

**COMPARATIVE ANALYSIS ON THE CORRELATION STUDY OF PM_{2.5} AND
METEOROLOGICAL PARAMETERS WITHIN SELECTED SCHOOLS IN OREDO
LOCAL GOVERNMENT AREA OF EDO STATE.**

BY

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CERTIFICATION

This is to certify that the project work was carried out by Edith Chidinma Osadebe (Miss) with Matriculation Number LSC1706124 of the Department of Science Laboratory Technology, Faculty of Life Science, University of Benin.

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ABSTRACT

Air is essential for sustaining life on Earth. It provides us with oxygen to breathe, and regulates the Earth's climate. Clean and healthy air is needed for our overall well-being and the environment. Unfortunately, our environment has been exposed to different air pollutants because of various daily activities. Most of these day-to-day activities of human occur in an indoor environment, as people spend more of their daily time indoors; hence, the tendency to be exposed to indoor air pollution is considerably high compared with the outdoor air pollutants. For young children, classrooms are a major indoor environment where they spend approximately 90% of their daily active time in a day, as such indoor air quality become crucial. Fine particulate matter (PM_{2.5}) have been linked to serious health issues. PM_{2.5} is a particulate matter which has an aerodynamic diameter of 2.5 or less and has the capacity to penetrate deep into the lungs, generated from transportation (Vehicular exhaust fumes, wear and tear of roads, brakes, and tyres) and industrial combustion processes such as cooking. It therefore becomes necessary to conduct a study on the atmospheric air condition of the indoor environment. The interaction between PM_{2.5} and meteorological parameters in schools is paramount as it plays a crucial role in air pollution analysis due to health implications on school children.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF STUDY

Most day-to-day activities of humans occur in an indoor environment, which are characterized by serious alteration of chemical composition of air quality. It is estimated that people spend more of their daily time indoors; hence, the tendency to be exposed to indoor air pollution is considerably high compared with outdoor air pollutants (Almeida et al., 2011). For young children, classrooms are a major indoor environment where they spend approximately 90% of their daily active time in a day, as such indoor air quality become crucial (Chen et al., 2019). Air pollution in general is recognized world over as a threat to the health of humans, even at small concentrations, since it has been, beyond any reservation, linked with many effects on human health, as well as increased mortality and morbidity rates (EEA, 2017). Also, several studies have shown that classroom air contain many of these toxic pollutants. Prominent among these pollutants is fine particulates (PM_{2.5}.)

PM_{2.5} is a major concern for public health due to its apparent visibility (Liang et al., 2016) and adverse effects on human health (Kulkarni and Grigg, 2008). PM_{2.5} refers to the presence of fine particulate matter with a diameter of 2.5 micrometers or smaller in the air. PM_{2.5} are generated from transportation (Vehicular exhaust fumes, wear and tear of roads, brakes and tyres) and industrial combustion processes such as cooking, heating and burning of fossil fuels which flow into the indoor from ambient pollutants as a primary source (Visser et al., 2001; Perez-Padilla et al., 2010). Other sources of PM_{2.5} include improper ventilation or air conditioning system, human activities such as smoking, presence of biological agents and the use of chemical substances in a building. These particles are so small that they can easily be inhaled and penetrate deep into the

respiratory system. The smallest fractions ($PM \leq 2.5 \mu m$) may behave similar to gas molecules that can reach gas exchange regions of lungs, even translocate lungs and reach the circulatory system.

Numerous scientific studies have established a strong link between exposure to $PM_{2.5}$ and various health problems. Some of the key health implications associated with $PM_{2.5}$ exposure are respiratory effects, which increases risk of respiratory symptoms such as coughing, wheezing, and shortness of breath, exacerbates asthma and other respiratory conditions (Pope & Dockery, 2006) and reduces lung function and impairs lung development in children (Gauderman *et al.*, 2004). Also, cardiovascular effects associated with increased risk of cardiovascular diseases such as heart attacks, strokes, and high blood pressure (Brook *et al.*, 2010), accelerated atherosclerosis (hardening of arteries) and impaired heart rate variability and changes in cardiac autonomic function (Pope *et al.*, 2009).

Another health implication is the neurological effects. This increases risk of cognitive impairment and neurodevelopmental disorders in children (Block & Calderón-Garcidueñas, 2009), increases prevalence of neurodegenerative diseases such as Alzheimer's and Parkinson's (Chen *et al.*, 2017) and negatively affects mental health.

It is important to note that the health impacts of $PM_{2.5}$ exposure can vary depending on factors such as the duration and intensity of exposure, individual susceptibility, and underlying health conditions. One of the most susceptible subsections of the population are children, as their respiratory, immune, reproductive, central nervous and digestive systems are not entirely developed, which makes them at higher risks for the potential health effects induced by air pollution. As a result of their size, physiology and activity level, children inhalation rates of

PM_{2.5} are higher than adults. In addition, they exhibit higher oxygen consumption and resting metabolic rate per unit body weight.

1.2 STATEMENT OF PROBLEM

With the continual improvement in our quality of life, indoor air quality has become a crucial area of concern in the 21st century most especially among our children. PM_{2.5} pollution is one of the major problems in major cities of developed world and has now become a serious and worsening situation in rapid growing cities in the developing world, especially in Africa due to urbanization and industrialization (Dotse *et al.*, 2012). The composition of inhalable particulate matter is complex and differs depending on the source and location. PM_{2.5} emissions also affect air quality on a regional basis. When fugitive dust enters the atmosphere, the larger particles of dust typically fall quickly to the ground, but smaller particles less than 10 microns in diameter may remain suspended for longer periods, giving the particles time to travel across a regional area and affecting receptors at some distance from the original emissions source (Reyes *et al.*, 2014). According to USEPA 1986, indoor air quality can be 2-5 times worse than the ambient air quality especially about air borne chemicals, which makes the air inside more harmful than the outside air. Meanwhile children spend as much as 90% of their time indoors. Notably, our classrooms are claustrophobic with decrease airflow that makes stagnant air recirculate inside, given the already bad air quality outdoors to continuously flow indoor, the air inside can potentially have a bigger impact on health than what they breathe outside.

1.3 SIGNIFICANCE OF THE STUDY

Every child should be able to breathe clean air, so they can grow and fulfil their potentials. But unfortunately their daily exposure to these harmful pollutants become a threat to their health and well being. Studies has shown that there is no safe level of PM_{2.5} that is not associated with

negative health effects, indicating that even at low concentrations of PM_{2.5} pose a significant health threat. The effect of early childhood exposure to PM_{2.5} have shown children are at risk of neurodevelopmental disorders such as reduced intelligence, decreased cognitive development, negative behavioural development and pattern of hemispheric brain development among others (Chiu *et al.*, 2016 and Mc Guinn, 2020). This pollutant can at the same time lead to long-lasting health problems on children. Selected schools in Oredo Local Government Area of Edo state is of interest for the air pollution studies because, prominent in this area are: residential homes, banks, small-scale businesses, various high institutions like the state secretariat complex, Edo State House of Assembly complex among others . A dense population of prospective school children and other group of people spend a sizeable part of their time in this environment. It therefore becomes necessary to conduct a study on the atmospheric air condition of the indoor environment. The interaction between PM_{2.5} and meteorological parameters in schools is paramount as it plays a crucial role in air pollution analysis due to health implications on school children. Studies have shown that indoor PM_{2.5} concentrations can be influenced by outdoor pollution sources, ventilation systems, and human activities (USEPA, 2018). Indoor PM_{2.5} levels therefore have the potential to exceed the outdoor counterpart levels. However, less is known about the specific impacts of indoor fine particulates on children's health. This would be facilitated by establishing reliable information about the source-receptor relationship of the pollutants hence the need for this research work.

