is a significance increase in precipitation in and around cities, and is due to air pollution. Air pollution causes weather to change on a continental or global basis (Makinde, 2000).

2. Effect of Air Pollution on humans health

Air pollution is a significant risk factor for a number of health conditions including respiratory infections, heart disease, chronic obstructive pulmonary disease, stroke and lung cancer (WHO 2014).

a. Respiratory system and diseases: The first target organs attacked by air pollutants are respiratory system. Considering the respiratory system of humans, from the nasal cavity to near the bronchi, which constitute the passage of air, mucus covers the mucous epithelium. The airway of trachea and the bronchi are provided with cilia to eliminate foreign substances. Also, there are alveolar macrophages of phagocyte in the alveoli of the lungs exchanging carbonic dioxide for oxygen. Also, carbon monoxide, when coming into contact with haemoglobin contained in the blood in alveoli, disturbs transportation of oxygen by the blood because the substance combines with haemoglobin more easily than oxygen. In the case where the air severely polluted, aged persons and patients with certain chronic base disease in particular are in danger of suffering from acute bronchitis. In many cases, however, air pollution causes chronic respiratory diseases especially asthma, chronic bronchitis and lung emphysema (Heinsohn and Kabel, 1999).

b. Senses (sense of smell): Humans use their five senses of sight, hearing, smell, touch and taste as a mean of acquiring information from the outside world. The sense of smell works to identify the nature of odours and, along with taste, may be called a chemical sense. Smell possesses functions that only respond to a limited number of chemical substances (those substances with odours). Humans mainly rely on their senses of sight and hearing to live, although sight

and hearing are well developed, smell is, by comparison, a somewhat primitive sense. Odours such as that of rotting food and of burned substances aim to provide advance warnings of impending danger. Airborne odours enter the nasal cavity along with inhaled air, and arrive at olfactory membrane in the roof of the cavity by passing along the nasal airway, where they dissolve into the mucous olfactory membrane. The olfactory membrane contains olfactory glands (Bowman's glad) centered on olfactory cells, which are sense receptor cells. The olfactory glands hairs extend from the length of the olfactory cells through the mucous, and the tip of the cells (the olfactory smell vesicle) also protrudes into the mucous membrane (Ibn, 2012).

c. **Mortality:** It is estimated that some 7 million premature deaths may be attributed to air pollution (WHO, 2014). India also has more deaths from asthma than any other nation according to the World Health Organization. In December 2013 air pollution was estimated to kill 500,000 people in China each year. Air pollution is estimated to reduce life expectancy by almost nine months across the European Union (British Broadcasting Corporation: BBC, 2005). Causes of deaths include strokes, heart disease, chronic obstructive pulmonary disease, lung cancer, and lung infections (WHO, 2014). The US EPA estimates that a proposed set of changes in diesel engine technology could result in 12,000 fewer premature mortalities, 15,000 fewer heart attacks, 6,000 fewer emergency room visits by children with asthma, and 8,900 fewer respiratory-related hospital admissions each year in the United States (US-EPA, 2004).

d. **Cardiovascular Disease:** A 2007 review of evidence found ambient air pollution exposure is a risk factor correlating with increased total mortality from cardiovascular events (range: 12% to 14% per 10 microg/m^3 increase) (Chen, Goldberg and Villeneuve, 2008*)*.Air pollution is also emerging as a risk factor for stroke, particularly in developing countries where pollutant levels are highest (Mateen and Brook, 2011). Air pollution was also found to be associated with increased incidence and mortality from coronary stroke in a cohort study in 2011 (Andersen et al., 2011). Associations are believed to be causal and effects may be mediated by vasoconstriction, low-grade inflammation and atherosclerosis. Other mechanisms such as autonomic nervous system imbalances have also been suggested (Brook et al., 2010).

e. **Cancer:** A review of evidence regarding whether ambient air pollution exposure is a risk factor for cancer in 2007 found solid data to conclude that long-term exposure to PM2.5 (fine particulates) increases the overall risk of non-accidental mortality by 6% per a 10 microg/m^3 increase. Exposure to PM2.5 was also associated with an increased risk of mortality from lung cancer and total cardiovascular mortality (Bhatia, 2006). The review further noted that living close to busy traffic appears to be associated with elevated risks of these three outcomes - increase in lung cancer deaths, cardiovascular deaths, and overall non-accidental deaths. The reviewers also found suggestive evidence that exposure to PM2.5 is positively associated with mortality from coronary heart diseases and exposure to $SO_{2(g)}$ increases mortality from lung cancer, but the data was insufficient to provide solid conclusions (Chen et al., 2008).

3. Effects of Air Pollution on the Environment

a. **Vegetation:** In terms of the damage to plants caused by air pollution, forests could be damaged and agricultural area recording poor growth and yield. This could be caused by Sulphur Dioxide ($SO_{2(g)}$) and hydrogen fluoride (HF) from stationary sources. Plantdamage could also result from mobile sources including automobiles (Chen et al., 2008)

b. **Wildlife**- Toxic pollutants in the air, or deposited on soils or surface waters, can impact wildlife in a number of ways. Like humans, animals can experience health problems if they are exposed to sufficient concentrations of air toxics over time. Studies by Odilara et al., (2006) show that air toxics are contributing to birth defects, reproductive failure, and disease in animals. Persistent toxic air pollutants (those that break down slowly in the environment) are of particular concern in aquatic ecosystems. These pollutants accumulate in sediments and may biomagnify in tissues of animals at the top of the food chain to concentrations many times higher than in the water or air (Chen et al., 2008).

c. **Crop and forest damage**: Air pollution can damage crops and trees in a variety of ways. Ground-level ozone can lead to reductions in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests and other environmental stresses (such as harsh weather). As described above, crop and forest damage can also result from acid rain and from increased UV radiation caused by ozone depletion (Bhatia, 2006)

d. **Ozone depletion:** Ozone is a gas that occurs both at ground -level and in the Earth's upper atmosphere, known as the stratosphere. At ground level, ozone is

a pollutant that can harm human health. In the stratosphere, however, ozone forms a layer that protects life on earth from the sun's harmful ultraviolet (UV) rays. But this "good" ozone is gradually being destroyed by man-made chemicals referred to as ozone-depleting substances, including chlorofluorocarbons, hydrochloro-fluorocarbons, and halons. These substances were formerly used and sometimes still are used in coolants, foaming agents, fire extinguishers, solvents, pesticides, and aerosol propellants. Thinning of the protective ozone layer can cause increased amounts of UV radiation to reach the Earth, which can lead to more cases of skin cancer, cataracts, and impaired immune systems. UV can also damage sensitive crops, such as soybeans, and reduce crop yields (Rao, 2006).

e. **Visibility degradation**: The main cause of visibility degradation due to air pollution are aerosol and gasses in the atmosphere, but the visibility conditions can differ greatly due to atmospheric condition such as humidity; the optical characteristics of the target; and the strength and distribution of the light at the time in question. When air pollution is severe, the atmosphere appears to be coloured (Sodhi, 2005).

2.5 Preventive Measures/Sustainable solutions to air Pollution Problems

The control measures for air pollution in the urban centers of Nigeria have not substantially reduced air pollution. It was particularly noted that most commuters and urban dwellers are constantly exposed to the hazards of air pollution on daily basis (Efe, 2008). It is based on this that the study puts forward preventive measures/sustainable solutions as listed below:

a. Vehicle inspection is an important preventive measure that will ensure drivers not only service their cars periodically but also old vehicles that emit to much smoke are taken off the roads and only vehicles in good condition ply the roads (Okoro, 2012).

b. Ensuring sufficient supply of oxygen to the combustion chamber and adequate temperature so that the combustion is complete thereby eliminating much of the smoke consisting of partly burnt ashes and dust.

c. To use mechanical devices such as scrubbers, cyclones, bag houses and electro-static precipitators in manufacturing processes. The equipment used to remove particulates from the exhaust gases of electric power and industrial plants are shown below. All methods retain hazardous materials that must be disposed safely. Wet scrubber can additionally reduce sulphur dioxide emissions (Okoro, 2012).

d. The air pollutants collected must be carefully disposed. The factory fumes are dealt with chemical treatment (Khan, 2005).

e. Improvement in electric power supply will drastically reduce the use of gasoline generators that are found at home, business premises, offices and industries. Nigeria has numerous sources of generating energy from renewable sources that could effectively harness to supply regular electricity to the people thereby reducing the use of gasoline generators (Khan, 2005).

f. The use of fuel wood can be reduced by providing readily available alternative means of cooking and heating both for homes and small scale industrial use. Biogas is an alternative energy source that can be promoted and subsidized to

the people to reduce the use of fuel wood that is a source of indoor and outdoor air pollution (Yan-Ju et al., 2008).

g. Effective refuse collection in the urban centers will ensure that waste materials do not accumulate in the locality to be burnt or incinerated. The regular waste collection and disposal will also ensure that there is no time for the waste to decompose and generate bad odour which pollutes the air (Khan, 2005).

h. Manufacturing industries operating in the urban centers should be compelled to adhere strictly to the various pollution control legislations that are enacted in the country. In line with this National Environmental Standards and Regulations Enforcement Agency (NESREA) should ensure that the industries fully comply with the pollution control regulations.

i. Enforcement of air pollution legislations across the country will ensure that people, organizations and groups that carryout activities that are sources of air pollution are reduced. It is important to enforce pollution control legislations as the laws are there for many years but not fully enforced (Sodhi, 2005).

j. There is the need to continuously enlighten and educate the public about the causes and effects of air pollution so that they realize the dangers and health hazards of living in polluted environment. Environmental organizations in Nigeria need to form themselves into pressure groups to not only raise awareness about environmental issues but also pressurize the government to take action against those who pollute the environment. The ministries of environment and the states environmental protection agencies carry out various programmes like Radio and television discussion programmes, production of

posters, pamphlets and leaflets to educate the people about air pollution, its effects and need for control for healthy living. This has indeed called for continuous environmental education as it provide the public with information on the causes of pollution, the effects of pollution and what they can do to prevent or mitigate the effects of pollution (Ladan, and Ajao, 2005).

