THESIS

AYETOR ABIGAIL

BSc Environmental Engineering

Gödöllő

2024

Hungarian University of Agriculture and Life Sciences

Szent István Campus

EXAMINATION OF GHANA AIR POLLUTION

Thesis of Bachelor of Science (BSc) environmental engineering

Supervisor: Dr. Gábor Géczi, PhD

Author: Ayetor Abigail

Institute: Institute of Environmental Sciences

Gödöllő, Hungary

Table of Contents

1. INTRODUCTION

1.1 Background of Study

For a healthy lifestyle, it's critical to regularly breathe in clean air. When chemical, physical, or organic materials contaminate an indoor or outdoor space and change the environment's inherent features, it is referred to as air pollution. Fires in homes, cars, factories, and forests are common causes of air pollution. Particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide are all examples of things that are pollutants to public health. Air pollution causes respiratory and other illnesses and is a leading cause of illness and death. Consequently, it is commonly acknowledged that exposure to contaminated air poses a significant risk for non-communicable diseases in humans. According to the World Health Organization (WHO), in 2016, it was predicted that 7 million people died around the world because of household and ambient air pollution. Ninety percent of these fatalities were reported in countries in Asia and Africa that had a middle-income or low-income level (Odonkor & Mahami, 2020). There is a wide range of hazardous substances that are associated with air pollution. Several respiratory and cardiovascular problems have been associated with particulate matter (PM), which is a pollutant that is both extremely dangerous and frequently found in the environment (Odonkor & Mahami, 2020).

Carbon dioxide emissions are mostly caused by the combustion of fossil fuels, which is the primary source that is believed to be the most significant contributor. Burning coal, natural gas, and crude oil are the three types of fossil fuels that are used in the combustion process. The industrial operations that release carbon dioxide into the atmosphere through chemical reactions are the second source of carbon dioxide. These processes are responsible for making carbon dioxide. The conclusion that can be drawn from this is that the interaction between carbon dioxide emissions and other factors is made up of chemical and physical components (Appiah et al, 2017). As a result of globalization and rapid economic activities, increases in carbon dioxide (CO2) emissions have been observed across the globe over the course of the past several years (Abdullah, 2015). The expansion of human activities, such as manufacturing, transportation, the generation of power, and the consumption of products and services, all contribute to the expansion of a nation's economy. On the other hand, these human activities are further contributors to the contamination of the environment.

Cities located in sub-Saharan Africa are currently undergoing tremendous expansion and are during an economic transition. Sub-Saharan African cities are facing significant levels of air

pollution from a variety of sources because of their dramatic rate of population increase. Additionally, the growth is causing a shift in the composition of air pollution as well as the relative responsibilities of the primary generators of emissions. According to the findings of recent research, the primary source of emissions that contribute to urban air pollution in Sub-Saharan Africa may be changing away from the burning of biomass in households and toward the traffic on roads. Accordingly, even though the concentrations of fine particulate matter pollution are exhibiting indications of reaching a plateau (Allis et al, 2021). Increasing formal and informal industrial activities, as well as household and commercial use of diesel generators, are also common in cities in Sub-Saharan Africa. These activities contribute significantly to the levels of NOx in the atmosphere, and the distribution of these sources in relation to land use and socioeconomic factors influences the spatial patterns of NOx pollution in local communities (Wang et al, 2021). Seasonal shifts in regional meteorological parameters (such as mixing layer depth, incident solar radiation, and water vapor mixing ratio) during the dry and dusty Harmattan period may also amplify NOx concentrations from local emissions during this time. This phenomenon is observed in cities across the West African sub-region (Knippertz et al, 2015)

Pollution in the atmosphere poses a risk to the advancement of socioeconomic conditions and has the potential to have a negative impact on the survival of the entire population. As a result, air pollution is the most significant threat to environmental health on a global scale. It puts the health of millions of people in jeopardy and places a significant financial burden on society (Owusu-Boateng et al, 2017). The factors that have led to a decline in air quality have become even more severe as urbanization and mass consumption have become the norm in a significant portion of the world.

Because of the aspirations of people all over the world to achieve sustainability, environmental challenges have become an increasingly important topic of discussion among researchers and policymakers. Initiatives aimed at ensuring environmental sustainability have gained momentum because of the growing consensus that economic growth and other economic goals should not be prioritized over the protection of the environment and the natural resources that are essential for achieving economic and welfare goals. It is important to note that Ghana is one of the African countries that is developing at the quickest rate (Odonkor & Mahami, 2020). Despite this, it appears that the country's gradual increases in air pollution have been influenced by the rapid

economic growth that has been occurring. As of September 2018, the Ghanaian government believed that air pollution was responsible for nearly 28,000 deaths (Odonkor & Mahami, 2020).

1.2 Problem Statement

Traditional sources of pollution are giving way to more contemporary ones on the African continent, which is causing environmental dangers to shift. Household air pollution is still the most prevalent sort of air pollution, even though it is decreasing. This is even though ambient air pollution is experiencing an increase.

In Agbogbloshie Market, which is in Accra, Ghana, close to a large e-waste recycling facility, a study conducted by Nafrah et al (2018) on the health of female vendors found that most of the female vendors suffered from respiratory health issues. These issues included sore throats, coughs, colds, and frequent sneezing. Street vendors and hawkers who work alongside busy roads in Accra are also susceptible to air pollution from passing automobiles and from the drivers themselves. This is in addition to the women who work in various markets.

Kioumourtzoglou et al. (2019) conducted a study in which they found that pregnant women who were frequently exposed to air pollution from vehicular traffic had a higher risk of experiencing premature loss of their fetus. Industries such as oil refineries are also capable of producing air pollutants to levels of pollution that are unhealthy. This is something that should be taken into consideration (Ragothaman & Anderson). Understanding how the environmental risk transition is influencing the epidemiological transition in Africa is crucial. It's important to comprehend how shifting pollution patterns are contributing to the growth in non-communicable diseases and having an impact on economic development. This research study is being conducted to examine the air problem in Ghana.

1.3 Aims and Objective of the study

The purpose of this study is to examine the air pollution problem in Ghana. The objectives of this study are:

1. Examine the negative impact of air pollution on the health of Ghanaian population
2. Examine the major causes of air pollution in Ghana.

3. Examine the negative impact on the socioeconomic status of the Ghanaian population.
4. Examine the major solution of air pollution in Ghana.

1.4 Relevance of the study

There are dire effects associated with the production of greenhouse gases into the atmosphere on a worldwide scale, and this poses a significant risk to the sustainable development of humans. The effects of global climate change are not only felt in temperature trends, but also in an increase in climatic phenomena such as hurricanes, floods, and droughts. This is because the melting of polar ice, increasing sea levels, and degradation of ecosystems are all contributing factors. Activities such as an increase in the country's foreign direct investment, an increase in agricultural activities, the development of industries, and most importantly, an increase in the consumption of energy are all contributing factors to the rise in economic growth (Appiah et al, 2017). As a result, one can draw the conclusion that the level of environmental pollution in a country is directly proportional to the rate of economic growth in that country.

This study on the problem of air pollution when published will give a general and an in-depth understanding of how the effects of air pollution in the larger Ghanaian society still is on the rise. Again, the study will aid in obtaining information for government to devise and put into action efficient strategies for the management of air pollution and to guarantee an improvement in the quality of the air we breathe. The study will also add to the already existing academic papers on the problem of air pollution. Lastly, the study would aid in awareness of the Ghanaian population view on the activities that leads to the pollution of the air.

2. LITERATURE REVIEW

Particulate matter with a diameter of 2.5 micrometers or less is referred to as PM2.5. If breathed, these particles can lead to severe health issues because they are so small. In addition to natural causes like dust storms and wildfires, PM2.5 is produced by combustion processes like those found in automobile engines, industrial operations, and home heating. Because of its harmful impact on human health, PM2.5 is considered an important pollutant. These effects include respiratory diseases: Breathing disorders including bronchitis, asthma, and other respiratory ailments can all be made worse by PM2.5. Cardiovascular Problems: Heart attacks, cardiac arrhythmias, and other cardiovascular illnesses have been related to PM2.5 exposure. Cardiovascular and respiratory issues brought on by prolonged exposure to high PM2.5 levels might result in premature death. Particulate matter that has a diameter of 2.5 micrometers or less is a significant contributor to the pollutants that are found in the air. It has been established that being exposed to these particles is directly associated with a variety of health issues, such as cardiovascular illness, neurological disease, and an increased chance of death. The 2015 World Air Quality Report, compiled by the non-profit organization IQ Air in collaboration with Greenpeace, provided an overview of air quality across different cities and countries worldwide according to WHO (2014). The report highlighted that air pollution remained a significant environmental and health issue globally in 2015, with many cities exceeding the (WHO, 2014) guidelines for air quality. The report identified several cities with the poorest air quality based on levels of fine particulate matter (PM2.5) and other pollutants. Some of the consistently high-ranking cities include New Delhi, India Beijing, China and Ulaanbaatar, Mongolia. The report highlighted regional disparities in air quality, with South Asia and East Asia consistently ranking among the regions with the poorest air quality due to rapid industrialization, urbanization, and high population densities. According to the ranking of cities, Asian locations dominated the top 100 highest average PM2.5 levels in 2018. Cities in India, China, Pakistan, and Bangladesh occupied the top 50 spots on the list of cities with the highest PM2.5 levels. Additionally, several cities located within the Middle East region have achieved high rankings. Kuwait City, Dubai, and Manama were all found to be surpassing the WHO guideline by more than 500 percent. At the country level, Bangladesh emerges as the most polluted country on average, closely followed by Pakistan and India. Middle Eastern countries, Afghanistan, and Mongolia are also included in the top 10 countries with the worst levels of

pollution. During the year 2018, the capitals of Southeast Asia, Jakarta and Hanoi, were the most polluted cities in the region. Additionally, other Thai cities ranked highly in this region.

The purpose of this report is to bring attention to the current condition of particle pollution around the world and to create awareness regarding public access to air quality data. The study contains PM2.5 data that was made accessible to the public during the year 2019. Most of this information has been made available in real time or very close to real time by governmental sources, in addition to independently run and confirmed non-governmental air quality monitors. Only six of the three hundred and fifty-five cities that were included in the study met the WHO's annual targets for fine particulate matter (PM2.5) pollution in these regions collectively. South Asia, Southeast Asia, and Western Asia are the regions that bear the greatest burden of PM2.5 pollution overall. The cities that are located within these regions also have a strong presence at the very top of the global city ranking. Twenty-one of the world's thirty most polluted cities in 2019 are in India, while twenty-seven of them are in South Asia. These thirty cities are all located inside broader Asia. Based on the data that is currently available, Bangladesh appears as the most polluted country in terms of PM2.5 exposure. The countries of Pakistan, Mongolia, Afghanistan, and India come in second, third, fourth, and fifth, respectively, with a deviation of less than ten percent from one another. Based on the national PM2.5 weighted average, Bosnia and Herzegovina is the highest-ranking country in Europe for PM2.5 pollution. It is also the fourteenth most polluted country in the world, with only four micrograms per cubic meter fewer than China's national PM2.5 average. The number of monitoring stations that are included in this report has increased by more than 200 percent since the previous year, indicating that the year 2019 witnessed a considerable expansion in the coverage of air quality monitoring procedures. A combination of factors, including the expansion or establishment of new government monitoring networks, as well as the contributions of sensors from non-governmental groups, private sector, and people, have led to these achievements. However, a significant number of people all around the world do not have access to information regarding air quality. In many cases, it is estimated that these regions have some of the most severe air pollution in the world, which puts the health of large populations at risk. To close the knowledge gap and improve our ability to combat air pollution on a worldwide scale, additional monitoring data is required. The ranking of the most polluted cities appears to be dominated by cities located in India, China, and other parts of Asia. In 2019, the city of Ghaziabad, located in India, was ranked as the most polluted city. This was followed by places such as Hotan,

located in China, Gujranwala, located in Pakistan, and Faisalabad (Pakistan). The year 2020 had a stunning 65 percent of cities around the world experiencing improvements in air quality compared to the previous year, while 84 percent of countries exhibited overall improvements. It is likely that the concentrations of pollutants will increase again because of the circumstances surrounding these advances. It is unfortunate that the year 2020 was also marked by several catastrophic air pollution events, such as dust storms and wildfires, which were connected to rising global temperatures because of climate change and agricultural activities. The United States of America, Australia, Siberia, and part of South America were all scorched by wildfires that broke records, and Indonesia and sections of Africa were also affected by agricultural fires that were exceptionally destructive. The World Air Quality Study for the year 2020 featured data from 4,745 locations across 106 countries and areas. However, the scope of the report for the year 2021 extended to include 6,475 locations throughout 117 countries, territories, and regions. This is in part due to the growing number of low-cost air quality monitors, the majority of which are managed by non-profit groups, governments, and citizen scientists. The increased number of PM2.5 stations contributes to the creation of a more accurate image of the air quality in hyper-local areas as well as the air quality in the entire world.