1.4 AIMS AND OBJECTIVES OF STUDY

The aim of this study is to compare the correlation of PM_{2.5} concentration and meteorological parameters in indoor environment within selected schools in Oredo Local Government Area of Edo State.

To achieve this aim, the following objectives were set.

1. To update the number of secondary schools in Oredo Local Government Area of Edo State.
2. To determine the level of PM_{2.5} concentration using Apex2Is Casella pump in the designated sampling points.
3. To assess the influence of meteorological factors.
4. To compare the variables using statistical tools.

1.5 JUSTIFICATION OF THE STUDY

Children's bodies are more vulnerable to environmental hazards in which PM_{2.5} is the chief among them. For their size, children breathe more air than adults do because, their airways are smaller and still developing as such they breathe more rapidly than adults and so absorb more pollutants (Salvi, 2009), thus are more exposure. Epidemiological studies shows that children are at higher risk due to these pollutants because their immune systems are still developing. Again, children depend on adults for their health and safety. Well-implemented indoor air quality solutions will result in cost savings. Hence, the need for this research work.

1.6 SCOPE OF THE STUDY

This research is centered on the following area;

- Indoor PM_{2.5} sampling and meteorological parameters collection across 5 selected sampling locations within schools in Oredo Local Government Area of Edo State between May and July, 2023.
- Determination of PM_{2.5} concentration using gravimetric method.
- Correlation of PM_{2.5} concentration and meteorological parameters using statistical tools.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Air Pollution

Air pollution is believed to be one of the most serious health problems that humans have faced, and it consists of solid, gases or liquids in indoor air in amounts that can be harmful to human health (Ayres *et al.*, 2006). The most common indoor air pollutants named by the United States environmental protection agency (USEPA) are ozone, particulate matter (PM), carbon monoxide, nitrogen oxides, sulphur dioxides and lead (Casse *et al.*, 2013). Particulate matter (PM) is one of the major constituent of indoor air pollution. Particulate matter is a complex chemical mixture consisting of heterogeneous group of components e.g. organic and inorganic substances and water with a large variation in relative concentrations (Goldstein and Galbaly, 2007).

Traditionally, particulate matter (PM) is categorized by size and the particle size ranges from nm to μm . Depending on the size, particles can be divided into two major groups; coarse and fine particles (Schwarze *et al.*, 2006). Coarse particles are particles with an aerodynamic diameter between $2.5\mu\text{m}$ to $10\mu\text{m}$ ($\text{PM}_{2.5-10}$), this group is produced from solid particles, i.e. non-exhaust vehicles emission such as fire tread, break wear and re-suspension of road dust (Heal *et al.*, 2012). Fine particles have an aerodynamic diameter equal to or smaller than $2.5\mu\text{m}$ ($\text{PM}_{2.5}$), whereas ultra-fine particles, a sub-group of fine particulate matter are smaller than $0.1\mu\text{m}$ ($\text{PM}_{0.1}$) (Heal *et al.*, 2012). Fine particulate matter ($\text{PM}_{2.5}$) is emitted into the atmosphere from sources such as exhaust from motorized vehicles, forest fire and smelting and processing metals (Thorpe and Harrison, 2008). Traffic related particles contribute as one of the major sources of particulate

matter air pollution in urban areas. Diesel engine exhaust particulate matter (DPM) consists of fine particles and can include a large number of ultra-fine particles. Diesel engine exhaust particulate matter has a great ability to adsorb different organic compounds due to its large surface area and the organic fraction is generally 20-40% of the total DPM mass (Wichmann, 2007). The main source of DPM is motorized heavy-duty and light-duty vehicles (Jaffe *et al.*, 2014). Fine Particles are suspended in air due to their small size and can be transported long distances (Liu and Harrison, 2011). The distribution of particulate matter in air can be explained as a function of particle diameter to number or volume concentration, whereas particles with diameter $> 0.1\mu\text{m}$ primarily contribute to the total mass concentration (mass concentration and mass volume can be the same when the particle density is very small). Both anthropogenic and meteorological parameters such as wind speed precipitation and long-distance transportation can have significant effects on the particle distribution (Niemi *et al.*, 2004). In a study by Qu and co-workers, it was shown that the concentration of $\text{PM}_{2.5}$ in air during winter was much higher compared to during summer mostly due to anthropogenic sources from domestic heating (Qu *et al.*, 2015). Air pollution may be described as contamination of the atmosphere by gaseous, liquid, solid wastes or by-products that can endanger the health of humans and the well-being of plants and animals, attack materials, reduce visibility or produce undesirable odors. Air pollution has also been defined as the emission of particulate toxic elements into the atmosphere by natural or anthropogenic sources (Bernstein *et al.*, 2004). The sources were further differentiated into mobile and stationary sources by the World Health Organization (WHO, 2008). Air pollution has been of primary concern globally due to the natural rapid flow ability of its medium (air) and hence potential health risk to humans. Although concerns have been raised with respect to the emission of air pollutants especially from anthropogenic sources, however our society still

depend on some of the activities that encourages air pollution; for instance, the use of fossil fuels for various applications in transportation, industrial and domestic heating, electric generation etc. Obviously the result is the deterioration of the quality of air, especially in developing countries (Leung, 2015). Studies have pointed out that anthropogenic air pollution started with human's systematic use of fire. Its historical development has been characterized by a steady increment in the total emissions, the invention of new pollution emission sources and also the emission of pollutants that had not been formerly developed by man-made sources (Zell *et al.*, 2010). So far, this development has had the greatest impact on the quality of air in mega-cities i.e. cities with over ten million inhabitants. The major sources of man-made air pollution today are motorized street traffic; especially exhaust gases and tire abrasion, the burning of fuels and larger factory emissions. Pollutants can be carried for distances of several thousand miles depending on the particles' sizes. The World Health Organization (WHO) estimates 7 million fatalities as a result of air pollution each year (WHO, 2014). In many countries, since health effects such as asthma, increased cardiovascular risks etc. have been traced to breathing of polluted air, laws have been made to control the air quality in the past decade (Zell *et al.*, 2010).

2.2 AIR POLLUTION IN THE INDOOR AND OUTDOOR MICROENVIRONMENT

Air pollution can be grouped into two categories: outdoor air pollution (OAP) and indoor air pollution (IAP) (United Nations, 2011). Outdoor air enters and leaves the indoor microenvironment by infiltration, natural and mechanical ventilation. Infiltration refers to the process whereby outdoor air enters the house via openings, joints/cracks in wall, floors and ceilings and around windows. When the air pollutants from outdoor air enter, they can either be diluted or accumulated depending on the ventilation condition.

The indoor environment can be the home, school, office, workplace or public building. Even time spent within the car or in public transport can be considered as being in an 'indoor' environment (Simoni *et al.*, 2003). People living in urban cities spend almost 90% of their time indoors (Schweizer *et al.*, 2007). Studies have shown that indoor sources significantly contribute to concentrations and personal exposures experienced in indoor microenvironments (Bruinen de Bruin *et al.*, 2005; Lanki *et al.*, 2006). Also, people's behavior, activities and ventilation condition of homes in different latitudes may significantly affect the concentrations of pollutants in indoor microenvironments and in personal exposures. High temperature and humidity levels can also result to increased concentration of some pollutants (Patterson and Eatough 2000; Gauvin *et al.*, 2002). Another significant source of indoor pollution is the outdoor environment.

