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Assessment of the Environmental Impact of Selected Industrial Gaseous Waste on Outdoor Air in Ilorin Metropolis

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Abstract

Industrial air pollution remains a growing environmental and public health concern in many developing urban centres. This study assessed the environmental impact of selected industrial gaseous emissions on outdoor air quality in Ilorin Metropolis, Kwara State, Nigeria. The study evaluated the concentration levels of particulate matter (PM2.5 and PM10), carbon monoxide (CO), volatile organic compounds (VOCs), and formaldehyde (HCHO) within the vicinity of selected industries. A descriptive and longitudinal study design was adopted. Fifteen sampling points were selected around five industries, namely Dangote Group of Companies, Doyin Group of Companies Nigeria Limited, International Tobacco Company, Tuyil Pharmaceutical Company, and Glister Quarry Company. Air quality measurements were conducted using calibrated handheld multi-gas monitors. In addition, 150 questionnaires were administered to residents to assess health impacts and awareness of air pollution regulations. Data were analysed using descriptive statistics and a paired-sample t-test at $p < 0.05$. The findings revealed that PM2.5, PM10, HCHO, and CO concentrations exceeded permissible limits in several locations, indicating poor air quality and potential environmental and health risks. VOC concentrations remained largely within acceptable limits. Significant differences were observed between morning and evening concentrations for HCHO, VOCs, and CO ($p < 0.05$), while PM2.5 and PM10 showed no significant variation. Frequent cough, wheezing, and nasal congestion were identified as major health complications associated with industrial emissions. Furthermore, 80% of respondents were unaware of legal provisions regulating industrial air pollution. The study concludes that industrial emissions significantly contribute to outdoor air pollution in Ilorin Metropolis and pose considerable health risks to nearby residents. Strengthening environmental regulations, enhancing public awareness, and implementing effective pollution control measures are recommended.

Keywords: Air pollution, Industrial emissions, Outdoor air quality, Carbon monoxide, Ilorin metropolis

INTRODUCTION

Air pollution has become one of the most significant environmental challenges affecting human health and ecological sustainability worldwide (World Health Organization [WHO], 2021). Rapid industrialization, urbanization, and increased energy consumption have contributed to the release of harmful pollutants into the atmosphere. Industrial activities emit large quantities of particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides, volatile organic compounds, and other hazardous pollutants that deteriorate ambient air quality (Lala et al., 2025).

In many developing countries, including Nigeria, industrial growth has occurred with limited environmental monitoring and weak enforcement of pollution control regulations. Consequently, urban centres with increasing industrial activities are experiencing rising levels of air pollution. Poor air quality has been associated with respiratory diseases, cardiovascular disorders, reduced life expectancy, and environmental degradation (Ibeneme et al., 2022).

Ilorin Metropolis, the capital city of Kwara State, has witnessed considerable industrial

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expansion over the years. Industries such as cement production, pharmaceuticals, quarry operations, and manufacturing activities contribute substantially to atmospheric emissions within the metropolis. Despite this growth, limited studies have assessed the environmental impact of industrial gaseous waste on outdoor air quality in the area.

Industrialization remains a major contributor to atmospheric pollution in Nigeria, with emissions from manufacturing zones frequently exceeding World Health Organization guideline values for particulate matter (Lala et al., 2025). Emissions from industrial processes often contain harmful pollutants such as particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides, volatile organic compounds, and heavy metals, which have been associated with adverse environmental and health effects.

Particulate matter, especially PM2.5 and PM10, is among the most dangerous air pollutants due to its ability to penetrate deep into the respiratory tract. Exposure to particulate matter has been linked to respiratory diseases, cardiovascular complications, asthma, and premature mortality (Kim et al., 2020; Jelili et al., 2020). Carbon monoxide reduces the oxygen-carrying capacity of blood and can result in dizziness, suffocation, and death at high concentrations.

Volatile organic compounds and formaldehyde are also significant industrial pollutants. Formaldehyde exposure may cause irritation of the eyes, nose, and throat, while prolonged exposure can lead to more severe respiratory complications. VOCs contribute to the formation of ground-level ozone and photochemical smog, and recent ambient sampling in Nigerian cities has shown that VOC exposure levels already exceed those typical of comparable cities in Europe and North America (Cordell et al., 2021).