When weighted by population, the nations, areas, and territories in Africa, Central Asia, and South Asia experienced the highest annual average PM2.5 concentrations in 2023. Even while the amount of data on air quality in Africa is gradually increasing, only 24 of the 54 countries were able to provide enough information for the study from 2023, leaving 30 countries unaccounted for. Twenty additional nations were represented in 2023, including Rwanda, the fifteenth most polluted nation in 2023, and Burkina Faso, the fifth most polluted nation in 2023 according to Jones, 2024. Even while the amount of data on air quality in Africa is gradually increasing, just 24 of the 54 countries in the continent have enough data available to be included in the study for 2023, leaving 30 countries unaccounted for. Afghanistan and Oman, which was listed as the sixth most polluted nation in 2022, are noticeably absent from the list since there is a dearth of data available. Afghanistan has been ranked in the top 15 most polluted countries every year since 2019. In the year 2023, there were twenty new countries that were represented. Among these were Rwanda, which ranked fifteenth on the list of most polluted countries, and Burkina Faso, which ranked fifth on the list of most polluted countries. Ten nations, territories, and areas met the WHO's yearly PM2.5 guideline in 2023; many of these were in the Oceania region. Air quality across various

regions worldwide compiled by the World Health Organization (WHO), the latest edition of the Ambient Air Quality Database includes data from over 7,182 human settlements in more than 120 countries. The report focuses on key pollutants such as nitrogen dioxide (NO2) and particulate matter (PM2.5 and PM10), which are primarily emitted from fossil fuel combustion and industrial activities (Air quality database, 2024).

Particulate matter (PM) is one of the most prevalent and hazardous contaminants in urban settings and air pollution is a major global public health concern. Scientists are now better able to comprehend the size and behavior of particles that can enter human respiratory systems and cause serious health effects because PM is divided into in addition to PM10, there are particles with a diameter of less than 2.5 micrometers known as PM2.5 (particles with a diameter of less than 10 micrometers). Urbanization, industrialization, vehicle emissions, and biomass burning have all contributed to the rise in PM pollution in Ghana's major cities, including Kumasi, Accra, and Tamale. Finding the origins, concentrations, and health effects of PM10 and PM2.5 pollution in these three locations is the main goal of this review of the literature, which focuses on studies done between 2020 and 2024.

2.1 Levels of PM10 and PM2.5 in Kumasi

Due to its status as a commercial and transportation center, Kumasi, Ghana's second-largest city, continues to experience serious air quality issues Cobbinah et al. (2019). According to recent research (2020–2024), there is a great deal of concern about PM2.5 and PM10 pollution, especially as urbanization and vehicle traffic have increased. The main causes of PM pollution in Kumasi are road dust, biomass burning, and vehicle emissions. Vehicle emissions are a major contributor to PM2.5 levels, particularly in core business districts and market areas, according to a study by Osei et al. (2021). Vehicle exhaust is a major source of PM2.5 due to the high number of automobiles, many of which are badly maintained and generate significant quantities of pollutants. Additionally, burning biomass still contributes to Kumasi's PM2.5 and PM10 pollution. Charcoal and firewood are still used for cooking in many homes, especially on the outskirts of the city. According to a study by Boateng et al. (2022), which looked at the role of burning biomass, fine particle emissions from both residential and commercial biomass energy use significantly increased PM levels overall, particularly during the dry season. PM10 levels are further aggravated by the re-suspension

of road dust from unpaved roads and active building projects, particularly during dry and windy weather.

According to recent monitoring studies, Kumasi's PM2.5 and PM10 concentrations frequently surpass WHO air quality standards. The WHO's annual mean standards of 20 μg/m³ for PM10 and 10 μg/m³ for PM2.5 were exceeded by the average concentrations of PM10 and PM2.5 in several sections of the city, according to a 2023 study by Antwi et al. According to the study, PM2.5 levels were much over the permissible limits, reaching up to 65 μg/m³ during rush hours and in crowded places like Adum and Asafo Market. Owusu et al. (2020) found that the import of Saharan dust during the Harmattan season causes a considerable increase in PM2.5 and PM10 levels. However, local activities like burning rubbish and automobile emissions exacerbate this seasonal rise, making December through February the worst months for air quality. In Kumasi, PM pollution has been connected to several cardiovascular and respiratory conditions. Higher PM2.5 levels are strongly associated with more hospital admissions for pneumonia, bronchitis, and asthma, especially in children and the elderly, according to a study by Aboagye et al. (2021). Because it can enter the circulation and go deep into the lungs, tiny particulate matter (PM2.5) is particularly dangerous because it raises the risk of lung cancer and cardiovascular illnesses.

2.2 Levels of PM2.5 in Accra

With more than five million inhabitants, Accra, Ghana's capital is the biggest and most developed metropolis in the nation. The city's fast expansion and growing car population have made air pollution worse, especially PM2.5 levels, which are the subject of recent research because of the detrimental impacts on public health. The main causes of PM2.5 pollution in Accra are open burning of rubbish, industrial operations, and vehicle emissions. According to studies done between 2020 and 2024, the main source of PM2.5 pollution is emissions from traffic (Amegah & Agyei-Mensah, 2021). Significant fine particulate emissions are caused by the high sulfur content of fuels used by commercial and public transportation vehicles, as well as the poor condition of many cars. Burning waste, both in official and informal contexts, is also important. Informal communities, such Agbogbloshie, where open burning e-waste and municipal solid garbage is frequent, have some of the highest PM2.5 concentrations in the city, according to a study by Anku et al. (2022). Air pollution in the larger Accra metropolitan area is a result of industrial activity

particularly that which occurs close to Tema. In a study conducted by Nyarku et al. (2019) to examine School children's human exposure to ultrafine particles in and around Accra, Ghana are both possible. Characterizing and quantitatively assessing the personal exposure to UFPs of a sensitive population group of school children in and around Accra was the primary objective of the study. This was done with the intention of allocating daily exposure to various microenvironments and determining the factors that are responsible for personal exposure to UFPs in the microenvironments. Accra has consistently high PM2.5 levels, according to several studies (2020–2024), particularly in crowded regions close to main roadways and industrial zones. According to a 2021 report by Ghana's Environmental Protection Agency (EPA), PM2.5 levels frequently surpassed the WHO's annual mean recommendation of 10 μg/m³ in several Accra neighborhoods, including Nima, Kaneshie, and Agbogbloshie. According to the EPA, there are serious health concerns associated with average yearly exposures in some places that can reach up to 70 μg/m³.

According to a study by Arku et al. (2020), which monitored PM2.5 levels in real time, concentrations of up to 120 μg/m³ were recorded during peak hours in specific hotspots, including market areas and bus terminals. Given the dense population in these places and the extended exposure of locals to dangerous contaminants, this was especially concerning.

In a study conducted by Gyasi et al (2022) on particulate matter pm2.5 measurements at cantonments in Ghana: an investigation into the relationship between air pollution and health? Cantonments is a residential district in Ghana's capital city, and the purpose of this study was to investigate further aspects of PM studies and to combine available data. The World Air Quality Project's website offers a variety of internet platforms that were utilized to acquire information regarding the PM2.5 concentrations for Cantonments. The time covered by the historical data is from April 2020 to August 2022. To make use of Origin Pro and Microsoft Excel, the data that was collected were combined and analysis. It is anticipated that particulate matter PM2.5 concentrations will rise in the Cantonments area and the city of Accra because of elevated levels of air pollution emissions.

There is serious public health consequences associated with Accra's elevated PM2.5 levels. Recent research, done by Mensah et al. (2022), has shown how common respiratory illnesses are in the city, especially among older people and children under five. The study connected an increase in

respiratory illnesses, such as asthma and chronic obstructive pulmonary disease (COPD), to elevate PM2.5 levels. A rising body of research (Owusu et al., 2023) links prolonged exposure to PM2.5 to a higher risk of heart attacks, strokes, and early mortality, further compromising cardiovascular health.

Furthermore, another study was conducted by Odonkor and Mahami (2020) to examine Accra, Ghana residents describe their knowledge, attitudes, and perceptions on air pollution. This is a critical survey. This research was conducted with the intention of determining the level of awareness, attitudes, and general perceptions on air pollution in Accra, Ghana. To collect quantitative data from 1404 participants, the research was conducted using a cross-sectional design, and the results were analyzed using SPSS version 23. It is important to note that companies such as oil refineries are also capable of producing air pollutants to unhealthy levels. One of these places is the Tema Oil Refinery in Ghana, which consistently releases PM2.5 and greenhouse gases at levels that are beyond the allowed limits. During the research, the researchers found that other factors that contributed to air pollution included fume chambers, smoke from dump sites, wood burning, and exhaust from cars.

2.3 Level of PM2.5 in Tamale

Although Tamale, the capital of Ghana's Northern Region, is less developed than Accra and Kumasi, it nonetheless has special problems with air quality, especially when it comes to PM2.5 pollution. Because of the city's reliance on biomass for energy and seasonal climate variations, PM2.5 levels fluctuate throughout the year. During the Harmattan season, natural dust from the Sahel and Sahara, vehicle emissions, and biomass burning are Tamale's main sources of PM2.5. One of the main causes of fine particulate emissions is the extensive use of firewood and charcoal for cooking, especially in rural and peri-urban regions. Nearly 70% of families in the Tamale metropolitan region rely on these conventional energy sources, which raises PM2.5 concentrations both indoors and outdoors, according to a study by Imoro and Braimah (2022). PM2.5 levels are significantly influenced by vehicle emissions, particularly as the city's road system grows and traffic volumes rise. Due to Tamale's arid climate, especially during the Harmattan, natural dust raises PM2.5 levels. Fine dust from the Sahara is brought in during the Harmattan season, and when it combines with local pollutants, it causes hazardous increases in PM2.5. According to recent research (2020–2024), Tamale occasionally sees increases in PM2.5, especially during

Harmattan. According to research by Abdul-Rahaman et al. (2023), PM2.5 concentrations during this time can significantly beyond acceptable thresholds, reaching as high as 150 μg/m³. Certain parts of the city, especially those where biomass burning is common, have PM2.5 values that are higher than WHO recommendations even when the Harmattan season is over.

According to Braimah et al. (2021), who monitored PM2.5 levels in Tamale for a whole year, the average yearly concentration was 35 μg/m³, which is significantly higher than the WHO's recommended limits. The study also found that low-income neighborhoods, where traditional cooking fuels are often used, had the highest amounts. Tamale's PM2.5 health effects are comparable to those seen in other Ghanaian regions. Children who lived in places with high PM2.5 concentrations had a higher risk of developing acute respiratory illnesses, such as pneumonia and bronchitis, according to a study by Issahaku et al. (2021). With high rates of hospitalizations for respiratory conditions like asthma and others during times of elevated PM2.5 pollution, the older population is particularly vulnerable. Like the trends seen in Accra and Kumasi, chronic respiratory and cardiovascular disorders have been associated with long-term exposure to PM2.5. In Ghana's main cities of Kumasi, Accra, and Tamale, the problem of PM pollution, especially PM10 and PM2.5, continues to be a serious public health concern. Studies conducted between 2020 and 2024 have repeatedly demonstrated that PM levels in these cities are higher than WHO recommendations, endangering the health of millions of inhabitants by increasing their risk of respiratory and cardiovascular conditions. Seasonal dust from the Harmattan, biomass burning, and vehicle emissions all contribute to these elevated pollution levels. A comprehensive strategy is needed to address this problem, one that promotes cleaner energy sources to lessen the burning of biomass, enhances waste management procedures, and regulates vehicle emissions more effectively.