Global data shows that, IAP is far more lethal than OAP. It has been estimated that about 500,000 women and children die yearly from indoor air pollution in India (Smith, 2000). In 2004, less than 300 deaths per million people arising from OAP was reported while approximately 2,200 deaths per million people arising from IAP around the globe was reported (Omole and Ndambuki, 2014). According to the World Health Organization, an estimated 7 million people were killed by diseases related to indoor and outdoor air pollution in 2012 alone. The organization also reported that, 1.6 million people died of fumes from cooking stove. Of the 1.6 million deaths, 396,000 deaths occurred in sub - Sahara Africa, with highest incidents occurring in Nigeria (WHO, 2006; Margulis *et al.*, 2006). Another WHO report posited that 78% of African population used charcoal and firewood burning (biomass fuel) to cook and that a third of infant deaths associated with IAP occurred in Africa (WHO, 2007). According to a recent comparative risk study by the World Health Organization, 28% of the overall disease and deaths is caused by indoor air particulate matter in developing countries. This may be attributed to the ample of time

people in urban areas spend indoors. Apart from death, inhalation of particulate matter in the indoor environment can cause various adverse health effects (Dominici *et al.*, 2003; Bai *et al.*, 2007). Particulates in the indoor environment occur from a wide variety of sources, depending on the type of activities and processes taking place. Some activities such as sweeping and cleaning of floors have potential to generate dust through mechanical attrition of solid materials in the indoor environment. Also, biomass fuel, cooking gas and liquid fuels combustion for cooking, domestic heating, and lighting purposes are regarded as sources of indoor air pollution (Onabowale and Owoade, 2015).

2.3 SOURCES AND COMPOSITION OF PM_{2.5}

The sources and composition of PM_{2.5} in schools can vary depending on various factors such as location, surrounding environment, and indoor activities. Particle pollution is produced by both primary and secondary sources. Primary particulate matter is emitted directly from construction sites, wildfires, wood burning, gravel pits, agricultural activities, and dusty roads. Secondary particulate matter is formed in the atmosphere through complex chemical reactions. PM_{2.5} precursors such as nitrogen oxides (NO_x), volatile organic compounds (VOCs), sulfur dioxides (SO₂), and ammonia contribute to the formation of secondary fine particulates. Precursors that lead to the formation of PM_{2.5} are emitted by a variety of sources, including power plants, industry, vehicles, small businesses, buildings, and homes.

Outdoor Sources of PM_{2.5} occur outside our environment such as, vehicle emissions where PM_{2.5} particles can be generated from vehicle exhaust, especially in areas with heavy traffic (USEPA 2021), and industrial emissions where industrial activities such as power plants and factories can release PM_{2.5} particles into the air. For indoor sources, they occur inside our environment such as combustion source (USEPA 2021) where PM_{2.5} particles can be generated

from combustion processes such as cooking, heating, and using fireplaces or wood-burning stoves, and tobacco smoke which contains various particulate matter, including PM_{2.5} particles. Also cleaning products particularly those with aerosolized sprays, can release PM_{2.5} particles into the air. And lastly building materials, such as paint, adhesives, and insulation, can emit PM_{2.5} particles.

Specific composition of PM_{2.5} can vary widely, and it may contain a mixture of organic and inorganic substances such as dust, pollen, soot, chemicals, metals, and biological particles. The exact composition depends on the emission sources and environmental factors.

2.4 HEALTH EFFECTS ASSOCIATED WITH EXPOSURE TO PM_{2.5} AND METEOROLOGICAL PARAMETERS.

Exposure to fine particulate matter (PM_{2.5}) and meteorological parameters can have significant health effects, particularly on vulnerable populations such as school children, which can result to **RESPIRATORY ISSUES**. Inhalation of PM_{2.5} particles can irritate the respiratory system, leading to coughing, wheezing, and shortness of breath. Prolonged exposure to high levels of PM_{2.5} pollution can exacerbate pre-existing respiratory conditions such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) (Pope *et al.*, 2002). It also increases the chances of **LUNG CANCER**, where studies have indicated a positive association between PM_{2.5} pollution and lung cancer incidence. The carcinogenic properties of certain components of PM_{2.5}, such as heavy metals and polycyclic aromatic hydrocarbons (PAHs), contribute to the development of lung cancer in exposed individuals (Bell *et al.*, 2006).

Influence of PM2.5 on the respiratory system (Gehring *et al.*, 2013).

Increases mortality
Increases the incidence of chronic pulmonary disease exacerbations such as COPD and asthma
Increases or worsens overall respiratory symptoms
Reduces lung function growth in children
Causes temporary loss of lung function in normal people
Increases airway inflammation and increases airway hyperresponsiveness
Reduces pulmonary diffusing capacity in lung function

NEUROLOGICAL EFFECTS is another health effect associated with PM2.5. Exposure to PM2.5 can lead to increased risk of cognitive impairment and neurodevelopmental disorders in children (Block & Calderón-Garcidueñas, 2009), greater prevalence of neurodegenerative diseases such as Alzheimer's and Parkinson's (Chen *et al.*, 2017) as well as negative impact on mental health, including depression and anxiety. A third health effect of this exposure is the **CARDIOVASCULAR EFFECT**. PM2.5 pollution has been linked to an increased risk of cardiovascular diseases (Brook *et al.*, 2010). When these tiny particles enter the bloodstream, they can trigger inflammation, promote the formation of blood clots, and negatively impact blood vessel function. This can lead to conditions such as heart attacks, strokes, and high blood pressure.

Long-term exposure to elevated levels of PM2.5 pollution has also been associated with **INCREASED MORTALITY** (higher mortality rates). The fine particles can contribute to respiratory and cardiovascular diseases, which can ultimately result in premature death. Vulnerable populations such as the elderly and individuals with pre-existing health conditions are particularly at risk (Ciencewicki *et al.*, 2007). Lastly, **DEVELOPMENTAL ISSUES** which

affect pregnant women exposed to high levels of PM_{2.5} pollution may experience adverse effects on fetal development. There is evidence linking PM_{2.5} exposure to preterm birth, low birth weight, and impaired neurological development in children.

It's worth noting that the specific health effects may vary depending on the duration and intensity of exposure, individual susceptibility, and other factors. Additionally, meteorological parameters such as temperature, humidity, and wind speed can interact with PM_{2.5} to influence its dispersion and impact on health.

2.5 KEY METEOROLOGICAL PARAMETERS AFFECTING AIR QUALITY.

Several key meteorological parameters can affect air quality in schools, some parameters are; Temperature which can influence the rate of chemical reactions and the formation of pollutants. Higher temperatures can promote the chemical reactions that produce ozone and other pollutants. Lower temperatures can increase the formation of particulate matter (EPA, 2016). Humidity which affects the concentration and behavior of airborne particles, including allergens and pollutants. High humidity can promote the growth of mold and bacteria, leading to indoor air quality issues. Low humidity can cause dryness and irritation of respiratory passages (WHO, 2009). Wind Speed and Direction which influences the dispersion of air pollutants. Higher wind speeds can help disperse pollutants, preventing their accumulation near the source. Wind direction determines the transport of pollutants from nearby emission sources (USEPA, 1995). Atmospheric Stability this refers to the vertical mixing and dispersion of air pollutants. Stable atmospheric conditions, such as temperature inversions, can trap pollutants near the ground, leading to increased pollution concentrations. Unstable conditions promote vertical mixing and dispersion of pollutants (USEPA, 1995). Precipitation such as rain or snow, can remove pollutants from the atmosphere, reducing their concentration. Rainfall can help cleanse the air by

washing away particulate matter and some gaseous pollutants (WHO, 2005). Lastly, Solar Radiation can initiate photochemical reactions that lead to the formation of ozone and other secondary pollutants. It can also influence temperature, atmospheric stability, and pollutant lifetimes (USEPA, 1995).

