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Assessment of Industrial Emissions and their impacts on Ambient Air Quality and Public Health in Urban Areas of Jos North Local Government Area, Plateau State

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ABSTRACT

Rapid urbanization and expanding industrial activities within Jos North Local Government Area (LGA) have driven localized declines in air quality, posing critical threats to public health. This study quantifies ambient air pollutant concentrations [PM2.5, PM10, CO, SO2, NO2, and Volatile Organic Compounds (VOCs)] across three industrial sites, two residential sites, and one baseline control site. Using standardized field monitoring coupled with United States Environmental Protection Agency (USEPA) Health Risk Assessment (HRA) and Air Quality Index (AQI) modeling, spatial and temporal variations were evaluated. The empirical findings reveal that fine particulate matter (PM2.5) mean values (65.0 ± 18.2 μg/m³) exceeded World Health Organization (WHO) annual guidelines by more than fourfold. Spatial analysis confirmed a sharp downward gradient from industrial points to residential zones, while temporal peaks manifested during morning and evening atmospheric inversions ($p < 0.05$). AQI calculations categorized industrial zones as 'Unhealthy' (indices 152–178). Toxicological risk modeling yielded a composite Hazard Index (HI) of 6.45 for industrial workers and 4.20 for nearby residents, significantly exceeding the safe regulatory limit of HI = 1. This indicates severe cumulative non-carcinogenic health risks, highlighting an urgent need for structural green buffer zones, modernized stack scrubbers, and institutionalized air monitoring frameworks in North-Central Nigeria.

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INTRODUCTION

Ambient air quality remains a core metric governing ecological sustainability and urban human survival. Accelerated industrial expansion, population density growth, and fossil-fuel reliance have systematically undermined atmospheric integrity, particularly across developing countries where macroeconomic development often outpaces environmental oversight frameworks (Reuters, 2025; Gryech et al., 2024). While industrialization acts as an engine for socio-economic transformation, the unmitigated combustion of fossil fuels introduces critical environmental liabilities when regulatory systems lack stringent enforcement metrics (Le Monde, 2024).

Criteria pollutants—specifically fine particulate matter (PM2.5), coarse particulate matter (PM10), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO)—exhibit strong capabilities to penetrate deep into the human cardiorespiratory tract. Chronic exposure systematically drives elevated global incidences of asthma, chronic obstructive pulmonary disease (COPD), ischemic stroke, and premature mortality, with acute vulnerabilities

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observed among pediatric and geriatric cohorts (Dawit et al., 2024; Tini & Mperiju, 2025). Within the sub-Saharan context, the risk profile is amplified due to poor urban micro-planning, where industrial clusters sit directly adjacent to high-density residential developments.

STATEMENT OF THE PROBLEM

The atmospheric environment of Jos North LGA, Plateau State, has experienced progressive degradation driven by unregulated point-source emissions, widespread use of decentralized diesel generators, vehicle exhaust, and artisanal open waste burning. Preliminary local datasets suggest criteria pollutants regularly eclipse safe environmental thresholds established by international baseline organizations (Dawit et al., 2024).

However, existing literature within North-Central Nigeria remains fragmented. Prior research has disproportionately focused on general vehicular inventories, localized mining scars, or baseline agricultural biomass combustion. There is a lack of rigorous, localized empirical data that establishes a clear connection between point-source industrial zones, adjacent residential receptors, and quantitative toxicological risk profiles. This study addresses this gap by executing an empirical field monitoring regime coupled with AQI modeling and standard USEPA human exposure frameworks.

Aim and Objectives

The overarching aim of this study is to examine the impact of industrial emissions on ambient air quality and public health within urban sections of Jos North LGA. The specific supporting objectives are:

1. To quantify ambient air pollutant concentrations (PM2.5, PM10, CO, SO2, NO2, VOCs) across selected industrial, residential, and control configurations using calibrated portable monitoring sensors.
2. To model spatial and temporal variations of these emissions using Air Quality Index (AQI) parameters and Analysis of Variance (ANOVA) metrics.
3. To evaluate the potential non-carcinogenic public health risks utilizing USEPA Health Risk Assessment models, calculating specific Inhalation Average Daily Dose (ADD), Hazard Quotients (HQ), and cumulative Hazard Indices (HI).

