ASSESSESSMENT OF NO_2 AND PM2.5 IN ETSAKO EAST USING SENTINEL-5P AND GOOGLE EARTH ENEGINE FROM 2019-2024

BY

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CERTIFICATION

This is to certify that this research titled **ASSESSMENT OF NO_2 AND $PM_{2.5}$ IN ESTAKO EAST, IN EDO STATE USING SENTINEL-5P AND GOOGLE EARTH ENGINE**", was carried out by "**Courage Omole ASEKOME**" and presented to the Department of Environmental Management and Toxicology, Faculty of Life Science, University of Benin, Benin City, in partial fulfillment of the requirements for the award of Bachelor of Science (B.Sc) in Environmental Management and Toxicology. It was conducted under suitable conditions, was carefully supervised and was subsequently approved as having met the requirements for the award of Bachelor of Science degree in Environmental Management and Toxicology.

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PROJECT SUPERVISOR

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PROF.A.A.ENUNEKU **DATE**

HEAD OF DEPARTMENT

DECLERATION

I "Courage Omole ASEKOME (MISS)", declare that "ASSESSMENT OF NO2 AND PM2.5 IN ESTAKO EAST LGA USING SENTINEL-5P AND GOOGLE EARTH ENGINE" is my work and that all sources that I have used or quoted have been acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other University.

DEDICATION

With a glad heart this project dedicated my aunt Dr. Miss Zuwairat Asekome for her care and support throughout my days in school.

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I give all the praise to The Almighty God for his constant love and his unending mercies and care.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This is carried out to assess the concentrations of Nitrogen dioxide (NO2) and Particulate matter ($PM_{2.5}$), in Etsako East Local Government Area. Secondary data collection method was employed for the assessment. Levels of Nitrogen dioxide (NO2) and Particulate matter ($PM_{2.5}$) were extracted biannually from Google Earth Engine using information from Sentinel-5-P satellite data (COPERNISCUS/5SP/NRT/L3_). A comparison of the levels of Nitrogen dioxide (NO2) and Particulate matter ($PM_{2.5}$) was done biannually from the year 2019 to the year 2024 in Etsako East LGA. Results showed that the annual mean concentrations of Nitrogen dioxide (NO2) ranged from 0.000048mol/m^2 to 0.000062mol/m^2, the highest and lowest concentrations were found in the first half of 2021, and the first half of 2022 respectively. Particulate matter ($PM_{2.5}$) ranged from -0.2341 to 0.4357. The highest and lowest concentrations were found in the first half of 2021, and the second half of 2022 respectively. This condition as an implication of irritating airways and exacerbating respiratory conditions on the residents. Government should play their role in policy making so as to enforce a cleaner production process by the cement factory located there. GIS applications should also be employed and used to foster air quality and check for any deviations.

CHAPTER ONE

INTRODUCTION

1.0.BACKGROUND OF STUDY

The assessment of NO_2 and $PM_{2.5}$ in Estako East using remote sensing necessitates comprehensive understanding of the pollutants' behaviour, sources, and influencing factors. $PM_{2.5}$, the fine particulate matter fraction, originates from various sources including combustion processes, industrial activities, and natural events like dust storms. In Europe, $PM_{2.5}$ constitutes a significant portion (40–80%) of PM_{10} mass concentration, highlighting its prevalence and potential impact (Eeftens *et al*., 2015). The high $PM_{2.5}$ levels in urban environments are often associated with vehicular emissions and industrial activities, whereas rural areas may see contributions from biomass burning and soil dust (Costa *et al*., 2014). NO_2 a gaseous pollutant, is primarily linked to traffic emissions and is a precursor to tropospheric ozone, impacting atmospheric chemistry and air quality (Pancholi *et al*., 2017). Both pollutants are well-documented for their adverse health effects. Short-term exposure to NO_2 has been shown to correlate with increased hospital admissions due to respiratory and cardiovascular issues, especially during colder months when pollutant dispersion is limited (Kendrick *et al*., 2015; Jeanjean *et al*., 2018). Similarly, chronic exposure to $PM_{2.5}$ is associated with long-term health risks, including reduced lung function and premature mortality (Costa *et al*., 2014). The spatial and temporal variability of NO_2 and $PM_{2.5}$ is influenced by meteorological conditions, seasonal changes, and local emission sources. For instance, temperature inversions during colder months can trap pollutants near the ground, exacerbating exposure levels (Jeanjean *et al*., 2018). In urban areas, diurnal variations in traffic patterns significantly affect NO_2 concentrations, with peaks during rush hours (Kendrick *et al*., 2015).

Particulate matter, particularly $PM_{2.5}$, is a critical pollutant due to its ability to penetrate deeply into the respiratory system and enter the bloodstream, causing severe health issues such as respiratory and cardiovascular diseases (Crouse *et al*., 2015). Studies in urban and semi-urban settings across sub-Saharan Africa have demonstrated that combustion processes, including those from vehicles and household cook stoves, contribute significantly to $PM_{2.5}$ emissions (Kendrick *et al*., 2015). In Etsako East, the reliance on biomass fuels for cooking is a major contributor to local air pollution levels. Such emissions are detrimental to local air quality and impact regional climate systems by altering the single scattering albedo, which influences the radiative balance of the atmosphere (Roberts *et al*., 2018).

Nitrogen dioxide is another pollutant of concern in Etsako East, primarily emitted from vehicle exhausts and industrial activities. Meteorological conditions and traffic density influence the spatial and seasonal variations of NO_2 (Eeftens *et al*., 2015). Exposure to NO_2 is strongly associated with adverse health effects, including increased risks of respiratory infections and exacerbation of asthma, particularly among vulnerable populations such as children and the elderly (Costa *et al*., 2014). In regions with limited infrastructure, such as Etsako East, the health burden of NO_2 exposure is amplified by the absence of adequate air quality regulations and mitigation strategies.

Biomass burning for agricultural purposes and waste disposal is another significant source of air pollution in Etsako East. This practice releases a variety of pollutants, including $PM_{2.5}$ and greenhouse gases, contributing to both local air quality degradation and global climate change. The heterogeneity of emissions from biomass burning poses challenges for accurately assessing their impact on air quality and climate (Xie *et al*., 2015). Furthermore, the widespread practice of indiscriminate waste disposal exacerbates the situation by producing emissions that include volatile organic compounds and particulate matter when waste is burned in open areas (Enemanya and Anthony, 2024).

The health impacts of poor air quality in Etsako East are significant. Long-term exposure to pollutants such as $PM_{2.5}$ and NO_2 is linked to increased mortality from cardiovascular and respiratory diseases (Crouse *et al*., 2015). Furthermore, emerging research suggests that air pollution exposure may also have mental health implications. For instance, Roberts *et al*. (2018) reported an association between childhood exposure to air pollution and an increased risk of developing depression in adolescence, highlighting the broader societal impacts of pollution.

Despite the evident risks, monitoring and mitigation efforts in Etsako East remain inadequate. Remote sensing offers a valuable tool for assessing air quality in regions with limited ground-based monitoring networks. Satellite data can provide insights into the spatial distribution and seasonal variations of pollutants such as NO_2 and $PM_{2.5}$, helping to identify hotspots and inform targeted interventions (Kendrick *et al*., 2015). However, the lack of localised ground-truthing data in Etsako East limits the accuracy of such approaches, underscoring the need for investment in air quality monitoring infrastructure.

Addressing air quality concerns in Etsako East requires a multifaceted approach that includes public education, policy interventions, and technological advancements. Reducing emissions from transportation and biomass burning through cleaner technologies and alternative fuels could significantly improve air quality. Moreover, integrating air quality considerations into urban planning and waste management strategies would help mitigate the impact of pollution on the environment and public health. The study of air pollution faces several limitations, particularly regarding pollutants' spatial extent and temporal patterns. Many studies do not prioritise spatial extent as a primary focus but treat it as an ancillary aspect of their findings. This has led to challenges in obtaining consistent and detailed spatial data. Researchers often contact authors for additional information or clarifications or use proxies based on their judgment to estimate spatial extent when direct information is unavailable. This lack of clarity introduces variability and reduces the reliability of analyses. Furthermore, less than half of the reviewed estimates included critical information such as wind speed and direction, essential for understanding pollutants' dispersion and distribution. This absence limits the ability to perform robust multivariate analyses, reducing the scope for comprehensive assessments (Crouse *et al.*, 2015).

The lack of sufficient studies focusing on particulate matter size fractions and definitions further compounds these challenges. Particulate matter (PM) is a key pollutant, with size fractions such as $PM_{2.5}$ and PM_{10} having varying sources, behaviours, and health implications. However, the limited number of studies examining these fractions in detail makes it difficult to assess their differential impacts comprehensively (Kendrick *et al.*, 2015). This knowledge gap is particularly evident in regions like Canada, where the long-term spatial and temporal patterns of pollutants such as NO_2 and $PM_{2.5}$ remain poorly understood. Fixed-site monitoring stations are primarily located in urban centers, leaving rural and remote areas underrepresented. Moreover, these stations often lack complete historical records, creating gaps in the long-term observational data needed for trend analysis and modelling (Eeftens *et al.*, 2015).

The reviewed studies also revealed inconsistencies in methodologies, pollutants measured, and site characteristics. The absence of standardised data collection and reporting protocols across different studies has resulted in significant variability. For instance, while some studies incorporate meteorological factors such as wind speed, others omit these variables, leading to incomplete analyses. Using simple categorical variables to describe site characteristics often overlooks important nuances, further limiting the robustness of findings. Such inconsistencies make it difficult to compare results across studies and hinder the ability to draw meaningful conclusions about the spatial extent and impacts of mobile source air pollution (Roberts *et al*., 2018).

Addressing these issues requires improved standardisation in air quality research methodologies, including uniform reporting of critical factors such as meteorology, site characteristics, and pollutant definitions. Additionally, expanding the network of monitoring stations to include rural and underrepresented areas would help fill data gaps and improve the understanding of spatial and temporal pollution patterns. Advanced technologies such as remote sensing and machine learning could further enhance data collection and analysis, providing more comprehensive insights into air pollution dynamics.

1.2 JUSTIFICATION OF STUDIES

Air pollution remains a critical environmental and public health challenge globally. In Nigeria, the issue is compounded by poor waste management practices, as highlighted by (Enemanya and Anthony 2024) in their study of Etsako West Local Government Area in Edo State. They reported that 80% of urban solid waste is disposed of in open spaces, leading to the contamination of water sources and outbreaks of diseases such as dysentery, cholera, and typhoid. This highlights the interplay between environmental mismanagement and public health and underscores the importance of effective waste disposal strategies.

The indiscriminate dumping of refuse contributes to waterborne diseases and air pollution. Decomposing waste in open dumps releases harmful gases, exacerbating local air quality issues. Additionally, such waste sites become breeding grounds for vectors like flies and rodents, increasing public health risks (Enemanya & Anthony, 2024). This points to the urgent need for public education on proper waste disposal and government-led initiatives for waste management.

A broader challenge in addressing air pollution lies in the insufficient data on pollutants such as nitrogen dioxide (NO_2) and delicate particulate matter ($PM_{2.5}$). Zhou and Levy (2006) highlighted that the scarcity of monitoring infrastructure, particularly in rural and underserved areas, hampers the ability to assess long-term trends and spatial patterns of these pollutants. Fixed-site stations are typically located in urban areas, leaving large swathes of the population unrepresented in air quality datasets. This lack of comprehensive data limits policymakers' ability to craft effective interventions to mitigate air pollution's impacts.

Further compounding the issue is the lack of consistency in methodologies and reporting across air pollution studies. Researchers often adopt varying techniques, focus on different pollutants, and consider diverse site characteristics. For instance, factors like wind speed and direction, critical for understanding pollutant dispersion, are inconsistently reported, making it difficult to draw meaningful comparisons between studies (Zhou & Levy, 2006). This inconsistency reduces the robustness of findings and undermines the development of effective, universally applicable policies.

Standardized guidelines for air pollution studies are urgently needed. These would ensure uniform data collection and reporting, allowing for more accurate comparisons and facilitating evidence-based policy decisions. For instance, harmonizing the measurement and reporting of NO_2 and $PM_{2.5}$ concentrations would enable policymakers to understand their spatial and temporal patterns better and design targeted interventions to protect public health.

Robust air quality monitoring and standardized methodologies are not just technical necessities but crucial for sustainable urban development and public health protection. Comprehensive data on air pollution enables policymakers to evaluate existing policies, identify gaps, and implement targeted interventions. Investments in monitoring infrastructure and research standardization are essential in mitigating the adverse effects of air pollution and ensuring a healthier environment.

1. 3 AIMS AND OBJECTIVES

This study aims to assess the variation of air pollutants NO_2 and $PM_{2.5}$ in Estako East Local Government Area in Edo State over five years.

1.4 THE SPECIFIC OBJECTIVES OF THE STUDY ARE;

1. To assess seasonal the variation of NO_2 from 2019 to 2024 in the study area
2. To assess seasonal the variation of $PM_{2.5}$ from 2019 to 2024 in in the study area
3. To compare the seasonal variation of NO_2 in in the study area
4. To compare the seasonal variation of $PM_{2.5}$ in in the study area.

CHAPTER TWO
LITERATURE REVIEW

2.1 AIR POLLUTION

Air pollution can be seen as the alterations of the condition of the indoors and outdoors by biological, chemical, and physical stressors that change the quality of the natural state of the air. Some types of air pollution stem from natural sources. However, as a result, most are caused by anthropogenic or human activities, which can impact every aspect of our lives (Akinnubi and Owombo, 2023). The atmosphere is a medium where various chemical and physical reactions involve aerosol, gases, and other atmospheric constituents. The atmosphere is changed by the indiscriminate contaminant release into the air (Tsuji *et al.*,2005).

Air pollution can also be defined as the release of biological materials, aerosols, and chemicals into the artificial or natural environment, which can cause anxiety and depression in humans and living organisms (Fagorite *et al.*, 2012).

The original state of the atmosphere can be degraded by human factors such as an increase in industrial and vehicular emissions, an increase in the growth of human populations, and rapid urbanization, which cause a spike in the level of gaseous and particulate pollutants in the atmosphere (Akande *et al.,* 2021).

2.2 AIR POLLUTANTS

Air pollutants are also regarded as any substances, chemicals, or elements that may compromise or impair human health, animals, vegetation, and any other material present. (Kampa and Castanas, 2018). Any agent, which could be physical, biological, or chemical, that degrades or changes the natural characteristics of the atmosphere is called an air pollutant (Penard-Morand and Annesi-Maesa$_{NO2}$004). The significant causes of air pollution include methane, Nitrogen dioxide, Particulate Matter ($PM_{1.0}$, $PM_{2.5}$. and PM_{10}), volatile organic compounds (VOCs), Carbon monoxide, and Sulfur dioxide (Lawal and Muhammed, 2022). These pollutants can be detrimental to urban air quality as regards to effect to human health and overall well-being (Sicard *et al.*, 2023)

Air pollutants are grouped into five based on their Sources, according to Osuji *et al.*

- Pollutants from burning of waste
- Pollutants from Mining and industrial activities
- Pollutants from vehicular road traffic and attrition forces which erode dust from the ground
- Biological occurring pollutants like pollen bacteria, spores, and pollens
- Pollutants from the combustion of fossilized fuel, e.g., natural gas, biomass burning, bush burning

According to Kampa and Castanas, in 2008, air pollutants were grouped into four classes based on their constituents.

- Particulate Matter
- Gaseous pollutants (CO, SO2, $_{NO2}$,Ozone, VOCs PCBs)
- Heavy Metals(cadmium, lead, mercury, arsenic)
- Persistent organic pollutants(PCBs and POPs)

2.3 CRITERIA AIR POLLUTANTS

There is a limitless number of air pollutants. Some are monitored closely because of a peculiar pollution source, such as vehicular emissions or industrial plants. Because they are known to cause detrimental effects on human health and the environment, these pollutants are called criteria or standard pollutants (Penard-Morand and Annesi-Maesona, 2004).

Pollutants suspected to be extremely harmful are detrimental to public health, the environment and ecosystems as a whole, as compared to primary and secondary pollutants. They are assigned under the Clean Air Act of 1971(Saxena and Sonwani, 2019). Below is the list of the criteria for standard air pollution.

- .Carbon monoxide(CO)
- Nitrogen oxide (NO_2)
- Sulfur dioxide (SO_2)
- Particulate Matter (PM)
- Lead(PB)
- Ozone

The Environmental Protection Agency (E.P.A), 2004, identified these pollutants as Criteria pollutants because it regulates and controls them by setting health-based or environmental-based guidelines for permissible levels; in other words, criteria air pollutants are pollutants that have a permissible and acceptable limit (Enuneku *et al.*, 2024).

Nationally, the Clean Air Act recognize two types of Ambient Air Quality Standards;

1. **PRIMARY STANDARDS;**

Protect sensitive health populations like children, the elderly, and asthmatics.

2. **SECONDARY STANDARD;**

It provides public welfare protection, such as protection against decreased visibility damage to infrastructure, vegetation, crops and animals. (Enuneku *et al.,* 2024)

SOURCES OF AIR POLLUTANTS

Air pollution refers to spots, activities or causer factors responsible for introducing pollutants into the atmosphere (Iwaugwu *et al.,* 2015). There are various sources of air pollution, such as, the burning of fossil fuels for cooking and heating, emissions from mining and industrial processes as well as deforestation, i.e. felling of trees (Kumar *et al.,* 2021)

Most developing countries still rely on private cars for transportation, which requires heavy use of fossil fuels, which leads to high vehicular emissions. The constituent of the vehicular emissions varies n composition depending on various factors, like the age of the vehicle, the type of fuel used because gases contain different concentrations of chemical compounds (Kumar *et al.,2021).*

Air pollution can be from either made-made or human source (natural) activities.

NON-HUMAN SOURCE: they are those types of pollution that stem from naturally occurring events. The burning of wooden biomass is a neutral renewable source of energy which emits CO: other harmful gaseous emissions like carbon monoxide (CO), nitrogen oxides (NOx), formaldehyde (HCHO) and particulate matter are emitted into the atmosphere aslso natural phenomena like duststorm, wildfire and oceanic activities (Enuneku *et* al.,2024).

MAN-MADE: Anthropogenic causes and emission levels of air pollutants vary across the globe depending on the level of advancement and technological development of a country, standard of living, cultural views of people in a given society and management policies and schemes put in place (Okedere *et al*., 2021).

