

**ASSESSMENTS OF AIR AND NOISE POLLUTION FROM ELECTRIC POWER
GENERATORS IN COMMERCIAL CENTERS IN BENIN CITY, EDO STATE,
NIGERIA.**

BY

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PLAGIARISM

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DEDICATION

I dedicate this endeavor primarily to God, who has been my unwavering support throughout my academic journey. A heartfelt tribute to my beloved parents, Mr. and Mrs. Monye, whose guidance, love, care and financial support have been instrumental in shaping my path. Gratitude extends to my siblings who stood by me in challenging moments. My prayer is that the benevolent forces above continue to safeguard, guide and bestow blessings upon them, Amen.

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ABSTRACT

The persistent problem of unreliable electricity supply in Nigeria has made the use of electrical power generators a daily necessity for many homes and businesses. While these generators provide temporary relief from frequent blackouts, their emissions and noise significantly degrade air quality and create health concerns. This study aimed to assess air and noise pollution from electric power generators in selected commercial centers in Benin City, Edo State. The objectives were to measure key air pollutants like PM_{2.5}, PM₁₀, CO, O₃, and TVOC at varying distances (0 m, 3 m, 5 m) from operating generators, evaluate their concentration trends, determine noise levels, and compare results with World Health Organization (WHO) standards.

The study was carried out across sixteen commercial sites including Ring Road, Mission Road, Akpakpava, and Forestry Road. Air quality data were obtained using a portable multi-gas analyzer and ozone meter, while noise levels were measured with a digital sound level meter. Measurements were recorded for three minutes at one-minute intervals during active generator operation (1 p.m.–3 p.m.). The data collected at 0 m, 3 m, and 5 m were averaged to determine representative pollution values and compared against WHO limits to evaluate compliance.

The results showed that air and noise pollution around generator sites were generally above recommended limits. The mean PM_{2.5} concentration ranged from 35–70 $\mu\text{g}/\text{m}^3$, and PM₁₀ from 40–85 $\mu\text{g}/\text{m}^3$, both exceeding the WHO 24-hour limits of 15 $\mu\text{g}/\text{m}^3$ and 45 $\mu\text{g}/\text{m}^3$ respectively. Carbon monoxide (CO) levels were between 28–307 ppm, far higher than the WHO limit of 26 ppm (1-hour mean). Ozone (O₃) concentrations varied from 0.04–7.18 ppm, and TVOC values ranged from 0.007–0.074 mg/m^3 , with higher values near generator exhausts. Noise levels ranged between 80.0 dB(A) and 96.8 dB(A), exceeding the WHO safe exposure limit of 70 dB(A). Pollutant levels decreased progressively with distance from the source, showing strong spatial attenuation within 5 m. These findings confirm that commercial generator clusters in Benin City contribute substantially to poor air quality and excessive noise exposure. The study concludes that generator emissions pose serious environmental and health hazards. It recommends strict enforcement of air quality standards, and the adoption of cleaner energy sources such as solar power to improve public health and urban livability.

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ACRONYMS

CO – Carbon Monoxide

NO₂ – Nitrogen Dioxide

SO₂ – Sulfur Dioxide

PM – Particulate Matter

VOCs – Volatile Organic Compounds

NESREA – National Environmental Standards and Regulations Enforcement Agency

WHO – World Health Organization

dB(A) – Decibels A-weighted (a sound level measurement adjusted to the human ear's sensitivity)

dB – Decibels

GPS – Global Positioning System

UNIBEN – University of Benin

NIHL – Noise Induced Hearing Loss

SLCPs – Short Lived Climate Pollutants

OSHA – Occupational Safety and Health Administration

EU – European Union

CAIN – Clean Air Initiative

NAAQS – National Ambient Air Quality Standard

PSS – Perceived Stress Scale

COPD – Chronic Obstructive Pulmonary Disease

PPM – Parts Per Million

KVA – Kilo-Volt-Amperes

AQI – Air Quality Index

EPA – Environment Protection Agency

USEPA – United State Environment Protection Agency

NIOSH – National Institutes of Occupational Safety and Health

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

In Nigeria, the persistent inadequacy of electricity supply has led to a widespread reliance on electric power generators. It stands out in cities, where power must not be interrupted for activities to continue without hindrance. Even though generators are useful during short power cuts, using them a lot has led to problems such as air and noise pollution (Okeyale et al., 2017).

Nigeria's demand for energy is growing rapidly but the sector has difficulty fulfilling it. Consequently, various individuals and businesses now rely on generators to make up for the energy shortage. In 2018, it was noted that 22 million small gasoline generators were being used in Nigeria. This number is expected to grow to 30 million by 2030. This surge underscores the critical role generators play in the country's energy landscape (World Bank 2018).

Carbon monoxide (CO), nitrogen dioxides (NO₂), Sulphur dioxide (SO₂), particulate matter (PM) and volatile organic compounds (VOCs) are some of the pollutants electric power generators produce (Ajani, A. O., et al. 2022). Due to these emissions, the air around the sites becomes polluted which is dangerous for the nearby inhabitants. A study found that in Nigeria, diesel generators emit CO to levels as high as 20.9 µg/m³ for 24 hours which is close to or exceeds the World Health Organization standards (Fakinle et al., 2020).

Power generators used everywhere in Nigeria can meet our current energy demands, but they also cause environmental and health issues. Bad air and noise caused by generators

can be risky, so these issues should be looked into and properly managed (Ogunbiyi et al., 2023).

1.2 STATEMENT OF PROBLEM

Nigeria's regular problems with electricity supply have led many people to depend on electricity generators for extra power. The primary concern here is with the fumes and noise emitted by electric generators and with measuring how good the air is (Ibhadode et al., 2019).

Most of this electric power generator use petrol or diesel, releasing various pollutants into the air. Among the emissions are carbon monoxide, nitrogen oxides, Sulphur dioxide, PM2.5 and PM10 and volatile organic compounds. People living near places where pollution is released face both short-term and long-term health problems (Ajani, A. O., et al. 2022).

There is still a major concern about what a safe amount of distance from an operating generator should be. In numerous cases, individuals think that being a few meters apart keeps them away from unsafe fumes. At the same time, many elements play a role in widely spreading pollutants, including wind speed, weather patterns, terrain and the generator being used (Wang, Emmerich, & Lin, 2014).

Past studies in similar places suggest that the WHO recommended levels for CO and PM2.5 can be surpassed even 20–30 meters away from the generator, except under strong wind conditions. It was found that levels of CO were still too high at a distance of 25 meters from a 10 KVA diesel generator (Fakinle et al. 2020).

Since the power grid in Nigeria frequently fails, using electric power generators becomes necessary, but it leads to emissions that are damaging to both air quality and the health of

the public. Using the guidelines provided by the public is not supported by proven data (Oguntoke & Adeyemi, 2016).

1.3 AIM AND OBJECTIVES

This project seeks to assess air and noise pollution from generator usage in some commercial centers in Benin city, Edo state, Nigeria.

The specific objectives of this project are to:

- i. Measure criterial air pollutants such as CO, PM_{2.5}, PM₁₀ and TVOCs around selected electric power generators in some commercial centers within Benin city, Edo state, Nigeria.
- ii. Evaluate air quality variations at different distances (0m, 3m, 5m) from operating generators.
- iii. Assess noise levels produced by generators using appropriate sound level meters.
- iv. Identify critical pollutants whose concentrations exceed World Health Organization (WHO) and Nigerian Ambient Air Quality Standards.
- v. Recommend policy and engineering controls to reduce air and noise pollution from generator use in environments.

1.4 SCOPE OF STUDY

The study examines how fumes and noise from electric generators at some commercial centers in Benin city affect the air quality. It requires measuring key pollutants, analyzing the noise generated and studying the distance they travel.

- i. At some commercial centers in Benin city, electric power generators were monitored for air and noise pollution. Measurements were gathered close to the pollution sources.
- ii. The criterial air pollutants monitored include particulate matter, carbon monoxide, ozone and total volatile organic compounds. Digital sound level meter was used to measure noise pollution.
- iii. Collection of data was done at various distances (0m, 3m, 5m) from active generators to know the distribution and weakening of pollutants and noises.
- iv. The study uses the World Health Organization (WHO) Air Quality Guidelines and National Ambient Air Quality Standards (NAAQS) to identify the level of pollution.

1.5 JUSTIFICATION OF STUDY

In Nigeria, where there are many power cuts, using electric power generators as a backup source is quite common in commercial centers. Unfortunately, the emissions and noises from these generators harm both humans and the environment. While these generators are common in commercial centers in Benin city, there are not many studies done in Benin City that demonstrate how much they impact air quality and cause noise pollution.

Thus, this investigation is important because it offers insight into pollutant concentrations and noise levels associated with generator usage in typical commercial centers.

CHAPTER TWO

LITERATURE REVIEW

A healthy environment heavily depends on good air quality which has a big impact on human beings and the ecosystem. When the level of pollutants in the air increases, it can harm people's health, negatively affect what we can see and damage the environment (UCAR Center for Science Education, n.d.). Air pollution and its related health effects are usually explained to the public using the Air Quality Index (AQI).

The AQI examines how many important pollutants are in the air, including particulate matter (PM10 and PM2.5), ozone (O₃), nitrogen dioxide (NO₂), sulfur dioxide (SO₂) and carbon monoxide (CO) and labels their amounts based on harm to humans. Doctors have confirmed that exposure to these pollutants is linked to health problems, including difficulties with breathing, cardiovascular functions and brain functioning (Meo et al., 2024).

Globally, organizations in charge of regulations have put standards in place to help control air pollution. WHO sets guidelines that help countries set proper health standards by reducing citizens' exposure to harmful pollutants (WHO, 2025). National Environmental Standards and Regulations Enforcement Agency (NESREA) is responsible in Nigeria for making sure laws on air quality are followed to safeguard the country's citizens (NESREA, n.d.).

Even so, problems are still faced, mainly in cities where many people depend on electric generators since the electricity supply is unreliable. Such generators release pollutants that negatively affect local air quality and put nearby people's health at risk (Giwa et al., 2019).

2.1 OVERVIEW OF AIR QUALITY

The condition of the air we breathe is essential for environmental health and it influences people's health and the environment. This term describes how much the air contains pollutants, with these pollutants ranging from chemicals, physical factors and biological agents that may damage both human health and nature. The concentration of gases such as particulate matter (PM), ozone (O₃), nitrogen dioxide (NO₂), Sulphur dioxide (SO₂) and carbon monoxide (CO) in the air is what air quality assessment looks at.

Around the globe, Air Quality Index (AQI) is used to make air quality information understandable and simple to share. The United States Environmental Protection Agency (EPA) developed the AQI to make daily air quality and risks clear to everyone by assigning numbers and colours to the data, with 0 being good and 300 being a hazardous level.

The World Health Organization (WHO) has set worldwide standards for air quality concerning main pollutants. The main purpose of these guidelines is to prevent health problems by setting parameters for pollutants including PM 2.5, PM 10, O₃, NO₂, SO₂ and CO. The WHO suggests that the average yearly exposure to PM 2.5 must not be above 5 µg/m³, since higher amounts are associated with an increase in both deaths and illnesses.

Table 2.1: AQI Basics for Ozone and Particle pollution.

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Source: (AirNow.gov)

2.1.1 AIR QUALITY IN NIGERIA

Urban areas in Nigeria are affected by air quality issues, as quick industrial growth, car emissions and the many generators in use all contribute to more pollution. A study assessing air quality in major Nigerian cities discovered high levels of PM_{2.5}, ranging 18.1 µg/m³ to 78.7 µg/m³ in Lagos in February 2021, breaking the standards set by the WHO. (IQAir, 2021).

