Journal of Basic Physical Research ISSN: 2141-8403 Prints, 2141-8411 Online
Vol.14, Issue 2, October, 2025, pp. 249– 256, Available online at https://journals.unizik.edu.ng/jbpr/

SPATIO-TEMPORAL ANALYSIS OF CARBON MONOXIDE CONCENTRATIONS AT MAJOR ROAD JUNCTIONS IN OWERRI, NIGERIA: EVALUATING THE IMPACT OF TRAFFIC CONGESTION AND ENGINE IDLING."

Ewurum N.B.B.[1], David-Okoro, I. L.*[2], Nwosu I.E.[1], & Umeoka N.[3]
[1] Department of Physics Imo State University, Owerri Nigeria
[2] Department of Physics, & Industrial Physics Nnamdi Azikiwe University Awka Nigeria
[3] Department of Plant Science & Biotechnology, Imo State University, Owerri Nigeria
Email: ijaydaveo@gmail.com

Abstract
Carbon monoxide (CO) poisoning is a seamless and dangerous problem in developing countries like Nigeria. Chronic exposure to low or moderate concentrations of CO cause harm to the body and can lead to death when the concentration is high. This study conducted an analysis of CO levels at three strategic high-traffic intersections within the Owerri Municipal, two high concentrated junctions; Control Junction, and Ama J.K., and one mild-concentrated junction (Rock View Junction) using a Crowcon Gasman electrochemical sensor. Data were collected simultaneously across three diurnal time blocks over a five-day period to capture peak commute fluctuations. The results reveal that CO concentrations significantly peak during morning rush (08:00–11:00) and evening peak (16:00–19:00) rush hours, driven primarily by high traffic density, prolonged engine idling, and the prevalence of poorly maintained second hand vehicles. Control Junction recorded the highest mean concentration of 54.67 ppm, with peak values reaching 58.1 ppm. Ama J.K. junction recorded a mean value of 46.33 ppm, with a peak value of 56.5 ppm, while Rockview recorded a mean value of 38.27 ppm with a peak value of 47.9 ppm The concentrations obtained significantly exceed the updated WHO (2021) safety thresholds for urban environments.
Keywords: *Spatio-temporal, Carbon Monoxide, Traffic, Congestion, Engine Idling,*

Introduction

Owerri, the capital of Imo State, is a rapidly urbanizing metropolitan center characterized by high population density and significant rural-to-urban migration. This growth has resulted in a surge of vehicular traffic as residents commute to conduct daily commercial activities. In Owerri, the transportation infrastructure is heavily dependent on automobiles due to the absence of functional railway lines or inland waterways. Unlike mass transit rail systems, which can transport large volumes of passengers simultaneously while minimizing per capita emissions, the reliance on individual automobiles and small commercial vehicles significantly increases the discharge of carbon monoxide (CO) and other pollutants into the atmosphere.

The overburdening of the road network by heavy-duty, commercial, and private vehicles has led to chronic traffic congestion. This congestion results in prolonged engine idling, which serves as a primary source of vehicular exhaust. Consequently, commuters, roadside vendors, and residents in high-traffic corridors are continuously exposed to hazardous emissions. The Nigerian context is particularly concerning; current reports indicate that a vast majority of the population is exposed to air pollution levels that far exceed the updated World Health Organization (WHO, 2021) safety guidelines.

Traffic Congestion and Air Quality in Owerri

In Owerri Municipal, the intersection of heavy commercial traffic and terminal bus stops has exacerbated bottlenecks at critical nodes such as Control Junction and Ama J.K. The transition from motorcycles to a high volume of tricycles (Keke Napep) and small commercial vehicles has further intensified congestion. David-Okoro et al. (2021) identified that the prevalence of "second-hand" (locally termed Tokunbo) vehicles, which often feature poorly maintained or aged engines, is a major driver of elevated emissions.

Vehicular exhaust is a complex mixture of pollutants, including CO and sulfur dioxide (SO_2). Exposure to SO_2 can cause severe respiratory irritation and may be fatal at high concentrations (David-Okoro et al., 2023). Furthermore, the synergistic effect of CO and SO_2 mixtures can lead to the rapid degeneration of cardiovascular and respiratory health (Diagi *et al*., 2022). Previous longitudinal studies by Ibe *et al*. (2016) found that while NO_2 and SO_2 occasionally fall within permissible limits, the mean concentration of general air pollutants in Owerri frequently exceeds both the Nigerian National Ambient Air Quality Standards (NAAQS) and the US NAAQS.

