Article

Not peer-reviewed version

Assessment of Particulate Matter (PM2.5) and Air Quality Index (AQI) in Eight Locations of Lagos State, Nigeria

Domenico Suriano * , Akinyinka Akinnusotu , Francis Olawale Abulude , Samuel Dare Oluwagbayide

Posted Date: 25 September 2024

doi: 10.20944/preprints202409.1991.v1

Keywords: particulate matter; PM2.5; Air Quality Index; AQI; Lagos State; AirQo; Air pollution; Health risks; air quality

Article

Assessment of Particulate Matter (PM2.5) and Air Quality Index (AQI) in Eight Locations of Lagos State, Nigeria

Domenico Suriano [1,*], AkinyinkaAkinnusotu [2], Francis Olawale Abulude [3] and Samuel Dare Oluwagbayide [4]

[1] ENEA—Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Brindisi Research Center, SS. 7 Appia, km 706, 72100 Brindisi, Italy
[2] University of Medical Sciences, Department of Science Laboratory Technology, Ondo, Nigeria
[3] Science and Education Development Institute, Akure, Ondo State, Nigeria
[4] Department of Agricultural and Bio-Environmental Engineering, Federal Polytechnic, Ilaro, Ogun State, Nigeria
* Correspondence: domenico.suriano@enea.it; Tel. +39-0831201490

Abstract: Air pollution, particularly fine particulate matter (PM2.5), poses a significant threat to public health, especially in rapidly urbanizing areas like Lagos State. Despite the severity of the issue, there is a lack of comprehensive data on PM2.5 levels and the Air Quality Index (AQI) in Lagos. This study leverages data from AirQo, an innovative air quality monitoring network using low-cost sensors, to provide a detailed assessment of PM2.5 concentrations and AQI across eight locations in Lagos State, Nigeria. This approach offers real-time, continuous monitoring, filling a critical data gap in the region's air quality management efforts. This study uses AirQo data to assess the concentration levels and spatial distribution of PM2.5 and AQI across the selected eight locations. Data on PM2.5 concentrations were obtained from AirQo sensors deployed across the eight strategic locations in Lagos. The spatial distribution of PM2.5 levels and AQI were analyzed, and the results were compared with national and international air quality standards. The findings revealed that PM2.5 levels (minimum – 6.28 µg/m3 (Ikeja) and maximum - 204.68 µg/m3 (Banana Island) in many areas of Lagos exceed annual WHO and national air quality guidelines, indicating significant health risks. The spatial analysis identified pollution hotspots, particularly in densely populated and industrial regions. The data suggested vehicular emissions and industrial activities as major contributors to high PM2.5 levels. This study underscores the severe air quality issues in Lagos State, emphasizing the need for immediate and targeted interventions to mitigate PM2.5 pollution. The use of AirQo sensors proved effective in providing accurate and timely data for air quality assessment. It is recommended that Lagos State implements stricter emission controls, promotes cleaner technologies, and enhances public transportation systems to reduce traffic-related pollution. Additionally, expanding the air quality monitoring network and incorporating more environmental data will provide a more comprehensive understanding of air pollution impacts, thereby facilitating better policy and public health decisions.

Keywords: particulate matter; PM2.5; Air Quality Index; AQI; Lagos State; AirQo; Air pollution; Health risks; air quality

---

1. Introduction

Air pollution is a global pervasive environmental health issue with significant implications for public health, particularly in urban areas. Particulate matter (PM), especially fine particles with a diameter of less than 2.5 micrometers (PM2.5), poses serious health risks as it can penetrate deep into the respiratory system and enter the bloodstream, leading to cardiovascular, respiratory, and other

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 September 2024 doi:10.20944/preprints202409.1991.v1

systemic health problems (WHO, 2021 [1]; Zhang et al., 2022 [2]; Li et al., 2023 [3]; Abbah et al., 2024 [4]; Bhattarai et al., 2024 [5]). There are several associated problems regarding air quality problems in low-income, low GDP, under developed and developing countries across the Africa regions. Notable factors that contributed to these poor air quality - both indoor and outdoor include industrialization and urbanization activities – ranging from road construction, factories effluents and wastes, over population in some cities such as Lagos, occasion natural disaster, poor waste and environmental management policies, low standard of living of the citizens, expensive or non-readily available and affordable waste management facilities across cities, very poor funding of concern enforcing agencies, poor or no funding of research project in line with air quality, instability of government ideology, urban development, including climate change, etc. All these factors summed together contributed in one way or the other to the poor outdoor and indoor air quality in Africa but not limited to Africa counties alone. It is important to note that air pollution can occur as a result of natural and or artificial reasons but more to the human factor (anthropogenic). Some of these air pollutants include particulate matter (PM 2.5 and PM 10.0), various gases such as oxygen (O2), carbon monoxide (CO), carbon dioxide (CO2), oxides nitrogen (NOx), sulphur dioxide (SO2), and ozone (O3), volatile organic compounds, etc., persistent organic pollutants (POPs) in the atmosphere (PAHs, OCPs, PCBs, etc.), and so on (Lee et al., 2022 [6]; Abulude et al., 2022 [7,8]; Mamontova and Mamontov, 2022 [9,10]; Akinnusotu et al., 2023 [11]; Soleimani et al., 2024 [12]; Alghamdi et al., 2024 [13]). Nigeria is one of the countries in Africa with the highest population density with several urban cities across the six geopolitical zones. One of such cities is Lagos with rapid urbanization, industrial activities, and high traffic density contributing significantly to air pollution, making the assessment of PM2.5 levels and the Air Quality Index (AQI) crucial for effective air quality management and public health protection (Zaib et al., 2022 [14]; Akinnusotu et al., 2023 [11]; Matandirotya, 2023 [15]).

The assessment of PM2.5 concentrations involves a combination of methods. Gravimetric analysis, a traditional approach, collects air samples on filters and measures the particulate mass by weighing these filters before and after sampling (USEPA, 2020 [16]). Additionally, advancements in technology have facilitated the use of low-cost sensors for real-time monitoring, providing continuous and immediate data on PM2.5 levels and other variables. These sensors are calibrated against standard reference instruments to ensure accuracy and reliability (Holstius et al.,2014 [17]; Rawat and Kumar, 2023 [18]; Suriano and Prato, 2023 [19]; Bhattarai et al., 2024 [5]). The Air Quality Index (AQI) is a standardized tool that communicates the current or forecasted air quality and its potential health effects. The AQI ranges are divided into categories that correspond to different levels of health concern. These health concerns are classified according to AQI six categories. These categories are color-coded so that they can be easily understood with value ranges. The categories are: good - green (0-50), moderate - yellow (51-100), unhealthy for sensitive groups - orange (101-150), unhealthy – red (151-200), very unhealthy – purple (201-300), and hazardous – maroon (301-500) (Akinnusotu et al., 2023 [11]; Almaliki et al., 2023 [20]; Horn and Dasgupta, 2023 [21]; Ravindra et al., 2024 [22]; https://www.epa.gov/outdoor-air-quality-data/air-data-basic-information).

Particulate matter (PM2.5) is a critical component of the AQI due to its severe health impacts. Prolonged exposure to high levels of PM2.5can cause chronic respiratory and cardiovascular diseases, decreased lung function, and increased mortality rates (Bousiotis et al., 2023 [23]; Deo et al., 2024 [24]). Lagos was one of the megacities reported to be with the highest PM2.5according to a World Bank project (Figure 1) (Croitoru et al., 2020 [25]).This has several implications on all levels or categories of human - children, women, and men. A research study conducted by Kalisa et al., (2023) [26] reported negative implications on children arising from the pollution of the atmosphere by particulate matter (WHO, 2016 [27]; WHO, 2022 [28]). The pollution of the atmosphere by either fine particles or other atmospheric pollutants will cause poor outdoor and indoor air quality and the deterioration of buildings and other facilities depending on the quality and structures of such facilities (Bousiotis et al., 2023 [23]; Okello et al., 2023 [29]; Deo et al., 2024 [24]; Bhattarai et al., 2024 [5]).

