ASSESSMENT OF AIR QUALITY AND ASSOCIATED RESPIRATORY HEALTH EFFECTS AMONG WORKERS AT BENIN CITY AIRPORT, SOUTHERN NIGERIA

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CERTIFICATION

This is to certify that this research titled **"Assessment Of Air Quality And Associated Respiratory Health Effects Among Workers At Benin City Airport, Southern Nigeria"** was carried out by **"Godsown Oghosa OSABUMWENRE (MISS)"** 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.

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DECLARATION

I **“Godsown Oghosa OSABUMWENRE (MISS)”** declare that **“Assessment of Air Quality and Associated Respiratory Health Effects among Workers at Benin City Airport, Southern Nigeria”** is my work and that all sources that I have used or quoted have been acknowledged using complete references and that this work has not been submitted before for any other degree at any other university.

Godsown Oghosa OSABUMWENRE **DATE**

DEDICATION

I dedicate this seminar report to the Almighty God and my beloved parents, whose unwavering support and encouragement have been my greatest source of strength in my journey.

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ABSTRACT

This study investigated the occupational health risks at an airport, focusing on air pollutant concentrations, their spatiotemporal variation, and the associated respiratory health effects among airport workers (N=129). Air quality monitoring was conducted in four areas (Runway, Parking Lot, Departure area, and Reception) during the morning and afternoon periods for carbon dioxide (CO_2), coarse particulate matter (PM_{10}), and fine particulate matter ($PM_{2.5}$). The data were analysed via ANOVA and paired samples t tests. A survey collected data on workers' sociodemographic, work-related risks, and self-reported respiratory symptoms. Environmental monitoring identified $PM_{2.5}$ as the primary air quality hazard. The highest observed mean $PM_{2.5}$ concentration (24.1 µg/m3) exceeded the strict WHO 24-hour guideline. Statistical analysis confirmed significant spatial variation in $PM_{2.5}$, with the Runway and Parking Lot acting as hotspots and a highly significant temporal spike in the afternoon ($p=0.001$). Coughing was the most prevalent reported symptom (57.4% of workers). Chi-square tests revealed a strong correlation between respiratory symptoms (cough, phlegm, shortness of breath, and chest pain) and both smoking and a family history of chronic respiratory issues ($p \leq 0.007$ for all). Furthermore, workers demonstrated critical systemic failure in safety protocols, with 83.7% lacking knowledge of the proper use of personal protective equipment (PPE) and 96.9% unaware of routine air quality monitoring. The airport environment presents a substantial and avoidable health risk driven by noncompliant $PM_{2.5}$ levels and systemic safety management failures. Recommendations include implementing mandatory, hands-on PPE training, establishing a transparent $PM_{2.5}$ monitoring system in hotspots, and creating an occupational health program to screen and counsel high-risk

CHAPTER ONE

INTRODUCTION

Air pollution represents a significant global health threat, defined by the World Health Organization as the introduction of foreign elements into the air that cause disequilibrium and become injurious to biological communities (WHO, 2021). The consequences are severe, with an estimated 3.1 million deaths each year attributed to ambient air pollution alone (Lelieveld *et al*., 2015; Newby *et al*., 2015). This crisis is not evenly distributed; developing nations such as Nigeria face a disproportionate burden due to a combination of factors, including rapid urbanization, industrialization, a lack of environmental regulations, and heavy reliance on fossil fuels (Amegah and Agyei-Mensah, 2017). While global life expectancy would increase by 2.2 years if air pollution was reduced to WHO standards, this figure increases to 4.3 years for Nigeria, a country that bears a significant portion of the global mortality and morbidity from air pollution (Greenstone, 2021). The outdoor air pollutants of primary concern for human health include particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), nitrogen oxides (NO_x), and volatile organic compounds (VOCs) (Oguntoke *et al*., 2019). These pollutants can cause a range of acute and chronic health issues, ranging from simple respiratory irritation to severe conditions such as asthma, lung cancer, and cardiovascular disease (Lelieveld *et al*., 2015; Eghomwanre and Oguntoke, 2022).

Airport environments are particularly complex and potent sources of air pollution. They generate a unique mixture of emissions from aircraft engines, auxiliary power units, ground support equipment, and other vehicular traffic (Zhang and Batterman, 2013; Baldauf, 2016). A critically vulnerable population within this environment is airport workers, including ground crews, baggage handlers, security guards, and maintenance staff, who are routinely exposed to high concentrations of pollutants for extended periods, often for 8--12 hours a day (Buonanno *et al*., 2012). This chronic occupational exposure contrasts sharply with the transient exposure of passengers and is a major concern for the long-term health and productivity of this workforce (WHO, 2021).

Despite the well-established global health hazards of air pollution, there is a severe lack of context-specific data on air quality and its corresponding health effects within Nigerian airports. Most of the existing research on airport-related air pollution has been conducted in high-income nations with robust monitoring and regulatory frameworks (Zhang and Batterman, 2013; Baldauf, 2016). This creates a critical knowledge gap, as Nigerian airports, including Benin city airports, lack reliable environmental monitoring systems, making it impossible to accurately characterize the extent of air pollution and its impact on employees (Amegah and Agyei-Mensah, 2017).

Specifically, two key data gaps exist: 1) there are no empirical data on the types and concentration levels of pollutants such as $PM_{2.5}$, NO_2, and CO to which airport workers in Benin city are exposed; and 2) there is a lack of information regarding the prevalence and nature of respiratory health problems among these workers. The absence of these data means that the true occupational health risks remain unknown, making it challenging for policymakers and researchers to design and implement effective, context-appropriate safety interventions and regulations.

This study is essential for bridging these significant knowledge gaps. This is justified by the urgent need to provide evidence-based data for a vulnerable, and largely unprotected, workforce in a high-risk environment. By employing a mixed-methods approach that combines environmental sampling to measure pollutant levels with a cross-sectional health survey to assess respiratory symptoms, this research will produce the first comprehensive dataset on this topic for the Benin city airport. This evidence is critical for understanding the direct relationship between occupational exposure and health outcomes. Unlike generic global studies, the findings will be tailored to the specific environmental and operational conditions of a Nigerian airport, making them highly relevant for local policy and practice. The study also highlights the importance of expanding environmental and occupational health research beyond urban centers to include critical transport hubs, where a significant portion of the workforce is exposed to unique and potent environmental risks. This study provides crucial data on pollutant levels and the respiratory health of aviation workers. The empirical data on pollutant concentrations provide a clear baseline for regulatory agencies, such as the National Environmental Standards and Regulations Enforcement Agency, to enforce national and international air quality standards and allow airport authorities and labor unions to implement specific interventions.

1.1 Aim and objectives

This project aims to assess the ambient air quality at Benin city airport and evaluate its associated respiratory health effects on airport workers to provide evidence-based recommendations for occupational health and environmental safety improvements.

The objectives of this project are as follows:

i. determine the concentrations of air pollutants ($PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, and VOCs) in various operating zones at airports

ii. determine the spatiotemporal variation in air pollutant concentrations

iii. determine the prevalence of reported respiratory symptoms and risk factors for airport workers

iv. Examine the association between the reported risk factors and the prevalence of respiratory symptoms.

CHAPTER TWO

LITERATURE REVIEW

2.1 Air Quality and Health in Nigeria

Air quality is the concentration of dangerous compounds (pollutants) in the atmosphere. Certain pollution indicators, including the concentrations of particulate matter (PM10, PM2.5), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O3), are commonly measured (WHO, 2021). To maintain the equilibrium of life on Earth, plants, animals, and natural resources require good air quality. Ecosystems and/or human health may be impacted by poor air quality. (Mohammed *et al*., 2020). When these contaminants surpass the limits established by national regulatory organizations such as the World Health Organization, poor air quality results. Because of aircraft and ground support operations, pollution levels in airport environments frequently surpass ambient regulations (Stettler *et al*., 2011). Chauhan and Johnston (2003) reported that the main sources of emissions are engine exhaust and fuel combustion. Certain gases, such as particulate matter (PM), which is a mixture of solid particles and liquid droplets found in the air,, such as smoke, dust, fumes, and aerosols, , and volatile organic compounds (VOCs), which are produced by certain solids or liquids and have undesirable effects in the atmosphere, can be present in amounts that can compromise air quality and have corresponding negative effects on public health (respiratory and cardiovascular diseases) (Ibe *et al*., 2017). Furthermore, illnesses linked to air pollution are thought to affect the lives of more than seven million people worldwide each year (Mannucci and Franchini, 2017). Population growth and artificial environmental pressures resulting from increased population density caused by mass rural–urban migration, uncoordinated spatiotemporal development clusters, unpredictable consumer behavior and consumerism, heavy reliance on fossil fuel-based operations, and lax environmental regulations have all been linked to increases in environmental urban air pollution and related public health effects (Mannucciand Franchini, 2017 and Komolafe *et al*., 2014). According to Ipeaiyeda and Adegboyega (2017), the cumulative risk of air pollution in residential and commercial areas, where potential exposure is high, is increasing and has caused widespread disruption of ecosystem services at both the local and regional levels. To determine the level of population exposure to air contaminants, air quality monitoring is essential.