2.6 Structure of the Atmosphere

The atmosphere consists of 4 layers: the troposphere, stratosphere, mesosphere, and thermosphere. Figure 1 shows the placement of the different layers of the atmosphere and how the temperature changes with height as you go from the ground up to space. The troposphere is the lowest layer of the atmosphere. This is the layer where we live and where weather happens. Temperature in this layer generally decreases with height. The boundary between the stratosphere and the troposphere is called the tropopause. The jet stream sits at this level and it marks the highest point that weather can occur. The height of the troposphere varies with location, being higher over warmer areas and lower over colder areas. Above the tropopause lies the stratosphere. In this layer the temperature increases with height. This is because the stratosphere houses the ozone layer. The ozone layer is warm because it absorbs ultraviolet (UV) rays from the sun. The mesosphere is the layer above the stratosphere. The temperature decreases with height here just like it does in the troposphere. This layer also contains ratios of nitrogen and oxygen similar to the troposphere, except the concentrations are 1000 times less and there is little water vapor there, so the air is too thin for weather to occur. The thermosphere is the uppermost layer of the atmosphere. In this layer the temperature increases with height because it is being directly heated by the sun.

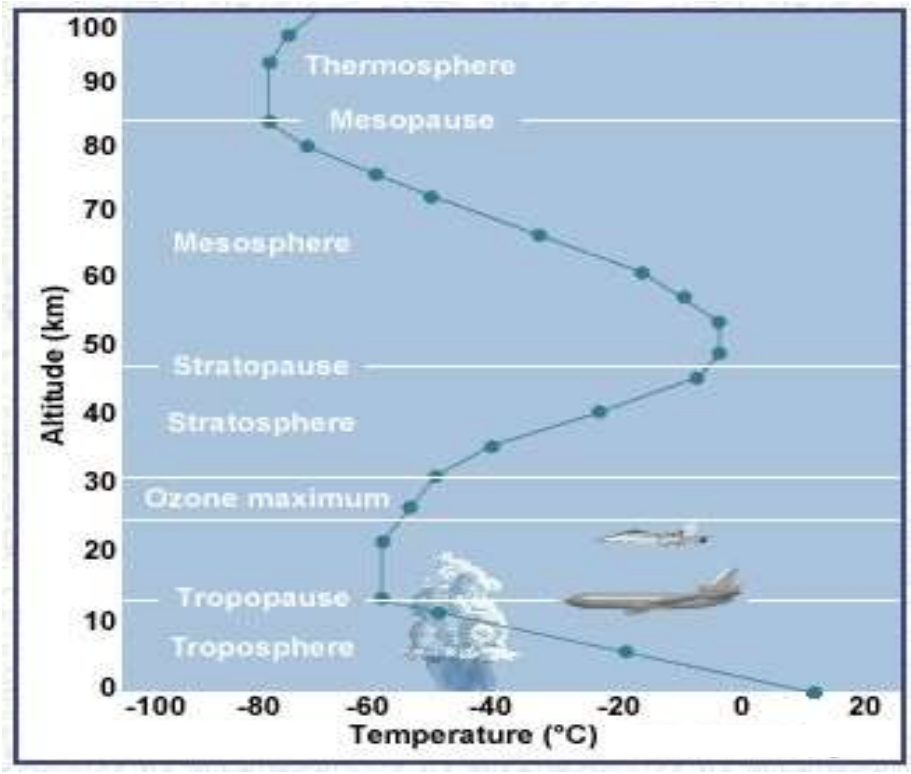

Fig 1: Layers of the Atmosphere

The molecules that make up the atmosphere are pulled close to the earth's surface by gravity. This causes the atmosphere to be concentrated at the Earth's surface and thin rapidly with height. Air pressure is a measure of the weight of the molecules above you. As you move up in the atmosphere there are fewer molecules above you, so the air pressure is lower. Figure 2 shows how pressure decreases with height. The black dotted lines show how much of the atmosphere is below you at a certain level. For example, at 10 miles up, 90% of the atmosphere is below you. At the peak of Mount Everest, as shown, the air pressure is 70% lower than it is at sea level. This means when mountain climbers breathe air on top of the mountain, they are only inhaling 30% of the oxygen they would get at sea level. It is no surprise that most climbers use oxygen tanks when they climb Mt. Everest.

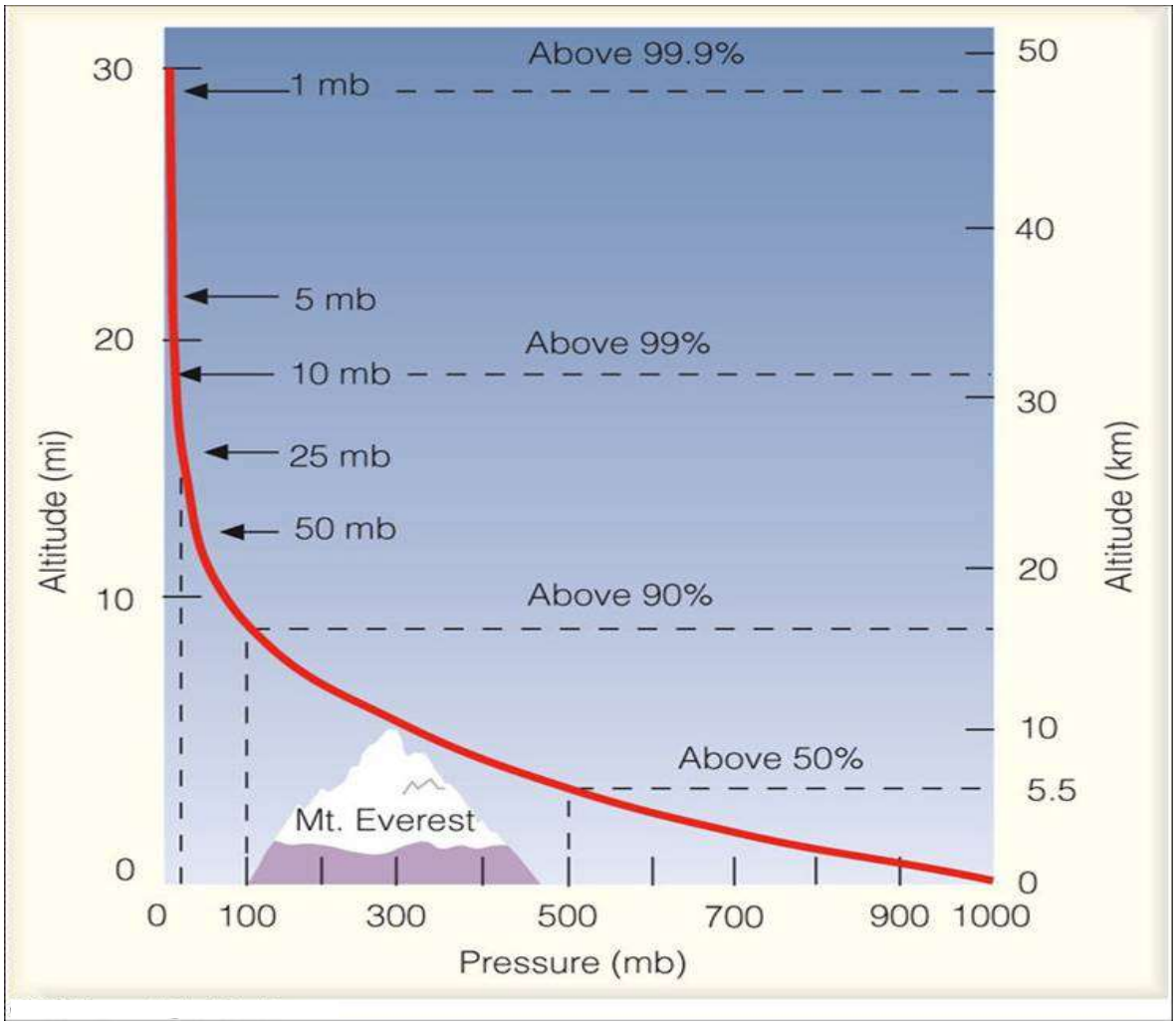

Figure 2: Pressure Decrease with Height Rapidly Above the Surface

Temperature decreases with height in the troposphere. This is true for a couple different reasons. First, even though the sun's energy comes down from the sky, it is mostly absorbed by the ground. The ground is constantly releasing this energy, as heat in infrared light, so the troposphere is actually heated from the ground up, causing it to be warmer near the surface and cooler higher up. Another reason is the decreasing air pressure with height. If the warm air at the surface gets blown upward into the cooler air above it, the surface air will continue to rise. As air rises into areas of lower pressure it expands because there are less molecules around it to compress it. The

molecules in the air use some of their energy to move apart from each other, causing the air temperature to decrease. The constantly decreasing air pressure in conjunction with the ground-up heating keeps the temperature in the troposphere decreasing with height.

