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Environmental Impacts of Mineral Exploration Activities on Air Quality Index ($PM_{2.5}$, PM_{10}, SO_2, NH_3 and O_3) in Jos and Environs, Plateau State-Nigeria.

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Abstract- ***Mineral exploration and associated activities can significantly influence ambient air quality and pose risks to human health and the environment. This study assessed the environmental impact of mineral exploration on air quality in Jos and its environs, Plateau State, Nigeria, by examining the concentrations of particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), ammonia (NH_3), and sulphur dioxide (SO_2), with emphasis on changes between 2021 and 2025. Air-quality data were obtained using the OpenWeatherMap API and analysed with the United States Environmental Protection Agency (US-EPA) 2016 Air Quality Index (AQI) standard. Monthly and annual pollutant patterns were evaluated in relation to the Harmattan, Pre-Rainy, Rainy, and Post-Rainy seasons. The results indicate a substantial overall improvement in air quality by 2025. $PM_{2.5}$ declined remarkably, with February values reducing from 209.66 µg/m³ in 2021 to 28.40 µg/m³ in 2025, while PM_{10} decreased from 736.26 µg/m³ to 73.42 µg/m³ over the same period. Sulphur dioxide (SO_2) decreased from 1.32 to 0.46 µg/m³ (65%), ammonia (NH_3) from 4.72 to 2.30 µg/m³ (51%), and O_3 from 40.5 to 32.9 µg/m³ (19%) respectively. Despite the observed improvement, elevated particulate matter persisted during some months, particularly in the Harmattan and Post-Rainy periods. The findings suggest that strengthened environmental regulation, improved mining and waste-management practices, control of open burning, continuous air-quality monitoring and sustained public-awareness programmes are important for maintaining and further improving air quality in Jos and its environs. The study also demonstrates the value of integrating accessible atmospheric data with AQI assessment to support environmental monitoring, public-health planning, and evidence-based interventions.***

Keywords: Environmental Impact, Air Quality index, Mineral Exploration Paticulate Matter (PM2.5, PM10), Ammonia (NH_3), Ozone (O_3), Sulphur Dioxide (SO_2), Jos and Environs, Health, Openweather API.

I. INTRODUCTION

Solid mineral exploration in Nigeria is considered an essential factor that has a direct influence on Nigeria's development through the exploitation of resources such as oil, minerals and metals. Despite this, mining operations often have devastating effects on the Earth's environment in manners including soil, water and air pollution, deforestation, habitat destruction, and interference with native ecosystems [9]. These issues are further compounded by weak regulatory enforcement, lack of environmental monitoring, and inadequate stakeholder engagement in mining governance [11]. Jos Plateau State has a long history of tin and columbite mining, stretching back to the early 20th century. While the industry contributed to Nigeria's economy during the colonial and post-colonial era, its environmental legacy remains severe. Abandoned mine pits (filled with contaminated water), degraded landscape that poses safety hazards to nearby communities, radioactive mine tailings and heavy metal residues from bauxite, rutile, gemstone, monazite, kaolin, zircon, copper, silica, sharp sand and granite [5]. This operation releases various pollutants into outdoor air, including particulate matter (PM2.5, PM10), ozone (O3), sulphur dioxide (SO2), nitrogen oxides (NOx), and carbon monoxide (CO), adversely affecting the local

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environment and population [1]. Successive industrial processes also release significant quantities of airborne pollutants, particularly fine particulate matter ($PM_{2.5}$ and PM_{10}). These particles can penetrate deeply into the lungs, leading to respiratory ailments such as asthma, chronic bronchitis, and frequent episodes of eye and throat irritation (WHO, 2024). Mining has led to deteriorating air quality, making it essential to evaluate its impact and develop effective management strategies [7]. Mechanized mining operations require proper systems by which they can minimize the toxicity of the waste product generated, common preventive techniques such as passive enclosures, wet suppression, stabilization of paved and unpaved surface for the control of fugitive particulate emissions is to enclose the source either fully or partially. Enclosures preclude or inhibit particulate matter from becoming airborne as a result of the disturbance created by ambient winds or by mechanical entrainment resulting from the operation of the source itself [14]. In this research, while many of the potential health impacts of air pollution through solid mineral exploration and processing industries have been documented, this information often scattered across articles focused on specific regions, clustered into meta-analyses or reviews. The National Space Research and Development Agency (NASRDA) leverage satellite technology to generate actionable data and evidence-based analysis for improved public health, planning and interventions in low-resource settings.