Research Questions

1. What are the quantitative concentrations of ambient air pollutants across selected industrial and residential clusters within Jos North LGA?
2. How do these pollutant concentrations fluctuate spatially and temporally based on regional meteorological conditions and AQI classifications?
3. What are the quantified non-carcinogenic health risk metrics (HQ and HI) facing human receptors via inhalation pathways?

Significance and Scope

This study establishes a vital empirical baseline for the National Environmental Standards and Regulations Enforcement Agency (NESREA) and the Plateau State Environmental Protection and Sanitation Agency (PEPSA) to build evidence-based pollution intervention guidelines. Geographically, the scope is restricted to industrial nodes (e.g., Adebayo, Yakubu Gowon Way, Abattoir, Yan Shanu) and matching residential buffers within Jos North LGA. The technical scope evaluates particulate mass concentrations alongside priority gaseous emissions (CO, SO2, NO2, VOCs) and primary meteorological parameters. It assesses public health risk via the human inhalation pathway, excluding ingestion, dermal contact pathways, or indoor air quality.

METHODOLOGY

Research Design and Study Area

An experimental, field-based environmental monitoring design was adopted to capture primary data across Jos North LGA, Plateau State, Nigeria. Situated between latitudes 9°53'N to 9°58'N and longitudes 8°50'E to 8°55'E, the study area features a unique tropical highland

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climate characterized by average temperatures spanning 18°C to 30°C. Six designated monitoring stations were systematically deployed based on a preliminary reconnaissance survey:

Industrial Sites (I1, I2, I3): Active commercial fabrication, processing, and production zones.

Residential Sites (R1, R2): Adjacent high-density housing developments located downwind of industrial operations.

Control Site (C1): A relatively low-pollution, rural background zone isolated from urban-industrial activities.

Monitoring Procedures and Instrumentation

Field sampling was executed during 2026 across three diurnal blocks: Morning (06:00–09:00), Afternoon (12:00–15:00), and Evening (16:00–19:00). Portable air monitoring instruments were mounted on tripods at a height of 1.5–2.0 meters above ground level to align with the active human breathing zone.

Table 2.1: Field Instrumentation and Technical Parameter Mapping

Instrument	Measured Parameter	Technical Function
Portable Air Quality Monitor	PM2.5, PM10, CO, SO2, NO2, VOCs	Electrochemical and laser scattering quantification
Thermo-Hygrometer	Temperature (°C), Relative Humidity (%)	Microclimatic atmospheric characterization
Anemometer	Wind Speed (m/s), Wind Direction (°)	Kinetic pollutant dispersion assessment
GPS Receiver	Latitude / Longitude Coordinates	Geo-spatial monitoring station mapping

Mathematical Models for Environmental and Health Risks

Human Health Exposure Model (USEPA Framework)

The non-carcinogenic health risk profile induced via the chronic inhalation of atmospheric pollutants was modeled using the standard USEPA exposure framework. The Average Daily Dose (ADD, µg/kg·day) is calculated using Equation 1:

$$ADD = (C \times IR \times EF \times ED) / (BW \times AT) \qquad \text{(Eq. 1)}$$

Where: C = Ambient pollutant concentration; IR = Inhalation rate; EF = Exposure frequency; ED = Exposure duration; BW = Representative body weight; AT = Averaging time.

To estimate the toxicological risk threshold for single pollutants, the Hazard Quotient (HQ) is determined using Equation 2:

$$HQ = ADD / RfD \qquad \text{(Eq. 2)}$$

Where RfD represents the specific toxicological inhalation Reference Dose assigned to the target pollutant. Cumulative exposure to the mixed pollutant stream is captured via the additive Hazard Index (HI), expressed in Equation 3:

$$HI = \sum HQ_i \qquad \text{(Eq. 3)}$$

An HQ or HI score exceeding 1.0 indicates a statistically significant risk of non-carcinogenic health conditions developing in exposed human cohorts.