They include fossil fuel combustion, transportation, power plant emissions or emissions from other industrial processes (Penard-Morand and Annesi-Macsano, 2004).

2.4 NITROGEN DIOXIDE AS AN AIR POLLUTANT

Nitrogen dioxide (NO_2) is a reddish-brown gas with a sharp, pungent odour. It is a major air pollutant and a key component of nitrogen oxides (NO_x), which play a role in atmospheric chemistry, including ozone formation and acid rain (WHO, 2021). NO_2 is highly reactive and contributes to the formation of secondary pollutants such as fine particulate matter ($PM_{2.5}$) and tropospheric ozone (Zhang *et al.*, 2019).

NO_2 is primarily formed through the oxidation of nitric oxide (NO) in the atmosphere. This reaction occurs in the presence of oxygen (O_2) or ozone (O_3) as follows:

$2NO+O_2 \rightarrow 2\,NO_2$

$NO+O_3 \quad \rightarrow NO_2+O_2$

The concentration of NO_2 in the atmosphere varies depending on location, time of day, and human activities. In urban areas, levels often range from **20–100 µg/m³**, with peak concentrations occurring during traffic congestion and industrial operations (WHO, 2021). In rural areas, NO_2 concentrations are typically lower, often below **10 µg/m³**, but can still be influenced by agricultural activities, biomass burning, and long-range transport of pollutants (Orellano *et al.*, 2020).

In cities, NO_2 primarily originates from combustion processes, including road traffic, which contributes up to **80%** of NO_2 emissions in urban environments (Brook *et al.*, 2010). Factories, power plants, and refineries release NO_2 through fossil fuel combustion (Burnett *et al.*, 2018).

Using coal, wood, and gas for heating and cooking generates significant NO_2 emissions into the air (Mills *et al.*, 2015). While NO_2 levels are generally lower in rural areas, they are influenced by Fertilizer application releasing ammonia (NH_3), which reacts with NO_2 to form secondary pollutants (Eze *et al.*, 2015). Wood and crop residue burning contribute to NO_2 emissions (Guarnieri and Balmes, 2014). Pollutants from urban and industrial areas can also travel long distances, affecting rural air quality (Zhang *et al.*, 2019).

2.4 PARTICULATE MATTER ($PM_{2.5}$) AS AN AIR POLLUTANT

$PM_{2.5}$ refers to fine particulate matter with an aerodynamic diameter of $_{2.5}$ micrometers or smaller. These particles are fine enough to penetrate deep into the respiratory system, reaching the alveoli of the lungs and even entering the bloodstream (Brook *et al.*, 2010). Due to their small size, $PM_{2.5}$ remains suspended in the air for long periods and can be transported over long distances, contributing to regional air pollution and affecting both urban and rural areas (Zhang *et al.*, 2019).

$PM_{2.5}$ particles originate primarily from direct emissions and secondary formation from atmospheric chemical reactions. Wildfires, volcanic eruptions, dust storms, and sea spray release $PM_{2.5}$ directly into the air naturally, while combustion processes from vehicles, industries, biomass burning, and household cooking using solid fuels contribute significantly (Burnett *et al.*, 2018).

Secondary $PM_{2.5}$ forms through atmospheric reactions of precursor gases such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), and volatile organic compounds (VOCs) (Mills *et al.*, 2015). These gases undergo oxidation and nucleation, producing fine particulate matter.

$PM_{2.5}$ concentrations vary based on location, season, and emission sources. The World Health Organization (WHO) guideline for annual $PM_{2.5}$ concentration is 5 µg/m^3**,** with a 24-hour mean limit of 15 µg/m^3 (WHO, 2021). However, many urban and industrial areas exceed these limits. $PM_{2.5}$ levels often exceed 30-100 µg/m^3 due to high traffic, industrial emissions, and construction activities (Guarnieri and Balmes, 2014). Concentrations can range from 5-50 µg/m^3**,** depending on biomass burning, agricultural activities, and regional transport of pollutants in rural areas (Li *et al.*, 2017).

In urban areas, $PM_{2.5}$ pollution is dominated by emissions from:

- **Vehicular emissions**: Diesel and gasoline combustion release carbonaceous particles, including black carbon (BC) and organic carbon (OC) (Zhao *et al.*, 2021).
- **Industrial processes**: Factories release metal oxides, sulfates, and nitrates, contributing to high urban $PM_{2.5}$ levels (Mills *et al.*, 2015).
- **Construction activities**: Dust from demolition, cement production, and land excavation adds to particulate pollution (Zhang *et al.*, 2019).
- **Waste burning**: Open burning of waste materials emits toxic $PM_{2.5}$, including dioxins and furans (WHO, 2021).

Rural $PM_{2.5}$ pollution is primarily from:

- **Biomass burning**: Wood, charcoal, and crop residue combustion for cooking and heating releases organic and black carbon particles (Brook *et al.*, 2010).

- **Agricultural emissions**: Fertilizer use and livestock farming produce ammonia (NH_3), which contributes to secondary $PM_{2.5}$ formation (Eze *et al.*, 2015).
- **Dust storms**: Wind-blown soil dust increases $PM_{2.5}$, particularly in arid and semi-arid regions (Burnett *et al.*, 2018).
- **Wildfires**: Large-scale forest and bushfires release significant amounts of $PM_{2.5}$, affecting air quality regionally (Pope *et al.*, 2009).

2.5 AIR QUALITY

Air quality has become a significant global concern due to its harmful effects on human health, ecosystems, and the climate (Amaechi *et al.*, 2024). Air quality can be seen as the concentration of pollutants in the air we inhale, which can arise from various sources, including natural events, industrial processes, agricultural processes, domestic activities, and transportation (WHO, 2024). Reduce air quality can lead to a spectrum of health issues, from acute discomforts like wheezing and coughing to chronic conditions like respiratory disorder, stroke, and heart attacks(Mackenzie, 2023)

The quality of air is usually measured using various metrics, including Nitrogen dioxide ($_{NO2}$), Particulate matter (PM), Sulfur dioxide (SO2), Carbon monoxide (CO2), and Ozone (O_3) (Nowek *et al.*, 2018). These pollutants can come from natural events like wildfires, volcanic eruptions, industrial processes, and vehicular emissions (Saxena and Srivastava, 2020; ClientEarth, 2021; Nowak *et al.*, 2018).

Nitrogen dioxide ($_{NO2}$) is released from agricultural processes, vehicle emissions, and industrial processes. It can cause respiratory issues and worsen existing conditions like Asthma (WHO, 2024; Wei *et al.*, 2023).

Particulate matter (PM) is among the most prevalent and harmful air pollutants. Particulate matter is tiny particles that can penetrate the respiratory tract and cling to the lungs to cause respiratory problems. PM can be emitted from different sources, including natural phenomena like volcanic eruptions, wildfires, vehicular exhaust, and industrial processes (Taylor, 2019; WHO, 2024).

Governments and organizations worldwide have collaborated and implemented various measures to mitigate air pollution through sustainable and cleaner energy sources, placing limits on emissions from vehicles and industrial processes, and developing public transport systems (WHO, 2024). However, individuals can also take bold steps to improve air quality. This can be achieved through afforestation, reduction in reliance on fossil fuel, consumption of less energy-intensive products, and use of public transportation (WHO, 2024).

2.6 AIR QUALITY IN RURAL AND URBAN AREA.

Rural emissions are considered one of the major contributors to globally, which is well known to cause serious adverse health effects in humans. Agricultural activities such as bush burning, ploughing, harrowing, cultivating, threshing, harvesting, and sowing are connected to the emission of airborne pollutants, typically particulate matter. Agricultural burning is seen as a cost-effective system for clearing and preparing the field for the growing seasons emits different air pollutants, especially Nitrogen dioxide (NO_2) and Particulate matter (PM), as well as other airborne pollutants(Borghi., *et al*., 2023).

Urban areas, on the other hand, are of significant concern as a result of the high level of pollutants from sources such as industries, power generation, construction, burning of wood, and vehicle emissions (clarity, 2023; Jonathan and Blake, 2023). Particulate matter (PM) and Nitrogen dioxide (NO_2) are the most prevalent pollutants, which have adverse effects on human health, causing respiratory diseases, cardiovascular issues, and even mortality (Hoffman, 2019; Ncas, 2023).

Urban areas often face the challenges of reduced air quality, with over 80% of people living in urban areas globally exposed to air quality higher than the recommended level by the World Health Organization (WHO) (Jonathan and Blake, 2023; Clarity, 2023). The issue of poor air quality is usually severe in low-income cities, where 98% of cities with over 100 000 residents do not meet the WHO air quality guidelines, compared to 56% in high-income countries (Jonathan and Blake, 2023)

Several innovative measures have been developed, including buffer zones (green spaces), urban gardens, wind tunnels, and low-emission zones to combat air pollution in urban areas (Jonathan, 2023). The above approaches aim to improve air quality, mitigate environmental degradation, and protect public health, especially in low-income areas that tend to have higher pollution levels and fewer buffer zones (Clarity, 2023).

Policies on urban development should integrate urban growth with greenness, ensuring adequate space protection of green spaces and access to greenery for a sustainable quality of life (Clarity, 2023). This approach can help reduce air pollution and promote a healthier environment for urban residents.

2.7 AIR POLLUTION IN ESTAKO EAST

Estako East Local Government Area is a rural area in Edo state. However, is characterized by industrial and agricultural processes, which are potent sources of pollution. The area is known for the industrial mining of limestone and the production of cement; the area is also known for the production of crops like maize and yam cassava and also for engaging in fishing. These activities carried out in this area can release Nitrogen dioxide (NO_2), Particulate Matter (PM), and other volatile organic compounds into the air, which is detrimental to the environment as well as the human lives inhabiting that area (EPA, 2020)

Air pollution is a significant concern, particularly in the three main towns, Okpella, Okugbe, and Agenegbode. The primary sources of pollution in these regions include industrial processes(mining of limestone and the production of cement), transportation, agricultural processes, high reliance on biomass as a source of cooking fuel, and natural events such as Wildfires (Borghi *et al.,*2023; Zhang *et al.*, 2019; Jain *et al.*,2021)

Exposure to air pollutants can cause adverse health impacts on vulnerable populations in this area, like the elderly, pregnant women, children, and even people with pre-existing health medical problems. Expose to Nitrogen dioxide (NO_2) and Particulate Matter (PM) causes cancer, respiratory difficulties, chronic Asthma, and cardiovascular diseases, as well as significant environmental impacts like acid rain deposition, which can damage properties and crops due to the release of sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) (Manisalidis *et al,* 2020;)

2.8 SENTINEL BASED AIR QUALITY MONITORING

Satellite-based air quality monitoring has revolutionized our understanding and analysis of atmospheric pollution on a large scale (Kuttippurath & Patel, 2025). Satellites equipped with specialized instruments provide a broad perspective, measuring concentrations of various pollutants such as nitrogen dioxide (NO_2), particulate matter ($PM_{2.5}$), carbon monoxide (CO), sulfur dioxide (SO_2), and ozone (O_3) (Mahmud *et al.*, 2023). This information is crucial for understanding air quality patterns, identifying pollution hotspots, and assessing the impact of air pollution on human health and the environment. Several satellite missions contribute to this effort, each with unique capabilities (Omrani *et al.*, 2020). A prominent example is Sentinel-5P, operated by the European Space Agency (ESA). Its TROPOMI (Tropospheric Monitoring Instrument) sensor provides high-resolution measurements of trace gases, including NO_2, CO, SO_2, and methane (CH4), making its data widely used for air quality studies due to its accuracy, spatial resolution, and frequent observations. Other important systems include MODIS (Moderate Resolution Imaging Spectroradiometer) on NASA's Terra and Aqua satellites, which measures aerosol optical depth (AOD) related to $PM_{2.5}$, and OMI (Ozone Monitoring Instrument) on NASA's Aura satellite, which monitors ozone levels (Zhang *et al.*, 2021).

Sentinel-5P, a polar-orbiting satellite, offers daily global coverage of atmospheric composition (Shetty *et al.*, 2024). Its TROPOMI instrument measures pollutants with high accuracy and a spatial resolution of approximately 3.5 x 5.5 km for NO_2, enabling detailed mapping of pollution hotspots and tracking pollution plumes. The free availability of Sentinel-5P data further enhances its value for air quality research and applications.

Focusing on its application in Etsako East LGA, Edo State, Sentinel-5P offers numerous advantages for seasonal assessments of NO_2 and $PM_{2.5}$. Its wide spatial coverage allows for a synoptic view of the entire LGA, including remote areas. Frequent observations enable monitoring of seasonal variations and changes in pollution levels over time (Orimoogunje *et al.*, 2015). The objective and consistent data from satellites avoids the limitations of potentially sparse or biased ground-based networks. For large areas like Etsako East LGA, satellite monitoring can be more cost-effective than establishing and maintaining a dense ground-based network

(Njambi, 2023). Finally, the free accessibility of Sentinel-5P data makes it available to a broad range of users (Cedeno & Brovelli, 2023).

However, satellite-based monitoring also has limitations (Prudente *et al.*, 2020). Cloud cover can obstruct observations, creating data gaps, especially during the rainy season. While Sentinel-5P's spatial resolution is relatively high, it may not capture highly localized pollution sources. The instrument measures pollutants in the atmospheric column, not at ground level, which can be a limitation in assessing human exposure (Khan *et al.*, 2018). Retrieving accurate NO_2 and $PM_{2.5}$ concentrations requires careful atmospheric correction and validation, which can be challenging. Finally, identifying specific pollution sources requires additional information (Shi *et al.*, 2024), like traffic data and industrial emissions (Mahmud *et al.*, 2023), which may not be readily available.

The European Space Agency (ESA) offers researchers worldwide the opportunity to study gaseous pollutants using advanced satellite image analysis techniques. Specifically, the Sentinel-5P satellite, with its Tropospheric Monitoring Instrument (TROPOMI), enables the development of current environmental scenarios applicable to air quality and human health assessments (Bodah *et al.*, 2022). This study analyzed NO_2 and CO gas concentrations using Sentinel-5P TROPOMI satellite images collected during 2019. The research focused on Passo Fundo, a city in the northern region of Rio Grande do Sul, Southern Brazil, from 2020 to early 2021, and applied environmental valuation methods to assess air quality pollution. Employing the Contingent Valuation Method (CVM), the study queried 514 Passo Fundo residents about their Willingness to Pay (WTP) for cleaner air. Results showed that NO_2 had the highest concentration at 7.88e+15 Column mol/cm2, while CO reached 9.43e+33 Column mol/cm2. The WTP survey revealed an average value of R$1,517,478.24 and a median value of R$599,390.00 when extrapolated to all households in the city. Based on these findings, the study suggests the implementation of public policies that would allow for the annual collection of similar amounts to mitigate the harmful effects of pollutants like NO_2 and CO currently present in Passo Fundo's air.

Research by Faisal and Jaelani (2023) investigated the relationship between COVID-19 related social restrictions, human mobility, and nitrogen dioxide (NO_2) concentrations in Jakarta, Indonesia. The increasing number of COVID-19 cases in Jakarta prompted the government to implement social restriction policies, which in turn limited people's mobility, particularly the use of motor vehicles. This study analyzed the impact of these restrictions on NO_2 levels, using Sentinel-5P satellite data processed through Google Earth Engine. The research spatially and temporally analyzed NO_2 changes and human mobility patterns (residential and workplace) using Google mobility data from January 2020 to December 2021. A moderate to strong correlation ($R = 0.426$–0.736, $p < 0.05$) was found between NO_2 concentrations derived from Sentinel-5P and those measured by ground-based air quality monitoring stations. Significant NO_2 decreases were observed during the initial Large-Scale Social Restriction (PSBB) period (April-May 2020) and the Implementation of Restrictions on Social Activities (PPKM) policy (July-August 2021), coinciding with periods of very low and low mobility in both residential and workplace categories. Specifically, NO_2 decreased by −11.381 µmol/m2 during the PSBB and -23.195 µmol/m2 during the PPKM. The largest increase in NO_2 (1 µmol/m2) occurred between May and June 2021, affecting an area of 641.571 km2, while no such increase was observed from November to December 2020. Interestingly, the study identified anomalies where NO_2levels decreased even when human mobility was very high, suggesting that factors beyond mobility, such as precipitation, also play a role in influencing $_{NO2}$ concentrations.

Amiri *et al.* (2023) investigated the impact of the COVID-19 pandemic and subsequent lockdown on air quality in Ahvaz, Iran. Following the first reported COVID-19 case in Iran on February 25, 2020, the government implemented lockdown measures. This study utilized Sentinel-5P images and the Google Earth Engine (GEE) platform to analyze concentrations of CO, NO_2, SO_2, and HCHO during the pandemic period (May 10 to June 1, 2021) and compared them to the same period in 2019 (pre-pandemic).

The research also considered the influence of meteorological parameters, specifically wind speed and precipitation, on pollutant concentrations in both periods. The analysis revealed significant decreases in pollutant concentrations during the pandemic: NO_2 decreased by 13.7%, CO by 6.1%, SO_2 by 28%, and HCHO by 9.5%. Statistical analysis showed no significant difference in wind speed or precipitation between the pandemic and pre-pandemic periods, thus discounting their influence on the observed pollutant changes. The study concluded that the COVID-19 pandemic and associated lockdown measures, including traffic restrictions and business closures, were the primary drivers for the significant reduction in air pollutant concentrations observed in Ahvaz.

2.9 HEALTH EFFECTS OF NO_2 AND $PM_{2.5}$

The effects of air pollution refer to the direct physiological and biochemical changes that occur in the human body due to exposure to pollutants like nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$). These pollutants trigger immediate and measurable alterations in respiratory, cardiovascular, and neurological health. The health effect of

NO_2 and $PM_{2.5}$ have been broadly studied. The exposure to Nitrogen dioxide (NO_2) has been linked to respiratory diseases, bronchitis in children who are asthmatic and reduction in pulmonary function (Ji *et al*, 2022). Based on cardiovascular impacts and high mortality, NO_2 is one of the US EPA's criteria for air pollutants recommended at a lower levels by WHO air quality guidelines (Ji *et al.*, 2022). Nitrogen dioxide (NO_2) has been widely recognized for its harmful effects on human health. Prolonged exposure is linked to numerous respiratory and cardiovascular problems. NO_2 irritates the airways, leading to coughing, wheezing, and shortness of breath, and exacerbating pre-existing respiratory conditions such as asthma and chronic bronchitis (Fecht *et al.*, 2016). Evidence also points to its role in increasingsusceptibility to respiratory infections due to its ability to impair immune defence mechanisms (Fenech and Aquilina, 2020).

