ASSESSMENT OF AIR AND NOISE POLLUTION IN SAWMILLS AND ENVIRONS IN BENIN CITY, EDO STATE

BY

ADAGBASA, Osereme Fortune

ENG2002083

A PROJECT SUBMITED IN PARTIAL FULFILLMENT OF THE

REQUIREMENT FOR THE AWARD OF

BACHELOR OF ENGINEERING (B.Eng) DEGREE

IN

THE DEPARTMENT OF CIVIL ENGINEERING,

FACULTY OF ENGINEERING,

UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

NOVEMBER, 2025

PLAGIARISM

This work **ASSESSMENT OF AIR AND NOISE POLLUTION IN SAWMILLS AND ENVIRONS IN BENIN CITY, EDO STATE** by ADAGBASA, Osereme Fortune With Number ENG2002083 of the Department of Civil Engineering, Faculty of Engineering, University of Benin City, Edo State, Nigeria has PASSED the PLAGIARISM TEST.

PROJECT COORDINATOR

Name: ____

Signature and Date:____

CERTIFICATION

This is to certify that this work was carried out by ADAGBASA, Osereme Fortune, Mat. No. ENG2002083, of the Department of Civil Engineering, Faculty of Engineering, University of Benin City, Edo State, Nigeria.

SUPERVISOR:

Name:____

Signature and Date:____

HEAD OF DEPARTMENT:

Name:____

Signature and Date:____

DEDICATION

This project is dedicated to God for His sustenance from time immemorial, my beloved parents Mr and Mrs Adagbasa, for their unwavering support, encouragement, and sacrifices that have shaped my academic journey.

My esteemed project supervisor, Engr. Chukwuemeka Okolie for his guidance, patience, and expertise through the project process.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to the Divine Engineer the One whose blueprint shaped existence itself. God, the Chief Architect of Creation, surveyed the void and saw potential.With perfect calculations and flawless design. He laid the foundations of the heavens and the earth stronger than the deepest bedrock, spanning farther than any suspension bridge.

My gratitude goes to Engr.C.M. Okolie; my supervisor, who gave me the understanding, encouragement and assistance to carry out this work. I also wish to acknowledge the vital role of the staff in the Department of Civil Engineering, who have consistently gone above and beyond to impart knowledge and foster good conduct, both in and out of the academic environment. I extend my gratitude to the Head of Department, Engr. Prof. (Mrs.) Ngozi Ihimekpen, as well as Prof. O.C. Izinyon, Prof. O.U. Orie, Prof. H.A.P. Audu, Prof. S.O. Osuji, Prof. S.D. Iyeke, Dr. Agbonaye Prof.. R.I. Umasabor, Prof. (Mrs) K.O.Ngozi, Prof. R.O. Ogirigbo, Dr. R.I. Ilaboya, Dr. (Mrs.) L.O. Bobor, Dr. (Mrs.) A. Rawlings, Engr. Dr. E.S. Okonofua, Engr. Dr U. Ukeme, Engr. Dr (Mrs) Lulu,Engr. E. Oria Usifo, Engr. C.M. Okolie, Engr.Dr P. Ogbeifun, Engr. Nosakhare Kent,Engr (Mrs) Agabi Engr. O. Osasu, Engr. B. Omosefe, Engr. O. Oriakhi, Engr.O Janet, Engr.(Mrs.) Gloria, and the all the laboratory staff and cleaners.

I would like to acknowledge my friends and family, Rev. Nicholas, The HOREB Nation, DEM BOYS, Mama Confidence, Egbon Wise for their unwavering moral support, motivation, and understanding during the challenging phases of this project.

To my roommates, Mary, Afolabi, John and Joy. God bless you all thanks for the constant push and motivation you all gave

It won't be an acknowledgement if I fail to thank my parents for their support both financially, materially and in every other way they assisted me

To my siblings; Marvelous, Ehis, Prosper and Princess thanks for the endless support, data sent, feeding money given through this period

Finally, I thank Almighty God for the strength, wisdom, and perseverance to complete this work.

ABSTRACT

This study assessed the levels of air and noise pollution generated by sawmill activities in selected locations within Benin City, Edo State, Nigeria. The investigation focused on key air quality parameters including particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), formaldehyde (HCHO), total volatile organic compounds (TVOC), carbon dioxide (CO_2), as well as environmental noise levels. Measurements were carried out using calibrated portable air quality monitors and sound level meters across five major sawmill locations. The aim was to determine the extent of environmental pollution, evaluate compliance with recommended standards, and examine potential health risks to workers and nearby residents.

Results revealed that $PM_{2.5}$ concentrations ranged from 24 $\mu g/m^3$ to 43 $\mu g/m^3$, while PM_{10} values ranged from 46 $\mu g/m^3$ to 68.5 $\mu g/m^3$ across the sampled locations. Noise levels varied between 68.35 dB(A) and 74.8 dB(A). Ozone concentrations ranged from 0.01 ppm to 0.08 ppm, while CO_2 levels were recorded between 408 ppm and 482 ppm. In several locations, particulate matter levels exceeded the World Health Organization (WHO) 24-hour guideline limits, indicating degraded air quality. Noise measurements in most sites were also above the recommended 55 dB(A) limit for residential environments, suggesting potential risks of long-term exposure.

The findings confirm that sawmill operations significantly contribute to environmental pollution within the study area. Elevated concentrations of $PM_{2.5}$ and PM_{10} pose respiratory health risks, while persistent exposure to high noise levels may result in hearing impairment, stress, and reduced productivity. The study highlights the need for stricter enforcement of environmental regulations, installation of dust control systems, proper zoning of industrial activities, and routine environmental monitoring. Implementing these measures will improve occupational safety and protect the health of surrounding communities.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

WHO	World Health Organization
EPA	Environmental Protection Agency
NESREA	National Environmental Standards and Regulations Enforcement Agency
OSHA	Occupational Safety and Health Administration
$PM_{2.5}$	Particulate Matter with diameter ≤ 2.5 microns
PM_{10}	Particulate Matter with diameter ≤ 10 microns
VOCs	Volatile Organic Compounds
CO	Carbon Monoxide
NO_2	Nitrogen Dioxide
O_3	Ozone
SLM	Sound Level Meter
PPE	Personal Protective Equipment
NIHL	Noise-Induced Hearing Loss
TWA	Time Weighted Average
FEV_1	Forced Expiatory Volume in 1 second
AQI	Air Quality Index
dB(A)	A-weighted Decibel
NAAQS	National Ambient Air Quality Standards
COPD	Chronic Obstructive Pulmonary Disease
IARC	International Agency for Research on Cancer
GIS	Geographic Information System

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Air pollution refers to the presence of harmful or excessive quantities of substances in the Earth's atmosphere that can negatively affect human health, the environment, and climate. These pollutants can be in the form of gases, particles, or biological molecules and come from both natural and human-made sources.

Noise Pollution refers to excessive or harmful levels of sound that disrupt normal activities, cause discomfort, and negatively impact human health and the environment. It is often caused by human activities and can affect both urban and rural areas.

Air and noise pollution from sawmills pose significant environmental and public health risks due to the release of wood dust, combustion emissions, and high-decibel machinery operations. Sawmills are essential for wood processing but generate substantial pollutants, including particulate matter ($PM_{2.5}$, PM_{10}), carbon monoxide (CO), volatile organic compounds (VOCs), and excessive noise from cutting, grinding, and sawing activities (World Health Organization [WHO], 2021). These pollutants contribute to respiratory diseases, hearing impairment, and environmental degradation in surrounding communities (Ogunleye, 2022).

In Nigeria, the National Environmental Standards and Regulations Enforcement Agency (NESREA) sets guidelines for industrial emissions and noise levels, but enforcement remains weak, particularly in informal sawmill clusters (NESREA, 2018). Studies indicate that sawmill workers and nearby residents are frequently exposed to pollution levels exceeding WHO-recommended limits (Ajayi & Ajayi, 2020).

This study seeks to evaluate air and noise pollution levels in sawmills and their environs, comparing them with regulatory standards and recommending mitigation measures.

Findings will contribute to occupational safety policies, environmental management, and public health interventions in wood-processing regions.

1.2 STATEMENT OF THE PROBLEM

Sawmills play a crucial role in the timber processing industry, contributing significantly to economic growth and employment. However, their operations generate substantial air and noise pollution, posing serious health and environmental risks to workers and nearby communities (World Health Organization [WHO], 2021). Despite increasing awareness of industrial pollution, many sawmills particularly in developing regions lack adequate pollution control measures, leading to prolonged exposure to hazardous conditions (Kumar et al., 2019). This study seeks to assess the extent of air quality deterioration and noise pollution in and around sawmill environments, evaluating compliance with established safety standards and identifying necessary mitigation strategies.

The primary sources of air pollution in sawmills include wood dust (particulate matter—$PM_{2.5}$ and PM_{10}), volatile organic compounds (VOCs) from treated wood, and combustion emissions from wood waste burning (Environmental Protection Agency [EPA], 2020). Prolonged inhalation of these pollutants is associated with respiratory diseases such as asthma, chronic obstructive pulmonary disease (COPD), and lung cancer (International Agency for Research on Cancer [IARC], 2018). Workers in sawmills are particularly vulnerable due to direct exposure, while nearby residents may also experience adverse health effects from ambient pollution dispersion (Odekanle et al., 2021). Despite regulatory frameworks such as the WHO Air Quality Guidelines (2021) and the National Ambient Air Quality Standards (NAAQS), enforcement remains weak in many regions, exacerbating public health risks.

Industrial sawmill operations produce high noise levels, primarily from **machinery (circular saws, planers, chippers), transportation vehicles, and manual wood processing activities (Occupational Safety and Health Administration [OSHA], 2022). Continuous exposure to noise levels exceeding 85 dB(A) can lead to noise-induced hearing loss (NIHL), hypertension, sleep disturbances, and reduced productivity (WHO, 2018). While occupational safety regulations, such as those by OSHA, mandate hearing protection and noise control measures, compliance is often inadequate, especially in small-scale and informal sawmills (Ajayi & Ajayi, 2020).

1.3 AIM AND OBJECTIVE

The aim of this study is to evaluate the levels of air and noise pollution generated by sawmill operations and their impact on the immediate environment and human health. Key objectives includes:

1. To Measure Air Quality Parameters in and Around Sawmill Facilities
2. To Assess Noise Pollution Levels in the Sawmill Environment
3. To Evaluate Health Risks for Sawmill Workers and Nearby Residents
4. To Identify Pollution Control and Mitigation Strategies
5. To Contribute to Existing Research on Industrial Pollution

1.4 SCOPE OF WORK

This study will comprehensively evaluate air quality and noise pollution levels associated with sawmill operations and their immediate surroundings. The study will be conducted in locations where sawmill operations are prominent. The assessment will cover the immediate sawmill premises, adjacent residential/commercial areas within a kilometer radius. Air quality assessment on particulate matter ($Pm_{2.5}$ and Pm_{10}) concentrations, volatile organic compounds (VOCs) levels, carbon monoxide (CO) emissions, noise pollution assessment.

