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Assessment of Near-Field Carbon Monoxide Concentrations along Bahadur Shah Zafar Marg Using the CALINE-4 Model

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ABSTRACT
Urban air quality has become a critical environmental concern due to rapid growth in vehicular traffic and associated emissions. Among traffic-related pollutants, carbon monoxide (CO) is of particular importance in roadside environments. In this study, average hourly CO concentrations along Bahadur Shah Zafar Marg, New Delhi, were estimated using the CALINE-4 dispersion model and evaluated against field-measured data. CO monitoring was carried out at four selected roadside locations using a portable online CO analyzer during daytime hours (08:00–20:00). Model simulations were performed using realistic traffic, emission, and meteorological inputs. Both observed and modeled results exhibited distinct morning and evening peaks corresponding to traffic activity. Although CALINE-4 successfully reproduced the temporal variation of CO, the predicted concentrations were generally lower than the measured values. The findings highlight the applicability of CALINE-4 for near-road air quality assessment while indicating the need for local calibration to improve prediction accuracy.
Keywords: Carbon monoxide, Roadside air quality, Monitoring, Dispersion modeling, CALINE-4

I. INTRODUCTION

Motorized transport is a major contributor to urban air pollution, particularly in densely populated cities. Carbon monoxide (CO), a product of incomplete combustion, is emitted by all categories of motor vehicles, with gasoline-powered light-duty vehicles being the dominant source. Elevated CO levels are commonly observed near busy roadways and intersections, where traffic congestion and reduced dispersion prevail.

Understanding the spatial and temporal distribution of traffic-related pollutants has motivated extensive research on urban air quality modeling. Dispersion models provide a cost-effective approach to estimate pollutant concentrations under varying traffic and meteorological conditions. These models range from simple Gaussian formulations to advanced numerical simulations based on fluid dynamics. Early regulatory initiatives, such as the National Environmental Policy Act in the United States, accelerated the development of roadway pollution models including CALINE, HIWAY, and related line-source approaches.

Despite the availability of sophisticated models, their application is often constrained by limited input data. Under such conditions, relatively simple models have been shown to perform comparably well for near-road assessments. In this context, the present study aims to predict average hourly CO concentrations along Bahadur Shah Zafar Marg using the CALINE-4 model and to compare the results with field observations collected at selected locations.

II. MATERIALS AND METHODS

2.1 Study Area and Site Selection

Bahadur Shah Zafar Marg, a major urban roadway in New Delhi, was selected for this investigation due to its high traffic volume and heterogeneous vehicle mix. The road is bordered by buildings of varying heights and configurations, creating a typical urban street environment. Four monitoring locations were identified along the corridor—two on the Delhi Gate side and two on the India Gate side—each situated approximately 150 m away from the main intersection.

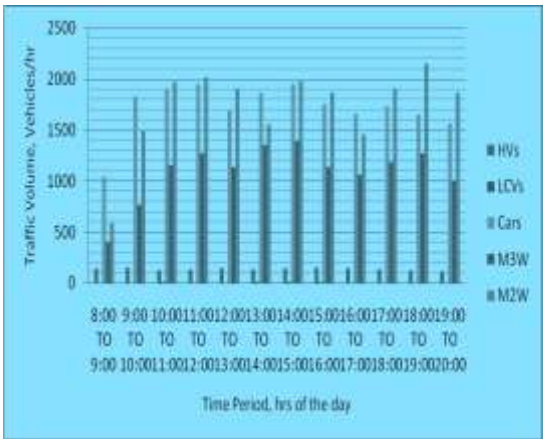

Fig.: Average hourly variation of traffic volume at Delhi Gate side on April, 2011

2.2 Carbon Monoxide Monitoring Instrument

Ambient CO concentrations were measured using a portable electrochemical CO detector (Model CO-84). The instrument allows real-time detection of CO through diffusion of ambient air into the sensing cell. It is capable of measuring CO concentrations in the range of 0.1–99 ppm, making it suitable for roadside monitoring applications.

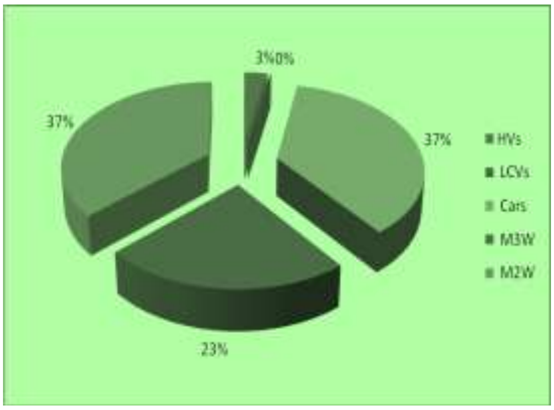

Fig.: Average traffic composition at Delhi Gate side on April, 2011

2.3 Monitoring Procedure

CO monitoring was conducted at each selected location between 08:00 and 20:00. Prior to deployment, the instrument was calibrated according to manufacturer guidelines. Since the device did not include an internal data-logging system, readings were recorded manually at three-minute intervals and subsequently averaged.