In the real atmosphere, the actual vertical temperature structure depends on air masses with specific properties of temperature and humidity being blown into the area as well as effects of daytime heating. If you have a layer of air with warm temperatures above the surface, we call that an “inversion”. That layer can act as a cap which prevents clouds and sometimes severe weather from forming.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Area

Four (4) commercial sites comprising of Petroleum Training Institute junction ($05^0$34'38.6N, $005^0$48'00.2E), Deco junction ($05^0$31'36.5N, $005^0$45'99.2E), Airport junction ($05^0$32'88.0N, $005^0$46'81.5E) and Oviore junction ($05^0$39'48.2N, $005^0$55'52.5E) respectively were selected as the geographical locations in Warri, Delta State, Nigeria. The study areas are located in three different local government areas namely: Warri South, Effurun and Ethiope East respectively. Warri has a population of about 407, 400. It has an annual temperature of 35^0c with 25% humidity and a tropical climate having a variation of dry and wet seasons. The major activities among the people of Warri that generate particulate pollution are usually; commercial activities by allied industries which generate particulate pollutants, combustion of solid waste, gas flaring etc especially in the selected locations.

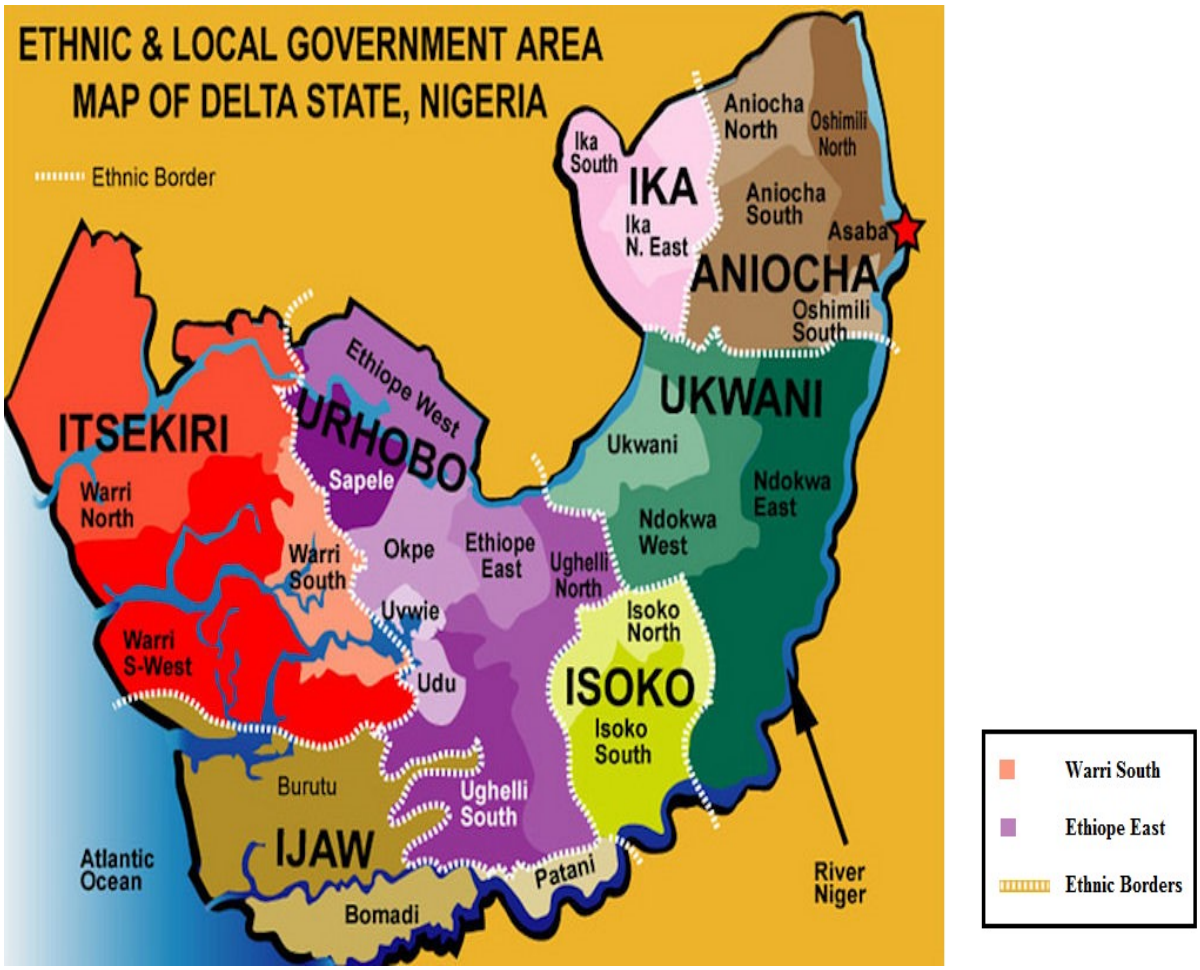

Figure 3: Sample Site in Delta State Nigeria

Source: Globalsecurity.org

3.2 Materials

Sampling of analyte is by the use of aeroqual gas detector kit model -ASTM D3249-95 (2011)

3.3 Sampling and Sample Collection

This study covered a period of 12 calendar months specifically the dry season (October – March) in 2014 and wet season (April – September) in 2015. Three of the commercial sites comprising of Petroleum Training Institute junction, Deco junction and Airport junctions were considered as the experimental stations owing to frequent

industrial activities in the region against Oviore junction station which served as the control station with lesser activities. The sampling was carried out between the hours of 7 - 10am (morning), 12 – 3pm (afternoon) and 4 - 7pm (evening) on daily basis for the selected commercial sites as represented in the Table 3.1.

Table 3.1: Sample Collection

S/N	Sample Stations	Seasons	Time	Date
1	Oviore Junction(Control)	Dry	7:00am – 10:00am 12:00pm – 3:00pm 4:00pm – 7:00pm	1st – 7th November, 2014
		Wet	7:00am – 10:00am 12:00pm – 3:00pm 4:00pm – 7:00pm	22nd – 28th May, 2015
2	Deco junction	Dry	7:00am – 10:00am 12:00pm – 3:00pm 4:00pm – 7:00pm	1st – 7Th October, 2014
		Wet	7:00am – 10:00am 12:00pm – 3:00pm 4:00pm – 7:00pm	14th – 21Tst May, 2015
3	Airport Junction	Dry	7:00am – 10:00am 12:00pm – 3:00pm 4:00pm – 7:00pm	1st – 7th December, 2014
		Wet	7:00am – 10:00am 12:00pm – 3:00pm 4:00pm – 7:00pm	1st – 7th June, 2015
4	Petroleum Training Institute Junction	Dry	7:00am – 10:00am 12:00pm – 3:00pm 4:00pm – 7:00pm	8th – 15Th December, 2014
		Wet	7:00am – 10:00am 12:00pm – 3:00pm 4:00pm – 7:00pm	8th – 15Th June, 2015

3.4 Determination of Air Quality Parameter

The ambient air quality was determined with the aid of aeroqual gas monitoring kit in each study site. It operates by gas diffusion through an air filter into the sensors which is graduated into the sensors just directly under the air filter. The concentration of air parameter is then displayed on the output meter. The instrument is calibrated by the manufacturer and was moved from one site to the other between the hours of 7am and 7pm daily.

3.5 Methods

Standard procedures were adopted in estimating the amount of pollutants in the ambient air analysis. The desired gas sensor (probe) was fixed for the gas to be analysed. Thereafter, the power button was pressed and the instrument was allowed to initialize for three (3) minutes, while, the readings were taken in duplicates at the expiration of three (3) minutes. Meanwhile, the instrument was put off and the process was repeated for another gas to be monitored.

3.6 Statistical Analysis

Data obtained from the field survey was analysed using descriptive statistic expressed in Mean±SD while the difference across the groups was statistically analyzed using one way ANOVA of variance and t-test between pollutants using SPSS version 20.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

Table 4.1 showed the average mean concentration of pollutants ($CO_{(g)}$, $CO_{2(g)}$ $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$) obtained across the sample sites (Airport junction, Petroleum Training Institute junction, Oviore junction and Deco junction) during dry season. Results showed that pollutants were more in Petroleum Training Institute junction when compared to other sites.