The research will employ; standardized air sampling techniques (gravimeter, real-time monitoring), noise measurement using calibrated sound level meters, worker interviews and health surveys, community perception assessments, comparative analysis with national and international standards

The scope of the study involved assessment of air quality data collected around high traffic roads, moderate traffic roads and low traffic residential streets. The scope of the work includes evaluating the adequacy of the monitoring carried out, the adequacy of the prediction and identification of the impacts expected due to project activities and to evaluate the appropriateness of the mitigation measures being proposed to curb air pollution problems

1.5 JUSTIFICATION OF THE STUDY

Previous studies have examined industrial pollution in various sectors, but few focus specifically on small and medium-scale sawmills, particularly in peril-urban and rural settings where regulatory oversight is limited (Fakinle et al., 2020). Additionally, most research emphasizes either air or noise pollution independently, neglecting their combined impact on workers and nearby populations. This study fills these gaps by:

1. Quantifying air and noise pollution levels in selected sawmills using standardized measurement techniques.
2. Comparing results with WHO, OSHA, and national regulatory limits to assess compliance.
3. Evaluating health risks for sawmill workers and nearby residents through exposure assessment.
4. Recommending practical mitigation measures to reduce pollution and enhance workplace safety.

The findings of this study will provide evidence-based data for policymakers, environmental agencies, and sawmill operators to implement stricter pollution control measures, ultimately safeguarding public health and promoting sustainable industrial practices.

CHAPTER TWO

LITERATURE REVIEW

2.1 GENERAL OVERVIEW OF AIR QUALITY AND NOISE POLLUTION

2.1.1 DEFINITION AND IMPORTANCE OF AIR QUALITY AND NOISE POLLUTION

Air quality refers to the condition of the air within a specific environment, determined by the concentration of pollutants present (World Health Organization [WHO], 2021). It is assessed based on the levels of harmful substances, including particulate matter ($Pm_{2.5}$ and Pm_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), and volatile organic compounds (VOCs) (Environmental Protection Agency [EPA], 2022). Good air quality indicates minimal pollution, while poor air quality signifies elevated pollutant concentrations that pose health and environmental risks.

Noise pollution is defined as unwanted or excessive sound that disrupts normal activities, causes discomfort, and adversely affects human health and well-being (WHO, 2018). It is typically measured in decibels (dB) and categorized based on sources such as industrial machinery, transportation, and construction activities. Prolonged exposure to noise levels exceeding 85 dB(A) can lead to hearing impairment and other physiological effects (Occupational Safety and Health Administration [OSHA], 2022).

A. IMPORTANCE OF AIR QUALITY

Air quality is a critical aspect of environmental and public health that directly affects the well-being of humans, animals, and ecosystems. Good air quality refers to the presence of clean, unpolluted air that is free from harmful levels of pollutants such as particulate matter (PM), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), and volatile organic compounds (VOCs). Maintaining high air quality is essential because air is a fundamental resource that humans inhale continuously. When polluted, it can cause severe health issues, environmental degradation, and economic consequences.

Poor air quality is linked to a range of health problems, including respiratory diseases like asthma and chronic obstructive pulmonary disease (COPD), cardiovascular conditions, lung cancer, and premature death. Children, the elderly, and individuals with preexisting health conditions are especially vulnerable. According to the World Health Organization (2021), air pollution is responsible for over seven million premature deaths globally each year.

Air pollutants contribute to problems such as acid rain, smog formation, and global warming. For example, excess nitrogen and sulfur compounds can damage forests, soil, and aquatic ecosystems, while ground-level ozone can harm crops and reduce agricultural yields (EPA, 2023).

B. IMPORTANCE OF NOISE POLLUTION CONTROL

Noise pollution, often referred to as environmental noise, is the presence of excessive or disturbing sounds that may harm human health or environmental quality. Common sources include traffic, industrial activities, construction, loudspeakers, and household appliances. Unlike air or water pollution, noise is an invisible threat that is often underestimated, but its effects can be deeply damaging, especially in urban and densely populated areas.

Continuous exposure to high noise levels has been associated with several health issues. These include hearing loss, sleep disturbances, increased stress levels, hypertension, and cardiovascular diseases. The World Health Organization (WHO, 2018) highlights that prolonged exposure to environmental noise can significantly impair quality of life and even lead to premature death due to cardiovascular complications.

Noise pollution adversely affects mental health and cognitive performance, particularly in children. Studies show that chronic noise exposure in schools or homes may lead to poor memory, lower reading skills, and reduced attention span (Basner et al., 2014).

Noise pollution also disrupts ecosystems. It can interfere with animal communication, mating rituals, and hunting behaviors, especially in birds, marine life, and nocturnal animals. Prolonged noise can cause species to flee their habitats, leading to ecological imbalances (Slabbekoorn & Ripmeester, 2008).

2.1.2 MAJOR SOURCES OF AIR AND NOISE POLLUTION IN INDUSTRIAL AREAS

A. AIR POLLUTION SOURCES

Some of the major sources of air pollution includes;

1. Emissions from manufacturing processes: Factories release large quantities of pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter (PM). These arise from combustion, chemical processing, and the handling of raw materials (US EPA, 2023).
2. Power Generation: Industries often operate on fossil fuels like coal, diesel, or natural gas, which release greenhouse gases and other air pollutants during combustion (Mukherjee & Agrawal, 2018).
3. Industrial Waste Burning and Open Dumping: Improper disposal or burning of industrial waste emits toxic chemicals and particulates into the air, severely impacting local air quality (Cheng et al., 2019).
4. Vehicle Emissions: Industrial zones experience heavy vehicular traffic from trucks, loaders, and cranes. These contribute to air pollution through exhaust emissions of CO, NO_2, and hydrocarbons.

B. NOISE POLLUTION SOURCES

Some of the major sources of noise pollution includes;

1. Heavy Machinery Operation: Industrial machines such as crushers, turbines, compressors, and generators produce high-decibel sounds. These noises are often continuous and exceed safe exposure limits, affecting workers' hearing and health (Basner et al., 2014).
2. Transportation and Logistics: The movement of heavy vehicles, loading and unloading of materials, and the operation of forklifts and rail systems contribute significantly to environmental noise in industrial settings.
3. Construction and Fabrication Activities: Ongoing construction, welding, and fabrication processes in industrial zones generate impulsive and repetitive noise that can cause both annoyance and health risks (WHO, 2018).
4. Cooling Systems and Ventilation Units: Large-scale ventilation systems, fans, and cooling towers often emit continuous noise that adds to the background industrial sound levels.

2.1.3 HEALTH AND ENVIRONMENTAL IMPACT OF POOR AIR QUALITY AND EXCESSIVE NOISE

A. HEALTH IMPACTS OF POOR AIR QUALITY

Poor air quality and excessive noise pollution are among the most pressing environmental concerns in urban and industrial regions today. These forms of pollution not only degrade the natural environment but also significantly harm human health and overall quality of life. Their combined impacts can be long-term, affecting populations, ecosystems, and even economies.

Some of the health impacts includes: respiratory and cardiovascular diseases- inhalation of polluted air can lead to conditions such as asthma, chronic bronchitis, lung cancer, and heart disease. Fine particulate matter ($PM_{2.5}$) and gases like NO_2 and SO_2 are particularly harmful as they penetrate deep into the lungs and bloodstream (WHO, 2021). Impaired immune and nervous systems- long-term exposure to air pollution may weaken the immune system and increase susceptibility to infections. Recent studies also link air pollutants to neuro developmental disorders in children and neuro degenerative diseases in adults (Power et al., 2016). And lastly, premature death- according to the World Health Organization, air pollution causes about 7 million premature deaths annually, mostly due to heart and lung diseases (WHO, 2021).

B. HEALTH IMPACTS OF EXCESSIVE NOISE

These includes; hearing loss- continuous exposure to high decibel levels, especially in industrial areas, can cause temporary or permanent hearing impairment (Basner et al., 2014). Sleep Disturbances and mental health- environmental noise, particularly at night, interferes with sleep patterns, leading to fatigue, anxiety, and depression. Chronic noise exposure is also associated with increased stress hormone levels and reduced overall well-being. Cardiovascular risks- noise pollution has been linked to elevated blood pressure, increased heart rate, and higher risk of cardiovascular diseases such as hypertension and ischemic heart disease (WHO, 2018).

C. ENVIRONMENTAL IMPACTS OF POOR AIR QUALITY

The environs is also at loss due to poor air quality, some of the impacts includes acid rain and soil degradation, pollutants like sulfur dioxide and nitrogen oxides react with atmospheric moisture to form acid rain, which damages soil, water bodies, forests, and crops (EPA, 2023). Climate change, air pollutants such as black carbon, methane, and CO_2 contribute to global warming by enhancing the greenhouse effect (UNEP, 2019). Damage to flora and fauna, polluted air harms plant tissues, reduces photosynthesis, and leads to reduced agricultural productivity. It also affects animals by contaminating food and water sources and altering habitats.

D. ENVIRONMENTAL IMPACTS OF EXCESSIVE NOISE

This includes disruption of wildlife, noise pollution interferes with animal communication, mating, and navigation, especially in birds and marine life. It causes habitat displacement and reduced reproductive success (Slabbekoorn & Ripmeester, 2008). Ecosystem imbalance prolonged noise exposure in natural settings can lead to reduced species diversity and altered predator-prey relationships, affecting ecological balance.

2.2 AIR POLLUTION IN SAWMILLS

2.2.1 SOURCES OF AIR POLLUTANTS

Sawmills are a significant source of air pollution, especially in regions where environmental regulations are weak or poorly enforced. The main air pollutants emitted from sawmill operations include particulate matter, volatile organic compounds (VOCs), carbon monoxide (CO), and other hazardous gases, all of which are harmful to both human health and the environment. These pollutants originate from various activities throughout the wood processing cycle, including cutting, drying, and burning of wood residues.

One of the primary sources of air pollutants in sawmills is wood dust generated during sawing, planing, sanding, and trimming operations. This fine particulate matter becomes airborne easily and can linger in the atmosphere, contributing to poor air quality in and around the mill. When inhaled, wood dust poses significant respiratory risks to workers and nearby residents, potentially causing asthma, chronic bronchitis, or even cancer with long-term exposure (WHO, 2021).

