

Distance Based Assessment of Ambient Air Quality in Residential Areas Surrounding Major Market Hubs in Awka South LGA, Anambra State

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ABSTRACT: Rapid urbanization in developing countries has intensified ambient air pollution, particularly within mixed residential-commercial environments. This study assessed distance-based variation in ambient air quality surrounding major market hubs in Awka South Local Government Area (LGA), Anambra State, Nigeria. A cross-sectional field measurement design was adopted using structured radial buffers (0–50 m, 50–100 m, and >100 m) extending from the geometric centers of Amaenyi and Eke Awka markets into adjacent residential zones. A portable multi-parameter air quality monitor measured wind speed, formaldehyde (HCHO), total volatile organic compounds (TVOC), carbon monoxide (CO), carbon dioxide (CO₂), fine particulate matter (PM_{2.5}), temperature, humidity, and Air Quality Index (AQI). Results indicate that pollutant concentrations were generally highest within the immediate 0–50 m commercial interface and declined with increasing distance, particularly at Amaenyi Market, supporting the distance-decay principle. CO decreased from 4 ppm (0–50 m) to 1 ppm (>100 m), while CO₂ declined from 823 ppm to 510 ppm across the same gradient. However, Eke Awka exhibited a pronounced pollution hotspot within 0–50 m, where CO (74 ppm), CO₂ (1505 ppm), and TVOC (7.343) were markedly elevated. PM_{2.5} concentrations (15–27 µg/m³) exceeded the WHO 24-hour guideline (15 µg/m³) at most sampling points. Wind speed demonstrated an inverse relationship with pollutant concentrations, indicating meteorological mediation of dispersion. The findings confirm that residential proximity to major market hubs significantly influences exposure intensity, with localized emission clustering and low wind conditions amplifying pollution levels. The study provides spatially differentiated evidence to inform urban zoning, buffer regulation, and environmental health policy in rapidly urbanizing Nigerian cities.

KEYWORDS: Ambient Air Quality; Air Pollution; Distance-Decay Principle; Market Emission Hotspots; Residential Exposure; PM_{2.5}; Urban Dispersion Dynamics; Awka South.

1.0 INTRODUCTION

Urbanization has become one of the most transformative global processes of the twenty-first century, fundamentally reshaping environmental systems and atmospheric composition. The United Nations (2019) notes that over half of the global population now resides in urban areas, with the most rapid growth occurring in low- and middle-income countries. Cohen (2006) emphasizes that this accelerated expansion is frequently accompanied by intensified environmental pressures, including deteriorating air quality. As cities expand spatially and commercially, atmospheric systems are increasingly burdened by emissions from transportation, energy generation, industrial activity, and informal economic processes. Unlike localized industrial pollution characteristic of earlier urbanization phases, contemporary urban air pollution is diffuse, multi-sourced, and embedded within daily economic activity (Seinfeld & Pandis, 2016).

Ambient air pollution has emerged as one of the most significant environmental health risks globally. The World Health Organization identifies air pollution as a leading cause of premature mortality, with exposure to particulate matter (PM_{2.5} and PM₁₀), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), carbon monoxide (CO), and ozone (O₃) linked to cardiovascular disease, chronic respiratory illness, lung cancer, and adverse pregnancy outcomes (WHO, 2021). The Health Effects Institute (HEI, 2020), through the Global Burden of Disease assessment, estimates that millions of deaths annually are attributable to ambient air pollution exposure. Fine particulate matter (PM_{2.5}) is particularly harmful due to its ability to penetrate deep into the respiratory tract and enter the bloodstream, triggering systemic inflammation and oxidative stress (Brauer et al., 2012). These findings underscore that air quality degradation represents not merely an environmental management issue but a profound public health concern requiring spatially precise monitoring and intervention.

In developing countries, the dynamics of urban air pollution are closely linked to informal economic structures and infrastructural constraints. Arku et al. (2011) and Amegah and Agyei-Mensah (2017) observe that weak regulatory enforcement, reliance on fossil fuel-powered generators, aging vehicle fleets, poor fuel quality, and high-density roadside commercial activity intensify pollutant

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concentrations in African cities. In Nigeria, multiple empirical studies report particulate matter and gaseous pollutant levels exceeding both national standards and international guidelines, particularly in commercial corridors and traffic-dense zones (Efe, 2008; Olukanni et al., 2014). Emissions from poorly maintained vehicles, petrol and diesel generators, open burning of waste, and re-suspended road dust collectively contribute to elevated ambient concentrations. These findings indicate that urban air pollution in Nigeria is systemic and spatially concentrated around economic activity nodes.