AirQo is an initiative by Makerere University in Uganda aimed at improving air quality monitoring across Africa. Utilizing a network of low-cost sensors, AirQo provides real-time data on

 doi:10.20944/preprints202409.1991.v

air pollution, with a particular focus on PM2.5 concentrations. This project supports the development of informed policies and raises public awareness about air quality issues (AirQo, accessed 2024; Bainomugisha et al., 2023). Previous studies on PM2.5 in Lagos have highlighted the severe air quality issues facing the city. Awopeju et al., (2017) [30] documented elevated levels of PM2.5 across various parts of Lagos, attributing these high concentrations to vehicular emissions and industrial activities. Similarly, Akinfolarin et al., (2017) [31] found that PM2.5 levels frequently exceed WHO's recommended limits, underscoring the significant health risks posed to residents. A study conducted by Iroegbulem et al., (2023) [32] on some air quality parameters such as total particulate matter, CO, and CO2 reported that air quality was poor throughout the year of study in Lagos when compared with WHO limit including a world bank research project on air quality carried out by Croitoru et al.,(2020) in Lagos.

The significance of this study lies in its potential to inform public health strategies and policy-making in Lagos State. By providing comprehensive data on PM2.5 levels and AQI across multiple locations, this study aims to identify pollution hotspots and temporal patterns, thereby enabling targeted interventions to mitigate health risks and improve air quality (WHO, 2016; WHO, 2022). Lagos State faces significant air pollution challenges due to its dense population, high traffic volumes, and extensive industrial activities. Despite the severity of these issues, there is limited data on the spatial distribution and levels of PM2.5 and AQI, hindering effective air quality management and mitigation efforts. This study seeks to address this critical data gap by assessing PM2.5 concentrations and AQI in eight locations across Lagos State. Assessing PM2.5 levels and AQI are crucial for several reasons. It helps understand the extent of air pollution and its health impacts, supports the formulation of local air quality standards, and aids in evaluating the effectiveness of current pollution control measures (Kumar, Gulia et al., 2015 [33]). Moreover, it raises public awareness and encourages community action towards improving air quality. One of the biggest environmental health dangers around the globe is air pollution hence the need for adequate monitoring. In 2019, 99% of people on Earth lived in areas where the WHO's recommended air quality criteria were unmet. Ambient (outside) air pollution is predicted to have contributed to 4.2 million premature deaths globally in 2019. The effects of ambient and residential air pollution are linked to 6.7 million premature deaths annually (WHO, 2022).

This study acknowledges several limitations. The accuracy of low-cost sensors, although improving, can vary compared to standard monitoring equipment. Additionally, the study's spatial coverage is limited to eight locations, which may not fully represent the entire state's air quality. Seasonal variations and specific local factors could also influence PM2.5 levels and AQI, potentially affecting the comprehensiveness of the study. The aim of this study is to utilize data from AirQo to assess the concentration levels and spatial distribution of PM2.5 and AQI across the selected eight locations in Lagos State, Nigeria. The objectives are to:

1. Analyze PM2.5 concentrations in eight locations in Lagos State using data obtained from AirQo sensors,
2. Evaluate the spatial distribution of PM2.5 levels and AQI across these locations,
3. Compare the measured PM2.5 levels and AQI with national and international air quality standards,
4. Provide recommendations for improving air quality based on the findings from the AirQo data.

2. Materials and Methods

2.1. Description of the Locations

Lagos State, located in the southwestern region of Nigeria, is the most populous state in the country and the economic hub of West Africa. It spans an area of approximately 3,577 square kilometers and is home to over 20 million people. The state is characterized by a diverse economy that includes industries such as finance, manufacturing, oil and gas, and telecommunications (Lagos State Government, https://lagosstate.gov.ng/about-lagos/). Lagos State is divided into five administrative divisions, which are further subdivided into 20 local government areas. The state's rapid urbanization and economic activities have made it a critical area for studying air quality and

 doi:10.20944/preprints202409.1991.v1

environmental impacts (Akinjare et al., 2011 [34]; Power et al., 2023 [35]; Aladejare et al., 2023 [36]; Thanvisitthpon et al., 2024 [37]).

Akoka (6.5261oN, 3.3921o E) is a residential area located in the Yaba district of Lagos (Table 1). It is known for housing the University of Lagos, one of Nigeria's leading academic institutions. The presence of the university contributes to a relatively high population density and significant vehicular traffic in the area. Akoka's air quality is influenced by both residential and educational activities (Fadeyi, 2011 [38]). Banana Island (6.4667o N, 3.4500o E) is an affluent neighborhood in Lagos, known for its exclusivity and luxury real estate. Situated off the coast of Ikoyi, Banana Island hosts high-end residential and commercial properties. The area is characterized by lower population density and controlled environmental standards, which generally result in better air quality compared to more industrial or densely populated areas (Thisday, 2020 [39]).

Egbeda (6.59160 N, 3.29110 E) is a bustling suburb located in the Alimosho Local Government Area of Lagos. It is a densely populated area with a mix of residential, commercial, and industrial activities. The high traffic congestion and numerous small-scale industries contribute to significant air pollution in Egbeda (Olajire, 2014 [40]). Ikeja (6.6018oN, 3.3515oE), the capital of Lagos State, is a major commercial and administrative center. It is home to the Murtala Muhammed International Airport, numerous businesses, and government offices. Ikeja experiences heavy traffic congestion and industrial emissions, which significantly impact its air quality (Abdul-Wahabet al., 2011 [41]).

Ikotun (6.5631o N, 3.2506o E) is a residential and commercial area in the Alimosho local government area. It is known for its busy markets and high population density. The air quality in Ikotun is affected by traffic emissions and the activities of numerous small businesses and vendors (Awokola, 2017 [42]). Lagos Island (6.4549o N, 3.4246o E) is the historic and commercial heart of Lagos State. It is the headquarter of many of the financial institutions, corporate headquarters, and major markets, such as Balogun international Market. The high concentration of commercial activities and traffic congestion contribute to significant air pollution on Lagos Island (Adeniji, 2020 [43]).

Lagos Port, also known as Apapa Port (6.4413o N, 3.3799o E), is the largest and busiest port in Nigeria. It handles a significant portion of the country's maritime trade, leading to heavy truck traffic and industrial activities in the area (Table 1). The port's operations are a major source of air pollution, including emissions from ships, trucks, and industrial activities (Ezeh, 2016 [44]).The Lagos State Property Development Corporation (LSPDC - 6.5576o N, 3.3653o E) is involved in real estate development across Lagos State. LSPDC-managed estates and developments are spread throughout the city, providing housing and commercial spaces. These developments vary in terms of population density and environmental impact, but they generally aim to implement sustainable building practices (Lagos State Government, n.d.).

Table 1. The coordinates and the activities within the monitored locations.

