CONCENTRATIONS OF AMBIENT AIR POLLUTANTS AND HEALTH RISK ASSESSMENTS IN UWELU SPARE PARTS MARKET IN BENIN CITY, NIGERIA

BY

SUCCESS OSETOHAMEN ODIGIE

LSC2006946

AN UNDERGRADUATE PROJECT WORK SUBMITTED TO THE DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA; IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR AWARD OF BACHELOR OF SCIENCE (B.SC.) DEGREE IN ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY.

FEBRUARY 2025

CERTIFICATION

This is to certify that this research titled "**CONCENTRATIONS OF AMBIENT AIR POLLUTANTS AND HEALTH RISK ASSESSMENTS IN UWELU SPARE PARTS MARKET IN BENIN CITY, NIGERIA"** was carried out by **"Success Osetohamen ODIGIW"** with matriculation number **"LSC2006946"** and presented to the Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City; in partial fulfilment 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 a Bachelor of Science degree in Environmental Management and Toxicology.

____________________ ________________

Dr. A. F. Eghomwanre **Date**
Project Supervisor

____________________ ________________

Prof. A. A. Enuneku **Date**
Head of Department

DECLARATION

I "**SUCCESS OSETOHAMEN ODIGIE** declare that "**CONCENTRATIONS OF AMBIENT AIR POLLUTANTS AND HEALTH RISK ASSESSMENTS IN UWELU SPARE PARTS MARKET IN BENIN CITY, NIGERIA"** 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.

SUCCESS OSETOHAMEN ODIGIE

…………………………

Date

DEDICATION

This project work is dedicated to God Almighty and to my eldest brother Dr Brown Odigie.

ACKNOWLEDGEMENTS

First and foremost, I give all glory to God Almighty for His grace, guidance, and strength throughout my academic journey. Without His divine help, this achievement would not have been possible.

I am also deeply grateful to my project supervisor, Dr. A.F. Eghomwanre, for his guidance, patience, and invaluable insights throughout my research process.

I sincerely appreciate my head of the department and course advisor for their guidance and contributions to my academic growth.

I am deeply grateful to my parents, whose unwavering love, encouragement, and sacrifices have been instrumental in shaping my path. A special appreciation goes to my eldest brother, Dr. Brown Odigie, for his immense support and sponsorship throughout my academic journey. His generosity and belief in my potential have been a driving force behind my success. I also extend my heartfelt gratitude to my siblings, whose support and encouragement have been invaluable.

To my dear friends – Annabel, Faith, Samuel, and Joy – thank you for your companionship, support, and encouragement, which have made this journey more fulfilling.

A big thank you to the traders at the Uwelu Spare Part Market for their cooperation and assistance during my research.

Finally, to my fiancé, I am profoundly thankful for your unwavering moral and financial support. Your belief in me has been a source of strength and motivation.

TABLE OF CONTENTS

Table of Contents

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Air pollution in market environments poses significant public health risks, particularly in urban areas with high commercial activities. This study aims to determine the concentrations and health risks associated with ambient air pollutants in the Uwelu Spare Parts Market, Benin city, Nigeria. Air quality monitoring was carried out weekly from October to December 2024 at morning and evening intervals. Carbon monoxide (CO), $PM_{2.5}$, and PM_{10} concentrations were measured via a Smart Sensor Model AS8700A, whereas temperature and relative humidity were recorded via an anemometer (BTMETER BT-100). A structured questionnaire was used to assess the respiratory health status of market users. The results revealed that CO concentrations ranged from 2.5–3.6 ppm in the morning and 2.3–3.2 ppm in the evening, remaining within the WHO (2021) limits. However, the $PM_{2.5}$ and PM_{10} levels exceeded the WHO guidelines in the evening, indicating increased pollution due to commercial activities, generator use, and waste burning. Statistical analysis revealed significant variations ($p<0.01$) in the PM_{10} concentrations in the morning and in the $PM_{2.5}$ and PM_{10} levels in the evening. Common respiratory symptoms reported among the respondents included cough (67%), phlegm (36%), and chest pain (20%). This study recommends improved waste management, regulated generator use, enhanced ventilation, and routine air quality monitoring to mitigate risks and protect public health. Implementing these measures can contribute to a safer market environment.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The quality of the air in our immediate surroundings is referred to as ambient air. It has a major impact on both environmental sustainability and public health. Substances in the air that have the potential to harm both people and the environment are known as ambient air pollutants (Nnaji *et al.,* 2023). Particulate matter (PM), nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3) are some of these contaminants. These contaminants come from a variety of sources, including industrial operations, natural processes, and emissions from moving vehicles (Agbo *et al.,* 2021). Particulate matter, particularly $PM_{2.5}$ and $PM_{10,}$ is among the ambient air pollutants that concern people the most since it may enter the respiratory system deeply and result in a number of health problems (Hopke *et al.,* 2020). Nitrogen oxides are mostly generated by industrial operations and automobile emissions. They play a major role in the creation of secondary particulate matter and ground-level ozone, both of which have detrimental effects on human health (Sharma and Sharma, 2021). Acid rain and respiratory issues can result from sulfur dioxide, which is mostly released by the burning of fossil fuels. The ability of the blood to carry oxygen can be compromised by carbon monoxide, an odourless and colourless gas produced when fuel burns incompletely (Rakitin *et al.,* 2021(). When sunlight reacts with pollutants such as NOx and volatile organic compounds (VOCs), it forms ozone, a secondary pollutant that can lead to respiratory disorders and other health concerns (Mozaffar and Zhang, 2020).

Numerous detrimental health impacts have been connected to exposure to ambient air pollution. Asthma flare-ups, lung function decline, and respiratory infections can all result from acute exposure (Zheng *et al.,* 2021). Chronic respiratory conditions, lung cancer, cardiovascular disorders, and early mortality are linked to long-term exposure. Children, elderly individuals, and people with preexisting medical disorders are among the vulnerable groups that are most vulnerable (Fagorite *et al.,* 2021). According to estimates from the World Health Organization (WHO), millions of premature deaths occur worldwide each year as a result of ambient air pollution (WHO, 2024).

To determine the concentrations of ambient air contaminants and their possible effects on health, air quality monitoring is crucial. Monitoring involves the methodical gathering of information on the concentrations of pollutants via a variety of tools and methods (Chojer *et al.,* 2020). These statistics support the comprehension of pollution trends, the identification of pollution sources, and the assessment of the efficacy of air quality control techniques (Ahmed *et al.,* 2022). Where significant pollution levels are anticipated, such as in urban and industrial regions, monitoring stations are frequently placed strategically (Madu *et al.,* 2022). One instrument for informing the public about the quality of the air is the air quality index (AQI). It converts intricate data on air quality into a straightforward scale that shows the degree of health risk connected to various pollutant concentrations. Increased values on the AQI scale, which normally range from 0--500, indicate poorer air quality and higher health hazards (Kumar, 2022). The categories within the AQI include "good," "moderate," "unhealthy for sensitive groups," "unhealthy," "very unhealthy," and "hazardous." With the help of the AQI, people may easily comprehend the levels of air quality and take the necessary precautions to keep their health safe (Ravindra *et al.,* 2024).

The Uwelu Spare Parts Market, located in Benin city, Nigeria, is a busy business district that may contribute to ambient air pollution due to its high volume of industrial activity and automobile traffic (Festus and Osaretin, 2022). Even though the origins of the pollution are clearly visible, nothing is known about the concentrations of these pollutants and the health concerns they pose in this particular location. To close this knowledge gap, this study measures the ambient air pollution concentrations in the Uwelu Spare Parts Market and evaluates any possible health consequences for the local populace. Comprehending local air quality is essential for formulating efficacious pollution mitigation tactics and safeguarding the wellbeing of the populace.

1.2 Aim and Objectives of the Study

The aim of this study was to determine the concentrations and health risks associated with ambient air pollutants in the Uwelu Spare Parts Market, Benin city, Nigeria.

The objectives of the study are as follows:

1. Measure the level of air pollutants at the selected sampling points.
2. Determine the non-carcinogenic risks associated with the measured pollutants.
3. Examine the factors contributing to air pollution in the area.
4. Determine the percentage occurrence of air-related health effects among the traders.
5. Examine the influence of the reported risk factors and health effects.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Ambient air pollution in Nigerian markets

Nigerian market ambient air pollution is a serious problem for the environment and public health. The ambient air in our immediate surroundings is referred to as "ambient air," and it can be contaminated with dangerous materials from a variety of sources (Oluoha *et al.,* 2023). This pollution affects both sellers and consumers in busy marketplaces in Nigeria, negatively affecting their general well-being and health (Diagi *et al.,* 2022). A variety of dangerous pollutants are included in ambient air pollution, such as particulate matter (PM), ground-level ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) (Criotoru *et al.,* 2020). These pollutants come from a variety of processes and activities, such as burning waste, burning fossil fuels, industrial operations, and vehicle emissions. Owing to the large number of people, cars, and activities packed into a small area, markets can have especially high concentrations of these pollutants (Okobia *et al.,* 2021).

The ambient air pollution in Nigerian markets has significant societal ramifications. Markets are essential to the economic lives of many Nigerians since they give the general public access to goods and services as well as a means of subsistence for many merchants (Oladejo *et al.,* 2020). Nonetheless, the unfavourable air quality in these settings may discourage consumers, lessen the allure of marketplaces, and even impede economic activity. The issue is further exacerbated by the fact that many Nigerian marketplaces are informal, which makes it difficult to enforce laws and regulations pertaining to pollution and emissions (Diagi *et al.,* 2022). Even more concerning are the potential health effects of ambient air pollution in marketplaces. Ambient air pollution has been recognized by the World Health Organization (WHO) as a significant risk factor for certain health problems (Taiwo and Fajoye, 2022). Chronic obstructive pulmonary disease, bronchitis, and asthma are among the respiratory conditions that are associated with high levels of air pollution exposure (COPD). Prolonged exposure can cause early mortality and increase the risk of cardiovascular illnesses. Children, elderly individuals, and people with preexisting medical disorders are among the vulnerable groups that are most vulnerable (Richard *et al.,* 2023).

Data from the World Health Organization indicate that air pollution causes an estimated 7 million premature deaths worldwide annually. The health impact is significant in Nigeria, where air pollution levels are frequently above WHO recommendations (Okobia *et al.,* 2021). Research has indicated that major air pollution occurs in places such as Lagos and Abuja, where particulate matter ($PM_{2.5}$) concentrations often exceed the WHO acceptable limits (Croitoru *et al.,* 2020). In marketplaces, where pollution sources are concentrated, this condition is representative of what continues. Acute health consequences, such as headaches, weariness, and irritation of the eyes and throat, can result from high levels of pollutants, including $PM_{2.5}$ and NO_2, in market areas (Oladejo *et al.,* 2020). The development of more severe health effects is facilitated by chronic exposure, which also exacerbates these disorders. There are also significant financial implications linked to these health effects, including medical bills and lost productivity as a result of illness (Richard *et al.,* 2023).

2.2 Sources of Air Pollutants in Market Places

Nigerian markets are thriving centres of economic activity, much like those in many other developing nations. In addition to giving the populace vital commodities and services, they also greatly worsen urban air pollution. Several factors contribute to the contamination of ambient air in these marketplaces, which results in higher than normal concentrations of air pollutants (Taiwo and Fajoye, 2022; Richard *et al.,* 2023).

2.2.1 Vehicular emissions

Vehicle emissions are among the main contributors to air pollution in marketplaces. Markets are usually characterized by high volumes of traffic, with a wide variety of vehicles running all day, including automobiles, buses, motorbikes, and delivery trucks (Ahmed *et al.,* 2022). Particulate matter, volatile organic compounds (VOCs), nitrogen oxides (NOx), and carbon monoxide (CO) are among the contaminants released by these cars (PMs). Frequent engine idling, heavy traffic, and the predominance of older, badly maintained cars without contemporary pollution controls all frequently make the issue worse (Madu *et al.,* 2022).

2.2.2 Power generating sets/plants

Market sellers sometimes rely on generators for energy because of the inconsistent power supply in many regions of Nigeria. These generators release carbon monoxide, sulfur dioxide (SO_2), nitrogen oxides, and particulate matter into the atmosphere, making them important causes of air pollution. High amounts of these pollutants are found in ambient air because of the frequent usage of generators in crowded market areas. Individual sellers frequently utilize tiny, portable generators that are particularly harmful due to their low efficiency and lack appropriate emission control systems (Ezeonyejiaku *et al.,* 2022; Okoroafor *et al.,* 2023).

2.2.3 Waste dumping and burning

Market air pollution is caused mostly by improper waste management techniques, such as burning rubbish outdoors. To manage the build-up of waste, vendors and market authorities frequently turn to burning trash, including plastics and organic waste. Numerous dangerous pollutants, including dioxins, sulfur dioxide, carbon monoxide, and particulate matter, are released during this process. Plastic debris burning is especially dangerous since it releases harmful chemicals that can seriously harm market personnel and the health of customers (Agbozu and Oghama, 2022).

