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Leveraging Remote Sensing Data to Monitor Air Quality in Nigeria

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Abstract

Air quality monitoring in Nigeria faces challenges due to infrastructure limitations, inadequate coverage, and data accessibility issues. This study focuses on leveraging remote sensing data to monitor air quality in Nigeria, specifically in Abuja, Benin City, and Warri. Theresearch aimto assess the current air quality status, identify pollution hotspots, and explore the potential of remote sensing data for effective monitoring. The study utilises satellite-based remote sensing data with ground-based measurements. Satellite data from sources like MODIS and OMI provided spatial and temporal information on pollutants, while ground stations measured parameters such as $PM_{2.5}$ and PM_{10} concentrations. Statistical tools, including Geographic Information System (GIS) analysis, were employed to process and validate the data. The results indicate varying air quality levels across the studied locations. Abuja exhibited moderate air quality, with PM, NO_2, and SO_2 being the primary pollutants. Benin City experienced unhealthy to very unhealthy air quality, with elevated concentrations of NO_2 and particulate matter attributed to industrial and vehicular emissions. Warri also showed unhealthy air quality, linked to industrial activities. The study concludes that remote sensing data integration enhances air quality monitoring in Nigeria, providing valuable insights for policymakers, researchers, and the public. Recommendations include expanding sensor networks, fostering data-sharing partnerships, and implementing targeted policies based on remote sensing insights to mitigate air pollution and promote sustainable development. In summary, leveraging remote sensing data offers a promising approach to addressing air quality challenges in Nigeria, contributing to better environmental management and public health outcomes.

Keywords: Air Quality, Monitoring, Remote Sensing, Environmental Policy and Public Health.

1.0 Introduction

Air quality is a significant environmental parameter that has a direct impact on the health and well-being of people all over the world (Rai et al, 2011; WHO, 2016). In Nigeria, a fast-expanding economy with a population of more than 200 million people, urbanization, industrialization, and automobile emissions have created considerable issues in maintaining acceptable levels of air quality (Ngele & Onwu, 2015; Njoku et al, 2016). Poor air quality has serious effecton public health, agriculture, and the environment as a whole (Hassan & Abdullahi, 2012).

Nigeria's existing air quality monitoring system confronts a number of issues, like

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Infrastructure Challenges, Limited Coverage, Data Accessibility and Transparency, Data Quality and Standardization, Funding Constraints, and Technological Obsolescence, while several major cities, including Lagos, Abuja, and Port Harcourt, have monitoring stations, they are generally focused in urban areas, leaving broad areas with little to no coverage (Ede et al, 2010; Gobo et al, 2012; Nwokocha et al, 2015; Njoku et al, 2016). Data from these stations are not always freely accessible to the general public, limiting community awareness and reaction to air quality issues. Furthermore, typical monitoring methods are time-consuming and may fail to capture the full spatial extent of air pollution, particularly in locations with poor infrastructure. As a result, we have an imperfect picture of the distribution and sources of contaminants across the country. Nonetheless, this research concentrated on three crucial urban areas in Nigeria: Abuja, Benin City, and Warri based on economic, and political significance.

In Nigeria, remote sensing technology offers a powerful alternative for monitoring air quality. Satellites outfitted with specialized sensors can provide continuous and broad-scale coverage, providing a comprehensive picture of air pollution levels across the country. Remote sensing can also identify pollution hotspots and follow pollutant transport over time, enabling more effective mitigation and policy implementation. There is an opportunity to significantly improve our understanding of air quality dynamics in Nigeria by leveraging remote sensing data and providing policymakers, researchers, and the public with valuable information to make informed decisions about public health, environmental protection, and sustainable development.The primary objectives of this study are to assess the current state of air quality in Nigeria; identify pollution hotspots and explore the potential of remote sensing data, such as satellite imagery and ground-based sensors, in monitoring air quality.

2.0 Literature Review

Remote sensing techniques, such as satellite-based observations and ground-based sensors, play a crucial role in monitoring air quality. Satellite data can provide spatial and temporal information on various pollutants, including particulate matter (PM), nitrogen dioxide (NO2), sulfur dioxide (SO2), and carbon monoxide (CO). Satellite platforms like

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MODIS (Moderate Resolution Imaging Spectroradiometer) and OMI (Ozone Monitoring Instrument) have been used to assess air quality parameters. Studies have employed data from these satellites to estimate concentrations of pollutants and analyze their spatial distribution over Nigeria (Chan et al., 2015).

