CONCENTRANTIONS OF PARTICULATES AND CARBON MONOXIDE AND ASSOCIATED HEALTH RISKS IN PUBLIC MOTOR PARKS IN OREDO AREA BENIN CITY, EDO STATE, NIGERIA.

BY

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CERTIFICATION

This is to certify that this research titled “Concentrations of Particulates and Carbon Monoxide And Associated Health Risks In Public Motor Parks in Oredo Area Benin City, Edo State, Nigeria” was carried out by Emmanuel Chukwuemeka DIALA and presented to the Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City; in partial fulfillment of the requirements for the award of Bachelor of Science (B.Sc.) in Environmental Management and Toxicology. It was conducted under suitable conditions, was carefully supervised and subsequently approved as having met the requirements for the award of Bachelor of Science degree in Environmental Management and Toxicology.

DR. M. O. AKHARAME **DATE**
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(HEAD OF DEPARTMENT)

DECLARATION

I “Godsgrace IGHORHIOHWUNU” declare that “The Effects of Aluminum Oxide Nanoparticles on The Liver of Male Wistar Rats” is my own work and that all sources that I have used or quoted have been acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other University.

EMMANUEL CHUKWUEMEKA DIALA **DATE**

DEDICATION

I dedicate this work to God almighty.

ACKNOWLEDGEMENT

I wish to express my utmost gratitude to God Almighty for His unending grace and mercies towards me, I am forever grateful for his goodness.

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TABLE OF CONTENTS

1.2 Aim and Objectives of the Study

LIST OF TABLE

Table **Title**

Page

LIST OF FIGURE

ABSTRACT

Air pollution in motor parks is a growing concern for public health in urban areas. This study aimed to assess the concentrations of carbon monoxide (CO), carbon dioxide (CO_2), particulate matter ($PM_{2.5}$ and PM_{10}), and their associated Air Quality Index (AQI) in selected motor parks in Benin City, Nigeria. The study was conducted from September to November 2024 across four randomly selected motor parks in Oredo Local Council, Benin City. Air quality measurements were taken at three different sampling points in each park using a handheld multigas detector. Meteorological parameters such as temperature, humidity, and wind speed were also recorded. Data were analyzed using descriptive and inferential statistical methods. The results showed that CO concentrations ranged from 1.2 to 5.8 ppm, $PM_{2.5}$ values ranged from 20.3 to 74.6 $\mu g/m^3$, and PM_{10} levels ranged from 45.2 to 112.4 $\mu g/m^3$. The AQI analysis revealed that some areas had air quality classified as "Moderate" to "Unhealthy for sensitive individuals." The findings show the urgent need for enhanced traffic regulation, stricter emission control, and public awareness campaigns to reduce air pollution in these areas. Recommendations include improving air quality monitoring systems, enforcing pollution control measures, and promoting the use of cleaner technologies in public transport to mitigate the adverse health effects of air pollution in motor parks within Benin City.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Due to numerous human activities, air pollution in metropolitan areas poses a serious threat to the environment and public health (Pona *et al.,* 2021). The main causes of urban air pollution include emissions from domestic heating, industrial operations, transportation, and building activities (Ibe *et al.,* 2020). Numerous pollutants are released by these sources, including as ozone (O_3), sulphur dioxide (SO_2), nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and volatile organic compounds (VOCs) (Urhie *et al.,* 2020; Eghomwanre *et al.,* 2022). Of them, carbon monoxide and particulate matter are especially dangerous because of their effects on health and frequency (Uzoekwe *et al.,* 2021).

A complex collection of small particles and droplets floating in the air is known as particulate matter. Size determines classification, with PM_{10} and $PM_{2.5}$ being the most often seen categories (Wambebe and Duan, 2020). Particles having a diameter of 10 micrometres or less are classified as PM_{10}, whilst particles with a diameter of 2.5 micrometres or less are classified as $PM_{2.5}$ (Ajieh *et al.,* 2023). These particles have the ability to enter the respiratory system deeply and can lead to a number of health problems, including lung cancer, cardiovascular disorders, and respiratory infections (Eghomwanre *et al.,* 2022; Lala *et al.,* 2023). Road dust, industrial emissions, car exhaust, and building activities are the main sources of PM in metropolitan areas (Jelili *et al.,* 2020; Akinwumiju *et al.,* 2021). The incomplete combustion of fossil fuels is the main source of carbon monoxide, a colourless and odourless gas. The main sources of CO in urban environments are domestic heating systems, industrial activities, and motor vehicles (Abaje *et al.,* 2020; Oyedele, 2022). Because CO attaches to haemoglobin in the blood, it can reduce oxygen carrying capacity and cause symptoms including headaches, dizziness, and in extreme situations, death. Exposure to CO can have detrimental consequences on health (Green and Abbey *et al.,* 2022).

The large population densities, heavy traffic, and industrial activity in urban areas make them more susceptible to air pollution (Egbetokun *et al.,* 2020; Ukaogo *et al.,* 2020). Weather patterns that keep pollutants near to the ground and prevent them from dispersing, such temperature inversions, frequently make the concentration of pollutants worse (Almetwally *et al.,* 2020). Urban heat islands can also accelerate the production of ground-level ozone and other photochemical pollutants (Manisalidis *et al.,* 2020). These are defined as regions with greater temperatures within urban areas than in their rural surrounds. The environment and economy are not the only things impacted by urban air pollution, in addition to health (Lelieveld *et al.,* 2020). In addition to impairing visibility and quality of life, it adds to the deterioration of urban infrastructure. In addition, the financial cost of treating diseases brought on by pollution and the lost productivity that results from these conditions is significant (Abaje *et al.,* 2020).

Like many other cities in underdeveloped nations, Benin City struggles with enforcing emission regulations and managing air quality (Ukpebor *et al.,* 2021). By supplying information on the precise pollution levels and health hazards in a significant urban area, this study seeks to close the knowledge gap in localized air quality data. Creating effective mitigation methods and policies to safeguard public health requires an understanding of the concentration levels and health effects of these pollutants. The focus of this study on public motor parks allows it to address a group that may be regularly exposed to hazardous pollutants: commuters, drivers, merchants, and surrounding residences. The results of this research will enhance comprehension of Nigerian urban air pollution dynamics and guide measures aimed at enhancing public health and air quality in comparable urban environments.

1.2 Aim and Objectives of the Study

The aim of this study is to determine the concentrations of particulate matter and carbon monoxide in public motor parks in Oredo area of Benin City, Nigeria.

The objectives of the study are to:

1. Determine the ambient CO, CO_2 and particulates and the meteorological parameters in the selected motor parks.
2. Determine the air quality index (AQI) of measured CO and Particulates
3. Examine the associations between the meteorological parameters and the measured pollutants concentrations
4. Examine the factors contributing to air pollution in the sampling sites.

CHAPTER TWO

LITERATURE REVIEW

2.1 Sources and Types of Air Pollutants

2.1.1 Particulate matter sources and characteristics

PM is an intricate blend of microscopic particles and aqueous droplets that are afloat in the atmosphere. PM is classified into three main categories according to their aerodynamic diameter: PM_{10}, which are particles with a diameter of 10 micrometres or less, $PM_{2.5}$, which are particles with a diameter of 2.5 micrometres or less, and ultrafine particles (UFPs) (particles with a diameter of less than 0.1 micrometres). The sources, traits, and health consequences of each size category are unique (Sidibe *et al.,* 2022; Onaiwu and Okuo, 2023).

The big particles that make up PM_{10} include mould, dust, and pollen. Industrial pollutants, unpaved roads, and building sites are common sources of PM_{10}. Wind may transport these particles across great distances and they are mostly produced by mechanical processes (Ekpo *et al.,* 2023). PM_{10} particles are often filtered via the nose and throat because of their bigger size, but they can still be harmful to health, especially for those who have respiratory disorders (Abaje *et al.,* 2020). $PM_{2.5}$ is made up of smaller particles including metals, chemical compounds, and combustion by-products. The primary sources of these particles are wildfires, industrial activities, domestic heating, and automobile emissions (Jelili *et al.,* 2020). Asthma flare-ups, heart attacks, and reduced lung function are just a few of the major health issues that can result from the ability of $PM_{2.5}$ to enter the bloodstream and deeply permeate the lungs. Additionally, because of their small size, they can stay in the air for longer stretches of time, which raises the risk of inhalation (Abulude *et al.,* 2024).