Table 4.1: Results of $CO_{(g)}$, $CO_{2(g)}$ $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ for Dry Season

Pollutant	Time	Airport junction	Petroleum Training Institute junction	Oviore junction	Deco junction	Department of Petroleum Resource standard limit ($\mu g/m^3$)
$CO_{(g)}$	8am - 9pm	7.69($\mu g/m^3$)	8.12($\mu g/m^3$)	4.04($\mu g/m^3$)	7.11($\mu g/m^3$)	12,500 -25,000
	12pm- 3pm	7.84($\mu g/m^3$)	8.13($\mu g/m^3$)	4.08($\mu g/m^3$)	7.05($\mu g/m^3$)	
	5pm-7pm	7.58($\mu g/m^3$)	8.11($\mu g/m^3$)	4.13($\mu g/m^3$)	7.07($\mu g/m^3$)	
$CO_{2(g)}$	8am-9pm	13.55($\mu g/m^3$)	12.51($\mu g/m^3$)	7.98($\mu g/m^3$)	14.15($\mu g/m^3$)	117.86
	12pm-3pm	14.22($\mu g/m^3$)	12.68($\mu g/m^3$)	8.03($\mu g/m^3$)	14.3($\mu g/m^3$)	
	5pm-7pm	13.72($\mu g/m^3$)	12.45($\mu g/m^3$)	7.94($\mu g/m^3$)	12.68($\mu g/m^3$)	
$H_2S_{(g)}$	8am-9pm	0.10($\mu g/m^3$)	0.13($\mu g/m^3$)	0.09($\mu g/m^3$)	0.17($\mu g/m^3$)	N/A
	12pm-3pm	0.1($\mu g/m^3$)	0.13($\mu g/m^3$)	0.07($\mu g/m^3$)	0.18($\mu g/m^3$)	
	5pm-7pm	0.11($\mu g/m^3$)	0.13($\mu g/m^3$)	0.05($\mu g/m^3$)	0.39($\mu g/m^3$)	
$NO_{(g)}$	8am-9pm	0.10($\mu g/m^3$)	0.07($\mu g/m^3$)	0.04($\mu g/m^3$)	0.14($\mu g/m^3$)	53.57 – 80.35
	12pm-3pm	0.10($\mu g/m^3$)	0.07($\mu g/m^3$)	0.05($\mu g/m^3$)	0.14($\mu g/m^3$)	
	5pm-7pm	0.09($\mu g/m^3$)	0.08($\mu g/m^3$)	0.04($\mu g/m^3$)	0.14($\mu g/m^3$)	
$CH_{4(g)}$	8am-9pm	4.18($\mu g/m^3$)	4.47($\mu g/m^3$)	0.41($\mu g/m^3$)	4.81($\mu g/m^3$)	114.29
	12pm-3pm	4.18($\mu g/m^3$)	4.45($\mu g/m^3$)	0.44($\mu g/m^3$)	4.94($\mu g/m^3$)	
	5pm-7pm	4.04($\mu g/m^3$)	4.46($\mu g/m^3$)	0.37($\mu g/m^3$)	4.78($\mu g/m^3$)	

Table 4.2 showed the average mean concentration of pollutants ($CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$) obtained across the sample sites (Airport junction, Petroleum Training Institute junction, Oviore junction and Deco junction) during wet season. Results showed that pollutants were more in Petroleum Training Institute junction when compared to other sites

Table 4.2: Results of $CO_{(g)}$, $CO_{(g)2}$ $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ for Wet Season

Pollutant	Time	Airport junction	Petroleum Training Institute junction	Oviore junction	Deco junction	Department of Petroleum Resource standard limit ($\mu g/m^3$)
$CO_{(g)}$	8am - 9pm	6.35($\mu g/m^3$)	7.94($\mu g/m^3$)	4.24($\mu g/m^3$)	5.95($\mu g/m^3$)	12,500 -25,000
	12pm- 3pm	6.41($\mu g/m^3$)	7.92($\mu g/m^3$)	4.20($\mu g/m^3$)	5.88($\mu g/m^3$)	
	5pm-7pm	6.24($\mu g/m^3$)	7.90($\mu g/m^3$)	4.23($\mu g/m^3$)	6.17($\mu g/m^3$)	
$CO_{2(g)}$	8am-9pm	11.94($\mu g/m^3$)	14.47($\mu g/m^3$)	7.30($\mu g/m^3$)	13.72($\mu g/m^3$)	117.86
	12pm-3pm	12.12($\mu g/m^3$)	14.5($\mu g/m^3$)	6.97($\mu g/m^3$)	13.62($\mu g/m^3$)	
	5pm-7pm	22.1($\mu g/m^3$)	14.17($\mu g/m^3$)	6.9($\mu g/m^3$)	13.78($\mu g/m^3$)	
$H_2S_{(g)}$	8am-9pm	0.11($\mu g/m^3$)	0.13($\mu g/m^3$)	0.02($\mu g/m^3$)	0.15($\mu g/m^3$)	N/A
	12pm-3pm	0.12($\mu g/m^3$)	0.03($\mu g/m^3$)	0.03($\mu g/m^3$)	0.15($\mu g/m^3$)	
	5pm-7pm	0.11($\mu g/m^3$)	0.03($\mu g/m^3$)	0.03($\mu g/m^3$)	0.14($\mu g/m^3$)	
$NO_{(g)}$	8am-9pm	0.17($\mu g/m^3$)	0.04($\mu g/m^3$)	0.03($\mu g/m^3$)	0.14($\mu g/m^3$)	53.57 – 80.35
	12pm-3pm	0.05($\mu g/m^3$)	0.04($\mu g/m^3$)	0.04($\mu g/m^3$)	0.14($\mu g/m^3$)	
	5pm-7pm	0.10($\mu g/m^3$)	0.04($\mu g/m^3$)	0.03($\mu g/m^3$)	0.15($\mu g/m^3$)	
$CH_{4(g)}$	8am-9pm	4.06($\mu g/m^3$)	4.21($\mu g/m^3$)	0.53($\mu g/m^3$)	3.68($\mu g/m^3$)	114.29
	12pm-3pm	4.04($\mu g/m^3$)	4.13($\mu g/m^3$)	0.44($\mu g/m^3$)	3.67($\mu g/m^3$)	
	5pm-7pm	4.04($\mu g/m^3$)	4.13($\mu g/m^3$)	0.44($\mu g/m^3$)	3.67($\mu g/m^3$)	

Table 4.2 showed significant difference in $H_2S_{(g)}$ on day 5 in dry season (0.0333±0.012) when compared with wet season (0.0300±0.01000) at $NO_{(g)}$ on day 3 in dry season (0.0400±0.0058); day 5 (0.0567±0.0033) when compared to wet season of (0.0333±0.0120) and (0.0567±0.0033) respectively at $P<0.05$ level of significance. Meanwhile, there was a significant difference in the mean concentration of $CH_{4(g)}$ during dry seasons for day 2 (0.5333±0.06667), day 3 (0.2333±0.3335), day 4 (0.5333±0.1333), day 5 (0.5333±0.21858), day 6 (0.4000±0.05774) when compared to wet season (0.7667±0.8819); (0.4667±0.333); 0.5333±0.27285; 0.7333±0.12079 and

0.5667±1201 respectively at P-value <0.05. By implication, this signifies 95% difference in $H_2S_{(g)}$, $CH_{4(g)}$ and $NO_{(g)}$, their mean value across the season at Oviore junction.

Table 4.3: *Statistical Mean and Standard Deviation Score of Dry and wet season in Airport Junction*

Days	Dry Season $CO_{(g)}$ ($\mu g/m^3$)	Wet Season $CO_{(g)}$ ($\mu g/m^3$)
1	13.643±0.261	13.767±0.176
2	13.866±0.033	13.800±0.208
3	9.943±3.373	13.567±0.120
4	13.567±0.233	13.967±0.497
5	13.317±0.205	13.733±0.240
6	15.167±0.783	13.600±0.057
7	15.533±0.167	13.800±0.450
	Dry Season $CO_{2(g)}$ ($\mu g/m^3$)	**Wet Season $CO_{2(g)}$ ($\mu g/m^3$)**
1	0.170±0.003	13.620±0.295
2	0.630±0.485	13.837±0.343
3	0.200±0.010	13.663±0.286
4	0.233±0.008	13.357±0.221
5	0.200±0.012	13.407±0.247
6	0.197±0.012	13.690±0.297
7	0.137±.007	13.163±0.018
	Dry Season $H_2S_{(g)}$ ($\mu g/m^3$)	**Wet Season $H_2S_{(g)}$ ($\mu g/m^3$)**
1	0.140±0.010	0.137±0.017
2	0.157±0.008	0.150±0.020
3	0.157±0.023	0.147±0.003
4	0.150±0.026	0.157±0.007
5	0.173±0.023	0.140±0.006
6	0.160±0.010	0.170±0.000
7	0.153±0.008	0.167±0.008
	Dry Season $NO_{(g)}$ ($\mu g/m^3$)	**Wet Season $NO_{(g)}$ ($\mu g/m^3$)**
1	0.107±0.003	0.213±0.143
2	0.107±0.008	0.340±0.280
3	0.097±0.008	0.050±0.010
4	0.070±0.012	0.033±0.008
5	0.097±0.003	0.040±0.006
6	0.107±0.015	0.043±0.008
7	0.127±0.008	0.070±0.010
	Dry Season $CH_{4(g)}$ ($\mu g/m^3$)	**Wet Season $CH_{4(g)}$ ($\mu g/m^3$)**
1	4.230±0.035	4.073±0.031
2	4.287±0.007	4.130±0.000
3	4.233±0.017	4.100±0.006
4	4.297±0.008	4.120±0.006
5	4.313±0.008	4.137±0.007
6	3.657±0.318	3.977±0.063
7	3.940±0.028	3.830±0.020

Values above are presented in Mean ±STD and the *level of significance for P-value is less than 0.05*

Table 4.3 showed the average mean concentration of pollutants ($CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$) in Petroleum Training Institute junction for both dry and wet seasons. Results obtained revealed that no significant difference was found in $CO_{(g)}$, $CO_{2(g)}$ and $H_2S_{(g)}$ when comparing dry and wet seasons. Meanwhile, there was a statistical significant difference in the concentration of $NO_{(g)}$ at day 5 (0.900±0.00000) when compared with wet season (0.0300±0.0000) at $P<0.05$; Whereas, the concentration of $CH_{4(g)}$ was significant in day 2, 3, 4, 5 and 6 when compared with wet season at $P <0.05$ level of significance.