Station ID	Location	Latitude	Longitude	Region	Activities/Land Use
1	Akoka	6.5261°N	3.3921°E	Southwest	Residential area. High population density and significant vehicular traffic
2	Banana Island	6.4667° N	3.4500° E	Southwest	Residential and commercial properties
3	Egbeda	6.5916° N	3.2911° E	Southwest	Residential, commercial, and industrial activities
4	Ikeja	6.6018°N	3.3515°E	Southwest	Commercial and administrative center
5	Ikotun	6.5631° N	3.2506° E	Southwest	Busy markets and high population density

6	Lagos Island	6.4549° N	3.4246° E	Southwest	Commercial activities and traffic congestion
7	Lagos Port	6.4413° N	3.3799° E	Southwest	Emissions from ships, trucks, port and industrial activities
8	LSPDC	6.5576° N	3.3653° E	Southwest	Housing and commercial activities. High population density

The methods employed in this study for assessing PM2.5 concentrations and Air Quality Index (AQI) in eight locations across Lagos State, Nigeria, primarily involved the utilization of data from AirQo sensors. These sensors provide real-time, continuous monitoring of air quality, offering a robust and cost-effective means of gathering data on particulate matter. To perform this study, the steps summarized in the following subsections were undertaken.

2.2. Sensor Deployment and Data Collection

AirQo sensors were strategically deployed across eight locations in Lagos State, selected based on factors such as population density, traffic volume, and proximity to industrial activities. These sensors continuously monitored PM2.5 levels, capturing data at regular intervals for three months (January to March 2024). AirQo's sensors are known for their reliability and have been calibrated against reference-grade monitoring equipment to ensure accuracy (Bainomugisha et al., 2023 [45]).

2.3. Data Validation and Calibration

To ensure the accuracy and reliability of the data, the AirQo sensors underwent rigorous calibration procedures. The calibration involved comparing the sensor readings with those from standard reference monitors in controlled settings. This process helped to adjust the sensor outputs, ensuring that they provide accurate PM2.5 measurements (Holstius et al., 2014; Zafra-Pérez et al., 2024 [46]).

2.4. Spatial and Temporal Analysis

The collected data were analyzed to understand the spatial distribution and temporal variations of PM2.5 levels across the eight locations. Geographic Information System (GIS) tools were used to map the spatial distribution of PM2.5 concentrations, highlighting areas with high pollution levels (Hossain et al., 2023 [47]). Temporal analysis involved examining the variations in PM2.5 levels over different times of the day and seasons, identifying patterns and trends (Li et al., 2016 [48]).

2.5. Air Quality Index (AQI) Calculation

The AQI for each location was calculated using the PM2.5 concentration data (https://www.airnow.gov/aqi/aqi-calculator/). The AQI is a standardized index that converts PM2.5 levels into a single number representing the overall air quality, categorized into different health impact levels. The calculation followed the guidelines set by the U.S. Environmental Protection Agency (EPA, 2020), which provide a clear framework for interpreting PM2.5 data in terms of health risks.

2.6. Data Analysis and Interpretation

The data analysis included statistical methods using Excel and Minitab software to determine the basic distributions and contributions. Comparative analysis was conducted against national and international air quality standards, including WHO (WHO, 2021) and NESREA (NESREA, 2021 [49]) guidelines, to evaluate the severity of pollution in Lagos.3.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 September 2024 doi:10.20944/preprints202409.1991.v

Results

Table 2 depicts the levels across various locations with mean values and standard deviations indicating both the average pollution levels and their variability. The high coefficient of variation in percent (61.90-104.50) shows wide variability, which are confirmed by the minimum and maximum values. Akoka (65.51 ± 47.13μg/m3) and Banana (46.51 ± 48.56 μg/m3) show the highest pollution levels and variability, suggesting severe and fluctuating pollution, likely due to intermittent industrial activities and traffic. Egbeda (39.27 ± 28.68μg/m3) and Ikotun (36.84 ± 28.01μg/m3) have moderate pollution levels with considerable variability, indicating a mix of constant and sporadic pollution sources. Also, Ikeja (28.26 ± 21.35μg/m3) and Lagos Island (35.04 ± 22.99μg/m3) show lower pollution levels with more stability, suggesting effective pollution control and fewer extreme pollution events, and Lagos port (19.12 ± 11.84μg/m3) and LSPDC (15.63 ± 9.11μg/m3) exhibit the lowest pollution levels and variability, indicating successful pollution management and a cleaner environment. The implications of these results include: high and variable pollution significant health risks, including respiratory and cardiovascular diseases, degradation of air and water quality, impacting biodiversity and soil health, increased healthcare expenses, reduced productivity, and lower property values which may be tagged economic consequences of high pollution. On this premise, there is a need for stricter pollution control regulations, effective monitoring, enforcement of policies, particularly in high-pollution areas, and enhancing community awareness and promoting green initiatives to reducing the pollution levels.

Table 2. Basic Description of the data in the different locations.

Parameter	Akoka	Banana Island	Egbeda	Ikeja	Ikotun	Lagos Island	Lagos Port	LSPDC
Mean	65.61	46.51	39.27	28.26	36.84	35.04	19.12	15.63
SE Mean	1.19	1.63	0.78	0.62	0.69	0.82	0.31	0.42
Stdev	47.13	48.56	28.68	21.35	28.01	22.99	11.84	9.11
CoefVar	71.84	104.40	73.02	75.55	76.02	94.18	61.90	58.23
Minimum	7.39	7.15	6.97	6.28	6.37	6.51	6.46	6.74
Q1	20.86	14.97	15.39	12.51	14.27	12.57	12.76	10.08
Median	53.62	22.54	31.42	20.01	28.21	21.10	15.42	13.47
Q3	114.41	56.03	55.71	36.42	52.64	46.61	200.78	16.92
Maximum	196.77	204.68	144.05	111.48	149.17	178.81	115.21	65.14
IQR	93.54	41.05	40.32	23.91	38.38	34.03	8.02	6.84
Skewness	0.47	1.50	1.10	1.24	1.11	1.74	2.53	2.59
Kurtosis	-1.12	0.85	0.56	0.55s	0.52	2.85	8.35	8.28

Figure 2 shows the air quality results concerning PM2.5 levels in Lagos. Akoka has the worst air quality, exceeding (annual) WHO (15 μg/m3) standards. Banana Island, Egbeda, Ikeja, and Ikotun also surpass WHO recommendations but fall within the national limit of NESREA (150 μg/m3). Only LSPDC meets both safety standards. These results highlight potential health risks for residents due to chronic exposure to PM2.5. Stricter regulations aligned with WHO guidelines and targeted interventions in high-pollution areas like Akoka are crucial. Continuous air quality monitoring is necessary to track progress in improving Lagos' air quality. The percentage contribution of PM2.5 across the eight locations studied can be expressed in this order: Akoka>Banana>Egbeda>Ikotun>Lagos Island>Ikeja>Lagos Port>LSPDC.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 September 2024 doi:10.20944/preprints202409.1991.v1

