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Carbon Monoxide Prediction Modelling at a Non-Signalized Roadway Intersection

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ABSTRACT
Accurate estimation of carbon monoxide (CO) concentrations generated by vehicular traffic at roadway intersections is essential for understanding exposure levels and for developing effective air-pollution mitigation strategies. Intersections represent complex micro-environments where frequent stopping, idling, acceleration, and deceleration of vehicles lead to elevated emissions and non-uniform dispersion patterns. This study focuses on predicting CO concentrations in the vicinity of a non-signalized roadway intersection (roundabout) using the CALINE-4 dispersion model and validating the results with field-monitored CO data. Input parameters such as intersection geometry, traffic volume, fleet composition, emission factors, and meteorological conditions were obtained through detailed field surveys and secondary data sources. Model results indicate that both 1-hour and 8-hour average CO concentrations remain within prescribed ambient air-quality standards under existing traffic conditions, including peak hours. Comparison between predicted and monitored concentrations shows that CALINE-4 tends to overestimate CO levels; however, the agreement between predicted and observed values demonstrates the model's satisfactory predictive capability for non-signalized intersections.
Keywords: Non-signalized intersection, Carbon monoxide, CALINE-4, Traffic emissions, Air-quality modelling

I. INTRODUCTION

Urban air pollution is dominated by emissions from road traffic, particularly in rapidly growing cities where vehicle ownership and usage continue to rise. Despite advancements in vehicle technology and fuel quality, the overall benefits are often offset by increased traffic volumes, higher travel speeds, and inadequate roadway infrastructure. Intersections are especially critical locations because vehicles operate in multiple driving modes, including cruising, deceleration, idling, and acceleration. Among these, idling and acceleration modes typically produce higher pollutant emissions compared with steady-speed travel.

As a result, pollutant dispersion near intersections is more complex than along uninterrupted road links. Numerous studies have shown that pollutant concentrations, particularly CO, are significantly higher near intersections where vehicle queues form. Vehicles spend longer durations in emission-intensive modes at such locations, leading to localized pollution hotspots. Several modelling approaches have been developed to estimate pollutant concentrations near intersections, including deterministic, stochastic, and hybrid models. Among these, CALINE-based and CAL3Q-based models have been widely applied and evaluated for their ability to predict CO concentrations in congested urban settings.

While most previous research has focused on signalized intersections, comparatively limited attention has been given to non-signalized intersections such as roundabouts, where traffic flow patterns and queuing behavior differ substantially. The present study addresses this gap by applying the CALINE-4 model to a non-signalized intersection and evaluating its performance against monitored CO concentrations.

II. MATERIALS AND METHODS

2.1 Study Area

The Sabz Burz roadway intersection in Delhi was selected for this study. The intersection is non-signalized, moderately congested, and characterized by heterogeneous traffic composition. The surrounding built environment consists of buildings with varying heights, widths, and shapes, providing relatively open ventilation conditions. The roundabout connects four major approach roads:

1. Dr. Zakir Hussain Marg
2. Bharat Scouts and Guides Marg
3. Mathura Road
4. Lodhi Road

These roads carry substantial traffic volumes and represent typical urban traffic conditions in Delhi.

