ENVIRONMENTAL AIR POLLUTANTS AS RISK FACTORS IN THE OCCURRENCE OF RESPIRATORY CONDITIONS IN SOME SELECTED LGAs OF BAYELSA STATE SANATORIAL ZONES

BY

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

MAY, 2025

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IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D.) DEGREE

MAY, 2025

CERTIFICATION

This is to certify that this Project on the "Environmental Air Pollutants as Risk Factors in the Occurrence of Respiratory Conditions in Some Selected LGAs of Bayelsa State Senatorial Zones" was carried out by **Ekiyor, Christopher Peres** with registration numbers **20174144698** in partial fulfillment of the requirement for the award of Doctor of Philosophy (Ph.D.) (Environmental Health Option) degree in the Department of Public Health, School of Health Technology, Federal University of Technology Owerri, Imo State.

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DEDICATION

This research proposal is dedicated to all members of the environmental pollution ravaged communities in the Niger Delta Region of Nigeria who had suffered for so long under the never-ending burden of environmental degradation occasioned by petroleum exploration and exploitation. It is also dedicated to all individuals and groups working tirelessly to provide succor for this people

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Dr. Chris Ekiyor
BDS, MBA, MPH

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ABBREVIATIONS

CH4	Methaene
CO	Carbon Monoxide
COPD	Chronic obstructive pulmonary disease
FMOEnv	Federal Ministry of Environment
GHGs	Greenhouse gases
NH	Ammonia
NO	Nitrous Oxide
NO_2	Nitrogen dioxide
O_3	Ozone
$PM_{2.5}$	Particulate matter (fine)
PM_{10}	Particulate matter (Coarse)
SO_2	Sulphur dioxide
TB	Tuberculosis
WHO	World Health Organisations

ABSTRACT

Ambient (outdoor) air pollution is a major cause of disease and death globally. Poor ambient air quality occurs when pollutants reach high enough concentrations to affect human health and the environment. Long-term exposure to air pollution reduces life expectancy, as an after effect of respiratory diseases such as lung cancer which is associated with exposure to air pollution. The present study was primarily aimed at establishing the level of risk of respiratory conditions that are contributed by the various environmental air pollutants which affect the residents of Bayelsa State. The study was designed as a population-based survey study performed in Bayelsa State Nigeria. The study involved measurement of some targeted air pollutants and their ambient concentrations which were compared with the WHO's permissible standards and the Federal Ministry of Environment recommended limit. In addition, a questionnaire was used to assess 428 adult residents of Bayelsa State on the level of knowledge of the respondents about respiratory conditions, specifically on causes, prevention and control. The respondents were recruited from several communities across different local government areas in two senatorial zones in the State representing (Bayelsa Central and Bayelsa West). The two zones were purposively selected to represent the two types of environments in Bayelsa State (fresh water and salt water activities). Further, purposive sampling technique was also used to purposively select LGAs the fall within the fresh water and salt water activities in each of the two study zones. The mean ambient air quality level of the study area was compared with the WHO permissible limit and also with Ministry of Environment recommended standard for each pollutant using t-test method. Also, t-test was used to compare the mean ambient air quality level between Bayelsa West and Bayelsa Central while ANOVA test was used to compare the mean ambient air quality level across the study LGAs, The respiratory condition of the study participants was measured using PEFR and the outcome was classified as normal or poor respiratory conditions. The relationship between exposure to air pollutants and respiratory conditions were assessed in a logistic regression method. The result shows that the knowledge was high on some of the common respiratory symptoms such as persistent cough (93.3%), wheezing (92.8%) and Fatigue and weakness (72.7%). Just 53.7% (230 out of 428), showed good knowledge of respiratory conditions rom ambient air pollutants within their environment. The mean ambient level was high and exceeded WHO and FMOEnv permissible limit for all the pollutants SO_2 (78.53 ± 22.32 μg/m^3), NO_2, (62.59 ± 17.78), C0 (8.47 ± 4.66), NH (0.37 ± 0.23), $PM_{2.5}$ (51.58 ± 17.17) and PM_{10} (170.19 ± 44.42).Southern Ijaw contained the highest level of SO_2 and NH (0.94μg/m^3), The NO_2 was found highest in Yenagoa (152.1 μg/m^3), while CO also high in Ekeremor LGA (23.4μg/m^3). The average PEFR was 451.6 ± 77.6 l/min for the study group. The mean PEFR was significantly lower in Bayelsa West (429.8 ± 73.4 l/min) than in Bayelsa Central (473.3 ± 87.5 l/min) ($p < 0.0001$). Common respiratory symptoms in the area were wheezing (25.7%), pneumonia (18.1%), 54 (11.6% for asthma (11.6%), COPD (11%), bronchitis (5.1%) and others. Association was found between exposure to air pollution and poor respiratory conditions ($P < 0.000$). The study concluded that the study area is well polluted and required urgent attention to enforcement of protective measures against ambient air pollutants.

Keywords: Air Pollutants, Risk Factors, Respiratory Conditions, Bayelsa State, Environment

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Environmental pollution is described basically as "the contamination of the physical and biological components of the earth/atmosphere system to such an extent that normal environmental processes are adversely affected (JPEC, 2023). The various components that made up the human environment including the air, water and land can be rendered inhabitable by the introduction into them of harmful substances which may be of natural or synthetic origin.

Air pollution is the introduction of harmful substance which can be airborne into the earth's atmosphere which makes the air unconducive for use by humans and other lives that inhabits such polluted environment. These harmful substances which are introduced to the atmosphere also have the ability to damage the climate and cause damages to the other materials in the environment (WHO, 2023). Air pollution involved the contamination of both the indoor and the outdoor surrounding air as a result of chemical activities, physical or biological agents that alters the natural features of the atmosphere (Manisalidis et al., 2020). There are different classes of air pollutants. There are the gases- including; ammonia (NH_3), carbon monoxide (CO), sulfur dioxide (SO_4), nitrous oxides (NO), methane (CH_4) and chlorofluorocarbons (CFCs); the particulate matters (both organic and inorganic); and the biological molecules. Pollution of the air can cause diseases, allergies, and even death to humans; it can also cause harm to other living organisms such as animals and crops, and may damage the natural environment- This is as seen in the case of climate change, ozone depletion and habitat degradation. The built environment can also be greatly degraded as a result of acid rain from

serious atmospheric pollution in and around industrial areas (Howell & Pickerill, 2016). Air pollution can be brought about by both human activities(Dimitriou & Christidou, 2011) and through natural phenomena (Gov.uk, 2018). Around the world, the quality of the air has a direct bearing on the climatic conditions and the entire ecosystem. It is worthy of mention that many of the contributors of air pollution are also sources of greenhouse gases (GHGs) emission- for instance, burning of fossil fuel, flaring of natural gas, CO emission from automobiles and industries are all sources of GHGs (Manisalidis et al., 2020).

Air pollution is a significant risk factor for a number of pollution-related diseases, including respiratory infections, heart disease, chronic obstructive pulmonary disease (COPD), stroke, and lung cancer (Allen et al., 2017). Growing evidence suggests that air pollution exposure may be associated with reduced IQ scores, impaired cognition (Newbury et al., 2021), increased risk for psychiatric disorders such as depression (Ghosh et al., 2021) and detrimental perinatal health (Stanek et al., 2011). The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to (Majumder et al., 2023; Vallero, 2014), the degree of exposure, and the individual's health status and genetics (J Lelieveld et al., 2019). Outdoor air pollution attributable to fossil fuel use alone causes an estimated 3.61 million deaths annually around the world, making it one of the top contributors to human mortality (Allen et al., 2017), with man-made activity generated ozone and Particulate Matter 2.5 ($PM_{2.5}$) contributing an estimated 2.1 million of these mortalities (Jos Lelieveld et al., 2020; Silva et al., 2013). Globally every years, air pollution results in the deaths of about 7 million people, which translates to a worldwide average loss of life expectancy (LLE) of 2.9 years (Cherian, 2022). This makes air pollution to be the world's

largest single environmental health risk, which has been without any visible improvement since at least 2015 (Allen et al., 2017; Fuller et al., 2022). According to a 2008 report of the Blacksmith institute, indoor air pollution and poor urban air quality were listed as two of the world's worst toxic pollution problems (Welch, 2021). According to multiple reports, the problem of the air pollution crisis is so large that about 90% of the world's population breathes dirty air to some extent. The consequences of air pollution on a global scale in terms of loss of productivity and degraded quality of life are estimated to cost an estimated $5 trillion annually (Batool et al., 2019; Lauren, 2016).

According to the WHO record, about 2.4 billion people worldwide- which is the equivalent of one third of the world's population- still do their cooking using open fires or inefficient stoves that are fueled by kerosene, biomass- wood, animal dung and crop waste- and coal, which generates harmful household air pollution. This household air pollution was responsible for an estimated 3.2 million deaths per year in 2020, including over 237,000 deaths of children under the age of 5. The combined effects of ambient air pollution and household air pollution are associated with 6.7 million premature deaths annually (WHO, 2022a). It was also reported that household air pollution exposure leads to non-communicable diseases including stroke, ischemic heart disease, chronic obstructive pulmonary disease (COPD) and lung cancer. It will also be important to emphasize that it is women and children, that are basically responsible for household chores such as cooking collecting firewood, that bear the greatest health burden from the use of polluting fuels and technologies in homes (WHO, 2022a).

In Nigeria, A large proportion (75%) of the petroleum is found in the coastal regions of the Niger delta areas of the country. This petroleum reserve is the largest oil reserve in Africa and

the 10th largest in the world (Moffat & Linden, 1995). Data from the Ministry of Petroleum Resources revealed that there are 150 oilfields and over 1,400 oil wells in the Niger delta regions (Watts & Zalik, 2020). This abundant reserve of crude Hydrocarbon in the region has attracted numerous industrial establishments, whose activities tend to affect the quality of the environment and health of the populations. Oil exploration causes a range of environmental problems including: contamination of both surface and ground water by benzene, xylene, toluene, ethylbenzene and other benzene derivatives; contamination of soil by oil spills and leaks; increased deforestation; economic loss and environmental degradation stemming from gas flaring (Ogolo et al., 2022). Gas flaring produces enormous amounts of greenhouse gases (GHG) including carbon dioxide (CO_2), methane (CH_4), and propane (C_3H_8) (Shaw et al., 2023). It has been estimated by the World Bank that about 10% of global CO_2 emissions come from gas flaring (The World Bank, 2022). Nigerian gas flaring alone releases an estimated 35m tonnes of CO_2 and about 12m tonnes of CH_4 (The World Bank, 2022). The World Bank 2022 It has been reported that CH_4 in particular has a more serious global warming potential than CO_2 (Watts, 2001). Apart from GHG, the gas flaring also produces hazardous compounds that harm human health and ecosystems leading to various lungs and respiratory conditions. Apart from the industrial revolution that is brought about by the crude oil reserves in the Niger Delta regions of Nigeria, many crude oil thieves operating illegal crude oil refineries popularly referred to as Bunkering (Amanze, 2022) have also emerged. The manner with which these illegal oil refiners processes the hydrocarbon to give yield to substandard semi-finished fuels have left the air and the general environment of the Niger Delta areas grossly polluted with its attendant consequences on the health and wellbeing of the people that are living the region. Despite the efforts of the Federal Government of Nigeria to rid the Niger Delta areas of these

illegal refineries operators, these Bunkers have continued to find means to remain and to continue to carry on with their illicit and environmentally damaging operations, moving deeper into the States especially in Rivers and Bayelsa States (Amanze, 2022).

It is against the backdrop of the oil exploration activities-gas flaring-, industrial activities and the operations of the illegal oil refineries in Bayelsa State, coupled with the gross pollution of the ambient and indoor air and atmosphere of the Bayelsa State environment and that of its neighboring States in the Niger Delta region that this study was conducted to identify the various respiratory conditions that are likely to be associated with this air pollution. This research will contribute to our understanding of the scope and magnitude of the problem of air pollution in the study area, especially as it relates to the development of various respiratory conditions among the residents of Bayelsa State. This study will also provide recommendations that will inform policy direction in the amelioration of the problems of respiratory disorders among the people that are associated with air pollution.

1.2 Problem Statement

According to the WHO, air pollution is the largest form of all environmental pollution, and poses the largest health risk among all forms of pollution. Three million annual deaths are associated with outdoor air pollution exposure alone (WHO, 2022b). In 2019 for instance, outdoor air pollution was responsible for an estimated 4.2 million death globally (WHO, 2022c). Approximately 90% of air pollution-related deaths occurring in low and middle-income countries are as a result of non-communicable diseases, such as cardiovascular diseases (CVDs), chronic obstructive pulmonary disease (COPD), and lung cancer all of which are directly related to air pollution (WHO, 2022c).

Report from the Nigeria's air quality status research which is contained in the Green Data Book 2017 (The World Bank, 2017) revealed that over 94% of the country's population are exposed to $PM_{2.5}$ in levels that exceed the WHO guidelines. This prevalence exceeds the Sub-Saharan Africa average which is at about 70% prevalence (The World Bank, 2017). Even though the scope of this research does not include the specific appraisal of the socioeconomic characteristics of the people in the study location, various reports have shown that air pollution and its consequences disproportionately affect the poor in the society (Godson & Sridhar, 2009; WHO, 2022b). Numerous studies have reported high level of air pollution and poor quality of air in the Niger Delta areas of Nigeria (Nwachukwu et al., 2012; Rim-Rukeh, 2015; Ubong et al., 2015).

A study that was conducted to assess the levels of indicator air pollutants in cities of Rivers State- one of the Bayelsa neighboring States- and their possible correlation with the development of various air borne diseases among the residents, revealed evidences of high correlation (Adoki, 2012). In a study to ascertain the disease prevalence associated with industrial-related air pollution in specified Niger Delta communities, Godson et al. (Ana et al., 2009) established strong relationships between air pollutants, including PM with morbidities, such as respiratory diseases, traumatic skin outgrowth, and child deformities. Another study revealed that the health consequences of air pollution including ling cancer is higher in prevalence in Port Harcourt, Rivers State than in Ibadan, Oyo State, confirming the contributions of industrial and mining activities to the overall air and environmental pollution (Ana et al., 2010).

Despite the wide spread oil exploration and exploitation activities across Bayelsa State, both legal and illegal, and the reported high prevalence of respiratory and cardiovascular disorders from the State, there has been no previous research study on the association between air pollution and the development of respiratory disorders in Bayelsa State. This study will therefore fill the gap to identify the risk level of respiratory disorders being contributed by air pollution due to mining and industrial activities in Bayelsa State.

1.3 Objectives of the Study

1.3.1. General Objective

The main objective of this study is to determine the level of risk of respiratory conditions that are contributed by the various environmental air pollutants that the residents of Bayelsa State are constantly being exposed to.

1.3.2. Specific Objectives

In order to achieve the aim of this research study, the following are the specific objectives are to;

1. Assess the knowledge level of respiratory conditions among the residents of Bayelsa State with particular focus on causes, control and prevention.
2. Determine the ambient level of common air pollutants from industries and mining activities including SO_2, CO_2, CO, NH and PM (2.5, 5 and 10) in the Bayelsa State atmosphere.
3. Compare the ambient levels of the air pollutants (SO_2, CO_2, CO, NH and PMs) in Bayelsa State with the WHO and the Federal Ministry of Environment permissible levels and standards.

4. Determine the various respiratory conditions that are common among the residents of Bayelsa State including Asthma, Emphysema, COPD, Bronchitis and Pneumonia.
5. Determine the association between air pollution exposure and the development of respiratory conditions among the residence of Bayelsa State.

1.4 Research Questions

In order for the aims and objectives of the research study to be achieved, and provide guidance to the direction of the study, the following research questions are posed;

1. What is the level of knowledge of Bayelsa State residents regarding respiratory conditions in term of the causes, the controls and modes of prevention?
2. What are the ambient levels of common air pollutants in the Bayelsa State atmosphere?
3. Are the ambient levels of common air pollutants in the Bayelsa State atmosphere within the WHO and the Federal Ministry of Environment permissible levels and standards?
4. What are the various respiratory conditions that are common among the residents of Bayelsa State?
5. Is there any association between air pollution exposure and the development of respiratory conditions among the residence of Bayelsa State?

1.5 Research Hypothesis

Hypothesis1.

Ho: The level of ambient air pollution that the Bayelsa State residents are exposed to is not significant enough to serve as a risk factor of respiratory conditions development among the people.

1.6 Justification of the Study

Without a doubt, the advantages from conducting research studies that sought to establish a correlation between air pollution exposure and health outcomes cannot be over-emphasized. When effectively conducted, this study will provide the needed evidence that can be used to engage the policy makers and the health authorities on means to protect the environment of the Bayelsa people, reduce exposure to poor air quality and toxic air, thereby, bringing about reduction in the overall prevalence of respiratory disorders among the people. The association between environment and health as shown in various studies is worthy of note (Ana et al., 2009; Carnell et al., 2019; Environment Agency, 2020). This means people that lives in locations with good environmental qualities tend to enjoy better health outcomes compared to people who are exposed to poor environmental conditions including poor quality ambient air on a daily basis.

Previous studies conducted in selected communities in Niger Delta areas of Nigeria, observed that communities that were cited away from factories, industries reported low prevalence of various respiratory disorders (Ana et al., 2009; Ejifugha & Ibhafidon, 2012).

In the light of the above highlighted importance environment to health, also as stated in sustainable development goals (SDG) 3 that a healthy environment is a requisite for the promotion of the health and wellbeing of all people of all ages (United Nations Department of Economic and Social Affairirs, 2021). It is therefore, important for this research to assess the level of air pollution in Bayelsa State and its implication in the existing respiratory conditions/ complications among the people. Findings will support recommendations to be made to the

appropriate stakeholders on more effective ways of tackling air pollution for the promotion of the health of Bayelsa citizens.

1.7 Scope of the Study

This study on the appraisal of environmental air pollutants as risk factor of respiratory conditions in Bayelsa State was conducted in among adults 18 years and above in the study area. The study was be conducted among all eligible respondents in households that were recruited from several communities across different local government areas in two senatorial zones in the State representing the two main types ecosystems that are obtainable in Bayelsa state.

The study involved measurement of some targeted air pollutants in comparison their ambient concentrations following the WHO's permissible standards. Questionnaire was used to assess the level of knowledge of the respondents about respiratory conditions, their causes, prevention and control.

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Air pollutants

Air pollution is a multifaceted and widespread environmental concern that carries substantial implications for the well-being of the general population. The correlation between the occurrence of air pollution and worsening of respiratory conditions and exposure to diverse air pollutants is widely recognized (WHO, 2022a). The main air pollutants that are of significant concern include particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), Sulphur dioxide (SO_2) and Carbon-monoxide (CO) (Dockery et al., 1993; WHO, 2022a). A variety of sources, such as vehicular emissions, industrial processes, and natural occurrences like wildfires, release these pollutants. The detrimental impacts of these pollutants on respiratory health have been extensively researched. The WHO has established a clear link between particulate matter (PM) and respiratory health. The infiltration of fine particulate matter ($PM_{2.5}$) into the respiratory system has been linked to heightened levels of inflammation, oxidative stress, and airway remodeling (Brook et al., 2010). The development of chronic respiratory diseases, such as chronic obstructive pulmonary disease (COPD) and asthma, has been found to be associated with prolonged exposure to PM2.5 (Pope III et al., 2004). Ozone, a prevalent constituent of smog, poses a substantial risk to respiratory health. Research has indicated that the exposure to ozone has been associated with the occurrence of airway inflammation, a decrease in lung function, and an increased vulnerability to respiratory infections (Jerrett et al., 2009).

The exacerbation of respiratory conditions, particularly among vulnerable populations such as children and the elderly, has been linked to nitrogen dioxide emissions primarily originating from combustion processes (Gent et al., 2003). In a similar vein, the emission of Sulphur dioxide, primarily derived from the combustion of fossil fuels, has the potential to induce irritation in the respiratory passages and exacerbate symptoms in individuals with pre-existing respiratory ailments such as asthma (WHO, 2022a). The multifaceted nature of the mechanisms that underlie the impact of air pollution on respiratory health is evident. The central role of inflammatory responses, which are initiated by exposure to pollutants, has been highlighted in previous research (Q. Li et al., 2017). Cytokine release and oxidative stress play pivotal roles in the inflammatory cascade, thereby contributing to the impairment and dysfunction of the airways. In addition, it should be noted that air pollution has the potential to initiate airway remodeling, resulting in alterations to the structure of the respiratory system, compromised lung function, and heightened vulnerability to respiratory ailments (Kelly & Fussell, 2015). Certain demographic groups, including children and the elderly, exhibit heightened vulnerability to the detrimental impacts of air pollution. According to Gauderman et al., (2004), there is evidence to suggest that children who are exposed to air pollution may encounter persistent challenges in the development of their lungs, which could result in the manifestation of respiratory conditions that persist throughout their lifetime. The elderly population is more susceptible to developing severe respiratory symptoms when exposed to polluted air, primarily due to age-related physiological changes (Bell et al., 2005). Efforts aimed at mitigating the effects of air pollutants on respiratory health encompass the implementation of regulatory policies and the establishment of air quality standards. Efforts have been made at both national and international levels to establish guidelines with the objective of mitigating the exposure to detrimental

pollutants. However, the successful implementation of these guidelines continues to face persistent challenges (WHO, 2022a). In addition, scholars have suggested various mitigation strategies, including urban planning, transitioning to cleaner energy sources, and implementing public awareness campaigns, as means to decrease the adverse effects of air pollution on respiratory health (Gardner & Moallef, 2015).

2.1.2 Air pollutants and their consequences on health

Air pollution, resulting from the release of various pollutants into the atmosphere, has been shown to have profound and often adverse effects on the respiratory system. Particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) are some of the key pollutants that have been implicated in respiratory health issues (WHO, 2022a). The association between air pollution and respiratory health is well-established, and numerous studies have highlighted the detrimental impact of these pollutants on lung function and the development and exacerbation of respiratory conditions. Particulate matter, specifically fine particles ($PM_{2.5}$), is known to pose a significant risk to respiratory health. These microscopic particles can penetrate deep into the lungs, triggering inflammation and oxidative stress (Brook et al., 2010). Long-term exposure to $PM_{2.5}$ has been linked to the development of chronic respiratory diseases such as asthma and COPD (Pope III et al., 2004). Furthermore, short-term exposure to elevated PM levels has been associated with increased hospital admissions for respiratory issues (Bell et al., 2005).

Ozone, a major component of urban smog, is another prominent air pollutant with adverse effects on respiratory health. Ozone exposure can cause airway inflammation and lead to decreased lung function (Jerrett et al., 2009). Studies have demonstrated that ozone exposure is associated with increased respiratory symptoms and exacerbations, particularly among

individuals with pre-existing respiratory conditions (Künzli et al., 2005). The interaction between ozone and other pollutants can further amplify the risk, emphasizing the need for a comprehensive approach to air quality management.

Nitrogen dioxide and sulfur dioxide, primarily emitted from combustion processes, have also been linked to respiratory health concerns. Nitrogen dioxide exposure has been associated with bronchial hyperresponsiveness and airway inflammation (Janneane F Gent et al., 2003). Sulfur dioxide, often originating from industrial sources, can exacerbate symptoms in individuals with asthma and other respiratory diseases (Khreis et al., 2019). The effects of these pollutants are particularly concerning for vulnerable populations, such as children and the elderly, who may experience more severe respiratory effects even at lower exposure levels. The mechanisms through which air pollution affects respiratory health are multifaceted. Inflammatory responses and oxidative stress play a central role in mediating the adverse effects of pollutants on the respiratory system (Li et al., 2003). These responses can lead to airway damage, increased mucus production, and compromised lung function. Furthermore, long-term exposure to air pollution has been linked to airway remodeling, a process characterized by structural changes in the airways that can contribute to chronic respiratory conditions (Kelly & Fussell, 2015).

Some of the air pollutant of public health important are described below.

Particulate Matter

Particulate matter (PM), a complex mixture of tiny solid particles and liquid droplets suspended in the air, is a significant air pollutant with far-reaching implications for respiratory health. PM is categorized based on its size, with $PM_{2.5}$ (particles with a diameter of 2.5 micrometers or smaller) being particularly concerning due to its ability to penetrate deep into the respiratory

system (Brook et al., 2010). The adverse health effects of PM, especially $PM_{2.5}$, have been extensively studied and are of paramount concern to public health. Exposure to PM has been associated with a range of respiratory health issues. Inhalation of PM can lead to acute effects such as irritation of the respiratory tract and exacerbation of existing respiratory conditions like asthma and chronic obstructive pulmonary disease (COPD) (Ciencewicki & Jaspers, 2007). Long-term exposure to elevated PM levels is linked to the development and progression of chronic respiratory diseases. Research has shown that $PM_{2.5}$ exposure is associated with decreased lung function and increased respiratory symptoms (Dockery et al., 1993). Furthermore, PM exposure has been linked to increased respiratory infections and hospital admissions (Bell et al., 2005).

The mechanisms by which PM affects respiratory health are complex and not fully understood. The small size of PM allows it to bypass the body's natural defense mechanisms and reach the deeper regions of the lungs, where it can induce inflammation and oxidative stress (Li et al., 2003). This inflammatory response can trigger airway remodeling, a process characterized by structural changes in the airways that contribute to chronic respiratory conditions (Kelly & Fussell, 2015). Additionally, PM exposure can lead to systemic effects, impacting cardiovascular health and further exacerbating respiratory issues (Brook et al., 2010). Vulnerable populations, such as children, the elderly, and individuals with pre-existing respiratory conditions, are particularly susceptible to the health effects of PM exposure. Children exposed to PM may experience impaired lung development and long-term respiratory issues (Gauderman et al., 2004). Similarly, the elderly is at a higher risk of experiencing exacerbations of respiratory conditions due to their reduced physiological reserve (Bell et al., 2005). Individuals with pre-existing conditions like asthma are more likely to experience

worsened symptoms and increased medication use in the presence of high PM levels (Jerrett et al., 2009). Addressing the impact of PM on respiratory health necessitates a comprehensive approach. Regulatory measures to limit PM emissions from various sources, including industry and transportation, are crucial. Additionally, urban planning that promotes green spaces and reduces exposure to high levels of PM can contribute to improved respiratory outcomes (Gauderman et al., 2004). Public awareness campaigns about the health risks of PM exposure can empower individuals to take protective measures, especially during periods of elevated pollution.

Ozone (O_3)

Ozone, chemically represented as O_3, is a gas characterized by its high reactivity, and it serves a dual function within the Earth's atmosphere. The presence of ozone in the upper stratosphere functions as a crucial barrier against ultraviolet (UV) radiation, safeguarding the environment. However, at ground level, ozone becomes a significant air pollutant, posing considerable risks to respiratory well-being. Ground-level ozone is not emitted directly into the atmosphere. Instead, it is produced through intricate chemical reactions that involve precursor pollutants, specifically nitrogen oxides (NOx) and volatile organic compounds (VOCs), in the presence of sunlight (WHO, 2022a). The phenomenon of ozone formation, referred to as a photochemical process, primarily takes place in urban and industrial regions characterized by elevated levels of vehicular emissions and industrial operations (Monks et al., 2015).

The documented impact of ground-level ozone on respiratory health is a matter of concern. Exposure to ozone has been found to be linked to various detrimental respiratory effects, particularly among individuals who already have underlying health conditions such as asthma and chronic obstructive pulmonary disease (COPD). According to Künzli et al., (2005), the act

of inhaling ozone has the potential to induce airway inflammation, oxidative stress, and heightened bronchial responsiveness. The aforementioned responses have been found to exacerbate respiratory symptoms and lead to a higher rate of hospital admissions for respiratory ailments (Bell et al., 2005).

Children, due to their ongoing respiratory system maturation, are especially susceptible to the impacts of ozone exposure. Research has indicated that there exists a correlation between exposure to ozone and negative effects on lung function and growth in children, which may result in the development of respiratory problems in the long run (Avol et al., 2001). In a similar vein, older individuals, who frequently exhibit decreased pulmonary capacity and diminished physiological reserves, face an elevated susceptibility to heightened respiratory symptoms upon exposure to elevated levels of ozone (Bell et al., 2005).

The influence of ozone on respiratory health extends beyond the exacerbation of pre-existing conditions. According to Malig et al., (2016), empirical evidence suggests that the exposure to ozone has the potential to enhance vulnerability to respiratory infections, thereby potentially resulting in more severe consequences. In addition, an increasing body of evidence indicates a correlation between ozone exposure and allergic reactions, implying that ozone might intensify the allergic response to prevalent allergens, thereby adding complexity to respiratory well-being (Malig et al., 2016). In order to comprehensively assess the effects of ozone on respiratory health, it is imperative to adopt a multidimensional strategy. The implementation of regulatory strategies targeting the mitigation of precursor pollutants, specifically nitrogen oxides (NOx) and volatile organic compounds (VOCs), plays a pivotal role in constraining the formation of ozone. According to Monks et al. (2015), the implementation of various strategies aimed at

managing vehicular emissions and industrial activities, along with the promotion of cleaner energy sources, can effectively contribute to the reduction of ozone levels.

Nitrogen Dioxide (NO_2)

Nitrogen dioxide (NO_2) is a prevalent atmospheric contaminant that predominantly originates from the combustion of fossil fuels, particularly in vehicular and industrial contexts (WHO, 2022a). The combustion process of these fuels results in the emission of nitrogen oxides (NOx), including NO_2, into the Earth's atmosphere. According to Carnell et al., (2019), urban areas that experience high traffic density and contain industrial zones are commonly associated with increased levels of nitrogen dioxide (NO_2) due to the clustering of emission sources. The potential negative impact of NO_2 on respiratory health has received considerable attention in academic discourse.