Particles smaller than 0.1 micrometres are classified as ultrafine particles (UFPs), the smallest category (Ukpebor *et al.,* 2021). The main sources of UFP emissions are motor vehicle exhaust, industrial operations, and combustion sources including power plants and home heating. Because UFPs are so small, they have the ability to pass through cell membranes and into the bloodstream, where they may have negative effects on the heart and nervous system (Pure, 2022). In comparison to $PM_{2.5}$ and PM_{10}, the health effects of UFPs are less known, but new study suggests they could be more dangerous because of their capacity to enter the body more deeply. Particulate matter in metropolitan environments comes from a variety of sources, including human and natural activity (Abulude *et al.,* 2024).

2.1.2 Carbon monoxide emissions in urban environments

The main source of carbon monoxide (CO), an odourless and colourless gas, is the incomplete burning of fuels containing carbon. Motor vehicles are the primary source of CO emissions in urban areas, hence transportation plays a significant role in raising CO levels in cities (Abaje *et al.,* 2020). A few other noteworthy sources are the heating of homes and businesses, as well as specific kinds of gear and equipment that burn fossil fuels. The main source of CO emissions in cities is motor vehicles, particularly those with internal combustion engines (Raimi *et al.,* 2021). CO is released by incomplete combustion in engines, especially in places where there is a lot of traffic congestion and stop-and-go driving. When compared to modern, well-kept cars, older cars with poorly maintained engines might release more carbon dioxide (Akeredolu *et al.,* 2024). High CO concentrations are frequently seen in urban locations with high traffic, such as public vehicle parks, endangering the health of adjacent inhabitants, drivers, and passengers. Processes involving the combustion of fossil fuels, such as the manufacture of chemicals, steel, and petroleum refinement, are examples of industrial sources of CO (Abaje *et al.,* 2020). Particularly in regions with a high concentration of industrial facilities, these industries may be a source of localised CO pollution. Inadequate ventilation and upkeep can result in the release of carbon monoxide (CO) from residential heating systems, especially those that run on wood, coal, or oil (Okedere *et al.,* 2021).

2.2 Air Quality Standards and Regulations

To safeguard the environment and public health, national and international air quality standards are set that restrict the amount of dangerous pollutants, such as carbon monoxide and particle matter (PM), in the air (CO). Certain guidelines are often revised to take into account new research results and are based on scientific information about the health impacts of these contaminants.

2.2.1 Particulate matter standards

The World Health Organization (WHO) sets global standards for $PM_{2.5}$ and PM_{10} concentrations. The World Health Organization states that the 24-hour mean and yearly mean concentrations of PM_{10} should not be more than 50 micrograms per cubic meter ($\mu g/m^3$) and $20\mu g/m^3$, respectively (World Health Organisation, 2021). When it comes to $PM_{2.5}$, the 24-hour mean and yearly mean should both not be more than $25\mu g/m^3$. The goal of these recommendations is to lessen the negative effects of both short-term and long-term particle matter exposure on health (Fowler *et al.,* 2020). The National Ambient Air Quality Standards in the United States are established by the Environmental Protection Agency (EPA) (NAAQS). The current $PM_{2.5}$ recommendations as per the US EPA are $12\mu g/m^3$ for the annual mean and $35\mu g/m^3$ for the 24-hour mean (). There is no yearly standard for PM_{10}; the 24-hour standard is $150\mu g/m^3$. Similar guidelines apply in the European Union (EU), where the 24-hour mean of PM_{10} is set at $50\mu g/m^3$ and the yearly mean at $40\mu g/m^3$. The yearly mean for $PM_{2.5}$ is $25\mu g/m^3$ (Rovira *et al.,* 2020; Hoffman *et al.,* 2021). Nigeria has enacted air quality regulations that comply with global best practices. The guidelines for particle matter align with those suggested by the World Health Organization and other international organizations. The 24-hour mean standard for $PM_{2.5}$ is $25\mu g/m^3$, but the standard for PM_{10} is $50\mu g/m^3$ (Stauffer and Perroud, 2020).

2.2.2 Carbon monoxide standards

A maximum 8-hour mean concentration of 10 mg/m^3 and a 1-hour mean of 30 mg/m^3 are recommended by the WHO for carbon monoxide, respectively. Nine parts per million (ppm) for an eight-hour average and 35 ppm for a one-hour average are the national air quality standards of the EPA for CO (World Health Organisation, 2021). By setting the 8-hour mean at 10 mg/m^3, the EU regulations deviate significantly from this. Particularly for vulnerable groups including children, the elderly, and those with pre-existing medical disorders, these guidelines are essential for protecting public health (Hoffmann *et al.,* 2021). Enforcing regulations targeted at lowering emissions from major sources, such as industry, transportation, and home heating, as well as conducting routine monitoring are necessary to ensure compliance with these requirements. The maximum allowed concentration of carbon monoxide in Nigeria for an 8-hour period is 10 mg/m^3 (Abaje *et al.,* 2020).

2.3 Health Impacts of Particulate Matter

Particulate matter (PM), especially $PM_{2.5}$ and PM_{10}, is known to cause serious health hazards to people, mostly to the cardiovascular and respiratory systems. The tiny sizes of these particles enables them to reach the bloodstream in the case of $PM_{2.5}$ and delve deeply into the lungs, where they can have a variety of harmful health impacts (Abulude *et al.,* 2024).

2.3.1 Respiratory and cardiovascular effects

Respiratory problems can arise from PM exposure both immediately and over time. Breathing in particles such as PM_{10} and $PM_{2.5}$ can irritate the respiratory tract, resulting in coughing, phlegm production, and dyspnea (Arias-Perez *et al.,* 2020). A reduction in lung function and the aggravation of pre-existing respiratory disorders including asthma and chronic obstructive pulmonary disease are linked to prolonged exposure to high PM levels

(COPD) (Yang *et al.,* 2021). Additionally, exposure to PM might make one more vulnerable to respiratory illnesses such as pneumonia and bronchitis (Gao *et al.,* 2020). Children are especially susceptible to the effects of PM because their respiratory systems are still growing. Long-term exposure to PM might potentially decrease lung development and function (Abulude *et al.,* 2024). Fine particulate matter exposure has a substantial effect on the cardiovascular system. These particles have the potential to enter the circulation and induce oxidative stress and systemic inflammation (Ekpo *et al.,* 2023). Exposure to $PM_{2.5}$ has been associated with a higher risk of cardiovascular conditions, such as high blood pressure, heart attacks, and strokes. Atherosclerosis, or the accumulation of lipids, cholesterol, and other materials in and on the arterial walls, as well as other vascular disorders, may result from it (Onaiwu and Okwo, 2023). According to studies, prolonged exposure to high $PM_{2.5}$ levels is linked to an increased risk of dying from cardiovascular illnesses, while short-term exposure might cause acute cardiovascular events like myocardial infarction (heart attack) (Yang *et al.,* 2021; Sidibe *et al.,* 2022).

2.3.2 Vulnerable populations

For a variety of physiological, socioeconomic, and environmental reasons, certain groups are more susceptible than others to the harmful effects of particulate matter (PM). In order to establish focused actions to preserve public health, it is imperative that these susceptible populations be identified (Abulude *et al.,* 2024).

Due to their still-developing immunological and respiratory systems, children are especially vulnerable to PM pollution. Considering their stature, they are exposed to more air than adults since they breathe more air per kilogram of body weight. There are several negative effects of PM exposure, including decreased lung function, asthma risk, and lung development impairment. Children are also exposed to higher levels of pollution because they spend more time outside and participate in activities that quicken their breathing

(Akintunde *et al.,* 2024). Another population that is particularly at risk is the elderly, as they frequently have underlying medical disorders that might be made worse by exposure to PM. Their immune systems and lung capacity deteriorate with age, leaving them more vulnerable to respiratory and cardiovascular problems. Research has indicated that during periods of excessive PM levels, older persons had greater rates of hospital admissions and mortality associated to respiratory and cardiovascular disorders (Ameghe *et al.,* 2022; Ucheje *et al.,* 2024).

Individuals who already have respiratory diseases like asthma or chronic obstructive pulmonary disease (COPD) are more vulnerable to the harmful effects of PM exposure. PM might exacerbate COPD symptoms and cause asthma episodes (Abulude *et al.,* 2024). In a similar vein, those suffering from cardiovascular conditions such as high blood pressure, heart disease, or stroke are more susceptible to the negative impacts of PM. Serious health problems including heart attacks and strokes can result from even brief exposure (Ayejoto *et al.,* 2023). An important contributing component to PM pollution susceptibility is socioeconomic status. Communities in low-income countries typically live in more polluted locations, including those close to major roads or industrial sites (Ucheje *et al.,* 2024). Managing chronic health disorders made worse by PM exposure might be challenging for these people because they may not have easy access to healthcare. Furthermore, the use of biomass fuels for cooking and heating is common in low-income homes, which raises their exposure to indoor PM pollution. Long-term exposure to elevated PM levels occurs among outdoor occupations such as construction workers, traffic cops, and street sellers (Ameghe *et al.,* 2022; Ucheje *et al.,* 2024).

