Ambient Carbon Dioxide and Carbon Monoxide Concentrations and Residents' Perception of Carbon Emission Sources in Selected Local Government Areas of Lagos State, Nigeria

Buhari Mohammed[1], Adiama B.Y[2], Olaniyi O.A[3], Sakariyawu O.A[4]

[1,2,3,4] *Department of Environmental Health Science, Faculty of Allied Health Sciences, Kwara State University, Malete, Nigeria*

ABSTRACT

This study assessed ambient carbon dioxide (CO_2) and carbon monoxide (CO) concentrations and residents' perception of the sources of carbon emissions in four selected Local Government Areas (Oshodi-Isolo, Ikeja, Apapa and Alimosho) of Lagos State, Nigeria. A cross-sectional analytical design was adopted, combining environmental monitoring with a structured questionnaire survey administered to 400 residents selected through multistage sampling. CO_2 and CO concentrations were measured at four locations during morning, afternoon and evening periods over a 30-day monitoring period using portable gas monitoring equipment, while residents' perceptions of seven potential emission sources were assessed on a five-point Likert scale. Data were analyzed using descriptive statistics and one-way analysis of variance (ANOVA) in SPSS version 24.0. Results showed that Location B recorded the highest overall mean CO_2 concentration (649.30 ± 53.21 ppm) while Location D recorded the highest overall mean CO concentration (7.00 ± 1.15 ppm); the overall means across all locations were 593.33 ± 60.14 ppm for CO_2 and 5.98 ± 1.23 ppm for CO. Concentrations of both pollutants varied significantly across the periods of the day, peaking in the evening (CO_2: $F = 19.23$, $p < 0.001$; CO: $F = 84.51$, $p < 0.001$), yet all 360 recorded readings for each pollutant remained below the WHO 8-hour guideline values (1,000 ppm for CO_2 and 9 ppm for CO). Residents perceived vehicular emissions from traffic as the leading source of carbon emissions (mean = 4.18 ± 0.91), followed by generator fumes from households (3.96 ± 1.05), industrial emissions (3.68 ± 1.15) and burning of waste/refuse (3.53 ± 1.24), giving a grand mean perception score of 3.57 ± 0.34. Perception scores differed significantly across the four locations ($F = 4.82$, $p = 0.003$), with the highest score recorded in Location B, the same location with the highest CO_2 concentration. The study concludes that although measured pollutant concentrations complied with WHO guidelines, spatial and temporal variability was evident and closely mirrored by residents' perception patterns, particularly around vehicular and generator-related emissions. Continuous environmental monitoring and targeted emission-reduction interventions, especially around traffic and household generator use, are recommended.

KEYWORDS

Carbon dioxide, carbon monoxide, ambient air quality, residents' perception, carbon emission sources, Lagos, Nigeria

I. INTRODUCTION

Rapid urbanization, industrialization and motorization have made cities across sub-Saharan Africa important contributors to, and sites of exposure to, ambient carbon emissions. Lagos State, Nigeria's foremost commercial and industrial hub, exemplifies this challenge: a dense concentration of vehicular traffic, manufacturing activity, and widespread reliance on petrol and diesel generators—driven by an irregular public electricity supply (International Energy Agency [IEA], 2021)—continually releases carbon dioxide (CO_2) and carbon monoxide (CO) into the urban atmosphere. Globally, fossil-fuel combustion in the energy, industrial and transport sectors remains the dominant source of such emissions (IEA, 2025), and urban atmospheric monitoring elsewhere has shown that CO concentrations are typically highest in areas of heavy vehicular traffic and industrial activity.

Environmental conditions and exposure to carbon emissions vary considerably across different parts of Lagos due to differences in land use, industrial activity, traffic density, housing quality and socioeconomic characteristics. Consequently, residents' perceptions of carbon emissions and their sources are likely to differ between communities, and these perceptions matter: how the public understands and attributes environmental risk shapes its support for, and engagement with, mitigation and behavior-change interventions. Yet in much of Lagos, actual measured concentrations of CO_2 and CO are rarely assessed alongside residents' own perceptions of where these emissions come from, leaving a gap between objective environmental data and the subjective understanding that ultimately informs public behavior and demand for policy action.