Nigeria is the fourth most air-polluted nation in the world. Nigeria has the greatest number of recorded deaths from poor air quality caused by high air pollution levels. Nigeria has 94% air pollution from particulate matter ($PM_{2.5}$) levels, which is higher than the WHO's recommended 72% for sub-Saharan Africa, according to the World Bank's "Little Green Data Book 2015" (Oguntoke *et al*., 2017). In 2000, 18.4% of all energy sector emissions came from the transport sector. The statistical rise in the number of private and commercial vehicle owners over time proves that Nigeria's transport sector has expanded significantly. These cars are powered by fossil fuels (diesel and petrol), which are thought to be the main contributors to the global emissions of certain air pollutants. In Nigeria, more than 90% of all petroleum product consumption occurs through road transport (Croitoru *et al*., 2020). With emissions from aircraft engines, ground support equipment, auxiliary power units, vehicle traffic, and onsite power generation, airports in Nigeria are becoming more significant sources of air pollution. Research at major airports, such as Lagos's Murtala Muhammed International Airport and Port Harcourt International Airport, has shed light on the types and levels of contaminants present in these settings. There are several features of Nigeria's transport system that seem to support its status as one of the main causes of anthropogenic air pollution emissions nationwide. One is due to the fact that even though the nation has a vast supply of crude oil with very low sulphur content (Okedere *et al*., 2017), the majority of the country's premiums motor spirit (gasoline) and diesel (automotive petrol oil) are imported because local refineries do not operate as planned. The use of these imported petroleum products has been linked to the atmospheric loading of pollutants such as SO2 and some heavy metals (Okedere *et al*., 2017). Owing to factors such as industrialization, vehicle emissions, urbanization, and a lack of environmental regulations, Nigeria has some of the highest air pollution levels in Africa (Amegah and Agyei-Mensah, 2017). According to studies conducted in Lagos, Port Harcourt, and Kano, PM_2 and NO_2 levels are higher than the WHO guidelines (Oguntoke *et al*., 2019). The ambient air pollution in Benin is caused by industrial activities, automobiles, and generators (Ede and Edokpa, 2015), but there is no regular monitoring in place. According to reports, the single major factor influencing environmental health hazards worldwide is air pollution. Industrialization, fast urbanization, and growing motorization have all been linked to the most noticeable effects of air pollution in emerging nations (Power *et al*., 2018). According to the World Health Organization, at least 80% of people who live in cities are at risk of experiencing air quality levels that are higher than permitted (WHO, 2021). Particulates (PM2.5 and PM10), carbon monoxide (CO), and gaseous pollutants,, including nitrogen (IV) oxide, sulphuric (IV) oxide, and volatile organic compounds (VOCs),, are among the outdoor air pollutants that are significant from a health standpoint (Oguntoke *et al*., 2019). Owing to an increase in emissions from numerous human sources in urban centers, these pollutants are currently reaching dangerous levels in emerging nations. The incomplete burning of fossil fuels releases air pollutants such as soot particles, nitrogen oxides, and sulphur dioxide directly into the atmosphere. This has been linked to the rise in urbanization and industrialization, which has increased the population and created crowded, air-polluted places (Burroughs *et al*., 2017). Asthma, lung cancer, and chronic obstructive pulmonary illnesses are among the respiratory conditions that are exacerbated by air pollution (Lelieveld *et al*., 2015;; Eghomwanre *et al*., 2022). Numerous studies conducted in Hong Kong have revealed correlations between elevated levels of ambient ozone (O3), NO2, SO2, and PM2.5 and increased hospital admissions for asthma and pneumonia (Ko *et al*., 2007; Cheng *et al*., 2014; Qui *et al*., 2014). Additionally, there is mounting evidence linking exposure to air pollution to myocardial infarction, cancer, coronary heart disease, stroke, and hypertension (Newby *et al*., 2015). For PM_{10}, $PM_{2.5}$, CO, NO_2, and $SO_{/}$, the World Health Organization has set yearly average outdoor air quality values of 20, 10, 40, and 20 µg/m3, respectively (WHO, 2021). However, the acceptable limits for PM_{10}, NO_2, and SO_2 under the Nigerian Ambient Air Quality Standards (NAAQS) are 150 µg/m3, 0.03 ppm, and 0.03 ppm, respectively. Since regulatory limits are effective thresholds below which there may not be any significant health impacts on the exposed individuals, continuous human exposure to air pollutants within these regulatory standards may also be of public health significance, particularly in children and those with underlying diseases. Since air quality data are frequently unavailable or inaccessible from government sources, air quality monitoring has virtually no place on the Nigerian government agenda. Thus, there is currently little public awareness of urban air pollution, which is typified by a lack of funding, incentives, policy guidelines, and a legal framework to help keep pollution concentrations within regional regulatory boundaries (Schwela, 2012). The lack of political support makes it difficult to implement current air pollution laws when they exist. Compared with that in industrialized countries, air pollution in developing countries is a complicated problem that is exacerbated by information gaps caused by a lack of legislation and regular monitoring (Knippertz *et al*., 2015). The identification and mapping of pollutant hot spots, as well as the control and development of suitable mitigation strategies for health hazards connected with air pollution, can benefit from an understanding of the variability of atmospheric pollutants and the health concerns they provide. This study aims to assess the respiratory health hazards associated with exposure to Benin city Airport's air quality and related respiratory health impacts among employees.

2.2 Air Pollution in airport environments

There are many potential pollutants situated in the airport atmosphere, such as VOCs, $Pm_{10/2.5,}$ SO, NOx, and CO_2. However, for the sake of simplicity, the general pollutants of concern in this paper are particulate matter ($Pm_{10/2.5}$), carbon dioxide and carbon monoxide from human sources. The NAAQS is used to monitor and measure these criterion air pollutants. A study of air pollutants revealed that the majority of these pollutants come from combustion sources,, including cars, airplanes, other engines, and industrial sources (EPA, 2012). There are many different kinds of operations at airports, many of which involve sources connected to combustion. While some of these sources are readily apparent, others might not be due to the quick increase in air travel volumes and the anticipated development to accommodate future capacity demands; airport emissions have drawn more attention recently (Amato *et al*., 2010; Kurniawan and Khardi, 2011). Airport emissions come from a variety of sources, including aircraft exhaust (ICAO, 2011). Even though it was once thought that the majority of emissions came from aircraft engine exhaust plumes, there are other sources of air pollution in contemporary airports that also contribute locally. However, only a small number of studies have examined their chemical and physical properties. Among these, tire, brake and asphalt wear, as well as the resuspension of particles due to the turbulence created by aircraft movements, can account for large fractions of the total particulate matter mass (e.g., British Airports Authority, 2006). Furthermore, despite their potential to have a significant impact on local air quality, emissions from units that power aircraft on the ground have received very little attention (Schafer *et al*., 2003; Ratliff *et al*., 2009; Mazaheri *et al*., 2011). Airport ground power units (GPUs) and auxiliary power units (APUs), which are tiny on-board gas turbine engines, are examples of such equipment. Furthermore, air quality is further impacted by airport ground service equipment (GSEs) (Seyfer., *et al*., 2003). The majority of the equipment that an airport provides to travelers and passengers is referred to as ground support equipment. This includes a wide range of vehicles, including passenger buses, baggage and food carriers, container loaders, reloading trucks, cleaning vehicles, and lavatory and deicing vehicles, as well as tugs that are used to move any equipment or push the aircraft between gates and taxiways. Air traffic-related emissions from ground services such as ground support equipment, ground power units or auxiliary power units are the subject of relatively few studies (Ratliff *et al*., 2009; Mazaheri, 2011). Airports may also have other sources, such as maintenance activities, heating systems, fugitive fumes from refuelling operations, passenger and operator dining areas, etc. Furthermore, because many airports are situated far from urban areas, sources that are not physically present in a terminal but that the airport affects should be included in emission inventories. Road traffic, which includes private vehicles, taxis, shuttle buses, and trucks for moving people and products into and out of the airport, may be one of these sources, as may multimodal transportation systems.