Health Implications of Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless, and non-irritating gas, making it particularly dangerous. Chronic exposure to moderate concentrations results in physiological distress, including headaches, dizziness, nausea, and cognitive impairment. CO possesses an affinity for hemoglobin approximately 200 times greater than that of oxygen. Upon inhalation, it binds to hemoglobin to form carboxyhemoglobin (COHb), effectively reducing the blood's oxygen-carrying capacity and leading to systemic tissue hypoxia (Lee & Chen, 2026).

According to Raub et al. (2000), COHb levels exceeding 10.0 ppm result in measurable hypoxia. These levels significantly surpass the WHO (2021) safety thresholds, which are set at approximately 3.5 ppm (4 mg/m^3) for a 24-hour period and 30.5 ppm for a 1-hour exposure. Such "hotspots" pose immediate and long-term neurological and cardiovascular risks, necessitating stricter emission standards and optimized traffic management by the Imo State environmental authorities.

Research Objectives

This study aims to quantify CO concentrations at high-traffic "hotspots" in comparison to milder traffic zones within Owerri. By assessing these concentrations, the research seeks to evaluate the environmental and public health risks posed to the population residing or working near these high-density locations.

Materials and Methods

Study Area

The study sites were 3 very busy junctions in Owerri Municipal in Imo State. Owerri, a capital city of Imo State, has a population of about 215,038. It is located in South Eastern Nigeria at 5.4851ºN and 7.0350ºE. Owerri has an elevation of 73m. The study sites chosen were three major junctions that have at least four major roads feeding it. The sites are: Control Junction, Ama J. K. and Rock view junctions. From the GPS used, Control Junction is located on the globe at (5.490, 7.020), Ama J. K is located at (5.488, 7.026), while Rock View is located at (5.493, 7032). These locations were purposively chosen as their anthropogenic activities differ. The criteria considered include locations with high population, high vehicular traffic, and waste combustion.

Control is positioned at a major road junction leading to World Bank area, Onitsha Road, Owerri Municipal and Port Harcourt Roads. The state secretariat is about one kilometer away in Porthacourt road which implies that people from different areas other than Porthacourt road in the municipal will likely pass through control. The junction witness many activities like it is an illegal bus stop for people travelling to, Port Harcourt, Onitsha, World Bank and people going to Owerri Municipal, it observes heavy traffic congestion all through the day.

Ama J.K. a junction situated on Dougla road, a major road passing through the middle of the city. This junction has roads which lead to the major Ekeonunwa market, Orji, Okigwe, Control, Amakohia to mention a few. It is at the hub of traffic and commercial activities. It links different parts of the city together.

Rock View junction connects the outskirt of the town to the main land of the city. The Government House is situated off the junction. The traffic is mild because there is freer flow of traffic as compared to the other two junctions.

Methodology

Crowcon Gasman Monitoring device was used to detect the CO concentration at each of the location. The experiment was performed for five days. Data were simultaneously taken at each of the three locations. Factors which will disturb the monitoring device from getting accurate readings like the rains, were avoided. The day was segmented into 3 diurnal blocks to align with the rhythm of Owerri Municipal's traffic and commerce. The three blocks are the morning rush (08:00 – 11:00), the mid-day transition (12:00 – 15:00), and the evening Peak (16:00 – 19:00). The purpose is to compare the daily result of these blocks.

The Crowcon Gasman air monitoring device is very simple to use in the sense that it is simplified for on the spot CO measurement. The gas meter is raised upward to a certain height (5 to 6) meers to capture the average breathing level of man. The measurement was done over a period of time. The knob was moved from the test position to on position. It makes a beep sound; this alarm indicates the measurement was working and that the battery was fully charged. A reading appears on the screen, it fluctuates until it gets stabilized at a certain level. The concentration of CO in ppm of that of the location was then read off on the screen and is recorded directly. This device gives a continuous measurement of CO within a relative time interval in that location.