2.4 Health Impacts of Carbon Monoxide

2.4.1 Acute and chronic health effects

People who are exposed to high quantities of CO for a brief amount of time can develop acute CO poisoning. This is frequently brought on by breathing in smoke from burning fires, being near car exhaust in confined areas, or having fuel-burning equipment break down (Manisalidis *et al.,* 2020). Hypoxia results from the inability of the body to transfer oxygen as a result of acute CO exposure (oxygen deficiency). Acute CO poisoning can cause disorientation, headaches, nausea, vomiting, and dizziness (Kinoshita *et al.,* 2020). Elevated exposure levels may cause convulsions, unconsciousness, and in extreme situations, even death. The reduction in the ability of blood to transport oxygen is the direct result of CO binding to haemoglobin in the blood to create carboxyhaemoglobin (COHb) (World Health Organisation, 2021).

Serious health effects can potentially result from prolonged, chronic exposure to reduced CO levels. Even at very low concentrations, prolonged exposure to CO can cause long-term health issues such persistent headaches, vertigo, and cognitive decline (Lu *et al.,* 2020). People with cardiovascular problems should be especially concerned about chronic CO exposure as it can worsen symptoms like angina (chest discomfort) and raise the risk of heart attacks (Manisalidis *et al.,* 2020). Due of CO being able to breach the placental barrier, pregnant women are additionally at risk for stillbirths and developmental problems in the foetus. Because prolonged hypoxia affects brain function, chronic exposure may cause permanent neurological symptoms, such as memory loss and poor coordination (World Health Organisation, 2021).

2.4.2 Mechanisms of carbon monoxide toxicity

Cellular effects: CO can disrupt mitochondrial respiration in cells in addition to its effects on haemoglobin. A crucial component of the mitochondrial electron transport chain, cytochrome c oxidase, is bound by CO, which prevents cellular respiration and lowers the synthesis of ATP (Nanagas *et al.,* 2022). Cellular energy shortages result from this inhibition, which especially affects organs with high energy demands like the heart and brain. Cell damage and apoptosis are caused by the oxidative stress and energy deprivation that follow (programmed cell death) (Siracusa *et al.,* 2021).

Haemoglobin binding: The most well-known method of CO toxicity is the formation of carboxyhaemoglobin when it binds to haemoglobin (COHb). Hemoglobin and CO attach to each other around 240 times more strongly than oxygen does. Tissue hypoxia results from the limited capacity of haemoglobin to carry oxygen due to this tight binding (Ahmed and Kumar, 2020). Consequently, insufficient oxygen is received by key organs and tissues, which is crucial for cellular respiration and energy generation. Hypoxia is exacerbated by the development of COHb, which also hinders oxygen from oxyhaemoglobin being released into tissues (Nanagas *et al.,* 2022).

Neurological impacts: The neural system can be profoundly affected by CO exposure. Because the brain is so susceptible to hypoxia, oxygen deprivation brought on by CO can cause neurological harm. Symptoms of acute CO poisoning might include headaches, lightheadedness, disorientation, convulsions, and even coma (Stucki and Stahl, 2020). On the other side, long-term neurological impairments like memory loss, cognitive dysfunction, and problems with motor coordination may arise with chronic exposure. Both direct hypoxia damage and the disruption of neurotransmitter activity and neuronal communication by CO are responsible for these effects (Ahmed and Kumar, 2022).

Cardiovascular impacts: CO poisoning has a major impact on the cardiovascular system as well. Myocardial ischemia, or decreased blood supply to the heart muscle, can result from hypoxia brought on by COHb production, raising the risk of angina, arrhythmias, and heart attacks (Kashfi and Patel, 2022). CO can also widen blood vessels, a condition known as hypotension that lowers blood pressure and reduces the amount of oxygen that reaches tissues.

The cardiovascular system is strained by the combined consequences of hypoxia and reduced oxygen supply, especially in people who already have heart issues (Siracusa *et al.,* 2021; Nanagas *et al.,* 2022).

2.5 Air Quality Monitoring Techniques

2.5.1 Particulate matter measurement

Gravimetric analyses: One of the methods for measuring PM that is most frequently employed is gravimetric analysis. It entails gathering airborne particles on a filter for a certain amount of time, and then weighing the filter to ascertain the mass of the particles gathered (Sousa *et al.,* 2024). PM mass concentration may be directly measured using this very precise technology. To prevent contamination, it has to be handled carefully and takes time. When calibrating other instruments, gravimetric techniques are frequently utilised as reference methods (Aarhaug *et al.,* 2023).

Beta attenuation monitoring (BAM): BAM is an automated technique for determining PM content by measuring the attenuation of beta particles. The drop in beta particle intensity brought on by particle deposition is assessed by drawing air through a filter tape (Shukla and Aggarwal, 2022). The mass of PM on the filter is correlated with this intensity drop. Compared to gravimetric approaches, BAM requires less effort and offers continuous, real-time observations. It has to be calibrated on a regular basis and is susceptible to changes in particle composition (Masic *et al.,* 2020).

Optical methods: PM concentrations are often measured using light scattering techniques and optical particle counters (OPCs). By measuring the amount of light emitted by each particle as it travels through a detection chamber, OPCs employ lasers to count and size individual particles (Vogt *et al.,* 2021). To quantify the concentration of PM, light scattering techniques measure the intensity of light scattered by a cloud of particles. These techniques may distinguish between various particle sizes and offer real-time data. They need to be regularly calibrated against reference techniques, though, as they could be less accurate for particles with different compositions (Molaie and Lino, 2021).

Tapered element oscillating microbalance (TEOM): By accumulating particles on a filter that is fastened to a vibrating device, the TEOM technique calculates the mass concentration of PM. The PM concentration is determined by measuring the shift in the element's oscillation frequency brought about by the additional mass of the particles (Su *et al.,* 2020). High sensitivity and accuracy continuous real-time measurements are provided by TEOM. Nevertheless, it might be impacted by changes in humidity and temperature, and the volatilization of the collected particles could cause the PM concentration to be underestimated (Shukla and Aggarwal, 2022).

2.5.2 Carbon monoxide detection

Electrochemical sensors: Industrial safety systems and portable CO detectors frequently employ electrochemical sensors. By oxidizing CO at an electrode, these sensors generate a current that is proportionate to the CO concentration. Real-time readings, a broad detection range, and excellent sensitivity are all features of electrochemical sensors (Liu *et al.,* 2020). They are appropriate for both industrial and domestic uses, small in size, and energy-efficient. Nevertheless, their longevity is limited, usually lasting between one and two years, and they need to be calibrated on a regular basis (Gan *et al.,* 2023).

Infrared spectroscopy: A popular method for determining CO concentrations is infrared spectroscopy, which is typically utilized in industrial and ambient air monitoring settings.

This technique depends on CO molecules' ability to absorb infrared light at particular wavelengths (Ning *et al.,* 2024). This class of sensors often uses non-dispersive infrared (NDIR) sensors, which combine an IR light source, a sample chamber, and a detector. The CO concentration determines how much the IR intensity is reduced as a result of CO absorption. High sensitivity and precision are offered by IR spectroscopy, which may run nonstop. It does, however, usually cost more and need to be calibrated and maintained more frequently (Liu *et al.,* 2020).

Chemical colorimetric detection: When CO is present, chemical colorimetric techniques use a colour change reaction. These techniques make use of colorimetric tubes or badges, which react chemically with CO to generate a change in colour that can be seen. Measurements can be qualitative or semi-quantitative since the CO concentration and the intensity of the colour change correspond (Kim *et al.,* 2024). Colorimetric detection works well for spot inspections and personal monitoring since it is easy to use, inexpensive, and power-free. It is not appropriate for continuous monitoring, though, as it lacks the electronic sensors' accuracy and real-time capabilities (Zhang *et al.,* 2022).

2.6 Factors Affecting Concentrations of Air Pollutants in Motor Parks

2.6.1 Traffic volume and vehicle types

There is a clear relationship between higher air pollution concentrations and high traffic volumes. Because more cars are crammed into a smaller area in motor parks with high traffic, emissions are higher (Campagnolo *et al.,* 2023). High amounts of exhaust emissions, such as hydrocarbons, PM, CO, and nitrogen oxides (NOx), result from this. Hotspots with poor air quality can be created by an increase in pollution concentrations during peak hours, when traffic volume is at its maximum (Zheng *et al.,* 2023). Since idling engines create pollutants continually without the benefit of efficient fuel combustion that happens during motion, idling vehicles - which are popular in parking lots while they wait for passengers - contribute greatly to emissions. Furthermore, because of incomplete combustion, emissions are made worse by repeated engine starts and stops in parking lots (Pinto *et al.,* 2020).