Nitrogen dioxide (NO_2) is a respiratory irritant that has the potential to induce airway inflammation and worsen respiratory conditions. Numerous epidemiological studies have consistently demonstrated a correlation between exposure to nitrogen dioxide (NO_2) and heightened occurrences of respiratory symptoms, hospital admissions, and visits to emergency rooms (Gent et al., 2003). According to Gauderman et al., (2004), prolonged exposure to increased levels of nitrogen dioxide (NO_2) has been associated with hindered development of lung function in children and worsened symptoms of asthma. Certain demographic groups, including children, the elderly, and individuals with pre-existing respiratory conditions, are particularly susceptible to encountering detrimental respiratory consequences as a result of exposure to nitrogen dioxide (NO_2) (WHO, 2022a).

The pathways through which individuals are exposed to nitrogen dioxide (NO_2) are intricately linked to activities associated with combustion. Motor vehicle emissions play a significant role in the contribution of ambient NO_2 levels within urban environments. In addition, the emission of NO_2 into the atmosphere is attributed to various sources such as industrial processes, power generation, and residential combustion of fossil fuels (Carnell et al., 2019). Indoor sources, such as gas stoves and tobacco smoke, have been identified as additional contributors to indoor exposure to nitrogen dioxide (NO_2) (Wolkoff, 2013). It is important to acknowledge that the indoor environment can have a substantial impact on overall exposure levels, particularly for individuals who spend prolonged periods of time indoors. The ramifications for respiratory health resulting from exposure to nitrogen dioxide (NO_2) are diverse and complex. Besides its immediate irritating effects, nitrogen dioxide (NO_2) has the potential to interact with other pollutants and allergens, thereby intensifying respiratory reactions. For example, nitrogen dioxide (NO_2) has the potential to amplify the allergic reaction to prevalent allergens, which may worsen symptoms in individuals suffering from allergic asthma (Malig et al., 2016). Furthermore, nitrogen dioxide (NO_2) has the potential to contribute to the generation of particulate matter (PM), which in turn has been associated with various detrimental impacts on respiratory health (Li et al., 2003). Addressing the respiratory health implications associated with exposure to nitrogen dioxide (NO_2) necessitates the implementation of focused interventions. The implementation of regulatory measures targeting the reduction of vehicle emissions and the promotion of cleaner transport technologies plays a vital role in mitigating ambient levels of nitrogen dioxide (NO_2). According to Carnell et al., (2019), the implementation of urban planning strategies that promote active transportation and alleviate traffic congestion can potentially lead to decreased levels of exposure. According to Wolkoff,

(2013), effective measures to reduce indoor exposure to NO_2 involve implementing appropriate ventilation systems and adopting cleaner cooking and heating technologies. Public health campaigns aimed at increasing awareness regarding the origins and health hazards associated with exposure to nitrogen dioxide (NO_2) have the potential to empower individuals to adopt precautionary measures, particularly those who are more vulnerable to its detrimental impacts.

Sulphur dioxide (SO_2)

Sulphur dioxide (SO_2) is a noxious gas and a major air pollutant with widespread sources, primarily the combustion of sulfur-containing fossil fuels. Power generation, oil refining, and manufacturing all contribute to SO_2 emissions into the atmosphere (WHO, 2022a). High SO_2 levels are frequently observed in urban and industrial areas with heavy energy production and transportation activities (Dockery et al., 1993). The effects of SO_2 on respiratory health have been well documented, emphasizing the critical need for effective mitigation strategies. Excessive SO_2 exposure can cause a variety of negative respiratory effects. SO_2 inhalation causes respiratory tract irritation, resulting in airway constriction and inflammation (Lippmann, 2014). This can cause acute respiratory symptoms as well as worsening of pre-existing conditions like asthma and chronic obstructive pulmonary disease (COPD) (Künzli et al., 2005). Long-term SO_2 exposure is linked to decreased lung function, increased respiratory symptoms, and an increased susceptibility to respiratory infections (Aguilar et al., 2021). Vulnerable populations, such as children, the elderly, and people with respiratory diseases, are especially vulnerable to these side effects (WHO, 2022a).

SO_2 exposure pathways are inextricably linked to combustion processes. Sulphur dioxide is released into the atmosphere when sulfur-containing fossil fuels are burned. Indoor sources such

as the combustion of coal and other solid fuels for heating and cooking also contribute to indoor SO_2 levels, particularly in areas without access to clean energy alternatives (Wolkoff, 2013).

SO_2's effects on the respiratory system are mediated by a variety of mechanisms, it can cause bronchoconstriction and increase airway hyperresponsiveness, especially in people who already have respiratory problems (Vonk et al., 2003). Furthermore, SO_2 can react with other pollutants to form fine particulate matter ($PM_{2.5}$), exacerbating respiratory problems (Lippmann, 2014). Also, long-term SO_2 exposure can cause airway remodeling, which is characterized by structural changes in the airways and contributes to the development of chronic respiratory diseases (Kelly & Fussell, 2015).

To address the respiratory effects of SO_2, comprehensive strategies that target its sources and promote cleaner alternatives are required. To reduce ambient SO_2 levels, regulatory measures aimed at reducing Sulphur emissions from industrial processes and vehicles are critical. Promoting the use of cleaner energy sources and developing technologies for fossil fuel combustion can help to reduce SO_2 emissions significantly (Aguilar et al., 2021). Indoor air quality can be improved by using cleaner cooking and heating methods, especially in low-resource settings (Wolkoff, 2013).

2.1.3 Mechanisms of air pollution-induced respiratory effects

These mechanisms encompass oxidative stress, inflammation, immune responses, and epigenetic modifications, ultimately contributing to the development and exacerbation of respiratory conditions. The intricate interplay of these processes underscores the multifaceted nature of air pollution's impact on respiratory health. Oxidative stress is a central mechanism underlying the respiratory effects of air pollution. Pollutants such as particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) generate reactive oxygen species

(ROS) upon interaction with cells in the respiratory tract (Li et al., 2003). These ROS cause cellular damage, impair antioxidant defenses, and disrupt redox signaling, leading to inflammation and tissue injury. Oxidative stress can initiate a cascade of events that activate inflammatory pathways, contributing to the exacerbation of respiratory symptoms and the progression of chronic respiratory diseases (Kelly & Fussell, 2015). Inflammation is a hallmark response to air pollution exposure and plays a pivotal role in respiratory health effects. PM and other pollutants can directly stimulate airway cells to release pro-inflammatory cytokines and chemokines (R. Li et al., 2009). These signaling molecules attract immune cells, such as neutrophils and macrophages, to the site of inflammation, amplifying the immune response. Chronic inflammation, as observed in individuals exposed to high levels of pollutants, can contribute to tissue remodeling and airway hyperresponsiveness, characteristic of conditions like asthma and COPD (Kelly & Fussell, 2015).

Immune responses also contribute significantly to the respiratory effects of air pollution. Pollutants can modulate immune cell function and differentiation, influencing the balance between pro-inflammatory and anti-inflammatory responses (Thomson et al., 2017). Immune dysregulation induced by air pollution exposure may result in increased susceptibility to respiratory infections, as well as an enhanced allergic response to environmental allergens (Malig et al., 2016; Thomson et al., 2017). Such interactions between air pollution, immunity, and respiratory health underscore the complexity of the mechanisms at play.

Epigenetic modifications provide further insights into the molecular mechanisms underlying air pollution-induced respiratory effects. Exposure to pollutants can lead to changes in DNA methylation, histone modifications, and non-coding RNA expression, altering gene expression

patterns relevant to respiratory health (Tarantini et al., 2009). These epigenetic changes may persist over time and contribute to the development of respiratory conditions. Furthermore, epigenetic modifications can occur in utero, impacting lung development and increasing susceptibility to respiratory diseases later in life (Breton et al., 2019).

Inflammatory responses

Inflammatory responses are the body's natural defense mechanism against harmful stimuli such as pollutants in the air. Airway cells initiate an inflammatory cascade when exposed to pollutants such as particulate matter (PM), ozone (O_3), and nitrogen dioxide (NO_2). Immune cells such as neutrophils and macrophages are drawn to the site of inflammation and release a variety of pro-inflammatory cytokines and chemokines (Li et al., 2009). While this response aims to remove the irritant and repair damaged tissues, long-term exposure to high levels of pollutants can cause chronic inflammation. This chronic inflammation is associated with airway remodeling, which is characterized by structural changes that contribute to respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD) (Kelly & Fussell, 2015).

Cytokine release is an important component of the inflammatory response and a key mediator of the respiratory effects of air pollution. Cytokines are signaling molecules that regulate inflammation and coordinate immune cell activity. Pollutants cause airway cells to release pro-inflammatory cytokines like interleukin-1 (IL-1) and interleukin-6 (IL-6) as well as tumor necrosis factor- (TNF-) (Li et al., 2009). These cytokines boost the immune response, attracting immune cells and adding to tissue damage. Overproduction of pro-inflammatory cytokines can

cause a dysregulated immune response, resulting in collateral damage to respiratory tissues and exacerbation of respiratory symptoms (Thomson et al., 2017).

Oxidative stress is a critical link between inflammatory responses and the respiratory effects of air pollution. When pollutants interact with cells, they produce reactive oxygen species (ROS), which disrupts the balance between oxidative stress and antioxidant defense mechanisms (Li et al., 2003). This disruption causes oxidative stress to cellular components such as lipids, proteins, and DNA. Cellular dysfunction and damage as a result of this contribute to the activation of inflammatory pathways and the release of pro-inflammatory cytokines. Together, oxidative stress and inflammation form a vicious cycle, with each process exacerbating the other (Kelly & Fussell, 2015).

The interaction of inflammatory responses, cytokine release, and oxidative stress emphasizes the complication of air pollution-induced respiratory effects. The activation of these mechanisms is not limited to a single pollutant but involves the combined impact of multiple pollutants present in the ambient air. Individual susceptibility factors, such as genetics and pre-existing health conditions, can also influence the magnitude of these responses. This complication highlights the difficulties in developing targeted interventions to reduce the respiratory health effects of air pollution. A comprehensive approach is required to address these mechanisms. Reduced pollutant emissions, particularly from transportation and industry, are critical to lowering pollutant concentrations and mitigating inflammatory responses (Carnell et al., 2019). Antioxidant-rich diets and nutritional interventions may offer potential anti-oxidative stress and inflammation strategies (Thomson et al., 2017). Furthermore, understanding the genetic and epigenetic factors that modulate inflammatory and oxidative

stress responses can provide insights into individual susceptibility and inform personalized respiratory health management approaches.

Airway remodeling, structural changes in airways, impaired lung function

The effects of air pollution on the respiratory system go beyond the immediate symptoms, often involving more subtle and long-term consequences such as airway remodeling and impaired lung function. These processes reflect the respiratory system's adaptive responses to chronic pollutant exposure and highlight the importance of understanding the structural changes that contribute to respiratory diseases. The structural changes that occur in the airways as a result of prolonged inflammation and repeated insults from pollutants are referred to as airway remodeling. Alterations in the cellular composition of the airway walls, deposition of extracellular matrix components, and changes in blood vessel distribution are all part of the remodeling process (Hogg et al., 2004). The thickening of airway walls, which narrows the air passages and impairs airflow, is a significant result of airway remodeling. Airway remodeling contributes to increased airway resistance in people with asthma and chronic obstructive pulmonary disease (COPD), exacerbating breathing difficulties and reducing lung function. Pollutant exposure, such as particulate matter (PM) and ozone (O_3), has been linked to airway remodeling and an increased risk of respiratory diseases (Kelly & Fussell, 2015).

Airway structural changes are an important component of airway remodeling and play an important role in respiratory health effects. Pollutants have a particularly negative impact on the epithelial cells that line the airways. Pollutant exposure over time can cause epithelial cell damage, dysfunction, and shedding. This compromises the airway epithelium's barrier function, allowing irritants and allergens to penetrate deeper into the airways and trigger inflammatory responses. Furthermore, collagen and other extracellular matrix components deposition

contributes to airway fibrosis by stiffening the airway walls and decreasing their ability to dilate during breathing (Hogg et al., 2004).

Impaired lung function is a direct result of airway remodeling and structural changes. Airway narrowing and increased airway resistance reduce the flow of air into and out of the lungs, resulting in breathing difficulties and reduced lung capacity. This is especially noticeable in conditions like asthma, where the bronchial tubes become hyperresponsive to irritants and constrict excessively. Furthermore, impaired lung function is a defining feature of chronic respiratory diseases like COPD, which is characterized by irreversible airflow limitation caused by a combination of airway remodeling, inflammation, and mucus production (López- Campos et al., 2016). Long-term exposure to pollutants such as nitrogen dioxide (NO_2) has been linked to impaired lung function in studies, highlighting the role of air pollution in the development of respiratory diseases (Dockery et al., 1993).

Mitigating airway remodeling and its effects on lung function necessitates a multifaceted approach. Pollutant emissions can be reduced through regulatory measures, transitioning to cleaner energy sources, and promoting sustainable transportation (Carnell et al., 2019). Early interventions, such as anti-inflammatory and anti-hyperresponsiveness pharmacological treatments, can help slow the progression of airway remodeling and preserve lung function (Kelly & Fussell, 2015). Additionally, efforts to raise public awareness about the health risks of air pollution and the importance of implementing clean air policies are critical in fostering a healthier respiratory environment.

Immune system dysregulation

Air pollution-induced immune system dysregulation frequently results in heightened allergic reactions, especially in people who are predisposed to allergies and asthma. Pollutants like

particulate matter (PM) and ozone (O_3) can act as adjuvants, causing an overreaction to common allergens (Malig et al., 2016). The activation of immune cells and the production of immunoglobulin E (IgE) antibodies in response to allergen exposure is known as allergic sensitization. As a result, people who are exposed to pollutants in the air are more likely to develop allergic asthma and other allergic respiratory diseases (Thomson et al., 2017). In addition, immune system dysregulation increases susceptibility to respiratory infections. Pollutants disrupt the delicate balance between pro-inflammatory and anti-inflammatory immune responses, resulting in impaired immune defenses against pathogens. Pollutants such as nitrogen dioxide (NO_2) and particulate matter (PM) can suppress immune cell function, impair respiratory pathogen clearance, and impair the immune system's ability to fight infections (Kelly & Fussell, 2015). This dysregulated immune response is especially concerning in vulnerable populations, such as children and the elderly, who may suffer from more severe respiratory infections as a result of weakened immune defenses (WHO, 2022a).

Modulation of immune cell functions and disruption of cytokine signaling are two mechanisms underlying immune system dysregulation. Pollutants can shift the balance of pro-inflammatory and anti-inflammatory cytokines in favour of the former, exacerbating inflammation (Thomson et al., 2017). Pollutants can also influence immune cell differentiation, leading to an increase in pro-inflammatory subsets and a decrease in regulatory T cells, which play an important role in immune homeostasis (Li et al., 2009). These changes, taken together, contribute to the chronic inflammation seen in respiratory diseases, as well as the increased susceptibility to infections.

Immune system dysregulation has consequences that go beyond respiratory health, affecting overall well-being and increasing the burden on healthcare systems. Not only do allergic reactions and infections cause acute exacerbations of respiratory conditions, but they also

contribute to disease progression and decreased lung function over time. This highlights the importance of developing comprehensive strategies to mitigate the immunomodulatory effects of air pollution while also protecting vulnerable populations.

Mitigating immune dysregulation requires a multifaceted approach that includes both individual and societal interventions. Reducing pollution exposure through regulatory measures, promoting green urban planning, and improving public transportation can all help to reduce the prevalence of immune system dysregulation (Carnell et al., 2019). Pharmacological interventions that target immune pathways may provide new avenues for preventing allergic sensitization and infections (Kelly & Fussell, 2015). Furthermore, public health campaigns that raise awareness about the link between air pollution, immune system dysregulation, and respiratory health can empower people to take precautions and advocate for clean air policies.

Vulnerable populations

Vulnerable populations, such as children, the elderly, and people with pre-existing respiratory conditions, bear a disproportionate share of the burden of air pollution's adverse respiratory effects. Children are an especially vulnerable population due to their developing respiratory systems and higher inhalation rates than adults. Long-term exposure to air pollution as a child can cause irreversible damage to lung growth and function, with potentially long-term consequences. According to studies, children who live in areas with high levels of air pollution have lower lung function, increased respiratory symptoms, and an increased risk of developing respiratory conditions such as asthma (Gauderman et al., 2004). Furthermore, early-life pollution exposure may have epigenetic effects on respiratory health outcomes later in life (Breton et al., 2019). To address the impact of air pollution on children's respiratory health,

comprehensive measures that prioritize clean air policies, promote active transportation, and reduce exposure to indoor pollutants are required.

The elderly, who have age-related physiological changes and a higher prevalence of chronic diseases, are also more vulnerable to the negative respiratory effects of air pollution. The elderly's ability to tolerate respiratory insults is reduced as they age, making them more vulnerable to exacerbations of pre-existing conditions and respiratory infections. Short-term exposure to pollutants like particulate matter (PM) and ozone (O_3) has been linked to an increase in hospitalizations and mortality among the elderly, especially those with cardiovascular and respiratory diseases (Cesaroni et al., 2014). Effective strategies for protecting the elderly population include issuing timely air quality advisories, improving indoor air quality, and ensuring access to respiratory health-related healthcare services.

When exposed to air pollution, people with pre-existing respiratory conditions, such as asthma and chronic obstructive pulmonary disease (COPD), face increased risks. Pollutants can aggravate inflammation and airway hyperresponsiveness in these people, resulting in worse symptoms and increased medication use (Kelly & Fussell, 2015). Furthermore, interactions between air pollution and allergens can cause severe asthma attacks. Furthermore, air pollution has been linked to the development of asthma in susceptible individuals, emphasizing the complex relationship between pollutants and respiratory conditions (J. F. Gent et al., 2019). Managing this population's respiratory health necessitates a multifaceted approach that combines effective asthma and COPD management with pollution reduction through regulatory interventions and public awareness campaigns.

It is critical to recognize that socioeconomic factors, such as access to healthcare, housing conditions, and environmental justice, influence vulnerability to the respiratory effects of air

pollution. Because of their proximity to pollution sources, lack of green space, and limited access to medical care, low-income communities frequently face a higher burden of pollution (Clougherty, 2010). This exacerbates existing health disparities and emphasizes the need for targeted interventions that address health's environmental and social determinants.

2.1.4 National and international guidelines

National and international guidelines are critical in shaping policies and interventions aimed at mitigating the effects of air pollution on respiratory health. These guidelines provide governments, organizations, and healthcare professionals with evidence-based recommendations, serving as a framework for regulatory measures and public health strategies. Nationally, countries develop air quality standards and guidelines to protect their populations' respiratory health. These standards are frequently based on extensive research and epidemiological studies that determine the levels of pollutants that are considered safe for human exposure. For example, the Environmental Protection Agency (EPA) in the United States establishes National Ambient Air Quality Standards (NAAQS) for common pollutants such as particulate matter (PM), ozone (O_3), Sulphur dioxide (SO_2), and nitrogen dioxide (NO_2). These standards serve as regulatory benchmarks for pollutant concentrations that are permissible and guide efforts to reduce air pollution levels (USA EPA, n.d.).

National guidelines' effectiveness in protecting respiratory health, on the other hand, is dependent on their rigour, enforcement, and alignment with international standards. Standards may fall short in regions with weaker environmental regulations in addressing the complex and interconnected nature of air pollution and its impact on respiratory health. Harmonizing national standards with internationally recognized guidelines, such as those developed by the WHO, can

result in a more comprehensive and globally consistent approach to air quality management (WHO, 2022c).

International guidelines, such as the WHO Air Quality Guidelines, provide a more comprehensive view of the health risks associated with air pollution. These guidelines synthesize a wealth of scientific evidence to establish pollution concentration-response relationships and health outcomes. They include a broad range of respiratory and non-respiratory health effects, such as mortality, morbidity, and quality of life. These guidelines provide a benchmark for nations to strive for in their air quality management efforts by setting pollutant thresholds based on the most recent research (WHO, 2022c).

Adoption and implementation of guidelines are critically dependent on the political will and commitment of governments and relevant stakeholders. While international guidelines provide a comprehensive framework, implementing these recommendations at the national level may face challenges due to resource constraints, infrastructure limitations, and competing interests. Air quality management strategies also rely on collaboration between sectors such as transportation, energy, and urban planning, emphasizing the importance of a multidisciplinary approach (Carnell et al., 2019).

The recognition of air pollution as a global health crisis in recent years has increased focus on national and international guidelines. Stakeholders are becoming more aware of the economic burden of air pollution-related health costs, as well as the potential for sustainable development through cleaner air policies (Landrigan et al., 2016). Efforts to strengthen guidelines and improve their implementation are ongoing, with advances in scientific understanding, technological innovation, and advocacy from health professionals and civil society driving the effort.

2.1.5 Efforts to reduce air pollution

Regulatory efforts are critical to reducing air pollution and the respiratory effects that it causes. Air quality standards, emission limits, and pollution control measures are all set and enforced by national and local governments. Implementing vehicle emission standards and industrial regulations, for example, has resulted in significant reductions in pollutants such as Sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM) (USA EPA, n.d.). The success of regulatory efforts, however, is dependent on their stringency, monitoring, and enforcement. Weak regulations, insufficient resources, and a lack of political will can all undermine the efficacy of these interventions and jeopardize respiratory health outcomes (Carnell et al., 2019).

Technological advancements provide promising avenues for reducing air pollution and its effects on respiratory health. Clean energy advancements, such as electric vehicles, renewable energy sources, and energy-efficient appliances, have the potential to significantly reduce pollutant emissions and improve air quality. Adoption of electric vehicles, for example, reduces tailpipe emissions of pollutants, contributing to lower exposure and better respiratory outcomes (Huang et al., 2014). Furthermore, emerging technologies that capture and filter pollutants at the source or in the ambient air have the potential to reduce the health effects of air pollution (Wang et al., 2023). However, widespread adoption of these technologies necessitates the removal of impediments such as cost, infrastructure development, and public acceptance.

Public participation and awareness campaigns are critical in fostering collective action to reduce air pollution. Reduced pollutant emissions and improved respiratory health can be achieved by educating people about the health risks of air pollution, promoting sustainable lifestyle choices, and encouraging active transportation. Grassroots movements and advocacy efforts can increase

public demand for cleaner air and hold policymakers accountable for putting effective measures in place. Collaborative initiatives involving communities, non-governmental organizations, and government agencies can result in improved air quality and respiratory outcomes (Laden et al., 2000). However, the effectiveness of efforts to reduce air pollution is dependent on their integration into larger strategies for sustainable development. Anenberg et al., (2017) found that urban planning that prioritizes green spaces, pedestrian-friendly infrastructure, and public transportation can reduce reliance on private vehicles and mitigate pollution-related respiratory risks. Furthermore, policies that address socioeconomic disparities and prioritize vulnerable populations are critical for ensuring equitable access to clean air and better respiratory health outcomes (Clougherty, 2010).

2.1.6 Challenges and gaps in policy implementation

One major challenge is the lack of consistent and rigorous enforcement of air quality regulations. While many countries have established air quality standards and emission limits, the monitoring and enforcement mechanisms are often inadequate. Insufficient resources, limited capacity, and a lack of political will can undermine the effectiveness of regulatory measures (Carnell et al., 2019). For instance, industries may fail to adopt pollution control technologies or circumvent regulations, leading to continued emissions of harmful pollutants and compromising respiratory health outcomes.

Ineffective coordination and communication among different sectors and levels of government pose another hurdle. Addressing air pollution requires a multidisciplinary approach that involves collaboration between environmental, health, transportation, and urban planning agencies. However, siloed decision-making and fragmented governance structures can impede the development and implementation of integrated strategies (Anenberg et al., 2017). The lack

of coordination can lead to conflicting priorities, insufficient resource allocation, and missed opportunities for synergistic interventions.

A critical gap in policy implementation lies in addressing the specific needs of vulnerable populations. While air pollution affects everyone, certain groups, such as children, the elderly, and low-income communities, are disproportionately impacted. These populations often face socio-economic disparities that limit their ability to access healthcare, adopt protective measures, or advocate for clean air policies. Failure to tailor interventions to the unique needs of vulnerable groups can exacerbate existing health inequalities and perpetuate the cycle of poor respiratory health (Clougherty, 2010). Furthermore, the dynamic nature of air pollution, characterized by varying sources, pollutants, and spatial distribution, poses challenges for effective policy responses. Traditional regulatory approaches may struggle to keep pace with rapidly evolving pollution patterns. Emerging sources of pollution, such as unconventional energy extraction and microplastics, underscore the need for flexible and adaptable policies that can address novel challenges (Wang et al., 2023). Failure to anticipate and respond to emerging pollutants and pollution sources can result in policy gaps that compromise respiratory health protection.

Public engagement and awareness also remain a challenge in policy implementation. While increasing public awareness about the health risks of air pollution is crucial, translating awareness into meaningful action and behavioral change can be complex. Information campaigns may not sufficiently motivate individuals to adopt cleaner practices or advocate for stronger policies. Additionally, a lack of understanding of the science behind air pollution may hinder public support for comprehensive air quality measures (Laden et al., 2000).

To address these challenges and gaps, a holistic and adaptive approach to air quality management is essential. Strengthening regulatory frameworks with clear targets, robust monitoring, and stringent enforcement mechanisms is imperative. Enhancing inter-agency collaboration and cross-sectoral coordination can facilitate the development of integrated strategies that address the complex nature of air pollution. Tailoring interventions to the needs of vulnerable populations, ensuring equitable access to clean air, and promoting social justice are fundamental principles that should underpin policy implementation. Furthermore, fostering public engagement through effective communication and education is crucial in generating sustained support for cleaner air policies.

2.1.7 Mitigation strategies as urban planning and green spaces

The field of urban planning assumes a critical role in shaping the spatial configuration of cities, exerting influence over transportation infrastructure, land utilization, and the dispersion of pollution origins (Lovasi et al., 2013). Urban planning can play a significant role in mitigating traffic-related air pollution by prioritizing walkability, cycling, and efficient public transport systems (Anenberg et al., 2017; Lovasi et al., 2013). This approach aims to reduce the dependence on private vehicles within cities. Urban areas that are well-designed also promote mixed land-use patterns, which in turn reduce the necessity for lengthy commutes. This has the effect of decreasing emissions and enhancing respiratory health outcomes. Nevertheless, the efficacy of urban planning as a means of mitigating adverse effects is contingent upon the incorporation of air quality factors into planning processes, necessitating the cooperation among urban planners, environmental specialists, and public health authorities.

The incorporation of green spaces, such as parks, gardens, and streets adorned with trees, is a crucial element within urban planning approaches aimed at alleviating the respiratory impacts of air pollution. Green spaces serve as natural mechanisms for air purification, effectively eliminating pollutants from the atmosphere through various processes such as dry deposition and plant uptake (Nowak et al., 2014). The presence of vegetation can also contribute to the reduction of ground-level ozone (O_3) formation and the decrease in ambient temperatures, thereby potentially mitigating the generation of secondary pollutants. In addition, green spaces provide recreational opportunities that facilitate physical activity and enhance overall well-being, thereby indirectly contributing to the improvement of respiratory health (Lovasi et al., 2013). Nevertheless, it is imperative to establish a fair and just allocation of green spaces, taking into account their distribution and accessibility, in order to guarantee that all communities, especially those that are more susceptible, are able to fully enjoy the advantages for their well-being.

The effective execution of urban planning and green space strategies necessitates the resolution of numerous obstacles. The establishment of green spaces in densely populated areas can be impeded by various factors, including but not limited to the scarcity of urban land, conflicting land-use objectives, and economic constraints. Furthermore, the preservation of green infrastructure requires continuous allocation of resources and active involvement of the community to guarantee its durability and efficiency (Lovasi et al., 2013). The imperative of maintaining and providing equitable access to green spaces for all residents, irrespective of their socio-economic status, is crucial in order to prevent the worsening of prevailing health inequalities. In addition, the effectiveness of green spaces in reducing air pollution can be influenced by factors such as their design and location. According to Baró Porras et al., (2021),

the optimal positioning of green infrastructure in close proximity to pollution sources or along heavily trafficked routes can effectively increase the removal of pollutants and consequently improve air quality. The utilization of a diverse array of vegetation types, including but not limited to trees, shrubs, and grasses, can effectively enhance the capture of pollutants while simultaneously offering a multitude of ecosystem services. In order to attain these objectives, it is imperative to foster collaboration among urban planners, landscape architects, environmental scientists, and members of the community.

2.1.8 Emerging Air Pollutants and Health Risks

Microplastics, which are tiny plastic particles that form as larger plastic items degrade, are one such emerging pollutant. Microplastics have been found in a variety of environmental media such as air, water, and soil. While research into the health effects of airborne microplastics is still in its early stages, concerns have been raised about their ability to act as carriers for other toxic compounds and allergens, potentially aggravating respiratory diseases (Malig et al., 2016). Microplastics inhalation can cause localized inflammation in the respiratory tract and interact with the immune system, potentially contributing to respiratory symptoms and diseases.

Electronic cigarette (e-cigarette) aerosols, also known as vaping aerosols, are another emerging air pollutant of concern. E-cigarettes have grown in popularity as a tobacco-free alternative, but their aerosols contain a complex mix of chemicals, including nicotine, volatile organic compounds (VOCs), and ultrafine particles. According to research, e-cigarette aerosol exposure may cause oxidative stress, inflammation, and impaired lung function, making people more susceptible to respiratory infections and exacerbating conditions like asthma and chronic obstructive pulmonary disease (COPD) (Lerner et al., 2015). The rapid spread of e-cigarette use

emphasizes the importance of researching their respiratory health effects and regulating their emissions.