This study, therefore, addressed two specific objectives: (i) to determine the concentrations of carbon dioxide (CO_2) and carbon monoxide (CO) in selected Local Government Areas of Lagos State, and (ii) to assess residents' perception of the sources of carbon emissions in the selected areas. By combining direct environmental measurement with a structured perception survey, the study provides evidence to support environmental health planning, targeted public awareness campaigns, and climate change mitigation strategies in Lagos State.

II. MATERIALS AND METHODS

A. Study Area

The study was conducted in Lagos State, southwestern Nigeria, the country's economic and commercial nucleus and its most densely populated state. Lagos combines highly urbanized metropolitan districts with semi-urban and peri-urban communities, and hosts major commercial and industrial clusters (e.g., Balogun, Oshodi and Ikeja markets; the Apapa and Tin Can Island ports; industrial zones in Apapa, Ikeja and Amuwo-Odofin) (National Bureau of Statistics [NBS], 2021). Persistent traffic congestion (Lagos Metropolitan Area Transport Authority [LAMATA], 2022) and widespread household and business reliance on petrol/diesel generators (IEA, 2021) are prominent features of the urban environment, together constituting major potential sources of ambient carbon emissions.

B. Research Design

A cross-sectional analytical design was adopted, combining environmental monitoring of ambient CO_2 and CO with a structured questionnaire survey administered at a single point in time. This design permitted simultaneous assessment of measured pollutant concentrations and residents' perceptions within the same communities.

C. Study Population, Sample Size and Sampling Technique

The study population comprised adult residents (18 years and above who had resided in the community for at least one year) of the selected communities. Using Cochran's (1977) formula for an unknown population proportion ($Z = 1.96$, $p = 0.5$, $e = 0.05$), a minimum sample size of 384 was calculated; adjusting for a 10% attrition rate yielded a target sample of 422, of which 400 valid responses were analyzed.

A four-stage sampling technique was employed. First, four LGAs—Oshodi-Isolo, Ikeja, Apapa and Alimosho—were purposively selected based on varying levels of urbanization, industrial and commercial activity, traffic density and potential emission sources. Second, communities within each LGA were selected by simple random sampling, and environmental monitoring points were identified within these communities based on areas of high traffic density, commercial activity, industrial operation and residential land use. Third, households within each community were selected by systematic random sampling. Fourth, one eligible adult resident per household was selected by simple random sampling to complete the questionnaire; 100 respondents were drawn from each of the four locations (total $N = 400$).

D. Data Collection

Ambient concentrations of CO_2 and CO were measured at the designated monitoring points using portable gas monitoring equipment during morning, afternoon and evening periods over a 30-day monitoring period (30 readings per period per location; 360 total readings per pollutant), consistent with recommendations for repeated, time-resolved measurement when characterizing urban pollutant exposure. A structured questionnaire, comprising a socio-demographic section and a section on residents' perceptions of seven potential sources of carbon emissions (vehicular emissions, generator fumes, industrial emissions, burning of waste/refuse, cooking with firewood/charcoal, deforestation and air-conditioner emissions) rated on a five-point Likert scale (Strongly Disagree to Strongly Agree), was administered to the 400 sampled residents.

E. Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 24.0. Descriptive statistics (frequencies, percentages, means and standard deviations) were used to summarize socio-demographic characteristics, measured CO_2 and CO concentrations, and residents' perception scores. A mean score of 3.0 was used as the cut-off for agreement on the five-point perception scale, and 3.50 was used to distinguish major from minor perceived sources. One-way analysis of variance (ANOVA) was used to test for significant differences in pollutant concentrations across periods of the day and in perception scores across the four locations. Statistical significance was set at $p < 0.05$. Measured concentrations were also compared against World Health Organization 8-hour ambient air quality guideline values (1,000 ppm for CO_2 and 9 ppm for CO).

F. Ethical Considerations

Confidentiality and anonymity of respondents were strictly maintained. No personal identifiers were collected, and all data were used solely for academic purposes.