Within urban systems, major market hubs function as micro-emission clusters. Markets concentrate vehicular inflow and outflow, prolonged engine idling, small-scale combustion from generators, food processing activities, waste handling, and dense human congregation within confined areas. Studies conducted in comparable urban contexts demonstrate that such commercial clusters often generate localized hotspots of particulate and gaseous pollutants (Amegah & Agyei-Mensah, 2017). The intensity of emissions within these hubs can significantly exceed background urban concentrations, particularly during peak trading periods. However, unlike large industrial facilities that may be spatially zoned and regulated, market hubs are typically embedded within mixed residential-commercial fabrics, allowing pollutants to disperse directly into surrounding living environments.

The spatial behavior of air pollutants is governed by emission–dispersion–exposure dynamics. Atmospheric science demonstrates that pollutant concentrations generally decline with increasing distance from dominant emission sources due to dilution, dispersion, and chemical transformation processes (Seinfeld & Pandis, 2016). This attenuation pattern aligns conceptually with the distance-decay principle, which posits that the intensity of a spatial phenomenon diminishes with increasing distance from its source (Batty, 2008). However, dispersion is influenced by multiple factors, including wind speed and direction, atmospheric stability, building density, and street-canyon effects (Brauer et al., 2012). In dense urban environments with limited ventilation corridors, pollutants may remain trapped, compressing expected concentration gradients and prolonging residential exposure.

Empirical literature on urban air quality in Nigeria reveals important methodological trends and limitations. Many studies employ fixed-point monitoring or short-term sampling within high-traffic corridors, reporting average pollutant concentrations without structured radial classification (Efe, 2008; Olukanni et al., 2014). While such approaches document exceedances relative to permissible standards, they often lack spatial differentiation necessary to model concentration gradients across residential buffers. Furthermore, temporal sampling durations are frequently limited, reducing the capacity to evaluate variability across peak and non-peak commercial periods. Although some international studies integrate Geographic Information Systems (GIS) and dispersion modeling techniques to map pollutant contours (Brauer et al., 2012), similar structured gradient-based assessments remain limited within Nigerian market environments.

The health implications of proximity to high-emission commercial hubs are well documented. Chronic exposure to elevated particulate matter concentrations has been associated with increased hospital admissions, reduced lung function, and heightened cardiovascular risk (WHO, 2021; HEI, 2020). Vulnerable populations including children, the elderly, and individuals with pre-existing respiratory conditions are particularly susceptible to inhalation-related morbidity. In mixed land-use settings where residential buildings are located adjacent to emission-intensive commercial clusters, sustained exposure becomes a significant concern. From an environmental planning perspective, proximity therefore emerges as a critical determinant of exposure intensity. Within this broader national context, Awka, the capital city of Anambra State, has experienced sustained commercial expansion and demographic growth over recent decades (National Population Commission, 2006; Anambra State Government Reports). Awka South Local Government Area hosts several major markets that function as primary economic nodes, attracting daily vehicular congestion, generator use, informal trading activities, and waste accumulation. Residential developments have simultaneously proliferated around these commercial corridors, reflecting spatial patterns characteristic of rapidly urbanizing southeastern Nigerian cities (Agbola, 2004). The resulting spatial intermingling of emission sources and residential dwellings creates potential exposure gradients whose magnitude remains empirically underexplored.

Despite growing concern regarding urban air pollution in Nigeria, three interrelated gaps remain evident. First, a geographical gap exists: no study has systematically quantified ambient air pollutant attenuation gradients around major market hubs in Awka South LGA. Second, a methodological gap persists: Nigerian urban air quality research rarely applies structured radial distance classification to assess dispersion patterns within residential–commercial interfaces. Most assessments rely on single-location sampling or generalized corridor analysis without explicitly modeling concentration decline across defined buffer intervals. Third, a policy-relevant gap is apparent: localized data comparing pollutant concentrations in market-proximal residential zones with international guideline thresholds remain scarce. Without such evidence, zoning decisions, buffer design strategies, and environmental regulation lack a robust empirical foundation.

Addressing these gaps requires a structured, distance-based assessment capable of generating spatially differentiated evidence regarding pollutant dispersion and residential exposure. By operationalizing radial distance as a primary analytical variable, this study seeks to determine whether ambient air pollutant concentrations surrounding major market hubs in Awka South LGA attenuate sufficiently to meet recommended standards or whether spatial proximity sustains elevated exposure levels. In doing so, the study situates market hubs within an emission–dispersion–exposure framework, providing data necessary for informed urban planning, environmental governance, and public health protection within the evolving urban landscape of Anambra State.