II. LITERATURE REVIEW

Over the years, air pollution has been a significant challenge that has affected many cities, it is intricate and severe, leading to detrimental impacts on both human health and the surrounding ecosystem. Pranav and Srinivas [10], proposed designs to calculate the air quality index that measures the concentration of different gases in the air such as CO, NO2, SO2, and O3. It was implemented using ADuC812 as an analogy device along with 3 different gas sensors to find the gases in the air. The gas sensor will detect the gas molecules and generate the electrical signals which will be send to the system for identifying the gas levels. Basically, it is a cost-effective system that will identify the air quality parameter of the different gases. Volatile Organic Compounds (VOCs) monitoring system also designed using a wireless sensor network for indoor environment the objective is to implement and optimized power ZigBee sensor structure and internode-based framework used to identify the level of air pollution from VOCs network. The designed network node consist of different sensors and the communication network system is to communicate to the centralized system with a remote system. A microcontroller and network-based system used to efficiently process communication data with minimum power utilization [2]. Another research also proposed a smart system for air pollution monitoring and also analyze the air quality index of 2 different cities in the selected areas near the school and the main objective of this was to provide an alert about the air quality to protect the children health. Statistical and artificial intelligence technology was used to identify air quality and health impact on children. It was revealed that particulate matter PM2.5 and PM10 were impacting on the health. The purpose of developing this system was to send alert to parents about the air quality of the school area where their children were studying and living [8].

Air Quality Index Scale and Color Legend

The WHO Ambient Air Quality Database compiles ground-level measurements of annual mean concentrations for nitrogen dioxide (NO2), and particulate matter with a diameter equal to or smaller than 10 µm (PM10) and 2.5 µm (PM2.5). These measurements aim to represent an average for the city or town, rather than for individual monitoring stations. Both groups of pollutants originate mainly from human activities related to mineral exploration activities, fossil fuel combustion, construction practices and various urban operations. To ensure the data accurately reflects population exposure, the database primarily utilizes urban measurements, encompassing urban background, residential, commercial, and mixed areas, as well as rural and industrial zones close to urban settlements [19].

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, such as asthma, should limit prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
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

Table 1: US-EPA 2016 standard

The WHO Ambient Air Quality provides foundational input for complex models combining ground measurements with topographic, population, satellite data, and chemical transport models to accurately estimate global air pollution exposure. This modelling framework ensures homogeneous and standardized exposure estimates across all countries and cities, regardless of local monitoring capacity. It raises awareness and advocacy for the expansion and improvement of air monitoring networks worldwide. It also acts as a cornerstone for calculating the mortality and morbidity burdens attributed to air pollution. WHO estimates that outdoor air pollution caused 4.3 million premature deaths in 2021 due to stroke, ischaemic heart disease, lung cancer, chronic obstructive pulmonary disease and acute lower respiratory infections [15].

Effects of Air Pollution on Public Health

Air pollution has various health effects. The health of susceptible and sensitive individuals can be impacted even on low air pollution days. Short-term exposure to air pollutants is closely related to COPD (Chronic Obstructive Pulmonary Disease), cough, shortness of breath, wheezing, asthma, respiratory disease, and high rates of hospitalization (a measurement of morbidity). The long-term effects associated with air pollution are chronic asthma, pulmonary insufficiency, cardiovascular diseases, and cardiovascular mortality. According to a Swedish cohort study, diabetes seems to be induced after long-term air pollution exposure [3]. More so, air pollution seems to have various malign health effects in early human life, such as respiratory, cardiovascular, mental, and perinatal disorders, leading to infant mortality or chronic disease in adult age [6].