Large airports in Nigeria are frequently located near crowded urban areas, which presents serious environmental and public health issues for local residents. This is true in many regions of the world. For example, both the Nnamdi Azikiwe International Airport in Abuja and the Murtala Muhammed International Airport in Lagos are situated inside or close to large metropolitan populations, potentially exposing locals to dangerous air pollutants (Akinyemi & Adewale, 2014). Nigeria does not, however, have extensive monitoring systems or publicly available data on the effects of its airports on air quality. The lack of comprehensive information on hydrocarbon speciation, particulate matter physicochemical characteristics, and secondary atmospheric transformations of pollutants from aircraft and ground-support emissions within Nigerian airports is highlighted in this review. The ability of environmental agencies to conduct efficient air quality assessments and create focused mitigation plans, such as emission control laws or the relocation of sensitive receptors such as hospitals and schools, is hampered by this lack of data (Ngele & Onwu, 2015). Regulatory and health protection activities will remain disjointed and inadequate if the full "airport system", which includes airplane operations, ground service equipment, passenger and freight vehicles, and airport infrastructure, is not considered.

2.3 Respiratory health effects of air pollution

Owing to its enormous surface area and ability to function as an interface between circulation and ambient air, the respiratory system is especially susceptible to the effects of air pollution (Cohen *et al*., 2011). The deposition, retention, and overall impact on the pulmonary system are all influenced by the characteristics of the inhaled pollutant (for a summary of pollutant characteristics, inflammation of the upper respiratory tract causes rhinitis, pharyngitis, and laryngitis; bronchial inflammation causes bronchitis and bronchopneumonia; and parenchymal inflammation causes pulmonary edema and pneumonia). For example, the location of pollutant deposition influences the type of symptoms that are observed.

Table 2.1: Health effects and susceptible populations to major air contaminants

Air contaminant	Health impact	Vulnerable populations	References
Particulate matter (Pm10/2.5)	Upper respiratory tract irritation and infection, exacerbation of and increased mortality from cardiorespiratory diseases Throat irritation; exacerbation of cardiorespiratory diseases, including asthma	Elderly people with respiratory and cardiovascular diseases; children with asthma People with respiratory diseases (eg. children with asthma)	(Ebi and McGregor, 2008)
Sulphur dioxide (SO_2)	Throat irritation; exacerbation of cardiorespiratory diseases, including asthma.	People with respiratory diseases (eg. children with asthma)	(Pikhart *et al*., 2001)
Oxides of nitrogen (NOx)	Eye irritation; upper respiratory tract infection (especially in children): exacerbation of asthma; irritation of bronchi	People with respiratory diseases (eg. children with asthma)	(Ezekwe *et al*., 2016)
Carbon monoxide		People with ischemic	(Levy, 2015)

(CO)	heart disease

(Abubakar and Haruna, 2020)

2.4 Previous studies on air quality in airports

2.4.1 Pollutants and their distribution

Research indicates a clear inverse relationship between pollutant concentration and the distance from an airport's operational platform (Cohen and Bronzaft, 2011). The primary pollutants in this environment include nitrogen oxides (NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), volatile organic compounds (VOCs), and ultrafine particles (UFPs). Soot particles and UFPs are of particular concern because of their small size, which allows them to penetrate the respiratory tract (Highwood and Kinnersley, 2006). A significant increase in black carbon particles has also been observed in the upper atmosphere due to aviation (Hendrick *et al*., 2004).

2.4.2 Sources of airport emissions

The majority of airport pollutants come from a mix of sources, including aircraft, ground-support equipment (GSE), and road vehicles (Winther *et al*., 2015). Aircraft jet engines produce a variety of pollutants, such as CO_2, NO_x, CO, and particulates, similar to other mobile sources (Federal Aviation Administration, 2005a). The emission rates of these pollutants vary depending on the flight phase. For example, NO_x emissions are higher during high-power operations such as takeoff, whereas CO emissions are higher during low-power activities such as taxiing, where engines are less efficient (Federal Aviation Administration, 2005a). Despite being idle, the extended duration of taxiing can make it a significant source of CO and NOx (USEPA, 1999). For example, Los Angeles International Airport is considered a major source of both NOx and CO within California because of taxiing (EPA, 2012).

2.4.3 Regulatory challenges

While regulations have long targeted emissions from cars and trucks, regulatory oversight for airport and aircraft emissions is still in its early stages. In the U.S., the Clean Air Act prohibits most agencies from regulating aircraft emissions, leaving them to the Federal Aviation Administration (FAA) (Federal Aviation Administration, 2005a).

However, gathering data for effective regulation is challenging. Airports, as large and secure environments, limit access for external researchers (Masiol and Harrison, 2014). Additionally, there is no official consensus on the best measurement and analytical techniques, complicating data comparison and risk assessment (Masiol *et al*., 2014; Stacey, 2019). Despite these issues, airports remain a compelling context for health studies because their daily operational data allow for a precise estimation of congestion and its associated pollution (Auffhammer & Kellogg 2011).

2.4.4 Health implications

Exposure to airport emissions, especially for workers, poses a significant health hazard (Masiol and Harrison, 2014). This background exposure to pollutants from traffic and industry is linked to negative health impacts (Pope *et al*., 2015). More research on human exposure risks and their health effects is still needed to develop effective risk management strategies (Harrison *et al*., 2015).

2.5 Previous studies on the respiratory health of airport workers

Early research on the health effects of aviation focused on the chemical and physical properties of pollutants, particularly their small size and ability to penetrate the respiratory tract (Highwood and Kinnersley, 2006). Studies have measured very small **ultrafine particles (UFPs)**, with sizes ranging from 23--36 nm near airport environments (Smekens *et al*., 2007) and even as small as 11 nm near major hubs such as Los Angeles International Airport (Hu *et al*., 2009). Despite these findings, some early analyses revealed that pollutant concentrations around airports were comparable to those in highly urbanized areas, making it difficult to isolate the specific impact of air traffic alone (EPA, 2012). Studies have linked direct occupational exposure to airport pollutants with respiratory symptoms in workers. For example, workers at Birmingham International Airport were found to have affected pulmonary function and respiratory symptoms from exposure to jet pollution and aircraft fuel.

A study on flight attendants, a group with chronic exposure to cabin air, revealed a higher prevalence of respiratory disorders than other female workers did (Wehlan *et al*., 2003). The study revealed that flight attendants had significantly more chest ailments than teachers did (33% vs. 19.3%). The lack of doctor-diagnosed asthma among flight attendants was attributed to job selection bias, as individuals with preexisting respiratory conditions might not be able to work in this profession. This research highlighted the distinct occupational nature of the symptoms, underscoring the health risks posed by the unique air cabin environment (Wehlan *et al*., 2003). More recent studies have evaluated the broader health impacts of aviation emissions at global, regional, and local scales. A modelling study by Yim *et al*. (2015) estimated that civil aviation emissions contribute to approximately 16,000 premature deaths annually worldwide. A key finding was that particulate matter ($PM_{2.5}$) was responsible for 87% of these deaths, and approximately one-third of them occurred within 20 km of an airport. These findings demonstrate that aviation's impact on public health near airports is a significant concern that persists despite the acknowledged uncertainties in such estimations.

2.6. Mitigation of Air Pollution in Airport Environments

Poor air quality is a significant global health risk, with key pollutants including nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), and particulate matter (PM) (WHO, 2021). Exposure to high concentrations of these pollutants can lead to serious health issues, such as lung cancer and respiratory illnesses (EPA, 2023). Although airport operations are major contributors to air quality deterioration, there is a notable lack of public support for mitigation efforts (Ramírez *et al*., 2019). Therefore, it is crucial to educate airport stakeholders, including tenants and employees, to secure their support for environmental initiatives (Sydney Airport, 2018; Melbourne Airport, 2019).

2.6.1 Collaborative Data Sharing

Data sharing among stakeholders—such as airlines, air traffic controllers, and ground handlers—is a viable strategy for enhancing the effectiveness of operations and improving environmental outcomes (Zheng *et al*., 2019). However, implementing collaborative data sharing, such as through an A-CDM (Airport Collaborative Decision Making) framework, can face challenges. These include a lack of advanced data analysis tools, difficulties in sharing information, and the potential for redundant system processes. Despite these hurdles, integrating a collaborative data-sharing policy can be a successful approach to improving an airport's environmental performance.