Using satellite information from 2018 to 2022, revealed that a wide range of pollutants, including nitrogen dioxide, sulphur dioxide, ozone, formaldehyde, methane, carbon monoxide and indicators of aerosols, were found at elevated levels across Nigeria. (IQAir, 2021).

2.2 ENVIRONMENTAL AND ATMOSPHERIC IMPACTS OF GENERATOR

2.2.1 EMISSIONS

Nigeria's large number of electricity generators is mainly because the power supply is unreliable which has created considerable environmental and atmospheric issues. Since they are most often driven by diesel or gasoline, these generators release various pollutants, like carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), particulate matter (PM) and volatile organic compounds (VOCs), into the environment. All the emissions eventually damage urban air quality which is harmful to people and nature. (Giwa et al., 2019)

2.2.2 EMISSION TYPES

The emissions from generators often harm the air we breathe. Carbon monoxide (CO) appears as a colourless, odourless gas when fossil fuels are incompletely burned. Too much CO can damage your vision and make your brain less efficient. Ground-level ozone and smog are increased by nitrogen dioxide which also aggravates lung problems. SO_x and more specifically Sulphur dioxide (SO₂), are a leading cause of acid rain that damages plants and water ecosystems. PM_{2.5} and PM₁₀ can pass deep into the lungs, where they increase a person's risk of heart disease and lung problems. There are organic chemicals called VOCs which help form the ozone and can result in headaches and liver damage.

2.2.3 CUMULATIVE CONTRIBUTION TO URBAN ATMOSPHERIC DEGRADATION

The overuse of generators in cities in Nigeria has caused a huge increase in air pollution. There are high levels of NO₂, SO₂, O₃, formaldehyde, methane, CO and aerosol indices

found throughout Nigeria, showing air quality is an issue across the nation (Omokpariola et al. 2024). The PM_{2.5} concentrations in Lagos cities was found to be way above World Health Organization's recommended limits and the amount ranged from 18.1 µg/m³ to 78.7 µg/m³ during February 2021 (IQAir, 2021).

In addition, running generators increases noise pollution and this, combined with air pollution, makes the environment worse in urban settings. When these pollutants are emitted, they damage both the environment and health, creating issues like acid rain which can kill crops and harm aquatic ecosystems and smog which reduces the beauty of our cities by making everything less visible (Adetoyi & Nganje, 2024).

2.3 HEALTH RISK ASSESSMENT OF GENERATOR FUMES

People, particularly children, the elderly and those with pre-existing health conditions, are highly vulnerable to the adverse impacts of generator exhaust emissions such as PM_{2.5}, CO and NO₂. This susceptibility is as a result of physiological process and social risks pattern which make them more susceptible to risks of ill health when compared to the general population (Maung, K. S., Amnuaylojaroen, T., & Parasin, N. 2022).

The children have their organs developing and are consuming more air compared to their body weight face greater exposure to air pollutants. The exposure to PM_{2.5} during childhood has always been linked with respiratory infections, exacerbation of asthma and impeded development of the lungs (Tischer et al. 2024). Nigeria Ambient PM_{2.5} has been associated with a rise in pediatric respiratory diseases in major cities like Lagos and Abuja whereby there was a significant escalation in admission of children into hospitals due to asthma and bronchitis as a result of an increase in PM_{2.5} (Obani, 2025). That is especially alarming considering the average annual concentrations of PM_{2.5} in Nigeria is 40 µg/m³) which is considerably higher than the recommended limit of 5 µg/m³ of PM

2.5 by WHO. Children are even more likely to get affected by CO; in young users of indoor generators, even a low concentration (35ppm) produces headaches and cognitive disturbances (Umahi-Ottah et al.,).

The elderly also have more susceptibility to the decline of health due to pollution because of age-related losses in respiratory, cardiovascular and immune systems. Receiving of PM 2.5 makes chronic obstructive pulmonary disease (COPD) worse, boosts cardiovascular events, and raises cerebrovascular risks. Estimating by the WHO in 2019 indicated that elderly individuals (it is more demanding in populations aged more than 65) are more susceptible to PM 2.5 exposure causing increased deaths due to stroke and heart diseases. The elderly population in Nigeria, who in most cases are exposed to PM 2.5 levels as much as $70\mu g/m^3$ in a given year, are at a much higher risk of having their health affected (Ezeh et al., 2018).

Individuals with pre-existing conditions such as asthma, cardiovascular disease, diabetes, or compromised immune systems are also at elevated risk. Exposure to PM 2.5 aggravates asthma and admissions to hospitals with heart ailments. PM 2.5, PM 10, and other pollutants are the most associated factors with negative health conditions occurring in people with chronic illnesses (Omokpariola et al., 2024).

2.4 PHYSIOLOGICAL AND PSYCHOLOGICAL IMPACTS OF GENERATOR NOISE

2.4.1 SOUND LEVEL THRESHOLDS AND HEARING DAMAGE

The electrical power generators that have been widely installed in Nigeria in a bid to bridge the gap that exists between supply of electric power through national grids, which is very unreliable, and demand have become the main contributor to noise pollution in the environment. They run at levels that are often beyond the international recommended

auditory safety levels thus putting the nearby populations at risk of acute and chronic auditory damage. According to the World Health Organization (WHO, 2021), the daily occurrence of noise level over 70 decibels (dB) can result in hearing damage, with 85 dB being the threshold at which prolonged exposure (over 8 hours per day) may lead to irreversible hearing loss (National Institute for Occupational Safety and Health, 2013).

In many Nigerian urban environments, generator noise frequently surpasses 90–100 dB, especially with larger diesel models or those operating without soundproof enclosures (Olayanju et al., 2020). The average diesel generator emits sound levels of approximately 95–105 dB at a distance of 7 meters, with peak levels reaching up to 120 dB during ignition or heavy load operations (Akanbi & Oladeji, 2019). These levels are comparable to those found in industrial zones or construction sites, where hearing protection is mandatory.

Noise-induced hearing loss (NIHL) is a condition that occurs when the hair cells in the inner ear, that are conformational to high sound-width, are destroyed because of consistent exposure to a sound with a high intensity. However, even though temporary threshold shifts, which are manifested as muffled audibility during certain periods before returning to their usual levels in a few hours, may improve, the problem still occurs repeatedly and most frequently ends up in permanent threshold shifts, especially in cases where generator noise is widespread and uncontrolled (Eze, 2022).

Measures established to mitigate hearing loss are methods such as installation of noise attenuating structures, or offering sound blocking enclosures, and having a way of making the activities of the generators run at a time when people are least active. Although the use of hearing-protection devices (such as earmuffs and earplugs) is widely

recommended as a valuable countermeasure, their use in Nigeria is not popular due to affordability and accessibility issues (Ifeanyi and Chukwuma, 2019).

2.4.2 PSYCHOLOGICAL EFFECTS: STRESS, ANXIETY, AND IRRITATION

The constant presence of high-intensity noise put in place by power-generation is a multifactorial environmental stressor. Sustained releases of loud sounds cause deficiencies in physiological homeostasis, thus triggering the neuroendocrine reactions, which have an adverse impact on psychological health. Most durable to such effects are high levels of cortisol, adrenaline, and noradrenaline, which are accompanied by a strong sense of stress, insomnia, and mood disorders (Babisch, 2018). The repeated exposures are also characterized by the symptoms of increased anxiety and irritabilities.

These results were supported by a survey in a sample of an industrial city by (Davies and Fergus, 2020): a continuous noise of more than 85 dB(A) was closely related to increased perceived stress. The participants complained about irritability, obstructed concentration, and insomnia. Similarly, proximity to generator in Lagos had also shown highly significant associations with sleep disturbance and low scores of mood among residents (Adebayo & Olusanya, 2021).

Ondo State residents in the area within 50m of running generators were questioned; the majorities (above 75%) complained about the irritability and disturbed mood, almost 40% found earplugs or white-noise devices solution. The households with kids or older people experienced more psychological distress highlighting the vulnerability of these categories (Okeke and Nwafor 2021).

Tools such as the Perceived Stress Scale (PSS) and the Noise Sensitivity Questionnaire (NoiSeQ) are used in noise impact research. These instruments were used in Nigeria and

findings revealed that those exposed to constant noise because of generators received an average of 20 points higher in perceived stress and sensitivity to noise when compared to dwellers living in quieter areas (Ojo and Balogun, 2023).

2.5 CLIMATE CHANGE NEXUS: BLACK CARBON AND SHORT LIVED POLLUTANTS

Electric power generators contribute substantially to atmospheric pollution not only through air quality degradation but also via climate change impacts driven by short-lived climate pollutants (SLCPs), particularly black carbon. Black carbon is generated by incomplete combustion and is constituted of fine particulates matter (PM) called soot; having a residence period in the troposphere of just between several days to a few weeks, but wields a disproportionately large warming influence relative to carbon dioxide (CO₂) (C2ES, n. d.; Wikipedia, 2025). Even though CO₂ still takes the lead as the most prominent long-lived greenhouse gas, short-lived climate pollutants, most specifically black carbon, serve as a second priority in terms of human-made warming (C2ES, n.d.). Due to their potential to trap heat, short-lived climate pollutants are cited as important elements of near-term mitigation approaches, as they provide co-benefits in regard to both climate mitigating and health benefits (C2ES, n.d.; Clean Air Fund, 2024).

Black carbon has three main warming effects which are: the first effect is absorption of incoming solar radiation; the second effect is the darkening of reflective areas once deposited in snow and ice; third effect is the effect of modulation of cloud-formation dynamics (Wikipedia, 2025; Clean Air Fund, 2024). Globally, it has global warming potential of 460 to 1500 times that of CO₂ in 100-year period (Wikipedia, 2025). As black-carbon emissions remain in the atmosphere such a short time, targeted strategies to mitigate these emissions can entail immediate cooling impacts, leading to reducing

global temperature trends, and even stopping climate tipping point, significant Arctic ice melt (Clean Air Fund, 2024).

Policies that reduce black carbon emissions have the potential to bring imminent climate, health and ecosystem improvement within the span of one generation, a tactic that can be of particular use in generator reliant countries, like Nigeria.

2.6 REGULATORY FRAMEWORKS AND POLICY APPROACHES

Electric power generators cause air and noise pollution, which is stipulated by both international guidelines and national regulations. On the global scale, the main air quality guidelines developed by the World Health Organization (WHO) aim at safeguarding the human health. The last revision, published in 2021, reduced the exposure limits of particulate matter (PM 2.5 and PM 10), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and carbon monoxide (CO) (World Health Organization, 2021). For example, the new annual level of exposure to PM 2.5 reduced to $5\mu g/m^3$, as opposed to the previous $10\mu g/m^3$, reflecting robust evidence linking low-level exposure to adverse health outcomes. In the same line, the WHO Environmental Noise Guidelines (2018) state that to eliminate potential adverse health outcomes like sleep disturbances and cardiovascular strain, daytime noise level in residential areas should not be higher than 45 dB(A) (World Health Organization, 2018).

The United States Environmental Protection Agency (USEPA) is a prominent example of a national body employing enforceable air quality standards. Usually, the USEPA currently has National Ambient Air Quality Standard (NAAQS) under the Clean Air Act that provides a 24-hour PM 2.5 standard of $35\mu g/m^3$ and an annual standard of $12\mu g/m^3$ (EPA, 2022). Additionally, noise exposure in occupational settings is regulated under OSHA's standard permitting up to 90 dB(A) for an eight-hour work period, with reduced

exposure times for higher levels (Occupational Safety and Health Administration, 2023). Even though this standard is not binding outside the U.S, they serve as benchmarks for evaluating national policies.