National reports have mentioned the increased risk of morbidity and mortality. These studies were conducted in many places around the world and show a correlation between daily ranges of particulate matter (PM) concentration and daily mortality. Climate shifts and global planetary warming could aggravate the situation [17]. Besides, increased hospitalization (an index of morbidity) has been registered among the elderly and susceptible individuals for specific reasons. Fine and ultrafine particulate matter seems to be associated with more serious illnesses as it can invade the deepest parts of the airways and more easily reach the bloodstream [17].

Sources of Exposure

It is a known fact that the majority of environmental pollutants are emitted through large-scale human activities such as the use of industrial machinery in various urban and human operations such as mineral mining and processing, power-producing stations, combustion engines, and cars. Because these activities are performed at such a large scale, they are by far the major contributors to air pollution. The classification of these pollutants is based mainly on the sources producing it. Therefore, it is worth mentioning the four main sources, following the classification system: Major sources, Area sources, Mobile sources, and Natural sources [13].

Major sources: include the emission of pollutants from power stations, refineries, and petrochemicals, the chemical and fertilizer industries, metallurgical and other industrial plants, and municipal incineration.

Indoor area sources: include domestic cleaning activities, dry cleaners, printing shops, and petrol stations.

Mobile sources: include automobiles, cars, railways, airways, and other types of vehicles.

Natural sources: involving physical disasters such as forest fire, volcanic erosion, dust storms, and agricultural burning [13].

III. METHODOLOGY

Description of Study Area

In this research, the study area is Jos town and environs. It lies within latitudes 9°45’00’’N to 09°57’00’’N and longitudes 8°48’00’’E to 8°58’00’’E. Jos metropolis is the administrative capital of Plateau State, Nigeria. This study covers mostly Jos North and Jos South Local Government Areas (LGAs) with an estimated population of 1,072,000 based on citypopulation.com, 2026. Jos metropolis covers an area of 249.7km². At an altitude of 1,217m (3,993ft) above sea level, it enjoys a more temperate climate than much of the rest of Nigeria. The climate is the wet and dry type classified as tropical rainy climate and characterized by a mean annual rainfall of 1,250mm, peaking between July and August. The mean annual temperature is about 22°C but mean monthly values vary between 19°C in the coolest month of December and 25°C in the hottest month, April. The city of Jos is the largest settlement in Plateau State. It owes its origin to the introduction of tin and columbite mining on the Jos Plateau and railway lines linking it with Port Harcourt and Lagos States respectively, thus bringing the area into the orbit of the world economy. The tin and columbite mining led to the influx of migrants, mostly Hausas, lgbos, Yoruba’s and Europeans who constitute about half of the population of the town, making it a highly cosmopolitan town.

