INFLUENCE OF AIR POLLUTANTS ON OCULAR HEALTH AMONG COMMERCIAL DRIVERS AND ROAD TRANSPORT WORKERS IN IMO STATE, NIGERIA

BY

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(OD, OPTOMETRY ABSU; MPH, PUBLIC HEALTH FUTO)

REG. NO: 20184143038

A DISSERTATION SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI IMO STATE

DECEMBER, 2024

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CERTIFICATION

This is to certify that this work "Influence of Air Pollutants on Ocular Health Among Commercial Drivers and Road Transport Workers in Imo State'' was carried out by Nwakanma, Gerald I., Reg. number (20184143038) in partial fulfillment for the award of the degree of Doctor of Philosophy (PhD) in Public Health in the Department of Public Health of the Federal University of Technology, Owerri.

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DEDICATION

This study is dedicated to GOD ALMIGHTY and the memories of my dear parents, Chief Noble Sir John A. Nwakamma and Lolo Noble Lady Dorathy A. Nwakamma. They laid the foundation upon which my academic achievements are built.

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ABSTRACT

Air pollution, resulting from sources like household combustion and high vehicular emissions, significantly contributes to the worldwide burden of disease, with notable pollutants including CO, CO_2, NO_2, SO_2, and Particulate Matter ($PM_{1.0,\ 2.5}$). While the respiratory and cardiovascular effects of air pollution are widely studied in Nigeria, a critical gap in knowledge exist regarding the specific ocular health implications for high-risk occupational groups like road transport workers. The statement of the research problem therefore hinged on the high level of ignorance among these workers regarding ocular risks, coupled with the apparent weak enforcement or absence of effective air quality policies in Imo State motor parks, leading to concentrated exposure. This study aimed to determine the prevalence of associated ocular problems, assess the level of awareness, and evaluate the efficacy of preventive strategies employed against air pollutants among road transport workers in Imo State. A cross-sectional survey and observational design was conducted among a sample of 552 park workers (Drivers, Road Transport Workers, and Traders) across five selected motor parks in the three senatorial zones of Imo State. Methodology involved the collection of data via a pre-tested structured questionnaire, comprehensive clinical ocular examinations (including Visual Acuity, Schirmer test, and Tonometry), and the measurement of ambient environmental parameters (NO_2, SO_2, CO_2, PM) at the study sites. The results showed a high prevalence of ocular problems (81.2%) among the eyes examined, with pterygium (57.9%) and dry eye syndrome (35.9%) being the most prevalent conditions. Awareness of the risks was high (84.1%), but a significant "awareness-practice gap" was found, as only 31.0% of participants used any preventive measures. A significant association was established between awareness and the practice of prevention ($P < 0.0001$). Furthermore, the use of eyeglasses ($P=0.002$) and avoiding smoke areas ($P=0.016$) were significantly effective in reducing ocular problem occurrence, while sunshades were not. In conclusion, there is a high burden of preventable ocular morbidity among road transport workers, characterized by Pterygium and Dry Eye Syndrome, largely due to a failure to translate high awareness into consistent protective behavior. The recommendations underscore the critical need for targeted public health interventions focusing on translating awareness into specific protective practices, promoting regular eye check-ups, and enforcing stricter environmental regulations in motor parks to mitigate occupational exposure.

Keywords: ocular health, environmental factors, air pollutants, dry eye, pterygium, road transport workers.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

All life on Earth depends on air for survival and development. Its quality has a direct impact on human health and is strongly influenced by the level of civilisation. Air pollution is a significant factor in the worldwide burden of disease. Despite stricter air quality rules, mortality from air pollution increased in both emerging and developed nations, including the United States (Cohen, Brauer, Burnett, Anderson, Frostad, Estep, Balakrishnan, Brunekreef, Dandona, Dandona, 2017). While there are many natural sources of air pollution, like volcanoes, wildfires, and bushfires in particular developing countries, the majority of significant air pollution has been spread by human technology since the Industrial Revolution. Industrialisation and international travel have progressed with human civilisation. Increased use of fuel-burning motorised vehicles and factories because of industrialisation have led to high levels of air pollution and poor air quality

For instance, the Central Weather Bureau of Taiwan reports that in January 2021, the air quality index (AQI) in south Taiwan, which is where majority of the island's power plants are located, was between 130 to 160, which is deemed unhealthy for the general population and discourages outdoor activities.

It goes without saying that air pollution is bad for one’s health. Exposure to the byproducts of burning the fuel used in most of our motor vehicles has been specifically linked to an elevated risk of lung cancer, respiratory infections, stroke, heart disease as well as death from these conditions. A recent study has included eye illness yet another alarming pollution-related risk.

Globally, there is growing worried over air pollution, particularly indoor and outdoor pollution in high-income and low-income nations, respectively (Shima, 2017). According to Brook et al. (2004) and Pope et al. (2004), most studies have concentrated on the connection between air pollution and cardiopulmonary disorders like asthma, chronic obstructive pulmonary disease (COPD), lung cancer, heart disease, and stroke. A growing body of evidence also reveals that other systems, including the reproductive, nervous, and ocular systems, are also impacted by air pollution. For instance, research has connected air pollution to psychological stress (Sass, et al., 2016), neurodegeneration (Calderon-Garciduenas, et al., 2016), and male and female infertility (Jurewicz, et al., 2018; Conforti, et al., 2018). Neurodegeneration affects the eye significantly and leads to age-related macular diseases (AMD).

According to Kemp, et al. (2011), air pollution is made up of a complex mixture of hazardous particles and gas-phase pollutants that are released into the atmosphere because of either natural or human activity. Sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon dioxide (CO_2), nitrogen monoxide (NO), carbon monoxide (CO), nitrogen oxides (NOx), particulate matter 2.5 (PM2.5), and particulate matter 10 (PM10) are just a few of the pollutants in the air that are primarily produced by burning fuels or by industrial processes. Daily activities such as cooking, decorating the home, and driving also produce COx, NOx, and volatile organic compounds (VOCs), in addition to traffic and industrial activity.

Exposure to the byproducts of burning the fuel used in most motor vehicles has been specifically linked to an elevated risk of lung cancer, respiratory infections, stroke, heart disease, as well as death from these conditions. Globally, most studies have concentrated on the connection between air pollution and cardiopulmonary disorders like asthma, chronic obstructive pulmonary disease (COPD), lung cancer, heart disease, and stroke (Brook et al., 2004; Pope et al., 2004). A growing body of evidence also reveals that other systems, including the reproductive, nervous, and ocular systems, are also impacted by air pollution. For instance, research has connected air pollution to psychological stress (Sass et al., 2016), neurodegeneration (Calderon-Garciduenas et al., 2016), and male and female infertility (Jurewicz et al., 2018; Conforti et al., 2018). Air pollution is made up of a complex mixture of hazardous particles and gas-phase pollutants that are released into the atmosphere as a result of either natural or human activity (Kemp et al., 2011). Key pollutants include Sulfur dioxide (SO2), Nitrogen dioxide (NO2), Carbon dioxide (CO2), Carbon monoxide (CO), Nitrogen oxides (NOx), Particulate matter 2.5 (PM2.5), and Particulate matter 10 (PM10), which are primarily produced by burning fuels or by industrial processes

1.2 Problem Statement

It has been established that some air pollutants have debilitating effects on visual health, including conditions that can lead to blindness. Air quality in Nigeria remains a severe public health concern. The World Health Organisation (WHO, 2018) estimated that air pollution accounted for over 150,000 premature deaths annually in Nigeria, a figure that underscores the high health risk. Studies focusing on environmental quality in major Nigerian cities, such as Owoade et al. (2015) in Lagos, and Eze et al. (2020) in the Southeast, have confirmed the pervasive high levels of vehicular emissions and Particulate Matter (PM2.5), often exceeding WHO guidelines by significant margins.

Nigeria has established regulatory frameworks aimed at controlling air pollution. The National Environmental Standards and Regulations Enforcement Agency (NESREA) is the primary body responsible, with specific regulations like the National Environmental (Air Quality Control) Regulations, 2014, and the National Environmental (Control of Vehicular Emissions from Petrol and Diesel Engines) Regulations, 2011. These regulations set permissible limits for various pollutants, including those from vehicular exhaust (CO, NOx, PM) which are central to this study. Furthermore, the Federal Ministry of Environment oversees broader environmental policies.

However, despite these regulations, their effectiveness in practice, particularly within high-exposure microenvironments like motor parks, appears limited. The continued observation of high pollution levels, as indicated by studies like Solaja et al. (2015) and suggested by the health outcomes explored in this thesis, points to significant challenges in enforcement and compliance. Factors such as the prevalence of old, poorly maintained vehicles, infrastructural deficits, and potentially inadequate monitoring contribute to this gap between policy on paper and reality on the ground.

Consequently, the overwhelming majority of Nigerian research, mirroring global trends, has concentrated on the connection between air pollution and cardiopulmonary disorders. A critical knowledge gap therefore exists concerning the specific ocular health implications of this persistent high pollution burden, despite existing regulations. Limited local studies have been conducted to ascertain the prevalence and type of ocular morbidity attributable to air pollution among high-risk occupational groups like road transport workers in Nigerian states, such as Imo State.

This deficiency is particularly concerning for commercial drivers and road transport workers whose occupation necessitates prolonged, concentrated exposure to vehicular emissions and dust in motor parks. The high level of ignorance or failure to act regarding the link between air pollutants and ocular health among these workers is compounded by the apparent ineffectiveness or weak enforcement of existing air quality policies within these specific occupational settings. This leaves the ocular surface—the body's most exposed mucous membrane—vulnerable to chronic irritation and disease from concentrated pollutants. This study was therefore designed to address this local research gap by providing the specific ocular morbidity data necessary to highlight the real-world health impacts in the context of existing, but seemingly inadequately enforced, regulations.

1.3 Aim and Objectives of the study

1.3.1 Aim of the Study

The general objective of this study was to determine the influence of air pollutants on ocular health among road transport workers in Imo State.

1.3.2 Specific Objectives

The specific objectives are to determine:

i. Which ocular problems are associated with air pollutants among road transport workers.
ii. the level of awareness of the influence of air pollutants on ocular health among road transport workers.
iii. the strategies employed in the prevention of air pollution on ocular health by road transport workers.
iv. the relationship between awareness and the practice of preventive measures against air pollution in ocular health and ocular problem occurrence among the study group.
v. the use of different preventive measures and the occurrence of ocular problems among the subjects using preventive strategies.

1.4 Research Questions

i. What are the ocular problems associated with air pollutants on the ocular health of road transport workers?
ii. What is the level of awareness of the influence of air pollutants on their ocular health?
iii. What strategies do they employ to prevent the influence of air pollutants on their ocular health?

iv. What is the relationship between awareness and the practice of preventive measures against air pollution in ocular health?

v. What is the relationship between awareness and the occurrence of ocular problems among the study group?

vi. What is the advantage of the use of different strategic preventive measures and the occurrence of ocular problems?

1.5 Research Hypotheses

There is no ocular problem associated with air pollutants among road transport workers in Imo State.

There is no awareness of the influence of air pollutants on their ocular health.

They do not employ any strategy to prevent the influence of air pollutants on their ocular health.

There is no relationship between awareness and occurrence of ocular problems.

There is no advantage between strategic preventive measures and occurrence of ocular problems.

1.6 Justification of Study

Anything that compromises ocular health creates a huge loss in human resources. Visual impairment among commercial drivers and road transport workers is a critical public safety issue that poses a potential cause of job loss and possible loss of lives on our roads due to reduced visual capacity. Therefore, commercial drivers, road transport workers, passengers, and the entire populace either visiting or resident in Imo State stand to benefit immensely from this study.

The relevance of the study is significantly amplified by the demographic reality of the study area. Imo State has a large population, estimated at approximately 4,928,000 people, many of whom rely heavily on road transportation daily (NPC, 2017). This large population, which includes the transport workers themselves, passengers, and residents near motor parks, magnifies the potential exposure and public health impact of air pollutants. Specifically, the high population density of the state, which varies from 230 to 1,400 people per square kilometre, leads to the concentration of vehicles and people in motor parks. This high concentration makes the motor parks a critical exposure microenvironment, where the effects of air pollution on ocular health are likely to be severe and widespread across the population. The study's findings are thus essential for evidence-based policy making, as they quantify a public health risk that affects not just a small occupational group, but one whose health directly impacts the safety and well-being of millions of citizens within the state.

1.7 Scope of the Study

This study is delimited to commercial drivers, road transport workers, traders, and people doing various legitimate businesses within the selected motor parks in Imo State.

The study intentionally excluded residents, pedestrians, or the general public around busy roads or outside the perimeter of the motor parks under consideration for the following reasons:

1. Concentrated Occupational Exposure: The primary objective of this research was to investigate the influence of air pollutants on the ocular health of an occupational group (road transport workers) subjected to high-intensity, chronic exposure. Workers within the motor park environment spend the majority of their working day (typically 8–12 hours) in close proximity to the point source of vehicular emissions (tailpipes) and high concentrations of dust and Particulate Matter (PM), leading to a higher, more direct occupational exposure dose compared to those residing or simply passing by busy roads.

2. Feasibility and Control: Delimiting the study population to those physically working within the motor parks provided a more controlled and feasible study environment, allowing for accurate measurement of both the ambient pollutants and the clinical outcomes within the defined occupational setting. Studying the general population around busy roads would have introduced significantly more confounding variables related to varying exposure times, intermittent presence, and less quantifiable occupational risk.

3. Targeted Intervention: By focusing on the motor park environment, the findings are directly applicable to targeted public health and occupational safety interventions that can be implemented by unions (like NURTW) or state regulators within these defined commercial boundaries.

Therefore, the scope was deliberately delimited to the motor park workers to assess the maximum impact of chronic occupational air pollutant exposure on ocular health.

1.8 Limitations

i. There were challenges in assessing long-term exposure accurately.

ii. There was potential for self-report bias in questionnaires.

iii. There was difficulty in establishing a direct causal link between air pollutants and specific ocular conditions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual Framework

This is a structure that connects the concepts, beliefs, theories, and assumptions that are relevant to a research project. It can be presented in a narrative, graphical, or pictorial format.

2.1.1 Consequences of air pollution on ocular health

Maximized vision, ocular health, and functional capacity are all indicators of Ocular health, which improves quality of life, general health and wellness, and social inclusion. Achieving many of the Sustainable Development Goals (SDGs) depends on ocular health. A person's quality of life is negatively impacted by poor ocular health and visual problems, which also limit their ability to succeed in school and at work. Financial repercussions of vision loss are significant for affected people, families, and communities. Conservative projections based on the most recent prevalence data for 2020 show that the yearly global productivity loss from vision impairment is roughly US4107 billion purchasing power parity, despite the lack of high-quality data for global economic calculations, particularly for Low-Middle-Income-Countries. Departure from ocular health impairs mobility, degrades mental health, increases dementia risk, increases the chance of falls and car accidents, necessitates more social care, and ultimately raises mortality rates (Burton, et al., 2021).

Globally, there is growing worried over air pollution, particularly indoor and outdoor pollution in high-income and low-income nations, respectively (Shima, 2017). According to Brook et al. (2004) and Pope et al. (2004), most studies have concentrated on the connection between air pollution and cardiopulmonary disorders like asthma, chronic obstructive pulmonary disease (COPD), lung cancer, heart disease, and stroke. A growing body of evidence also reveals that other systems, including the reproductive, nervous, and ocular systems, are also impacted by air pollution. For instance, research has connected air pollution to psychological stress (Sass, et al., 2016), neurodegeneration (Calderon-Garciduenas, et al., 2016), and male and female infertility (Jurewicz, et al., 2018; Conforti, et al., 2018). Neurodegeneration affects the eye significantly and leads to age-related macular diseases (AMD).

Air pollution has a wide range of effects on human health involving many organs and systems. The ocular surface is a great model for studying how air pollution affects human health because it is always in direct contact with the outside world and is easily accessible, making disease monitoring easier. In most cases, the effects of air pollutants on the ocular surface show up as dry eye (DE) symptoms and signs. These symptoms and indicators typically include itching, a scratchy feeling, tears, and conjunctival redness.

According to Kemp, et al. (2011), air pollution is made up of a complex mixture of hazardous particles and gas-phase pollutants that are released into the atmosphere as a result of either natural or human activity. Sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon dioxide (CO_2), nitrogen monoxide (NO), carbon monoxide (CO), nitrogen oxides (NOx), particulate matter 2.5 (PM2.5), and particulate matter 10 (PM10) are just a few of the pollutants in the air that are primarily produced by burning fuels or by industrial processes. Daily activities such as cooking, decorating the home, and driving also produce COx, NOx, and volatile organic compounds (VOCs), in addition to traffic and industrial activity.

According to the U.S. Environmental Protection Agency (EPA), 6 major air pollutants that cause major health effects include:

i. Ground-level ozone.

ii. Nitrogen dioxide.

iii. Sulfur dioxide.

iv. Carbon monoxide.

v. Lead.

vi. Microscopic particles called particulate matter.

Air pollutant emissions emitted by motor vehicle exhausts include:

Carbon monoxide (CO),

Nitrogen oxides (NOx),

Particulate matter (PM); and

Volatile organic compounds (VOC).

Most greenhouse gas emissions from transportation are carbon dioxide (CO_2) emissions resulting from the combustion of petroleum-based products, like gasoline and diesel fuel, in internal combustion engines.

2.1.2 Exhaust Gas Emission Test

Exhaust gas emission testing is a process where test equipment is used to measure the gases produced by a car's engine. A probe is placed in the tail pipe of the car and the exhaust gases are measured following a strict procedure. The exhaust gas analyser is used for measuring 4 gases: oxygen (O_2), carbon monoxide (CO), carbon hydroxide (CO_2) and hydrocarbons (HC) as well as calculating lambda a measure of air/fuel ratio. These measurements together provide a very accurate way of measuring the combustion efficiency of an engine.

The vehicle exhaust emission test legislation requires that the instrument used to test the vehicles is type approved by a national recognized body. In addition, the instrument must be calibrated using a Certified Reference Standard produced in accordance with ISO 17025.

2.1.3 List of Instruments in Measuring Emission

Vehicles generate potentially harmful and toxic emissions through their exhaust pipes, especially when they are not properly maintained. Many states require that vehicles pass emissions testing before they are deemed road-worthy. Special instrumentation is used to analyze emissions and detect gases like nitrogen oxides (NOx), carbon dioxide (CO_2), carbon monoxide (CO) and hydrocarbons (HC).

2.1.4 5 Gas Analyzers

Utilizing specialized tools like the assortment of Dyne System five-gas portable analyzers, gas pipe exhaust is analyzed. These devices analyze and quantify the quantity of engine exhaust for particular gas constituents, such as CO, CO_2, NO, HC, and oxygen. Prior to each use, the equipment is calibrated using ambient air to assure precise results. Analyzers have a two-stage filter system that can detect and capture both large and small particles, as well as a sample line for collecting exhaust gases. Systems have touch-screen user interfaces that let users manage manual tasks. Instruments can optionally be stored in wall-mounted enclosures while not in use.

2.1.5 Dynamometer

In auto inspection bays, dynamometers, an electronic roller device, are used to measure exhaust emissions. The test vehicle is driven onto the dynamometer rollers, and then the testing begins. While the car is still in the bay, this gadget simulates the exhaust that the vehicle actually makes when accelerating and moving at a modest speed (15 mph). It is used in conjunction with a five-gas analyser for instant data reading.

2.1.6 Scanning apparatus

Many post-1980 automobiles and all models made after 1996 come equipped with an on-board computerized diagnostic system (OBD). These computers may monitor components of the vehicle, such as the oxygen and exhaust sensors. These on-board computers are easily attachable to scanning tools made to evaluate emissions using OBD technology. When assessing vehicle emissions, portable electronic scanning devices can offer real-time evaluations.

2.1.7 Gas Cap Testing

Testing of gas caps looks for leaks around the gas cap seals on vehicles. Visible gasoline or diesel fumes are volatile gases, and if inspections are not conducted, leakage into the atmosphere may go unnoticed. The evaporation of gasoline from faulty gas caps is responsible for nearly 40% of hydrocarbon emissions in the atmosphere, according to the Illinois Environmental Protection Agency. An attached pressured gauge is located at the end of a short, wide tube that serves as the testing instrument. The removed gas cap is screwed onto the opposite end of the tube, which has one end connected to the exposed gas cap on the car. When pressure is applied, any leaks are shown by the gauge's reading (Moseley, 2022).

2.1.8 Conditions to Pass CT Emissions

There are a few things you can do to ensure the emissions test goes well. These include:

The Fuel Cap

The gas cap test will show if there is gas leaking from the tank through the gas cap. The emission test is passed if the cap seals. The gas cap should be checked for cracks, missing pieces, or damage to the seal. The gas cap cannot be an improvised cap from another container, a piece of cloth tailored to fit the tank opening, or any other non-official gas cap-related item.

Integrated Circuit

Those automobiles built after 1996 are subjected to this test. The part that keeps an eye on your vehicle and alerts you to problems via a light on your dashboard is the on-board diagnostics computer. It is commonly referred to as a "check engine" light. The chances of passing the Emission test are significantly decreased if it is on before the test.

Mufflers and Tail Pipes Vehicles produced prior to 1996 will undergo an acceleration simulation mode test that resembles a treadmill. A sensor is inserted within the tailpipe for the test. Have your tailpipe checked for leaks and damage that can affect the emissions reading. On vehicles manufactured prior to 1996, the Pre-conditioned Two-speed Idle Test is also conducted in the same manner.

Converter Catalytic

A catalytic converter must be installed in every vehicle. The car won't pass inspection without one. Usually found directly before the muffler, underneath the car, is the catalytic converter. The owner of a vehicle without a catalytic converter must install one before the vehicle may be registered. Emissions test cannot be passed until the converter is properly placed.

2.1.9 Common air pollutants

Ground-level Ozone

Ground-level ozone is a colorless and highly irritating gas that forms just above the earth's surface. It is called a "secondary" pollutant because it is produced when two primary pollutants react in sunlight and stagnant air. These two primary pollutants are nitrogen oxides (NOx) and volatile organic compounds (VOCs).

NO_x and VOCs come from natural sources as well as human activities. About 95 per cent of NO_x from human activity come from the burning of coal, gasoline and oil of motor vehicles, homes, industries and polp plants. VOCs from human activity come mainly from gasoline combustion and marketing, upstream oil and gas production, residential wood combustion, and from the evaporation of liquid fuels and solvents. Significant quantities of VOCs also originate from natural (biogenic) sources such as coniferous forests.

Ozone is known to have significant effects on human health. Exposure to ozone has been linked to pre-mature mortality and a range of morbidity health end-points such as hospital admissions and asthma symptom days. In addition to its effects on human health, ozone can significantly impact vegetation and decrease the productivity of some crops. It can also injure flowers and shrubs and may contribute to forest decline in some parts of Canada. Ozone can also damage synthetic materials, cause cracks in rubber, accelerate fading of dyes, and speed deterioration of some paints and coatings. As well, it damages cotton, acetate, nylon, polyester and other textiles.

The Ozone Annex was added to the Canada-United States Air Quality Agreement (December 2000) to address the transboundary air pollution leading to high levels of ground-level ozone, a major component of smog.

2.1.10 Disastrous Effects of Air pollution

Respiratory and Heart Problems. The effects of air pollution are alarming.

Child Health Problems. Air pollution is detrimental to your health even before you take your first breath.

Other disastrous effects of air pollution include:

i. Global Warming.

ii. Acid Rain.

iii. Eutrophication.

iv. Effect on Wildlife.

v. Depletion of the Ozone Layer.

The ocular surface is an excellent model with which to study the effect of various air pollutants on human health as it is constantly in direct contact with the environment and airborne matter and it can be non-invasively accessible, facilitating disease monitoring. The ocular surface includes the corneal and conjunctival epithelial layer, nerves, and tear lake (Sridhar, 2018) and serves as a barrier to chemicals, microbes, water, and other substances to protect the eye. A healthy eye should maintain a moist surface and normal pH value in various conditions thereby allowing individuals to remain asymptomatic throughout various physical and biological aggressions. However, air pollutants and weather conditions can compromise tear film and ocular surface health and affect the eye's ability to lubricate and protect itself. In addition, adverse environmental conditions can activate corneal nerves, leading the dry eye symptoms that include sensations of dryness, aching, tenderness, and burning, to name a few (Kalangara et al, 2017). The ocular surface is easily examined with a slit lamp and disease metrics quantified such as tear break up time (TBUT, lower scores more abnormal), corneal epithelial cell disruption (e.g., staining, higher scores more abnormal), and tear production via Schirmer strips (lower scores more abnormal). While with other organs, biospecimen collection can be challenging, in the eye tear collection is easy and non-invasive. For example, impression cytology can be performed to examine the superficial layers of the ocular epithelium.

The goal of this study is to assess the state of awareness on the effects of air pollution (PM and gases) and weather on symptoms and signs on ocular health and to examine whether severity and types of adverse health effects differ by levels and types of air pollutants. This information is needed so that source specific interventions can be developed to mitigate and prevent the adverse health effects of air pollution on the ocular surface, particularly in the indoor air environment as its quality is not regulated by the EPA.

Annual averages according to WHO guideline for outdoor air quality for NO_2, SO_2, PM_{10} and $PM_{2.5}$ are 40, 20, 20 and 10µg/m^3 respectively (WHO, 2018), while Nigerian Ambient Air Quality Standards (NAAQS) allowable limits for PM_{10}, NO_2, SO_2 and H_2S are 150µg/m^3, 0.03, 0.03 and 0.005ppm respectively (FEPA, 1999). By reducing air pollution levels, countries can reduce the burden of disease, and long and short-term illnesses. The current guidelines state that annual average concentrations of $PM_{2.5}$ should not exceed 5µg/m^3, while 24-hour average exposures should not exceed 15µg/m3 more than 3-4 days per year.

2.1.10 The Effects of Air Pollution to Human Eyes

Air pollution affects daily life activities in societies and even threatens the survival of humans. Air pollution affects health adversely and induces several health problems and diseases, such as cardiovascular disorders, respiratory tract diseases, ocular disease, neurologic disease, cancer, and even death (Eftim, et al., 2008; Pope, 2004, 2006 & Saxena, et al., 2003)

The numerous innervation on the ocular surface makes the cornea the most sensitive structure in the human body and therefore very sensitive to external agents (Tuominen, et al.,2003; Al-Aqaba, et al., 2019). Through the thin precorneal tear film layer, the eye fights against potentially harmful external materials and as such is susceptible to the adverse effect of air pollution (Koh, et al., 2018).

Air pollutants such as CO, NOx, PM, and O_3 frequently causes irritation and inflammation on the human eyes and oftentimes, conjunctivitis (Schwela, 2000). Numerous studies have tried to determine the impact of environmental toxins on the ocular surface. Studies show that persons who traveled to highly polluted areas where the particulate matter level was five times higher than the WHO annual average limit of 60 μg/m^3 suffered from extensive subclinical ocular surface changes (Saxena, et al., 2003). Versura et al, (2000) reported that the mixture of air pollutants led to cytological changes and inflammation in the ocular surface, leading to eye discomfort. An increasing number of studies have indicated that air pollutants such as particulate matter (PM) are associated with allergic conjunctivitis and glaucoma (Mimura et al., 2004; Hong, et al., 2016; Wang, et al., 2019; Chua, et al., 2019), and exposure to tobacco smoke can cause cataracts (Raju, et al., 2006). Moreover, age-related macular degeneration (AMD) is related to exposure to traffic-related air pollutants (Chang, et al., 2019). Another recent study from India found that 24% of the 210 young people in New Delhi who participated in the survey had abnormal Schirmer test results, which measure whether the eyes produce enough tears to stay moist. According to another scientific study, American veterans over 50 who reside in cities are more likely to develop dry eye syndrome. It found that "most metropolitan areas, including New York City, Chicago, Los Angeles, and Miami showed relatively high prevalence of dry eye syndrome (17 to 21%) and high levels of air pollution."

Air pollutants like nitric oxide can cause burning feelings in the eyes. These dangerous substances are known to irritate, swell, and make the eyes watery. According to Bourcier, et al. (2003) and Schwela (2000), the most common effect of air pollution on the eyes is irritation, which should be felt as soon as air pollutants come into contact with the eyes. According to Eftim et al. (2008), Pope (2006) and Pope & Dockery (2006), air pollution causes a variety of health issues and diseases, such as cancer, heart disease, respiratory issues, eye irritation, and death. It also causes various health impacts and effects on the eyes. The ocular surface's dense innervations are incredibly sensitive to environmental factors (Tuominem, 2003). Additionally, only a thin layer of tear film shields the eyes from potentially harmful outside stimuli (Wang et al. 2003). Thus, air pollution has a highly negative impact on human eyes. Conjunctivitis is a big issue when it comes to the negative consequences of air pollution on human eyes, which are mostly irritation and inflammation (Bourcier et al. 2003; Schwela, 2000). Toxins from the environment can affect the surface of the eye, and this has been the subject of numerous research studies. According to one study, many people who often travel through high-pollution locations experience subclinical ocular surface changes (Saxena et al. 2003). According to another study (Versura et al. 2000), air pollution affects cells and causes ocular surface inflammation, which can be uncomfortable.

Unknown processes underlie the impact of air pollution on conjunctivitis. Lacrimal pH changes brought on by tears becoming more acidic in an environment with a strong oxidant power (NO_2, SO_2), could irritate the ocular surface. Ozone can severely irritate the mucosa of the respiratory tract, and its effects are also noticeable on the mucosa of the eye. In this study, the number of outpatient visits was significantly affected solely by PM with a greater diameter (PM10). This may be because fine PM is easily removed from the ocular surface by tears without generating ocular pain, whereas coarse PM causes stronger feelings of a foreign body.

A particularly invasive chemical known as Hydrogen Sulphate has also been linked to cases of chemical conjunctivitis, overall eye irritation and in extreme cases blindness. Whilst found naturally in volcanic gas and animal protein, it is also used regularly within industrial processes, like combustion of biomass and fossil fuels. The US' Environmental Protection Agency (EPA) has stated that within urban areas, approximately 1to 92 ug/m^3 (micrograms) of Hydrogen Sulphate is found in the air, the general average being 0.11-0.33ppb (parts per bill) but still maybe higher in particular areas.