The kinds of cars that are driven in parking lots also have a big impact on how much air pollution there is. Pollutant emissions from different vehicle types vary depending on the fuel type, engine technology, and state of maintenance (Abdull *et al.,* 2020). For instance, automobiles with diesel engines significantly increase PM and NOx emissions. They release more $PM_{2.5}$ and PM_{10} into the air than cars that run on gasoline (Tang *et al.,* 2020). Motor parks are frequently dominated by buses, lorries, and older cars, which have greater emission rates because of laxer maintenance and less severe emission regulations (Deepinta and Thanacharoenchanaphas, 2023). On the other hand, pollution levels are reduced in more recent cars that have sophisticated emission control systems like particle filters and catalytic converters. By lowering total emissions, the presence of alternative fuel vehicles - such as electric or hybrid cars - can also favourably affect pollutant concentrations (Campagnolo *et al.,* 2023). Emissions are influenced by the gasoline that cars in parking lots consume. Particulate matter (PM) and sulphur dioxide (SO_2) emissions are increased by using low-quality fuels with high sulphur content. Motor parks might experience worsening air pollution due to the use of contaminated or inferior fuels in areas where regulations on fuel quality are not rigorously implemented (Zheng *et al.,* 2023).

2.6.2 Meteorological conditions

Wind speed and direction: The two main variables influencing the dispersion of air pollution are wind speed and direction. Pollutant concentrations in automobile parks can be decreased by high wind speeds, which can increase the dilution and dispersion of pollutants (Lucky *et al.,* 2021). On the other hand, low wind speeds may cause contaminants to build up and result in greater concentrations. Pollutant transportation is also influenced by wind direction (Shiada *et al.,* 2023). Motor parks might experience the movement of pollutants either in the direction of the predominant winds or away from them. For example, because of transported emissions, a vehicle park situated downwind of a busy road or an industrial region may have greater quantities of pollutants (Idris *et al.,* 2022).

Temperature: The generation and dispersal of air pollutants are influenced by temperature. Elevated temperatures have the potential to accelerate chemical processes leading to the production of secondary pollutants like ozone (O_3) (Omokungbe *et al.,* 2020). Moreover, temperature inversions - a phenomenon in which warm air traps pollutants close to the ground - can cause higher than usual levels of PM and CO in parking lots. These inversions, which stop the air from mixing vertically and cause contaminants to build up close to the surface, usually happen in calm weather (Idris *et al.,* 2022).

Relative humidity: The creation and behaviour of particulate matter can be influenced by humidity levels. Chemical processes involving gaseous precursors such as sulphur dioxide (SO_2) and nitrogen oxides can result in the creation of secondary aerosols when there is high humidity (NOx) (Antai *et al.,* 2020). Motor parks may experience poor air quality due to the production of fine particulate matter ($PM_{2.5}$) from these processes. Furthermore, moisture absorption by particulate matter can lead to size growth and an impact on respiratory health and vision in high humidity environments (Omokungbe *et al.,* 2020).

Atmospheric stability: The propensity of the atmosphere to either oppose or encourage vertical mixing is referred to as atmospheric stability. Containing little vertical air movement, stable atmospheric conditions can cause contaminants to build up close to the ground. Since temperature inversions are more common at night and in the early morning, this frequently happens at those times (Owoade *et al.,* 2021). On the other hand, unstable air conditions that involve active vertical mixing aid in the dispersal of contaminants and the reduction of their concentrations. Another factor is the time of day; whereas colder circumstances at night might increase stability and pollutant build-up, sun warmth during the day can break up inversions and encourage mixing (Lucky *et al.,* 2021).

Precipitation: By removing contaminants from the atmosphere, rainfall can have a purifying impact. The air quality in parking lots is momentarily improved by wet deposition, which eliminates soluble gasses and particulate debris. But the strength and length of the precipitation determine how effective this process is. Though large rains can efficiently clean the air, light or intermittent rains may not considerably lower pollution concentrations (Antai *et al.,* 2020).

2.7 Review on Air Quality Related studies in Motor Parks

Folarin *et al.* (2020) determined the variations in ambient particulate matter and carbon dioxide by seasons and the impacts of climate parameters in Lagos, Nigeria. The results showed that the maximum monthly mean values of PM_{10} and CO were 258.6$\mu g/m^3$ and 3.31 ppm, respectively. Even if the CO value was below the recommended threshold values established by the Federal Ministry of Environment (FMEnv) and the World Health Organisation (WHO), the PM_{10} level was above the WHO-specified limit of 50$\mu g/m^3$ for a 24-hour exposure period. Ambient concentrations of both air pollutants were higher during the dry season than during the wet season. However, there was a noticeable seasonal shift in the ambient PM_{10} concentrations. Regression analysis indicates that wind speed considerably ($p<0.05$) affects the detectable concentration of CO, but RH had no discernible effect on the availability of CO in the study area. However, relative humidity (RH) significantly influenced PM_{10} concentration, and there was a direct positive correlation between particulate matter and the climatic index, although wind speed had no appreciable impact on suspended particles.

Adeniyi *et al.* (2021) studied the pollution of ambient air around a highway in south-west Nigeria. NOx concentrations ranged from 9.9±3.2 to 33.8±3.3$\mu g/m^3$ during the wet season and from 19.0±1.2 to 35.4±2.3μg/m^3 during the dry season, according to the results. In the dry season, the sulphur dioxide concentration along this road ranged from 89.1±20.9 to 225.4±57.9μg/m^3, while in the wet season, it ranged from 49.7±38.1 to 219±18.1μg/m^3. The range of TSP during the wet season was 54.4±25.6 to 126.8±25.6μg/m^3. The WHO and FMEnv criteria of 150–230 mg/m^3 and 250 mg/m^3 were higher than these levels. In contrast, TSP readings during the dry season ranged from 85.9±44.6 to 277.8±213.5 μg/m^3. The average correlations between traffic density and NOx, SO_2, and TSP throughout the wet and dry seasons were 0.7, 0.6, and 0.7, respectively. Air pollution along the Nigerian route is strongly correlated with vehicle traffic.

Raji *et al.* (2021) assessed the emissions from vehicles in certain parts of Benin City, Nigeria. Carbon monoxide (CO), hydrogen sulphide (H_2S), formaldehyde (HCHO), and total volatile organic compound were the vehicle emissions pollutants that were assessed (TVOC). The H-4S gas analyser was utilized to sample the CO and H2S gaseous pollutants, and the JCG60 gas detector was employed to quantify the TVOC and HCHO. HTC-1 hygrometer thermometer was used to measure the climatic parameters. To ascertain the state of the ambient air quality in the research regions, the AQI was computed. The results show that the range of carbon monoxide concentrations is 3.11–16.1 ppm, with position C having the highest concentration at 16.1 ppm, exceeding the 10 ppm threshold set by the Federal Environmental Protection Agency (FEPA). The study regions are all contaminated, according to the computed AQI.

Ukpebor *et al.* (2021) determined the impacts of improved traffic control on the quality of air and levels of noise in Benin City, Nigeria. As demonstrated by a 49.4% drop in SPM concentrations and a decline in the baseline mean from 447.00 μg/m^3 in 2006 to 226.06 μg/m^3 in 2018, the interventions were successful. In 2018, the average baseline CO concentration was 2.0 parts per million, which is an 89.7% reduction from 19.4 parts per million in 2010. It was shown that although the SPM concentration fell, this drop was not statistically significant ($p<0.05$). Noise pollution has not diminished, with an average of 73.17 dB(A) as of 2018 and a baseline mean of 78.18 dB(A) in 2005 (6.41 percent). Using a multivariate study that includes Principal Component Analysis, Multiple Linear Regression, and Varimax rotation, it was shown that road traffic was the main source of noise in Benin City.

Agbozu and Oghama (2022) investigated the spatial and diurnal distribution of CO and the adverse impacts on health in the Niger Delta region of Nigeria. In situ measurements were conducted with Pyle carbon monoxide meters. With a mean value of 120.6 ppm, Rumuola Junction in Port Harcourt, Rivers State, rated highest in terms of spatial distribution across all the sample locations, while the DSC Roundabout in Effurun/Warri, Delta State, ranked lowest, with a mean value of 6.1 ppm. Only the sample locations at Airport Road and PTI Junction (Effurun-Warri, Delta State), Berger Junction, and Swali Market (Yenagoa, Bayelsa State) showed statistically significant ($P < 0.05$) daily changes in CO distribution. The amounts recorded were significantly more than the ambient air limit of 10 ppm set by the Federal Ministry of Environment. Among other things, heavy vehicle traffic density and frequent traffic congestion were blamed for the elevated emissions, build-up, and dispersion of CO.