Ground-based monitoring networks complement satellite observations. These networks include ground stations equipped with sensors to measure concentrations of various air pollutants. Combining ground-based data with satellite observations enhances the accuracy and reliability of air quality assessments (Balogun et al., 2018). Despite the progress, challenges such as data integration, calibration, and validation persist. Ongoing research focuses on addressing these challenges and exploring new opportunities for improving the accuracy of air quality monitoring using remote sensing data (Adeyemi et al., 2019). Leveraging remote sensing data for air quality monitoring in Nigeria is an active area of research, with studies employing both satellite-based observations and ground-based monitoring to assess and address air pollution challenges.

3.0 Materials and Method

This study assessed and monitored air quality in Abuja, Benin City, and Warri using a multi-step technique.

Data Sources: To assess air quality, we utilized a combination of satellite-based remote sensing data and ground-based measurements, which were captured between September to October, 2023.The primary sources of data include Satellite data captured from Air Pollution in World: Real-time Air Quality Index Visual Map (aqicn.org), which provides high-resolution information on various atmospheric pollutants, including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and particulate matter ($PM_{2.5}$) (Njoku et al, 2016). The study utilized satellite data at ground-based monitoring stations. These stations are part of a sensor network of AirNet sensors Data Quality Validation Service.

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Table 1: Sampled Location with Ground Based Stations Used

City	Locations	Ground Based Stations
Abuja	Abuja U. S. Embassy. Federal Capital Territory	Lagos Air Quality Monitor-US EPA Space Environment Research Laboratory, Center for Atmospheric Research, Abuja, Nigeria.
Benin City	Around University of Benin, Ugbowo, Benin City.	Space-Earth Research Laboratory, Center for Atmospheric Research, Ugbowo, Benin City
Warri	Along Waari – Patani Road.	Federal University of Petroleum Resources, Effurum-CAR, Iterigbi.

Source: Authors' Compilation, 2024.

Ground Based Measurement:was done from various Ground stations in Abuja, Benin City, and Warri to provide real-time data on air quality parameters such as $PM_{2.5}$ and PM_{10} concentrations, volatile organic compounds (VOCs), and meteorological variables.

Data Pre-Processing: the satellite data collected was edited and preprocessed to derive spatial distributions of pollutants, and integrated ground-based measurements to validate the satellite data. Statistical analysis, such as utilizing Geographic Information System (GIS) tools to map pollutant levels and identify hotspots or regions with high pollution is conducted to identify the temporal trends, spatial patterns, and correlations between different pollutants.

Air Quality Index (AQI) Calculation: This was calculated based on concentrations of key pollutants to provide a comprehensive indicator of air quality in Abuja, Benin City, and Warri. The study also considered meteorological data, land use patterns, and emission inventories to comprehensively assess air quality. The meteorological data, including temperature, humidity, wind speed, and atmospheric pressure, is essential for understanding the dispersion and transformation of air pollutants. Land use patterns offer insights into the sources and types of emissions, such as industrial

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activities, transportation, and residential areas. Emission inventories provide detailed information on the quantity and composition of pollutants released into the atmosphere. The table 2 defines the Air Quality Index scale as defined by the US-EPA 2016 standard.

Table 2:Air Quality Index and Pollution Measurement Scale with Health Implications

AQI	Air Pollution Level	Health Implications	Colours
0 – 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	Green
51 -100	Moderate	Air quality is acceptable; however, some pollutants may be a moderate health concern for small number of people who are unusually sensitive to air pollution.	Yellow
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Orange
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Red
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Purple
300+	Hazardous	Health alert: everyone may experience more serious health effects	Maroon

Source: *U.S. Environmental Protection Agency (EPA) Standards, 2016.*

4.0 Findings and Discussion

Using remote sensing data to monitor air quality in Abuja, Nigeria's federal capital area, and Benin City and Warri, two of the country's major industrial cities, is a critical endeavor given the city's rapidly growing population and increasing industrialization. The air quality index at Abuja's two measured locations is moderate with values of 71 and 80, indicating

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that the air quality is acceptable. Particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) are the principal pollutants of concern in Abuja (Hassan and Abdullahi, 2012). These contaminants are linked to vehicle emissions, industrial activity, and biomass combustion (Ngele and Onwu, 2015; Njoku et al, 2016). As indicated in Figures 1 and 2, ozone (O_3) and carbon monoxide (CO) are also monitored since they have a role in secondary air quality issues and can be used to assess overall air quality.