For the Delhi Gate side locations, monitoring was carried out from 18 March to 2 April 2011, while measurements at the India Gate side locations were performed between 20 April and 4 May 2011. At each site, 242 samples were collected per day. Hourly and eight-hour average CO concentrations were computed from the recorded data.

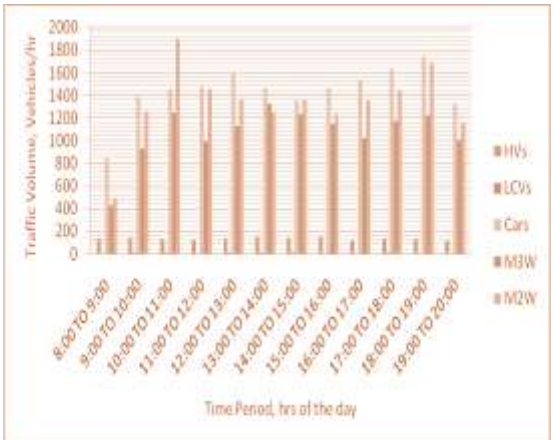

Fig.: Average hourly variation of traffic volume at India Gate side on April, 2011

2.4 Meteorological Data Collection

Meteorological parameters required for dispersion modeling—wind speed, wind direction, ambient temperature, atmospheric stability, and mixing height—were obtained from the India Meteorological Department, Mausam Bhawan, and the Central Road Research Institute (CRRI). Monthly datasets were analyzed to derive representative daily average values for model input. Wind rose analysis indicated prevailing winds predominantly along a west-to-east direction during April 2011.

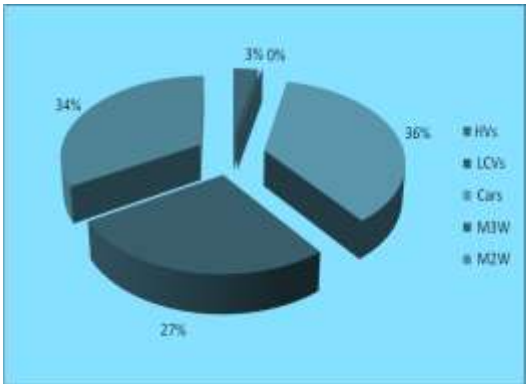

Fig.: Average traffic composition at India Gate side on April, 2011

2.5 Traffic Data Collection and Analysis

Traffic volume and composition data were collected during April 2011 through manual counting. Vehicles were classified into heavy vehicles (buses and trucks), light commercial vehicles, cars, three-wheelers, and two-wheelers. Counts were performed hourly from 08:00 to 20:00 for three consecutive days, and average hourly traffic volumes were calculated. Vehicle age distribution and emission factors were obtained from published CRRI reports.

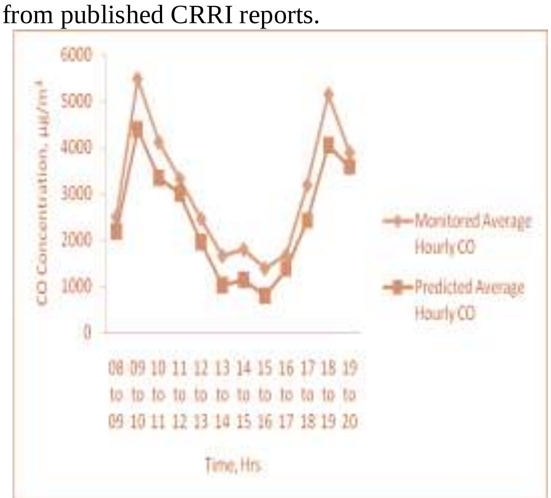

Fig.: Comparative monitored and predicted average hourly CO concentration at location 1

2.6 Traffic Characteristics: Delhi Gate Side

On the Delhi Gate approach, traffic volumes varied significantly throughout the day. Cars and two-wheelers constituted the largest share of traffic, followed by three-wheelers. Peak volumes were observed during mid-day and evening hours, reflecting typical urban commuting patterns. Heavy vehicles accounted for a relatively small but consistent proportion of the total traffic.

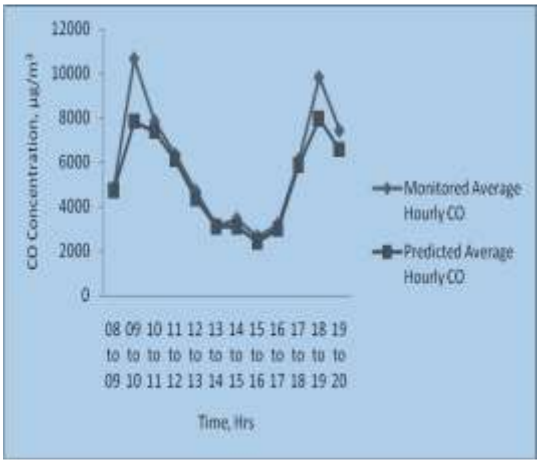

Fig.: Comparative monitored and predicted average hourly CO concentration at location 2

2.7 Traffic Characteristics: India Gate Side

Similar diurnal variations were observed on the India Gate side, although overall traffic volumes were slightly lower than those on the Delhi Gate side. The traffic mix was dominated by cars and two-wheelers, with three-wheelers also contributing substantially. Differences in roadside geometry and ventilation conditions were noted between the two approaches.