2.4 Standards of WHO, EU and African on PM 10 and 2.5

A study showed that increased by 10 micrograms of aerosols, the mortality rate of 1 to 3 percent increases and particular matter emissions are a key health concern with estimated economic damage costs much higher than other pollutants (Mirhoseini et.al, 2013). These pollutants have the highest diversity and complexity and the wide dissemination. Size, concentration and chemical composition of particulate matter are their most important characteristics. Specific topographic conditions in this region by farmers burning farms around the city to eliminate weeds is an

important role in increasing the density of particulate matter in various regions across the globe. Particulate matter concentration depends on meteorological/weather variables such as humidity, wind speed, and recent rain.

Governments at the national, regional, and local levels can strive to improve the health of their citizens by lowering air pollution by using the World Health Organization's Air Quality Guidelin es (AQG) as a global aim.The World Health Organization (WHO) has produced ambient air poll ution guidelines that are commonly used as benchmarks by international governments to define objective and standards for managing air quality.The recommendations offer cities evidence-based, health-based standards for particular air contaminants to use as targets for air quality. The initial set in 2005; they were revised in 2021 to consider extensive data demonstrating several ways that air pollution, even at low concentrations, impacts health. The suggested limits that are currently in place of exposure and concentration are less than the prior recommend ations of all pollutants. Cities all throughout the world suffer greatly from the health effects of air pollution. The WHO has identified air pollution as the greatest threat to world health in the twenty-first century, along with the related problem of climate change. It is estimated that exposure to ambient air pollution results in approximately 4.5 million premature deaths worldwide each year, with indoor air pollution accounting for an additional 2.3 million deaths. In contrast, the World Health Organization estimates that the COVID-19 pandemic killed about 5 million people worldwide in 2020 and about 12 million in 2021. PM2.5, or small particulate matter with a diameter of 2.5 micrometers or less, is the most harmful pollutant because it can pass through the blood-brain barrier and into the lungs, where it can lead to cancer, respiratory, and cardiovascular illnesses. More people are impacted by it than others. Even at very low concentrations, it has an influence on health and affects a greater number of people than other pollutants. Countries can lessen the burden of sickness, including both acute and chronic illnesses, by lowering air pollution levels. According to WHO guidelines, average yearly concentrations of PM2.5 should not be more than 5 µg/m3, and average 24-hour exposures should not be higher than 15 µg/m3 on more than three or four days annually.

The city of Accra has grown significantly during the past few decades. The Greater Accra Metropolitan Area (GAMA) has a population of roughly 4 million as of the 2010 census, with 1.85 million of that number living in the city of Accra. By 2030, estimates show that the number will

rise to 6.3 million and nearly 3 million, respectively. Seasonal variations impact the levels of air pollution; in particular, there are large peaks in the dry season because of desert dust. However, year-round high average levels and detrimental effects on public health are caused by man-made sources of air pollution. A variety of sources, including satellites and government monitoring stations, provide data on air pollution. Satellites and government monitoring stations are two of the many sources of air pollution data. After values are gathered and modeled, the health risk assessment shows: in 2014 and 2015, data from residential monitoring sites indicated an average concentration of 49.5 μg/m3 for PM2.5 in the city of Accra. Similarly, satellite data from 2014 and 2015 showed an average of 36.0 μg/m3 across the Greater Accra region. Public health is negatively impacted by these levels of air pollution. Several ways to lower the present PM2.5 levels to meet interim targets and WHO air quality criteria modeled and investigated in the report.

3. MATERIALS AND METHOD

3.1 Site selection

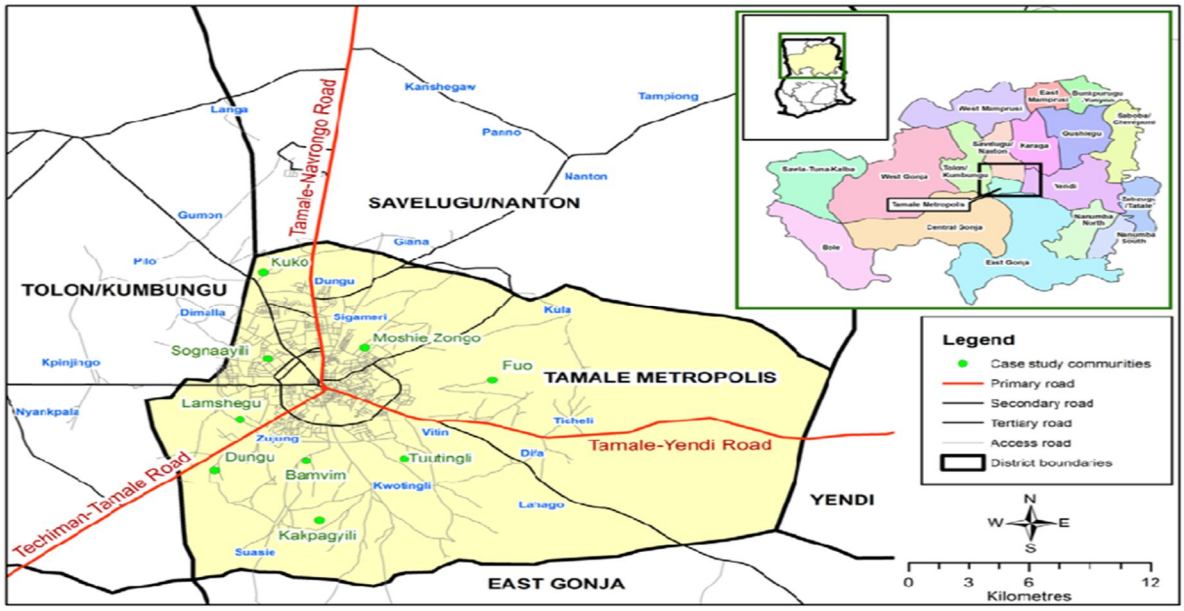
The targeted areas for this study were Accra, Kumasi and Tamale of Ghana (Figure 1.). The study areas were considered owing to their dominance in large population density, diversity, and high smoking prevalence.

Figure 1: Geographical location of examined cities in Ghana (Source: google maps)

Figure 2: Geographical location of Accra (Source:wikimediacommons, 2012)

Figure 3: Geographical location of Kumasi (Source: Korah, et.al 2017)

Figure 4. Geographical location of Tamale (Source: Napari & Cobbina, 20214)



3.2 Data collection

Data have been collected from PM2.5 for Accra and Kumasi and PM 10 for Kumasi concentration levels between January 2019 to November 2024 from Ghana USA Embassy air quality database (aqicn.org/data-platform/) . The data for Tamale PM 2.5 was taken from a work conducted by Sing et, al 2020 on the topic exposure to secondhand smoke in hospitality settings in Ghana. Evidence of changes since implementation of smoke-free legislation.

3.3 Data Analysis

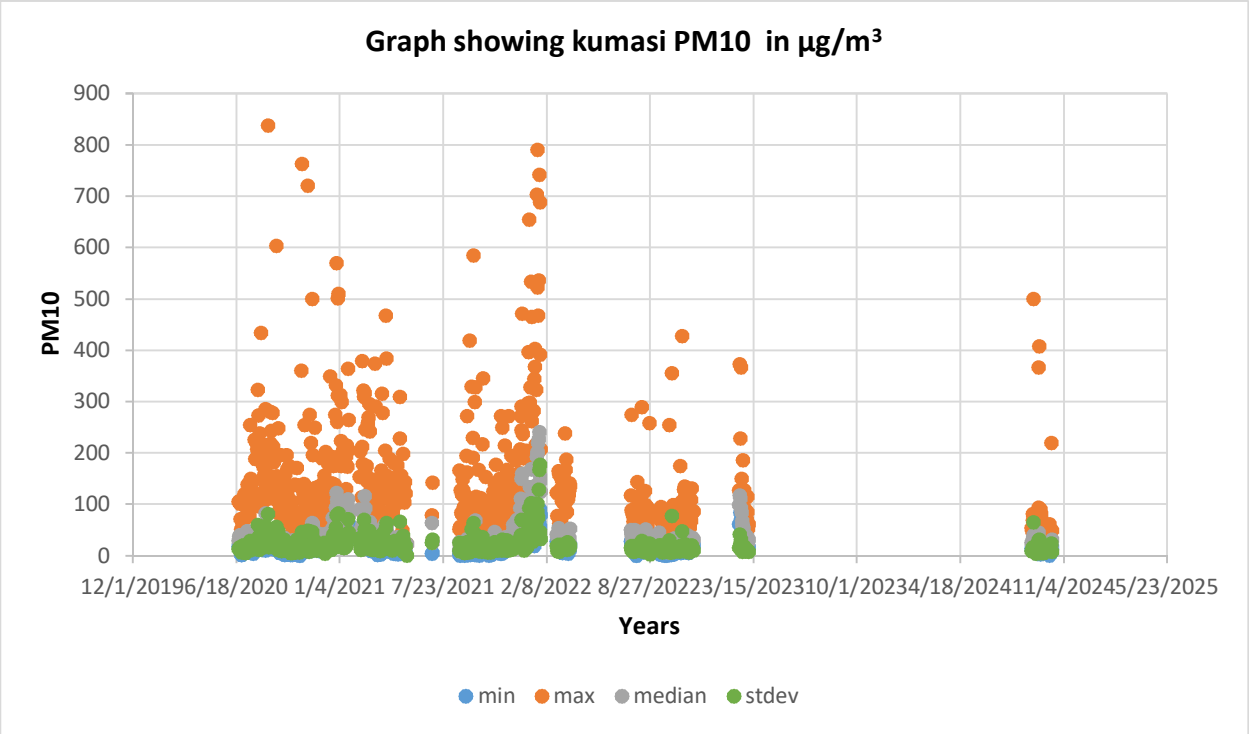
The data for the three cities were entered onto an excel sheet namely Kumasi PM10, Kumasi PM2.5, Kumasi Month, Kumasi Yearly Summary, Kumasi Temperature, Kumasi Summary, Kumasi 2024 September, Kumasi vs Accra and PM2.5 Levels in Kumasi, Accra and Tamale.

Descriptive statistics including the daily minimum, maximum and median were generated for the PM levels across the whole dataset and then subdivided by cities in excel. Graphs were developed from the data in the excel sheet to measure the concentration of PM 2.5 for Kumasi, Accra and Tamale to show the difference in their concentration levels in the atmosphere. Kumasi PM 10 data concentration was also measured through the development of graphs in the excel sheet.

4. RESULTS AND DISCUSSION

4.1 Kumasi PM10

Figure 5. Kumasi PM10 (Source: Own Work)



Particulate matter (PM10) data for Kumasi is available every day starting on June 2020, according to the Kumasi PM10 (Figure 5.). The median, minimum, maximum, and standard deviation are the important metrics. PM10 is the term for particulate matter that is 10 micrometers or smaller in diameter and that can be inhaled. If it gets into the lungs, it can cause health issues. PM10 levels vary from day to day, as indicated by the minimum, maximum, and median readings. Occasionally, maximum values surpass 100 µg/m³, a sign of dangerous air quality. The average daily exposure is better represented by the median, which is typically lower than the maximum. For example, values above 15 µg/m³ imply a higher standard deviation, which suggests greater fluctuation in daily PM10 levels. The daily statistics' accuracy may be impacted by variations in the number of samples collected. On some days, the highest PM10 levels are over 100 µg/m³ (June 24, 2020: 106.07 µg/m³), which is significantly higher than the 50 µg/m³ 24-hour mean that the WHO

recommends as a safe threshold. These levels point to a risk of acute respiratory disorders and other health issues, especially for vulnerable groups (elderly people, children, and people with underlying medical illnesses). Significant variations in PM10 levels throughout the day are suggested by days with high standard deviation (for example, June 25, 2020, with a standard deviation of 16.18 μg/m³). This could be caused by different emissions from industrial processes, traffic, or natural occurrences like dust storms. Repeated examination of PM10 levels over the course of the year may show seasonal patterns, such as greater pollution during dry seasons (owing to more dust) or during times of high vehicle traffic, despite the dataset's limitations.