2.6.2 Emissions assessment and carbon management

A key strategy is to assess emissions from aircraft ground idling and delays. By evaluating these emissions, airports can better understand their impact on local air quality and implement targeted measures to reduce pollution. Such assessments also provide evidence to support policies that encourage airlines to adopt more efficient ground operations, leading to both environmental benefits and operational cost savings. A complementary approach is to participate in initiatives such as the Airport Carbon Accreditation program. This framework can guide airports in adopting sustainable practices and cleaner technologies, which can improve local air quality and position airports favourably for future environmental regulations. While these strategies are effective, they can be complex and expensive, potentially imposing a burden on smaller airports.

2.6.3 Air pollutant emission monitoring

Another crucial step is to monitor and track air pollutant emissions consistently. Maintaining a detailed emissions inventory allows for long-term trend analysis, a better understanding of pollutant patterns, and a clear way to evaluate the effectiveness of reduction strategies. An emissions inventory provides transparent data for risk assessment and enables benchmarking against industry standards, thereby increasing stakeholder transparency. However, this method has its own challenges, including ensuring data consistency and accuracy across multiple sources and owners. It also provides only a snapshot of emissions at a given time, which may not capture sudden changes or emerging issues.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Overview of the study area

Benin City, a humid tropical urban settlement, is located in southern Nigeria. It encompasses five local government areas: Oredo, Ikpoba Okha, Egor, Ovia North East, and Uhunmwonde. The city is situated between latitudes 6°20′N and 6°58′N and longitudes 5°35′E and 5°41′E, covering an area of approximately 112.552 km^2. As estimated in 2015, its population was approximately 1.5 million people (NPC, 2015), making it the fourth most populous city in Nigeria. This high population density, combined with industrial activities, vehicle emissions, and the widespread use of generators, contributes to ambient air pollution (Ede and Edokpa, 2015). The airport's location within this crowded urban environment means that emissions from its operations directly impact the local populace. Benin City airport is a key transportation hub in Nigeria and is located in Edo State. The airport's strategic location is a notable characteristic, as it lies at the heart of Benin City, the state capital. This means that its runway is effectively located in the middle of a densely populated urban area, which presents significant environmental and public health challenges. The airport is approximately 7 kilometres northeast of the city centre. The airport's proximity to residential and commercial areas increases the exposure risk for both its employees and the surrounding community. In addition to air pollution, noise pollution from aircraft is also a major concern for host communities around airports.

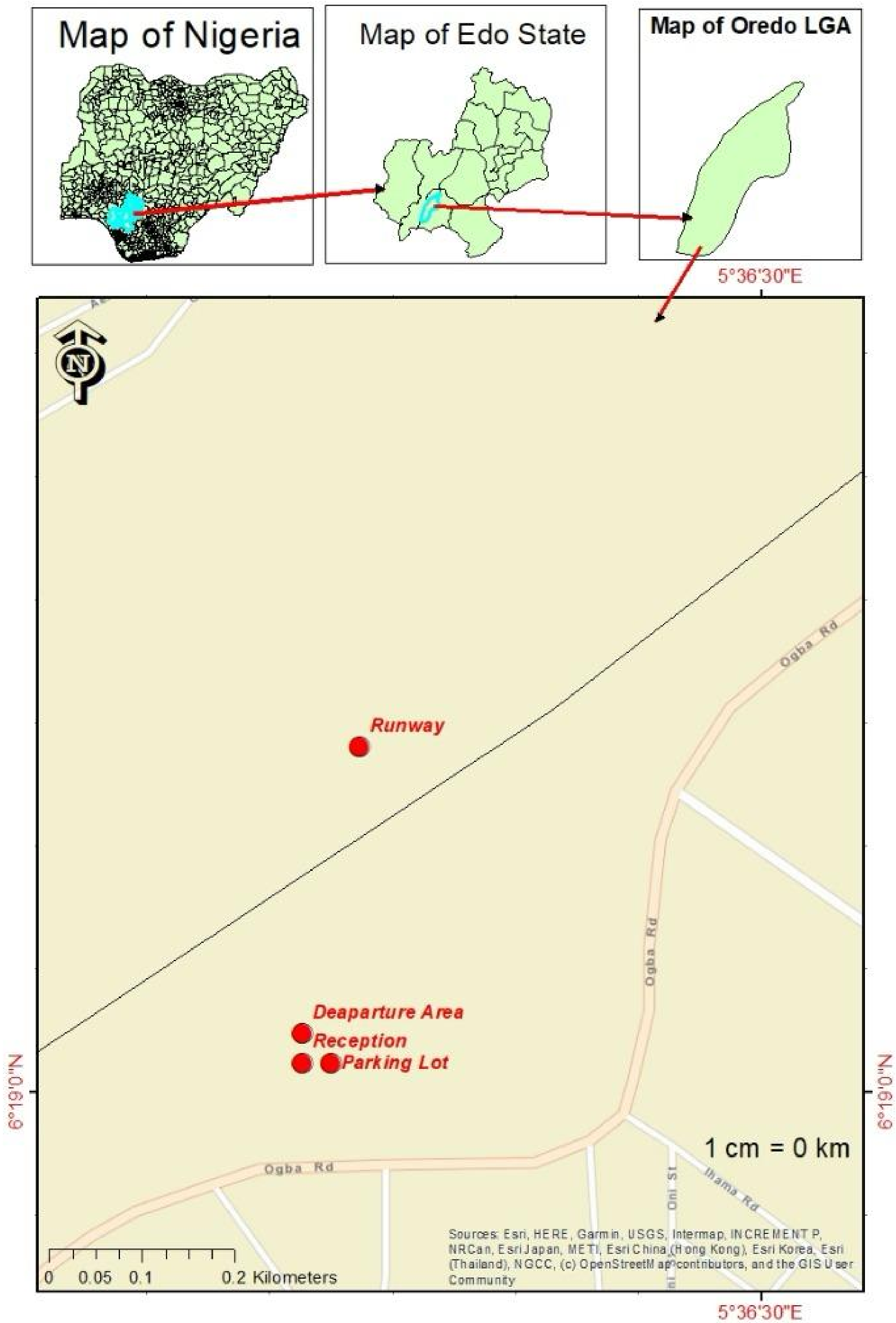

Figure 3.1: Map of the study area indicating the sampling points

3.2 Selection and description of the sampling sites

The Benin City airport was selected as the study site to assess the air quality and its respiratory health effects on staff. The airport's operational environment, with its continuous cycle of arriving and departing aircraft, exposes a staff population of approximately 300 to potentially harmful emissions. The rationale for choosing the airport as the study area is its nature as a localized source of human-made emissions, making it an ideal setting to investigate the direct effects of real-time occupational exposure. The study was designed to capture a representative range of air quality conditions and staff exposure levels. The sampling sites at Benin city airport were **purposely selected** to represent different levels and types of air pollution exposure relevant to airport staff on the basis of the study's focus on "air quality and respiratory symptoms among Benin city airport staff." The rationale for selecting these specific locations is to capture the spatial variation in pollutants and exposure risks across key operational areas. The four chosen sites were selected because they represent distinct micro environments within the airport, each with its own unique exposure profile for staff;

3.2.1 Runway (Airside)

Located behind the terminal building, this is the area where aircraft land and take off. This site represents the highest level of direct exposure to aircraft engine exhaust. The coordinates are **6°19′12″N** and **5°36′12″E**. This site was chosen to measure **direct occupational exposure** to aircraft engine exhaust. Staff working on the air side, such as ground crews, are exposed to the highest concentration of pollutants from landing and departing aircraft, making this a critical location for assessing peak exposure levels.

3.2.2 **Departure Area**:

This is the passenger waiting area before boarding. This location captures exposure levels for both passengers and staff working within the terminal, away from the most direct emission sources. The coordinates are **6°19′02″N** and **5°36′14″E**. This location represents an area of **indirect exposure** to a mix of outdoor and indoor pollutants. The staff working in this section are not as directly exposed to engine exhaust as the ground crew but are still at risk from pollutants that drift from the runway and other sources.

3.2.3 **Reception (Concourse Area)**:

As the main entrance to the terminal building, this is the busiest part of the airport, where check-in and other necessary flight-related paperwork are completed. The high level of foot traffic and mixing of indoor and outdoor air make this a critical site for measuring public and staff exposure. The coordinates are **6°19′01″N** and **5°36′14″E**. This site was selected because it is the **busiest and most central point** of the terminal. It provides data on pollutant levels in a high-traffic area with a constant influx of people, vehicles, and a mix of indoor and outdoor air, which is highly relevant to staff working in administrative or customer-facing roles.