Data Analysis and Discussions

This experiment was conducted simultaneously at the sites for five (5) days. The results are shown in Table 1.0

The result from the CO monitor is as shown in table 1

Table 1 readings obtained from the CO u at the 3 junctions

		Control Junction	Ama J. K. Junction	Rock view Junction
Day1	8.0 -11.0 am	54	45	38.9
	12.0-3.0 pm	50.5	40.5	31.3
	4.0 -7.0 pm	58	43.8	36.8
	8.0 -11.0 am	56.5	44.5	38.8
Day 2	12.0-3.0 pm	51	41	30.6
	4.0 -7.0 pm	58	43.6	35.8
	8.0 -11.0 am	55	49.9	43.7
Day 3	12.0-3.0 pm	50.3	47.8	40.2
	4.0 -7.0 pm	57.6	45.9	43.3
	8.0 -11.0 am	56.4	53.9	42.8
Day 4	12.0-3.0 pm	50.9	47.8	43.3
	4.0 -7.0 pm	57.8	56.5	42.8
	8.0 -11.0 am	54.2	47.9	38.8
Day 5	12.0-3.0 pm	50.3	42.3	31
	4.0 -7.0 pm	58.1	44.6	35.9

Analysis of Carbon Monoxide (CO) Concentrations by Study Site
The spatial distribution of Carbon Monoxide (CO) across the selected sites revealed a direct correlation between traffic density, vehicle idling, and pollutant concentration. The measured levels at each junction reflect the varying degrees of anthropogenic pressure and topographical flow within Owerri Municipal.

Graphs of the readings for the five days are plotted and analyzed. A plot of the concentrations got at the three junctions was plotted and the result is as seen in figure 1.0.

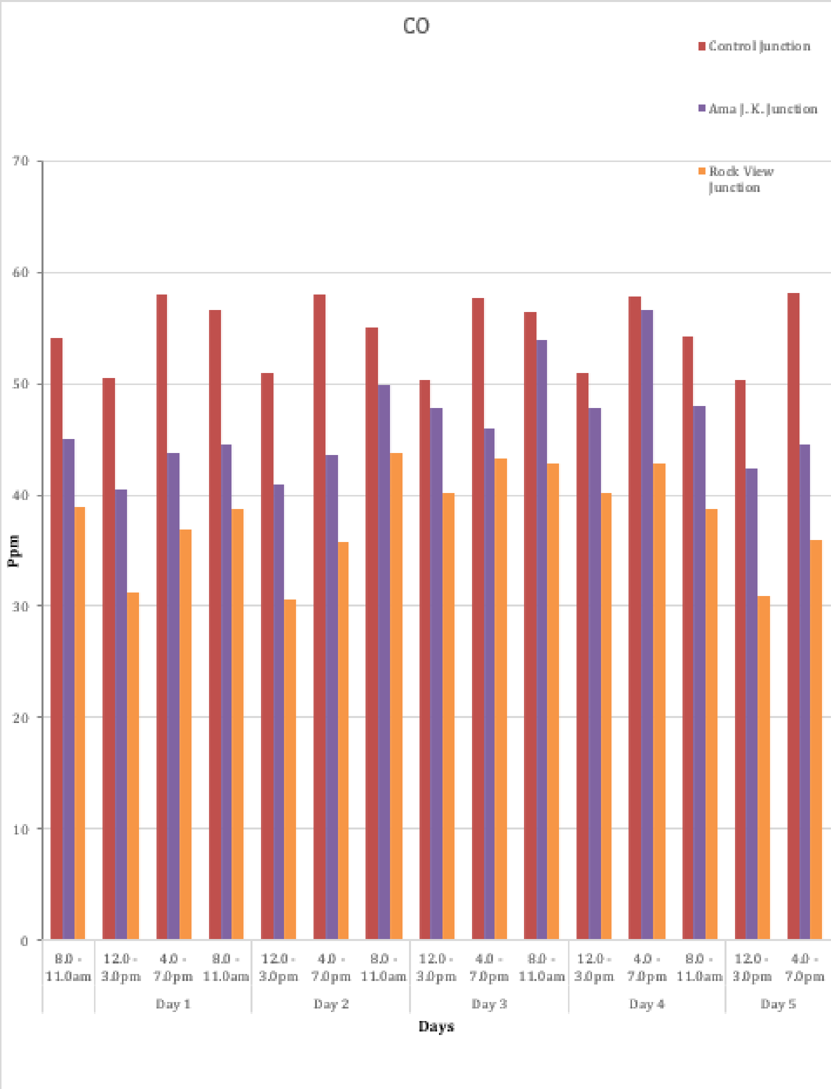


Figure 1.0, A graph of CO concentration for the three junctions monitored.

From figure 1.0, the highest concentration of 58.1 ppm was observed at Control Post followed by Ama J.K while the least concentration for all the data was observed at Rockview junction. Traffic at Rockview is not as concentrated as the traffic at both Ama J.k. and Control.