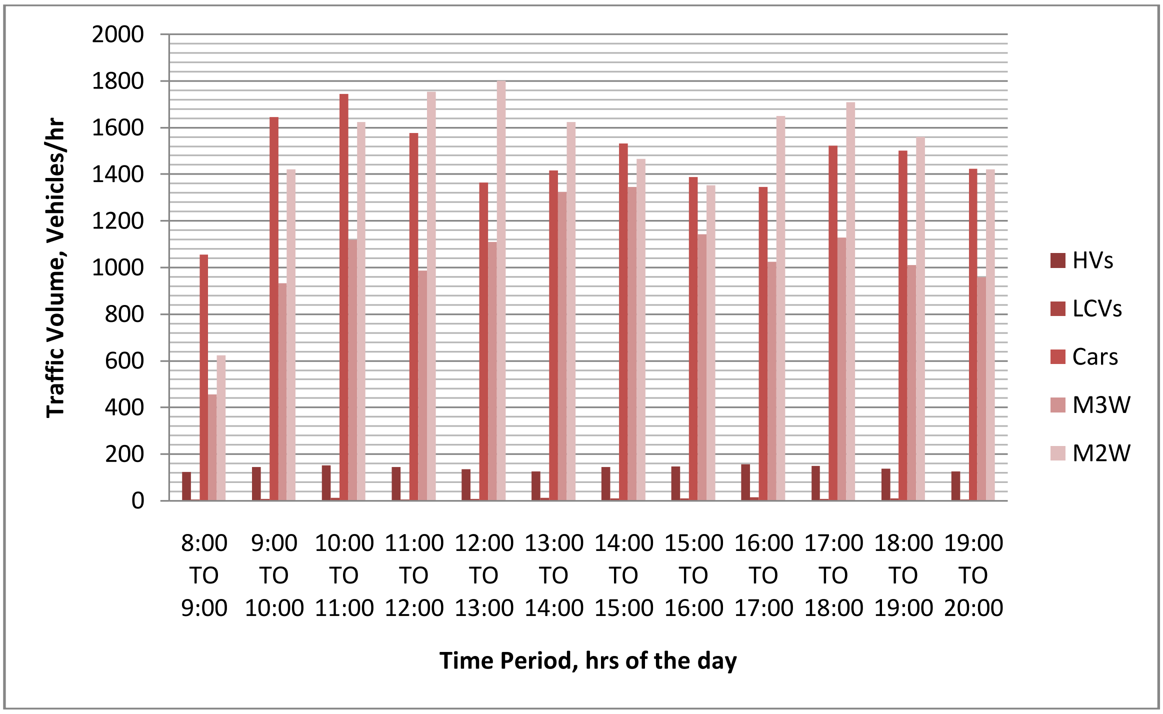


Fig.: Average hourly variation of traffic volume on March, 2011

2.2 Meteorological Data Collection

Meteorological parameters required for dispersion modelling—including wind speed, wind direction, ambient temperature, atmospheric stability, and mixing height—were obtained from the India Meteorological Department (IMD), Mausam Bhawan, and the Central Road Research Institute (CRRI), New Delhi. One-month data were analyzed to derive representative daily average values for model input.

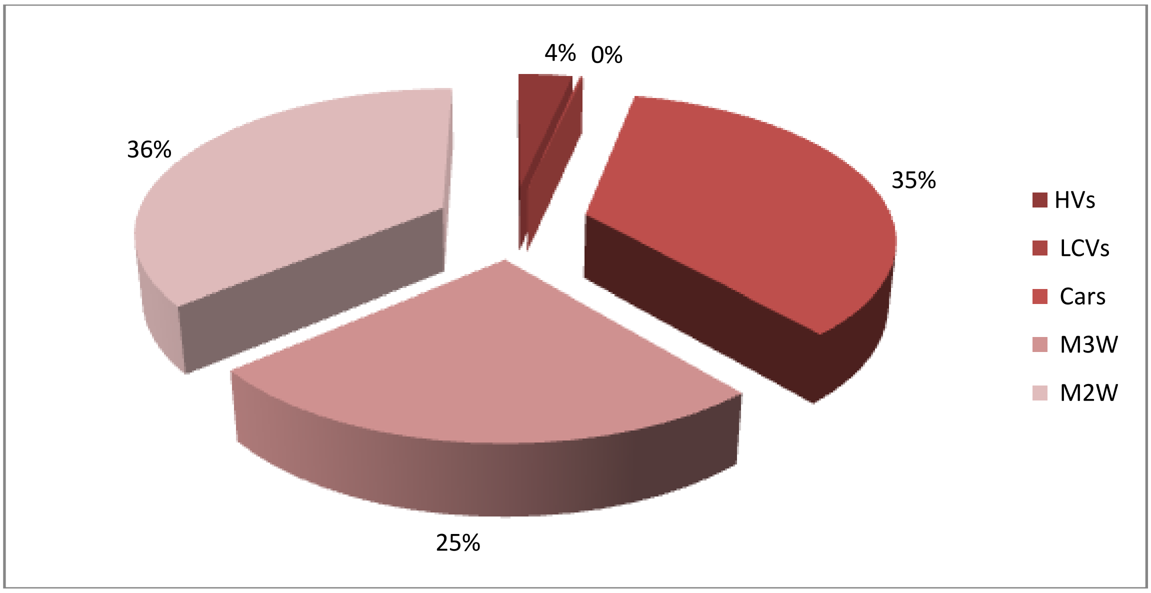


Fig.: Average traffic composition on March, 2011

2.2.1 Wind Pattern Analysis

Wind speed and direction data for March 2011 were processed to generate a wind-rose diagram using Win-Met software. The analysis indicated a dominant wind flow from the south-southwest to north-northeast direction, broadly corresponding to a west-to-east pattern. This information was used to determine appropriate receptor locations for CO concentration prediction.