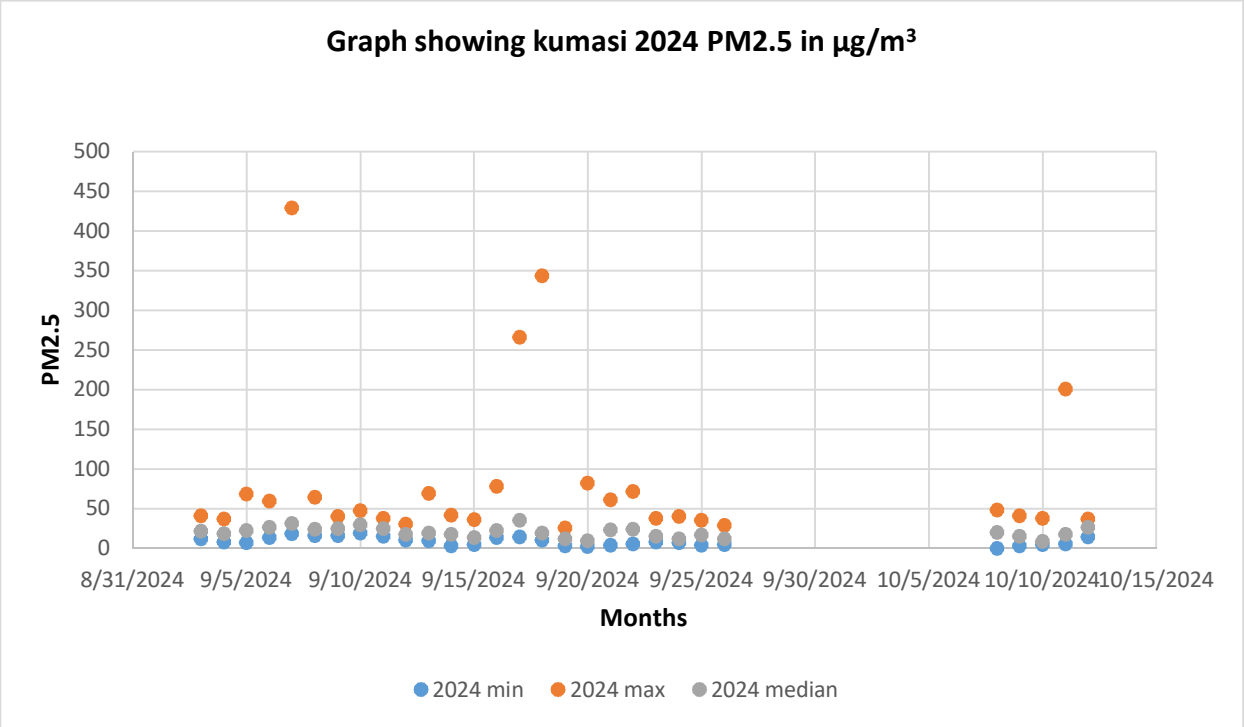
4.2 Kumasi PM2.5

The Kumasi PM2.5 sheet offers comprehensive daily data on PM2.5 concentrations. PM2.5 particles can enter the lungs deeply and have more detrimental effects on health than PM10 particles since they are significantly smaller (2.5 micrometers or less). Vehicle emissions, the burning of biomass, and industrial operations are some examples of combustion processes that frequently produce these particles. These readings represent the daily range of PM2.5 concentrations, with certain days (such as March 26, 2020) seeing maximum levels exceeding 50 μg/m³. The standard deviation captures the variation in pollution, and the count indicates the number of samples collected daily. Significant Variations: Kumasi's PM2.5 values exhibit significant variations. The highest PM2.5 value was 48.75 μg/m³ on March 24, 2020, and it decreased to 39.04 μg/m³ on March 25. Changes in local pollutants, wind patterns, or other environmental conditions may be the cause of this unpredictability. Persistent Elevated Levels: The WHO's recommended threshold of 25 μg/m³ for a 24-hour mean is often exceeded by PM2.5 levels. For example, the maximum concentration on March 26, 2020, was 54.38 μg/m³, which was more than double the advised limit. Through the lungs, PM2.5 particles can enter the circulation and cause serious illnesses like lung cancer, heart disease, and stroke. Chronic exposure, especially to youngsters and the elderly, can potentially worsen asthma and impair lung function. Vehicle traffic probably affects PM2.5 levels because Kumasi is a significant business and transportation center in Ghana. Burning biomass, which is frequently done for cooking and disposing of garbage, also greatly raises the levels of fine particulate matter. Because fine dust from the Sahara Desert is brought in by seasonal dust storms that occur throughout the Harmattan period (December to

February), PM2.5 levels may rise. Particulate matter dispersal can also be influenced by temperature and wind speed. Air pollution can be made worse by calm, stagnant weather that allows PM2.5 to build up close to ground level.

4.3 Kumasi 2024 PM2.5

Figure 6. Kumasi 2024 PM2.5 Graph (Source: Own Work)

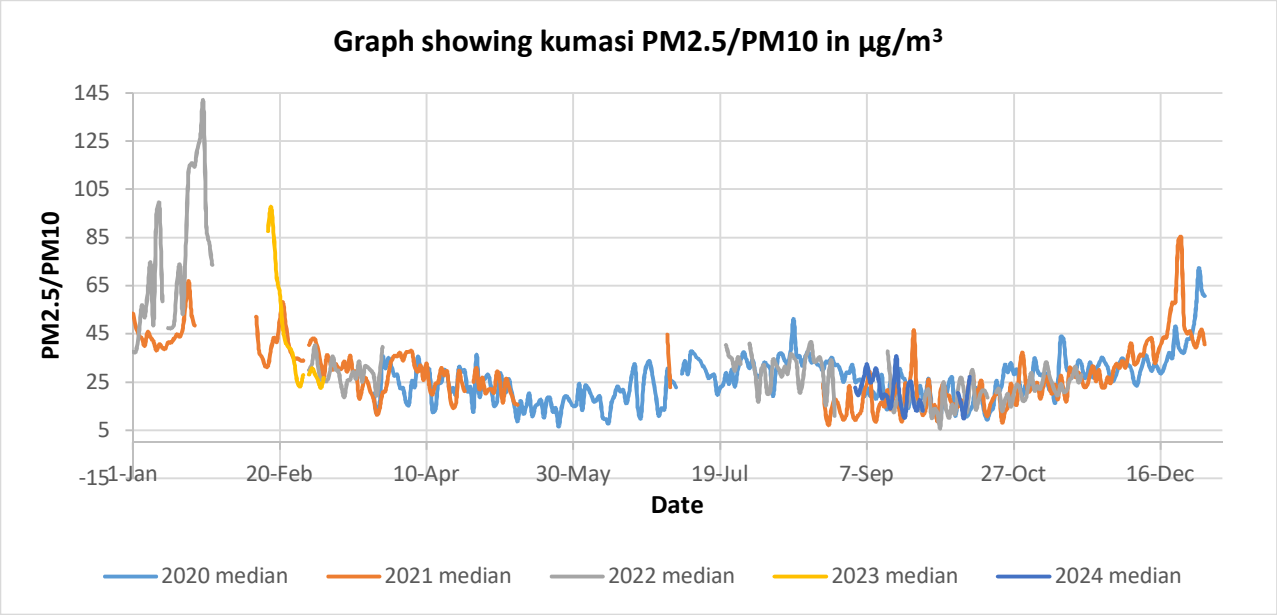


PM2.5 statistics in Kumasi for 2024 are included in the Kumasi sheet, which provides the minimum, maximum, and median readings for the year 2024. Understanding how trends in air pollution have evolved over time and whether things are getting better or worse is made easier with the help of this dataset. The graph illustrates the variations in PM2.5 concentrations from year 2024 which stands out because of its exceptionally high maximum value of 262.95 µg/m³. These offer a more consistent measure of exposure than the occasionally rising maximum readings, and they shed light on the overall state of air quality for the year. Air Quality Declines in September 2024. The median values stayed comparatively constant despite the high peaks. This implies that, despite occasional episodes of exceptionally bad air quality, daily exposure levels are continuously

high but not disastrous. Evaluation of Medians and Maximums: The difference between the median and highest values indicates that pollution spikes are significant when they do happen, despite being relatively rare.

4.4 Kumasi Yearly Summary PM2.5 AND PM10

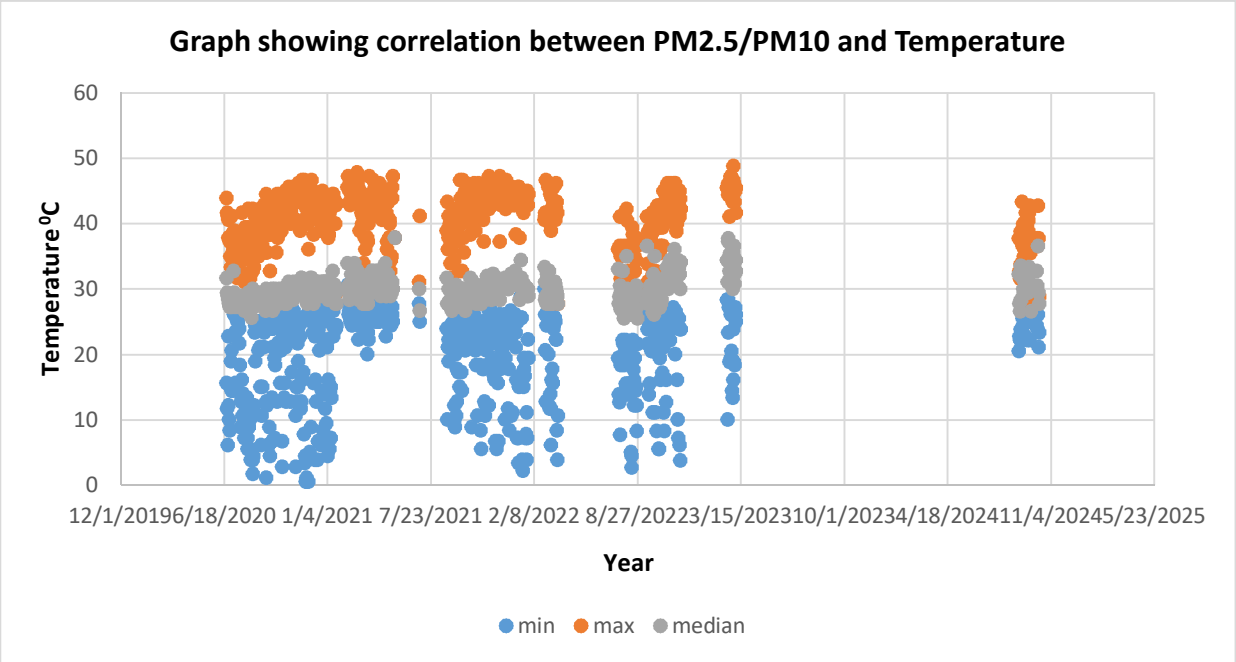
Figure 7. Kumasi Yearly Summary (Source: Own Work)



With daily statistics for each component, the Kumasi Sum Year sheet compiles temperature, PM2.5, and PM10 data starting in January 2020. A comprehensive view of the year-round variations in temperature and particle matter is provided by this dataset. The information for PM2.5 and PM10 includes the number of samples collected daily, along with the minimum, maximum, and average concentrations. Alongside the particle matter data, daily temperatures are also collected, enabling the examination of possible relationships between pollution levels and temperature. This doesn't seem to be a consistent relationship between temperature and PM concentrations, according to the summary statistics. PM2.5 and PM10 levels are not necessarily higher on days with high temperatures. For example, the temperature was measured at 26.6°C on June 23, 2020, and the PM10 concentrations peaked at 106 µg/m³. But on June 25, 2020, when the temperature was slightly higher at 27°C, PM10 levels were much lower, reaching a peak of 33.42 µg/m³. This implies that although temperature may have an impact on particulate matter dispersion, Kumasi's pollution levels are not primarily caused by it. The dataset suggests that PM

concentrations may vary seasonally, even if it doesn't directly cover a whole year. Since Kumasi has a dry Harmattan season (December to February), when local pollution combines with fine desert dust, PM levels are probably higher. On the other hand, the rainy season may contribute to air purification by removing particulate matter from the environment. The fact that there is no discernible correlation between temperature and PM levels suggests that other variables, such dust storms, biomass burning, and vehicle emissions, have a bigger influence on air quality than temperature alone. It would be helpful to track other environmental factors, like wind speed and humidity, in addition to PM and temperature data to gain a better understanding of the factors influencing air pollution in Kumasi. Tracking other variables like humidity and wind speed, which may affect the dispersion of pollutants, may be beneficial to gain a better knowledge of the dynamics of air pollution in Kumasi, even though the existing data offers insightful information. Given the serious health concerns associated with high PM levels, Kumasi authorities must give priority to cutting emissions from major sources, like burning biomass and cars.