2.0 MATERIALS AND METHODS

2.1 Research Design

This study adopted a cross-sectional field measurement design to evaluate ambient air quality across defined radial distances from selected major market hubs in Awka South Local Government Area (LGA). A structured distance-based assessment framework was employed to examine pollutant attenuation patterns in line with the distance-decay principle (Batty, 2008). The design enables systematic comparison of pollutant concentrations across residential zones situated at varying proximities to emission-intensive commercial hubs.

2.2 Study Area

The study was conducted in Awka South Local Government Area, located in Awka, the capital of Anambra State in southeastern Nigeria. Awka South constitutes the administrative and commercial core of the state and is characterized by rapid urban expansion, mixed land-use development, and high population density.

Two major market hubs; Amaenyi Market and Eke Awka Market were purposively selected due to their high commercial intensity and direct spatial integration with surrounding residential neighborhoods. These markets experience substantial vehicular inflow and outflow, frequent generator use, roadside trading activities, and waste accumulation, making them significant localized emission sources. In many instances, residential buildings are situated within immediate proximity to market corridors, creating minimal buffer separation between emission sources and living spaces.

The study area lies within a tropical climatic zone marked by distinct wet and dry seasons. The urban morphology is characterized by compact building arrangements, limited ventilation corridors, and closely interconnected road networks. Such spatial configuration may influence pollutant dispersion and potential concentration trapping within residential–commercial interfaces.

2.3 Air Quality Measurement Procedure

Ambient air pollutant concentrations were measured using a calibrated portable multi-parameter air quality monitor capable of simultaneously detecting:

Wind speed

Formaldehyde (HCHO)

Total Volatile Organic Compounds (TVOC)

Carbon Monoxide (CO)

Carbon Dioxide (CO₂)

Fine Particulate Matter (PM_{2.5})

Ambient Temperature

Relative Humidity

Air Quality Index (AQI)

The instrument was factory-calibrated prior to deployment and field-checked to ensure measurement accuracy.

To ensure methodological consistency and minimize bias:

Measurements were taken at approximately 1.5 meters above ground level, approximating average human breathing height.

The device was positioned away from immediate reflective or obstructive surfaces.

Readings were recorded under stable placement conditions to prevent artificial airflow interference.

Each sampling session was conducted over 15 minutes standardized monitoring intervals to ensure comparability across sites.

Pollutant concentrations were recorded in appropriate units (µg/m³ for PM_{2.5}, ppm for CO and CO₂, mg/m³ or ppb for HCHO and TVOC where applicable). The AQI values were recorded as generated by the monitoring device, based on integrated pollutant concentrations.

2.4 Distance Classification and Sampling Framework

A structured radial distance approach was adopted. Measurement points were established along transects extending outward from the geometric center of each market hub into adjacent residential zones.

Distance bands were classified as follows:

0–50 meters: Immediate commercial interface

50–100 meters: Transitional residential zone

100 meters and above: Outer residential buffer

Multiple sampling points were established within each distance band to enhance spatial representativeness and reduce sampling bias. This approach enabled structured comparison of pollutant concentrations across defined proximity intervals.

2.5 Temporal Sampling

Measurements were conducted during:

Peak market activity periods (morning and afternoon hours)

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Relatively lower activity periods, where feasible

This temporal stratification accounted for variability in emission intensity associated with vehicular congestion, generator operation, and commercial activity patterns. Meteorological variables, including wind speed, temperature, and relative humidity were recorded concurrently with pollutant concentrations to account for atmospheric influences on dispersion dynamics.

2.6 Data Analysis

Collected data were organized according to market hub and radial distance classification. Data analysis involved:

Computation of descriptive statistics (mean, minimum, maximum, and standard deviation) for each pollutant within each distance band.

Comparative analysis across radial intervals to assess attenuation patterns consistent with theoretical distance-decay expectations.

Evaluation of observed pollutant concentrations against recommended international ambient air quality guidelines, particularly for PM_{2.5} and CO.

Examination of relationships between meteorological parameters (wind speed, temperature, humidity) and pollutant levels to interpret dispersion behavior.

Attenuation gradients were assessed to determine whether pollutant concentrations decline with increasing distance from market hubs or whether spatial confinement and urban morphology sustain elevated exposure within residential buffers.

The structured distance-based analytical approach provides spatially differentiated evidence necessary for environmental planning, zoning regulation, and public health protection within rapidly urbanizing market-centered urban environments.

3.0 RESULTS AND FINDINGS

3.1 Overview of Measured Ambient Air Quality Parameters

Ambient air quality parameters measured across the selected sampling points in Amaenyi Market and Eke Awka Market are presented in Table 1.