3.2.4. **Parking Lot**:

Situated at the front of the airport, this area is a significant source of emissions from ground vehicles, including cars and shuttle buses. It represents a different type of emission source than aircraft does and is important for obtaining a complete picture of airport air quality. The coordinates are **6°19′01″N** and **5°36′15″E**. This site was chosen to isolate and measure emissions from **ground-based vehicle traffic**. The pollution here is primarily from cars, buses, and shuttles, offering a comparative data point on non-aircraft-related emission sources that still affect staff working in this area

3.3 Study Design and Rationale

This study used a cross-sectional design to investigate the relationship between air quality and the respiratory health of airport staff. The research employed a two-pronged approach: Air quality levels were monitored simultaneously at four distinct sampling sites within the Benin city airport. This was done to capture the spatial variation in pollutants and determine the level of exposure at different operational areas. A questionnaire was administered to airport workers to collect data on their respiratory health status and self-reported symptoms. The rationale for this combined approach was to directly link the air quality data from the monitored sites with the respiratory health information from the staff.

3.4 Sample size determination

The sample size for this study was determined via the Cochran formula for a finite population (Cochran, 1967). This method ensures that the sample is statistically representative of the total staff population at Benin City airport, which is approximately 300. The calculation was based on a standard 95% confidence level and a 5% margin of error.

First, the uncorrected sample size (n_0) was calculated via the following formula:

$n_0 = Z^2 \times p(1-p) \quad /e2$ …………Equation 1

Where:

Z is the Z score for the 95% confidence level, which is 1.96.

p is the estimated population proportion. Since no prior data on staff health were available, a conservative value of 0.5 was used to ensure the largest possible sample size.

e is the desired margin of error, which is 0.05

$n^o = 1.96^2 \times 0.5(1-0.5)/ 0.05^2 = 384$

$n = n_0/1 + n_0 - 1 \quad /N$…………..Equation 2

Where:

- n_0 is the uncorrected sample size (384).
- N is the total population size (300).

On the basis of this calculation, a final sample size of 169 staff members was required to en e that the study's findings are statistically significant and can be generalized to the entire population with a high degree of confidence.

3.5 Measurement of air pollutants and meteorological parameters

Air quality sampling at the airport of Benin City was conducted to assess pollutant levels and their variations over time. The methodology involved measuring multiple pollutants and environmental parameters via specialized equipment and a specific temporal and spatial approach. Sampling was carried out for a period of four weeks to capture a comprehensive dataset. This study employed a temporal approach by taking measurements during both the morning and afternoon periods to account for variations in airport activity, flight schedules, and other operational factors that influence air pollution levels. This approach allowed for a more detailed analysis of how pollutant concentrations fluctuate throughout a typical workday. Two primary real-time air quality detectors were used for the study. A BOSEAN air quality detector was used to monitor the levels of carbon monoxide (CO), carbon dioxide (CO_2), and volatile organic compounds (VOCs), as well as the ambient temperature and relative humidity. A BR-Smart-126S hand-held meter was used to measure particulate matter (PM) levels. These portable devices are built with a high-precision sensor chip that uses a light scattering mechanism to convert atmospheric particulate concentrations into visual data. The meter has a precision range of 0–999 $\mu g/m^3$ and a resolution of 1.0 $\mu g/m^3$. At each sampling site, the meters were positioned 2 meters above ground level to ensure that the readings were not influenced by fugitive dust. To ensure data reliability, the devices were calibrated before and after each sampling activity according to the manufacturer's instructions. Several preliminary measurements were taken at each site before the official readings were recorded. Measurements were performed daily and in triplicate at each of the selected sites. The data obtained were meticulously cleaned for outliers, and the average particulate concentrations were calculated. These average concentrations were then compared with the WHO 24-hour air quality standards (WHO, 2021) to evaluate the health risks posed by the measured pollutants.

3.6 Questionnaire survey

A well-structured questionnaire was designed to assess the respiratory health status of airport staff and investigate potential links to occupational air pollution exposure. The questionnaire was divided into four distinct sections to collect comprehensive data.

3.6.1. Questionnaire Section

- **Section A: Sociodemographic Information** This section presents basic personal data, including age, gender, marital status, educational level, monthly income, and work position.

- **Section B: Exposure levels and personal history.** This part of the questionnaire focused on staff exposure to the airport environment. It included questions on the number of years of work experience, daily duration of stay, specific work area within the airport, smoking history, and any family history of chronic respiratory symptoms.
- **Section C: Respiratory health status:** This section assesses the respondents' respiratory health by asking about the occurrence of symptoms such as coughing, phlegm, wheezing, shortness of breath, and chest tightness within the past 12 months.
- **Section D: Awareness and** control measures. The final section gauged the staff's awareness of the health effects of air pollution and their knowledge of available control measures. The questions covered whether they were aware of the potential for respiratory dysfunction from pollutants, the necessity of personal protective equipment (PPE), their personal use of PPE, and their knowledge of any government intervention programs or routine air pollution monitoring at the airport.

3.6.2 Participant Selection and Validity

3.6.2.1 Inclusion criteria:

Participants were required to have been working consistently at the airport for a period of at least one year. This criterion was essential to ensure that all respondents had a sufficient duration of exposure to the airport's air quality, making the analysis of potential health effects more reliable.

3.6.2.2 Exclusion criteria

3.6.2.3 To minimize confounding variables and ensure that the study findings were directly related to occupational exposure, two groups were excluded: staff with a reported history of preexisting or underlying chronic illnesses that could affect respiratory health. Recently, staff who would not have met the one-year work experience requirement were recruited.

3.6.3 **Questionnaire validation (pretest)**

To ensure that the questionnaire was clear and effective, a pretest was conducted. This involved administering the survey to a small, representative group of staff members who were not included in the main study. The pretest helped identify any ambiguities in the questions and confirmed the questionnaire's ability to capture the required information accurately through a Cronbach's alpha test, thereby ensuring the validity of the data collected.

3.7 Statistical analysis

Statistical analysis was conducted via SPSS for Windows, Version 22.0, to analyse both the air quality data and questionnaire responses. The choice of tools was guided by the need to describe the data, compare groups, and identify potential associations between variables.

Descriptive statistics (means and standard deviations) were used to summarize the air quality data (pollutant concentrations). The mean provides the average pollutant level at each sampling site, whereas the standard deviation indicates the dispersion or variability of the data around that average. The Analysis of variance (ANOVA) was employed to compare the mean concentrations of pollutants across the different sampling sites within the airport. ANOVA is an appropriate tool for determining if there is a statistically significant difference in air quality between three or more independent groups (the four sampling sites). The questionnaire data were analysed via descriptive statistics (frequencies and percentages) to summarize the questionnaire results. This method provided a clear overview of the demographic characteristics of the respondents and the prevalence of specific reported respiratory symptoms. The chi-square test was used to examine the associations between categorical variables, such as work location and the presence of respiratory symptoms. The chi-square test determines whether the observed distribution of one variable is independent of the other. A logistic regression model was used to investigate the relationship between multiple independent variables (e.g., years of experience, smoking history, work location) and the probability of a dichotomous outcome—in this case, the presence or absence of a reported respiratory symptom (yes or no). It helps identify which risk factors are most strongly associated with health outcomes. A p value of < 0.05 was considered statistically significant for all inferential tests, meaning that the results were unlikely to have occurred by random chance.

CHAPTER FOUR

RESULTS

4.1 Concentrations of air pollutants at the air port

Figure 4.1 presents the CO_2 concentration for each sampled area, separated by the morning and afternoon periods. The mean carbon dioxide (CO2) concentration in parts per million (ppm) was recorded at four specific sample locations throughout the morning and afternoon hours. The standard error of the mean is shown by error bars. Across the four sampling areas, the mean concentrations of CO_2 showed little variation in runway, departure areas, and parking lots all presented discernible patterns of increased CO_2 concentrations in the afternoon as opposed to those in the morning. This is consistent with either less atmospheric mixing in the afternoon, more activity, or warming of the ground. With a mean CO_2 concentration significantly lower in the afternoon (below 399.9 ppm) than in the morning (approximately 399.9 ppm), the reception area was the glaring exception to this pattern. This implies that localized factors, such as building ventilation or occupancy shifts, have a significant effect on lowering indoor CO_2 levels later in the day.

The runway region had the highest total CO_2 concentration in terms of space, reaching a peak of approximately 400.5 ppm in the after n. On the other hand, the Reception area had the best CO_2

air quality performance, with the lowest concentrations continuously recorded, especially in the afternoon. During both time periods, the concentration profiles in the parking lot and departure areas were extremely similar, with levels ranging between 399.5 ppm and 400.0 ppm.