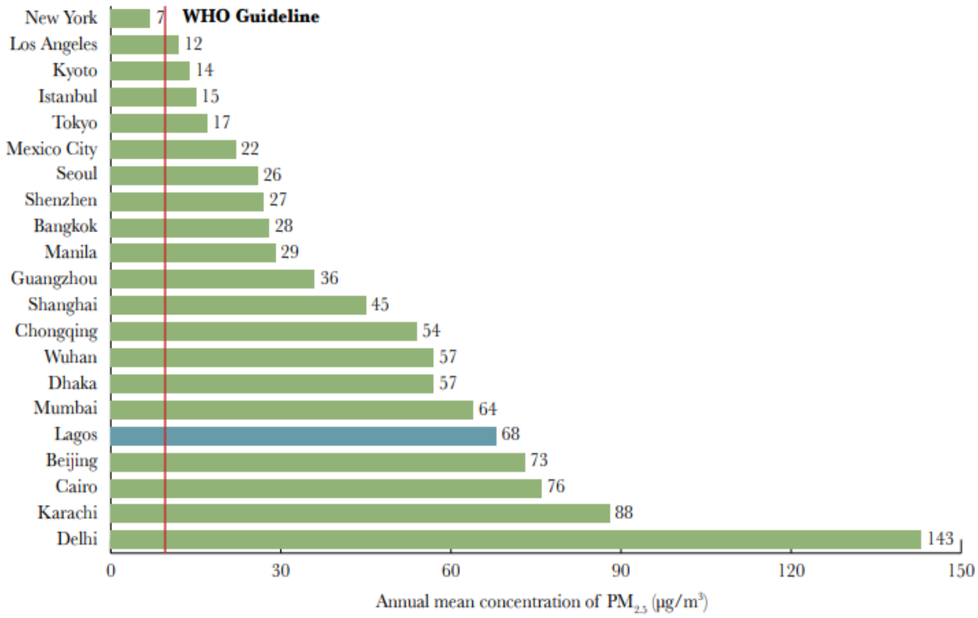

Figure 1. Annual mean concentration of PM 2.5 in some megacities across the globe with WHO limit. Source: Croitoru et al.,(2020).

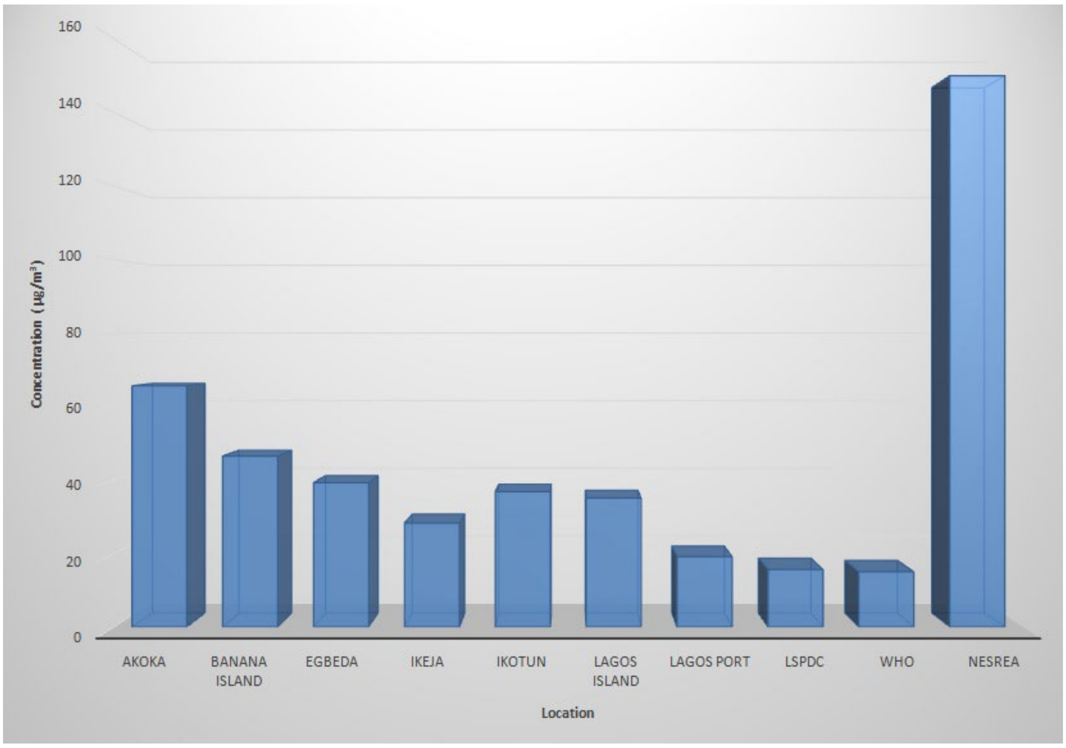

Figure 2. The comparisons of the PM values of each location with the national and international safety standards.

Figures 3 and 4 show the percentage contributions and spatial distributions of PM2.5 vary significantly across the eight locations used in the study. Akoka has the highest contribution (23%), indicating that within specified locations, PM2.5 contributed most of air pollution in that area. Other locations like Banana Island (16%) and Egbeda (14%) also have substantial contributions. While the specific health impacts can vary depending on factors like age, pre-existing health conditions, and duration of exposure, here are some general health concerns associated with PM2.5: Exposure to

PM2.5 can irritate the lungs, leading to respiratory problems like asthma, bronchitis, and difficulty breathing (WHO, 2021; Zhang et al., 2022; Abbah et al., 2024). This is a concern for all locations in Lagos with PM2.5 contributions above 0%. PM2.5 can increase the risk of heart disease by affecting the cardiovascular system. All locations with PM2.5 contributions in Lagos should be aware of this potential risk. Long-term exposure to PM2.5 is linked to an increased risk of lung cancer. Locations with higher contributions, like Akoka (23%), Banana Island (16%), and Egbeda (14%), have a greater potential risk. PM2.5 is just one of many air pollutants. The combined effects of various pollutants can be more harmful than individual exposures. Children, older adults, and people with pre-existing health conditions are more susceptible to the negative health effects of PM2.5 (Zhang et al., 2022; Abbah et al., 2024).

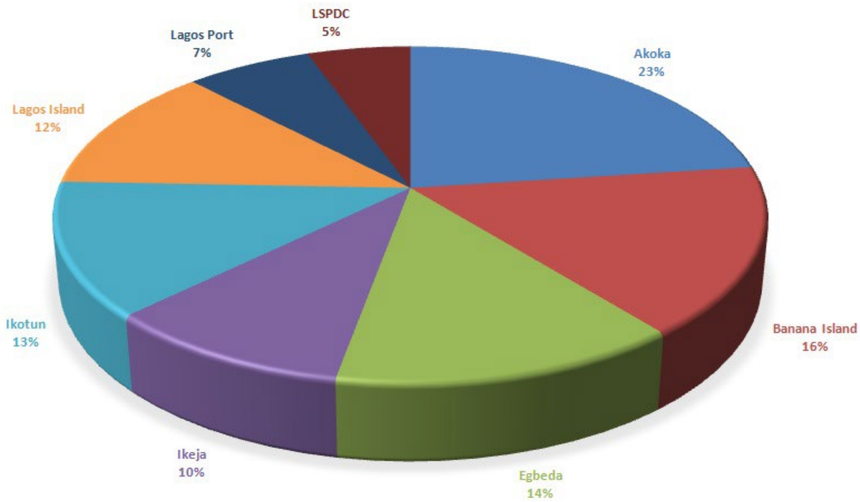

Figure 3. The contributions of PM2.5 in each location of the various locations.