Table 1: Measured Ambient Air Quality Parameters Across Sampling Points

Location	Wind Speed (m/s)	HCHO	TVOC	CO (ppm)	CO ₂ (ppm)	PM _{2.5} (µg/m ³)	Humidity (%)	Temp (°C)	AQI
Amaenyi – >100m	0.5	0.058	0.205	4	823	25	58	36.1	17
Amaenyi – 100-50m	2.2	0.055	0.034	1	540	25	53	40.6	17
Amaenyi – <50m	1.1	0.060	0.019	1	510	22	55	37.5	12
Eke Awka – >100m	3.1	0.041	0.023	1	555	17	59	35.1	12
Eke Awka – 100-50m	3.5	0.042	0.020	1	524	15	57	36.0	15
Eke Awka – <50m	0.1	0.065	7.343	74	1505	27	56	35.0	48

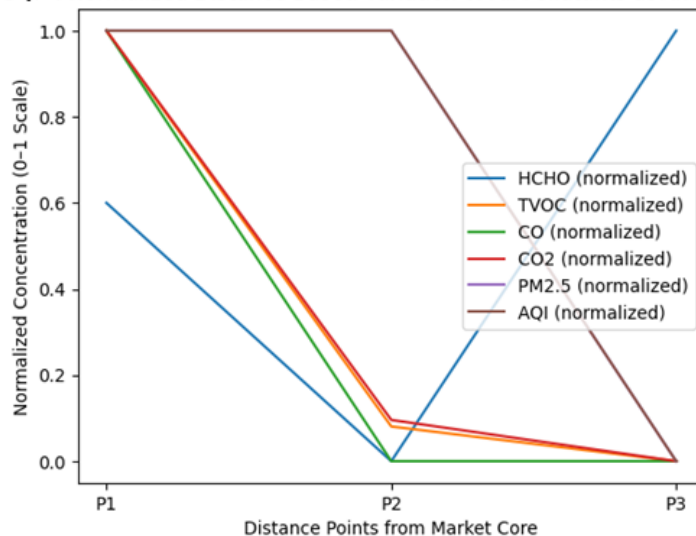
Across all sampling locations, wind speed varied between 0.1 and 3.5 m/s, indicating considerable differences in atmospheric dispersion potential across the study area. Formaldehyde (HCHO) concentrations ranged from 0.041 to 0.065, while Total Volatile Organic Compounds (TVOC) showed a broader variation from 0.019 to 7.343. Carbon monoxide (CO) levels ranged from 1 to 74 ppm, and carbon dioxide (CO₂) concentrations varied between 510 and 1505 ppm. Fine particulate matter (PM_{2.5}) concentrations were observed within the range of 15 to 27 µg/m³, while the Air Quality Index (AQI) values ranged from 12 to 48, reflecting varying degrees of air quality across the sampled locations. Notably, the highest pollutant concentrations were recorded at Eke Awka – P3, where CO (74 ppm), CO₂ (1505 ppm), and TVOC (7.343) were markedly elevated compared to other sampling points, indicating the presence of a localized pollution hotspot within the study area.

3.2 Distance-Based Variation in Pollutant Concentrations

3.2.1 Amaenyi Market

At Amaenyi Market, pollutant concentrations generally exhibited a declining trend with increasing distance from the market core. Carbon monoxide (CO) concentrations decreased markedly from 4 ppm at P1 (above 100m) to 1 ppm at both P2 (100m – 50m) and P3 (less than 50m), indicating a substantial reduction in combustion-related emissions away from the immediate commercial interface. Similarly, carbon dioxide (CO₂) concentrations declined from 823 ppm at P1 to 510 ppm at P3, reflecting reduced emission intensity with spatial separation from the market center. Fine particulate matter (PM_{2.5}) showed a slight decrease from 25 µg/m³ at P1 and P2 to 22 µg/m³ at P3. The Air Quality Index (AQI) also reduced from 17 at P1 and P2 to 12 at P3. Overall, this spatial pattern suggests partial conformity with the distance-decay principle, indicating that pollutant concentrations attenuate progressively as distance from the primary emission source increases.

Figure 1 : Normalized Distance-Based Variation of All Pollutants at Amaenyi Market