2.2.4 Cooking and food preparation

Markets usually have many food sellers that prepare and cook meals there. Significant quantities of air pollutants are produced when cooking by using kerosene burners, charcoal stoves, and open flames. Particulate matter, CO, and other volatile organic compounds are released during these actions. Both food sellers and consumers may be negatively impacted by severe local air pollution caused by the concentration of food vendors in a limited area (Raheem *et al.,* 2022).

2.2.5 Dust and particulate matter

Another significant source of air pollution in marketplaces is dust. Dust is released into the air due to the movement of people and cars on unpaved or poorly maintained surfaces. This is especially hazardous in the dry season when there is a possibility of very high dust levels. Dust and other particle matter are also produced by operations such as handling and transporting commodities, particularly those involving agricultural products (Okoroafor *et al.,* 2023).

2.2.6 Industrial and artisanal activities

Small-scale industrial and artisanal operations, including metalworking, carpentry, and textile manufacturing, are conducted in some marketplaces. These actions have the potential to be major contributors to air pollution. For example, welding equipment that releases vapours containing heavy metals and other hazardous materials is frequently used in metalworking procedures. Dust, volatile organic compounds, and other pollutants that lower air quality can also be produced by carpentry and textile manufacturing (Raheem *et al.,* 2022).

2.2.7 Agricultural produce and livestock

Markets that handle livestock and agricultural products may also be a source of air pollution. Methane (CH_4) and ammonia (NH_3) are produced during the breakdown of organic materials, including fruits, vegetables, and animal manure. These gases can cause air pollution and offensive smells. In addition, VOCs and other pollutants may be released into the market environment as a result of the use of fertilizers and pesticides in adjacent agricultural operations (Adjei-Mantey *et al.,* 2023).

2.2.8 Construction activities

Continuous building and remodelling projects inside or close to marketplaces can be a major source of air pollution. Dust, particulate matter, and emissions from the vehicles and equipment used in construction are produced. VOCs and other dangerous compounds are released into the environment as a result of the use of materials such as paint, cement, and solvents. These operations may momentarily increase pollution levels, which might have an impact on both market employees and customers (Ogwu, 2023).

2.2.9 Atmospheric conditions

The concentration and dispersion of air pollutants in marketplaces can be influenced by meteorological conditions. The way that pollutants build up and spread depends on a number of variables, including temperature, humidity, wind direction, and air pressure. Inversions in temperature and wind speed, for example, have the ability to trap pollutants near the ground, increasing the concentration of contaminants in market regions. Strong winds, on the other hand, can aid in the dispersal of contaminants and lower their concentration in the air (AdjeiMantey *et al.,* 2023).

2.3 Criteria for Air Pollution and Associated Health Efficacy

2.3.1 Particulate matter

Tiny particles floating in the air are known as particulate matter (PM), and because of their size, $PM_{2.5}$ and PM_{10} are the most dangerous. $PM_{2.5}$ comprises particles with a diameter of no more than 2.5 micrometres, whereas PM_{10} refers to particles with a diameter of no more than 10 micrometres (Hopke *et al.,* 2020). There are several possible sources of these particles, such as industrial operations, construction sites, automobile emissions, and natural occurrences such as dust storms and wildfires. These particles can enter the respiratory system deeply because of their size; $PM_{2.5}$ can even enter the alveoli of the lungs (Thangavel *et al.,* 2022). High particulate matter exposure over an extended period of time is linked to a number of health concerns, such as cardiovascular difficulties, respiratory disorders, and early mortality. PM may be deposited onto surfaces and impair the quality of soil and water. It also adds to environmental problems such as haze, which decreases vision (Kyung and Jeong, 2020).

2.3.2 Ground-level ozone (O_3)

When sunlight reacts with primary pollutants such as nitrogen oxides and volatile organic compounds (VOCs), ground-level ozone (O3), a secondary pollutant (NOx), is formed. Ground-level ozone is detrimental to both the environment and human health, in contrast to the stratosphere's protective ozone layer (Sicard, 2021). It can worsen asthma, impair lung function, and cause respiratory issues. It is a key contributor to smog. Elevated ozone levels can also damage flora, which can affect crop productivity and the health of forests. Urban regions with significant traffic and industrial activity tend to produce more ozone than other types of places do, especially in warm, bright weather (Fang *et al.,* 2020).

2.3.3 Carbon monoxide (CO)

The incomplete burning of fossil fuels releases carbon monoxide (CO), an odourless and colourless gas. The major sources are wildfires, automobiles, industrial activities, and household heating. Because CO may bind with haemoglobin in the blood to produce carboxyhaemoglobin, it can act as a strong asphyxiant, impairing the capacity of the body to transport oxygen (Sharma and Sharma, 2021). This decreases the quantity of oxygen that can reach important organs and tissues, resulting in symptoms such as headaches, light-headedness, disorientation, and, in extreme cases, death. Severe health consequences can also result from prolonged exposure to decreased CO levels, especially for those who already have cardiovascular conditions (Rakitin *et al.,* 2021).

2.3.4 Sulfur dioxide (SO_2)

Colorless and odorous, sulfur dioxide (SO_2) is mostly released during the combustion of fossil fuels such as coal and oil as well as during industrial operations such as metal smelting. Volcanic eruptions are examples of natural sources (Zheng *et al.,* 2021). Owing to its capacity to produce acid rain and fine particulate matter ($PM_{2.5}$), SO_2 is a noteworthy pollutant. Shortterm symptoms, including coughing, shortness of breath, and throat irritation, can result from the inhalation of SO_2. This is especially true for those with asthma or other lung disorders (Firdausi *et al.,* 2022). Long-term exposure can exacerbate preexisting cardiovascular disorders and cause more severe respiratory ailments (Orellano *et al.,* 2021). Owing to its acidifying effect on soils and water bodies, acid rain, which is a result of SO_2 emissions, can harm aquatic ecosystems, forests, and crops (Shikwambana *et al.,* 2020).

2.3.5 Nitrogen dioxide (NO_2)

Combustion operations in automobiles, power plants, and industrial facilities are the main sources of nitrogen dioxide (NO_2), a reddish-brown gas with an unpleasant stench. Nitrogen oxide (NO_2) and nitric oxide (NOx) are two of the gases that constitute this assemblage (NO) (Shikwambana *et al.,* 2020; Kumar, 2021). The formation of fine particulate matter and groundlevel ozone makes NO2 an important contaminant ($PM_{2.5}$). Reduced lung function, an increased risk of respiratory infections, and respiratory disorders can all result from this disease (Firdausi *et al.,* 2022). Chronic respiratory conditions, including asthma, are related to the onset and exacerbation of long-term exposure. In addition to its detrimental effects on aquatic life, NO_2 also plays a role in environmental problems, including acid rain and eutrophication (Islam *et al.,* 2020).

2.3.6 Lead (Pb)

The use of leaded gasoline, mining, and industrial operations are the main sources of lead (Pb), a hazardous element that is present in the air (this, although phased down in many nations, still has an impact on areas where it is widely utilized) (Mielke *et al.,* 2022). Metal smelting, batteries, and paints with lead content are further sources. When lead from the air lands on surfaces and tains food and drink, it can be breathed in or consumed (Mandal *et al.,* 2022). Children who are exposed to lead are especially vulnerable to developmental abnormalities, behavioural disorders, and lowered IQs (Collin *et al.,* 2022). Lead exposure in adulthood can cause renal damage, reproductive difficulties, and cardiovascular problems. Lead poses longterm ecological and health problems because of its ability to remain in the environment and accumulate in soil and water (Raj and Das, 2023).

2.3.7 Polycyclic Aromatic Hydrocarbons (PAHs)

Organic molecules composed of several aromatic rings are referred to as polycyclic aromatic hydrocarbons (PAHs). Their primary production occurs when organic resources such as wood, tobacco, coal, oil, and gas are not completely burned (Xu *et al.,* 2024). The combustion of waste, industrial activities, automobile exhaust, and home heating are the main causes of PAHs in the surrounding air. Because they may produce tiny particulate matter and are persistent in the environment, PAHs are a cause for concern ($PM_{2.5}$) (Ali *et al.,* 2021). They pose health concerns, including cancer and lung problems, when they adsorb onto particles and are breathed in. Carcinogenic, mutagenic, and teratogenic PAHs are some of the classifications given to PAHs (Anyahara, 2021).

2.3.8 Volatile organic compounds (VOCs)

Groups of organic molecules that readily evaporate at room temperature are known as volatile organic compounds (VOCs). Vehicle emissions, industrial operations, solvent usage, paints, and home items are examples of common sources (Mozaffar and Zhang, 2020). By interacting with nitrogen oxides (NOx) in the presence of sunlight, volatile organic compounds (VOCs) significantly contribute to the generation of ground-level ozone and particulate matter (PM2.5) (Zhou *et al.,* 2023). Poor air quality can also be caused by indoor sources of VOCs, such as construction materials, furniture, and cleaning products. Exposure to volatile organic compounds (VOCs) can not only irritate the eyes and respiratory tract but also lead to more serious health problems, including liver and kidney damage. Certain VOCs are even proven carcinogens (Li *et al.,* 2021).

2.4 Control Measures for Ambient Air Pollution

Nigerian market ambient air pollution control calls for an in-depth strategy that addresses the many causes of pollution and incorporates sustainable practices. Implementing efficient strategies may greatly enhance air quality, which will benefit suppliers and consumers alike and foster a more salubrious atmosphere (Ezeanokwasa, 2020).

Reducing and regulating vehicle emissions is one important step. Markets frequently have high traffic volumes, which add to air pollution from several automobiles, motorbikes, and trucks. It is imperative to impose more stringent pollution regulations on automobiles. It is possible to guarantee that older, poorly maintained cars are either replaced or taken off the road through routine vehicle inspections (Nnaji *et al.,* 2023). Emissions can also be decreased by encouraging the use of alternative energy sources such as electric or hybrid cars and cleaner fuels. Enhancing the infrastructure for public transit can also aid in reducing the number of private automobiles, which will relieve traffic and reduce pollution (Okedere *et al.,* 2021).

Another major cause of pollution in markets is the extensive use of generators as a result of unstable power supplies. Making the switch to greener energy sources is essential. The requirement for generators would decline if the national grid could reliably supply power

(Agbo *et al.,* 2021). Encouraging the use of solar power and other renewable energy sources can offer a more sustainable and clean option in situations where grid expansion is not practical. This switch might be facilitated by financial incentives or subsidies for market merchants that use solar generators (Okedere *et al.,* 2021). To reduce air pollution, better waste management techniques are essential. Waste is frequently burned in open air at markets, which produces a number of dangerous contaminants. By implementing systematic waste collection and disposal procedures, it is possible to stop the build-up of waste and lessen the need for burning (Ezeanokwasa, 2020). Initiatives for recycling and composting organic waste might help reduce its effects. It is recommended that market authorities implement legislation prohibiting open burning and establish sufficient infrastructure for managing waste (Fagorite *et al.,* 2021).

The preparation and cooking of food in marketplaces is a major source of air pollution. Emissions can be decreased by encouraging the adoption of cleaner cooking technologies, such as upgraded cookstoves and liquefied petroleum gas (LPG), in place of conventional biomass fuels. Adoption requires vendor education and awareness campaigns on the advantages of cleaner cooking methods (Akomolafe *et al.,* 2024). In marketplaces, dust management methods are crucial, especially for unpaved areas. Market areas can experience a major reduction in dust production by being paved. In addition, dust levels can be reduced by routinely maintaining and cleaning market areas. Dust emissions can be further reduced by misting unpaved areas with water or dust suppressants (Abaje *et al.,* 2020).

Enforcing regulations is essential to accomplish these goals. Government agencies are required to create and implement laws restricting emissions from motor vehicles, generators, and industrial processes in and around marketplaces (Nnaji *et al.,* 2023). To guarantee compliance and pinpoint areas in need of improvement, air quality monitoring on a regular basis is necessary. Increasing the resources and training available to regulatory organizations can improve their efficacy (Agbo *et al.,* 2021).

To reduce air pollution, public awareness and education are essential. Customers and market sellers should be aware of the causes of air pollution, its effects on health, and the steps that may be taken to minimize it. Workshops, informational campaigns, and community involvement programs can help cultivate an environmentally conscious culture (Abaje *et al.,* 2020). To properly execute these policies, cooperation between the government, market authorities, and business sector is necessary. Partnerships can help provide a coordinated approach to lowering air pollution by facilitating the exchange of resources, knowledge, and technology (Okedere *et al.,* 2021).