Cardiovascular impacts of NO_2 exposure include increased heart rate, elevated blood pressure, and heightened cardiovascular mortality. Studies have highlighted a significant relationship between long-term NO_2 exposure and an increased risk of ischemic heart disease and other cardiovascular conditions (Crouse *et al.*, 2017). Neurological effects, including headaches, dizziness, and impaired cognitive function, have also been linked to NO_2 exposure. Recent findings suggest that high levels of NO_2 might contribute to neuroinflammation and mental decline over time (Roberts *et al.*, 2018). Furthermore, emerging evidence points to a potential increase in the risk of lung cancer associated with NO_2 exposure, emphasizing the pollutant's carcinogenic potential (Fenech and Aquilina, 2020). Particulate Matter ($PM_{2.5}$) is even more harmful due to its ability to penetrate deep into the respiratory system. $PM_{2.5}$ has been shown to trigger respiratory problems, including coughing, wheezing, and difficulty breathing. Long-term exposure is a known contributor to the development of chronic respiratory diseases such as asthma and chronic obstructive pulmonary disease (Song *et al.*, 2014).

The cardiovascular implications of $PM_{2.5}$ are profound, with studies indicating its role in increasing heart rate, elevating blood pressure, and contributing to cardiovascular events like heart attacks and strokes (Kloog *et al.*, 2012). $PM_{2.5}$ exposure is also strongly associated with premature death from cardiovascular and respiratory causes (Chen *et al.*, 2016). In terms of neurological health, $PM_{2.5}$ has been implicated in cognitive decline and the development of neurodegenerative diseases such as Alzheimer's and Parkinson's. Its ability to induce systemic inflammation, including neuroinflammation, is a key mechanism underlying these effects (Roberts *et al.*, 2018). $PM_{2.5}$ also has a significant impact on maternal and infant health, with associations noted between high exposure levels and adverse birth outcomes, including premature birth, low birth weight, and infant mortality. Additionally, prolonged exposure to $PM_{2.5}$ increases the risk of lung cancer and exacerbates the progression of existing cancers (Song *et al.*, 2014).

2.10 IMPACT OF AIR POLLUTION; A THREAT TO SUSTAINABLE DEVELOPMENT, ENVIRONMENTAL JUSTICE AND HUMAN WELL-BEING

Air pollution is one of the top priority environmental menaces and it is among the important challenges faced by the modern world .it is responsible for climate change due to high release of harmful gases resulting in greenhouse effects, acid rain and the depletion of the protective ozone layer in the atmosphere (Khallaf, 2011) . Air pollution even though is a global problem that threatens overall human well-being, is greatly connected with environmental injustice (Marthiarasan and Nuls, 2021)

According to E.P.A, Environmental injustice is the exposure of the environment to danger with air inclusive. The impact of air pollution extends beyond its immediate physiological effects, encompassing broader societal, environmental, and economic consequences. For example air pollution damage agricultural crops and reduced productivity, further exacerbating the problem of food scarcity. It also leads to increase in healthcare cost due to high level of respiratory disease (wikipidia) . Air pollution tamper with the health justice of vulnerable populations such as children, elderly, also low income communities who are close to the source of pollution carry the heavier burden of the impact of air pollution.

It influences public health at a global population level, contributes to increased healthcare burdens, affects economic productivity, and exacerbates ecological degradation. Numerous studies have confirmed the link between exposure to NO_2 and $PM_{2.5}$ and increased morbidity and mortality rates (Sangkham *et al.*, 2024; Ma *et al.*, 2024). These pollutants, primarily emitted from vehicle exhaust and industrial activities, deeply penetrate the respiratory system, leading to widespread health problems (Shetty *et al.*, 2023). Vulnerable populations, such as children, older adults, and individuals with pre-existing respiratory or cardiovascular conditions, face heightened risks (Tran *et al.*, 2023). Children, in particular, are more susceptible due to their developing lungs, while elderly individuals experience exacerbated chronic illnesses due to pollution exposure.

Air pollution also has significant economic implications. Increased hospital admissions due to respiratory and cardiovascular illnesses place a burden on healthcare systems, leading to higher medical costs and loss of productivity. Studies suggest that regions with high levels of NO_2 and $PM_{2.5}$ experience increased absenteeism from work and school due to pollution-related illnesses, reducing overall economic output (Kelly and Fussell, 2015). Additionally, long-term exposure to these pollutants increases the incidence of chronic diseases, further straining public health infrastructure and resources (Krittanawong *et al.*, 2023).

From an environmental perspective, NO_2 and $PM_{2.5}$ contribute to atmospheric degradation and climate change. NO_2 is a precursor to ground-level ozone, which exacerbates air quality issues and leads to smog formation. $PM_{2.5}$, due to its fine particulate nature, can persist in the atmosphere, contributing to poor visibility and environmental pollution. In regions like Etsako East LGA, analyzing NO_2 and $PM_{2.5}$ concentrations using remote sensing data provides critical insights into seasonal variations in pollution levels and their associated impacts (Vîrghileanu *et al.*, 2020).

Public health interventions are crucial in mitigating the impacts of air pollution. Strategies such as air quality monitoring, implementation of stricter emission regulations, and public awareness campaigns can help reduce exposure risks (Liu *et al.*, 2016). Seasonal assessments of NO_2 and $PM_{2.5}$ levels enable policymakers to implement targeted interventions, such as issuing air quality alerts during high-pollution periods and promoting cleaner transportation and industrial practices (Pan *et al.*, 2018). Additionally, integrating satellite-based air quality monitoring with epidemiological studies enhances understanding of pollution-health interactions, leading to informed policy decisions (Khreis *et al.*, 2023). While the effects of air pollution manifest as direct physiological health consequences, its impacts extend to broader societal, economic, and environmental dimensions. Addressing air pollution requires a comprehensive approach involving scientific research, policy development, and community engagement to mitigate its immediate and long-term effects.

2.10 FACTORS INFLUENCING NO_2 AND $PM_{2.5}$ CONCENTRATION IN ETSAKO EAST

AGRICULTURE

Agriculture is a major contributor to both $PM_{2.5}$ and NO_2 levels in Etsako East. Crop residue burning, a common practice to clear fields for subsequent planting, releases fine particulate matter and nitrogen oxides into the atmosphere. This activity is particularly prevalent during the dry season, exacerbating air pollution (Ede and Edokpa, 2015). Livestock farming also contributes significantly. Manure decomposition emits ammonia and nitrous oxide, which can react with other atmospheric gases to form $PM_{2.5}$ and NO_2 (Basu and Sharma, 2021). Fertilizer application further adds to the burden, as nitrogen-based fertilizers like urea release nitrous oxide when metabolized by soil microbes, especially during the rainy season (Davidson and Kanter, 2014).

Biomass Burning

Biomass burning is a widespread activity in Etsako East, influencing levels of both pollutants. Households in rural areas heavily depend on firewood and charcoal for cooking, producing large quantities of fine particulate matter and nitrogen oxides

(Arku *et al*., 2018). Agricultural waste burning, particularly of rice and maize residues, also contributes to elevated pollution levels. Wildfires, although less frequent, can further exacerbate the issue by releasing both $PM_{2.5}$ and NO_2 into the atmosphere (Adepoju *et al*., 2020).

Industrial Activities

Industrial activities in and around Etsako East, though limited, influence air quality. Mining and quarrying operations release fine particulate matter through material handling and dust generation (Ede and Edokpa, 2015). Cement production, common in nearby urban areas, emits nitrogen oxides and particulate matter, which can be transported into rural regions by prevailing winds. Small-scale industries and the use of diesel generators for power also contribute to localized emissions of $PM_{2.5}$ and NO_2 (World Health Organization, 2018).

Natural Sources

Natural factors play a role in the air quality of Etsako East. Unpaved roads generate dust, a major source of $PM_{2.5}$, especially during the dry Harmattan season (Adepoju *et al*., 2020). Soil microbial processes, such as nitrification and denitrification, release nitrous oxide, contributing to NO_2 levels. These emissions are particularly pronounced during the rainy season when soil moisture and temperature favor microbial activity (Davidson and Kanter, 2014). Occasionally, wildfires and windblown dust from surrounding areas add to the pollution load (Ede and Edokpa, 2015).

Transportation

Transportation activities influence both $PM_{2.5}$ and NO_2 levels in Etsako East. Agricultural vehicles, such as tractors and irrigation pumps, emit nitrogen oxides and fine particulate matter due to diesel combustion. Motorcycles, the primary mode of transportation in many rural areas, add to the emissions, particularly in settlements near major roads. Poor road conditions further exacerbate the issue by generating dust and increasing localized $PM_{2.5}$ pollution (World Health Organization, 2018).

Fossil Fuel Combustion

Fossil fuel combustion for residential heating, lighting, and cooking is a significant contributor to $PM_{2.5}$ and NO_2 levels. In Etsako East, households commonly use kerosene lamps and firewood, both of which release particulate matter and nitrogen oxides during combustion. Diesel-powered generators, frequently used during electricity shortages, further increase emissions (Arku *et al.*, 2018).

Seasonal Variations and Interactions

The levels of $PM_{2.5}$ and NO_2 in Etsako East vary seasonally. During the dry Harmattan season, dust from unpaved roads and biomass burning leads to sharp increases in $PM_{2.5}$ levels (Adepoju *et al.*, 2020). The dry conditions also enhance the spread of wildfires, which release both pollutants. Conversely, the rainy season sees a rise in soil-derived NO_2 emissions due to intensified microbial activity facilitated by wet and warm conditions (Davidson and Kanter, 2014). While transportation and industrial activities contribute year-round, their impact is often amplified by seasonal factors.

In Etsako East, the interplay of agricultural activities, biomass burning, transportation, natural sources, and fossil fuel combustion drives the levels of $PM_{2.5}$ and NO_2. Mitigating these emissions requires targeted interventions, such as promoting cleaner cooking methods, improving road infrastructure, encouraging sustainable agricultural practices, and reducing reliance on fossil fuels. By addressing these factors, air quality and health outcomes can be significantly improved in rural regions like Etsako East.

2.12 EXISTING DATA AND RESEARCH GAPS.

Studies on air pollution in Nigeria, including Edo State, often focus on specific local government areas or broader regional trends. For example, research conducted in Etsako West Local Government Area of Edo State used a questionnaire to collect data from 50 respondents and highlighted issues related to indiscriminate refuse dumping and potential health hazards. While the study's data was analyzed using sample percentages, it lacked detailed quantitative findings on pollution levels (Imimole, 2014). This highlights a gap in concrete data on air pollutant concentrations, which are necessary for thorough analysis and informed policymaking. In another study examining migration patterns within Edo State, researchers documented the number of migrants from various Local Government Areas, such as Egor with 19 migrants and Akoko-Edo with 3. While this data does not directly address air pollution, it could provide insight into socio-economic factors that influence population exposure to pollution and the potential strain on infrastructure in urban areas (Imimole, 2014). Such migration-related data is essential for understanding how settlement patterns may interact with air quality. Research conducted in Kano State, Northwestern Nigeria, provides insights into seasonal variations in atmospheric pollutants such as NO_2, CO, and aerosols between 2019 and 2023. This study revealed that seasonal changes significantly influence the dispersal and concentration of air pollutants (Amaechi *et al.*, 2024). While not directly conducted in Edo State, these findings underscore the importance of incorporating meteorological factors into air quality studies in similar Nigerian regions.

A literature review on the spatial extent of air pollution from mobile sources emphasized that many studies do not explicitly explore spatial distribution but provide this information as secondary findings. This review highlighted that pollution from traffic and other mobile sources, such as construction equipment and ports, is a significant contributor to urban air pollution. Factors like pollutant type, emission rates, and meteorological conditions were identified as critical in determining spatial distribution (Bigazzi & Rouleau, 2017). The review suggests that expanding research to include diverse pollution sources beyond traffic, particularly in Edo State, is necessary to understand the full scope of air pollution.

Existing studies highlight several gaps in air pollution research in Edo State. Limited spatial coverage restricts understanding of how pollution impacts rural and urban areas. For instance, while the study in Etsako West highlights health risks from refuse dumping, it does not provide specific pollutant data. Additionally, there is minimal focus on identifying key pollutants and their sources. Longitudinal studies are also lacking, which are essential for tracking changes in air quality and health impacts over time. Furthermore, there is insufficient research on green infrastructure's role in mitigating air pollution and improving public health in Edo State (Kumar *et al.*, 2019).

Continuous air quality monitoring and stricter enforcement of regulations on industrial emissions are recommended. Investments in renewable energy sources, such as solar and wind, could also help reduce air pollution and promote sustainability. Studies suggest that integrating green infrastructure into urban planning can mitigate air pollution while providing health and environmental benefits (Kumar *et al.*, 2019).

CHAPTER THREE

METHODOLOGY

3.1 RESEARCH DESIGN

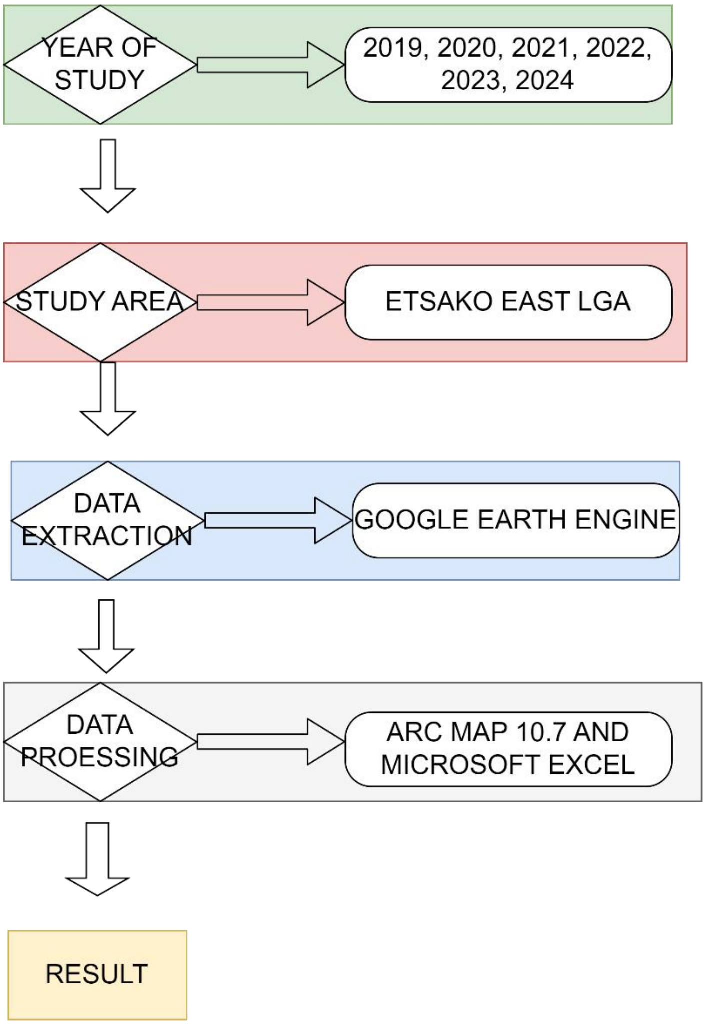


Figure3.1: Flowchart of methodology

3.1 STUDY AREA DESCRIPTION

Estako East is located in the Northern part of Edo State in Nigeria and is predominantly characterized by semi-urban and rural area. The study focuses on both towns within Estako East which includes the headquarters Agenebode and other major towns such as Okpella,, Okpekpe, Uzanu, and Weppa-Wanno. The study focuses bon the major towns with the local government including, Opkella, Aghenebode, Weppa-Wanno, known for their economics and urban development. Over the years, developments in urbanization, industrialization, and Agriculture in Estako East have led to concerns about the air quality, while this is insufficient baseline information on the current pollution levels, the growing agriculture practices, traffic congestion, industrial emissions, and other human activities are known contributors to pollution. These activities, if left unchecked, are likely to exacerbate air quality issues, possibly affecting the environment as well as public health.

Geographic characteristics: Estako East is suited at latitude 7^0 45’N and longitude 6^0 45’E within a tropical savanna biome, characterize dominated by a mix of secondary forests and savanna grasslands as well as riparian vegetation along the River Niger and other watercourses, high humidity, and distinct wet and dry seasons. The topography of the region features gentle slopes, with some areas having flat plains near the Niger River. The river Nigeria, is one of the major waterways forming part of the region boundary with Kogi state, influencing local climate and hydrology.

Economic Activities: Etsako East Local Government Area is primarily rural, with its economy deeply rooted in agriculture. The region's fertile soil and favorable climate create a conducive environment for farming, which is the backbone of the local economy. Farmers in the area engage in the cultivation of staple crops such as yams, cassava, maize, and rice. These crops serve as both subsistence food for the local population and commercial products traded in nearby markets, supporting livelihoods and fostering economic sustainability. Fishing is another vital economic activity in Etsako East, largely facilitated by the River Niger, which flows through the region. This waterway provides an abundant supply of fish, making it a critical biological resource for the local fishing industry. The fish are consumed domestically and sold in local markets, contributing significantly to the income of households involved in this sector. The presence of this river also supports ancillary industries such as fish drying and preservation. In addition to agriculture and fishing, Etsako East has seen the growth of formal sector industries, which are expanding the economic base of the region. Manufacturing firms have established a presence in the area, engaging in the production of cement for the construction of buildings. These industries not only generate revenue but also create employment opportunities for the local population. Commerce also plays an essential role in the economy of Etsako East. The local government area hosts vibrant markets and trading centers that serve as hubs for buying and selling goods. These markets facilitate the distribution of agricultural produce, fish, and manufactured goods, linking rural producers with urban consumers and fostering economic interconnectivity. The services sector is a growing contributor to the local economy, with businesses providing essential services such as transportation, hospitality, and financial services. These services support the agricultural and industrial activities in the region by ensuring the efficient movement of goods and people, accommodating visitors, and facilitating financial transactions. Etsako East’s economy reflects a mix of traditional and modern activities, with agriculture forming the foundation and emerging formal sectors adding diversity. This economic structure underscores the region’s potential for sustainable development, driven by its natural resources and an industrious population

Environmental challenges: Despite the economic significance, towns in Etsako East is however still face with diverse environmental challenges, including air pollution, deforestation, waste management issues such as inadequate sanitation infrastructure as well as inadequate healthcare facilities and infrastructure. Rapid growth in agriculture and industrialization has exacerbate these challenges resulting in strain on the biological resources and causing the degradation of the rural environment.

