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Analysis of Temporal Variations in Carbon Monoxide Concentration at a Highly Congested Urban Roadway Intersection

Ghanshyam
Research Scholar, Department of Civil Engineering, F/O Engineering & Technology, Jamia Millia Islamia (A Central University), Jamia Nagar, New Delhi – 110025, India

Abstract: *Carbon monoxide (CO) is one of the principal pollutants emitted from vehicular traffic, along with particulate matter, nitrogen oxides, volatile organic compounds, and ozone. It is primarily produced due to incomplete combustion of fuel in motor vehicles. Signalized urban intersections experience frequent vehicle idling and stop-and-go movement, resulting in increased emissions and elevated pollutant concentrations. This study investigates the temporal variation of hourly average CO concentrations at a congested urban roadway intersection. Four approach roads forming the intersection were selected, and two monitoring locations were identified along each approach. CO concentrations were monitored from 8:00 AM to 8:00 PM using a portable real-time CO analyzer during March–May 2011. The analysis revealed two distinct daily peaks corresponding to morning and evening traffic rush hours. Both one-hour and eight-hour average CO concentrations frequently exceeded the prescribed ambient air quality standards. Spatial variations indicated higher CO levels near high-rise buildings and lower concentrations near open or low-rise areas, highlighting the combined influence of traffic volume and urban geometry on roadside air quality.*
Keywords: *Carbon monoxide, Urban traffic, Road intersection, Temporal variation, Air quality monitoring*

I. Introduction

Rapid urbanization and economic growth have led to a substantial increase in vehicular traffic in Indian cities. Although improvements in vehicle technology and fuel quality have helped reduce emissions at the source, traffic-related air pollution remains a significant environmental and public health concern. Motor vehicles are now among the largest contributors to urban air pollution, accounting for a major share of total emission loads.

Carbon monoxide (CO) is a dominant traffic-generated pollutant, particularly under congested driving conditions. It is a colorless, odorless, and toxic gas that interferes with the oxygen-carrying capacity of blood. Exposure to elevated CO levels can cause adverse cardiovascular and neurological effects, especially among individuals with pre-existing health conditions. Long-term exposure, even at relatively low concentrations, may result in chronic health impacts.

Urban road intersections are recognized as pollution hotspots due to frequent acceleration, deceleration, and prolonged idling of vehicles. Previous studies have reported elevated concentrations of traffic-related pollutants near major roadways compared to urban background levels. These concentrations are influenced by traffic characteristics, meteorological conditions, roadway geometry, and surrounding building configurations. The present study aims to assess the temporal variation of CO concentrations at a heavily congested urban intersection and examine the influence of surrounding built environments on pollutant distribution.

II. Materials and Methods

A. Study Area

The study was conducted at the ITO intersection in Delhi, India, a fully signalized and heavily trafficked junction. The intersection consists of four major approach roads leading toward Laxmi Nagar, Minto Road, Delhi Gate, and India Gate. The surrounding land use includes institutional buildings, schools, police headquarters, and open spaces, providing varied urban geometries and ventilation conditions.

B. Selection of Monitoring Locations

Two receptor locations were selected along each approach road, resulting in a total of eight monitoring points. The locations were chosen to represent contrasting roadside environments, such as proximity to high-rise buildings and relatively open areas, in order to capture spatial variability in CO concentrations.

C. Reconnaissance Survey

A reconnaissance survey was conducted to document roadway characteristics, including road width, number of lanes, and median configuration. Traffic volume and composition data were collected during the monitoring period and classified into heavy commercial vehicles, light commercial vehicles, cars, three-wheelers, and two-wheelers. Traffic counts were recorded on an hourly basis, with special emphasis on morning, afternoon, and evening peak periods.

Meteorological parameters such as wind speed, wind direction, atmospheric stability, and mixing height were obtained from the Indian Meteorological Department to aid in the interpretation of dispersion conditions.

D. CO Monitoring and Data Analysis

Carbon monoxide concentrations were measured using a portable online CO monitor with a resolution of 0.1 ppm. The instrument was calibrated prior to use. Monitoring was carried out from 8:00 AM to 8:00 PM at each location over three consecutive days per month from March to May 2011.

Due to the absence of an internal data logging system, CO readings were manually recorded at three-minute intervals. Hourly average concentrations were calculated from twenty readings per hour. The collected data were analyzed using spreadsheet software to evaluate temporal trends and spatial variations across the intersection approaches.

III. Results and Discussion

A. Diurnal Variation of CO Concentration

Across all monitoring locations, CO concentrations exhibited a consistent diurnal pattern with two prominent peaks. The morning peak typically occurred between 9:00 AM and 11:00 AM, while the evening peak was observed between 6:00 PM and 8:00 PM. These peaks coincided with maximum traffic density and reduced vehicle speeds, leading to increased emissions and pollutant accumulation.

Both one-hour and eight-hour average CO concentrations frequently exceeded the prescribed ambient air quality standards, indicating persistent non-compliance at the study location.

B. CO Variation along Minto Road Approach

Figure 1 shows the typical layout of the study intersection with the four approach roads and monitoring locations.

Figure 1: Layout of ITO intersection showing approach roads and monitoring locations (not to scale). The Minto Road approach is flanked by the INSA Building on one side and the Andhra School Building on the other. Higher CO concentrations were consistently recorded near the taller INSA Building, particularly during peak traffic hours.

Figure 2: Hourly variation of CO concentration at monitoring locations along the Minto Road approach. This can be attributed to reduced ventilation and a step-down street canyon effect, which promotes pollutant accumulation near high-rise structures.

C. CO Variation along Delhi Gate Approach

Figure 3: Hourly variation of CO concentration at monitoring locations along the Delhi Gate approach. Along the Delhi Gate approach, elevated CO levels were observed near the INSA Building and the Police Headquarters. One-hour average concentrations at both locations exceeded permissible limits during peak hours, while eight-hour averages also indicated significant non-compliance. The built-up environment and restricted dispersion contributed to higher pollutant levels.

D. CO Variation along Laxmi Nagar Approach

Figure 4: Hourly variation of CO concentration at monitoring locations along the Laxmi Nagar approach. The Laxmi Nagar approach exhibited notable spatial variation in CO concentrations. Higher levels were measured near the Police Headquarters, whereas lower concentrations were observed near the Institution of Engineers Building. Improved ventilation and open surroundings at the latter location facilitated better dispersion of pollutants.

E. CO Variation along India Gate Approach

Figure 5: Hourly variation of CO concentration at monitoring locations along the India Gate approach. On the India Gate approach, CO concentrations were generally higher near the Institution of Engineers Building compared to the Andhra School Building. Although exceedances were observed during peak hours at both locations, the relatively open urban configuration allowed for enhanced dispersion and comparatively lower accumulation than at other approaches.

IV. Conclusions

The present study demonstrates that carbon monoxide concentrations at congested urban intersections show significant temporal and spatial variability. Two consistent daily peaks were identified during morning and evening rush hours. Observed one-hour and eight-hour average CO concentrations frequently exceeded ambient air quality standards, indicating potential health risks for commuters and nearby residents.

Higher CO concentrations were generally associated with locations adjacent to high-rise buildings, where reduced ventilation and street canyon effects limited pollutant dispersion. In contrast, open or low-rise environments exhibited lower concentrations due to improved airflow. These findings underscore the importance of integrating traffic management and urban planning strategies to mitigate roadside air pollution.

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