2.5 Review of Air pollution-related Studies in Markets

Odekanle *et al.* (2020) determined atmospheric emissions and assessed health risks in the vicinity of an abattoir. This study evaluated the effects of slaughterhouse operations on ambient air quality and the potential health risks of exposure to H_2S, SO_2, NH_3, $PM_{2.5}$, and PM_{10}. Throughout the course of sixty days (October to November), three simultaneous air samplings were conducted around the slaughterhouse via conventional procedures for both sampling and analysis. By utilizing attributable fractions, relative risk, and the additional lifetime cancer risk, health hazards related to exposure to PM_{10} and $PM_{2.5}$ were calculated. The hazard quotient was also used to assess the noncarcinogenic hazards associated with the inhalation of H_2S, SO_2, and NH_3 (HQ). According to the findings, the mean concentrations of 18.75 $\mu g/m^3$, 89.17 $\mu g/m^3$, and 0.1 ppm for $PM_{2.5}$, PM_{10}, and NO_2, respectively, were higher than the acceptable limits set by the Federal Ministry of Environment (FMEnv), the World Health Organization (WHO), and the National Ambient Air Quality Standard (NAAQS). The ambient air quality was shown by the air quality index to be very acceptable for CO and NH_3, moderate for PM_{10}, and extremely poor for NO_2 and SO_2. It was also demonstrated that lowering $PM_{2.5}$ to 3 μg/m^3 could prevent 0.32% of lung cancer deaths and 0.23% of cardiac deaths, whereas lowering PM_{10} to 10 μg/m^3 might prevent approximately 0.14% of all-cause fatalities. Similarly, there is a minimum 0.45% chance that a person in a group exposed to $PM_{2.5}$ 100 meters away from the burning point would develop lung cancer as opposed to a person in a different group exposed to a baseline value of 3 μg/m^3. The fact that all of the HQ values were higher than the threshold value of unity suggests that the area is likely to experience negative health consequences from H_2S, SO_2, and NH_3.

Amesho *et al.* (2021) assessed the chemical composition of $PM_{2.5}$ and air quality in a night market located in Taiwan. To simulate $PM_{2.5}$ diffusion, the industrial source complex shortterm (ISCST3) air quality model was used. The model as a tool may analyse the effect between the source and the receiver by simulating the sources, diffusions, transportation, and emissions of pollutants in certain locations. As a result, we contrasted our sample data from three separate Kaohsiung city sampling locations with data on pollutant emissions from several air quality monitoring stations. The results of this investigation revealed that the average $PM_{2.5}$ concentration during the opening hours of the night market ranged from 29–61 μg/m^3, whereas the average $PM_{2.5}$ concentration prior to the opening hours of the night market ranged from 22–38 μg/m^3. Inductively coupled plasma optical emission spectroscopy (ICP–OES) was used to assess the concentrations of metallic elements (MEs) (Mg, Na, Cr, Mn, Fe, Cu, Al, Ba, Cd, Pb, and Ca). The results revealed that the ME concentrations in PM2.5 during the night market opening hours increased in the following order: Na > Fe > Al > Ca. Regarding the amount of carbonaceous species present, our findings indicated that the peak total carbon (TC) concentration during the downwind measurement interval was 6.52 μg/m^3. The greatest concentrations of elemental carbon (EC) and organic carbon (OC) were 2.70 μg/m^3 and 6.53 μg/m^3 of $PM_{2.5}$, respectively.

Chukwu *et al.* (2022) compared the air quality in two selected cities (Enugu and Abuja) in Nigeria. The study employed a questionnaire-based survey (n = 262) in the state capital of Enugu (n = 125) and the federal capital city of Abuja (n = 137) in Nigeria. The poll was conducted between October 2020 and March 2021 during the COVID-19 epidemic. The data were stratified to guarantee participation from a range of demographic categories, including age, gender, income, and education. The Kruskal–Wallis nonparametric test and Hochberg post hoc test, both of which are included in SPSS version 28, were used to analyse the data. The study revealed that respondents from both cities and demographic groups agreed quite slightly on the ranking of perceptual markers and the primary causes of PAQ. The most significant markers of $PM_{2.5}$ are smoke, odours, and dust particles. On the other hand, the primary causes of $PM_{2.5}$ were power generators, vehicles, and waste and bush burning. The two most favoured control strategies were avoiding bush burning and managing waste properly. Regarding the primary agencies in charge of handling PAQ, there was a notable distinction between the two cities: respondents from Abuja mentioned the federal government, whereas those from Enugu mentioned the state government. Interestingly, while the elderly population in Enugu felt that the government should be in charge of managing PAQ, the younger generation in that city did not share this opinion in Abuja. Overall, this study revealed that people in these two Nigerian cities are aware of their exposure to PAQ, which implies that establishing policies to address this significant issue should consider these perceptual markers, as well as opinions on sources and remedies.

Diagi *et al.* (2022) evaluated emissions from vehicles in selected markets within Owerri, Nigeria. The following five air pollutants from vehicle emissions were tracked: particulate matter ($PM_{2.5}$), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), and particulate matter (PM_{10}). Using authorized standard techniques, assessments were completed every two diurnal segments every three hours. The morning and afternoon sample periods (7–

10 am and 2–5 pm) were then translated to a one-hour mean. Within the research region, these times are recognized as the busiest for both pedestrian and car traffic. The greatest CO content

(0.293–0.387 ppm) was found in the Alaba market, according to the results, and it is below the 35 ppm national ambient air quality standard permitted limit (NAAQS). The Alaba market reported the largest CO_2 range (1153–1875 ppm), which is greater than the ambient standard of 314 ppm. In the Relief market, the highest NO_2 concentration (0.116 - 0.297 ppm) was observed, above the allowable limit of 0.100 ppm recommended by the NAAQS. The Relief market had the largest range of $PM_{2.5}$ and PM_{10} particulate matter, measuring 0.011 to 0.029 µg/m^3 and 0.065 to 0.172 µg/m^3, respectively. These levels are significantly lower than the acceptable limit of 150 µg/m^3 set by the WHO and NAAQS (based on Target 1) standards. As a consequence, the study concluded that vehicle emissions have a major influence on the markets in the Owerri metropolis. The high concentrations of CO_2 and NO_2 in the marketplaces suggest a high risk of health issues in the market.

Ezeonyejiaku *et al.* (2022) conducted an exhaustive evaluation of the concentrations of particulate and gaseous pollutants in parts of Anambra State, Nigeria. Aeroqual air quality monitoring devices were used to measure the concentrations of known air pollutants in different study areas. These pollutants included suspended particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), methane (CH_4), volatile organic compounds (VOCs), hydrogen sulfide (H_2S), ammonia (NH_3), ozone (O_3), carbon dioxide (CO_2), and carbon monoxide (CO). The results were compared with the WHO air quality guidelines for health impact assessment. The danger categories of the air quality conditions across the study locations were determined by interpolating the air quality index (AQI) from the pollutant concentrations. In the Awka, Ekwulobia, and Nnewi residential areas, the average values of SO_2, CH_4, and VOCs were found to be higher than the WHO air quality guidelines, ranging from 200 to 8000 µg/m^3. Only the concentrations of VOCs (500 to 1100 µg/m^3) in Awka and Ekwulobia surpassed the WHO standards, but the concentrations of CO_2, SO_2, and CH_4 (3.25– 1,027,000 µg/m^3) at the commercial sites of Awka, Ekwulobia, and Nnewi did. Only two particle concentration ranges, 62–181 µg/m^3 and 40–295 µg/m^3, were found to surpass the World Health Organization recommended limits for health aspects of air pollution inside the commercial areas of Nnewi and Ekwulobia. The AQI computations indicated that there may be health hazards associated with the air quality in certain areas.

Sidibe (2022) studied ambient and indoor air pollution in Bamako, Mali. The locals went about their regular lives with optical sensors measuring the size of their palms. The levels of exposure were higher than the WHO's recommended daily and annual limits of 25 µg/m^3 and 10 µg/m^3, respectively. The exposure amount and daily activities were clearly related. When incense and insecticide (IST) were burned inside, the greatest exposure concentration (ICS) was noted. The maximum values recorded were 999 µg/m^3 and 145 µg/m^3, respectively. This was followed by cooking (150 µg/m^3) and traffic (216 µg/m^3). Consequently, it was decided that these were the most exposed activities and/or microenvironments in this area. To further define the chemical composition and ascertain the health hazards associated with exposure to PM released from routine everyday activities, such as transportation emissions, cooking emissions, and the burning of domestic IST and ICS products, PM was also tested on quartz and Teflon filters. The composition differed from one emission source to another. The results of the health risk assessment research revealed that the PM generated from routine everyday activities was harmful to human health in addition to its high concentration. According to the ambient PM source distribution analysis, the main cause of outdoor PM pollution was dust resuspension (70%). Significant effects were also caused by car emissions and the burning of biomass. The concentrations of primary ambient air pollutants (NO_2, O_3, SO_2, CO, $PM_{2.5}$, and PM_{10}) were evaluated over a period of six months. There was a noticeable distinction in the quantities recorded during the wet and dry seasons, and the concentrations were quite high. Air pollution is caused mostly by everyday human activity. Local factors affect air quality, as reflected by the correlations between pollution concentrations and meteorological parameters, including humidity and wind speed.

Ebong *et al.* (2023) determined the air quality indices of commercial centres located in Uyo, Nigeria. On the basis of the activities conducted at each location, this study examined the impact of many commercial centres in Uyo Metropolis, including Akpanadem Market, Uyo Plaza, Itam Market, and Itam Abattoir, on air quality. Standard instruments were used to measure the following parameters at the examined locations: NO_2, SO_2, H_2S, CO, Cl_2, NH_3, HCN, CH_2O, TVOCs, $PM_{2.5}$, and PM_{10}. The findings revealed that, with the exception of SO2, the mean concentrations of all the air pollutants were higher than the Federal Environmental Protection Agency's recommended thresholds (FEPA). The Itam Abattoir was found to be the source of the greatest amount of air pollutants generated by its operations. In the analysed areas, the main sources of these pollutants were the use of condemned tires, petroleum products, generator and vehicle emissions, the dumping of organic waste in markets, and cigarette smoking. The multivariate analysis revealed that the primary pathway for the release of these contaminants into the air environment was the human source. Air quality index studies have revealed that humans can have negative effects on both sensitive and nonsensitive groups if they are exposed to these pollutants at all times and for extended periods.

Nemakhavhani (2023) evaluated compliance with air quality standards within Tshwane, South Africa. Data on PM_{10}, NO_2, and SO_2, all of which are often measured and deemed significant, were taken from the SAAQIS database for the years 2016 through 2020. The information supplied relates to the ambient air monitoring network stations located within the Metropolitan

Municipality of the city of Tshwane. In compliance with the South African National Ambient Air Quality Standards, the concentrations of PM_{10}, NO_2, and SO_2 were evaluated (NAAQS). Thus, the goals of this study were to assess the quality of the air in the city of Tshwane Metropolitan Municipality, investigate seasonal fluctuations in the levels of NO_2, PM_{10}, and SO_2, and examine the spatial distributions of these pollutants. The present study employed Microsoft Excel and the Statistics Package for the Social Sciences (SPSS) to conduct the data analysis. Furthermore, the data were analysed through the use of box and whisker plots and bar graphs. According to the research findings, the city of Tshwane did not meet the National Ambient Air Quality Standards (NAAQS) for the reported yearly values of PM_{10} (78.18 μg/m^3), NO_2 (60 μg/m^3), and SO_2 (163.76 μg/m^3) in the Booysens neighborhood.

Okponmwense and Ehinomen (2023) employed measurements of lead and cadmium in the estimation of air quality in markets in Benin city, Nigeria. Harvested from the vegetable markets of Oba, Ekiosa, New Benin, and Ikpoba-Hill in Edo State, Nigeria, the leaves of pumpkin (*Telfairia Occidentalis*) and greens (*Amaranthus hybridus*) were cleaned with deionized water, spread, and exposed on tables positioned at ten different points, 10 m apart near the roadside outside and inside each market, from 8:00 am to 6:00 pm every day (Monday– Friday) for a period of three months (from November--March). Wet digestion of the various collectors was followed by an analysis of the lead and cadmium contaminants in the dust deposit via an atomic absorption spectrophotometer. The dust collected from the exposed vegetable leaves inside each market contained no cadmium. Cadmium levels of up to ≤0.01 mg/kg were detected in the atmospheric dust that was deposited on the vegetable leaves outside of each market. The investigation further demonstrated that lead was present in the air dust both inside and outside of each market. The lead concentrations in the dust deposits collected from outside each market varied from 0.03 to 1.04 mg/kg, whereas the air dust deposits collected from within each market had lead concentrations between 0.02 and 0.69

mg/kg. For cadmium both within and outside of the market environment, the air quality index (AQI) forecast was excellent (very clean). However, both outside and within the market, the AQI rating varies from moderate (very clean) to extremely bad (severely polluted). The Ikpoba-Hill market was moderately clean, and the Ekiosa market was very poor (severely polluted) because of lead pollutants in dust that formed owing to vehicles and human activity. Oragba *et al.* (2023) carried out a study determining the levels of air quality within selected markets located in Owerri, Nigeria. Readings were obtained in the morning, afternoon, and evening at each market during the three days the study was conducted. A hazy dust particle monitor, a Crowcon gas man monitor, a GPS, and an MRU AMPRO2000 gas monitor were used to measure the concentrations of the gases released in the research area. Particulate matter (PM_{10}), hydrogen sulfide (H_2S), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ammonia (NH_3), nitrogen dioxide (NO_2), and methane (CH_4) were the parameters studied. The values of the produced data were compared to the limits recommended by the Federal Ministry of Environment. According to the observed results, the average concentration of carbon monoxide (CO) fluctuated between 0.00 and 28.80 (7.09±0.60) parts per million. The mean nitrogen dioxide (NO_2) concentration ranged from 0.02–0.41 (0.17±0.01) ppm, whereas the mean ammonia (NH_3) concentration ranged from 0.00–25.00 (1.96±0.40) ppm. The average values of hydrogen sulfide (H_2S) were between 0.00 and 2.81 (0.38±0.040) ppm, whereas the average values of sulfur dioxide (SO_2) were between 0.02 and 0.83 (0.26±0.01) ppm. The average concentration of particulate matter (PM_{10}) was 3.48–36.00 (18.9±0.69) mg/m^3. Methane (CH_4), a flammable gas, has an average concentration of 0.00-1.50 (0.23±0.04) LEL percent. The standards recommended by the Federal Ministry of Environment were surpassed for PM_{10}, NO_2, and SO_2.