Additionally, emerging pollutants from unconventional energy extraction, such as hydraulic fracturing (fracking), have raised concerns about potential respiratory health risks. Pollutants such as volatile organic compounds (VOCs), particulate matter, and diesel exhaust are released during fracking, which can contribute to air pollution in nearby communities. The proximity of fracking sites has been linked to an increase in asthma exacerbations, respiratory symptoms, and hospitalizations (Requia et al., 2017). The unique composition of fracking emissions necessitates careful assessment and regulation to mitigate their impact on respiratory health.

While research on emerging air pollutants is progressing, several obstacles are impeding our ability to fully understand and address the health risks they pose. Because emerging pollutants are so diverse, developing comprehensive risk assessments and regulatory strategies requires interdisciplinary collaboration among scientists, healthcare professionals, and policymakers. Furthermore, to keep up with evolving pollution patterns, the rapid pace of technological innovation and the introduction of new pollutants necessitates flexible and adaptable monitoring and assessment approaches (Jiang et al., 2021).

Long-term health effects

Extensive research has found a link between long-term exposure to air pollutants like fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) and a variety of chronic respiratory diseases. Longitudinal studies have consistently shown that long-term exposure to elevated levels of $PM_{2.5}$ is associated with an increased risk of respiratory diseases such as

COPD, asthma, and lung cancer (Cohen et al., 2017)(Cohen et al., 2017). Fine particles can enter the respiratory system and cause inflammation, oxidative stress, and genetic changes, all of which contribute to the development and progression of these conditions. Furthermore, long-term $PM_{2.5}$ exposure has been linked to decreased lung function growth in children, potentially setting the stage for lifelong respiratory health issues (Gauderman et al., 2004).

Similarly, NO_2, which is primarily emitted by combustion processes, has been linked to long-term respiratory health deterioration. Long-term NO_2 exposure has been linked to increased asthma incidence and exacerbations, decreased lung function, and an increased risk of hospitalization for respiratory issues (Gehring et al., 2015). Airway inflammation, increased bronchial reactivity, and impaired lung development in children are among the mechanisms underlying these effects.

Chronic respiratory outcomes have also been linked to long-term exposure to ground-level ozone, a secondary pollutant formed by the photochemical reaction of precursor pollutants. Ozone exposure has been linked to increased medication use, worsened asthma symptoms, and decreased lung function (Bell et al., 2005). These health effects are exacerbated by ozone-induced inflammation and oxidative stress in the respiratory tract, making ozone a major concern for long-term respiratory health.

Importantly, vulnerable populations such as children, the elderly, and those with pre-existing respiratory conditions are especially vulnerable to the long-term health effects of air pollution. Longitudinal studies have shown that early-life air pollution exposure can have long-term effects on respiratory health, with implications that extend into adulthood (Bowatte et al., 2017).

Furthermore, socioeconomic factors such as proximity to pollution sources and limited access to healthcare can exacerbate the risk (Clougherty, 2010).

While there has been significant progress in understanding the long-term health effects of air pollution, several challenges and gaps remain. Long-term exposure assessments are difficult to perform because they frequently necessitate sophisticated modelling techniques to account for spatial and temporal variability in pollutant levels. Furthermore, determining specific pollutant thresholds that cause health effects is still a work in progress. The fact that respiratory diseases are multifactorial complicates attributing health outcomes solely to air pollution, necessitating rigorous epidemiological approaches that account for confounding factors (Jerrett et al., 2009). To protect respiratory health, it is necessary to address the complex interplay of environmental, genetic, and socioeconomic factors that contribute to long-term health effects.

Evaluating effectiveness of mitigation measures

The use of epidemiological studies is a common approach to evaluating mitigation measures. These studies compare changes in air quality and health outcomes before and after specific interventions are implemented. For example, studies have been conducted to assess the health effects of vehicle emission reduction programmes such as the use of cleaner fuels or the implementation of stricter emissions standards. In highly polluted areas, research has shown that these measures can reduce ambient air pollutant levels and, as a result, improve respiratory health indicators (Ghosh et al., 2016). While such studies provide valuable insights, it is often difficult to attribute health improvements solely to mitigation measures because other factors can influence respiratory health.

Another useful tool for assessing the effectiveness of mitigation measures is health impact assessments (HIAs). HIAs project the potential health outcomes of specific policy changes or interventions. HIAs provide decision-makers with a tangible basis for evaluating the benefits of mitigation strategies by quantifying the potential reduction in respiratory diseases and related healthcare costs. HIAs, on the other hand, are based on assumptions and data inputs, and their accuracy is determined by the quality of available data and models (Ostro et al., 2016).

Air quality monitoring networks are critical for assessing the effectiveness of mitigation measures in real time. Continuous monitoring of air pollutants allows for the evaluation of changes in pollutant concentrations following intervention implementation. For example, the impact of pollution control technologies or the implementation of low-emission zones on air quality can be directly monitored. These data help gauge the immediate effects of mitigation measures and inform strategy adjustments as needed. However, in order to provide accurate and representative data, monitoring networks must be well-designed, adequately distributed, and equipped with reliable instruments (Jerrett et al., 2009).

Air quality models and health risk assessments, for example, provide a comprehensive approach to evaluating mitigation measures under various scenarios. These models simulate pollutant dispersion, estimate exposure levels, and project health outcomes based on various policy scenarios. Simulation models enable the assessment of long-term health impacts as well as the investigation of potential synergies or trade-offs between various mitigation strategies. However, simulation model accuracy is dependent on the availability of accurate emissions inventories, meteorological data, and exposure-response relationships (Doherty et al., 2013). While these evaluation methods are useful, there are still challenges and limitations. Because air

pollution and respiratory health outcomes are so complex and interconnected, confounding factors that could influence the observed effects of mitigation measures must be carefully considered. Furthermore, the long-time lag between exposure and health outcomes for some respiratory diseases makes it difficult to attribute changes in health to recent interventions. Furthermore, mitigation measures' effectiveness can vary depending on local contexts, population demographics, and implementation strategies.

2.2 Theoretical Framework

This research study on "Environmental Air Pollutants as Risk Factors in the Occurrence of Respiratory Conditions in Bayelsa State" will be underpinned by the various theories that are described below.

2.2.1 Ecological systems theory

The Ecological Systems Theory, formulated by Bronfenbrenner, (1979), offers a comprehensive conceptual framework for comprehending the multifaceted impact of interconnected environments on individuals. This theory emphasises the intricate interaction among diverse systems, encompassing the immediate environment of individuals as well as wider societal frameworks. When examining the relationship between environmental air pollutants and their role as risk factors in the development of respiratory conditions, the application of ecological systems theory provides significant contributions in understanding the intricate dynamics between environmental elements, individual well-being, and wider societal influences. The fundamental principle of ecological systems theory revolves around the notion of nested environments, referred to as "ecological systems," which encompass the entirety of an individual's life. Bronfenbrenner (1979) proposed a framework consisting of various systems, namely the microsystem, mesosystem, exosystem, and macrosystem. The microsystem refers to the immediate surroundings of an individual, while the mesosystem encompasses the

interactions between different microsystems. The exosystem involves indirect influences on an individual, and finally, the macrosystem encompasses cultural and societal values. When this framework is applied to the investigation of environmental air pollutants and their impact on respiratory conditions, it becomes apparent that air pollution operates within a complex network of environments, exerting its effects at various levels.

The microsystem, encompassing an individual's immediate physical and social environment, exerts a significant influence on the level of exposure to air pollutants and consequent respiratory health outcomes. The exposure of individuals to pollutants is directly influenced by the quality of indoor and outdoor air in various settings such as neighbourhoods, homes, schools, and workplaces (Nieuwenhuijsen et al., 2015). This is particularly pertinent in urban environments where there is a concentration of air pollution sources, such as emissions from vehicular traffic and industrial operations. Individuals who frequently occupy polluted microenvironments may be subjected to elevated respiratory health hazards, thereby emphasising the necessity for targeted interventions at the local level.

The mesosystem places emphasis on the interconnectedness that exists between various microsystems. Within the framework of the study, this may encompass the interactions that occur between an individual's domestic and educational environments, or between their professional and communal contexts. The presence of substandard air quality within a given microsystem can have an indirect impact on other microsystems, thereby exacerbating potential health hazards. An example of this phenomenon is the potential impact on children's respiratory health due to exposure to air pollution both at school and at home (Clark et al., 2010). In order to thoroughly examine the respiratory health effects of air pollution, it is imperative for

interventions to take into account the interconnected microsystems and potential synergies that may arise from mitigation strategies.

The exosystem encompasses various external factors that individuals do not have direct contact with but nonetheless exert an influence on their lives. These factors include policies, institutions, and media. Within the realm of academic research, the term "exosystem" can encompass a range of regulatory policies that are designed to mitigate air pollution, urban planning choices, and public awareness initiatives. The implementation of effective policies and regulations has the potential to establish conducive environments that foster clean air and alleviate respiratory health hazards. As illustrated by Anenberg et al., (2017), the implementation of emission controls on vehicles or industrial facilities has the potential to exert a direct influence on pollutant levels and subsequently mitigate exposure. Moreover, it has been argued that public awareness campaigns have the potential to facilitate modifications in behaviour that restrict the extent of individuals' exposure to air pollutants, particularly among populations that are more susceptible to their adverse effects (Clougherty, 2010). The macrosystem, in its entirety, encompasses a wide range of cultural, societal, and economic factors that play a significant role in shaping attitudes, norms, and values. The influence of socioeconomic status on an individual's exposure to air pollutants and their access to healthcare, for example, is noteworthy. Hou et al., (2019) argue that individuals belonging to vulnerable populations who have limited access to resources may experience heightened vulnerability as a result of constraints related to housing and occupational circumstances. In addition, the prevailing societal perspectives regarding the preservation of the environment and the prevention of pollution can significantly shape policy-making processes and impact the execution of measures aimed at mitigating environmental harm.

2.2.2 The exposure-response framework

The Exposure-Response Framework (ERF) is a significant tool utilised in comprehending the correlation between environmental exposures, specifically air pollutants, and health outcomes, with a particular focus on respiratory conditions. The aforementioned framework serves to quantify the health risks that are linked to different degrees of exposure. By doing so, it offers valuable insights into the relationship between dosage and response, thereby contributing to the process of risk assessment and aiding in the formulation of policy decisions. The Exposure-Response Framework provides a structured approach for understanding the intricate connections between environmental air pollutants and the development of respiratory conditions, particularly when examined through a critical lens.

The ERF generally encompasses three fundamental elements: the evaluation of exposure, the quantification of the dose metric, and the assessment of health outcomes. Within the realm of air pollution and respiratory ailments, exposure assessment encompasses the quantification of distinct pollutants, namely particulate matter (PM2.5), nitrogen dioxide (NO2), and ozone (O3), across various settings. The acquisition of these measurements is of utmost importance in order to precisely assess an individual's extent of exposure across different temporal and spatial dimensions (Schikowski et al., 2014). Metrics, which serve to quantify the quantity of pollutants that reach a specific organ or system, play a crucial role in establishing a connection between exposure and the resulting health effects. One illustration of this concept is the utilisation of cumulative exposure metrics to effectively represent long-term exposure, whereas short-term peaks can be accurately captured by employing hourly or daily concentrations (Schwartz, 1993). Finally, health outcome assessments encompass the examination of respiratory

conditions, such as asthma, COPD, and lung function impairment, in correlation with the quantified exposures.

By utilising the Exposure-Response Framework, researchers are able to establish a quantitative association between levels of environmental air pollutants and respiratory conditions in the study. For example, previous research has employed the Excess Risk Function (ERF) to illustrate the heightened likelihood of asthma exacerbations linked to temporary rises in PM2.5 levels (Bell et al., 2005). In a similar vein, Gehring et al. (2015) have demonstrated through long-term exposure-response relationships that increased levels of nitrogen dioxide (NO_2) are associated with a greater incidence of asthma and diminished lung function among children. The results of this study are crucial in providing information for the establishment of regulatory standards and public health guidelines that are designed to decrease air pollution and address respiratory health hazards.

Nevertheless, the utilisation of the Exposure-Response Framework in air pollution research encounters certain obstacles. The association between exposure and health outcomes is frequently impacted by confounding variables, including socioeconomic status, genetic factors, and lifestyle choices. These aforementioned factors have the potential to introduce bias and add complexity to the interpretation of exposure-response relationships. Moreover, the ERF (Emission Rate Function) operates under the assumption of a linear or monotonic correlation between exposure and health outcomes. However, this assumption may not adequately account for potential threshold effects or non-linear associations, as noted by Burnett et al., (2014). Hence, it is imperative for researchers to thoroughly deliberate upon these intricacies and utilise suitable statistical methodologies in order to address confounding factors and potential non-linear relationships.

Moreover, the ERF offers a concise representation of the correlation between air pollutants and respiratory health outcomes; however, it is possible that it does not encompass the entirety of the effects. For example, certain subgroups characterised by pre-existing medical conditions, such as children or individuals afflicted with respiratory ailments, may exhibit increased vulnerability to the effects of air pollution. It may be necessary to modify the ERF in order to incorporate these varying sensitivities and potential modifications of effects. Additionally, it is worth noting that the ERF may not fully encompass the wider societal ramifications of air pollution, including the financial strain caused by healthcare expenses and reduced productivity resulting from respiratory ailments. The Exposure-Response Framework provides a systematic and quantitative methodology for comprehending the intricate correlation between environmental air pollutants and respiratory health consequences. Through a systematic evaluation of exposure, dose, and health effects, researchers are able to quantify the potential risks presented by pollutants and provide valuable information to support decision-making based on evidence. Nevertheless, it is crucial to address the challenges associated with confounding, non-linearity, and differential susceptibility in order to guarantee precise and significant interpretations of exposure-response relationships. The incorporation of the ERF (Exposure-Response Function) into research pertaining to environmental air pollutants and respiratory ailments contributes to the advancement of our comprehension regarding the health hazards associated with air pollution, as well as informs the development of strategies aimed at mitigating its detrimental impacts.

2.3 Empirical Studies

2.3.1 Air pollutants investigations

Obanya et al., (2018) assessed the levels of air pollution near neighbourhoods and transportation sector locations (TSLs) in Lagos, Nigeria. The residential areas in the Lagos Mainland's Yaba Local Council Development Area, are regions encompassing inner streets and living quarters. At the same time, TSLs featured dual carriageways, active roads, bus stations, and large parking lots. Using calibrated handheld instruments, in-situ air quality measurements were taken at specified residential and TSL sites. Every sampling site was georeferenced, and generation of distribution maps were made for concentrations of multiple characteristics. particulate matter (PM_{10} and $PM_{2.5}$), temperature, Carbon monoxide (CO), noise, sulphur dioxide (SO2), and humidity levels were ranged around 0.00 - 0.20.17 ppm, 1.00 - 6.0 5.97 43.345.2 - 127.2159.7g/m3, ppm, 20.3 23.25 - 69.058.16 g/m3; Hydrogen sulphide (H_2S), ammonia (NH_3) and Nitrogen oxide (NO_2), concentrations were under the limit of detection both sites sampled, whereas volatile organic carbons concentrations (VOCs) in the TSLs ranged from 0.00 to 0.10 ppm.

Obaseki et al., (2014) conducted a descriptive cross-sectional study of traffic laborers and college students in Lagos. The sample consisted of individuals who were qualified, accessible, and enthusiastic to participate. All participants' respiratory symptoms and anthropometry were measured using a modified Medical Research Council (MRC) questionnaire, and they all underwent spirometry and exhaled carbon monoxide (CO) testing. Fifty-nine individuals with comprehensive data participated, including 47 traffic officers and 12 students who served as controls. The presentation of respiratory and non-respiratory symptoms was not significantly different between the two groups. Compared to students, the adjusted forced expiratory volume

and forced vital capacity in one second of traffic employees were greater. P 0.006 indicates that traffic officers exhaled a higher concentration of CO than students.

Ogunseye et al., (2018) employed a non-invasive pulse CO-dosimeter (Rad 57) to assess a biomarker of CO exposure, carboxyhaemoglobin levels (%COHb), among traders at three motor parks (NMP, IMP, and AMP in addition to non-motor park workers or traders in the city of Ibadan, Nigeria, utilizing a cross-sectional comparative design. Ninety-three vendors were assigned at random to various vehicle parks, while the remaining ninety-three were selected based on predetermined research inclusion criteria. Overall, the mean% COHb for automobile park merchants was significantly higher than the mean% COHb for all traders (p 0.05). Despite this, the mean percentage of COHb in both groups exceeded the 2.5% threshold recommended by the WHO. According to this study, automotive park merchants had a higher percentage of COHb, making them exceedingly susceptible to exposure and more prone to the well-established hazards of adverse health effects from CO exposure.

Kheirbek et al., (2016) utilized estimates from high-spatial-resolution emissions, local health incidence data and air quality modelling to evaluate impacts variations by neighbourhood, area socioeconomic status and vehicle class in order to approximate morbidity from air pollution generated by on-road vehicles in the city of New York (NYC) area. Several ‘zero-out' emission scenarios for local and regional automobiles buses, and vehicles, were developed, in the metropolitan area of New York City. The Community Multi-Scale Air Quality Model having a spatial resolution of 1 km, was used to simulate the concentrations of $PM_{2.5}$ over the city of New York, before combining the values simulated with observed data between 2010 and 2012. They used the local health data and health impact functions to compute the $PM_{2.5}$ burden on the health of residents in 42 neighbourhoods of New York City. They estimated that all on-road

mobility sources in the New York City metropolitan area contribute to 870 hospitalizations, 320 deaths, and emergency department visits yearly due to exposure to $PM_{2.5}$, resulting in a loss of 5850 years of life. In New York City, trucks and buses contributed the most to mobile-attributable ambient $PM_{2.5}$ on-road, accounting for about 14.9% of yearly average concentrations over 1 km grid cells and linked with 170 PM2.5-related fatalities annually.

Using a cross-sectional design, G. Ana et al., (2014) assessed the ambient concentration of the pulmonary function status and respirable particulate matter (PM_{10}) of residents of 4 Ibadan neighbourhoods within the period of January to March 2008. The study at random evaluated the 140 subjects for their lung function status (FEV1). The average daily concentration of PM10 was compared to WHO recommendations. At a significance level of 5%, 2-way ANOVA, Spearman-rank correlation and descriptive analysis were employed. In general, PM10 concentrations were higher in the afternoon at every location. A negative correlation was seen between FEV1 and PM_{10} load across all study sites ($r = -0.371$, p 0.05). It was discovered that most regions with higher particle loads exhibited deteriorating lung function. To establish more robust relationships, a longitudinal investigation was suggested.

Odeshi et al., (2014) investigated particle-bound trace metals in the environment in four areas of Ibadan, Nigeria. The concentrations of trace metals in PM_{10}-particulate matter in the four residential neighbourhoods' ambient air in Ibadan, Nigeria, were measured with a volumetric sampler and compared to WHO guidelines. Glass-fibre filter sheets in contact with particulate matter were decomposed with the combinations of an appropriate acid and analysed the digest for metals trace including Zn, Cr, Ni, Pb, and Mn using the ICPMS technique, with levels compared to WHO threshold limits. At the 5% significance level, the data were analysed using ANOVA and the Pearson correlation test. The afternoon had the highest PM10 concentrations,

with an average of 502.3 39.9 g/m^3, while the morning had the lowest concentration, at 220.6 69.9 g/m^3. A significant difference in levels of PM10 between locations (p 0.05) was seen, with all levels exceeding the WHO limit of 50 g/m^3. Significant (p 0.05) was the correlation between PM_{10} and Ni. PM_{10} and hazardous trace metals concentrations are higher in urban areas with more human activity, especially vehicle traffic.

About 59 mother-child pairs were examined for superoxide dismutase (SOD), retinol-binding protein (RBP), albumin, pre-albumin, malondialdehyde (MDA), vitamins C and E, and C-reactive protein (CRP) from three rural communities in southwest Nigeria. The indoor concentrations of $PM_{2.5}$ were assessed using spirometry. The median indoor $PM_{2.5}$ concentration was 1,575.10 g/m^3 (IQR 943.60-2847.00, p0.001), which is higher significantly than the limit of 25 g/m^3 by the WHO. Women had significantly lower RBP (0.030.03 g/dl) and pre-albumin (0.210.14 g/dl) mean levels than their corresponding normal ranges (0.2-0.6 g/dl and 1-3 g/dl, respectively, p0.05). Correspondingly, RBP (0.010.01 g/dl) and pre-albumin (0.190.13 g/dl) mean levels were markedly lower in children than their corresponding normal ranges (0.2-0.6 g/dl and 1-3 g/dl, respectively, p0.05). MDA serum concentrations in children (5.441.88 mol/L) were positively inversely related to lung function (FEV1/FVC) and related to CRP serum concentrations (r=0.30, p=0.040) in both mothers and children (r=-0.30, p0.05). Additionally, based on the regression analysis, there was an indication that SOD and CRP are linked with deterioration in both children (-5.963.05, p=0.05) and mothers' lung function (-2.551.08, p=0.05). Diminished antioxidant defence, pulmonary dysfunction, and airway inflammation were found to be associated with exposure to HAP from biomass fuel (Oluwole et al., 2013).

Ana et al., (2009) conducted a study to analyse sources of air pollution surrounding schools as an alternative for air quality and how the health of students in selected secondary schools are adversely affected in urban Ibadan, Nigeria. A cross-sectional study was conducted at eight secondary institutions. Data was collected using self-administered, pre-tested questionnaires, observational checklists for measuring specific environmental health indicators, and interviews. Using stratified random sampling, 50 students each were selected from eight different institutions. The reported perception of poor air quality in school environments is correlated with the location of the schools, specifically if it is adjacent to streets with high traffic. According to most students, air pollution in the school environs is majorly open waste incineration and emissions from cars on adjacent streets. Asthma and Cough were the commonly reported health effects reported. The study concluded that the schools' proximity to certain pollutants and commercial activities, such as waste incineration in the open and closeness to main highways, appeared to significantly increase the risk of students developing respiratory illness in those urban Ibadan schools.

Another study that collected 16 grabs soil samples, 14 air samples, and 18 surface water samples physicochemical parametric analysis, involving polycyclic aromatic hydrocarbons (PAHs) and heavy metals as part of a study to determine the occurrence of many health outcomes linked with environmental risk exposures, such as industrial pollution, in some communities of the oil-rich Niger delta area of Nigeria. To 349 randomly selected respondents, a 77-item questionnaire was distributed. Health facilities in both regions were surveyed for a five-year record. Compared to Ahoada East, the Eleme PAH median concentration significantly exceeded the recommended limit of 50 ng/l for surface waters. Eleme had a higher mean TSP concentration than Ahoada East, exceeding the 100 microg/m3 guideline limit. According to the

results of the survey, at Eleme, the effect of air pollutants was substantially linked to respiratory issues (p = 0.044) and community air pollution was strongly linked to excruciating body outgrowths (p = 0.027). At Ahoada East, commonly ingested sea foods were associated with discomfort in body expansion (p 0.0001), whereas infant anomalies (p 0.0001) were linked to domestic heating fuel types. Males at Eleme (3.85%) and females at Eleme (4.39%) had a higher incidence of respiratory disorders than those at Ahoada East (3.68%) and Ahoada East (4.19%). The study found that Eleme as an industrialised community, is more susceptible to respiratory morbidities, skin problems, and other health risks due to higher air pollution levels (G. R. E. E. Ana et al., 2009).

The relationship between respiratory symptoms, particulate concentrations, and lung function was examined in a survey conducted in three Ile-Ife, Nigeria, communities. The Gent stacked filter unit sampler was utilized to capture in two size fractions, the atmospheric aerosol (PM_{10} and $PM_{2.5}$) for the evaluation of indoor PM_{10} concentrations. A questionnaire developed by the Medical Research Council (MRC) was used, and then a spirometry test was performed. The average concentration of PM10 for individuals who used kerosene, liquefied petroleum gas (LPG), and firewood was 9.52, 80.8, and 269,93.7 g/m3, respectively. Forced vital capacity (FVCs) revealed a similar pattern. The FEV1 and FVC of wood-burners were significantly inferior to those of LPG-burners (P 0.05). The highest rates of symptoms, pulmonary and non-pulmonary (57.1%) were seen in participants who utilized charcoal, while those who utilized LPG had the lowest rate (23.8%). According to Ibhafidon et al., (2014), there is significant particulate matter pollution in residential indoor environments of Ile-Ife, which has negative respiratory effects.

In a study investigating the association between symptoms of asthma and lung function with biomass fuel use in Nigerian children (Thacher et al., 2013), information on the used culinary fuels and the daily duration of exposure to cooking smoke exposure was collected from 299 village children. Symptoms of Asthma were evaluated using an International Study of Asthma and Allergies in Childhood (ISAAC) modified questionnaire, whereas the lung function was evaluated using spirometry. A lifetime history of wheezing was discovered in 9.4% of individuals (95% CI: 6.3%-13.0%). Fourteen (4.7%) infants developed obstructed airways (FEV1/FEV6 85%). Females demonstrated reduced FEV6 and FEV1 (120 and 110 % predicted, respectively) than their male counterparts (130 and 121 % predicted, respectively, P 0.001). Increasing age was linked with a 7.8% annual decrease in projected FEV1 value (r = -0.61; P = 0.001). There was no significant increase in the risk of asthma-related symptoms among children residing in households that regularly used firewood (OR = 2.36, 95% CI: 0.50-8.50). Similarly, airway obstruction between children who lived in households that used biomass daily and those who showed no significant difference ($\bar{x}$, FEV6/ FEV1 of 0.97 and 0.95, respectively; P = 0.40).

Mustapha et al., (2011) investigated the relationships between respiratory health and outdoor and domestic air pollution among 7 to 14-year-old pupils from low-income communities of the Niger Delta Area. A self-reported questionnaire evaluated residential exposure to outdoor and indoor air pollution. Traffic counts, school distances from major roadways, and carbon monoxide and particulate matter measurements were mixed with principal components analysis to quantify school air pollution exposures. Adjusting for pertinent confounding factors, logistic regression was used to observe the correlations with respiratory health issues reported. Phlegm (OR = 1.49; 95% CI, 1.09-2.04), Night cough (OR = 1.37; 95% CI, 1.03-1.82), and nose

symptoms (OR = 1.40; 95% CI, 1.03-1.90) were associated with wheeze, while wheeze was linked with exposure to a component variable in school, indicating exposure to fine particles was related with wheeze. They determined that road pollution is linked to respiratory problems in schoolchildren.

Chronic bronchitis (CB) incidence and its relationship with tobacco use and socio-demographic factors were investigated in a few rural villages in Ekiti, Nigeria. A multistage cluster sampling strategy was used to select participants. A questionnaire developed by the European Coal and Steel Community was distributed by health professionals trained to collect socio-demographic information, housing data, tobacco smoking history, respiratory symptoms, and occupational exposure to pollution. All the 391 participants were not smokers at the time of the study, but 36.4% of patients with chronic bronchitis had smoked before. The multivariate logistic regression analysis revealed that age 65-74 (OR= 9.66, 95% C.I 3.43-27.20), tobacco smoking (OR= 6.37, 95% C.I 2.12-19.14) and age e"75 (OR= 3.88, 95% C.I 1.08-13.98) had the greatest connection with Chronic bronchitis. Occupational exposure to organic and inorganic dust (OR= 1) and Poor housing (OR=1.80; 95% C.I 0.56-6.51) were also correlated (Desalu et al., 2011).

A study conducted to ascertain how smoking by sawmill workers in Benin City affects respiratory function and symptoms. 150 male sawmill workers aged between 18 to 50 years and employed continuously for minimum of one year in sawmill factories were surveyed. Using a two-stage random sampling, the workers were compared a similar subset without exposure as controls to evaluate how exposure to sawdust exposure affects their respiratory system. A questionnaire was used to elicit morbidity patterns and anthropometric measurements were also made. Respiratory rates, Peak Expiratory Flow Rates and Blood Pressures were measured in both groups. Although blood pressure was similar in both groups, respiratory rates were higher

and Peak Flow Rates were lower in the sawmill workers compared to the controls (20.83 +/- 2.02 cycles/minute and 516.72 +/- 38.48 L/minute for the sawmill workers; 15.45 +/- 1.23 cycles/minute and 575.37 +/- 27.34 L/minute for the controls, respectively). Less than 5% of the sawmill workers wore protective devices/clothing, and health and safety standards were neither practiced nor enforced. The findings suggest that respiratory symptoms especially sputum production and chest pain are common in sawmill workers (Ugheoke et al., 2006).

The effect of chronic exposure to dust from local woods such as ebony, achi, and iroko on lung function of timber market workers in Calabar, Nigeria, was studied by Okwari et al., (2005). Forced vital capacity (FVC), Forced Expiratory Volume in one second, (FEV1), Forced Expiratory Volume as a percentage of forced vital capacity (FEV1 %), and Peak Expiratory Flow Rate (PEFR) were measured in 221 workers (aged 20-25 years) exposed to wood dust to assess their lung function and compared with 200 age- and sex- matched control subjects who were not exposed to any known air pollutant. The concentration of respirable dust was significantly higher in the test ($P<0.001$) than in control site. The mean values of FVC, FEV1, FEV1% and PEFR of the timber workers were significantly lower ($P<0.01$) than in control subjects. Respiratory symptoms such as cough, chest pain and nasal irritation had higher prevalence in the test group than in the control group. Non-respiratory symptoms (skin and eye irritation) were prevalent in the test group but not found in the control group. Workers exposed to wood dust had restrictive pattern of ventilatory function impairment.