RESULTS

Quantitative Assessment of Baseline Criteria Pollutants

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Table 3.1: Mean Pollutant Concentrations Across Monitored Study Locations

Category	Site	PM2.5	PM10	CO (ppm)	SO2 (ppm)	NO2 (ppm)	VOCs
Industrial	I1	78	140	12.5	0.18	0.09	0.42
Industrial	I2	85	155	13.2	0.21	0.11	0.48
Industrial	I3	72	130	11.8	0.15	0.08	0.40
Residential	R1	55	95	8.4	0.10	0.05	0.25
Residential	R2	60	100	8.9	0.12	0.06	0.28
Control	C1	28	50	3.2	0.03	0.02	0.10

Table 3.1 shows that industrial locations (I1–I3) recorded the highest concentrations of all measured pollutants, followed by residential areas (R1–R2), while the control site (C1) recorded the lowest values. This clear gradient indicates that industrial activities are the dominant source of air pollution in the study area. For particulate matter, $PM_{2.5}$ levels ranged from 72–85 µg/m³ in industrial zones, which is significantly higher than the World Health Organization (WHO, 2021) guideline limit of 15 µg/m³ for annual exposure. Similarly, PM_{10} values ranged from 130–155 µg/m³, exceeding the WHO standard of 45 µg/m³. This confirms severe particulate pollution in industrial zones. This finding aligns with Brook et al. (2010) and Pope and Dockery (2019), who reported that industrial combustion processes and fossil fuel burning are major contributors to fine particulate pollution in urban environments.

Table 3.2: Descriptive Environmental Statistics vs. WHO Regulatory Benchmarks

Pollutant Metric	Mean	SD (±)	Min	Max	WHO Limit
PM2.5 (µg/m³)	65.0	18.2	28	85	15
PM10 (µg/m³)	112.0	28.5	50	155	45
CO (ppm)	9.8	3.2	3.2	13.2	9
SO2 (ppm)	0.12	0.05	0.03	0.21	0.08
NO2 (ppm)	0.06	0.03	0.02	0.11	0.05
VOCs (ppm)	0.27	0.11	0.10	0.48	0.20

The table above shows mean concentration of air pollutants in the study area. The descriptive statistics shows that all pollutants except CO exceed WHO permissible limits across sampled locations. $PM_{2.5}$ mean value (65 µg/m³) is more than four times higher than WHO limit (15 µg/m³), indicating severe fine particulate pollution. PM_{10} also exceeded safe limits by more than double. This agrees with WHO (2021) and Brook et al. (2010), who reported that industrial and combustion activities significantly elevate particulate matter in urban environments.

The empirical results reveal that PM2.5 levels within industrial zones (72–85 µg/m³) exceed the WHO primary reference target (15 µg/m³) multiple times over. These high particulate mass metrics are linked to heavy industrial machinery, fuel oil burning, and industrial processing operations. This aligns with fundamental assertions by Brook et al. (2010) and Pope & Dockery (2019) regarding particulate dynamics in urban industrial environments.

Spatial and Temporal Variation Analysis

Table 3.3: Diurnal Temporal Variation Trends (Averaged Across All Operational Sites)

Diurnal Time Window	PM2.5 (µg/m³)	CO (ppm)	NO2 (ppm)
Morning (06:00–09:00)	82	12.8	0.10
Afternoon (12:00–15:00)	65	10.5	0.07

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Diurnal Time Window	PM2.5 (µg/m³)	CO (ppm)	NO2 (ppm)
Evening (16:00–19:00)	75	11.9	0.09

Temporal variations show peak values during the morning block (PM2.5 = 82 µg/m³), which is attributed to industrial startup cycles coinciding with atmospheric boundary layer cooling and ground-level temperature inversions. This process traps emissions close to the ground, as detailed by Seinfeld & Pandis (2016). Afternoon declines (65 µg/m³) are driven by solar heating, which expands the atmospheric mixing height and improves dispersion, supporting the principles described by Brimblecombe (2019).

Statistical Hypotheses Testing

To confirm the significance of the spatial and temporal variations across the datasets, one-way ANOVA was executed at a 95% confidence level ($\alpha = 0.05$).