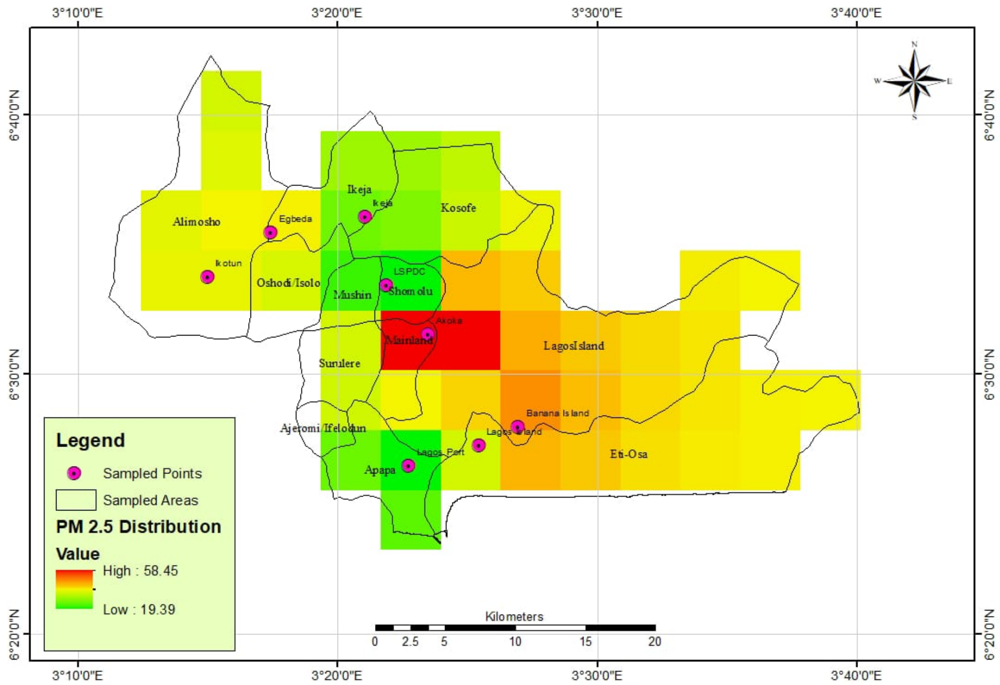

Figure 4. The distributions of PM2.5 in each location of the various locations.

Table 3 shows the comparisons between our study and previous studies on PM2.5 air pollutions. The data provided reveals significant variations in PM2.5 concentrations across different Nigerian

 doi:10.20944/preprints202409.1991.v

cities. PM2.5 levels range from a low of 4.22 µg/m3 in Gwagwalada according to Ezeonyejiaku et al., (2022) [50] to a high of 236.6 µg/m3 in Ile-Ifeby Abulude et al.,(2021) [51], showcasing a substantial difference in air quality across these locations. Lagos falls (15.63 – 65.61 µg/m3) within the range observed in other cities. While some areas in Lagos have concerning levels, others seem comparable to cities like Yenagoa (Abulude et al., 2022 [52]) and Abuja (Lala et al., 2023 [53]). Owerri, Ezihe village (Nicholas and Ukoha, 2023 [54]), Ile-Ife (Abulude et al., 2021), Port Harcourt (Akinfolarin et al., 2017), and Nsukka (Osimobi et al., 2019 [55]) have particularly concerning PM2.5 levels, consistently exceeding WHO guidelines (15µg/m3).Several factors can contribute to these variations which include, highly urbanized and industrialized cities like Lagos, Kano, and Port Harcourt have higher PM2.5 emissions from vehicles, factories, and power plants, cities with heavy traffic congestion, like Lagos, experience increased PM2.5 emissions from vehicle exhaust, open waste burning practices could have significantly elevated PM2.5 levels, particularly in densely populated areas, the wind patterns and weather conditions could have affected how PM2.5 disperses in the atmosphere inGwagwalada including industrial effluents. Lastly, variations in data collection methodologies and timeframes across different studies could have contributed to the discrepancies.

The high PM2.5 levels in several cities pose significant health risks to residents, including respiratory problems, heart disease, and lung cancer. There is the need to reduce the PM2.5 pollution by implementing stricter regulations on industries and vehicles can significantly reduce PM2.5 emissions, transitioning to cleaner energy sources like solar and wind power can reduce reliance on fossil fuels and improve air quality, phasing out open waste burning and implementing efficient waste collection systems are crucial, educating the public about the health risks of PM2.5 and promoting protective measures like wearing masks can empower residents, and consistent monitoring across cities is essential to track progress and identify areas needing the most attention.

Table 3. Analyzing and contrasting our study's findings with earlier research from different Nigerian cities.

Location	$PM_{2.5}$ (µg/m^3)	AQI	References
Lagos, Nigeria	15.63 – 65.61	63 – 157	Our study
Abuja, Nigeria	30.79 - 105.43	205 - 702.86	Lala *et al.*, 2023
Owerri and Ezihe village, Nigeria	99.30-124.70	-	Nicholas and Ukoha, 2023
Yenagoa, Nigeria	11.1-26.2	46-80	Abulude *et al.*, 2022
Ile-Ife, Nigeria	9.1 - 236.6	128	Abulude *et al.*, 2021a
Abuja, Nigeria	18 – 95	4-42	Kanee *et al.*, 2020 [56]
Ikeja, Nigeria	20 - 123	70 – 188	Abulude *et al.*, 2021b
Port-Harcourt, Nigeria	>200	-	Akinfolarin *et al.*, 2017
Nsukka, Nigeria	57-106	50.00-99.87	Osimobi *et al.*, 2019
Kano, Nigeria	22-110	19.62- 106.11	Meseke *et al.*, 2022 [57]
Gwagwalada, Nigeria	4-4.22	17	**Ezeonyejiaku *et al.*, 2022**
Ilorin, Nigeria	44.36-60.70	114-154	Salami *et al.*, 2020 [58]

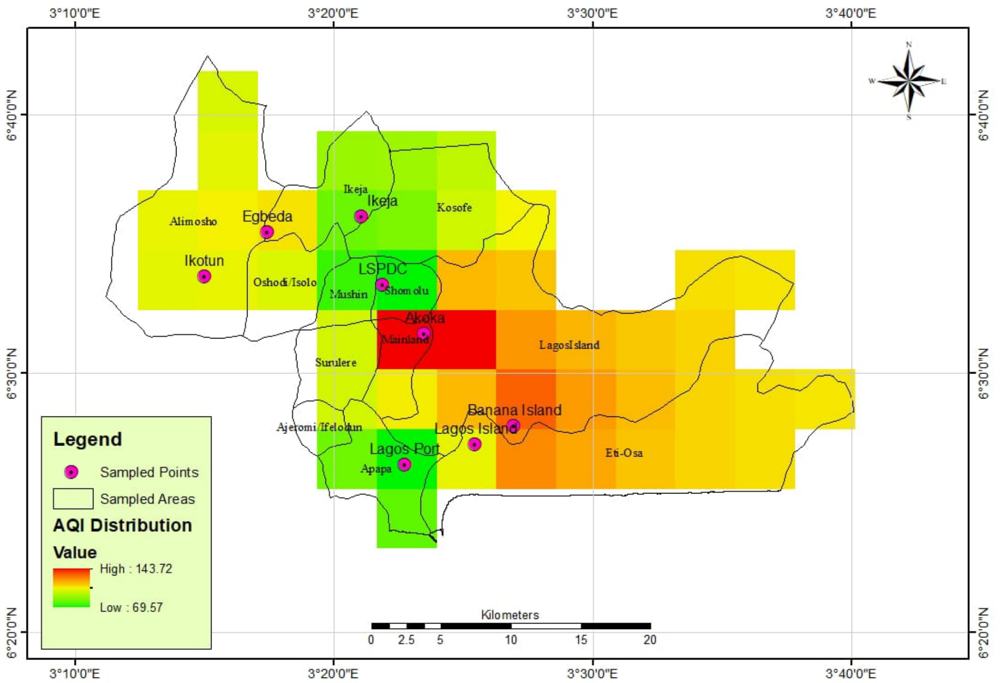

Figure 5. The AQI distribution of PM2.5 in the different locations.