Maduka et al., (2009) studied the effect of occupational exposure to local powdered tobacco (snuff) on pulmonary function. Snuff industry workers in Onitsha and Enugu markets in Nigeria were studied and compared with age, weight, and height-matched control not exposed to any known air pollutant. The pulmonary indices studied include forced vital capacity [FVC], forced

expiratory volume in one second [FEV1] and ratio of FEV1/FVC as percentage using a vitalograph spirometer and Peak Expiratory Flow Rate [PEFR], using a mini–Wright Peak Expiratory Flow Meter. The respiratory and non-respiratory symptoms frequently associated with these workers were also analysed and dust sampling in both test and control environments was also done. The results obtained showed statistically significant impairment of lung function of workers chronically exposed to snuff. FVC, FEV1 and PEFR in the exposed [test] subjects were significantly decreased in comparison with the control subjects [P<0.05]. However, the mean value of FEV1/FVC [%] of the test subjects was 86.8% which was within the normal range and was not significantly different from control. This signified that the test subjects had restrictive pattern of lung function defect. All respiratory symptoms, such as cough, chest tightness had a higher prevalence in test subjects than their control group. The lung function indices of snuff-producing workers proportionately decreased with their length of exposure in the industry. The respirable dust level in the vicinity [indoor] of the snuff-workers [1.11+/-0.35 mg/m3] was significantly [P<0.001] higher than in the control environment [0.37+/-0.086 mg/m3]. The dust sampling result showed that chronic exposure to Nigerian snuff [powered tobacco] dust impairs lung function and the effect is progressive with time.

Ige & Awoyemi, (2002) studied five hundred bakery workers were to assess occupational induced lung impairment as a result of exposure to grain and flour dust. Occupational related symptoms were recorded using structured questionnaire. Age and sex matched controls consisting of 500 University College Hospital (UCH) Ibadan workers and students were used. They were apparently healthy and work and live at places free of fumes and smoke. Peak expiratory flow rate (PEFR) was measured in all subjects. However, full spirometry work up was done on 100 bakery workers and 100 control subjects that had been selected using simple

random sampling technique. The most frequent pulmonary symptoms among the bakery workers were sneezing and running nose (53.30%) and periodic breathlessness/chest tightness (23.16%) while the symptom of cough/phlegm present in (21.53%) of the subjects. The mean PEFR of the bakery workers (463.20 + 51.39 L/ min) was significantly lower ($P < 0.0001$) than that of the control subjects (538.0 + 47.23 L/min). Similarly, the mean values of FEV1, FVC and FEV1% were also significantly lower than the control subjects. The findings indicate that respiratory symptoms are common during the working hours among the bakery workers and 23.16% of the subjects studied suffered some degree of airway obstruction.

2.3.2 Comparing ambient air pollutants concentration with standards

Ipeaiyeda & Adegboyega, (2017) examined the concentrations of Ozone (O_3), Sulphur dioxide (SO_2), Ammonia (NH_4), Carbon monoxide (CO) and Nitrogen oxides (NOx) at 10 distinct sites in Ibadan, Nigeria, in an effort to identify potential anthropogenic sources. During a four-week period, air samples were collected twice daily, in the morning and afternoon, into specific absorbing solutions. The resultant solutions were evaluated using specified colourimetric procedures and standard analytical procedures. The typical concentrations differed between sampling locations. All exceeded the baseline levels of the control site. These quantities were 15 times, 31 times, 17 times, five times, and three times the background levels of CO, O_3, SO_2, NH_3, and NO_X at the study sites. During this limited period, the SO2 level surpassed WHO recommendations.

2.3.3 Prevalence of respiratory disorders

Adetiloye et al., (2019) investigated the challenges of diagnosing and managing bronchiectasis in resource-limited settings. The management of bronchiectasis can be challenging because its pathogenetic mechanisms are still evolving. Its diagnosis and management are especially more

demanding, especially in resource-limited settings like Nigeria, due to delayed diagnosis and improper management with devastating consequences.

Kuti et al., (2017) studied the rural-urban disparity in lung function parameters of Nigerian children. Multistage sampling was used to select rural and urban secondary school students in Ilesa, Nigeria, and the children's socio-demographic, nutritional status, and lung function parameters were obtained and compared between the rural and urban children.

The prevalence and determinants of airflow limitation in urban and rural children exposed to cooking fuels in South-East Nigeria was studied by Oguonu et al., (2018). The aim of the study was to investigate the impact of cooking fuels on lung function in children in urban and rural households in South-East Nigeria. The multi-stage sampling method was used to enrol children exposed to cooking fuel in the communities. Lung function values FEV1, FVC and the FEV1/FVC ratio, were measured with ndd EasyOneR spirometer. Airflow limitation was determined with FEV1/FVC Z-score values at -1.64 as the lower limit of normal (LLN5). The Global Lung Function Initiative 2012 software was used to calculate the lung function indices. The median age (range) of the 912 children enrolled was 10.6 years (6-18). Altogether, 468 (51.6%) children lived in rural areas. Seven hundred and thirty-seven (80.7%) were directly exposed to cooking fuels (418/737, 56.5% in rural areas). Wood and kerosene were the dominant fuels in rural and urban households. The respective mean Z-scores of the exposed children in rural and urban were zFEV1 -0.62, FVC -0.21, FEV1/FVC -0.83 and zFEV1 -0.57, zFVC -0.14, FEV1/FVC -0.75. Few (5.2%, 38/737) of the children had airflow limitation. Most of them (60.5%, 25/38) lived in the rural community; the lowest FEV1/FVC Z-scores were those of exposed to a combination of fuels. Exposure to cooking fuels affects lung function in

children with airway limitation in a small proportion, Control measures are advocated to reduce the morbidity related to cooking fuels exposure.

Oluwole et al., (2013) studied the relationship between household air pollution from biomass smoke exposure, and pulmonary dysfunction, oxidant-antioxidant imbalance and systemic inflammation in rural women and children in Nigeria. Fifty-nine mother-child pairs from 59 households that used firewood exclusively for cooking in three rural communities in southwest Nigeria underwent blood test for albumin, pre-albumin, retinol-binding protein (RBP), superoxide dismutase (SOD), vitamins C, vitamin E, malondialdehyde (MDA) and C-reactive protein (CRP). Spirometry was performed and indoor levels of PM2.5 were determined. The mean levels of pre-albumin (0.21±0.14 g/dL) and RBP (0.03±0.03 g/dL) in women were significantly lower than their respective normal ranges (1-3 g/dL and 0.2-0.6 g/dL, respectively, $p<0.05$). Exposure to HAP from biomass fuel is associated with pulmonary dysfunction, reduced antioxidant defence and inflammation of the airways. Further studies are needed to better define causal relationships and the mechanisms involved.

Q. Li et al., (2017) published a case report on multiple pulmonary emboli caused by renal cell carcinoma. The current study describes the case of a 43-year-old male who experienced' squeezing' chest pain, which was believed to be acute coronary syndrome. After multiple diagnostic examinations, the patient was diagnosed with pulmonary embolism, which led to the diagnosis of RCC.

Nakano et al., (2003) studied microscopic pulmonary tumour embolism secondary to adenocarcinoma of the prostate. They reported a case of pulmonary tumour embolism involving multiple emboli from an unusual site, an adenocarcinoma of the prostate. A 78-year-old Japanese man was diagnosed with stage IV moderately differentiated adenocarcinoma of the

prostate in December 1997. He underwent bilateral orchiectomy and hormonal therapy with flutamide was started. The patient suffered from relapse in April 1998, and estramustine phosphate was administered as a treatment for hormone-refractory prostate cancer. He noticed a dry cough in May 1998, and on June 13, he developed acute progressive dyspnea and was admitted to our hospital. Radiological findings, blood gas analysis, and clinical symptoms suggested pulmonary thrombosis. Despite anticoagulation and oxygen therapy, he remained severely dyspnoeic. He died of respiratory failure 4 days after admission. Autopsy confirmed dissemination of poorly differentiated adenocarcinoma of the prostate to the majority of the pulmonary muscular arteries.

McAllister et al., (2019) studied global, regional, and national estimates of pneumonia morbidity and mortality in children younger than 5 years between 2000 and 2015. They aimed to estimate morbidity, mortality, and prevalence of risk factors for child pneumonia at the global, regional, and national level for developing countries for the Millennium Development Goal period. They estimated the incidence, number of hospital admissions, and in-hospital mortality due to all-cause clinical pneumonia in children younger than 5 years in developing countries at 5-year intervals during the Millennium Development Goal period (2000-15) using data from a systematic review and Poisson regression. We estimated the incidence and number of cases of clinical pneumonia, and the pneumonia burden attributable to HIV for 132 developing countries using a risk-factor-based model that used Demographic and Health Survey data on prevalence of the various risk factors for child pneumonia. We also estimated pneumonia mortality in young children using data from multicausal models based on vital registration and verbal autopsy. Globally, the number of episodes of clinical pneumonia in young children decreased by 22% from 178 million (95% uncertainty interval [UI] 110-289) in

2000 to 138 million (86-226) in 2015. In 2015, India, Nigeria, Indonesia, Pakistan, and China contributed to more than 54% of all global pneumonia cases, with 32% of the global burden from India alone. Between 2000 and 2015, the burden of clinical pneumonia attributable to HIV decreased by 45%. Between 2000 and 2015, global hospital admissions for child pneumonia increased by 2·9 times with a more rapid increase observed in the WHO South-East Asia Region than in the African Region.

Omoniyi-Esan et al., (2005) presented the case of a 22-year-old sickle cell anaemia patient with an incidental finding of PAM. The purpose of this report was to demonstrate that, while uncommon, PAM is not entirely unheard of in this environment and should be considered as a cause of diffuse opacities of the lungs.

Particles internalization, oxidative stress, apoptosis and pro-inflammatory cytokines in alveolar macrophages exposed to cement dust was studied by Ogunbileje et al., (2014). Cement dust (N) and clinker (C) samples collected from Nigeria and another sample of cement dust (U) collected from USA were evaluated using alveolar macrophage (NR8383) cell culture to determine the contribution of different sources of cement dust in the severity of cement dust toxicity. Cement dust particles internalization and morphologic alterations using transmission electron microscopy (TEM), cytotoxicity, apoptotic cells induction, intracellular reactive oxygen species generation, glutathione reduction, TNF-α, IL-1β, and CINC-3 secretion in alveolar macrophages (NR8383) exposed to cement dust and clinker samples were determined. Particles were internalized into the cytoplasmic vacuoles, with cells exposed to U showing increased cell membrane blebbing. Also, NR8383 exposed to U show more significant ROS generation, apoptotic cells induction and decreased glutathione. Interleukin-1β and TNF-α secretion were significantly more in cells exposed to both cement dust samples compared with clinker, while

CINC-3 secretion was significantly more in cells exposed to clinker ($p < 0.05$). Endocytosis, oxidative stress induced apoptosis and induction of pro-inflammatory cytokines may be key mechanisms of cement dust immunotoxicity in the lung and toxicity may be factory dependent.

Biological responses of workplace particles and their association with adverse health effects on miners was studied by Chen et al., (2004). The current study was designed to evaluate the biological responses of workplace particles containing crystalline silica using an in vitro cell test. Respirable particle samples were sampled from four tin mines, where the standardized mortality ratio (SMR) for pneumoconiosis was 51.6 and SMR for lung cancer was 2.2 in dust-exposed miners. Alveolar macrophages (AM) are considered as the target cells for primary dust effects. The samples were then measured at 15, 30, 60 and 120 microg particle per 10(6) AM for cytotoxicity with the release of glucuronidase, lactate dehydrogenase, for reactive oxygen damage with H(2)O(2) release, and for ability to induce fibrosis using the secretion of tumour necrosis factor-alpha (TNF-alpha). Pure quartz (DQ12) and corundum were used as controls. The results showed the samples from tin mines caused a higher cytoxicity when compared to corundum, yet lower when compared to quartz. However, reactive oxygen species release (148-177 nmol/3 x 10(5) AM in high concentration of 120 microg/10(6) AM) induced by the samples were significantly higher than that induced by quartz (57 nmol/3 x 10(5) AM) and corundum (62 nmol/3 x 10(5) AM). Furthermore, particle samples induced higher TNF-alpha secretion than corundum, the samples from Limutin mine induced much higher TNF-alpha levels than that induced by DQ12 quartz. The results from the in vitro tests help elucidate the degree of hazard of dust particles in tin mines. The in vitro reaction patterns of AM also constitute a powerful tool to monitor biological and pathogenic responses of humans following dust particle exposure.

2.3.4 Exposure and respiratory conditions

According to a study by Ekpenyong et al., (2012) investigated the respiratory health effects of ambient air pollutants of the city on transit and non-transit employees and compared the effects by occupational exposure, transportation mode, and participant socio-demographics. One hundred and sixty-eight out of 245 male participants (60 motorcyclists, 58 civil servants and 50 taxi drivers) were recruited and included in the study. The criteria for inclusion in the study include being between 18 and 35, a man working in transit, or a public servant employed in Uyo, Nigeria, for less than a year prior to the study and have not reported or any respiratory impairment/ disorders history or added incapacitating condition. The respiratory function impairment odds ratios (ORs) (FEV1/FVC70% predicted or FVC and/or FEV180% predicted) were calculated using the National Institute for Health and Clinical Excellence (NICE) and Global Initiative for Chronic Obstructive Lung Diseases (GOLD) criteria. The ambient air pollution exposure of participants by mode of transportation and occupation was independently linked with incident respiratory symptoms and impaired respiratory function. With an adjusted OR of 3.10 for FVC80% predicted and an adjusted OR of 1.71 for FEV1/FVC70% predicted according to the NICE and GOLD criteria, motorcyclists had the greatest effect. In addition, non-educated, cigarette-smoking transit employees with more than a year of experience, three journeys daily, and greater than an hour of transit time for each trip had a p0.001 significantly increased risk of respiratory function impairment.

Adeniran et al., (2019) assessed air quality in a major Cement Plant in Ibese Ogun State, Nigeria, through an *ambient air quality monitoring* and air emission dispersion modelling. *Particulate Matter* (PM) and *gaseous pollutants* were measured using portable samplers and AERMOD View was used for the emission dispersion modelling. *Combustion products* including SO_2, NO, NO_2, *CO* and VOCs were the *gaseous pollutants* detected along the

complex fenceline and in the receptor environments. Pollutants measurements were undertaken at 23 locations within the fence line and receptor locations. The daily SO_2 and NO_2 Federal Ministry of Environment - Nigeria (FMEnv) limits were exceeded in ten (10) and five (5) locations along the fenceline, respectively. Particulates were detected in all the locations along the fenceline and in the communities. The cumulative gaseous pollutants resulting from simultaneous operations of all the identified plant air emission point sources are 0.01–276.13% of their respective 24-h limits along the fenceline, with 1-h SO_2 within the threshold limit at all fenceline locations, but 1-h NO_X exceeds the threshold limit at all locations 16–21 times. The 24-h *CO* and VOCs are within their limits at all fenceline locations; however the 24-h SO_2 and NO_X are breaching the limits at some locations 30–34 times (0.34–0.39% of the investigation period) and 44–87 times, respectively. Daily and Annual averaging concentrations of PM_{10} was 14.32–31.54% and 4.90–52.60% of their respective limits. Process facilities are the major point sources of *atmospheric emissions* identified in the factory. Several fugitive emission sources were also identified during the *field work*. Comprehensive evaluation of the fugitive emission sources should be carried out in the cement plant for immediate attention.

Ibrahim et al., (2022) aimed to explore the relationship between short-term exposure to air pollution and hospital admissions for respiratory diseases among children in a natural gas industrial area in Bintulu, Malaysia. Daily hospital admissions for respiratory diseases among children were collected from a hospital in Bintulu from 2010 to 2019. Data on six *air pollutants* (PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, and CO) in the study area were obtained from the Department of Environment Malaysia. Quasi-Poisson time series regressions with distributed lag non-linear models (DLNM) were applied to explore the associations between ambient air pollution and childhood hospitalizations for respiratory diseases. Stratification analyses were performed by

gender and age group to identify the vulnerable populations. A 10 μg/m^3 increased $PM_{2.5}$ and SO_2 was associated with hospital admissions for respiratory diseases among children with the greatest relative risk of RR 1.089 (95% CI 1.001–1.183) at cumulative lag 0–2 days and RR 1.229 (95% CI 1.073–1.409) at cumulative lag 0–6 days, respectively. There was no significant association between short-term exposure of PM_{10}, NO_2, *CO*, and O_3 with childhood respiratory hospitalisation. The association between $PM_{2.5}$ and SO_2 exposure and hospital admissions for childhood respiratory diseases in the two pollutants model remained statistically significant. There were stronger associations in younger children aged 0–4 years and girls. This study reveals that short-term exposure to SO_2 was associated with a higher risk of respiratory hospitalisations among children in Bintulu than $PM_{2.5}$. Better *air quality control* is necessary for children's health living in the natural gas industrial area.

In a study by Hei et al., (2022), 13 industrial parks in seven cities in Henan Province were chosen to evaluate their emission of air pollutants and CO_2 in 2017, their reduction potential under different green measures, and their air quality improvements under a Green Upgrade scenario. The results show that (1) The total emissions of SO_2, NO_x, CO, PM_{10}, $PM_{2.5}$, VOCs and CO_2 in the 13 industrial parks were 43, 39, 351, 19, 7, 18, 2 kt and 36 Mt, and would decrease by 72, 56, 19, 30, 26, 77 and 30%, respectively, under the Green Upgrade scenario. (2) The industrial process was the major source of CO, $PM_{2.5}$, VOCs and NH_3, whereas power plants were the largest source of SO_2 and NO_x, and they would be reduced by 93, 59, 94, 91, 23 and 28%, respectively, under the Green Upgrade scenario. (3) The terminal energy use sector (including industrial boilers and industrial process sources) was the main source of CO_2, accounting for 75% of total CO_2 emissions, and would be reduced by 76% under the Green Upgrade scenario. (4) WRF-CMAQ simulation results show that, under the Green Upgrade

scenario, the concentration of $PM_{2.5}$ in a transmission channel city would be improved by 1–36 $\mu g/m^3$, with an annual average value of 9 $\mu g/m^3$. Our results demonstrate the significant effect of the synergistic reduction in air pollutants and CO_2 emissions using Green Technologies in industrial parks and the subsequent improvement in regional air quality.

Tao et al., (2014) conducted a study were Daily $PM_{2.5}$ (aerosol particles with an aerodynamic diameter of less than 2.5 μm) samples were collected at an urban site in Chengdu, an inland megacity in southwest China, during four 1-month periods in 2011, with each period in a different season. Samples were subject to chemical analysis for various chemical components ranging from major water-soluble ions, organic carbon (OC), element carbon (EC), trace elements to biomass burning tracers, anhydrosugar levoglucosan (LG), and mannosan (MN). Two models, the ISORROPIA II thermodynamic equilibrium model and the positive matrix factorization (PMF) model, were applied to explore the likely chemical forms of ionic constituents and to apportion sources for $PM_{2.5}$. Distinctive seasonal patterns of $PM_{2.5}$ and associated main chemical components were identified and could be explained by varying emission sources and meteorological conditions. $PM_{2.5}$ showed a typical seasonality of waxing in winter and waning in summer, with an annual mean of 119 $\mu g\ m^{-3}$. Mineral soil concentrations increased in spring, whereas biomass burning species elevated in autumn and winter. Six major source factors were identified to have contributed to $PM_{2.5}$ using the PMF model. These were secondary inorganic aerosols, coal combustion, biomass burning, iron and steel manufacturing, Mo-related industries, and soil dust, and they contributed 37 ± 18, 20 ± 12, 11 ± 10, 11 ± 9, 11 ± 9, and 10 ± 12%, respectively, to $PM_{2.5}$ masses on annual average, while exhibiting large seasonal variability. On annual average, the unknown emission sources that were not identified by the PMF model contributed 1 ± 11% to the measured $PM_{2.5}$ mass.

Various chemical tracers were used for validating PMF performance. Antimony (Sb) was suggested to be a suitable tracer of coal combustion in Chengdu. Results of LG and MN helped constrain the biomass burning sources, with wood burning dominating in winter and agricultural waste burning dominating in autumn. Excessive Fe (Ex-Fe), defined as the excessive portion in measured Fe that cannot be sustained by mineral dust, is corroborated to be a straightforward useful tracer of iron and steel manufacturing pollution. In Chengdu, Mo / Ni mass ratios were persistently higher than unity, and considerably distinct from those usually observed in ambient airs. V / Ni ratios averaged only 0.7. Results revealed that heavy oil fuel combustion should not be a vital anthropogenic source, and additional anthropogenic sources for Mo are yet to be identified. Overall, the emission sources identified in Chengdu could be dominated by local sources located in the vicinity of Sichuan, a result different from those found in Beijing and Shanghai, wherein cross-boundary transport is significant in contributing pronounced $PM_{2.5}$. These results provided implications for $PM_{2.5}$ control strategies.

Q. Li et al., (2017) conducted a review which briefly introduces current status of indoor and ambient air pollution originating from household coal and biomass combustion in mainland China. Owing to low *combustion efficiency*, emissions of *CO*, $PM_{2.5}$, black carbon (BC), and polycyclic aromatic hydrocarbons have significant adverse consequences for indoor and ambient air qualities, resulting in relative contributions of more than one-third in all anthropogenic emissions. Their contributions are higher in less economically developed regions, such as Guizhou (61% $PM_{2.5}$, 80% BC), than that in more developed regions, such as Shanghai (4% $PM_{2.5}$, 17% BC). Chimneys can reduce ~ 80% indoor $PM_{2.5}$ level when burning dirty solid fuels, such as plant materials. Due to spending more time near stoves, housewives suffer much more (~ 2 times) $PM_{2.5}$ than the adult men, especially in winter in northern China

(~ 4 times). Improvement of stove combustion/thermal efficiencies and solid fuel quality are the two essential methods to reduce *pollutant emissions*. $PM_{2.5}$ and *BC emission* factors (EFs) have been identified to increase with volatile matter content in traditional stove combustion. EFs of dirty fuels are two orders higher than that of clean ones. Switching to clean ones, such as semi-coke *briquette*, was identified to be a feasible path for reducing > 90% $PM_{2.5}$ and BC emissions. Otherwise, improvement of thermal and combustion efficiencies by using under-fire *technology* can reduce ~ 50% CO_2, 87% NH_3, and 80% $PM_{2.5}$ and BC emissions regardless of volatile matter content in solid fuel. However, there are still some knowledge gaps, such as, inventory for the temporal impact of household combustion on air quality, statistic data for deployed clean solid fuels and advanced stoves, and the effect of socioeconomic development. Additionally, further technology research for reducing air pollution emissions is urgently needed, especially low cost and clean stove when burning any type of solid fuel. Furthermore, emission-abatement oriented policy should base on sound scientific evidence to significantly reduce pollutant emissions.

Anwar et al., (2021) examined point and non-point sources of air pollution and *particulate matter* and their associated socioeconomic and health impacts in South Asian countries, primarily India, China, and Pakistan. The legislative frameworks, policy gaps, and targeted solutions are also scrutinized. The major cities in these countries have surpassed the permissible limits defined by WHO for *sulfur dioxide*, *carbon monoxide*, *particulate matter*, and *nitrogen dioxide*. As a result, they are facing widespread health problems, disabilities, and causalities at extreme events. Populations in these countries are comparatively more prone to air pollution effects because they spend more time in the open air, increasing their likelihood of exposure to *air pollutants*. The elevated level of *air pollutants* and their long-term exposure increases the

susceptibility to several chronic/acute diseases, i.e., obstructive pulmonary diseases, acute respiratory distress, chronic bronchitis, and emphysema. More in-depth spatial-temporal air pollution monitoring studies in China, India, and Pakistan are recommended. The study findings suggest that policymakers at the local, national, and regional levels should devise targeted policies by considering all the relevant parameters, including the country's economic status, local meteorological conditions, industrial interests, public lifestyle, and national literacy rate. This approach will also help design and implement more efficient policies which are less likely to fail when brought into practice.

Rim-Rukeh, (2014) experimentally assessed the contribution of municipal solid waste dump site fires to atmospheric pollution in the Niger Delta, Nigeria. Five (5) municipal solid waste dump sites where fire incidence is a frequent and regular occurrence were chosen for the study. At each of the identified municipal solid waste dump site, eight (8) air quality monitoring parameters, suspended particulate matter (SPM_{10}), nitrogen dioxide (NO_2), carbon dioxide (CO_2), carbon monoxide (CO), Sulphur dioxide (SO_2), methane (CH_4), ammonia (NH_3) and Hydrogen sulphide (H_2S) were determined using a series of hand-held air quality monitoring equipment. Results indicate the levels of SPM ranged between 773 and 801 $\mu g/m^3$ and the levels of CO ranged between 133.7 and 141.6 ppm. The levels of CO_2 ranged between 401 ppm and 404.5 ppm while that of NO_2 ranged between 21.0 ppm and 27.3 ppm. The levels of SO_2 ranged between 27.7 ppm and 37.1 ppm while that of NH_3 ranged from 14.7 to 19.5 ppm. The levels of methane in the study area ranged between 2310 ppm and 2771 ppm and within the vicinity of dump site fires H_2S concentration ranges from 3.4 to 7.7 ppm. Levels of SPM, CO, CO_2, and CH_4 within the vicinity of the dump site fires were above regulatory limits. Dump site fires in the study area could threaten the health of anyone especially the dump site workers that

are regularly exposed to the thick smoke and can be implicated in climate change debate. There is a need to develop better practices with regard to municipal solid waste open dump site operation and emission control.

According to Amoatey et al., (2018), *indoor air pollution* is one of the human health threat problems in the Gulf Cooperation Council (GCC) countries. In these countries, due to unfavorable meteorological conditions, such as elevated ambient temperature, high relative humidity, and natural events such as dust storms, people spend a substantial amount of their time in *indoor environments*. In addition, production of physical and biological aerosols from air conditioners, cooking activities, burning of Arabian incense, and overcrowding due to pilgrimage programs are common causes of low-quality indoor air in this region. Thus, due to *infiltration* of outdoor sources as well as various indoor sources, people living in the GCC countries are highly exposed to indoor *air pollutants*. Inhalation of indoor air pollutants causes mortalities and morbidities attributed to cardiorespiratory, pulmonary, and lung cancer diseases. Hence, the aim of this review study is to provide a summary of the major findings of indoor air pollution studies in different microenvironments in six GCC countries. These include characterization of detected indoor air pollutants, exposure concentration levels, source identifications, sustainable *building designs* and ventilation systems, and the mitigation strategies. To do so, >130 relevant indoor air pollution studies across the GCC countries were critically reviewed. *Particulate matters* (PM_{10} and $PM_{2.5}$), total volatile organic compounds (TVOCs), carbon dioxide (CO_2), *sulfur dioxide* (SO_2), *nitrogen dioxide* (NO_2), and heavy metals were identified as the reported indoor air pollutants. Apart from them, *indoor Radon* and bioaerosols were studied only in specific GCC countries. Thus, future studies should also focus on the investigation of emerging indoor air pollutants, such as ultrafine and *nanoparticles* and

their associated health effects. Furthermore, studies on the mitigation of indoor air pollution through the development of advanced *air purification* and ventilation systems could improve the indoor air quality (IAQ) in the GCC region.

Ibrahim et al., (2022) explored the relationship between short-term exposure to air pollution and hospital admissions for respiratory diseases among children in a natural gas industrial area in Bintulu, Malaysia. Daily hospital admissions for respiratory diseases among children were collected from a hospital in Bintulu from 2010 to 2019. Data on six *air pollutants* (PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, and CO) in the study area were obtained from the Department of Environment Malaysia. Quasi-Poisson time series regressions with distributed lag non-linear models (DLNM) were applied to explore the associations between ambient air pollution and childhood hospitalizations for respiratory diseases. Stratification analyses were performed by gender and age group to identify the vulnerable populations. A 10 $\mu g/m^3$ increased $PM_{2.5}$ and SO_2 was associated with hospital admissions for respiratory diseases among children with the greatest relative risk of RR 1.089 (95% CI 1.001–1.183) at cumulative lag 0–2 days and RR 1.229 (95% CI 1.073–1.409) at cumulative lag 0–6 days, respectively. There was no significant association between short-term exposure of PM_{10}, NO_2, *CO*, and O_3 with childhood respiratory hospitalization. The association between $PM_{2.5}$ and SO_2 exposure and hospital admissions for childhood respiratory diseases in the two pollutants model remained statistically significant. There were stronger associations in younger children aged 0–4 years and girls. This study reveals that short-term exposure to SO_2 was associated with a higher risk of respiratory hospitalizations among children in Bintulu than $PM_{2.5}$.

Nazar & Niedoszytko, (2022) aimed to analyze current findings on air pollution and health in Poland, with a focus on respiratory diseases, including COVID-19, as well as the Poles'

awareness of air pollution. PubMed, Scopus and Google Scholar databases were searched. In total, results from 71 research papers were summarized qualitatively. In Poland, increased air pollution levels were found to be linked to increased general and respiratory disease mortality rates, higher prevalence of respiratory diseases, including asthma, lung cancer and COVID-19 infections, reduced forced expiratory volume in one second (FEV1) and forced vital capacity (FVC). The proximity of high traffic areas exacerbates respiratory health problems. People living in more polluted regions (south of Poland) and in the winter season have a higher level of air pollution awareness. There is an urgent need to reduce air pollution levels and increase public awareness of this threat. A larger number of multi-city studies are needed in Poland to consistently track the burden of diseases attributable to air pollution.

According to Schwartz, (1993), chronic exposure to particulates has been associated with increased rates of bronchitis and other respiratory ailments, with loss of lung function, and with increased risk of lung cancer. This issue was examined by looking at reported rates of chronic respiratory illness by standardized questionnaire across 53 urban areas in the United States. Diagnosis of respiratory illness by an examining physician in the First National Health and Nutrition Examination Survey was also considered as an outcome. After controlling for age, race, sex, and cigarette smoking, annual average total suspended particulate concentrations (TSP) were associated with increased risk of chronic bronchitis (odds ratio (OR) = 1.07, 95% confidence interval (CI) 1.02–1.12) and of a respiratory diagnosis by the examining physician (OR = 1.06, 95% CI = 1.02–1.11). The odds ratios are for a 10 $\mu g/m^3$ increase in TSP. When the analysis was restricted to never smokers, the associations remained, with a slight increase in the relative odds associated with airborne particles. Plots of the relative odds by quartiles of TSP exposure, adjusting for covariates, showed dose-dependent increases in risk with increasing

exposure. The risk appeared to continue to concentrations below the ambient air quality standard. Given the other recent findings of both acute and chronic effects of particulate pollution, these associations are likely causal.