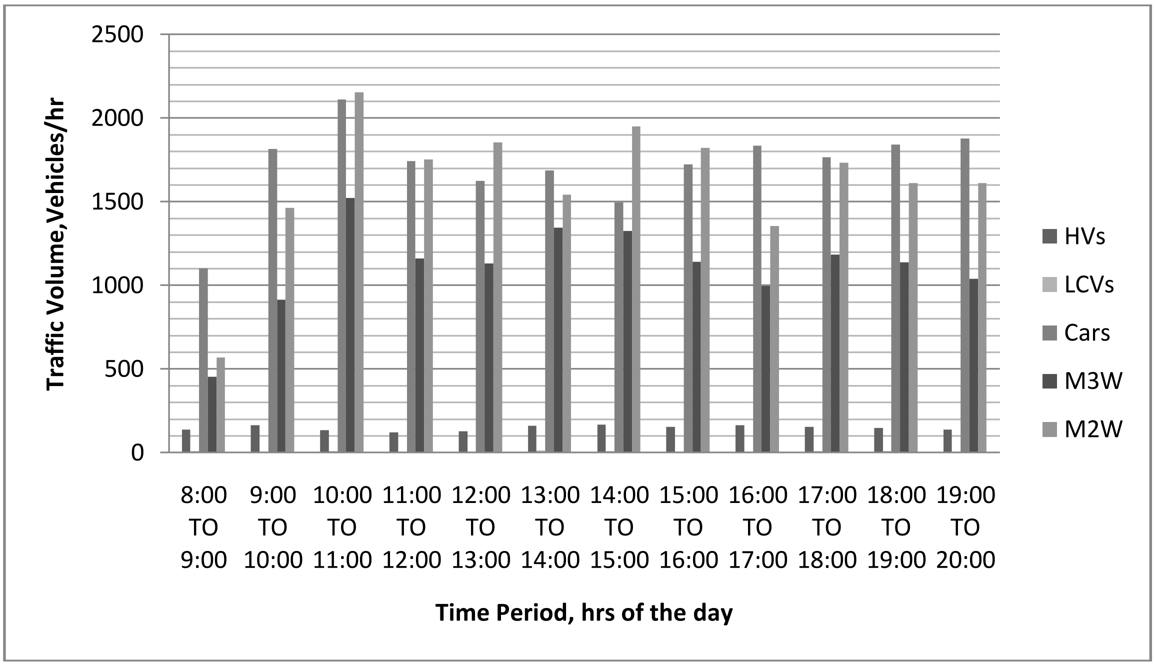


Fig.: Average hourly variation of traffic volume at Delhi Gate side on March, 2011

2.3 Traffic Data Collection and Analysis

Traffic volume and composition data were collected manually during March 2011. Vehicles were classified into heavy vehicles (buses and trucks), light commercial vehicles, cars, three-wheelers, and two-wheelers. Traffic counts were conducted on an hourly basis from 08:00 to 20:00 for three consecutive days on all four approach roads. Average hourly traffic volumes were then computed.

Emission factors corresponding to different vehicle categories and ages were obtained from published CRRI and CPCB reports. Traffic data analysis and emission calculations were performed using spreadsheet tools.