Table 4 presents a concerning picture of air quality in various locations across Lagos. All locations, except LSPDC, have PM2.5 concentrations exceeding the WHO guideline. Akoka has the highest level (65.61 µg/m3), followed by Banana Island, Egbeda, Ikotun, and Lagos Island. These areas fall under the "Unhealthy for Sensitive Groups" AQI category (101-150), indicating a risk for people with respiratory or heart conditions, the elderly, and children. Ikeja, Lagos Port, and LSPDC fall under the "Moderate" AQI category (51-100), suggesting less risk but still with potential health effects for sensitive individuals during prolonged exertion. Table 4 also highlights the increased risk of respiratory problems, heart disease aggravation, and premature mortality for sensitive groups across most locations. Even in "Moderate" AQI areas, unusually sensitive people might experience health effects during extended physical activity.

The widespread presence of PM2.5 above safe levels poses a significant public health threat to Lagos residents, especially vulnerable populations. Urgent action is required to reduce PM2.5emissions and improve air quality. This could involve, implementing stricter emission controls for vehicles and industries, investing in cleaner energy sources like solar and wind power, phasing out open waste burning and promoting efficient waste collection, educating the public about the risks of PM2.5 and promoting protective measures like wearing masks and Akoka, with the highest PM2.5 level, needs immediate investigation to identify pollution sources and implement targeted interventions.

Table 4. The PM Concentration, Air Quality Index, AQI Category, Sensitive Groups, and Health effects and Cautionary Statements.

Location	$PM_{2.5}$ Concentration	AQI	AQI Category	Sensitive Groups	Health Effects Statements	Cautionary Statements
Akoka	65.61	157	Unhealthy	People with respiratory or heart disease, the elderly	Elevated respiratory effects in the general population; increased	Extended physical activity should be limited for everyone else,

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 September 2024 doi:10.20944/preprints202409.1991.v1

				and children are the groups most at risk	exacerbation of heart or lung disease and early mortality in individuals with cardiopulmonary disease and the elderly.	but it should be avoided by those with heart or respiratory conditions, the elderly, and the children.
Banana Island	46.91	129	Unhealthy for sensitive group	People with respiratory or heart disease, the elderly and children are the groups most at risk.	An increased risk of respiratory symptoms in susceptible people, worsening heart or lung illness, and early death in older people and those with cardiopulmonary disease.	Prolonged exercise should be limited in the elderly, children, and those with heart or pulmonary conditions.
Egbeda	39.37	110	Unhealthy for sensitive group	People with respiratory or heart disease, the elderly and children are the groups most at risk.	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly.	People with respiratory or heart disease, the elderly and children should limit prolonged exertion.
Ikeja	28.26	86	Moderate	People with respiratory or heart disease, the elderly and children are the groups most at risk.	Unusually sensitive people should consider reducing prolonged or heavy exertion	Unusually sensitive people should consider reducing prolonged or heavy exertion

Ikotun	36.84	103	Unhealthy for sensitive group	People with respiratory or heart disease, the elderly and children are the groups most at risk	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly.	People with respiratory or heart disease, the elderly and children should limit prolonged exertion
Lagos Port	19.12	69	Moderate	People with respiratory or heart disease, the elderly and children are the groups most at risk.	Unusually sensitive people should consider reducing prolonged or heavy exertion.	Unusually sensitive people should consider reducing prolonged or heavy exertion.
LSPDC	15.64	63	Moderate	People with respiratory or heart disease, the elderly and children are the groups most at risk.	Unusually sensitive people should consider reducing prolonged or heavy exertion.	Unusually sensitive people should consider reducing prolonged or heavy exertion.
Lagos Island	35.04	103	Unhealthy for sensitive group	People with respiratory or heart disease, the elderly and children are the groups most at risk	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmona	People with respiratory or heart disease, the elderly and children should limit prolonged exertion

 doi:10.20944/preprints202409.1991.v1

	ry disease and the elderly.	

4. Conclusions

This study provides a comprehensive assessment of PM2.5 concentrations and AQI across eight locations in Lagos State, Nigeria, utilizing data obtained from AirQo sensors. The findings underscore the critical issue of air pollution in Lagos, revealing that PM2.5 levels in many areas exceed both national and international air quality standards. This indicates a significant risk to public health, particularly in densely populated and industrial regions of the state. The spatial analysis of PM2.5 and AQI highlights specific pollution hotspots, which can be attributed to factors such as vehicular emissions, industrial activities, and urban development. These insights are crucial for policymakers and public health officials in Lagos State to develop targeted strategies to mitigate air pollution and protect public health.

This study also emphasizes the importance of continuous and real-time air quality monitoring. The use of AirQo array of sensors has proven effective in providing accurate and timely data, which is essential for informed decision-making and public awareness.

Despite its limitations, such as the potential variability in sensor accuracy and the limited spatial coverage, this study contributes valuable information to the understanding of air quality in Lagos State. Future research should aim to expand the monitoring network and incorporate additional environmental and health data to provide a more comprehensive picture of the impacts of air pollution.

In all, addressing the high levels of PM2.5 in Lagos State is imperative for improving public health outcomes and ensuring a sustainable urban environment. The findings from this study serve as a crucial step towards achieving these goals, highlighting the need for collaborative efforts between government agencies, research institutions, and the community to combat air pollution effectively.

5. Recommendations

Based on the findings from the assessment of PM2.5 and AQI in eight locations across Lagos State, the following recommendations are proposed to address the air quality issues and mitigate health risks:

Enforce stricter emissions standards for vehicles, promote regular vehicle maintenance, and encourage the use of cleaner fuels and electric vehicles. Implement stringent regulations for industrial emissions, ensure regular monitoring, and mandate the adoption of cleaner production technologies. Develop and expand public transportation networks to reduce the reliance on private vehicles. This includes investing in buses, trains, and other mass transit systems with the best available practices (bap). Promote the use of non-motorized transport, such as cycling and walking, by creating dedicated lanes and safe pathways.

Conduct public awareness campaigns to educate residents about the health impacts of air pollution and ways to reduce personal exposure. Encourage community involvement in air quality monitoring and pollution reduction initiatives. Increase the number of monitoring stations across Lagos State to provide more comprehensive coverage and capture local variations in air quality. Utilize advanced monitoring technologies, such as satellite observations and mobile monitoring units, to supplement ground-based sensors. Collaborate with local governments, communities, and stakeholders to develop tailored air quality action plans that address specific pollution sources and local conditions. Set clear targets and timelines for reducing PM2.5 levels and improving overall air quality.

Support ongoing research on air pollution sources, dispersion patterns, and health impacts to inform policy decisions. Facilitate the sharing of air quality data among government agencies, research institutions, and the public to enhance transparency and collective action. Integrate green infrastructure, such as parks, green roofs, and urban forests, into city planning to enhance air quality

 doi:10.20944/preprints202409.1991.v

and provide additional environmental benefits. Implement zoning regulations that separate industrial areas from residential neighborhoods to minimize exposure to pollutants.

Lastly, foster collaboration between various government agencies, including environmental, health, transportation, and urban planning departments, to ensure integrated and cohesive air quality management strategies. Align air quality improvement efforts with broader environmental and public health policies to maximize impact and resource efficiency.

Author Contributions: Conceptualization, AA, S.D.A., and F.O.A.; methodology, F.O.A.; software, A.A. and F.O.A; validation, A.A.; formal analysis, A.A.; investigation, F.O.A.; resources, F.O.A.; data curation, A.A.; writing—original draft preparation, F.O.A.; writing - review and editing, A.A, S.D.A., D.S. and F.O.A.; visualization, A.A.; project administration, F.O.A.A.A., and S.D.A. Authors have read and agreed to the published version of the manuscript

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are publicly unavailable due to privacy.