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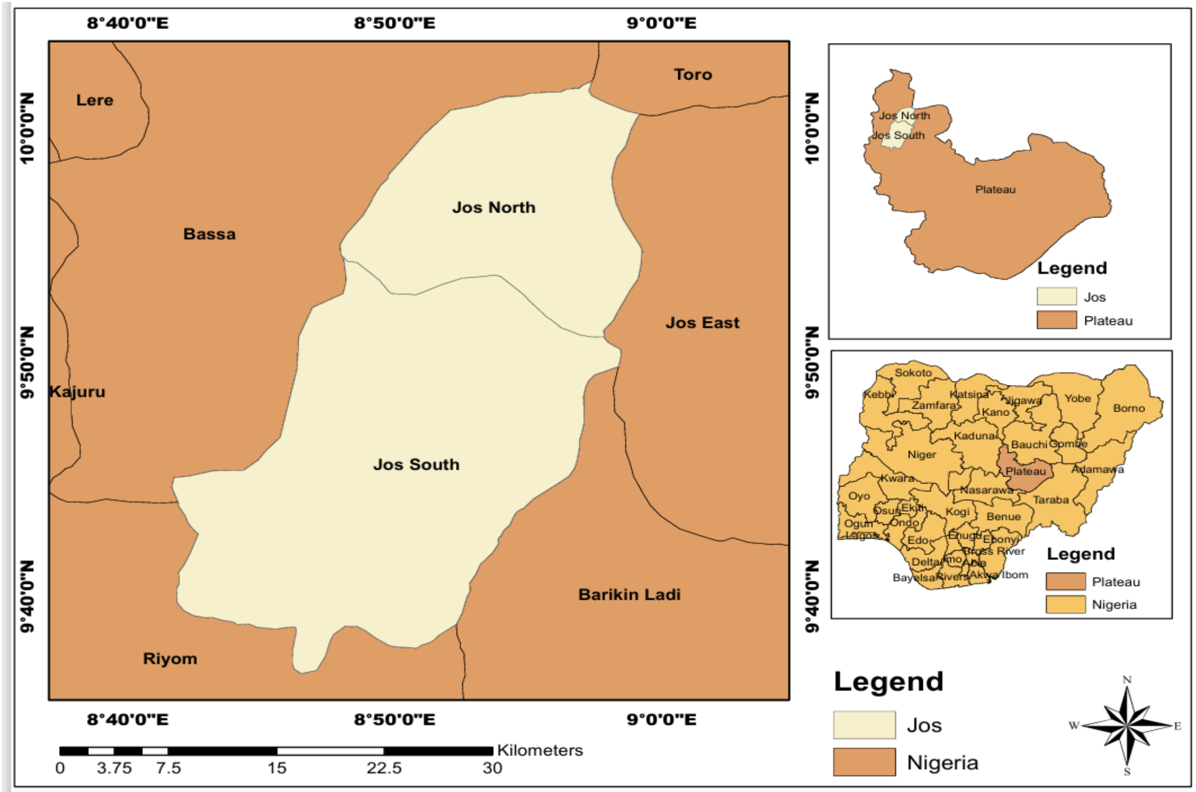

Figure 1: Research Location Map

Data Acquisition

Research data was acquired through a method described by [16], with modification. A real-time weather monitoring system (OpenWeather map API) with integrated Air Quality Index (AQI) tracking and dynamic data visualization was used in this study. This automated system has a modular setup such as cloud-based data retrieval, server-side logic, and interactive front-end visualization. The approach has four main parts: data acquisition, back-end processing, front-end visualization and integration. It is programmed to receive AQI data per hour and each day of the week, with estimated AQI average values for the corresponding target gasses. This data was further analysed to estimate the average monthly/yearly air quality index for further analysis.

IV. RESULTS AND ANALYSIS

This research presents a comprehensive comparative analysis of air quality data in Jos, Plateau State-Nigeria, covering the years 2021 and 2025. The analysis evaluates five key pollutants $PM_{2.5}$, PM_{10},

O_3, NH_3, and SO_2 using the United States Environmental Protection Agency (US-EPA) 2016 Air Quality Index (AQI) standard to assess temporal trends, seasonal patterns, pollution sources and the overall improvement or deterioration of ambient air quality over the four-year interval.

Table 2: AQI Values for Jos Metropolis 2021

AQI	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
$PM_{2.5}$	139	209	149	55.8	23.3	32.5	16.1	23.6	46.9	69.6	81.5	176
PM_{10}	432	736	567	158	44.3	55.3	24.9	32.9	74.4	163	196.	538
O_3	59.0	66.1	48.2	39.3	24.9	19.8	25.8	21.6	19.6	30.6	43.8	56.1
NH_3	3.87	4.4	3.69	5.48	3.8	4.86	2.66	3.19	4.97	6.47	7.85	3.77