III. RESULTS

A. Socio-demographic Characteristics of Respondents

Of the 400 respondents, 220 (55.0%) were male and 180 (45.0%) were female. The largest age group was 26–35 years (140, 35.0%), followed by 18–25 years (95, 23.8%), 36–45 years (88, 22.0%) and 46 years and above (77, 19.2%). Regarding education, 175 (43.8%) had tertiary education, 160 (40.0%) secondary education, 45 (11.2%) primary education, and 20 (5.0%) had no formal education. Half of the respondents (200, 50.0%) had resided in their community for more than 10 years, 130 (32.5%) for 5–10 years, and 70 (17.5%) for less than 5 years.

B. Ambient CO_2 and CO Concentrations by Location and Period

Mean CO_2 and CO concentrations varied by location and time of day. Across all locations and periods ($N = 360$ per pollutant), the overall mean CO_2 concentration was 593.33 ± 60.14 ppm and the overall mean CO concentration was 5.98 ± 1.23 ppm.

By location, Location B recorded the highest overall mean CO_2 concentration (649.30 ± 53.21 ppm; 95% CI: 638.18–660.42), followed by Location D (580.60 ± 54.33 ppm), Location C (574.47 ± 57.89 ppm) and Location A (568.93 ± 45.67 ppm, the lowest). For CO, Location D recorded the highest overall mean (7.00 ± 1.15 ppm; 95% CI: 6.76–7.24), followed by Location A (6.01 ± 1.19 ppm) and Location C (5.61 ± 1.20 ppm), with Location B recording the lowest mean CO (5.29 ± 0.93 ppm).

By period of day, mean CO_2 concentration rose from 572.00 ± 66.84 ppm in the morning to 592.10 ± 45.22 ppm in the afternoon and 615.88 ± 57.31 ppm in the evening; this difference was statistically significant ($F = 19.23$, $p < 0.001$). Mean CO concentration followed a broadly similar but non-linear pattern, at 6.00 ± 0.79 ppm in the morning, dropping to 5.14 ± 1.20 ppm in the afternoon before rising to a peak of 6.82 ± 1.09 ppm in the evening; this difference was also statistically significant ($F = 84.51$, $p < 0.001$).

Despite this spatial and temporal variability, none of the 360 CO_2 readings (0.0%) exceeded the WHO 8-hour guideline of 1,000 ppm (maximum recorded: 740 ppm), and none of the 360 CO readings (0.0%) exceeded the WHO guideline of 9 ppm (maximum recorded: 8.7 ppm), indicating full (100.0%) compliance with WHO ambient guideline values during the monitoring period.

Table 1: Mean Concentrations of CO_2 and CO by Location (Objective 1)

Location	N	Mean CO_2 ± SD (ppm)	95% CI	Mean CO ± SD (ppm)	95% CI
Location A	90	568.93 ± 45.67	559.38–578.48	6.01 ± 1.19	5.76–6.26
Location B	90	649.30 ± 53.21	638.18–660.42	5.29 ± 0.93	5.10–5.48
Location C	90	574.47 ± 57.89	562.35–586.59	5.61 ± 1.20	5.36–5.86
Location D	90	580.60 ± 54.33	569.23–591.97	7.00 ± 1.15	6.76–7.24
Total	360	593.33 ± 60.14	587.10–599.56	5.98 ± 1.23	5.85–6.11

C. Residents' Perception of Sources of Carbon Emissions

Residents' perception scores indicated general agreement that all seven listed activities were sources of carbon emissions, with a grand mean of 3.57 ± 0.34 on the five-point scale. Vehicular emissions from traffic recorded the highest mean score (4.18 ± 0.91) and were the most strongly perceived source, followed by generator fumes from households (3.96 ± 1.05), industrial emissions from factories (3.68 ± 1.15), and burning of waste/refuse (3.53 ± 1.24)—all exceeding the 3.50 major-source cut-off. Cooking with firewood/charcoal (3.28 ± 1.28), deforestation (3.23 ± 1.27) and air-conditioner emissions (3.08 ± 1.21) were rated above the 3.00 agreement threshold but below the 3.50 cut-off, and were accordingly classified as minor perceived sources.