Control Junction.
From figure 1.0, the highest concentration was recorded during the evening peak at Control junction, it recorded 58.1ppm followed by days 1 and 2 both recorded 58.0ppm. The least concentrations at Control junction was observed during the mid-day transition. It recorded a

value of 50.3 ppm for both days 3 and 5. Morning rush hours at Control was relatively high but not as high as the evening peak.

The traffic congestion at Control could be due to the fact that passengers board the vehicles to different places like Lagos, Onitsha and Port Harcourt to mention but a few for those travelling outside the state. Passengers going to local destinations also board vehicles there. This can account for the heavy traffic congestion, more engine idling and hence the highest level of concentration of CO.

b). Ama J.K. is the commercial hub of the town. Ama J. K. has lots of congestion from vehicles moving to the market due to traders blocking the road, vehicles conveying people and turning around to pick up passengers, heavy trucks conveying goods to and from the market. Many shops are cited around Ama J.K. There is congestion of shops and most of them use generators during most of the time because of irregular supply of electricity. This can add to the high concentration of CO during morning rush at Ama J. K. The concentration of CO during evening peak is high even though it is not as high the morning rush.

Rockview Junction

The traffic at Rockview is flowing. At the junction people going to Orji and Control board transportation at different roads at the junction. The idling of engine is not as intense as those at Ama J. K. and Control.

Mean Average Concentration
The mean Concentration for each site was calculated and the result is as shown in figure 2.0

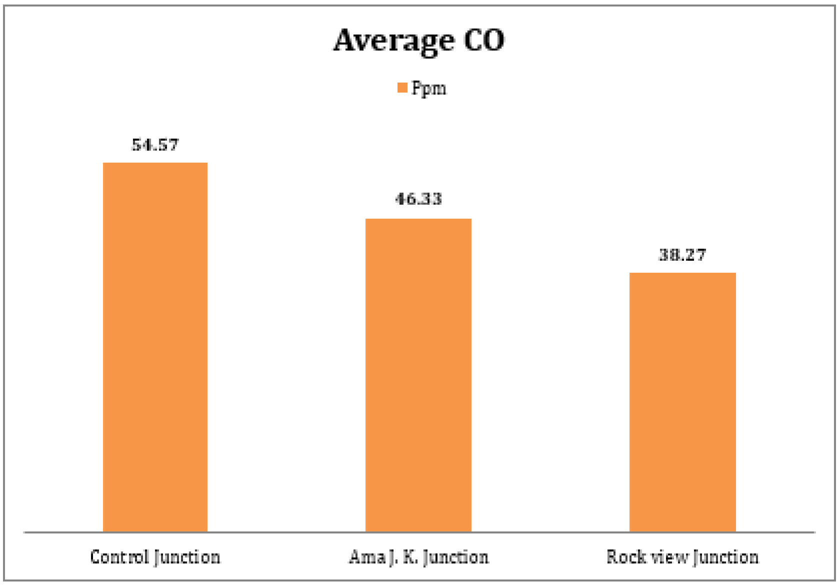
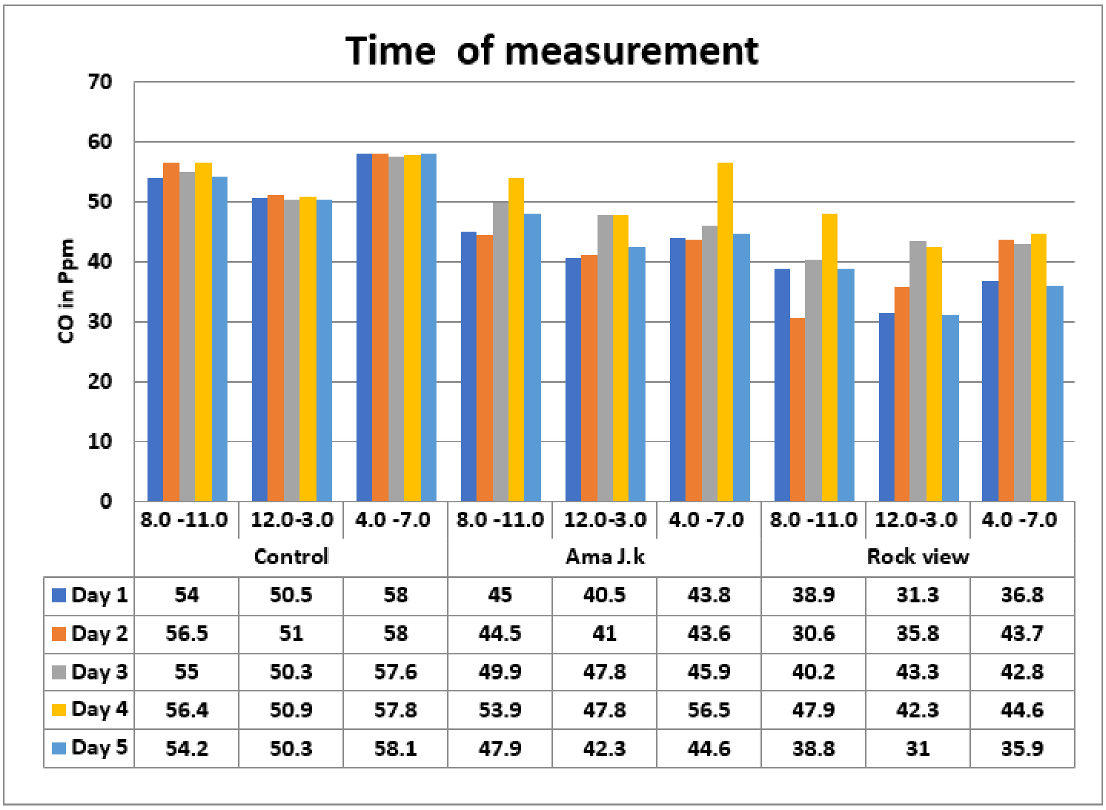