SO_2	1.23	1.4	1.04	1.51	1.04	1.47	0.87	1.11	1.6	1.78	2.14	1.16

Table 3: AQI Values for Jos Metropolis 2025

AQI	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
$PM_{2.5}$	79.5	28.4	54.3	17.5	20.5	15.5	9.17	10.5	15.4	84.4	10.5	84.4
PM_{10}	252	73.4	162	27.4	41.6	20.6	11.8	13.5	19.9	201	13.5	201
O_3	70.3	32.7	62.8	24.4	25.6	21.1	21.0	19.2	17.0	41.2	19.2	41.2
NH_3	4.64	2.54	6.17	2.67	2.91	1.11	0.65	0.71	1.09	2.51	0.71	2.51
SO_2	1.29	0.61	1.87	0.3	0.31	0.28	0.21	0.21	0.26	0.68	0.21	0.68

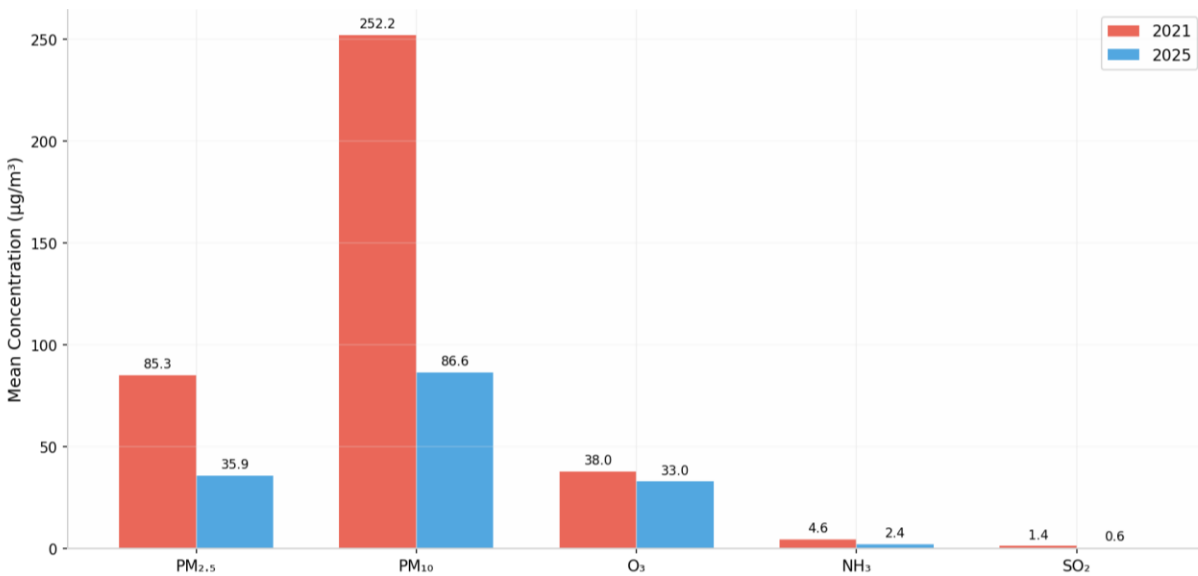

Figure 2: Annual Average Concentration Comparison for $PM_{2.5}$, PM_{10}, O_3, NH_3, and SO_2.