Figure 8. correlation between Kumasi PM2.5 and Temperature (Source: Own Work)

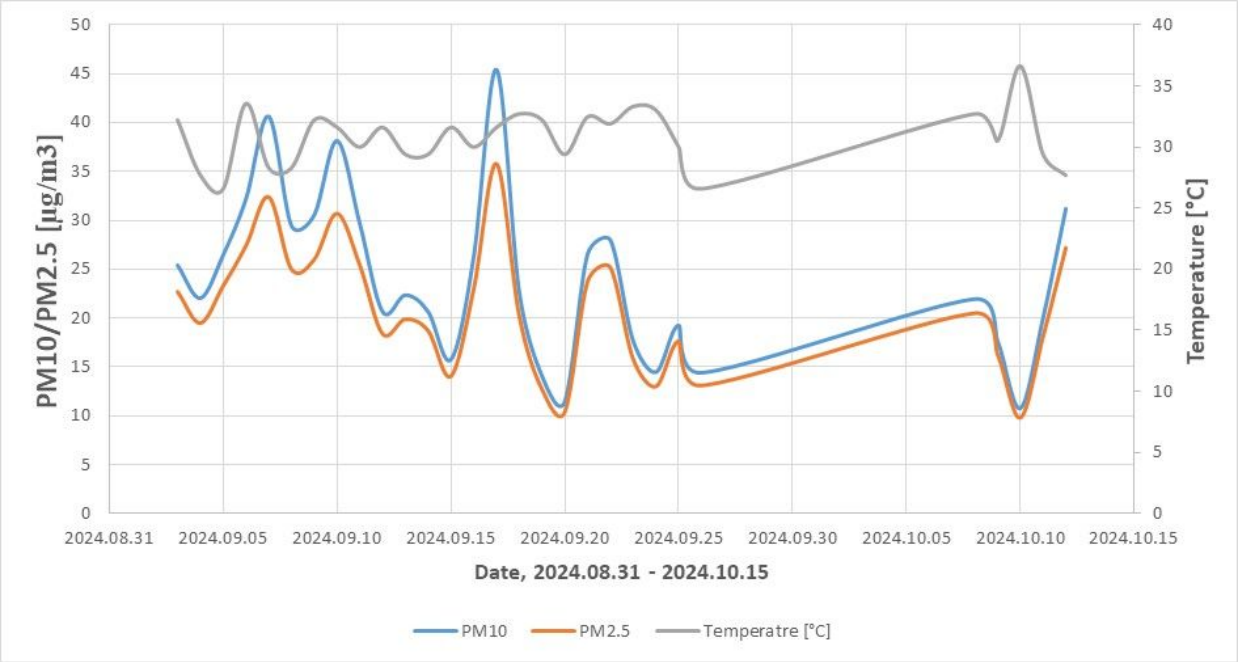


4.5 Kumasi Temperature

The Kumasi Temperature sheet records temperature and PM concentrations in Kumasi throughout the same time as the particulate matter data. °C Temperatures range from about 26°C to 33.5°C

and are measured in degrees Celsius each day. The sheet highlights temperature, but it also lists PM2.5 and PM10 concentrations, allowing one to evaluate the relationship between temperature and air pollution levels. The Kumasi Sum Year sheet indicates that there isn't much of a relationship between PM concentrations and temperature. There is not always a direct correlation between high pollution levels and high temperatures. On September 6, 2024, for instance, the temperature rose to 32.46°C, but the PM10 concentrations were only mild at 34.66 µg/m³. However, on June 23, 2020, when the temperature was lower at 26.60°C, PM10 levels peaked at 106 µg/m³, demonstrating that even on colder days, high particulate matter levels might occur. Temperature might not be the primary cause of changes in air quality on its own, but it may combine with other meteorological elements, including wind direction and speed, to affect how pollutants spread.

Figure 9. Kumasi 2024 PM10/PM2.5 Monthly Summary (Source: Own Work)

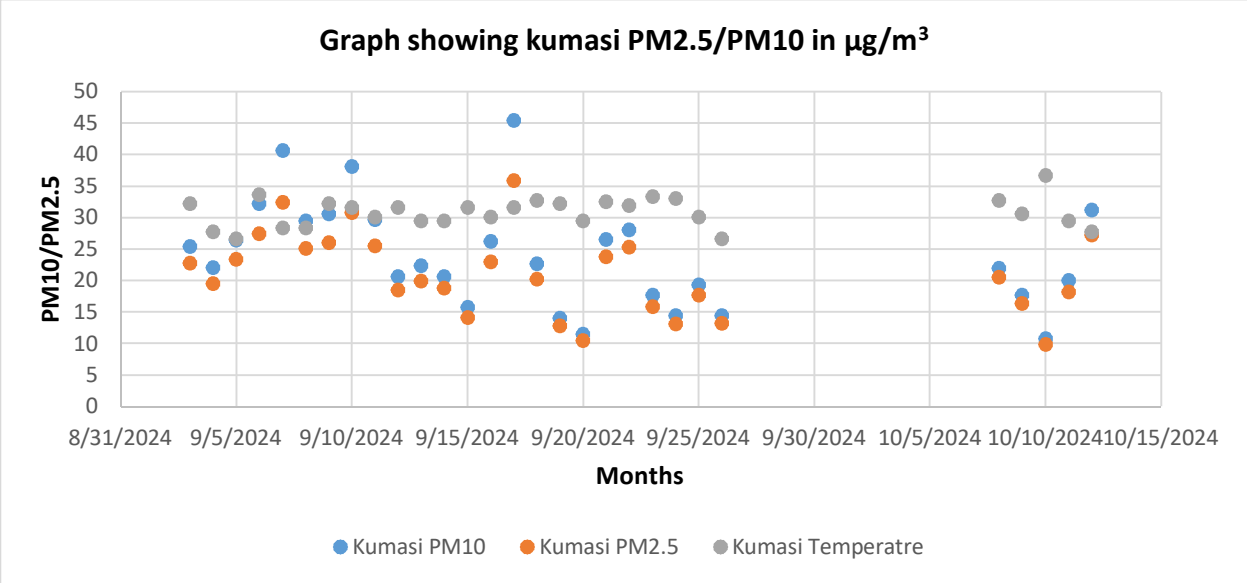


4.6 Kumasi 2024 Summary

A succinct overview of PM10 and PM2.5 data is given by the KUMASI SUM sheet, which may aggregate daily or monthly data over the years. It provides an overview of Kumasi's air quality at a high level. Both pollutants' data are summarized and probably include monthly or annual averages, maximums, and minimums. According to the summary data, PM2.5 and PM10 levels

are continuously high all year long. Maximum PM10 and PM2.5 concentrations regularly surpass WHO safety standards by exceeding 100 µg/m³ and 50 µg/m³, respectively. There are noticeable increases in pollution levels at specific times, which most likely correspond with a rise in traffic, industrial emissions, or seasonal weather patterns like the Harmattan. Although the daily maximums fluctuate, the average values of PM2.5 and PM10 are still alarmingly high, suggesting that Kumasi inhabitants regularly encounter dangerous air quality.

Figure 10. Kumasi 2024 September (Source: Own Work)

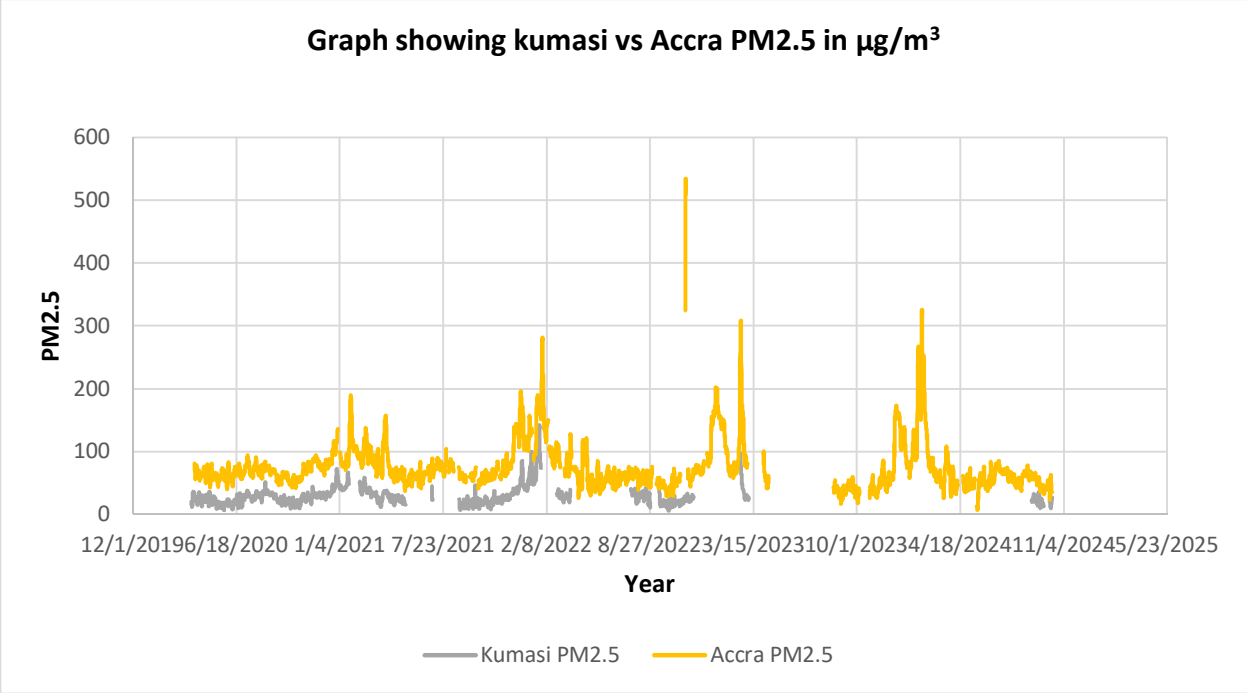


4.7 Kumasi 2024 September

For the month of September 2024, the KUMASI 2024 September on Figure 10 focuses on daily temperature, PM2.5, and PM10 data. For both PM2.5 and PM10, the daily average, minimum, and maximum concentrations are noted. Temperature: °C Temperatures range from 29.68°C to 32.46°C every day. In September 2024, PM2.5 and PM10 values are often higher than those advised by the WHO. At a peak of 32.40 µg/m³ on September 2, 2024, PM2.5 levels were significantly higher above the WHO 24-hour limit of 25 µg/m³. Like earlier sheets, the data does not clearly indicate a correlation between PM levels and temperature. For example, PM10 levels were 39.73 µg/m³ on September 5, 2024, when the temperature was 30.22°C, and 35.74 µg/m³ on September 7, which was hotter and had a temperature of 31.83°C.