Green and Abbey (2022) carried out a study assessing the degree of pollution by carbon monoxide in the Niger Delta, Nigeria. The findings indicated that the Niger Delta lacked regulations for protecting the environment from CO pollution, a poisoning registry, and a system for tracking the levels of CO in indoor and outdoor air. Tobacco smoke, generators, firewood, kerosene, burning waste and shrubs, fire extinguishers, grills, burning fossil fuels in antiquated cars, and the crude oil and gas sector were among the sources of pollution (three refineries, oil wells, flow stations and gas flaring, crude oil and condensate spills, vapours from crude and refined oil storage, processing and transportation facilities, petrochemical plants and gas liquefaction plants). In conclusion, there were a lot of CO_2 emission sources in the Niger Delta, and there were also insufficient environmental protection regulations.

Joshua *et al.* (2023) studied the ambient air quality near roads with different traffic densities in south-west Nigeria. Throughout the dry and wet seasons, four sample locations were set up over an average of twenty-four hours. At each location, meteorological and ambient observations were done concurrently. Air metric particulate matter sampler was used to measure the concentrations of particulate matter ($PM_{2.5}$), and the CO data logger, Ogawa sampler, and 3 M air monitor badge were used to measure the ambient gaseous concentrations of carbon monoxide (CO), nitrogen oxides (NO_2), sulphur dioxide (SO_2), ozone, and volatile organic compounds (VOC). Ion chromatography and gas chromatography were used to evaluate the samples that were taken with the Ogawa sampler and 3 M air monitor badge. In Lagos, the ambient mean $PM_{2.5}$ concentrations were measured to be $152.6 \pm 61.7 \mu g/m^3$, but in Ile-Ife, it was $93.1 \pm 2.2 \mu g/m^3$. The NO_2 concentrations in Lagos and Ile-Ife, respectively, were tested and varied from 22.0 to $65.0 \mu g/m^3$. In Lagos, the range of SO_2 content was 20.6 to $58.1 \mu g/m^3$, whereas in Ile-Ife, it was 16.4 to $60.7 \mu g/m^3$. CO concentrations varied between 1030.7 and $3000.4 \mu g/m^3$ in Ile-Ife and between 1030.7 and $3664.6 \mu g/m^3$ in Lagos sample locations. Lagos reported a higher average level of volatile organic compounds (VOCs) ($40.0 \pm 8.5 \mu g/m^3$) than Ile-Ife ($17.3 \pm 5.5\ \mu g/m^3$). With the exception of $PM_{2.5}$ and SO_2, all ambient pollutant readings were below Federal Ministry of Environment and World Health Organization guidelines.

The concentrations of particulate matter and gaseous pollutants in the air around road junctions in Port-Harcourt, Nigeria were evaluated by Aroh *et al.* (2023) The study employed a multi-parameter gas monitor, namely a multi-RAE PLUS (PGM-50), to gather air samples at five distinct intersections. Analysis was done on the amounts of wind, temperature, relative humidity, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particle matter ($PM_{2.5}$, PM_{10}). The outcome showed that the number of cars at intersections with traffic followed the order Rumuola>Choba Junction>Garrison>Lagos Bus Stop>Mile 3/UST Roundabout. The greatest pollution concentration was found near Choba Junction. The morning was the time when the concentration of vehicle pollution was maximum. The concentration of carbon monoxide (CO) was greatest, followed by that of SO_2 and NO_2. In contrast, $PM_{2.5}$ had a greater concentration of particulate matter than PM_{10} did.

Yahaya *et al.* (2024) conducted an assessment of the concentrations and health risks linked to PM_{10} in Lagos, Nigeria. The health risks associated with PM_{10} and related gaseous components, such as ozone, carbon monoxide, and nitrogen dioxide (NO_2), in the ambient air of certain areas in Lagos, Nigeria, were evaluated in this study (O_3). Yaba, Obalende, Agege, Oshodi, Oto-Awori, Odogunyan, Ikeja, Apapa, Idumota, and Ojodu were the places. These contaminants' hazard quotient (HQ), average daily dose (ADD), and average hourly dose (AHD) were computed. According to the data, CO and PM_{10} levels were above WHO permitted limits in all locations, ranging from $12.46 \pm 0.84 \mu g/m^3$ in Obalende to $58.50 \pm 3.64 \mu g/m^3$ in Agege ($45 \mu g/m^3$ for CO and $7 \mu g/m^3$ for PM_{10}). PM10 concentrations were $48.05 \pm 0.97 \mu g/m^3$ in Obalende and $115.00 \pm 1.74 \mu g/m^3$ in Apapa. At each location, the levels of NO_2 and O_3 were found to be below the permitted limits of $25 \mu g/m^3$ and $100 \mu g/m^3$, respectively. Yaba and Obalende had NO_2 and O_3 values of $0.00 \mu g/m^3$, Oshodi had $23.98 \pm 2.06 \mu g/m^3$, and Odogunyan had $2.25 \pm 0.20 \mu g/m^3$ to 38.71 ± 2.41 $\mu g/m^3$. Agege and Oshodi were the only locations where the ADD's HQ for PM_{10} and CO levels were higher than the cut-off, indicating that the local air quality may be detrimental.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was conducted in selected motor parks in Benin, a principal city of Edo State in southern Nigeria with a latitude of 6^0 20’N and a longitude of 5^0 37’E. The city occupies a landmass of 1,204 km^2, with an elevation of 89 ft. and a vast network of trunk roads. There are five local government areas in the city: Oredo, Ikpoba-Okha, Egor, Ovia North East China and Uhumwonde.

3.2 Description of the study sites

The coordinates of different locations in the study area were obtained via a global positioning system (GPS). Four public motor parks within the Oredo Local Council, Benin city, were randomly selected for air quality measurements and questionnaire surveys from September to November 2024.

The parks include Etebite Motor Park and the Mission Road Market, which serve as facilitators of local transportation and commerce. It is mostly used by people travelling to and from Benin city and other locations, and it is located along Mission Road. Small-scale vendors selling food items, fruits, snacks, and basic home items are well known in the market area surrounding motor parks. Its advantageous position makes it a bustling hub for local vendors and transportation providers, meeting the daily transportation demands of city residents and providing a variety of quick-stop shopping opportunities.

Ebo Motor Park by Oba Market Road (6°20'9"N, 5°37'9"E) is one of the busiest transportation hubs in Benin city. Movement between the city centre and surrounding areas is facilitated by this motor park. The market offers a wide range of goods, such as fresh produce, apparel, and electronics, and is often frequented by a steady stream of customers and vendors.

This area is a commercial hotspot that promotes a dynamic blend of commerce and transportation activities due to its closeness to the Oba Market, one of the main marketplaces within the city.

Uniben Motor Park, New Benin (6°21'4"N, 5°37'47"E), is a vital transportation hub for students, faculty, and traders commuting between the university and other parts of Benin city. The nearby market is a bustling area with vendors offering textbooks, student supplies, food, and local crafts. New Benin, where the park is situated, is known for its dense population and commercial vibrancy, making this motor park a vital node for daily economic and academic activities.

Benin Central Park Obakhavbaye (6°20'7"N, 5°37'1"E) is a major transportation hub that serves as a gateway to different parts of Benin city and neighboring towns. There are many small vendors selling a range of products in the market area surrounding the park, such as groceries, snacks, and travel-related services. It is crucial for passengers travelling long distances and between cities because of its strategic location. Another factor contributing to the significance of the park as a vital hub for public transportation and promoting connectedness throughout the area is the residential and business mix of the Obakhavbaye area.

3.3 Selection of Emission Sampling Points

Three randomly chosen locations (P1, P2, and P3) at each automobile park were used to measure the ambient concentrations of CO and particles. To assess the level or degree of clean air in these areas, these points indicate entry into the parks along the road, inside the parks, and behind the parks. The data are essential for demonstrating how different sources of pollutants affect the air quality of parks. The average daily concentration of contaminants from each sampling point was compared to the current World Health Organization limits. The ambient air quality index was calculated from the average daily concentrations.