Acknowledgments: The authors are grateful to AirQo, Makerere University, Uganda for the permission to use their data for the publication of the article. Again, thanks to the reviewers who assisted to improve the quality of this work.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. World Health Organization (WHO). (2021). WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Retrieved from https://apps.who.int/iris/handle/10665/345329
2. Zhang, X., Han, L., Wei, H., Tan, X., Zhou, W., Li, W., andQian, Y. (2022). Linking urbanization and air quality together: A review and a perspective on the future sustainable urban development. Journal of Cleaner Production, 346, 130988.
3. Li, H., Huang, W., Qian, Y., and Klemeš, J. J. (2023). Air pollution risk assessment related to fossil fuel-driven vehicles in megacities in China by employing the Bayesian network coupled with the Fault Tree method. Journal of Cleaner Production, 383, 135458.
4. Abbah, A. P., Xu, S., and Johannessen, A. (2024). Long-term health effects of outdoor air pollution on asthma and respiratory symptoms among adults in low-and middle-income countries (LMICs): a systematic review and meta-analysis. Frontiers in Environmental Health, 3, 1352786.
5. Bhattarai, H., Tai, A. P. K., Martin, M. V., and Yung, D. H. Y. (2024). Responses of fine particulate matter (PM2.5) air quality to future climate, land use, and emission changes: Insights from modeling across shared socioeconomic pathways, Science of The Total Environment, 174611, https://doi.org/10.1016/j.scitotenv.2024.174611.
6. Lee, T., Go, S., Lee, Y. G., Park, S. S., Park, J., and Koo, J. H. (2022). Temporal variability of surface air pollutants in megacities of South Korea. Frontiers in Environmental Science, 10, 915531.
7. Abulude, F.O., Arifalo, K.M., Kenni, A.M., Akinnusotu, A., Oluwagbayide, S.D., and Sunday, A. (2022). Air Quality Index Levels of Particulate Matter (PM2.5) In Yenogua, Nigeria. JurnalGeografiGea, Volume 22 (2), 95-105.
8. Abulude, F. O., Ratford, V., Ratford, J., Seelam, R., Akinnusotu, A., Olayinka, Y.V., Arifalo, K.M., Adamu, A., and Bello, L.J. (2022). Canāree, a novel low-cost sensor for indoor air quality monitoring: A case study of indoor assessments from Akure, Nigeria. Available at SSRN: https://ssrn.com/abstract=4054652.
9. Mamontova, E. A., and Mamontov, A. A. (2022a). Air monitoring of polychlorinated biphenyls and organochlorine pesticides in Eastern Siberia: Levels, temporal trends, and risk assessment. Atmosphere, 13(12), 1971.
10. Mamontova, E. A., and Mamontov, A. A. (2022b). Spatial and temporal variations of polychlorinated biphenyls and organochlorine pesticides in snow in Eastern Siberia. Atmosphere, 13(12), 2117.
11. Akinnusotu, A.,Abulude, F.O., Adeoya, E.A., Adeyemi, O.O., Jiddah-Kazeem, S.B., Arifalo, K.M., Awogbidin, E. and Sunday, A. (2023). Comprehensive Air Quality Index Assessment Incorporating NO2, PM 2.5, PM10, and O3 in Ondo State, Nigeria. JurnalGeografiGea, 23(2), pp.91-106.

12. Soleimani, A., Atafar, Z., Nemati-Mnsor, S., Ahmed, M., Ahmadi, H., Ravan, P., Miri, M. and Mohammadi, A. (2024). Impact of PAHs Compounds on Air Quality in Maragheh City: Probabilistic Risk Assessment and Source Apportionment. Toxicology Reports, p.101686.
13. Alghamdi, M. A., Hassan, S. K., Shetaya, W. H., Al Sharif, M. Y., Nawab, J., and Khoder, M. I. (2024). Polycyclic aromatic hydrocarbons in indoor mosques dust in Saudi Arabia: Levels, source apportionment, human health and carcinogenic risk assessment for congregators. Science of The Total Environment, 174331.
14. Zaib, S., Lu, J., and Bilal, M. (2022). Spatio-temporal characteristics of air quality index (AQI) over Northwest China. Atmosphere, 13(3), 375.
15. Matandirotya, N. R. (2021). Research trends in the field of ambient air quality monitoring and management in South Africa: A bibliometric review. Environmental Challenges, 5, 100263.
16. U.S. Environmental Protection Agency (EPA). (2020). Particulate Matter (PM) Basics. Retrieved from https://www.epa.gov/pm-pollution/particulate-matter-pm-basics
17. Holstius, D. M., Pillarisetti, A., Smith, K. R., and Seto, E. (2014). Field calibrations of a low-cost aerosol sensor at a regulatory monitoring site in California. Atmospheric Measurement Techniques, 7(4), 1121-1131. https://doi.org/10.5194/amt-7-1121-2014.
18. Rawat, N. and Kumar, P. (2023). Interventions for improving indoor and outdoor air quality in and around schools. Science of the Total Environment, 858, 159813.
19. Suriano, D., and Prato, M. (2023). An investigation on the possible application areas of low-cost PM sensors for air quality monitoring. Sensors, 23(8), 3976.
20. Almaliki, A. H., Derdour, A., and Ali, E. (2023). Air Quality Index (AQI) Prediction in Holy Makkah Based on Machine Learning Methods. Sustainability, 15(17), 13168.
21. Horn, S. A., and Dasgupta, P. K. (2023). The Air Quality Index (AQI) in historical and analytical perspective a tutorial review. Talanta, 125260.
22. Ravindra, K., Singh, V., and Mor, S. (2024). Why we should have a universal air quality index?. Environment International, 187, 108698.
23. Bousiotis, D., Alconcel, L. N. S., Beddows, D. C., Harrison, R. M., and Pope, F. D. (2023). Monitoring and apportioning sources of indoor air quality using low-cost particulate matter sensors. Environment International, 174, 107907.
24. Deo, S.V., Elgudin, Y., Motairek, I., Ho, F., Brook, R.D., Su, J., Fremes, S., deSouza, P., Hahad, O., Rajagopalan, S. and Al-Kindi, S. (2024). Air pollution and adverse cardiovascular events after coronary artery bypass grafting: a 10-year nationwide study. JACC: Advances, 3(2), p.100781.
25. Croitoru, L., Chang, J. C., and Akpokodje, J. (2020). The health cost of ambient air pollution in Lagos. Journal of Environmental Protection, 11(09), 753.
26. Kalisa, E., Kuuire, V., and Adams, M. (2023). Children's exposure to indoor and outdoor black carbon and particulate matter air pollution at school in Rwanda, Central-East Africa. Environmental Advances, 11, 100334.
27. World Health Organization (WHO). (2016). Ambient air pollution: A global assessment of exposure and burden of disease. Retrieved from https://apps.who.int/iris/handle/10665/250141
28. WHO (2022) Ambient (Outdoor) Air Quality and Health. Available online: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health. (accessed on 29thJune 2024).
29. Okello, G., Nantanda, R., Awokola, B., Thondoo, M., Okure, D., Tatah, L., Bainomugisha, E. and Oni, T.(2023). Air quality management strategies in Africa: A scoping review of the content, context, co-benefits and unintended consequences. Environment International, 171, p.107709.
30. Awopeju, K. A., Williams, A. B., and Anyakora, C. A. (2017). The level of PM2.5 in Lagos, Nigeria. Environmental Research, 152, 103-110. https://doi.org/10.1016/j.envres.2016.10.015.
31. Akinfolarin, O. M., Boisa, N., and Obunwo, C. C. (2017). Assessment of particulate matter-based air quality index in Port Harcourt, Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 11(4), 1-6. https://doi.org/10.9790/2402-1104010106
32. Iroegbulem, I. U., Egereonu, U. U., Ogukwe, C. E., Akalezi, C. O., Egereonu, J. C., Duru, C. E., and Okoro, N. J. (2023). Assessment of seasonal variations in air quality from Lagos metropolis and suburbs using chemometric models. Chemistry Africa, 6(2), 1061-1085.
33. Kumar, P., Gulia, S., Harrison, R. M., and Khare, M. (2015). The influence of odd-even car trial on fine and coarse particles in Delhi. Environmental Pollution, 225, 20-30. https://doi.org/10.1016/j.envpol.2015.07.005.
34. Akinjare, O. A., Fakinlede, O. A., and Ematerere, U. J. (2011). Urbanization and air pollution: Lagos case study. International Journal of Environmental Studies, 68(6), 821-835. https://doi.org/10.1080/00207233.2011.587276.
35. Power, A. L., Tennant, R. K., Stewart, A. G., Gosden, C., Worsley, A. T., Jones, R., and Love, J. (2023). The evolution of atmospheric particulate matter in an urban landscape since the Industrial Revolution. Scientific Reports, 13(1), 8964.