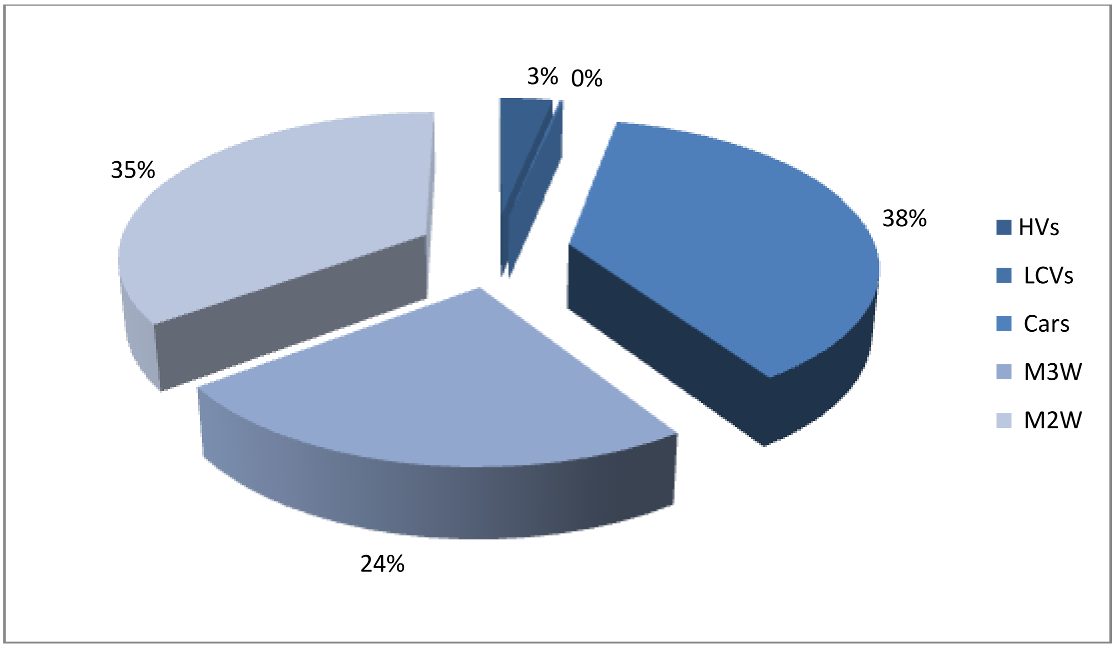


Fig.: Average traffic composition at Delhi Gate side on March, 2011

2.4 Vehicle Age Distribution and Emission Factors

Previous studies indicate that the vehicle fleet in Delhi is relatively young, with a substantial proportion of vehicles incorporating newer technologies. Age-dependent emission factors and deterioration factors were applied to estimate average emission factors for each vehicle category. Composite emission factors were then calculated by weighting category-specific emission factors with their respective traffic shares. These composite values were converted into the units required for CALINE-4 model input.

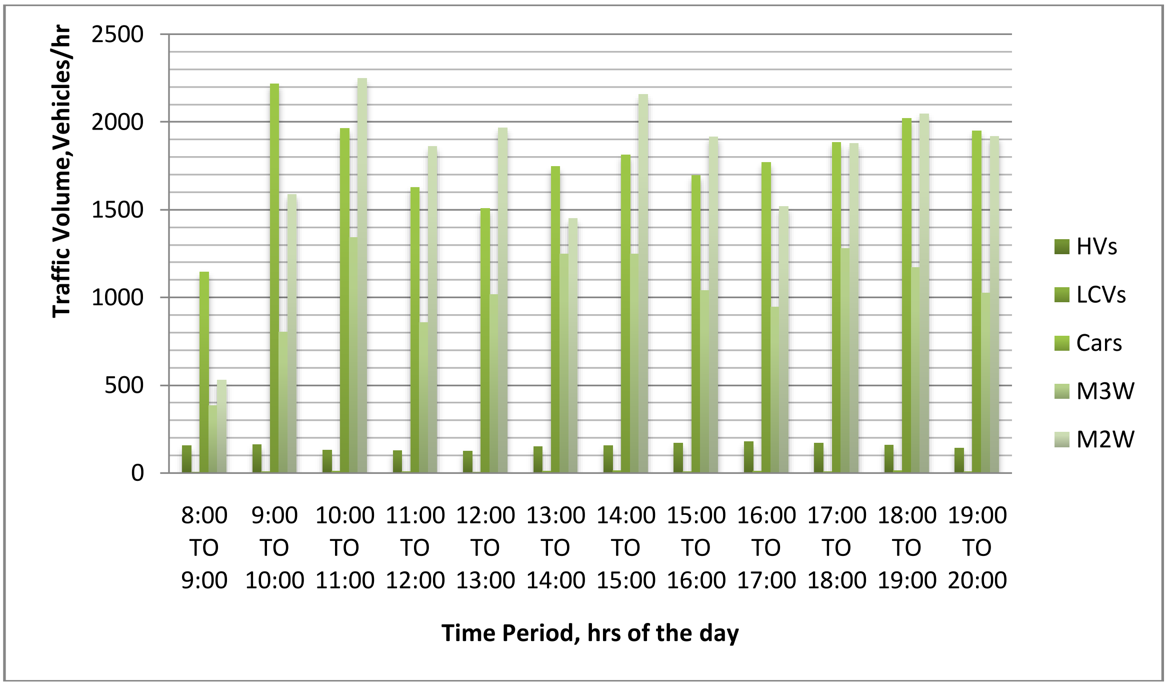


Fig.: Hourly variation of traffic volume at Mathura Road

2.5 CO Concentration Modelling

CO concentrations at selected receptor locations around the intersection were predicted using the CALINE-4 dispersion model. Input parameters included traffic volumes, composite emission factors, roadway geometry, and meteorological conditions. Model simulations were conducted for different time periods, with particular emphasis on peak traffic hours in March 2011. The model output provided hourly average CO concentrations at predefined receptor locations.