Even though complete vision loss due to air pollution exposure is uncommon, according to US EPA, 2016, "If exposed to air pollution for a long time, these impairments could become irreversible. One may have to endure harm for a longer period. It has been shown that pollution also makes the eyes blurry and impairs eyesight. Additionally, there have been instances where consumers had issues with color contrast.

The rods and cones of the retina's photoreceptors, which are responsible for human vision. While scotopic vision, or seeing in low light, is mediated by the rods, cones are in charge of seeing in bright light. In a 1992 electrophysiological investigation on rats, Fox and Katz found that exposure to low and moderate levels of lead (peak blood lead concentrations of 19 and 59 g/dL, respectively) resulted in long-term changes in rod sensitivity.

Electroretinographic (ERG) data demonstrate that such modifications exist at the retinal level. They discovered a rise in the calcium of the rod outer segment (ROS), a fall in the amount of rhodopsin (a photopigment found in rods) in each eye, and a decrease in the sensitivity of the rods to lead2 in the dark adaption function. Evidently, lead can significantly impair our eyes' capacity to function in low light, especially when it comes to adjusting to the dark. Air is essential for the survival and development of all lives on Earth. Its quality directly influences human health and is closely affected by the extent of civilization. Air pollution is a major contributor to the global burden of disease. There was increased mortality related to air pollution in both developing countries and developed countries such as the United States, despite more rigorous air quality standards. Although there are many natural sources of air pollution, for example, wildfires and volcanoes, since the Industrial Revolution, human technology has distributed the majority of substantial air pollution. The evolution of human civilization has been accompanied by industrialization and global transportation. Due to the development of industrialization, increasing numbers of fuel-burning motorized vehicles and factories have resulted in high levels of air pollution and poor air quality. For example, according to the Central Weather Bureau of Taiwan, the air quality index (AQI) in south Taiwan, where the main power plants of this island were located, was between 130~160 in January 2021, which is considered harmful to the normal population, and outdoor activities were not suggested.

2.1.11 The Composition of Air Pollution

Air pollution comprises a complex mixture of gas-phase pollutants and particles at harmful levels that are disbursed into the atmosphere due to either natural or human activities (Kemp et al., 2011). There are many pollutants in the atmosphere, such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon dioxide (CO_2), nitrogen monoxide (NO), carbon monoxide (CO), nitrogen oxides (NOx), particulate matter 2.5 ($PM_{2.5}$), and particulate matter 10 (PM_{10}), mostly generated from burning fuels or industrial production. In addition to traffic and industry activities, daily life activities, including tobacco smoking, household decorating and cooking, also produce COx, NOx, and volatile organic compounds (VOCs). For example, formaldehyde can cause DNA damage in animal cells, and its carcinogenicity has been assessed by many studies in the past three decades (Swenberg et al., 2013).

Indoor activities with poor ventilation of buildings in modern life are another cause of health problems. There is an increasing prevalence of asthma, autism, and childhood cancer with everyday exposure to these indoor chemical pollutants (Zhang et al., 2003).

2.1.12 The influences of air pollution to human eye

Air pollution influences daily living in societies and even jeopardizes the survival of humans. It is widely known that outdoor air pollution influences health. Air pollution induces many health problems and diseases, such as cardiovascular disorders, respiratory tract problems, ocular disease, neurologic disease, cancer, and death (Eftim et al., 2008, Pope., 2004, Pope & Dockery 2006 and Saxena et al., 2003).

The cornea is the most sensitive structure in the human body due to numerous innervations in the ocular surface and thus is extremely sensitive to environmental agents (Tuominen et al., 2003 and Al Aqaba et al., 2019). The eyes defend against potentially harmful external material with only a thin layer of precorneal tear film; as a result, human eyes are susceptible to the adverse effects of air pollution (Koh et al., 2018).

The adverse effects of air pollutants such as CO, NOx, PM, and O_3 on human eyes consist of mostly irritation and inflammation, with conjunctivitis being a frequent problem (Schwela, 2000). Numerous studies have tried to determine the impact of environmental toxins on the ocular surface. Saxena and colleagues found that persons who traveled to highly polluted areas where the PM level was five times higher than the WHO annual average limit of 60 $\mu g/m^3$ suffered from extensive subclinical ocular surface changes (Saxena et al., 2003). Versura and associates reported that the mixture of air pollutants led to cytological changes and inflammation in the ocular surface, contributing to eye discomfort (Versura et al., 1999). An increasing number of studies have indicated that air pollutants such as $PM_{2.5}$ are associated with allergic conjunctivitis (Mimura et al., 2014 and Hong et al., 2016) and glaucoma (Wang et al., 2019 and Chua et al., 2019), and exposure to tobacco smoke can cause cataracts (Raju et al., 2006). Moreover, age-related macular degeneration (AMD) is related to exposure to traffic-related air pollutants (Chang et al., 2019).

Many research investigations have surveyed the association between air quality and outpatient or emergency room visits with respect to respiratory or cardiovascular symptoms. However, only a limited number of studies have investigated the relationship between air pollution and ocular diseases. In the past three decades, no updated review has provided an overview of the impact of air pollution on the eye. This article aimed to determine the significance of the influence of air pollution on the eye and will discuss the effects of various outdoor and indoor pollutants on human eyes by reviewing papers in the last three decades.

The authors performed a review of the literature using PubMed databases, Medline databases and Google Scholar from 1 January 1990 to 31 July 2021. The main inclusion criterion for this review was data on ocular diseases associated with air pollution. The following keywords were used to search the databases: environmental pollution, air pollution, eye disease, ocular disease, acute effect, chronic or long-term effect, ocular surface, inflammation, conjunctivitis, cornea, dry eye, cataract, glaucoma, retinal disease, and retinal vascular disease. Health issues about moisture damage and microbiology-related topics were excluded from this overview. To provide the most up-to-date evidence, we preferred to choose more recent articles that were published in the last five years. The results were restricted to publications in English. Totally, 28 review papers and 83 research papers were cited in the review paper.

There are multitudes of studies elucidating that environmental pollution is harmful to the health of human organ systems, including the skin, oropharyngeal, and respiratory systems (Cohen et al., 2015; Di et al., 2017; Eftim et al.,2008; Pope, 2004; Pope & Dockery, 2006; Saxena et al., 2003). Eyes, as the most important sensory organs, are inevitably the first to be affected by air pollution. Therefore, in the past three decades, the number of studies evaluating the harmful effects of air pollution on the eye has increased.

Our analysis of the relevant studies included in this narrative review (see Table 1) demonstrated that the most common ophthalmologic disorder related to air pollution was inflammation of the conjunctiva (conjunctivitis). Figure 1 illustrates the outline of this article and the impact of air pollution on the eye. Here, we discuss each adverse effect of air pollution according to the origin of the compound.

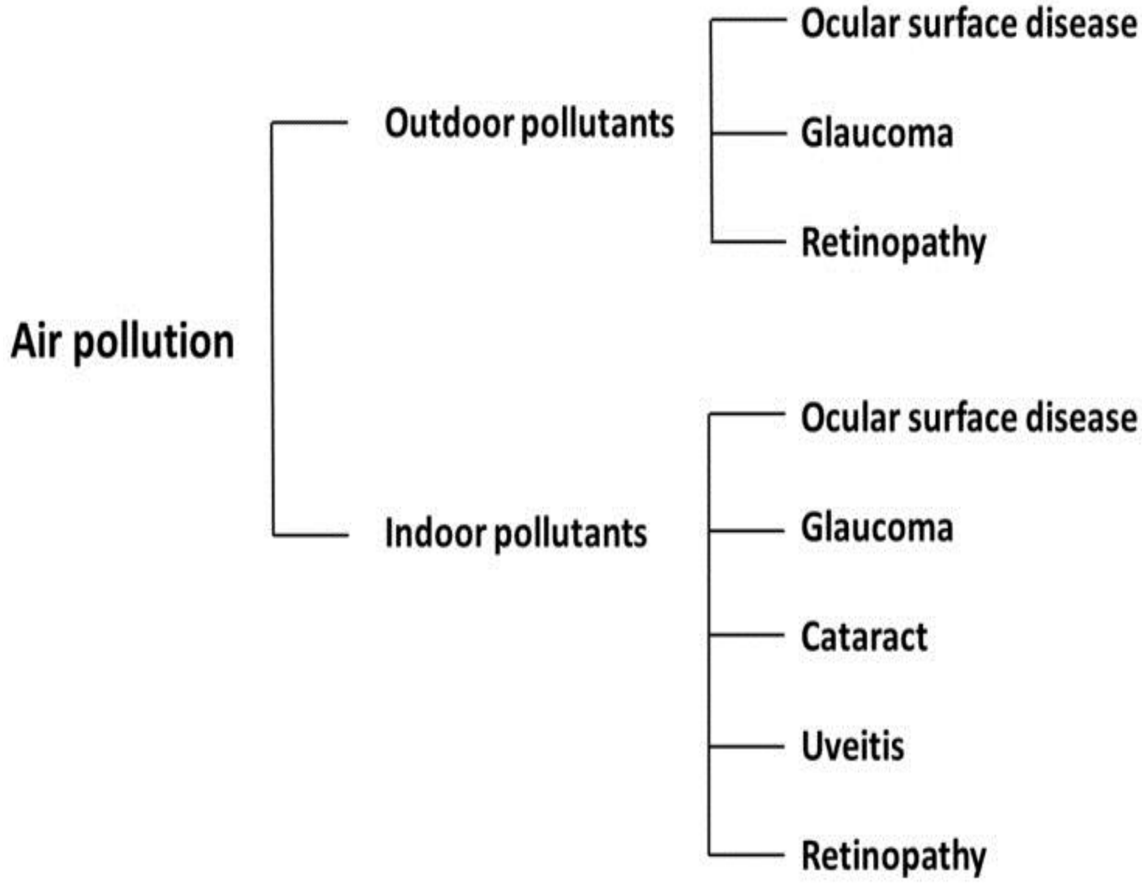

Figure 2.1: The impact of air pollutants on eye diseases from outdoor and indoor sources

Table 2.1: Eye-damaging air pollutants and their relevant studies on eye diseases.

Pollutant(s)	Ocular Disorder(s)	Study Model	Reference
Outdoor pollutant(s)			
CO	AMD	Population-based study	Chang et al. 2019
NO	Conjunctivitis	Data collection	Jetten et al. 2014
NO_2	AMD	Population-based study	Chang et al. 2019
	Conjunctivitis	Data collection	Aitio et al. 2016
	Nonspecific conjunctivitis		Huff et al. 2019
NO_x	Myopia	Data collection	Kappos et al. 2004
		In vivo/hamster model	
O_3	Nonspecific conjunctivitis	Data collection	Huff et al. 2019
$PM_{2.5}$	DR	National cross-sectional study	Holguin, 2008
	Myopia	Data collection	Kappos et al. 2004
		In vivo/hamster model	
	Nonspecific conjunctivitis	Data collection	Huff et al. 2019
	POAG	Nested case–control study	Hetland, 2005
	Retinal layer thinning	Community-based cohort study	McCreanor et al. 2007
PM_{10}	Childhood glaucoma	Retrospective cohort study	Vohra et al. 2021
	Nonspecific conjunctivitis	Data collection	Huff et al. 2019
	Retinal layer thinning	Community-based cohort study	McCreanor et al. 2007
SO_2	Nonspecific conjunctivitis	Data collection	Huff et al. 2019
Indoor pollutant(s)			
Acrolein	OSD	In vivo/rabbit model	Bourcier et al. 2003
Aldehydes	Tear film instability and lipid layer peroxidation	Tears from subjects	Jetten et al. 2014
CSE	AMD	In vitro/ARPE-19 cells	Chang et al. 2012
	Glaucoma	In vitro/primary rat RGCs	Torricelli et al. 2011 & Novaes et al. 2007
Formaldehyde	OSD	In vitro/WKD cells	Zhong et al. 2018
Naphthalene	Cataracts	In vivo/rat model	Liu et al. 2009 & Bron et al. 2007
Nicotine	OSD	In vitro/corneal epithelial cells	Tan et al. 2018
	Uveitis	Subjects' and patients' AqH	Yoon et al. 2018, Li et al. 2021, Zeng et al. 2021, Sun et al. 2021
$PM_{2.5}$	Dry eye syndrome	In vitro/HCE cells	Min & Min, 2019
		In vivo/mouse model	
Tabaco smoking	OSD	In vitro/HCE cells	Lodovici et al. 2011
		In vivo/mouse model	
	Rhino-conjunctivitis	Cross-sectional study	Baccarelli et al. 2007

2.1.13 Outdoor air Pollution

Outdoor air pollution is a significant public health problem in population centers worldwide. For decades, studies have demonstrated a strong association between air pollution and a spectrum of ill health effects. Outdoor air pollution is a major environmental health hazard that was associated with 3.7 million deaths worldwide in 2012 (Brook et al., 2010) and 4.2 million deaths in 2016 (Jarret and Boulton., 2012). The increasing trend in attributable deaths from 1990 to 2015 was partially due to the increase in outdoor air pollution levels in low- and middle-income countries Cohen et al., 2015). In 2016, the International Agency for Research on Cancer (IARC) classified outdoor air pollution as a human carcinogen, according to adequate evidence, especially for lung cancer (Lee et al., 2020). Automobile traffic is the predominant source of outdoor air pollution in developed urban areas. The components of outdoor air pollution are complicated and dynamic and include ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), lead (Pb), carbon monoxide (CO), and particulate matter (PM). The components vary seasonally and are affected by human activity and climatic events (Wei et al., 2019). PM is further classified into coarse PM (PM_{10}, PM with an aerodynamic diameter $\leq$ 10 μm), fine PM ($PM_{2.5}$, PM with an aerodynamic diameter $\leq$ 2.5 μm), and ultrafine PM ($PM_{1.0}$, PM with an aerodynamic diameter $\leq$ 1.0 μm) (Chua et al., 2020).

Pollutants originate from different sources. For example, NO_2 and ground-level O_3 (which derives from the effect of ultraviolet light on nitrogen dioxide) are primarily emitted from vehicle exhaust systems, while SO_2 originates from the burning of sulfur-containing fuels (e.g., coal-burning plants). Coarse PM primarily results from scattered ground or airborne dust; fine and ultrafine PM derive primarily from vehicular exhaust (Pan et al., 2020). Coarse and fine particulates differ in not only their physical properties and size but also their chemical components. PM_{10} primarily consists of geological materials, in comparison to $PM_{2.5}$ and $PM_{1.0}$, which have larger fragments of elemental and organic carbon (Shan et al., 2021). These variations in PM chemical composition are related to different toxicity profiles and can be used as tracers of vehicular emanations. For example, elemental carbon can be used to track traffic-related emissions (West et al., 2013). Outdoor air pollution consists of both primary pollutants released directly into the atmosphere and secondary pollutants formed in the air due to chemical transformation of primary pollutants. These chemical reactions are affected by temperature and thus can be affected by global climate warming. In addition, accumulated evidence has implied that air pollution can not only exacerbate ocular symptoms but also cause new-onset ocular disease. Table 2 demonstrates the 2021 World Health Organization (WHO) air quality guidelines, which were tightened following recommendations in 2005. According to the UN organization, the new recommendations reflect the recent evidence of the significantly higher-than-thought impact of even lower concentrations of air pollution on human health and wellbeing. A recent study estimated the death toll of air pollution at 8.7 million per year (Kabir & Kim, 2011).

Table2. 2: WHO 2021 air pollution guidelines in comparison with guidelines in 2005.

Pollutant(s)	Averaging Time	WHO 2021 Air Quality Guideline	WHO 2005 Air Quality Guideline	Change
$PM_{2.5}$ (µg/m^3)	Annual	5	10	−50%
	24-h	15	25	−40%
PM_{10} (µg/m^3)	Annual	15	20	−25%
	24-h	45	50	−10%
O_3 (µg/m^3)	Peak season	60	N/A	Newly introduced
	8-h	100	100	Unchanged
NO_2 (µg/m^3)	Annual	10	40	−75%
	24-h	25	N/A	Newly introduced
	1-h	200	200	Unchanged
SO_2 (µg/m^3)	24-h	40	20	+100%
	10-min	500	500	Unchanged
CO (mg/m^3)	24-h	4	N/A	Newly introduced
	8-h	10	N/A	Newly introduced
	1-h	35	N/A	Newly introduced
	15-min	100	N/A	Newly introduced

Ocular surface diseases (OSDs)

Traffic- and industry-related airborne byproducts account for most outdoor air pollution. For example, in New Delhi, India, the transportation component of air pollution was 72%, and the industry component was 20% in 2003. The level of suspended particulate matter (SPM) in New Delhi was five times higher than the annual average control limit of 60 mg/m^3 set by the World Health Organization (WHO). One study showed that people in New Delhi who commuted daily to the workplace using open vehicles (e.g., scooters, motorcycles, or bicycles) for more than 10 years had more ocular surface symptoms, such as redness, irritation, lacrimation, burning, and dryness, than people living near their workplace (Saxena et al., 2003). NO and NO_2, the primary products of diesel oil consumption by trucks and large vehicles, can travel long distances. A study indicated that higher nitric oxide (NO) and NO_2 concentrations were related to more severe conjunctivitis in people in Paris (Aitio et al., 2016). Another study from Taiwan reported that visiting an ophthalmologic outpatient clinic was associated with an increased chance of visiting an ophthalmology clinic for nonspecific conjunctivitis due to increased exposure to PM_{10} and $PM_{2.5}$, NO_2, SO_2, and O_3 (Huff, Carlsten and Hirota, 2019). Conjunctival disease caused by air pollution can manifest as subclinical ocular surface changes (Wolkolf, 2017) that frequently cause major discomfort, such as burning and grittiness, and require a clinical visit. Moreover, persistent exposure to air pollution can result in cellular transformation, including goblet-cell hyperplasia in the human conjunctival epithelium Wolkolf, 2017). Discomfort due to eye disorders can disrupt people's daily work efficiency and reduce road traffic safety.

In addition, air pollution may exacerbate dry eye disease (Jaen & Dalton, 2014). Dysfunction of the tear film is considered to be caused by two interrelated mechanisms: hyperosmolarity and tear film instability (Luengas et al., 2015). Tear hyperosmolarity may lead to changes on the ocular surface by inducing a series of inflammatory events in the ocular epithelium, which induce the expression of inflammatory mediators in the tear film. Consequent damage to the epithelium causes cell death via apoptosis, loss of goblet cells and decreased mucin production, leading to tear film instability. This instability subsequently disrupts the hyperosmolarity of the ocular surface, intensifying a vicious cycle (de Juniac et al., 2012). A study induced dry eye syndrome in mice with $PM_{2.5}$ eyedrops, and apoptosis of corneal superficial and basal epithelial cells was observed (Sarigiannis et al., 2011).

Glaucoma

Among air pollutants, $PM_{2.5}$ is one of the strongest and most consistent predictors of mortality. It is associated with pulmonary and cardiovascular disease and central nervous system conditions such as Alzheimer's disease, Parkinson's disease, and stroke (Cohen et al., 2015). Wang and associates reported that glaucoma was positively related to national levels of $PM_{2.5}$ (Wang et al 2019). $PM_{2.5}$ has been shown to be toxic to intraocular tissues and contribute to the development of ocular hypertension and glaucoma. Mechanistically, $PM_{2.5}$ and PM_{10} induce the production of NO and interleukin 8, causing increased oxidative stress (Jordan et al., 2011). Furthermore, $PM_{2.5}$ also increased oxidative stress and induced NLRP3 inflammasome-mediated pyroptosis, a form of nonapoptotic cell death in trabecular meshwork cells, in an in vitro study Blanc et al., 2005). Another study also reported that $PM_{2.5}$ exposure inhibited the proliferation of and increased apoptosis in neural retina cells, resulting in the abnormal development of the neural retina (Rushton, 2004).

According to the results of a UK Biobank study, participants in areas with higher $PM_{2.5}$ concentrations were more likely to report a diagnosis of glaucoma and to have a thinner macular ganglion cell–inner plexiform layer (GCIPL), as measured by spectral-domain optical coherence tomography (SD-OCT), than their counterparts (Chua et al., 2019). There was no association between intraocular pressure (IOP) and $PM_{2.5}$ exposure, suggesting that the relationship may occur through a pressure-independent mechanism, possibly neurotoxic and/or vascular effects (Chua et al., 2019). Sun and associates designed a nested case–control study to investigate whether exposure to $PM_{2.5}$ was related to the diagnosis of primary open-angle glaucoma (POAG) in Taiwanese adults (Hetland, 2005). They found that increased exposure to $PM_{2.5}$ was associated with the incidence of POAG. In a retrospective cohort study, Min and colleagues evaluated whether exposure to PM_{10} was related to the occurrence of childhood glaucoma (Vohra et al., 2021). Their results demonstrated that short-term and long-term exposure to PM_{10} increased the probability of developing childhood glaucoma. This finding implies that PM_{10} exposure may be a risk factor for childhood glaucoma.

Retinopathy and Maculopathy

Air pollution can induce oxidative stress, activate inflammatory pathways, and increase coagulation (Gawande et al., 2020, Martheswaran et al., 2021 and Choi et al., 2016). The retina is susceptible to oxidative stress due to its high consumption of oxygen and high proportion of polyunsaturated fatty acids and exposure to visible light (Young et al., 2019). In addition, oxidative damage increases with age, leading to retinal dysfunction and cell loss. A study reported that epithelial–mesenchymal transition (EMT) and activation downstream of cellular reactive oxygen species (ROS) may be responsible for $PM_{2.5}$-induced dysfunction in retinal cells (Bascom, 1991). As a result, the aging retina is potentially particularly susceptible to damage caused by air pollution. There are studies describing myopic macular degeneration, age-related macular degeneration, and diabetic retinopathy in association with air pollution (Kappos et al., 2004, Holguin, 2008, McCreanor et al., 2007 and Annesi-Maesano et al., 2004). In one study, exposure to $PM_{2.5}$ and NOx was reported to increase ocular surface inflammation and retinal inflammation, increasing the risk of developing myopic macular diseases (Kappos et al., 2004). A UK Biobank study including more than 50,000 people demonstrated that exposure to higher $PM_{2.5}$ and PM_{10} concentrations and more $PM_{2.5}$ absorbance were associated with inner and outer retinal layer thinning (McCreanor et al., 2007). Another 10-year cohort study analyzing links between the national health database and the air quality database showed that chronic exposure to a higher concentration of ambient NO_2 or CO significantly increased the risk of AMD (Chang et al., 2019). One study from Taiwan demonstrated a positive association between diabetic retinopathy and PM ≤ 2.5 and 2.5 to 10 μm in diameter, with odds ratios of 1.29 (1.11–1.50) and 1.37 (1.17–1.61), respectively (Annesi-Maesano et al., 2004). In a national cross-sectional study in rural China, Shan et al. enrolled 3111 diabetic patients, 329 of whom had diabetic retinopathy Holguin, 2008). Their results showed that increased exposure to a high concentration of $PM_{2.5}$ was related to an increased risk of diabetic retinopathy (DR) among diabetic patients in rural China. They postulated that PM could raise glucose levels and induce oxidative stress, inflammation, specific cytokine activity, and endothelial dysfunction, contributing to diabetic retinopathy.

2.1.14 Indoor Air Pollution

Indoor air pollution is associated with indoor tobacco smoking, dissipation of compounds used in building materials and decorations in buildings, cooking with oil and high heat, burning coal or biomass for cooking or heating, using pesticides, etc. (Diaz et al., 2007 and Vitoux et al., 2018). Moreover, building products and materials, cleaning products, and consumer products emit many chemically nonreactive volatile organic compounds (VOCs) and biologically reactive compounds, such as formaldehyde (FA) and acrolein.

Several VOCs, especially aldehydes, have low odor thresholds (Gupta et al., 2020). This influences the perceived indoor air quality and possibly overall sensory symptoms (Li et al., 2020). Therefore, personality factors, such as expectations about odor, anxiety level, or attitude toward health risks, may affect complaints of symptoms (Lee et al., 2016).

Exposure to high concentrations of indoor air pollutants, for example, concentrations of carbon monoxide at 60×10^3 $\mu g/m^3$ for 30 min or 100×10^3 $\mu g/m^3$ for 15 min, could lead to health effects (Smith, Vianna & Chauhan, 2017. Examples of acute effects are exacerbation of allergic symptoms, such as conjunctivitis, rhinitis, atopic dermatitis, and intoxication or death due to short-term exposure to very high concentrations of carbon monoxide (Lee et al., 2003). Examples of chronic health effects include cancer and noncancer effects related to

VOCs (Jain et al., 2017), respiratory diseases associated with secondhand tobacco smoke (e.g., chronic obstructive pulmonary disease (COPD)) (Perez-de-Arcelus et al., 2017), elevated susceptibility to respiratory infections, and cardiovascular disease (Tan et al., 2018). Some pollutants, including tobacco smoke and other combustion products, may exacerbate asthma symptoms (The Health Consequences of Smoking), whereas FA and other VOCs have been associated with sick building syndrome (SBS) (Nagata, Kojima, Sasaki, 1999).

These indoor air pollutants are reported to be harmful to the human eye, as discussed below.

Ocular surface disease

Tobacco smoking affects the ocular surface, resulting in symptoms such as itchiness, redness, and irritation of the eyes. The changes on the ocular surface include alteration of the lipid layer of the tear film, reduced tear secretion, and decreased corneal and conjunctival sensitivity and can cause disorders such as atopic kerato-conjunctivitis and allergic conjunctivitis. Tanisha et al. reported that aldehydes and free radicals released from electronic cigarettes may disturb the stability of the tear film and vape flavoring may damage the lipid layer through peroxidation. Furthermore, nicotine and acrolein in cigarette vapors cause an inflammatory response in corneal epithelial cells (Jetten et al., 2014 and Ambient Air Quality and Health, 2021).

Indoor smoking can cause an increased level of $PM_{2.5}$ that is 10 times higher than that in nonsmoking homes. Long-term exposure to fine PM induced oxidative stress in human corneal epithelial transformed (HCE) cells and altered the cytokine content of tears; moreover, inflammation of the ocular surface and dry eye syndrome subsequently developed in a mouse model (Min & Min, 2019). According to a questionnaire study, 82% of participants with household indoor tobacco smoking exposure reported eye irritation (Xu, Zigler & Lou, 1992). In addition, a large cross-sectional study including over 14,500 adolescents in France showed that environmental tobacco smoke exposure increased the risk of rhinoconjunctivitis by 20% (Baccarelli et al., 2007).

Indoor smoke can be produced by other sources, such as cookstoves. For example, a study in Guatemala showed that more than 60% of women who used cookstoves for cooking reported that their eyes were always irritated. However, when these participants were divided into those with exposure to miniature chimney stoves and those with exposure to open stoves, the chimney stove group had less eye irritation than the open stove group (Schaumberg et al., 2004).

Many in vivo and in vitro studies have focused on outdoor air pollution-induced eye disease; however, other studies have revealed correlations between eye diseases and indoor air pollutants. For example, Vitoux's in vitro study investigated the cytotoxic and inflammatory responses of the conjunctival cell line WKD exposed to combinations of environmental pollutants, such as air–liquid interface conditions combining low humidity, airflow, and formaldehyde gas, to mimic the inflammatory responses observed in dry eye patients (Zhong et al., 2018). Furthermore, the in vivo study by Suneel et al. investigated acrolein toxicity in rabbit eyes (Bourcier et al., 2003). The results of Suneel showed that topical or vapor application of acrolein severely injured rabbit eyes and led to a series of ocular pathologies, such as swelling of the eye, ocular surface inflammation, abnormalities, irregular collagen accumulation, and corneal opacity. Additionally, Li et al.'s study evaluated long-term cigarette smoke exposure using both in vivo mice and the in vitro conjunctival cell line HCEC, and their results showed that cigarette smoke stimulates ocular surface changes with dry eye, which may be correlated with inflammation and activation of the NF-κB pathway (Lodovici & Bigagli, 2011).

Glaucoma

Cigarette smoking is associated with many chronic disorders that have been considered serious global public health problems. However, investigations on the correlation between smoking and ocular disorders are scarce. Mechanistically, cigarette smoke extract (CSE) caused injury in primary rat retinal ganglion cells (RGCs) via apoptosis and autophagy by upregulating the mRNA levels of proapoptotic Bad and Bax and the protein level of the autophagy marker LC3B II (Torricelli et al., 2011). This mechanism contributes to the development and progression of glaucoma (Novaes et al., 2007).

Blue Mountains Eye Study data implied a moderate positive association between smoking and elevated IOP (a significant risk factor for glaucoma) (Nita & Grzybowski, 2017). A systematic review to evaluate the association between cigarette smoking and POAG included 17 papers in the final analysis. Their results showed that the link between current smoking and POAG was stronger than that between past smoking and POAG, and recent studies have implied that heavy smoking may elevate the risk of POAG (Fullerton, Bruce & Gordon, 2008). In a prospective and dynamic cohort study, Pérez-de-Arcelus et al. enrolled 16,797 participants without glaucoma and followed them for a median of 8.5 years. In the 8.5-year follow-up period, 184 new glaucoma cases were diagnosed. Current smoking was associated with a higher glaucoma incidence than never smoking (Saha et al., 2005).

Cataract

Cataracts have long been linked to cigarette smoking Pokhrel et al., 2005. The mechanism may be direct or indirect effects of inhaled toxic substances on lens tissues. A study enrolled 3924 subjects in rural southern India to investigate the impact of tobacco use on cataract formation; the results demonstrated that cataract formation was significantly associated with tobacco use (Raju et al., 2006). Although the exact compounds in cigarettes responsible for lens toxicity are unknown, one compound, naphthalene, is known to be cataractogenic and is used to induce cataracts in rat models (Liu et al., 2009, and Bron et al., 2007). Naphthalene, along with another metal toxin, Pb, is also found in biomass fuel (BMF) smoke. The production of smoke during the consumption of this fuel can cause cataract formation (Gonzalez et al., 2018). A systematic review of the impact of tobacco smoking on the pathogenesis of many disorders of the anterior segment of the eye in adults and children reported that smoking was a strong risk factor for age-related nuclear cataracts (Yuen et al., 2015).