36. Aladejare, S. A., and Nyiputen, I. R. (2023). Ecological response to industrialisation drivers in Africa. Environmental Development, 47, 100896.
37. Thanvisitthpon, N., Kallawicha, K., and Chao, H. J. (2024). Effects of urbanization and industrialization on air quality. In Health and Environmental Effects of Ambient Air Pollution (pp. 231-255). Academic Press.
38. Fadeyi, M. O. (2011). Indoor and outdoor air quality assessment in Akoka, Lagos. Indoor and Built Environment, 20(4), 442-448. https://doi.org/10.1177/1420326X11409429.
39. Thisday. (2020, March 22). Banana Island: Nigeria's most exclusive neighborhood. Thisday. Retrieved from https://www.thisdaylive.com/index.php/2020/03/22/banana-island-nigerias-most-exclusive-neighbourhood/
40. Olajire, A. A. (2014). Air pollution monitoring in metropolitan Lagos: A pilot study. Environmental Monitoring and Assessment, 186(1), 1-19. https://doi.org/10.1007/s10661-013-3352-4.
41. Abdul-Wahab, S. A., Odigure, J. O., and Owoade, A. A. (2011). Assessment of air quality in Lagos, Nigeria. Journal of Environmental Science and Technology, 4(6), 495-506. https://doi.org/10.3923/jest.2011.495.506.
42. Awokola, B. I. (2017). Assessment of environmental pollution in Ikotun, Lagos State. Environmental Monitoring and Assessment, 189(4), 196. https://doi.org/10.1007/s10661-017-5889-0.
43. Adeniji, O. (2020). Air quality assessment in Lagos Island, Nigeria. Nigerian Journal of Environmental Sciences, 14(1), 23-34. https://doi.org/10.4314/njens.v14i1.3.
44. Ezeh, O. K. (2016). Environmental impact assessment of Lagos Port operations. Journal of Marine and Coastal Science, 10(2), 67-81. https://doi.org/10.5897/JMCS2016.0211.
45. Bainomugisha, E., Ssematimba, J., Okedi, D., Nsubuga, A., Banda, M., Sttala, and G.W., Lubisia (2023). AirQo sensor kit: A particulate matter air quality sensing kit custom designed for low-resource settings. HardwareX. Volume 16: https://doi.org/10.1016/j.ohx.2023.e00482.
46. Zafra-Pérez, A., Medina-García, J., Boente, C., Gómez-Galán, J. A., de la Campa, A. S., & de la Rosa, J. D. (2024). Designing a low-cost wireless sensor network for particulate matter monitoring: Implementation, calibration, and field-test. Atmospheric Pollution Research, 102208.
47. Hossain Md. M., Hassan Md. R., and Miah Md. A., (2023) GIS-based Spatial Mapping of the Atmospheric Particulate Pollutant (PM2.5 and PM10) at Mymensingh City Corporation Areas of Bangladesh, J. Mater. Environ. Sci., 14(9), 1007-1036.
48. Li, T., Henze, D. K., Jack, D., and Kinney, P. L. (2016). The influence of air quality model resolution on health impact assessment for fine particulate matter and its components. Air Quality, Atmosphere & Health, 9(1), 51-68. https://doi.org/10.1007/s11869-015-0321-z.
49. NESREA National Environmental (Air Quality Control) Regulations, (2021). National Environmental Standards and Regulations Enforcement Agency (establishment) (amended) act, 2018 National Environmental (air quality control). Federal Republic of Nigeria Official Gazette. Vol 108, no 161.
50. Ezeonyejiaku, C.D., Okoye, C.O., Ezeonyejiaku, N.J., andObiakor, M.O. (2022). Air Quality in Nigerian Urban Environments: A Comprehensive Assessment of Gaseous Pollutants and Particle Concentrations. Current Applied Science and Technology. 22(5), 1-15. https://doi.org/10.55003/cast.2022.05.22.011.
51. Abulude, F. O., Damodharan U, Acha S, Adamu A, and Arifalo, K. M. (2021). Preliminary assessment of air pollution quality levels of Lagos Nigeria. Aerosol Sci Eng. 5: 275-284. https://doi.org/10. 1007/ s41810-021- 00099-1.
52. Abulude, F.O., Abulude, A.I. (2021b). Monitoring Air Quality in Nigeria: The Case of Center for Atmospheric Research-National Space Research and Development Agency (CAR-NASRDA). Aerosol Science and Engineering https://doi.org/10.1007/s41810- 021-00116-3.
53. Lala, M.A., Onwnzo, C.S., Adesina, O.A., and Sonibare, J.A. (2023). Particulate matters pollution in selected areas of Nigeria: Spatial analysis and risk assessment. Case Studies in Chemical and Environmental Engineering.Doi: https://doi.org/10.1016/j.cscee.2022.100288.
54. Nicholas, E.S. and Ukoha, P.O. (2023). An Assessment of Atmospheric Pollutants (PM 2. 5, PM 10, CO2, SO2, NO2 and CO) concentrations on Air Quality Using Air Quality Index in Eastern Nigeria. Journal of Chemical Society of Nigeria, 48(4).
55. Osimobi, O. J., Yorkor, B. and Nwankwo, C. A. (2019). Evaluation of daily pollutant standard index and air quality index in a university campus in Nigeria using PM10 and PM2.5 particulate matter. Journal of Science, Technology and Environment Informatics, 07(02), 517-532. Crossref: https://doi.org/10.18801/jstei.070219.54.
56. Kanee, R. B., Adeyemi, A., Edokpa, D. O., and Ede, P. N. (2020). Particulate matter-based air quality index estimate for Abuja, Nigeria: Implications for health. Journal of Geoscience and Environment Protection, 8(5), 313-321.
57. Meseke, N. O., Akpootu, D. O., Falaiye, O. A., and Targema, T. V. (2022). Comparative Assessment of Particulate Matter Using Low Cost Sensor: A Case Study of Abuja and Kano, Nigeria. Fudma Journal of Sciences, 6(4), 203 - 211. https://doi.org/10.33003/fjs-2022-0604-1066.
58. Salami, J.T., Sawyerr, H.O., Dada, A.A. (2020). Assessment of Air Quality in Major Motor Parks in Ilorin Metropolis, Kwara State, Nigeria. International Journal of Health Sciences and Research. 10(10), 86-95.

 doi:10.20944/preprints202409.1991.v1