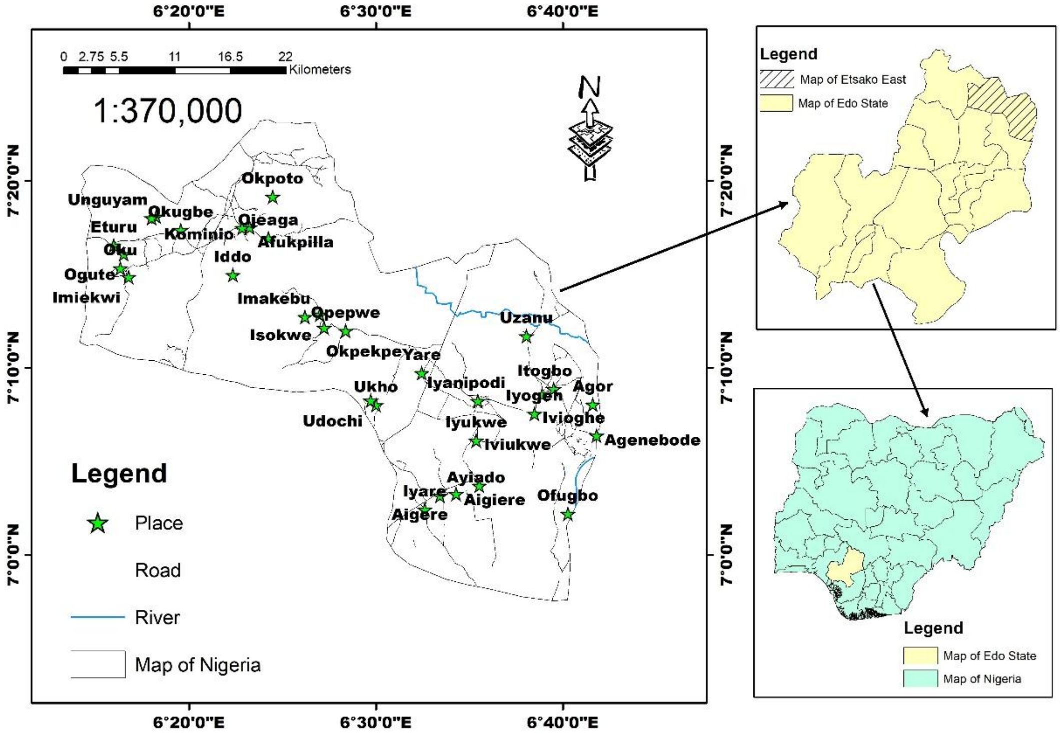


FIGURE 3.2: The location map of the study area

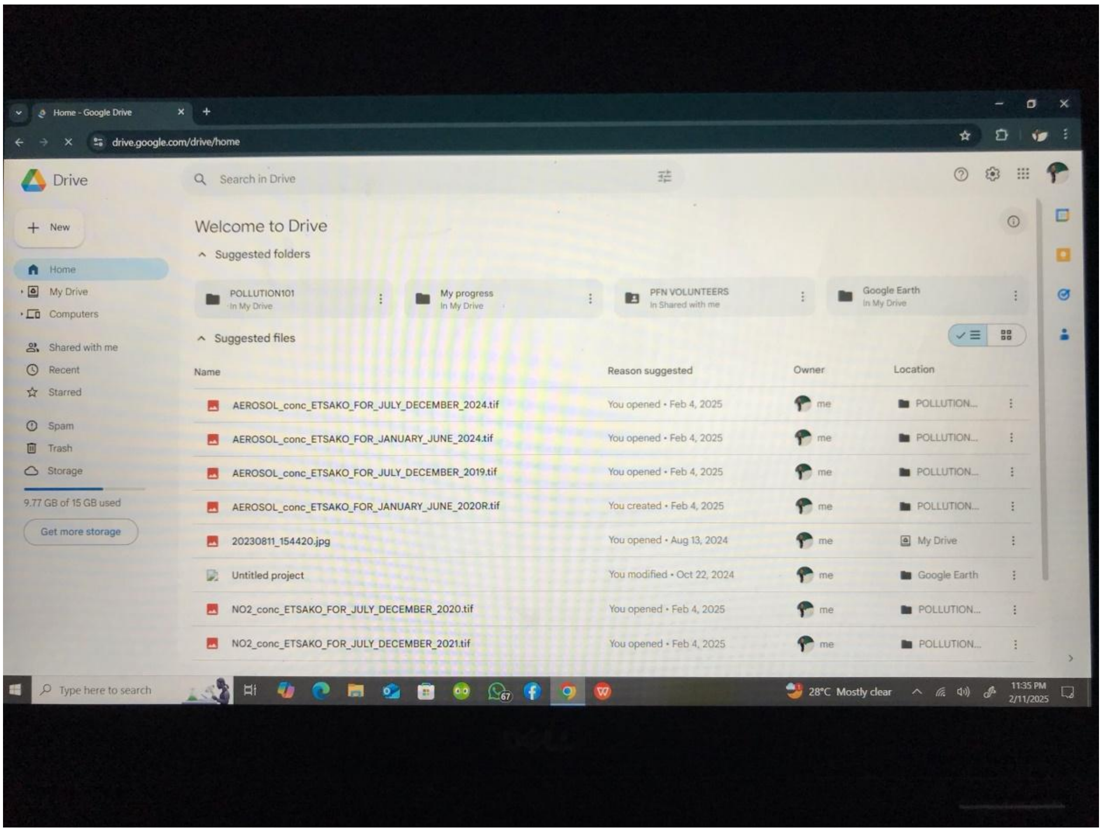
DATA COLLECTION

The type of data utililize for this research is the RASTER data , secondary data . A Secodary data which is an information gotten directly from the google carth engine as its source . Google Earth Engine (GEE) is a virtual platform made to allow remote sening easily allow remote sensing user easily achieve vast data analyses without increasing the request for local computing resources (Enda el 2007) This study relied only on than RASTER data gotten from Google Earth Engine using information from satellite data (COPERNISCUS/SSP/NRTVL3), Google Earth Engine combines multipetabyte catalog of satellite imagery and spatial datasets with planetary-scale analysis capabilities (Earth engine data catalogs). The Sentinel 5P houses the passive grating imaging spectrometer called the TROPOspheric Monitoring (TROPOMI) The TROPOMI has a sampling size of 7x7km^2and a swath width of 2.600km. It has a 4 spectrometer cach electronically split in two bands (2 in UV, 2 is VIS, 2 NIR, 2 in SWIR) with a radiometric accuracy of 1.6% (SWIR) to 19% (UV) of the measured earth spectral reflectance which makes it ideal for monitoring air quality and pollution Data gotten from Sentinel-5P and those from field measurements have been seen to display substantial relations which affirms the value of data gotten from the Sentinel 5P repository

METHOD OF DATA COLLECTION

The study area Etsako East was created using the EARTH ENGINE CODE EDITOR tool within the GOOGLE EARTH ENGINE, which works with scripts and codes Script for the atmospheric pollutants (Nitrogen dioxide (NO_2) and Particulate Matter were written in JavaScript (COPERNICUS/S5P/NRTI/L3_AER_AI), with the filter date for year of study. The geometry of the study location is highlighted, saved and Run and a RASTER imagery file of the study area is generated after the task has been completed with a projection and an extent in the Geographic Tagged Image File Format (.tiff) and downloaded from Google drive and save into a folder.

The Raster data was collected biannually for each pollutant with the filter date ('2019-07-31','2019-12-31')



Welcome to Drive

Suggested folders

POLLUTION101 In My Drive
My progress In My Drive
PFN VOLUNTEERS In Shared with me
Google Earth In My Drive

Suggested files

Name	Reason suggested	Owner	Location
AEROSOL_conc_ETSAKO_FOR_JULY_DECEMBER_2024.tif	You opened • Feb 4, 2025	me	POLLUTION...
AEROSOL_conc_ETSAKO_FOR_JANUARY_JUNE_2024.tif	You opened • Feb 4, 2025	me	POLLUTION...
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AEROSOL_conc_ETSAKO_FOR_JANUARY_JUNE_2020R.tif	You created • Feb 4, 2025	me	POLLUTION...
20230811_154420.jpg	You opened • Aug 13, 2024	me	My Drive
Untitled project	You modified • Oct 22, 2024	me	Google Earth
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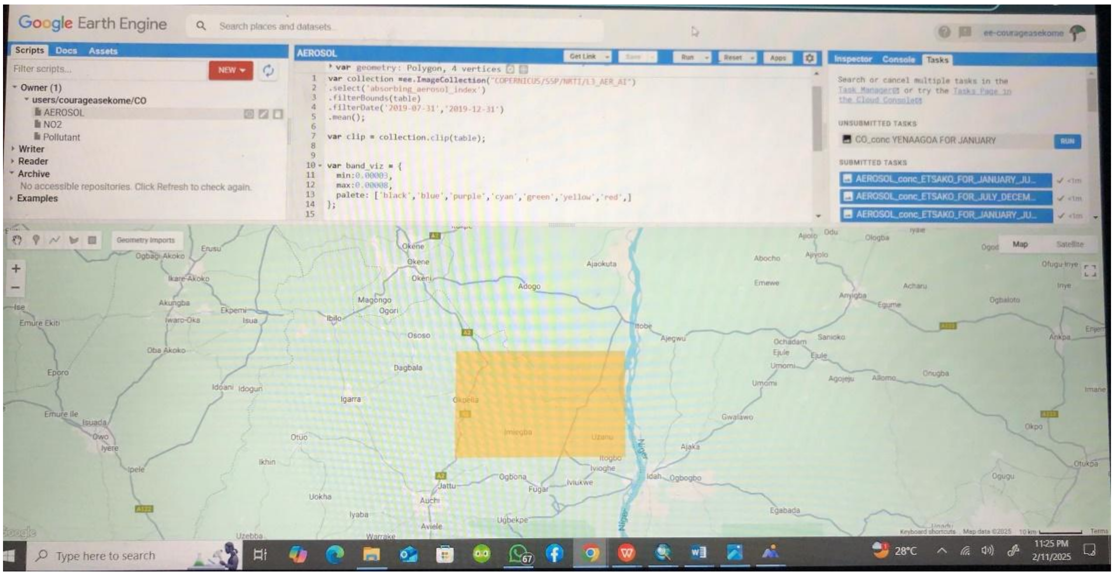

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▸ var geometry: Polygon, 4 vertices
var collection =ee.ImageCollection("COPERNICUS/S5P/NRTI/L3_AER_AI")
.select('absorbing_aerosol_index')
.filterBounds(table)
.filterDate('2019-07-31','2019-12-31')
.mean();

var clip = collection.clip(table);