One-third of the world's population burns organic material, including wood, feces, or charcoal (BMF), for cooking, heating, and lighting. This form of energy usage is related to high levels of indoor air pollution and an increase in the incidence of respiratory diseases, cardiovascular disorders, and cataracts (Lin et al, 2010). Epidemiological research from India and Nepal has shown that indoor cooking using BMF is related to cataracts and blindness (Roesel et al., 2011 & Sarir et al., 2009). Smoke causes oxidative stress and consumes plasma ascorbate, carotenoids, and glutathione, which offer antioxidant protection against cataract formation.

Uveitis

As uveitis develops due to immune dysregulation, data on the association between smoking and uveitis are rare. An epidemiological study in the American adult population using data from the National Health and Nutrition Examination Survey (NHANES) for 2009 and 2010 demonstrated that smoking was positively associated with uveitis (Goncalves et al., 2011). The Pacific Ocular Inflammation Study implied that cigarette smoking was significantly associated with new-onset uveitis (Iho et al., 2003). There is a stronger association between smoking and noninfectious uveitis. In a retrospective case–control study, Lin and associates reported that smoking was related to both infectious and noninfectious uveitis (Curnow et al., 2005). An observational cross-sectional study enrolled 350 patients with noninfectious uveitis. Roesel and colleagues found that smoking had a positive association with uveitis activity, resulting in an increased dose of steroid eye drops and increased occurrence of cataract and macular edema (Valenticic et al., 2011).

Chronic exposure to ROS in cigarette smoke upregulates the expression of TLR4 by human macrophages, promoting NF-κB activation and the production of interleukin (IL)-8 (Khera et al., 2012 and Quintana et al., 2008). Nicotine plays a similar role in neutrophils by generating peroxynitrite, a nitrate isomer that binds acetylcholine receptors to promote NF-κB-mediated cytokine IL-8 transcription (Yoon et al., 2018 and Quintana et al., 2008). Increased concentrations of IL-8, as found in the aqueous humor (AqH) in uveitis, act together with IL-6 and TNF-α to facilitate the migration and activation of macrophages that assault the uvea (Li et al., 2021, Zeng et al., 2021 and Sun et al., 2021).

Several carcinogenic compounds cause Th17 cell expansion by binding aryl hydrocarbon receptors on memory T cells (Veldhoen et al., 2008 and Torii et al., 2011). The resultant increase in the Th17 population results in the elevated secretion of IL-17 and IL-22, which conversely facilitate the migration and extravasation of leukocytes into various tissues (Escobar et al., 2013). Updated data have thus suggested that Th17 cells play a role in the pathological mechanism of not only uveitis but also multiple sclerosis, rheumatoid arthritis, and psoriasis (Escobar et al., 2013, Wang et al., 2012, Jadidi-Niaragh & Mirshafiey, 2011, van Hamburg et al., 2011, Zhang et al., 2011 and Smith et al., 2001). This shared pathogenesis perhaps illustrates why smoking is related to several and often concomitantly occurring autoimmune disorders.

Retinal and macular diseases.

Previous studies have shown that cigarette smoking is related to an increased risk of AMD (Khan et al., 2006). Regarding environmental cigarette smoke exposure, a case–control study showed increased risks of neovascular and atrophic AMD (Smith, Mitchell & Leader, 1996). However, in the Blue Mountains Eye Study, Smith and associates found that passive smoking does not significantly increase the risk for late AMD (Bai et al., 2021). Cigarette vapor was reported to accelerate the progression of inflammation and angiogenesis in the retina of mice, which were possibly associated with the onset of wet AMD (Pons, & Marin-Castano, 2011. In addition, nicotine inhaled in passive smoking increased the VEGF-to-PEDF ratio in RPE cells in an in vitro study. This alteration in the ratio may play a key role in the progression to wet AMD in passive smokers (Nita & Grzybowski, 2017).

A systematic review of the impact of direct tobacco smoking on the pathogenesis of many disorders of the posterior segment of the eye in adults and children revealed that tobacco smoking had a positive association with AMD, polypoidal choroidal vasculopathy, and inflamed cystoid macular edema in adults. Tobacco smoking decreases retinal and choroidal thickness. In addition, maternal smoking is a significant risk factor for stage 3 and 4 retinopathy of prematurity and a thinner retinal nerve fiber layer in children (Govindaraju, Bodas & Vij, 2017). Govindaraju et al. reported cigarette smoke-induced proteostasis and autophagy impairment, which may be associated with AMD pathogenesis, in retinal pigmental ARPE-19 cells (Chang et al., 2012).

Household fuel consumption is related to an increased indoor concentration of fine particles. Exposure to fine particles associated with solid fuel use causes systemic inflammatory responses and cytokine production. To our knowledge, AMD is due to genetic polymorphisms, and innate immune reactions and inflammation are recognized as etiologies.

Although there is a lack of evidence, chronic inflammation induced by indoor air pollution is a possible cause of AMD (Diaz et al., 2007).

2.1.15 Health effects of NO_2 exposures

Lung function can alter as a result of even slight daily variations in NO_2 (Int. Panis, L, 2017). Chronic NO_2 exposure can have negative consequences on the respiratory system, including airway inflammation in healthy individuals and an increase in asthmatic patients' respiratory symptoms. Ozone is produced by NO_2, which irritates the eyes and aggravates respiratory disorders. As a result, there are more visits to emergency rooms and hospital admissions for respiratory conditions, particularly asthma (US EPA, 2016).

The association between NO_2 and asthma has been investigated utilizing questionnaires and in-person interviews to explore the impact of toxicity on health. Since the majority of people in the world spend more than 80% of their time inside, indoor air pollution has a significant impact on health (Heinrich & Joachim, 2011). The amount of time spent indoors depends upon on several factors including geographical region, job activities, and gender among other variables. Additionally, as housing insulation advances, indoor air contaminants like NO_2 may be retained longer (Heinrich & Joachim, 2011). According to location, the prevalence of asthma has varied from 2 to 20%, with no obvious explanation for the variation (Heinrich & Joachim, 2011). This might be due to the "hygiene hypothesis" or "western lifestyle," which encapsulates the ideas of well-insulated homes with fewer occupants (Heinrich & Joachim, 2011). A different study that looked at the connection between indoor nitrogen exposure and respiratory symptoms discovered a statistically significant odds ratio of 2.23 (95% CI: 1.06, 4.72) among those who had been exposed to gas stoves and had a medical diagnosis of asthma (Garret et al., 1998).

A significant factor in indoor NO_2 exposure is the use of gas burners for cooking or heating homes. According to the 2000 Census, more than 50% of US households had gas stoves. Indoor NO_2 exposure levels are, on average, at least three times higher in gas-versus-electric stove-equipped residences, with multifamily dwellings having the greatest levels. The effects of NO_2 exposure are particularly negative for children who have asthma. Children with asthma who live in homes with gas stoves are more likely to experience respiratory symptoms such wheezing, coughing, and chest tightness, according to studies (Garret et al., 1998; & US EPA, 2016). In addition, females with asthma who used gas stoves had lower lung function, although this association was not found in boys (Chapman et al., 2003). Using ventilation when operating gas stoves may reduce the risk of respiratory symptoms in children with asthma.

In a cohort study with inner-city minority African American Baltimore children to determine if there was a relationship between NO_2 and asthma for children aged 2 to 6 years old, with an existing medical diagnosis of asthma, and one asthma related visit, families of lower socioeconomic status were more likely to have gas stoves in their homes. The study concluded that higher levels of NO_2 within a home were linked to a greater level of respiratory symptoms among the study population. This further exemplifies that NO_2 toxicity is dangerous for children (Hansel, et al., 2016).

2.1.16 Sulphur dioxide as an air pollutant

Sulfur dioxide (IUPAC-recommended spelling) or sulphur dioxide (traditional Commonwealth English) is the chemical compound with the formula SO_2. The odor of burnt matches is caused by a poisonous gas. It is emitted naturally by volcanic activity and is a byproduct of the extraction of copper and the combustion of fossil fuels that include sulfur. Nitric acid-like sulfur dioxide smells strongly of it. Sulfur dioxide is found on Earth, although only in minute amounts, with an atmospheric concentration of roughly 1ppm, according to Owen and Pickering (1977).

The atmosphere of Venus has the highest concentration of sulfur dioxide, at 150 ppm, making it the third most abundant atmospheric gas. Sulfur dioxide is present on other planets in a range of concentrations. It is an essential component of the planet's global sulfur cycle, where it reacts with water to form sulfuric acid clouds that cause global warming (Marcq et al., (2012). It has been implicated as a key agent in the warming of early Mars, with estimates of concentrations in the lower atmosphere as high as 100 ppm (Halevy, et al., 2007), though it only exists in trace amounts. On both Venus and Mars, as on Earth, its primary source is thought to be volcanic. The atmosphere of Io, a natural satellite of Jupiter, is 90% sulfur dioxide (Lellouch, et al., 2007) and trace amounts are thought to also exist in the atmosphere of Jupiter. Sulfur dioxide is a noticeable component in the atmosphere, especially following volcanic eruptions. According to the United States Protection Agency (EPA) (US, EPA), the amount of sulfur dioxide released in the U.S. per year was:

Year	SO_2
1970	31,161,000 short tons (28.3 Mt)
1980	25,905,000 short tons (23.5 Mt)
1990	23,678,000 short tons (21.5 Mt)
1996	18,859,000 short tons (17.1 Mt)
1997	19,363,000 short tons (17.6 Mt)
1998	19,491,000 short tons (17.7 Mt)

1999 18,867,000 short tons (17.1 Mt)

Sulfur dioxide is a major air pollutant and has significant impacts upon human health (US, EPA). In addition, the concentration of sulfur dioxide in the atmosphere can influence the habitat suitability for plant communities, as well as animal life (Hogan, 2010). Sulfur dioxide emissions are a precursor to acid rain and atmospheric particulates. Due largely to the US EPA's Acid Rain Program, the U.S. has had a 33% decrease in emissions between 1983 and 2002. This improvement resulted in part from flue-gas desulfurization, a technology that enables SO_2 to be chemically bound in power plants burning sulfur-containing coal or oil. In particular, calcium oxide (lime) reacts with sulfur dioxide to form calcium sulfite:

$CaO + SO_2 \rightarrow CaSO_3$

Aerobic oxidation of the $CaSO_3$ gives $CaSO_4$, anhydrite. Most gypsum sold in Europe comes from flue-gas desulfurization.

To control sulfur emissions, dozens of methods with relatively high efficiencies have been developed for fitting of coal-fired power plants (Lin et al. 2018).

Sulfur can be removed from coal during burning by using limestone as a bed material in fluidized bed combustion (Lindeburg, 2006).

Sulfur can also be removed from fuels before burning, preventing formation of SO_2 when the fuel is burnt. The Claus process is used in refineries to produce sulfur as a byproduct. The Stretfort process has also been used to remove sulfur from fuel. Redox processes using iron oxides can also be used (US Dept of Energy, 2011).

According to a study, the 221 coal plants in the EU combined release 2 and a half times as much sulfur dioxide as the 18 coal-fired power plants in the western Balkans (Carrington, 2021).

To reduce the emission of sulfur dioxide emissions into the atmosphere, marine engines may employ fuel additives such calcium additives and magnesium carboxylate (May, 2015). China was the biggest source of sulfur dioxide pollution as of 2006, with emissions in 2005 estimated to have been 25,490,000 short tons (23.1 Mt). This quantity, which has increased by 27% since 2000, is about equivalent to U.S. emission.

2.1.17 Health Effect of Sulphur dioxide

Sulfur dioxide irritates the skin and mucous membranes of the eyes, nose, throat, and lungs. High SO_2 concentrations can irritate the respiratory system and cause inflammation, especially while engaged in strenuous physical activity. Possible adverse effects include pain after taking a big breath, coughing, throat inflammation, and breathing difficulty. High SO_2 levels have the potential to worsen pre-existing heart illness, intensify asthma attacks, and decrease lung function in those who are sensitive. This gas may react with other airborne chemicals to change into a tiny particle that can enter the lungs and cause harm to health in a manner similar to that of other airborne chemicals.

2.1.18 Carbon monoxide (CO)

CO is a gas that is always present in the air, whether or not there is a fire or smoke. It has no flavor, no aroma, no taste, and doesn't irritate. It has been observed to be the most frequent cause of fatal poisoning, with a 31% incidence rate. Children are involved in 4% to 10% of poisoning cases on average, and 58% to 75% of poisoning-related fatalities are caused by CO inhalation. CO poisoning in the workplace occurs most frequently (11%) and is followed by thinner inhalation (31%). According to Uyasol et al. (2011) and Basar (2000), indoor heating accidents throughout the winter, especially when it's windy, are the most common cause of CO poisoning in our country. CO poisoning is the third-most common cause of unintentional mortality in the USA, most of which (57%) were due to inhalation of exhaust gases (Wolf, et al., 2008; Geehr, et al., 1989).

Sources of CO

1) Endogenous production: As a result of hemoglobin metabolism in humans, CO is created endogenously. It serves as a neurotransmitter, and every person produces extremely small amounts of it (0–5%). The amount is higher in babies (3–7%), smokers, and hemolytic anemia patients (5–10%). It is known as COHb when it saturates 0.5% of hemoglobin under physiological conditions (Blumenthal, 2000).

4) Hydrocarbons: CO is created when carbon-containing substances including coal, wood, petroleum, fertilizers, dry dung, and natural gas burn partially. Even though the concentration of hydrocarbons in the atmosphere is normally less than 0.001%, the ratio rises when incomplete combustion occurs. Greater air pollution is present in urban settings.

3) Exhaust emissions from automobiles are a major lethal source of carbon monoxide (CO). Within 10 minutes, exposure to gases generated in a closed garage might cause lethal blood levels of CO. Semi-closed garages and places beside them may also expose people to potentially lethal levels of radiation (Ernst and Zibrak, 1998).

4) Fire: Any item that is burned releases CO.

5) Propane and methane: Gases that don't completely burn produce CO. Leaks from poorly maintained or improperly used heating systems can be a source, as well as petrochemical industry use of natural gas and crude oil.

6) Methylene chloride: Vapor of methylene chloride, component of thinners and other solvents, penetrates the skin, is inhaled through the lungs, and transported to the liver via

blood circulation, where it is metabolized, resulting in release of CO (Ernst and Zibrak, 1998).

7) Cigarette smoke**:** Cigarette smoke is 4% CO. Baseline COHb level in smokers and nonsmokers living in metropolitan cities have been detected at 10% and 2%, respectively (Blumenthal., 2001).

Pathophysiology of CO poisoning

CO gas may be readily absorbed by the lungs and remain unaltered. Following absorption, it mostly binds to hemoglobin (90%) and myoglobin and cytochrome C oxidase sporadically (10%). Less than 1% of carbon monoxide is oxidized to carbon dioxide, and less than 1% of carbon monoxide is dissolved in plasma. In both human and animal studies, it has been shown that brain and perivascular injuries were hypoxic as a result of oxidative stress (reoxygenation) related to CO exposure, and that cardiac injury has been linked to hypoxia. Hypoxia-induced injury to the central nervous system (CNS) may result in cardiovascular insufficiency when CO levels are high enough to act on smooth muscle and cause hypotension (Tomaszewski, 2000; Hampson, 2000). CO can either cause cellular damage by:

Reducing the blood's ability to carry oxygen and oxygen diffusion. enters hemoglobin via diffusion. Compared to oxygen, CO has a 200-fold higher affinity for hemoglobin. When someone is poisoned, CO and oxygen struggle to attach to hemoglobin; CO prevails in this race. As a result, poisoning could result from even a slight increase in CO levels (Haldane effect; Ernst and Zibrak, 1998). It stops hemoglobin from carrying oxygen to tissues. The oxygen-hemoglobin dissociation curve shifts to a hyperbola because CO binds to hemoglobin more strongly than oxygen. when a result of this change, tissue hypoxia develops when hemoglobin's ability to carry oxygen to tissues declines (Blumenthal, 2001).

Causing tissue damage: Not all pathophysiological effects of CO poisoning can be accounted for by CO's binding to hemoglobin. Observations in various animal studies suggest that direct effect of CO on cells is more important than decrease in oxygen carrying capacity of hemoglobin.

Cells' regular respiratory processes are hampered by CO. Cellular respiratory failure results from CO's irreversible binding to hemeproteins (cytochrome a-3 and myoglobin), which transport oxygen into the cell. The result is mitochondrial degradation in CNS and heart cells, which leads to cellular damage, tissue damage, and a need for more energy. Although oxygen therapy improves mitochondrial activities, cellular damage cannot be repaired (Blumenthal, 2001; Turner et al., 1999).

By attaching to cardiac myoglobin, CO damages the myocardium. Myoglobin and CO have an attraction for one another that is 60 times greater than that of oxygen. Arrhythmias, hypotension, and myocardial depression are brought on by the CO's binding to cardiac myoglobin. In a vicious loop, developing cardiac dysfunction as a result of CO poisoning makes tissue hypoxia even worse.

CO causes CNS reoxygenation damage. CO promotes formation of oxygen free radicals. CO causes hypoxia, which induces production of oxygen free radicals, resulting in reversible demyelinization in brain (Gozubuyuk, et al., 2017).

Clinical findings in CO poisoning

Pregnant women, infants, children, the elderly, people with cardiovascular illness, anemia, or lung disease are more vulnerable to CO poisoning than other patients. The amount of CO inhaled, the length of exposure to CO, and the general health of the affected person all determine how severe the clinical symptoms of CO poisoning are. Despite the fact that CO poisoning is damaging to all systems, the CNS and cardiovascular systems are more frequently impacted. Neurological symptoms are well-defined; however, information on cardiac diseases, particularly in youngsters, is scarce and might be challenging to identify. Myocardial damage can occur even in the absence of any overall symptoms. In cases of CO poisoning, cardiac arrest brought on by ventricular arrhythmia is the most common cause of death. Clinical findings differ between cases of acute and chronic poisoning (Gozubuyuk, et al., 2017).

2.1.19 Exposure and Vision

Due to its toxicity to our important organs, including our bones, heart, kidneys, and nervous system, lead exposure is known to alter a variety of bodily functions (Needleman, 2004). However, little research has been done on how it affects vision, a core cognitive function. Due to the close connection between our eyes and the central nervous system (CNS), it is obvious that lead's capacity to impede the nervous system's growth will definitely have an impact on our eyesight. According to studies, lead exposure can cause diminished rod photoreceptor sensitivity (Fox and Katz, 1992), blurred vision (IPCS, 2004), itchy eyes (Hazardous Substance Fact Sheet, 2002), and an increased risk of cataracts (Schaumberg et al. 2004) and optic neuritis Gilfillan, 1990). Interestingly, although high concentrations of lead exposure are detrimental, a recent study has shown the beneficial effects of small amounts of lead in preventing and treating eye disease.

Lead Accumulation May Lead to Cataract

Despite the fact that lead toxicity in humans had long been known, throughout the twentieth century lead was widely used in industrial products and processes, leading to widespread exposures and dispersion of its consequences. Lead is a common ingredient in a variety of consumer goods around the world, including paint, plumbing supplies, fuel, and craft items. Lead is still a problem in several nations outside of the United States because of some of these methods of exposure.

Lead has been linked to a variety of harmful health impacts, including neurotoxic effects and learning disabilities in children. According to other research, the introduction of lead into the eye's lens may alter the protein's structure, reducing the transparency of the lens. Cataracts are the leading cause of blindness. About 13 million people over the age of 40 in the United States alone have cataracts, and the costs of cataract surgery reach almost 4 billion annually.

Particulate Matter

According to Ciencewicki and Jaspers (2007) and the US EPA (1996), particulate matter is a mixture of particles and droplets in the air that includes a variety of substances like dust, soil, metals, acids, and organic compounds.

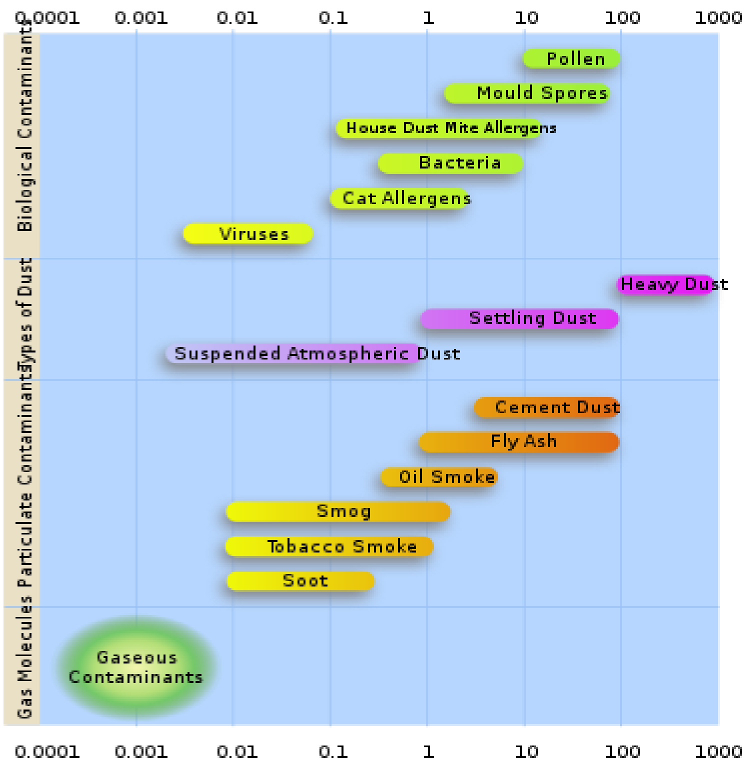

Figure 2.2: Types, and size distribution in micrometres (µm), of atmospheric particulate matter.

Source: Airborne particulate size charts. Wikipedia

Particulates: Microscopic particles of solid or liquid substance suspended in the air are often referred to as atmospheric aerosol particles, atmospheric particulate matter, particulate matter (PM), or suspended particulate matter (SPM). In contrast to the particulate matter alone, the word "aerosol" frequently refers to the particle/air mixture (Seinfeld & Pandis). Both natural and man-made sources of particulate matter exist (Plainiotis & Pericleous, 2010). In addition to direct inhalation, they have effects on the climate and precipitation that are harmful to human health.

According to Brown et al. (2013), the types of atmospheric particles include suspended particulate matter, thoracic and respirable particles, inhalable coarse particles (PM10), which are defined as coarse particles with a diameter of 10 micrometers (m) or less, and fine particles (PM2.5), which are defined as fine particles with a diameter of 2.5 m or less. (US EPA, 2016); ultrafine particles, with a diameter of 100 nm or less; and soot.

The IARC and WHO designate airborne particulates as a Group 1 carcinogen (EHP, 2016). Particulates are the most harmful form (other than ultrafines) of air pollution (Wasley et al., 2019), due to their ability to penetrate deep into the lungs, blood streams and brain, causing health problems including heart attacks, respiratory disease, and premature death (US EPA, 2016). In 2013, a study involving 312,944 people in nine European countries revealed that there was no safe level of particulates and that for every increase of 10 $\mu g/m^3$ in PM_{10}, the lung cancer rate rose 22% (95% CI [1.03–1.45]). The smaller $PM_{2.5}$ were particularly deadly, with an 18% increase in lung cancer per 5 $\mu g/m^3$ (95% CI [0.96–1.46]) as it can penetrate deeper into the lungs (Raaschou-Nielsen, 2013). Worldwide exposure to $PM_{2.5}$ contributed to 4.1 million deaths from heart disease and stroke, lung cancer, chronic lung disease, and respiratory infections in 2016 (State of Global Air/2018). Overall, ambient particulate matter ranks as the sixth leading risk factor for premature death globally (The Weight of Numbers).

Health Effects of Particulate Matter

The effects of inhaling particulate matter that have been widely studied in humans and animals include asthma, lung cancer, respiratory diseases, cardiovascular disease, premature delivery, birth defects, low birth weight, developmental disorders, (Perraud, et al., 2012; Schiffer, et al., 2018; International Panis, 2008) neurodegenerative disorders, mental disorders, and premature death. Outdoor fine particulates with diameter less than 2.5 microns accounts for 4.2 million annual deaths worldwide, and more than 103 million disability-adjusted life-years lost, making it the fifth leading risk factor for death. Air pollution has also been linked to a range of other psychosocial problems. Particulates may cause tissue damage by entering organs directly, or indirectly by systemic inflammation. Adverse impacts may obtain even at exposure levels lower than published air quality standards deemed safe. Compromised quality of air contains harmful gases such as carbon monoxide**,** nitrogen dioxide and coarse dust particles which have to lead to a greater number of people complaining of red and watery eyes and various eye allergies.

In children, volatile organic compounds (VOCs) are a frequent source of eye and airway discomfort. Additionally, they are able to produce the gas ozone. When ozone is high in the atmosphere, it protects the earth from ultraviolet radiation, but when it is close to the ground, it may be quite harmful. VOCs are typical chemical substances; some are produced by humans, and some occur naturally. Although the word "organic" appears in the name, this is not the kind of organic that your preschooler will not eat, such as organic broccoli. Instead, "organic" here just refers to how chemists categorize these substances.

Air quality can be significantly impacted by VOCs. Studies have shown that the quality of indoor air can be up to 10 times worse than that of outdoor air. The issue is largely caused by VOCs. Some VOCs react with sunlight to create ozone, a gas that contributes significantly to pollution.

2.2 Theoretical framework

This is a set of ideas, concepts, theories, and assumptions that help researchers understand a specific problem or phenomenon. It is a blue-print that researchers use to design, conduct, and analyse their research.

One theoretical model that can be used to support the study topic of "influence of air pollutants on ocular health of road transport workers in Imo state Nigeria" is the Social Ecological Model (SEM). The Social Ecological Model provides a comprehensive framework for understanding the complex interplay of various factors that influence health behaviours and outcomes, including those related to air pollution. The social ecological is a framework that helps to understand how health is affected by a variety of factors, including the individual, their community, and their physical, social, and political environments. The model is based on the idea that health is a broad concept that includes physical, mental, and social wellbeing (World Health Organisation, 1947).

The Social Ecological Model

The Social Ecological Model developed by Bronfenbrenner (1979) emphasizes that health is influenced by multiple levels of influence ranging from individual factors to interpersonal relationships, community settings, and broader societal contexts. It recognizes that health behaviours and outcomes are shaped not only by individual characteristics but also by the interactions between individuals and their social and physical environments.

Application of the Social Ecological Model to the study

Applying the Social Ecological Model to the influence of air pollutants on ocular health study allows for a holistic understanding of the factors that influence the implementation and effectiveness of carrying out this study. Here is a breakdown of how each level of the Social Ecological Model can be applied:

Individual Level: This level focuses on individual characteristics, knowledge, attitudes, and behaviours towards various health topics as well as their engagement in environmental health activities.

Interpersonal Level: This level explores the influence of relationships and social networks on health. Assessing the interpersonal level may involve examining the role of drivers and other road transport workers in influencing healthy activities. It may also involve evaluating the collaboration and communication between these stakeholders in maintaining healthy motor park activities that will ameliorate air pollution.

Organisational/Institutional Level: This level examines the characteristics of the motor park organization and its policies, practices, and resources related to health. Assessing the organizational level may involve evaluating the availability of resources for health education, the presence of supportive policies, the integration of maintenance of healthy air pollution limit and the coordination of healthy services within the motor parks.

Community Level: This level considers the influence of the broader community and its resources, norms, and values on health. Assessing the community level may involve examining community partnerships, engagement with local health agencies, and the availability of community resources that support controlled air pollution in motor parks.

Policy/Systems Level: This level focuses on the broader societal and policy factors that influence health. Assessing the policy/systems level may involve evaluating national and regional policies, guidelines, and regulations related to motor park health programmes. It may also involve examining the coordination between different sectors in implementing and supporting healthy friendly air initiatives in the motor parks.

By utilizing the Social Ecological Model, researchers can assess and understand the multi-level factors that influence the implementation and effectiveness of healthy motor park air pollution limit activities. This model helps identify the complexities and interactions between various levels, providing a comprehensive framework for conducting a thorough assessment and informing strategies for improving healthy motor park activities that will ameliorate air pollution.

2.2.1 Disastrous Effects of Air pollution

Respiratory and Heart Problems. The effects of air pollution are alarming.

Child Health Problems. Air pollution is detrimental to your health even before you take your first breath.

Air pollution effect in the atmosphere include:

Global Warming.

Acid Rain.

Eutrophication.

Effect on Wildlife.

Depletion of the Ozone Layer.

The ocular surface is an excellent model with which to study the effect of various air pollutants on human health as it is constantly in direct contact with the environment and airborne matter and it can be non-invasively accessible, facilitating disease monitoring. The ocular surface includes the corneal and conjunctival epithelial layer, nerves, and tear lake (Sridhar, 2018) and serves as a barrier to chemicals, microbes, water, and other substances to protect the eye. A healthy eye should maintain a moist surface and normal pH value in various conditions thereby allowing individuals to remain asymptomatic throughout various physical and biological aggressions. However, air pollutants and weather conditions can compromise tear film and ocular surface health and affect the eye's ability to lubricate and protect itself. In addition, adverse environmental conditions can activate corneal nerves, leading the dry eye symptoms that include sensations of dryness, aching, tenderness, and burning, to name a few (Kalangara et al, 2017). The ocular surface is easily examined with a slit lamp and disease metrics quantified such as tear break up time (TBUT, lower scores more abnormal), corneal epithelial cell disruption (e.g., staining, higher scores more abnormal), and tear production via Schirmer strips (lower scores more abnormal). While with other organs, biospecimen collection can be challenging, in the eye tear collection is easy and non-invasive. For example, impression cytology can be performed to examine the superficial layers of the ocular epithelium.

The goal of this study is to assess the state of awareness on the effects of air pollution (PM and gases) and weather on symptoms and signs on ocular health and to examine whether severity and types of adverse health effects differ by levels and types of air pollutants. This information is needed so that source specific interventions can be developed to mitigate and prevent the adverse health effects of air pollution on the ocular surface, particularly in the indoor air environment as its quality is not regulated by the EPA.