In Richard *et al.* (2023), the concentrations of air pollutants, which vary with season along a major highway in Nigeria, were assessed. A total of 108 air samples were taken during Nigeria's dry seasons, which run from November to March, and wet seasons, which run from May to September. The samples were used to measure the concentrations of various particulates, such as $PM_{2.5}$ (particulate matter 2.5), PM_{10} (particulate matter 10), and total suspended particulate (TSP), as well as some known gaseous pollutants, such as CO (carbon monoxide), NH_3

(ammonia), H_2S (hydrogen sulfide), volatile organic compounds (VOCs), NO_2 (nitrogen dioxide), and sulfur dioxide (SO2). The findings for NH_3, H_2S, CO, NO_2, SO_2, VOC, $PM_{2.5}$, PM_{10}, and TSP ranged from 0.00 - 0.30 ppm, 0.00 - 0.20 ppm, 0.00 - 0.70 ppm, 0.00 - 0.30 ppm, 0.00 - 0.20 ppm, 4.20 - 19.60 ppm, 16.30 - 51.40 $\mu g/m^3$, 43.20 - 266.00 $\mu g/m^3$, and 56.30 - 434.60 $\mu g/m^3$, respectively. With the exception of NH_3, H_2S, and CO, most air pollutant concentrations significantly differed ($p<0.05$) between the dry and rainy seasons. Certain gaseous pollutants (CO, NO_2, and SO_2) and particle TSPs were found in amounts that fell within the parameters set by the Nigerian Ambient Air Quality Standard. The guidelines for $PM_{2.5}$ and PM_{10} set by the World Health Organization, which are 25 $\mu g/m^3$ and 50 $\mu g/m^3$, respectively, were exceeded for an average of 24 hours. These notable fluctuations might be linked to human activity as well as the seasonal effects of thermodynamic agents such as wind and temperature.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

This present study was conducted in Benin City, Nigeria. Benin City is the capital of Edo State, which is located in the southern tropical rainforest ecological zone and lies latitudes 6^o 11' and 6^o 29'N, and longitudes 5^o 33' and 5^o 47'E. There are five local government areas which make up the city: Egor, Ikpoba-Ohka, Oredo, Ovia North-East and Uhunmwonde LGAs. Bini is the major native language spoken within the city. In total, the land area of the city is approximately

112.5km^2 at a mean height of 77.8m above sea level and average annual rainfall ranging from 2,000 to 3,000mm. Relative humidity values are high in the area, ranging from 75 to 80% There are two major seasons; the wet and dry seasons. November to April are dry, April to October are wet with a short 'August break' in August, and a harmattan period between December and January, which is dry and dusty (Ikpe *et al.,* 2020).

3.2 Sampling locations

The sampling location for this study was Uwelu Spare Parts Market. It is a major marketplace for automobile spare parts in Benin City. It is well-known for having an extensive inventory of both new and used car parts and for acting as a regional hub for auto technicians, dealers, and consumers. The market is a go-to place for auto repairs and maintenance requirements as it caters to various automobile models and brands (Ezedi and Ogbeifun, 2024). The market is geographically located at 6.36°N and 5.60°E. Sources of air pollution around the market include passing vehicles, dust, power generating plants, waste incineration. There are fewer pollution sources within the market particularly for carbon monoxide. Three sampling points were selected for the study: SP1 (just outside the market - 6.3785°N, 5.5916°E); SP2 (inside the market - 6.3782°N, 5.5910°E); and SP3 (behind the market - 6.3790°N, 5.5899°E).

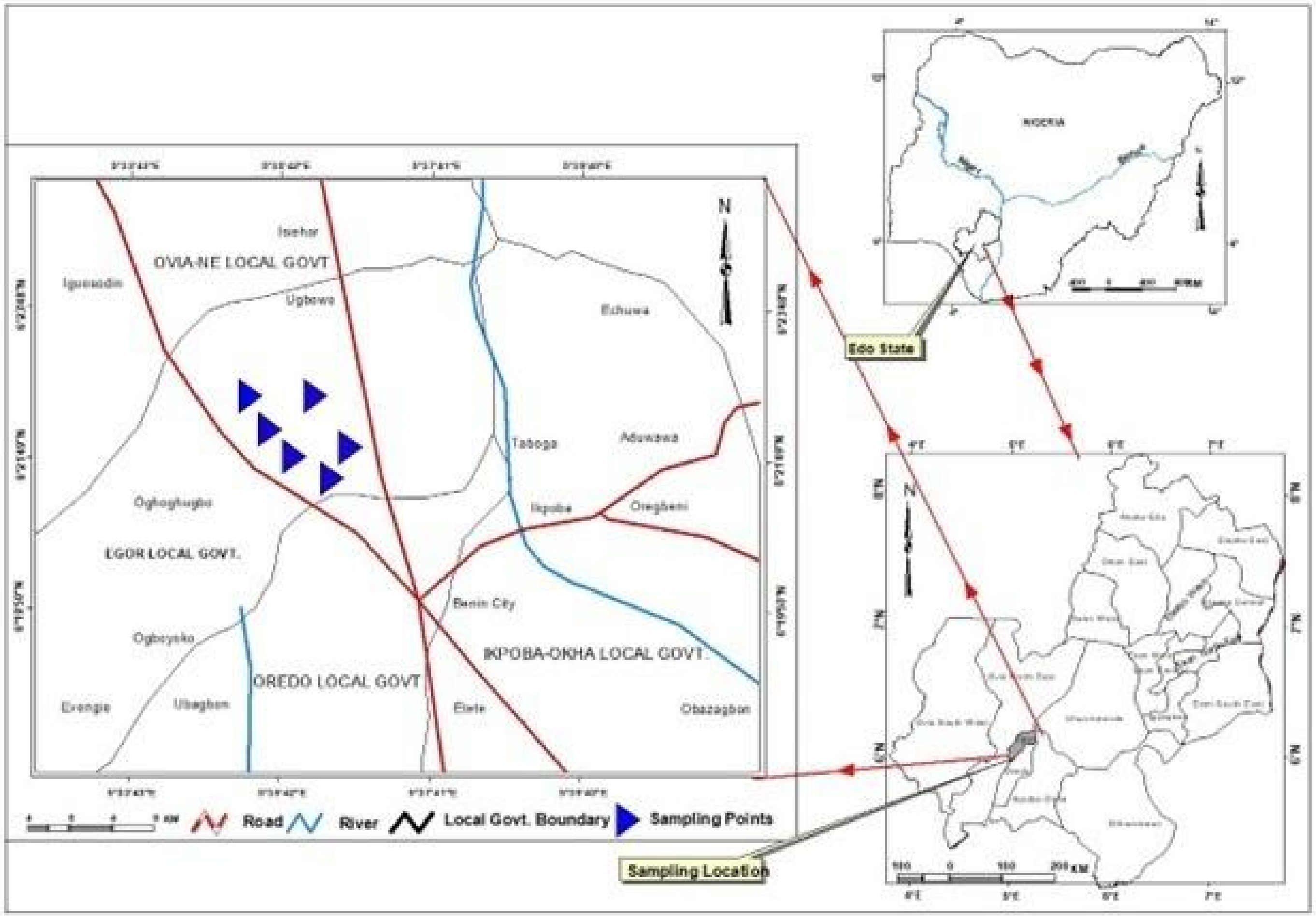

Figure 3.1: Map of the study area with sampling locations indicated

3.3 Sampling duration and frequency

The sampling and measurements for this study were done on a weekly basis from October to December 2024. Sampling was done three times a day - morning, afternoon and evening.

3.4 Air quality sampling procedure

Carbon monoxide and particulate matter concentrations (CO, $PM_{2.5}$, PM_{10}) were monitored on a weekly basis. A hand-held Multi-gas detector (Smart Sensor Model AS8700A) was used to measure gaseous and particle pollution levels at the selected sampling locations. Prior to and during the sampling activity, the samplers were calibrated according to the instructions from the manufacturer. This was done in the laboratory to guarantee that the specified parameters were accurately read. Prior to the correct readings and documentation, air quality sampling was done many times at each sample location. Measurements were taken in triplicate at a height of 2 meters above ground level (the most likely level to which persons are exposed). The digitally displayed value of each parameter was recorded when the sampler reached its maximum level.

The mean of the results was recorded for each sampling point.

3.5 Determination of meteorological parameters

Meteorological data, including temperature and relative humidity, were collected concurrently with air pollutants. The measurements, were taken in triplicate every week throughout the sampling sites together with those of the air pollutants. While the relative humidity was measured using the Smart Sensor type AS8700A, an anemometer (BTMETER BT-100) was used to determine temperature.

3.6 Health profile of residents of nearby areas

A systematic questionnaire was created and utilised to collect data from people in various segments of the market. It was broken into three sections: Section A contained questions regarding the family and household information. Section B contained questions about the Spare Part Market Park environment. Section 3 contained questions regarding the respiratory health status of respondents.

3.8 Data analyses

All of the data collected in this study was recorded and organised in Microsoft Excel spreadsheets. The mean values of the air quality metrics evaluated were computed. The data on the health profile of people in the market was evaluated using frequencies and percentages, and the results were presented in tables.

CHAPTER FOUR

4.0. RESULTS

4.1 Mean concentrations of air pollutants

Figures 4.1 to 4.3 show the mean concentrations of the selected pollutants in the study area. The concentrations of CO ranged from 2.5 ppm to 3.6 ppm in the morning and from 2.3 ppm to 3.2 ppm in the evening. The concentrations of $PM_{2.5}$ ranged from 19.2 $\mu g/m^3$ to 20.0 $\mu g/m^3$ in the morning and from 29.4 $\mu g/m^3$ to 40.1 $\mu g/m^3$ in the evening. The PM_{10} concentrations ranged from 19.8 $\mu g/m^3$ to 24.3 $\mu g/m^3$ in the mornings and from 36.5 $\mu g/m^3$ to 51.2 $\mu g/m^3$ in the evenings.