Arbex et al., (2009) conducted a study to investigate the relationship between the daily number of COPD emergency department visits and the daily environmental air concentrations of PM_{10}, SO_2, NO_2, CO and O_3 in the City of São Paulo, Brazil. The sample data were collected between 2001 and 2003 and are categorised by gender and age. Generalised linear Poisson regression models were adopted to control for both short- and long-term seasonal changes as well as for temperature and relative humidity. The non-linear dependencies were controlled using a natural cubic spline function. Third-degree polynomial distributed lag models were adopted to estimate both lag structures and the cumulative effects of air pollutants.PM_{10} and SO_2 readings showed both acute and lagged effects on COPD emergency department visits. Interquartile range increases in their concentration (28.3 $\mu g/m^3$ and 7.8 $\mu g/m^3$, respectively) were associated with a cumulative 6-day increase of 19% and 16% in COPD admissions, respectively. An effect on women was observed at lag 0, and among the elderly the lag period was noted to be longer. Increases in CO concentration showed impacts in the female and elderly groups. NO_2 and O_3 presented mild effects on the elderly and in women, respectively. These results indicate that air pollution affects health in a gender- and age-specific manner and should be considered a relevant risk factor that exacerbates COPD in urban environments.

CHAPTER THREE

MATERIALS AND METHODS

This section describes all the procedure that was taken to conduct this research on "Environmental air pollutants as risk factors of occurrences of respiratory conditions in Bayelsa State Nigeria" This procedure is described below.

3.1 Study Design

This research was designed as a community-based survey. Different air quality sampling and measuring equipment were used to assess the ambient concentration of some important and common air pollutants and particles. Some of the targeted gases and particles are SO_2, CO, NO_2, $PM_{2.5}$ and $PM_{10.}$ Semi-structured interviewer-administered questionnaire was used to assess the knowledge level of the Bayelsa State residents about various respiratory conditions.

The study was designed to capture both descriptive and analytical techniques. Some of the data were be presented in tables and charts while inferential statistics was used to test the level of association between some other variables of interest.

3.2 Area of Study

Bayelsa is one of the State in the South-South geopolitical zones of Nigeria. It falls in the region that is commonly referred to as the Niger Delta region because they are situated around the Niger river delta where the river empties into the Gulf of Guinea. Bayelsa State as other States in the Niger Delta area is ecologically significant due to its unique wetland ecosystem and biodiversity. It is home to a variety of plant and animal species, including fish, birds, and wildlife. The region is rich in natural resources, particularly oil and gas deposits. A significant portion of Nigeria's oil wealth comes from Bayelsa State. The exploitation of these resources

has had a profound impact on the economy of Nigeria, and Bayelsa is often associated with oil production and its related industries.

The Bayelsa is inhabited by numerous ethnic groups, including the Ijaw, Ogoni, Itsekiri, Urhobo, Ison, and others. Each of these groups has its own unique cultural practices and languages.

Despite its economic significance, the Niger Delta region faces several challenges. The environmental impact of oil exploration and production has resulted in pollution, habitat destruction, and conflicts over resource control. Additionally, there have been longstanding issues related to social and economic development, leading to tensions and unrest in the region.

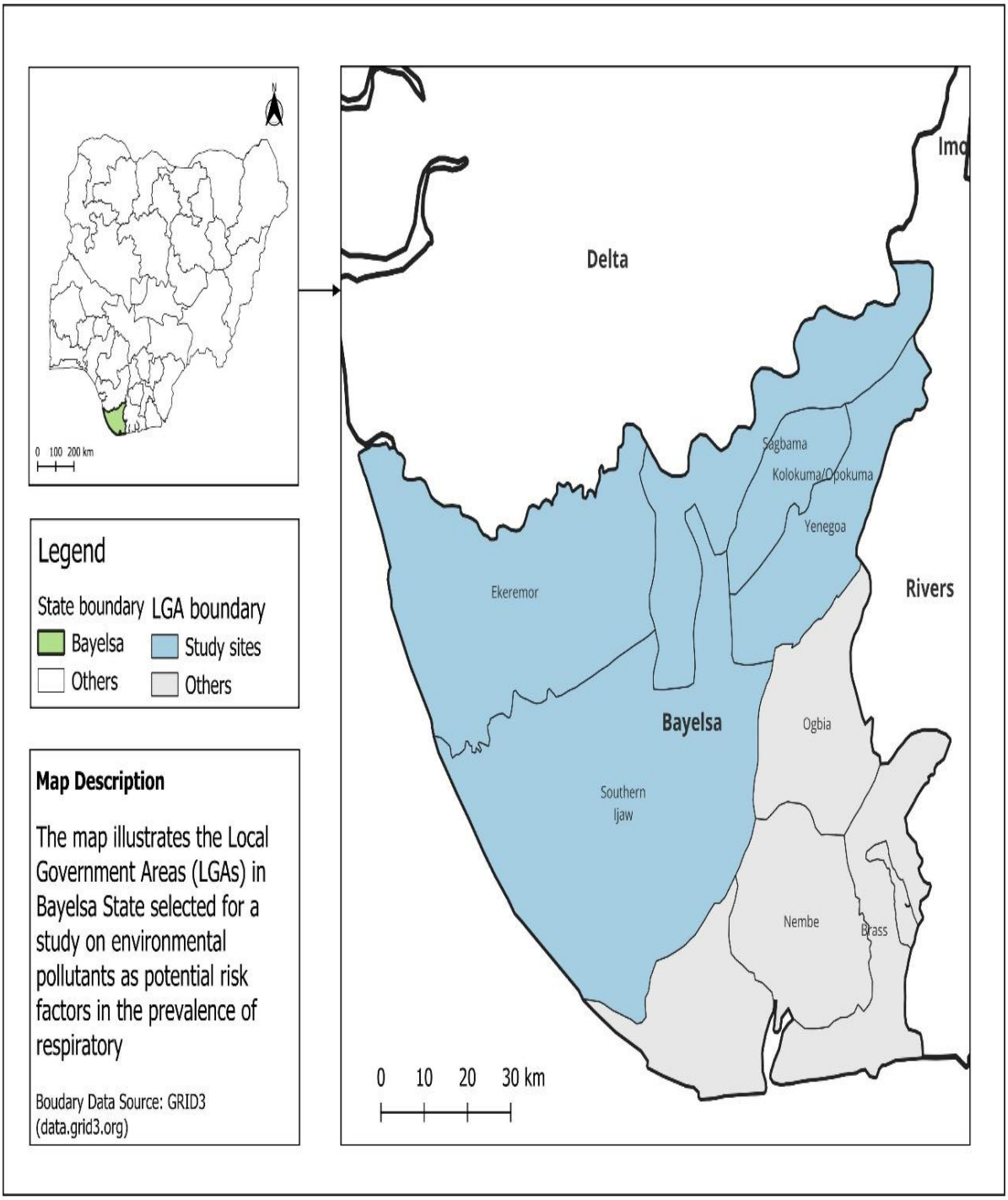

Figure 3.1: Map of Bayelsa State (BNMT, 2012)

3.3 Study Population

This study was conducted among 428 adults 18 years and above from an estimated 214 households in 69 communities from five local government areas in two senatorial zones of the State.

3.4 Sample Size and Sampling Method

3.4.1 Sample size

The appropriate sample size for the study was determined using the Leslie Kish formula for determining single proportion (for descriptive studies) (Kish, 2003). This sample size estimation method is best employed when the baseline data of the target population not known. The prevalence of the outcome of interest (good knowledge of respiratory conditions in this case) from a previous study from similar setting was used to establish prior proportion ("p" in the formular) as described below.

Formula, $n = \frac{Z\alpha^2 pq}{d^2}$

Where;

n = minimum sample size

Zα = standard normal deviate corresponding to the probability α i.e. the probability of making a type 1 error at 5% = 1.96

p = the proportion with the outcome variable.

q = 1 – p

d = degree of precision (5 % = 0.05)

p =50 % (Maximum sample size that can be obtained when the true proportion from the population is unknown and cannot be estimated from a previous research)

p =0.50

q =1-0.50= 0.50

d=0.05×0.05=0.0025

$Z_{\alpha}^{2} = 1.96 \times 1.96 = 3.8416$

$$n = \frac{3.8416 * 0.50 * 0.50}{0.0025}$$

=384.76

In anticipation of a non-response rate of 10%, the new sample size "N" is as follows:

N=n/1-NR

N=n/1-10%

384.76/1-10%

384.76/1-0.1

384.76/0.9

$=427.5 \approx 428$

N (sample size) =428

3.4.2 Sampling methods

A multi-stage sampling procedure was employed. This is to ensure the external validity of findings; the procedure is as described below;

Stage 1

Bayelsa west and Bayelsa central senatorial zones of Bayelsa State was purposively selected as the zones for the conduct of the study. These two zones effectively divide the state into the mainland and riverine locations where everyone in the State basically fall into. The residents of Bayelsa are either living on land or on water. These purposively selected zones represent the two ecosystems in the State.

Stage 2

In the second stage, all three LGAs in Bayelsa central senatorial district and all the two LGAs in Bayelsa west senatorial district were purposively selected as the study LGAs. The reason for

this purpose selection is that the LGAs are not too much and they cut across the length and breadth of the LGAs thereby providing the researcher with access to almost all parts of the State.

Stage 3

In this stage, all the wards in the five LGAs were used as the sampling frame. There were a total of 69 wards/communities in these five LGAs, proportion-to-size allocation was used to determine the number of households that was visited in each ward/community.

Stage 4

In the fourth and final stage of this multistage sampling procedure, a simple random technique was adopted to selected the households recruited into the study. Balloting was employed considering that the houses have been previously enumerated by the researcher with each households having a unique identifier. It is these numbers that were put into the ballot where the study households were finally selected.

$$\frac{\text{Number of wards in each local government area}}{\text{Total number of wards in all the 5 local government areas}} \times 214$$

From the sampling frame,
Ekeremor = 12 wards/ communities
Sagbama East= 14 wards/ communities
Yenogoa West= 15 wards/communities
Southern Ijaw= 17 wards/communities
Kolokuma/Opukuma= 11 wards/communities
Total = 69

Number of households to be selected in each ward/community is therefore presented below

Table 3.1: Proportion to size allocation of study households to all the wards in the sampling frame

LOCAL GOVERNMENT AREAS	PROPORTIONAL ALLOCATION TO SIZE	NUMBER OF HOUSEHOLDS	INTERVAL NUMBER
Ekeremor	12/69 x 214	37	3
Sagbama	14/69 x 214	43	3
Southern Ijaw	17/69 x 214	53	3
Yenogoa	15/69 x 214	47	3
Kolokuma/Opukumo	11/69 x 214	34	3

Sampling of Study participants from Households

Systematic random sampling technique was used to select the study participants at household level from each of the study LGA. Following the procedures for systematic sampling, the allocated sample size was used to divided number of household samples in each LGA to arrive at an interval number for each study LGA (Table 3.1). Household number was used to select a starting household in each LGA. This selection was done randomly using computer selection of random numbers. Other households were selected from the starting household by using an interval. The sample numbers were used to systematically select household participants (head of household or representative), At situations whereby a selected household was not available for survey the immediate household nest to that was selected.

3.5 Instruments for Data Collection

The data collection instruments consist of;

- Structured interviewer-administered questionnaire presented in three different sections; demographic; awareness of respiratory conditions; and knowledge assessment (Appendix 1). The knowledge questions were scored and graded as good, poor, and

average knowledge (Bosede et al., 2022). The instrument was used to assess the knowledge level of the respondents about respiratory conditions, their causes, prevention and control.

- Equipment for the collection and measurement of the ambient concentrations of the targeted air pollutants. Theses equipment include; Passive sampler for SO_2, Non-dispersive Infrared (NDIR) sensor for CO, Gas filter correlation analyzer for NO_2, and High-volume sampler for $PM_{2.5,10.}$
- To assess the respondents for common respiratory conditions, rapid lung function test was conducted using the using the Peak flow meter. This test is referred to as Peak Expiratory Flow Measurement.

3.5.1 Validity of Instruments

The questionnaire for information gathering from the respondents was carefully designed following the research specific objectives that relate to it. The questionnaire was then presented to the research supervisor for his input and validation.

The instruments for lung function test and air sampling are already graded and calibrated tools. They were however, tested for functioning, their battery capacities were also be checked to ensure that they perform optimally before they were be deployed on the field.

3.5.2 Reliability of Instruments

Reliability test was carried out to assess the accuracy of the data collection instruments. A pre-test was carried out in two selected communities in the Bayelsa state. These locations are not among the original study locations. Respondets from twenty households were assessed, Cronbach alpha test was then be carried out on the data collected during the pre-test. The test yielded a score of 0.70 ascertaining the reliability of the instruments.

The air sampling equipment was tested by using them to sample air of known pollutant concentrations. Correct reading was used to establish the reliability of the instruments.

In order to establish the reliability of the Peak flow meter for lung function test, the instrument was applied on five individuals with known lung function capacities.

3.6 Method of Data Collection

The methods of the data collection for the different categories of data are described below;

1. The demographic data of the respondents and information regarding their awareness and knowledge level of respiratory conditions were collected using the questionnaire. The structured questionnaire was made interviewer-administered so that interpretation can be done to respondents who may not be able to read and write. Research assistants were recruited from each of the five study LGAs so that they were able to speak the language of the people. These research assistants were trained on how to ethically administer the instrument.
2. Collecting ambient concentrations of air pollutants including; SO_2, CO_2, NO_2, $PM_{2.5}$, and PM_{10} requires careful planning, proper equipment, and adherence to established protocols. The procedures that was be taken are described below;

    - **Sulphur Dioxide (SO_2)**

      A Passive sampler an SO_2 monitor was placed at the location where the measurement was taken. Factors like wind direction, sources of emissions, and population exposure were all be put into consideration. The monitor was calibrated before and after each sampling session to maintain accuracy. The

reading was taken and the ambient concentration of SO_2 was recorded at regular intervals over the sampling period. This reading was taken twice six times, twice daily (morning and evening) for three days so that average reading of the ambient concentration can be used at the concentration levels for the gas in the different locations.

- **Carbon Dioxide (CO)**

  A non-dispersive Infrared (NDIR) CO sensor was used to measure the CO concentrations in the air in the study locations. While calibrating the analyzer before and after each reading, other factors that may impact the ambient concentration of the CO like wind speed, wind direction, time of the day and industrial activities in the environment were put into consideration. The reading was taken six times (twice daily for three days) and the average reading was taken as the concentration level for that study location.

- **Nitrogen Dioxide (NO_2)**

  Gas filter correlation NO_2 monitor was used to measure the ambient concentration of NO_2 in the study location. The reading was also taken six time while considering local emission sources, traffic patterns, and population exposure. The instrument was calibrated before and after each sampling session to ensure its reliability.

- **Particulate Matter ($PM_{2.5}$ and PM_{10})**

  High-volume PM sampler was used to measure both the $PM_{2.5}$. The reading was taken six times so that average reading can be obtained for use. Also, the instrument was calibrated before and after sampling to ensure accurate measurements.

  For the $PM_{2.5}$, a size-selective inlet was used to ensure that only particles with a diameter of 2.5 micrometers or smaller are collected. While for PM_{10}, an inlet that captures particles with a diameter of 10 micrometers or smaller was used on the instrument.

  Proper documentations of the sampling process, including the location, time, and meteorological conditions during the sampling period were maintained. This documentation was made to ensure that the data collected is reliable and can be used for analysis and comparison with regulatory standards or air quality guidelines.

3. Peak Expiratory Flow (PEF) measurement:

PEF is a measure of how fast a subject can blow air out of his/her lungs. It is often used to monitor changes in lung function and to assess conditions like asthma. The procedure that was used to perform the PEF is described below;

A handheld peak flow meter was utilized. The averaged baseline PEF value of an individual of particular age, sex and height was used as the reference for comparison

with the study participants. The meter was set to zero. The subjects were asked to stand up straight and take a deep breath. Seal the lips tightly around the mouthpiece of the peak flow meter. The participants were then requested to blow out as hard and as fast as he/she can in one continuous breath. The value that was displayed on the peak flow meter was then noted. The test was repeated three times and the highest value was recorded.

This result was then compared with the reference for the subjects' age, height and sex, to determine a proper function or a decline in lung function.

3.7 Method of Data Analysis

Statistical data analysis was performed using Microsoft Office Excel 2023 and IBM SPSS Statistics software version 27 (27 Armonk, NY: IBM Corp). At the initial analysis, descriptive method was used to describe the data characteristics. The demographic characteristics, and other categorical variables were presented through constructed frequency distribution tables, while summary statistics such as the means and standard deviations were computed for measured continuous variables. Charts including bar charts and line charts were used to represent the data. The mean ambient air quality level of the study area was compared with the WHO permissible limit and also with Ministry of Environment recommended standard for each pollutant using t-test method. The ANOVA test was used to compare the mean ambient air quality level across the study LGAs, Also t-test was used to compare the average respiratory rate of re**sidents** between Bayelsa West and Bayelsa Central. The respiratory condition of the study participants was measured using PEFR and the outcome was classified as normal or poor respiratory conditions. The relationship between exposure to air pollutants and respiratory conditions were

assessed in a logistic regression method. Similarly, the influence of sociodemographic factors to respiratory conditions were analysed in a logistic regression. The odd ratio was used to establish effect size measures. All statistical test were performed at 5% level of significance, and probability value (p) was used to establish significance. Hence $p < 0.05$ was considered significance.

3.8 Ethical Consideration/ Informed Consent

Ethical approval was obtained from the Health Research Ethics Committee of the Bayelsa State Ministry of Health, Yenagoa. Written informed consent was gotten from all individuals who participated in the study after the research would have been properly explained to them and what their involvements were all about.

Participation was made voluntary; there was no identifier on the questionnaire. Confidentiality was ensured in line with the approved procedure for obtaining consent to participate in the study. This was achieved by the use of codes on the forms that participants completed rather than their names.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Demographic Characteristics of the study Participants

A total of 428 adults participated in the study comprising of 180 from Bayelsa West and 248 from Bayelsa Central. Table4.1 contained the demographic information of the study respondents. The average age was 46.8 ± 6.7. the youngest person was 19 years old while the oldest person was 71 years old. The largest age group among them were the 30 -44 years old at 145 (33.9%), (35.6 at Bayelsa West and 32.2% at Bayelsa Central). followed by the 45-54 years at 116 (27.1%) (26.7% at Bayelsa West and 27.4% at Bayelsa Central). The lowest was the 70 years and above (4.9).

The male female ratio is 65.4% to 34.6%. Approximately 37.8% of the group were from Bayelsa West and 33.5% were from Bayelsa Central. They have been resident in the area for more 10 -15 years. The common occupation reported were trading (26.9%). There were also white collar job (20.6%), fishing (13.6%), farming (17.5%), mining (6.3%) and others. From the data collected, those with secondary education accounted for 181 (42.3%), tertiary education were 125 (29.2%) and 45 (10.5%) did not have any formal education. Only 40 (9.3%) earn up to 150,000 naira in a month, 18.2% earn below 30,000 naira and about one fifth (20.8%) earn between 100,000 to 149,000 naira.

Table 4.1: Demographic Information of the study Participants

Demographic Information	Bayelsa West (n=180)		Bayelsa Central (n=248)		Overall	
	Freq	**%**	**Freq**	**%**	**Freq**	**%**
Age years (Mean: 46.8 ± 6.7)						
18 -29	19	10.6	31	12.5	50	11.7
30-44	64	35.6	81	32.7	145	33.9
45-54	48	26.7	68	27.4	116	27.1
55 – 64	41	22.8	55	22.2	96	22.4
65+	8	4.4	13	5.2	21	4.9
Total	180	100.0	248	100.0	428	100.0
Gender						
Male	116	64.4	164	66.1	280	65.4
Female	64	35.6	84	33.9	148	34.6
Total	180	100.0	248	100.0	428	100.0
Duration since resident in the community						
Less than 5 years	23	12.8	37	14.9	60	14.0
5 – 9 years	35	19.4	55	22.2	90	21.0
10 -15	68	37.8	83	33.5	151	35.3
Above 15	54	30.0	73	29.4	127	29.7
Total	180	100.0	248	100.0	428	100.0
Occupation						
Fishing	27	15.0	31	12.5	58	13.6
Farming	39	21.7	36	14.5	75	17.5
White collar	27	15.0	61	24.6	88	20.6
Trading	51	28.3	64	25.8	115	26.9
Mining	14	7.8	13	5.2	27	6.3
Unemployed	12	6.7	21	8.5	33	7.7
Other (eg student)	10	5.6	22	8.9	32	7.5
Total	180	100.0	248	100.0	428	100.0
Educational Level						
Primary	34	18.9	43	17.3	77	18.0
Secondary	84	46.7	97	39.1	181	42.3
Tertiary	38	21.1	87	35.1	125	29.2
Non-formal	24	13.3	21	8.5	45	10.5
Total	180	100.0	248	100.0	428	100.0
Monthly Income Level (in Naira)						
Below 30,000	37	20.6	41	16.5	78	18.2
30,000- 59000	55	30.6	56	22.6	111	25.9

59,000 - 99,0000	43	23.9	67	27.0	110	25.7
100,000- 149000	28	15.6	61	24.6	89	20.8
150,000 and above	17	9.4	23	9.3	40	9.3
Total	180	100.0	248	100.0	428	100.0

4.1.2 Awareness and knowledge of respiratory conditions among the residents of Bayelsa

4.1.2.1 Awareness of respiratory conditions

In table 4.2, 92.1% have heard of lung diseases, comprising of 91.7% (Bayelsa West) and 92.3% (Bayelsa Central). Furthermore the following were recorded for respiratory diseases: Tuberculosis (81.1%), asthma (76.6%) and pneumonia (67.8%). In terms of having any respiratory conditions known to them, a total of 54 (12%) responded "yes" (Bayelsa West = 11.7%, Bayelsa Central=12.6%); while 38.9% and 42.6% respectively mentioned asthma and pneumonia as the diseases.

However, 50% among those that reported having heard of lung diseases they responded that have been on the condition for 5-9 years (51.5% in Bayelsa central), and 35.9% reported that they have been on the disease within 5 years (33.3% in Bayelsa West).

Large number of the study group indicated that they usually get information about lung diseases through social media network (40.9%), followed by the community health workers (32.9%) and the Healthcare professionals such as doctors, nurses and others (30.4%).

Table 4.2: Awareness of respiratory conditions among residents in Bayelsa State

GENERAL AWARENESS OF RESPIRATORY CONDITIONS	Bayelsa West (n=180)		Bayelsa Central (n=248)		Overall (n=428)	
	Freq	%	Freq	%	Freq	%
Heard of lung diseases before this survey						
Yes	165	91.7	229	92.3	394	92.1
No	15	8.3	19	7.7	34	7.9
If yes, please specify the lung diseases you are aware of (Select all that apply)						
Tuberculosis	139	77.2	208	83.9	347	81.1
Ashma	136	75.6	192	77.4	328	76.6
Pneumonia	126	70.0	164	66.1	290	67.8
Bronchitis	57	31.7	104	41.9	161	37.6
Lung Cancer	61	33.9	129	52.0	190	44.4
Other (eg flu)	34	18.9	76	30.6	110	25.7
Do you have any respiratory condition you are aware of?						
Yes	21	11.7	33	13.3	54	12.6
No	162	88.38	220	86.7	382	87.4
If yes, what is the name of the condition?					0	0.0
Asthma	7	33.3	14	42.4	21	38.9
Pneumonia	9	42.9	14	42.4	23	42.6
Flu	3	14.3	4	12.1	7	13.0
Other (eg Bronchitis)	2	9.5	1	3.0	3	5.6
Since when have you had the condition (Years)?						
Less than 5 years	7	33.3	7	21.2	14	25.9
5 – 9 years	10	47.6	17	51.5	27	50.0
10=15	3	14.3	6	18.2	9	16.7
Above 15	1	4.8	3	9.1	4	7.4
Where do you usually get information about lung diseases? (Select all that apply)						
Traditional Media. Radio, Tv	48	26.7	75	30.2	123	28.7
Social media- Facebook, WhatsApp, X, internet	67	37.2	108	43.5	175	40.9
Healthcare professionals (doctors, nurses, etc.)	54	30.0	76	30.6	130	30.4
Community Health workers	73	40.6	68	27.4	141	32.9
Friends and family	21	11.7	61	24.6	82	19.2
Other	11	6.1	15	6.0	26	6.1

4.1.2.2 Participants knowledge of respiratory conditions

In table. 4.3, 71.5% in all (75.8% in Bayelsa Central; 65.6% in Bayelsa West) reported genetic factor as a risk in respiratory conditions. A total of 299 (69.9%) comprising of 77.0% (Bayelsa Central), 60% (Bayelsa West) perceived TB as a risk factor, while only 45.3% of the total participants (43.3% in Bayelsa West and 46.8% in Bayelsa Central) perceived air pollution as a risk factor of respiratory conditions. Those who identified occupational exposure such as artisan refining of crude, construction work as risk factors of respiratory conditions were 237 (55.4%), while only 28.3% were able to understand that secondhand smoking exposure is a risk factor.

In terms of common symptoms of lung diseases, knowledge was high on persistent cough (93.3%), wheezing (92.8%) and Fatigue and weakness (72.7%). It was low on chest pain (16.1%) and shortness of breath (24.3%).

Concerning prevention for lung diseases, the largest knowledge was on seeking early medical attention as as preventive mechanism against respiratory symptoms (85.7%), followed by getting vaccinated (64.5%). Less than half of the respondent showed knowledge from avoiding air pollution and toxins exposure (42.5%).

A total of 253 (59.1%) responded in the affirmative knowledge that lung diseases are associated with smoking, 45% perceived pneumonia as a contagious disease. Up to 38% responded that they “do not know” whether pneumonia is a contagious disease or not. A total of 55% were of good knowledge that TB has the capacity to affect lung, while 69.2%, showed knowledge that lung cancer is more common in smokers than in non-smokers.

Table 4.3 knowledge level of respiratory conditions among Residents in Bayelsa state

KNOWLEDGE ASSESSMENT	Bayelsa West (n=180)		Bayelsa Central (n=248)		Overall (n=428)	
	Freq	%	Freq	%	Freq	%
Which of the following are risk factors for respiratory conditions? (Select all that apply)						
Smoking	105	58.3	150	60.5	255	59.6
Air pollution	78	43.3	116	46.8	194	45.3
Tuberculosis	108	60.0	191	77.0	299	69.9
Genetic Factors	118	65.6	188	75.8	306	71.5
Occupational exposure (Artisan refining of crude, gas flaring)	82	45.6	155	62.5	237	55.4
Secondhand smoke exposure	46	25.6	75	30.2	121	28.3
Poor diet and nutrition	51	28.3	74	29.8	125	29.2
Other	34	18.9	37	14.9	71	16.6
Can you identify common symptoms of lung diseases? (Select all that apply)						
Persistent cough/	156	86.7	244	98.4	400	93.5
Shortness of breath	37	20.6	67	27.0	104	24.3
Chest pain	66	36.7	3	1.2	69	16.1
Coughing up blood	45	25.0	85	34.3	130	30.4
Fatigue and weakness	123	68.3	188	75.8	311	72.7
Wheezing	156	86.7	241	97.2	397	92.8
Fever	101	56.1	163	65.7	264	61.7
No symptoms	14	7.8	16	6.5	30	7.0
Other	3	1.7	0	0.0	3	0.7
How can lung diseases be prevented? (Select all that apply)						
Quitting smoking	95	52.8	146	58.9	241	56.3
Avoiding air pollution and toxins exposure	64	35.6	118	47.6	182	42.5
Getting vaccinated (e.g., flu, pneumonia)	112	62.2	164	66.1	276	64.5
Regular exercise and healthy lifestyle	66	36.7	166	66.9	232	54.2
Seeking early medical attention	131	72.8	236	95.2	367	85.7
Other	13	7.2	7	2.8	20	4.7
Lung diseases are only caused by smoking						
TRUE	94	52.2	159	64.1	253	59.1
FALSE	67	37.2	72	29.0	139	32.5
Don’t know	19	10.6	17	6.9	36	8.4
Pneumonia is a contagious disease						
TRUE	68	37.8	124	50.0	192	44.9
FALSE	46	25.6	24	9.7	70	16.4
Don’t know	66	36.7	100	40.3	166	38.8
Tuberculosis primarily affects the lungs						
TRUE	98	54.4	138	55.6	236	55.1
FALSE	46	25.6	45	18.1	91	21.3
Don’t know	36	20.0	65	26.2	101	23.6
Lung cancer is more common in smokers than in non-smokers						
True	118	65.6	178	71.8	296	69.2
FALSE	36	20.0	33	13.3	69	16.1
Don’t know	26	14.4	37	14.9	63	14.7

4.1.2.3 Summary Knowledge Level of respiratory conditions among Residents in Bayelsa state

Figure 4.1 is a compound bar chart in two clusters of good knowledge and poor knowledge representing the summary of knowledge of respiratory conditions among study residents in Bayelsa State. The figure shows the overall good knowledge was 53.7% (230 out of 428), while a total of 198 (46.3%) showed poor knowledge. The level of good knowledge was found to be slightly higher in Bayelsa central at 56.9%, but it was a bit below 50% among residents in Bayelsa West (49.4%).