var band_viz = {
  min:0.00003,
  max:0.00008,
  palete: ['black','blue','purple','cyan','green','yellow','red',]
};
```

No accessible repositories. Click Refresh to check again.

Search or cancel multiple tasks in the Task Manager or try the Tasks Page in the Cloud Console

UNSUBMITTED TASKS

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SUBMITTED TASKS

AEROSOL_conc_ETSAKO_FOR_JANUARY_JU... ✓ <1m
AEROSOL_conc_ETSAKO_FOR_JULY_DECEM... ✓ <1m
AEROSOL_conc_ETSAKO_FOR_JANUARY_JU... ✓ <1m

Figure 3.3: An image depicting the (a) GOOGLE EARTH ENGINE interphase (b) EARTH ENGINE CODE EDITOR scripts (c) geometry of study area (d) completed RUN tasks

Figure 3.4: An image depicting the Google drive interphase and the downloaded Geo.TIFF image.

METHOD OF ANALYSIS

The raster imagery generated from the GOOGLE EARTH ENGINE is downloaded from the GOOGLE DRIVE and imported in ArcMap where the raster image is projected to the Universal Transverse Mercator (UTM) as before a data can be a GIS data, it must be projected .The study area Etsako East extracted from the raster image was used to analyze and monitor the spatial distribution of Nitrogen dioxide (NO_2) and Particulate Matter ($PM_{2.5}$) from the year 2019 to the year 2024. The analyzed data was classified into three (5) classes: 'Very low', 'Low' and 'Moderate' 'High' and 'Very high' and visualized into the different classes.

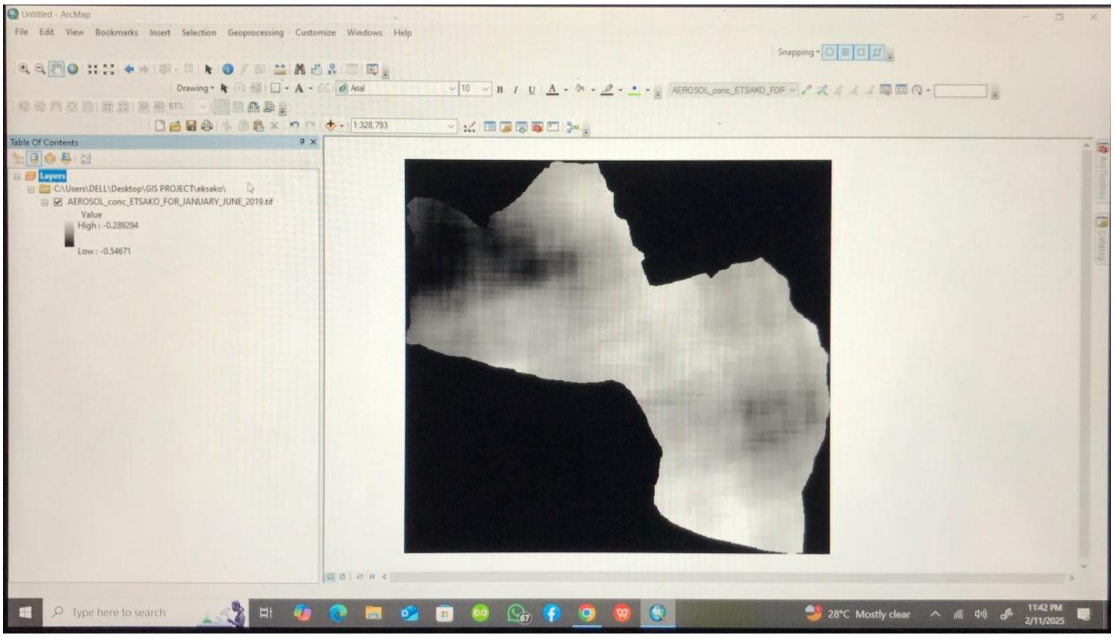

Figure 3.5: an image depicting the raster imagery generated from Google Earth engine and imported into Arc Map interphase

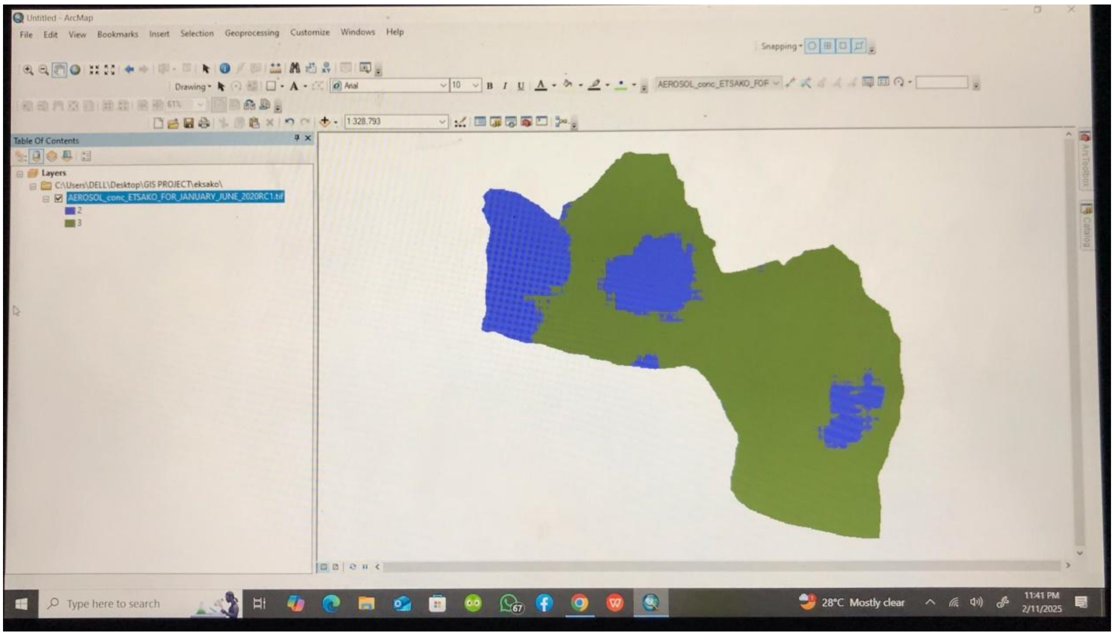

Table Of Contents

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🟦 2
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Figure 4.6: An image depicting a classified and visualized raster data

DATA SOURCES: Sentinel-5p TROPOMI

The European Space Agency (ESA), launched Sentinel-5p satellite mission, features the TROPOHERIC Monitoring Instrument, which measures various atmospheric pollutants, including Nitrogen dioxide (NO_2), with high resolution and coverage. Level-2 data products from Sentinel-5p were employed to obtain NO_2 concentration at a spatial resolution. The study spanned six years from 2019 to 2024, capturing data. Data collection is acquired biannually, enabling the examination of seasonal variations, long-term trends, and the impact of temporal factors on air quality dynamics within rural towns of Etsako East

DATA ANALYSIS

Satellite imagery from the sentinel-5P TROPOMI sensor, acquired through the Google Earth engine was utilized to analyze $PM_{2.5}$ and NO_2 concentration in Etsako East of the towns of the area of study over the period from 2019 to 2024 January to June: July to December segmented to biannual intervals. Preprocessing involved filtering the imagery to isolate pollutant concentrations around the towns in Etsako East, resulting in six-month temporal composite images for each pollutant. These composite images were then imported into ArcGIS 10.7 for spatial analysis, including spatial mapping hotspot analysis, and spatial correlation assessment to identify spatial patterns and relationships. Temporal analysis techniques, such as trend analysis and seasonal variation assessment, were assigned to discern temporal fluctuations in the pollutant concentrations. Interpretations and visualization of analysis of the outcome were conducted using thematic mapping and temporal animation to communicate findings effectively. Quality assurance measures were implemented to ensure the analysis results' reliability and accuracy, including data validations and verifications against ground-truth measurements or existing air quality monitoring data. Trend analysis and seasonal variation assessment were applied to design temporal trends and fluctuations in pollutant concentrations

CHAPTER FOUR

4.0: RESULTS PRESENTATION

Nitrogen dioxide (NO_2) and Particulate Matter ($PM_{2.5}$) concentrations were collected between the years of 2019 to 2024. A six-month average of January to June and July to December, were used for comparison within a Season in a year. The results are presented below

4.1 ATMOSPHERIC CONCENTRATIONS OF NITROGEN DIOXIDE (NO_2) AND PARTICULATE MATTER ($PM_{2.5}$) FOR THE YEAR 2019

In the year 2019, as shown in Figure4.1., Figure 4.2, and presented in Table 4.1., and Nitrogen covered an area of "40638" (ha) in DEEP GREEN, indicating areas with 'Very low' concentrations, and a percentage concentration of 33.1, LIGHT GREEN covering an area of "79401(ha)" and a percentage of 64.5% indicating areas with Low concentration, YELLOW indicating areas with 'Moderate' concentrations covering 3071(ha) and a percentage concentration of 2.49%. In the last season within the year from July to December, Nitrogen covered an area of "112498" (ha) in DEEP GREEN, indicating areas with 'Very low' concentrations, and a percentage concentration of 91.37%, LIGHT GREEN covered an area of "10619" (ha) indicating area with low concentration with a percentage of 8.6%.

$PM_{2.5}$, in the first half season from January to June, covered an area of 10428(ha) with a percentage concentration of 8.47%, with LIGHT GREEN indicating areas with Low concentration. YELLOW indicating areas with 'Moderate' concentrations, and a percentage concentration of 91.53.%.In the last season within the year from July to December, $PM_{2.5}$ covered an area of 123112 (ha) with a percentage concentration of 100% DEEP GREEN indicating the area having Very low concentration

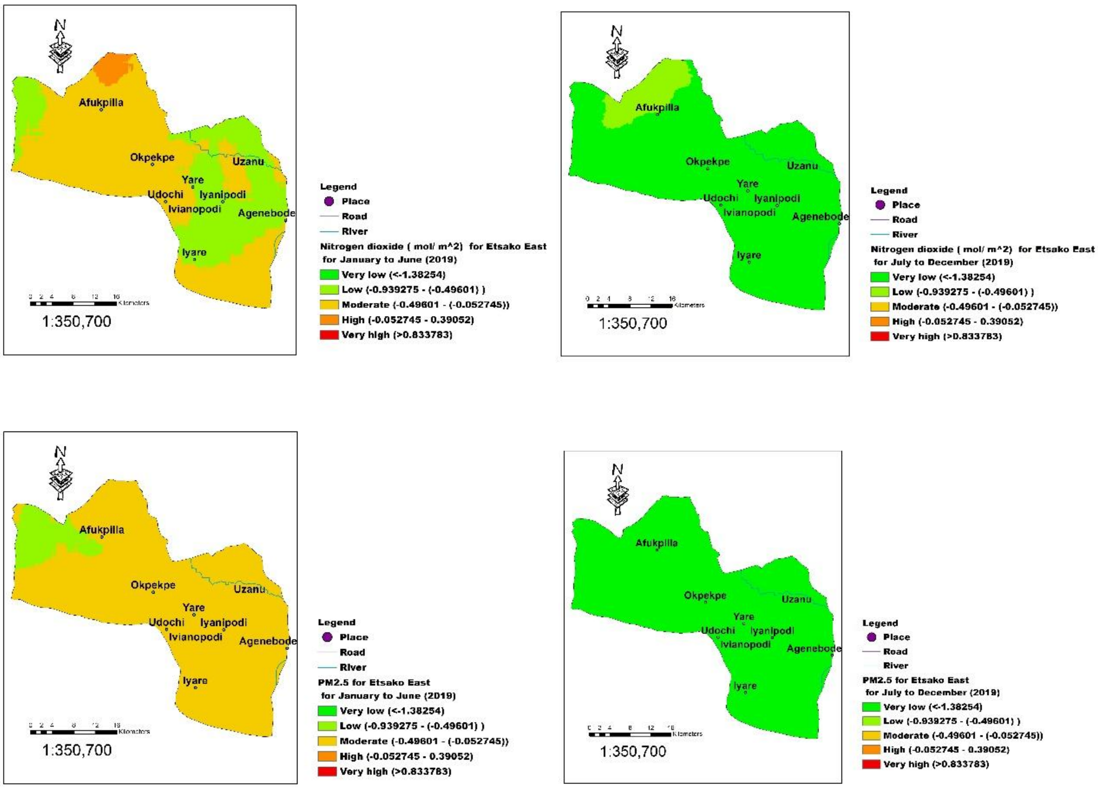


Figure 4.1: Spatial distribution of NO_2 and $PM_{2.5}$ concentration for January to June and July to December 2019.

Table 4.1: Area and percentage (%) cover NO_2 and $PM_{2.5}$ concentration for the year 2019'

NO_2 JANUARY TO JUNE 2019

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
1	Very Low	O.000044-0.000052	40638	33.01
2	Low	0.000052-0.00006	79401	64.5
3	Moderate	0.00006-0.000871	3071	2.49

NO_2 JULY TO DECEMBER 2019

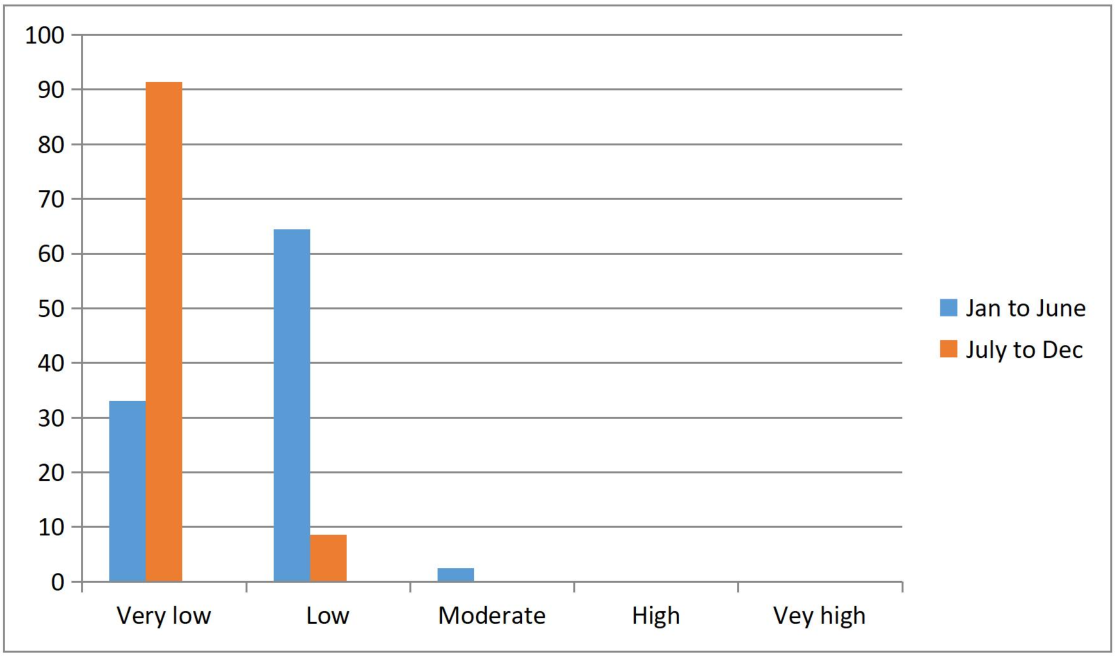
S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
1	Very Low	O.000044-0.000052	112498	91.37
2	Low	0.000052-0.00006	10619	8.63

$PM_{2.5}$ JANUARY TO JUNE 2019

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
2	Low	-0.939275--049601	10428	8.47
3	Moderate	0.0463-0.0528	112684	91.53

$PM_{2.5}$ JULY TO DECEMBER 2019

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA(ha)	PERCENTAGE
1	Very Low	-1.38254-0.939275	123112	100



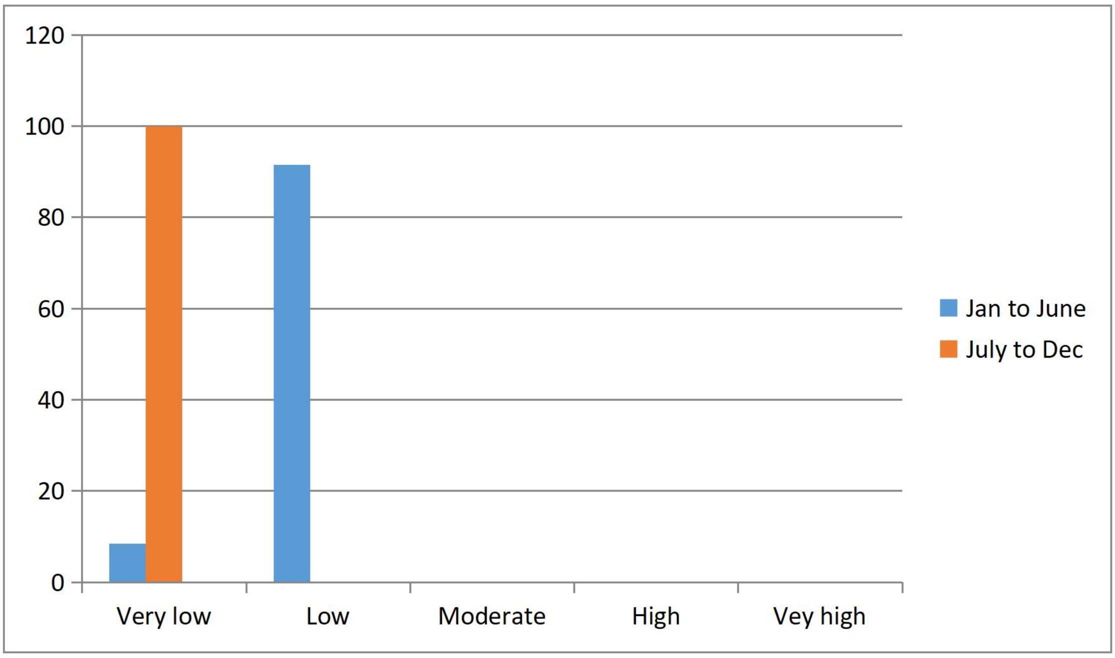


Figure 4.2: Graph showing percentage area coverage of (a) NO_2 from January to June, and July to December, 2019 (b) $PM_{2.5}$ from January to June, and July to December, 2019.

4.2: ATMOSPHERIC CONCENTRATIONS OF NITROGEN DIOXIDE (NO_2) AND PARTICULATE MATTER ($PM_{2.5}$) FOR THE YEAR 2020

In the year 2020, as shown in Figure4.3., Figure 4.4, and presented in Table 4.3., Nitrogen covered an area of "11382" (ha) in DEEP GREEN indicating areas with 'Very low' concentrations, and a percentage concentration of 92.09%, LIGHT GREEN covering an area of "8993(ha)" and a percentage of 7.3% indicating areas with Low concentration, YELLOW indicating areas with 'Moderate' concentrations covering 745(ha) and a percentage concentration of 0.61%. In the last season within the year from July to December, Nitrogen covered an area of "5002" (ha) in DEEP GREEN indicating areas with 'Very low' concentrations, and a percentage concentration of 4.06%, LIGHT GREEN covered an area of "103176" (ha) indicating area with low concentration with a percentage of 83.8%. YELLOW covered area of 12689 (ha) with a percentage concentration of 10.31 % indicating areas with moderate concentration, DEEP ORANGE covered an area of 2250(ha) with a concentration percentage of 1.83% indicating areas with high concentrations