It's important to note that the specific impacts of these meteorological parameters on air quality can vary depending on local conditions, emission sources, and the types of pollutants present in the area.

2.6 IMPACT OF METERELOGICAL PARAMETERS AFFECTING AIR QUALITY.

The impact of meteorological parameters on air quality in schools is well-documented. Several meteorological factors can influence the dispersion and concentration of air pollutants, thereby affecting the air quality within school environments. Some key parameters and their impacts are;

Temperature: Higher temperatures can enhance the chemical reactions that produce secondary pollutants such as ozone (O₃) and increase the volatility of volatile organic compounds (VOCs), leading to poorer air quality (Riahi & Cervinka, 2019). A study conducted in schools in Spain found a positive correlation between temperature and indoor concentrations of ozone and formaldehyde (Janssen *et al.*, 2011).

Humidity: High humidity levels can promote the growth of mold and fungi, which can release spores and allergens into the air, potentially causing respiratory problems and reducing air quality (Mendell *et al.*, (2002). On the other hand, low humidity levels can increase the dispersal of particulate matter (PM) and dust, leading to higher concentrations of airborne particles (Karagulian *et al.*, (2015).

Wind speed and direction: Wind speed and direction play a crucial role in pollutant dispersion. Higher wind speeds can help dilute pollutants and disperse them over a larger area, reducing their concentration (Wang *et al.*, 2016). However, strong winds may also transport pollutants from nearby industrial or traffic sources into school environments (Yao *et al.*, 2020). Wind direction is significant in determining the potential source of pollutants and their impact on air quality.

Atmospheric stability: Atmospheric stability refers to the vertical movement of air masses. Stable atmospheric conditions, characterized by weak vertical mixing, can trap pollutants near the ground and result in higher concentrations (Li *et al.*, 2019). Unstable atmospheric conditions, with enhanced vertical mixing, promote the dispersal and dilution of pollutants (Zhang *et al.*, 2015). A study examining air pollution in schools in Taiwan found that high atmospheric stability was associated with higher PM_{2.5} concentrations indoors (Lin *et al.*, 2020).

Precipitation: Rainfall can effectively remove airborne particles and pollutants by acting as a natural "cleaner" for the atmosphere. It can wash out pollutants and reduce their concentration, resulting in improved air quality (Sarwar *et al.*, 2015). However, certain pollutants, such as nitrogen oxides (NO_x), can undergo chemical reactions in the presence of rain and form secondary pollutants like nitric acid (HNO₃) and nitrogen dioxide

2.7 STUDIES INVESTIGATING THE CORRELATION BETWEEN PM_{2.5} AND METEOROLOGICAL PARAMETERS.

Investigating the correlation between PM_{2.5} and meteorological parameters is an important area of research in understanding air pollution dynamics. Several studies have explored this correlation.

Janssen *et al.* (2011) examined the relationship between PM_{2.5} and meteorological variables in the Netherlands. They found that PM_{2.5} concentrations were positively correlated with

temperature, wind speed, and solar radiation, suggesting that higher temperatures and increased solar radiation can enhance the formation and dispersion of PM_{2.5}.

Liu et al. (2017) investigated the impact of meteorological factors on PM_{2.5} concentrations in Beijing, China. They found that temperature, relative humidity, wind speed, and atmospheric pressure were all significantly correlated with PM_{2.5} levels. In particular, temperature and wind speed showed positive correlations, indicating that higher temperatures and stronger winds can increase PM_{2.5} concentrations.

Wang et al. (2018) conducted a study in Guangzhou, China, to explore the relationship between PM_{2.5} and meteorological factors. They observed that temperature, relative humidity, and wind speed were positively correlated with PM_{2.5} concentrations. Additionally, wind direction played a significant role in the spatial distribution of PM_{2.5}, as it affected the transport of pollutants from local and regional sources.

These studies provide evidence of the correlation between PM_{2.5} and various meteorological parameters. However, it is important to note that the specific correlations may vary depending on the geographical location, local emission sources, and other factors. It is recommended to conduct a comprehensive analysis specific to your school's location to determine the correlation between PM_{2.5} and meteorological parameters in your study area.

2.8 GAPS AND LIMITATIONS IN EXISTING LITERATURE.

The study of PM_{2.5} and meteorological parameters in schools is an important area of research, as it can provide insights into air pollution exposure and its potential impacts on students' health and well-being. While existing literature has contributed valuable knowledge in this field, there are several gaps and limitations that should be addressed such as;

Limited geographical coverage has Many studies on PM_{2.5} and meteorological parameters in schools which focuses on specific regions or cities, resulting in a lack of generalizability. It is essential to have studies conducted in diverse geographical locations to understand the broader implications (Liu et al., 2017). Insufficient long-term studies which have focused on short-term measurements, limiting our understanding of the long-term trends and variations of PM_{2.5} and meteorological parameters in schools. Long-term studies are crucial to identify patterns, seasonal variations, and potential changes over time (Bell et al., 2014). There is a lack of standardized protocols for measuring PM_{2.5} and meteorological parameters in schools, leading to variations in measurement techniques and data quality. Standardized protocols are crucial for ensuring comparability across studies and facilitating meta-analyses (WHO, 2018). Limited understanding of pollutant sources. While studies have examined the concentrations of PM_{2.5} in schools, there is often a lack of detailed information on pollutant sources. Understanding the specific sources of PM_{2.5} and their contributions can help design effective mitigation strategies (Zhang et al., 2013). Limited investigation of meteorological parameters. While the relationship between PM_{2.5} and meteorological parameters is often explored, there is a lack of comprehensive studies investigating the influence of various meteorological factors on PM_{2.5} concentrations in schools. Understanding these relationships can provide valuable insights into the dynamics of PM_{2.5} pollution (Lin et al., 2017). Limited consideration of indoor factors. Many studies focus on outdoor PM_{2.5} concentrations but overlook the potential contributions of indoor sources and factors that influence indoor air quality in schools. Indoor factors such as ventilation, building materials, and activities can significantly impact students' exposure to PM_{2.5} (Mendell et al., 2016).

Addressing these gaps and limitations can enhance our understanding of the relationship between PM_{2.5}, meteorological parameters, and school environments, leading to more effective interventions and policies to protect students' health.

2.9 AIR POLLUTION MANAGEMENT

For ages, man has been emitting wastes into the atmosphere, and these pollutants have disappeared with the wind and so there is an urgent need to prevent the emissions. In order to protect the environment from the adverse effects of pollution, many nations worldwide have enacted legislation to regulate various types of pollution as well as to mitigate the adverse effects of pollution. In the hierarchy of controls, pollution prevention and waste minimization are more desirable than pollution control. Steps are being taken to control pollution at source (prevention) as well as after the release into the atmosphere. The control of emissions can be realized in number of ways. There are two basic approaches or strategies for air pollution control viz: source correction and dilution of pollutants.

2.9.1 Source Correction

The most effective approaches or strategies for air pollution control would be to prevent the pollution from occurring in the first place. Complete source shutdown would accomplish this, but shutdown is only practical under emergency conditions, and even then it causes economic loss. Nevertheless, state public health officials can force industries to stop operations and can curtail highway traffic if an air pollution episode is imminent or occurring.