European Union (EU) regulates air quality with strict directives, such as the Ambient Air Quality Directive (2008/50/EC), limiting the annual mean concentrations of PM 2.5 to $25 \mu\text{g}/\text{m}^3$ (European Commission, 2023). EU also provides noise directives like the Environmental Noise Directive, (2002/49/EC), that directs member states to accomplish strategic noise maps and action plans at the key transportation and industrial origins, which involve generator stations (European Commission, 2022).

The environmental regulation in Nigeria is under the purview of National Environmental Standards and Regulations Enforcement Agency (NESREA), which came to existence in 2007. NESREA requirements set the limits on the concentration of the ambient air pollutants and noise values in the public and residential areas. The Noise Standards and Control Regulations (2009) consider the following as the noise limits in the daytime residential areas: 55 dB(A) and the night-time residential areas: 45 dB(A). Nonetheless, Nigeria is yet to adopt certain emission limits in terms of generator usage or to require such pollution control measures as particulate filters or silencers (NESREA, n.d.).

Policy controls to govern generators usage have started surfacing up. The Electricity Act Amendment (2023) made in Lagos State also included conditions where the operators of the license generator are to use the list of low-emission fuels and retain the noise level of 75 dB(A). Nevertheless, its implementation is exclusive with inconsistency because of disparity in regulatory competencies. Meanwhile, environmental non-governmental organizations such as Clean Air Initiative Nigeria (CAIN) are using demonstrations in sensitizing people and testing noise control strategies in urban residential areas.

2.7 DEFINITION OF PARAMETERS

2.7.1 Carbon Monoxide (CO)

Carbon monoxide (CO) is a gas, which is colorless and non-odorous and is released as a result of incomplete combustion of fossil fuel-both those used in electric power generators (EPA, 2024).

2.7.2 Sulfur Dioxide (SO₂)

Sulfur dioxide (SO₂) is a colorless gas bearing an irritative odor, and is produced mainly when fossil fuels which contain sulfur are perused; diesel is a regular constituent of electric-generator activity. SO₂ qualifies as a pollutant to air and at the same time acts as a source of acid rain which cause adverse effects to the vegetation and aquatic life (EPA, 2025).

2.7.3 Nitrogen Dioxide (NO₂)

Nitrogen dioxide is a reddish-brown gas formed in high temperature burning of the fossil fuels. In the case of generator effluents, NO₂ comes out as a super-pollutant by diesel and petrol-driven engines (American Lung Association, 2025; WHO, n.d.).

2.7.4 Particulate Matter (PM_{2.5} and PM₁₀)

Particulate matter (PM) is an aqueous and solid heterogeneous airborne mixture of particles. PM_{2.5} involves the inclusion of particles with aerodynamic diameters that happen to be less than 2.5 micrometers, and PM₁₀ entails the inclusion of particles with diameters of less than 10 micrometers. PM_{2.5} is particularly harmful because it can penetrate deep into lung tissue and enter the bloodstream, leading to cardiovascular,

respiratory, and neurological diseases (Omokpariola et al., 2024). The WHO (2021) recommends annual mean exposure limits of $5 \mu\text{g}/\text{m}^3$ for PM_{2.5} and $15 \mu\text{g}/\text{m}^3$ for PM₁₀.

2.7.5 Total Volatile Organic Compounds (VOCs)

Volatile organic compounds/VOCs are a category of organic chemicals which is easily volatilized at normal temperatures. The common ones are benzene, formaldehyde and toluene.

2.7.6 Ozone (O₃)

Ozone (O₃) is a pale blue, highly reactive gas composed of three oxygen atoms. It occurs naturally in the Earth's upper atmosphere. However, at ground level (the troposphere), ozone becomes a harmful air pollutant and a major component of photochemical smog. Ground-level ozone is not directly emitted into the air but is formed through complex chemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight.

2.7.7 Decibel (dB) and A-Weighted Decibel (dB(A))

Levels of sound pressure are measured in decibels (dB), a logarithmic unit that reflects sound intensity. For environmental and occupational assessments, dB(A) is used, which applies an A-weighting filter to approximate human hearing sensitivity. Prolonged exposure to sound levels above 85 dB(A) can result in permanent hearing damage (WHO, 2018).

2.7.8 Ambient Air Quality Standards

Indicators on the allowed concentration of pollutants in outdoor air are specified by transnational and national health agencies to protect human health and the environment in general. Most of the recommendations made by the World Health Organization (WHO)

are closely consistent with the recommendations of the National Environmental Standards and Regulations Enforcement Agency (NESREA) in Nigeria.

2.8 REVIEW OF PREVIOUS WORKS DONE

Nwabueze et al. (2024) conducted a study on noise pollution from petrol-powered generators in urban roadside settings in Nigeria, focusing on how distance, generator capacity, and age influence noise levels.

The researchers tested five commonly used generators ranging from 2 to 14 kVA and between 1 to 5 years of use. Noise levels were measured at distances of 0 to 20 meters using digital sound meters. Analysis using two-way ANOVA revealed that both the age and capacity of generators significantly affected noise output. Older and higher-capacity generators produced louder noise, with levels at 0 meters reaching up to 97 dB(A) and still exceeding 65 dB(A) even at 15 meters—well above WHO's recommended daytime limit of 55 dB(A).

The study concluded that petrol generators, particularly older and high-capacity ones, are major contributors to environmental noise in Nigerian cities. To reduce these impacts, the authors recommended routine maintenance, the use of quieter generator models, enforcing minimum separation distances of 10 meters from buildings, and the implementation of local noise regulations. Public awareness on the health risks of prolonged noise exposure was also encouraged.

A study by Abulude et al. (2018) investigated the growing noise pollution in Akure, Nigeria, caused by widespread generator use due to unstable power supply. The study aimed to assess noise levels in residential, commercial, and industrial zones and compare the results with national and international noise standards.

The researchers measured noise at 100 locations using digital sound meters during peak generator usage in the daytime and early evening. Recorded levels ranged from 82 to 113 dB(A), significantly exceeding the limits set by NESREA and WHO. Commercial zones recorded the highest levels, followed by residential areas, where generators were often placed close to living spaces. Industrial areas were slightly quieter, benefiting from better spacing and noise containment.

The study concluded that generator noise in Akure poses serious health risks, including hearing loss, stress, and reduced productivity. It recommended stronger noise control policies, mandatory use of soundproof generator covers, zoning laws to keep generators away from occupied buildings, and public awareness campaigns.

A study by Ogunyemi et al. (2018) investigated the combined effects of air and noise pollution from industrial sources and generator use in Ibadan, a growing Nigerian city facing energy and infrastructure challenges.

Using handheld air monitors and sound level meters, the researchers measured pollutants like carbon monoxide (CO), sulfur dioxide (SO₂), hydrogen sulfide (H₂S), and suspended particulate matter (SPM), along with ambient noise, across wet and dry seasons. Results showed higher pollution levels during the wet season due to more frequent generator use and limited air dispersion. CO and SO₂ levels often exceeded WHO and NESREA limits, and noise levels between 78–100 dB(A) were recorded—well above safe exposure thresholds.

The study concluded that pollution from generators and small-scale industries poses serious health risks in urban Ibadan, particularly in crowded neighborhoods. The authors

recommended clearer zoning laws, financial support for clean energy adoption, regular generator maintenance, and stronger environmental monitoring.

Bello et al. (2025) studied noise pollution caused by generators within the Air Force Institute of Technology (AFIT), focusing on its effects on academic spaces. Due to frequent power outages, the institution relies heavily on diesel and petrol generators, raising concerns about how this affects learning and concentration.

Using a randomized cross-sectional approach, the researchers measured noise levels at distances of 0 to 20 meters from generators with capacities ranging from 5 to 20 kVA. Measurements taken inside lecture halls and offices showed that noise levels frequently exceeded recommended WHO limits for academic environments, with outdoor noise reaching over 85 dB(A) and indoor levels as high as 60 dB(A), interfering with focus and teaching.

The study concluded that current generator setbacks are insufficient to prevent noise disruption. It recommended fitting generators with sound-absorbing cabinets, using barriers like green hedges, and shifting toward cleaner energy alternatives such as solar systems.

Akugbe Oviasogie (2020) examined how generator noise impacts urban business areas in Benin City, especially in relation to land-use patterns. The study focused on understanding how noise levels vary across residential, and commercial zones, with a particular emphasis on generators as the primary source of disturbance. Measurements were taken in neighborhoods like G.R.A. and Ogbe using sound level meters, and questionnaires were distributed to residents and shop owners to assess their perceptions and experiences.

Findings showed that commercial zones recorded the highest average noise levels, at 72 dB(A) and 68 dB(A) respectively well above the WHO's 55 dB(A) recommendation. Even residential areas were not spared, averaging 62 dB(A). Over 80% of respondents in commercial areas found generator noise highly disruptive, citing sleep disturbance, communication problems, and increased stress.

The study concluded that poor land-use planning in Benin City has intensified noise exposure, especially in commercial zones where generator usage is high. It recommended integrating noise control into urban planning through zoning laws, maintaining at least a 20-meter distance between generators and buildings, and using sound barriers or vegetation screens.

Taylor and Ezekiel (2023) developed a predictive model for forecasting air quality in Port Harcourt, Nigeria, using a Bi-Directional Long Short-Term Memory (Bi-LSTM) neural network. The study responded to the need for accurate real-time air quality forecasting in urban Nigerian environments, where generator use, traffic emissions, and dust regularly lead to unhealthy air conditions.

Using two years of data (2020–2022) from government monitoring stations, the researchers trained and tested their Bi-LSTM model on variables such as PM_{2.5}, PM₁₀, CO, NO₂, temperature, humidity, and generator activity. The model's performance was evaluated using metrics like R², RMSE, and MAE, and was compared to conventional models like ARIMA and feedforward neural networks. The Bi-LSTM model showed strong predictive accuracy, with R² scores of 0.92 for PM_{2.5} and 0.89 for PM₁₀, outperforming all traditional methods tested.

The study concluded that Bi-LSTM models are highly effective for forecasting air quality in Nigerian cities.

Adeyemo et al. (2013) conducted a study in Lagos using data mining techniques to estimate pollution loads across different economic sectors, with a focus on generator emissions. The study addressed challenges in collecting reliable emissions data in rapidly growing urban centers and proposed artificial neural networks (ANN) and Integrated Pollution Prevention Strategies (IPPS) as tools for estimating pollution from under-monitored sources like small-scale generators.

The researchers analyzed data on industrial activity, fuel consumption, electricity use, and vehicle registrations. Using ANN models trained on historical emissions patterns, and validated by IPPS forecasts, they found that small-scale generators contributed between 15–20% of total urban emissions just slightly below transport and industrial sectors. The ANN model demonstrated high predictive accuracy ($R^2 \approx 0.87$), confirming that generators emit significant levels of pollutants.

The study concluded that generator emissions are a major but under-recognized contributor to urban air pollution in Lagos. It recommended integrating generator data into national emissions inventories and enforcing mandatory reporting of generator fuel use.

Uchegbu et al. (2005) conducted an early study on the impact of industrial noise and emissions, particularly from generators, in densely populated zones of Benin City, Nigeria. The research aimed to measure both the environmental stressors, noise and air pollution and how residents perceived their effects on daily life.

Using a mixed-methods approach, the researchers collected quantitative data on noise levels and visible emissions and conducted surveys with over 200 residents in four zones: Ogida, Airport Road, New Benin, and Ugbowo. Noise measurements consistently exceeded 85 dB(A), particularly in areas where generators operated close to homes. Emission assessments showed frequent visible smoke and elevated CO levels. Survey responses revealed that over 75% of residents reported sleep disturbance, stress, and reduced concentration, with many feeling helpless about the situation.