Table 4.4: *Statistical Mean and Standard Deviation Score of Dry and wet season in Petroleum Training Institute Junction*

Days	Dry Season $CO_{(g)}$ $(\mu g/m^3)$	Wet Season $CO_{(g)}$ $(\mu g/m^3)$
1	12.103±0.098	13.867±0.033
2	12.477±0.175	13.733±0.120
3	12.377±0.261	14.400±0.200
4	12.283±0.072	14.467±0.384
5	12.463±0.220	14.700±0.152
6	12.673±0.278	14.733±0.033
7	12.577±0.223	14.533±0.167
	Dry Season $CO_{2(g)}$ $(\mu g/m^3)$	**Wet Season $CO_{2(g)}$ $(\mu g/m^3)$**
1	0.147±0.008	0.033±0.003
2	0.123±0.008	0.023±0.007
3	0.113±0.013	0.037±0.007
4	0.116±0.007	0.020±0.006
5	0.137±0.008	0.037±0.017
6	0.137±0.003	0.020±0.006
7	0.180±0.006	0.037±0.003
	Dry Season $H_2S_{(g)}$ $(\mu g/m^3)$	**Wet Season $H_2S_{(g)}$ $(\mu g/m^3)$**
1	0.110±0.020	0.047±0.003
2	0.087±0.027	0.083±0.007
3	0.083±0.018	0.053±0.033
4	0.100±0.006	0.057±0.012
5	0.100±0.010	0.037±0.007
6	0.097±0.047	0.197±0.151
7	0.110±0.026	0.043±0.028
	Dry Season $NO_{(g)}$ $(\mu g/m^3)$	**Wet Season $NO_{(g)}$ $(\mu g/m^3)$**
1	0.083±0.007	0.037±0.013
2	0.067±0.007	0.087±0.003
3	0.057±0.008	0.023±0.007
4	0.090±.006	0.047±0.003
5	0.090±0.000	0.030±0.000
6	0.073±0.031	0.047±0.003
7	0.087±0.008	0.020±0.006
	Dry Season $CH_{4(g)}$ $(\mu g/m^3)$	**Wet Season $CH_{4(g)}$ $(\mu g/m^3)$**
1	4.603±0.015	4.120±0.109
2	4.583±0.017	4.103±0.007
3	4.677±0.023	4.147±0.026
4	4.530±0.017	4.173±0.023
5	4.540±0.083	4.233±0.028
6	4.187±0.012	4.287±0.024
7	4.137±0.007	4.187±0.007

Values above are presented in Mean ±STD and the *level of significance for P-value is less than 0.05*

The comparison of the statistical different between the experiment sites and control site was also considered in the analysis.

Table 4.4 showed the result of the comparative statistical difference between gas emission in Deco junction and that of Oviore junction. The result from these analysis showed that there was significant difference between the emission of $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ in Deco junction and Oviore junction. ($t=18.165$, $P<0.05$), ($t=20.241$, $P<0.05$), ($t=4.135$, $P<0.05$), ($t=24.007$, $P<0.05$) and ($f=34.911$, $P<0.05$) respectively. Judging with t-statistics result to determine the level of significant difference, the variation in $CH_{4(g)}$, $NO_{(g)}$ and $CO_{2(g)}$ was more than that of $CO_{(g)}$ and $H_2S_{(g)}$ between the two junctions.

Table 4.5: *Statistical Mean and Standard Deviation Score of Dry and wet season in Oviore Junction*

Days	Dry Season $CO_{(g)}$ ($\mu g/m^3$)	Wet Season $CO_{(g)}$ ($\mu g/m^3$)
1	4.566±0.033	4.200±0.000
2	4.200±0.057	4.333±0.088
3	4.366±0.120	4.233±0.033
4	4.166±0.133	4.567±0.033
5	4.233±0.133	4.200±0.152
6	3.766±0.088	4.233±0.120
7	3.300±0.057	3.767±0.176
	Dry Season $CO_{2(g)}$ ($\mu g/m^3$)	**Wet Season $CO_{2(g)}$ ($\mu g/m^3$)**
1	7.623±0.176	7.033±0.033
2	8.500±0.152	7.033±0.088
3	8.167±0.133	6.800±0.115
4	7.733±0.176	6.833±0.120
5	8.033±0.088	6.300±0.200
6	7.700±0.200	7.933±0.145
7	8.133±0.067	7.467±0.466
	Dry Season $H_2S_{(g)}$ ($\mu g/m^3$)	**Wet Season $H_2S_{(g)}$ ($\mu g/m^3$)**
1	0.096±0.052	0.020±0.005
2	0.236±0.116	0.036±0.003
3	0.050±0.005	0.013±0.003
4	0.063±0.012	0.016±0.006
5	0.033±0.012	0.030±0.010
6	0.023±0.013	0.023±0.006
7	0.016±0.006	0.016±0.006
	Dry Season $NO_{(g)}$ ($\mu g/m^3$)	**Wet Season $NO_{(g)}$ ($\mu g/m^3$)**
1	0.057±0.003	0.037±0.015
2	0.033±0.012	0.060±0.006
3	0.040±0.005	0.033±0.012
4	0.030±0.015	0.030±0.010
5	0.057±0.003	0.030±0.000
6	0.073±0.015	0.030±0.010
7	0.023±0.006	0.040±0.015
	Dry Season $CH_{4(g)}$ ($\mu g/m^3$)	**Wet Season $CH_{4(g)}$ ($\mu g/m^3$)**
1	0.133±0.033	0.067±0.024
2	0.533±0.067	0.767±0.088
3	0.233±0.133	0.467±0.033
4	0.533±0.273	0.267±0.167
5	0.533±0.218	0.733±0.120
6	0.400±0.057	0.567±0.120
7	0.500±0.173	0.367±0.088

Values above are presented in Mean ±STD and the *level of significance for P-value is less than 0.05*

Table 4.5 showed the statistical mean and standard deviation obtained from Deco junction for the pollutants ($CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $CH_{4(g)}$, and $NO_{(g)}$) in dry and wet seasons. Season average of $CO_{(g)}$ in dry season showed significant difference on day 5 (13.3167±2.0480) and day 6 (15.9667±0.333) when compared to that of $CO_{(g)}$ in wet season (13.2667±0.17638) and (13.6000±0.05774) at P-value less than 0.05 level of significance. However, when compared to other days, there was a statistically significant increase in $CO_{(g)}$ concentration in the region. Meanwhile, $CO_{2(g)}$ and $H_2S_{(g)}$ showed no significant difference. The results for $NO_{(g)}$ showed significant difference for dry season on day 5 (0.1533±0.0033) when compared (4.9333±0.6667) at p<value 0.016. Meanwhile, the concentration of $CH_{4(g)}$ of the dry season was significant on day 2 (3.4333±0.333), day 3 (3.333±0.333); day 4 (3.7667±0.333), day 5 (3.8000±0.5774) and day 6 (4.0000±0.00000) when compared to wet season (4.9300±0.6506); (4.4000±0.5774); (4.5667±0.18559); (4.9333±0.6667) and (5.1000±0.5774) at p-value <0.05. This implies that the highest concentration of pollutants of $CO_{(g)}$ and $CH_{4(g)}$ were present in dry season in Deco junction.

Table 4.6: *Statistical Mean and Standard Deviation Score of Dry and wet season in Deco junction*

Days	Dry Season $CO_{(g)}$ $(\mu g/m^3)$	Wet Season $CO_{(g)}$ $(\mu g/m^3)$
1	13.710±0.195	13.570±0.293
2	13.867±0.033	13.733±0.145
3	13.277±0.129	13.567±0.120
4	13.567±0.233	13.900±0.550
5	13.316±0.205	13.267±0.176
6	15.967±0.033	13.600±0.057
7	15.867±0.440	13.233±0.120
	Dry Season $CO_{2(g)}$ $(\mu g/m^3)$	**Wet Season $CO_{2(g)}$ $(\mu g/m^3)$**
1	0.173±0.003	0.170±0.010
2	0.637±0.481	0.170±0.015
3	0.187±0.020	0.137±0.008
4	0.237±0.007	0.150±0.015
5	0.173±0.017	0.407±0.247
6	0.200±0.015	0.133±0.003
7	0.133±0.008	0.163±0.018
	Dry Season $H_2S_{(g)}$ $(\mu g/m^3)$	**Wet Season $H_2S_{(g)}$ $(\mu g/m^3)$**
1	0.140±0.010	0.137±0.017
2	0.157±0.008	0.150±0.020
3	0.157±0.023	0.147±0.003
4	0.150±0.026	0.157±0.007
5	0.173±0.023	0.140±0.006
6	0.160±0.010	0.170±0.000
7	0.153±0.008	0.667±0.008
	Dry Season $NO_{(g)}$ $(\mu g/m^3)$	**Wet Season $NO_{(g)}$ $(\mu g/m^3)$**
1	0.140±0.010	0.117±0.003
2	0.143±0.008	0.133±0.003
3	0.133±0.008	0.147±0.003
4	0.117±0.012	0.157±0.007
5	0.153±0.003	0.143±0.003
6	0.170±0.000	0.173±0.003
7	0.147±0.003	0.177±0.003
	Dry Season $CH_{4(g)}$ $(\mu g/m^3)$	**Wet Season $CH_{4(g)}$ $(\mu g/m^3)$**
1	3.533±0.033	5.057±0.023
2	3.433±0.033	4.930±0.065
3	3.333±0.067	4.400±0.057
4	3.767±0.033	4.567±0.186
5	3.800±0.057	4.933±0.067
6	4.000±0.000	5.100±0.057
7	3.933±0.088	4.933±0.066

Values above are presented in Mean ±STD and the *level of significance for P-value is less than 0.05*

Table 4.6 showed the average mean concentration for pollutants ($CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$)for Airport junction for both dry and wet seasons. It revealed that there was a significant difference of $CO_{(g)}$ in dry season of day 5 (13.3167±2048) and day 6 (15.9667±0.333) when compared to $CO_{(g)}$ of wet season (13.2667±17.63) and (13.6000±0.05774) respectively at P-value <0.05. No difference was observed on the concentration of $CO_{2(g)}$ and $H_2S_{(g)}$ when comparing dry with wet seasons. However, there was a significant difference in the concentration $NO_{(g)}$ in the concentration of dry season of Friday (0.0967±0.0333) when compared to wet season (0.0400 ± 0.0577). Finally, there was significant difference ranging from day 2,3,4,5 and 6 for $CH_{4(g)}$ when comparing dry season (4.2867±0.00667) with wet season at p-value <0.05 level of significance.