An important approach for air pollution control is to encourage industries to make fuel substitutions or process changes. This can be achieved by:

- modifying the process in such a way that pollutants do not form at all beyond permissible concentration
- reducing the pollutant concentration to tolerable levels before they are released to the environment, by use of suitable equipment to destroy, alter or trap the pollutants formed.

For example, making more use of solar, hydroelectric, and geothermal energy would eliminate much of the pollution caused by fossil fuel combustion at power generating plants. Nuclear power would do the same, but other problems related to high level radioactive waste disposal and safety remain to be solved. Fuel substitutions are also effective in reducing pollution from mobile sources. Also, the use of reformulated gasoline or alternative fuels such as liquefied petroleum gas, compressed natural gas, or methanol for highway vehicles would help to clear the air. The use of correct operation and maintenance practices is important for minimizing air pollution and should not be overlooked as an effective control strategy.

2.9.2 Pollutant Dilution

Dilution of the pollutant in the atmosphere to permissible levels before they can reach the receptor. This can be achieved by using tall stacks, controlling the process parameter, with due regard to the local meteorological conditions and proper community planning to prevent accumulation of dangerous ground level concentration within the designated areas.

CHAPTER THREE

3.0 METHODOLOGY

3.1 STUDY AREA

Oredo is one of the rapidly industrialized and urbanized Local Government Area domiciled in Edo State, South-south geopolitical zone of Nigeria. covers a total of 249 square kilometers and has an average wind speed of 10 km/h with a geographical coordinates of latitude 6°23'55" N to 6°27'39" N and longitude 5°36'18" E to 5°44'30" E (Anegbe et al., 2017). Oredo has a tropical climate characterized by two distinct seasons, the wet and dry seasons with the average humidity level in the area put at 61 percent. She lies in the thick equatorial rainforest zone that experiences heavy rainfall. The wet season usually lasts from April to November and the dry season from December to March. Weli (2014) expanded the season to wet (Jul to Oct), transition (Mar to Jun), and dry (Nov to Feb) seasons. Oredo LGA therefore, enjoys abundant rainfall almost all year-round, except December to March when dry season sets in, due to the influence of the north-east trade wind. The Area hosts several government establishments, banks, various strata of educational institutions, hotels, industries and privately owned firms, which forms a robust formal sector. Also, a vibrant informal sector and hosts several markets such as Ekiosa, Edaiken and Oba markets as well as numerous small scale businesses with all of these contributing to the

socio-economy of the area. A total of 45 samples was collected for PM_{2.5}, temperature, relative humidity, pressure, wind speed, wind direction, etc in 5 locations from May to July, 2023 using a standard method.

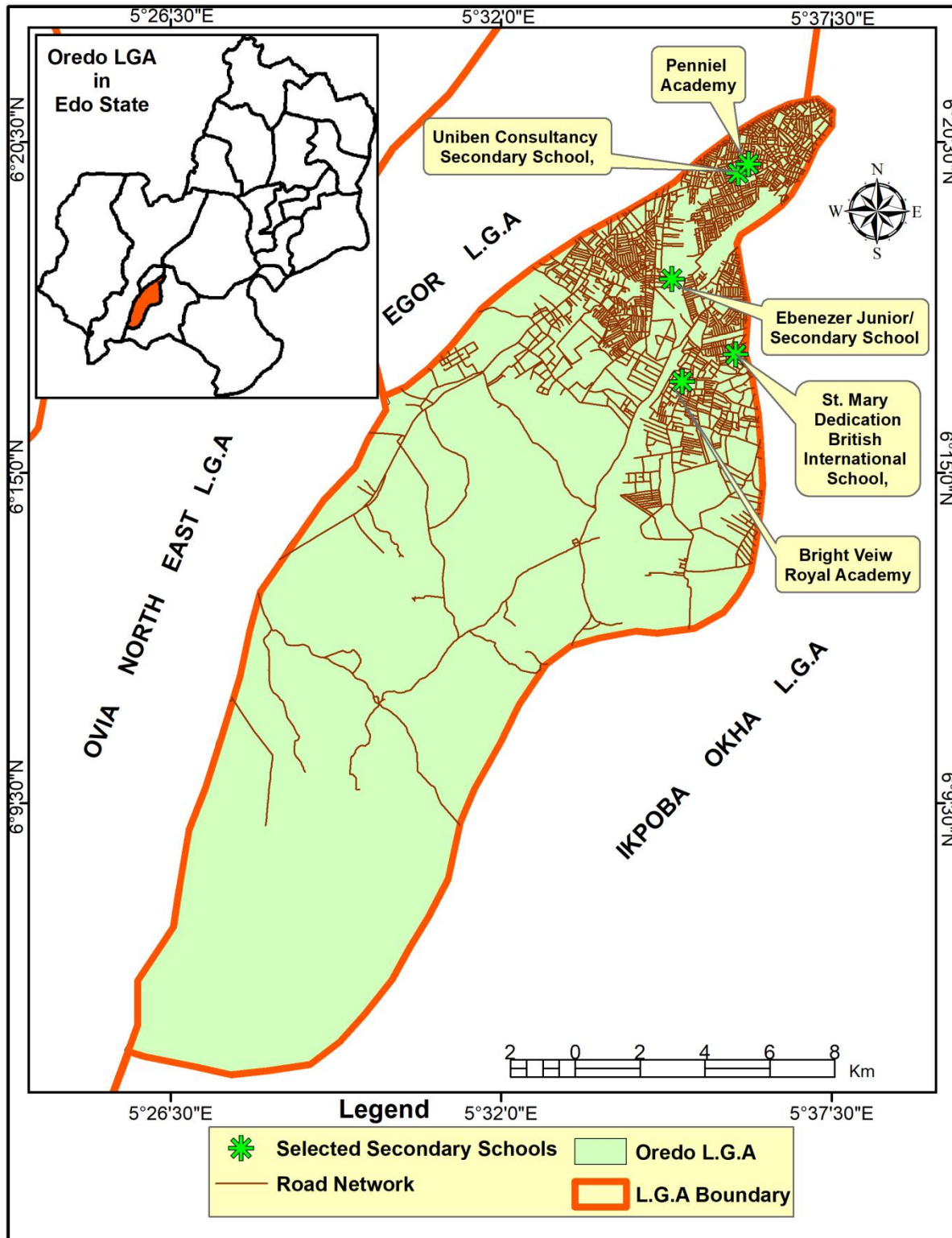


Plate 1: Oredo Local Government Area Showing Sampled Private Secondary Schools
Source: Compiled using Google Earth Database (2023)

CORDINATES

S/No	NAME	Location Code	Coordinates (Decimal degrees)		Elevation (meters)
			Latitudes	Longitudes	
1	Uniben Consultancy Secondary School, Benin City	Location 1	6.333020	5.599021	84.1
2	St. Mary Dedication British International, Benin City	Location 2	6.312173	5.628137	58.6
3	Penniel Academy, Ekenwan Road, Benin City	Location 3	6.335532	5.601939	84.7
4	Bright View Royal Academy, Benin City	Location 4	6.275223	5.583497	54.7
5	Ebenezer Junior/Secondary School, Benin City	Location 5	6.308846	5.618696	61.2

CRITERIA FOR SAMPLING SITE SELECTION.