Perception of carbon emission sources differed significantly across the four locations (one-way ANOVA: $F = 4.82$, $p = 0.003$). Location B recorded the highest mean perception score (3.72 ± 0.48), followed by Location A (3.61 ± 0.52) and Location D (3.51 ± 0.50), while Location C recorded the lowest mean score (3.45 ± 0.55). Notably, Location B, which recorded the highest perception score, was also the location with the highest measured CO_2 concentration.

Table 2: Residents' Perception of Sources of Carbon Emissions (Objective 2), N = 400

Sources of Carbon Emissions	SA	A	N	D	SD	Mean ± SD
Vehicular emissions from traffic	180	150	40	20	10	4.18 ± 0.91
Generator fumes from households	160	140	50	30	20	3.96 ± 1.05
Industrial emissions from factories	120	130	80	40	30	3.68 ± 1.15
Burning of waste/refuse	110	125	70	55	40	3.53 ± 1.24
Cooking with firewood/charcoal	90	100	90	70	50	3.28 ± 1.28
Deforestation	85	95	100	65	55	3.23 ± 1.27
Air conditioner emissions	70	85	110	80	55	3.08 ± 1.21
Grand Mean						3.57 ± 0.34

IV. DISCUSSION

The environmental measurements revealed clear spatial and temporal heterogeneity in ambient CO_2 and CO concentrations across the four study locations. The higher CO_2 concentration observed in Location B may reflect greater human activity, traffic intensity, or combustion-related activity in that area, a pattern consistent with evidence that urban CO and CO_2 concentrations tend to be highest in zones of heavy vehicular traffic and industrial activity which align with the findings of.

The rise in both CO_2 and CO concentrations toward the evening period likely reflects increased human activity, traffic movement and combustion activity later in the day. This is consistent with the broader methodological literature emphasizing that temporal variation in urban pollutant concentrations is shaped by traffic and activity patterns, and that repeated measurement across different times of the day is essential for accurately characterizing urban air pollutant exposure which is inclined with. Importantly, although statistically significant differences existed between locations and periods, all recorded concentrations remained within WHO guideline values throughout the 30-day monitoring period. This finding should not be read as an indication that no monitoring is needed; rather, it suggests that continued and, ideally, more frequent monitoring—particularly in locations and periods associated with comparatively higher concentrations—is warranted, since actual exposure risk can vary with duration and intensity of activity even within guideline-compliant environments.

Residents’ perceptions closely paralleled the environmental evidence. Vehicular emissions were rated the leading perceived source of carbon emissions, consistent with the general tendency of the public to associate transportation and fossil-fuel use with environmental emissions (Ballew et al., 2020), and with the broader evidence that traffic and household energy use rank among the foremost drivers of public climate-risk perception (Lee et al., 2015). The prominence given to generator fumes further reflects the well-documented reliance on small-scale petrol/diesel generators in Lagos households and businesses in response to irregular public electricity supply.

The significant difference in perception scores across locations, with Location B recording both the highest perception score and the highest measured CO_2 concentration, suggests a degree of correspondence between residents’ lived environmental experience and objectively measured pollution levels: residents in locations with more noticeable emission-generating activity appear to display greater awareness of emission sources, in line with evidence that direct environmental experience and exposure shape public risk perception. This correspondence is a useful, if indirect, indicator that community-level perception data can meaningfully complement instrumented monitoring in identifying priority areas for intervention, even though perception cannot substitute for direct measurement or source apportionment.

V. CONCLUSION AND RECOMMENDATIONS

Carbon dioxide and carbon monoxide concentrations varied significantly across the selected locations and across periods of the day, with the evening period consistently associated with the highest concentrations of both pollutants; nonetheless, all measured concentrations remained within WHO 8-hour guideline values throughout the monitoring period. Residents demonstrated a generally positive (agreement-level) perception of the major sources of carbon emissions, identifying vehicular traffic, household generators, industrial activity and waste burning as the principal sources, with perception levels differing significantly by location in a pattern that broadly mirrored measured CO_2 concentrations.