4.8 Kumasi PM2.5 vs Accra PM2.5

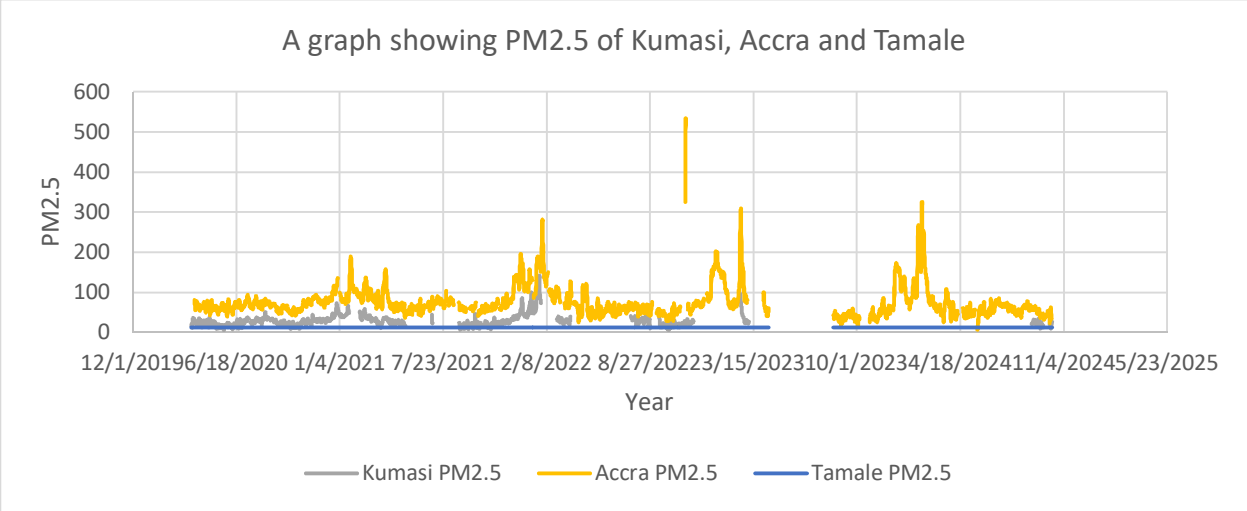
Figure 11. Kumasi vs Accra (Source: Own Work)



The Kumasi vs Accra sheet compares the PM2.5 values in Ghana's two largest cities, Kumasi and Accra. Metrics like the lowest, maximum, and median PM2.5 concentrations for each city are included. Kumasi and Accra's pollution levels may be directly compared thanks to the data for each city, which includes daily minimums, maximums, and medians. The correlation coefficients are: According to the correlation matrix, there is a positive correlation of 0.737 between the PM2.5 values in Accra and Kumasi. Given that the two cities' sources of pollution are probably similar, this shows that the changes in air quality are somewhat similar. Kumasi's Higher PM Levels: In general, Kumasi seems to have higher PM2.5 concentrations than Accra, even though both cities have serious air quality issues. Kumasi's higher reliance on burning biomass and the city's dense traffic are the reasons why its median PM2 levels are continuously higher than Accra's. According to the association between PM2.5 levels in the two cities, seasonal pollution patterns are similar in Accra and Kumasi, most likely caused by emissions from the dry season and the Harmattan winds.

4.9 PM2.5 Levels in Kumasi, Accra and Tamale

Figure 12. PM2.5 Levels in Kumasi, Accra and Tamale (Source: Own Work)



Three Ghanaian cities Kumasi, Accra, and Tamale are compared in the graph for PM2.5 concentration levels between January 2019 to November 2024.The PM2.5 concentration is displayed on the y-axis, most frequently in micrograms per cubic meter (µg/m³), and the time series data over several years is shown on the x-axis. It can be observed from figure 15 above that the PM2.5 air pollution is similar between Kumasi and Accra between 18th June 2020 and 8th February 2022 where the data taken were consistent. However, only a single data was recorded in the database on tamale which makes it impossible to compare with two other cities. The following is highlighted in the chart, which shows PM2.5 levels visually: Accra (yellow line), Kumasi (grey line), and Tamale (blue line). The PM2.5 readings in Kumasi are comparatively lower than those in Accra. One can make the following observations. In Kumasi, the PM2.5 concentrations are largely still below 50 µg/m³. This indicates comparatively better air quality than Accra, which exhibits higher and more frequent surges. According to the data for Kumasi, there are modest rises in the middle of each year along with moderate seasonal changes. Dry spelling or regional activities like burning biomass or car emissions may be connected to this. Early in 2022 and late in 2023, there are some discernible peaks that point to temporary spikes in pollution. These surges may be

caused by seasonal weather patterns or transient occurrences like localized burning, festivals, or construction. PM2.5 levels are much higher and more variable in Accra. Accra experiences more fluctuations in PM2.5 levels than Kumasi, with some strong spikes over 500 μg/m³ and multiple peaks exceeding 100 μg/m³. This suggests intense pollution episodes that may be harmful to one's health. There are increases in PM2.5 levels throughout the timeframe, although they are most noticeable in early 2022, mid-2022, and early 2023. Several variables, such as increasing urban activity, traffic congestion, industrial pollutants, and perhaps the Harmattan season, which transports dust from the Sahara, could be responsible for these rises. The capital city of Accra probably has higher pollution levels because of things like buildings, industry, a dense population, and more cars. The chart's fluctuation may be a sign that air quality management is difficult in an urban setting. The data on PM2.5 in Tamale indicates a flat trend during the period, indicating continuously low values. Very low PM2.5 concentrations are indicated by the blue dashed line, which stays near zero throughout the timeline. This implies that Tamale has superior air quality than Accra and Kumasi. Due to less industrial activities, less urbanization, and maybe better environmental management, PM2.5 levels have remained stable. This may also be influenced by the geographic location and decreased traffic because they may promote natural air dispersal.

4.10 Discussion

The charts (figure 1 to 15) allow for the drawing of the following significant conclusions. The difference between urban and suburban/rural environments is highlighted by contrasting the three cities. Accra's consistently high PM2.5 levels demonstrate the challenges of managing pollution in a densely populated urban setting. Tamale's flat line, in contrast, shows a cleaner atmosphere, which might be the consequence of less urbanization and industry. Given that Accra's figures indicated significant increases in early 2022 and early 2023, this is concerning. These could be related to human activities (such as increased building, traffic, or industrial emissions) or environmental conditions (such as Harmattan dust). It is essential to understand the cause of these increases to effectively control air quality challenges. Exposure to high levels of PM2.5 over an extended period can have negative health impacts, such as respiratory and cardiovascular diseases and even early death. The Accra data is quite concerning since it demonstrates numerous instances of hazardous air quality that require immediate attention. The seasons can have a significant impact. For example, Saharan dust can increase PM2.5 levels during the Harmattan season (December to February), especially in the central and northern regions of Ghana. Traffic

emissions, burning biomass (including agricultural waste and cooking with solid fuels), industrial discharges, and buildings are the main sources of PM2.5. In heavily populated areas like Accra, PM2.5 levels are predicted to rise because of these activities. The distribution of contaminants is also influenced by geographic features. Inland communities might be more widely distributed, depending on the topography and vegetation cover, whereas coastal cities like Accra might have challenges due to land-sea wind dynamics.

5. CONCLUSIONS AND SUGGESTIONS

5.1 Conclusion

Since the early 1990s, economic growth has been robust and consistent, averaging over 5% annually. As a result, poverty has decreased by half, from 52.7% in 1993 to 23.4 percent in 2016. Inequalities persist in some areas, although the pace of poverty reduction has slowed recently. In the meantime, rising debt hardship is driving up living expenses and threatening government spending. These demands are exacerbated by the expense of air pollution. The main causes of air pollution are industrial estates, inadequate public transportation infrastructure, and rubbish burning. Ghana's average annual PM2.5 concentration in 2019 was eleven times higher than the levels recommended by the WHO for 2021. The socioeconomic prospects and general well-being of Accra's population will deteriorate in the absence of prompt construction of a clean expansion. This will consequently hurt its rapidly expanding industrial and services sectors. In Kumasi, conventional passenger cars make up most fleet stocks, and they surely have a significant impact on vehicle emissions across the board. This can be attributed to the growing number of older cars being imported into the nation as well as the densely populated older car population in Kumasi. Because most of these outdated cars are utilized for business purposes, they burn a lot of fuel to travel relatively short distances, especially in urban areas with heavy traffic. This suggests that inefficient fuel utilization results in increased vehicle emissions. Vehicular air pollutants impacted considerably on the deterioration of the ambient air quality of the Kumasi Metropolis. There are no efforts done towards the development of alternative source of energy for vehicles in underdeveloped countries and Kumasi being one of the regions in Ghana instead of relying solely on the fossil fuel. The elevated levels of PM10 in Kumasi pose a significant risk to public health. Respiratory disorders like asthma and chronic bronchitis, as well as cardiovascular issues, have been linked to prolonged exposure to these levels. Although PM10 particles are larger than PM2.5 particles and may not penetrate the lungs as deeply, they can still irritate and inflame the airways. The management of particulate matter sources, such as industrial operations, construction projects, and vehicle emissions, should be the primary objective of initiatives to reduce PM10 levels. PM10 pollution reduction may also be facilitated by the incorporation of greener infrastructure and traffic congestion reduction techniques into urban planning. The significant increases in PM2.5 concentrations call for targeted actions, especially during high-risk periods. They may entail

temporary restrictions on industrial or traffic activity on days with high pollution levels. Residents of Kumasi are constantly exposed to dangerously high amounts of fine particulate matter, as evidenced by the median concentrations being higher than WHO standards but below the extreme maximum values. Air quality needs to be regularly monitored to identify trends and seasonal spikes in pollution. To raise awareness and encourage preventative measures, such as informing residents to stay indoors on days with high pollution levels, the public should have access to this data. In cities with heavy traffic and industrial activity, reducing the sources of PM2.5 pollution should be the primary objective of government activities. Stronger enforcement of air quality regulations and investments in cleaner technology are necessary to lessen the health risks associated with prolonged exposure to PM2.5. Each of these graphics shows the air quality in Kumasi in detail, emphasizing the persistent issue of particulate matter pollution and the health risks it poses. PM2.5 and PM10 levels are frequently excessive, which emphasizes the necessity for robust local and national controls. Kumasi residents are at risk for health problems because the PM concentrations there are regularly greater than WHO guidelines, regardless of temperature. Further study using a larger dataset that includes other meteorological components like wind patterns may uncover more detailed correlations between temperature and air quality, even though they are not immediately apparent from the data. Regardless of the weather, authorities should educate the public about the health risks associated with air pollution and encourage protective behaviors such as wearing face masks or staying indoors on days when pollution levels are high.

Excessive PM2.5 and PM10 exposure can cause chronic respiratory and cardiovascular diseases. The aggregated data shows that Kumasi's low air quality puts residents at risk for long-term health issues. The summary data emphasize industrial emissions and traffic, requiring immediate action to reduce air pollution. Authorities should prioritize business adoption of cleaner technologies and stricter auto emissions standards. Pollution could be decreased by raising awareness of air pollution and encouraging behavioral changes like driving less and using cleaner fuels.

5.2 Suggestions

Given the persistently high particulate matter levels in September 2024, it would be advantageous for authorities to impose dry-season air quality measures, including limiting vehicle emissions or encouraging mask use. Both cities are experiencing high levels of fine particulate matter, and the correlation between their pollution levels indicates that regional causes, such as Saharan dust and

regional transportation emissions, may have an impact on both. Given that the air quality issues in both cities are comparable, a coordinated strategy to reduce air pollution may work. One method to do this might be to harmonize environmental laws and public health programs between the two cities. Accra and Kumasi authorities should collaborate on air quality control initiatives, such as coordinated campaigns to reduce vehicle emissions and encourage the use of cleaner energy sources for cooking and heating. To raise awareness and encourage public participation in pollution reduction efforts, governments should make the public's access to air quality data from both cities simple. This research covers the remaining sheets and provides detailed insights into each dataset, highlighting the severe air quality problems that Accra and Kumasi suffer. The high levels of particulate matter in these places underscore the urgent need for action to reduce air pollution and protect human health. Thorough and continuous monitoring of the air quality in major cities can help identify pollution hotspots and follow improvements or reductions in air quality. Enforcing stricter pollution standards, improving public transportation, and promoting the use of electric vehicles can all significantly lower PM2.5 levels. Industries must be monitored and regulated to ensure that their emissions remain within permissible limits. Adoption of greener technologies can also lead to less pollution. More sustainable behaviors, including burning less trash and using cleaner cooking fuels, can be promoted by educating the public about the causes and effects of air pollution. The figure provides crucial information on the differences in air quality through its in-depth examination of PM2.5 levels in three significant Ghanaian cities. While Tamale frequently experiences low PM2.5 readings, Accra frequently encounters major pollution surges that are hazardous to human health. The primary objectives of initiatives to solve these issues should be greater awareness of the importance of air quality, better urban planning, and stricter legislation. The patterns, insights, and implications of the data shown in the figure are clearly communicated by this comprehensive explanation. Additionally, it provides recommendations on how to improve air quality, particularly in areas with high pollution levels.