Another major source of air pollution is the use of combustion-powered equipment and backup diesel generators. These machines emit carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur dioxide (SO_2), especially when operated in confined or poorly ventilated areas. Additionally, open burning of sawmill waste such as sawdust, wood shavings, and bark—a common practice in some parts of Nigeria—produces harmful pollutants including poly cyclic aromatic hydrocarbons (PAHs) and VOCs, which are known to affect both respiratory health and atmospheric chemistry.

Sawmills may also release pollutants during the kiln drying process, where heat is applied to remove moisture from timber. If fossil fuels are used to generate the heat, emissions from combustion—especially if unfiltered—can contribute significantly to air pollution. Furthermore, chemical treatments applied to wood, such as preservatives and adhesives, may emit VOCs during processing and storage, especially in facilities lacking adequate ventilation.

2.2.2 HEALTH EFFECTS ON WORKERS AND NEARBY RESIDENTS

For sawmill workers, inhalation of fine wood dust is a daily hazard. Prolonged exposure to airborne dust particles can lead to chronic respiratory conditions such as bronchitis, asthma, and allergic reactions. In more severe cases, it may cause occupational lung diseases, including pulmonary fibrosis and nasal or lung cancer, especially if hardwoods are being processed. Workers operating without proper respiratory protection or in poorly ventilated environments are at a much higher risk (WHO, 2021).

Nearby residents are also vulnerable, particularly in densely populated areas where sawmills operate close to homes and schools. When wood dust and combustion emissions are released into the surrounding air, they contribute to ambient air pollution that affects the broader community. Children, the elderly, and people with preexisting conditions are especially at risk of asthma attacks, cardiovascular complications, and reduced lung function due to long-term exposure. Fine particulate matter (PM2.5), which can penetrate deep into the lungs and even enter the bloodstream, is strongly associated with heart disease, stroke, and premature death (Brook et al., 2010).

Furthermore, the open burning of sawmill waste releases harmful gases and volatile compounds, which contribute to eye irritation, headaches, fatigue, and, in some cases, neurological issues. When these pollutants accumulate in the air without proper control, they not only threaten health but also degrade the overall quality of life in the affected area.

2.3 NOISE POLLUTION IN SAWMILS

2.3.1 SOURCES OF NOISE

Sawmills, which process raw logs into usable timber products, are significant sources of industrial noise pollution. The various machines and mechanical processes used in wood processing generate continuous, high-intensity sounds that pose health risks to workers and contribute to environmental noise in nearby communities.

1. Sawing Equipment: Circular saws, band saws, and gang saws are primary contributors to noise in sawmills. These machines produce high-frequency, high-decibel sounds during the cutting process, especially when operated at high speeds or with dull blades (Singh & Davar, 2004).
2. Debarking and Chipping Machines: They create impulsive, loud noises as they strip bark and break down logs into chips. The intensity of noise depends on the size and moisture content of the wood and the machine's operating speed.
3. Material Handling Systems: Conveyors, feed rollers, and mechanical sorters used to move logs and timber produce constant rumbling and clanking sounds, particularly when loaded heavily or lacking proper maintenance.

4. Planers and Sanders: These machines, used for smoothing and finishing wood surfaces, generate high-pitched grinding and humming sounds, often continuously throughout the workday.
5. Auxiliary Equipment: Other sources include forklifts, compressors, dust extraction systems, and ventilation fans, which add to the overall noise levels in the working environment.

2.3.2 HEALTH AND SOCIAL IMPACTS

Sawmills are among the noisiest industrial workplaces due to the continuous operation of high-powered machinery like saws, chippers, and conveyors. Prolonged exposure to such noise not only affects the physical health of workers but also leads to broader social and psychological consequences for individuals living near these facilities.

1. Health Impacts

a. Hearing Loss: Continuous exposure to noise levels above 85 decibels (dB), common in sawmills, can lead to Noise-Induced Hearing Loss (NIHL). This damage is often irreversible and can occur gradually without noticeable symptoms at first (Basner et al., 2014).

b. Sleep Disturbance: Workers and nearby residents often experience sleep disruptions due to constant industrial noise, especially when sawmill operations run into the night. Poor sleep quality can lead to fatigue, irritability, and reduced cognitive performance.

c. Cardiovascular Issues: Chronic noise exposure has been linked to elevated stress hormones, which increase the risk of high blood pressure, heart disease, and stroke (WHO, 2018).

d. Psychological Stress and Anxiety: Sustained loud environments can cause mental fatigue, anxiety, and irritability, impacting both workplace productivity and emotional well-being.

2. Social Impacts

a. Reduced Quality of Life: Noise pollution from sawmills can make daily life uncomfortable for nearby residents. Constant noise interferes with rest, communication, and recreational activities, reducing overall life satisfaction.

b. Decreased Work Efficiency: Excessive noise impairs concentration and focus, leading to reduced productivity and increased workplace accidents in sawmill settings (Singh & Davar, 2004).

c. Community Conflicts: Persistent industrial noise often leads to tensions between sawmill operators and surrounding communities, particularly when operations violate acceptable noise thresholds.

d. Social Isolation: Individuals with noise-induced hearing loss may experience difficulty in social interaction, leading to withdrawal and social isolation over time.

2.4 MONITORING AND ASSESSMENT TECHNIQUES

2.4.1 AIR QUALITY MONITORING METHODS

Air quality monitoring in sawmills is essential for assessing the level of pollutants generated during wood processing activities and for protecting the health of workers and surrounding communities. Given the volume of particulate matter, wood dust, and gaseous emissions produced by sawmill operations, proper monitoring ensures compliance with environmental regulations and guides the implementation of control measures. Several methods are used to track and evaluate air pollutants in these settings, ranging from manual sampling to advanced, real-time electronic systems.

One of the most common methods used in sawmills is particulate matter (PM) monitoring, which involves measuring airborne dust levels—especially PM_{10} and $PM_{2.5}$. These are fine particles that can penetrate deep into the lungs and cause respiratory issues. Devices such as gravimetric samplers, optical particle counters, and real-time aerosol monitors are often employed to measure dust concentration in and around sawmill environments. Gravimetric methods involve collecting airborne particles on a filter over time, which is then weighed in a lab to determine dust concentration. Though accurate, this method is time-consuming and does not provide real-time data.

Gas analyzers are used to detect and measure harmful gases such as carbon monoxide (CO), nitrogen oxides (NO_x), and volatile organic compounds (VOCs) that may be emitted from generators, kilns, or burning of sawmill waste. These devices typically use electrochemical sensors, infrared spectroscopy, or photo-ionization detectors (PID) to quantify gas concentrations. Continuous Emission Monitoring Systems (CEMS) can also be installed on stacks or exhausts to provide real-time data on pollutant emissions, enabling immediate response if levels exceed safety limits.

In some sawmills, ambient air monitoring stations are set up near the facility to assess the impact of emissions on the surrounding environment. These stations use integrated systems to simultaneously track multiple pollutants and weather conditions such as wind speed and direction, which help model the dispersion of pollutants. Portable air quality monitors are also useful for conducting site-specific assessments, especially in remote or small-scale sawmills.

2.4.2 NOISE MEASUREMENT TECHNIQUES

Accurately measuring noise levels in sawmills is essential for assessing occupational exposure, identifying health risks, and implementing effective noise control measures. Sawmills typically operate with machinery that generates high-intensity, continuous, and sometimes impulsive noise, making proper measurement critical for compliance with workplace safety regulations.

1. Sound Level Meter (SLM): A Sound Level Meter is a handheld device used to measure instantaneous sound pressure levels in decibels (dB). It is suitable for identifying high-noise areas within a sawmill.
2. Integrating-Averaging Sound Level Meter (Leq Meter): This device measures the equivalent continuous sound level (Leq) over a given period. It helps determine the average noise exposure in a sawmill over an 8-hour shift.
3. Dosimeter (Personal Noise Dosimeter): A dosimeter is a wearable device that measures the total noise exposure experienced by an individual throughout their workday.
4. Octave Band Analyzer: This instrument divides the noise into octave frequency bands to identify the specific frequency ranges most responsible for excessive noise.
5. Smartphone-Based Noise Apps (Supplementary Use): While not recommended for regulatory or industrial compliance, some mobile apps with calibrated microphones can be used for preliminary assessments or community awareness.

2.5 MITIGATION AND CONTROL MEASURES

2.5.1 FOR AIR POLLUTION

Sawmills contribute to air pollution primarily through the release of wood dust, particulate matter, and emissions from diesel-powered machinery and generators. To mitigate this pollution, a combination of engineering controls, administrative strategies, and environmental regulations must be implemented. One of the most effective engineering controls is the installation of dust extraction and filtration systems. These systems, including cyclone separators, bag house filters, and electrostatic precipitants, help capture fine wood particles and prevent them from being released into the air.

Regular maintenance of this equipment ensures efficiency and compliance with air quality standards.

Another major source of air pollution in sawmills is the use of combustion engines and backup generators that emit carbon monoxide (CO), nitrogen oxides (NO_x), and not burned hydrocarbons. Replacing or retrofitting outdated engines with cleaner, fuel-efficient models or transitioning to renewable energy sources such as solar-powered systems can significantly reduce emissions.

In addition, installing stack emissions monitors helps track pollutant levels and ensures that emissions stay within permitted limits.

Administrative controls, such as establishing clear operational protocols for minimizing dust generation and providing proper ventilation in enclosed spaces, are also vital. Sawmills should implement scheduled maintenance routines to avoid emissions caused by equipment malfunction or wear. Enclosing high-dust activities and separating them from areas with human occupancy can reduce workers' exposure. Ensuring that personal protective equipment (PPE) like dust masks or respirators is used by workers further reduces health risks from airborne particulates.

Good waste management is also critical. Open burning of wood scraps and sawdust should be avoided as it releases harmful smoke and volatile organic compounds (VOCs). Instead, sawmills can adopt eco-friendly disposal methods such as composting, briquette production, or using sawdust as raw material for other wood-based products. Establishing green buffer zones—such as planting trees around the sawmill—can also act as natural air filters and improve the surrounding air quality.

2.5.2 FOR NOISE POLLUTION:

Sawmills are characterized by high levels of noise pollution generated by heavy machinery such as saws, chippers, conveyors, and planers. Continuous exposure to such noise poses significant health risks to workers, including hearing loss, stress, fatigue, and decreased productivity. Therefore, implementing effective mitigation and control measures is essential to protect both workers and nearby residents.