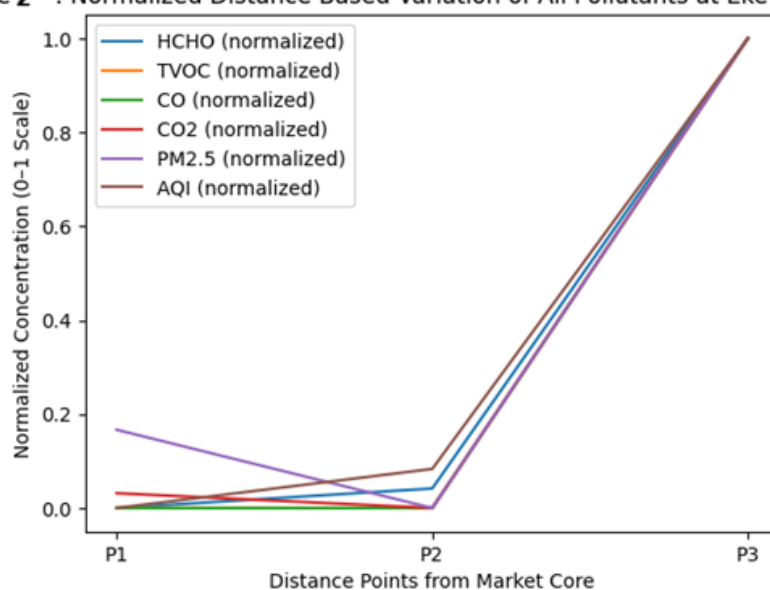


3.2.2 Eke Awka Market

At Eke Awka Market, the attenuation pattern was less consistent and did not clearly conform to the expected distance-decay trend. Under normal dispersion conditions, pollutant concentrations would be expected to decrease progressively from P3 (less than 50 m) to P1 (100 m and above). However, the observed pattern deviated from this theoretical expectation. While P1 and P2 recorded relatively moderate pollutant levels, a pronounced concentration spike was observed at P3, the immediate commercial interface. Carbon monoxide (CO) increased sharply to 74 ppm at P3, compared to only 1 ppm at both P1 and P2, indicating intense localized combustion-related emissions near the market core. Similarly, carbon dioxide (CO₂) rose substantially to 1505 ppm at P3, relative to 555 ppm and 524 ppm at P1 and P2, respectively.

Total Volatile Organic Compounds (TVOC) also exhibited a marked increase at P3 (7.343), significantly exceeding concentrations recorded at the outer sampling points. Fine particulate matter (PM_{2.5}) increased to 27 µg/m³ at P3, compared to 15–17 µg/m³ at P1 and P2, further reinforcing the presence of concentrated emission activity in the immediate market zone. The Air Quality Index (AQI) correspondingly peaked at 48 at P3, indicating comparatively poorer air quality conditions within the immediate commercial interface. Unlike the relatively structured attenuation observed at Amaenyi Market, the concentration gradient at Eke Awka did not demonstrate a smooth progressive decline from the market core outward. Instead, pollutant levels remained moderate at P2 and P1 but escalated sharply at P3. This suggests the influence of intense localized emission sources such as prolonged vehicular idling, generator clusters, confined street-canyon geometry, or atmospheric stagnation limiting dispersion. Overall, the findings indicate that proximity remains a dominant exposure determinant at Eke Awka, though micro-environmental conditions appear to disrupt a simple linear distance-decay pattern.

Figure 2 : Normalized Distance-Based Variation of All Pollutants at Eke Awka Market



3.3 Influence of Meteorological Conditions on Pollutant Dispersion

Wind speed varied considerably across the sampling locations and appeared to play a significant role in influencing pollutant distribution patterns. Higher wind speeds recorded at Eke Awka P1 and P2 (3.1–3.5 m/s) were associated with lower concentrations of fine particulate matter (PM_{2.5}), ranging from 15 to 17 µg/m³, and relatively stable carbon monoxide (CO) levels of 1 ppm. In contrast, the lowest wind speed observed at Eke Awka P3 (0.1 m/s) coincided with the highest recorded concentrations of CO, CO₂, TVOC, and PM_{2.5}. This pattern suggests that limited air movement may have reduced atmospheric dispersion capacity at P3, thereby contributing to the accumulation of pollutants. The observed relationship between wind speed and pollutant concentration aligns with established atmospheric dispersion theory, which posits that lower wind velocities can promote pollutant stagnation and elevated exposure levels within localized environments.