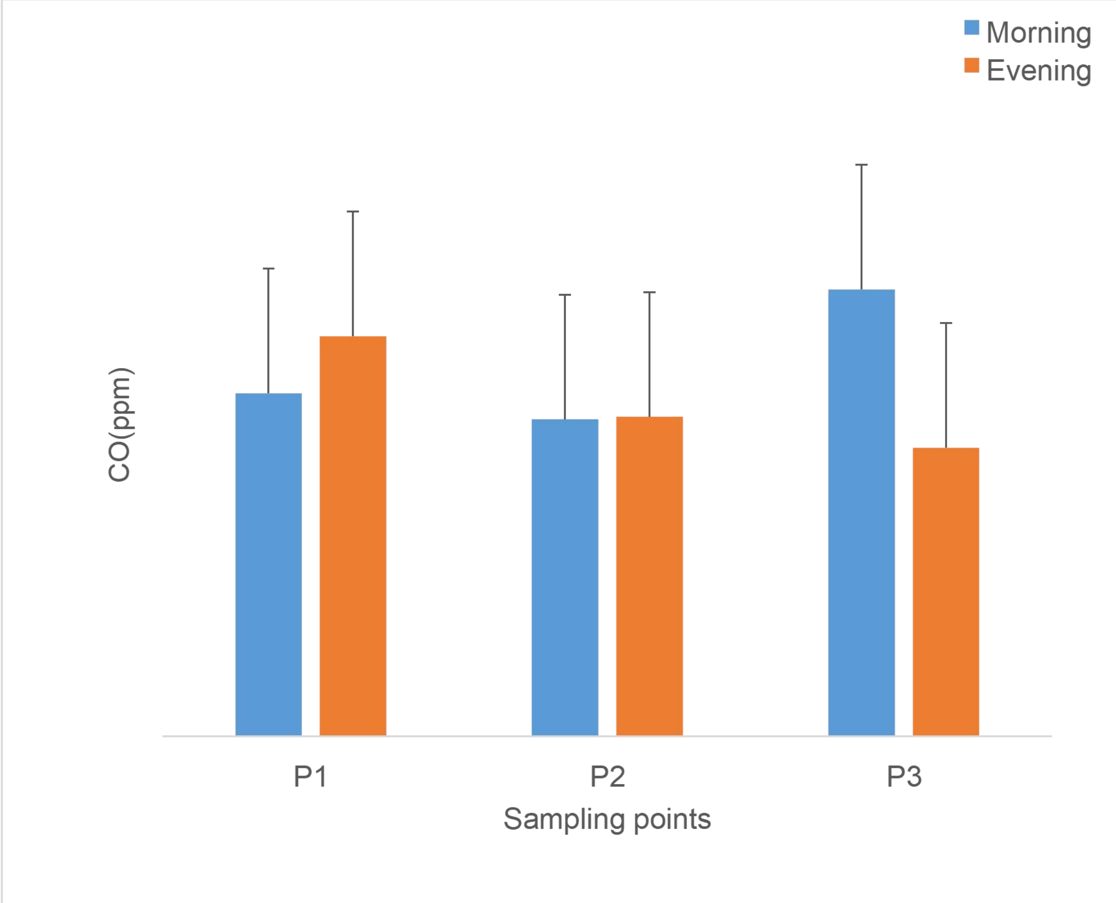

Figure 4.1: Mean concentrations of CO

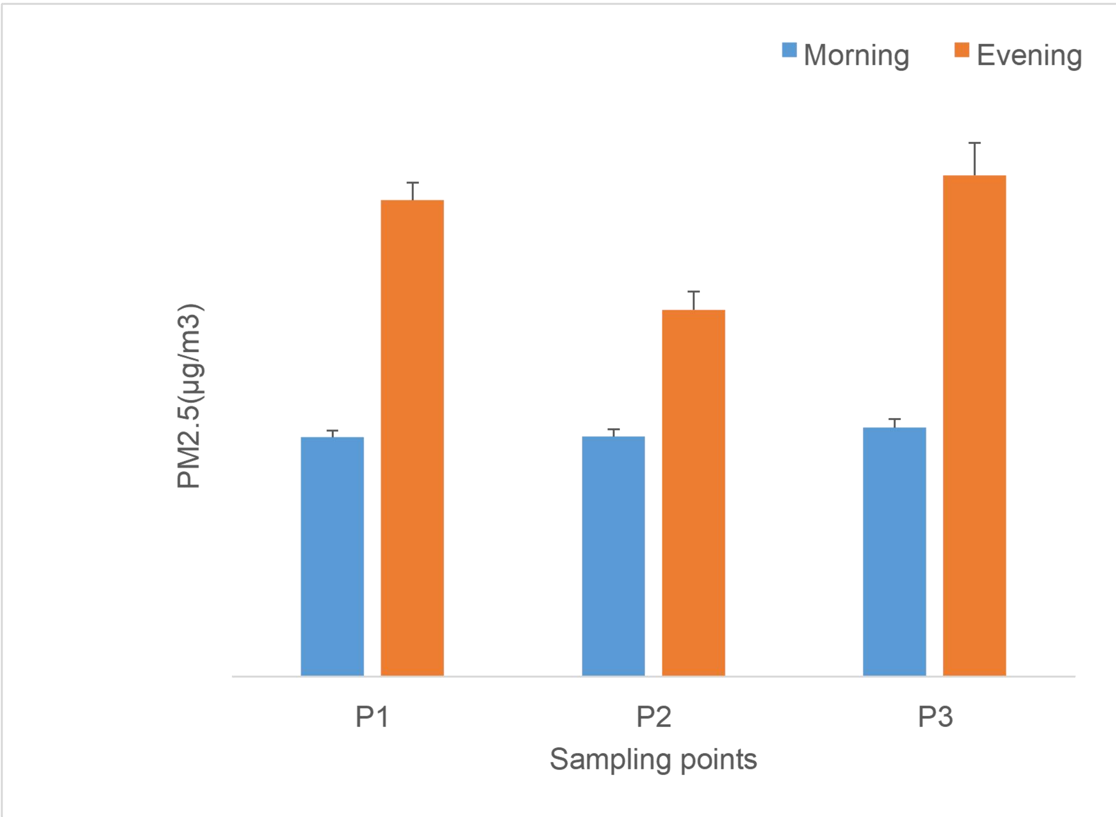

Figure 4.2: Mean concentrations of $PM_{2.5}$

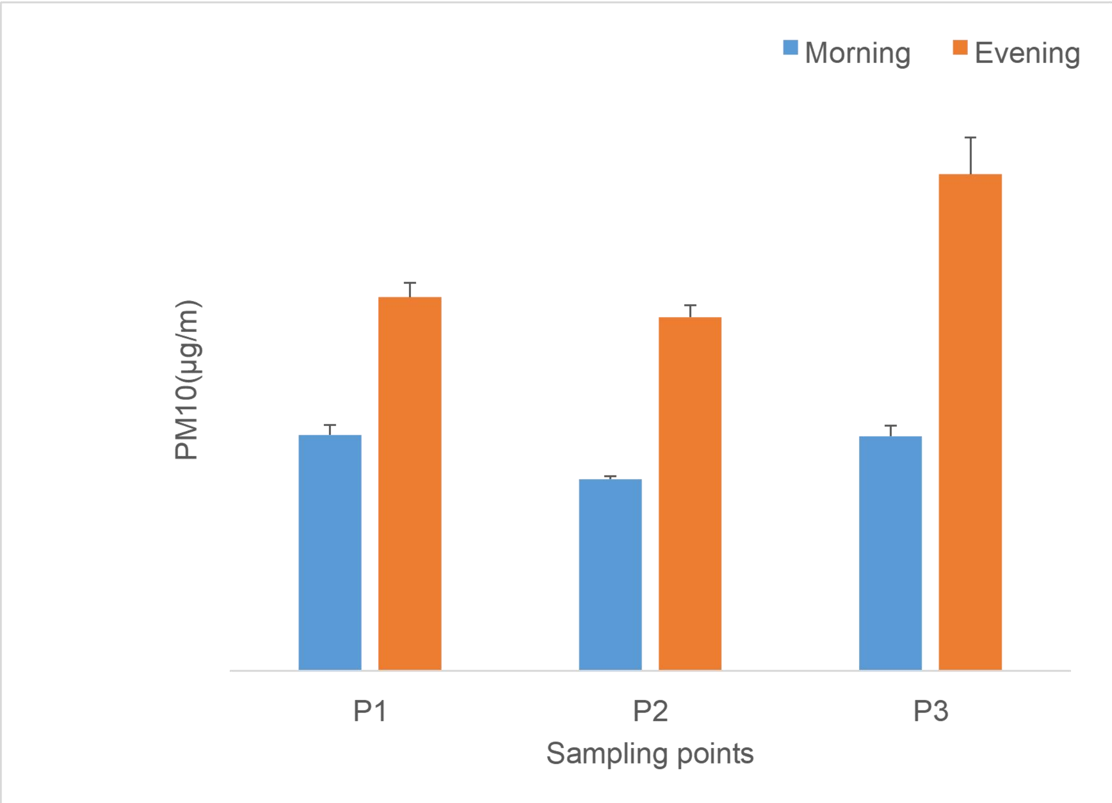

Figure 4.3: Mean concentrations of PM_{10}

4.2 Meteorological parameters

Figures 4.4 and 4.5 show the meteorological parameters in the study area.

The relative humidity recorded in the morning ranged from 52.2% to 55.1%, whereas in the evening, it ranged from 48.3% to 50.8%. The values recorded for temperatures ranged from

32.3°C to 35.8°C in the mornings and from 33.6°C to 34.5°C in the evenings.

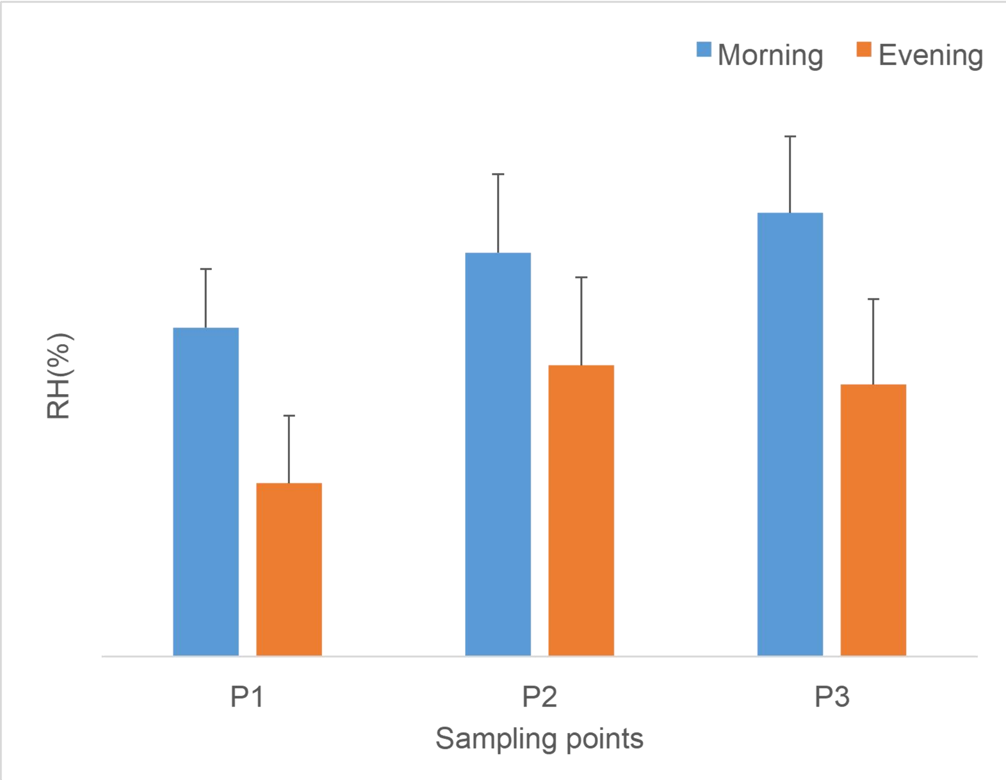

Figure 4.4: Relative humidity values

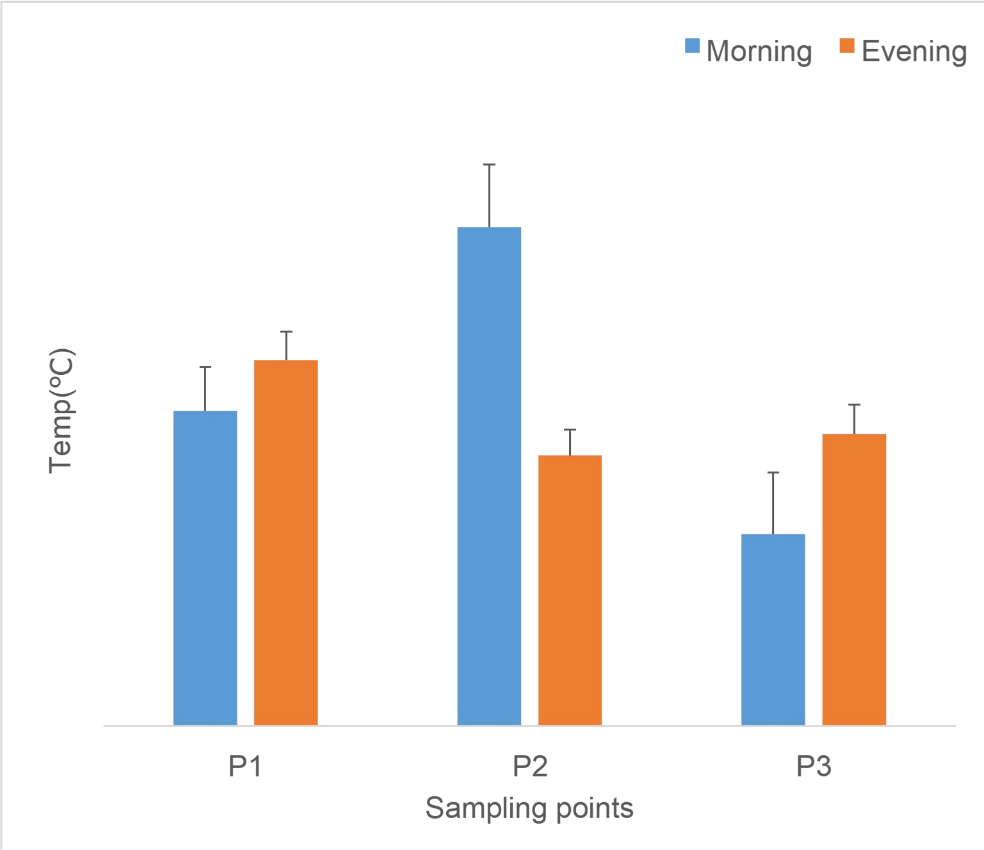

Figure 4.5: Mean temperature values

4.3 Variations in pollutant concentrations

The variations in the concentrations of air pollutants recorded during the sampling period are presented in Tables 4.1 to 4.3.

In the morning, the concentrations of CO and $PM_{2.5}$ did not significantly vary at $p<0.05$. However, the concentrations of PM_{10} varied significantly ($p<0.01$). The values from the evening measurements revealed no significant variations in the concentrations of CO, whereas there were significant variations in the concentrations of $PM_{2.5}$ and PM_{10}. Comparing the values recorded in the mornings and evenings (Table 4.3), the concentrations of CO were not significantly different ($p>0.05$). The differences in the morning and evening concentrations of $PM_{2.5}$ and PM_{10} were significant ($p<0.01$).