One of the most effective ways to manage noise in sawmills is through engineering controls. This includes installing noise enclosures or acoustic barriers around high-noise machinery to absorb or block sound. The use of vibration dampening materials and machine mounts can reduce the transmission of mechanical noise to the surrounding environment. Additionally, switching to modern, low-noise machinery or properly maintaining older equipment helps lower the overall noise output. Regular lubrication and replacement of worn parts also prevent noise from increasing due to mechanical wear and tear.

Administrative controls play a key role in noise mitigation as well. These include scheduling noisy tasks during designated times and limiting the duration of exposure for workers by rotating tasks. Establishing "quiet zones" and locating high-noise equipment away from offices, rest areas, or residential boundaries can significantly reduce exposure. Furthermore, conducting regular noise level assessments using sound level meters or personal dosimeters helps monitor noise exposure and ensure compliance with occupational safety regulations.

The use of Personal Protective Equipment (PPE) is another critical layer of protection. Workers in noisy environments should be provided with earplugs or earmuffs that meet approved safety standards. Providing training on the correct use and maintenance of hearing protection devices is necessary to ensure their effectiveness. Implementing a Hearing Conservation Program is also recommended, which includes baseline hearing tests, periodic monitoring, and awareness education.

In addition to internal controls, environmental planning can further help reduce the impact of noise on nearby communities. Planting trees or installing sound barriers along the perimeter of the sawmill can help absorb and deflect noise away from residential areas. Limiting sawmill operations during night hours and ensuring compliance with local noise ordinances can reduce community complaints and improve relations with surrounding populations.

2.6 ENVIRONMENTAL AND ECONOMIC IMPACTS

2.6.1 EFFECT OF SAWMILL POLLUTION ON NEARBY ECOSYSTEMS IN NIGERIA

Sawmill operations in Nigeria, especially in urban and peril-urban areas, contribute significantly to environmental degradation. These facilities emit various pollutants, including wood dust, particulate matter, noise, and waste by-products, which affect nearby land, water, and biological systems. The cumulative impact of these pollutants poses a serious threat to the integrity of local ecosystems, biodiversity, and the health of surrounding communities.

One of the primary ecological effects of sawmill pollution is soil degradation. Wood dust and residues often accumulate around sawmills due to poor waste disposal practices. These residues alter the pH and nutrient balance of the soil, affecting its fertility and the growth of native plants. In cases where sawdust piles are burned, the release of toxic gases and ash further contaminates the soil, making it uninhabitable for beneficial microorganisms and plant species.

Sawmill runoff and improper waste disposal can also impact aquatic ecosystems. During rainfall, sawdust, chemicals (e.g., lubricants, fuel), and fine particles are washed into nearby streams, rivers, or drainage channels. This results in sedimentation, which clogs waterways, reduces oxygen levels, and disrupts aquatic life. In Nigeria, where many sawmills operate near wetlands and water bodies, this runoff contributes to the decline of fish populations and the overall ecological balance of freshwater habitats (Olorunfemi & Odipe, 2017).

Air pollution from sawmills, particularly through the open burning of wood scraps and the operation of diesel-powered machinery, leads to the release of harmful pollutants like carbon monoxide, sulfur dioxide, and fine particulates. These pollutants not only degrade local air quality but also affect photosynthetic activity in surrounding vegetation. Prolonged exposure can cause leaf discoloration, stunted growth, or even the death of sensitive plant species, resulting in reduced forest cover and biodiversity around sawmill zones.

In addition to air and water contamination, noise pollution from sawmill machinery disrupts wildlife behavior. Loud, constant noise interferes with the communication, mating, and feeding patterns of birds and small mammals, often driving them away from their natural habitats. This leads to a loss of species diversity and affects the ecological equilibrium of these areas.

Overall, the unregulated operation of sawmills in Nigeria poses significant risks to nearby ecosystems. The combined effects of air, water, noise, and soil pollution reduce biodiversity, alter natural processes, and degrade the quality of the environment. Implementing sustainable sawmill practices, such as proper waste management, pollution control technology, and environmental monitoring, is essential to preserve the surrounding ecosystems and maintain ecological balance.

2.6.2 ECONOMIC COSTS OF POLLUTION-RELATED HEALTH ISSUES IN NIGERIA

Pollution-related health issues in Nigeria come at a significant economic cost, affecting individuals, families, businesses, and the national economy. Air and water pollution, poor waste management, industrial emissions, and indoor smoke exposure from biomass fuel use are major contributors to the nation’s health burden. These environmental hazards increase the incidence of respiratory infections, cardiovascular diseases, cancers, and waterborne illnesses, placing intense pressure on the country's already underfunded healthcare system.

The direct health costs of pollution include increased spending on medical treatment, hospitalization, medication, and diagnostic tests. For example, respiratory diseases triggered by air pollution—such as asthma, chronic bronchitis, and lung infections—require frequent clinic visits and long-term care, especially for vulnerable populations like children and the elderly. These costs are often borne out-of-pocket by families, many of whom live below the poverty line. According to the World Bank, the total annual welfare losses from ambient air pollution in Nigeria were estimated at over $2.1 billion USD as of 2016, accounting for about 0.6% of the country’s GDP (World Bank, 2021).

In addition to medical expenses, indirect economic losses stem from lost productivity due to illness or premature death. Workers affected by pollution-related diseases often miss work or become less efficient, leading to income loss and reduced output for businesses. When breadwinners fall ill or die early, entire households can slip into deeper poverty, increasing the dependency ratio and slowing economic development. In sectors like agriculture and informal markets, where labor is intensive and health services are limited, these productivity losses are particularly damaging.

The burden on public health infrastructure also adds to national costs. Treating pollution-related diseases diverts government funds from other pressing sectors like education, infrastructure, and clean energy. Urban centers like Lagos, Port Harcourt, and Kano face growing health challenges due to vehicle emissions, industrial pollution, and poor waste management, yet health systems remain under-equipped to handle the rising number of pollution-related cases.

Moreover, there are long-term opportunity costs associated with pollution-related health impacts. Children exposed to air pollution during early development are at risk of reduced cognitive function and educational attainment, which diminishes their future economic potential. In the long run, this contributes to a cycle of low human capital development and reduced national productivity.

2.7 REVIEW OF PREVIOUS WORKS

Ezeh, Ezeh and Obinna (2015) conducted a study in Abakaliki, Nigeria, to evaluate particulate matter emissions around sawmill areas. Methodologically, they used high-volume air samplers to measure concentrations of PM_{10} and $PM_{2.5}$ at sawmill sites and control locations. Results showed that PM concentrations in sawmill zones were significantly higher (PM_{10}: 312 µg/m^3; $PM_{2.5}$: 225 µg/m^3) compared to control sites (PM_{10}: 92 µg/m^3; $PM_{2.5}$: 64 µg/m^3). The study concluded that wood dust and emissions from burning of waste wood are major contributors to poor air quality. Recommendations included improved waste management and the use of dust extractors in milling processes.

Okedere, Adewole and Adedeji (2017) assessed gaseous pollutants such as CO, SO_2, and NO_2 in the vicinity of sawmills in Ibadan. Using a calibrated portable gas analyzer, they took air samples at 10 m intervals from the sawmill. Results indicated CO levels reaching up to 29 ppm, which exceeds WHO permissible limits. They concluded that the use of diesel-powered machines and combustion of waste were key pollution sources. Recommendations included promoting the use of cleaner energy sources and regular air monitoring.

Oguntoke, Ojelede and Annegarn (2013) used the US EPA Air Quality Index model to assess health risks of $PM_{2.5}$ in Ilorin sawmill clusters. Their method involved daily sampling using portable particulate monitors over a 30-day period. Findings revealed $PM_{2.5}$ concentrations often exceeded 250 $\mu g/m^3$, categorized as "very unhealthy". The study concluded that exposure posed serious respiratory health risks. They recommended relocating sawmills away from residential areas and enforcing air pollution control laws.

Awoyemi and Ipeaiyeda (2016) evaluated noise levels in selected sawmills in Ilorin using a digital sound level meter. Measurements were taken at 10 m distances in all directions during work hours. Results showed noise levels ranged from 82 dB to 98 dB, significantly higher than WHO's 70 dB threshold for occupational noise. They concluded that workers were at risk of hearing damage and stress-related disorders. The study recommended the provision of personal protective equipment (PPE) like earplugs and training on occupational health hazards.

Adewoyin, Ogunbanwo and Lawal (2020) conducted a similar study in Lagos State, using continuous noise monitoring over 8-hour work periods. Their findings indicated peak noise levels at 104 dB, especially near generators and saw blades. Conclusions highlighted the absence of regulatory enforcement and health monitoring in these facilities. They recommended zoning policies to separate sawmills from residential areas, installation of noise barriers, and mandatory health checks for workers.

Adesina, Akinpelu and Oladipo (2019) conducted a community-based health survey around sawmill areas in southwestern Nigeria. Using questionnaires and spirometry tests, they assessed respiratory health among 150 residents. Findings showed increased prevalence of symptoms such as coughing (65%), wheezing (42%), and shortness of breath (38%). Lung function tests revealed reduced FEV_1 values among residents within 500 m of sawmills. The study concluded that prolonged exposure to air and noise pollution from sawmills contributes to deteriorating respiratory health. Recommendations included awareness campaigns, regular medical screening, and improved environmental policies.

Ugbebor and Ogundipe (2011) carried out an integrated environmental assessment of sawmill operations in Lagos, combining air quality sampling, noise monitoring, and socio-environmental surveys. They used portable air quality monitors to measure CO, SO_2, and PM levels, and used digital sound level meters at peak operation hours. In addition, structured questionnaires were administered to workers and local residents.

Results showed CO levels up to 35 ppm and PM_{10} levels of 300 µg/m³, which are significantly higher than the acceptable limits by the Federal Ministry of

Environment and WHO. Noise levels ranged from 85 dB to 105 dB during machine operations. The study concluded that both workers and nearby residents are consistently exposed to harmful environmental stressors. Recommendations included health surveillance programs, proper zoning laws, and the introduction of green buffer zones to minimize pollutant dispersion.

Onuorah et al. (2020) studied seasonal variations in air quality and noise levels around sawmill sites in Enugu. Their method involved conducting measurements in both dry and wet seasons using calibrated devices. Gaseous pollutants (CO, NO_2, and SO_2) and particulate matter were measured alongside noise levels at 15 different points around sawmills. Findings indicated higher concentrations of pollutants and noise levels during the dry season. PM_{10} reached 320 µg/m³ during the dry season compared to 180 µg/m³ during the wet season, while average noise levels remained above 90 dB in both periods. The study concluded that environmental conditions and climatic factors influence pollution intensity, and mitigation strategies must be tailored seasonally.