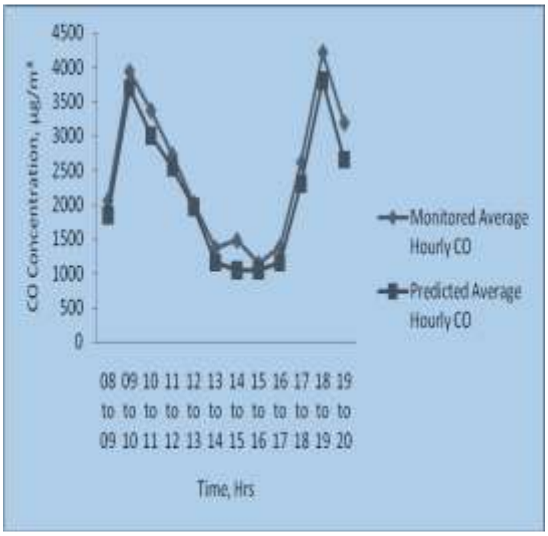

Fig.: Comparative monitored and predicted average hourly CO concentration at location 3

2.8 Estimation of Emission Factors

Average emission factors for CO were estimated for each vehicle category by accounting for vehicle age and deterioration effects. Composite emission factors were then calculated by weighting the category-specific emission factors according to their respective traffic volumes. These composite values were converted into appropriate units for use in the CALINE-4 model.

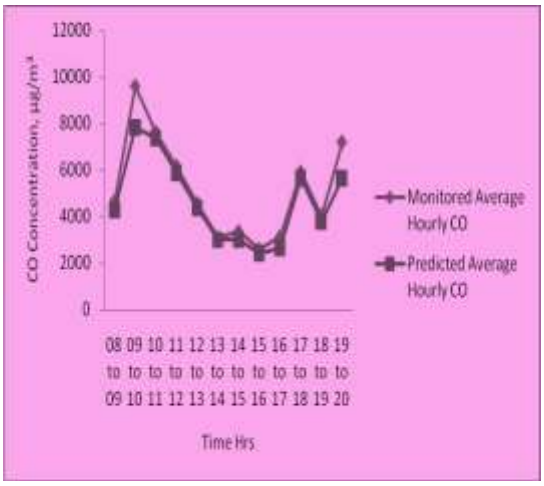

Fig.: Comparative monitored and predicted average hourly CO concentration at location 4

2.9 CALINE-4 Modeling Procedure

The CALINE-4 model was used to simulate hourly average CO concentrations at the predefined receptor locations. Model inputs included traffic volume, composite emission factors, roadway geometry, and representative meteorological conditions. Simulations were conducted for the monitoring periods corresponding to March and April 2011.

III. RESULTS AND DISCUSSION

3.1 Delhi Gate Side Locations

Modeled CO concentrations at the Delhi Gate side locations exhibited temporal patterns similar to those observed in the field measurements. Distinct morning and evening peaks were evident, corresponding to increased traffic density. However, CALINE-4 consistently produced lower concentration estimates than those measured, indicating under-prediction by the model.

3.2 India Gate Side Locations

At the India Gate side locations, both monitored and predicted CO concentrations followed comparable diurnal trends. Peak concentrations occurred during morning and evening hours, although absolute values were lower than those observed at the Delhi Gate side. The relatively open road environment and better ventilation on this side likely contributed to enhanced pollutant dispersion.

Overall, the agreement between modeled and observed trends demonstrates the capability of CALINE-4 to capture the influence of traffic patterns on near-road CO levels. Nevertheless, discrepancies in magnitude suggest that local factors such as street geometry, signalized intersections, and background concentrations may not be fully represented in the model.

IV. CONCLUSIONS

The present study assessed near-field carbon monoxide concentrations along Bahadur Shah Zafar Marg using a combination of field monitoring and dispersion modeling. Both observed and predicted results revealed pronounced morning and evening peaks associated with traffic activity. CALINE-4 successfully reproduced the temporal variation of CO concentrations but tended to under-estimate observed values.

Higher CO levels were recorded on the Delhi Gate side compared to the India Gate side, likely due to differences in traffic volume and ventilation conditions. The findings indicate that CALINE-4 is a useful tool for preliminary roadside air quality assessments in urban environments. However, incorporation of locally calibrated emission factors and refined representation of urban geometry could further improve model performance.

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