Table 4.1: Variations in air pollutant concentrations in the morning

		Sum of Squares	df	Mean Square	F	Sig.
CO	Between Groups	29.167	2	14.583	2.168	0.118
	Within Groups	948.583	141	6.728		
	Total	977.750	143			
$PM_{2.5}$	Between Groups	17.056	2	8.528	0.505	0.605
	Within Groups	2382.833	141	16.900		
	Total	2399.889	143			
PM_{10}	Between Groups	642.389	2	321.194	8.364	**0.001**
	Within Groups	5414.500	141	38.401		
	Total	6056.889	143			

Table 4.2: Variations in air pollutant concentrations in the evening

		Sum of Squares	df	Mean Square	F	Sig.
CO	Between Groups	20.514	2	10.257	2.295	0.104
	Within Groups	630.042	141	4.468		
	Total	650.556	143			
$PM_{2.5}$	Between Groups	3160.097	2	1580.049	9.060	**0.001**
	Within Groups	24590.542	141	174.401		
	Total	27750.639	143			
PM_{10}	Between Groups	6106.347	2	3053.174	10.545	**0.001**
	Within Groups	40826.292	141	289.548		
	Total	46932.639	143			

Table 4.3: Variations in air pollutant concentrations across sampling periods

Parameter	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2tailed)
COm - COe	0.264	2.481	0.207	1.277	143	0.204
$PM_{2.5}m$ $PM_{2.5}e$	-16.430	13.699	1.142	-14.392	143	0.001*
$PM_{10}m$ -$PM_{2.5}e$	-19.319	19.065	1.588	-12.160	143	0.001*

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

4.4 Sociodemographic information of the participants

The sociodemographic information of the respondents is presented in Figures 4.6 to 4.8.

Individuals aged 35--44 years were the most common group among the respondents (40%), whereas those aged 18--24 years composed the smallest group (8%). For education level, the least common group was those with no education, which made up 7% of the respondents; however, those with tertiary education (38%) were the highest. The income level was above

N150,000 for 37% of the participants, whereas the smallest group included those who earned N100,000 (17%).

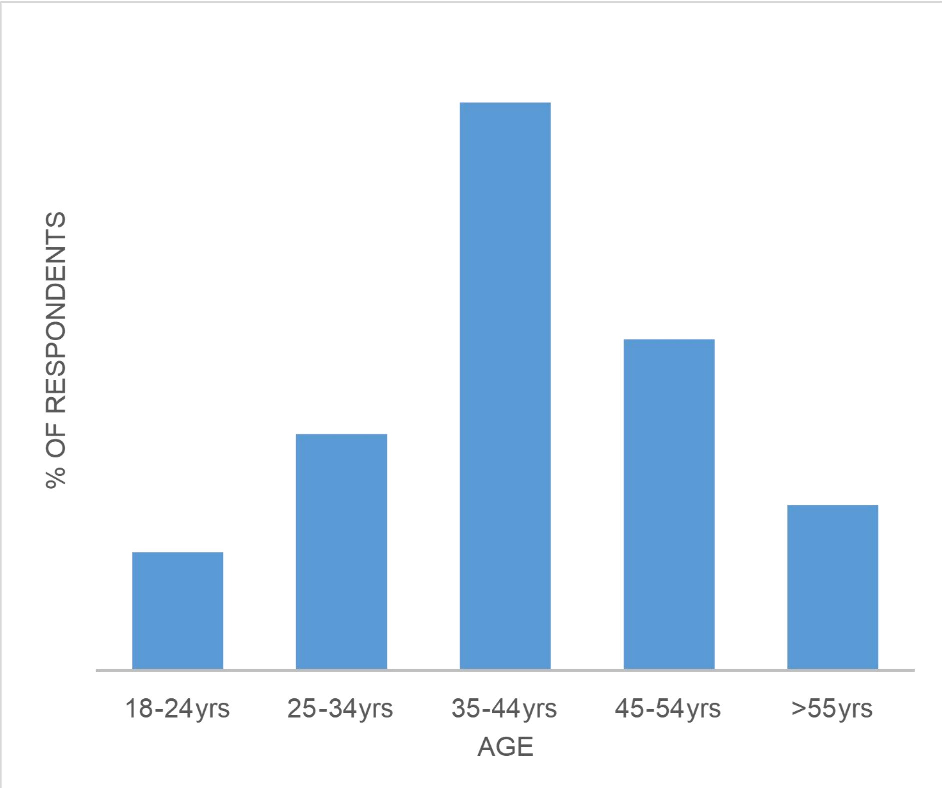

Figure 4.6: Age distribution of the respondents

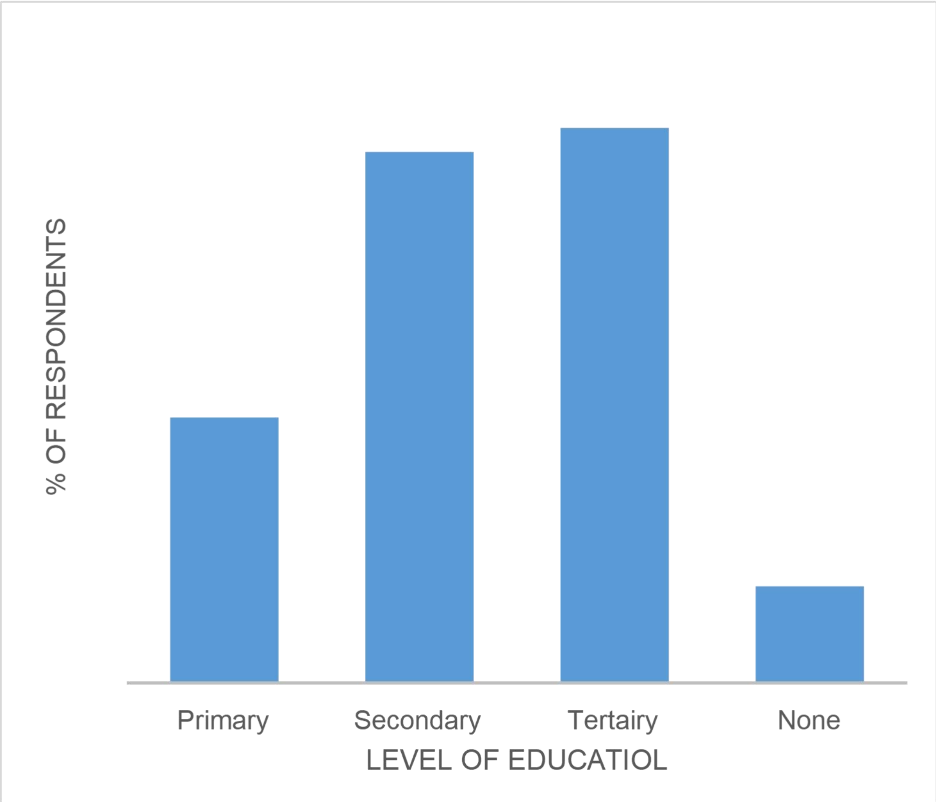

Figure 4.7: Level of education of the respondents

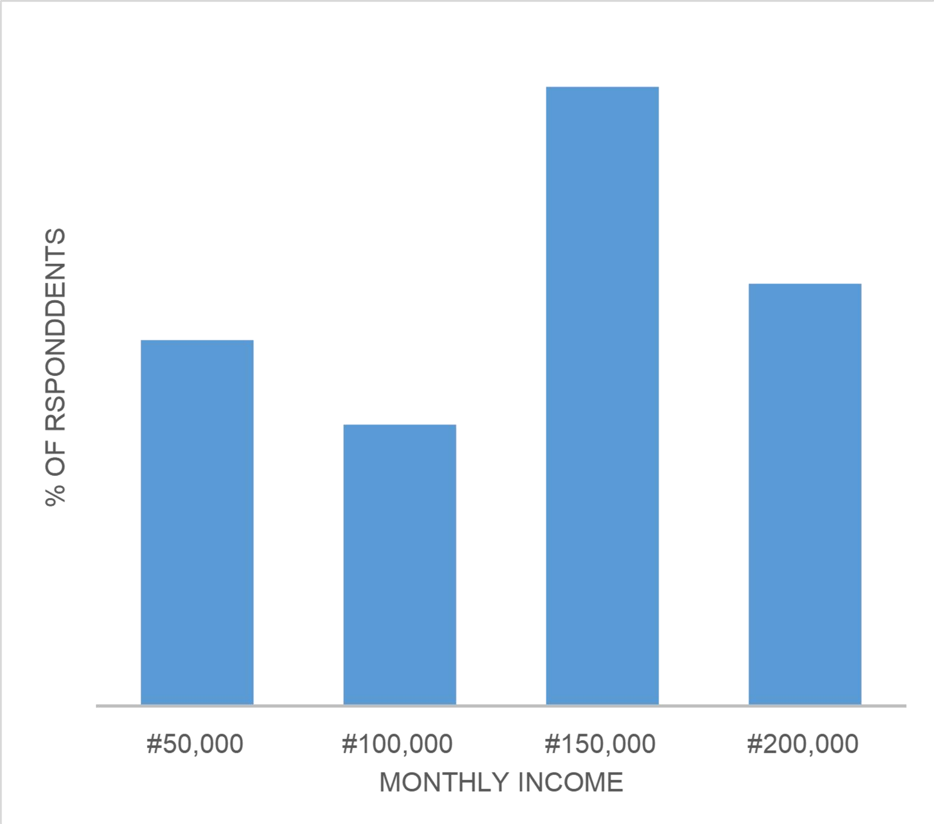

Figure 4.8: Monthly income of the respondents

4.5 Risk factors and respiratory symptoms among participants

The reported respiratory symptoms of the respondents are shown in Figures 4.9 to 4.11.

For risk factors, the order of decreasing prevalence was as follows: proximity to markets > use of generators in the market > waste burning > smoking. The majority of participants (55%) spent between 8 and 12 hours in the market on a daily basis. A total of 67% of the respondents experienced cough, and 36% reported experiencing phlegm. Wheezing was reported by 18%, shortness of breath by 15%, and chest pain by 20% of the respondents. The occurrence of these symptoms, denoted by a 'Yes' response, was in the following order: cough > phlegm > chest pain > wheezing > shortness of breath.