$PM_{2.5}$ in the first half of the season from January to June, covered an area of 28123(ha) with a percentage concentration of 22.84% with LIGHT GREEN indicating areas with Low concentration. YELLOW indicating areas with 'Moderate' concentrations, with a percentage concentration of 77.16.% .In the last season within the year from July to December $PM_{2.5}$ covered an area of 123112 (ha) with a percentage concentration of 100% DEEP GREEN indicating the area all having Very low concentrations

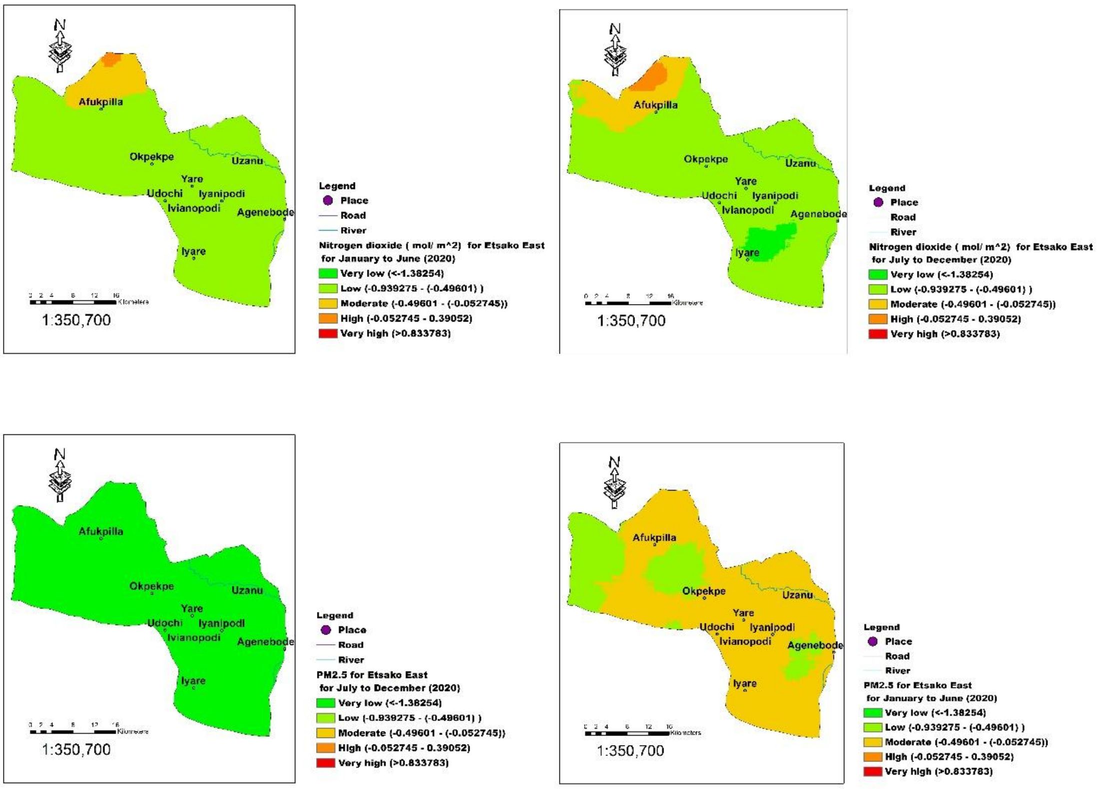


Figure 4.3: Spatial distribution of NO_2 and $PM_{2.5}$ concentration for January to June and July to December 2020.

Table4.2: Area and percentage (%) cover NO222 and $PM_{2.5}$ concentration for the year 2020

NO_2JANUARY TO JUNE 2020

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
1	Very Low	O.000044-0.000052	113382	92.09
2	Low	0.000052-0.00006	8993	7.3
3	Moderate	0.00006-0.000871	745	0.61

NO_2 JULY TO DECEMBER 2020

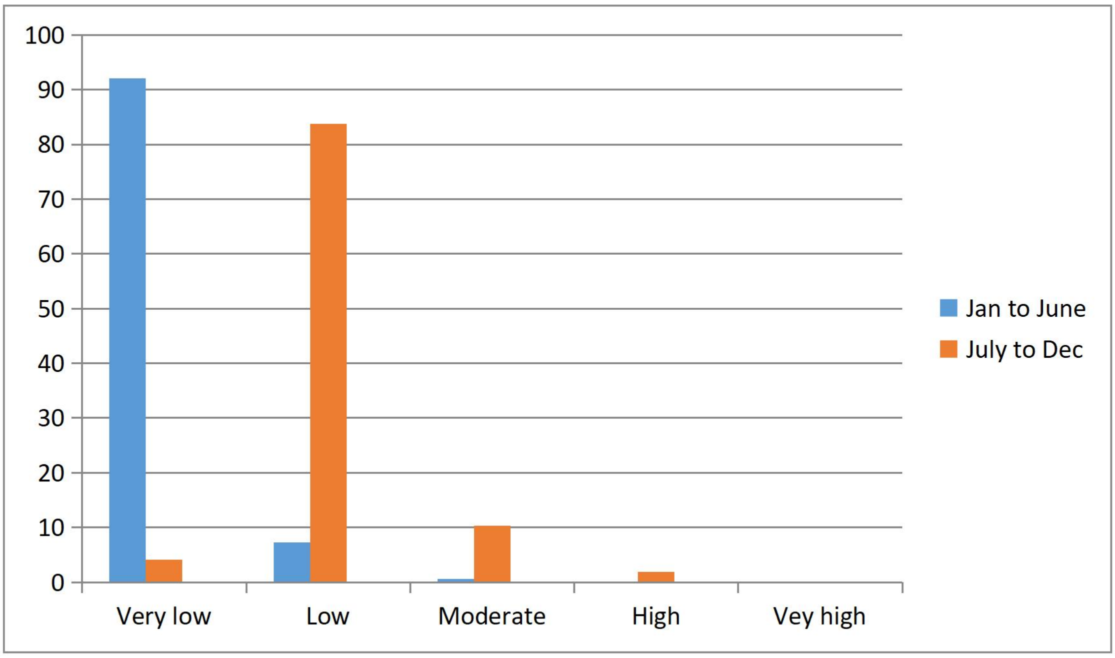
S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
1	Very Low	O.000044-0.000052	5002	4.06
2	Low	0.000052-0.00006	103176	83.8
3	Moderate	0.00006-0.00067	12689	10.31
4	High	0.000067-0.000075	2250	1.83

$PM_{2.5}$ JANUARY TO JUNE 2020

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
2	Low	-0.939275--0.49601	28123	22.84
3	Moderate	-0.49601--0.052745	94994	77.16

$PM_{2.5}$ JULY TO DECEMBER 2020

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
1	Very Low	-1.38254--0.939275	123112	100



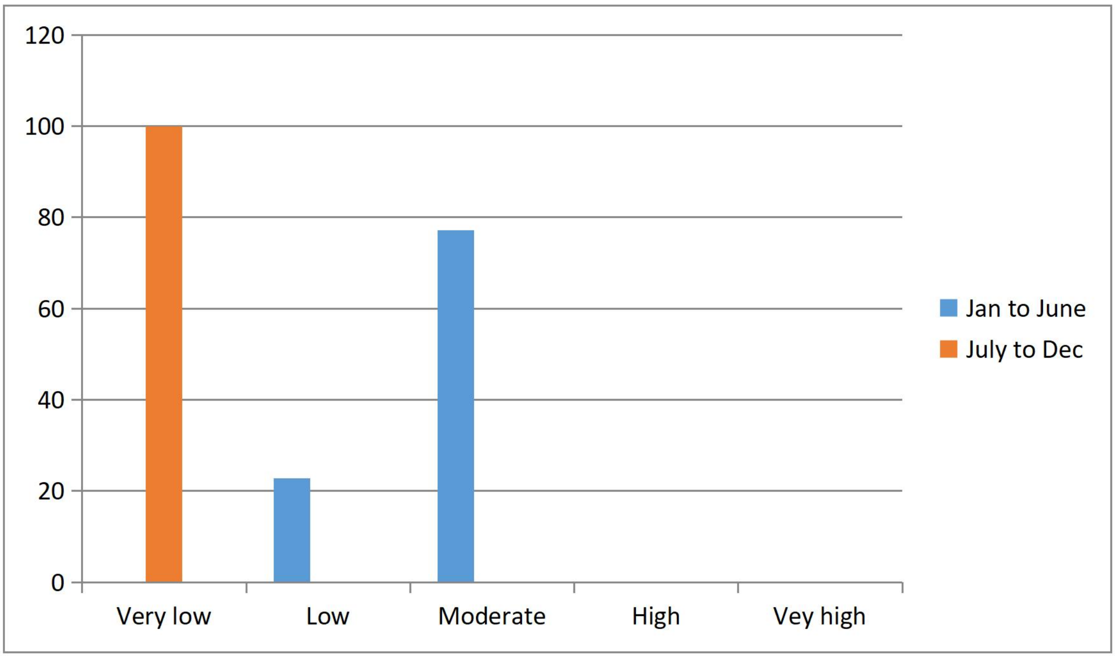


Figure 4.4: Graph showing percentage area coverage of (a) NO_2 from January to June, and July to December, 2020 (b) $PM_{2.5}$ from January to June, and July to December, 2020.

4.3: ATMOSPHERIC CONCENTRATIONS OF NITROGEN DIOXIDE (NO_2) AND PARTICULATE MATTER ($PM_{2.5}$) FOR THE YEAR 2021

In the year 2021, as shown in Figure4.5., Figure 4.6, and presented in Table 4.5., and Nitrogen covered an area of “274774” (ha) in LIGHT GREEN indicating areas with ‘Low’ concentrations, and a percentage concentration of 22.31%, YELLOW indicating areas with Moderate concentrations covered an area of “86397(ha)” and a percentage of 70.17%, ORANGE indicating areas with ‘High’ concentrations covering 6833(ha) and a percentage concentration of 5.55%. RED, indicating areas with Very high concentration covered an area of 2420(ha) with a percentage concentration of 1.97%. In the last season within the year from July to December, Nitrogen covered area of “31619” (ha) in LIGHT GREEN indicating areas with ‘Low’ concentrations, and a percentage concentration of 25.68%, YELLOW indicating areas with Moderate concentration covered an area of 74775(ha) with a concentration percentage of 62.12%.. ORANGE indicating areas with HIGH concentrations covered area of 13708 (ha) with a percentage concentration of 11.13 % , RED indicating areas with Very high concentrations covered an area of 1314(ha) with a concentration percentage of 1.07%

$PM_{2.5}$ in the first half of the season from January to June, covered an area of 123112(ha) with a percentage concentration of 100% with ORANGE indicating the whole area having High concentration. .In the last season within the year from July to December $PM_{2.5}$ covered an area of 123112 (ha) with a percentage concentration of 100% with YELLOW indicating the whole area having Moderate concentrations.

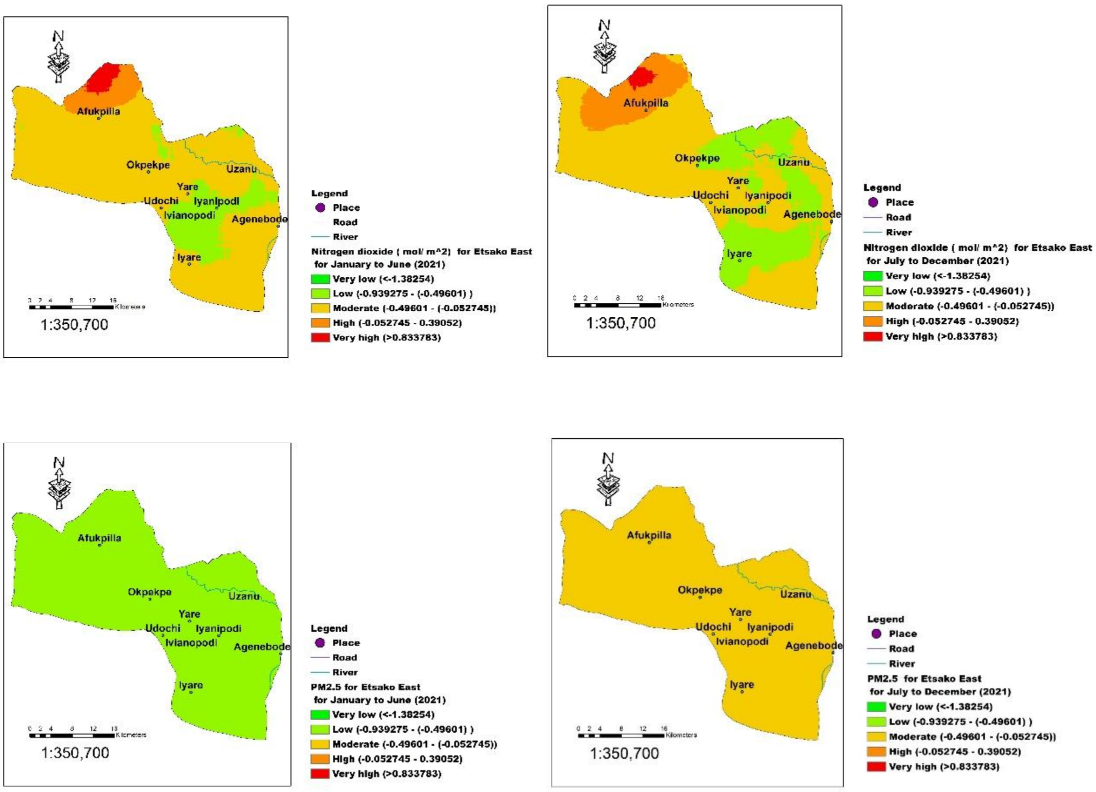


FIGURE4.5: Spatial distribution of NO2 and $PM_{2.5}$concentration for January to June and July to December 2021.

4.3: Area and percentage (%) cover NO_2 and $PM_{2.5}$ concentration for the year 2021

NO_2 FOR JANUARY TO JUNE 2021

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
2	Low	0.000052-0.00006	274774	22.31
3	Moderate	0.00006-0.000067	86397	70.17
4	High	0.000067-0.000075	6833	5.55
5	Very High	0.000075-0.000082	2420	1.97

NO_2 JULY TO DECEMBER 2021

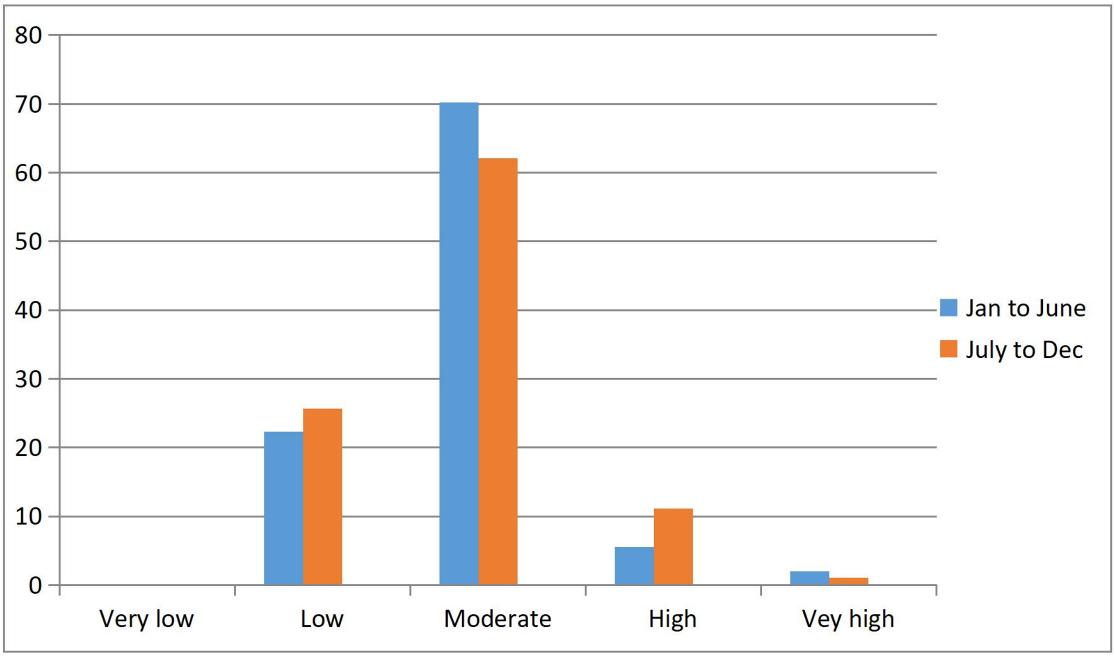
S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
2	Low	0.000052-0.00006	31619	25.68
3	Moderate	0.00006-0.000067	74775	62.12
4	High	0.000067-0.000075	13708	11.13
5	Very High	0.000075-0.000082	1314	1.07

$PM_{2.5}$ JANUARY TO JUNE 2021

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
4	High	-O.052745-0.39052	123112	100

$PM_{2.5}$ JULY TO DECEMBER2021

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
3	Moderate	-0.49601--O.O52745	123112	100



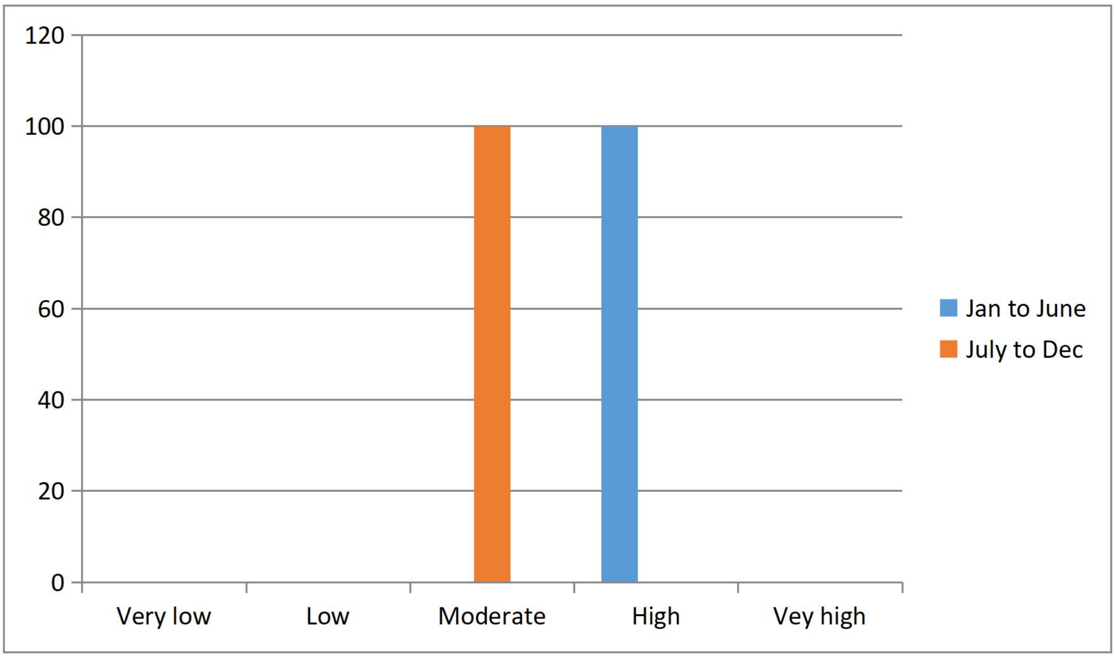


Figure 4.6 Graph showing percentage area coverage of (a) NO_2 from January to June, and July to December, 2021 (b) $PM_{2.5}$ from January to June, and July to December, 2021.

4.4.ATMOSPHERIC CONCENTRATIONS OF NITROGEN DIOXIDE (NO_2) AND PARTICULATE MATTER ($PM_{2.5}$) FOR THE YEAR 2022

In the year 2022, as shown in Figure4.7., Figure 4.8, and presented in Table 4.7., and Nitrogen covered an area of "10990" (ha) in DEEP GREEN indicating areas with 'Very Low' concentrations, and a percentage concentration of 9%, LIGHT GREEN indicating areas with Low concentrations covered an area of "102657(ha)" and a percentage of 83%, YELLOW indicating areas with 'Moderate' concentrations covered 6072(ha) and a percentage concentration of 5%. ORANGE, indicating areas with High concentration, covered an area of 2420(ha) with a percentage concentration of 3%. In the last season within the year from July to December, Nitrogen covered area of "65507" (ha) in LIGHT GREEN indicating areas with 'Low' concentrations, and a percentage concentration of 53.2%, YELLOW indicating areas with Moderate concentration covered an area of 41323(ha) with a concentration percentage of 33.56%.. ORANGE indicating areas with HIGH concentrations covered area of 13167(ha) with a percentage concentration of 10.69%, RED indicating areas with Very high concentrations covered an area of 31232ha) with a concentration percentage of $_{2.5}$4%

$PM_{2.5}$ in the first half of the season from January to June, covered an area of 30785(ha), ORANGE indicating areas with High concentrations with a percentage concentration of 25.01%. RED indicating areas with Very high concentrations covered an area of 92329(ha) with a percentage concentrations of 74.99%. In the last season within the year from July to December $PM_{2.5}$ covered an area of 123112 (ha) with a percentage concentration of 100% with YELLOW indicating the area having Moderate concentrations.

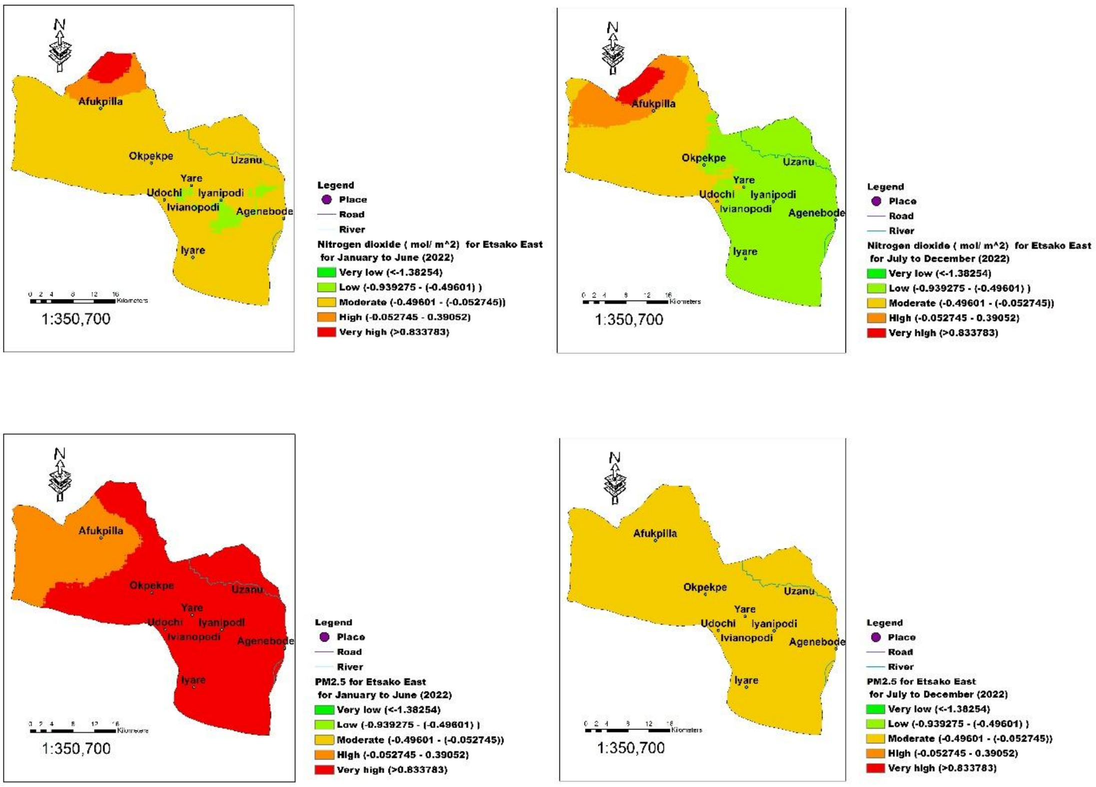


Figure: 4.7.Spatial distribution of NO_2 and $PM_{2.5}$concentration for January to June and July to December 2022

4.4: Area and percentage (%) cover NO_2 and $PM_{2.5}$ concentration for the year 2022

NO_2 JANUARY TO JUNE 2022

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
1	Very low	O.000044-0.000052	10990	9
2	Low	0.000052-0.00006	102657	83
3	Moderate	0.00006-0.000067	56072	5
4	High	0.000067-0.000075	3395	3

NO_2 JULY TO DECEMBER 2022

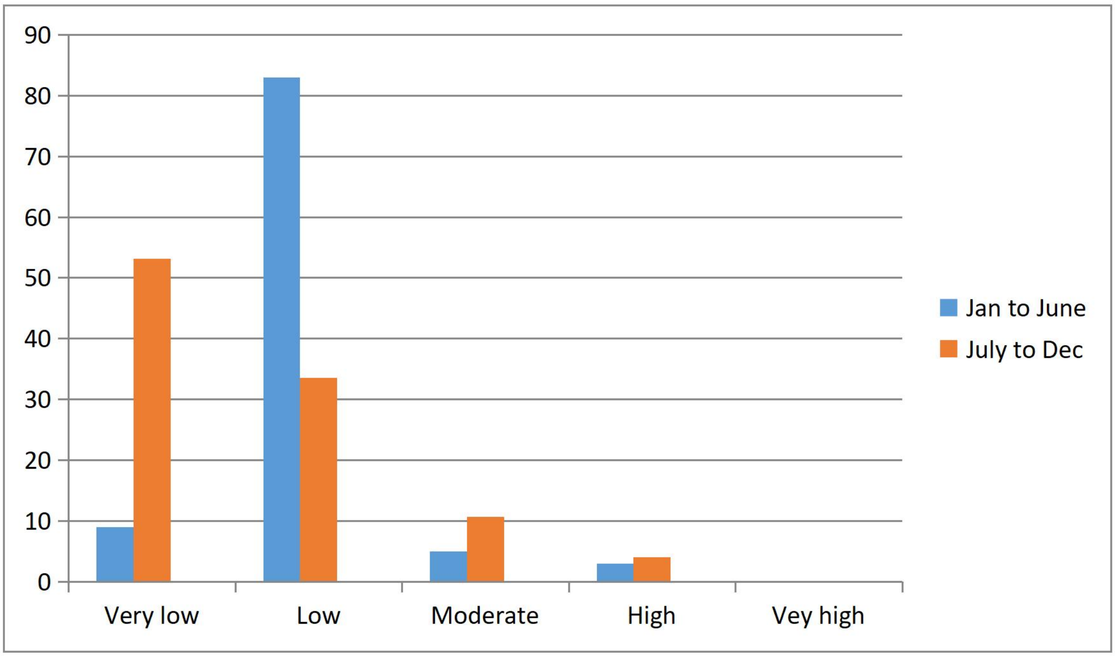
S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
1	Very Low	O.000044-0.000052	65507	53.2
2	Low	0.000052-0.00006	41323	33.56
3	Moderate	0.00006-0.000067	13167	10.69
4	High	0.000067-0.000075	3132	4

$PM_{2.5}$ JANUARY TO JUNE 2022

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
4	High	-O.052745-0.39052	30785	25.01
5	Very High	0.39052-0.833783	92329	74.99

$PM_{2.5}$ JULY TO DECEMBER 2022

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
3	Moderate	-0.49601--0.052745	123112	100



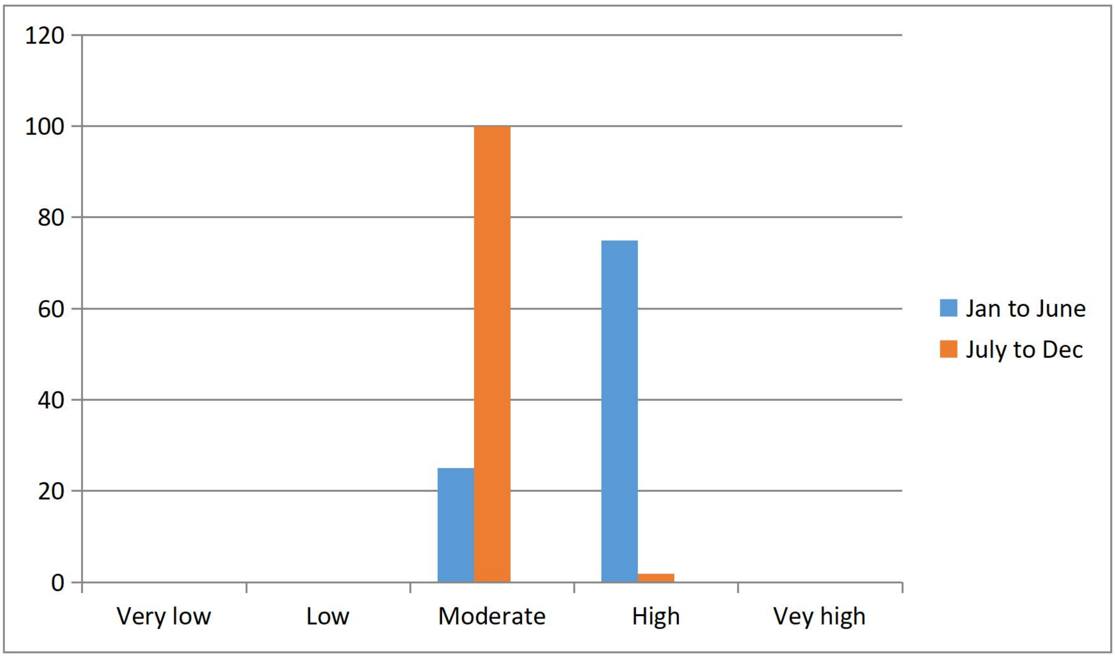


Figure 4.8 Graph showing percentage area coverage of (a) NO_2 from January to June, and July to December, 2022 (b) $PM_{2.5}$ from January to June, and July to December, 2022.

4.5 ATMOSPHERIC CONCENTRATIONS OF NITROGEN DIOXIDE (NO_2) AND PARTICULATE MATTER ($PM_{2.5}$) FOR THE YEAR 2023