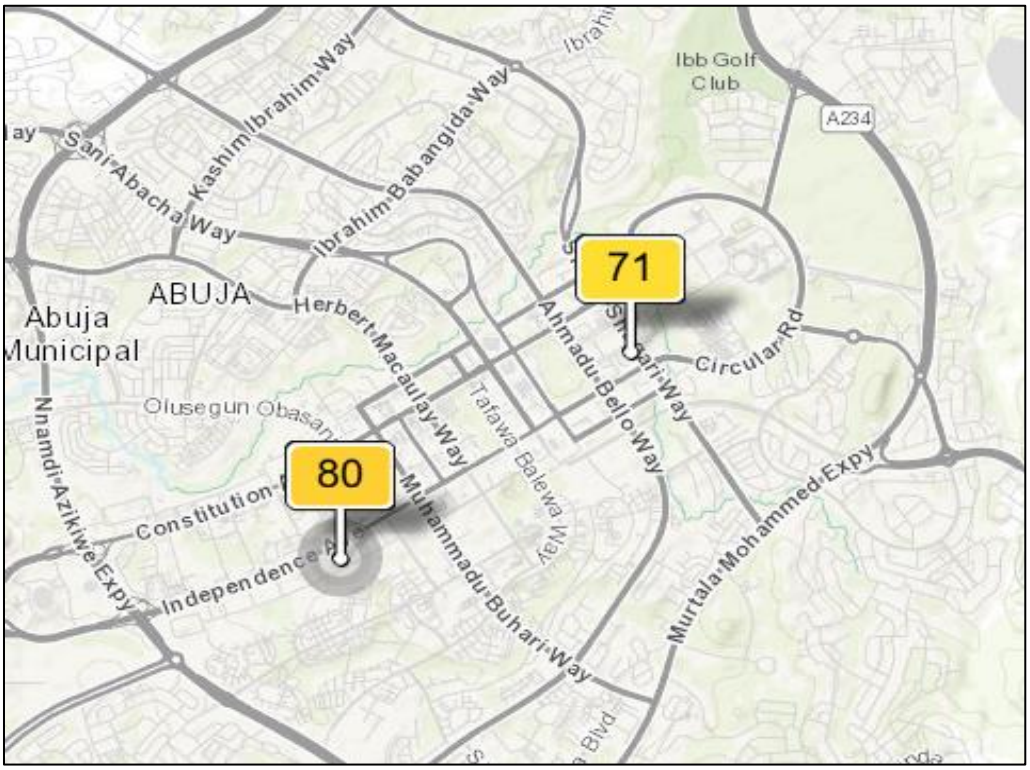


Figure 1: Air Quality Index Map of Independence Area and Shagari Way in Abuja.

Source: *Lagos Air Quality Monitor-US EPA, 2024 and Space Environment Research Laboratory, Center for Atmospheric Research, Abuja, Nigeria, 2024.*

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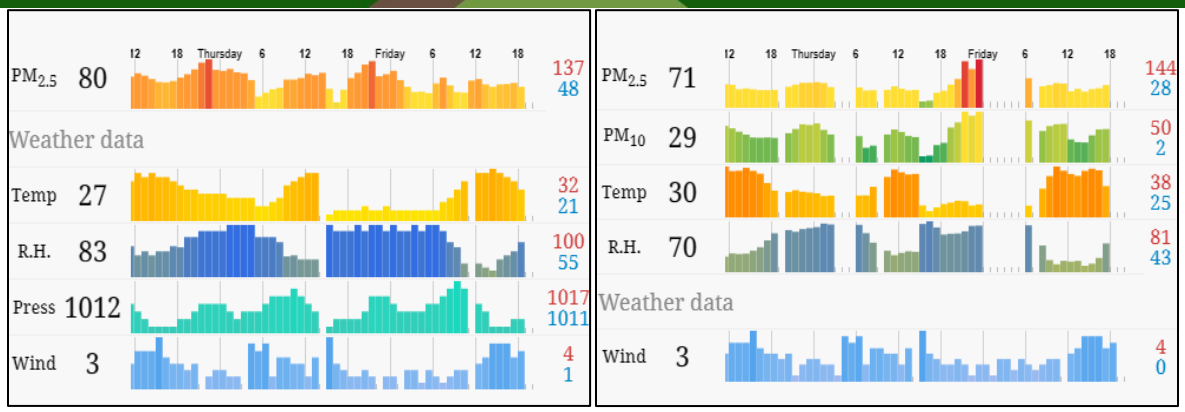
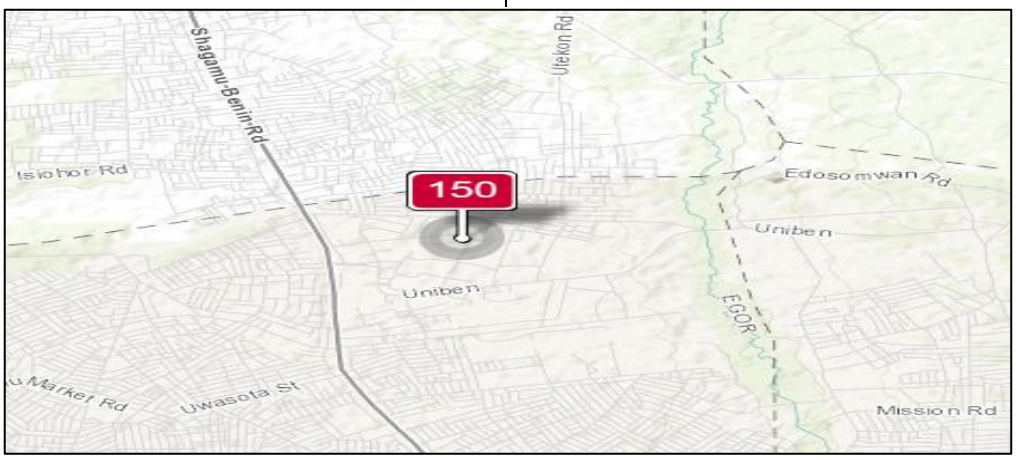