Table 4.7: T-test comparing the statistical difference between Deco junction and Oviore junction in their level of gas emission

		Paired Differences				
		Mean	**Std. Deviation**	**Std. Error Mean**	**T**	**p-value (2-tailed)**
Pair 1	**$DCO_{(g)}$ - $OCO_{(g)}$**	2.4	.85	.13	18.17	.000
Pair 2	**$DCO_{2(g)}$ - $OCO_{2(g)}$**	6.2	2.0	.31	20.24	.000
Pair 3	**$DH_2S_{(g)}$ - $OH_2S_{(g)}$**	.15	.24	.04	4.135	.000
Pair 4	**$DNO_{(g)}$ - $ONO_{(g)}$**	.11	.03	.04	24.07	.000
Pair 5	**$DCH_{4(g)}$ - $OCH_{4(g)}$**	3.83	.71	.11	34.91	.000

Note: t= calculated value, P=level of significance, *df*= Degree of freedom, D = Deco junction, O=Oviore junction

Table 4.7 showed the significant difference between gas emitted in Airport junction (experimental site) and Oviore junction (control site), the result in the table 4.7 showed that there is significant difference in $CO_{(g)}$ gas emitted in Airport junction and that of Oviore Junction (t=17.867, P<0.05), $CO_{2(g)}$ gas emitted in Airport junction and Oviore junction (t=28.782, P<0.05). Significantly $H_2S_{(g)}$, $NO_{(g)}$, $CH_{4(g)}$ emitted in Airport junction and Oviore junction (t=5.034,P<0.05), (t=2.934, P<0.05) and (t=66.637, P<0.05) respectively.

Table 4.8: T-test: comparing the statistical difference between Airport junction and Oviore junction in their level of gas emission.

		Paired Differences				
		Mean	**Std. Deviation**	**Std. Error Mean**	**T**	**p-value (2-tailed)**
Pair 1	**$ACO_{(g)}$ - $OCO_{(g)}$**	2.87	1.04	.160	17.87	.000
Pair 2	**$ACO_{2(g)}$ - $OCO_{2(g)}$**	5.44	1.23	.189	28.78	.000
Pair 3	**$AH_2S_{(g)}$ - $OH_2S_{(g)}$**	.062	.080	.012	5.034	.000
Pair 4	**$ANO_{(g)}$ - $ONO_{(g)}$**	.066	.146	.023	2.934	.005
Pair 5	**$ACH_{4(g)}$ - $OCH_{4(g)}$**	3.66	.356	.055	66.64	.000

Note: t= calculated value, P=level of significance, *df*= Degree of freedom, A = Airport junction, O=Oviore junction

The result was not seen different on comparing the statistical difference between the emission at Petroleum Training Institute junction and Oviore junction. As shown in Table 4.8, $CO_{(g)}$ (t=51.078, P<0.05), $CO_{2(g)}$ (t=25.771, P<0.05) and $CH_{4(g)}$ (t=68.783, P<0.05) were significantly difference between Petroleum Training Institute junction and Oviore junction and also higher than that of $H_2S_{(g)}$ (t=3.204, P<0.005) and $NO_{(g)}$ (t=3.844, P<0.05). In essence, emission of gas in all the experimental site were significantly different from the control site and the positive values of the mean

difference (as shown in all the tables) reveals that there were more emission in the experimental sites than the control site.

Table 4.9: T-test: comparing the statistical difference between Petroleum Training Institute junction and Oviore junction in their level of gas emission.

		Paired Differences				
		Mean	**Std. Deviation**	**Std. Error Mean**	**T-test**	**p-value (2-tailed)**
Pair 1	**$PCO_{(g)}$ - $OCO_{(g)}$**	3.85	.49	.075	51.08	.000
Pair 2	**$PCO_{2(g)}$ - $OCO_{2(g)}$**	5.94	1.49	.231	25.77	.000
Pair 3	**$PH_2S_{(g)}$ - $OH_2S_{(g)}$**	.052	.106	.016	3.204	.003
Pair 4	**$PNO_{(g)}$ - $ONO_{(g)}$**	.019	.032	.005	3.844	.000
Pair 5	**$PCH_{4(g)}$ - $OCH_{4(g)}$**	3.88	.366	.056	68.78	.000

Note: t= calculated value, P=level of significance, *df*= Degree of freedom, P = Petroleum Training Institute junction, O=Oviore junction

Table 4.3 showed the significant difference between the emission of $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ in the Dry season and Wet season in Deco junction. The emission of $CO_{(g)}$ in the Dry season is significantly different that of the Wet season ($f= 35.591$ $p<0.05$). While the $CO_{2(g)}$ emission in both Dry and Wet season was seen to be statistically insignificant ($F=0.00$. $P<0.00$). The same statistical insignificant results also applies for the emission of $H_2S_{(g)}$ and $NO_{(g)}$ both in the Dry and Wet season ($f=2.065$. $P<0.05$) and ($F=0.984$, $P>0.05$) respectively. However, the emission of $CH_{4(g)}$ both in the Dry and Wet season was considered to be statistically significant ($F=197.902$, $P<0.05$). Hence, $CO_{(g)}$ was present in all the study location at a lower quantity when converted to ppm.

From the Table 4.4 above, showed that the emission of $CO_{(g)}$, $CO_{2(g)}$, and $H_2S_{(g)}$ in Airport junction in the dry season significantly different from that of the Wet season representing ($F=47.116$, $p<0.05$), ($F=28.743$, $p<0.05$) and ($F=16.696$, $P<0.05$)

respectively. While at the same Airport junction the emission of $NO_{(g)}$ and $CH_{4(g)}$ in the Dry season is not significantly different from that of the dry season (F=0.064, P>0.005) and (F=1.504, P>0.05). this result findings contradicts with the result findings of Okunola et al., (2012) that assessed the level of gaseous pollutants along high traffic roads in northern Nigeria consequently, in a study conducted by Jerome, (2000) on ambient air pollutants in Lagos and Niger Delta Area, it was found that NO in Non-traffic urban Zone was between 81-81.5, 34-131.6 in Traffic zone, 22.0-295.0 in Niger delta area oil communities and 35-370 in Cities. However, this was above the normal FEPA Standards of 40-60ppm

The ANOVA result on the variation of gas emission at Petroleum Training Institute junction both in the Dry and Wet season in Table 4.5 showed all significant results especially the emission of $CO_{(g)}$ was significantly different in both season (F=4.554, P<0.05). The emission of $CO_{2(g)}$ in the Dry season was highly significant in variation with that emitted in wet season (F=158.734, P<0.05). The result was also the case of $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ resulting that the emission of gas in the Dry season was significantly different that of the Wet season (F=9.265, P<0.05), (F=26.165, P<0.05) and (F=34.868, P<0.05) respectively. The findings from this study agree with the findings of IPCC (2014) on carbon dioxide ranged between 400ppm Buguma to 450ppm in Port Harcourt. Although, the measurements taken near oil processing facilities like gas flares regularly rise above 450ppm. It was also observed that the $C0_{2(g)}$ was below the average normal range in the study conducted by Tawari and Abowei, (2012) air pollution in the Niger Delta area of Nigeria between when

compared to the Nigerian Ambient Air Quality Standard (NAAIQS) which stipulates a range of 600ppm.

Result from Oviore junction (which is the control site) showed a different result from other location (Deco junction, Airport junction and Petroleum Training Institute junction). From the table 4.6, it could be observed that the emission of $CO_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ at Oviore junction was not significantly different in both season. ($F=1.465$, $p<0.05$), ($F=1.438$, $p<0.05$) and ($F = 0.366$, $p<0.05$) respectively. On the other hand, there was a significant difference in the emission of $CO_{2(g)}$ and $H_2S_{(g)}$ in the both seasons. ($f=38.007$, $P<0.05$) and ($f=5.391$, $P<0.05$) respectively. In essence, the variation in the emission level of gas in the experimental sites (Deco junction, Airport junction and Petroleum Training Institute junction) is more than that in the control site (Oviore junction).The findings from this study is contrary to the study outcome of Uno et al., (2013) that found out that Nitrogen dioxide concentration was highest in Bonny (187 µg/m3). The least concentrations of $NO_{2(g)}$ were at Ahoada, Buguma and Odukpani (53µg/m3). Though, the authors noted that Nitrogen dioxide is a chemical compound that is among one of the most prominent air pollutants. This result collaborates with the research findings of Kalabokas et al., (1999) that found a high correlation coefficient between traffic and $NO_{(g)}$ in dry season as well as Okafor et al., (2009) that discovered low concentration of $NO_{(g)}$ for Calabar metropolis in Nigeria.