The sampling sites were fairly similar; however, sampling locations were chosen based on the following criteria;

Absence of trees at least 50feet from the class room

A minimum proximity of 100feet from a major road junction

REAGENTS, APPARATUS AND INSTRUMENT USED

2.2 Reagents Used

- Acetone (Analytical grade)
- Dichloromethane (Analytical grade)
- Silica gel
- Nitrogen gas

2.2.1 Apparatus/ Instruments Used

- Forcep
- Glassware (conical flasks, measuring cylinder, forceps,)
- Desiccator
- Ultrasonic bath (Sonication bath)
- Apex 2IS Casella pump (Bedford, UK)
- Conical Inhalable sampler (Bedford, UK)
- Quartz filter – 37mm diameter
- Polyurethane foams, PUF
- Professional weather station
- Analytical weighing balance

DETERMINATION OF PM_{2.5} MASS CONCENTRATION

The particle mass concentrations were determined using the gravimetric method of analysis. This was done by subtracting the initial average mass of the blank filter from the final average mass of sampled filter. Filters were repeatedly weighed using an analytical weighing balance until a constant value was obtained. The total volume of air collected by the sampler was determined

from the measured flow rate and the sampling time (Enyoh et al., 2020). The mass concentration of PM_{2.5} in the indoor air was then determined by the following equations (WHO, 2006):

$$M_{2.5} = M_{f.(2.5)} - M_{i.(2.5)} \times 10^6 \quad (3.1)$$

Where:

M_{2.5} = mass of fine particulate matter collected during sampling period (µg)

M_{f. (2.5)} = final mass of conditioned filter after sample collection (g)

M_{i. (2.5)} = initial mass of conditioned filter before sample collection (g)

Therefore,

$$PM_{2.5} = \quad (3.2)$$

Where,

PM_{2.5} = mass concentration of PM_{2.5} particulate (µg/m³)

M_{2.5} = mass of fine particulate matter collected during sampling period (µg)

V = total volume of air sampled (m³)

$$V = Q_{avg} \times t \times 10^{-3} \quad (3.3)$$

Where,

Q_{avg} = average flow rate over the entire duration of the sampling period 3.5 (L/min)

t = duration of sampling period in minutes

10⁻³ = unit conversion factor for liters (L) into the cubic metre (m³)

COLLECTION OF METEOROLOGICAL DATA

Meteorological data such as ambient temperature, relative humidity (RH), wind speed (WS), wind direction (WD), pressure, solar radiation, and ultra-violet were recorded through an automatic weather monitoring system (Professional weather station) mounted 2.5-3.0 meters above the ground level at the sampling site. It was programmed to collect data at 5-minute intervals and store it in memory to be downloaded to a computer using software and an average of 1-hour calculated (Liu *et al.*, 2016).

QUALITY ASSURANCE/CONTROL

To ensure the accuracy and precision of the PM_{2.5} sampling in this study, the follow quality control measures were taken.

- (i) Clear forceps were used to handle the filters to avoid any contamination
- (ii) A pre and post-calibration sampling pump was carried out in the field to ensure an accurate flow rate.
- (iii) Flow rate was well monitored during the 8 hours sampling duration.
- (iv) Filters used for sample collection were equilibrated before and after sampling. Before PM_{2.5} estimation, the filter cassette containing particulates was equilibrated in a desiccator to prevent degradation and hydration.
- (v) All glasswares were properly washed and oven dried before use. Glasswares were soaked overnight with 1% HNO₃, washed with detergent, and properly rinsed the distilled water follow by dichloromethane and allowed to dry at room temperature. Thereafter, the glasswares were treated in a dry oven at a temperature set at 120°C for about 30 minutes to remove all interfering organics
- (vi) All reagents were of analytical reagent grade.

CHAPTER FOUR

RESULTS AND DISCUSSION

Locations	Location 1	Location 2	Location 3	Location 4	Location 5
Month 1	43.33	41.63	82.33	53.63	50.67
Month 2	72.67	67.67	85.33	76.63	64.67
Month 3	34.67	37.33	55.33	43.67	80.67
Mean	50.22±5.04	48.87±3.78	74.33±6.43	57.97±4.87	65.33±5.72

Table 3.1: Average PM_{2.5} concentration (g/m³) in the different location for the period of three months

Tables 3.1 show the concentrations of PM_{2.5} obtained from the different locations in Oredo Local Government Area for the month of May, June and July,2023 respectively. The PM_{2.5} levels obtained ranged from 34.67 to 85.33 µg/m³. The average concentration obtained during sampling in all the locations rose above the daily average standard of PM_{2.5} for the United States Environmental Protection Agency (U.S EPA) of 35µg/m³ (U.S EPA., 2007) and World Health Organization daily average standard of 25µg/m³ (WHO, 2006). The average concentration of PM_{2.5} obtained in all locations found to be higher than the WHO daily average standard of 25µg/m³ and the USEPA daily average standard of 35µg/m³. However this may be as a result of the activities going on in that area which includes increase in vehicular movements constituting busy high ways and markets, small business enterprises and the industrial emissions from the industries, banks, governmental offices and hospitality outfits around the area as a contributing factor to the high concentration of the average particulate matter obtained in those locations. The

PM_{2.5} concentration was higher in month 2 in almost all the locations except location 5 which recorded the highest value of 80µg/m³, this may be attributed to low precipitation at that period. Vehicular emissions as well as cooking, frying, firewood and kerosene smokes could well induce the generation of fine particulates (Heal *et al.*, 2004). The concentration of PM_{2.5} in all the locations were found to be slightly low because it was wet season. This may be attributed to meteorological factors like humidity, temperature, cloudy weather and rainfall which can affect the concentration of particulate matter in air. Particulate matter are trapped in moisture at high humidity and lower temperature and thus washed down by rain or water droplets. During the dry season, higher temperatures give rise to lower humidity and as such results to higher concentration of the particulate matter in air. Variation in anthropogenic activities in those locations could be a major contributing factor to the observed differences in particulate matter levels in the various locations.

Comparison of the average concentration of PM_{2.5} across all locations and in different months.

Locations	May	June	July
Location 1	44.00a	74.00b	34.67a
Location 2	41.67a	67.33a	37.33a
Location 3	82.33c	85.33c	55.33c
Location 4	54.33b	76.67b	43.67b
Location 5	50.67b	64.67a	80.67d
Sig.	Significant	Significant	Significant

Significance level: $p < 0.05$.

From Table 2, it can be deduced that there is no significant difference between the concentration of $PM_{2.5}$ in Location 1 and Location 2 and Location 4 and Location 5. Although these four locations differ significantly from the $PM_{2.5}$ deposition in Location 3 which is the location of the most deposit of $PM_{2.5}$ in May. In June, Location 3 also recorded the highest deposition of $PM_{2.5}$, which is significantly different from other locations. Location 5 had the highest deposition of $PM_{2.5}$ which is significantly different from other locations. In July, a significant difference exist between the concentration of $PM_{2.5}$ in the various locations.

Meteorological parameters and pollutants monthly data from May to July

Table 2 shows the variation in the Meteorological parameters with respect to particulates matter concentration in different months. The air temperature was highest in July which consequently, reduced the relative humidity in the atmosphere. The air pressure was highest in May and the highest dew precipitation was recorded in July. The highest wind intensity was recorded in June and this contributed to the increase in the particulate matter deposition. This agrees with the findings of Li *et al.*, 2019 and Guerra *et al.*, 2016.

Meteorological parameters	May	June	July
Temp. ($^{\circ}C$)	30.17	33.97	36.35
RH (%)	63.80	58.00	50.60
Pressure	1008.90	1008.87	1008.40
Dew	23.20	23.14	23.44
Wind	3.38	4.04	3.69

PM _{2.5}	54.30	73.13	53.67
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RH - Relative humidity.