2.2.2 Ocular Surface Diseases

According to the most recent definition of ocular surface disease (OSD), it is a multifactorial disease of the ocular surface that causes progressive histopathologic and clinical alterations to the ocular surface along with symptoms like pain, vision abnormalities, and tear film instability. The tear film's enhanced osmolarity and an elevation of inflammatory mediators are its defining characteristics. The more frequent causes of OSD are prolonged topical preservative usage, meibomian gland dysfunction, and anterior blepharitis **(**Ittoop, et al., 2015**)**

Ocular surface disease typically enters its acute stage within the first two weeks of symptom development. Conjunctival inflammation, necrosis, and lid edema are the primary ocular findings. Between 15 and 75 percent of patients experience bilateral, difficult-to-control membranous conjunctivitis About 25% of hospitalized patients have corneal involvement, including epithelial abnormalities and corneal infiltrates (Vieira, et al., 2013). Some ocular surface diseases include; pterygium, dry eyes, pinguecula, blepharitis, etc.

Research has shown that people in New Delhi who use open vehicles such as bicycles, motorcycles or scooters daily to their workplace for more than 10 years had more ocular surface symptoms, such as irritation, redness, lacrimation, burning, and dryness, than people living close to their workplace (Saxena, et al., 2003). Nitric oxide (NO) and NO_2, the primary products of diesel oil consumption by trucks and large vehicles, can travel long distances and are major causes of severe conjunctivitis (Aitio, et al., 2016). Most outdoor air pollutions are caused by traffic- and industry-related airborne byproducts. Studies have shown that the transportation component of air pollution in New Delhi, India, was 72%, and the industry component was 20% in 2003. The level of suspended particulate matter (SPM) in New Delhi was five times higher than the annual average control limit of 60 mg/m^3 set by the World Health Organization (WHO). Another study from Taiwan found that due to increased exposure to PM10 and PM2.5, NO_2, SO_2, and O_3, going to an ophthalmologic outpatient clinic was linked to a higher likelihood of going to an ophthalmology clinic for nonspecific conjunctivitis (Huff, et al., 2019). Air pollution-related conjunctivitis might present as subclinical ocular surface alterations (Wolkoff, et al., 2017), which frequently result in severe discomfort like burning and grittiness and necessitate seeing a doctor. Additionally, long-term exposure to air pollution can change cells, including the human conjunctival epithelium, which develops goblet-cell hyperplasia. Eye diseases can cause discomfort that interferes with everyday productivity and lowers the safety of the road.

Air pollution may also make dry eye condition worse. Hyperosmolarity and tear film instability are two linked processes that are hypothesized to be involved in tear film dysfunction (Luengas, et al., 2015). By causing a cascade of inflammatory events in the ocular epithelium, which promote the expression of inflammatory mediators in the tear film, tear hyperosmolarity may cause alterations on the ocular surface. Tear film instability results from subsequent injury to the epithelium, which also results in goblet cell loss, a reduction in mucin synthesis, and cell death by apoptosis. This instability then disturbs the ocular surface's hyperosmolarity, increasing a vicious cycle (De Juniac, et al., 2012). According to Sarigiannis, et al., PM2.5 eyedrops cause dry eye syndrome, and corneal superficial and basal epithelial cells death when administered to mice.

Studies have shown that a high concentration of airborne toxins can interrupt the blood flow in the eyes' blood vessels. If normal blood flow in the eyes is blocked or restricted, it can lead to eye stroke, retinal vein occlusion, glaucoma and more. Exposure to air pollution can cause several symptoms in the eyes (Wu et al., 2019). These symptoms include:

i. Burning and redness sensations
ii. Irritation
iii. Watering
iv. Discharge
v. Allergy with severe itching, redness, discharge, swelling of the eyes and difficulty in opening the eyes. (Wu et al., 2019).

Multiple studies in various cities around the world have found that increased air pollution is correlated with more cases of dry eye, conjunctivitis (pink eye), and other eye infections and irritations.

Environmental factors like pollutants, toxic gases and chemicals, bacteria, smoking, various drugs, variable humidity, temperature variations, ultraviolet radiations, cosmetics affect the various parts of eyes like cornea, conjunctiva, etc. in several ways leads to plenty of eye disorders like cataract, conjunctivitis, glaucoma and dry eye.

2.2.3 Pterygium

A pterygium is a wing-shaped, vascular, fleshy growth that starts on the conjunctiva and can expand to the corneal limbus and beyond (its name comes from the Greek word pterygos, which means "little wing"). Pterygia are relatively prevalent in the general population and normally have little impact on vision and the eye itself, changing just slightly in appearance. Few studies have been done on the natural history and management of early pterygia since they are typically asymptomatic, and most ophthalmologists typically view them as a minor issue until the lesions encroach on the visual axis. On how to manage pterygia appropriately, there is no agreement.

Morphology

A pterygium consists of three distinct parts: the cap, the head and the body/tail.

The cap or leading edge is a flat zone on the cornea that consists mainly of fibroblasts that invade and destroy Bowman’s membrane.

The head is a vascular area that lies behind the cap and is firmly attached to the cornea.

The body/tail is the mobile area of the bulbar conjunctiva, which can be easily dissected from the underlying tissue (Krachmer, et al., 2005).

Stocker’s line, which is iron deposition in the basal layer of corneal epithelium anterior to the cap, indicates that the pterygium is chronic.

Etiology and Pathogenesis

Many theories exist that attempt to explain the pathophysiology of a pterygium, however the etiology has not yet been identified. Most studies have found that incidence varies geographically, with countries nearer the equator having greater rates of occurrence. The main contributing factor to pterygia is assumed to be exposure to excessive ultraviolet (UV) light. People who live in sunny climates and those whose jobs expose them to UV light (such as farmers, fishers, arc welders, and drivers) are more likely to experience this.

According to a well-known notion, UV radiation, notably UV-B radiation, is to blame for the increasing prevalence of pterygium in inhabitants of tropical regions. The working hypothesis is that this radiation causes mutations in the p53 tumor suppressor gene, thus facilitating the abnormal proliferation of limbal epithelium (Ang et al. 2007). Also, some other studies have implicated wind, dust, sunlight and gases.

Histologically, the subepithelial tissue shows senile elastosis (basophilic degeneration) of the substantia propria with abnormal collagen fibers. There is dissolution of Bowman’s membrane, followed by invasion of the superficial cornea.

A unique feature of the pterygium epithelial cell is its positive immunohistochemical staining for different types of matrix metalloproteinases that are absent in normal conjunctival, limbal or corneal cells (Krachmer, et al., 2005).

2.2.4 Pinguecula and Pterygium

A pinguecula consists of a limbal (at junction of cornea and sclera) and bulbar conjunctival degenerative process caused by ultraviolet light damage to the subepithelial tissue. It is very common and rarely causes symptoms. If the supportive tissue degeneration extends into the cornea, it becomes a pterygium, which may cause corneal astigmatism and require surgical excision. Pterygium is therefore defined as: A growth that starts on the clear tissue of the eye that can spread to the cornea. It is a noncancerous, triangular growth which may occur on one or both eyes. It is more common in people who spend a lot of time in the sun, such as those who work outdoors. About 2 to 10% with a pterygium have a coexisting squamous carcinoma, which often is clinically unsuspected and diagnosed only by histopathologic examination.

2.2.5 Dry Eye

Dry eye disease is a common condition that occurs when your tears aren't able to provide adequate lubrication for your eyes. Inflammation and injury to the ocular surface, neurosensory abnormalities, and tear film instability and hyperosmolarity all play a part in the development of dry eye, a multifactorial illness of the ocular surface characterized by a loss of tear film homeostasis and accompanied by visual symptoms. A complicated condition affecting both the ocular surface and adnexa, dry eye disease. Increased tear film osmolarity and ocular surface inflammation, which are accompanied by ocular symptoms (discomfort, visual disruption), are crucial components in the diagnosis. Hyperemia and inflammation are not always related, and this can be verified using a variety of tools and approaches. However, there is currently no "gold standard" or adequate assays to identify ocular surface inflammation in clinical practice (Zemanová, 2021). Tears can be inadequate and unstable for many reasons. For example, dry eyes may occur if you don't produce enough tears or if you produce poor-quality tears. This tear instability leads to inflammation and damage of the eye's surface. Dry eyes feel uncomfortable. If you have dry eyes, your eyes may sting or burn. You may experience dry eyes in certain situations, such as on an airplane, in an air-conditioned room, while riding a bike or after looking at a computer screen for a few hours.

Causes.

Dry eyes are caused by a variety of reasons that disrupt the healthy tear film. Your tear film has three layers: fatty oils, aqueous fluid and mucus. This combination usually keeps the surface of your eyes lubricated, smooth and clear. Problems with any of these layers can cause dry eyes.

Reasons for tear film dysfunction are many, including hormone changes, autoimmune disease, inflamed eyelid glands or allergic eye disease. For some people, the cause of dry eyes is decreased tear production or increased tear evaporation.

2.2.6 Decreased Tear Production

Dry eyes can occur when you're unable to produce enough liquid tears, also called aqueous fluid. The medical term for this condition is keratoconjunctivitis sicca. Common causes of decreased tear production include:

Aging

Certain medical conditions including Sjogren's syndrome, allergic eye disease, rheumatoid arthritis, lupus, scleroderma, graft vs. host disease, sarcoidosis, thyroid disorders or vitamin A deficiency

Certain medicines, including antihistamines, decongestants, hormone replacement therapy, antidepressants, and medicines for high blood pressure, acne, birth control and Parkinson's disease

Corneal nerve desensitivity caused by contact lens use, nerve damage or laser eye surgery, though symptoms of dry eyes related to this procedure are usually temporary.

2.2.7 Increased Tear Evaporation

The oil film produced by small glands on the edge of your eyelids (meibomian glands) might become clogged. Blocked meibomian glands are more common in people with rosacea or other skin disorders.

Common causes of increased tear evaporation include:

Posterior blepharitis (meibomian gland dysfunction)

Blinking less often, which tends to occur with certain conditions, such as Parkinson's disease; or when you're concentrating during certain activities, such as while reading, driving or working at a computer

Eyelid problems, such as the lids turning outward (ectropion) and the lids turning inward (entropion).

Eye allergies

i. Preservatives in topical eye drops
ii. Wind, smoke or dry air
iii. Vitamin A deficiency

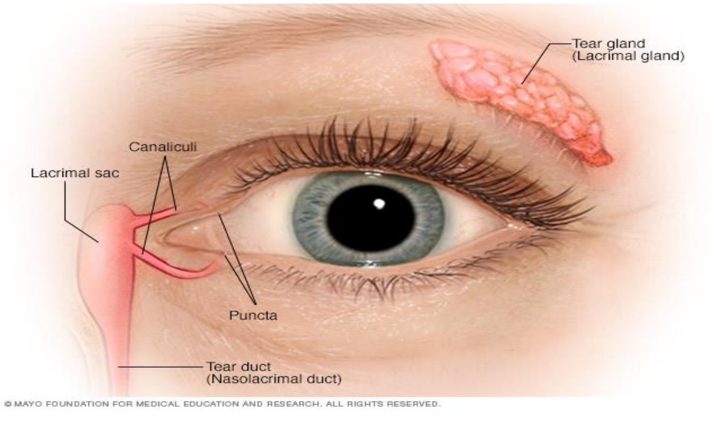

Figure 2.3: Tear glands and tear ducts open pop-up dialog box

Source: Mayo Foundation for Medical Education and Research.

2.2.8 Diagnosis

Tear break up time (TBUT)

The TBUT is the amount of time needed for the tear film to separate after a blink. It measures the stability of the tear film quantitatively (DEW, 2007). 15-20 seconds is the typical tear film breakup time. The inferior cul-de-sac is covered with a fluorescein strip that has been dampened with saline. A broad beam slit lamp with a blue filter is used to evaluate the tear film after several blinks for the emergence of the first dry spots on the cornea. Patients with mild to moderate dry eye disease have TBUT values of less than 5 to 10 seconds, which indicate tear instability. Noninvasive BUT (NIBUT), a method for measuring TBUT without adding fluorescein to the tear film, is another option (Abelson, et al., 2002).

2.2.9 Schirmer Test

The Schirmer test monitors the quantity of tears produced by the lacrimal gland over a predetermined period (Pflugfelder, et al., 2000). A thin strip of filter paper is placed in the inferior cul-de-sac after topical anesthetic has been applied to perform the fundamental test. After the patient's eyelids have been closed for five minutes, the number of tears that moisten the paper are calculated by how long the wet strip is. By stimulating the lacrimal reflex arc, the Schirmer II test evaluates lacrimal gland tear (Phadatare, et al., 2015); wetness of 15 mm after 5 minutes is regarded as abnormal. The test's outcomes are unpredictable since any modification of the eyelid can change them. Additional tear leakage may impact the outcomes. Less than 6 mm of strip wetting in 5 minutes is considered a reliable diagnostic indicator of aqueous tear insufficiency. Like the basic test but without using a topical anesthetic, the Schirmer I test evaluates both basic and reflex tearing (Javadi and Feizi, 2011).

2.2.10 Questionnaires

A variety of dry eye disease-related topics are covered in differing depths by questionnaires, including diagnosis, attribution of precipitating events, and impact on quality of life (Phadatare, et al., 2015). There can be anywhere from 3 to 57 items asked in a given questionnaire. Clinicians can evaluate patients for possible dry eye disease by giving them a standardized questionnaire. Depending on the intended use of the data, such as for diagnosis-only usage, patient recruitment for a clinical study, or treatment, a particular questionnaire might be chosen. The Ocular Surface Disease Index (OSDI) questionnaire is divided into three sections: section 1 examines the relative frequency of occurrence of each symptom (such as a gritty sensation in the eye, sensitivity to light, and blurred vision); section 2 asks about restrictions on particular activities (such as reading, nighttime driving, and watching television); and section 3 examines the impact of environmental factors (such as wind, low humidity, and air conditioning) on the eyes (Perry and Donnenfeld, 2004).

2.2.11 Fluorophotometer

The degradation of sodium fluorescein is used in this expensive technique to assess the volume and flow of tears. Patients with symptomatic DES also have lower tear turnover rates, which are calculated as the percentage by which the fluorescein concentration in tears drops each minute after instillation. Increased tear cytokine concentration and delayed clearance have both been linked, and this may be a factor in chronic inflammation (Phadatare, et al., 2015).

2.2.12 Epithelial staining

Special dyes including Rose Bengal, Lissamine Green, and Fluorescein are employed in a staining approach to detect anomalies in the surface of the eye, the caliber of the tear film, and the degree of dryness. The degree of the dryness can be determined in a straightforward and uncomplicated manner. Conjunctiva is stained more intensely than the cornea in mild cases of DES, and Rose Bengal is more effective at detecting them than fluorescein stain (Phadatare, et al., 2015). One of several scoring systems can be used to photograph and score a staining pattern (DEW, 2007). The cornea is more stained by fluorescein than the conjunctiva because it accumulates in epithelial erosions and stains dying or degenerating cells. Lissamine green and rose bengal stain both healthy and unhealthy cells with insufficient protection (Kim and Foulks, 1999). Rose Bengal should not be used in place of lissamine green since it causes less pain, discomfort, and corneal toxicity. On slit-lamp examination, it is more challenging to understand since it is a little less sensitive and fleeting (DEW, 2007)

2.2.13 Conjunctivitis

Inflammation and swelling of the conjunctival tissue, engorgement of the blood vessels, ocular discharge, and discomfort are all symptoms of conjunctivitis. Conjunctivitis affects many people globally and is one of the most common causes of office visits to general medical and ophthalmology clinics. It has been stated that non-ophthalmologists such as internists, family medicine doctors, pediatricians, and nurse practitioners diagnose more than 80% of all acute instances of conjunctivitis (Shekhawat, et al., 2017). This places a significant financial strain on the healthcare system and accounts for a significant amount of office visits across several medical specialties. Conjunctivitis is one of the most commonly diagnosed conditions in ophthalmologic outpatient and emergency room visits (Cohn & Kurtz, 1992 & Lee et al. 1994). According to statistics from the Bureau of Taiwan National Health Insurance, conjunctivitis is diagnosed in more than 40% of ophthalmologic outpatient visits each year. Air pollution-related conjunctival illnesses can cause subclinical alterations to the ocular surface (Saxena et al. 2003), but they frequently cause severe discomforts like burning and irritation that necessitate seeing a doctor. In addition, prolonged exposure to air pollution might cause biological alterations, such as goblet-cell hyperplasia on the ocular surface (Novaes et al. 2007). Burning, irritation, stinging, and tearing are symptoms of ocular disorders that can make it difficult for people to go about their everyday lives, which can affect their productivity at work and their safety on the road. Occasionally, using steroid eye drops to treat ocular illnesses causes cataracts, glaucoma, and other severe adverse effects that can cause irreversible vision loss. (Gerometta et al. 2009). Even allergic conjunctivitis, which is brought on by airborne particles like pollen as opposed to other bacterial infections and is a byproduct of smoke and fumes, can be brought on by air pollution. Allergic conjunctivitis symptoms include swelling, blurred vision, and excruciating eye pain. It is brought on by the conjunctiva's irritation, which is the eyeball's outer covering.

2.2.14 Diagnosis

Eye discharge, conjunctival injection, the presence of red eyes, eyelashes that stick together in the morning, grittiness of the eye(s), eyelid or conjunctival edema, and a history of contact with people who have conjunctivitis are a few of the clinical signs and symptoms that are used to help diagnose infectious conjunctivitis (Everitt, 2002). It's possible that allergic conjunctivitis goes undiagnosed and untreated (La Rosa, et al., 2013). In the absence of any considerable corneal involvement, it manifests as itching, chemosis, and redness. Conjunctival edema frequently exceeds conjunctival hyperemia in terms of severity. The appearance of huge papillae in the superior tarsal conjunctiva and intense itching are the key symptoms of vernal keratoconjunctivitis (VKC), while the presence of conjunctival scar and an anterior subcapsular cataract helps to confirm the diagnosis of atopic keratoconjunctivitis (AKC) (Bielory & Bielory, 2012). Chronic toxic conjunctivitis, another related illness, may exhibit watery discharge, a punctate epithelial erosion of the cornea, a follicular reaction that follows a papillary reaction, and dermatitis of the eyelids (Soparkar, et al., 1997).

2.2.15 Retinopathy and Maculopathy

The macular is the area of the eye that is most vulnerable due to its blood supply. We are aware that reactive chemicals, or free radicals, caused by NO_2 and CO air pollution can harm cells. The harm caused by nerve damage to the eye or brain is similarly irreparable. Oxidative stress, inflammatory responses, and exposure to visible light can all be brought on by air pollution (Yang, et al., 2019). Additionally, when coagulation rises, more oxidative damage is done (Choi, et al., 2016). Due to its high oxygen consumption and high content of polyunsaturated fatty acids, which can result in retinal malfunction and cell death, the retina is vulnerable to oxidative stress. According to a study, epithelial-oxygen species (ROS) may be to blame for the dysfunctional effects of PM2.5 on retinal cells (Bascom, et al., 1991). Retinal hemorrhages, according to Blumenthal, are hardly encountered. This can speak more to how thoroughly the patient was examined than to how frequently this symptom actually occurs. Many doctors have a "blind spot" when it comes to ophthalmoscopy, which can be made worse by subpar equipment and the avoidance of mydriatics in an emergency. All patients who had been exposed to carbon monoxide for more than 12 hours (about half of the patients in that series) had retinal hemorrhages (Kelley and Sophocleus, 1978).

According to case studies and series, retinal hemorrhages tend to be peripapillary and can happen either superficially or deeper in the nerve fiber layer (flame haemorrhages). Venous alterations can be seen as engorgement and tortuosity, as well as oedema of the optic disc. In general terms these changes reflect the extent of the hypoxic insult to the retina (Ferguson et al. 1985). Therefore, the retina of the elderly may be more vulnerable to harm from air pollution. Studies have linked air pollution to myopia, age-related macular degeneration, and diabetic retinopathy (Holguin, 2008; Kappos, et al., 2004; McCreanor, et al., 2007). Exposure to PM2.5 and NOx increases the likelihood of retinal and ocular surface inflammation (Kappos, et al., 2004). According to a UK Biobank study involving more than 50,000 participants, the inner and outer retinal layers are thought to shrink as a result of exposure to higher PM2.5 and PM10 concentrations as well as increased PM2.5 absorption (McCreanor, et al., 2007). Another 10-year cohort study that examined connections between the air quality and national health databases found that long-term exposure to greater ambient NO_2 or CO concentrations significantly increased the incidence of AMD (Chang, et al., 2019). In a study conducted in Taiwan, the odds ratios for diabetic retinopathy and PM with diameters between 2.5 and 10 m were 1.29 (1.11-1.50) and 1.37 (1.17-1.61), respectively. In a cross-sectional study conducted by Shan et al. in rural China, 3111 diabetic individuals were included, and 329 of them later developed diabetic retinopathy. They discovered that diabetics in rural China were more likely to develop diabetic retinopathy (DR) when exposed to greater PM2.5 concentrations. They proposed that PM might result in endothelial dysfunction, oxidative stress, inflammation, and specific cytokine activity, all of which might result in diabetic retinopathy.

2.2.16 Glaucoma

Increased cases of glaucoma may also be a result of an increase in hazardous substances in the atmosphere. Researchers in the UK discovered that among 100,000 people who had glaucoma eye exams, those who lived in densely populated areas had a 6% higher risk of having the disease. In fact, people who live in cities are 50% more likely than those who do not to receive a glaucoma diagnosis. The increased risk of heart disease and blood vessel narrowing associated with air pollution raise the possibility that these conditions may potentially contribute to the onset of glaucoma. The potential that particles could directly harm the neurological system and cause inflammation is another option.

$PM_{2.5}$ is one of the most potent and reliable indicators of death among air contaminants. It is linked to stroke, Alzheimer's disease, Parkinson's disease, and cardiovascular, pulmonary, and nervous system disorders (Cohen, et al., 2017)). Glaucoma was found to be favorably correlated with national PM2.5 levels, according to Wang, et al. (2019). It has been established that PM2.5 is harmful to intraocular tissues and promotes the growth of glaucoma and ocular hypertension. $PM_{2.5}$ and PM_{10} induce the production of NO and interleukin 8, causing increased oxidative stress. Additionally, $PM_{2.5}$ also increased oxidative stress and induced NLRP3 inflammasome-mediated pyroptosis, a form of nonapoptotic cell death in trabecular meshwork cells, in an in vitro study (Jordan, et al.,2011; Blanc, et al., 2005). Another study found that exposure to PM2.5 reduced neural retinal cell proliferation and increased apoptosis, leading to the aberrant development of the neural retina (Rushton, 2004).

Results from a UK Biobank study showed that participants who lived in areas with higher PM2.5 concentrations were more likely to report having been diagnosed with glaucoma and to have a thinner macular ganglion cell-inner plexiform layer (GCIPL) than their counterparts. The lack of an association between intraocular pressure (IOP) and PM2.5 exposure suggests that the link may be due to a pressure-independent mechanism, most likely including neurotoxic and/or vascular effects (Chua, et al., 2019). To determine if exposure to PM2.5 was associated with the diagnosis of primary open-angle glaucoma (POAG) in Taiwanese people, Sun and collaborators created a nested case-control study (Hetland, et al., 2005). POAG incidence was correlated with increased exposure to PM2.5. Min and coworkers examined whether exposure to PM10 was associated with the development of childhood glaucoma in a retrospective cohort research (Vohra, et al., 2021). Their findings showed that both short- and long-term exposure to PM10 increased the risk of a kid getting glaucoma. This finding suggests that exposure to PM10 may increase the chance of developing glaucoma in children.

Bangladesh is another nation with some of the worst air quality in the world. Over 50,000 higher than in 2017, there were 173500 air pollution-related deaths in 2019. Additionally, glaucoma affects at least 560000 adults over the age of 40. In Europe, cities like

Birmingham and Madrid are looking to create ‘clean air zones’, implementing driving restrictions within inner city spaces. However, a lot more large-scale solutions are in need around the world to ensure a great chance of permanently cutting life-shortening emissions and improving eye health around the world to prevent unnecessary illnesses that could permanently alter vision.

The mean estimated effects during the cool seasons were 2-3 times stronger than those during the warm seasons, and it was only statistically significant during cool periods. These results are supported by previous studies that reported larger estimates of NO_2 in the cool seasons for conjunctivitis (Bao *et al*., 2021) and psychosis (Tong, et al., 2016) in China. The reasons behind seasonal differences can be complex, but possible causes may be that the concentrations of NO_2 were lower during the warm seasons than cool seasons and there were more heavy rains in warm seasons to clean up ambient pollution and reduce the outdoor time for people in Chongqing.

2.2.17 Cataract

A cataract is a clouding of the eye's crystalline lens, which prevents light from reaching our retina. Age-related cataract risk can be increased by cumulative lead exposure, according to research by Schaumberg et al. (2004). A cataract is an eye condition where the normally clear lens has become opaque, obstructing the flow of light. It is a slowly progressing illness that accounts for a sizable portion of global blindness (Nizami and Gulan, 2022). A group of Boston-area men aged 60 to 93 (mean age: 69) had their bone lead levels assessed in the tibia and patella5. Men with the highest tibial lead concentrations (7.78 4.85 g/dL) had a more than 2.5-fold higher risk of cataract than men with the lowest concentrations (4.49 2.65 g/dL). After age was considered, it was estimated that 42% of cataracts in this cohort were attributed to lead exposure. Lead has been found to be present in lenses with cataract in various studies. It is thought that the invasion of lead into the lens may alter its redox status and cause conformational changes in protein, hence reducing lens clarity. Lead is known to disrupt glutathione metabolism in the lens[9] and raise the protein-bound glutathione and cysteine content[5]. Moreover, lead can hinder the biological balance of calcium in our system, that is, the calcium homeostasis, which is vital in maintaining lens transparency. Evidently, many studies reveal that lead may be present at higher concentrations in cataractous lenses compared to transparent lenses, 9-11. [redox: a reversible chemical reaction in which one reaction is an oxidation and the reverse is a reduction.

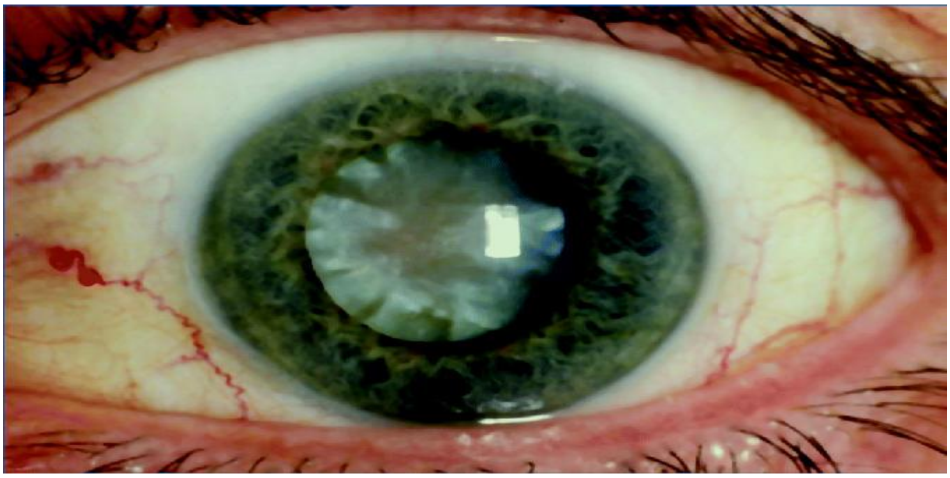

Figure 2.4: An eye with cataract

Source: Environ Health Perspect. 2005 Mar;113(3):A163.

2.3 Empirical Studies

In empirical study, conclusions of the study are drawn from concrete empirical evidence. This evidence is also referred to as verifiable evidence. This evidence is gathered either through quantitative market research or qualitative market research methods. The empirical research cycle involves:

1. Observation

2. Induction
3. Deduction
4. Testing
5. Evaluation

A study used SRM 2786 as a standard reference material to assess the effects of fine particulate matter (PM) on cultured human corneal epithelial (HCE) cells and on the ocular surfaces of mice. For up to six months, a fine PM suspension in the C57BL/6 was placed in the mice's eyes. The tear film break-up time (TBUT), ocular fluorescein staining, and tear secretion were all examined in vivo in the third and sixth months. Conjunctival goblet cells and corneal histological abnormalities were investigated by staining at the conclusion of the in vivo investigation, and cytokines in tissue were also found. Additionally, fine PM was applied to HCE. cells for 12 and 24 hours. Reactive oxygen species (ROS) production and cell death were thereafter discovered. Results showed that PM damages the mouse eye in a dose- and time-dependent manner. Tear production and tear film break-up time were both dramatically reduced in mice, and corneal epithelial injury, conjunctival epithelial cell apoptosis, and hypoplasia of conjunctival goblet cells also developed. Additionally, following 12 and 24 hours of exposure to fine PM, higher levels of apoptosis and ROS generation were seen in HCE cells in a time- and dose-dependent manner. Therefore, the study concluded from the results that fine PM is harmful to the ocular surface as well as HCE cells. Topical administration of fine PM suspension over an extended period of time in mice causes ocular surface alterations resembling those seen in dry eye (Yang Q et al.).

Electronic cigarette use, also known as vaping, was first developed as a way to help smokers quit, but it has since gained popularity as a smoking alternative. These gadgets, which are marketed as being safer than traditional cigarettes, have been found to contain heavy metals, air pollution, and chemical carcinogens. Martheswaran, et al. did a review to elucidate on vaping's recognized impacts on the ocular environment and bring up any other possible implications that would necessitate more research. It was discovered after a thorough review of the literature that vape flavorings may cause lipid layer damage by peroxidation, and that aldehydes and free radicals present in electronic cigarettes may cause a change in the stability of the tear film. It has been demonstrated that exposure to e-cigarette vapor causes corneal staining, with nicotine and acrolein perhaps triggering an inflammatory response in corneal epithelial cells. Additionally, nicotine has been proven to cause nystagmus, have ocular blood flow-restricting effects, and perhaps impair retinal light-adapted vision. Although unpredictable, explosions caused by vaping may also cause long-term ocular injuries and impaired visual acuity. Therefore, further research and improved awareness of the damage that electronic cigarettes may cause to sensitive organs are necessary due to the possible risks of compounds like nicotine and aldehydes.

Electrodiagnostic testing are able to identify modest visual changes brought on by carbon monoxide overdose. These alterations are typical of optic neuropathy and imply that cigarette amblyopia and toxic neuropathy have similar etiological pathways (Simons and Good, 1998). It's interesting to note that smokers seem to be especially susceptible to increased ambient carbon monoxide, which can have negative impacts on light sensitivity and dark adaptation (von Restorff and Hebisch, 1988).