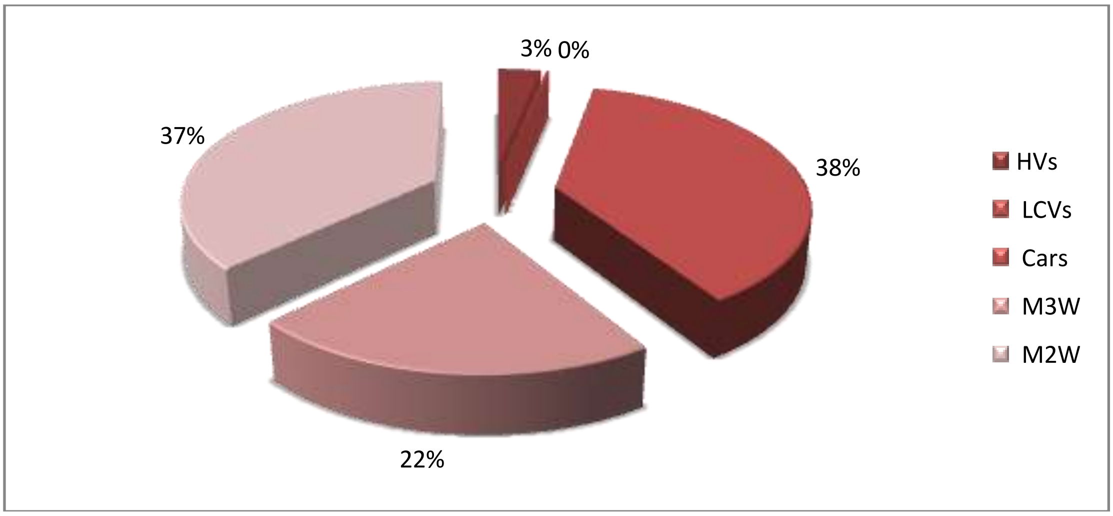


Fig.: Average traffic composition at Mathura Road

III. RESULTS AND DISCUSSION

3.1 Predicted CO Concentrations During Morning Peak (09:00–10:00)

Model results indicate that an increase in traffic volume during the morning peak leads to a corresponding rise in CO emissions. Maximum predicted concentrations of approximately 2.7 ppm were observed at a downwind distance of about 25 m under prevailing wind conditions. Concentrations decreased progressively with increasing distance from the intersection and varied with wind direction, demonstrating the strong influence of dispersion conditions.