Figure 2: Air Quality Index Data of Independence Area and Shagari Way in Abuja.
Source: *Authors' Compilation, 2024.*

The sampled location in Benin City has an unhealthy air quality index. The study found considerable regional variations in air quality throughout Benin City. Pollutant concentrations were higher in industrial and heavily populated areas, particularly in NO_2, PM_1, and $PM_{2.5}$. Pollution levels are often higher during the day due to increased industrial and automobile traffic (Akuro, 2012). The computed AQI found that air quality in Benin City is usually "unhealthy" to "very unhealthy," particularly in certain regions. This data can be utilized to offer timely public health alerts and inform urban design decisions (as illustrated in Figures 3 and 4).


Shagamu-Benin Rd
Ugbowo
Ekosodin Rd
Ugbowo Rd
Ekosodin
Ugbowo
Ugbowo
Ugbowo

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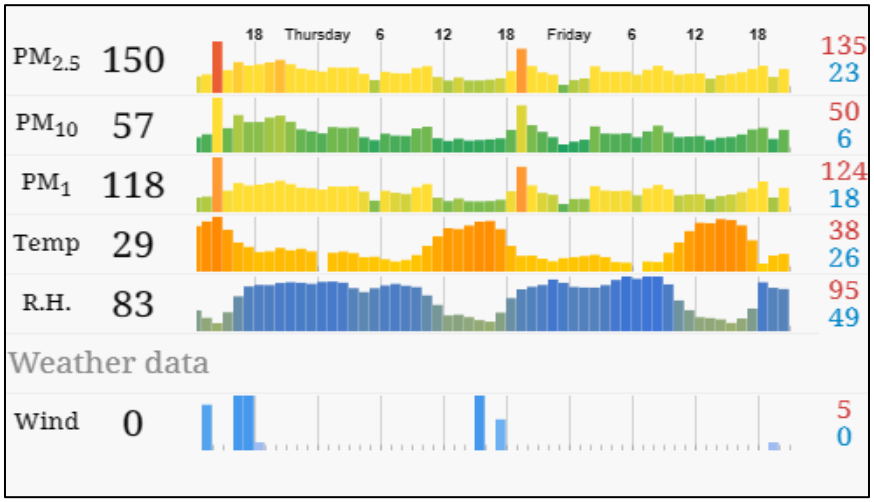


Figure 4: Figure 3: Air Quality Index Map of Ugbowo, Benin City, Edo State.
Source: *Authors' Compilation, 2024.*

The sampled site along Warri-Patani Road has an unhealthy air quality index. Particulate matter (PM2.5 and PM1), nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), ozone (O3), and volatile organic compounds (VOCs) are all measured by these stations. All of these pollutants have negative impacts on human health, causing respiratory problems, cardiovascular problems, and other health complications. Identifying pollution sources is critical for effective pollution mitigation measures. The principal sources in the studied location in Warri are believed to be related to industrial activities, such as oil and gas operations, as well as traffic emissions (Ngele & Onwu, 2015), as indicated in Figures 5 and 6 below.