Based on these findings, it is recommended that:

- environmental authorities institute regular, and where feasible continuous, monitoring of ambient CO_2 and CO levels, with particular attention to locations and periods associated with higher concentrations;
- Targeted measures be implemented to reduce the major perceived and measured sources of emissions, particularly vehicular traffic and household generator use; and
- Public environmental health education be strengthened to build on residents' existing awareness of emission sources and translate this awareness into supportive behavior for emission-reduction interventions.

REFERENCES

[1] Adebayo, T. S., Udemba, E. N., Ahmed, Z., & Kirikkaleli, D. (2021). Determinants of environmental degradation in Sub-Saharan Africa: Energy consumption, economic growth, and carbon emissions. Environmental Science and Pollution Research, 28(35), 48984–48998. https://doi.org/10.1007/s11356-021-13878-7.

[2] Adelekan, I. O. (2016). Flood risk management in the coastal city of Lagos, Nigeria. Journal of Flood Risk Management, 9(3), 255–264. https://doi.org/10.1111/jfr3.12179.

[3] Ballew, M. T., Marlon, J. R., Leiserowitz, A., Maibach, E. W., Rosenthal, S. A., Kotcher, J. E., Bergquist, P., Goldberg, M. H., & Gustafson, A. (2020). Climate change risk perceptions, attitudes, and behavior. Current Opinion in Behavioral Sciences, 42, 1–8. https://doi.org/10.1016/j.cobeha.2021.02.007.

[4] Bekun, F. V., Emir, F., & Sarkodie, S. A. (2019). Another look at the relationship between energy consumption, carbon dioxide emissions, and economic growth in South Africa. Science of the Total Environment, 655, 759–765. https://doi.org/10.1016/j.scitotenv.2018.11.271.

[5] Cochran, W. G. (1977). Sampling techniques (3rd Ed.). John Wiley & Sons.

[6] International Energy Agency. (2021). Nigeria energy outlook 2021. International Energy Agency.

[7] International Energy Agency. (2025). Global energy review 2025: CO_2 emissions. International Energy Agency.

[8] Lagos Metropolitan Area Transport Authority. (2022). LAMATA annual report 2022. Lagos Metropolitan Area Transport Authority.

[9] Lee, T. M., Markowitz, E. M., Howe, P. D., Ko, C.-Y., & Leiserowitz, A. A. (2015). Predictors of public climate change awareness and risk perception around the world. Nature Climate Change, 5(11), 1014–1020. https://doi.org/10.1038/nclimate2728.

[10] Lewis, A. C., Lee, J. D., Edwards, P. M., Shaw, M. D., Evans, M. J., Moller, S. J.,

Smith, K. R., Buckley, J. W., Ellis, M., Gillot, S. R., White, A., Vaughan, A., & Fleming, Z. L. (2018). Evaluating the performance of low-cost chemical sensors for air pollution research. Faraday Discussions, 200, 85–103. https://doi.org/10.1039/C7FD00092J.

[11] Liu, Z., Deng, Z., Davis, S. J., Giron, C., Ciais, P., & Guan, D. (2023). Near-real-time monitoring of global CO_2 emissions. Nature Reviews Earth & Environment, 4, 205–217. https://doi.org/10.1038/s43017-022-00379-5.

[12] Morawska, L., Thai, P. K., Liu, X., Asumadu-Sakyi, A., Ayoko, G., Bartonova, A., Bedini, A., Chai, F., Christensen, B., Dunbabin, M., Gao, J., Hagler, G., Jayaratne, R., Kumar, P., Lau, A. K. H., Louie, P. K. K., Mazaheri, M., Ning, Z., Motta, N., & Williams, R. (2021). Applications of low-cost sensing technologies for air quality monitoring and exposure assessment: How far have they gone? Environment International, 116, 286–299. https://doi.org/10.1016/j.envint.2018.04.018.

[13] National Bureau of Statistics. (2021). Nigerian gross domestic product report (Annual report 2021). National Bureau of Statistics. https://www.nigerianstat.gov.ng.