6. SUMMARY

For a healthy lifestyle, it's critical to regularly breathe in clean air. When chemical, physical, or organic materials contaminate an indoor or outdoor space and change the environment's inherent features, it is referred to as air pollution. Fires in homes, cars, factories, and forests are common causes of air pollution. Particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide are all examples of things that are pollutants to public health. Air pollution causes respiratory and other illnesses and is a leading cause of illness and death. Consequently, it is commonly acknowledged that exposure to contaminated air poses a significant risk for non-communicable diseases in humans. According to the World Health Organization (WHO), in 2016, it was predicted that 7 million people died around the world because of household and ambient air pollution. Ninety percent of these fatalities were reported in countries in Asia and Africa that had a middle-income or low-income level (Odonkor & Mahami, 2020). There is a wide range of hazardous substances that are associated with air pollution. Several respiratory and cardiovascular problems have been associated with particulate matter (PM), which is a pollutant that is both extremely dangerous and frequently found in the environment (Odonkor & Mahami, 2020).

Carbon dioxide emissions are mostly caused by the combustion of fossil fuels, which is the primary source that is believed to be the most significant contributor. Burning coal, natural gas, and crude oil are the three types of fossil fuels that are used in the combustion process. The industrial operations that release carbon dioxide into the atmosphere through chemical reactions are the second source of carbon dioxide. These processes are responsible for making carbon dioxide. The conclusion that can be drawn from this is that the interaction between carbon dioxide emissions and other factors is made up of chemical and physical components (Appiah et al, 2017). As a result of globalization and rapid economic activities, increases in carbon dioxide (CO2) emissions have been observed across the globe over the course of the past several years (Abdullah, 2015). The expansion of human activities, such as manufacturing, transportation, the generation of power, and the consumption of products and services, all contribute to the expansion of a nation's economy. On the other hand, these human activities are further contributors to the contamination of the environment.

Cities located in sub-Saharan Africa are currently undergoing tremendous expansion and are during an economic transition. Sub-Saharan African cities are facing significant levels of air

pollution from a variety of sources because of their dramatic rate of population increase. Additionally, the growth is causing a shift in the composition of air pollution as well as the relative responsibilities of the primary generators of emissions. According to the findings of recent research, the primary source of emissions that contribute to urban air pollution in Sub-Saharan Africa may be changing away from the burning of biomass in households and toward the traffic on roads. Accordingly, even though the concentrations of fine particulate matter pollution are exhibiting indications of reaching a plateau (Allis et al, 2021). Increasing formal and informal industrial activities, as well as household and commercial use of diesel generators, are also common in cities in Sub-Saharan Africa. These activities contribute significantly to the levels of NOx in the atmosphere, and the distribution of these sources in relation to land use and socioeconomic factors influences the spatial patterns of NOx pollution in local communities (Wang et al, 2021). Seasonal shifts in regional meteorological parameters (such as mixing layer depth, incident solar radiation, and water vapor mixing ratio) during the dry and dusty Harmattan period may also amplify NOx concentrations from local emissions during this time. This phenomenon is observed in cities across the West African sub-region (Knippertz et al, 2015)

Pollution in the atmosphere poses a risk to the advancement of socioeconomic conditions and has the potential to have a negative impact on the survival of the entire population. As a result, air pollution is the most significant threat to environmental health on a global scale. It puts the health of millions of people in jeopardy and places a significant financial burden on society (Owusu-Boateng et al, 2017). The factors that have led to a decline in air quality have become even more severe as urbanization and mass consumption have become the norm in a significant portion of the world.

Because of the aspirations of people all over the world to achieve sustainability, environmental challenges have become an increasingly important topic of discussion among researchers and policymakers. Initiatives aimed at ensuring environmental sustainability have gained momentum because of the growing consensus that economic growth and other economic goals should not be prioritized over the protection of the environment and the natural resources that are essential for achieving economic and welfare goals. It is important to note that Ghana is one of the African countries that is developing at the quickest rate (Odonkor & Mahami, 2020). Despite this, it appears that the country's gradual increases in air pollution have been influenced by the rapid economic growth that has been occurring. As of September 2018, the Ghanaian government

believed that air pollution was responsible for nearly 28,000 deaths (Odonkor & Mahami, 2020). The targeted areas for this study were Accra, Kumasi and Tamale of Ghana. The study areas were considered owing to their dominance in large population density, diversity, and high smoking prevalence. Data have been collected from PM2.5 for Accra and Kumasi and PM 10 for Kumasi concentration levels between January 2019 to November 2024 from Ghana USA Embassy air quality database (aqicn.org/data-platform/). The data for Tamale PM 2.5 was taken from a work conducted by Sing et, al 2020 on the topic exposure to secondhand smoke in hospitality settings in Ghana. Evidence of changes since implementation of smoke-free legislation. The data for the three cities were entered onto an excel sheet namely Kumasi PM10, Kumasi PM2.5, Kumasi Month, Kumasi Yearly Summary, Kumasi Temperature, Kumasi Summary, Kumasi 2024 September, Kumasi vs Accra and PM2.5 Levels in Kumasi, Accra and Tamale. Descriptive statistics including the daily minimum, maximum and median were generated for the PM levels across the whole dataset and then subdivided by cities in excel. Graphs were developed from the data in the excel sheet to measure the concentration of PM 2.5 for Kumasi, Accra and Tamale to show the difference in their concentration levels in the atmosphere. Kumasi PM 10 data concentration was also measured through the development of graphs in the excel sheet.

The charts (figure 1 to 12) allow for the drawing of the following significant conclusions. The difference between urban and suburban/rural environments is highlighted by contrasting the three cities. Accra's consistently high PM2.5 levels demonstrate the challenges of managing pollution in a densely populated urban setting. Tamale's flat line, in contrast, shows a cleaner atmosphere, which might be the consequence of less urbanization and industry. Given that Accra's figures indicated significant increases in early 2022 and early 2023, this is concerning. These could be related to human activities (such as increased building, traffic, or industrial emissions) or environmental conditions (such as Harmattan dust). It is essential to understand the cause of these increases to effectively control air quality challenges. Exposure to high levels of PM2.5 over an extended period can have negative health impacts, such as respiratory and cardiovascular diseases and even early death. The Accra data is quite concerning since it demonstrates numerous instances of hazardous air quality that require immediate attention. The seasons can have a significant impact. For example, Saharan dust can increase PM2.5 levels during the Harmattan season (December to February), especially in the central and northern regions of Ghana. Traffic emissions, burning biomass (including agricultural waste and cooking with solid fuels), industrial

discharges, and buildings are the main sources of PM2.5. In heavily populated areas like Accra, PM2.5 levels are predicted to rise because of these activities. The distribution of contaminants is also influenced by geographic features. Inland communities might be more widely distributed, depending on the topography and vegetation cover, whereas coastal cities like Accra might have challenges due to land-sea wind dynamics.

BIBLIOGRAPHY

Ababio, B. A., Nkansah, M. A., Hogarh, J. N., Agyekum, T. P., & Commeh, M. K. (2023). In-kitchen particulate matter emissions in high schools in the Kumasi metropolis, Ghana: Levels and the health risk assessment. *Journal of Hazardous Materials Advances*, *11*, 100358.

Abdullah, L., 2015, Linear Relationship between CO2 Emissions and Economic Variables: Evidence from a Developed Country and a Developing Country. Journal of Sustainable Development, 8 (2).

Abdul-Rahaman, A., Alhassan, S., & Issahaku, A. (2023). Seasonal variation in PM2.5 concentrations and its health impacts in Tamale, Northern Ghana. Atmospheric Environment, 269, 118760. https://doi.org/10.1016/j.atmosenv.2023.118760

Aboagye, E., Asante, P., & Adusei, P. (2021). The effect of particulate matter (PM10 and PM2.5) pollution on respiratory health in Kumasi, Ghana. Journal of Environmental Science and Health, 56(7), 640-649. https://doi.org/10.1080/10934529.2021.1897050

Adjei-Mantey, K., Matsumoto, K. I., Shigetomi, Y., Yamamoto, Y., & Nakayama, T. (2023). Factors affecting household air pollutants in West Africa: Evidence from Ghana and Nigeria. Energy for Sustainable Development, 76, 101288.

Agyemang-Bonsu, K. W., Dontwi, I. K., Tutu-Benefoh, D. A., Bentil, D. E., Boateng, O. G., Asuobonteng, K., & Agyemang, W. (2010). Traffic-data driven modelling of vehicular emissions using COPERT III in Ghana: A case study of Kumasi.

Air Pollution. (2024, January 25). European Environment Agency. https://www.eea.europa.eu/en/topics/in-depth/air-pollution

Air Pollution: African Invisible silent killer (2020, October 19). UNEP. https://www.unep.org/news-and-stories/story/air-pollution-africas-invisible-silent-killer-1

World Health Organization. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World

Health Organization. https://iris.who.int/handle/10665/345329. License: CC BY-NC-SA 3.0 IGO

Antabea R , Atuoyea N.K, Kuuireb Z.V , Sanoc Y , Arkud G & Luginaahd I (2016) Community health impacts of surface mining in the Upper West Region of Ghana: The roles of mining odors and dust HUMAN AND ECOLOGICAL RISK ASSESSMENT 2017, VOL. 23, NO. 4, 798–813 http://dx.doi.org/10.1080/10807039.2017.1285691

Amegah, A. K., & Agyei-Mensah, S. (2021). Urban air pollution in Accra, Ghana: Causes, effects, and solutions. Environmental Pollution, 272, 116417. https://doi.org/10.1016/j.envpol.2020.116417

Anku, Y. S., Tutu, A. O., & Ackah, M. A. (2022). Air quality challenges in Accra: A focus on PM2.5 pollution in informal settlements. International Journal of Environmental Research and Public Health, 19(3), 945. https://doi.org/10.3390/ijerph19030945

Antwi, K. A., Akuffo, J. A., & Boateng, P. (2023). Monitoring PM10 and PM2.5 pollution in Kumasi: Impacts of urbanization and traffic congestion. Science of the Total Environment, 806, 150598. https://doi.org/10.1016/j.scitotenv.2022.150598

Arku, R. E., Dionisio, K. L., & Batterman, S. (2020). Real-time monitoring of PM2.5 concentrations in urban hotspots: Evidence from Accra, Ghana. Journal of the Air & Waste Management Association, 70(12), 1324-1335. https://doi.org/10.1080/10962247.2020.1805229

Appiah, K., Du, J., Musah, A. A. I., & Afriyie, S. (2017). Investigation of the relationship between economic growth and carbon dioxide (CO2) emissions as economic structure changes: evidence from Ghana. Resources and Environment, 7(6), 160-167.

Barnes DF, Krutilla K, Hyde WF. (2005). The Urban Household Energy Transition: Social and Environmental Impacts in the Developing World. Washington, DC: RFF Press

Boateng, E., Asamoah, K. E., & Owusu, A. (2022). Biomass burning and particulate matter pollution in Kumasi, Ghana. Energy Policy and Environment, 14(2), 203-212. https://doi.org/10.1016/j.energy.2022.203477

Braimah, I., & Imoro, Z. (2021). Assessing PM2.5 concentrations in Tamale, Ghana: A focus on biomass burning. Environmental Monitoring and Assessment, 193, 486. https://doi.org/10.1007/s10661-021-09132-6

Emetere ,M.E., & Abodunrin T.J. (2019) Air quality estimation Over Tamale using aerosol loading parameters Journal of Physics: Conf. Series 1299 (2019) 012024. https://doi.org 10.1088/1742-6596/1299/1/012024

Fisher, S., Bellinger, D. C., Cropper, M. L., Kumar, P., Binagwaho, A., Koudenoukpo, J. B., & Landrigan, P. J. (2021). Air pollution and development in Africa: impacts on health, the economy, and human capital. The Lancet Planetary Health, 5(10), e681-e688.