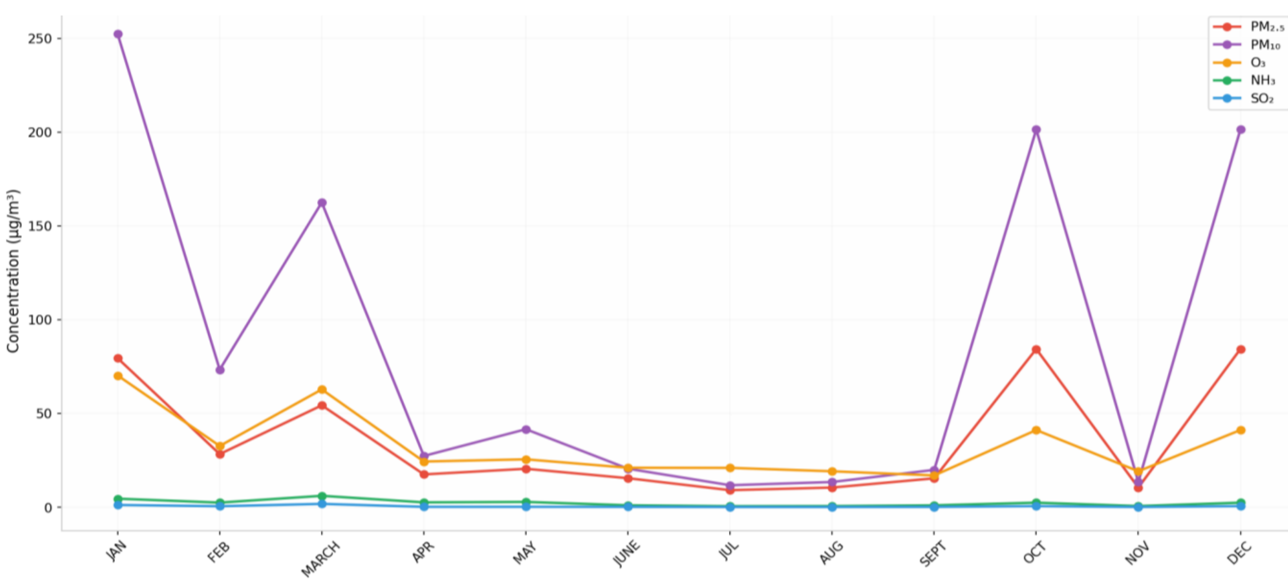

Figure 3: All Pollutants Monthly Trends In 2025

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Table 4: Monthly $PM_{2.5}$ AQI Classification

Month	2021 (µg/m³)	2021 AQI	2025 (µg/m³)	2025 AQI
JAN	139.49	Unhealthy	79.5	Unhealthy
FEB	209.66	Very Unhealthy	28.4	Moderate
MAR	149.22	Unhealthy	54.39	Unhealthy for Special groups
APR	55.8	Unhealthy	17.58	Moderate
MAY	23.31	Moderate	20.58	Moderate
JUN	32.55	Moderate	15.55	Moderate
JUL	16.16	Moderate	9.17	Good
AUG	23.68	Moderate	10.57	Good
SEP	46.99	Unhealthy for Special groups	15.49	Moderate
OCT	69.67	Unhealthy	84.41	Unhealthy
NOV	81.5	Unhealthy	10.57	Good
DEC	176.02	Unhealthy	84.41	Unhealthy