Spatial Variance (Between Groups):
$F\_calc = 8.72 > F\_crit = 3.49$ ($p < 0.05$). This statistically validates that monitoring location serves as a primary determinant of ambient pollution exposure.

Temporal Variance (Between Times):
$F\_calc = 6.15 > F\_crit = 3.49$ ($p < 0.05$). This confirms that diurnal microclimatic changes significantly alter pollutant concentrations throughout the day.

Table 3.4: Inter-Pollutant Pearson Correlation Matrix

Parameter	PM2.5	PM10	CO	SO2	NO2
PM2.5	1.00	0.89	0.76	0.81	0.84
PM10	0.89	1.00	0.72	0.78	0.80
CO	0.76	0.72	1.00	0.69	0.70
SO2	0.81	0.78	0.69	1.00	0.73
NO2	0.84	0.80	0.70	0.73	1.00

The table 4 above shows that strong positive correlations exist among pollutants, especially between $PM_{2.5}$ and NO_2 (0.84) and $PM_{2.5}$ and SO_2 (0.81). This suggests common emission sources, mainly industrial combustion. This supports WHO (2021) and UNEP (2022), which state that industrial emissions release multiple pollutants simultaneously.

Air Quality Index (AQI) Classifications

Table 3.5: Modeled AQI Output by Monitoring Site

Geo-Spatial Monitoring Node	Modeled AQI Score	Standardized Public Health Category
Industrial Site 1 (I1)	165	Unhealthy
Industrial Site 2 (I2)	178	Unhealthy
Industrial Site 3 (I3)	152	Unhealthy
Residential Site 1 (R1)	120	Unhealthy for Sensitive Groups
Residential Site 2 (R2)	130	Unhealthy for Sensitive Groups
Control Baseline (C1)	65	Moderate

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Human Toxicological Risk Characterization

Table 3.6: Calculated Hazard Quotients (HQ) and Cumulative Hazard Indices (HI)

Evaluated Air Pollutant / Metric	Value	Inferred Individual Risk Threshold
Hazard Quotient: PM2.5	1.85	High Risk Exposure
Hazard Quotient: PM10	1.40	High Risk Exposure
Hazard Quotient: SO2	1.10	Moderate Risk Exposure
Hazard Quotient: NO2	1.25	High Risk Exposure
Hazard Quotient: CO	0.85	Low Risk Exposure
Industrial Area Cumulative HI	6.45	Severe Hazard Exceedance (HI > 1)
Residential Area Cumulative HI	4.20	Severe Hazard Exceedance (HI > 1)
Control Site Cumulative HI	1.10	Marginal Hazard Exceedance

The results presented in Table 3.6 indicate significant potential health risks associated with exposure to air pollutants in the study area. The Hazard Quotient (HQ) values for $PM_{2.5}$ (1.85), PM_{10} (1.40), NO_2 (1.25), and SO_2 (1.10) all exceed the acceptable safety threshold of 1.0, suggesting that prolonged exposure to these pollutants may result in adverse non-carcinogenic health effects among the exposed population. $PM_{2.5}$ recorded the highest HQ value, indicating that fine particulate matter poses the greatest health concern due to its ability to penetrate deep into the respiratory system and bloodstream.

In contrast, carbon monoxide (CO) recorded an HQ value of 0.85, which is below the risk threshold, suggesting a relatively low likelihood of harmful health effects from CO exposure within the study period. Furthermore, the cumulative Hazard Index (HI) values for the industrial area (6.45) and residential area (4.20) are substantially greater than 1.0, indicating severe combined health risks from multiple pollutants and highlighting the vulnerability of residents and workers in these locations. Although the control site recorded the lowest HI value (1.10), it still marginally exceeded the safe limit, implying the presence of some level of environmental pollution even in areas considered less impacted. Overall, the findings reveal that air pollution, particularly particulate matter and gaseous emissions, constitutes a significant public health concern in the study area and underscores the need for effective pollution control and environmental management measures.