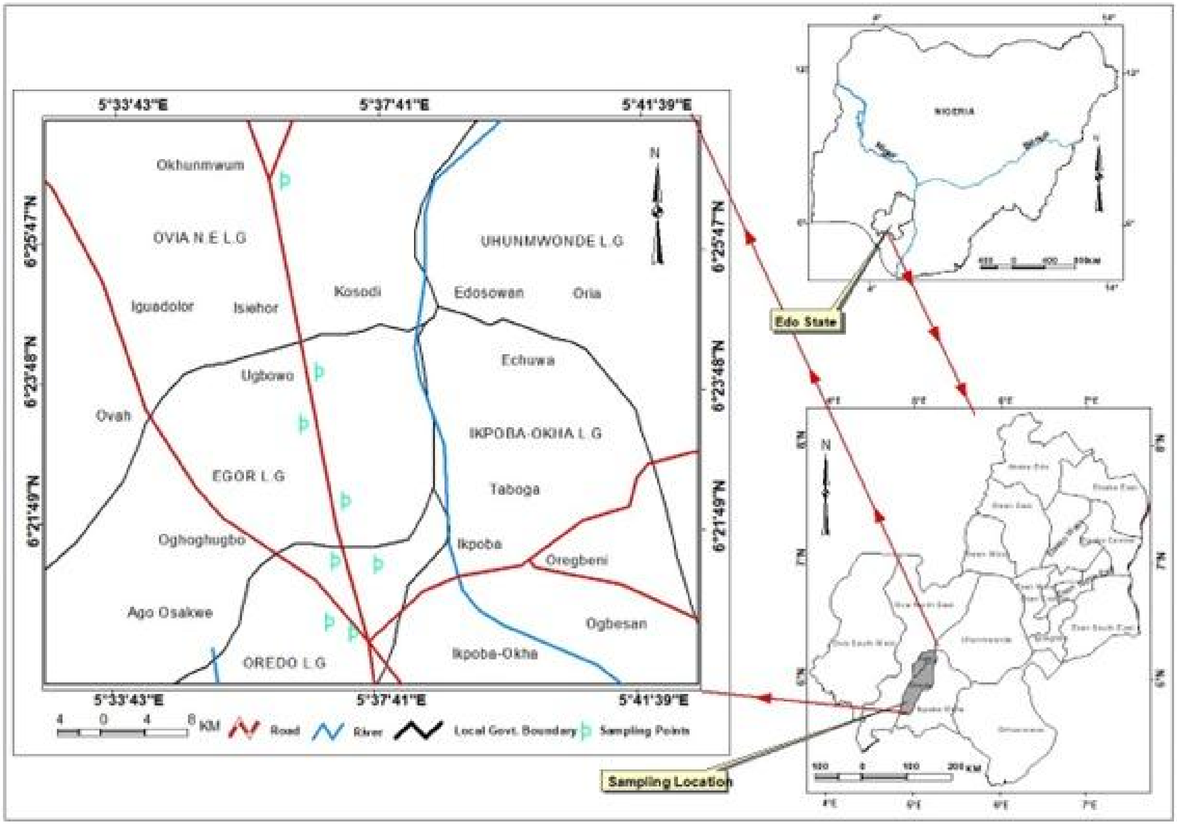

Figure 3.1: Map of the study area

3.4 Measurement of Air Quality Parameters

Using a hand-held multigas detector, the levels of particulate matter ($PM_{2.5}$ and PM_{10}) and carbon monoxide (CO) were determined (Smart Sensor Model AS8700A). With a high-precision sensor chip, the meter is a portable real-time air quality monitoring instrument. It uses a light scattering technique to monitor air pollutants and converts the concentrations of atmospheric particulates into visual data. The meter has a resolution of 1.0 $\mu g/m^3$ and an accuracy range of 0–999 $\mu g/m^3$. To ensure that the data being gathered were accurate and satisfied the goals of the study, the samplers were calibrated both before and after each sampling activity following the instructions from the manufacturer. To guarantee high-quality data, measurements were taken multiple times at each location before the precise result was recorded. To ensure that fugitive dust would not affect the readings, the meter was positioned two metres above the ground at the chosen sampling locations. For a period of twelve weeks, the measurements were conducted in duplicate every week at the specified sampling points (P1, P2, and P3) located across the chosen car parks. After anomalies were removed from the data, the average values of carbon monoxide and particulate matter were calculated and compared to the WHO 24-hour air quality standard (WHO, 2021).

3.5 Determination of Meteorological Parameters

The meteorological parameters, such as temperature, humidity, and wind speed, were recorded at each sampling point. Throughout the sampling period, the measurements were made once a week in duplicate. The relative humidity and temperature were measured by a Smart Sensor type AS8700A and an anemometer (BTMETER BT-100), respectively.

3.6 Determination of the air quality index

The AQI values were calculated for all the sampling sites via the 24-hour average concentrations of the measured air pollutants. The mean levels of each air pollutant were calculated via an Excel spreadsheet. The individual air quality index for a given pollutant concentration (Cs) based on the linear segmentation principle was calculated via the formula described by the United States Environmental Protection Agency (USEPA, 2006) below:

$$\text{AQI} = \frac{Ihigh - Ilow}{BPhigh - BPlow} X \; (Cp - Bplow) + Ilow \qquad \text{(Equation 1)}$$

where AQI = Index of the pollutant; Cp = the rounded concentration of pollutant p; BP_{high} = the breakpoint greater than or equal to Cp; BP_{low} = the breakpoint less than or equal to Cp; I_{high} = the AQI corresponding to BP_{high}; and I_{low} = the AQI corresponding to BP_{low}.

3.7 Statistical analysis

The air quality data obtained were subjected to descriptive (mean, standard deviation) and inferential (analysis of variance) statistical analyses via SPSS for Windows version 22.0. The questionnaire data are presented as frequencies and percentages, and the relationships among the reported individuals, motor park environment characteristics and respiratory symptoms among the respondents were determined via the chi-square test of significance and a logistic regression model. A value of $p<0.05$ was considered statistically significant.

CHAPTER FOUR

RESULTS

4.1 Air quality and meteorological parameters

The mean values recorded for meteorological and air quality parameters in the study area for mornings and afternoons are shown in Tables 4.1 and 4.2, respectively.

The values from the mornings show that: temperature ranged from 29.1±1.4°C in Motor park1 to 34.5±1.5°C in Motor park3; relative humidity was lowest in Motor park3 (58.3±2.0%) and highest in Motor park4 (79.1±2.8%). CO was not detected in any of the sampling points except Motor park4 (2.4±0.3ppm), and these values were within the WHO (2021) safe limits. The concentrations of CO_2 ranged from 400.1±1.9ppm in Motor park1 to 1253.1±359.0ppm in Motor park4, which exceeded the WHO (2021) safe limits. The concentrations of $PM_{2.5}$ and PM_{10} ranged from 25.2±2.8 $\mu g/m^3$ to 64.5±15.3 $\mu g/m^3$, and 31.2±4.0 $\mu g/m^3$ to 75.1±17.5 $\mu g/m^3$, respectively. The values for $PM_{2.5}$ all exceeded WHO limits, while those of PM_{10} exceeded safe limits at Motor park2 and Motor park4.

The values from the afternoons show that: temperature ranged from 30.8±1.1°C in Motor park1 to 37.3±1.7°C in Motor park3; relative humidity was lowest in Motor park3 (38.2±1.9%) and highest in Motor park4 (63.4±2.4%). CO was only detected at Motor park1 and Motor park4 (0.1±0.1ppm for both), with the values being within the WHO (2021) safe limits. The concentrations of CO_2 ranged from 399.8±1.5ppm in Motor park1 to 400.5±7.3ppm in Motor park4, which were in line with the WHO (2021) safe limits. The concentrations of $PM_{2.5}$ and PM_{10} ranged from 26.5±3.1 $\mu g/m^3$ to 46.0±6.1 $\mu g/m^3$, and 36.0±3.1 $\mu g/m^3$ to 55.5±.6.3$\mu g/m^3$, respectively. The values for $PM_{2.5}$ all exceeded WHO limits, while those of PM_{10} exceeded safe limits at only Motor park4.