A study from China Medical University in Taiwan looked into the connection between long-term retinal degeneration and two prevalent air pollutants, Carbon Monoxide (CO) and Nitrogen Dioxide (NO_2). Nearly 40,000 persons over 50 who lived in Taiwan's comparable urban areas were included in the study, and data on their health insurance and air quality were examined. Four types of exposure to contaminants were created for people. A greater proportion of the 40 000 participants over 50 who resided in areas with high CO and NO_2

concentrations had age-related macular degeneration. Only extremely high exposure levels were linked to danger. The risk begins to materialize once the exposure exceeds a certain point. In comparison to those exposed to the lowest levels of the pollutants, those exposed to the highest concentrations of CO had an 84% higher risk of acquiring the condition, and those exposed to the highest concentrations of NO_2 had a nearly 200% higher risk. Individuals who had only minor exposure to the two contaminants did not exhibit noticeably greater risk. There was no evidence prior to this investigation that air pollution might increase the prevalence of eye problems. Juo took a gamble and concentrated on macular degeneration since he was aware that toxins like NO_2 and CO are delivered by the bloodstream and that the macula, or the bundle of nerve cells in the center of the retina, is nourished by numerous blood vessels (Chan*g*, et al., 2009).

Another research reveals a summary of a critical examination of the real data on exposure and health effects (aside from cancer) of fine particle air pollution conducted by a working group of the German commission on air pollution prevention of VDI and DIN. In Germany, average yearly PM10 (PM2.5) ambient particle concentrations range from 10 to 45 micrograms per cubic meter to a high of 200 micrograms per cubic meter. PM2.5/PM10 ratios typically range from 0.7 to 0.9. impacts on health: Over the past ten years, a large number of new toxicological and epidemiological research on the health impacts of particulate matter (PM) have been published. In conclusion, prolonged exposure to PM over many years or decades is linked to higher rates of overall, cardiovascular, and neonatal death. Lung development, respiratory symptoms, and immune system performance are all impacted by morbidity. Studies conducted in the short term consistently link exposure to daily PM concentrations with death and morbidity on the same day or the days that follow. Patients with cardio-vascular diseases, diabetes, pneumonia, asthma, and other respiratory illnesses are particularly impacted. There is no suggestion of a threshold value for the health consequences, however the strongest connections are reported for PM2.5 and PM10, respectively. The epidemiological findings are supported by the current toxicological data, which also provides suggestions about the processes underlying the impacts. In conclusion, further lowering the limit values recommended for 2005 will significantly lessen the health risks associated with particle air pollution. (Kappos et al., 2004).

Bourcier, et al. (2003), investigated short-term associations between ophthalmologic emergency room visits and air pollution. It was concluded after the study that there is a relation between NO_2, O_3, PM_{10}, and SO_2 and conjunctivitis,

In Xinxiang, China, Song et al.'s (1994) investigation looked on the short-term relationship between NO_2 and the risk of eye and adnexa illnesses. It was shown that NO_2 exposure was closely linked to keratitis, which raises the possibility of hospital outpatients developing eye and adnexa disorders.

Road traffic air pollution is a severe health concern, and those who already have respiratory conditions may be more vulnerable. In a bid to throw more light on the effects of air pollution, McCreanor, et al. conducted randomized, crossover research to look into the effects of short-term exposure to diesel traffic on people with asthma in an urban, roadside setting. 60 persons with either mild or moderate asthma were enlisted. Each participant strolled for two hours along Oxford Street in London then, on a different occasion, in Hyde Park, a nearby park. The assessments of the exposure, the body's physiological state, and the immune system were noted. Participants were considerably more exposed to ultrafine particles, elemental carbon, nitrogen dioxide, and fine particles (2.5 microm in aerodynamic dimension) on Oxford Street than in Hyde Park. In comparison to the decreases in FEV1 and FVC after exposure in Hyde Park, walking for two hours on Oxford Street caused asymptomatic but consistent decreases in FEV1 (up to 6.1%) and FVC (up to 5.4%) The results were more pronounced in persons with intermediate asthma compared to participants with moderate asthma. Following these changes, airway acidification and neutrophilic inflammation markers increased (4.24 ng/ml of sputum myeloperoxidase after exposure in Hyde Park vs. 24.5 ng/ml after exposure on Oxford Street; P=0.05). (maximum decrease in pH, 0.04% after exposure in Hyde Park and 1.9% after exposure on Oxford Street; P=0.003). The changes were associated most consistently with exposures to ultrafine particles and elemental carbon. Therefore, the study findings serve to illustrate and clarify the epidemiologic data linking the amount of traffic exposure to lung function in asthma.

Fossil fuel combustion, in particular the burning of coal, gasoline, and diesel, is a significant source of airborne fine particulate matter (PM2.5) and a significant cause of mortality and disease worldwide. Prior risk evaluations have employed a concentration-response function with little support from the literature using data at both high and low concentrations to investigate the health response to total $PM_{2.5}$, not just $PM_{2.5}$ from fossil fuel burning. Vohra, et al. (2021) conducted this study using a recent meta-analysis of more recent data with a wider range of exposure to investigate mortality related to PM2.5 from only fossil fuel combustion. In America and Europe, where there is accurate information on the relative risk of this health outcome from exposure to PM2.5, the study also assessed the mortality due to lower respiratory infections (LRI) among children under the age of five. The global exposure levels to $PM_{2.5}$ attributable to fossil fuels in 2012 was calculated using the chemical transport model GEOS-Chem. From the calculation obtained from this study, fossil fuel component of PM2.5 causes 10.2 (95% CI: -47.1 to 17.0) million premature deaths worldwide each year. The regions with the highest mortality impact are those with significant levels of PM2.5 from fossil fuels, such as China (3.9 million) and India (2.5 million) and parts of eastern US, Europe and Southeast Asia. The estimate for China predates a significant reduction in fossil fuel emissions, which results in a decrease of 2.4 million premature deaths due to a 43.7%

decrease in fossil fuel PM2.5 from 2012 to 2018. This brings the global total to 8.7 million premature deaths. Additionally, the study showed an additional 876 deaths per year in North America, 747 in South America, and 605 in Europe among youngsters (0–4 years old) who were exposed to LRI. This study shows that a significant portion of the death load is caused by the fossil fuel component of $PM_{2.5}$. This is a clear signal to policymakers and stakeholders to further encourage a switch to clean sources because fossil fuel combustion is easier to control than other sources and precursors of PM2.5 like dust or wildfire smoke.

Previous studies have shown links between air pollution and human ocular symptoms, but no studies have looked at the potentially dangerous impact of air pollution on nonspecific conjunctivitis. This necessitated the study by Chan*g*, et al. (2009) which looks on the connection between air pollution and outpatient conjunctivitis visits in Taiwan. The hazards of the short-term impacts of particulate matter (PM), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide on nonspecific conjunctivitis were investigated and assessed using a multiarea study. Seven air quality monitoring areas provided data from outpatient visits for nonspecific conjunctivitis. An area-specific, case-crossover study was done to discover the immediate and lag impacts of air pollution, and a meta-analysis with random effects was utilized to combine the area-specific analyses. The results revealed that impacts on outpatient visits for nonspecific conjunctivitis are greatest for O_3 and NO_2, increasing by 2.5% for an increase in O_3 concentration of 16.4 ppb (parts per billion) and by 2.3% for an increase in NO_2 concentration of 11.47 ppb. Effects are also observed for SO_2 and PM_{10}, which have aerodynamic diameters less than 10 m. Due to the stratified analysis by season, effects are more pronounced in the winter. The study therefore concluded that air pollutants NO_2, SO_2, O_3, and PM_{10} do not appear to have any lag effects but do increase the likelihood of outpatient visits for nonspecific conjunctivitis.

The impact of high levels of outdoor air pollution on tear osmolarity and its potential relationship with clinical signs and symptoms were examined by Torricelli, et al. (2013) 71 Brazilian cab drivers and traffic police officers from So Paulo participated in this panel survey. Four distinct times were used to measure each person's average 24-hour exposure to nitrogen dioxide (NO_2) and particulate matter smaller than 2.5 microns ($PM_{2.5}$). The Ocular Surface Disease Index questionnaire, a slit-lamp examination, a calculation of the tear breakup time (BUT), the Schirmer test, and vital staining of the cornea and conjunctiva were all performed on the individuals on the first and third visits. Tear samples were taken for osmolarity tests on the second and fourth visits. Statistical analysis was performed using generalized estimating equations. Results showed that despite being exposed to high concentrations of NO_2 and $PM_{2.5}$, the cab drivers and traffic controllers in our sample reported minor symptoms on the Ocular Surface Disease Index questionnaire. Despite considerable fluctuation, BUT values were lowered while vital staining and Schirmer test mean findings were within normal ranges. $PM_{2.5}$ concentrations and tear film osmolarity levels were shown to be significantly correlated and negatively correlated (P 0.05). Tear osmolarity decreased by 10.9 mOsm/L for every 10 µg/m rise in $PM_{2.5}$. Although not statistically significant, there was a negative association between NO_2 and tear osmolarity as well. Therefore, the stability and osmolarity of tear films are both impacted by exposure to air pollution. Understanding of ocular surface response to high levels of air pollution may be improved by combining clinical evaluation with tear osmolarity measurement.

In a different study, Somayajulu, et al. (2023) examined in vitro and in the mouse cornea the effects of whole-body animal exposure to airborne particulate matter (PM) with an aerodynamic diameter of 10 m (PM_{10}). For two weeks, C57BL/6 mice were given either the control or 500 g/m3 PM_{10}. Malondialdehyde (MDA) and reduced glutathione (GSH) were examined in vivo. Inflammatory markers and nuclear factor erythroid 2-related factor 2

(Nrf2) signaling levels were assessed using RT-PCR and ELISA. The levels of GSH, MDA, and Nrf2 were measured after topically applying the new mitochondrial antioxidant SKQ1. PM_{10}, SKQ1 was applied to cells in vitro, and further tests on cell survival, MDA, mitochondrial ROS, ATP, and Nrf2 protein were performed. In contrast to control exposure, PM_{10} exposure dramatically decreased GSH, elevated MDA levels, and thickened the cornea in vivo. The mRNA levels for downstream targets, pro-inflammatory chemicals, and decreased Nrf2 protein were all noticeably greater in corneas exposed to PM10. SKQ1 restored GSH and Nrf2 levels and decreased MDA in corneas exposed to PM10. In vitro, PM10 raised MDA and mitochondrial ROS, decreased cell viability, Nrf2 protein, and ATP, and restored these effects with SKQ1. Exposure to whole-body PM10 causes oxidative stress, which interferes with the Nrf2 pathway. In vivo and in vitro, SKQ1 counteracts these negative effects, indicating that it may be useful in humans.

In their study of the relationship between air pollution and asthma emergency room visits, Villeneuve and colleagues found that NO_2 and CO have particularly strong relationships. Additionally, their findings demonstrate a robust correlation between CO and warmer seasons, with longer lags contained in moving averages increasing the predicted hazards.

To add to the existing and growing body of research has linking fine particulate matter ($PM_{2.5}$) to ocular illnesses, Yang, et al. (2021) studied the effects of long-term exposure to $PM_{2.5}$ on glaucoma. 33,701 persons 40 years of age or older were enrolled in national cross-sectional research of the Rural Epidemiology for Glaucoma that was carried out in 10 provinces of China. The estimated $PM_{2.5}$ concentrations were assigned to each participant based on their geocoded home addresses and were calculated using a satellite-based model with a 1-km resolution level. To look at the relationships between long-term $PM_{2.5}$ exposure and glaucoma and its subtypes, a logistic regression model was used. The estimated range of PM2.5 values was 28.0 to 96.4 g/m3. The adjusted odds ratios (ORs) for glaucoma and primary angle-closure glaucoma (PACG) were 1.07 and 1.14, respectively, for each 10 g/m3 increase in $PM_{2.5}$. Long-term exposure to PM2.5 was found to be positively but not statistically associated with the risk of primary open-angle glaucoma. Residents in their middle age and those who did not smoke were more susceptible to the harmful effects of PM2.5. In Conclusion, long-term PM2.5 exposure was linked to glaucoma and PACG in Chinese adults, offering new information on the harmful effects of $PM_{2.5}$ on the eyes.

Similarly, a study was done to determine whether the presence of greenery near schools was related to the prevalence of visual impairments and levels of visual acuity in Chinese school children, and whether the connections could be explained by lower levels of air pollution. We enlisted 61,995 kids and teenagers (6-18 years old) from 94 schools throughout seven Chinese provinces and localities in September 2013. Between July and August 2013, the normalized difference vegetation index (NDVI) and the soil-adjusted vegetation index (SAVI) were used to measure the amount of greenness exposure. A minimum visual acuity level of 4.9 (Snellen 5/6 equivalent) was used to define visual impairment. Machine learning techniques were used to evaluate the three-year annual averages of particulate matter (PM) with an aerodynamic diameter of 1 m (PM1) and nitrogen dioxide (NO_2) at each school. This study estimated the relationships between greenness and the prevalence of visual impairment, and degrees of visual acuity using generalized linear mixed models and conducted mediation analyses to investigate the potential mediating effect of air pollution. Results showed an increase in NDVI's interquartile range was linked in the adjusted model to a decreased risk of widespread visual impairment. The same increase in NDVI was connected to rises in left- and right-eye visual acuity, respectively. Furthermore, according to our findings, the link between NDVI and visual impairments was considerably mediated by PM1 and NO_2. These results imply that more vegetation around schools may minimize the incidence of visual impairment, probably because to reduced PM1 and NO_2 levels in vegetation. (Yang , et al., 2021).

The first randomized controlled trial on the health effects of solid fuel use was conducted in Guatemala and is called RESPIRE (Randomized Exposure Study of Pollution Indoors and Respiratory Effects). Its objective was to evaluate how exposure and health effects in a rural population that relies on wood fuel are affected by better stoves (planchas). A starting group of 504 women (259 randomly allocated to planchas; aged 27.4±7.2 years and 245 utilizing traditional open fires (28.1±7.1 years) were questioned about their symptoms at baseline and on a regular basis after the intervention. At each visit, the amount of carbon monoxide (CO), a biomarker of recent exposure to air pollution from biomass combustion, was assessed in exhaled breath. The plancha may improve health by altering working posture to an upright position in addition to lowering IAP levels. Results: Backache, headaches, and eye discomfort were all very common. In comparison to the group utilizing open fires throughout the follow-up period, the plancha group's odds of getting sore eyes and a headache were significantly lower. Women in the intervention experiment had considerably lower median CO in breath than the controls. In addition to easing women's discomfort, plancha may become more widely accepted if there are noticeable improvements in the symptoms that a sizable portion of women suffer (Diaz, et al., 2007).

Research aimed to find out if tobacco smoke directly harms retinal ganglion cells (RGCs) and to assess the ways in which cells die was conducted by Lee K et al. Newborn rats that were 3 or 4 days old were used to collect primary rat RGCs, which were then subjected to cigarette smoke extract (CSE). Using the adenosine 5'-triphosphate (ATP) assay, cell viability was evaluated. TdT-mediated deoxyuridine triphosphate (dUTP) nick-end labeling (TUNEL) and real-time reverse transcription polymerase chain reaction (RT-PCR) for the Bcl-2 family were used to assess apoptosis. Light chain (LC) 3B Western immunoblots were also used to evaluate autophagy. Results: The primary Retinal Ganglion Cells were exposed to CSE for 2 hours, and adenosine 5'-triphosphate assay measurements revealed a dose-dependent reduction in cell viability. In comparison to control cells, the RGC vitality was 77.68% 7.60% in the presence of 0.05% CSE and 47.48% 2.56% in the presence of 1.0% CSE. TUNEL revealed that CSE dose-dependently increased the apoptotic RGCs. Apoptosis occurred in 26.55% 1.97% of the control cells in the presence of 0.05% CSE and in 41.07% 3.75% of the control cells in the presence of 2.5% CSE. Exposure to 0.05% CSE resulted in a considerably higher production of Bad, Bax, Bcl-2, and Bcl-XL mRNA when apoptosis was assessed by real-time RT-PCR. Exposure to 0.05% CSE markedly raised the expression of LC3B II, which was used to measure autophagy by Western immunoblots. The findings of this study indicate that CSE directly damages primary RGCs, and both autophagy and apoptosis, which are two types of cell death, appear to be involved in this CSE-induced RGC damage.

To ascertain how cumulative lead exposure relates to cataract development, a subset of individuals in the Normative Aging Study (NAS), a Boston-based longitudinal study of aging in men, had their levels of lead evaluated by K x-ray fluorescence between 1991 and 1999 in the tibial (cortical) and patellar (trabecular) bones. Eye examination data (regularly gathered every 3-5 years) was studied for the time frame following the bone lead measurements among the first 795 NAS participants. Men 60 years and older who had access to appropriate eye test data made up the cohort we focused on (n = 642). Lead levels in the blood were also assessed. The examination of cataracts was done while the results of the lead level were hidden. Any participant who had undergone cataract surgery or who had a cataract that was clinically evaluated as 3+ or higher on a 4-point scale was deemed to have cataracts. In logistic regression models, odds ratios (ORs) and 95% confidence intervals were generated as assessments of the strength and significance of the association between lead exposure and cataract. Results showed that 122 men were found to have cataracts, with a mean age of 69 among research participants. Men in the highest versus lowest quintile of tibia lead level had an age-adjusted odds ratio for cataract of 2.68 (1.31-5.50). An additional adjustment for diabetes, blood lead levels, pack-years of cigarette smoking, vitamin C, vitamin E, and carotenoids intake led to an Odds Ratio of 3.19. In terms of patella lead level, the highest vs lowest quintiles had a higher risk of cataract (OR, 1.88), however the trend was not statistically significant (P =.16). Blood lead levels, which are more indicative of short-term exposure levels, were not significantly linked with cataract. These epidemiological findings, therefore, imply that cumulative lead exposure, like that which is frequently encountered by people in the United States, may be a significant but underappreciated cataract risk factor. According to this study, lowering lead exposure may aid in lowering cataract prevalence worldwide. (Schaumberg, et al., 2004).

2.3.1 Studies on the link between poor air quality and ocular surface disease

There are several studies indicating that exposure to poor air quality can lead to worsening of ocular surface diseases. A study by Saxena et al. found that inhabitants of strongly polluted areas of Delhi complained of reddening and irritation of the eyes two times more often than the control group. These participants also had increased signs of ocular surface disease as measured by the Schirmer test and tear breakup time (Saxena et al., 2003).

A Canadian study, which included 77,439 people who presented to the emergency department with conjunctivitis, looked at the associations between conjunctivitis and ambient air pollution levels. A strong association between conjunctivitis and air pollution, especially NO_2 level, was shown (Szyszkowicz, Kousha & Castner, 2016).

Exposure to air pollutants such as vehicle emissions or forest fires also results in an increase in matrix metalloproteinases (MMPs); in particular, MMP-9 (Lund et al., 2009) MMP-9 is an inflammatory marker that has been associated with increased inflammation seen in patients with dry eye (Messmer et al., 2016).

A study concluded that patients with exposure to air of a higher AQI due to forest fires had chronic dry eye and increased MMP-9 (Periman, 2021). This study also found that treatment of the dry eye with intense pulse light; (IPL) therapy resulted in an improvement in MMP-9 levels; however, there was reduced improvement in patients given IPL treatment while being exposed to poor air quality (Periman, 2021).

Glaucoma

Glaucoma can arise from exposure to outdoor and indoor air pollutants. Particulate matter less than 2.5µm in diameter has been shown to be positively associated with the development of glaucoma (Wang et al., 2019).

Particulate matter was not found to be a cause of increased intraocular pressure, thus alluding that this mechanism is likely neurotoxic or vascular and not pressure-dependent (Sharon et al. 2019).

However, exposure to higher concentrations of particulate matter is associated with structural characteristics seen in glaucoma, such as thinning of the macular ganglion cell-inner plexiform layer (Lin et al., 2022).

2.3.2 Retinopathy

Exposure to air pollution has also been associated with increased levels of retinopathy, in particular, diabetic retinopathy. A study by Shih-Chun et al. concluded that diabetic patients who are exposed to pollutants, such as particulate matter, are more likely to develop diabetic retinopathy (Shih-Chun et al., 2020).

The exact mechanism was unknown; however, it was thought to be due to the particulate matter inducing oxidative stress, increasing glucose levels, and causing inflammation (Shih-Chun et al., 2020).

Maculopathy

Maculopathy, such as age-related macular degeneration (AMD), can also arise from exposure to air pollutants. A longitudinal study in Taiwan investigated the ocular effects of chronic exposure to carbon monoxide and nitric oxide.

It was concluded that exposure to these traffic-related air pollutants significantly increased the risk of developing AMD (Chang et al., 2019).

Cataract

Currently, there is no strong evidence connecting cataract formation with air pollution. Some studies from developing countries have found that household burning of biomass (charcoal, wood, and animal feces) used in stoves for cooking by poorer social groups is responsible for high levels of air pollutants.

This study in India showed a positive connection between using biomass in household stoves and cataract formation in women; however, this is not something seen in developed countries (Ravilla et al., 2016).

Precautions to recommend to patients to avoid ocular damage

The first line of treatment is often to avoid the offending agent. It is important to limit exposure to outdoor air pollutants by staying indoors. Therefore, the indoor air must be free of pollution as well.

Exposure to indoor air pollution can be reduced by installing air purifiers, changing filters on heating and cooling systems, and ensuring that stoves and fireplaces are vented (Barn et al., 2008 and Mandell et al., 2020). Avoiding open flames at home can prevent pollutants from entering the air.

Another way to reduce indoor air pollutants is to avoid the use of aerosol products indoors. These products can include pesticides, hairsprays, and cooking sprays Mandell et al., 2020). In the general population, smoking has been found to have a statistically significant relationship to dry eye (Xu et al., 2016). Therefore, advocating for smoking cessation is crucial in limiting exposure to pollutants in the air and preventing dry eye symptoms.

Ambient (outdoor) Air pollution

i. Air pollution is one of the greatest environmental risks to health. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma.
ii. In 2019, 99% of the world's population was living in places where the WHO air quality guidelines levels were not met.
iii. The combined effects of ambient air pollution and household air pollution are associated with 6.7 million premature deaths annually.
iv. Ambient (outdoor) air pollution is estimated to have caused 4.2 million premature deaths worldwide in 2019.
v. Some 89% of those premature deaths occurred in low- and middle-income countries, and the greatest number in the WHO South-East Asia and Western Pacific Regions.
vi. Policies and investments supporting cleaner transport, energy efficient homes, power generation, industry and better municipal waste management would reduce key sources of outdoor air pollution. Access to clean household energy would also greatly reduce ambient air pollution in some regions.

Overview of air pollution

Outdoor air pollution is a major environmental health problem affecting everyone in low-, middle-, and high-income countries.

Ambient (outdoor) air pollution in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide per year in 2019; this mortality is due to exposure to fine particulate matter, which causes cardiovascular and respiratory disease, and cancers.

WHO estimates that in 2019, some 37% of outdoor air pollution-related premature deaths were due to ischemic heart disease and stroke, 18% and 23% of deaths were due to chronic obstructive pulmonary disease and acute lower respiratory infections respectively, and 11% of deaths were due to cancer within the respiratory tract.

People living in low- and middle-income countries disproportionately experience the burden of outdoor air pollution with 89% (of the 4.2 million premature deaths) occurring in these areas. The greatest burden is found in the WHO South-East Asia and Western Pacific Regions. The latest burden estimates reflect the significant role air pollution plays in cardiovascular illness and death.

Policies reducing air pollution.

Addressing air pollution, which is the second highest risk factor for noncommunicable diseases, is key to protecting public health.

Most sources of outdoor air pollution are well beyond the control of individuals, and this demands concerted action by local, national and regional level policy-makers working in sectors like energy, transport, waste management, urban planning and agriculture.

There are many examples of successful policies that reduce air pollution:

i. **For industry:** clean technologies that reduce industrial smokestack emissions; improved management of urban and agricultural waste, including capture of methane gas emitted from waste sites as an alternative to incineration (for use as biogas);

ii. **For energy:** ensuring access to affordable clean household energy solutions for cooking, heating and lighting.

iii. **For transport:** shifting to clean modes of power generation; prioritizing rapid urban transit, walking, and cycling networks in cities as well as rail interurban freight and passenger travel; shifting to cleaner heavy-duty diesel vehicles and low-emissions vehicles and fuels, including fuels with reduced sulfur content.

iv. **For urban planning:** improving the energy efficiency of buildings and making cities greener and more compact, and thus energy efficient.

v. **For power generation:** increased use of low-emissions fuels and renewable combustion-free power sources (like solar, wind or hydropower); co-generation of heat and power; and distributed energy generation (e.g. mini-grids and rooftop solar power generation);

vi. **For municipal and agricultural waste management:** strategies for waste reduction, waste separation, recycling and reuse or waste reprocessing, as well as improved methods of biological waste management such as anaerobic waste digestion to produce biogas, are feasible, low-cost alternatives to the open incineration of solid waste – where incineration is unavoidable, then combustion technologies with strict emission controls are critical; and

vii. **for health-care activities:** putting health services on a low-carbon development path can support more resilient and cost-efficient service delivery, along with reduced environmental health risks for patients, health workers and the community. In supporting climate friendly policies, the health sector can display public leadership while also improving health service delivery.

Pollutants

Particulate matter (PM)

PM is a common proxy indicator for air pollution. There is strong evidence for the negative health impacts associated with exposure to this pollutant. The major components of PM are sulfates, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water.

Carbon monoxide (CO)

Carbon monoxide is a colourless, odourless and tasteless toxic gas produced by the incomplete combustion of carbonaceous fuels such as wood, petrol, charcoal, natural gas and kerosene.

Ozone (O_3)

major constituents of photochemical smog and it is formed through the reaction with gases in the presence of sunlight.

Nitrogen dioxide (NO_2)

NO_2 is a gas that is commonly released from the combustion of fuels in the transportation and industrial sectors.

Ozone at ground level – not to be confused with the ozone layer in the upper atmosphere – is a colourless and highly irritating gas that forms just above the earth's surface. It is called a "secondary" pollutant because it is produced when two primary pollutants react in sunlight and stagnant air.

Sulfur dioxide (SO_2)

SO_2 is a colourless gas with a sharp odour. It is produced from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulfur.

Air quality guidelines

The WHO Global air quality guidelines (AQG) offer global guidance on thresholds and limits for key air pollutants that pose health risks. These guidelines are of a high methodological quality and are developed through a transparent, evidence-based decision-making process. In addition to the guideline values, the *WHO Global air quality guidelines* provide interim targets to promote a gradual shift from high to lower concentrations.

The guidelines also offer qualitative statements on good practices for the management of certain types of particulate matter (PM), for example black carbon/elemental carbon, ultrafine particles, and particles originating from sand and dust storms, for which there is insufficient quantitative evidence to derive AQG levels.

Note: A table highlighting the recommended air quality guideline (AQG) could be seen in the appendix

WHO response

Recognizing the gravity and urgency of the problem, all WHO Member States approved resolution A68.8, "Health and the Environment: addressing the health impact of air pollution," at the World Health Assembly in 2015, complemented by a road map for action the following year.

WHO, as the coordinating authority on international health, supports countries in protecting public health through evidence-based policies and actions. Considering the significant health burden and the multiple potential benefits of interventions, WHO supports countries by providing evidence, building institutional capacity and leveraging the health argument to convene sectors to tackle air pollution.

To support reducing air pollution levels and to protect populations from health risks, WHO's Air Quality and Health Unit works in three cross-cutting areas:

1. knowledge, evidence and measuring progress
2. institutional capacity building and technical support
3. leadership and coordination.

Member States and sub-national entities are typically responsible for the implementation and monitoring of policies to promote air quality for health. Successful policies and solid governance depend on coordinated action between a variety of stakeholders and sectors. Cooperation with other UN agencies and non-state actors is essential and is integrated into WHO's work to ensure synergies and maximize impact on the ground.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Design

The study design adopted was a cross-sectional, descriptive, and observational approach, which was conducted in both rural and urban motor parks across Imo State. A cross-sectional design was essential because it allowed for the simultaneous measurement of both the exposure (air pollutant levels) and the outcome (ocular health status and awareness) at a single point in time. This design was most appropriate for determining the prevalence of the associated ocular problems and the level of awareness within the specified population group (Levin, 2006).

Furthermore, the design combined quantitative assessments of ocular health and air pollution exposure with qualitative insights gathered via the questionnaire. This combination provided a holistic view of the problem, enabling the identification of existing health burdens, environmental risk factors, and perceived preventive barriers among the transport workers. Data on the influence of air pollutants on ocular health were determined using a well-structured questionnaire and standardised instruments for clinical examinations of subjects.

3.2 Area of Study

The study was conducted in designated motor parks in the three senatorial zones in Imo State, southeast, Nigeria. Imo State is comprised of 27 local government areas with the capital at Owerri. It has a population of 4.928 million (2017). The population density varies from 230 to 1,400 people per square kilometer. The people of the State are mainly Christians.

Figure 3.1: showing map of Imo state with the 27 LGAs

3.3 Study Population

In the context of this study, the study population is defined as the entire group of registered road transport workers, commercial drivers, and associated traders/businesspeople operating within the designated motor parks and transport hubs of Imo State. This population was targeted because they share the defining characteristic of chronic occupational exposure to high levels of vehicular and environmental air pollutants, making them the most relevant group for investigating the influence of air quality on ocular health.

The study population was based in Imo State, with the target population consisting of approximately four thousand (4,000) registered road transport workers in Imo State. This figure was determined not through independent research or estimation, but by obtaining official data from the State Ministry of Transport and collaborating with the Nigerian Union of Road Transport Workers (NURTW), Imo State Chapter.

The process of determining this population size involved advocacy and formal liaison. This advocacy was directed to two key entities:

1. The State Ministry of Transport: Formal approval and data requests were made to the Ministry, which is the regulatory body responsible for licensing and oversight of transportation activities in the state. This source provided the official, registered count of transport workers.