The World Health Organization has shown that millions of deaths annually are associated with both indoor and outdoor air pollution (WHO, 2021). Urban and industrial regions in developing countries are particularly vulnerable due to weak environmental regulations and inadequate monitoring systems. In Nigeria, major sources of ambient air pollution include industrial activities, transportation, energy generation, and domestic emissions. Recent assessments across the country's major manufacturing zones confirm that particulate matter concentrations around industrial clusters consistently exceed national and WHO ambient air quality standards (Lala et al., 2025). Previous studies have identified increasing pollution levels in major cities such as Lagos, Port Harcourt, Kano, and Kaduna. However, there remains limited data regarding industrial air pollution in Ilorin Metropolis.

This study therefore evaluated the concentrations of selected air pollutants around major industries in Ilorin Metropolis and examined their potential effects on public health and environmental quality.

Objectives of the Study

The specific objectives of this study were to:

1. Assess the concentration of selected industrial gaseous pollutants in outdoor air around selected industries in Ilorin Metropolis.
2. Compare morning and evening variations in air pollutant concentrations around the selected industries.
3. Determine the health effects of industrial gaseous emissions on residents living near the industries.

MATERIALS AND METHODS

Study Area

The study was conducted in Ilorin Metropolis, Kwara State, Nigeria. Ilorin lies between latitude 8°30'N and 8°50'N and longitude 4°20'E and 4°35'E. The city serves as the administrative and commercial center of Kwara State and hosts several industrial establishments. The map of the study area, showing the distribution of the five selected industries and fifteen sampling points, is presented as Figure 1 in the Results section.

Research Design

A descriptive and longitudinal study design was adopted to assess outdoor air quality around selected industries in Ilorin Metropolis. Repeated field measurements were taken at each sampling point to capture temporal (morning versus evening) variation in pollutant concentration, consistent with the study's second objective.

Sampling Locations and Rationale for Site Selection

Five industries were purposively selected for the study: Dangote Group of Companies (cement and allied manufacturing), Doyin Group of Companies Nigeria Limited (food and beverage manufacturing), International Tobacco Company (tobacco processing), Tuyil Pharmaceutical Company (pharmaceutical manufacturing), and Glister Quarry Company (quarrying and stone-crushing operations). These industries were selected because they represent the dominant categories of industrial activity operating within Ilorin Metropolis, and because each has a known history of gaseous and particulate emissions associated with its core production process. Site selection was further guided by (i) the scale of production activity and inferred emission potential, (ii) the proximity of the facility to residential settlements, and (iii) the accessibility of the surrounding area for repeated air quality monitoring.

Three sampling points were selected around each industry, resulting in a total of fifteen sampling locations. At each industry, the three points were distributed to capture a gradient of exposure: one point close to the factory fence-line, one point along the predominant downwind direction of likely plume dispersion, and one point at the nearest residential cluster. This arrangement allowed near-source and community-level exposure to be compared.

Data Collection

Air quality measurements were conducted during daytime hours (9:00 a.m. to 6:00 p.m.), with paired morning (9:00 a.m.-12:00 p.m.) and evening (3:00 p.m.-6:00 p.m.) readings taken at each of the fifteen sampling points to allow the diurnal comparison required by the study's second objective. The parameters assessed included particulate matter (PM2.5 and PM10), carbon monoxide (CO), volatile organic compounds (VOCs), and formaldehyde (HCHO).

Data collection was carried out using handheld multi-gas monitors (Model AS8900 BLATN BR-Smart Series Air Quality Monitor and B-SIDE EET100). Both instruments were calibrated before each day's sampling session following the manufacturer's zero- and span-calibration procedure, using the reference calibration standard supplied with each device, to minimise instrument drift and ensure the reliability of recorded concentrations. Sampling was repeated across multiple non-consecutive days at each location, and the mean of the repeated readings was recorded as the concentration value for that point and period. In addition, a total of 150 questionnaires were administered to residents living within the vicinity of the selected industries to obtain information on their awareness of air pollution and the associated health effects and regulations.

Data Analysis

Descriptive statistics including means, percentages, and charts were used to summarise the data. A paired-sample t-test was employed to compare morning and evening pollutant concentrations at a significance level of $p < 0.05$. Statistical analyses were performed using SPSS and R software.

RESULTS

Study Area and Sampling Distribution

Figure 1 shows the map of the study area, indicating the location of the five selected industries and the fifteen air-quality sampling points within Ilorin Metropolis.