The study concluded that generator and industrial noise, combined with unregulated emissions, posed serious health risks in urban neighborhoods. Recommendations included enforcing zoning laws to separate residential areas from heavy generator use, and promoting renewable energy sources like solar.

Wambebe and Duan (2021) conducted a detailed study on generator-related noise and air pollution in Abuja, focusing on the UTC commercial zone and surrounding municipal areas. The first part assessed noise pollution using measurements taken both inside offices and in outdoor commercial areas. Results showed average personal exposure at 74.7 dB(A) and ambient noise at 71.9 dB(A), exceeding WHO's recommended limit of 55 dB(A), although still under OSHA's 85 dB(A) occupational threshold. The researchers linked these high levels primarily to generator use and warned of health risks such as stress, hearing loss, and reduced productivity.

To address this, they recommended planting trees as sound barriers, enforcing stricter generator placement rules in business zones, mandating regular noise audits, and encouraging the adoption of quieter generator models.

The second part of the study focused on air pollution, particularly PM_{2.5} and PM₁₀ levels across 20 sites in Abuja. Using smart detectors and back-trajectory analysis, they found that PM_{2.5} levels frequently exceeded WHO safety thresholds, with readings reaching up to 70.2 µg/m³ and AQI values as high as 280 indicating unhealthy conditions. The primary pollution sources were traced to generator emissions.

CHAPTER THREE

METHODOLOGY

3.1 STUDY AREA

The study was carried out in Benin City the capital of Edo State which is within the South South geopolitical zone of Nigeria. Benin City is a city in southern Nigeria, which is among the largest and economically active centers. It is located at a geographical position of approx. 6.3349° N with longitude of around 5.6037° E and it is about 80 meters above sea level. It is a commercial cultural, education, and administrative center of the country and base of many government offices, financial institutions, educational institutions (University of Benin), and small and medium industries (Ogundele, 2017).

Owing to the habitual unavailability of power in Benin City, the application of electric power generators especially the petrol and diesel-sourced generators has become a common practice mostly by the business owners. The use of generators is common in business hubs like the Ring Road, Urelu, Mission Road, New Benin, Akpakpava and Sapele road where there is a dire need of constant power to run the business continuously.

These trading centers are known to have several generators simultaneously working especially when there is a case of blackout or power branch fluctuations. Besides air pollution, these places also record high rates of environmental noise.

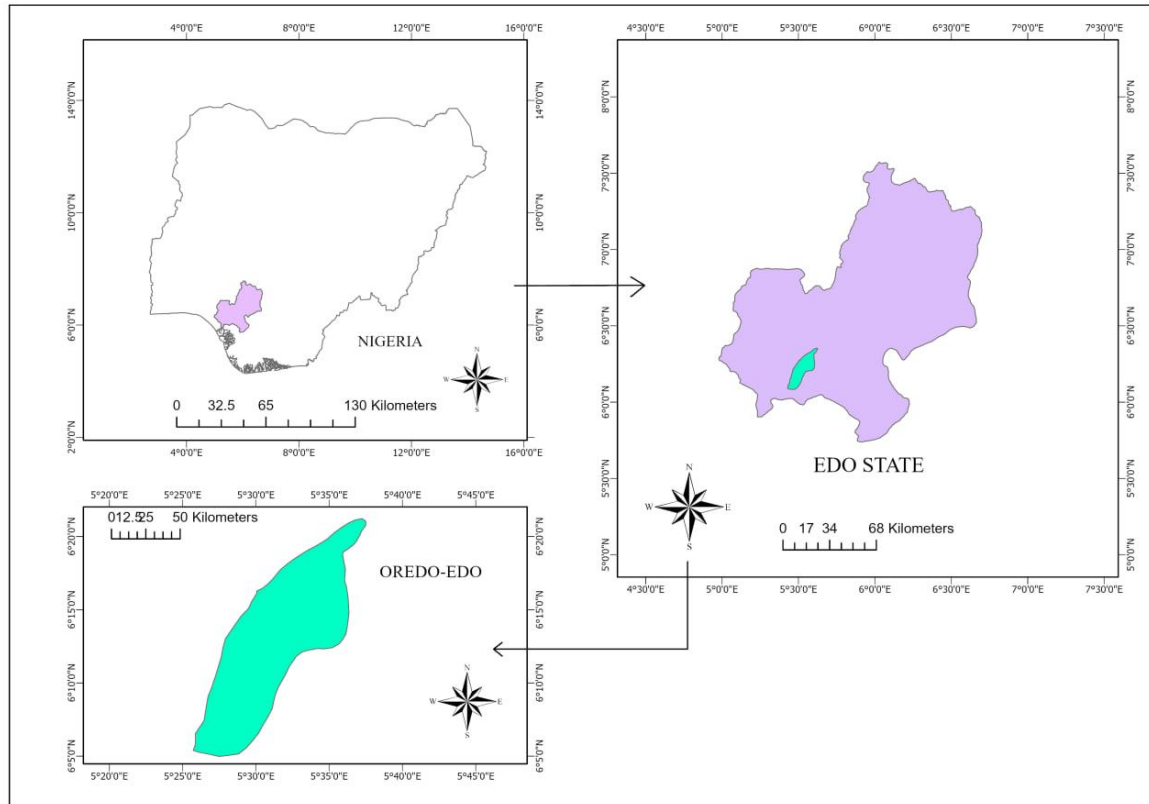


FIGURE 3.1 Map of Edo State showing the Study Area (Oredo LGA)

3.2 SAMPLING

The findings were done on generator usage intensity over some commercial centers where there has often been a lack of consistent power supply and therefore the use of electric power generator as alternative sources of energy is on the regular use.

At the selected commercial centers, three fixed sampling points were established at specific distances from an actively running electric generators:

- i. 0 meters (proximal zone, typically representing generator housing)
- ii. 3 meters (intermediate exposure zone)

iii. 5 meters (moderate background zone)

Data collection was done within three (3) days (Wednesday – Friday) in the afternoon between 1pm and 3pm. This time of the day was adopted because it was observed that at this time there is usually power outage.

A monitoring of 3 minutes was adopted per point of sampling whereby continuous reading at 1-minute interval was taken to obtain adequate average values of each parameter.

Sampling plan strictly adhere to the set standards of air quality and noise exposure assessment which includes the standards proposed by the World Health Organization (WHO), the United States Environmental Protection Agency (USEPA), and Nigeria National Environmental Standards and Regulations Enforcement Agency (NESREA).

3.3 SAMPLE COLLECTION PROCEDURES

The process of sample collection was well outlined such that there was consistency, accuracy and relevance of data collected in the chosen commercial centers in Benin City.

The sampling sites were placed in known distances relative to active generator exhausts: 0m, 3m, and 5m. These distances are chosen to enable the evaluation of pollutant levels.

All measurements were conducted at about 1.5 meters from the ground that is the average height at which human beings breathe. This is essential in measuring the real-life contact of human beings to air load and noise in the factory where the generators are working.

At each sampling point, the following procedure was followed:

- i. Instrument Setup: The air quality monitor was turned on and tuned to work in accordance with the manufacturer's instructions. The device starts measuring the pollutant levels (PM2.5, PM10, CO, O₃, and TVOCs). At the same time, digital sound level meter was used to monitor environmental noise and record sound pressure levels in decibels (dB(A)) during the sampling time.
- ii. Measurement Period: Each sampling point was measured by a 3-minute continuous process of measurement. Within this period, data of pollutants were taken with one-minute intervals, which yielded a total of 3 readings per parameter. Such readings were then averaged to take representative values to be analyzed.
- iii. After data collection, the instruments were powered down, and all data were backed up onto digital storage devices.
- iv. This procedure was repeated across other selected sampling points.

3.4 AIR QUALITY MONITOR

A handheld air quality monitor (Portable Multi Gas Analyzer) was used.



FIGURE 3.2 Portable multi gas analyzer

3.5 SOUND/NOISE MONITOR

A handheld sound/noise monitor (Digital sound level meter) was used.



FIGURE 3.3 Digital sound level meter

3.6 OZONE MONITOR



FIGURE 3.4 Ozone meter

3.7 OTHER EQUIPMENTS

3.7.1 LOCATION FINDING

Global positioning system(GPS) was used to locate our sample areas.

3.7.2 LATERAL / LONGITUDINAL MEASUREMENT

A measuring tape was used.



FIGURE 3.5 Measuring tape.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 AIR QUALITY ASSESSMENT

Air quality assessment is the process of checking how clean or polluted the air in a particular area is. It helps to identify the presence and concentration of harmful substances such as carbon monoxide, particulate matter, and other pollutants. Through this assessment, we can understand how different activities, such as the use of generators affect the surrounding environment. The results guide decisions on how to reduce air pollution.

4.2 PARTICULATE MATTER

Table 4.1 and 4.2 shows the measured concentrations of **PM2.5** and **PM10** respectively across selected locations in the study area. Readings were taken at different distances from running electric generators and averaged over one-minute intervals. The table also includes AQI values.

Table 4.1: READINGS FOR PM2.5 (Particulate Matter (Ug/m^3))

S/N	Locations	Number of Actively running Electric Generators.	Coordinates	Parameters at distances away from the Electric Generators.	Readings at one (1) minute intervals.			Average	AQI
					1 min	2 min	3 min		
1.	Osawarhun Complex (Ibewe	Fifteen(15)	6°20'6.83"N 5°37'15.87"E	PM2.5 at 0 meters	70	71	69	70	161
				PM2.5 at 3	64	66	62	64	157

	street)			meters					
				PM2.5 at 5 meters	55	55	53	55	149
2.	Osarentin Complex (Ibewe street)	Three (3)	6°20'9.11"N 5°37'15.51"E	PM2.5 at 0 meters	45	46	46	47	129
				PM2.5 at 3 meters	40	40	40	40	112
				PM2.5 at 5 meters	40	39	35	38	107
3.	Swarhele complex (Ibewe street)	Three (3)	6°20'11.24"N 5°37'14.81"E	PM2.5 at 0 meters	50	49	48	49	134
				PM2.5 at 3 meters	49	49	50	49	134
				PM2.5 at 5 meters	35	35	35	35	99
4.	Guinness Plaza (Ibewe street)	Four (4)	6°20'13.13"N 5°37'14.9"E	PM2.5 at 0 meters	56	57	56	56	151
				PM2.5 at 3 meters	50	51	52	51	139
				PM2.5 at 5 meters	45	45	46	45	124
5.	Rince Shoes (Ibewe street)	One (1)	6°20'13.47"N 5°37'14.91"E	PM2.5 at 0 meters	35	35	38	35	99
				PM2.5 at 3 meters	30	31	31	31	92
				PM2.5 at 5 meters	25	30	31	29	88
6.	Jay Doherty (Ibewe street)	One (1)	6°20'15.25"N 5°37'13.6"E	PM2.5 at 0 meters	38	38	36	38	107
				PM2.5 at 3 meters	35	36	37	36	102
				PM2.5 at 5 meters	30	31	30	30	90
7.	Ken Diuwa Shopping mall (Ibewe street)	Four (4)	6°20'15.25"N 5°37'13.6"E	PM2.5 at 0 meters	55	56	55	55	149
				PM2.5 at 3 meters	50	51	54	52	142
				PM2.5 at 5 meters	43	40	42	42	117
8.	Divine KC cosmetics (Lagos street)	Two (2)	6°20'8.38"N 5°37'18.47"E	PM2.5 at 0 meters	41	42	41	41	115
				PM2.5 at 3 meters	35	37	35	35	99
				PM2.5 at 5 meters	37	32	33	34	97
9.	Bazuaze Complex	Four (4)	6°20'12.2"N	PM2.5 at 0 meters	59	58	60	59	153