Ghana Statistical Service. (2022). Ghana 2021 Population and Housing census. General Report Volume 3K. Ghana Statistical Service Accra.

Gyasi, P. A., Amu-Darko, J. N. O., Issaka, E., & Amarteifio, E. N. A. (2022). AIR POLLUTION AND HEALTH: PARTICULATE MATTER PM2. 5 MEASUREMENTS IN CANTONMENTS, GHANA. EPRA International Journal of Multidisciplinary Research (IJMR), 8(10), 131-138.

Hansen CP, Lund JF,& Treue T .(2009) Neither fast, nor easy: the prospect of Reduced Emissions from Deforestation and Degradation (REDD) in Ghana. International Forestry Review 11(4):439–455

IEA, IRENA, UNSD, World Bank, WHO. 2022. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC. © World Bank. License: Creative Commons Attribution—NonCommercial 3.0 IGO (CC BY-NC 3.0 IGO). Available from: https://trackingsdg7.esmap.org/downloads

Mir Alvarez, C., Hourcade, R., Lefebvre, B., & Pilot, E. (2020). A scoping review on air quality monitoring, policy, and health in West African cities. International Journal of Environmental Research and Public Health, 17(23), 9151.

Imoro, Z., & Braimah, I. (2022). Understanding the sources of PM2.5 pollution in Northern Ghana: A study in Tamale. Environmental Science and Pollution Research, 29, 7253-7264. https://doi.org/10.1007/s11356-021-15748-4

Issahaku, A., Alhassan, S., & Braimah, I. (2021). Exposure to air pollution and acute respiratory infections among children in Tamale, Ghana. Environmental Research, 200, 111654. https://doi.org/10.1016/j.envres.2021.111654

Mensah, S., Ampofo, A., & Owusu, D. (2022). Health impacts of PM2.5 exposure in urban Accra: An epidemiological study. Journal of Urban Health, 99(2), 270-284. https://doi.org/10.1007/s11524-022-00602-8

Ntim M., G. Owusu-Boateng, & J. Plange-Rhule. (2013). Air Quality and the Lung Function of Communities in the Concessional Area of the Chirano Gold Mines Limited, Bibiani-Ghana, 479–88. doi:10.5251/ajsir.2013.4.5.479.488

Nyarku, M., Buonanno, G., Ofosu, F., Jayaratne, R., Mazaheri, M., & Morawska, L. (2019). Schoolchildren's personal exposure to ultrafine particles in and near Accra, Ghana. Environment international, 133, 105223.

Odonkor, S. T., & Mahami, T. (2020). Knowledge, attitudes, and perceptions of air pollution in Accra, Ghana: a critical survey. Journal of Environmental and public health, 2020

Osei, E., Owusu-Sekyere, E., & Antwi, A. (2021). Sources and spatial distribution of PM10 and PM2.5 in Kumasi, Ghana. Journal of Environmental Science and Pollution Research, 28(3), 4050-4061. https://doi.org/10.1007/s11356-020-10683-7

Owusu Boadi K, & Kuitunen M. (2006) Factors affecting the choice of cooking fuel, cooking place and respiratory health in the Accra metropolitan area, Ghana. Journal of Biosocial Science 38:403–412

Puthumana JS, Ngaage LM, Borrelli MR, Rada EM, Caffrey J, Rasko Y: Risk factors for cooking-related burn injuries in children, WHO Global Burn Registry. Bull World Health Organ. 2021 Jun 1;99(6):439-445. https://doi.org/10.2471%2FBLT.20.279786

Vinti, G., & Vaccari, M. (2022). A simplified model for estimating household air pollution in challenging contexts: a case study from Ghana. Clean Technologies, 4(3), 703-713.

Wang, J., Alli, A. S., Clark, S. N., Ezzati, M., Brauer, M., Hughes, A. F., ... & Arku, R. (2024). Inequalities in urban air pollution in sub-Saharan Africa: An empirical modelling of ambient NO and NO2 concentrations in Accra, Ghana. Environmental Research Letters.

World Health Organization, World Health Statistics 2016: Monitoring Health for the SDGs Sustainable Development Goals, World Health Organization, Geneva, Switzerland

WHO. 2006a. WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide, and Sulfur Dioxide. Global Update: 2005. World Health Organization. 2006. Available at https://apps.who.int/iris/handle/10665/69477

Zhou P, Appiah O. M, Jamshidi H.A , Oduro C , Sarfo I, & Dai Z (2021) Review on Connecting the Complex Dots of Environmental Problems in Greater Accra Metropolitan Area Journal of Geography, Environment and Earth Science International 25(7): 47-64, 2021; Article no.JGEESI.72284 ISSN: 2454-7352 (GAMA) of Ghana

https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database/2016

https://air.emb.gov.ph/wp-content/upload/2021/07/NAQSR-2016-2018-FV.

https://WWW.iqair.com/world-most-polluted-cities/world-air-quality-report-2019-en.

https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database2020

https://WWW.iqair.com/world-most-polluted-cities/world-air-quality-report-2021-en

https://WWW.iqair.com/world-most-polluted-cities/world-air-quality-report-2022-en

https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database2023

https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database2024

https://giovanni.gsfc.nasa.gov/giovanni/

https://gna.org.gh/2023/09/air-quality-makola-agbogbloshie-among-five-polluted-hotspots-in-accra

https://commons.wikimedia.org/wiki/File:Districts_of_the_Greater_Accra_Region_(2012).

https://link.springer.com/article/10.1007/s10708-016-9731-1

https://www.researchgate.net/figure/Geographical-Map-Tamale-Metropolis_fig1_350323357

LIST OF TABLES AND FIGURES

Tables

Figures

ANNEXES

Annex I. Air Quality Index scale as defined by the US-EPA 2016 standard

(Source: US-EPA report, 2016)

AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0-50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	None
51-100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease.
10-150	Unhealthy for sensitive groups	Members of sensitive groups may experience health effects. The public is not likely to be affected.	Active children and adults, and people with respiratory disease.
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
300<	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should avoid all outdoor exertion

Annex II: Air pollution Hotspot zones in Accra

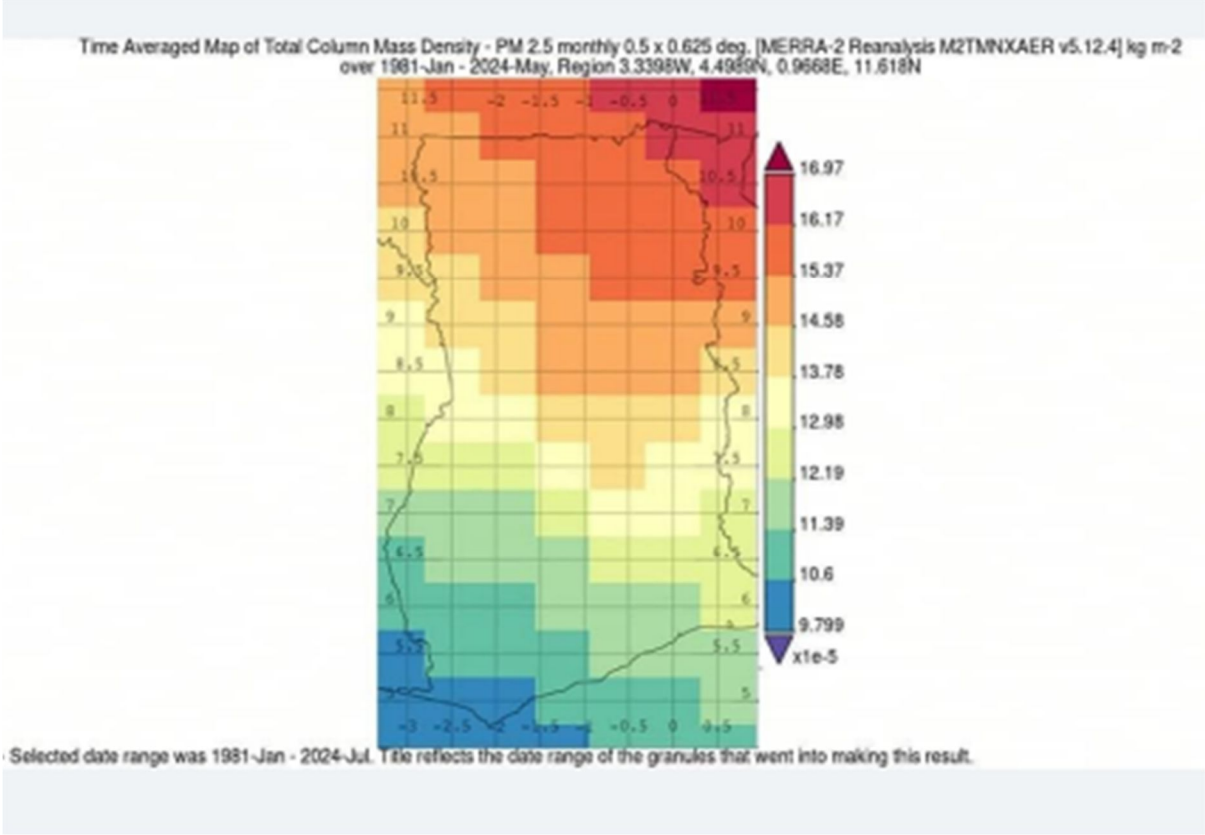
(Source: Ghana News Agency, 2023)

Annex III. Map of Accra with air pollution hotspots

(Source: Ghana News Agency, 2023)

Annex IV. Time-Averaged Map of Total Column Mass Density

(Source: giovanni.gsfs, 2024)



Annex V: Dust pollution in Tamale (Source: Asaaseradio, 2023)

STUDENT DECLARATION

The public access and authenticity of the thesis/dissertation/portfolio[1]

Student's name: Abigail Ayetor

Student's Neptun code: UDB7G7

Title of thesis: Examination of Ghana air pollution

Year of publication: 2024

Name of the consultant's institute: Institute of Environmental Sciences

Name of consultant's department: Department of Environmental Analysis and Technologies

I declare that the final thesis/thesis/dissertation/portfolio submitted by me is an individual, original work of my own intellectual creation. I have clearly indicated the parts of my thesis or dissertation which I have taken from other authors' work and have included them in the bibliography.

If the above statement is untrue, I understand that I will be disqualified from the final examination board and that I will have to take the final examination after writing a new thesis. I do not allow editing of the submitted thesis, but I allow the viewing and printing, which is a PDF document.

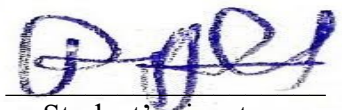
I acknowledge that the use and exploitation of my thesis as an intellectual work is governed by the intellectual property management regulations of the Hungarian University of Agricultural and Life Sciences.

I acknowledge that the electronic version of my thesis will be uploaded to the library repository of the Hungarian University of Agricultural and Life Sciences. I acknowledge that the defended and

- not confidential thesis after the defense
- confidential thesis 5 years after the submission

will be available publicly and can be searched in the repository system of the University.

Date: _____2024_____ year _____11_____ month __5TH_____ day



Student's signature

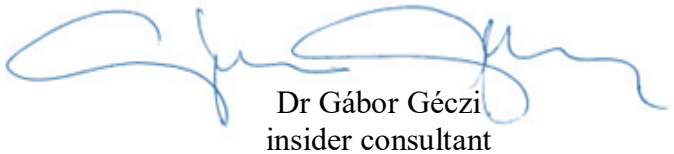
CONSULTANCY STATEMENT

Dr. Gábor Géczi (name) (Neptun code:I5AYJ4) as a consultant, I declare that I have reviewed the final thesis/thesis/dissertation/portfolio[1] and that I have informed the student of the requirements, legal and ethical rules for the correct handling of literary sources.

I recommend / do not recommend[2] the thesis / dissertation / portfolio to be defended in the final examination.

The thesis contains a state or official secret: yes no

Date: _____2024_____ year _____11____ month ___5____ day



Dr Gábor Géczi
insider consultant