Table 4.1: Mean air quality and meteorological parameters in the morning

Sampling Locations	Temp (°C)	R/H (%)	CO (ppm)	CO_2 (ppm)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)
Motor park1	29.1±1.4^a	67.7±3.2^b	0.0±0.0^a	400.1±1.9^a	33.4±5.9^b	43.2±9.7^b
Motor park2	29.5±1.2^b	70.7±3.5^c	0.0±0.0^a	403.5±4.8^a	34.6±4.7^b	47.4±10.6^b
Motor park3	34.5±1.5^b	58.3±2.0^a	0.0±0.0^a	398.2±2.5^a	25.2±2.8^a	31.2±4.0^a
Motor park4	28.5±1.3^a	79.1±2.8^d	2.4±0.3^b	1253.1±359.0^b	64.5±15.3^c	75.1±17.5^c
WHO (2021)			7	300-400	15	45
FEPA (1999)			10			

Values are means ± standard deviation of thirty replicates. Different superscripts in the same column indicate significant differences at $p < 0.05$ according to Duncan Multiple Range Test (DMRT). FMEnv: Federal Ministry of Environment; WHO: World Health Organisation

Table 4.2: Mean air quality and meteorological parameters in the afternoon

Sampling Locations	Temp (°C)	R/H (%)	CO (ppm)	CO_2 (ppm)	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)
Motor park1	30.8 ± 1.1^{a}	58.9 ± 3.0^{c}	0.1 ± 0.1^{ab}	400.2 ± 1.5^{a}	29.8 ± 3.0^{b}	38.5 ± 4.8^{a}
Motor park2	35.4 ± 1.9^{b}	55.4 ± 3.4^{b}	0.0 ± 0.0^{a}	400.1 ± 1.4^{a}	32.4 ± 6.8^{c}	44.0 ± 6.1^{a}
Motor park3	37.3 ± 1.7^{c}	38.2 ± 1.9^{a}	0.0 ± 0.0^{a}	399.8 ± 1.5^{a}	26.5 ± 3.1^{a}	36.0 ± 3.1^{b}
Motor park4	35.0 ± 2.6^{b}	63.4 ± 2.4^{d}	0.1 ± 0.1^{b}	400.5 ± 7.3^{a}	46.0 ± 6.1^{d}	$55.5\pm.6.3^{c}$
WHO (2021)			7		15	45
FEPA (1999)			10			

Values are means ± standard deviation of thirty replicates. Different superscripts in the same column indicate significant differences at $p < 0.05$ according to Duncan Multiple Range Test (DMRT). FMEnv: Federal Ministry of Environment; WHO: World Health Organisation

4.2 Variations in air pollutant concentrations

The variations in the concentrations of the selected air pollutants during the mornings, afternoons and across the sampling period are shown in Tables 4.3, 4.4 and 4.5, respectively.

The concentrations measured for all air pollutants in the morning showed significant differences ($p<0.01$). For pollutant concentrations from the afternoon period, those of CO and CO_2 showed no significant differences ($p>0.05$), while those of $PM_{2.5}$ and PM_{10} showed significant differences ($p<0.01$). Furthermore, the comparison of the morning and afternoon values for each pollutant showed that the concentrations of CO, $PM_{2.5}$ and PM_{10} were significantly different at $p>0.01$, while those of CO_2 were significantly different at $p<0.05$.

Table 4.3: Variations in air pollutant concentrations at sampling points in the morning

		Sum of Squares	df	Mean Square	F	Sig.
CO	Between Groups	133.225	3	44.408	58.963	.000
	Within Groups	87.367	116	.753		
	Total	220.592	119			
CO_2	Between Groups	16352021.000	3	5450673.667	5.639	.001
	Within Groups	112134018.467	116	966672.573		
	Total	128486039.467	119			
$PM_{2.5}$	Between Groups	26677.358	3	8892.453	119.224	.000
	Within Groups	8651.967	116	74.586		
	Total	35329.325	119			
PM_{10}	Between Groups	30973.358	3	10324.453	78.294	.000
	Within Groups	15296.633	116	131.868		
	Total	46269.992	119			

Table 4.4: Variations in air pollutant concentrations at sampling points in the afternoon

		Sum of Squares	df	Mean Square	F	Sig.
$PM_{2.5}$	Between Groups	6620.467	3	2206.822	82.786	.000
	Within Groups	3092.200	116	26.657		
	Total	9712.667	119			
PM_{10}	Between Groups	6804.067	3	2268.022	77.245	.000
	Within Groups	3405.933	116	29.361		
	Total	10210.000	119			
COa	Between Groups	.425	3	.142	2.665	.051
	Within Groups	6.167	116	.053		
	Total	6.592	119			
CO_2a	Between Groups	9.233	3	3.078	.207	.891
	Within Groups	1722.067	116	14.845		
	Total	1731.300	119			

Table 4.5: Variations in air pollutant concentrations across the sampling period

Parameter`	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
COm - COa	0.550	1.365	0.125	4.414	119	0.000
CO_2m - CO_2a	213.583	1038.934	94.841	2.252	119	0.026
PM_{10}m - PM_{10}a	5.742	16.709	1.525	3.764	119	0.000
$PM_{2.5}$m - $PM_{2.5}$a	-5.758	13.329	1.217	-4.732	119	0.000

*p value significant at the 0.01 level (2-tailed)

4.3 Correlation between air pollutants and meteorological parameters

The correlations between air pollutants and meteorological parameters in the morning and afternoon are presented in Tables 4.6 and 4.7.

In the morning, there were significant positive correlations at $p<0.01$ between the following pairs: CO-CO_2; CO and $PM_{2.5}$; CO and PM_{10}; CO and relative humidity; CO_2 and $PM_{2.5}$; $PM_{2.5}$ and PM_{10}; $PM_{2.5}$ and relative humidity; and PM_{10} and relative humidity. The correlations between $PM_{2.5}$ and temperature; PM_{10} and temperature; and relative humidity and temperature were significantly negative (i.e. inverse correlations). At a significance level of $p<0.05$, CO_2 and PM_{10}; and CO_2 and relative humidity, were significantly positively correlated, while CO and temperature were significantly negatively correlated.

In the afternoon, significant positive correlations at $p<0.01$ were recorded for: $PM_{2.5}$ and PM_{10}; $PM_{2.5}$ and relative humidity; PM_{10} and relative humidity; and CO and relative humidity, while the significant negative correlations at the same level was between relative humidity and temperature. A significant positive correlation at $p<0.05$ was recorded for CO and PM2.5, while a significant negative correlation at the same level was recorded for CO and CO_2.

Table 4.6: Correlation between air pollutants and meteorological parameters in the morning

	COm	CO_2m	$PM_{2.5}$m	PM_{10}m	RHm	TEMPm
COm	1					
CO_2m	0.600^{**}	1				
$PM_{2.5}$m	0.658^{**}	0.244^{**}	1			
PM_{10}m	0.609^{**}	0.225^{*}	0.971^{**}	1		
RHm	0.511^{**}	0.190^{*}	0.779^{**}	0.781^{**}	1	
TEMPm	-0.216^{*}	-0.059	-0.488^{**}	-0.507^{**}	-0.731^{**}	1

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

Table 4.7: Correlation between air pollutants and meteorological parameters in the afternoon

	$PM_{2.5}a$	PM10a	COa	CO_2a	RHa	TEMPa
$PM_{2.5}a$	1					
$PM_{10}a$	0.940^{**}	1				
COa	0.215^{*}	0.141	1			
CO_2a	-0.157	-0.118	-0.197^{*}	1		
RHa	0.575^{**}	0.562^{**}	0.252^{**}	0.078	1	
TEMPa	-0.078	0.026	-0.106	-0.101	-0.485^{**}	1

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

4.4 Influence of meteorological parameters on air pollutant concentrations

Table 4.8 shows the influence of relative humidity and temperature on the concentrations of air pollutants recorded during the study.

The results show that in the morning measurements relative humidity and temperature have a strong, significant effect on the concentrations of $PM_{2.5}$ (R=0.788, p=0.001) and PM_{10} (R=0.786, p=0.001), a moderate, significant effect on CO (R=0.561, p=0.001) and little impact on CO_2 although the correlation is significant (R=0.223, p=0.009).

For the measurement in the afternoon, relative humidity and temperature had a strong, significant effect on PM_{10} (R=0.786, p=0.003), a moderate, significant effect on $PM_{2.5}$ (R=0.619, p=0.002), and a weak but significant effects on CO_2 (R=0.106, p=0.011), while its effect on CO was not significant.

Air parameter	**Regression Model (Morning)**	***R***	r^2	r^2 **(%)**	**Sig. F**
CO	$Y_{CO} = -13.431 + - 0.129Rh + 0.169\ Temp$	0.561	0.315	31.5	0.001
CO_2	$Y_{CO2} = -4207.616 + 40.958Rh + 65.672Temp$	0.223	0.050	5.0	0.009
$PM_{2.5}$	$Y_{PM2.5} = -128.839 + 1.952Rh + 1.107Temp$	0.788	0.621	62.1	0.001
PM_{10}	$Y_{PM10} = -130.371 + 2.169Rh + 0.990Temp$	0.786	0.618	61.8	0.001
	Regression Model (Afternoon)				
CO	$Y_{CO} = -0.332 + - 0.005Rh + 0.002\ Temp$	0.252	0.064	6.4	0.354
CO_2	$Y_{CO2} = 4207.973 + 0.0148Rh + -0.104Temp$	0.106	0.011	1.1	0.011
$PM_{2.5}$	$Y_{PM2.5} = -27.794+ 0.638Rh + 0.781Temp$	0.619	0.383	38.3	0.002
PM_{10}	$Y_{PM10} = -35.408+ 0.699Rh + 1.189Temp$	0.786	0.618	61.8	0.002

Table 4.8: Influence of temperature and relative humidity on air pollutant concentrations

R^2 = Regression coefficient, P value significant at $p<0.05$

4.5 AQI values and ratings of pollutants

The AQI ratings for the air quality parameters are presented in Table 4.9.