	(Mission Rd)		5°37'25.19"E	PM2.5 at 3 meters	50	50	50	50	137
				PM2.5 at 5 meters	40	41	45	42	117
10.	Electro mall (Mission)	Four (4)	6°20'26.8"N	PM2.5 at 0 meters	58	52	55	55	149
			5°37'33.72"E	PM2.5 at 3 meters	50	55	52	52	142
				PM2.5 at 5 meters	53	50	51	51	139
11.	Mobil filling Station (Mission Rd)	Three (3)	6°20'32.02"N	PM2.5 at 0 meters	45	45	46	45	124
			5°37'34.59"E	PM2.5 at 3 meters	45	40	40	40	112
				PM2.5 at 5 meters	42	42	42	42	117
12.	High Quality Doors	Two (2)	6°20'31.33"N	PM2.5 at 0 meters	42	41	42	42	117
			5°37'36.68"E	PM2.5 at 3 meters	38	38	38	38	107
				PM2.5 at 5 meters	35	35	34	35	99
13.	Digital Show room (Mission Rd)	Three (3)	6°20'33.45"N	PM2.5 at 0 meters	50	52	50	50	137
			5°37'38.73"E	PM2.5 at 3 meters	48	48	48	48	132
				PM2.5 at 5 meters	42	42	42	42	117
14.	Authentic House of Fabric (Forestry Rd)	Two (2)	6°20'10.57"N	PM2.5 at 0 meters	43	42	42	42	117
			5°37'28.68"E	PM2.5 at 3 meters	40	40	40	40	112
				PM2.5 at 5 meters	35	36	36	36	102
15.	Generator Repair shop (Forestry Rd)	Three (3)	6°20'19.86"N	PM2.5 at 0 meters	49	43	45	46	127
			5°37'36.82"E	PM2.5 at 3 meters	46	45	44	45	124
				PM2.5 at 5 meters	44	43	44	44	122
16.	Awesome God shop (Akpakpava Rd)	Two (2)	6°20'18.1"N	PM2.5 at 0 meters	44	45	45	44	122
			5°37'47.14"E	PM2.5 at 3 meters	39	39	39	39	110
				PM2.5 at 5 meters	34	34	34	34	97

Table 4.2: READINGS FOR PM10 (Particulate matter (Ug/m³))

S/N	Locations	Number of Actively running Electric Generators.	Coordinates	Parameters readings at distances away from the Electric Generators.	Readings at one (1) minute intervals.			Average	AQI
					1 min	2 min	3 min		
1.	Osawarhun Complex (Ibewe street)	Fifteen(15)	6°20'6.83"N	PM10 at 0 meters	85	85	85	85	66
			5°37'15.87"E	PM10 at 3 meters	80	81	81	80	63
				PM10 at 5 meters	75	75	75	75	61
2.	Osarentin Complex (Ibewe street)	Three (3)	6°20'9.11"N	PM10 at 0 meters	55	54	56	55	51
			5°37'15.51"E	PM10 at 3 meters	54	53	53	53	49
				PM10 at 5 meters	50	49	51	50	46
3.	Swarhele complex (Ibewe street)	Three (3)	6°20'11.24"N	PM10 at 0 meters	56	50	54	53	49
			5°37'14.81"E	PM10 at 3 meters	53	53	53	53	49
				PM10 at 5 meters	50	50	50	50	46
4.	Guinness Plaza (Ibewe street)	Four (4)	6°20'13.13"N	PM10 at 0 meters	60	66	67	64	55
			5°37'14.9"E	PM10 at 3 meters	55	56	60	57	52
				PM10 at 5 meters	50	54	53	52	48
5.	Rince Shoes (Ibewe street)	One (1)	6°20'13.47"N	PM10 at 0 meters	48	48	48	48	44
			5°37'14.91"E	PM10 at 3 meters	44	46	45	45	42
				PM10 at 5 meters	45	44	43	44	41

6.	Jay Doherty (Ibewe street)	One (1)	6°20'15.25"N 5°37'13.6"E	PM10 at 0 meters	47	48	44	46	43
				PM10 at 3 meters	40	40	41	40	37
				PM10 at 5 meters	40	39	39	39	36
7.	Ken Diuwa Shopping mall (Ibewe street)	Four (4)	6°20'15.25"N 5°37'13.6"E	PM10 at 0 meters	66	60	64	63	55
				PM10 at 3 meters	60	63	59	61	54
				PM10 at 5 meters	55	55	55	55	51
8.	Divine KC cosmetics (Lagos street)	Two (2)	6°20'8.38"N 5°37'18.47"E	PM10 at 0 meters	51	51	51	51	47
				PM10 at 3 meters	43	45	43	44	41
				PM10 at 5 meters	40	41	41	41	38
9.	Bazuaze Complex (Mission Rd)	Four (4)	6°20'12.2"N 5°37'25.19"E	PM10 at 0 meters	60	61	62	61	54
				PM10 at 3 meters	55	57	57	56	51
				PM10 at 5 meters	50	49	46	48	44
10.	Electro mall (Mission)	Four (4)	6°20'26.8"N 5°37'33.72"E	PM10 at 0 meters	60	61	60	60	53
				PM10 at 3 meters	55	56	55	55	51
				PM10 at 5 meters	50	50	48	49	45
11.	Mobil filling Station (Mission Rd)	Three (3)	6°20'32.02"N 5°37'34.59"E	PM10 at 0 meters	54	53	54	54	50
				PM10 at 3 meters	52	52	52	52	48
				PM10 at 5 meters	50	49	46	48	44
12.	High Quality Doors	Two (2)	6°20'31.33"N 5°37'36.68"E	PM10 at 0 meters	51	49	51	50	46
				PM10 at 3 meters	46	43	43	44	41
				PM10 at 5 meters	40	40	40	40	37
13.	Digital Show room (Mission Rd)	Three (3)	6°20'33.45"N 5°37'38.73"E	PM10 at 0 meters	55	55	56	55	51
				PM10 at 3 meters	50	50	50	50	46
				PM10 at 5 meters	55	51	49	52	48

14.	Authentic House of Fabric (Forestry Rd)	Two (2)	6°20'10.57"N 5°37'28.68"E	PM10 at 0 meters	51	54	53	53	49
				PM10 at 3 meters	44	42	43	43	40
				PM10 at 5 meters	42	44	40	42	39
15.	Generator Repair shop (Forestry Rd)	Three (3)	6°20'19.86"N 5°37'36.82"E	PM10 at 0 meters	56	55	56	56	51
				PM10 at 3 meters	49	51	49	50	46
				PM10 at 5 meters	43	44	45	44	41
16.	Awesome God shop (Akpakpava Rd)	Two (2)	6°20'18.1"N 5°37'47.14"E	PM10 at 0 meters	52	51	51	51	47
				PM10 at 3 meters	47	49	46	47	44
				PM10 at 5 meters	43	43	43	43	40

4.3 DISCUSSION OF PM2.5 AND PM10 RESULTS.

PM2.5 and PM10 concentrations were consistently higher at 0 m and gradually decreased at 3 m and 5 m from the generator sources. For instance, Osawarhun Complex (with 15 generators) recorded average PM2.5 and PM10 levels of $70 \text{ Ug}/m^3$ and $85 \text{ Ug}/m^3$ respectively at 0 m, whereas Rince Shoes, which had only one generator, recorded lower levels of $35 \mu\text{g}/m^3$ (PM2.5) and $48 \text{ Ug}/m^3$ (PM10). This reduction with distance reflects normal dispersion and dilution of particulates in open air.

When compared with the World Health Organization (WHO) air quality guidelines $15 \text{ Ug}/m^3$ (24-hour mean) for PM2.5 and $45 \text{ Ug}/m^3$ (24-hour mean) for PM10, it is clear that all the sampled sites exceeded safe exposure limits, particularly at 0 m and 3 m distances (World Health Organization [WHO], 2021). Such elevated particulate levels have been associated with respiratory and cardiovascular diseases and can pose serious public-health risks to workers and customers exposed for prolonged periods.

4.4 CARBON MONOXIDE

Table 4.3 shows the measured concentrations of **CO** across selected locations in the study area. Readings were taken at different distances from running electric generators and averaged over one-minute intervals. The table also includes AQI values.

Table 4.3: READINGS FOR CO (Carbon monoxide (ppm))

S/N	Locations	Number of Actively running Electric Generators.	Coordinates	Parameter readings at distances away from the Electric Generators.	Readings at one (1) minute intervals.			Average	AQI		
					1 min	2 min	3 min				
1.	Osawarhun Complex (Ibewe street)	Fifteen(15)	6°20'6.83"N 5°37'15.87"E	CO at 0 meters	300	310	312	307	3066		
				CO at 3 meters	210	210	220			213	2126
				CO at 5 meters	130	131	131			131	1306
2.	Osarentin Complex (Ibewe street)	Three (3)	6°20'9.11"N 5°37'15.51"E	CO at 0 meters	89	89	90	89	886		
				CO at 3 meters	75	81	81			79	786
				CO at 5 meters	64	67	67			66	656
3.	Swarhele complex (Ibewe street)	Three (3)	6°20'11.24"N 5°37'14.81"E	CO at 0 meters	85	86	87	86	856		
				CO at 3 meters	73	74	76			74	736
				CO at 5 meters	60	62	63			62	616
4.	Guinness Plaza	Four (4)	6°20'13.13"N	CO at 0 meters	100	110	120	110	1096		

	(Ibewe street)		5°37'14.9"E	CO at 3 meters	85	86	87	86	856
				CO at 5 meters	70	71	75	72	716
5.	Rince Shoes (Ibewe street)	One (1)	6°20'13.47"N	CO at 0 meters	26	27	30	28	284
			5°37'14.91"E	CO at 3 meters	17	19	19	18	218
				CO at 5 meters	8	8	8	8	86
6.	Jay Doherty (Ibewe street)	One (1)	6°20'15.25"N	CO at 0 meters	24	34	35	31	306
			5°37'13.6"E	CO at 3 meters	16	16	17	16	204
				CO at 5 meters	9	10	11	10	109
7.	Ken Diuwa Shopping mall (Ibewe street)	Four (4)	6°20'15.25"N	CO at 0 meters	99	86	91	92	916
			5°37'13.6"E	CO at 3 meters	86	79	83	83	826
				CO at 5 meters	70	74	74	73	726
8.	Divine KC cosmetics (Lagos street)	Two (2)	6°20'8.38"N	CO at 0 meters	40	41	41	41	406
			5°37'18.47"E	CO at 3 meters	39	39	39	39	386
				CO at 5 meters	31	31	31	31	306
9.	Bazuaze Complex (Mission Rd)	Four (4)	6°20'12.2"N	CO at 0 meters	95	95	95	95	946
			5°37'25.19"E	CO at 3 meters	70	71	72	71	706
				CO at 5 meters	55	51	56	54	536
10.	Electro mall (Mission)	Four (4)	6°20'26.8"N	CO at 0 meters	100	105	105	103	1026
			5°37'33.72"E	CO at 3 meters	90	89	93	91	906
				CO at 5 meters	67	70	74	70	696
11.	Mobil filling Station (Mission Rd)	Three (3)	6°20'32.02"N	CO at 0 meters	80	90	88	86	856
			5°37'34.59"E	CO at 3 meters	70	73	75	73	726
				CO at 5 meters	60	64	64	63	626
12.	High Quality	Two (2)	6°20'31.33"N	CO at 0 meters	40	41	42	41	406