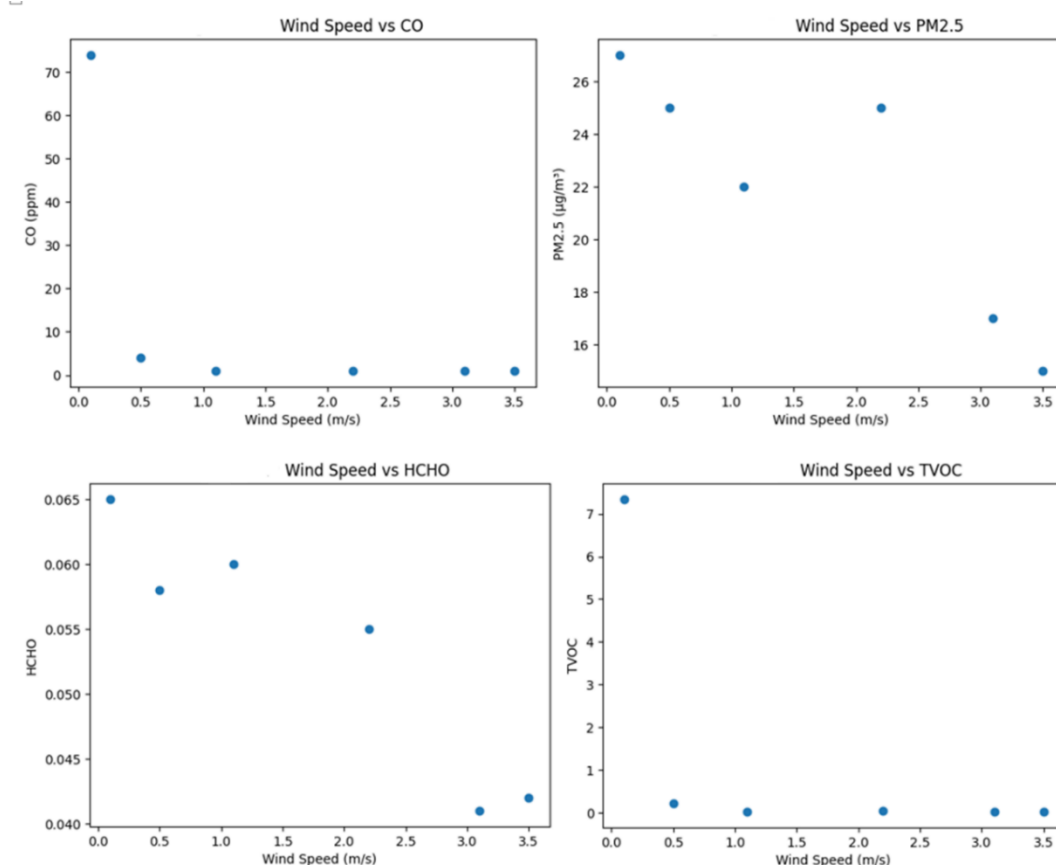


Figure 3: Influence of Meteorological Conditions on Pollutant Dispersion

The scatter plots illustrating the relationship between wind speed and selected pollutants reveal important patterns in atmospheric dispersion across the study area. An inverse relationship is observable between wind speed and fine particulate matter (PM_{2.5}), where higher wind speeds correspond with lower PM_{2.5} concentrations. This trend suggests that increased air movement enhances pollutant dilution and dispersion, thereby reducing particulate accumulation in ambient air. A similar pattern is evident for carbon monoxide (CO) and total volatile organic compounds (TVOC); however, both variables display a pronounced outlier at the lowest recorded wind speed (0.1 m/s). At this wind speed, CO and TVOC concentrations rise sharply, indicating that near-stagnant atmospheric conditions may facilitate significant pollutant build-up. Formaldehyde (HCHO) also demonstrates a moderate negative association with wind speed, with relatively higher concentrations occurring at lower wind velocities. Collectively, these patterns provide empirical support for atmospheric dispersion theory, which posits that reduced wind speeds limit horizontal pollutant transport and promote localized concentration increases. The findings therefore reinforce the role of meteorological conditions, particularly wind speed, as a critical determinant of pollutant distribution and exposure intensity within residential areas surrounding major market hubs.

3.4 Comparison with International Air Quality Guidelines

When the measured values were compared with recommended air quality standards, several exceedances were observed. The World Health Organization (WHO) 24-hour guideline for PM_{2.5} (15 µg/m³) was exceeded at all sampling locations except Eke Awka P2, indicating that fine particulate matter concentrations in most areas surpassed recommended safe exposure limits. Carbon monoxide (CO) levels at most locations remained within relatively moderate ranges; however, the concentration recorded at Eke Awka P3 (74

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ppm) was substantially elevated compared to other points and raises potential health concerns. Similarly, carbon dioxide (CO₂) levels at Eke Awka P3 (1505 ppm) were considerably higher than typical background ambient concentrations, suggesting localized emission intensity or limited atmospheric mixing. The Air Quality Index (AQI) values ranged from “Good” (12–17) at several locations to “Moderate” (48) at Eke Awka P3, reflecting spatial variation in air quality conditions and indicating differing levels of potential health risk within residential zones surrounding the market hubs.

3.5 Summary of Key Findings

Pollutant concentrations generally decline with distance at Amaenyi Market, supporting the distance-decay principle.

Eke Awka Market shows evidence of localized emission hotspots disrupting expected attenuation patterns.

Wind speed appears to significantly influence pollutant dispersion.