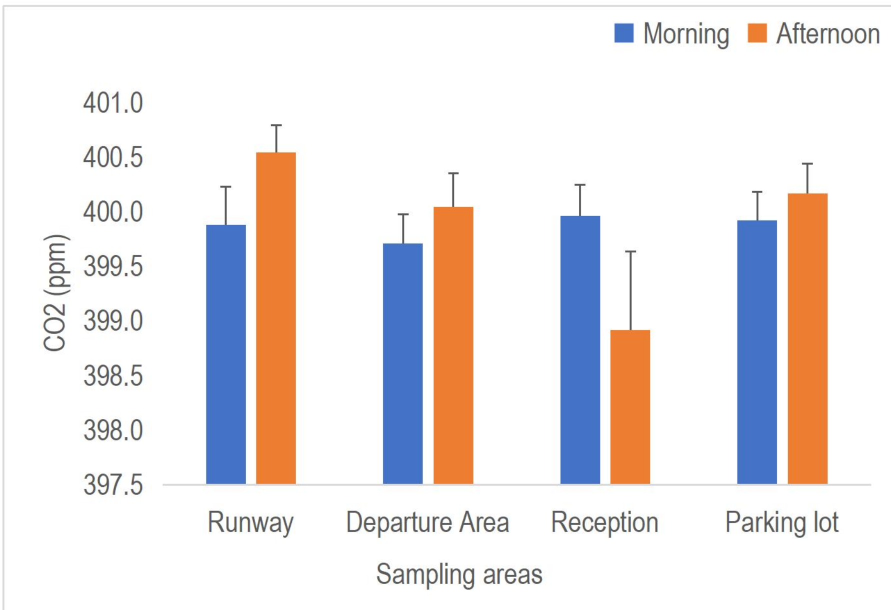

Figure 4.1 Levels of carbon (iv) oxide

Figure 4.2 displays the mean concentration of coarse particulate matter (PM_{10}) for each runway morning; the runway area had the highest total PM_{10} concentrations. On the other hand, the lowest PM_{10} concentrations were consistently found in the Departure and Reception areas. The reception area had lower levels.

Figure 4.3 shows that the analysis of $PM_{2.5}$ concentrations revealed distinct differences between the morning and afternoon measurement periods as well as among the four designated sampling areas during the morning and afternoon periods. The mean concentrations of fine particulate matter are shown by error bars, which represent the standard error of the mean. There was a noticeable difference in the $PM_{2.5}$ concentration among the sites. The mean $PM_{2.5}$ levels were consistently highest at the Runway and Parking Lots in the afternoon. The lowest $PM_{2.5}$ concentrations were found in the departure and reception areas. The departure area had the lowest absolute value in the morning.

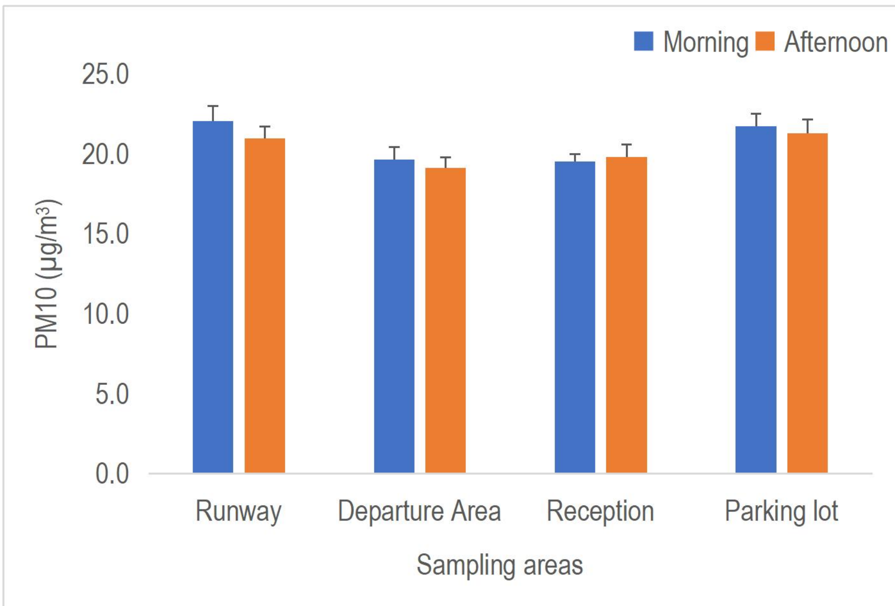

Figure 4.2. Mean concentrations of PM_{10}

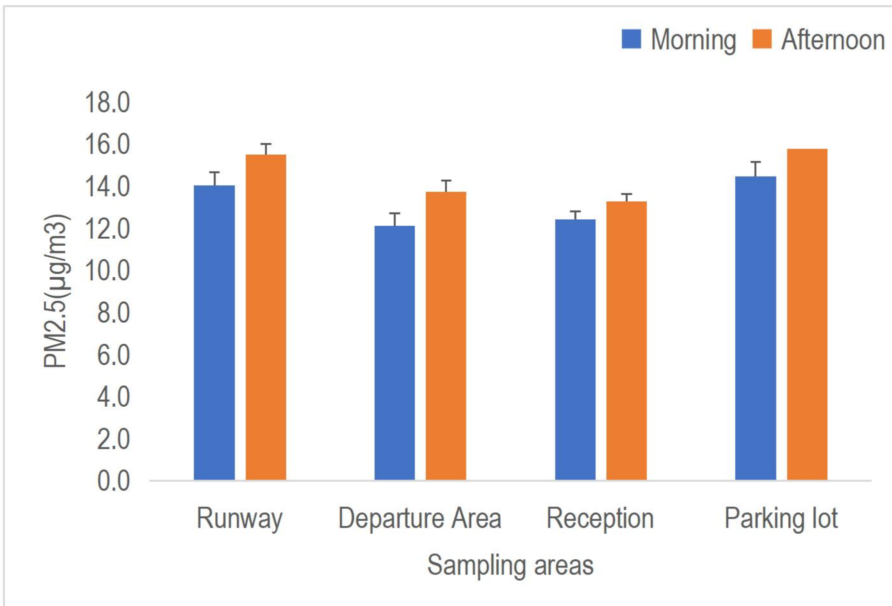

Figure 4.3. Mean **concentrations of $PM_{2.5}$**

Table 4.1 displays the results of the one-way analysis of variance, which was utilized to assess the variation in air pollutant concentrations across multiple sampling areas. According to the data in Table 4.1, the mean concentration of Morning CO_2 did not differ significantly among the four sampling regions ($F = 0.139$, $p = 0.936$). Likewise, there was no statistically significant change in the mean concentration of Afternoon CO_2 ($F= 2.611$, $p = 0.056$). Statistically, the data indicate that CO_2 levels are rather consistent throughout the study area during both measurement times, even though the p value is near the (0.05) threshold. The mean concentration of Morning CO_2 did not significantly among the four sampling regions according to the analysis ($F(3, 92) = 0.139$, $p = 0.936$). Similarly, there was no statistically significant change in the mean concentration of afternoon CO_2 ($F= 2.611$, $p = 0.056$). Statistically, the data indicate that CO2 levels are rather consistent throughout the study area during both measurement times, even though the p value is near the (0.05) threshold. The mean concentration of Morning PM_{10} varied significantly throughout the sampling areas ($F= 3.074$, $p = 0.032$). This suggests that, in the morning, the mean PM_{10} concentration in at least one sampling location is either significantly greater or lower than that in the other locations. However, it was not statistically significant for afternoon PM_{10} ($F= 1.754$, $p = 0.162$). This implies that afternoon concentrations are more consistent, whereas morning PM_{10} concentrations are area dependent. There were statistically significant differences in the morning and afternoon $PM_{2.5}$ concentrations between the sampling areas. There were significant differences in the mean concentration of Morning PM_2 between the locations (F=

3.881, p = 0.012). Additionally, there was a very statistically significant variance in afternoon $PM_{2.5}$ (F = 5.965, p = 0.001). With the lowest p value, this result implies that atmospheric dispersion or $PM_{2.5}$ sources are highly localised and vary across regions, especially in the afternoon.