	Doors		5°37'36.68"E	CO at 3 meters	31	34	35	33	326
				CO at 5 meters	24	25	25	25	264
13.	Digital Show room (Mission Rd)	Three (3)	6°20'33.45"N	CO at 0 meters	87	88	88	88	876
			5°37'38.73"E	CO at 3 meters	74	74	74	74	736
				CO at 5 meters	60	60	65	62	616
14.	Authentic House of Fabric (Forestry Rd)	Two (2)	6°20'10.57"N	CO at 0 meters	40	41	39	40	396
			5°37'28.68"E	CO at 3 meters	20	24	25	23	251
				CO at 5 meters	9	10	13	11	126
15.	Generator Repair shop (Forestry Rd)	Three (3)	6°20'19.86"N	CO at 0 meters	87	89	99	92	916
			5°37'36.82"E	CO at 3 meters	76	69	73	73	726
				CO at 5 meters	63	63	63	63	626
16.	Awesome God shop (Akpakpava Rd)	Two (2)	6°20'18.1"N	CO at 0 meters	45	40	42	42	416
			5°37'47.14"E	CO at 3 meters	23	25	29	26	271
				CO at 5 meters	15	13	13	14	176

4.5 DISCUSSION OF CO RESULTS.

CO levels were notably high at sites with multiple generators. At Osawarhun Complex, the average CO concentration at 0 m was 307 ppm, dropping to 131 ppm at 5 m. In contrast, single-generator locations such as Rince Shoes and Jay Doherty recorded CO levels between 28 ppm and 31 ppm at 0 m. These findings reveal a clear relationship between the number of generators, proximity, and CO concentration.

The WHO's one-hour exposure guideline for CO is 26 ppm (30 mg/m³) (WHO, 2021).

Therefore, almost all recorded CO values especially at 0 m and 3 m were several times

above the recommended limit. This suggests that individuals working close to generator exhausts are at risk of headaches, fatigue, and even mild hypoxia resulting from CO inhalation. The results align with those of Anuforom (2019), who reported similarly high CO concentrations in commercial zones relying on diesel generators in southern Nigeria.

4.6 OZONE

Table 4.4 shows the measured concentrations of **O₃** across selected locations in the study area. Readings were taken at different distances from running electric generators and averaged over one-minute intervals. The table also includes AQI values.

Table 4.4: READINGS FOR O₃ (Ozone (ppm))

S/N	Locations	Number of Actively running Electric Generators.	Coordinates	Parameter readings at distances away from the Electric Generators.	Readings at one (1) minute intervals.			Average	AQI
					1 min	2 min	3 min		
1.	Osawarhun Complex (Ibewe street)	Fifteen(15)	6°20'6.83"N 5°37'15.87"E	O ₃ at 0 meters	7.16	7.19	7.19	7.18	6
				O ₃ at 3 meters	4.11	4.13	4.16	4.13	4
				O ₃ at 5 meters	2.10	1.90	1.99	1.99	1
2.	Osarentin Complex (Ibewe street)	Three (3)	6°20'9.11"N 5°37'15.51"E	O ₃ at 0 meters	1.43	1.44	1.44	1.44	1
				O ₃ at 3 meters	0.57	1.00	0.55	0.71	0
				O ₃ at 5 meters	0.06	0.31	0.41	0.26	0
3.	Swarhele complex (Ibewe street)	Three (3)	6°20'11.24"N 5°37'14.81"E	O ₃ at 0 meters	1.53	1.52	1.52	1.52	1
				O ₃ at 3 meters	0.61	0.63	0.57	0.60	0
				O ₃ at 5 meters	0.29	0.31	0.33	0.31	0

4.	Guinness Plaza (Ibewe street)	Four (4)	6°20'13.13"N 5°37'14.9"E	O3 at 0 meters	1.91	1.91	1.91	1.91	1
				O3 at 3 meters	1.31	1.22	1.29	1.27	1
				O3 at 5 meters	0.60	0.50	0.60	0.60	0
5.	Rince Shoes (Ibewe street)	One (1)	6°20'13.47"N 5°37'14.91"E	O3 at 0 meters	0.45	0.45	0.45	0.45	0
				O3 at 3 meters	0.26	0.24	0.29	0.26	0
				O3 at 5 meters	0.04	0.07	0.08	0.06	0
6.	Jay Doherty (Ibewe street)	One (1)	6°20'15.25"N 5°37'13.6"E	O3 at 0 meters	0.47	0.45	0.39	0.44	0
				O3 at 3 meters	0.23	0.24	0.30	0.26	0
				O3 at 5 meters	0.03	0.05	0.03	0.04	0
7.	Ken Diuwa Shopping mall (Ibewe street)	Four (4)	6°20'15.25"N 5°37'13.6"E	O3 at 0 meters	1.93	1.94	1.93	1.93	1
				O3 at 3 meters	1.34	1.33	1.36	1.34	1
				O3 at 5 meters	0.70	0.60	0.40	0.60	0
8.	Divine KC cosmetics (Lagos street)	Two (2)	6°20'8.38"N 5°37'18.47"E	O3 at 0 meters	0.95	0.95	0.96	0.95	0
				O3 at 3 meters	0.70	0.71	0.80	0.74	0
				O3 at 5 meters	0.45	0.44	0.42	0.44	0
9.	Bazuaze Complex (Mission Rd)	Four (4)	6°20'12.2"N 5°37'25.19"E	O3 at 0 meters	1.95	1.93	1.89	1.92	1
				O3 at 3 meters	1.31	1.38	1.29	1.33	1
				O3 at 5 meters	0.56	0.60	0.61	0.59	0
10.	Electro mall (Mission)	Four (4)	6°20'26.8"N 5°37'33.72"E	O3 at 0 meters	1.94	1.91	1.93	1.93	1
				O3 at 3 meters	1.32	1.34	1.35	1.34	1
				O3 at 5 meters	0.5	0.4	0.5	0.5	0
11.	Mobil filling Station (Mission Rd)	Three (3)	6°20'32.02"N 5°37'34.59"E	O3 at 0 meters	1.54	1.43	1.56	1.51	1
				O3 at 3 meters	0.54	0.57	0.57	0.56	0
				O3 at 5 meters	0.07	0.03	0.06	0.05	0

12.	High Quality Doors	Two (2)	6°20'31.33"N 5°37'36.68"E	O3 at 0 meters	0.92	0.89	0.87	0.89	0
				O3 at 3 meters	0.71	0.70	0.69	0.70	0
				O3 at 5 meters	0.43	0.44	0.41	0.43	0
13.	Digital Show room (Mission Rd)	Three (3)	6°20'33.45"N 5°37'38.73"E	O3 at 0 meters	1.48	1.48	1.50	1.49	1
				O3 at 3 meters	0.66	0.62	0.62	0.63	0
				O3 at 5 meters	0.25	0.29	0.28	0.27	0
14.	Authentic House of Fabric (Forestry Rd)	Two (2)	6°20'10.57"N 5°37'28.68"E	O3 at 0 meters	0.93	0.97	0.83	0.91	0
				O3 at 3 meters	0.70	0.71	0.79	0.73	0
				O3 at 5 meters	0.43	0.42	0.44	0.43	0
15.	Generator Repair shop (Forestry Rd)	Three (3)	6°20'19.86"N 5°37'36.82"E	O3 at 0 meters	1.61	1.51	1.53	1.55	1
				O3 at 3 meters	0.57	0.77	0.65	0.66	0
				O3 at 5 meters	0.28	0.29	0.33	0.30	0
16.	Awesome God shop (Akpakpava Rd)	Two (2)	6°20'18.1"N 5°37'47.14"E	O3 at 0 meters	1.11	0.95	0.95	1.00	1
				O3 at 3 meters	0.70	0.71	0.80	0.74	0
				O3 at 5 meters	0.34	0.35	0.39	0.36	0

4.7 DISCUSSION OF O3 RESULTS.

Measured ozone concentrations were generally low across all sampling sites, ranging between 0.03 ppm and 7.18 ppm. The highest levels were recorded at Osawarhun Complex (7.18 ppm) and the lowest at small single-generator locations such as Rince Shoes (0.45 ppm). The WHO guideline for ambient O₃ concentration is 0.1 ppm (8-hour mean) (WHO, 2021). Although a few isolated readings appeared above this threshold, these may be attributed to photochemical reactions involving nitrogen oxides and volatile

organic compounds from generator exhausts. The relatively low O₃ values overall suggest limited secondary photochemical activity during the sampling period.

4.8 TOTAL VOLATILE ORGANIC COMPOUNDS

Table 4.5 shows the measured concentrations of TVOC across selected locations in the study area. Readings were taken at different distances from running electric generators and averaged over one-minute intervals.

Table 4.5: READINGS FOR TVOC (Total Volatile Organic Compounds (mg/m³))

S/N	Locations	Number of Actively running Electric Generators.	Coordinates	Parameter readings at distances away from the Electric Generators.	Readings at one (1) minute intervals.			Average
					1 min	2 min	3 min	
1.	Osawarhun Complex (Ibewe street)	Fifteen (15)	6°20'6.83"N 5°37'15.87"E	TVOC at 0 meters	0.072	0.074	0.077	0.074
				TVOC at 3 meters	0.022	0.024	0.031	0.026
				TVOC at 5 meters	0.017	0.016	0.018	0.017
2.	Osarentin Complex (Ibewe street)	Three (3)	6°20'9.11"N 5°37'15.51"E	TVOC at 0 meters	0.024	0.025	0.024	0.024
				TVOC at 3 meters	0.019	0.020	0.018	0.019
				TVOC at 5 meters	0.013	0.012	0.014	0.013
3.	Swarhele complex (Ibewe street)	Three (3)	6°20'11.24"N 5°37'14.81"E	TVOC at 0 meters	0.023	0.023	0.024	0.023
				TVOC at 3 meters	0.020	0.017	0.019	0.019
				TVOC at 5 meters	0.013	0.014	0.013	0.013

4.	Guinness Plaza (Ibewe street)	Four (4)	6°20'13.13"N 5°37'14.9"E	TVOC at 0 meters	0.034	0.034	0.034	0.034
				TVOC at 3 meters	0.029	0.031	0.027	0.029
				TVOC at 5 meters	0.024	0.023	0.022	0.023
5.	Rince Shoes (Ibewe street)	One (1)	6°20'13.47"N 5°37'14.91"E	TVOC at 0 meters	0.015	0.016	0.016	0.016
				TVOC at 3 meters	0.012	0.012	0.012	0.012
				TVOC at 5 meters	0.010	0.009	0.010	0.010
6.	Jay Doherty (Ibewe street)	One (1)	6°20'15.25"N 5°37'13.6"E	TVOC at 0 meters	0.014	0.016	0.017	0.016
				TVOC at 3 meters	0.011	0.010	0.012	0.011
				TVOC at 5 meters	0.009	0.008	0.008	0.008
7.	Ken Diuwa Shopping mall (Ibewe street)	Four (4)	6°20'15.25"N 5°37'13.6"E	TVOC at 0 meters	0.035	0.036	0.034	0.035
				TVOC at 3 meters	0.028	0.026	0.029	0.028
				TVOC at 5 meters	0.024	0.023	0.022	0.023
8.	Divine KC cosmetics (Lagos street)	Two (2)	6°20'8.38"N 5°37'18.47"E	TVOC at 0 meters	0.019	0.019	0.019	0.019
				TVOC at 3 meters	0.011	0.012	0.013	0.012
				TVOC at 5 meters	0.009	0.008	0.007	0.008
9.	Bazuaze Complex (Mission Rd)	Four (4)	6°20'12.2"N 5°37'25.19"E	TVOC at 0 meters	0.033	0.034	0.040	0.036
				TVOC at 3 meters	0.028	0.029	0.028	0.028
				TVOC at 5 meters	0.023	0.024	0.025	0.024
10.	Electro mall (Mission)	Four (4)	6°20'26.8"N 5°37'33.72"E	TVOC at 0 meters	0.030	0.031	0.031	0.031
				TVOC at 3 meters	0.025	0.024	0.027	0.025
				TVOC at 5 meters	0.022	0.022	0.022	0.022
11.	Mobil filling Station (Mission Rd)	Three (3)	6°20'32.02"N 5°37'34.59"E	TVOC at 0 meters	0.024	0.023	0.025	0.024
				TVOC at 3 meters	0.019	0.019	0.019	0.019
				TVOC at 5 meters	0.013	0.014	0.015	0.014