Figure 2.0 Average CO at each location

From figure 2.0, Control junction recorded an average of 54.67 ppm, followed by Ama J. K., which recorded 46.3 ppm while Rockview recorded 38.27 ppm.

Spatio-Temporal measurement at each site

The time of measurement for each site for the five days was assessed and is as shown as shown in figure 3.0



	8.0 -11.0	12.0-3.0	4.0 -7.0	8.0 -11.0	12.0-3.0	4.0 -7.0	8.0 -11.0	12.0-3.0	4.0 -7.0
	Control			Ama J.k			Rock view		
Day 1	54	50.5	58	45	40.5	43.8	38.9	31.3	36.8
Day 2	56.5	51	58	44.5	41	43.6	30.6	35.8	43.7
Day 3	55	50.3	57.6	49.9	47.8	45.9	40.2	43.3	42.8
Day 4	56.4	50.9	57.8	53.9	47.8	56.5	47.9	42.3	44.6
Day 5	54.2	50.3	58.1	47.9	42.3	44.6	38.8	31	35.9

Figure 3.0, Time of measurement of carbon monoxide (CO).

The temporal study was specified into three blocks.

The first block is the morning peak or 8am to 11 am (08:00 – 11:00). The second block is the mid-day Transition or 12.0am to 3.0 pm (12:00 – 15:00), while the evening Peak or 4.0-7.0pm (16:00 – 19:00) is the third block.

i). The morning peak (08:00 – 11:00), which coincides with the "rush hour" as residents strive to get to their different places of work. Early in the morning, there is high volume of cold-start engines which normally emit more CO than warm engines (Jayaratne, et al. 2021). The Planetary Boundary Layer (PBL) trapping pollutants closer to the ground where people breathe is another driver of high CO in the mornings (Garratt, 2023; Okafor, et al. (2024). These three phenomenons may account for high and heavy congestion at major entry points like Control Junction and high activity areas like Ama J. K.

ii). The mid-day Transition (12:00 – 15:00).

a). Control Junction.

From figure 3.0, the least values observed for all the days at Control Junction were observed between 12:00 – 15:00. This is characterized by a slight dip in through-traffic seen in each of the sites in in figure 1.

b). Ama J. K. Junction

The highest concentrations were recorded in the mornings except on the third day when a lower value of 53.9 ppm was recorded at 8am to 11am and a higher value of 56.5 ppm was observed at 3pm to 7pm. This shows that the time of the peak concentration for CO at Ama J.K. is the morning peak (08:00 – 11:00).

c). Rockview junction recorded it's highest values in the mornings of days 1, 4 and 5 while on day 2, the highest value of 43.7 ppm was recorded at 16.00 to 19.00 hours. A significant change in trend was observed on day 3 at Rockview junction when the highest value of 43.7ppm was observed at 12.00 to 16.00 hours.

The data demonstrates that CO concentrations are spatio-temporally dynamic, with the evening peak hour (4.00–7.00 pm) representing the most hazardous period for human exposure. The primary drivers of these elevated levels are identified as chronic traffic congestion, prolonged engine idling, and the prevalence of poorly maintained "used" vehicles. Without immediate intervention, urban growth will likely exacerbate these concentrations, leading to severe long-term cardiovascular and respiratory health consequences for the population.