4.1 Summary of Findings

The following are summary of important findings;

i. The research has shown that the global environmental problem of air pollution has necessitated the evaluation of air pollution status in selected cities in Delta state, Nigeria. This is with the view of ascertaining the average seasonal variations of $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and $CH_{4(g)}$ concentration in the selected cities. The results as shown in the Tables and Figures indicated that; the mean concentration of $CO_{(g)}$ ranged from 5.01 – 7.90µg/m³ in Deco junction 6.01 – 8.80µg/m³ in Airport junction, 7.01 – 8.20µg/m³ in Petroleum Training Institute junction and 3.20 – 4.60µg/m³ in Oviore junction (control).

ii. The research has shown that the mean concentration of $CO_{2(g)}$ ranged from 3.20 – 16.20µg/m³ in Deco junction, 11.00 – 15.90µg/m³ in Airport junction, 11.90 – 15.80µg/m^{3}in Petroleum Training Institute junction and 6.50 – 8.80mg/m³ in Oviore junction. Hence, $CO_{2(g)}$ were present in all the studied locations. This showed that there are other sources contributing to the emissions of $CO_{2(g)}$ in the study area such as; refuse burning, car exhaust, power generations and flaring at the Warri refinery.

iii. The research has shown that the mean concentration of $H_2S_{(g)}$ ranged from 0.13–1.60µg/m³ in Deco junction, 0.09 – 0.15µg/m³ in Airport junction, 0.01 – 0.19µg/m³in Petroleum Training Institute junction and 0.01 – 0.40µg/m³ in Oviore junction. Meanwhile, $H_2S_{(g)}$ were present in all sites. This showed that there are other sources contributing to the emission of $H_2S_{(g)}$ such as; automobile exhausts, power generators, refuse burning and flaring from Warri refinery.

iv. The research has shown that the mean concentration of $NO_{(g)}$ ranged from 0.10 – 0.18µg/m³ in Deco junction, 0.02 – 0.90µg/m³in Airport junction, 0.01– 0.11µg/m³ in Petroleum Training Institute junction and 0.01 – 0.10µg/m³ and Oviore junction. Hence, $NO_{(g)}$ were present in all sites at a lower quantity. This showed that the emission of $NO_{(g)}$ was possibly from the flaring at Warri refinery and that of fertilizer in agricultural activities in the region.

v. The research has shown that the mean concentration of $CH_{4(g)}$ ranged from 3.20 – 5.20µg/m³ in Deco junction, 3.02 – 4.33µg/m³in Airport junction, 4.09 – 4.69µg/m³ in Petroleum Training Institute junction and 0.00 – 0.09µg/m³ in Oviore junction. Hence, $CH_{4(g)}$ were found to be present in all the study locations at a low quality. This showed that there are other contributory factors to emission of $CH_{4(g)}$ such as automobile exhaust, power generators and flaring from Warri refinery. $CH_{4(g)}$ was lower than DPR Nigeria limit at all sites which may due to the control emission in the industrial activities in the area.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The results of this study showed that the residents of Deco junction, Airport junction, Petroleum Training Institute junction and its environs in Warri Delta State Nigeria are not being exposed to high level of air pollutants such as $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $CH_{4(g)}$, and $NO_{(g)}$. The statistical analysis of the concentration of $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $CH_{4(g)}$ and $NO_{(g)}$ measured in the various site were below the ambient air quality monitoring stipulated by Department of Petroleum Resources.

5.2 Recommendations

Based on the findings and conclusion drawn from this study, the following were the recommendations of this study:

i. Ensure that various industries and commercial firms in Warri and its environs in Delta State do not exceed the required level of gas emissions possible for polluting the air.

ii. Government should set up viable environmental protection agencies to monitor policies on pollution as well as supervise the various activities in the industries in commercial sites of Warri.

iii. There should be a set target on how to reduce the level of gas emitted into the environment by individuals and industries to curb incidence of air pollution.

iv. Public enlightenment should be carried out in other to educate the people of the hazards associated with air pollution.

v. Government should embark renewable energy, clean energy and clearer air initiative.

5.3 Contributions to Knowledge

1. The study has established that the concentrations of $CO_{(g)}$, $CO_{2(g)}$, $H_2S_{(g)}$, $NO_{(g)}$ and CH_4 are higher in the dry season than in the wet season.

2. The study also established that the concentrations of the pollutants are within the regulatory guidelines.

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APPENDIX I

RAW RESULT

APPENDIX

Days	$CO_{(g)}$ (µg/m3)	$CO_{2(g)}$ (µg/m3)	$H_2S_{(g)}$ (µg/m3)	$NO_{(g)}$ (µg/m3)	$CH_{4(g)}$ (µg/m3)
1	12.01	0.14	0.15	0.07	4.58
	12.3	0.15	0.09	0.09	4.63
	12	0.13	0.09	0.09	4.6
2	12.13	0.11	0.14	0.08	4.55
	12.7	0.11	0.06	0.06	4.61
	12.6	0.14	0.06	0.06	4.59
3	12.13	0.14	0.12	0.04	4.67
	12.9	0.1	0.07	0.07	4.72
	12.1	0.1	0.06	0.06	4.64
4	12.15	0.14	0.11	0.08	4.5
	12.3	0.13	0.09	0.09	4.53
	12.4	0.11	0.1	0.1	4.56
5	12.19	0.17	0.12	0.09	4.69
	12.9	0.14	0.09	0.09	4.4
	12.3	0.15	0.09	0.09	4.53
6	12.12	0.14	0.17	0.1	4.21
	12.9	0.14	0.01	0.01	4.18
	13	0.13	0.11	0.11	4.17
7	12.12	0.12	0.16	0.09	4.15
	12.8	0.17	0.1	0.1	4.13
	12.8	0.19	0.07	0.07	4.13

Days	$CO_{(g)}$ (µg/m3)	$CO_{2(g)}$ (µg/m3)	$H_2S_{(g)}$ (µg/m3)	$NO_{(g)}$ (µg/m3)	$CH_{4(g)}$ (µg/m3)
1	13.98	0.02	0.04	0.01	4.28
	13.8	0.03	0.05	0.05	4.17
	13.9	0.04	0.05	0.05	3.91
2	13.02	0.03	0.07	0.08	4.11
	13.8	0.01	0.09	0.09	4.11
	13.5	0.03	0.09	0.09	4.09
3	14.03	0.08	0.12	0.03	4.15
	14.8	0.05	0.01	0.01	4.19
	14.2	0.03	0.03	0.03	4.1
4	14.94	0.09	0.08	0.05	4.21
	14.8	0.01	0.04	0.04	4.13
	13.7	0.02	0.05	0.05	4.18
5	13.01	0.03	0.05	0.03	4.2
	14.9	0.01	0.03	0.03	4.29
	14.4	0.07	0.03	0.03	4.21
6	14.7	0.08	0.5	0.05	4.32
	14.7	0.01	0.05	0.05	4.3
	14.8	0.02	0.04	0.04	4.24
7	14.24	0.08	0.1	0.03	4.2
	14.7	0.04	0.01	0.01	4.18
	14.7	0.04	0.02	0.02	4.18

Days	$CO_{(g)}$ (µg/m3)	$CO_{2(g)}$ (µg/m3)	$H_2S_{(g)}$ (µg/m3)	$NO_{(g)}$ (µg/m3)	$CH_{4(g)}$ (µg/m3)
1	4.6	7.27	0.04	0.05	0.1
	4.6	7.8	0.05	0.06	0.1
	4.5	7.8	0.2	0.06	0.2
2	4.1	8.8	0.4	0.04	0.4
	4.3	8.3	0.3	0.05	0.6
	4.2	8.4	0.01	0.01	0.6
3	4.6	8.3	0.05	0.03	0.1
	4.3	8.3	0.06	0.04	0.1
	4.2	7.9	0.04	0.05	0.5
4	3.9	8	0.04	0.01	0.7
	4.3	7.8	0.07	0.06	0.9
	4.3	7.4	0.08	0.02	0.6
5	4.1	8.2	0.04	0.06	0.8
	4.1	7.9	0.05	0.06	0.1
	4.5	8	0.01	0.05	0.7
6	3.8	7.3	0.05	0.1	0.3
	3.6	7.9	0.01	0.07	0.5
	3.9	7.9	0.01	0.05	0.4
7	3.2	8	0.03	0.01	0.5
	3.4	8.2	0.01	0.03	0.8
	3.3	8.2	0.01	0.03	0.2

Days	$CO_{(g)}$ (µg/m3)	$CO_{2(g)}$ (µg/m3)	$H_2S_{(g)}$ (µg/m3)	$NO_{(g)}$ (µg/m3)	$CH_{4(g)}$ (µg/m3)
1	4.2	7.1	0.01	0.04	0.02
	4.2	7	0.03	0.06	0.08
	4.2	7	0.02	0.01	0.1
2	4.2	7	0.04	0.05	0.8
	4.5	7.2	0.04	0.07	0.9
	4.3	6.9	0.03	0.06	0.6
3	4.3	7	0.02	0.01	0.5
	4.2	6.8	0.01	0.04	0.5
	4.2	6.6	0.01	0.05	0.4
4	4.6	6.9	0.01	0.04	0.6
	4.6	7	0.01	0.04	0.1
	4.5	6.6	0.03	0.01	0.1
5	4.5	6.5	0.01	0.03	0.8
	4.1	5.9	0.04	0.03	0.5
	4	6.5	0.04	0.03	0.9
6	4.4	8.2	0.03	0.04	0.5
	4	7.9	0.01	0.01	0.4
	4.3	7.7	0.03	0.04	0.8
7	3.5	8.4	0.01	0.05	0.5
	3.7	7	0.03	0.06	0.4
	4.1	7	0.01	0.01	0.2