2. The Nigerian Union of Road Transport Workers (NURTW): Advocacy was also directed to the leadership of the NURTW, Imo State Chapter. The NURTW is the umbrella body responsible for the day-to-day organisation of the park workers, and their records were used to cross-validate the population figure and to facilitate access to the parks and the subjects during the data collection phase.

Therefore, the approximate figure of 4,000 registered workers is a secondary data point sourced directly from the government and union bodies responsible for the sector, thus providing the empirical basis for calculating the study's minimum sample size of 552.

3.3.1 Inclusion Criteria

The inclusion criteria in this study were drivers, road transport workers and traders/business people from the respective motor parks under study, who carry out their daily activities in the park.

Drivers and Road Transport Workers who are not on any topical application for the eyes.

3.3.2 Exclusion Criteria

The exclusion criteria were other drivers, road transport workers, traders and passengers who do not carry out their daily activities at the designated parks under study.

Drivers, Road Transport Workers and traders/business people who applied eye drop less than two weeks ago.

3.4 Sample Size Determination

According to the 2017 census, Imo State has a population of approximately 4.928 million people spread across the State. The subjects (drivers and road transport workers) were drawn from randomly selected motor parks in the three senatorial zones of Imo State selected through lottery. The lottery was done between the accredited parks in the three senatorial zones of Imo state. The accredited parks in Imo state were gotten from the state ministry of Transport before the random selection of the motor parks, population of the respective workers of each motor park were gotten from their data base.

The sample size determination was based on standard epidemiological principles for calculating sample size in descriptive health surveys. It is crucial to note that the overall population of Imo State (approximately 4.928 million people) was not used for this calculation, as the study's findings were only intended to be generalized to the target population of registered road transport workers, commercial drivers, and associated traders in the state.

The minimum sample size (n) was calculated using the standard formula for descriptive studies:

$n = Z^2 Pq/d^2$

In this calculation, the following established parameters were used:

Z (Standard Normal Variate): Set at 1.96, corresponding to the standard 95% confidence level.

d (Absolute Sampling Error/Margin of Error): Set at 0.05 (or 5%), which is the accepted margin for health research.

P (Proportion of the total population required for the study): Set at 0.5 (50%). This value was purposively chosen because, in the absence of a prior prevalence study on air pollutant-related ocular problems within this specific occupational group in Nigeria, setting P at 0.5 maximizes the calculated sample size. This provides the most statistically conservative and robust sample estimate, ensuring the findings have sufficient power and validity.

q: This is 1 - P, resulting in 0.5

The application of these standard parameters resulted in an initial minimum sample size of 384 subjects. To account for potential non-response, improperly filled questionnaires, and data loss inherent in field studies within transient occupational settings, a substantial 52% non-response adjustment was proactively applied to the initial calculated size. This strategic upward adjustment provided the final, robust sample size of **552** subjects, which was the target number for recruitment from the nine designated motor parks across the three senatorial zones of Imo State.

3.4.1 Selection of Motor Parks and Sampling Technique

The selection process for the study locations was systematic, utilizing a combination of Stratified and Simple Random Sampling methods to ensure representativeness across the state's diverse geographical areas. A total of nine (9) designated motor parks were selected for the study. The state was first divided into its three political and geographical strata: Owerri, Orlu, and Okigwe senatorial zones. The parks were distributed across these zones as follows: Three (3) parks were selected from the Owerri Zone, three (3) park from the Orlu Zone, and three (3) park from the Okigwe Zone. This selection distribution ensured that both urban (Owerri) and semi-urban/rural (Orlu and Okigwe) environments were included in the study, providing a comprehensive assessment of air pollutant exposure and ocular health across the state.

The specific selection method for the nine parks was a multi-stage process: the first stage involved dividing Imo State into the three senatorial zones (Stratification); the second stage involved a combination of Purposive and Simple Random Sampling. The selection of three parks in the Owerri Zone was done purposively and strategically because Owerri is the commercial and capital hub of the state, serving as the central convergence point for the three major travel routes connecting to the other two senatorial zones (Orlu and Okigwe). This strategic choice was based on the need to include major transport hubs that served the three cardinal destinations of the state (i.e., three park for routes heading to Owerri, three for routes heading to Orlu, and three for routes heading to Okigwe). This maximized the diversity of vehicular traffic and, critically, the highest volume and concentration of vehicular emissions within the primary urban centre, thereby increasing the likelihood of capturing the most severe environmental exposure. Conversely, the one park in the Orlu Zone and the one park in the Okigwe Zone were selected using Simple Random Sampling from a list of registered motor parks in those respective zones to represent the less densely populated semi-urban/rural transport environments. This robust mixed sampling technique guaranteed that the selected parks were representative of the concentrated occupational exposure conditions prevalent in major transport environments across the entire state.

3.4.2 Participant Selection

Within the final nine selected motor parks, the participants who met the inclusion criteria (drivers, road transport workers, and traders) were selected via convenience sampling until the predetermined sample size of 552 was reached. This approach was practical given the transient nature of the park environment and the challenges of achieving complete randomisation in an active occupational setting.

3.5 Instruments for Data Collection

The instruments used for data collection were carefully selected and calibrated to directly address the specific objectives of the study, combining quantitative clinical and environmental measurements with qualitative survey data.

To address Objectives 2 (assessing awareness) and 3 (determining preventive strategies), and to gather foundational self-reported data for Objective 1 (ocular problems), a well-structured Questionnaire was employed. This instrument was designed to elicit necessary information from the participants concerning their demographic and occupational history, medical background, and self-reported ocular symptoms. The data gathered via the questionnaire also formed the basis for analysing the relationships explored in Objectives 4 and 5.

For the objective and clinical determination of ocular problems (Objective 1), a suite of standardised examination instruments was utilised. Visual Acuity (VA) was assessed at a distance of 6 metres using the Distant Snellen Chart. External features of the eyes and pupillary responses were assessed using a Pen Torch. Deeper structures of the anterior and posterior eye, including the cornea, conjunctiva, and retina, were examined using an Ophthalmoscope. The quantity and quality of tears were assessed using Paper Strips for the Schirmer Test, while the integrity of the corneal and conjunctival surfaces was checked using Fluorescein Strips to rule out abrasion or anomaly. Finally, intraocular pressure was measured in millimetres of mercury (mmHg) using the Schiotz Tonometer.

To characterise the specific environmental exposure relevant to the overall study context and the clinical outcomes (Objective 1), various environmental measurement instruments were used at the motor parks. Measurements with the gas meters and particulate detectors were carried out in the morning and evening. Specifically, the most appropriate times for these measurements are:

Morning (Peak Hours): 7:00 AM – 9:00 AM. This period captures the rush hour when most transport workers arrive, start their vehicles (often cold starts leading to higher emissions), and passengers generate peak activity. This represents the first major daily exposure window.

Evening (Peak Hours): 4:00 PM – 6:00 PM. This period captures the evening rush hour when vehicles return, idle, and the atmospheric boundary layer tends to drop (atmospheric inversion), often trapping pollutants closer to the ground, potentially leading to the highest concentration of exposure.

The precise locations of the parks were confirmed using a GPS MAP78 Garmin geographic position system (Garmin Ltd, USA). Specific pollutants were measured using the following dedicated instruments: the NO2 Nitrogen Dioxide detector FD-90A-NO^2 Forensics Detector (USA); the SO2 Sulfur Dioxide detector FD-90A-SO^2Forensics Detector (USA); and the Extech CO240 Air Quality detector (Extech Instruments, Knoxville, USA). Particulate matter levels were determined using the BT-5800S, BT Meter gas and Particulate Matter Detector (BT Meter, Beijing, China), which provided readings for PM_{2.5, PM_{10, and PM_{1.0. Additionally, the temperature at the motor parks was determined using a Thermometer at the same intervals that the gas values were measured. Finally, general health indicators were assessed using a Sphygmomanometer (Blood Pressure) and an Electronic Spirometer (SF-1) (Jiangsu Jintan Med Instruments Factory, Jingsu China) to provide essential baseline cardiorespiratory context for the participants.

3.6 Validity of Instruments

The study questionnaire was carefully prepared by me and was approved by my supervisor after some corrections. Before the main study commenced, the developed questionnaire was subjected to a rigorous pre-test to assess its clarity, reliability, validity, and the time required for administration.

The pre-testing was carried out on a sample of 50 road transport workers who possessed characteristics similar to the final study population but were located in a motor park outside the nine designated parks selected for the main study. Specifically, the pre-testing was conducted at the Control Post Motor Park in Owerri, which was not among the final selected nine parks, thus ensuring that the pre-test participants did not contaminate the actual study data.

The purpose of the pre-testing was threefold:

1. To Establish Reliability: The process helped determine the consistency of the questions, identifying and rectifying ambiguous or confusing terminology that could lead to varied interpretations by the subjects.

2. To Establish Validity: It ensured that the questions genuinely measured the intended constructs, such as the actual level of awareness and the actual types of preventive strategies employed.

3. To Gauge Administration Time: The pre-test allowed for an estimate of the average time required to complete the questionnaire, which was essential for planning the logistical execution of the main data collection phase.

Based on the findings from the pre-test, necessary modifications were made to the questionnaire, specifically to rephrase complex or technical terms into simpler language relevant to the subjects' understanding, thereby enhancing the overall instrument quality before it was deployed in the final study.

Distant Snellen Chart: approved by both Optometrists and Dispensing Opticians Registration Board of Nigeria (ODORBN) and World Council of Optometrists (WCO) for the assessment of visual acuities of subjects.

Pen Torch: approved by both ODORBN and WCO for the external examination of subjects.

The Ophthalmoscope: is certified by the board of the Optometrists and Dispensing Opticians Registration Board of Nigeria (ODORBN) and the World Council of Optometry (WCO).

Schirmer Paper Strip is certified by both ODORBN and WCO for assessment of Tear quality and quantity. The paper is graded and measured in millimeters.

Fluorescein Strip is certified by both ODORBN and WCO for the assessment of cornea and conjunctiva integrity.

The Schiotz Tonometer is approved both by ODORBN and WCO for the measurement of the intraocular pressure of the eyes. It is measured in millimeter of mercury (mmHg).

3.7 Reliability of Instruments

The questionnaire used and the clinical examinations done, were approved by my supervisor, department of Public Health and the School of Health Technology. Tests and re-tests using Spearman's correlation coefficient etc were applied to certify the results.

3.8 Method of Data Collection

The data collection strategy was a rigorous, multi-stage process, combining survey administration, detailed clinical examination, and objective environmental measurement. The entire procedure was meticulously aligned to address the study's five specific objectives (Polit & Beck, 2017).

3.8.1. Questionnaire Administration (Objectives 1, 2, 3, 4, and 5)

The Questionnaire was administered by the primary researcher and trained research assistants on the field after informed consent was obtained from each participant (Levin, 2006). The number of questionnaires shared was dependent on the calculated sample size of 552, while allowing for anticipated invalid or unreturned forms. Data were collected using a questionnaire designed to extract relevant and reliable information on the demographic background, occupational history, medical history, and self-reported ocular symptoms (Objective 1), awareness levels regarding the influence of air pollutants on ocular health (Objective 2), and the specific preventive measures used (Objective 3). The literate respondents were allowed to fill the forms themselves though with guidance, while for the non-literate respondents, the questions were translated to them, and their answers were filled by the researcher.

3.8.2. Clinical Examinations (Objective 1)

After the completion of the forms, each respondent was subjected to clinical examinations to determine the objective influence of air pollutants on the visual health of subjects under study (Objective 1). Each respondent was first assessed by a medical team, comprising a general practitioner and a nurse, to determine the subject's suitability. Mandatory preliminary examinations included checking of the Blood Pressure (BP) using a Sphygmomanometer, Pulse rate, and Blood sugar test. If the respondent was found suitable, he or she was then made to undertake visual and ocular examination, which included the following detailed tests:

Visual Acuity Test: This test was done using the Distant Snellen Chart to determine the extent the respondent could see. It was carried out monocularly and binocularly at a distance of 6 metres (Kansara, 2014).

Pen Torch Test: The Pen Torch was used as a primary diagnostic tool to directly shine light onto the eye to assess the external features, ascertain the integrity of the cornea, conjunctiva, and assess the anterior chambers, including its depth.

Schirmer Paper Strip Test: This test was performed to determine the quality and quantity of tears produced by the eye. Filter paper strips were placed inside the lower lid of the eye (tarsal conjunctiva). The lower lid was brought down, and the strip was inserted for 5 minutes, after which the paper was removed and measured for its moisture content (Remington, 2012). This procedure was crucial to determine whether the eye produced enough tears. This test was strictly performed before the Fluorescein Strip test to avoid interference with tear production.

Fluorescein Strip Application: This test was used to determine the integrity of the cornea and conjunctiva. The orange dye (fluorescein) on the strip was touched to the lower conjunctival sac, and the eye was then examined under a blue light to detect foreign bodies, abrasions, or anomaly on the ocular surfaces (Kansara, 2014). The entire process took about 20 minutes.

Ophthalmoscopic Test: The Ophthalmoscope was used to illuminate and magnify the internal structures of the eye, assessing both the anterior and posterior chambers.

Schiotz Tonometry Test: This was used to measure the intraocular pressure of the eyes in millimeters of mercury (mmHg). The Schiotz Tonometer determines the intraocular pressure by indentation of the cornea (Remington, 2012).

3.8.3. Environmental Measurement (Contextual Support for Objective 1)

The Gas Meter Test was used in the motor parks to determine the types and quantity of gases in each of the parks. This data was essential for establishing the exposure context for Objective 1.

Exhaust Gas Analysis: Exhaust gas emission testing was a process where a test probe was placed in the tail pipe of selected vehicles, and the exhaust gases were measured following a strict procedure (BT Meter, 2015). The exhaust gas analyzer was used for measuring four gases: oxygen (O_2), carbon monoxide (CO), carbon dioxide (CO_2), and hydrocarbons (HC). It also calculated Lambda, a measure of the air/fuel ratio. These objective measurements provided a very accurate way of measuring the combustion efficiency and pollutant load.

Ambient Gas and Particulate Measurement: Dedicated detectors like the NO_2 and SO_2 detectors, and the BT-5800S Particulate Matter Detector (Extech, 2014), were strategically placed within the working zone of the parks to capture $PM_{2.5}$, PM_{10} and $PM_{1.0}$ levels, providing the primary exposure data for the ocular problems observed.

3.9 Method of Data Analysis

The software name originally stood for Statistical Package for the Social Sciences (SPSS), has now been changed to Statistical Product and Service Solutions also known as IBM SPSS, is a software package used for the analysis of statistical data. The analysis followed these steps:

1. Determining the data to be analysed.
2. Gathering the data.
3. Preparing the data for analysis.
4. Examining the data to find patterns and relationships.
5. Drawing conclusions from the analysis.

Data were analyzed using SPSS package as the micro software while chi square, frequency tables, histogram, pie chart, figures etc. were the statistical tools used to draw conclusions for the analysis.

3.10 Informed Consent

Informed consent was gotten verbally from all the participants in this study. The confidentiality of participants" personal and health information were ensured. Nevertheless, a written consent was gotten from the State Ministry of Transport and Nigerian Union of Road Transport Workers (NURTW).

CHAPTER FOUR

RESULT AND DISCUSSIONS

4.1 Result

4.1.1 Socio-Demographic Distribution of the Study Participants

The presentation of the socio-demographic distribution of the study participants serves a critical function by establishing the characteristics of the population for whom the prevalence of ocular problems (Objective 1) was determined, and by providing the key independent variables (age, occupation, income, and geographical zone) for the correlation analyses presented in Objectives 4 and 5. A total of 552 transport workers were included in the present study, comprising 374/552 (67.7%) drivers, 62/552 (11.2%) Road Transport Workers (RTWs), and 116/552 (21.0%) traders or business workers.

The age distribution of the study participants results showed that, in the overall study group, the largest proportion of participants, 172/552 (31.2%), were concentrated between 41–50 years old, closely followed by 151/552 (27.4%) within the 51–60 years old bracket. The lowest proportion of the group were the 21–30 years old (31/552: 5.6%), followed by those aged over 60 years at 79/552 (14.3%). Among the drivers, the largest age groups were the 41–50 and the 51–60 age brackets, each representing 118/374 (31.6%). Only 9/374 (2.4%) of the drivers were between 21–30 years of age. Among the RTWs, there were coincidentally 15/62 (24.2%) workers each for the 31–40, 41–50, and 51–60 age groups. The 41–50 years age group was the largest among the traders or business workers at 39/116 (33.6%), while the 51–60 and the above 60s were 18/116 (15.5%) each.

The results further showed that the clear majority of the study group were of male gender (486/552: 88.0%). Specifically, all drivers and conductors (374/374: 100.0%) were male.

Among the RTWs, 48/62 (77.4%) were male, and 64/116 (55.2%) of the traders/business workers were male. The largest rate of females was found within the traders (52/116: 44.8%).

The data on marital status showed that the clear majority of the study group were married (438/552: 79.3%). This included 299/374 (79.9%) of the drivers, 48/62 (77.4%) of the RTWs, and 91/116 (78.4%) of the traders/business workers. The major group was predominantly Christians (538/552: 97.5%), with only few Muslim (3/552: 0.5%) and other religions such as traditional religion (11/552: 2.0%). Up to 217/552 (39.3%) in all made ₦4,000–₦5,999 in a day, while slightly above one-quarter of the group (142/552: 25.7%) made up to ₦6,000 and above. Among the drivers, 148/374 (approximately 2/5: 40.0%) made ₦2,000–₦3,999 daily, while among RTWs, 42/62 (67.7%) made ₦4,000–₦5,999 in a day. For the traders and those engaged in business, 54/116 (46.6%) made ₦4,000–₦5,999 on a daily basis.

The largest percentage of the study group, 255/552 (46.2%), was drawn from the Owerri geographical zone of Imo state, which included 47.9% of drivers, 43.5% of RTWs, and 42.2% of traders/business workers. This reflects the stratified sampling approach (Section 3.4.1), which proportionally assigned more parks to the commercial hub. The remaining participants were 163/552 (29.5%) from Orlu and 134/552 (24.3%) from Okigwe zones, respectively. The Okigwe zone recorded the lowest number of participants among each occupational group, consistent with the sampling design.

Table 4.1 Socio-Demographic Distribution of the Study Participants

Socio-Demographic	Drivers & Conductors		RTWS		Traders / Business		OVERALL	
	Number	%	number	%	Number	%	number	%
21 – 30	9	2.4	8	12.9	14	12.1	31	5.6
31- 40	77	20.6	15	24.2	27	23.3	119	21.6
41- 50	118	31.6	15	24.2	39	33.6	172	31.2
51 – 60	118	31.6	15	24.2	18	15.5	151	27.4
>60	52	13.9	9	14.5	18	15.5	79	14.3
Total	374	100.0	62	100.0	116	100.0	552	100.0
Sex								
Male	374	100.0	48	77.4	64	55.2	486	88.0
Female	0	0.0	14	22.6	52	44.8	66	12.0
Total	374	100.0	62	100.0	116	100.0	552	100.0
Marital Status								
Married	299	79.9	48	77.4	91	78.4	438	79.3
Single	62	16.6	12	19.4	16	13.8	90	16.3
Separated/Divorced	13	3.5	3	4.8	9	7.8	25	4.5
Total	374	100.0	62	100.0	116	100.0	552	100.0
Religion								
Christianity	371	99.2	59	95.2	108	93.1	538	97.5
Moslem	1	0.3	0	0.0	2	1.7	3	0.5
Other	2	0.5	3	4.8	6	5.2	11	2.0
Total	374	100.0	62	100.0	116	100.0	552	100.0
Daily Income								
< 2000	15	4.0	0	0.0	12	10.3	27	4.9
2000- 3999	148	39.6	6	9.7	21	18.1	175	31.7
4000- 5999	121	32.4	42	67.7	54	46.6	217	39.3
6000+	105	28.1	14	22.6	23	19.8	142	25.7
Total	374	100.0	62	100.0	116	100.0	552	100.0
Zone								
Owerri	179	47.9	27	43.5	49	42.2	255	46.2
Orlu	106	28.3	18	29.0	39	33.6	163	29.5
Okigwe	89	23.8	17	27.4	28	24.1	134	24.3
Total	374	100.0	62	100.0	116	100.0	552	100.0

4.1.1.1: Zonal Distribution for the Imo State Transport Workers Studied

Contained in table 4.1b is the zonal distributional classifications for the designation of the study group. The table shows that a total of 255 (46.2%) were from Owerri zone, 163 (29.5%) were from Orlu zone and 134 (24.3%) were obtained from Okigwe zone. The drivers make up the largest proportion of the sample (262: 47.5%), followed by the conductors (112: 20.3%). Those engaged in trading or business were also high (108: 19.6%). Within the zones, the drivers were 118 (46.3%) among the Owerri zone group, 79 (48.5%) among the Orlu zone group and 65 (48.5%) among the Okigwe zone group.

Table 4.1b: Distribution by zone for the designation of the study Participants.

Designation at Park	OWERRI ZONE		ORLU ZONE		OKIGWE ZONE		OVERALL	
	Freq	%	Freq	%	Freq	%	Freq	%
Drivers	118	46.3	79	48.5	65	48.5	262	47.5
Conductors	61	23.9	27	16.6	24	17.9	112	20.3
Ticket/Toll givers	8	3.1	3	1.8	3	2.2	14	2.5
Loaders	13	5.1	12	7.4	11	8.2	36	6.5
Security	6	2.4	3	1.8	3	2.2	12	2.2
Traders/Business	46	18.0	36	22.1	26	19.4	108	19.6
Other businesses	3	1.2	3	1.8	2	1.5	8	1.4
Total	255	100.0	163	100.0	134	100.0	552	100.0

4.1.2 Ocular Problems Associated with Road Transport Workers in Imo State Nigeria

This section presents the clinical findings relating to the prevalence and types of ocular problems identified among the road transport workers, thereby directly addressing Specific Objective 1: to determine the associated ocular problems of air pollutants among road transport workers.

4.1.2.1 Presence of Ocular Problems among Road Transport Workers in Imo State Nigeria

The presence of ocular problems was determined following the clinical examination of all participants. For a total of 1,104 eyes examined (i.e., 552 persons) , ocular issues were found to be present in 896/1104 (81.2%) of the eyes. The remaining 208/1104 (18.8%) of the eyes were not found with ocular problems.

It must be clarified that the rate of occurrence, or prevalence, of ocular problems among the studied group was found to be 896/1104 (81.2%) in this study, while 18.8% represents the proportion of eyes that were clinically normal. Figure 4.1 is a pie chart showing the distribution for ocular problems among the road transport workers studied.

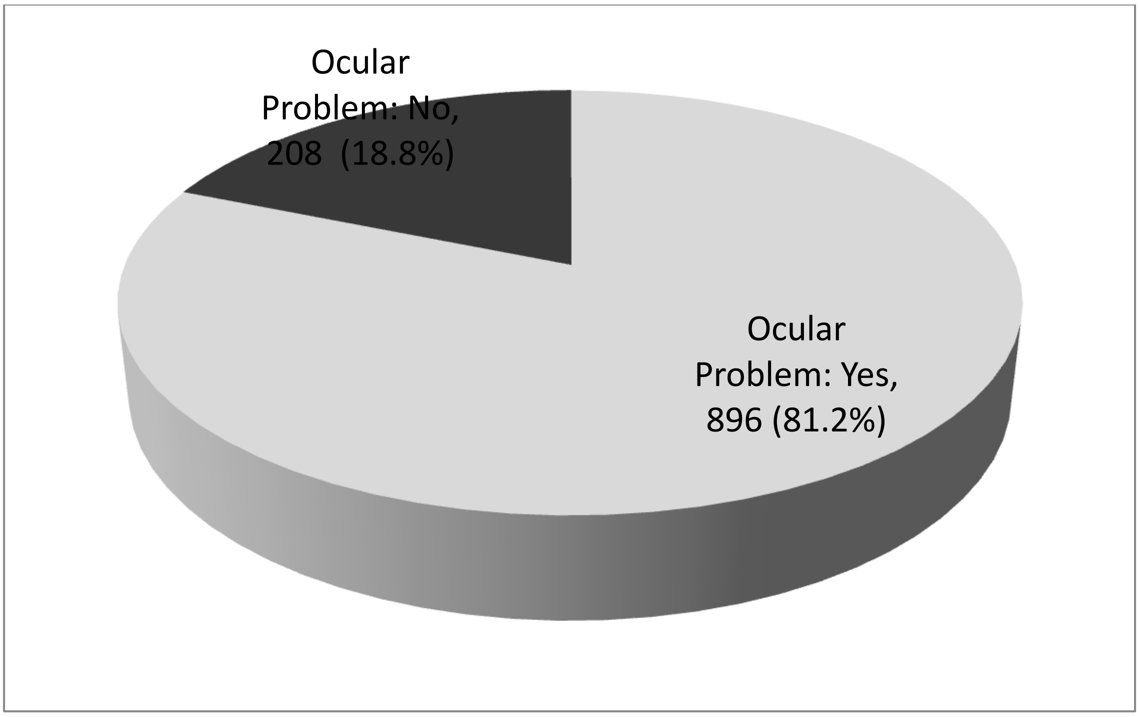

Figure 4.1 Presence of Ocular Problems among Road Transport Workers in Imo State Nigeria (Both eyes were examined each participant)

Figure 4.2 represents the distribution of the study group showing the proportion that did not record any ocular problem along with the rate of occurrence of each type of ocular problem found from the eyes of the participants.

The figure indicates that while in all 57% showed good vision, 57.9% of the eyes shows pterygium, 35.9% showed dry eye vision while 31% showed moderate vision. Glaucoma was found on 2.4% of the eyes while 1.7% of the eyes showed macular degeneration.

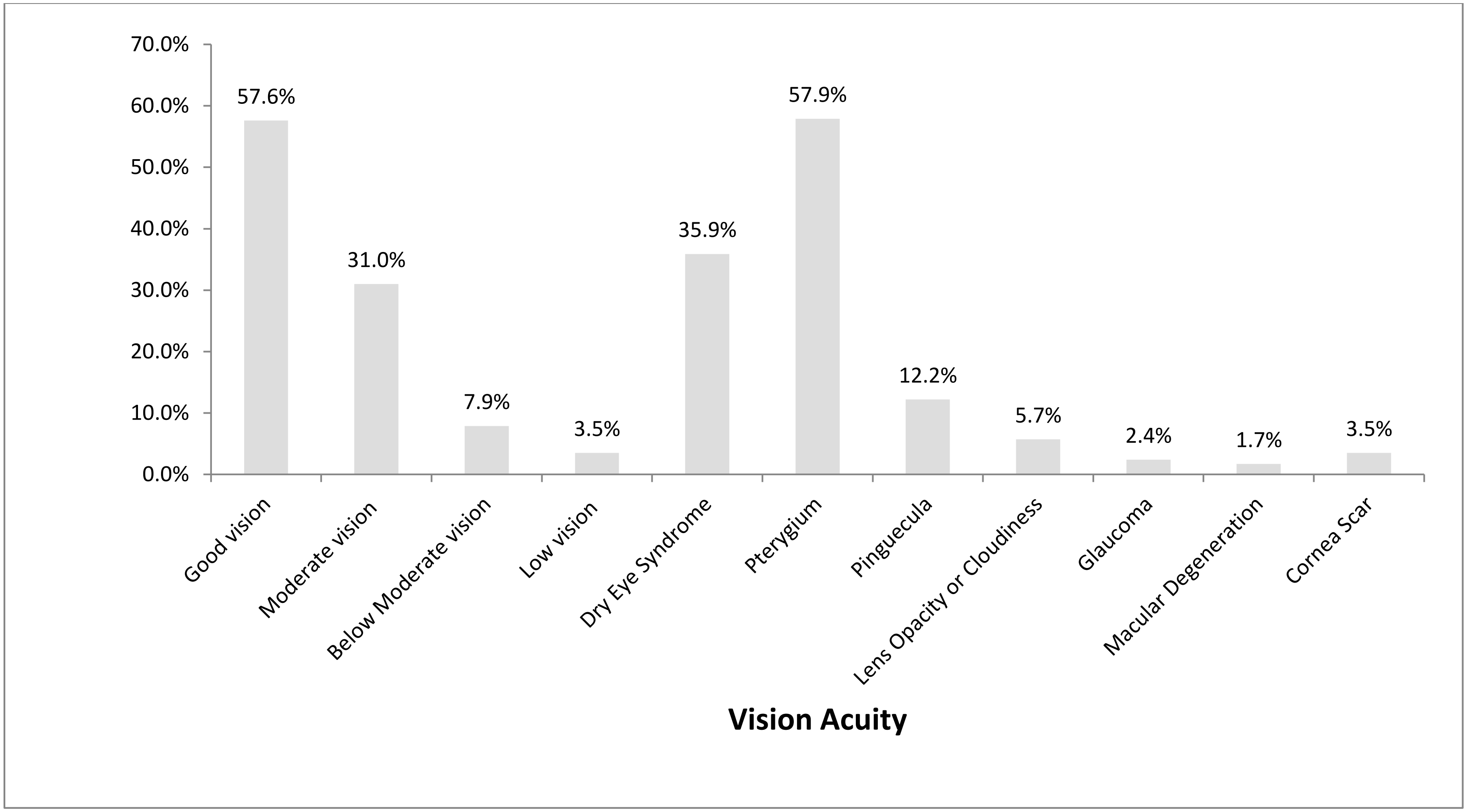

Figure 4.2: Distribution for Ocular Defects among Road Transport Workers with Ocular Issues in Imo State

(Note that more than one ocular issue was detected in some eyes).

4.1.2.2 Distribution for Types and number of ocular problems among the eyes that showed ocular Issues

To further address Specific Objective 1, the various types of ocular problems diagnosed in the eyes showing issues were enumerated. The results showed that a total of 1,786 ocular problems were detected from the 896 eyes that showed at least one ocular problem. This indicated that multiple ocular issues were common among the eyes examined.