Recommendations

To mitigate the rising threat of CO-related health risks in Owerri, the following measures are recommended:

Policy Enactment & Enforcement: Environmental management agencies in Imo State must develop and strictly enforce emission standards, particularly targeting the mechanical fitness of imported used vehicles.

Strategic Traffic Management: Urban planners should implement measures to reduce "stop-and-go" idling at identified hotspots through optimized signal timing, road expansions, or the introduction of low-emission zones during peak hours.

Continuous Monitoring Infrastructure: The establishment of a permanent, real-time air quality monitoring network is essential to provide data-driven insights for public health advisories and future urban policy.

Public Awareness: Educational campaigns are necessary to inform the populace—especially street vendors and commuters—of the risks associated with peak-hour exposure and the benefits of vehicle maintenance.

References

Abiodun, O. O., & Jerome, O. (2023). Spatial analysis of vehicular emissions and air quality in Nigerian urban centers: A review. Journal of African Earth Sciences, 198, 104–112. https://doi.org/10.1016/j.jafrearsci.2023.104812

David-Okoro, I. L., Chineke, C. T., Osuafor, M. A., Ewurum, N. B. B., Nwosu, I. E., & Nwofor, K. O. (2021). Spatio-temporal assessment of surface concentration of carbon monoxide over Nigeria from 2007 to 2016 using remote sensing data. Conference Proceedings, 2(1), 66-81.

David-Okoro, I. L., Chineke, T. C., Nwofor, O. K., Ewurum, N. B. B., & Chinaka, J. (2023). Regional assessment of remotely sensed surface concentration of Sulphur dioxide (SO_2) in Nigeria from 2003 to 2019 using NASA Giovanni air quality. International Journal of Innovative Science and Research Technology (IJISRT), 8(4), 2511-2516. https://www.scirp.org/journal/paperinformation

Diagi, B., Ajiere S., Okorondu N., Ekweogu, C., Chidinma Acholonu, C., Obanaka E. (2022). An Assessment of Vehicular Emission in the Vicinity of Selected Markets in Owerri, Imo State, Nigeria Journal of Geoscience and Environment Protection > Vol.10 No.1, January 2022

Ezeja, C. C., Ologunla E. S., & Oniore J. (2024). Economic Contribution of Transportation Modes to the Growth of the Industrial Sector in Nigeria: 1986-2023. *International Journal of Advanced Studies in Economics and Public Sector Management | IJASEPS* Vol. 12, (2) https://internationalpolicybrief.org/wp-content/uploads/2024/11/ARTICLE-2.pdf

Garratt, J. R. (2023). The Atmospheric Boundary Layer. Cambridge University Press.

Ibe, F. C., Alinnor J. C., Njoku, A. I., Opara, A. I. (2016). Evaluation of Ambient Air quality in parts of Imo state, Nigeria. *Journal of Geoscience and Environment Protection* Vol.10 (1)https://www.scirp.org/journal/paperinformation

Jayaratne, R., Phong, T. K., Christensen, B., Liu, X., Thai, P., Dunbabin, M., ... & Morawska, L. (2021). The effect of cold-start emissions on the diurnal variation of carbon monoxide concentration in a city centre. Atmospheric Environment, 245, 118035. https://www.google.com/search?q=https://doi.org/10.1016/j.atmosenv.2020.118035

Lee, C., & Chen, N. (2026). The rationalization of carbon monoxide and hemoglobin association. PLOS One, 21(3), e0346152. https://www.google.com/search?q=https://doi.org/10.1371/journal.pone.0346152k

Okafor, C. U., Emeka, S. J., & Nnaji, C. E. (2024). Meteorological influences on urban air quality in West African cities. African Journal of Environmental Science, 18(2), 45-59.10.

Garratt, J. R. (2023). The Atmospheric Boundary Layer. Cambridge University Press. (This is a foundational text for explaining the "trapping" mechanism).

Raub, J. A., Mathieu-Nolf, M., Hampson, N. B., Thom S. R., (2000)Carbon monoxide poisoning—a public health perspective. 2000;145:1–14. doi: 10.1016/s0300-483x(99)00217-6. [DOI

USEPA (2024). Criteria air pollution US Environmental Protection Agency https://www.epa.gov/criteria-air-pollutants

World Health Organization. (2021). WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. https://iris.who.int/handle/10665/34532