Variations in Morning Air Pollutant Concentrations

The assessment of morning air quality around the selected industries revealed elevated concentrations of PM2.5, PM10, HCHO, and CO above recommended permissible limits, as shown in Figure 2. PM2.5 recorded a mean concentration value of 4343.127, while PM10 recorded 1906.249. HCHO and CO concentrations were 0.368 and 863.889 respectively. VOC concentration remained within acceptable limits.

Variations in Evening Air Pollutant Concentrations

Evening air quality measurements also showed high concentrations of pollutants around the industrial areas, as illustrated in Figure 3. PM2.5 recorded 3013.656, PM10 recorded 3462.300, HCHO recorded 0.324, and CO recorded 129.962. VOC concentrations remained relatively low and within permissible standards.

Paired Sample t-Test between Morning and Evening Concentrations

The paired-sample t-test, summarised in Table 1, showed no statistically significant difference between morning and evening concentrations of PM2.5 ($p = 0.076$) and PM10 ($p = 0.764$). However, significant differences were observed for HCHO ($p = 0.000$), VOCs ($p = 0.017$), and CO ($p = 0.001$), indicating temporal variations in gaseous pollutant concentrations.

Health Effects Associated with Industrial Air Pollution

Findings from the questionnaire survey, presented in Figure 4, revealed that frequent cough was the most common health complaint among residents exposed to industrial emissions, with approximately 76.4% occurrence, and that industries were identified by respondents as the leading perceived source of these symptoms. Other reported health conditions included wheezing and nasal congestion. Statistical analysis showed a significant relationship between air pollution exposure and health complications among residents ($p < 0.05$).

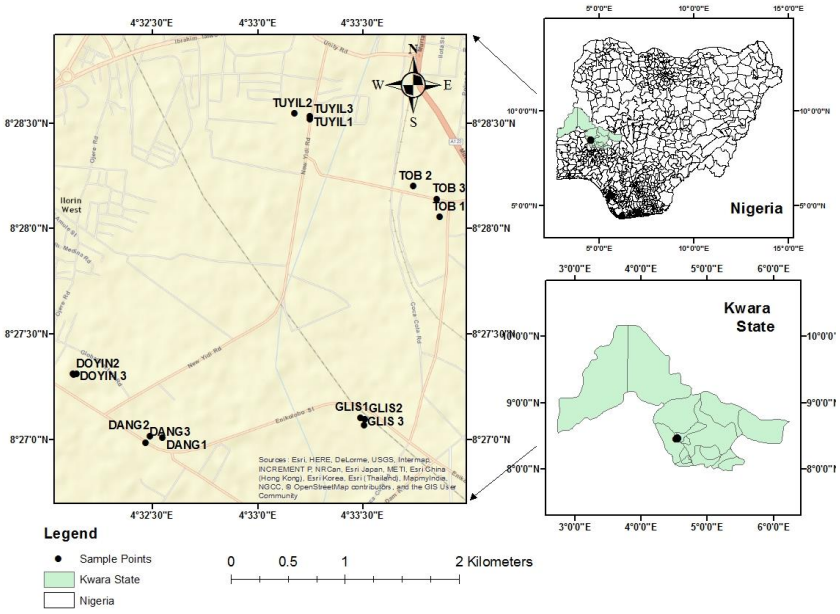

Figure 1. Map of the Study Area.

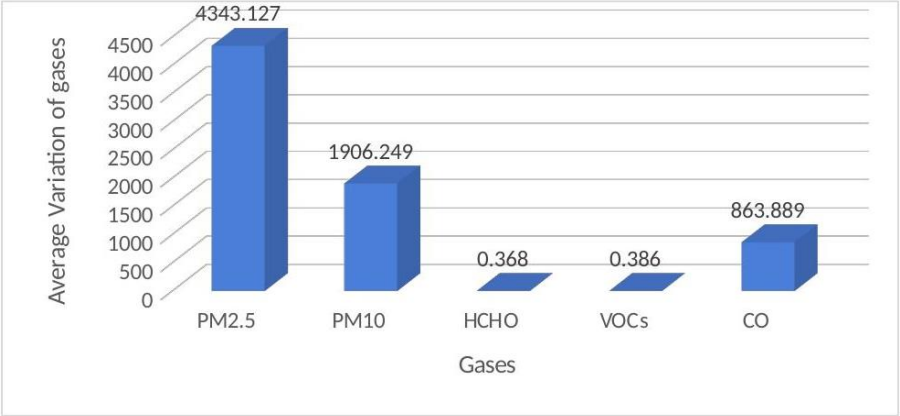

Figure 2. The variations for PM2.5, PM10, HCHO, VOCs, and CO levels for Morning.