The AQI values for CO in all sampling points for both morning and afternoon, and those of PM_{10} at MP1 and MP3 (morning), MP1, MP2 and MP3 (afternoon) were all in the “Good” quality range. AQI for $PM_{2.5}$ at MP3 (morning), MP1, MP2 and MP3 (afternoon), and PM_{10} at MP2 and MP4 (morning) and MP4 (afternoon) were in the range of “Moderate” quality. However, the value for $PM_{2.5}$ at MP4 in the morning was in the “Unhealthy to sensitive individuals” range suggesting potential adverse health effects.

Table 4.9: AQI values and rating of air pollutants across sampling periods and points

Sampling Locations	CO	PM$_{2.5}$	PM$_{10}$
MP1morning	50	101	47
MP2morning	50	103	51
MP3morning	50	85	34
MP4morning	50	162	81
MP1afternoon	50	94	36
MP2afternoon	50	99	41
MP3afternoon	50	88	33
MP4afternoon	50	126	52
AQI Rating	0-50 (Good)	51-100 (Moderate)	101-150 (Unhealthy to Sensitive individuals)

CHAPTER FIVE

DISCUSSION

The findings of the motor park air quality measurements varied depending on the sample location and time period, with a number of noteworthy findings that either support or contradict the body of previous research and WHO guidelines. Morning temperatures varied from 29.1°C to 34.5°C, while afternoon temperatures ranged from 30.8°C to 37.3°C. These temperatures are consistent with those found by Yahaya *et al*. (2024), who also noted that high temperatures may worsen pollution levels by promoting the production of secondary pollutants such as ozone in metropolitan areas. The higher afternoon temperatures at Motor Park 3 (37.3°C) could, however, be attributed to the impact of vehicle emissions and environmental factors like the built environment of the area (such as traffic congestion). These findings are in line with those of Aroh *et al*. (2023), who proposed that areas with high traffic and density tend to have higher temperatures and pollutant levels.

The range of relative humidity was 38.2 to 63.4% in the afternoon and 58.3 to 79.1% in the morning. The area with the highest relative humidity throughout both times was Motor Park 4. The findings of Joshua *et al*. (2023), which showed a connection between high humidity and the persistence of pollutants such particulate matter, are consistent with this discovery. Interestingly, in both morning and afternoon hours, there was a strong association between relative humidity and $PM_{2.5}$ and PM_{10}, confirming the findings of Raji *et al*. (2021), who showed that relative humidity influences the movement and deposition of particulate matter.

One important observation is that, with the exception of Motor Park 4, CO was absent in the majority of sample locations throughout both times. The CO content that was found at Motor Park 4 (2.4 ± 0.3 ppm) was still within the WHO (2021) suggested range. While isolated hotspots of elevated CO levels were noted in locations with significant vehicular traffic, Green and Abbey (2022) found comparable effects in urban transportation hubs where CO levels were typically under tolerable thresholds. Conversely, Folarin *et al*. (2020) discovered that business areas had greater CO levels. This might be because of regional differences in car emissions and fuel use or different traffic intensities. Particularly in Motor Park 4 in the morning, the observed CO_2 concentrations exceeded WHO standards, ranging from 400.1 ± 1.9 ppm to 1253.1 ± 359.0 ppm (1253.1 ppm). Similar high CO2 levels were discovered in Nigerian cities by Adeniyi *et al*. (2021), particularly in places with poor ventilation. These numbers are alarming since CO_2 can both enhance the greenhouse impact and serve as a sign of inadequate ventilation or air exchange in confined spaces, both of which were present at Motor Park 4.

The concentrations of $PM_{2.5}$ and PM_{10} in the morning ranged from 25.2 ± 2.8 $\mu g/m^3$ to 64.5 ± 15.3 $\mu g/m^3$ for $PM_{2.5}$ and from 31.2 ± 4.0 $\mu g/m^3$ to 75.1 ± 17.5 $\mu g/m^3$ for PM_{10}; all of the $PM_{2.5}$ values were above the WHO limits, and some of the PM_{10} values, especially at Motor Parks 2 and 4, exceeded the safe limits. This result is in line with that of Agbozu and Oghama (2022), who found that excessive traffic and vehicle emissions frequently cause urban motor parks in Nigeria to surpass $PM_{2.5}$ and PM_{10} criteria. Additionally, Ukpebor *et al*. (2021) pointed out that PM pollution is typically worse in transportation hubs, where the main source of pollution is vehicle emissions. The $PM_{2.5}$ values exceeding the WHO threshold of 10 $\mu g/m^3$ per year is a serious health concern, and $PM_{2.5}$ in particular has been connected to a number of health problems, such as respiratory and cardiovascular disorders.

It appears that traffic-related pollution rises throughout the day, as seen by the notable difference in pollutant concentrations between the early and afternoon hours. According to Aroh *et al*. (2023), this is in line with their results that pollution concentrations tend to peak during the day when vehicle activity is at its maximum. Notably, Raji *et al*. (2021) found that particulate matter concentrations were greater in the morning, and $PM_{2.5}$ and PM_{10} were continuously higher in the morning, but CO_2 concentrations stayed rather constant throughout the day. Further supporting the significance of vehicle emissions in the concentration of pollutants are the noteworthy connections seen in the morning, such as those between CO and $PM_{2.5}$, PM_{10}, and CO_2. In their investigation of traffic-related air pollution, Joshua *et al.* (2023) discovered comparable associations between CO and particle matter. Lower morning temperatures may lessen the dispersion of pollutants, resulting in greater concentrations, according to the negative relationships found between temperature and $PM_{2.5}/PM_{10}$ levels. This finding is consistent with research by Adeniyi *et al.* (2021), which noted that pollutants may be trapped close to the ground as a result of lower temperatures.

Different trends were seen in the afternoon, with positive correlations found between relative humidity, $PM_{2.5}$, and PM_{10}. These associations imply that the effects of particulate matter can be worsened by increased humidity. According to Folarin *et al.* (2020), comparable outcomes were seen in high-humidity metropolitan regions, where the combination of airborne moisture and particulate matter enhanced the risk of health issues. A stronger potential for pollution dispersion may be reflected in the negative association between temperature and PM_{10} recorded in the afternoon, since higher ambient temperatures facilitate vertical mixing of the atmosphere, which permits pollutants to spread.

With the exception of the high $PM_{2.5}$ levels at Motor Park 4 in the morning, which the AQI scale classified as "Unhealthy to sensitive persons," the AQI readings for CO, PM_{10}, and $PM_{2.5}$ usually indicated satisfactory air quality for the majority of locations in both the morning and afternoon. This result is consistent with that of Adeniyi *et al.* (2021), who also pointed out that sensitive populations may be at danger from localised pollution hotspots in high-density vehicle parks. Overall, the findings show that although the majority of pollutant levels were below allowable bounds, particulate matter remains a problem, particularly in more populated regions.

Recommendations

The following recommendations are made:

1. Reduce $PM_{2.5}$ and PM_{10} concentrations in automobile parks by putting traffic management techniques into practise, such as easing traffic during peak hours.
2. To reduce elevated CO_2 levels and enhance general air quality, car parks should increase ventilation and air movement.
3. To find pollution hotspots and guarantee prompt solutions, establish routine air quality monitoring at urban transportation hubs.
4. Increase public knowledge of the dangers excessive particle pollution poses to health, especially for vulnerable populations, and promote the use of protective gear.

CONCLUSION

This study effectively evaluated the levels of CO, CO_2, and particulate matter ($PM_{2.5}$ and PM_{10}) in automobile parks within Benin City, along with the associated Air Quality Index (AQI). Some automobile parks had particulate matter levels over WHO acceptable limits, especially for $PM_{2.5}$, according to the data, which showed notable variances in pollutant concentrations. It was discovered that pollution levels were significantly impacted by temperature and relative humidity, particularly in the morning. According to the AQI investigation, some places were in the "Good" range, while others particularly in the morning reached "Moderate" to "Unhealthy to sensitive persons" levels. These results highlight the necessity of better air quality monitoring, traffic law enforcement, and increased public knowledge in order to reduce possible health hazards and improve the commuting environment in Benin City.

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