Recommendations included intensified monitoring during high-risk seasons and installation of real-time pollution sensors.

Oluwaseun and Ayoade (2014) investigated occupational exposure of sawmill workers to pollutants in Akure, Nigeria. Using personal air sampling devices and audio-metric testing, they evaluated dust exposure levels and hearing loss in 75 workers over a 6-month period. Results revealed that over 60% of the workers were exposed to dust concentrations exceeding 250 $\mu g/m^3$ and 48% had varying degrees of hearing impairment. The study concluded that lack of protective gear and poor workplace design contributed to significant occupational health risks. Recommendations focused on mandatory use of PPE, routine health screenings, and workplace redesign to reduce direct exposure.

CHAPTER THREE

METHODOLOGY

3.1 STUDY AREA

Benin City, Edo State, Nigeria, is a major hub for timber processing, with numerous sawmills located in areas such as Ikpoba-Hill, Ekenwan Road, and Ugbowo. These sawmills operate near residential and commercial zones, making them suitable for assessing air and noise pollution impacts. It has a geographical location of Latitude 6.3350° N and Longitude 5.6037° E

3.1.1 INDUSTRIAL ACTIVITIES (SAWMILLS IN BENIN)

Benin city has multiple sawmills and wood workshops that engage in timber processing. Common activities includes Log cutting, sawing, wood sanding, and burning of sawdust, which contributes to air and noise pollution. Other pollution sources: Traffic from trucks transporting timber, generators, and commercial activities.

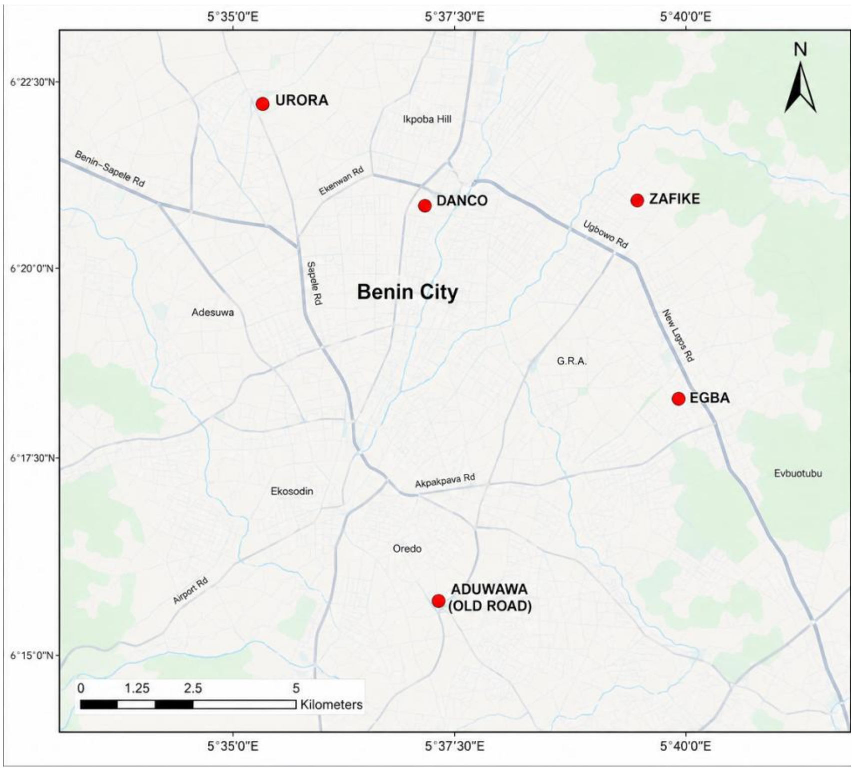

FIGURE 3.1: Map of the study area

3.2 MATERIALS AND EQUIPMENTS

The study utilized the following equipment and tools:

1. Portable multi Air Quality Monitors for measuring $PM_{2.5}$, PM_{10}, NO_2, CO, and SO_2.
2. Noise Level Meters (Extech 407730) for measuring sound levels in dB.
3. GPS Device to accurately record sampling locations.
4. Data Recording Sheets and Logbooks for field entries.
5. Protective Gear such as safety boots, helmets, and masks for safety compliance on site.

3.3 SAMPLING TECHNIQUES

The sampling process involved systematic monitoring at each sawmill during different time of the day. This schedule helped capture variations in air and noise pollution based on work intensity and environmental conditions.

Air quality samples was collected at multiple points across the sawmill, especially near machinery operation zones

Noise levels was measured at 1.5 meters above ground level, using standardized sound meters, with a 10-minute recording at each location. Background noise levels was also be recorded in an area far from the sawmill for comparison.

3.4 AIR QUALITY TEST

Ambient air quality refers to the physical and chemical characteristics of outdoor air in our surrounding environment. It represents a critical indicator of environmental health, directly impacting ecosystems, climate patterns, and human well being. The assessment of ambient air involves systematic monitoring of various atmospheric constituents to determine compliance with established air quality standards and identify potential pollution sources.

Air pollution represents one of the most pressing environmental concerns of our era, characterized by the introduction of harmful substances into Earth's atmosphere. These contaminants alter atmospheric composition, creating adverse effects on human health, ecosystems, and climate systems. The complexity of air pollution stems from its diverse sources, varying chemical compositions, and wide-ranging spatial-temporal distribution patterns.

1. Parameters Measured

I tested for six critical air quality indicators:

TABLE 3.1: AIR QUALITY INDICATORS

PARAMETER	MEASUREMENT METHOD	EQUIPMENT USED	UNITS	WHO GUIDELINE
$PM_{2.5}$	Laser scattering	Aeroqual 500	µg/m³	25 (24-hr avg)
PM_{10}	Beta attenuation	TSI DustTrak	µg/m³	50 (24-hr avg)
NO_2	Electrochemical	AQY v1.2	ppm	0.106 (1-hr)
CO	NDIR sensor	CO-BTA	ppm	9 (8-hr avg)
O_3	UV absorption	O_3-3E-1	ppm	0.05 (8-hr)
Noise	A-weighted SLM	Extech 407780	dB(A)	55 (daytime)

An air quailty monitor is a device used for measuring and analyzing pollutants in ambient air at high accuracy and thus it was used for this study

Figure 3.2: Air quality monitor

3.5 NOISE LEVEL TEST

Noise level testing is essential for assessing environmental and occupational sound exposure to ensure compliance with health and safety regulations.

1. Measurement Instruments

Noise levels are measured using a sound level meter (SLM) or noise dosimeter, which quantify sound pressure levels in decibels (dB) (Occupational Safety and Health Administration [OSHA], 2023). Proper calibration according to IEC 61672 standards is required for accuracy (International Electrotechnical Commission [IEC], 2013).

2. Testing Procedures

a. Environmental Noise Assessment

i. Measurements should be taken at 1.5 meters above ground and 1-3 meters from noise sources (World Health Organization [WHO], 2018).

ii. A weighting (dBA) is used to reflect human hearing sensitivity (Environmental Protection Agency [EPA], 2022).

b. Occupational Noise Testing

i. OSHA (2023) mandates 8-hour time-weighted averages (TWA) for workplace noise.

ii. If levels exceed 85 dBA, employers must implement hearing protection programs (National Institute for Occupational Safety and Health [NIOSH], 2021).

3. Acceptable Noise Levels

TABLE 3.2: ACCEPTABLE NOISE LEVELS

SETTING	DAYTIME LIMIT (DBA)	NIGHTTIME LIMIT (DBA)	REFERENCE
Residential Areas	≤ 55	≤ 45	WHO (2018)
Commercial Areas	≤ 65	≤ 55	EPA (2022)
Industrial Workplaces	≤ 85 (8-hr TWA)	-	OSHA (2023)

A. AMBIENT NOISE LEVEL TESTING STANDARDS

Ambient noise level testing measures background sound in an environment to assess compliance with health, safety, and environmental regulations. Standards vary by region but generally follow guidelines from the World Health Organization (WHO), Environmental Protection Agency (EPA), and International Organization for Standardization (ISO).

B. Key Standards for Ambient Noise Testing

1. Measurement Instruments

a. Sound Level Meter (SLM): Must meet IEC 61672 Class 1 or 2 for precision.

b. Noise Dosimeters: Used for long-term exposure monitoring.

2. Measurement Procedures

a. General Ambient Noise Assessment (ISO 1996)

i. Measurement Duration: Minimum 15 minutes per location.

ii. Height: 1.2–1.5 meters above ground (approximates human ear level).

iii. Distance from Reflective Surfaces: At least 3.5 meters to avoid echo distortion.

iv. Weather Conditions: Avoid high winds (>5 m/s) and precipitation.

b. Time-Weighted Measurements

i. LAeq (Equivalent Continuous Noise Level): Average noise over time.

ii. Lden (Day-Evening-Night Noise Indicator): Used in the EU for 24-hour noise assessment.

TABLE 3.3: ACCEPTABLE NOISE LEVELS (WHO AND EPA GUIDELINES)

LAND USE CATEGORY	DAYTIME (DBA)	NIGHTTIME (DBA)
Residential Areas	≤55	≤45
Commercial Zones	≤65	≤55
Industrial Areas	≤75	≤65
Hospital/School Zones	≤50	≤40

Source: WHO, 2018; EPA, 2022

3. Regulatory Compliance

a. United States (EPA & OSHA)

i. EPA: Recommends ≤55 dBA (residential) to prevent annoyance.

ii. OSHA: Sets 85 dBA (8-hour TWA) as the workplace exposure limit.

b. European Union (EU Directive 2002/49/EC)

i. Requires noise mapping in cities with >250,000 residents.

ii. Lnight (Night Noise) Limit: ≤40 dBA for sleep protection.

c. India (CPCB Standards)

i. Residential Areas: 55 dBA (day) / 45 dBA (night).

ii. Silence Zones (near hospitals/schools): 50 dBA (day) / 40 dBA (night).

3.6 SOUND LEVEL METER

A sound level meter (SLM) is an electronic device used to measure sound pressure levels in decibels (dB). It is essential for Environmental noise monitoring, Occupational safety assessments, Industrial noise control, Community noise studies.