Among the 1,786 total ocular problems detected, Pterygium was the most frequent finding, present in 639/1786 (35.8%) of the issues. Dry Eye Syndrome was the next most common issue, found present in 396/1786 (22.2%) of the problems. This was followed by Moderate Vision impairment (6/9 – 6/18) which accounted for 342/1786 (19.1%) of the issues, and Pinguecula at 135/1786 (7.6%). The less common issues included Lens Opacity or Cloudiness (63/1786: 3.5%), Below Moderate Vision impairment (87/1786: 4.9%), and Low Vision (39/1786: 2.2%).The lowest three of the ocular issues found were Macular Degeneration (19/1786: 1.1%), Glaucoma (Ocular Hypertension) (27/1786: 1.5%), and Cornea Scar (39/1786: 2.2%). The detailed distribution for the types and number of ocular problems is presented in the accompanying Table 4.2.

Table 4.2: Distribution for Types and number of ocular problems among the eyes that showed ocular Issues

Ocular Problem Type	Number of ocular problems	Percent
Moderate vision (6/9 – 6/18)	342	19.1
Below Moderate vision (6/24 – 6/60)	87	4.9
Low vision (HM –NLP)	39	2.2
Dry Eye Syndrome	396	22.2
Pterygium	639	35.8
Pinguecula	135	7.6
Lens Opacity or Cloudiness	63	3.5
Glaucoma (Ocular Hypertension)	27	1.5
Macular Degeneration	19	1.1
Cornea Scar	39	2.2
Total	1786	100

Note: Both eyes were examined each participant and some of the eyes showed more than one ocular issues

4.1.3: Awareness of Air Pollution in Ocular Health

This section directly addresses Specific Objective 2: to determine the level of awareness of the influence of air pollutants on ocular health among road transport workers.

The overall results demonstrated that awareness of air pollution risks in ocular health was generally high among the studied group. A clear majority of the participants, 464/552 (84.1%), showed awareness, compared to 88/552 (15.9%) who were not aware

The level of awareness was notably high among the drivers, with 230/262 (87.8%) reporting awareness, and among the conductors, where it reached 104/112 (92.9%). For other Road Transport Workers (RTWs), awareness was found to be highest among the loaders at 32/36 (88.9%). In contrast, the awareness rate was slightly lowered among the group that was engaged in trading or business activities in the park, where 72/108 (66.7%) reported awareness. The detailed patterns of awareness of air pollution in ocular health among the studied group are shown in the accompanying Table 4.3.

Table 4.3: Awareness of Air Pollution in Ocular Health

Class	Drivers & Conductors		Other Road Transport Workers			Business		
Awareness	Drivers	Conductors	Loaders	Ticket Givers	Security	Traders/ Business	Other business	Total
	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Aware	230 (87.8)	104 (92.9)	32 (88.9)	11 (78.6)	9 (75.0)	72 (66.7)	6 (75.0)	464 (84.1)
Not Aware	32 (12.2)	8 (7.1)	4 (11.1)	3 (21.4)	3 (25.0)	36 (33.3)	2 (25.0)	88 (15.9)
Total	262	112	36	14	12	108	8	552

On table 4.3b, those that have awareness of air pollution in ocular health recorded lower rate of ocular problems (79.5%) compared to the rate among those that are unaware (88.8%). The odds ratio (OR = 0.44) shows that the rate of having ocular problem was found to be 56% significantly lower among the awareness group compared to the unaware group (P = 0.024, χ^2 =5.08). This indicates that awareness of air pollution has significant association with ocular health among the study group

Table 4.3b: Awareness of Air Pollution in Ocular Health and ocular problem occurrence among the study group

Awareness Status	Total	Ocular Issue: Yes number	Ocular Issue: Yes %	Ocular Issue: No number	Ocular Issue: No %	Chi-sq (df)	*P*	Odds Ratio
Aware	464	369	79.5	95	20.5			
Not Aware	88	79	88.8	9	10.2			
Total	552	448	81.2	104	18.8	5.08 (1)	0.024	0.44

4.1.4: Use of Preventive Measures against Air Pollution in Ocular Health

This section presents the results on the overall practice of preventive measures, which is the first and most fundamental part of addressing Specific Objective 3: to determine the strategies employed in the prevention of air pollution on ocular health by road transport workers. The detailed strategies are subsequently presented in Section 4.1.5, completing the evidence for this objective.

The results showed that the use of preventive measures against air pollution in ocular health was quite poor among the study group. A clear minority of the participants, 171/552 (31.0%), were using protective measures, compared to a large majority of 381/552 (69.0%) that did not use it.

The poor application of the preventive measures was most pronounced among the traders and business dealers, with just 23/108 (21.3%) using them. The usage was also quite poor among the security group (3/12: 25.0%) and the drivers (84/262: 32.1%). In contrast, the use of preventive measures was highest among the ticket givers, with 6/14 (42.9%) using them. The detailed distribution for the use of preventive measures against air pollution in ocular health is contained in the accompanying Table 4.4.

Table 4.4: Use of Preventive Measures against Air Pollution in Ocular Health

Class	Drivers & Conductors		Other Road Transport Workers			Business		
Use of Preventive Measures	**Drivers**	**Conductors**	**Loaders**	**Ticket Givers**	**Security**	**Traders/ Business**	**Other business**	**Total**
	Freq (%)	**Freq (%)**	**Freq (%)**	**Freq (%)**	**Freq (%)**	**Freq (%)**	**Freq (%)**	**Freq (%)**
Yes	84 (32.1)	40 (35.1)	13 (36.1)	6 (42.9)	3 (25.0)	23 (21.3)	2 (25.0)	171 (31.0)
No	178 (67.9)	72 (64.9)	23 (63.9)	8 (57.1)	9 (75.0)	85 (78.7)	6 (75.0)	381 (69.0)
Total	262	112	36	14	12	108	8	552

4.1.4.2 Applications of preventive strategies against Air Pollution in Ocular Health and ocular problem occurrence among the study group

This section provides the results that directly address Specific Objective 5: to determine the use of different preventive measures and the occurrence of ocular problems.

The results showed a marked difference in the rate of ocular problem occurrence based on the use of general preventive strategies. Ocular problems occurred in 88/171 (51.5%) of those who applied preventive strategies against air pollution, compared to 360/381 (94.5%) of those that did not apply preventive techniques.

The finding clearly indicates that those that do not use preventive measures against air pollution are at a greater disadvantage for ocular health problems. This is because the odds of having an ocular problem were found to be 94% significantly lower among those that applied preventive measures compared to those that did not apply preventive measures (OR} = 0.06, P} = 0.001, \chi^2 = 142.89, df}=. The detailed results for the application of preventive strategies and ocular problem occurrence are presented in the accompanying Table 4.4b.

Table 4.4b: Applications of preventive strategies against Air Pollution in Ocular Health and ocular problem occurrence among the study group

Applied preventives		Ocular Issue: Yes		Ocular Issue: No		Chi-sq (df)	*P*	*Odds Ratio*
	Total	Number	%	number	%			
Yes	171	88	51.5	83	48.5			
No	381	360	94.5	21	5.5			
Total	552	448	81.2	104	18.8	142.89 (1)	0.0001	0.06

4.1.4.3 Relationship between Awareness and the practice of preventive against Air Pollution in Ocular Health and ocular problem occurrence among the study group

This section presents the analysis to address Specific Objective 4: to determine the relationship between awareness and the practice of preventive measures against air pollution in ocular health and ocular problem occurrence among the study group.

The results showed that awareness is significantly associated with the practice of preventives against air pollutants in the study group (P} < 0.0001, χ^2=18.84).

Specifically, 161/464 (34.7%) among the awareness group were applying air preventive practices against air pollutants, compared to only 10/88 (11.4%) found among the non-awareness group. The odds for non-use of preventive practices were found to be over 4 times higher among the non-awareness group compared to that of the awareness group [OR}=4.14, 95\% CI}: (2.06 – 9.21). The relationship between awareness and the practice of preventives is presented in the accompanying Table 4.4c.

Table 4.4c Relationship between Awareness and the use of preventive against Air Pollution in Ocular Health and ocular problem occurrence among the study group

Awareness Status	**Total**	**Use of Preventives**				**Chi-sq (df)**	***P***	**OR (95% CI)**
		Yes	**%**	**No**	**%**			
Aware	464	161	34.7	303	65.3			
Not Aware	88	10	11.4	78	88.6			
Total	552	171	31.0	381	69.0	18.84 (1)	< 0.0001	4.14 (2.06 –9.21)

4.1.5: Strategies Used in Preventing Air Pollutants on Ocular Health

This section serves to provide detailed evidence regarding the specific techniques and strategies adopted by the participants, thereby fully addressing Specific Objective 3: to determine the strategies employed in the prevention of air pollution on ocular health by road transport workers. This result is presented alongside the prior finding (Section 4.1.4) that a significant majority of 381/552 (69.0%) of the total study group do not apply preventive measures against air pollutant on ocular health.

The results on the specific strategies applied to prevent air pollutant are presented in the accompanying Table 4.5. It can be observed from the table that the most frequently used strategy was wearing a sunshade, with 40/552 (7.2%) of the study population wearing sunshade as a preventive measure against air pollutants. This was closely followed by those who wear eyeglasses as a preventive measure, accounting for 38/552 (6.9%) of the study population.

Self-medication was also reported by 28/552 (5.1%) of the participants. A total of 28/552 (5.1%) indicated that they close their eyes when exposed to pollutants, while 12/552 (2.2%) avoid areas of smoke and 11/552 (2.0%) wind up glasses. Only 10/552 (1.8%) of the study group do go for eye checkup as a preventive measure against air pollutants. It was further observed that less than 1% of the drivers (2/262: 0.8%) and the conductors (1/112: 0.9%) go for eye checkup as a preventive strategy.

Table 4.5: Strategies Used in Preventing Air Pollutants on Ocular Health

Use of Preventive Measures	Drivers & Conductors		RTWS			Traders / Business	TOTAL	
	Drivers & Conductors		Other Road Transport Workers			Business		
	Drivers	Conductors	Loaders	Ticket Givers	Security	Traders/ Business	Other business	Total
	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Wear Glasses	25 (9.5)	7 (6.3)	0 (0.0)	2 (14.3)	0 (0.0)	4 (37.0)	0 (0.0)	38 (6.9)
wear Sunshade	21 (8.0)	7 (6.3)	1 (2.8)	1 (7.0)	1 (8.3)	8 (7.4)	1 (12.5)	40 (7.2)
Self-medication	10 (3.8)	7 (6.3)	4 (11.1)	0 (0.0)	1 (8.3)	5 (4.6)	1 (12.5)	28 (5.1)
Eye check-up	2 (0.8)	1 (0.9)	1 (2.8)	2 (14.3)	1 (8.3)	3 (2.7)	0 (0.0)	10 (1.8)
Close eyes	15 (5.7)	11 (9.8)	4 (11.1)	0 (0.0)	0 (0.0)	2 (1.9)	0 (0.0)	32 (5.8)
Avoid Area of Smoke	5 (1.9)	2 (1.8)	3 (8.3)	1 (7.0)	0 (0.0)	1 (0.9)	0 (0.0)	12 (2.2)
Wind-up glass	6 (2.3)	5 (4.5)	0 (0.0)	0 (0.0)	0. (0.0)	0 (0.0)	0 (0.0)	11 (2.0)
None	178 (67.9)	72 (64.3)	23 (63.9)	8 (57,1)	9 (75.0)	85 (78.7)	6 (75.0)	381 (69.0)
Total	262	112	36	14	12	108	8	552

4.1.6 Use of different preventives and the occurrence of ocular Issues among the subjects using preventive strategies

This section presents the results of the inferential analysis on the effectiveness of specific preventive measures, thereby directly addressing Specific Objective 5: to determine the use of different preventive measures and the occurrence of ocular problems. The analysis focused only on the 171 subjects who reported using at least one preventive strategy against air pollution.

The results showed that three specific preventive practices were found to be statistically significant against the occurrence of ocular issues, which included wearing eye glass (P} = 0.002), having eye checkup (P} = 0.040), and avoiding smoke areas (P} = 0.016).

The occurrence of ocular issues was notably reduced among those who reported wearing eye glass as a preventive measure (10/38: 26.3%), compared to those who did not wear it (78/133: 58.6%). For those that do not wear eye glass, the odds for ocular issues were found to be more than 4 times significantly higher compared to those that do wear it (OR} = 4.28, 95\% CI} = 1.81 - 10.67).

Furthermore, among those that had eye check-up, only 2/10 (20.0%) had ocular issues against 86/161 (53.4%) found among those that never had eye check. The odds ratio indicates that the risk for having ocular problems was almost 5 times higher on those that do not go for eye check (OR} = 4.59, 95\% CI} = 0.87 - 45.28).

Similarly, avoiding areas of smoke was found to be associated with less ocular issues in this study, with only 2/12 (16.7%) of those who avoided smoke areas having issues, against 86/159 (54.1%) of those who did not. The odds ratio shows that non avoidance for areas of smoke is significantly accompanied with about 5.6 times more odds for ocular issues (OR} = 5.58, 95\% CI} = 1.13 - 53.53).

Conversely, ocular issues were recorded lower among those that wear sunshade (18/40: 45.0%), compared to the rate among those that do not wear it (70/131: 53.4%). It was much higher on the use of self-medication (17/28: 60.7%). However, both the use of sunshade and self-medication were not found as significant factors for ocular issues in this study (p} > 0.05). Similarly, closing of eyes and winding up of glasses were not found significant. The detailed results on the use of different preventives and the occurrence of ocular Issues are presented in the accompanying Table 4.6.

Table 4.6 Use of different preventives and the occurrence of ocular Issues among the subjects using preventive strategies

Use of Preventives	Total n=171	Having Ocular Issues Yes n=88	%	No n=83	%	P (χ^2)	OR (95% CI)
Wear Glasses							
Yes	38	10	26.3	28	73.7		
No	133	78	58.6	51	38.3	0.002 (13.73)	4.28 (1.81 -10.67
wear Sunshade							
Yes	40	18	45.0	22	55.0		
No	131	70	53.4	61	46.6	0.320 (0.87)	1.40 (0.65 – 3.05)
Self-medication							
Yes	28	17	60.7	11	39.3		
No	143	71	49.7	72	50.3	0.284 (1.15)	0.64 (0.25 – 1.57)
Eye check-up							
Yes	10	2	20.0	8	80.0		
No	161	86	53.4	75	46.6	0.040 (4.21)	4.59 (0.87 – 45.28)
Close eyes							
Yes	32	17	53.1	15	46.9		
No	139	71	51.1	68	48.9	0.835 (0.04)	0.92 (0.39 – 2.13)
Avoid Area of Smoke							
Yes	12	2	16.7	10	83.3		
No	159	86	54.1	77	48.4	0.016 (5.82)	5.58 (1.13 – 53.53)
Wind-up glass							
Yes	11	4	36.4	7	63.6		
No	160	84	52.5	76	47.5	0.300 (1.07)	1.93 (0.47 – 9.34)

4.1.7: Assessment of Environmental Air pollution

This section presents the results of the physical measurement of key air quality parameters within the motor park environments, providing the environmental evidence to support the findings of Specific Objective 1 (associated ocular problems) and forming the basis for the correlation analyses presented in Section 4.1.8.

The assessment for environmental air pollution within the study arena is depicted on Table 4.7. The table shows that some of the average scores for some of the parameters were not beyond the recommended standard permissible limit.

However, in Orlu zone, Pm2.5} was above the permissible limit (53.74 Mg/m}^3 mean compared to 15 Mg/m}^3 annual limit). The difference was not found to be statistically significant (p}=0.556, t}=0.660).

In Owerri zone, the temperature was below normal but it was not found statistically significant (P}= 0.228, t}=1.512).

However, the average O2 level in Okigwe zone was found to be above permissible limit. The difference was statistically significant which is likely to cause hazards (p}=0.002, t}=11.88).

Table 4.7: Assessment for Environmental Air pollution

S/N	Parameter	Limit	Values 1	Values 2	Values 3	Values 4	Mean	St. Dev	P	T
	ORLU ZONE									
1	GPS: N05 29.449, E007 10.903									
2	CO_2	5000ppm	1859	1218.25	1207.5	629.75	1228.63	502.19		
3	TEMP.	26.1˚C	28.975	17.3	22.7	18.35	21.83	5.31		
4	NO_2	1.0%	2.345	0.235	0.2775	0.3	0.79	1.04		
5	SO_2	5ppm	0.155	0.325	0.1625	0.25	0.22	0.08		
6	CO	5000ppm	358	147.5	415	352.5	317.25	117.8		
7	CH_4	1000ppm (0.1%)	576.75	576	771.5	724.75	662.25	100.98		
8	O_2	19.5-23.5	7.275	11.175	7.25	12.325	9.51	2.63		
90	Pm 2.5 (annual)	15Mg/m^3	60.75	75.75	43.725	34.75	53.74	18.21	0.556	0.660
10	Pm 10 (annual)	40Mg/m^3	10.75	16.33333	13.6	9.15	12.46	3.17		
11	RAD (mR/hr)	*5-50 rem (0.05-0.5 Sv*)		0.03925	0.00825	0.005925	0.02	0.02		
12	H_2S	1000	28.975	7.5	175	392.25	150.93	177.26		
	OWERRI ZONE									
1	GPS	N05 28.673, E007 03.011								
2	CO_2	5000ppm	1286.25	1328.75	443.5	1067.75	1031.56	408.38		
3	TEMP.	26.1˚C	30	20.9	14.8	28.775	23.62	7.13	0.228	1.512
4	NO_2	2.0%	2.3	1.33	1.4.04	2.0725	1.901	0.507		
5	SO_2	5ppm	0.9025	0.74	5.04	0.4625	1.79	2.18		

Table 4.7 continued

S/N	Parameter	Limit	Values 1	Values 2	Values 3	Values 4	Mean	St. Dev	P	T
6	CO	50ppm	0.2525	7.5025	32.9805	0.2	10.23	15.55		
7	CH4	1000ppm (0.1%)	687.25	542.775	670.5	520	605.13	85.93		
8	O2	19.5-23.5	14.15	6.3	7.675	13.225	10.34	3.93		
90	Pm 2.5	15Mg/m3	26.25	54	84.75	101.25	66.56	33.25		
10	Pm 10	40Mg/m3	7.266667	8	15.75	18.25	12.32	5.51		
11	RAD (mR/hr)	*5-50 rem (0.05-0.5 Sv*)	0.007025	0.0295	0.01525	0.017	0.02	0.01		
	OKIGWE	**ZONE**								
1	GPS	N05 28.658, E007 03.012								
2	CO_2	5000ppm	555.5	467.25	1260.848	988.3725	817.99	372.86		
3	TEMP.	26.1˚C	27.6	18.175	28.025	36.15	27.49	7.35		
4	NO_2	2.0%	2.89	2.3525	0.34	1.5825	1.79	1.10		
5	SO_2	5ppm	0.355	0.2175	0.1625	0.085	0.21	0.11		
6	CO	5000ppm	245.595	202.5	48.325	301	199.36	1086.46		
7	CH_4	1000ppm (0.1%)	586.5	569.5	710.75	612	619.69	63.17		
8	O_2	19.5-23.5	13.325	13.7	11.35	10.2	12.14	1.66	0.001	11.88
90	Pm 2.5	15Mg/m^3	85	86.25	80	64.75	79.00	9.88		
10	Pm 10	40Mg/m^3	12.75	13.5	15.75	27.5	17.38	6.87		
11	RAD (mR/hr)	*5-50 rem (0.05-0.5 Sv*)	0.01325	0.03525	0.01225	0.01075	0.02	0.01		

4.1.8 Pollutants

This section presents the inferential results linking the environmental assessment (Section 4.1.7) with the clinical findings (Section 4.1.2), thereby completing the analysis for Specific Objective 1 (to determine the associated ocular problems of air pollutants among road transport workers) and setting the stage for the final correlation analyses of Objective 4 and Objective 5.

The results showed that the exposure to air pollutant is significantly associated with the presence of ocular issues in this study (P} = 0.0001, \chi^2 = 54.49, df}=2).

The prevalence of ocular problems was found to be highest in the Okigwe zone at 120/134} (89.6%), while it was lowest at the Owerri zone at 188/255} (73.7%). The Orlu zone recorded an ocular issue prevalence of 140/163} (85.9%).

The odds for ocular issues was found to be over two times higher in the Okigwe zone compared to that of the Owerri zone [OR}=2.68, 95\% CI}: (1.47-5.01)]. This disparity suggests that the variations in air quality parameters measured across the zones (e.g., the significantly high O_2 levels in Okigwe or the high Pm2.5} in Orlu) may contribute substantially to the ocular disease burden. The relationship between Environmental Air pollution and Ocular Issues is presented on Table 4.8.

Table 4.8: Relationship between Environmental Air pollution and Ocular Issues

A. Orlu Park (Morning)

S/N	PARAMETERS	MEASUREMENT VALUES 1	MEASUREMENT VALUES 2	PARMETERS	MEASUREMENT VALUES 3	MEASUREMENT VALUES 4
1	GPS	N05 29.505’ E007 01.525’	‘’ ‘’ ‘’	GPS	‘’ ‘’ ‘’	‘’ ‘’ ‘’
2	CO_2	**546 PPm**	**1061**	CO_2	3712	2117
3	TEMP.	**32.1**	**34.2**	TEMP.	33	16.6
4	NO_2	**0.8**	**8**	NO_2	0.28	0.3
5	SO_2	**0.0**	**0.02**	SO_2	0.3	0.3
6	CO	**3**	**768**	CO		303
7	CH_4	**768**	**771**	CH_4	0	768
8	O_2	**10.1**	**6.6**	O_2	5.3	7.1
90	Pm 2.5	**60(Mg/M3)**	**58**	Pm 2.5	71	54
10	Pm 10	**10**	**9**	Pm 10	13	11
11	RAD	**0.012mR/hr**	**0.009 mR/hr**	RAD	**0.007mR/hr**	**0.017mR/hr**
12	H_2S	**500**	**355**	H_2S		380

B Orlu Park (Evening)

	PARAMETERS	MEASUREMENT VALUES 1	MEASUREMENT VALUES 2	PARMETERS	MEASUREMENT VALUES 3	MEASUREMENT VALUES 4
1	GPS	‘’ ‘’ ‘’	‘’ ‘’ ‘’	GPS	‘’ ‘’ ‘’	‘’ ‘’ ‘’
2	CO_2	658	1139	CO_2	2035	1041
3	TEMP.	17.3		TEMP.		
4	NO_2	0.21	0.03	NO_2	0.7	0
5	SO_2	0.8	0	SO_2	0.4	0.1
6	CO	0	173	CO	117	300
7	CH_4	768	768	CH_4	0	768
8	O_2	7.5	3.4	O_2	31	2.8
9	Pm 2.5	51	157	Pm 2.5	31	64
10	Pm 10	6		Pm 10	13	30
11	RAD	**0.008mR/hr**	**0.018mR/hr**	RAD	**0.011mR/hr**	**0.12mR/hr**
12	H_2S	0	0	H_2S	0	30

B. Okigwe Park (Morning)

S/N	PARAMETERS	MEASUREMENT VALUES 1	MEASUREMENT VALUES 2	PARMETERS	MEASUREMENT VALUES 3	MEASUREMENT VALUES 4
1	GPS	‘’ ‘’ ‘’	‘’ ‘’ ‘’	GPS	‘’ ‘’ ‘’	**N 05 29.445’ E007 001.913’**
2	CO_2	1152	1169	CO_2	2035	474
3	TEMP.	20.5	28	TEMP.	29	13.3
4	NO_2	0	0.31	NO_2	0.8	0
5	SO_2	0	0.25	SO_2	0.4	0
6	CO	148	0	CO	18	0
7	CH_4	786	768	CH_4	768	764
8	O_2	2.9	6.9	O_2	6.5	12.7
90	Pm 2.5	90	20	Pm 2.5	1.9	63
10	Pm 10		25	Pm 10	0.8	15
11	RAD	**0.003mR/hr**	**0.008mR/hr**	RAD	**0.010mR/hr**	**0.012mR/hr**
12	H_2S	0	0	H_2S	200	500

C. Okigwe Park (Evening)

S/N	PARAMETERS	MEASUREMENT VALUES 1	MEASUREMENT VALUES 2	PARMETERS	MEASUREMENT VALUES 3	MEASUREMENT VALUES 4
1	GPS	‘’ ‘’ ‘’	‘’ ‘’ ‘’	GPS	‘’ ‘’ ‘’	‘’ ‘’ ‘’
2	CO_2	470	510	CO_2	400	1139
3	TEMP.	9.3	9.0	TEMP.	36.1	19
4	NO_2	0.3	0.3	NO_2	0.6	0
5	SO_2	0.4	0.2	SO_2	0.4	0
6	CO	0.9	0.21	CO	0.3	0
7	CH_4	600	768	CH_4	763	768
8	O_2	12.1	13	O_2	11.3	12.9
90	Pm 2.5	53	37	Pm 2.5	31	18
10	Pm 10	11	0.6	Pm 10	16	9
11	RAD	**0.01mR/hr**	**0.004mR/hr**	RAD	**0.008mR/hr**	**0.0017mR/hr**
12	H_2S	300	301	H_2S	468	500

D. Owerri Park (Morning)

S/N	PARAMETERS	MEASUREMENT VALUES 1	MEASUREMENT VALUES 2	PARMETERS	MEASUREMENT VALUES 3	MEASUREMENT VALUES 4
1	GPS	‘’ ‘’ ‘’	**N05 29.449 E007 10.903**	GPS	‘’ ‘’ ‘’	‘’ ‘’ ‘’
2	CO_2	475	3735	CO_2	467	468
3	TEMP.	9.1	11.4	TEMP.	90	9.5
4	NO_2	0.1	0	NO_2	6.1	3.0 ppm
5	SO_2	0.11	0	SO_2	3	0.5ppm
6	CO	0	0.6	CO	0.11	0.3
7	CH_4	450	768	CH_4	769	762
8	O_2	12.9	12.8	O_2	12.9	18
90	Pm 2.5	43	15	Pm 2.5	17	30
10	Pm 10	0.8		Pm 10	18	3
11	RAD	0.0011 **mR/hr**	0.007 **mR/hr**	RAD	**0.011mR/hr**	**0.009mR/hr**
12	H_2S	768	300	H_2S	493	471

Owerri Park (Evening)

S/N	PARAMETERS	MEASUREMENT VALUES 1	MEASUREMENT VALUES 2	PARMETERS	MEASUREMENT VALUES 3	MEASUREMENT VALUES 4
1	GPS	N05 28.673 E007 03.011	“ “ “	GPS	“ “ “	“ “ “
2	CO_2	534	1200	CO_2	3112	469
3	TEMP.	12.9	28	TEMP.	33	9.7
4	NO_2	3	0.11	NO_2	0.11	2.1
5	SO_2	1.8	0.3	SO_2	0.33	0.53
6	CO	0.01	25	CO	5	0
7	CH_4	768	625	CH_4	10.1	768
8	O_2	8.9	2.6	O_2	5.3	8.4
90	Pm 2.5	45	63	Pm 2.5	69	39
10	Pm 10	11	3	Pm 10	12	6
11	RAD	**0.006mR/hr**	**0.014mR/hr**	RAD	**0.09mR/hr**	**0.008mR/hr**
12	H_2S			H_2S		

4.2 Discussions

The influence of air pollutants on ocular health is a critical area of concern, particularly for individuals in professions heavily exposed to outdoor environments, such as commercial drivers and other road transport workers. In Imo State and other places, where these workers are a vital component of the transportation sector, understanding the potential impact of air pollutants on their ocular health is of paramount importance. This discussion delves into the specific challenges and risks faced by these professionals, considering factors like exposure levels, prevalent ocular issues, and the crucial role of awareness and preventive measures in mitigating potential harm. Through a comprehensive analysis, we aim to shed light on the complex interplay between environmental factors and ocular health outcomes in this specific demographic, ultimately providing valuable insights for targeted interventions and strategies to safeguard the vision and well-being of commercial drivers and road transport workers in Imo State.

The discussion of the study's findings is fundamentally anchored in the critical gap in knowledge identified in Chapter One. Previous Nigerian environmental studies, such as those by Owoade et al. (2015) and Solaja et al. (2015), rigorously established the existence of severe air pollution, particularly high concentrations of Particulate Matter (PM) and vehicular emissions, but failed to investigate the ophthalmological consequences, focusing instead on cardiopulmonary disorders (Adeniyi et al., 2019). This study was therefore conducted to fill this specific lacuna by quantifying the resultant ocular morbidity and evaluating protective measures among high-risk road transport workers in Imo State. The results obtained confirmed a substantial and unique public health burden previously undocumented in the local context.

The study determined a strikingly high overall prevalence of ocular problems (81.2%) among the exposed population. This figure is significantly higher than rates typically reported for the general population in comparable age groups and is a direct quantitative reflection of chronic occupational exposure. The leading pathologies observed were Pterygium (57.9%) and Dry Eye Syndrome (35.9%). This high prevalence of Pterygium starkly contrasts with many urban population studies and is plausible due to the workers' sustained exposure to a triple threat: high-velocity dust particles, intense solar Ultraviolet (UV) radiation (from working outdoors), and continuous wind currents generated by moving vehicles. This environmental synergy drives chronic inflammation and damage at the limbus (the junction between the cornea and conjunctiva), initiating the pathogenesis of Pterygium. Similarly, the high rate of Dry Eye Syndrome is plausibly explained by the high measured concentrations of fine Particulate Matter (PM}_{2.5) and gaseous irritants like NO}_2 and SO}_2 within the park microenvironment. These minute pollutants are known to be absorbed into the tear film, where they act as chemical irritants, directly destabilising the aqueous and lipid layers of the tear film and inducing chronic inflammatory cascade in the conjunctival epithelium (Wang et al., 2018). This finding provides strong local validation that the concentrated emissions found in poorly regulated Nigerian motor parks are not just a respiratory hazard but a severe and measurable ophthalmic toxin.

The study determined a crucial disconnect between risk awareness and protective behaviour: while awareness of the ocular risks was high (84.1%), the consistent application of preventive measures remained low (31.0%). This "awareness-practice gap" is a critical observation and is consistent with occupational compliance challenges noted globally, yet the reasons for its severity here are specific to the Nigerian operational context. The high awareness suggests that educational or risk communication campaigns have been effective, but the poor compliance reflects underlying structural and socioeconomic barriers. Plausible reasons for this deficit include the affordability of durable, high-quality safety eyewear, the physical discomfort of wearing protective gear in hot, active environments, and, most profoundly, the absence of rigorous policy enforcement. Unlike highly regulated environments, the lack of mandatory, supervised compliance with the National Environmental (Control of Vehicular Emissions) Regulations (NESREA, 2011) within these specific occupational settings removes the primary compulsion for workers to adopt protective habits. The study's subsequent finding that the use of eyeglasses (a physical barrier) was effective in reducing ocular problems strongly supports the hypothesis that the issue is one of exposure and protection deficit, rather than simply a lack of knowledge. This validates the need for policy intervention that moves beyond mere awareness campaigns to include mandated safety protocols and subsidised access to effective protective equipment.