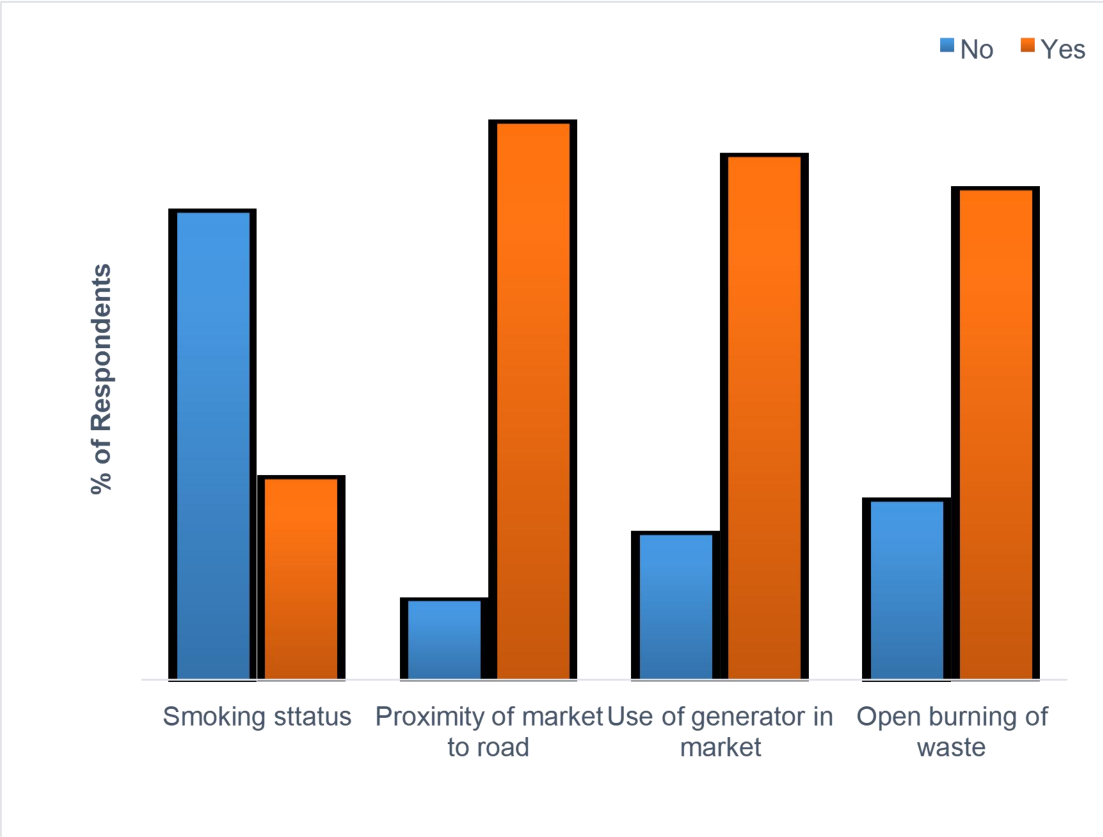

Figure 4.9: Risk factors for the respondents

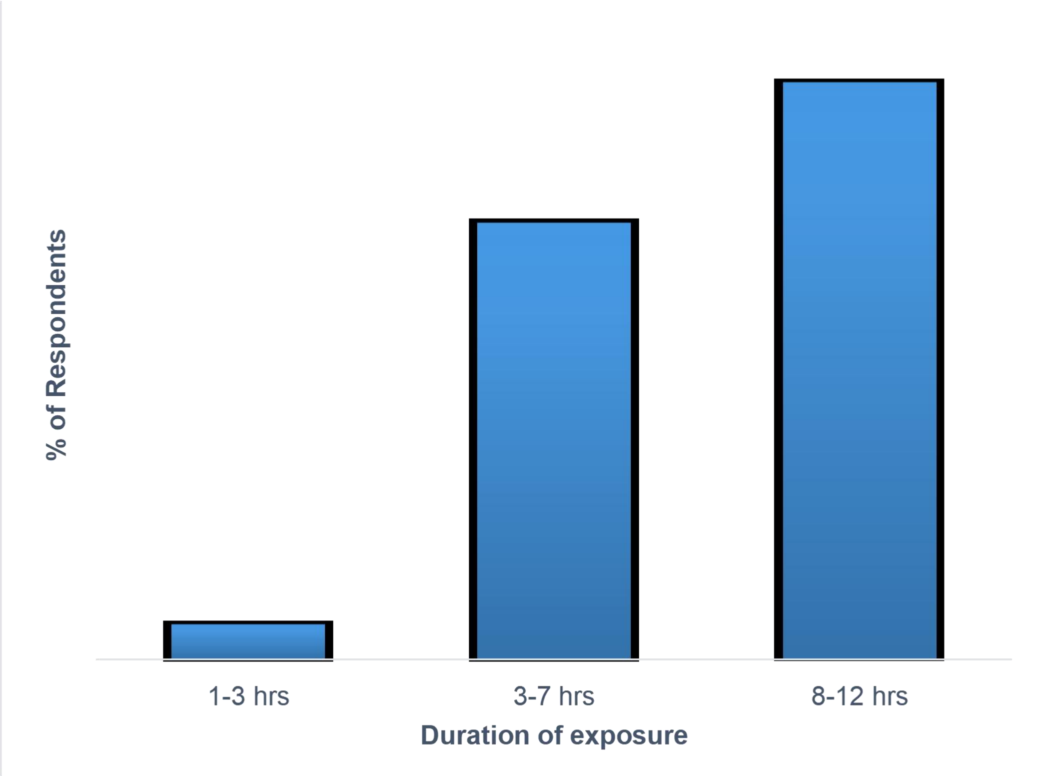

Figure 4.10: Number of hours spent in the market

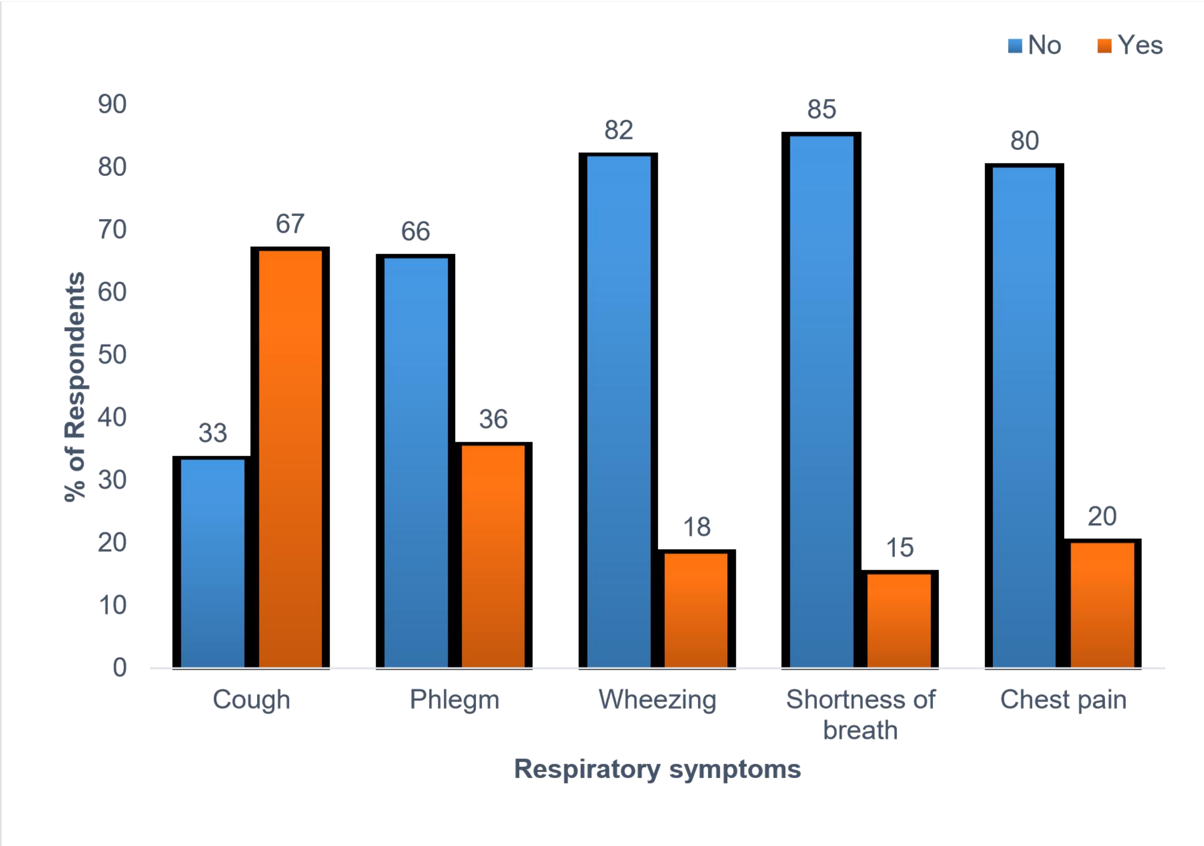

Figure 4.11: Respiratory symptoms reported by respondents

CHAPTER FIVE

DISCUSSION

5.1 Discussion

The morning and evening carbon monoxide (CO) values varied from 2.5 ppm to 3.6 ppm and from 2.3 ppm to 3.2 ppm, respectively. The WHO (2021) air quality standards recommend a 24-hour exposure limit of 4 mg/m^3. The results recorded from the study are within these ranges, indicating that there is no immediate acute health risk associated with CO exposure in this market environment. However, long-term exposure to even low CO levels can lead to cardiovascular stress and chronic respiratory conditions, especially for traders who work long hours on the market (Okponmwense and Ehinomen, 2023). Odekanle *et al*. (2020) reported that CO levels in crowded metropolitan locations were greater than those reported in earlier studies, ranging from 5.1 to 6.4 ppm. This suggests that market architecture and air circulation have substantial impacts on pollution dispersion. In a similar vein, Amesho *et al*. (2021) reported CO levels higher than 4 ppm in markets with a high generator usage rate. Even though the current analysis shows lower CO levels, the discrepancies might be explained by ventilation, emission sources, and market congestion. Even at levels under the WHO guidelines, prolonged exposure to CO can affect blood oxygen transport and increase the risk of cardiovascular illnesses, especially in people with underlying medical disorders (Ezeonyejiaku *et al*., 2022).

The morning and evening concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) varied considerably. The morning and evening $PM_{2.5}$ and PM_{10} levels varied from 19.2 to 24.3 µg/m^3 and from 29.4 to 40.1 µg/m^3, respectively, and from 36.5 to 51.2 µg/m^3 and from 19.2 to 20.0 µg/m^3, respectively. According to the WHO (2021) air quality standards, the 24-hour mean limits for $PM_{2.5}$ and PM_{10} are 15 µg/m³ and 45 µg/m³, respectively. The $PM_{2.5}$ levels in both the morning and evening periods were above these limits, indicating a serious health concern.

In contrast, while morning PM_{10} concentrations were within safe limits, evening PM_{10} concentrations were higher than the WHO 24-hour standard. The differences between the morning and evening concentrations of particulates were statistically significant ($p<0.01$), suggesting that higher levels of pollution later in the day are caused by greater market activity, vehicle emissions, and rubbish burning. Similar trends were noted by Chukwu *et al*. (2022) and Ebong *et al*. (2023), who reported that during peak hours, $PM_{2.5}$ levels in urban markets with active waste burning and generator use reached 45--60 µg/m³. Additionally, Diagi *et al*. (2022) noted that nighttime particulate matter accumulation occurs in markets with high human activity and restricted air circulation. Because small particulate matter ($PM_{2.5}$) may enter the lungs deeply and cause chronic respiratory conditions such as asthma, bronchitis, and lung cancer, exposure to $PM_{2.5}$ poses serious dangers to public health. Exposure to PM_{10} has been associated with an increase in hospitalisations due to the worsening of preexisting illnesses and cardiovascular disorders (Richard *et al*., 2023). The results of this study are consistent with those of Sidibe (2022), who reported that hospital visits due to respiratory conditions rose in West African cities even at moderate PM exposure levels. Furthermore, prolonged exposure to high PM levels has been linked to lung infections and deteriorated lung function, especially among street vendors and traders who operate in polluted areas (Ezeonyejiaku *et al*., 2022).

Pollutant dispersion in the marketplace is also impacted by meteorological factors, such as temperature and relative humidity. The temperature fluctuated from 32.3°C to 35.8°C in the morning and 33.6°C to 34.5°C in the evening, whereas the relative humidity varied from 52.2

to 55.1% in the morning and 48.3 to 50.8% in the evening. High temperatures exacerbate problems with air quality by promoting the production of secondary pollutants. According to Nemakhayhani (2023), high temperatures promote the production of secondary organic aerosols, which can increase the levels of particulate matter in metropolitan areas. In a similar vein, Oragba *et al*. (2023) reported that regions with high temperatures and low humidity had greater amounts of airborne particulates because the pollutants were bound together more quickly by decreased atmospheric moisture. These weather patterns make heat stress, dehydration, and respiratory issues worse, especially for people who spend much of their time in a market environment. Given that a sizable fraction of traders work on the market for eight to twelve hours every day, extended exposure to high temperatures and pollutants can increase the risk of cardiovascular illnesses and cause weariness and heat exhaustion (Sidibe, 2022).

This study also evaluated the incidence of respiratory symptoms among market participants and revealed that coughing (67%), phlegm production (36%), chest discomfort (20%), wheezing (18%), and shortness of breath were highly prevalent (15%). The sequence of these symptoms included cough, phlegm, chest discomfort, wheezing, and shortness of breath. These results are consistent with those of Richard *et al*. (2023), who reported that those who are exposed to high PM levels often experience tightness in their chest, phlegm, and persistent cough. Additionally, Sidibe (2022) reported that prolonged exposure to $PM_{2.5}$ was linked to deteriorating lung function and ongoing wheezing, especially in women employed in crowded markets. Smoking, generator usage, rubbish burning, and proximity to major highways were the main risk variables identified in this study. These activities are known to contribute to poor air quality. Long-term exposure to $PM_{2.5}$ from these sources considerably increases the risk of lung infections and chronic obstructive pulmonary disease (COPD), according to Okponmwense and Ehinomen (2023). According to Oragba *et al*. (2023), women who worked in polluted markets experienced respiratory problems at a rate that was 30% greater than that of women who worked in less polluted settings.

5.2. Conclusion

This study examined the quality of the air in market settings and reported that $PM_{2.5}$ and PM_{10} levels were higher than the WHO (2021) limits, especially in evenings. Although the quantity of carbon monoxide remains within tolerable limits, extended exposure still poses dangers. Increased human and economic activity may be a contributing factor to pollution levels, as reflected by the notable difference in particulate matter between the morning and evening observations. Cough and phlegm are common respiratory symptoms that suggest possible negative health consequences associated with air pollution. The need for focused actions is indicated by the prevalence of risk factors, including garbage burning and generator use. These hazards can be reduced by putting regulations into place, enhancing waste management, and raising public awareness. Maintaining a safer market environment and protecting public health require routine air quality monitoring.

5.3 Recommendations

The following recommendations have been made on the basis of the study findings:

1. Strict rules on the usage of generators and the promotion of alternative energy sources should be enforced by market authorities to lower carbon monoxide emissions.

2. Stronger waste management regulations are needed to stop open burning in marketplaces, which will lower particulate matter pollution.

3. To increase air quality and reduce heat stress, urban design projects could include green areas and improved ventilation in marketplace settings.

4. Campaigns for public health awareness should be put in place to inform vendors and consumers about the dangers of air pollution and to promote the usage of protective gear such as face masks.

5. Regular monitoring of air quality in and around urban markets by government organisations is necessary to ensure that the WHO

REFERENCES

Abaje, I. B., Bello, Y. and Ahmad, S. A. (2020). A review of air quality and concentrations of air pollutants in Nigeria. *Journal of Applied Sciences and Environmental Management*, *24*(2), 373-379.

Adjei-Mantey, K., Matsumoto, K. I., Shigetomi, Y., Yamamoto, Y. and Nakayama, T. (2023). Factors affecting household air pollutants in West Africa: Evidence from Ghana and Nigeria. *Energy for Sustainable Development*, *76*, 101288.

Agbo, K. E., Walgraeve, C., Eze, J. I., Ugwoke, P. E., Ukoha, P. O. and Van Langenhove, H. (2021). A review on ambient and indoor air pollution status in Africa. *Atmospheric Pollution Research*, *12*(2), 243-260.