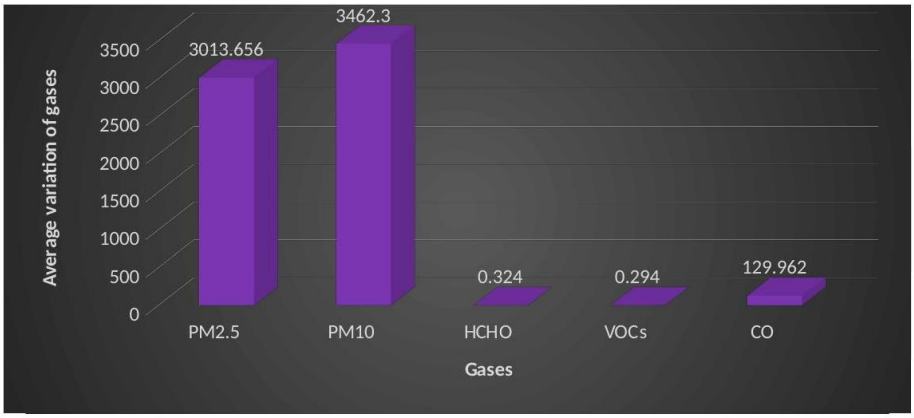

Figure 3. The variations for PM2.5, PM10, HCHO, VOCs, and CO levels for evening.

Table 1 Paired-Sample t-Test Comparing Morning and Evening Pollutant Concentrations.

Pollutant	Morning Mean	Evening Mean	*p*	Interpretation
$PM_{2.5}$ (µg m^{-3})	4343.13	3013.66	0.076	Not significant
PM_{10} (µg m^{-3})	1906.25	3462.30	0.764	Not significant
HCHO (mg m^{-3})	0.368	0.324	< .001	Significant
VOCs (mg m^{-3})	0.386	0.294	.017	Significant
CO (ppm)	863.89	129.96	.001	Significant

Note. *$PM_{2.5}$ = particulate matter ≤ 2.5 µm; PM_{10} = particulate matter ≤ 10 µm; HCHO = formaldehyde; VOCs = volatile organic compounds; CO = carbon monoxide. Statistical significance was determined at α = .05.*

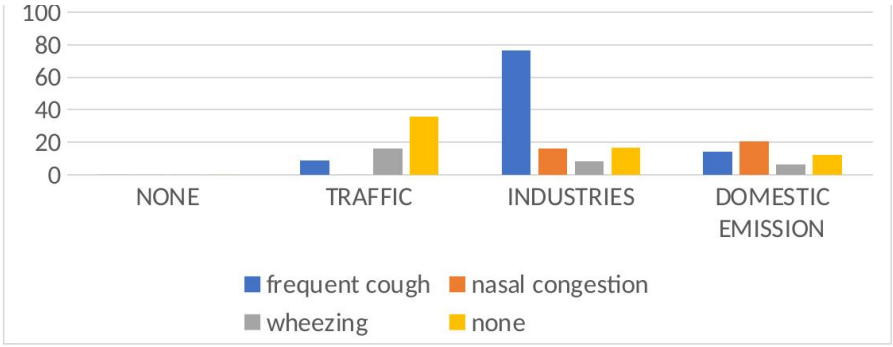

Figure 4. Health Effects Associated with Industrial Air Pollution.

DISCUSSION

The present study revealed elevated concentrations of PM2.5, PM10, HCHO, and CO in both morning and evening periods around the selected industrial areas, with VOCs remaining within permissible limits (Table 1; Figures 2 and 3). The dominance of particulate matter pollution is consistent with findings from several industrial and urban studies in Nigeria and other developing regions, where PM2.5 and PM10 are frequently reported above WHO air quality guidelines due to emissions from industrial combustion processes, vehicular activities, and re-suspended dust (Adeleke et al., 2020; Nwachukwu et al., 2019). This pattern mirrors the recent national assessment by Lala et al. (2025), who reported that ambient PM2.5 and PM10 levels around Nigeria's major manufacturing industrial zones consistently exceeded the WHO (2021) guideline values, reinforcing the conclusion that industrial clusters such as those in Ilorin Metropolis remain a significant, under-regulated source of particulate exposure.