PM_{2.5} levels exceed recommended health guidelines at multiple locations.

Residential areas in close proximity to market hubs remain exposed to elevated pollutant concentrations.

Overall, the findings indicate that while spatial attenuation occurs under favorable atmospheric conditions, localized emission clusters and limited ventilation may sustain elevated exposure levels within residential buffers surrounding major market hubs in Awka South LGA.

4.0 DISCUSSION

This study examined whether ambient air pollutant concentrations surrounding major market hubs in Awka South LGA attenuate with increasing distance from the emission source and whether residential proximity sustains exposure above recommended health thresholds. By operationalizing structured radial buffers (0–50 m, 50–100 m, and >100 m), the findings offer spatially differentiated insight into the emission–dispersion–exposure dynamics of market-centered urban environments.

4.1 Validation and Limits of the Distance-Decay Principle

The results from Amaenyi Market demonstrate a clear spatial gradient consistent with the distance-decay principle (Batty, 2008). Pollutant concentrations were highest within the immediate commercial interface (0–50 m) and declined progressively beyond 100 m. Carbon monoxide increased from 1 ppm at >100 m (P1) to 4 ppm within 0–50 m (P3), while CO₂ rose from 510 ppm to 823 ppm across the same gradient. PM_{2.5} similarly increased from 22 µg/m³ at the outer buffer to 25 µg/m³ at the market interface.

These patterns support atmospheric dispersion theory, which posits that pollutant concentrations decline with increasing distance from emission sources due to dilution and turbulent mixing (Seinfeld & Pandis, 2016). The structured radial evidence strengthens this theoretical proposition in the context of Nigerian market environments, where prior studies have largely relied on fixed-point sampling without modeling spatial attenuation (Efe, 2008; Olukanni et al., 2014).

However, the magnitude of attenuation at Amaenyi is modest rather than dramatic. PM_{2.5} declines only slightly across buffers, suggesting that while dilution occurs, background urban emissions may maintain elevated baseline concentrations. This reflects Cohen’s (2006) observation that contemporary urban pollution is diffuse and multi-sourced rather than strictly localized. Thus, attenuation operates within a broader matrix of ambient urban emissions, limiting the extent of decline.

4.2 Emission Hotspots and Spatial Disruption at Eke Awka

In contrast, Eke Awka Market exhibits a sharply intensified gradient within the 0–50 m buffer. The spike in CO (74 ppm), CO₂ (1505 ppm), and TVOC (7.343) at P3 represents not merely a gradual increase but a localized emission hotspot. Unlike Amaenyi, where attenuation appears relatively smooth, Eke Awka reflects a concentration surge at the immediate commercial core.

This divergence highlights the non-uniformity of distance-decay dynamics in complex urban systems. Batty (2008) conceptualizes distance-decay as a probabilistic rather than deterministic principle; spatial intensity typically declines with distance but may be interrupted by localized reinforcements of activity. In this case, concentrated generator use, vehicular clustering, or waste combustion likely intensified emissions within the 0–50 m zone.

Such patterns align with findings from Amegah and Agyei-Mensah (2017), who observed that high-density African market environments frequently produce micro-scale pollution peaks embedded within residential zones. The Eke Awka anomaly therefore illustrates how informal economic activities and infrastructural deficits, particularly reliance on fossil-fuel generators (Arku et al., 2011) can amplify emission intensity beyond simple radial expectations.

4.3 Meteorological Mediation and Stagnation Effects

Wind speed emerges as a critical mediating variable. The lowest wind speed (0.1 m/s) coincided with the highest pollutant concentrations at Eke Awka P3, while higher wind speeds (3.1–3.5 m/s) corresponded with lower concentrations in outer buffers. This inverse relationship empirically reinforces atmospheric dispersion theory (Seinfeld & Pandis, 2016), which emphasizes wind velocity as a primary determinant of pollutant transport.

Brauer et al. (2012) further note that in dense urban morphologies, low wind conditions can lead to pollutant entrapment within street canyons and confined commercial corridors. Awka South’s compact building configuration likely exacerbates such stagnation.

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Thus, the Eke Awka hotspot is not solely a function of emission intensity but also of meteorological suppression of dispersion. This interaction underscores a critical analytical point: proximity determines exposure potential, but meteorological conditions determine exposure realization. Distance-decay operates within atmospheric constraints. Where wind is insufficient, even short radial distances may sustain high pollutant accumulation.

4.4 Public Health Significance of PM_{2.5} Exceedances

Across both markets, PM_{2.5} concentrations frequently exceeded the WHO (2021) 24-hour guideline of 15 µg/m³. Even the lowest recorded values approach or surpass recommended thresholds. According to the Health Effects Institute (2020), chronic exposure to elevated PM_{2.5} contributes substantially to global cardiovascular and respiratory disease burden.