Agbozu, I. E. and Oghama, O. E. (2022). Spatial and diurnal distribution of carbon monoxide (CO) and its health and environmental implications in selected locations in the Niger Delta Area of Nigeria. *African Journal of Science, Technology, Innovation and Development*, *14*(5), 1327-1336.

Ahmed, M. J., Dogo, B., Baba, S. U., Muhammed, A. Y. and Abdulqadir, M. (2022). Assessment of concentration and spatial variation of air pollution in Zaria metropolis, Nigeria. *Science World Journal*, *17*(2), 221-226.

Akomolafe, O. O., Olorunsogo, T., Anyanwu, E. C., Osasona, F., Ogugua, J. O. and Daraojimba, O. H. (2024). Air quality and public health: a review of urban pollution sources and mitigation measures. *Engineering Science & Technology Journal*, *5*(2), 259271.

Ali, M. U., Siyi, L., Yousaf, B., Abbas, Q., Hameed, R., Zheng, C. and Wong, M. H. (2021). Emission sources and full spectrum of health impacts of black carbon associated polycyclic aromatic hydrocarbons (PAHs) in urban environment: A review. *Critical Reviews in Environmental Science and Technology*, *51*(9), 857-896.

Anyahara, J. N. (2021). Effects of Polycyclic Aromatic Hydrocarbons (PAHs) on the environment: A systematic review. *International Journal of Advanced Academic Research*, *7*(3).

Chojer, H., Branco, P. T. B. S., Martins, F. G., Alvim-Ferraz, M. C. M. and Sousa, S. I. V. (2020). Development of low-cost indoor air quality monitoring devices: Recent advancements. *Science of The Total Environment*, *727*, 138385.

Collin, M. S., Venkatraman, S. K., Vijayakumar, N., Kanimozhi, V., Arbaaz, S. M., Stacey, R. S. and Swamiappan, S. (2022). Bioaccumulation of lead (Pb) and its effects on human: A review. *Journal of Hazardous Materials Advances*, *7*, 100094.

Croitoru, L., Chang, J. C. and Kelly, A. (2020). *The cost of air pollution in Lagos*. World Bank Group..

Diagi, B., Suzan, A., Nnaemeka, O., Ekweogu, C., Acholonu, C. and Emmanuel, O. (2022). An assessment of vehicular emission in the vicinity of selected markets in Owerri, Imo State, Nigeria. *Journal of Geoscience and Environment Protection*, *10*(1), 1-12.

Ezeanokwasa, J. O. (2020). Air Pollution Control in South-East Zone of Nigeria as a Sine-QuaNon for Sustainable Development in the Zone: Legal Evaluation. *IRLJ*, *2*, 51.

Ezedi, O. M. and Ogbeifun, N. P. (2024). Recyclable Potential of Car Wash Effluent for Concrete Production. *Journal of Energy Technology and Environment*, *6*(2), 180-192.

Ezeonyejiaku, C. D., Okoye, C. O., Ezeonyejiaku, N. J. and Obiakor, M. O. (2022). Air quality in Nigerian urban environments: a comprehensive assessment of gaseous pollutants and particle concentrations. *Current Applied Science and Technology*, 10-55003.

Fagorite, V. I., Anifowose, F. A. and Chiokwe, V. N. (2021). Air pollution; causes, effects and remediation in Nigeria. *Journal DOI*, *7*(1), 1-18.

Fang, X., Xiao, H., Sun, H., Liu, C., Zhang, Z., Xie, Y. and Wang, F. (2020). Characteristics of ground-Level ozone from 2015 to 2018 in BTH Area, China. *Atmosphere*, *11*(2), 130.

Festus, A. A. and Osaretin, E. J. The Determinants of Market Patronage in Benin City, Nigeria.

Firdausi, S. A., Azizah, R., Jalaludin, J. and Zakaria, Z. A. (2022, April). Association of shortterm exposure to sulphur dioxide and nitrogen dioxide with number of hypertensions in East Java, Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1013, No. 1, p. 012009). IOP Publishing.

Hopke, P. K., Dai, Q., Li, L. and Feng, Y. (2020). Global review of recent source apportionments for airborne particulate matter. *Science of the Total Environment*, *740*, 140091.

Ikpe, A. E., Ndon, A. I. E. and Etim, P. J. (2020). Assessment of the waste management system and its implication in Benin City metropolis, Nigeria. *Journal of Applied Research on Industrial Engineering*, *7*(1), 79-91.

Islam, S. N., Jackson, P. L., Kharol, S. K. and McLinden, C. A. (2020). Impact of natural gas production on nitrogen dioxide and sulphur dioxide over Northeast British Columbia, Canada. *Atmospheric Environment*, *223*, 117231.

Kumar, A. (2021). Spectral and statistical analysis of nitrogen dioxide and sulphur dioxide air pollutants using wavelet transforms.

Kumar, P. (2022). A critical evaluation of air quality index models (1960– 2021). *Environmental Monitoring and Assessment*, *194*(5), 1-45.

Kyung, S. Y. and Jeong, S. H. (2020). Particulate-matter related respiratory diseases. *Tuberculosis and respiratory diseases*, *83*(2), 116.

Li, A. J., Pal, V. K. and Kannan, K. (2021). A review of environmental occurrence, toxicity, biotransformation and biomonitoring of volatile organic compounds. *Environmental Chemistry and Ecotoxicology*, *3*, 91-116.

Madu, F. U., Agoro, E. Y. S. and Madu, M. C. (2022). Exhaled breath condensate markers of oxidative stress in male storekeepers of chemical stores in the Ariaria international market Aba Abia state Nigeria. *Toxicology and Industrial Health*, *38*(12), 801-809.

Mandal, G. C., Mandal, A. and Chakraborty, A. (2022). The toxic effect of lead on human health: A review. *Human Biology and Public Health*, *3*.

Mielke, H. W., Gonzales, C. R., Powell, E. T. and Egendorf, S. P. (2022). Lead in air, soil, and blood: Pb poisoning in a changing world. *International Journal of Environmental Research and Public Health*, *19*(15), 9500.

Mozaffar, A. and Zhang, Y. L. (2020). Atmospheric volatile organic compounds (VOCs) in China: a review. *Current Pollution Reports*, *6*, 250-263.

Nnaji, C. C., Chibueze, C. and Afangideh, C. B. (2023). The menace and mitigation of air pollution in the built environment: A review. *Nigerian Journal of Technology*, *42*(1), 12-

29.

Ogwu, M. (2023). Seasonal Variations in Air Pollutants in Southern Nigerian Highway. *Journal of Environmental Studies*, *30*(1), 10-25.

Okedere, O. B., Elehinafe, F. B., Oyelami, S. and Ayeni, A. O. (2021). Drivers of anthropogenic air emissions in Nigeria-A review. *Heliyon*, *7*(3).

Okobia, E. L., Makwe, E. and Mgbanyi, L. L. O. (2021). Air pollution and human health implications in urba n settlements of abuja, Nigeria. *GSJ*, *9*(8), 2540-65.

Okoroafor, F. O., Ichoku, H. E. and Ihuoma, A. A. (2023). The impact of air pollution on urban health in Nigeria: Possible solutions. *Open Access Research Journal of Science and Technology*, *9*(1), 043-051.

Oladejo, O. J., Odeyale, T. O. and Adiamo, B. R. (2020). Effect of air pollution from pedestrian traffic in an open market: a case study of Bodija market, Nigeria. *Int J Sustain Dev Plan*, *15*(7), 1137-44.

Oluoha, R. U., Offiong, A. A., Nzomiwu, D. C. and Nsodukwa, C. O. (2023). Knowledge of Air Pollution and its Predictors among Traders in Douglas Market, Imo State, South–Eastern Nigeria. *Int. J. Trop. Dis. Health*, *44*(24), 22-30.

Orellano, P., Reynoso, J. and Quaranta, N. (2021). Short-term exposure to sulphur dioxide (SO2) and all-cause and respiratory mortality: A systematic review and metaanalysis. *Environment international*, *150*, 106434.

Raheem, M., Jimoh, G. and Abdulrahim, H. (2022). Assessment of kitchen air pollution: Health implications for the residents of ilorin south, nigeria. *Journal of Environmental and Public Health*, *2022*(1), 7689141.

Raj, K. and Das, A. P. (2023). Lead pollution: Impact on environment and human health and approach for a sustainable solution. *Environmental Chemistry and Ecotoxicology*, *5*, 79-

85.

Rakitin, V. S., Elansky, N. F., Skorokhod, A. I., Dzhola, A. V., Rakitina, A. V., Shilkin, A. V. and Kazakov, A. V. (2021). Long-term tendencies of carbon monoxide in the atmosphere of the Moscow megapolis. *Izvestiya, Atmospheric and Oceanic Physics*, *57*, 116-125.

Ravindra, K., Singh, V. and Mor, S. (2024). Why we should have a universal air quality index? *Environment International*, *187*, 108698.

Richard, G., Izah, S. C. and Ibrahim, M. (2023). Air pollution in the Niger Delta region of Nigeria: sources, health effects, and strategies for mitigation. *Journal of Environmental Studies*, *29*(1), 1-15.

Sharma, R. C. and Sharma, N. (2021). Assessment of variations and correlation of ozone and its precursors, benzene, nitrogen dioxide, carbon monoxide and some Meteorological Variables at two sites of significant spatial variations in Delhi, Northern India. *Pollution*, *7*(3), 723-737.

Shikwambana, L., Mhangara, P. and Mbatha, N. (2020). Trend analysis and first time observations of sulphur dioxide and nitrogen dioxide in South Africa using TROPOMI/Sentinel-5 P data. *International Journal of Applied Earth Observation and Geoinformation*, *91*, 102130.

Sicard, P. (2021). Ground-level ozone over time: an observation-based global overview. *Current Opinion in Environmental Science & Health*, *19*, 100226.

Taiwo, A. O. and Fajoye, O. S. (2022). Traders' perceptions of environmental quality as tools in improving public space: a study of markets in Ile-Ife, Nigeria. *Management of Environmental Quality: An International Journal*, *33*(2), 435-450.

Thangavel, P., Park, D. and Lee, Y. C. (2022). Recent insights into particulate matter (PM2. 5)-mediated toxicity in humans: an overview. *International journal of environmental research and public health*, *19*(12), 7511.

Xu, P., Liu, B., Chen, H., Wang, H., Guo, X. and Yuan, J. (2024). PAHs as environmental pollutants and their neurotoxic effects. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, 109975.

Zheng, X. Y., Orellano, P., Lin, H. L., Jiang, M. and Guan, W. J. (2021). Short-term exposure to ozone, nitrogen dioxide, and sulphur dioxide and emergency department visits and hospital admissions due to asthma: a systematic review and meta-analysis. *Environment international*, *150*, 106435.

Zhou, X., Zhou, X., Wang, C. and Zhou, H. (2023). Environmental and human health impacts of volatile organic compounds: A perspective review. *Chemosphere*, *313*, 137489.

APPENDIX I

APPENDIX II

APPENDIX III

Research Questionnaire

Department of Environmental Management and Toxicology
Faculty of Life Sciences
University of Benin, Benin City, Nigeria

***Research Topic**:*

Concentrations of ambient air pollutants and health risk assessments in Uwelu Spare Part Markets in Benin city, Nigeria

To Participants:

This is a research survey; your cooperation in giving correct information on all the questions asked will be highly appreciated. Please complete ALL questions by selecting the response most appropriate to the question. The information so gathered will be used for **academic purposes only.**

***SECTION A:* Family and Household information**

1. What is your age? 18 – 24 yrs () 25-34 yrs () 35-44 yrs () 45-54 yrs () >55 yrs
2. What is your sex? Male () Female ()
3. Educational level? Primary () Secondary () Tertiary () None ()
4. What is your Occupation? Farming () Industry () Business () Education () Other -------
5. How much is your monthly income? #50,000 () #100,000 () #200,000 () >#200,000 ()
6. How many persons are permanently living in your home? 1 person () 2 persons () 3 persons () 4 or more persons ()
7. Do you smoke? Yes () No ()
8. Do anyone smoke in this park or in your home Yes () No ()
9. What kind of floor material is in your room? Wooden () Cement () Carpets () Rug () Tiles ()
10. Which type of fuel do you have for cooking? Firewood () Kerosene () Gas () Electric ()
11. What is the location of your kitchen Inside () Outside ()
12. Which kind of cooling system is available in your residence? Air conditioning () Electric fans () By opening windows ()

***SECTION B:* Information concerning the Spare Part Market Park environment**

13. Is the market located along high way or main road? Yes () No ()
14. Presence of gasoline powered generators at the markets Yes () No ()
15. Is the market waste burnt openly in the market? Yes () No ()

16. How long do you stay in the market each day? 1-2hrs () 3-7hrs () 8-12hrs ()

SECTION C: Questions related to Respondents Respiratory health status

17. Any family history of chronic respiratory health symptoms? Yes () No () 18. Have you ever had cough in the past 12 months? Yes () No ()

19. Have you ever had phlegm for the past 12 months?

20. Have you ever experienced wheezing or whistling in the chest in the past 12 months? Yes () No ()

21. Have you ever experienced shortness of breath in the past 12 months? Yes () No ()

22. Have you ever experienced chest pain/tightness in the past 12 months? Yes () No ()

Thank you for your time!