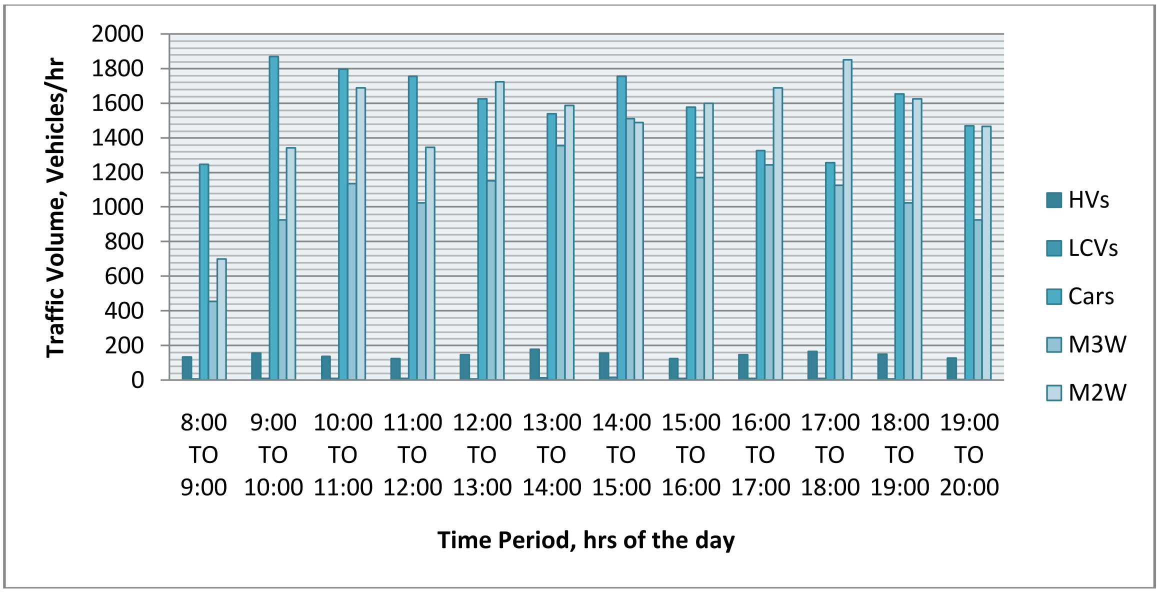


Fig.: Hourly variation of traffic volume at Lodhi Road

3.2 Predicted CO Concentrations During Midday Peak (13:00–14:00)

During midday hours, higher traffic activity resulted in slightly elevated CO concentrations, with maximum values reaching approximately 3.0 ppm at near-road receptors. The zone of maximum impact remained within 25 m of the intersection, beyond which concentrations declined steadily toward background levels.

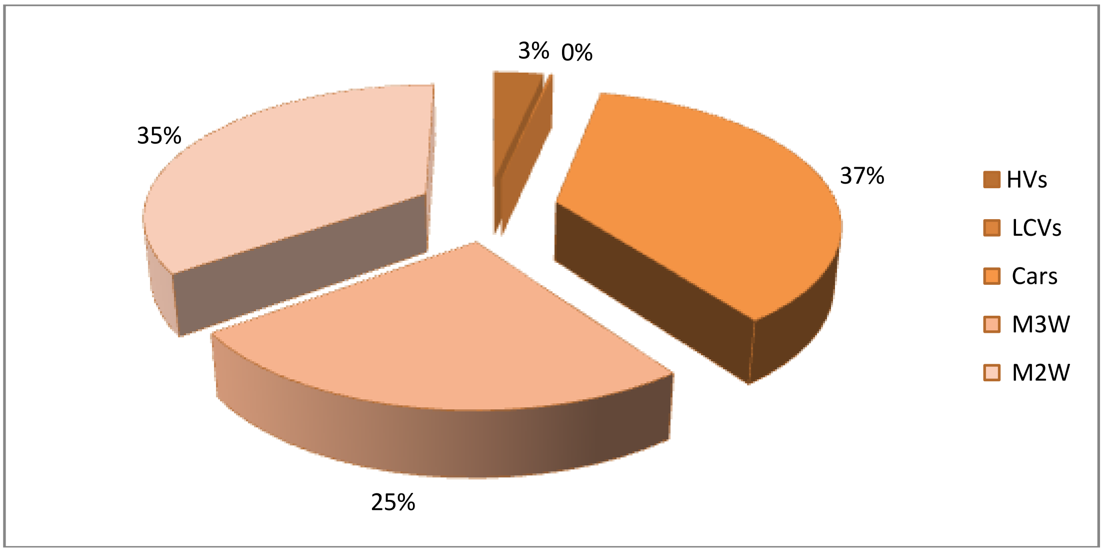


Fig. : Average traffic composition at India Gate sideon March, 2011

3.3 Predicted CO Concentrations During Evening Peak (17:00–18:00)

Evening peak predictions showed maximum CO concentrations of about 2.9 ppm at near-road locations. Although concentrations decreased with distance, detectable impacts extended farther downwind compared with morning conditions due to changes in traffic intensity and meteorological factors.