Figure 3.3: Sound Level Meter

CONDITIONS FOR MEASURING NOISE ACCORDING TO ISO STANDARDS

a. Sound Level Meter (SLM) must comply with IEC 61672-1 (Class 1 or 2)

b. -Field calibration before/after measurements using a Class 1 acoustic calibrator (e.g., 94 dB at 1 kHz)

c. Microphone Type: Free-field or random-incidence condenser microphone

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 OVERVIEW OF RESULTS

This chapter presents and analyzes the results obtained from field measurements conducted at five selected sawmill locations in Benin City: Urora, Danco, Zafike, Egba, and Aduwawa (Old Road). The assessment covered air quality parameters, meteorological conditions, and environmental noise levels.

To ensure clarity and ease of comparison, the mean values of the measured pollutants and environmental indicators are presented in Table 4.1. The results are further interpreted in relation to World Health Organization (WHO) guidelines and other relevant environmental standards.

TABLE 4.1: MEAN LEVEL OF AIR POLLUTANTS, NOISE POLLUTANTS AND METEROLOGICAL PARAMETERS MEASURED AT THE STUDY AREA(SAWMILLS)

LOCATION	**TEMP (℃)**	**HUM(%)**	**PM 2.5 (ug/m^3)**	**PM 10**	**HCHO (mg/m^3)**	**TVOC (mg/m^3)**
URORA	27.6	75	41	46.5	0.002	0.007
DANCO	28	81	37	46	0.004	0.007
ZAFIKE	31.8	84	43	68.5	0.005	0.008
EGBA	40.2	80	33	58	0.011	0.015
ADUWAWA(OLD ROAD)	41.5	74	24	47	0.009	0.012

LOCATION	NOISE(DB)	OZONE(PPM)	NNI	CO_2 (PPM)	AQI
URORA	73.85	0.03	53	460	ORANGE(115)
DANCO	68.35	0.02	41	423	ORANGE(105)
ZAFIKE	72.2	0.08	76	439	ORANGE(119)
EGBA	70.25	0.03	49	482	YELLOW(95)
ADUWAWA (OLD ROAD)	74.8	0.01	44	408	YELLOW(76)

4.2 AIR QUALITY ASSESSMENT

4.2.1 PARTICULATE MATTER ($PM_{2.5}$ AND PM_{10})

Particulate matter remains one of the most critical indicators of air pollution in industrial environments, especially in sawmills where wood processing generates significant dust emissions.

The measured concentrations of $PM_{2.5}$ across the five locations ranged from 24 µg/m³ to 43 µg/m³. The highest concentration (43 µg/m³) was recorded at Zafike, while the lowest value (24 µg/m³) was observed at Aduwawa (Old Road). When compared to the WHO 24-hour guideline value of 25 µg/m³, it is evident that most locations exceeded the recommended limit, indicating unhealthy air conditions for sensitive groups.

Similarly, PM_{10} concentrations ranged between 46 µg/m³ and 68.5 µg/m³, with Zafike again recording the highest value (68.5 µg/m³). The WHO guideline limit for PM_{10} is 50 μg/m³ (24-hour average). Locations such as Zafike and Egba exceeded this threshold, suggesting substantial wood dust emissions and inadequate dust control mechanisms.

4.2.2 GASEOUS POLLUTANTS

The study also measured ozone (O_3), formaldehyde (HCHO), total volatile organic compounds (TVOC), and carbon dioxide (CO_2).

Ozone concentrations ranged from 0.01 ppm to 0.08 ppm, with the highest level recorded at Zafike. While some values remained within acceptable limits, the peak ozone concentration approached levels that may pose respiratory irritation risks.

Formaldehyde (HCHO) concentrations varied between 0.002 mg/m³ and 0.011 mg/m³, with Egba recording the highest level. Although these values appear relatively low, continuous exposure in poorly ventilated industrial environments may still contribute to long-term health effects.

TVOC levels ranged from 0.007 mg/m³ to 0.015 mg/m³, with Egba again recording the highest concentration. VOC emissions may originate from treated wood, fuel combustion, and machine lubricants.

Carbon dioxide (CO_2) concentrations ranged from 408 ppm to 482 ppm. Although these levels are within typical outdoor background concentrations, slightly elevated readings in some locations may indicate limited air circulation and localized combustion activities.

4.3 METEOROLOGICAL PARAMETERS

Temperature and relative humidity play an important role in pollutant dispersion and concentration.Temperatures recorded during sampling ranged from 27.6°C to 41.5°C, while relative humidity values ranged from 74% to 84%. Higher temperatures, particularly in Egba and Aduwawa, may have influenced pollutant concentration levels by enhancing atmospheric reactions and reducing vertical dispersion.

Humidity levels above 75% may also promote the suspension of fine particulate matter in the atmosphere, prolonging exposure duration.

4.4 NOISE POLLUTION ASSESSMENT

Environmental noise levels were measured using a calibrated sound level meter at a height of 1.5 meters above ground level.

Noise levels across the five sawmill locations ranged from 68.35 dB(A) to 74.8 dB(A). Aduwawa recorded the highest noise level (74.8 dB(A)), while Danco recorded the lowest (68.35 dB(A)).

The Noise Nuisance Index (NNI) results further classified some locations as experiencing elevated to high nuisance levels, particularly Zafike and Urora.

4.5 AIR QUALITY INDEX (AQI) INTERPRETATION

The Air Quality Index (AQI) values ranged from 76 to 119 across the study locations.

1. Urora, Danco, and Zafike recorded AQI values within the Orange category, indicating air quality that is unhealthy for sensitive groups.
2. Egba and Aduwawa recorded values within the Yellow category, suggesting moderate air quality conditions. These classifications indicate that individuals with respiratory conditions, children, and elderly residents may experience adverse health effects in most of the assessed location.