In the year 2023, as shown in Figure4.9., Figure 4.10, and presented in Table 4.9., Nitrogen covered an area of “57944” (ha) in LIGHT GREEN indicating areas with ‘Low’ concentrations, and a percentage concentration of 47.07%, YELLOW indicating areas with Moderate concentrations covered an area of “59171(ha)” and a percentage of 48.06%, ORANGE indicating areas with ‘High’ concentrations covered 56072(ha) and a percentage concentration of 5%. RED, indicating areas with Very high concentration covered an area of 5998(ha) with a percentage concentration of 4.87%. In the last season within the year from July to December, Nitrogen covered area of “83898” (ha) in LIGHT GREEN indicating areas with ‘Low’ concentrations, and a percentage concentration of 68.15%, YELLOW indicating areas with Moderate concentration covered an area of 28172(ha) with a concentration percentage of 22.88%.. ORANGE indicating areas with HIGH concentrations covered area of 9728 (ha) with a percentage concentration of 7.9% , RED indicating areas with Very high concentrations covered an area of 1317(ha) with a concentration percentage of 1.07% $PM_{2.5}$ in the first half of the season from January to June, covered an area of 123112(ha) with a percentage concentration of 100%.In the last season within the year from July to December $PM_{2.5}$ covered an area of 110500 (ha) with a percentage concentration of 89.39% with YELLOW indicating the area having Moderate concentrations, ORANGE indicating areas with High concentration covered an area of 13067(ha) with a percentage concentration of 10.61%.

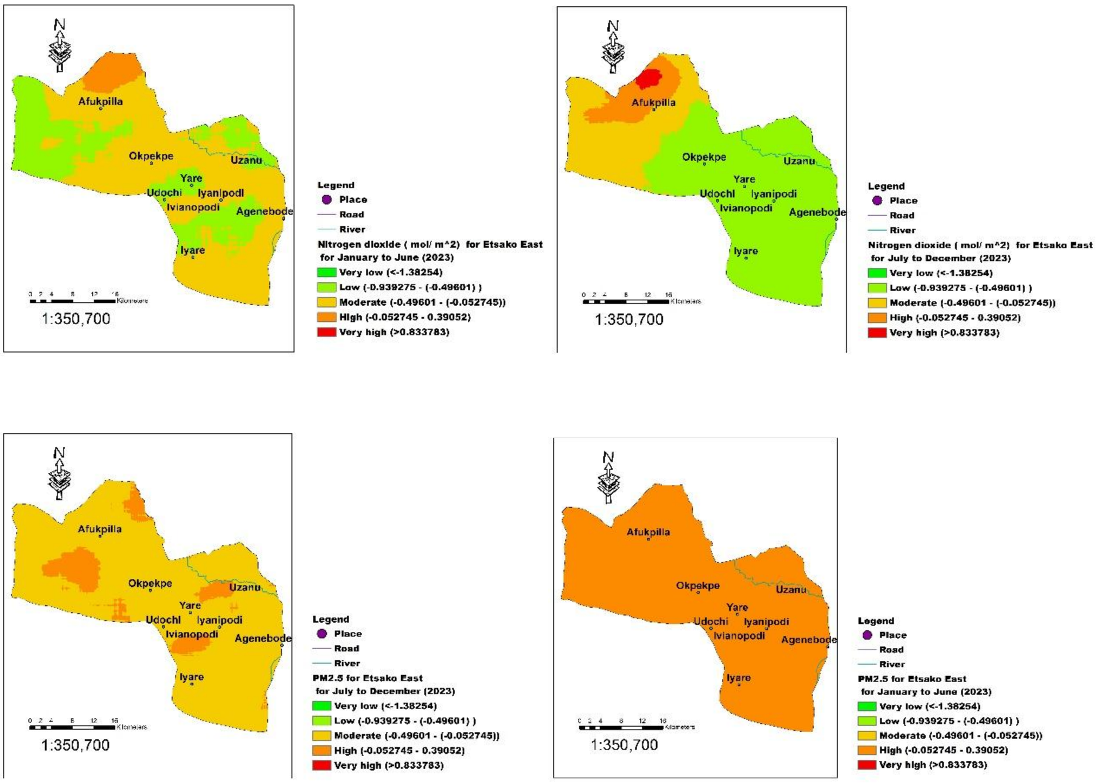


Figure 4.9: Spatial distribution of NO_2 and $PM_{2.5}$concentration for January to June and July to December 2023

Table 4.5 Area and percentage (%) cover $NO_2$and $PM_{2.5}$ concentration for the year 2023

NO_2JANUARY TO JUNE 2023

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
2	Low	0.000052-0.00006	57944	47.07
3	Moderate	0.00006-0.000067	59171	48.06
4	High	0.000067-0.000075	5998	4.87

NO_2JULY TO DECEMBER 2023

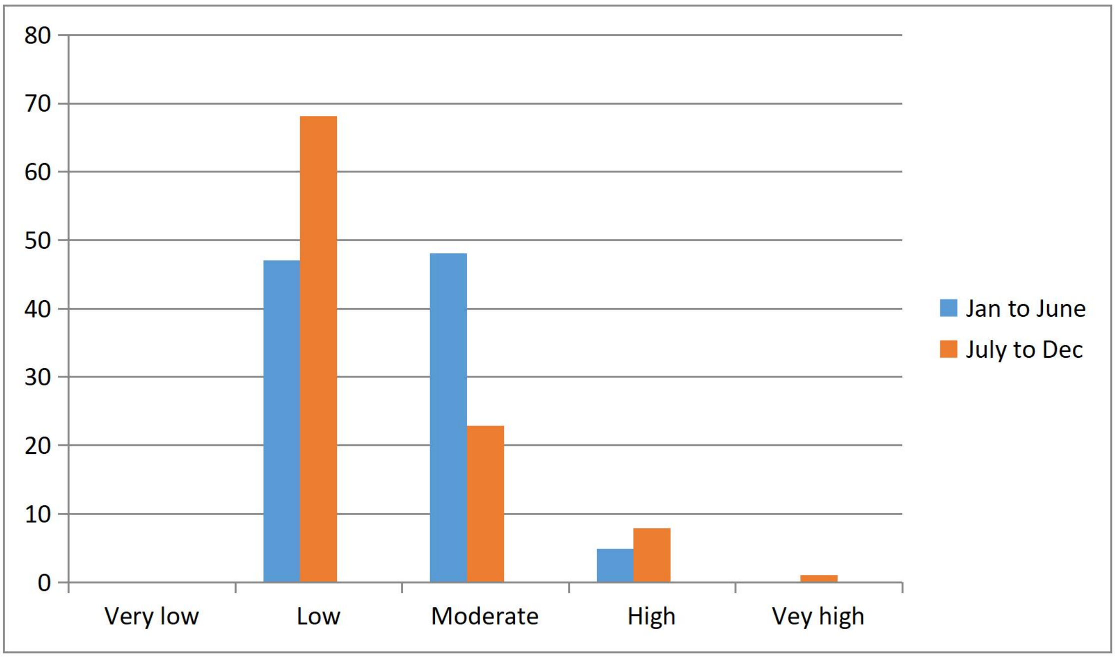
S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
2	Low	0.000052-0.00006	83898	68.15
3	Moderate	0.00006-0.000067	28172	22.88
4	High	0.000067-0.000075	9728	7.9
5	Very High	0.000075-0.000082	1317	1.07

$PM_{2.5}$ JANUARY TO JUNE 2023

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
4	High	-0.052745-0.039052	123112	100

$PM_{2.5}$ JULY TO DECEMBER 2023

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
3	Moderate	-0.49601--0.052745	110500	89.39
4	High	-0.052745-0.39052	13067	10.61



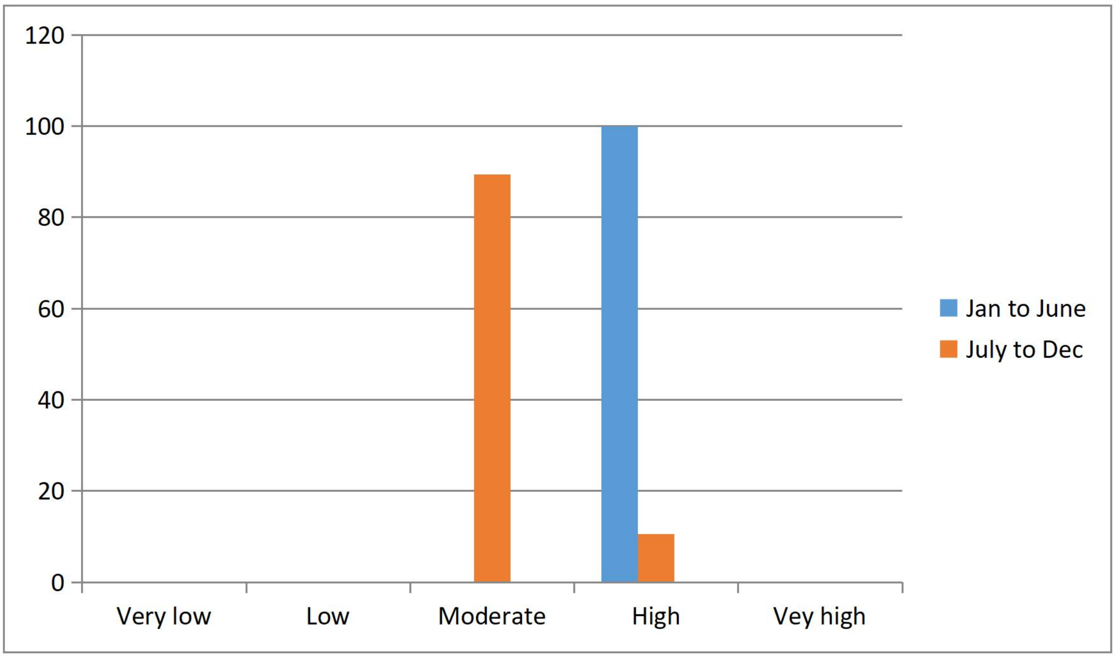


Figure 4.10 Graph showing percentage area coverage of (a) NO_2 from January to June, and July to December, 2023 (b) $PM_{2.5}$ from January to June, and July to December, 2023.

4.6 ATMOSPHERIC CONCENTRATIONS OF NITROGEN DIOXIDE (NO_2) AND PARTICULATE MATTER ($PM_{2.5}$) FOR THE YEAR 2024

In the year 2024, as shown in Figure4.11., Figure 4.12, and presented in Table 4.11., Nitrogen covered an area of “3166” (ha) in DEEP GREEN indicating areas with ‘Low’ concentrations, and a percentage concentration of $_{2.5}$7%, YELLOW indicating areas with Moderate concentrations covered an area of “111329(ha)” and a percentage of 90.43%, ORANGE indicating areas with ‘High’ concentrations covered 4356(ha) and a percentage concentration of 3.53%. RED, indicating areas with Very high concentration covered an area of 4265(ha) with a percentage concentration of 3.46% . In the last season within the year from July to December, Nitrogen covered area of “83898” (ha) in DEEP GREEN indicating areas with ‘Very Low’ concentrations, and a percentage concentration of 68.15%, LIGHT GREEN indicating areas with Low concentration covered an area of 28172(ha) with a concentration percentage of 22.88%.. YELLOW indicating areas with Moderate concentrations covered area of 9728 (ha) with a percentage concentration of 7.9% , ORANGE indicating areas with High concentrations, covered an area of 1317(ha) with a concentration percentage of 1.07%

$PM_{2.5}$ in the first half of the season from January to June, covered an area of 43877(ha) with a percentage concentration of 35.64% ORANGE indicating areas with High concentrations, RED indicating areas with Very high concentrations covered 79235(ha) with a percentage concentration of 64.36. In the last season within the year from July to December $PM_{2.5}$ covered an area of 123112 (ha) with a percentage concentration of 100%.

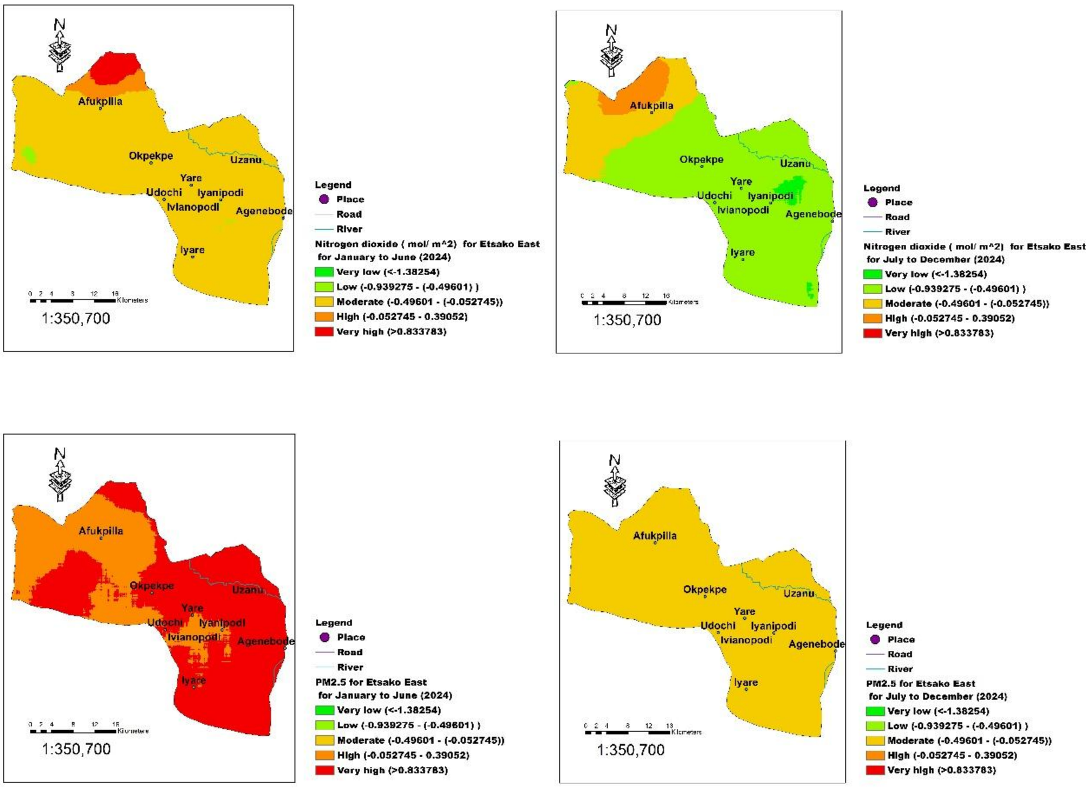


Figure 4.11: Spatial distribution of NO_2 and $PM_{2.5}$concentration for January to June and July to December 2024

Table: 4.6 Area and percentage (%) cover NO_2 and $PM_{2.5}$ concentration for the year 2024.

NO_2 JANUARY TO JUNE 2024

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
2	Low	0.000052-0.00006	3166	2.57
3	Moderate	0.00006-0.000067	111329	90.43
4	High	0.000067-0.000075	4356	3.53
5	Very High	0.000075-0.000082	4265	3.46

NO_2 JULY TO DECEMBER 2024

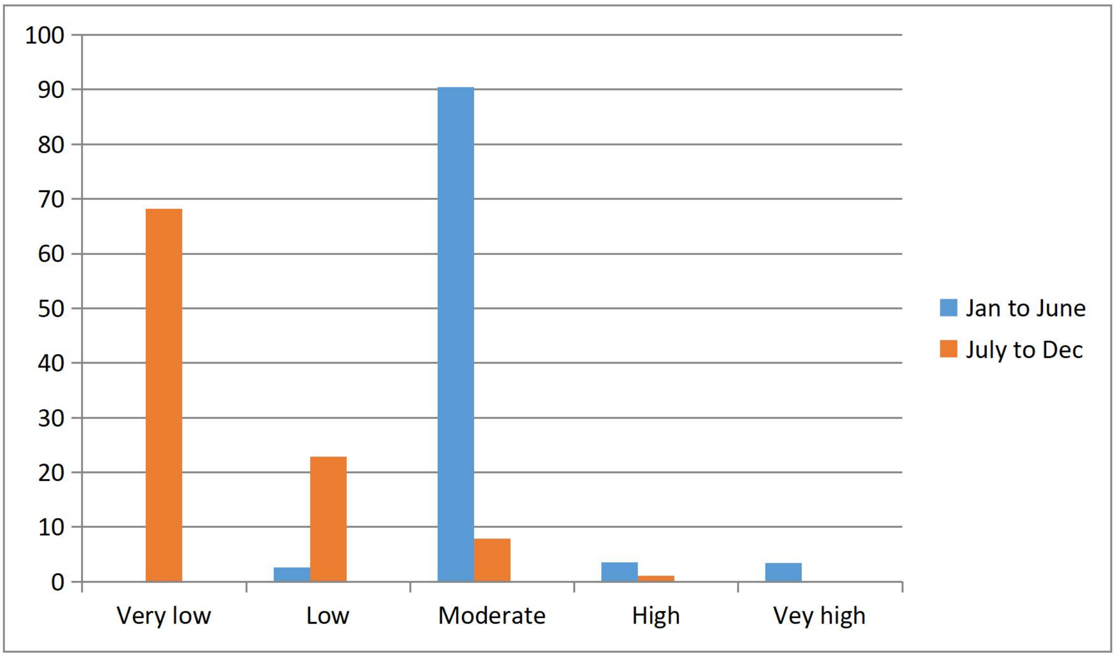
S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
1	Very Low	O.000044-0.000052	83898	68.15
2	Low	0.000052-0.00006	28172	22.88
3	Moderate	0.00006-0.000067	9728	7.9
4	High	0.000067-0.000075	1317	1.07

$PM_{2.5}$ JANUARARY TO JUNE 2024

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
4	High	-0.052745-0.39052	43877	35.64
5	Very high	0.39052-0.833783	79235	64.36

$PM_{2.5}$ JULY TO DECEMBER 2024

S/N	CONCENTRATION RANGE	VALUE RANGE	AREA (ha)	PERCENTAGE
3	Moderate	-0.49601--0.052745	123112	100



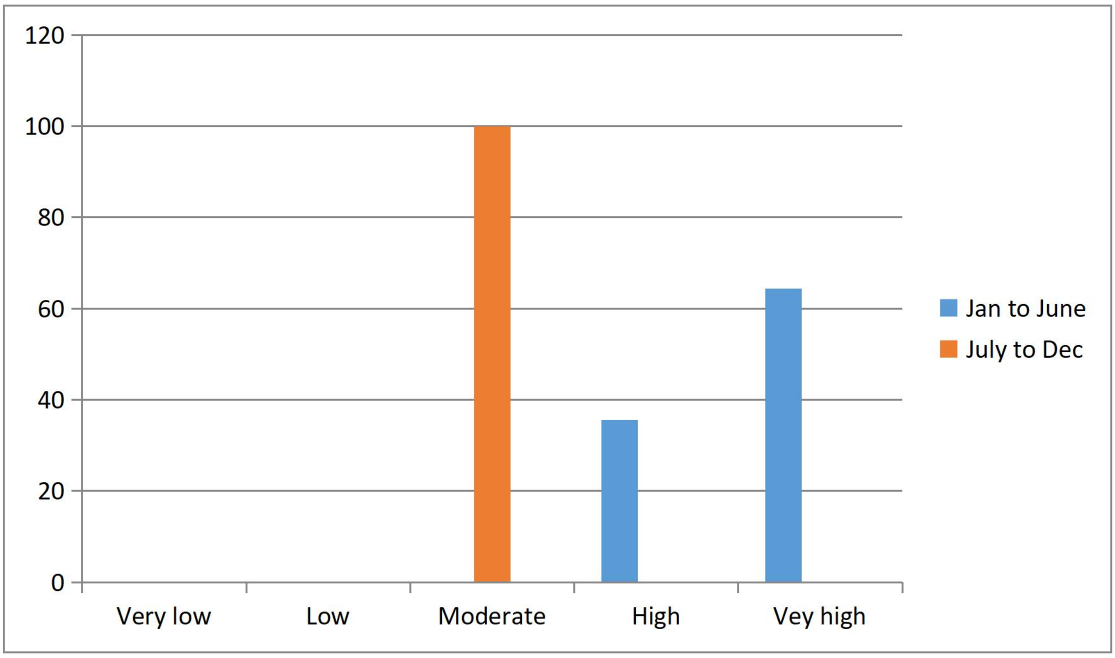


Figure 4.12: Graph showing percentage area coverage of (a) NO_2 from January to June, and July to December, 2024 (b) $PM_{2.5}$ from January to June, and July to December, 2024.

SPATIAL DISTRIBUTION OF Nitrogen dioxide (NO_2) FROM 2019 TO 2024

SPATIAL DISTRIBUTION OF PARTICULATE MATTER (2.5) FROM 2019 TO 2024

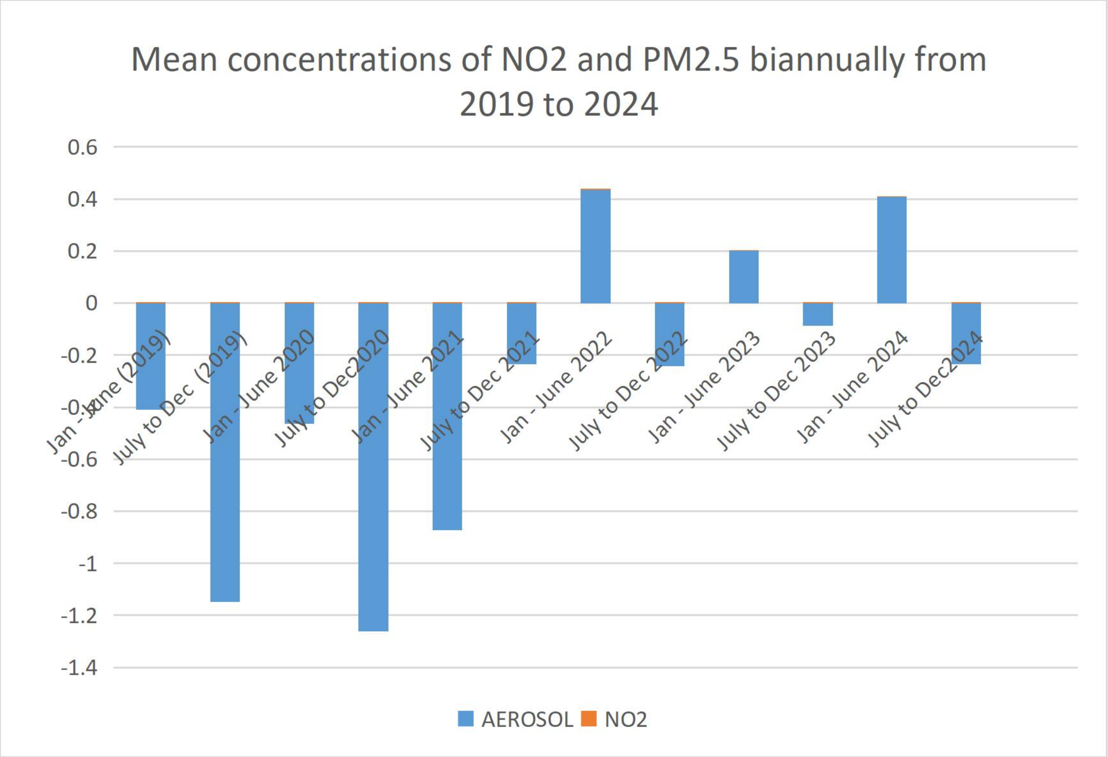


FIGURE 4.13:. Bar chart showing statistical summary of NO_2 and $PM_{2.5}$ from 2019 to 2024

CHAPTER FIVE
DISCUSSION

Spatial variations in the concentration of NO_2 and $PM_{2.5}$ within the study area of Etsako East Local Government Area were observed biannually through the six-year (2019-2014) comparison using the images resultant from the analyses and visualized by the ArcMap and acquired through the Google Earth Engine platform

The result from the mean concentration of Particulate Matter ($PM_{2.5}$) in Etsako East using sentinel-5P from 2019 to 2024 biannually are -0.4105,-1.1482, -0.4648, -1.2614 -0.8736, -0.2341, 0.4357, -O.2426, 0.2000, -0.0868, 0.4065,-0.2348 respectively.

The results from the mean concentration of Nitrogen dioxide (NO_2) in Etsako East using sentinel-5P from 2019 to 2024 biannually are; 0.00061mol/m^2, 0.00048mol/m^2, 0..00057mol/m^2, 0.0056mol/m^2, 0.00062mol/m^2, 0.00062mol/m^2, 0.00062mol/m^2, 0.00061mol/m^2, 0.00061mol/m^2, 0.00059mol/m^2, 0.00062mol/m^2 and 0.00057mol/m^2 respectively.

The highest mean concentration of PM2.5 occurred from July to December of 2021, with a value of -0.2341. The lowest value was observed within the months of July to December 2020, with a mean concentration value of -1.2614. This observation showed much activity that led to particulate matter discharge took place in the months of July to December of 2021.). in contrast, the months with the lowest concentration were observed during the lockdown, where activities were halted due to the pandemic. It is shown that low concentrations of $PM_{2.5}$ can result to milder DNA damage. Interestingly, most cells that survived repeated low-level treatment had several aberrant adaptive responses, including epigenetic deregulation and suppression of mitochondrial biogenesis. Accumulating evidence has also demonstrated that long-term low-level $PM_{2.5}$ exposure can also contribute to a variety of chronic pulmonary diseases, including chronic obstructive pulmonary disease (COPD), fibrosis and even lung cancer.