Table 4.1 Variations in air pollutant concentrations across sampling areas

	Sum of Squares	df	Mean Square	F	Sig.
CO_2_M	0.865	3	.288	0.139	0.936
	190.375	92	2.069		
	191.240	95			
CO_2_A	35.250	3	11.750	2.611	0.056
	414.083	92	4.501		
	449.333	95			
PM_{10}_M	129.865	3	43.288	3.074	0.032
	1295.542	92	14.082		
	1425.406	95			
PM_{10}_A	73.333	3	24.444	1.754	0.162
	1282.500	92	13.940		
	1355.833	95			
$PM_{2.5}$_M	97.115	3	32.372	3.881	0.012
	767.375	92	8.341		
	864.490	95			
$PM_{2.5}$_A	111.917	3	37.306	5.965	0.001
	575.417	92	6.255		

M=Morning, A=Afternoon

Table 4.2 shows the mean concentrations of each pollutant in the morning (M) and afternoon (A) across all the sampling areas carried out to investigate how air pollutant concentrations change over time between the morning (M) and afternoon (A) periods. According to the footnote, statistical significance was evaluated at the 0.01 level. The average difference between the morning and afternoon values of CO_2 was -0.0521 ppm. This finding validates that the total CO_2 concentration does not change considerably between the morning and afternoon when it is averaged across all the sampling regions. There was no statistically significant difference in the PM10 concentration between the morning and afternoon (t = 1.644, p = 0.103). The morning concentrations were, on average, marginally greater than afternoon concentrations, according to the mean difference of 0.4271 µg /mg^3 nevertheless, at the 0.01 significance level, this difference was too small to be regarded as statistically significant.

The morning and afternoon $PM_{2.5}$ concentrations differ in a highly statistically significant way (t= -4.214, p = 0.001). The interpretation depends on the negative mean difference of -1.322 µg/m3. The negative result shows that the afternoon was, on average, significantly higher than the morning concentration (Morning) - (Afternoon). This finding strongly shows that factors contributing to the release or accumulation of fine particulate matter are much stronger during the afternoon.

Table 4.2. Variations in air pollutant concentrations across the sampling period

Variables	**Mean**	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed)**
CO_2_M - CO_2_A	-0.0521	2.4639	0.2515	-0.207	95	0.836
PM_{10}_M - PM_{10}_A	0.4271	2.5454	0.2598	1.644	95	0.103
$PM_{2.5}$_M - $PM_{2.5}$_A	-1.3229	3.0762	0.3140	-4.214	95	0.001

M= Morning, A= Afternoon, *p value significant at the 0.01 level (2-tailed)

Table 4.3 displays the sociodemographic profile of the (N=129) airport employees who participated in the survey. The majority of the study population is made up of younger employees. In particular, 18--30 years (29.5%) and <18 years (28.7%) are the two largest age groups. Together, employees under 30 years of age make up 58.2% of the sample as a whole. As people age, the percentage of workers steadily decreases. The middle-aged group (31–40) years constitute 24.8%, whereas older workers (41–50) years and (>51) years make up a distinct minority, with the (>51) years category being the smallest at just (3.1%). There is a minor bias towards male respondents in the workforce's sex distribution. The sample is compose of 55.0% (N=71) male workers and 45.0\% (N=58) female workers. The workers' marital status is quite evenly distributed: 55.0\% (N=71) are married, whereas 45.0% (N=58) are single. The group studied has a very consistent level of education. Notably, 100.0% (N=129) of the airport employees stated that they had completed tertiary education. The consistency suggests that the workforce in the population under study has a high level of education.

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Table 4.3: Sociodemographic characteristics of airport workers

Variable	Category	Frequency (N)	Percentage (%)
Age	<18yrs	37	28.7
	18-30yrs	38	29.5
	31-40yrs	32	24.8
	41-50yrs	18	14.0
	>51yrs	4	3.1
Sex	Male	71	55.0
	Female	58	45.0
Marital Status	Married	71	55.0
	Single	58	45.0
Educational Level	Tertiary	129	100.0

Table 4.4 presents descriptive statistics regarding work-related and lifestyle risk factors for the airport workers who participated in this study (N=129). The majority of the polled personnel have been engaged at the airport for a relatively short to medium length. The largest group, representing 41.9% (N=54), reported working at the airport for 2--4 years. A comparable percentage of employees are classified as having 5–7 years of experience (24.8%), 8–15 years of experience (25.66% Altogether, approximately 92.3% of the employees had been with the company for 15 years or less. Only a small minority (7.7%) (N=10) reported working at the airport for more than 15 years. With a slight majority working longer hours, the daily work hour distribution is generally equally distributed, While 46.5% (N=60) reported working (3--7) hours, 53.5% (N=69) of the workers reported working 8--12 hours. Among the study participants, smoking was not very common. A sizable majority (85.3%) (N=110) of the participants stated that they did not smoke. Among the employees, only 14.7% (N=19) reported smoking. Most participants said that they had no family history of long-term respiratory issues. While (16.3%) (N=21) reported having a family history of such issues, (83.7\%) ((N=108)) of the workers responded "No" to this variable.

Table 4.4: Reported risk factors among airport workers

Variable	Category	Frequency (N)	Percentage (%)
Years of working at the Airport	2-4yrs	54	41.9
	5-7yrs	32	24.8
	8-15yrs	33	25.6
	>15yrs	10	7.7
Work hour duration	3-7 hrs	60	46.5
	8-12 hrs	69	53.5
smoking	No	110	85.3
	Yes	19	14.7
Family history of chronic respiratory issues	No	108	83.7
	Yes	21	16.3

The employees' self-reported respiratory problems throughout the previous 12 months are presented in Table 4.5. Coughing was the most common respiratory symptom recorded. Most employees (57.4%) (N=74) said that they had coughed within the previous 12 months. On the other hand, no such symptoms were reported by 426% (N=55) of the patients. Given how common a cough is, more research into any possible connections to work exposure is necessary. A sizable minority of employees reported experiencing dyspnoea. Among the participants, 4.0% (N=31) reported had dyspnea within the previous 12 months, whereas 76.0% (N=98) did not. A total of 14.0% of the respondents (n=18) that that they had ph m. As with shortness of breath, a significant minority experienced tightness or pain in the chest. The majority of the workers (82.9%, N=107) did not report any chest symptoms, whereas 17.1% (N=22) did.

Table 4.5: Reported Respiratory Health Effects among Airport Workers (N=129)

Variable	**Category**	**Frequency (N)**	**Percentage (%)**
Reported Health Effects			
Cough in the past 12 months	No	55	42.6
	Yes	74	57.4
Phlegm in the past 12 months	No	111	86.0
	Yes	18	14.0
Shortness of breath in the past 12 months	No	98	76.0
	Yes	31	24.0
Chest pain/tightness in the past 12 months	No	107	82.9
	Yes	22	17.1

Table 4.6 show relationships between health effects and reported risk factors. According to Table 4.6, there is a significant disconnect between theoretical knowledge and practical application/institutional support. The employees were highly aware of the possible negative of air pollution on their health. Only 13.2% indicated no awareness of health impacts, which is a significant major, 86.8% reported knowing about them. There was a moderate level of knowledge of specific air quality, regularly slightly more than half of the employees .6%, 73) that hat they were aware of the safe limit of air pollutants, whereas 43.4% were not. Awareness of the requirement to use PPE in the workplace was very high. A total of 88.4% (N=114) of the workers were aware of the PPE requirements. There appears to be a serious gap in training and practical application, as a considerable majority (83.7%) (N=108) reported not knowing how to utilize personal protective equipment (PPE). There was almost no knowledge of internal management procedures. A resounding (96.9%) (N=125) of the employees did not know that the airport was regularly monitoring air pollution.

Table 4.6: **Reported Awareness of Air Pollution Effects and Control among Airport Workers (N=129)**

Variable	Category	Frequency (N)	Percentage (%)
Knowledge of air pollution health effects	No	17	13.2
	Yes	112	86.8
Knowledge of Safe limit of air pollutants	No	56	43.4
	Yes	73	56.6
Aware of PPE requirement	No	15	11.6
	Yes	114	88.4
Knowledge on use of PPE	No	108	83.7
	Yes	21	16.3
Knowledge of government intervention on Air pollution	No	116	89.9
	Yes	13	10.1
Routine Monitoring of air pollution in Airport	No	125	96.9
	Yes	4	3.1

Table 4.7 presents the results of a chi-square test of association, which is used to determine if there is a statistically significant relationship between categorical risk factors (age, smoking, etc.) and categorical health outcomes. The worker's age category and the report of shortness of breath during the previous 12 months have a statistically significant association, indicating that the prevalence of shortness of breath varies significantly across the various age groups and probably increases with age. This association is borderline and not statistically significant. Phlegm and Smoking: Phlegm reporting is highly and significantly correlated with smoking. This is a compelling conclusion in line with known respiratory pathophysiology, which shows that smoking causes an increase in mucus formation. In addition, there was a strong and significant correlation between smoking and reporting chest pain or tightness. The most widespread set of noteworthy correlations with respiratory health impacts is seen in family history. It has a strong and significant correlation with cough ($p = 0.004$), phlegm, breathing difficulties, and chest tightness or discomfort. The risk variables, such as working at the airport for years and the length of the workday, did not exhibit a statistically significant correlation with the health impacts that were investigated (p values > 0.05).