APPENDIX II

ANOVA RESULT

Deco Junction

		Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
$DCO_{(g)}$	Dry Season	7.0790	.56785	.12392	6.8206	7.3375	6.00	7.90
	Wet Season	6.0062	.59723	.13033	5.7343	6.2780	5.01	7.10
	Total	6.5426	.79124	.12209	6.2961	6.7892	5.01	7.90
$DCO_{2(g)}$	Dry Season	13.7133	2.60907	.56935	12.5257	14.9010	3.20	16.20
	Wet Season	13.7143	.39152	.08544	13.5361	13.8925	13.00	14.90
	Total	13.7138	1.84266	.28433	13.1396	14.2880	3.20	16.20
$DH_2S_{(g)}$	Dry Season	.2505	.31080	.06782	.1090	.3919	.13	1.60
	Wet Season	.1529	.01736	.00379	.1450	.1608	.13	.19
	Total	.2017	.22295	.03440	.1322	.2711	.13	1.60
$DNO_{(g)}$	Dry Season	.1433	.01932	.00422	.1345	.1521	.10	.17
	Wet Season	.1495	.02109	.00460	.1399	.1591	.11	.18
	Total	.1464	.02022	.00312	.1401	.1527	.10	.18
$DCH_{4(g)}$	Dry Season	4.8505	.28227	.06160	4.7220	4.9790	4.20	5.20
	Wet Season	3.6857	.25355	.05533	3.5703	3.8011	3.20	4.10
	Total	4.2681	.64627	.09972	4.0667	4.4695	3.20	5.20

Airport Junction

		Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
$ACO_{(g)}$	Dry Season	7.7086	.82199	.17937	7.3344	8.0827	6.20	9.30
	Wet Season	6.3367	.40398	.08816	6.1528	6.5206	6.00	7.30
	Total	7.0226	.94404	.14567	6.7284	7.3168	6.00	9.30
$ACO_{2(g)}$	Dry Season	13.8381	1.38365	.30194	13.2083	14.4679	11.00	15.90
	Wet Season	12.0905	.56294	.12284	11.8342	12.3467	10.90	12.90
	Total	12.9643	1.36772	.21104	12.5381	13.3905	10.90	15.90
$AH_2S_{(g)}$	Dry Season	.1010	.00831	.00181	.0972	.1047	.09	.12
	Wet Season	.1195	.01910	.00417	.1108	.1282	.10	.15
	Total	.1102	.01732	.00267	.1048	.1156	.09	.15
$ANO_{(g)}$	Dry Season	.1014	.02104	.00459	.0918	.1110	.05	.14
	Wet Season	.1129	.20592	.04493	.0191	.2066	.02	.90
	Total	.1071	.14468	.02233	.0621	.1522	.02	.90
$ACH_{4(g)}$	Dry Season	4.1367	.29359	.06407	4.0030	4.2703	3.02	4.33
	Wet Season	4.0524	.11406	.02489	4.0005	4.1043	3.80	4.15
	Total	4.0945	.22408	.03458	4.0247	4.1644	3.02	4.33

Petroleum Training Institute Junction

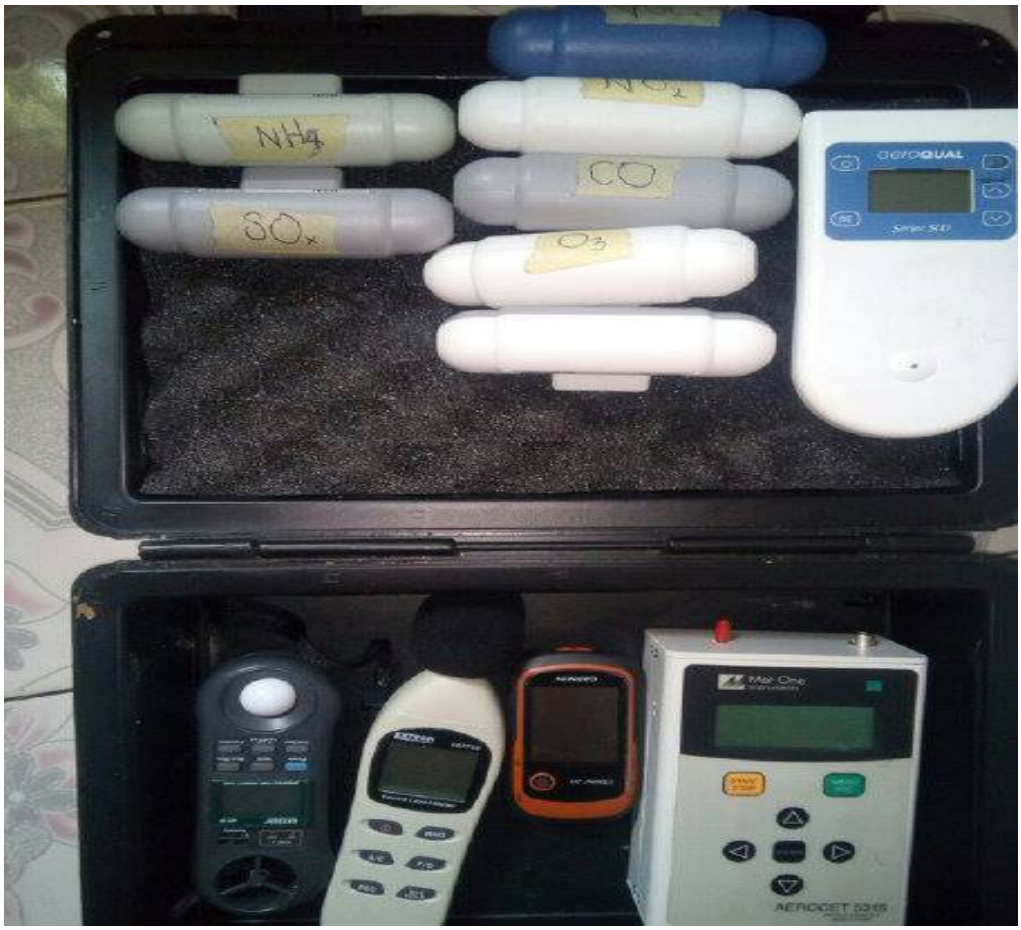
		Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
$PCO_{(g)}$	Dry Season	8.1233	.04408	.00962	8.1033	8.1434	8.01	8.20
	Wet Season	7.8900	.49912	.10892	7.6628	8.1172	7.01	8.99
	Total	8.0067	.36934	.05699	7.8916	8.1218	7.01	8.99
$PCO_{2(g)}$	Dry Season	12.5524	.36554	.07977	12.3860	12.7188	11.90	13.20
	Wet Season	14.3714	.55149	.12035	14.1204	14.6225	13.50	15.80
	Total	13.4619	1.03003	.15894	13.1409	13.7829	11.90	15.80
$PH_2S_{(g)}$	Dry Season	.1362	.02418	.00528	.1252	.1472	.10	.19
	Wet Season	.0652	.10405	.02271	.0179	.1126	.01	.50
	Total	.1007	.08280	.01278	.0749	.1265	.01	.50
$PNO_{(g)}$	Dry Season	.0781	.02316	.00505	.0676	.0886	.01	.11
	Wet Season	.0414	.02330	.00508	.0308	.0520	.01	.09
	Total	.0598	.02951	.00455	.0506	.0690	.01	.11
$PCH_{4(g)}$	Dry Season	4.4652	.20865	.04553	4.3703	4.5602	4.13	4.72
	Wet Season	4.1738	.08726	.01904	4.1341	4.2135	3.91	4.32
	Total	4.3195	.21611	.03335	4.2522	4.3869	3.91	4.72

Oviore Junction

		Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
$OCO_{(g)}$	Dry Season	4.0857	.42460	.09266	3.8924	4.2790	3.20	4.60
	Wet Season	4.2190	.27316	.05961	4.0947	4.3434	3.50	4.60
	Total	4.1524	.35902	.05540	4.0405	4.2643	3.20	4.60
$OCO_{2(g)}$	Dry Season	7.9843	.36930	.08059	7.8162	8.1524	7.27	8.80
	Wet Season	7.0571	.58187	.12697	6.7923	7.3220	5.90	8.40
	Total	7.5207	.67218	.10372	7.3112	7.7302	5.90	8.80
$OH_2S_{(g)}$	Dry Season	.0743	.10171	.02220	.0280	.1206	.01	.40
	Wet Season	.0224	.01221	.00266	.0168	.0279	.01	.04
	Total	.0483	.07622	.01176	.0246	.0721	.01	.40
$ONO_{(g)}$	Dry Season	.0448	.02228	.00486	.0346	.0549	.01	.10
	Wet Season	.0371	.01875	.00409	.0286	.0457	.01	.07
	Total	.0410	.02070	.00319	.0345	.0474	.01	.10
$OCH_{4(g)}$	Dry Season	.4095	.27911	.06091	.2825	.5366	.00	.90
	Wet Season	.4619	.28163	.06146	.3337	.5901	.02	.90
	Total	.4357	.27820	.04293	.3490	.5224	.00	.90

APPENDIX III

Aeroqual gas monitoring kit



One of the Locations