The EPA developed the Air Quality Index (AQI) in the 1990s to provide the public with a simple, color-coded way to communicate air quality. The AQI provides the $PM_{2.5}$ concentration, level, and color code (Brook *et. al*).

When air pollution levels are between 0 and 12 ug/m^3, they fall into the green color range. Level one indicates that the air quality is adequate and that there is little to no risk to human health. With a color code of yellow and a concentration between 12 and 35.4 ug/m^3, level 2 indicates that the air quality is moderate. However, it will be a problem for those who are health compromised, e.g., children, elderly and asthmatic people. level 3 with the range of 101-1501ug/m^3 with the hue orange implies the air is unhealthy It may have an impact on a particular demographic, such as youngsters and those with respiratory conditions like asthma. Anyone, even those without health issues, may be impacted by the toxic air, which is indicated by a red color and a concentration of 151-200 ug/m^3 on level 4. People with respiratory conditions like asthma should stay away from. Ai on level 4r quality that is between 201 and 300 ug/m^3, which is shown by the color purple. Air quality that is above 300, which is indicated by the color maroon, is dangerous and should be avoided by everyone.

The highest mean concentration for NO_2 occurred repeatedly across the study duration. The highest value was 0.00062mol/m^2 and it occurred within the months of January to June 2021, aside from the epidemiological effects, this can lead to moist deposition of NO_2 (acid rain), which corrodes buildings and other structures (Tidblad et al) . Additionally, acid rain can wash into the study area's water bodies, increasing their PH and contributing to the acidity of the water. For aquatic animals that cannot withstand an acidic environment, this is a serious issue. As a result of species decline, this can inevitably lead to a decrease in the habitat's natural richness and ecological imbalances. Also Since they rely heavily on fishing as a source of income, the study area's location that borders a body of water will be significantly influenced, as will the decline in fish or aquatic life. Due to reduced sales input, this will also have an effect on the local economy.

Acidic rain solutions make their entry of NO_2 into the leaf tissue through the cuticle and produce marked effects on plants as acid rain, generally retards the growth of plants by stimulating abnormalities in metabolism of the plants, like photosynthesis, nitrogen and sulfur metabolism (Singh , 2007) a , January to June 2022, and January to June 2024 and July to December 2022. This is an interesting display, as the highest concentrations occurs repeatedly which poses high risk of damage to pollen morphology, pollen cell wall, pollen protein content or release, and pollen protein itself (Frank and Ernst , 2016.). Additionally, Von Nieding and Wagner, (1979) noted that.

in contrast to irritating air pollutants like SO_2, which in certain bronchitis induce substantial increases in airway resistance at very low concentrations due to reflex bronchoconstriction, NO_2 may act by releasing histamine, resulting in bronchiolar, alveolar, and interstitial edema. Enuneku *et al.,* (2014) in an assessment of NO_2 trends in Benin-city noted a mean concentration value of 0.000663. Showing slightly higher levels than Etsako east, which is the area under this study? This is due to the high population of vehicles resulting in emissions higher than that of Etsako East. the severity of the effects of NO_2 pollutant vary depending on status , age, and duration of exposure, for example because preschool children spend much of their time in the home they may be especially at risk to the adverse effects of indoor NO_2 exposure (Hansel et al., 2008

The lowest mean concentration values were observed during the months of July to December 2019 and July to December 2020, as 0.00048mol/m^2 and 0.00056mol/m^2 respectively. This is due to the closure of activities due pandemic. According to According to a study by Benchrif et al. on the AQI of NO_2 and $PM_{2.5}$ in cities with a population of over a million, the implementation of quarantines due to lockdowns caused by the ongoing novel coronavirus (the agent of COVID-19) has a significant impact on both air quality and human mobility and economic activity. Since then, a lot of debate has been sparked on whether the lockdown is a suitable alternative countermeasure for improving air quality because of the dramatic decline in pollution levels in cities all around the world. The purpose of this study was to examine the levels of $PM_{2.5}$, tropospheric NO_2, and the Air Quality Index (AQI) in 21 cities worldwide during three lockdown phases: before, during, and after. A straightforward before-and-after comparative method was to compare the air pollution readings and record the decreasing trend brought on by the shutdown limitations. According to the findings, the frequency distribution of NO_2 is flatter from 2020 to the baseline 2018–2019 period and more variable than that of $PM_{2.5}$. In addition, the AQI was moderate prior to the lockdown and has fluctuated between high and mild pollution in the majority of the cities. Despite the fact that daily NO_2 concentrations decreased by 3 to 58% in all cities during the lockdown, three cities—Abidjan (1%), Conakry (3%), and Chengdu (10%)—saw increases. Notwithstanding this contradictory pattern, the NO_2 time series amply demonstrated the impact of the unlocking phase, during which time NO_2 levels rose in practically every city. In a similar vein, PM2.5 levels have risen since the lockdown, with 50% of the cities reporting notable improvements in comparison to the lock and unlock phases. Then, compared to other times, $PM_{2.5}$ levels were greater during the pre-lockdown period

From the result gotten we can infer that the level of low concentration of NO_2 throughout the period of study of the study area it can also be trace down to the type of location under study, the study area is a rural area with most of it activities majors on Agriculture, this area still uses crude method and implement for their faming activities instead of the synthetic products use to enhance crop yield with could release a significant amount of NO_2 into the atmosphere. In a study of spatial patterns of nitrogen dioxide (NO_2) and its impact factors by Müller et al (2022), studied the area of interest in twofold; base on hotspots and cold spot on the other hand, non-meteorological factors influencing tropospheric. NO_2. Identifying 61 24 major hotspot, these hotspot happens to be located in urban areas.

One likely cause of anemia(a condition or a disorder defined by a lack of hemoglobin in the blood), is exposure to air pollutants, such as fine particulate matter ($PM_{2.5}$) and NO2, which is common in orderly population (Honda *et al*., 2017). Aside health effect NO_2

CONCLUSION

High concentrations of Nitrogen dioxide was observed as compared to particulate matter in which occurred highly in several biennials as recorded within the six (6) years of this study. This is closely linked to the industrial activity of cement manufacturing prevalent in this locality, coupled with the vehicular emissions from the vehicles used to transport the cement to the various distributors and consumers. Health impacts closely linked with the pollutants include chronic asthma, cancers, respiratory and cardiovascular diseases.

RECOMMENDATIONS

Although cement production is integral in our society today, its production has some detrimental effects on human health. Measures such as geospatial continuous monitoring of air quality around the environs, enforcing of cleaner energy practices, government policy regulations should be employed to achieve a sustainable development in this regards, as concerning Etsako East.

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