Table 4.7: Association between reported risk factors and health effects among airport workers

Risk Factor	Reported Health Effect	X^2 Value	p value (Sig.)
Age	Phlegm in the past 12 months	7.931	0.088
	Shortness of breath in the past 12 months	10.357	**0.029**
Years of working at the Airport	Cough in the past 12 months	3.820	0.429
	Phlegm in the past 12 months	0.886	0.892
Work hour duration	Cough in the past 12 months	0.745	0.476
	Phlegm in the past 12 months	0.489	0.613
	Shortness of breath in the past 12 months	1.995	0.215
Smoking	Phlegm in the past 12 months	9.393	**0.002**
	Chest pain/tightness in the past 12 months	8.243	0.007
Family history of chronic respiratory issues	Cough in the past 12 months	8.500	**0.004**
	Phlegm in the past 12 months	107.583	**0.001**
	Shortness of breath in the past 12 months	11.043	**0.002**
	Chest pain/tightness in the	121.996	**0.001**

	past 12 months

p values indicate a statistically significant association (p value).

CHAPTER FIVE

DISCUSSION

Environmental monitoring data have established that particulate matter (PM) is the primary air pollution concern at airports, exhibiting significant spatial and temporal variability. The analysis of variance (ANOVA) indicated that CO2 concentrations were relatively consistent across all sampling areas in both the morning (p=0.936) and afternoon (p=0.056), suggesting that general gaseous pollutant mitigation is likely effective and than C_{O2} is not the primary health hazard. The lack of substantial spatial or temporal variation in CO_2 ($p > 0.836$) suggests that internal dilution ventilation is effective, leading to the conclusion that CO levels are probably well within the Nigerian NAAQS limit of 10 ppm to 20 ppm (Adeyanju and Manohar, 2017). In contrast, fine particulate matter (PM2.5) exhibited highly significant spatial (p=0.001 in the afternoon) and temporal variations. The Runway and Parking Lot were confirmed as exposure hotspots, particularly for PM2.5, with concentrations increasing significantly in the afternoon (p=0.001), directly linking the health risk to peak operational traffic and activities such as vehicular and aircraft emissions. The highest recorded mean PM2.5 concentration (24.1 µg/m) exceeded the strict World Health Organization (WHO) 24-hour guideline of 15 µgm3 (WHO, 2021). This, in turn, is a major indicator of an intolerably high health risk (NESREA, 2024), indicating a failure to meet international standards. Conversely, indoor areas such as the reception and departure zones consistently recorded lower PM2.5 levels, suggesting that the building envelope provides some degree of protection. The study revealed a high prevalence of self-reported respiratory symptoms, with coughing being the most common symptom among workers (57.4%). The analysis of risk factors via the chi-square test revealed several statistically significant associations with these health outcomes: Smoking and Phlegm/Chest Symptoms. Smoking was strongly correlated with both reported phlegm ($p=0.002$) and chest pain/tightness ($p=0.007$), which aligns with known respiratory pathophysiology where smoking increases mucus production and causes bronchial irritation. A strong and significant correlation was found between a family history of chronic respiratory issues and all four reported symptoms (cough, phlegm, shortness of breath, and chest pain, with $p\leq0.004$ for all). This finding indicates that a sensitive subgroup of the workforce is disproportionately vulnerable to environmental hazards at airports. Age was significantly associated with shortness of breath ($p=0.029$), suggesting a compounding effect of exposure over time on lung function, although years of work experience itself did not significantly correlate with the investigated health effects. A critical gap was identified between workers' awareness and institutional support. While a large majority of employees were aware of the health of air pollution and personal protective equipment knowledge on how to use PPE properly. This deficiency, coupled with the near-total absence of routine air pollution monitoring (96.9% of employees were unaware of it), confirms a systemic breakdown in surveillance, control, and duty of care toward employees. To address the verified health risks and noncompliance with WHO guidelines, the Airport Authority must implement immediate, targeted interventions. It is imperative to establish an operational and publicly transparent monitoring system in designated hotspots (Runway/Parking Lot) to ensure regulatory adherence and supply for NESREA enforcement actions. Simultaneously, a critical knowledge gap necessitates the immediate implementation of a hands-on, practical respiratory training program focused on the proper selection, fitting, and upkeep of masks to satisfy the legal duty of care. Furthermore, an occupational health program should be initiated to screen high-risk workers (smokers and those with a family history) and offer targeted counselling. Finally, to mitigate the significant afternoon spike (), management must enforce "no-idling" regulations for ground support equipment (GSE) and accelerate the replacement of high-emission GSE with cleaner electric alternatives.

CONCLUSION

According to this study, two noncompliant factors, fine particulate matter ($PM_{2.5}$) pollution and extreme heat stress, are the main causes of the substantial and avoidable occupational health risk that the airport environment poses to its employees. The highest observed PM2.5 concentration exceeded the strict WHO 24-hour guideline, driven by spatially concentrated hotspots and peak afternoon activity confirming regulatory failure against international health standards. The high prevalence of respiratory problems among workers is directly caused by this exposure, which is exacerbated by the concurrent inability to satisfy ASHRAE criteria for temperature and relative humidity. Conclusively, a very sensitive group is disproportionately affected by this environmental danger, and their symptoms are substantially correlated with a family history of chronic respiratory problems. The persistence of this risk ultimately stems from systemic management failures: workers lack protection due to a critical deficiency in PPE proficiency training, confirming a total breakdown in surveillance and control, and the environment owing to the near-total absence of routine monitoring.

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APPENDIX

APPENDIX I: Research tool (Questionnaire)

The questionnaire that was given to the airport employees is included in this section (N=129).

Research Topic: Assessment of Air Quality at Benin City Airport, Southern Nigeria, to Respondents:
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: Sociodemographic information

1. What is your age? 18-24 yrs 0) 25-34 yrs () 35-44 yrs () 45-54 yrs 0>55 yrs
2. What is your sex? Male () Female)
3. What is your marital status? Single (Married O
4. Educational level? Primary () Secondary () Tertiary
5. How much is your monthly income? #50,000) #100,0000#200,000 (>#200,000
6. Type of work at the airport? ---

SECTION B: Respondents' exposure to air pollutants in the airport environment

1. Number of years of airport work experience? 2-4 yrs () 5-7 yrs () 8-15 yrs (Above 15 yrs 0
2. Duration of stay at the airport each day? 1-2 hrs 07 hrs hrs 0) 8-12 hrs
3. What part of the airport do you work?
4. Do you smoke?
5. Is there any family history of chronic respiratory health symptoms? Yes 0 No 0

SECTION C: Questions related to respondents' respiratory health status

1. Have you ever had a cough in the past 12 months? Yes (No 0
2. Have you ever had phlegm for the past 12 months? Yes 0 No 0
3. Have you ever experienced wheezing or whistling in the chest in the past 12 months?
   Yes (No 0
4. Has you experienced shortness of breath in the past 12 months? Yes () No ()
5. Have you ever experienced chest pain/tightness in the past 12 months? Yes (No 0)

SECTION D: Awareness of air pollution-related health and control measures

1. Are you aware that exposure to air pollutants in the airport can cause respiratory problems?
   Yes () No ()
2. Do you have any knowledge of the safe limits of any air pollutant levels in the airport environment? Yes () No ()
3. Are you aware that people should wear protective equipment if the air pollutant levels exceed harmful levels. Yes () No.
4. Do you use any form of personal protective equipment during work! Yes (No 0)
5. Do you know about any government intervention programmes on air pollution at the airport? Yes () No ()
6. Do you know about any routine air pollution monitoring at the airport? Yes (No)

APPENDIX II: Visual Documentation of Monitoring Equipment and Sampling Sites

Plate 1: Real-Time Monitoring at the Runway (Airside) via the BOSEANQuality Detector

Plate 2: Common Runway (Airside) Operational Activity (Major Source of PM2.5)

Plate 3: A Parked Aircraft at the Terminal Gate (Ground Support and Auxiliary Power Unit (APU)

Plate 4: Overview of the Runway/Airside Environment Showing the Sampling Zone's Scope

Plate 5: Benin city airport Parking Lot (sampling site) as the main source of ground vehicle emissions

Plate 6: Airport Terminal Concourse Area Sampling Site in Benin

Plate 7: The waiting departure area sampling site (gate and terminal staff exposure monitoring)