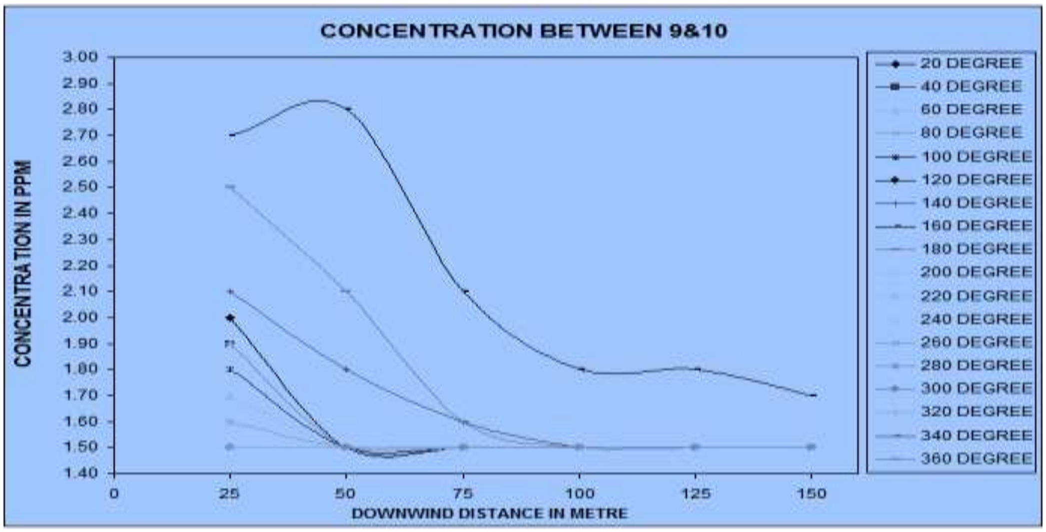


Fig.: CO concentration with downwind distances for various wind directions

3.4 Model Validation with Monitored Data

Monitored CO concentrations were obtained for upwind and downwind locations during selected time periods. Average background CO concentration in the upwind direction was approximately 1.5 ppm. Downwind concentrations were consistently higher, with maximum observed values occurring during the evening peak. Comparison of model predictions with measured data revealed that CALINE-4 overestimated CO concentrations by roughly 20–25%. Despite this bias, the model captured the overall temporal and spatial trends reasonably well, indicating good predictive performance.