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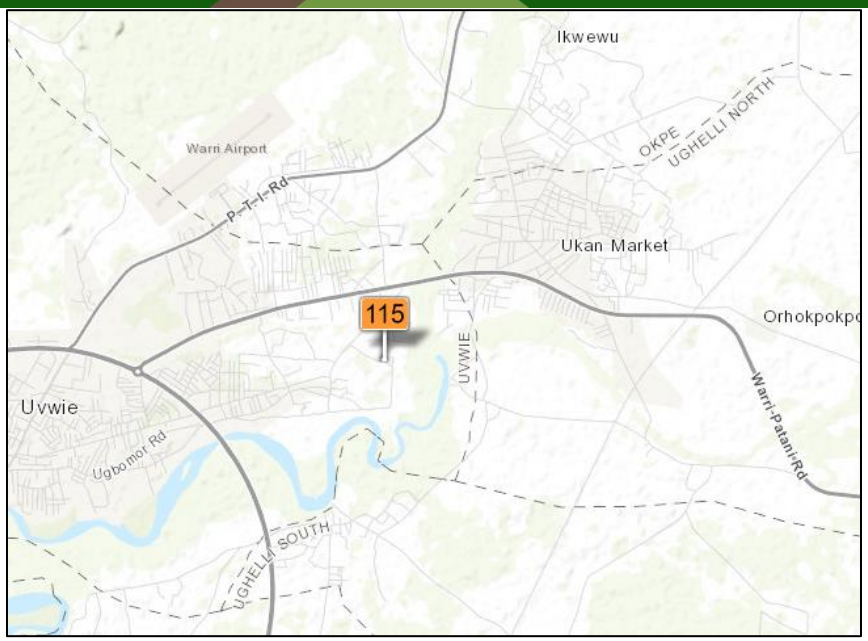


Figure 5: Air Quality Index Map along Waari – Patani Road, Delta State.
Source: *Federal University of Petroleum Resources, Effurum-CAR, Iterigbi.*

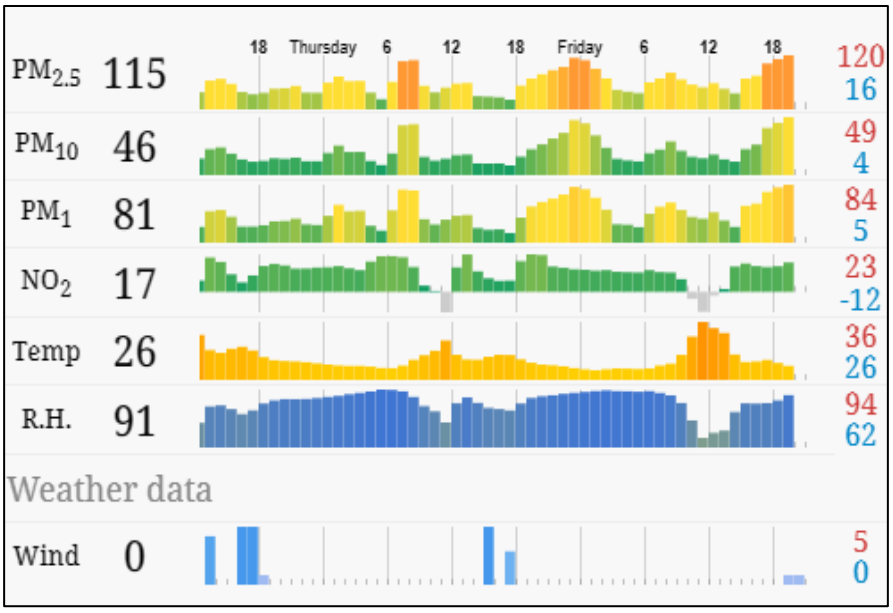


Figure 6: Air Quality Index Data along Waari – Patani Road, Delta State
Source: *Authors' Compilation, 2024.*

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5.0 Conclusion and Recommendations

In conclusion, leveraging remote sensing data for monitoring air quality in Nigeria presents a promising avenue for addressing environmental challenges. The integration of advanced satellite technologies and ground-based sensors has proven effective in providing comprehensive and real-time insights into air quality parameters. The use of remote sensing data to monitor air quality in areas such as Abuja, Benin City, and Warri is a major advancement in addressing both health and environmental concerns.

The study recommends that investing in the deployment of a more extensive network of sensors, fostering international partnerships for data sharing, and developing targeted policies based on the insights gained from remote sensing technologies. By embracing these recommendations, Nigeria can proactively mitigate air pollution, safeguard public health, and promote sustainable development.

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