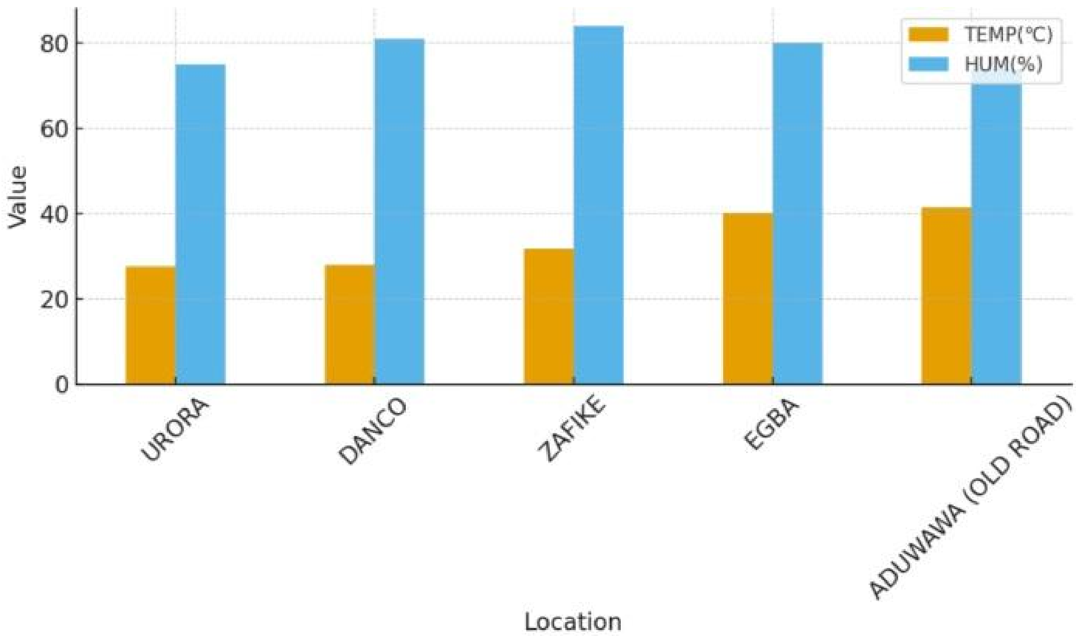

FIGURE 4.1 CHART OF TEMPERATURE AND HUMIDITY

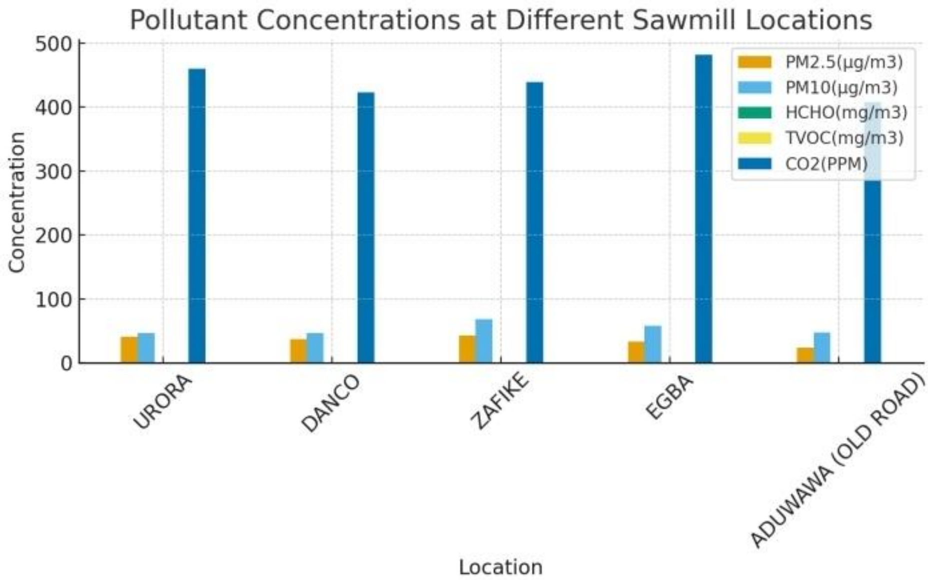

FIGURE 4.2: CHART OF THE POLLUTANTS

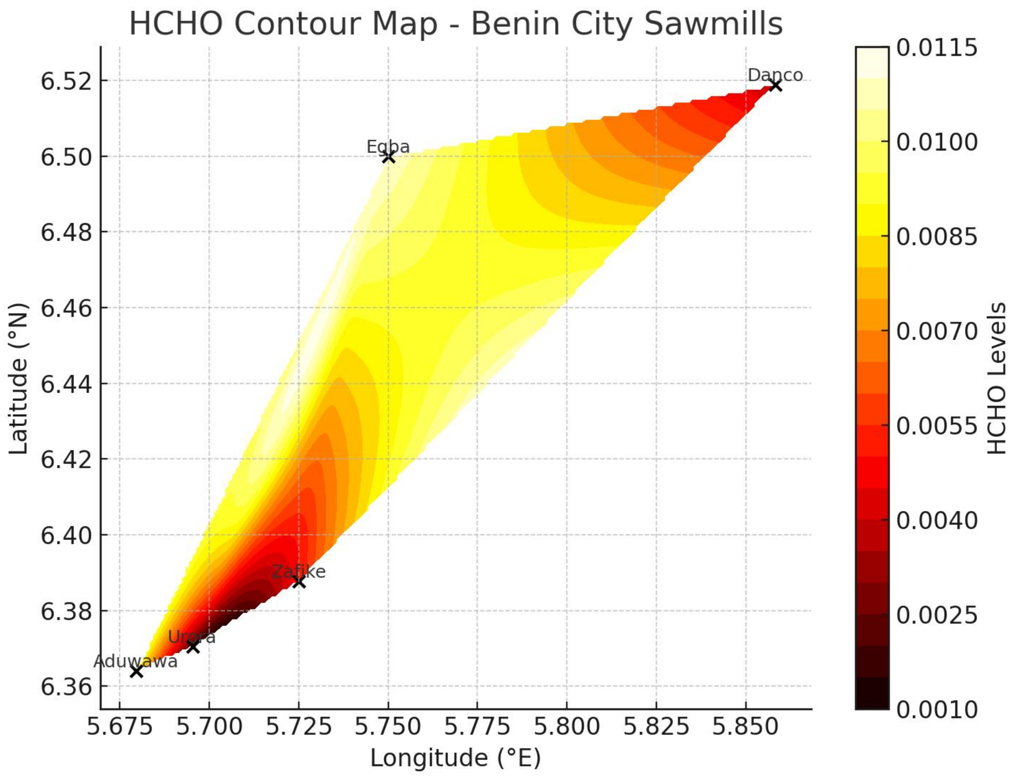

FIGURE 4.3: HCHO CONTOUR MAP

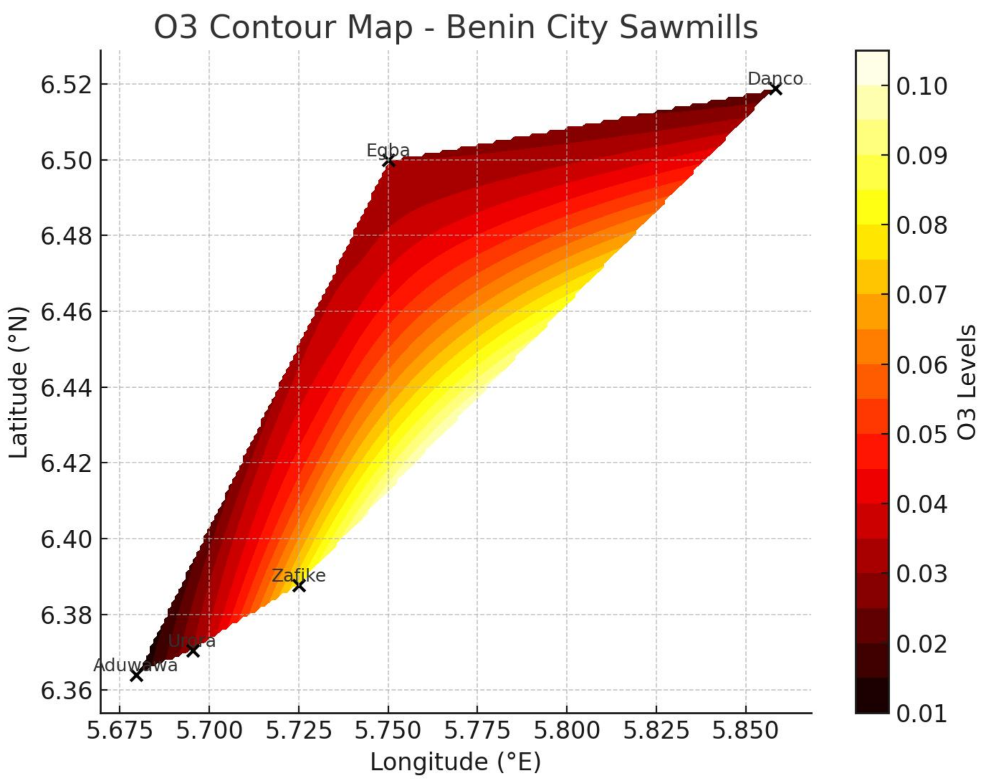

FIGURE 4.4: O_3 CONTOUR MAP

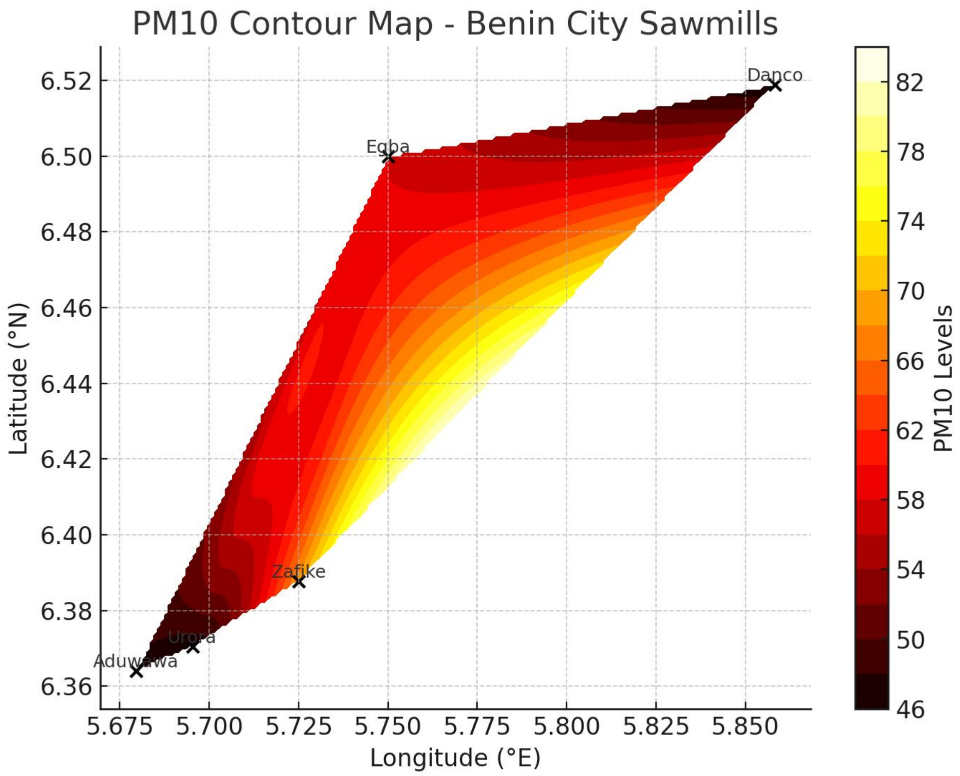

FIGURE 4.5: PM10 CONTOUR MAP

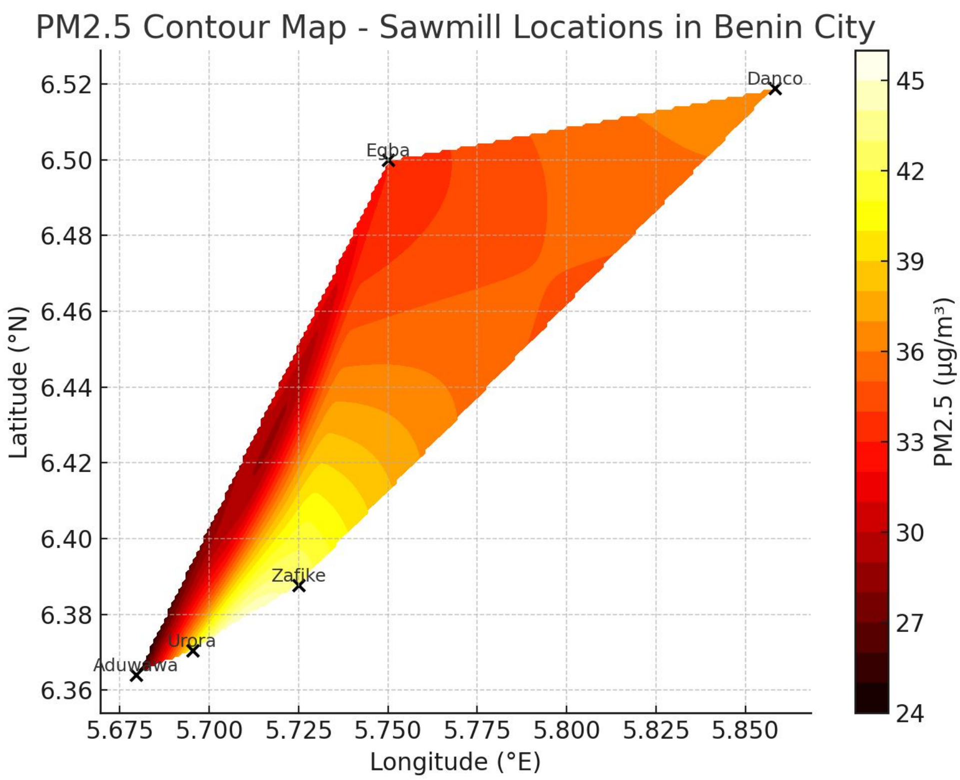

FIGURE 4.6: PM2.5 CONTOUR MAP

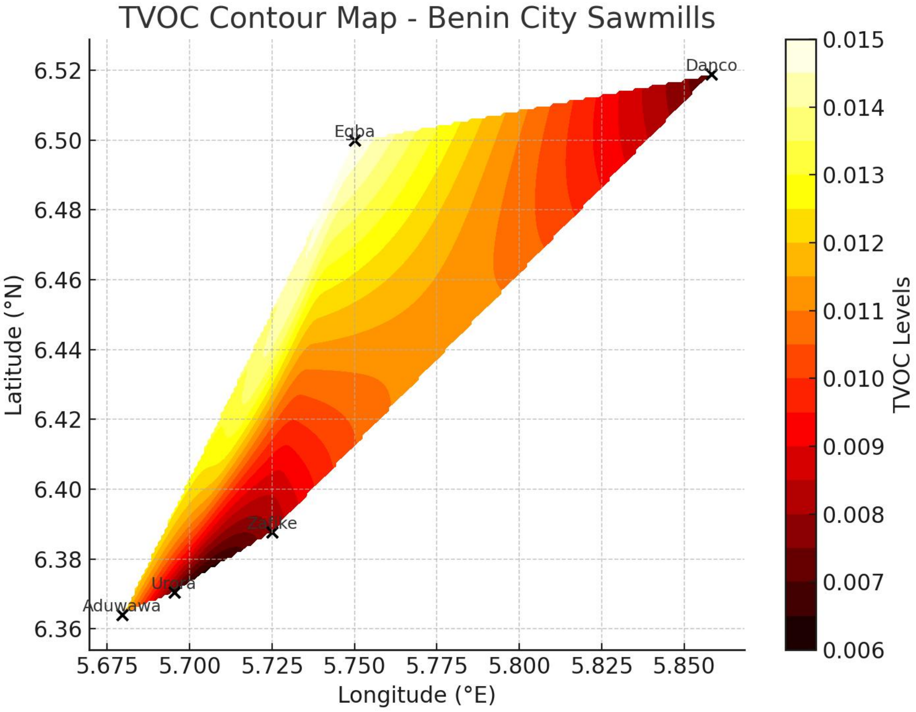

FIGURE 4.7: TVOC CONTOUR MAP

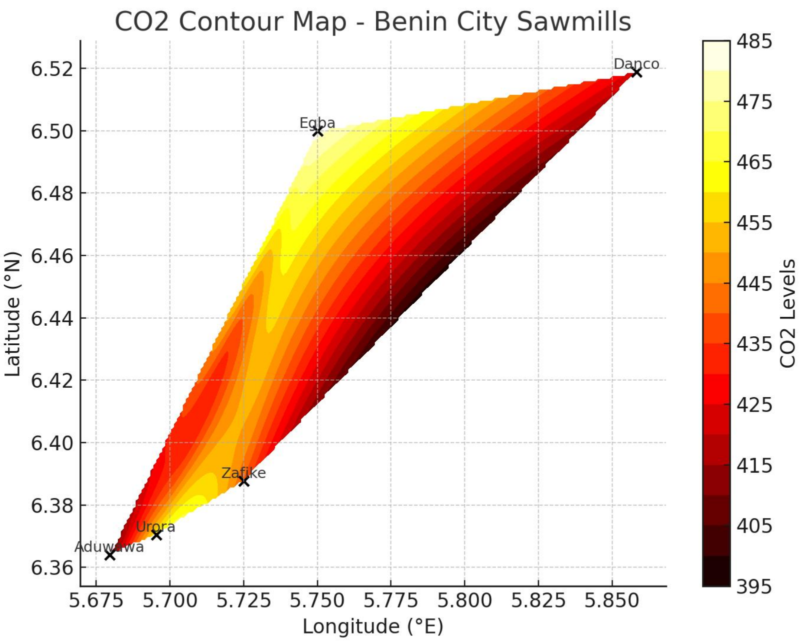

FIGURE 4.8: CO_2 CONTOUR MAP

4.6 COMPARATIVE ANALYSIS OF LOCATIONS

Among the five assessed sawmills:

1. Zafike showed the highest combined pollution burden, particularly in $PM_{2.5}$, PM_{10}, and ozone levels.
2. Urora exhibited elevated particulate and noise levels.
3. Egba recorded moderate particulate concentrations but relatively higher gaseous pollutant levels.
4. Aduwawa showed the lowest $PM_{2.5}$ concentration but recorded the highest noise level.
5. Danco demonstrated comparatively lower noise levels but still exceeded recommended air quality standards.

This variation suggests differences in operational intensity, pollution control practices, machinery condition, and surrounding environmental characteristics.

4.7 SUMMARY OF KEY FINDINGS

1. $PM_{2.5}$ ranged from 24–43 µg/m³ (mostly above WHO limit).
2. PM_{10} ranged from 46–68.5 µg/m³ (exceeded standard in several locations).
3. Noise levels ranged from 68.35–74.8 dB(A) (above residential limits).
4. AQI ranged from 76–119, indicating moderate to unhealthy air quality.
5. Zafike recorded the highest overall pollution intensity.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study assessed the levels of air and noise pollution generated from sawmill operations in selected areas of Benin City — URORA, DANCO, ZAFIKE, EGBA, and ADUWAWA (Old Road). The results indicate that most of the measured pollutants exceeded the permissible limits recommended by the World Health Organization (WHO) and the National Environmental Standards and Regulations Enforcement Agency (NESREA).

The concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) were particularly high in URORA, DANCO, and ZAFIKE, signifying a high degree of air contamination primarily caused by wood dust, combustion emissions, and poor waste handling. The Air Quality Index (AQI) for these areas ranged from 105 to 119, classified as "Unhealthy for Sensitive Groups."

The Noise Pollution Levels were also above the acceptable 70–75 dB(A) threshold, with NNI results indicating elevated nuisance conditions in most sawmills.

The findings confirm that sawmill operations significantly contribute to environmental degradation and health risks in Benin City. Workers and nearby residents are at risk of respiratory illnesses, hearing impairment, and reduced quality of life. The study also revealed that most sawmills lack proper pollution control facilities such as dust extractors, silencers, and ventilation systems, and that regulatory enforcement remains inadequate.

In conclusion, the research demonstrates the urgent need for sustainable pollution management practices in the sawmill industry. Controlling air and noise emissions will protect public health, reduce environmental damage, and promote safer industrial development in Edo State and Nigeria as a whole.

5.2 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. Installation of Pollution Control Equipment
2. Sawmills should install dust extraction units, air filters, and proper ventilation systems to reduce particulate emissions.
3. Noise barriers and acoustic enclosures should be used to minimize sound levels from machinery.
4. Regulatory Enforcement and Monitoring
5. NESREA and state environmental agencies should conduct routine inspections and enforce compliance with existing air and noise pollution laws.
6. Establish environmental monitoring units within sawmill clusters to continuously assess pollutant levels.

REFERENCES

Adesina, A., Akinpelu, A., & Oladipo, K. (2019). Community-based assessment of respiratory health around sawmill areas in southwestern Nigeria. Nigerian Journal of Environmental Health, 16(2), 33–41.

Adewoyin, A., Ogunbanwo, R., & Lawal, T. (2020). Noise level monitoring in selected Lagos sawmills. Journal of Occupational and Environmental Safety, 12(1), 45–53.