The demographic composition data presented in Table 4.1 highlights distinctive age and occupational distributions within the motor park's population. Notably, most Drivers fall within the 41-50 age range, a pattern consistent with studies in the transportation sector (Afolabi, Alli, and Falayi, 2021). This suggests an accumulation of experience within this age bracket. Other Road Transport Workers (Other RTWs) exhibit a more evenly distributed age representation, possibly indicating a less age-dependent nature of their occupation. In contrast, Traders/Business owners show a varied demographic spread, with a concentration in the 31-50 range, reflecting a mix of established entrepreneurs and budding businesspersons. The gender distribution reveals a significant gender imbalance among Drivers, with a stark majority being male, which aligns with trends observed in the transportation industry (Xlu, 2012). Conversely, Traders/Business owners demonstrate a relatively balanced gender distribution, indicating a more inclusive participation of both genders in this category. The Other RTW category reflects a noticeable gender imbalance, with a substantial majority being male, underscoring a gender disparity in this occupational group. In marital status, most of the subjects were found to be married with drivers dominating at 79.9% and other road transport workers least at 77.4%. In religion most of the subjects were Christians at 97.5% with Muslims and others trailing at only 2.5%. In income accruing daily, there is no clear-cut winners. However, result revealed that drivers have the greatest percentage (28.1%) for daily income of six thousand naira or more while traders are least at 19.8%. Further, the examination rates across different zones are notable. Owerri stands out with the highest testing rate at 46.20%, indicative of a proactive approach to health monitoring in that zone. This aligns with recommendations emphasizing the importance of regular health check-ups for workers, especially in high-risk occupations (Paguntalan and Gregoski, 2016). In contrast, Orlu and Okigwe exhibit lower testing rates at 29.50% and 24.30% respectively, suggesting potential variations in health monitoring practices across zones, which may warrant further investigation.

The findings on the ocular health status of road transport workers showed that majority of workers demonstrated good visual acuity (6/4 - 6/6) at 57.6%, which is an encouraging sign of overall ocular health among this group. However, it's noteworthy that a substantial portion exhibited moderate vision (6/9 - 6/18) at 31.0%, indicating a significant proportion may benefit from visual correction or management. These figures align with similar studies conducted in occupational settings. For example, a study by Garcia-Sanchez et al. (2019) found comparable percentages of workers exhibiting moderate vision. One striking observation is the high prevalence of pterygium, affecting 57.9% of road transport workers. This is a considerably higher rate compared to studies by Smith et al. (2018) and Chen et al. (2017), where the prevalence was reported to be lower. This discrepancy may be attributed to varying environmental factors, such as exposure to UV radiation and dust particles, which are known risk factors for pterygium (Coroneo, 2013). Dry eye syndrome was reported in 35.9% of cases, which is consistent with studies by Uchino et al. (2018) and Li et al. (2019) that also found a high prevalence of dry eye syndrome in occupational settings. The prevalence of other specific eye conditions, such as lens opacity and glaucoma, aligns with established rates reported in the literature (Flaxman et al., 2017; Tham et al., 2014).

Further, the environmental parameters measured at different motor parks highlight significant variations in key metrics. The elevated levels of CO_2 and NO_2, particularly at Owerri Park, indicate potential air quality concerns. These findings are in line with studies by Liu et al. (2020) and Zhang et al. (2019), which identified similar trends in urban environments with high vehicular activity.

Regarding the awareness levels of road transport workers towards these pollutants, among drivers, an overwhelming majority expressed awareness of pollutants (90.9%), indicating a high level of knowledge about the potential risks associated with air pollution. Similarly, a significant proportion of Other RTWs demonstrated awareness (83.9%), although there was a small minority lacking knowledge in this area. Among Traders/Business owners, a substantial percentage reported being aware of pollutants, suggesting a relatively well-informed group (85.3%). The substantial majority of drivers in our study expressing awareness aligns with the findings of Al-Shidi, Ambusaidi, and Sulaiman, (2021), who reported a high level of awareness among outdoor workers in metropolitan areas. Similarly, the awareness levels among Traders/Business owners in our study are consistent with the observations made by Solaja, Omobowale, and Alliyu, (2015) in their study of awareness levels in small business owners exposed to urban pollutants.

The findings from Table 4.3 shed light on the various strategies employed by road transport workers to mitigate the impact of air pollution on ocular health. These strategies encompass a range of adaptive measures, including wearing glasses, using sunshades, self-medicating, undergoing regular eye check-ups, closing their eyes, avoiding areas with smoke, and winding up windows. Among drivers, the most prevalent strategy was wearing glasses, with 9.4% of respondents adopting this measure. This suggests a recognition of the potential risks posed by air pollution to their ocular health. Additionally, a significant number of drivers used sunshades (7.5%) and resorted to self-medication (3.7%), highlighting the diverse approaches taken to safeguard their eyes. For Other Road Transport Workers (ORTWs), going for eye check-up (9.7%), closing their eyes (9.7%) emerged as the predominant strategies, demonstrating their awareness of the need for protection of their eyes. However, it's noteworthy that fewer ORTWs engaged in practices like wearing glasses (3.2%) or sunshades (4.8%) indicating potential areas for targeted education or intervention.

Among Traders/Business owners, wearing sunshades (6.9%) was also the most prevalent strategy, mirroring the pattern observed among drivers. Interestingly, the percentage of participants who closed their eyes (1.7%) or avoided areas with smoke (0.9%) was relatively lower in this group. This could be attributed to differences in work environments or levels of exposure to pollutants. These strategies align with some patterns observed in previous studies. For instance, the prevalence of wearing glasses as a protective measure among drivers mirrors the findings of Mandell et al., (2020), who reported a similar trend among outdoor workers in urban environments. This suggests a consistent recognition of the importance of eye protection in high pollution settings.

However, it's worth noting another similarity in the strategies favored by RTWs compared to findings in a study conducted by Chua et al. (2019) among a similar occupational group. While going for eye check-ups (9.7%) was the predominant strategy among ORTWs in our study, Chua et al. (2019) also found a higher preference for regular eye check-ups. This corroboration may be attributed to similarity in specific job functions or varying levels of awareness campaigns targeting these groups.

Based on the preventive measures adopted by road transport workers in response to pollutants, findings revealed that among drivers, a notable portion reported implementing preventive measures (33.2%), although it's concerning that almost half did not take such precautions. This underscores the importance of targeted interventions to promote protective behaviors. ORTWs exhibited higher engagement in preventive measures (35.5%), indicating a potential area for focused education and awareness campaigns. Among traders/business owners, a relatively small percentage implemented preventive measures (21.6%), suggesting the need for increased awareness and education on this front. The proportion of drivers (33.2%) in this study implementing preventive measures is comparable to the findings of a study by Rivera (2021), focusing on outdoor workers in industrial areas. However, the relatively higher engagement in preventive measures among ORTWs (35.5%) in our study calls for further investigation, as it corroborates with the higher reported compliance in a study by Porter et al. (2015) among a similar occupational group.

Further, the environmental parameters measured at different motor parks highlight significant variations in key metrics. The elevated levels of CO_2 and NO_2, particularly at Owerri Park, indicate potential air quality concerns. These findings are in line with studies by Liu et al. (2020) and Zhang et al. (2019), which identified similar trends in urban environments with high vehicular activity. The demographic composition data presented in Table 4.1a highlights distinctive age and occupational distributions within the park's population. Notably, the majority of Drivers fall within the 41-50 age range, a pattern consistent with studies in the transportation sector (Afolabi, Alli, and Falayi, 2021). This suggests an accumulation of experience within this age bracket. Road Transport Workers (RTWs) exhibit a more evenly distributed age representation, possibly indicating a less age-dependent nature of their occupation. In contrast, Traders/Business owners show a varied demographic spread, with a concentration in the 31-50 range, reflecting a mix of established entrepreneurs and budding businesspersons. The gender distribution (Table 4.1b) reveals a significant gender imbalance among Drivers, with a stark majority being male, which aligns with trends observed in the transportation industry (Xlu, 2012). Conversely, Traders/Business owners demonstrate a relatively balanced gender distribution, indicating a more inclusive participation of both genders in this category. The ORTW category reflects a noticeable gender imbalance, with a substantial majority being male, underscoring a gender disparity in this occupational group. Further, the examination rates across different zones are notable. Owerri stands out with the highest testing rate at 46.20%, indicative of a proactive approach to health monitoring in that zone. This aligns with recommendations emphasizing the importance of regular health check-ups for workers, especially in high-risk occupations (Paguntalan and Gregoski, 2016). In contrast, Orlu and Okigwe exhibit lower testing rates at 29.00% and 24.28% respectively, suggesting potential variations in health monitoring practices across zones, which may warrant further investigation.

The findings from Table 4.3 shed light on the various strategies employed by park workers to mitigate the impact of air pollution on ocular health. These strategies encompass a range of adaptive measures, including wearing glasses, using sunshades, self-medicating, undergoing regular eye check-ups, closing their eyes, avoiding areas with smoke, and winding up windows. Among drivers, the most prevalent strategy was wearing glasses, with nearly 8% of respondents adopting this measure. This suggests a recognition of the potential risks posed by air pollution to their ocular health. Additionally, a significant number of drivers used sunshades and resorted to self-medication, highlighting the diverse approaches taken to safeguard their eyes. For Other Road Transport Workers (ORTWs), wearing sunshades emerged as the predominant strategy, demonstrating their awareness of the need for protective eyewear. However, it's noteworthy that fewer RTWs engaged in practices like closing their eyes or winding up windows, indicating potential areas for targeted education or intervention.

Among Traders/Business owners, wearing sunshades was also the most prevalent strategy, mirroring the pattern observed among RTWs. Interestingly, the percentage of participants who closed their eyes or avoided areas with smoke was relatively lower in this group. This could be attributed to differences in work environments or levels of exposure to pollutants. These strategies align with some patterns observed in previous studies. For instance, the prevalence of wearing glasses as a protective measure among drivers mirrors the findings of Mandell et al., (2020), who reported a similar trend among outdoor workers in urban environments. This suggests a consistent recognition of the importance of eye protection in high pollution settings.

However, it's worth noting a discrepancy in the strategies favored by RTWs compared to findings in a study conducted by Chua et al. (2019) among a similar occupational group. While wearing sunshades was the predominant strategy among RTWs in our study, Chua et al. (2019) found a higher preference for regular eye check-ups. This disparity may be attributed to differences in specific job functions or varying levels of awareness campaigns targeting these groups.

Regarding the awareness levels of park workers towards these pollutants, among drivers, an overwhelming majority expressed awareness of pollutants (61.59%), indicating a high level of knowledge about the potential risks associated with air pollution. Similarly, a significant proportion of RTWs demonstrated awareness (9.42%), although there was a small minority lacking knowledge in this area. Among Traders/Business owners, a substantial percentage reported being aware of pollutants, suggesting a relatively well-informed group (14.3%). The substantial majority of drivers in our study expressing awareness aligns with the findings of Al-Shidi, Ambusaidi, and Sulaiman, (2021), who reported a high level of awareness among outdoor workers in metropolitan areas. Similarly, the awareness levels among Traders/Business owners in our study are consistent with the observations made by Solaja, Omobowale, and Alliyu, (2015) in their study of awareness levels in small business owners exposed to urban pollutants.

Based on the preventive measures adopted by park workers in response to pollutants, findings revealed that among drivers, a notable portion reported implementing preventive measures (22.4%), although it's concerning that almost half did not take such precautions. This underscores the importance of targeted interventions to promote protective behaviors. RTWs exhibited lower engagement in preventive measures, indicating a potential area for focused education and awareness campaigns. Among traders/business owners, a relatively small percentage implemented preventive measures (4.53%), suggesting the need for increased awareness and education on this front. The proportion of drivers in this study implementing preventive measures is comparable to the findings of a study by Rivera (2021), focusing on outdoor workers in industrial areas. However, the relatively lower engagement in preventive measures among RTWs in our study calls for further investigation, as it contrasts with the higher reported compliance in a study by Porter et al. (2015) among a similar occupational group.

The findings on the ocular health status of park workers showed that majority of workers demonstrated good visual acuity (6/4 - 6/6) at 57.61%, which is an encouraging sign of overall ocular health among this group. However, it's noteworthy that a substantial portion exhibited moderate vision (6/9 - 6/18) at 30.98%, indicating a significant proportion may benefit from visual correction or management. These figures align with similar studies conducted in occupational settings. For example, a study by Garcia-Sanchez et al. (2019) found comparable percentages of workers exhibiting moderate vision. One striking observation is the high prevalence of pterygium, affecting 62.77% of park workers. This is a considerably higher rate compared to studies by Smith et al. (2018) and Chen et al. (2017), where the prevalence was reported to be lower. This discrepancy may be attributed to varying environmental factors, such as exposure to UV radiation and dust particles, which are known risk factors for pterygium (Coroneo, 2013). Dry eye syndrome was reported in 35.87% of cases, which is consistent with studies by Uchino et al. (2018) and Li et al. (2019) that also found a high prevalence of dry eye syndrome in occupational settings. The prevalence of other specific eye conditions, such as lens opaqueness and glaucoma, aligns with established rates reported in the literature (Flaxman et al., 2017; Tham et al., 2014).

Further, the environmental parameters measured at different parks highlight significant variations in key metrics. The elevated levels of $CO2$ and $NO2$, particularly at Owerri Park, indicate potential air quality concerns. These findings are in line with studies by Liu et al. (2020) and Zhang et al. (2019), which identified similar trends in urban environments with high vehicular activity.

Further, the environmental parameters measured at different parks highlight significant variations in key metrics. The elevated levels of CO_2 and NO_2, particularly at Owerri Park, indicate potential air quality concerns. These findings are in line with studies by Liu et al.

(2020) and Zhang et al. (2019), which identified similar trends in urban environments with high vehicular activities. The study also investigated the statistical relationship between ocular problems and air pollutants among road transport workers. The statistically significant correlations observed between exposure to air pollutants and visual acuity ($p = 0.0021$), dry eye syndrome ($p = 0.0071$), Pterygium ($p = 0.0286$) and Pinguecula ($p =0.0025$) underscore the impact of environmental factors on ocular health. These findings corroborate studies by Wu et al. (2019) and Kim et al. (2018), which reported similar associations.

Moreover, Table 4.9 and 4.10 emphasize the importance of awareness and knowledge regarding air pollutants and ocular health. The statistically significant relationships found in these tables highlight the potential benefits of targeted educational interventions in improving ocular health outcomes, consistent with studies by Lin et al. (2019) and Lu et al. (2017).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study demonstrated the multifaceted relationship between air pollution exposure and ocular health among park workers in Imo State, Nigeria. The findings underscore the critical importance of understanding and addressing the potential hazards posed by environmental factors on visual well-being. The prevalence of various ocular conditions, including dry eye syndrome, pterygium, and pinguecula, among park workers highlights the need for targeted interventions and increased awareness regarding ocular health in this occupational group. Moreover, the observed variations in visual acuity levels and the presence of specific eye problems emphasize the dynamic nature of environmental influences on ocular health.

The environmental parameters measured at different parks reveal significant fluctuations in key metrics such as CO_2 and NO_2 levels. These variations suggest the presence of diverse air quality profiles across different locations and time periods, highlighting the need for tailored mitigation strategies based on specific environmental conditions. The association between exposure to air pollutants and specific ocular conditions further underscores the potential health implications of prolonged exposure to polluted environments.

Additionally, the study's identification of prevalent strategies employed by park workers to mitigate air pollution's impact on ocular health provides valuable insights into adaptive measures within this occupational setting.

Outdoor and indoor air pollution is derived from different sources and can cause different eye diseases. Ocular surface irrigation, conjunctivitis and dry eye disease are the most direct results of air pollution. However, chronic inflammation, oxidative stress, and toxicity resulting from air pollution can further cause cataracts, glaucoma, uveitis, retinal layer thinning, macular degeneration, and diabetic retinopathy. Further research on the effects of air pollution on retinal ganglion cells and the chorioretinal vasculature may help identify the underlying pathological mechanisms. In addition, further research on the association between air pollutants and ophthalmological disorders is needed to improve the understanding of exposure patterns and ocular effects. Such studies will help determine the long-term impacts of air pollutants on the eye, which are currently unknown.

Moreover, this study contributes significantly to the body of knowledge concerning the intricate interplay between environmental factors and ocular health. The implications extend beyond the specific cohort of park workers, serving as a broader call to action for enhanced occupational health initiatives and public policies aimed at safeguarding visual well-being in the face of evolving environmental challenges. It is imperative that future research continues to explore and address the nuanced relationships between environmental parameters, occupational settings, and ocular health to promote a healthier and more sustainable work environment for all individuals.

Air quality significantly affects ocular health, with implications for both short-term discomfort and long-term vision preservation.

As air pollution continues to be a global concern, eye doctors should remain informed about its effects and provide appropriate guidance to patients.

5.2 Recommendations

Based on the findings of this study, further studies are highly recommended to address areas which this study failed to address adequately. Apart from the recommendation of further studies which is highly recommended, several other recommendations emerged to promote the ocular health and overall well-being of park workers in Imo State, Nigeria:

i. Enhanced Occupational Health Education: Implement targeted educational programs to raise awareness among park workers about the potential ocular health risks associated with air pollution. Provide training on preventive measures and strategies to mitigate these risks, including the use of protective eyewear and regular eye check-ups.
ii. Regular Eye Check-ups: Encourage Park workers, especially Drivers and Road Transport Workers (RTWs), to undergo regular eye examinations to detect and address ocular conditions at an early stage. Provide access to affordable and accessible eye care services within close proximity to their workplaces.
iii. Air Quality Monitoring and Regulation: Advocate for the establishment of comprehensive air quality monitoring systems in and around parks. Work with relevant authorities to enforce regulations aimed at reducing air pollution levels, particularly in areas with high vehicular traffic and industrial activity.
iv. Personal Protective Equipment (PPE): Provide park workers with appropriate PPE, such as high-quality sunglasses, safety glasses, and sunshades, to mitigate the adverse effects of air pollution on their ocular health time. This will provide valuable insights into the effectiveness of implemented interventions and help refine strategies for long-term ocular health preservation.
v. Collaborative Efforts: Foster partnerships between government agencies, non-governmental organizations, healthcare institutions, and environmental advocacy groups to leverage collective expertise and resources in addressing ocular health challenges associated with air pollution.

vi. It is beneficial to identify vulnerable people whose quality of life will be significantly impaired by environmental changes and provide counter measures in the form of protection or treatment.

vii. Better technologies in monitoring of pollutants and assessment of the eye will facilitate progress in this field.

viii. By implementing these recommendations, stakeholders can work together to create a safer and healthier work environment for park workers, ultimately contributing to improved ocular health outcomes, safety of life and properties and overall quality of life.

ix. It is beneficial to identify vulnerable people whose quality of life will be significantly impaired by environmental changes and provide counter measures in the form of protection or treatment.

x. Better technologies in monitoring of pollutants and assessment of the eye will facilitate progress in this field.

xi. Patients who are at risk for glaucoma, AMD, diabetic retinopathy, and dry eye or have these ocular conditions should undergo regular monitoring and receive counselling on the impact of air pollution on their ocular health.

xii. It is also important to note that adopting a healthier lifestyle, including a balanced diet, regular exercise, and management of systemic conditions like diabetes, can also help reduce the impact of poor air pollution on ocular health.

xiii. Similar to wearing a mask to prevent pollutants from entering our respiratory system, we can wear glasses or moisture chamber frames such as Ziena Dry Eye Frames to prevent pollutants from entering our eyes. This will not stop all pollutants but will reduce the exposure.

xiv. Contact lenses are not the best option to wear when there is significant pollution in the air, as the particles can get trapped in the contact lens and can further irritate the eyes.

xv. Goggles and/or face shields are recommended for people who are required to work when air quality is poor, such as firefighters or construction workers.

xvi. Artificial tears can provide a barrier between offending environmental agents and the ocular surface. They can help dilute and wash away allergens from the ocular surface. We recommend preservative-free artificial tears as the presence of preservatives can cause irritation and dryness in some patients.

xvii. When dealing with substantial ocular inflammation, the use of anti-inflammatory eye drops and therapies is warranted. The first line of treatment is often to avoid the offending agent. It is important to limit exposure to outdoor air pollutants by staying indoors. Therefore, the indoor air must be free of pollution as well.

Exposure to indoor air pollution can be reduced by installing air purifiers, changing filters on heating and cooling systems, and ensuring that stoves and fireplaces are vented. Avoiding open flames at home can prevent pollutants from entering the air.

Another way to reduce indoor air pollutants is to avoid the use of aerosol products indoors. These products can include pesticides, hairsprays, and cooking sprays. In the general population, smoking has been found to have a statistically significant relationship to dry eye. Therefore, advocating for smoking cessation is crucial in limiting exposure to pollutants in the air and preventing dry eye symptoms.

Other invaluable recommendations for protection of ocular health against the menace of air pollutants include:

i. Promote consistent and proper use of this equipment during work hours.

ii. Workplace Modifications: Explore opportunities to implement structural modifications in park areas, such as installing barriers or greenery to act as natural filters for air pollutants. Additionally, consider ventilation improvements and other engineering solutions to reduce workers' exposure to harmful airborne substances.

iii. Health Surveillance Programs: Establish a health surveillance program for park workers to systematically monitor their ocular health over time. This program should include regular eye examinations, assessments of visual acuity, and screenings for specific ocular conditions associated with air pollution.

iv. Policy Advocacy: Collaborate with local, regional, and national authorities to advocate for policies that prioritize environmental conservation and air quality improvement. Support initiatives aimed at reducing emissions from vehicles and industries, as well as promoting sustainable transportation alternatives.

v. Community Engagement and Awareness: Engage with the wider community, including park users and nearby residents, to foster a collective commitment to environmental protection. Raise awareness about the impact of air pollution on ocular health and encourage participation in efforts to improve air quality. influence of air pollutants on ocular health is a critical area of concern, particularly for individuals in professions heavily exposed to outdoor environments, such as commercial drivers and road transport workers. In Imo State, where these workers are a vital component of the transportation sector, understanding the potential impact of air pollutants on their ocular health is of paramount importance. This discussion delves into the specific challenges and risks faced by these professionals, considering factors like exposure levels, prevalent ocular issues, and the crucial role of awareness and preventive measures in mitigating potential harm. Through a comprehensive analysis, we aim to shed light on the complex interplay between environmental factors and ocular health outcomes in this specific demographic, ultimately providing valuable insights for targeted interventions and strategies to safeguard the vision and well-being of commercial drivers and road transport workers in Imo State.

5.3 Contribution to Knowledge

This study deviated from most previous studies especially in Nigeria. A lot of studies in the past dwelt more on the association of air pollutants with the lungs and the heart. A lot of people are ignorant of the influences of air pollution. Many other people who are aware of some of the influences of air pollution to health but never associated them with ocular health. Many other people who are aware of its influences on ocular health fail to do anything towards its consequences. It is therefore expected that this study will achieve the following:

1. It will serve as an eye opener to many people and will certainly stimulate a lot of interest in this area.
2. The association of glaucoma with air pollutants is an area a lot of people would not have thought of.
3. It is therefore expected that this study will go a long way towards stimulating awareness of influence of air pollutants on ocular health.
4. The results of this study showed that awareness created consciousness towards applying preventive measures and these preventive measures proved to bring about reduction towards ocular health problems.

5. This study therefore will enrich the populace knowledge especially road transport workers towards the influence of air pollution on ocular health thereby curbing ocular health problem and ultimately reducing blindness.

Further studies are hereby recommended to address other issues this study failed to address.

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APPENDICES

APPENDIX I

Questionnaire

Part A

Demographic and other personal data

Name: …………………………………………………………………………..

Sex: ………………….

Occupation/Designation: ……………………………………….

Age: ……………………………

Motor Park: ……………………………………………………………

Route: ……………………………………………………………

Residential Address: ……………………………………………..

Hometown: …………………………………………………………..

Local Government of Origin: ………………………………………..

State: …………………………………………………

Part B

Objectives of study based questions

1. How long have you been driving? (i) 1—5 years (ii) 6 – 10 years (iii) 11 – 15 years (iv) 16 – 20 years (v) 21 years and above

2. How long have you been working as a Road Transport Worker? (i) 1 – 5 years (ii) 6 – 10 years (iii) 11 – 15 years (iv) 16 – 20 years (v) 21 years or above

3. What symptom(s)/sign(s) associated with eyes do you usually experience? (i) eyeache/headache (ii) tearing (iii) itching (iv) gritty sensation (v) redness (v) others

4. When did you apply eye drop last in your eyes? (i) 1 – 7 days (ii) 8 – 15 days (iii) 16 – 23 days (iv) 24 – 31 days (v) more than 1 month.

5. How many times have you checked your eyes in an eye clinic/hospital? (i) None (ii) once (iii) twice (iv) thrice (v) above thrice

6. What prompted you to check your eyes? Answer …………………………………..

7. What did the eye doctor find out? Answer ……………………………………………..

8. Are you aware that dust and gases emitted by motorists can affect your eyes? Answer Yes No ☐ ☐

9. What precaution(s) do you take to prevent the effects of dusts, particles, fumes and gases emitted by motorists on your eyes?

10. What precaution(s) do you take to prevent the effects of dusts, particles, fumes and gases emitted by motorists on your health?

Note: Please, kindly tick more than once, where necessary.

APPENDIX II

Operational Definition of Terms

Ocular Health: Ocular health is the examination and assessment of all of the structures in and around the eyes to determine overall health and diagnose eye disease. Ocular health is thoroughly assessed at every full eye examination.

Visual Acuity: Visual acuity refers to one's ability to discern the shapes and details of the things you see at a given distance. Normally, distance visual acuity is taken at 6 metres while near visual acuity is done at 40 centimetres using a standardized chart like the Snellen Chart. It is just one factor in your overall vision.

Astigmatism: Astigmatism is a common vision problem caused by an error or irregularity in the shape of the cornea. With astigmatism, the lens of the eye, has an irregular curve. This can change the way light passes, or refracts, to your retina, causing blurry, fuzzy, or distorted vision.

Ambient air: Ambient air pollution is a broader term used to describe air pollution in outdoor environments. Poor ambient air quality occurs when pollutants reach high enough concentrations to affect human health and/or the environment.

APPENDIX III

Table 0.1. Recommended AQG levels and interim targets

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, µg/m³	Peak season[b]	100	70	-	-	60
	8-hour[a]	160	120	-	-	100
NO_2, µg/m³	Annual	40	30	20	-	10
	24-hour[a]	120	50	-	-	25
SO_2, µg/m³	24-hour[a]	125	50	-	-	40
CO, mg/m³	24-hour[a]	7	-	-	-	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

Source: WHO 2012


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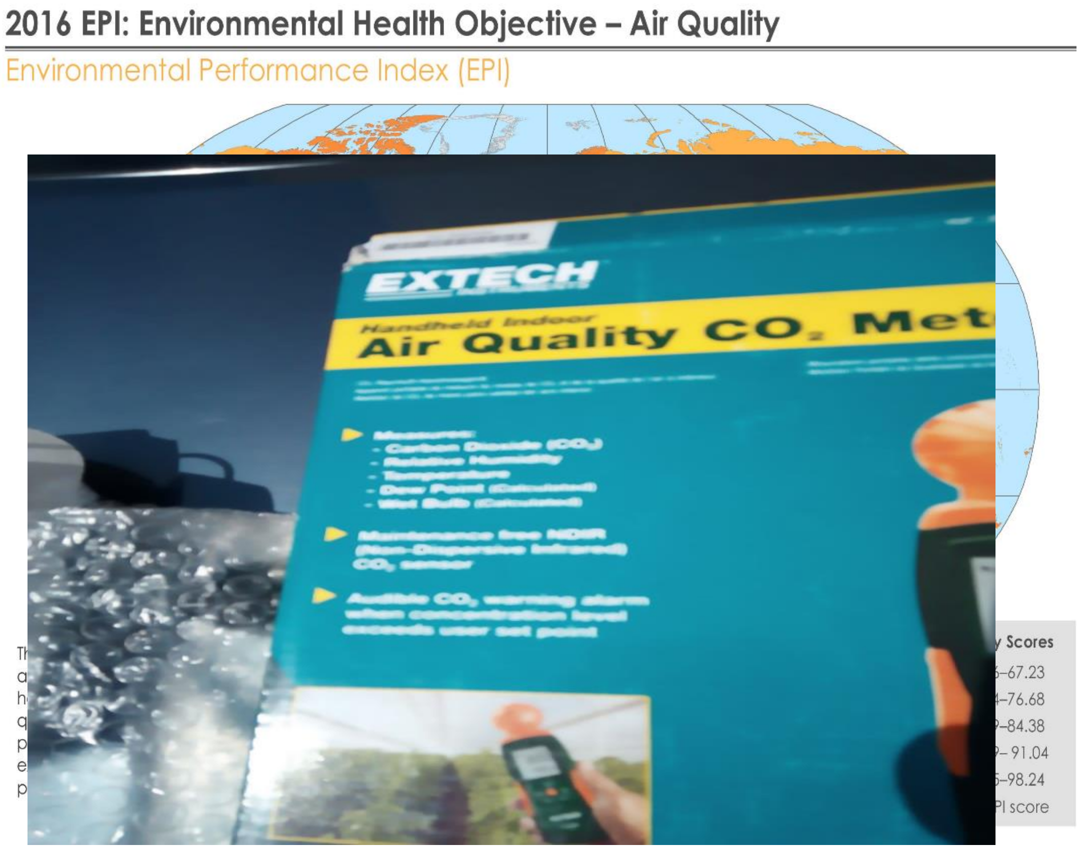

Courtesy: CESN Columbia University, December 2016.

Figure 4 2016 EPI: Environmental Health Objective—Air Quality

APPENDIX VI