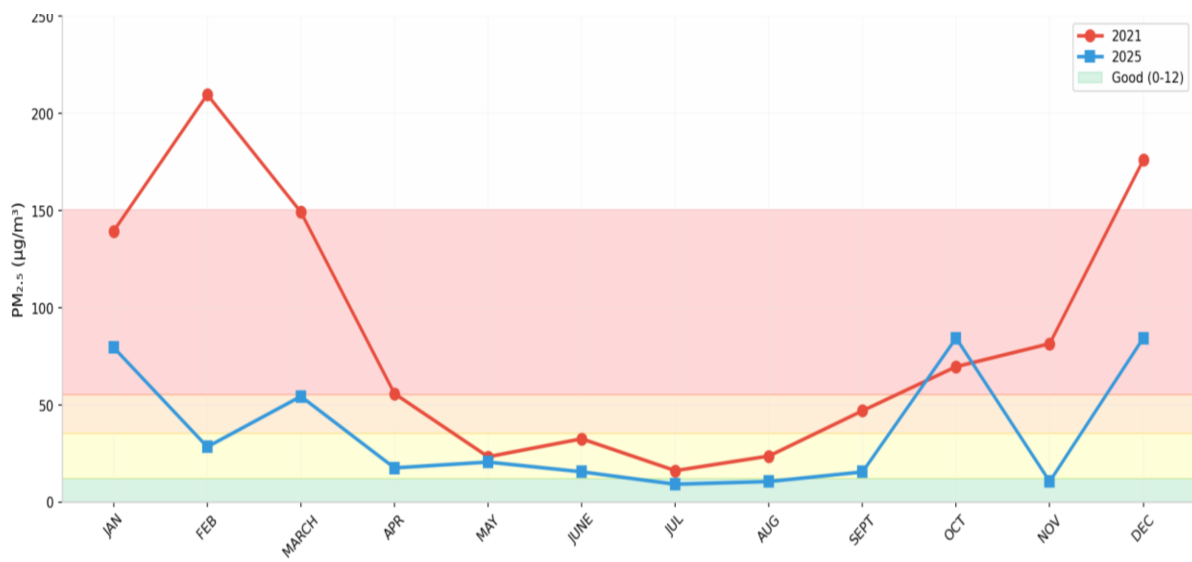

Figure 4: $PM_{2.5}$ Comparative Analysis, 2021 Against 2025

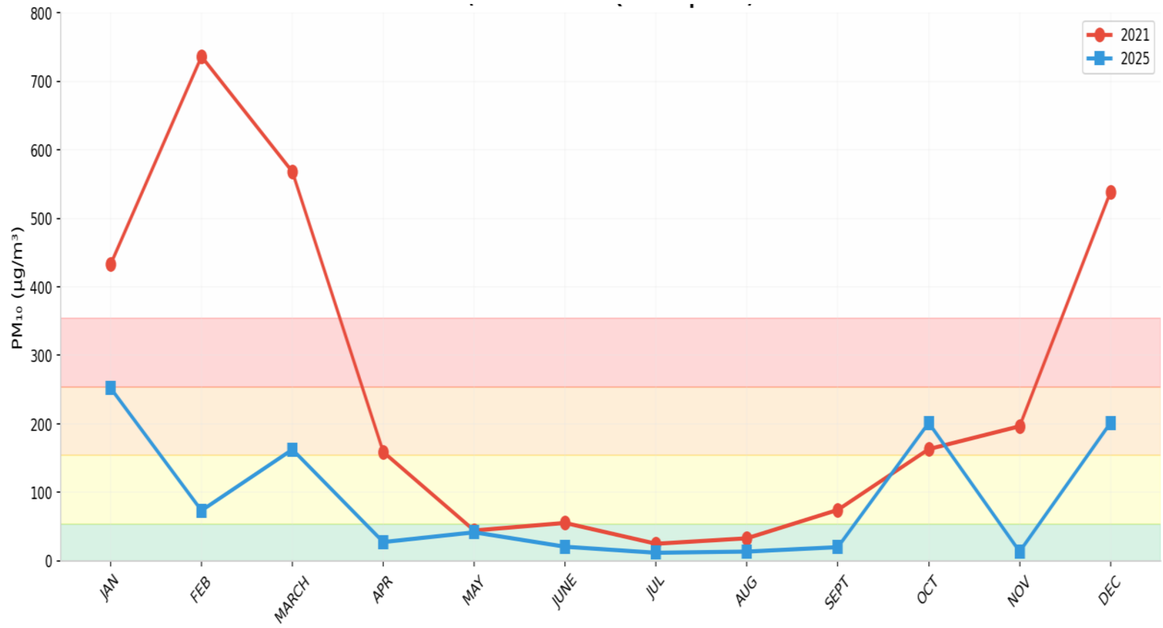

Figure 5: PM_{10} Comparative Analysis, 2021 Against 2025

V. DISCUSSION

The results obtained from this analysis revealed a staggering improvement in the air quality ($PM_{2.5}$, PM_{10}, O_3, NH_3, and SO_2) of Jos and environs between 2021 and 2025 (table 3). This across-the-board improvement strongly suggests the implementation of systemic policy interventions rather than isolated or coincidental factors. The magnitude and consistency of reductions point to coordinated environmental governance, including strict and improved mineral mining monitoring, waste management infrastructure and public awareness campaigns. Seasonal grouping according to Nigerian climatology; Harmattan (November–February), Pre-Rainy (March), Rainy (April–September), and Post-Rainy (October) revealed that although every season improved, but the magnitude and underlying drivers may vary.