Table 2: Meteorological parameters and pollutants monthly data from May to July

Correlation between PM_{2.5} concentration and meteorological parameters.

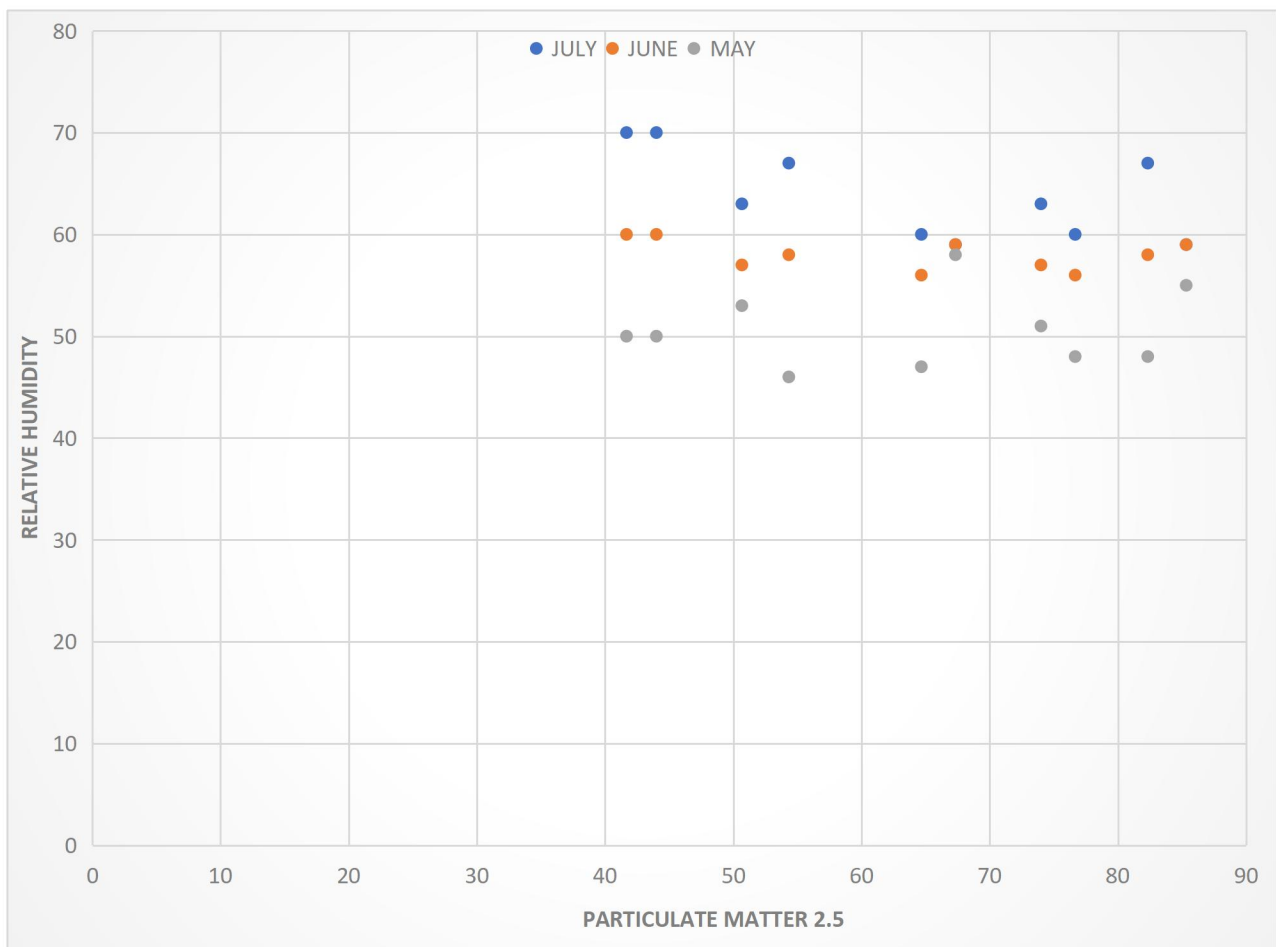
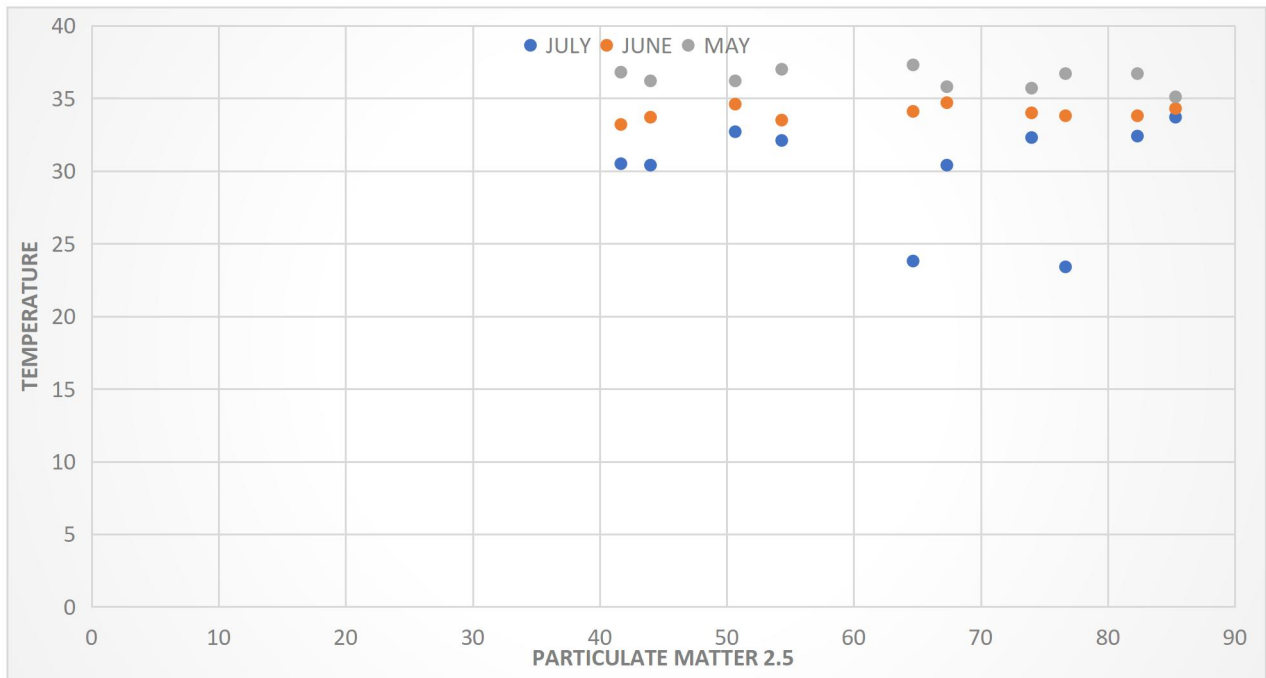
The result in table 2 show that in May and July, there is a significant negative correlation between the PM_{2.5} and Relative humidity. This means that the higher the relative humidity of the atmosphere, there will be a significant decrease in the deposition of PM_{2.5}. The table also shows that there is a negative correlation between atmospheric pressure and particulate matter deposition. This shows also, that the higher the atmospheric pressure, the higher the mass deposition of PM_{2.5}. There is a non-significant negative correlation between particulate matter deposition and dew precipitation in May and July, as opposed to June where there exist a significant positive correlation between the deposition of PM_{2.5} and dew precipitation. In June and July, there was a negative correlation between particulate matter deposition and wind intensity. This means that the higher the wind intensity, the lower the deposition of particulate matter deposition in the environment.