Ajayi, O., & Ajayi, T. (2020). Exposure to noise and particulate matter among sawmill workers in Nigeria: A review. African Journal of Environmental Research, 6(2), 77–85.

Awoyemi, A. O., & Ipeaiyeda, A. R. (2016). Assessment of noise pollution in sawmills in Ilorin. Journal of Environmental Science and Technology, 9(3), 199–207.

Brook, R. D., Rajagopalan, S., Pope, C. A., Brook, J. R., Bhatnagar, A., Diez-Roux, A. V., & Kaufman, J. D. (2010). Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. Circulation, 121(21), 2331–2378.

Cheng, M., Lu, Y., & Wang, Y. (2019). Industrial waste management and environmental pollution in developing countries. Environmental Monitoring and Assessment, 191(7), 419.

Environmental Protection Agency [EPA]. (2020). Guidelines for industrial air emissions. https://www.epa.gov

Environmental Protection Agency [EPA]. (2022). Noise guidelines and regulations. https://www.epa.gov

Environmental Protection Agency [EPA]. (2023). Air quality and public health overview. https://www.epa.gov

Ezeh, E., Ezeh, M., & Obinna, N. (2015). Evaluation of particulate matter in Abakaliki sawmills. Nigerian Journal of Environmental Studies, 13(4), 54–61.

Fakinle, B. S., Odekanle, E. L., & Sonibare, J. A. (2020). Air pollution impact of sawmills in developing cities. International Journal of Environmental Monitoring and Analysis, 8(1), 12–21.

International Agency for Research on Cancer [IARC]. (2018). Wood dust and formaldehyde classification. https://www.iarc.who.int

Kumar, R., Singh, V., & Shukla, A. (2019). Industrial noise and air pollution exposure in sawmill operations. Journal of Occupational Health, 61(5), 380–388.

Mukherjee, A., & Agrawal, M. (2018). Air pollution from coal-fired thermal power plants in India. Energy, Ecology and Environment, 3(1), 1–14.

NESREA. (2018). National environmental standards and regulations for wood processing industries. Federal Ministry of Environment, Nigeria.

National Institute for Occupational Safety and Health [NIOSH]. (2021). Workplace noise exposure and hearing conservation. https://www.cdc.gov/niosh

Occupational Safety and Health Administration [OSHA]. (2022). Noise and hearing protection standards. https://www.osha.gov

Occupational Safety and Health Administration [OSHA]. (2023). Noise exposure limits in industrial settings. https://www.osha.gov

Odekanle, E., Fakinle, B., & Oyesiku, O. (2021). Pollution hazards in Nigerian sawmill industries. Environmental Risk Assessment, 15(2), 105–117.

Oguntoke, O., Ojelede, M., & Annegarn, H. (2013). Health risks of particulate matter in Ilorin sawmills using AQI models. Environmental Research Journal, 7(4), 153–163.

Okedere, T., Adewole, A., & Adedeji, O. (2017). Assessment of gaseous pollutants in sawmill zones of Ibadan. Journal of Air Quality and Environment, 11(3), 122–129.

Olorunfemi, F. B., & Odipe, A. I. (2017). Impact of sawmill activities on aquatic ecosystems in Nigeria. Nigerian Journal of Environmental Sciences, 10(1), 87–94.

Oluwaseun, O., & Ayoade, O. (2014). Occupational exposure to air and noise pollution in Akure sawmills. Journal of Environmental and Occupational Health, 6(2), 112–120.

Onuorah, C., Eze, J., & Nwafor, C. (2020). Seasonal variations in air and noise pollution in Enugu sawmill clusters. Journal of Environmental Pollution and Control, 5(2), 89–97.

Power, M. C., Weisskopf, M. G., Alexeeff, S. E., Coull, B. A., Spiro, A., & Schwartz, J. (2016). Traffic-related air pollution and cognitive function in a cohort of older men. Environmental Health Perspectives, 119(5), 682–687.

Singh, N., & Davar, S. C. (2004). Noise pollution–sources, effects and control. Journal of Human Ecology, 16(3), 181–187.

Slabbekoorn, H., & Ripmeester, E. A. (2008). Birdsong and anthropogenic noise: Implications and applications for conservation. Molecular Ecology, 17(1), 72–83.

Ugbebor, J., & Ogundipe, B. (2011). Integrated environmental assessment of sawmill operations in Lagos. Nigerian Environmental Journal, 8(1), 25–35.

United Nations Environment Programme [UNEP]. (2019). Short-lived climate pollutants: Science and policy brief. https://www.unep.org

World Bank. (2021). The cost of pollution in Nigeria: Economic and environmental analysis. https://www.worldbank.org

World Health Organization [WHO]. (2018). Environmental noise guidelines for the European region. https://www.who.int

World Health Organization [WHO]. (2021). Global air quality guidelines: Particulate matter, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. https://www.who.int