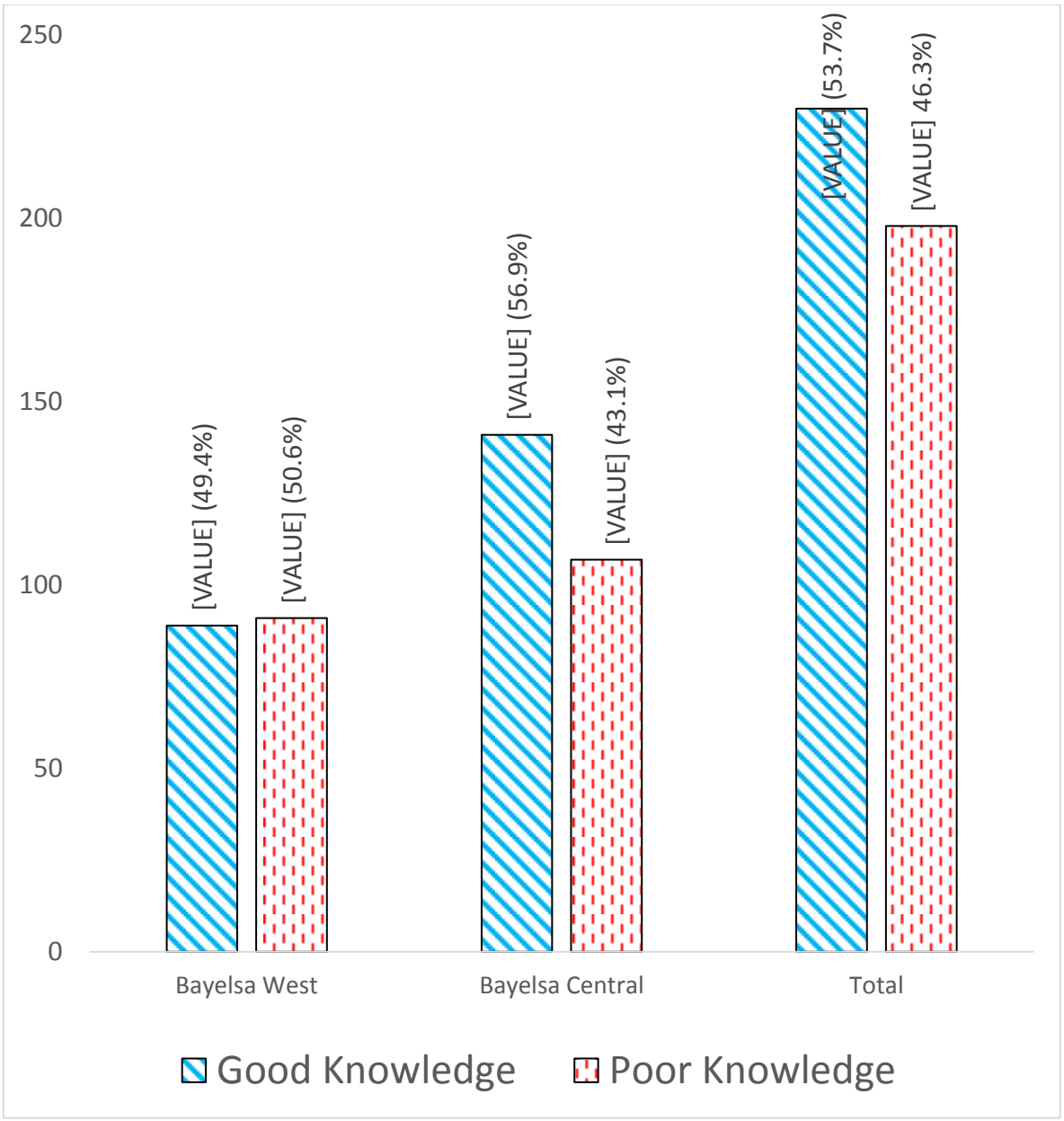

Figure 4.1 is a compound bar chart representing the summary of knowledge of respiratory conditions among study residents in Bayelsa State.

4.1.3 The Ambient Air Quality level of Common air pollutants (SO_2, CO_2, CO, NH and PM (2.5, and 10) in the Study area of Bayelsa State.

The summary for the ambient air quality level of common air pollutants such as SO_2, NO_2, CO, NH and PM (2.5, and 10) in the study area in Bayelsa state is presented in table 4.4. The table shows that the overall mean (standard deviations) ambient air quality level was found as follows for the air pollutant: SO_2 (78.53 ± 42.65 μg/m^3), NO_2, (62.59 ± 35.89), C0 (9.11 ± 6.96), NH (0.37 ± 0.30), PM 2.5 (53.72 ± 23.22) and PM 10 (170.19 ± 44.40). It also shows that the air pollutants were relatively high in most of the LGAs sampled. The highest level of SO_2 was obtained in parts of Southern Ijaw LGA (201.2 μg/m^3), while the NO_2 was found highest in an industrial location at Yonagua at 152.1 μg/m^3, but was lowest in Kolokuma/ Opukumo LGA.

Other air pollutants such as Carbon monoxide (CO) was found highest and lowest respectively at locations in Ekeremor LGA (23.4μg/m^3) and Kolokuma/ Opukumo LGA (0.34μg/m^3), while ammonia (NH) was found highest in one of the industrial locations in Southern Ijaw LGA (0.94μg/m^3) followed by another industrial locations at Yonagua LGA (0.834μg/m^3), but was lowest at a location in Sagbama LGA (0.001μg/m^3). The coarse particulate matter (PM10) and fine particulate matter (PM2. 5) were found highest in Southern Ijaw LGA (PM10: 275.4 μg/m^3; PM2.5= 113.4 μg/m^3), but were lowest in Yenagoa for PM10 (84.60μg/m^3) and Kolokuma/ Opukumo for PM2.5 (18.9μg/m^3). Figure 4.2 showed clearly that PM10 was high in all the LGAs. It also shows that SO2, PM 2.5 and PM10 was found highest at Southern Ijaw LGA, NO2 was found largest at Yonagua LGA, while CO was largest in Ekeremor LGA (14.14 μg/m^3),

Table 4.4: The Ambient level of Common air pollutants from industries and mining activities including SO_2, CO_2, CO, NH and PM (2.5, and 10) in the Bayelsa State atmosphere.

Air pollutants at LGAs	Sample	Mean	Std. Deviation	Minimum	Maximum
No2 (µg/m3)					
Ekeremor	5	68.74	40.53	26.20	132.20
Sagbama	5	63.46	23.80	43.60	103.40
Southern Ijaw	5	114.84	60.02	44.30	201.20
Yenogoa	5	84.78	45.26	29.70	133.80
Kolokuma/ Opukumo	5	60.84	23.92	37.20	97.40
Total	25	78.53	42.65	26.20	201.20
No2 (µg/m3)					
Ekeremor	5	52.12	17.87	32.60	75.20
Sagbama	5	50.50	41.98	22.10	123.40
Southern Ijaw	5	54.12	15.99	32.60	72.40
Yenogoa	5	97.54	41.31	47.60	152.10
Kolokuma/ Opukumo	5	58.68	41.60	21.10	120.40
Total	25	62.59	35.89	21.10	152.10
Co (µg/m3)					
Ekeremor	5	14.14	6.32	7.30	23.40
Sagbama	5	3.61	3.12	0.37	8.30
Southern Ijaw	5	13.60	6.32	4.70	21.60
Yenogoa	5	10.78	7.43	3.60	21.70
Kolokuma/ Opukumo	5	3.43	2.67	0.34	7.30
Total	25	9.11	6.96	0.34	23.40
NH (µg/m3)					
Ekeremor	5	0.17	0.13	0.03	0.33
Sagbama	5	0.23	0.27	0.001	0.63
Southern Ijaw	5	0.72	0.16	0.54	0.94
Yenogoa	5	0.49	0.32	0.09	0.83
Kolokuma/ Opukumo	5	0.25	0.25	0.01	0.61
Total	25	0.37	0.30	0.00	0.94

Table 4.4 continued

Air pollutants at LGAs	Sample	Mean	Std. Deviation	Minimum	Maximum
Pm 2.5 (µg/m3)					
Ekeremor	5	52.26	10.95	39.70	67.40
Sagbama	5	47.57	14.86	27.80	63.70
Southern Ijaw	5	79.66	24.33	57.80	113.40
Yenogoa	5	53.40	24.85	23.40	77.20
Kolokuma/ Opukumo	5	35.70	19.67	18.90	67.60
Total	25	53.72	23.22	18.90	113.40
Pm 10 (µg/m3)					
Ekeremor	5	158.28	20.28	134.00	182.90
Sagbama	5	175.28	11.30	165.40	191.50
Southern Ijaw	5	186.42	67.80	105.60	275.40
Yenogoa	5	160.76	70.36	84.60	242.20
Kolokuma/ Opukumo	5	170.00	33.15	132.40	215.20
Total	25	170.19	44.41	84.60	275.40

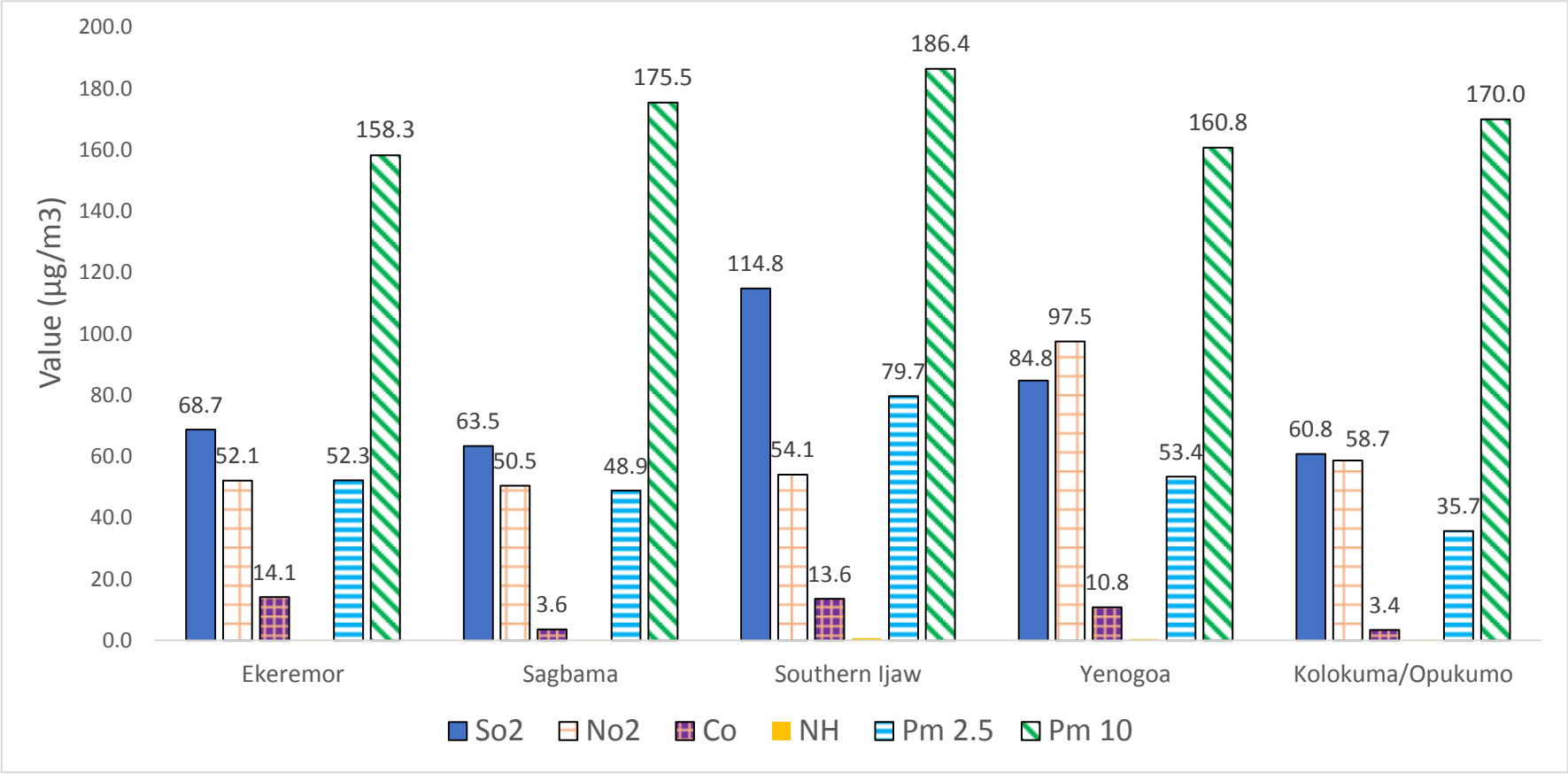

Figure 4.2: Compound Bar Chart for distribution of Ambient level of Common air pollutants (SO_2, CO_2, CO, NH, PM2.5, and PM 10) in the study LGAs of Bayelsa

Differences in Average Ambient Air Pollution Across the study LGAs in Bayelsa State

Table 4.5 is the analysis of variance table for differences in the mean ambient air pollution in Bayelsa state. The test shows that at 5% level, significant differences were found in carbon monoxide (CO: P =0.009, F=4.556), Ammonia (NH: P =0.008, F=4.669), and PM 2.5 (P =0.033, F=3.248).

Table 4.5: ANOVA table for Differences in Mean Ambient Air Pollution Across the study LGAs in Bayelsa State

Air Pollution	Sum of Squares	Df	Mean Square	F	Sig.
So2 (µg/m3)					
Between Groups	9966.82	4	2491.71	1.479	0.246
Within Groups	33692.16	20	1684.61		
Total	43658.97	24			
No2 (µg/m3)					
Between Groups	7821.60	4	1955.40	1.693	0.191
Within Groups	23100.26	20	1155.01		
Total	30921.86	24			
Co (µg/m3)					
Between Groups	553.71	4	138.43	4.556	0.009
Within Groups	607.66	20	30.38		
Total	1161.37	24			
NH (µg/m3)					
Between Groups	1.05	4	0.26	4.669	0.008
Within Groups	1.13	20	0.06		
Total	2.18	24			
Pm 2.5 (µg/m3)					
Between Groups	5188.18	4	1297.05	3.347	0.030
8Within Groups	7750.52	20	387.53		
Total	12938.70	24			
Pm 10 (µg/m3)					
Between Groups	2611.030	4	652.79	0.292	0.880
Within Groups	44743.16	20	223.16		
Total	47354.19	24			

Subsequent to the above ANOVA test, table 4.3 is the ANOVA Post-Hoc test for group differences in Air Pollution in the study area. Significant differences were found in air pollution mostly between Southern Ijaw LGA and some other LGAs. For CO ($\mu g/m^3$) Southern Ijaw showed slight significant difference from Kolokuma/ Opukumo LGA at mean difference of 10.71 (P=0.046, 95% Confidence Interval= 0.2812, 21.705). Similar significant difference was obtained between Southern Ijaw and Kolokuma/ Opukumo LGAs on PM2.5 (P=0.047, 95% Confidence Interval= 0.3771, 87.5429). Significant difference were also found in Ammonia (NH) between Southern Ijaw LGA with Ekeremor LGA ((P=0.047, 95% Confidence Interval= 0.0769, 1.0231), and between Southern Ijaw LGA with Sagbama LGA (P=0.047, 95% Confidence Interval= 0.0145, 0.9607).

Table 4.6: ANOVA Post-Hoc test for group differences in Air Pollution in the study Area

LGA Difference	Mean Difference	Std. Error	P value.	95% Confidence Interval	
				Lower	Upper
Co (µg/m3)					
Southern Ijaw vs Kolokuma/ Opukumo	10.710	3.486	0.046	0.2812	21.705
NH (µg/m3)					
Southern Ijaw vs Ekeremor	0.550	0.150	.015	0.0769	1.0231
Southern Ijaw vs Sagbama	0.488	0.150	.040	0.0145	0.9607
Pm 2.5 (µg/m3)					
Southern Ijaw vs Kolokuma/ Opukumo	43.960	13.821	.047	0.3771	87.5429

4.1.4 Ambient levels of the air pollutants (SO_2, NO_2, CO, NH and PMs) in Bayelsa State Compared with the WHO and the Federal Ministry of Environment permissible levels and standards.

4.1.4.1 Ambient levels of the air pollutants (SO_2, NO_2, CO, NH and PMs) in Bayelsa State Compared with the WHO permissible levels.

Figure 4.3 is a figure representing the ambient levels of the air pollutants (SO_2, NO_2, CO, NH PM2.5 and PM10) in the study LGAs of Bayelsa State Compared with WHO recommended Permissible limit (thickest line). Clearly the figure shows that Pm2.5 and PM10 were quite higher in Southern Ijaw and Yenagoa LGAs. Though the pollutants were lowered or getting very closer to the WHO limit on CO and NH, none of them were below the WHO chart, indicating that the study areas were very polluted. Statistical test is expected to reveal if some of the exceeding levels above the limits are significant.

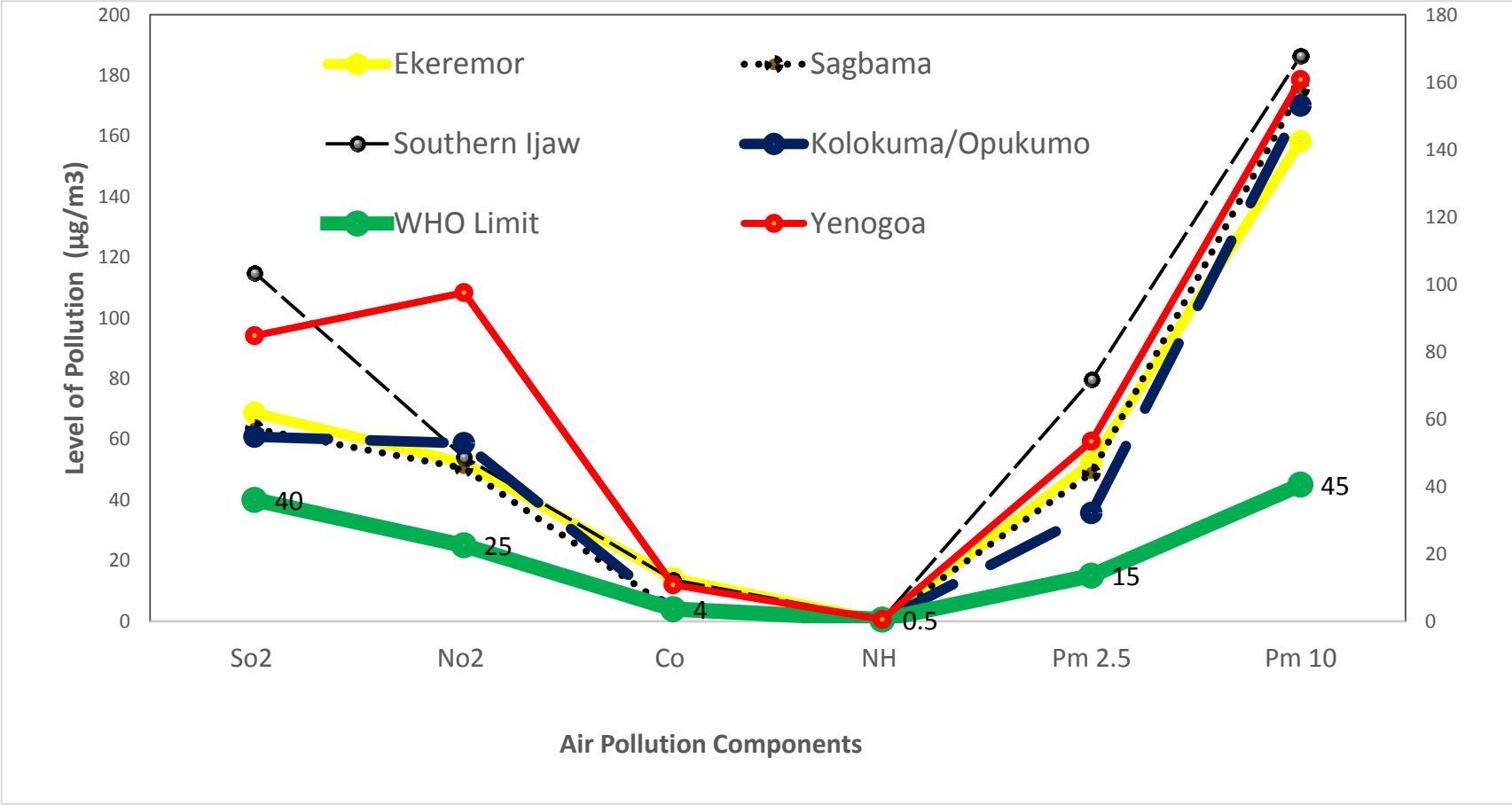

Figure 4.3: Line plot comparison of ambient levels of the air pollutants (SO_2, NO_2, CO, NH PM2.5 and PM10) in Bayelsa State Compared with WHO recommended Permissible limit

In table 4.7, some off the ambient levels of the air pollutants were found to have exceeded the WHO permissible level to a significant extent. In Southern Ijaw, most of the ambient levels (5 out of 6) for the air pollutants recorded largest exceeding scores against the WHO permissible level with 74.84 $\mu g/m^3$for SO2, 9.6 $\mu g/m^3$ for CO, 0.22 $\mu g/m^3$ for NH, 64.66 $\mu g/m^3$ for PM2.5 and 141.42 $\mu g/m^3$ for Pm10. The largest exceeding difference for NO2 was 57.54 $\mu g/m^3$ found in Yenagoa, while that of CO $\mu g/m^3$ was10.14 at Ekeremor.

For SO2, significant exceeding area was in Southern Ijaw LGA (P=0.049, 95% CI = 0.31, 149.37), while NO2 was found to have exceeded significantly in Yenagoa (P=0.036, 95% CI = 6.25, 108.83). Carbon monoxide CO was above limit significantly in Ekeremor 5 (P=0.023, 95% CI = 2.29, 17.99) and Southern Ijaw (P=0.027, 95% CI = 7.75, 17.45), while NH was also significantly above the limit in Southern Ijaw (P=0.039, 95% CI = 0.02, 0.41).

The fine particulate matter (PM2.5) differ significantly in Ekeremor (P=0.002, 95% CI = 23.67, 50.85), Sabgama (P=0.020, 95% CI = 7.21, 48.51), Southern Ijaw (P=0.004, 95% CI = 34.45, 94.87) and Yenogoa (P=0.026, 95% CI = 7.22, 69.25). The coarse particulate matter (PM10) significantly exceed the limit at Sabgama (P=0.042, 95% CI = 4.23, 144.73), Southern (P=0.010, 95% CI = 57.23, 225.61). and Yenagoa (P=0.021, 95% CI = 28.39, 203.12).

The coarse particulate matter (PM10) significantly exceed the limit at all the study LGAs such as Ekeremor (P= 0.000, 95% CI =88.10, 138.46) Sabgama (P=0.022, 95% CI = 22.22, 166.74), Southern Ijaw (P=0.010, 95% CI = 57.23, 225.61), Yenagoa (P=0.021, 95% CI = 28.39, 203.12) and Kolokuma/ Opukumo (P=0.001, 95% CI = 83.84, 166.16).

Table 4.7 Ambient levels of the air pollutants (SO_2, NO_2, CO, NH and PMs) in Bayelsa State Compared with the WHO permissible levels

Ambient Air Pollutants	Mean ± SD	Mean Difference	T	P-value	95% Conf. Interval	
					Lower	Upper
SO_2 (µg/m^3) (WHO limit: 40)						
Ekeremor	68.74 ± 40.53	28.74	1.586	0.188	-21.59	79.07
Sagbama	63.46 ± 23.60	23.46	2.223	0.090	-5.84	52.76
Southern_Ijaw	114.84± 60.02	74.84	2.788	0.049	0.31	149.37
Yenogoa	84.78 ± 45.26	44.78	2.212	0.091	-11.42	100.98
Kolokuma/ Opukumo	60.84 ± 23.92	20.84	1.948	0.123	-8.86	50.54
No2 (µg/m^3) WHO Limit: 25						
Ekeremor	52.12 ± 17.87	12.12	1.517	0.204	-10.07	34.31
Sagbama	50.5 ± 41.99	10.50	0.559	0.606	-41.63	62.63
Southern_Ijaw	54.12 ± 15.99	14.12	1.975	0.120	-5.73	33.97
Yenogoa	97.54 ± 41.31	57.54	3.115	0.036	6.25	108.83
Kolokuma/ Opukumo	58.68 ± 41.60	18.68	1.004	0.372	-32.98	70.34
Co (µg/m^3) WHO Limit: 4						
Ekeremor	14.14 ± 6.32	10.14	3.588	0.023	2.29	17.99
Sagbama	3.614 ± 3.12	-0.39	-0.276	0.796	-4.27	3.49
Southern_Ijaw	13.6 ± 6.32	9.60	3.396	0.027	1.75	17.45
Yenogoa	10.78 ± 7.43	6.78	2.042	0.111	-2.44	16.00
Kolokuma/ Opukumo	3.428 ± 2.67	-0.57	-0.479	0.657	-3.89	2.75
NH (µg/m^3), WHO Limit: 0.5						
Ekeremor	0.166 ± 0.13	-0.33	-5.827	0.004	-0.49	-0.17
Sagbama	0.228 ± 0.27	-0.27	-2.274	0.085	-0.60	0.06
Southern_Ijaw	0.716 ± 0.16	0.22	3.017	0.039	0.02	0.41
Yenogoa	0.492 ± 0.32	-0.01	-.0055	0.959	-0.41	0.39
Kolokuma/ Opukumo	0.252 ± 0.25	-0.25	-2.207	0.092	-0.56	0.06

Table 4.7 continued

Ambient Air Pollutants	Mean ± SD	Mean Difference	T	P-value	95% Conf. Interval	
					Lower	Upper
Pm 2.5 (µg/m^3)						
WHO Limit: 15						
Ekeremor	52.26 ± 10.95	37.36	7.610	0.002	23.67	50.85
Sagbama	42.86 ± 16.63	27.86	3.745	0.020	7.21	48.51
Southern_Ijaw	79.66 ± 24.33	64.66	5.943	0.004	34.45	94.87
Yenogoa	53.4 ± 24.85	38.40	3.456	0.026	7.55	69.25
Kolokuma/ Opukumo	35.7 ± 19.69	20.70	2.351	0.078	-3.74	45.14
Pm 10 (µg/m^3)						
WHO Limit: 45						
Ekeremor	158.28 ± 20.28	113.28	12.49	0.000	88.10	138.46
Sagbama	139.48 ± 58.20	94.48	3.63	0.022	22.22	166.74
Southern_Ijaw	186.42 ± 67.80	141.42	4.66	0.010	57.23	225.61
Yenogoa	160.76 ± 70.36	115.76	3.68	0.021	28.40	203.12
Kolokuma/ Opukumo	170.0 ± 33.15	125.00	8.43	0.001	83.84	166.16

4.1.4.2 Ambient levels of the air pollutants (SO_2, NO_2, CO, NH and PMs) in Bayelsa State Compared with the Federal Ministry of Environment permissible levels and standards.

The ambient levels of the air pollutants (SO_2, NO_2, CO, NH PM2.5 and PM10) in the study LGAs of Bayelsa State in comparison to the Federal Ministry of Environment (FMOEnv) permissible limit for the pollutants is represented in figure 4.4. Clearly the figure shows that Pm2.5 and PM10 were higher than FMOEnv pollution limit in Southern Ijaw, Yenagoa LGAs, Ekeremor and Sagbama. Also PM10 was higher than the limit in Kolokuma/ Opukumo LGA, and CO was slightly above the limit in Southern Ijaw and Ekeremor LGAs. Though the pollutants were lowered or getting very closer to the WHO limit on CO and NH, none of them were below the WHO chart, indicating that the study areas were very polluted.