Similarly, studies in Port Harcourt and Kano industrial zones reported persistently high particulate matter levels, indicating continuous exposure risk to surrounding populations (Okedere et al., 2021).

The absence of a significant difference between morning and evening concentrations of PM2.5 and PM10 in this study (addressing objective two) suggests stable emission sources throughout the day, most plausibly linked to the continuous, non-intermittent operating schedules of the cement, quarry, and processing plants in the study area. This aligns with findings by Nwachukwu et al. (2019), who reported minimal diurnal variation in particulate pollution in high-traffic and industrial environments, attributing this to continuous industrial operations and poor dispersion conditions. In contrast, the significant variation observed for CO and HCHO agrees with studies by Obanya et al. (2018), which showed that gaseous pollutants fluctuate with daily human activities, traffic intensity, and photochemical reactions influenced by temperature and sunlight; this suggests that, unlike particulate emissions, the gaseous pollutant load in Ilorin Metropolis is driven by a combination of industrial and time-varying sources such as traffic and domestic burning.

The relatively low VOC levels observed in this study differ from findings in petrochemical-dominated regions such as the Niger Delta, where VOC concentrations are often elevated due to oil and gas activities (Ukpebor et al., 2020), and are also lower than VOC exposure levels recently measured at roadside and background locations in Lagos (Cordell et al., 2021). This suggests that the study area may have fewer solvent-based, hydrocarbon-intensive, or vehicular emission sources compared to heavily industrialised petrochemical or high-traffic urban zones, and that the elevated pollutant burden identified in this study (objective one) is driven primarily by particulate rather than volatile organic emissions.

The health findings further support established evidence linking industrial air pollution to respiratory outcomes (objective three). The high prevalence of cough (76.4%), wheezing, and nasal congestion, and the identification of industrial emissions as the leading perceived source of these symptoms (Figure 4), is consistent with epidemiological studies showing strong associations between PM2.5 exposure and respiratory irritation and reduced lung function (WHO, 2021; Kim et al., 2020; Jelili et al., 2020). This finding is comparable to occupational and community-level observations in Enugu, where workers and residents in industrial and traffic-exposed environments recorded measurable seasonal changes in pulmonary function linked to airborne particulate concentration (Ibeneme et al., 2022). The statistically significant relationship between pollution exposure and health complaints in this study reinforces the inference that residents are experiencing measurable adverse health effects from ambient industrial emissions, even though a large proportion (80%) remain unaware of the regulatory protections available to them.

Taken together, the findings directly address the three objectives of the study: elevated concentrations of PM2.5, PM10, HCHO, and CO were confirmed around the selected industries (objective one); temporal variation was significant for the gaseous pollutants (HCHO, VOCs, CO) but not for particulate matter (objective two); and industrial emissions were associated with measurable respiratory health complaints among nearby residents (objective three). Overall, the findings align with previous research indicating that industrial environments in developing countries are characterised by persistent particulate pollution and variable gaseous pollutants, both of which contribute to respiratory health risks among nearby populations.

CONCLUSION AND RECOMMENDATIONS

Based on the findings of the study, it is concluded that outdoor air quality around selected industries in Ilorin Metropolis is poor, as evidenced by the high concentrations of PM2.5, PM10, HCHO, and CO, which exceeded permissible limits in both morning and evening periods. Although VOC levels remained relatively low, significant temporal variations were observed for HCHO, VOCs, and CO ($p < 0.05$). The study further confirms that industrial emissions contribute to respiratory health problems among residents, with cough being the most reported symptom

(76.4%) and low awareness of air pollution laws (20%) indicating poor environmental knowledge in the study area. It is therefore recommended that: (i) relevant environmental regulatory agencies should strengthen enforcement of industrial emission standards to ensure strict compliance with air quality limits; (ii) industries within Ilorin Metropolis should adopt and maintain effective air pollution control technologies such as filters and scrubbers to reduce particulate and gaseous emissions; and (iii) continuous public health education and awareness programmes should be implemented to improve residents' understanding of air pollution risks, environmental regulations, and preventive health practices.

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