12.	High Quality Doors	Two (2)	6°20'31.33"N 5°37'36.68"E	TVOC at 0 meters	0.018	0.019	0.018	0.018
				TVOC at 3 meters	0.012	0.011	0.014	0.012
				TVOC at 5 meters	0.008	0.007	0.006	0.007
13.	Digital Show room (Mission Rd)	Three (3)	6°20'33.45"N 5°37'38.73"E	TVOC at 0 meters	0.024	0.023	0.027	0.025
				TVOC at 3 meters	0.018	0.019	0.017	0.054
				TVOC at 5 meters	0.012	0.013	0.014	0.013
14.	Authentic House of Fabric (Forestry Rd)	Two (2)	6°20'10.57"N 5°37'28.68"E	TVOC at 0 meters	0.019	0.019	0.019	0.019
				TVOC at 3 meters	0.011	0.012	0.013	0.012
				TVOC at 5 meters	0.008	0.008	0.008	0.008
15.	Generator Repair shop (Forestry Rd)	Three (3)	6°20'19.86"N 5°37'36.82"E	TVOC at 0 meters	0.024	0.023	0.027	0.025
				TVOC at 3 meters	0.018	0.019	0.017	0.018
				TVOC at 5 meters	0.012	0.013	0.014	0.013
16.	Awesome God shop (Akpakpava Rd)	Two (2)	6°20'18.1"N 5°37'47.14"E	TVOC at 0 meters	0.019	0.017	0.018	0.018
				TVOC at 3 meters	0.011	0.012	0.014	0.012
				TVOC at 5 meters	0.009	0.008	0.007	0.008

4.9 DISCUSSION OF TVOC RESULTS.

TVOC readings followed the same pattern observed for CO and particulate matter: higher at 0 m and lower at 5 m. Osawarhun Complex recorded the highest average of 0.074 mg/ m^3 at 0 m, while single-generator sites such as Jay Doherty and Rince Shoes recorded between 0.016 mg/ m^3 and 0.018 mg/ m^3 . Although WHO has not set a specific limit for total VOCs, the European Indoor Air Quality Standard recommends concentrations below 0.2 mg/ m^3 for comfort and health protection (European

Commission, 2022). Hence, all measured values were below this limit, implying that VOC emissions were present but within tolerable ranges.

4.10 NOISE

Table 4.6 shows the measured concentrations of **NOISE** across selected locations in the study area. Readings were taken at different distances from running electric generators and averaged over one-minute intervals.

Table 4.6: READINGS FOR NOISE (dB)A

S/N	Locations	Number of Actively running Electric Generators.	Coordinates	Noise Readings.
1.	Osawarhun Complex (Ibewe street)	Fifteen (15)	6°20'6.83" N 5°37'15.87"E	96.8
2.	Osarentin Complex (Ibewe street)	Three (3)	6°20'9.11" N 5°37'15.51"E	88.0
3.	Swarhele complex (Ibewe street)	Three (3)	6°20'11.24" N 5°37'14.81"E	88.5
4.	Guinness Plaza (Ibewe street)	Four (4)	6°20'13.13" N 5°37'14.9"E	89.9
5.	Rince Shoes (Ibewe street)	One (1)	6°20'13.47" N 5°37'14.91"E	82.0
6.	Jay Doherty (Ibewe street)	One (1)	6°20'15.25" N 5°37'13.6"E	80.0

7.	Ken Diuwa Shopping mall (Ibewe street)	Four (4)	6°20'15.25" N 5°37'13.6" E	89.0
8.	Divine KC cosmetics (Lagos street)	Two (2)	6°20'8.38" N 5°37'18.47"E	85.0
9.	Bazuaze Complex (Mission Rd)	Four (4)	6°20'12.2" N 5°37'25.19"E	91.0
10.	Electro mall (Mission)	Four (4)	6°20'26.8" N 5°37'33.72"E	91.9
11.	Mobil filling Station (Mission Rd)	Three (3)	6°20'32.02" N 5°37'34.59"E	90.0
12.	High Quality Doors	Two (2)	6°20'31.33" N 5°37'36.68"E	85.5
13.	Digital Show room (Mission Rd)	Three (3)	6°20'33.45" N 5°37'38.73"E	90.5
14.	Authentic House of Fabric (Forestry Rd)	Two (2)	6°20'10.57" N 5°37'28.68"E	85.0
15.	Generator Repair shop (Forestry Rd)	Three (3)	6°20'19.86" N 5°37'36.82"E	89.9
16.	Awesome God shop (Akpakpava Rd)	Two (2)	6°20'18.1" N 5°37'47.14"E	85.5

4.11 DISCUSSION OF NOISE RESULTS.

Noise measurements ranged from 80 dB(A) at Jay Doherty (one generator) to 96.8 dB(A) at Osawarhun Complex (15 generators). According to the WHO Environmental Noise Guidelines, continuous exposure above 70 dB(A) over 24 hours can lead to hearing impairment and other health effects (WHO, 2018). In this case the Noise is not constant for 24 hours, as of the time when the readings were taken there was outage of power and it was later observed that power was restored. The high readings can be attributed to the

proximity of generators, absence of soundproofing, and reflective concrete surfaces that amplify sound intensity.

It was also observed that shops with single generators typically positioned them directly at the entrance, primarily for ease of access and ventilation. However, this placement significantly exposes both workers and customers to noise and exhaust fumes at the point of entry, increasing health risks despite the lower total emissions.

4.12 BAR CHART REPRESENTATIONS

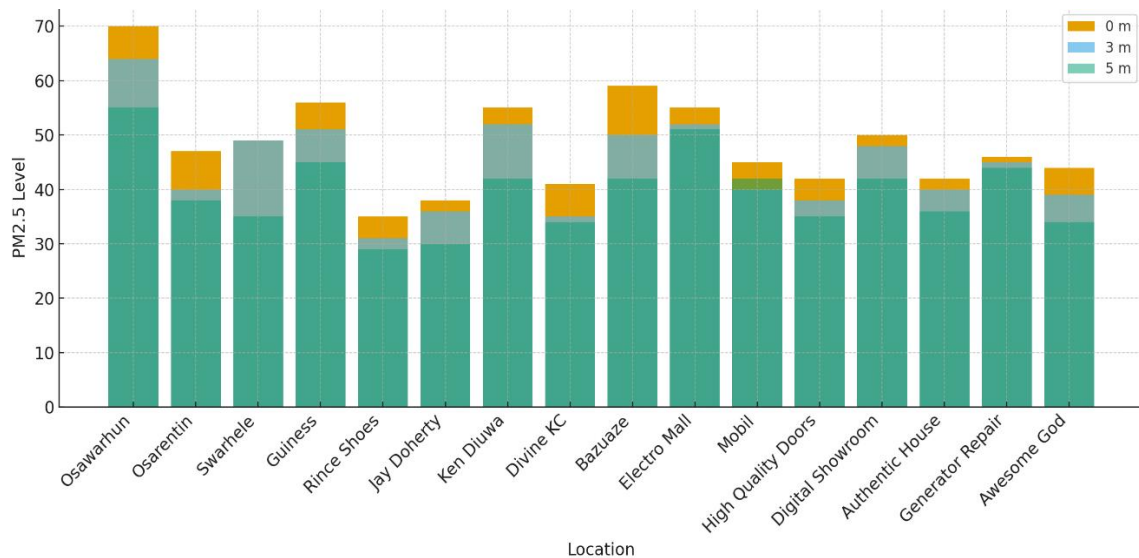


Figure 4.1: PM2.5 Concentration at different distances from Actively running Generators

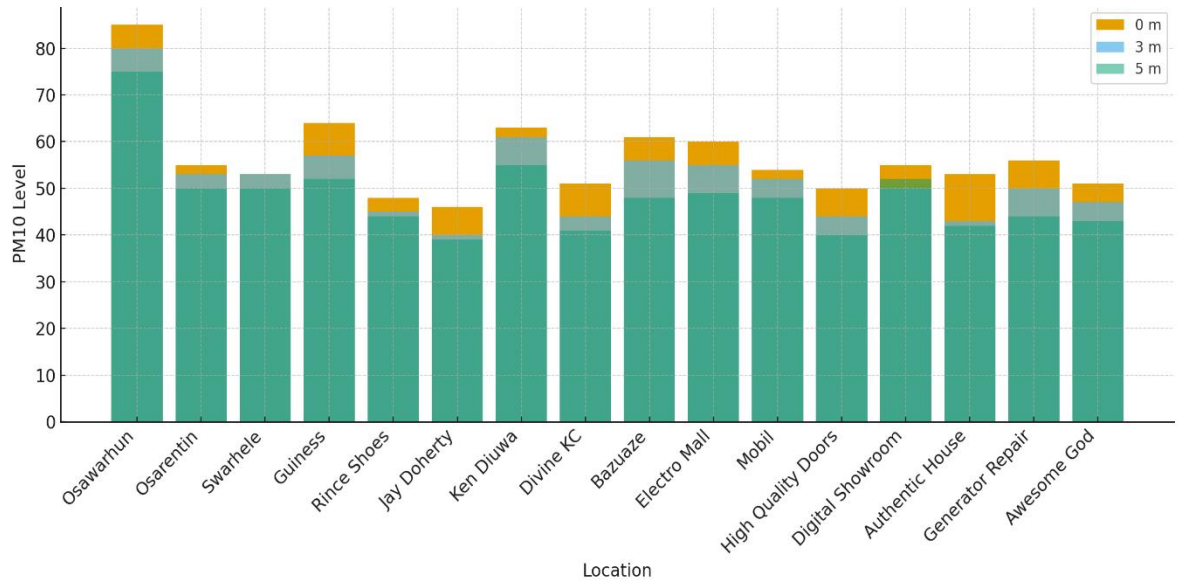


Figure 4.2: PM10 Concentration at different distances from Actively running Generators