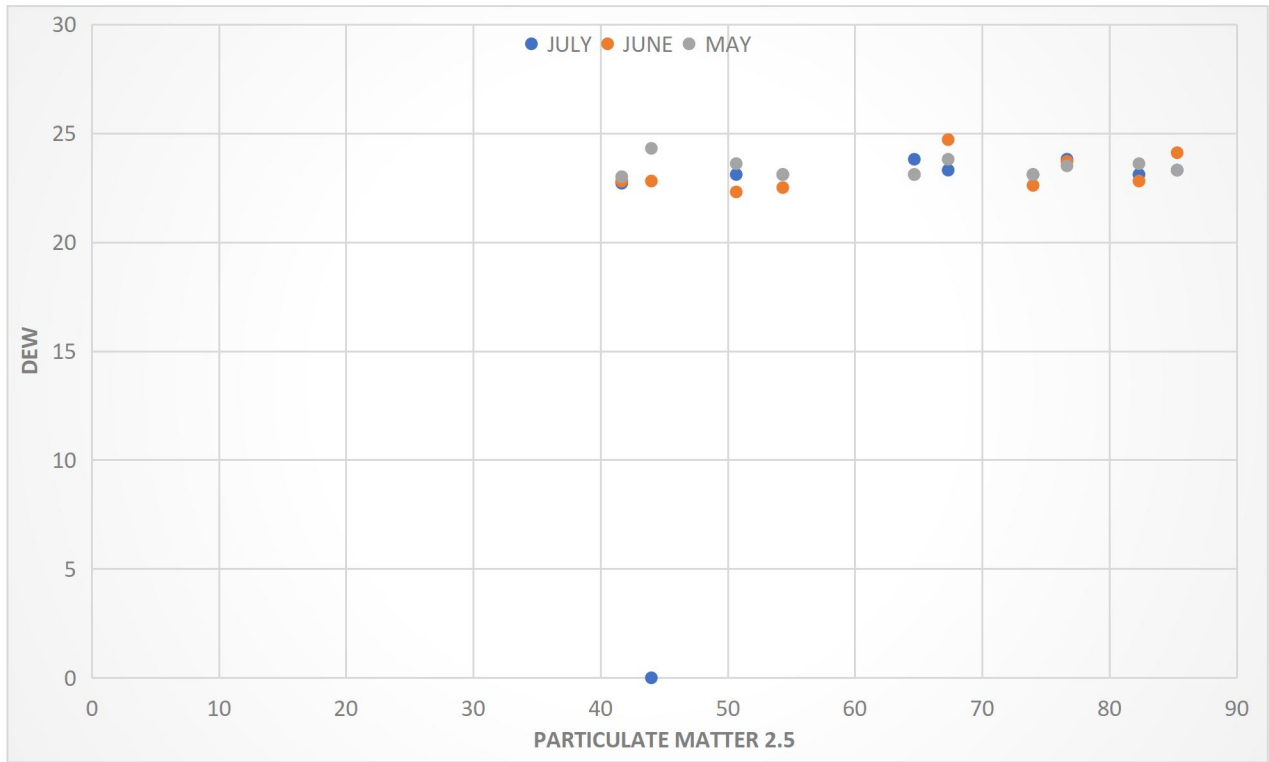
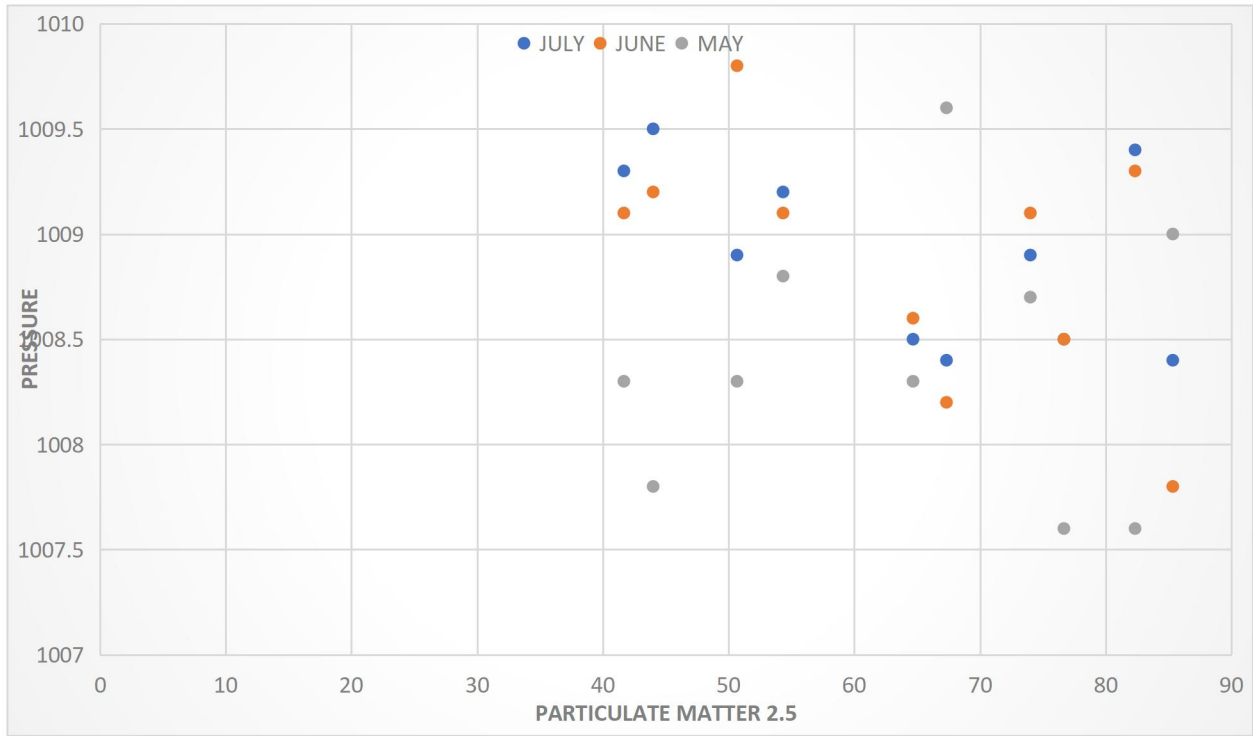
May

	Temp.	RH	Pressure	Dew	Wind
Temp. (0C)	1	-0.897**	-0.514	-0.624	-0.530
RH		1	0.766*	0.846**	0.330
Pressure			1	0.807*	0.622
Dew				1	0.299

Wind					1
June					
	Temp.	RH	Pressure	Dew	Wind
Temp. (°c)	1	0.270	0.136	0.195	-0.075
RH		1	-0.861**	0.918**	-0.819*
Pressure			1	-0.832*	0.648
Dew				1	-0.657
Wind					1
July					
	Temp.	RH	Pressure	Dew	Wind
Temp.	1	-0.810*	-0.491	-0.273	-0.116
RH		1	0.651	0.353	-0.023
Pressure			1	-0.190	-0.016
Dew				1	-0.173
Wind					1

RH - Relative humidity





CHAPTER FIVE

CONCLUSION

The indoor air environment of classrooms is sacrosanct to the wellbeing of the students and as such care should be taken to ensure that clean air be made available via proper ventilation measures in the private schools. Monitoring of the indoor quality of public secondary schools in Oredo local Government Area is of utmost importance as it has been found that the health of the children will be greatly influenced by the quality of the indoor air which is being inhaled.

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