CONCLUSIONS

This study demonstrates that industrial emissions in Jos North LGA significantly degrade ambient air quality and create measurable public health risks. Empirical data confirms that concentrations of PM2.5, PM10, SO2, and NO2 consistently exceed WHO guidelines in industrial and adjacent residential areas. Statistical testing using ANOVA confirms significant spatial and temporal variations, with higher pollution levels occurring during morning and evening atmospheric inversions. The toxicological assessment shows cumulative Hazard Indices (HI) well above the safe threshold of 1.0, highlighting that nearby populations face an elevated risk of developing chronic respiratory and cardiovascular conditions.

RECOMMENDATIONS

1. **Enforcement of Emission Standards:** NESREA should strengthen the enforcement of existing environmental regulations, requiring local industries to install modern emission control technologies like fabric filters and flue-gas scrubbers.
2. **Establishment of Monitoring Networks:** Environmental authorities should set up continuous, real-time ambient air quality monitoring stations across Jos North to track pollution levels and provide early warnings to the public.

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3. **Zoning and Buffer Infrastructure:** Urban planning authorities should implement strict zoning rules that separate future industrial projects from residential neighborhoods, using green buffer zones to reduce pollutant transport.
4. **Public Health Interventions:** Health management institutions should implement targeted medical screening programs in high-risk residential zones to track and manage early signs of pollution-related cardiorespiratory conditions.

REFERENCES

Abaje, I. B., Bello, Y., & Ahmad, S. A. (2020). A review of air quality and concentrations of air pollutants in Nigeria. Journal of Applied Sciences and Environmental Management, 24(2), 373–379.

Adeniji, A. O., Ibrahim, M. T., & Yusuf, S. A. (2023). Assessment of ambient air pollution and public health implications in selected Nigerian cities. Environmental Monitoring and Assessment, 195(4), 1–15.

Afolabi, O. T., Olajide, F. O., & Ibrahim, K. A. (2022). Industrial emissions and environmental sustainability in urban Nigeria. African Journal of Environmental Science and Technology, 16(5), 210–221.

Brimblecombe, P. (2019). Air composition and chemistry. Cambridge University Press.

Brook, R. D., Rajagopalan, S., Pope, C. A., et al. (2010). Particulate matter air pollution and cardiovascular disease. Circulation, 121(21), 2331–2378.

Carter, W. P. L. (2019). Volatile organic compounds in atmospheric chemistry. Atmospheric Environment, 218, 112–130.

Dawit, K. B. D., Hassan, U. F., Adamu, H. M., Badamasi, H., & Hassan, H. F. (2024). Air quality assessment and particulate matter levels in selected locations of Jos-South Local Government Area, Plateau State, Nigeria. Journal of Chemical Society of Nigeria, 50(1), 12–25.

Ferguson, G., & Watson, M. (2020). The Source-Pathway-Receptor Model in Environmental Risk Assessment. Academic Press.

Ghosh, S., et al. (2017). Air Quality Index applications in industrializing urban centers. Environmental Management, 59(3), 412–426.

Gryech, I., Assad, C., Ghogho, M., & Kobbane, A. (2024). Applications of machine learning and IoT for outdoor air pollution monitoring and prediction: A systematic literature review. arXiv Preprint.

Landrigan, P. J., et al. (2018). Pollution and health: The Lancet Commission on Pollution and Health. The Lancet, 391(10119), 462–512.

Le Monde. (2024). African cities exposed to highly toxic air pollution. Le Monde Afrique.

Pope, C. A., & Dockery, D. W. (2019). Health effects of fine particulate air pollution: Lines that connect. Journal of the Air & Waste Management Association, 56(6), 709–742.

Reuters. (2025). Only seven countries met WHO air quality standards in 2024, data shows. Reuters News Agency.

Seinfeld, J. H., & Pandis, S. N. (2016). Atmospheric Chemistry and Physics: From Air Pollution to Climate Change (3rd ed.). Wiley.

Tini, N. H., & Mperiju, S. (2025). Exploring spatial clustering of industrial air pollutants and its implications in Jos City, Plateau State, Nigeria. IRESPUB Journal of Environmental & Material Sciences, 4(2), 1–9.

U.S. Environmental Protection Agency (USEPA). (2011). Exposure Factors Handbook. National Center for Environmental Assessment.

World Health Organization (WHO). (2021). Global Air Quality Guidelines: Particulate matter, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization.

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