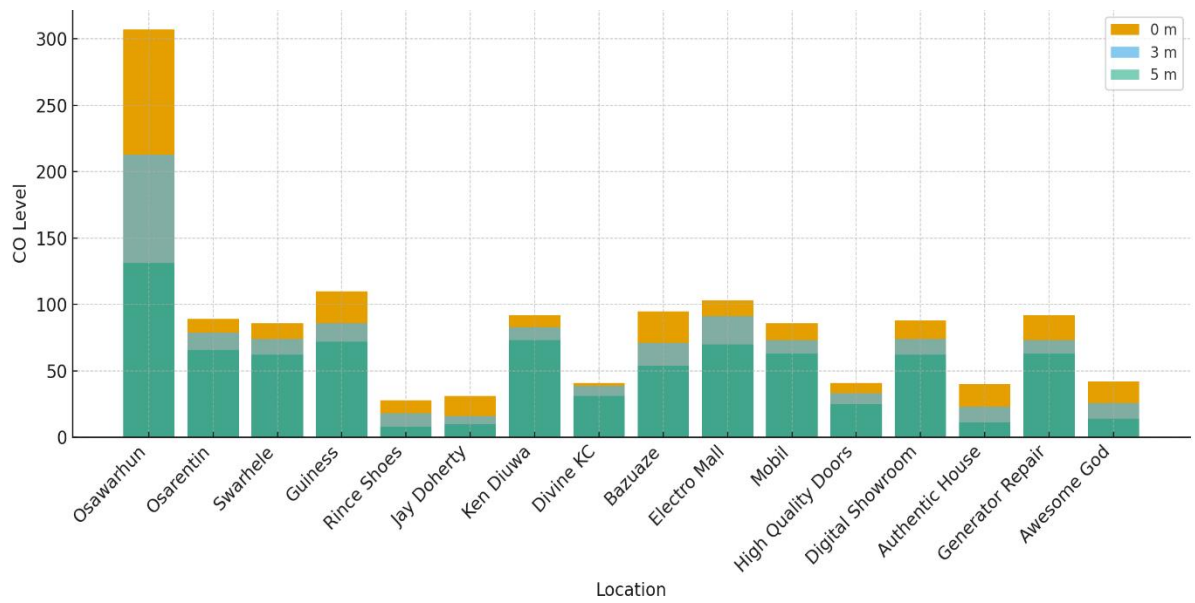


Figure 4.3: CO Concentration at different distances from Actively running Generators

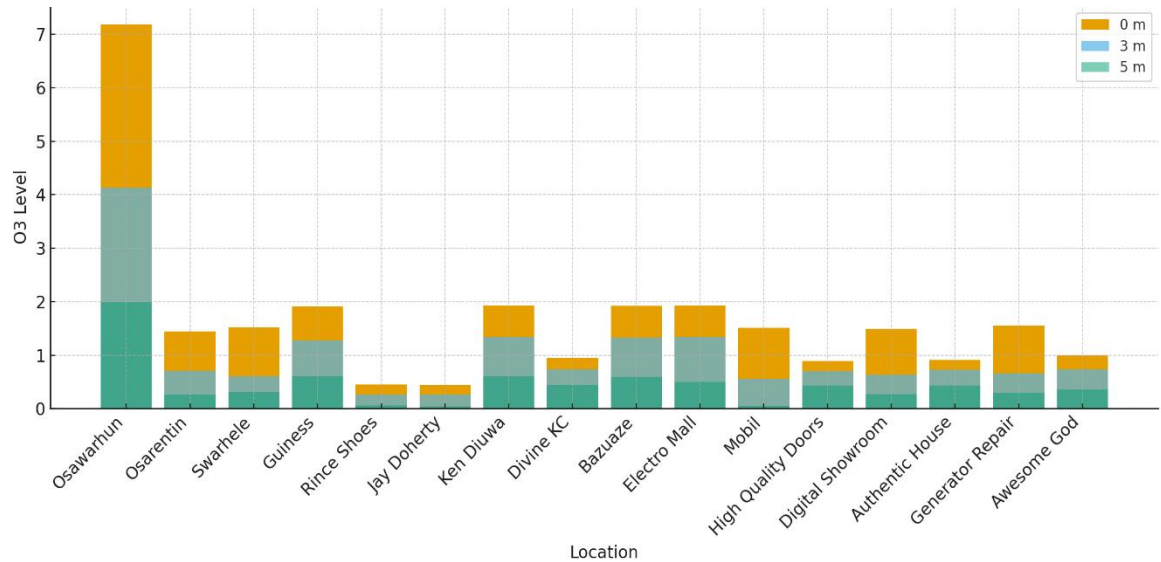


Figure 4.4: O3 Concentration at different distances from Actively running Generators

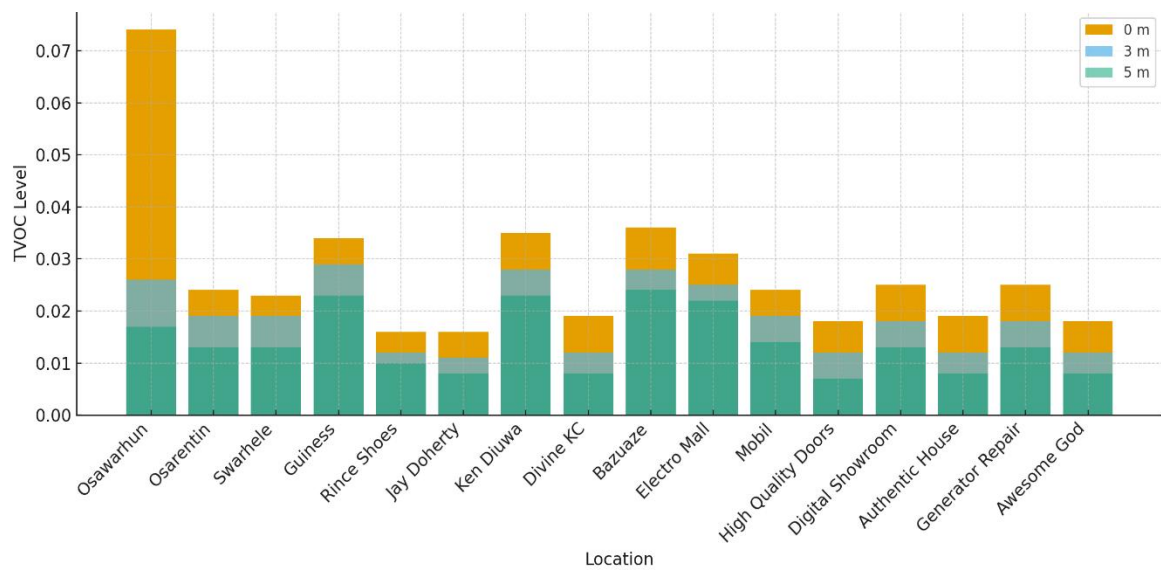


Figure 4.5: TVOC Concentration at different distances from Actively running Generators

4.13 GENERAL DISCUSSION OF RESULTS

The results presented in Tables 4.1 to 4.6 indicate clear variations in air pollutant concentrations and noise levels across the sixteen monitored commercial locations in

Benin City. In general, sites with a higher number of actively running generators such as Osawarhun Complex and Guinness Plaza recorded substantially higher pollutant concentrations compared to locations with one or two generators. The elevated readings at these sites are largely due to the cumulative emissions from multiple generator exhausts operating simultaneously in confined spaces.

Table 4.7: International Air Quality and Noise Standards for Comparison

Parameter	Standard Limit	Averaging Time	Reference Organization	Remarks / Health Implication
PM2.5	15 $\mu\text{g}/\text{m}^3$	24-hour mean	World Health Organization (WHO, 2021)	Levels above this can cause respiratory and cardiovascular problems
PM10	45 $\mu\text{g}/\text{m}^3$	24-hour mean	(WHO, 2021)	Long-term exposure may trigger asthma and lung irritation.
CO (Carbon Monoxide)	26 ppm (\approx 30 mg/m^3)	1-hour average	(WHO, 2021)	High concentrations cause headaches, dizziness, and reduced oxygen uptake.
O3 (Ozone)	0.1 ppm (\approx 100 $\mu\text{g}/\text{m}^3$)	8-hour mean	(WHO, 2021)	Can irritate airways and reduce lung function
TVOC (Total Volatile Organic Compounds)	\leq 0.2 mg/m^3	Long-term exposure	(WHO, 2021)	Above 0.2 mg/m^3 may cause eye and

				throat irritation or headaches.
NOISE LEVEL	70 dB(A)	24-hour average	(WHO, 2021)	Prolonged exposure > 70 dB can lead to hearing loss, stress, and sleep disturbance.

Source: (WHO 2021)

When compared with WHO, the measured concentrations of PM2.5, PM10, and CO in all sampled locations exceeded permissible limits, particularly at 0 m and 3 m distances from generator sources. This confirms that the air around commercial generator clusters in Benin City poses potential health risks to both workers and customers.

4.14 GENERAL INTERPRETATIONS

Overall, the data indicate that generator usage contributes significantly to localized air pollution and noise in Benin City's commercial areas. PM2.5, PM10, and CO values were consistently above WHO permissible limits, especially in areas with multiple running generators. The strong negative gradient with increasing distance from the generators further confirms that generator exhaust is the major pollution source. These results agree with the findings of Ezeonu et al. (2020), who reported that generator clusters in Nigerian urban markets emit high particulate and gaseous pollutants exceeding international safety limits.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study investigated the impact of electric power generators on air and noise quality across selected commercial areas in Benin City, Edo State. Measurements were taken for key air pollutants including particulate matter (PM_{2.5} and PM₁₀), carbon monoxide (CO), ozone (O₃), and total volatile organic compounds (TVOCs) as well as ambient noise levels at various distances from the generators. The findings revealed a consistent pattern: pollutant concentrations and noise intensity were highest near generator exhausts and decreased gradually with distance.

Locations with multiple operating generators, such as Osawarhun Complex and Guinness Plaza, showed the highest pollution levels. In contrast, shops with only one generator recorded lower readings, although many of these single units were positioned directly at

shop entrances, exposing occupants and customers to harmful exhaust emissions at close range.

The comparison of measured values with the **World Health Organization (WHO)** air quality and noise standards clearly indicates that most of the observed pollutant concentrations exceeded recommended limits. PM_{2.5} and PM₁₀ values were several times higher than WHO's 24-hour limits of 15 $\mu\text{g}/\text{m}^3$ and 45 $\mu\text{g}/\text{m}^3$ respectively. Similarly, the CO readings in most locations surpassed the one-hour WHO guideline of 26 ppm.

From these observations, it can be concluded that the use of electrical power generators in commercial centers significantly contributes to localized air pollution and noise hazards in Benin City. The situation is worsened by the high density of generators, poor maintenance culture, and the absence of soundproof or emission control mechanisms. If left unchecked, these conditions pose serious risks to public health, including respiratory problems, hearing impairment, and general discomfort for both traders and customers.

5.2 RECOMMENDATIONS

Based on the findings and conclusions of this research, the following recommendations are made to individuals, business owners, government bodies, and relevant agencies:

1. Adoption of Cleaner Energy Alternatives:

Individuals and business operators should be encouraged to use renewable or cleaner power sources such as solar panels, and inverter systems. These alternatives can significantly reduce dependence on petrol and diesel generators.

2. Proper Siting and Housing of Generators:

Generators should not be placed at shop entrances or walkways. Instead, they

should be located in well-ventilated outdoor spaces or enclosed in soundproof housings fitted with exhaust outlets directed away from people and buildings.

3. Regular Maintenance and Emission Control:

Routine servicing of generators should be made mandatory for commercial users to ensure complete fuel combustion and lower emission of harmful gases like CO.

4. Government Regulation and Enforcement:

Environmental agencies such as NESREA and Edo State Ministry of Environment should enforce strict guidelines for generator placement. Periodic inspection of commercial areas will help ensure compliance.

5. Public Awareness and Education:

Awareness campaigns should be organized to inform traders, artisans, and the public about the dangers of prolonged exposure to generator fumes and high noise levels. Simple safety practices such as keeping safe distances can reduce health risks.

6. Further Research:

Future studies should expand to include continuous long-term monitoring of pollutants and assess their seasonal variations. Health impact assessments could also be conducted to link pollution levels with respiratory and auditory conditions among exposed populations.

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