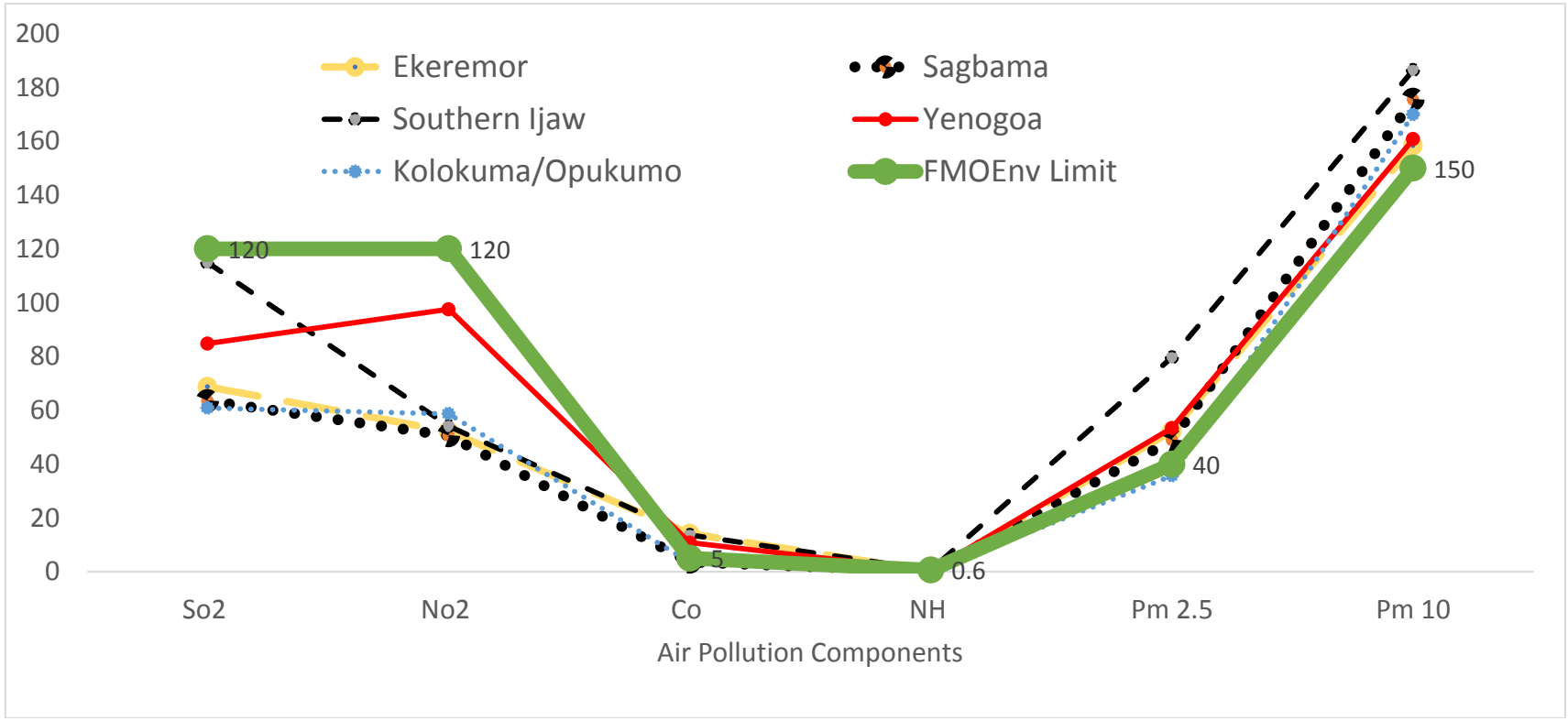

Figure 4.4: Line plot comparison of ambient levels of the air pollutants (SO_2, NO_2, CO, NH PM2.5 and PM10) in Bayelsa State Compared with FMOEnvir recommended Permissible limit

Table 4.8 shows that for the ambient levels of the study air pollutants in Bayelsa State in comparison with their respective permissible limits as recommended from the Federal Ministry of Environment (FMOEnv) Nigeria, none of the mean scores for SO2 and NO2 pollutants were found to have exceeded the FMOEnv limit in the LGAs of study. However, CO was found to have significantly exceeded the limit in Ekeremor LGA (P=0.032, 95% CI = 1.29, 16.99) and Southern Ijaw LGA (P=0.038, 95% CI = 0.75, 16.45). The limit was also exceeded in Yenagoa but no evident of significant difference with the FMOEnv limit was established in this study (P >5%). The average pollution for Ammonia (NH) was found to be higher than the FMOEnv limit in Southern Ijaw area, but no evidence of significant difference between the two was found in the index study.

The table also showed that PM2.5 pollution exceeded the FMOEnv limit at Ekeremor (52.26 ± 10.95 μg/m^3), Southern Ijaw (79.66 ± 24.33 μg/m^3) and Yenagoa (53.4 ± 24.85 μg/m^3). However, while it was significant at Southern Ijaw (P=0.022, 95% CI = 9.45, 69.87), the difference was not fount significant at Ekeremor and Yonagoa (p>5%).

The average PM10 pollution was found to have exceeded the FMOEnv limit at Southern Ijaw (186.42 ± 67.8 μg/m^3) and Yenagoa LGAs (160.76 ± 70.36 μg/m^3) but no evidence of significant difference was established in both cases (P >5%).

The average PM10 pollution was found to have exceeded the FMOEnv limit at Ekeremor (158.28 ± 20.28 μg/m^3), Southern Ijaw (186.42 ± 67.8 μg/m^3), Yenagoa (160.76 ± 70.36 μg/m^3) and Kolokuma/ Opukumo (170.0 ± 33.15 μg/m^3) LGAs but no evidence of significant difference was established in both cases (P >5%).

Table 4.8: Ambient levels of the air pollutants (SO_2, NO_2, CO, NH and PMs) in Bayelsa State Compared with the Federal Ministry of Environment permissible levels and standards.

Ambient Air Pollutants	Mean ± SD	Mean Difference	T	P value	95% Conf. Interval	
					Lower	Upper
So2 (µg/m3)						
FMOEnv Limit : 120						
Ekeremor	68.74 ± 40.53	-51.26	-2.828	0.047	-101.59	-0.93
Sagbama	63.46 ± 23.60	-56.54	-5.358	0.006	-85.84	-27.24
Southern_Ijaw	114.84± 60.02	-5.16	-0.192	0.857	-79.69	69.37
Yenogoa	84.78 ± 45.26	-35.22	-1.740	0.157	-91.42	20.98
Kolokuma/ Opukumo	60.84 ± 23.92	-59.16	-5.531	0.005	-88.86	-29.46
No2 (µg/m^3)						
FMOEnv Limit: 120						
Ekeremor	52.12 ± 17.87	-67.88	-8.494	0.001	-90.07	-45.69
Sagbama	50.5 ± 41.99	-69.50	-3.701	0.021	-121.63	-17.37
Southern_Ijaw	54.12 ± 15.99	-65.88	-9.213	0.001	-85.73	-46.03
Yenogoa	97.54 ± 41.31	-22.46	-1.216	0.291	-73.75	28.83
Kolokuma/ Opukumo	58.68 ± 41.60	-61.32	-3.296	0.030	-112.98	-9.66
Co (µg/m^3)						
FMOEnv Limit: 5						
Ekeremor	14.14 ± 6.32	9.14	3.235	0.032	1.29	16.99
Sagbama	3.614 ± 3.12	-1.34	-0.992	0.377	-5.27	2.49
Southern_Ijaw	13.6 ± 6.32	8.60	3.042	0.038	0.75	16.45
Yenogoa	10.78 ± 7.43	5.78	1.741	0.157	-3.44	15.00
Kolokuma/ Opukumo	3.428 ± 2.67	-1.57	-1.316	0.259	-4.89	1.74
NH (µg/m^3),						
FMOEnv Limit: 0.6						
Ekeremor	0.166 ± 0.13	-0.43	-7.571	0.002	-0.59	-0.28
Sagbama	0.228 ± 0.27	-0.37	-3.111	0.036	-0.70	-0.04
Southern_Ijaw	0.716 ± 0.16	0.13	1.620	0.181	-0.08	0.32
Yenogoa	0.492 ± 0.32	-0.11	-0.756	0.497	-0.51	0.29
Kolokuma/ Opukumo	0.252 ± 0.25	-0.35	-3.097	0.036	-0.66	-0.04

Table 4.8 Continued

Ambient Air Pollutants	Mean ± SD	Mean Difference	T	P value	95% Conf. Interval	
					Lower	Upper
Pm 2.5 (µg/m^3) FMOEnv Limit: 40						
Ekeremor	52.26 ± 10.95	12.26	2.504	0.066	-1.33	25.85
Sagbama	42.86 ± 16.63	2.86	0.384	0.720	-17.79	23.52
Southern_Ijaw	79.66 ± 24.33	39.66	3.645	0.022	9.45	69.87
Yenogoa	53.4 ± 24.85	13.40	1.206	0.294	-17.45	44.25
Kolokuma/ Opukumo	35.7 ± 19.69	-4.30	-0.488	0.651	-28.74	20.14
Pm 10 (µg/m^3) FMOEnv Limit: 150						
Ekeremor	158.28 ± 20.28	8.28	0.913	0.413	-16.90	33.46
Sagbama	139.48 ± 58.17	-10.52	-0.404	0.707	-82.78	61.74
Southern_Ijaw	186.42 ± 67.80	36.42	1.201	0.296	-47.77	120.61
Yenogoa	160.76 ± 70.36	10.76	0.342	0.750	-76.60	98.12
Kolokuma/ Opukumo	170.0 ± 33.15	20.00	1.349	0.249	-21.16	61.16

4.1.4.3 Summary Comparison: Total Ambient levels of the air pollutants (SO_2, NO_2, CO, NH PM2.5 and PM10) in Bayelsa State Compared with WHO and the Federal Ministry of Environment permissible levels and standards

The exploratory analysis of the total ambient levels for the study air pollutants SO_2, NO_2, CO, NH PM2.5 and PM10) in Bayelsa State in depicted in figure 4.5. The figure showed that NH, PM2.5 and PM10 were all above both the WHO limit and the FMOEnv limit which showed poor and unhealthy air quality available in Bayelsa state.

However, only SO2 and NO2 were below FMOEnv permissible limit and the WHO permissible limit.

In table 4.9, all the air pollution indicators studied show significant pollution above the WHO recommended permissible limit/ Also the comparison with the FMOEnv, different permissible limits for each of the air pollutants indicates that the variable were all significantly above the FMoEnv permissible limits include CO (P=0.007, 95% CI=1.24, 6.98); and PM2.5 (P= 0.007, 95%CI =(4.13.353, -0.105) and others.

Significant difference was found in the study overall data representing Bayelsa state between the study ambient air pollutants and the WHO permissible limit in all the study pollutants at 5%. The 95% confidence interval indicated all interval positive values for the pollutants except in NH. This is a clear indication that apart from NH, all other study air pollutants significantly exceeded the WHO respective permissible limits.

Similarly significant difference was also between the study data for the air pollutants and the FMOEnv permissible limit in some of the air pollutants. For instance, CO (P=.007, 95%CI = (1.24, 6.98), PM2.5 (P=0.007, 95%CI= 4.13, 23.30) and PM10 (P=0.032, 95%CI= 1.85, 38.52)

significantly exceeded the permissible limit from the FMOEnv (Nigeria). It is therefore a clear indication that most of the air ambient air quality available in Bayelsa State Nigeria are very likely to be poor, polluted and unhealthy.

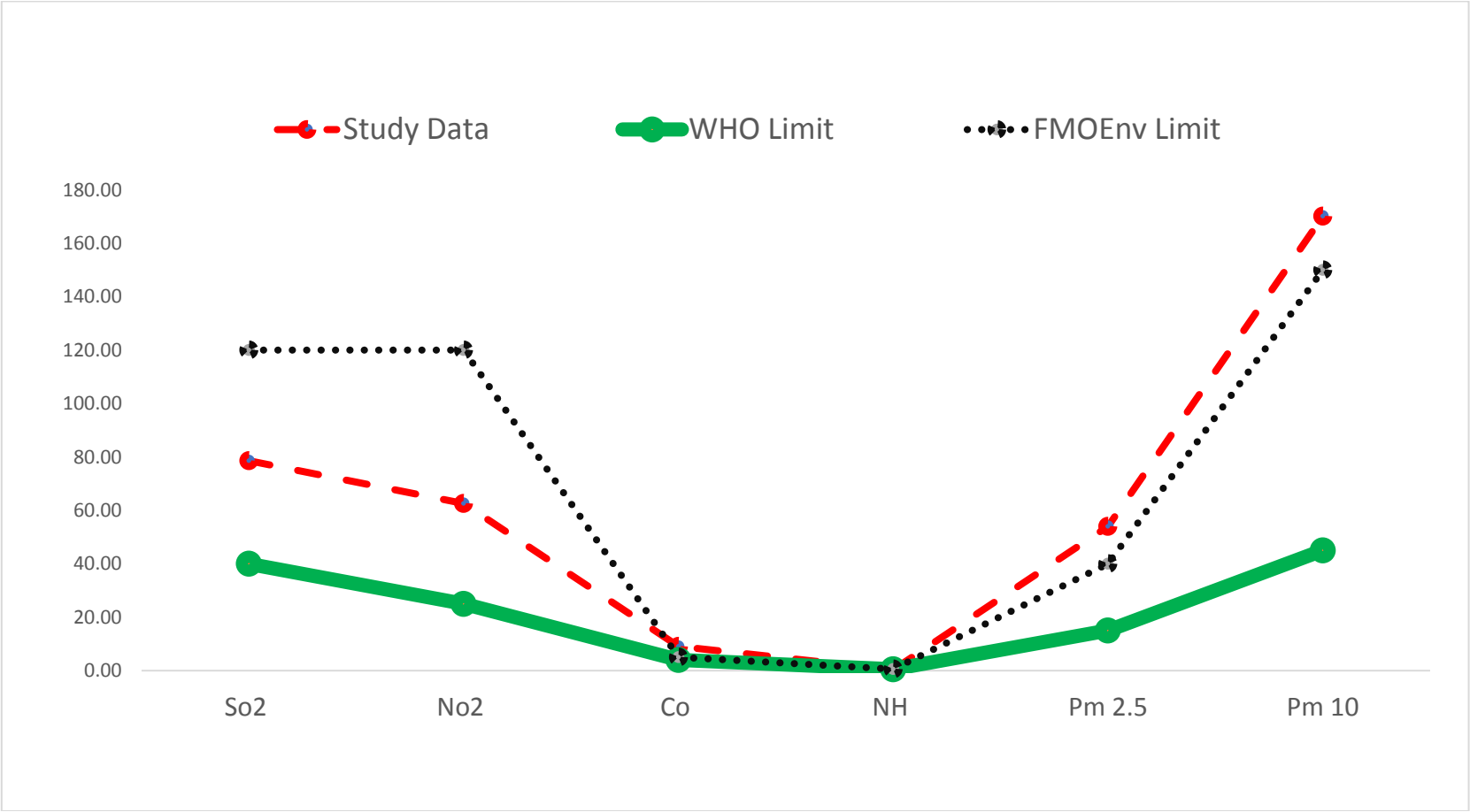

Figure 4.5: Side by side Ambient air quality level (AAQL) using assessing air pollution (SO2, NO2, CO, NH, PM2.5 and PM10) in Bayelsa State Nigeria.

Table 4.9: Summary Comparison for Total Ambient levels of the air pollutants (SO_2, NO_2, CO, NH PM2.5 and PM10) in Bayelsa (Study Level Compared with WHO and the Federal Ministry of Environment permissible levels and standards)

Mean Total for Study LGAs	**So2 (µg/m^3)** Mean ± SD	**No2 (µg/m^3)** Mean ± SD	**Co (µg/m^3)** Mean ± SD	**NH (µg/m^3)** Mean ± SD	**Pm 2.5 (µg/m^3)** Mean ± SD	**Pm 10 (µg/m^3)** Mean ± SD
Ekeremor	68.74 ± 40.53	52.12 ± 17.87	14.14 ± 6.32	0.166 ± 0.13	52.26 ± 15.99	158.28 ± 20.28
Sagbama	63.46 ± 23.60	50.5 ± 41.99	3.614 ± 3.12	0.228 ± 0.27	48.86 ± 16.63	175.48 ± 11.30
Southern Ijaw	114.84 ± 60.02	54.12 ± 15.99	13.6 ± 6.32	0.716 ± 0.16	79.66 ± 24.33	186.42 ± 67.80
Yenogoa	84.78 ± 45.26	97.54 ± 41.31	10.78 ± 7.43	0.492 ± 0.32	53.4 ± 24.85	160.76 ± 70.36
Kolokuma/ Opukumo	60.84 ± 23.92	58.68 ± 41.60	3.428 ± 2.67	0.252 ± 0.25	35.7 ± 19.69	170.0 ± 33.15
Overall	78.53 ± 22.32	62.59 ± 17.78	8.47 ± 4.66	0.37 ± 0.23	51.58 ± 17.17	170.19 ± 44.42
WHO Limit	40	25	4	0.5	15	45
FMOEnv Limit	120	120	5	0.6	40	150
Study vs WHO standard						
P-value (95% conf. Interval)	<0.0001 (20.93, 56.14)	<0.0001 (22.78, 52.41)	0.001 (2.24, 7.98)	0.04 (-0.253, -0.005)	<0.0001 (24.80, 45.05)	<0.0001 (106.85, 143.52)
Study vs FMOEnv Standard						
P-value (95% conf. Interval)	0.000 (-50.07, -23.86)	0.000 (-23.86, -42.59)	0.007 (1.24, 6.98)	0.001 (-0.353, -0.105)	0.007 (4.13, 23.30)	0.032 (1.85, 38.52)

4.1.5 Common Respiratory conditions among the residents of Bayelsa State including

4.1.5.1. Reported Common symptoms of Respiratory concerns among the study group

Reported Common symptoms respiratory problems encountered among the residents of Bayelsa State is presented in table 4.10. From the table, majority (323: 75.5%), had no common respiratory symptom or issues reported (Bayelsa West: 71.7%; Bayelsa Central: 78.2%). Up to 10.7% (Bayelsa West: 12.8%; Bayelsa Central: 9.3%) reported that they have experienced a cough that lasted more than 4 weeks duration. 11 % responded that they had sputum production, while those that had chest pain were 15.6% (Bayelsa West: 17.2%; Bayelsa Central: 14.5%). Those that have history of Asthma /COPD were 1.4%. Only 3.5% responded that they had a respiratory check up within 6 months (Bayelsa West: 3.9%; Bayelsa Central: 3.2%).

Sputum production, chest pain, History of Asthma/COPD and cough duration of over 4 weeks were reported more in Bayelsa West while having fast breeding was reported more among residents of Bayelsa Central.

Table 4.10: Reported Common symptoms of Respiratory Symptoms/check-up among residents of Bayelsa State (within 6 months)

Reported Common respiratory symptoms	Bayelsa West	Bayelsa Central	Total
No respiratory disease symptom	129 (71.7%)	194 (78.2%)	323 (75.5%)
Have cough for more than 4 weeks duration	23 (12.8%)	23 (9.3%)	46 (10.7%)
Sputum production	22 (12.2%)	25 (10.1%)	47 (11.0%)
Chest pain	31 (17.2%)	36 (14.5%)	67 (15.6%)
Fast breeding	16 (8.9%)	26 (10.5%)	42 (9.8%)
Had respiratory check up within 6 months	7 (3.9%)	8 (3.2%)	15(3.5%)
History of Asthma/COPD	3 (1.7%)	3 (1.3%)	6 (1.4%)

4.1.5.2 Respiratory Condition Among the Study Group

Table 4.11 represented the respiratory status of the study group. It can be observed from the table that the peak expiratory flow rate (PEFR) indicates that the average PEFR was 451.6 ± 77.6 l/min for the study group. The mean PEFR was slightly lower in Bayelsa West (429.8 ± 73.4 l/min) than in Bayelsa Central (473.3 ± 87.5 l/min).

A total of 349 (81.5%) was within the normal range (of 400 - 600 L/min for normal), while 79 (18.5%) had respiratory issues. The mean PEFR was 483.4 ± 79.3 l/min for those with normal respiration but was lowered for those with respiratory concerns (342.4 ± 76.2 l/min). The difference in mean between the two groups was found to be l significant at 5% level [p=0.000 (95% confidence Interval=111.8 – 150.4)].

Table 4.11: Respiratory Conditions among the residents of Bayelsa State

Item	Normal PEFR (400 - 700 L/Min)	Abnormal (Low PEFR)	Mean PEFR	t test	P (95% Conf. Interval)
Bayelsa West (n=180)	142 (78.9%)	38 (21.1%)	429.8 ± 73.4		
Bayelsa Central (n =248)	207 (83.5%)	41 (16.5%)	473.3 ± 87.5		
Total (n=428)	349 (81.5%)	79 (18.5%)	451.6 ± 77.6		
Mean	483.4 ± 79.3	342.4 ± 76.2		13.224	< 0.0001 (111.8 – 150.4)

4.1.5.3 Respiratory conditions that are common among the residents of Bayelsa State

Figure 4.3 is a bar chart which represents the distribution of common respiratory conditions among the study residents in Bayelsa state. It clearly shows more than one quarter of the study group (110: 25.7%) have wheezing, 81(18.1%) of the responded were found to have pneumonia, 54 (11.6% for asthma, while 47 (11.0%) were found with COPD. Others include bronchitis (22: 5.1%), short bread (10: 2.3%), emphysema (9: 2.1%) and pleural pathologies (8: 1.9%).

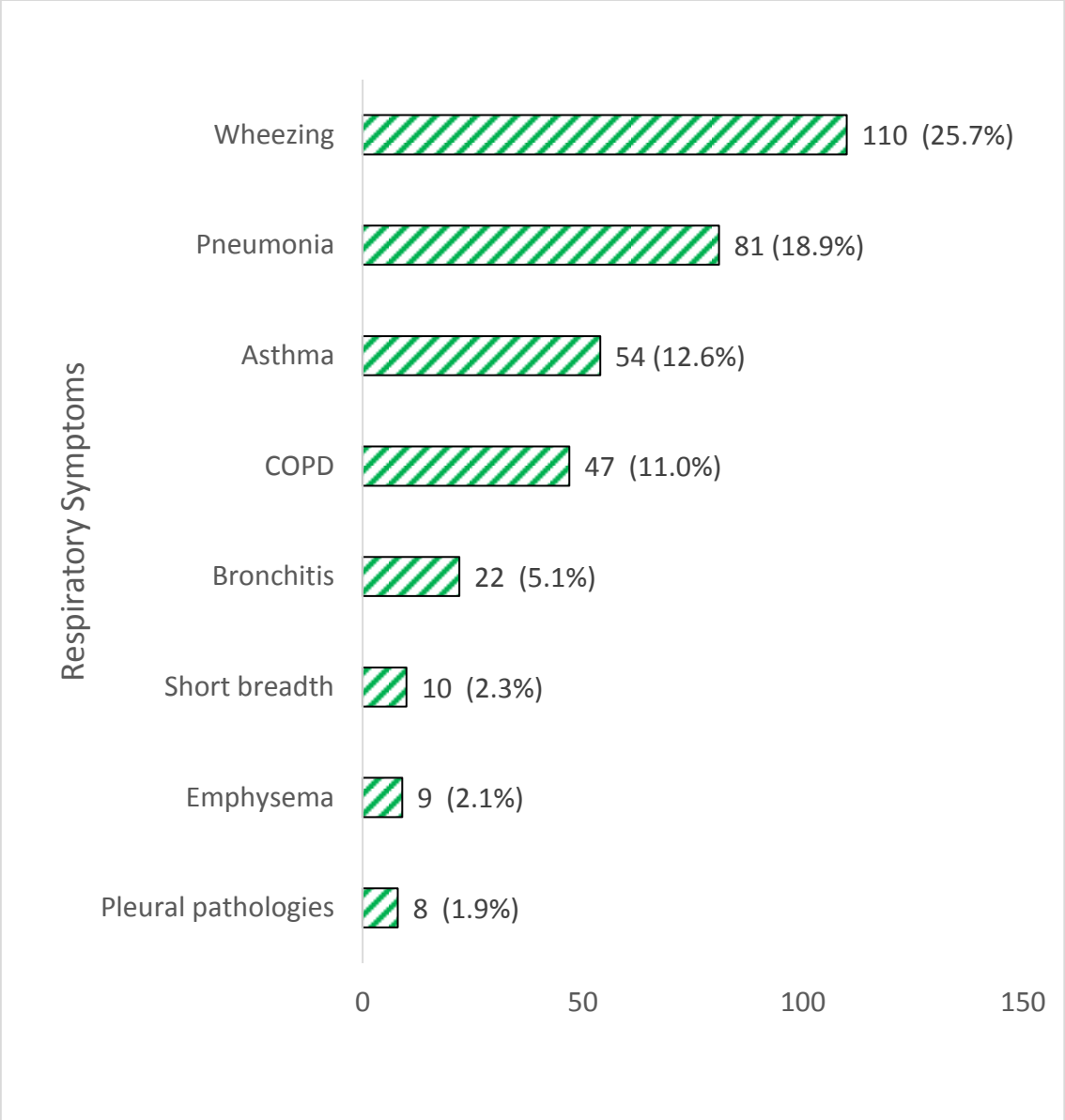

Figure 4.6: Bar chart for Distribution of Common respiratory conditions that are common among the residents of Bayelsa State including Asthma, Emphysema, COPD, Bronchitis and Pneumonia

4.1.6 Association between air pollution exposure and the development of respiratory conditions among the residence of Bayelsa State.

Table 4.12 represents the association between air pollution exposure and the development of respiratory conditions among the residence of Bayelsa State. It shows that up to 293 (68.5%)

were exposed to SO2. Among those exposed to SO2, 22,2% had poor respiratory condition compared to 10.4% for the unexposed group. The odds ratio (OR) shows that odds for having poor respiratory conditions was found to be 2.5 times significantly more in the exposed group than the unexposed group (P =0.0031, OR =2.5, 95% CI=1.31 – 4.99).

Also exposure to NO2 showed significant associate on with poor respiratory conditions and the risk was found to be over 2.9 folds significantly higher in the exposed group than the unexposed group (P =0.0015, OR= 1.8, 95% CI=1.44 – 6.28).

A total of 31% of those exposed to CO had poor respiratory conditions xompared to 14.4% in the unexposed group, and being exposed to CO is significant (P =0.0234) and contained about 2 times higher odds for poor respiratory conditions compared to unexposed (OR=2.1, 95%CI=1.07-4.27). There were 21.3% of the NH exposed group that had poor respiratory conditions against13% in the unexposed, Being exposed to ammonia (NH) was also found significant with greater odds of 1.8 times more compared to the unexposed group (P =0.0367, OR= 1.8, 95% CI=1.01 – 3.35).

A total of 329 (74.5%) and 317 (74.1%) were respectively exposed to fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}). Exposure to particulate matter showed significant association with poor respiratory conditions among the study group ($PM_{2.5}$: p =0.0042; PM_{10}: p=0.0029). For $PM_{2.5,}$ 21.6% of the exposure group had poor respiratory conditions against 9.3% found among the unexposed group. Similarly, for $PM_{10,}$ 21.5% of the exposure group had poor respiratory conditions against 9.2% found among the unexposed group. The odds ratio indicates that the odd for poor respiratory conditions was 2.7 times significantly higher in the

exposed than the unexposed on both air pollutants ($PM_{2.5}$: p=0.0042, OR=2.7, 95% CI = 1.31–6.12; PM_{10}: p=0.0029, OR=2.7, 95% CI = 1.35 – 5.89).

Table 4.12 Association between air pollution exposure and the development of respiratory conditions among the residence of Bayelsa State

Exposure Status	Poor PEFR < 400 L/Min)		Normal PEFR (400 - 700 L/Min)					95% CI	
	Freq	**%**	**Freq**	**%**	**Total**	**P**	**OR**	**Lower**	**Upper**
SO2,									
Exposed	65	22.2	228	77.8	293 (68.5)	0.0031	2.5	1.31	4.99
Unexposed	14	10.4	121	89.6	135 (31.5)				
NO_2									
Exposed	68	22.2	238	77.8	306 (71.5)	0.0015	2.9	1.44	6.28
Unexposed	11	9.0	111	91.0	122 (28.5)				
CO									
Exposed	66	21.0	248	79.0	314 (73.4)	0.0234	2.1	1.07	4.27
Unexposed	13	11.4	101	88.6	114 (26.6)				
NH									
Exposed	60	21.3	222	78.7	282 (65.9)	0.0367	1.81	1.01	3.35
Unexposed	19	13.0	127	87.0	146 (34.1)				
$PM_{2.5}$									
Exposed	69	21.6	250	78.4	319 (74.5)	0.0042	2.7	1.31	6.12
Unexposed	10	9.3	98	90.7	108 (25.2)				
PM_{10}									
Exposed	68	21.5	249	78.5	317 (74.1)	0.0029	2.7	1.35	5.89
Unexposed	11	9.2	109	90.8	120 (28.0)				

4.1.7 Relationship between Sociodemographic factors and respiratory conditions among the residence of Bayelsa State

In table 4.13, significant association was found between age and respiratory conditions and and younger age group has lower risk. For instance, poor respiratory conditions were 14% and 13.1% respectively for the 18-29 and 30 -44 years compared to 47.6% risk among the 65 years and above. The odds for poor respiratory conditions was found to be 82% (ie 1-0,18)% significantly lower among the 18 – 29 years compared to the 65years and above (OR=0.18, 95%CI= 0.47 – 0.67). The risk was significantly higher among females (29.1%) than males (12.9%) with approximately 2.8 folds odds (OR=2.78, 95%CI= 1.63 – 7.71, p<0.0001).

Also significant was occupation. Odds were significantly lower among those doing white collar jobs (OR=0.32, 95%CI= 0.13 – 0.79, p=0.0057), trading (OR=0.33, 95%CI= 0.14 – 0.76, p=0.0036) and students (OR=0.29, 95%CI= 0.07 – 1.03, p=0.0349), The odds were lower among those that had tertiary education (OR=0.41, 95% CI= 0.17 – 1.03) and also on among the secondary school level participants (OR=0.49, 95% CI= 0.22 – 1.14) compared to those without formal education.