In 2021, $PM_{2.5}$ concentrations reached catastrophic levels during the harmattan and pre-rainy seasons, with February recording 209.66 µg/m³ (Very Unhealthy) and December reaching 176.02 µg/m³ (Unhealthy). By 2025, these values plummeted to 28.40 µg/m³ (Moderate) and 84.41 µg/m³ (Unhealthy) respectively (table 4). PM_{10} (coarse particulate matter) shows an even more dramatic reduction than $PM_{2.5}$. In 2021, Jos and environs experienced extreme coarse dust with February reaching 736.26 µg/m³ and March recording 567.99 µg/m³, both deep in the US-EPA 'Unhealthy' zone and approaching 'Very Unhealthy' thresholds. By 2025, these catastrophic values were reduced to 73.42 µg/m³ (Moderate) and 162.53 µg/m³ (Unhealthy only for sensitive groups such as children and people with respiratory disease like asthma) respectively (figure 5). In the same vein, SO_2, O_3 and NH_3 fell within the Green (figure 2) region in both 2021 and 2025 where AQI is considered satisfactorily and air pollution poses little or no risk based on US-EPA 2016 standard [15]. SO_2 reduced from 1.32 to 0.46 µg/m³ representing 65% improvement, NH_3 reduced from 4.72 to 2.30 µg/m³ (51%) and O_3 recorded a decrease from 40.5 to 32.9 µg/m³ also representing 19% improvement. SO2 as a gaseous pollutant is a product of various human activities including, illegal mineral mining, combustion, metal processing and other anthropogenic sources. It is a pollutant that irritates the respiratory system, eye irritation and inflammation of the breathing system that can trigger cough or mucous secretion, thus triggering the onset of asthma or chronic bronchitis [12]. In Jos and environs, mineral mining and other anthropogenic activities resulting to ozone depletion causes a series of health challenges such as skin cancer and in malignant melanoma development. It is also linked to the development of cataracts, chest pain, coughing, throat irritation, and airway inflammation. Ozone depletion through anthropogenic activities also affects sensitive vegetation and ecosystems, including forests, parks, wildlife refuges and wilderness areas [1]. The halving of ammonia points to reduced agricultural burning, improved livestock waste management, or lower fertilizer volatilization. Atmospheric nh3 can participate in multiple chemical processes and to the formation of the particulate matter [20].

A similar research on environmental impact of air pollution through anthropogenic activities also revealed that children are particularly more vulnerable to air pollution, especially during their development. It also stated that air pollution has adverse effects on our lives in many different respects. Diseases associated with air pollution have not only an important economic impact but also a societal impact due to absences from productive work and school [4].

VI. CONCLUSION

This research demonstrates a substantial improvement on the air quality of Jos and its environs between 2021 and 2025, with reductions recorded across all assessed pollutants ($PM_{2.5}$, PM_{10}, SO_2, NH_3 and O_3). Air-quality conditions varied according to the four Nigerian climatological seasons—Harmattan (November–February), Pre-Rainy (March), Rainy (April–September), and Post-Rainy (October) and although all seasons showed improvement by 2025, the magnitude of change and the factors driving pollution differed between seasons. These findings also emphasize that pollutant exposure can have important respiratory and other health effects on human health, while air pollution and related environmental changes can affect vegetation and ecosystems. The strongest gains were observed in particulate matter ($PM_{2.5}$ and PM_{10}) and SO_2, suggesting that continued environmental regulation, effective mining and waste-management practices, control of open burning, and sustained public-awareness campaigns could help maintain and further improve these air-quality conditions.

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