The persistence of PM_{2.5} above recommended limits beyond the immediate commercial interface (>100 m) suggests that residential populations are exposed not only episodically but chronically. Brauer et al. (2012) emphasize that fine particulates penetrate deeply into the respiratory tract, triggering systemic inflammation. Therefore, even moderate elevations within residential buffers may carry cumulative health implications.

The extreme CO value at Eke Awka P3 further raises concerns about acute exposure events within immediate commercial zones. While long-term averages may moderate such spikes, episodic peaks in densely populated areas warrant regulatory attention.

4.5 Contribution to Nigerian Urban Air Quality Research

Methodologically, this study advances Nigerian air quality research by incorporating structured radial classification rather than relying solely on fixed-point corridor monitoring. Previous studies (Efe, 2008; Olukanni et al., 2014) document exceedances but do not systematically quantify attenuation gradients across residential-commercial interfaces.

By demonstrating measurable concentration differences between 0–50 m and >100 m zones, this research fills a geographical and methodological gap identified in the introduction. It provides empirical support for integrating spatial proximity into environmental planning decisions, particularly in rapidly urbanizing southeastern Nigerian cities (Agbola, 2004).

4.6 Planning and Policy Implications

The findings underscore that residential dwellings within 50 meters of major market hubs experience the highest pollutant exposure. While attenuation occurs beyond this range, exceedances of PM_{2.5} guidelines remain common. This suggests that current mixed land-use configurations in Awka South inadequately protect residential populations.

Urban planning responses may include:

- Enforcing buffer setbacks between high-intensity commercial zones and housing

- Regulating generator clustering

- Promoting cleaner energy alternatives

- Enhancing ventilation corridors in urban design

As urbanization intensifies (United Nations, 2019), unmanaged spatial intermingling of residential and commercial activities may exacerbate exposure gradients.

In sum, the study confirms that pollutant concentrations are highest within the immediate 0–50 m commercial interface and generally decline with distance, validating the distance-decay principle under favorable dispersion conditions. However, localized emission intensification and meteorological stagnation can significantly disrupt expected attenuation patterns.

The interplay of proximity, emission density, and atmospheric dynamics defines exposure intensity in market-centered urban systems. Residential proximity to major market hubs in Awka South LGA therefore constitutes a measurable environmental health concern. Structured distance-based assessments such as this provide essential empirical grounding for zoning regulation, environmental governance, and public health protection in rapidly urbanizing African cities.

5.0 CONCLUSION

This study assessed ambient air quality across structured radial distances surrounding major market hubs in Awka South LGA in order to determine whether pollutant concentrations attenuate with increasing distance from emission sources. The findings confirm that pollutant concentrations are highest within the immediate 0–50 m commercial interface and generally decline toward outer residential buffers (>100 m), particularly at Amaenyi Market. This pattern validates the distance-decay principle and supports established atmospheric dispersion theory. However, the pronounced pollution spike observed at Eke Awka within the 0–50 m zone demonstrates that localized emission clustering and low wind conditions can significantly intensify exposure levels.

PM_{2.5} concentrations exceeded WHO recommended thresholds at most sampling locations, indicating that residential areas surrounding market hubs are exposed to pollutant levels with potential long-term health implications. The results therefore highlight the environmental health vulnerability associated with mixed residential-commercial land-use patterns in rapidly urbanizing Nigerian cities. Overall, proximity to market cores emerges as a critical determinant of exposure intensity, moderated by meteorological conditions and urban morphology.

6.0 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

Establishment of Spatial Buffer Zones: Urban planning authorities should consider enforcing minimum setback distances between major market cores and residential dwellings to reduce exposure within the 0–50 m high-risk zone.

Regulation of Generator Use: Given the likely contribution of fossil fuel generators to localized emission spikes, stricter regulation and promotion of cleaner alternative energy sources within market environments are recommended.

Improved Traffic Management: Traffic congestion around market hubs should be managed through controlled entry systems, designated loading zones, and improved public transportation options to reduce vehicular emissions.

Routine Air Quality Monitoring: Continuous or periodic air quality monitoring programs should be institutionalized within Awka South LGA to track pollutant trends and identify emerging hotspots.

Urban Design Interventions: Enhancing ventilation corridors and reducing building congestion in commercial cores may improve pollutant dispersion and reduce stagnation effects.

Public Health Awareness: Community education initiatives should inform residents and traders about air pollution risks and mitigation practices.

Implementing these measures will contribute to improved environmental governance, reduced residential exposure, and enhanced public health protection within rapidly urbanizing market-centered urban systems.

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