Income was significantly associated with respiratory conditions. Compared to those earning below 30,000 naira in a month, the odds for having poor of abnormal respiratory condition is 57% significantly lower among those earning between #59,000 – 99,000 compare to those earning below #30,000 (OR=0.43 ,95%CI=0.04 – 0.81

Table 4.13: Relationship between Sociodemographic factors and respiratory conditions among the residence of Bayelsa State

Demographic Information	Overall		Poor PEFR < 400 L/Min)		Normal PEFR (400 - 700 L/Min)		p	OR	95% CI	
	Freq	%	Freq	%	Freq	%			Lower	Upper
Age years										
18 -29	50	11.7	7	14.0	43	86.0	0.0024	0.18	0.47	0.67
30-44	145	33.9	19	13.1	126	86.9	0.0001	0.17	0.06	0.51
45-54	116	27.1	19	16.4	97	83.6	0.0012	0.21	0.07	0.65
55 – 64	96	22.4	24	25.0	72	75.0	0.039	0.37	0.12	1.1
65+	21	4.9	10	47.6	11	52.4				
Gender										
Male	280	65.4	36	12.9	244	87.1				
Female	148	34.6	43	29.1	105	70.9	<0.0001	2.78	1.63	7.71
Duration since resident in the community										
Less than 5 years	60	14.0	12	20.0	48	80.0				
5 – 9 years	90	21.0	17	18.9	73	81.1	0.8659	0.93	0.38	2.34
10 -15	151	35.3	22	14.6	129	85.4	0.3331	0.68	0.3	1.64
Above 15	127	29.7	28	22.0	99	78.0	0.75	1.13	0.5	2.66
Total	428	100.0	79	18.5	349	81.5		Reference		
Occupation										
Fishing	58	13.6	19	32.8	39	67.2		Reference		
Farming	75	17.5	14	18.7	61	81.3	0.0621	0.47	0.19	1.13
White collar	88	20.6	12	13.6	76	86.4	0.0057	0.32	0.13	0.79
Trading	115	26.9	16	13.9	99	86.1	0.0036	0.33	0.14	0.76
Mining	27	6.3	9	33.3	18	66.7	0.9581	1.03	0.34	2.97
Unemployed	33	7.7	5	15.2	28	84.8	0.0669	0.37	0.96	1.19
Other (eg student)	32	7.5	4	12.5	28	87.5	0.0349	0.29	0.07	1.03
Total	428	100.0	79	18.5	349	81.5				
Educational Level										
Primary	77	18.0	18	23.4	59	76.6	0.4998	0.75	0.3	1.9
Secondary	181	42.3	30	16.6	151	83.4	0.0596	0.49	0.22	1.14
Tertiary	125	29.2	18	14.4	107	85.6	0.0309	0.41	0.17	1.03
Non-formal	45	10.5	13	28.9	32	71.1		Reference		
Total	428	100.0	79	18.5	349	81.5				
Income Level										
Below 30,000	78	18.2	21	26.9	57	73.1		Reference		
30,000- 59000	111	25.9	25	22.5	86	77.5	0.4876	0.79	0.38	1.64
59,000 - 99,0000	110	25.7	15	13.6	95	86.4	0.0225	0.43	0.04	0.81

100,000- 149000	89	20.8	13	14.6	76	85.4	0.0486	0.46	0.2	1.07
150,000 and above	40	9.3	5	12.5	35	87.5	0.0736	0.39	0.11	1.19
Total	428	100.0	79	18.5	349	81.5				

4.2 Discussion

Ambient air pollution, occurring in the atmosphere from several pollutants such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter (PM) and others often has profound and negative consequences on human respiratory conditions.(WHO, 2022a). Therefore the index study was primarily aimed at investigating environmental air pollutants as risk factors in the occurrence of respiratory conditions in Bayelsa State Nigeria.

4.2.1 Awareness and knowledge of respiratory conditions among the residents of Bayelsa State Studied

The index study found that clear majority of the study participants showed nigh awareness of some lung diseases such as Tuberculosis (81.1%),, asthma (76.6%) and pneumonia pneumonia (67.8%), Similar to this findings, high awareness had been reported in another study in a Nigerian community with 97.3% of the study participants having prior knowledge and awareness about tuberculosis as a disease (Anochie et al., 2013). In Chinwendu-Amorha et al. (2022) , while the awareness level for asthma was found high (98.1%) among the study group, yet only approximately 33% showed good knowledge of the disease in that study.

The reason for high awareness could likely be as a result of being a victim of the respiratory diseases or having someone known to them that have suffered from such diseases. For instance, slightly more than half of the study group indicated that at least one of Asthma and pneumonia is well known to them. It has also been reported earlier that TB, asthma and pneumonia as the

leading causes of respiratory disease-related morbidity in Nigeria (Olufemi, Joshua, & Ololade , 2009).

This finding is not actually a surprise finding considering that large number of the study participants responded that the get information about lung diseases through social media network, community health workers and healthcare professionals. Yet another study in Nigeria (Adepoju, et al., 2022) found the major source of information about TB treatment facility was from a Health care worker (48.9%) followed by Radio (20.4%). However, it is possible that they were triggered to sought for information through personal experience or by having an encounter with people that suffer from the diseases.

On the other hand, despite the high awareness, only about half of the study group showed good knowledge about respiratory conditions among the population studied. This level of knowledge found in the present study is not a welcomed information in a state like Bayelsa State which is most times highly ravaged by environmental polluted with several risk factors of respiratory conditions present. It therefore implies that many are yet to comprehend that many diseases the suffer in the area could possibly be traced to their lack of knowledge of respiratory risk around them. The finding is this study is higher than 33% level of knowledge for Asthma reported in another study in Nigeria (Chinwendu-Amorha et al., 2022).

Knowledge about genetic factors as a risk factor for respiratory conditions was high, but low on air pollutants. High knowledge obtained from participants for genetic factor as a risk factor of respiratory conditions could probably be a resultant burden of the disease observed from a family relative victim which could invariable lead to raised awareness and knowledge on association between genetics and respiratory conditions. A study on Asthma in Nigeria which

included up 25% of people with family history of asthma the study and found high level of awareness (98%) among the study group (Chinwendu-Amorha et al., 2022). It may therefore mean that the disease burden is likely to trigger concerns among relatives and invariably increases their awareness and knowledge about the disease.

Knowledge of effects of for occupational exposure such as artisan refining of crude, construction work, and others to the risk of respiratory conditions was not high among the study group as only just about half of the study showed good Knowledge concerning occupational exposure/

The knowledge obtained concerning respiratory risk relating to secondhand smoking exposure were quite low. In line with this study findings, Adediji, Adeniran, and Dangana,(2021) also found very poor knowledge of passive smoking with only 17.8% showing good knowledge in an IIbadan South west Nigerian study. On the contrary, high knowledge about the effects of secondhand smoking has been reported in some other studies (Kaoje et al., 2021; Iloh & Collins, 2017).

The most common symptoms of lung diseases identified by the group were cough and fatigue. Majority were not able to identify chest pain and shortness of breath. While many of them reported having chest pain, only few showed awareness that chest pain can be a common symptom of lung disease and thus do not perceive the chest pain as something likely to be relating to exposure to air pollution.

On prevention and management of respiratory conditions, majority agreed that medical attention should be sought on early symptoms of respiratory conditions and getting vaccinated

but more than half of the group showed poor knowledge based on avoidance of air pollution and toxins.

4.2.2 Ambient levels of the air pollutants in Bayelsa State Compared with WHO and the Federal Ministry of Environment permissible levels and standards

In the index study, air pollutants were relatively high in the study area. Significant ambient air pollution found in this study include carbon monoxide, Ammonia , Also, NH, PM2.5 and PM10 were all above both the WHO limit and the FMOEnvir limit which showed poor and unhealthy air quality available in Bayelsa state. The Pm2.5 and PM10 exceeded the limit in Southern Ijaw and Yenagoa LGAs. Though the pollutants were lowered or getting very closer to the WHO limit on CO and NH, none of them were below the WHO permissible limit indicating that the study areas were very polluted.

The pneumonia and influenza were associated with increased $PM_{2.5}$ concentrations (Croft, et al., 2019). A study in Turkey (Arslam et al., 2022) reported that as a result of only local emission sources, pollutants such as PM_{10} and SO_2 values exceeded the WHO daily permissible limit by 68% and 79% respectively of which Asthma symptoms in children (0–14) were found to be positively correlated with both SO_2 (OR = 1.37; 95% Cl: 0.95–1.98) and PM_{10} concentrations (OR: = 3.41; 95% CI: 1.96–5.95).

Exposure to nitrogen dioxide is an established cause of cause respiratory illnesses especially in worsening the effects of pre-existing respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD) (Chauhan, & Johnston, 2003). ambient CO exposure and hospitalization risk from respiratory diseases has been established with increase in CO

concentration leading to hospitalizations for total respiratory diseases, asthma, COPD, and influenza-pneumonia (Song, et al., 2023)

Therefore most of the air ambient air quality available in Bayelsa State Nigeria are very likely to be poor, polluted and unhealthy.

4.2.3 Respiratory Condition Among the Study Group

The present study finding indicates that the average peak expiratory flow rate (PEFR) indicates was 451.6 ± 77.6 l/min for the study group. Significant difference was found in the mean PEFR between those with normal respiration (483.4 ± 79.3 l/min) and those whose have respiratory concerns with lowered PEFR (342.4 ± 76.2 l/min). The mean PEFR falls within the normal range of (400 - 600 L/min), but 18.5% had respiratory issues.

The mean value found in the index study is lower than PFR of 482·1 1/min (±83·3) for males (average age 34·9 years) and 385·6 1/min (±65·7) for females (average age 29·4 years) reported in an earlier study in Nigeria (Elebute, & Femi-Pearse, 1971). It is also lower than a pooled mean prevalence of respiratory disease was 43% (95% CI: 32–54%) (Moneke,et al., 2022).

The most common reported respiratory conditions found among the study group were wheezing, pneumonia Asthma, COPD and bronchitis. This finding in the present study is within reach of the commonest respiratory conditions is similar studies. For instance, both Asthma and in 17.5%) and pneumonia (in 15.3%), and all three were more common respiratory conditions reported in another Nigerian study (Dasalu et al., 2009). In Umoh, Otu, Okpa and Effa, (2013), pneumonia (24.9%) was also reported as among the commonest respiratory conditions along with tuberculosis. COPD has also been reported as among the major respiratory related diseased

in Ale et al. (2022) at 9.2%, of a study group which is closer to the present study range though slightly lower than 11% found in the present study.

However, reported Common symptoms respiratory symptoms encountered among the residents of Bayelsa State include having cough that lasted more than 4 weeks duration. sputum production, and chest pain. Similar to this finding, a study reported that the common prevalent ailments suffered by sawmill workers in Akure Nigeria within one month of a study were cough (52.0%), followed by phlegm production (49.0%) and chest pain (20.7%) (Olarewaju et al., 2024). Another study reported that approximately 54% of dye workers in Abeokuta, Nigeria have respiratory disorders (Thomas et al., 2023). The finding in this study is slightly lower than the reported respiratory conditions in another Bayelsa State Nigerian study (Ephraim-Emmanuel, 2023.

4.2.4. Association between air pollution exposure and the development of respiratory conditions among the residence of Bayelsa State.

Exposure to air pollutants such as SO_2, NO_2, CO, NH, $PM_{2.5}$ and PM_{10} showed significant association poor respiratory condition in the present study. An increase exposure of concentrations of PM_{10}, $PM_{2.5}$ and So_2 are established risk factors of Asthma and persistent wheezing especially among children (Cho et al., 2023; Holst et al., 2020). Extended exposure to some pollutants such as $PM_{2.5}$, PM_{10}, and NO_2 easily initiate reactions, relating to oxidative stress and inflammation, which can cause respiratory symptoms or aggravate pre-existing conditions like that are likely to cause COPD and asthma, particularly in individuals with high genetic risk and an unhealthy lifestyle (Wang et al., 2022). Such exposures could also give rise to chronic bronchitis (Ji et al., 2024). Unfortunately Respiratory issues such as COPD, Asthma,

bronchitis are common cause of respiratory preventable deaths and burden of disease attributable to air pollution exposure (European Environment Agency, 2023).

This study findings is therefore not a surprise finding considering that there were many reported cases of some respiratory diseases such as COPD, asthma, wheezing, pneumonia, bronchitis. and others in the study area. The finding is in line with reported rising respiratory conditions associated with ambient air pollutant exposures within many cities in the African continent, due to some levels of urbanizations (Glenn, Espira, Larson & Larson, 2022). Nigeria was ranked second in terms of PM2.5 exposure among countries in sub Saharan Africa and clear majority of the Nigerian population live in areas where PM2.5 levels are above the WHO permissible level (State of Global Air, 2020). In Bayelsa and likewise many cities in Nigeria, there exist constant sources of human-made air pollution such as vehicle emissions, fuel oils and natural gas to heat homes, by-products of manufacturing and power generation, particularly fueled power plants, and fumes from chemical production. The use of unclean fuel was found to be associated with higher levels of $PM_{2.5}$, and consequently to poor respiratory health of women and children (Aigbokhaode & Isara, 2021). Similarly a study in Norther Nigeria founds association between exposure to outdoor pollutants such as $PM_{2.5}$, and PM_{10} with poor respiratory conditions in the study population (Aliyu & Botai, 2018).

4.2.5 Socio demographic factors and Respiratory Condition Among the Study Group

Socio demographic factor associating with respiratory conditions in this study include age, gender, income and occupation. For age, the younger age group has lower risk compared to the elderly age. It therefore signifies that age differences exist for PEF, which is in line with earlier report (Ebomoyi & Iyawe, 2005). The risk was significantly higher among females (29.1%)

than males (12.9%) with approximately 2.8 folds odds. Similarly, respiratory disease symptoms have also been reported more among female subjects (Ephraim-Emmanuel, 2023),

Also significant was occupation. Odds were significantly lower among those doing white collar jobs, trading and students. Income was also found as a significant factor of respiratory conditions with greater odds against the lower income earners. In Lowe et al., 2018, low socio-economic status has been linked to respiratory diseases including pulmonary disease progression, while living below the relative poverty line has also been found to have association with the prevalence of chronic obstructive pulmonary disease (Lee et al., 2019).

CHAPTER FIVE

CONCLUSION AND RECCOMMENDATIONS

5.1 Conclusion

The study area (Bayelsa State) was found to be well polluted. Individuals who are residents in the area are exposed to high air pollutants and consequently at the risk for many respiratory conditions, including asthma, Pneumonia, chronic obstructive pulmonary disease (COPD). The ambient air quality level in Bayelsa State indicates that most of the air pollutants in the area exceeded the permissible limits and standards.

There exist high knowledge on some of the common respiratory symptoms yet the conditions were poorer in among residents especially in Bayelsa West compared to Bayelsa Central.

5.2 Recommendations

The followings are being recommended in this study:

1. Raising public awareness about air pollutants including the origin, mode or vehicle of transmission and their accompanying health hazards should be made a priority at all times through organized campaigns and public engagements, Increasing public awareness about the health risks of air pollution should be made crucial. Efforts to raise public awareness about the health risks of air pollution and the importance of

implementing clean air policies are critical in fostering a healthier respiratory environment.

2. Bayelsa residents who are more exposed and vulnerable to its harmful effects of air pollution either through workplace, residence or other ways should be well informed to embrace the recommended protective precautionary measures against hazards associating exposure to air pollutants.
3. Adequate measures such as intensified awareness and policy enforcements should be taken to facilitate translating awareness into meaningful action and behavioral change that restrict the extent of individuals' exposure to air pollutants, particularly among populations that are more susceptible to their adverse effect. This is mostly needed in Bayelsa West.
4. Studies targeting air pollution should work to draw attention to questions of ambient air pollution and health, especially as most cities are going more urbanized.
5. There should be holistic and adaptive approach to air quality management is Bayelsa West and other parts of Bayelsa experiencing air pollution
6. The Environmental agencies and other bodies in charge of regulatory frameworks against air pollution should be strengthened with clear targets,
7. The environmental air quality monitoring activities should be made robust monitoring, and followed with stringent enforcement mechanisms so the defaulter should be made liable.
8. Proper and comprehensive urban planning should be introduced and made to assume critical roles in shaping the spatial configuration of cities and communities with exerting

influence over, pollution dispersions, land utilization, and transportation infrastructure including mitigating traffic-related air pollution.

9. Other efficient less polluted and healthier transportation system should be made available in city and community road network planning to decongest the roads. these may include construction of different roads for mostly vehicles transporting health hazard equipment and substances
10. The creation of green spaces, such as parks, gardens, and streets adorned with trees, is a crucial element within urban planning approaches aimed at alleviating the respiratory impacts of air pollution. Therefore such greener techniques should be incorporated in town planning schemes in Bayelsa State and other states in Nigeria.
11. Enhancing inter-agency collaboration and cross-sectoral coordination can facilitate the development of integrated strategies that address the complex nature of air pollution. Therefore environmental protection agencies and other health agencies should be encourage to collaborate with synergy in information and assignments /
12. Tailoring interventions to the needs of vulnerable populations, ensuring equitable access to clean air should be introduced as a way of promoting social justice are fundamental principles that should underpin policy implementation.
13. Furthermore, fostering public engagement through effective communication and education is crucial in generating sustained support for cleaner air policies.

5.3 Contribution to Knowledge

The study contributed to the actual insight to knowledge and understanding of sources of air pollution that are mostly haboured within their environment and then the necessary protective

measures needed to navigate within such an environment in order to be free from poor respiratory conditions.

The study was able to establish the major air pollutants in the study area with clear identification of these pollutants which is the first step needed in improving respiratory conditions in the area. The present study succeeded in expanding the knowledge on the actual air pollutants that exceeded recommended permissible limits and standards, as well as identifying parts of Bayelsa where activities leading to such pollutions are rampant. Therefore this study could serve as a useful asset to policy making and implementations aimed at addressing air pollution in Bayelsa State.

5.4 Suggestions For Further Studies

This study leaves questions for future research. This study identified artisan refining of crude, gas flaring as part of the activities that exposes individual's resident in Bayelsa State to the air pollutants and consequently to the risk of respiratory conditions. However, the extent to which such activities contributed to air pollution in the study area was not accounted for in the index study. Hence future studies should address the core causes of air pollutants in Bayelsa, with attention given to the contributory effects of artisan refining of crude, and gas flaring activities air pollution in the area.

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APPENDICES

Appendix 1

Questionnaire on Knowledge of respiratory conditions among the respondents of Bayelsa State

Dear Respondent,

I am Dr. Christopher Peres Ekiyor, a PhD student in the department of Public Health, School of Health Technology, Federal University of Technology Owerri, Imo State with Registration number 20174144698. I am conducting a research study on Environmental Air Pollutants as Risk Factor in the Occurrence of Respiratory Conditions in Bayelsa State.

This is academic research and the findings are solely for academic purpose, your honest response to the below question will be highly appreciated.

Thanks for your time.

Dr. C. P. Ekiyor

Section A: Demographic Information

1. Age (Years): _____

2. How long have you lived in this community (Years): _____

3. Gender: [Male] [Female]

4. Occupation: [Fishing] [Farming] [White collar] [Trading] [Unemployed] [Student] [Mining] [Industry]

5. Educational Level: [Primary] [Secondary] [Tertiary] [Non-formal]

6. Location: [Specify the area within Bayelsa State]

7 Monthly Income (in Naira) : [Less than 30,000] , [30,000- 59000], [59,000 - 99,0000], [100,000- 149000], [150,000 and above]

_____

_____

Section B: General Awareness of respiratory conditions

7. Have you heard of lung diseases before this survey? [Yes] [No]

8. If yes, please specify the lung diseases you are aware of:

_____

_____

_____

_____

9. Do you have any respiratory condition that you are aware of? [Yes] [No]

10. If yes, what is the name of the condition? _____

11. Since when have you had the condition (Years)? _____

12. Have you ever attended any awareness programs or workshops related to lung diseases in Bayelsa State? [Yes] [No]

13. If yes, please specify the type of program(s) you attended:

_____

14. Where do you usually get information about lung diseases? (Select all that apply)

Television Radio Internet

Healthcare professionals (doctors, nurses, etc.) Community health workers

Friends and family Other (please specify): _____

Section C: Knowledge Assessment

15. Which of the following do you believe are causes or risk factors for respiratory conditions? (Select all that apply)

Smoking Air pollution Tuberculosis Genetic factors

Occupational exposure (e.g., miners, construction workers)

Secondhand smoke exposure Poor diet and nutrition

Other (please specify):

_____

_____

_____

16. Can you identify common symptoms of lung diseases? (Select all that apply)

Persistent cough Shortness of breath

Chest pain Coughing up blood Fatigue and weakness

Wheezing Fever No symptoms

Other (please specify):

_____

_____

17. How can lung diseases be prevented? (Select all that apply)

Quitting smoking Avoiding exposure to air pollution and toxins

Getting vaccinated (e.g., flu, pneumonia) Regular exercise and healthy lifestyle

Seeking early medical attention for respiratory symptoms

Other (please specify):

_____

_____

18. True or False: Lung diseases are only caused by smoking.

19. True or False: Pneumonia is a contagious disease.

20. True or False: Tuberculosis primarily affects the lungs.

21. True or False: Lung cancer is more common in smokers than in non-smokers.

22. Name any common respiratory symptoms /check-up observed within the last six month (multiple options allowed). [

No respiratory disease symptom], [Have cough that lasted for more than 4 weeks duration], [Sputum production seen], (had chest pain], [presence of fast breeding], had respiratory check-up within the last six month] Other (specify).....

23. Is there anything else you would like to share or any comments you have about lung diseases in Bayelsa State? ___

_____

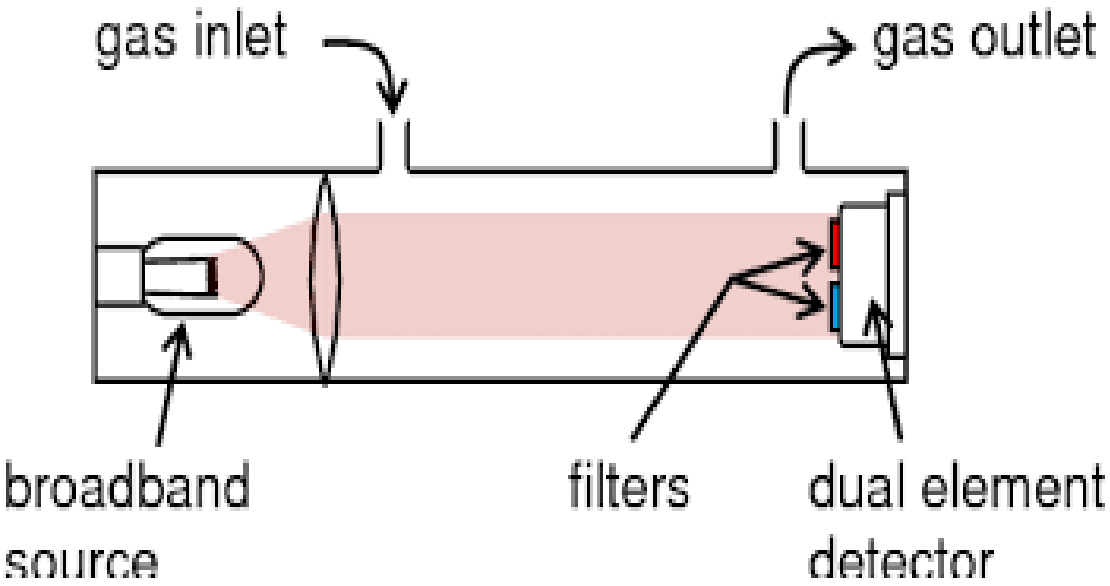
_____

Appendix 2

Passive SO_2 Sampler

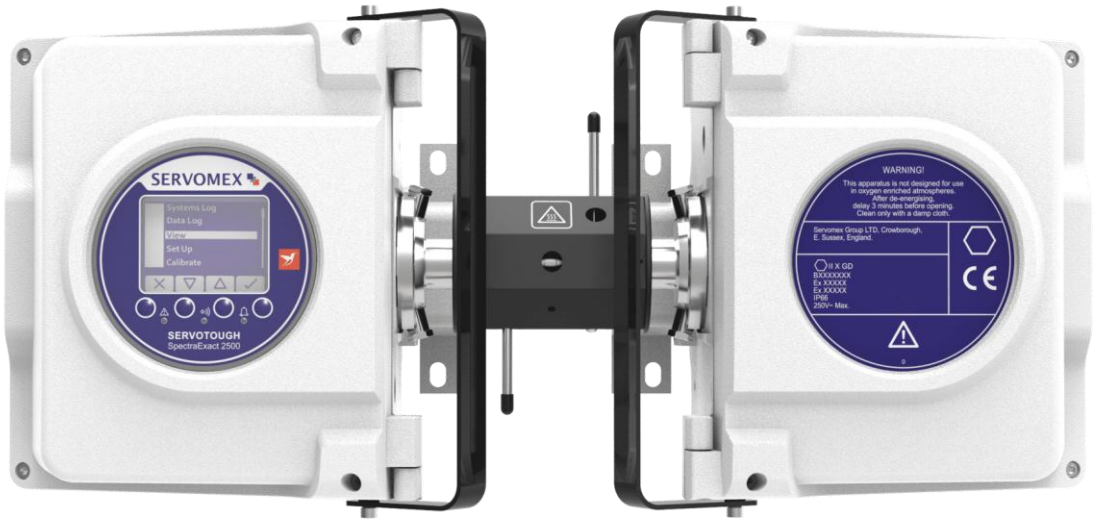
Appendix 3

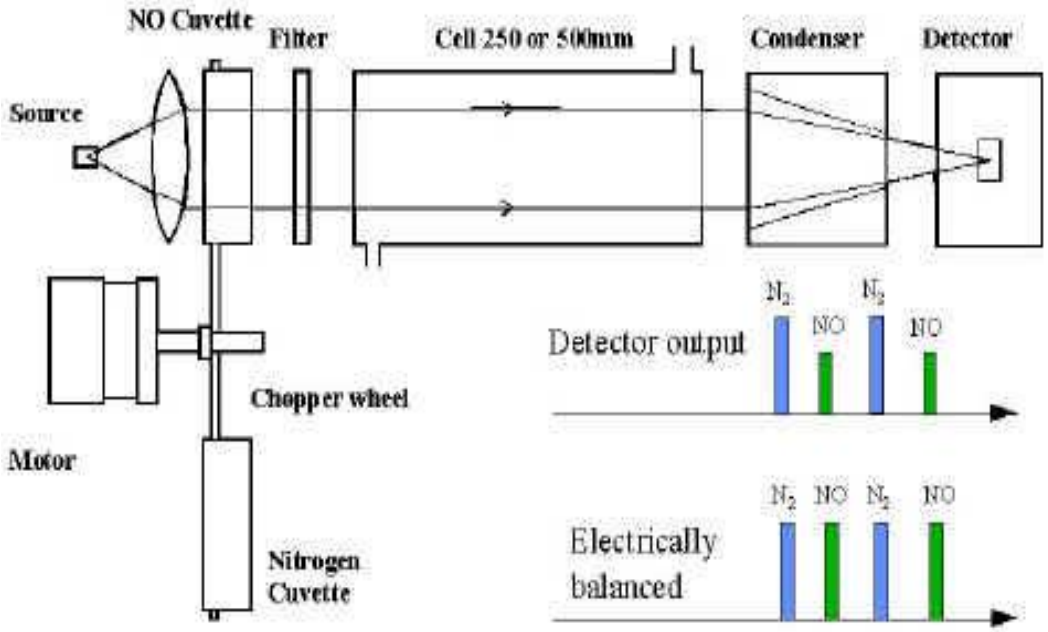
Non-dispersive infrared CO Analyzer



Appendix 4

Gas filter correlation NO_2 monitor



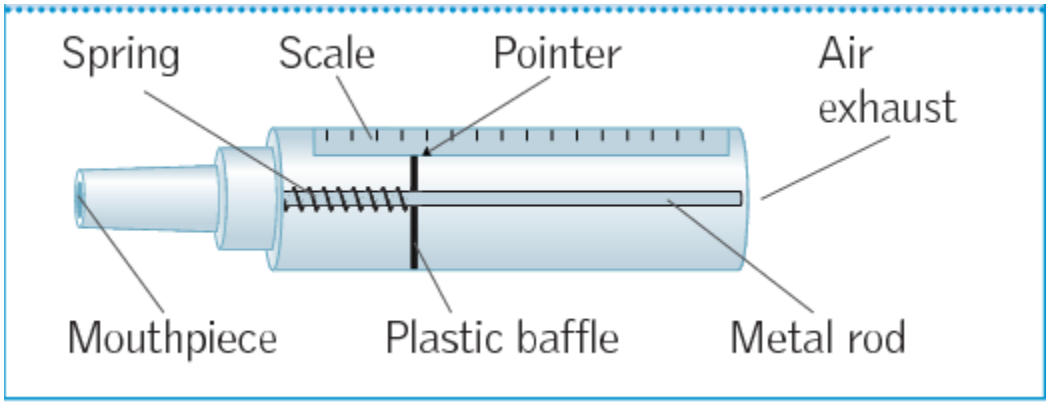


Appendix 5

High-volume PM Analyzer

Appendix 6

Peak expiratory flow meter



APPENDIX 7 WHO Recommended Air Quality Guideline (WHO, 2022)

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.

Pollutant	Averaging Time	2005 AQGs	2021 AQGs
$PM_{2.5}$, µg/m³	Annual	10	5
	24-hour[a]	25	15
PM_{10}, µg/m³	Annual	20	15
	24-hour[a]	50	45
O_3, µg/m³	Peak season[b]	-	60
	8-hour[a]	100	100
NO_2, µg/m³	Annual	40	10
	24-hour[a]	-	25
SO_2, µg/m³	24-hour[a]	20	40
CO, mg/m³	24-hour[a]	-	4

Appendix 8: Federal Ministry of Environment Ambient Air Quality Standard

AMBIENT AIR QUALITY STANDARDS FOR CRITERIA POLLUTAN
AND AIR TOXICS

S/N	Pollutants	Time Weighted Average	Concentration in Ambient Air
1.	Sulphur dioxide (SO_2)	Annual	80 µg/m³
		24 hours	120 µg/m³
		1hour	350 µg/m³
2.	Nitrogen dioxide (NO_2)	Annual	80 µg/m³
		24 hours	120 µg/m³
		1hour	200 µg/m³
3.	Carbon monoxide (CO)	8 hours	5.0 mg/m$_3$ 10.000[a]
		1 hour	10 mg/m³ 25,000[a]
4.	Particulate Matter (PM_{10})	Annual	60 µg/m³
		24 hours	150 µg/m³
5.	Particular Matter ($PM_{2.5}$)	Annual	20 µg/m³
		24 hours	40 µg/m³
6.	Ozone (O_3)	8 hours	100 µg/m³
		1 hour	180 µg/m³
7.	Lead (Pb)	Annual	1.0 µg/m³ 0.5
		24 hours	1.4 µg/m³
8.	Arsenic (As)	Annual	6,000 µg/m
9.	Nickel (Ni)	Annual	20,000 µg/m³
10.	Cadmium (Cd)	Annual	5,000 µg/m³
11.	Ammonia (NH_3)	Annual	0.2 mg/m³
		24 hours	0.6 mg/m³