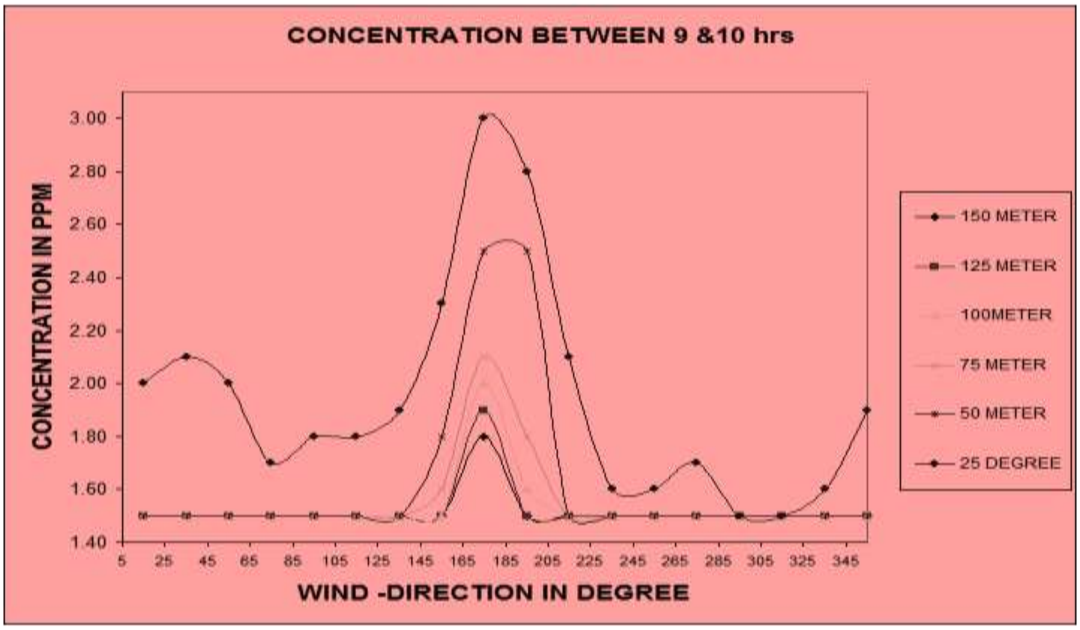


Fig.: CO Concentration with wind flow direction and downwind distances

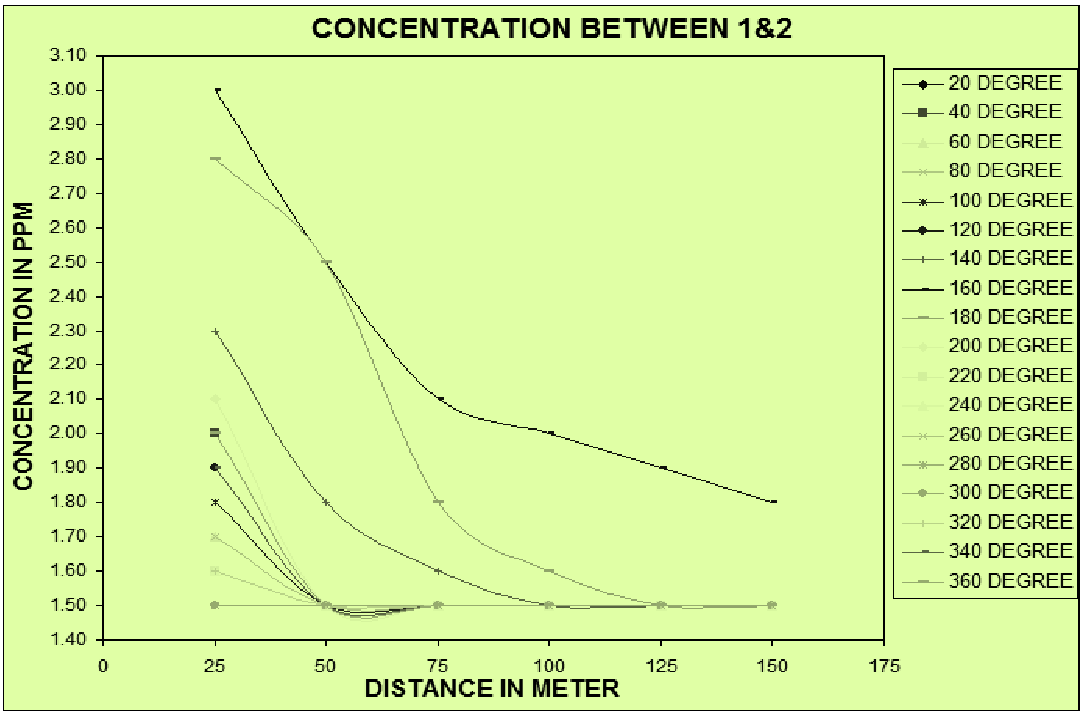
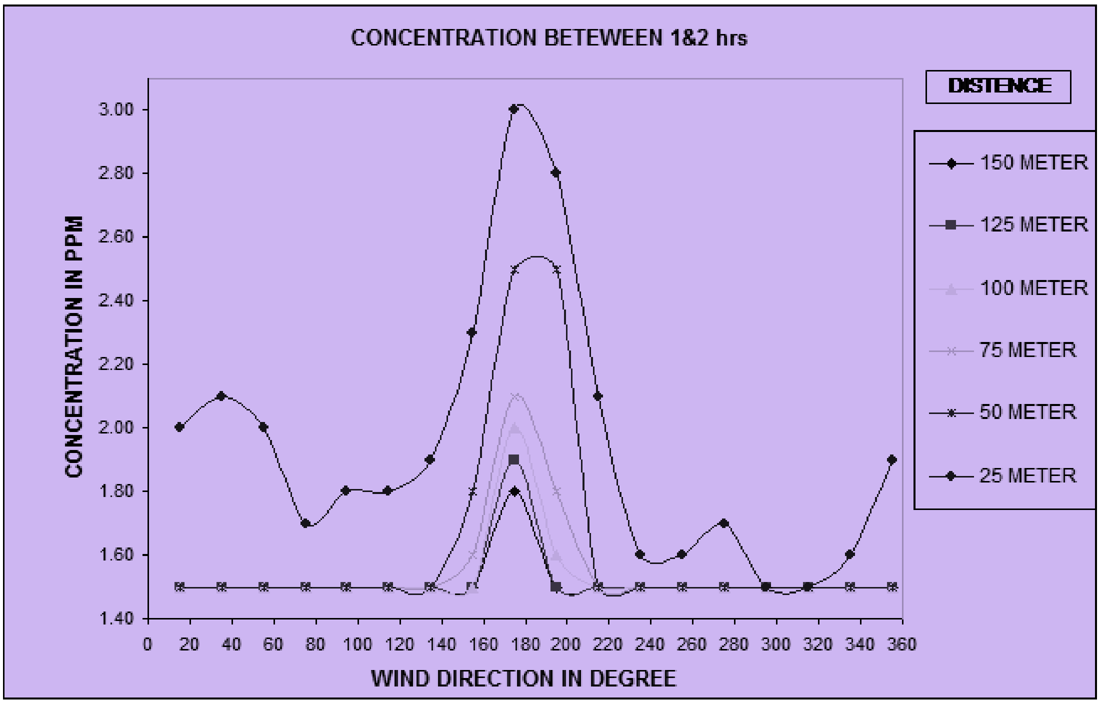


Fig.: CO concentration with downwind distances for various wind directions



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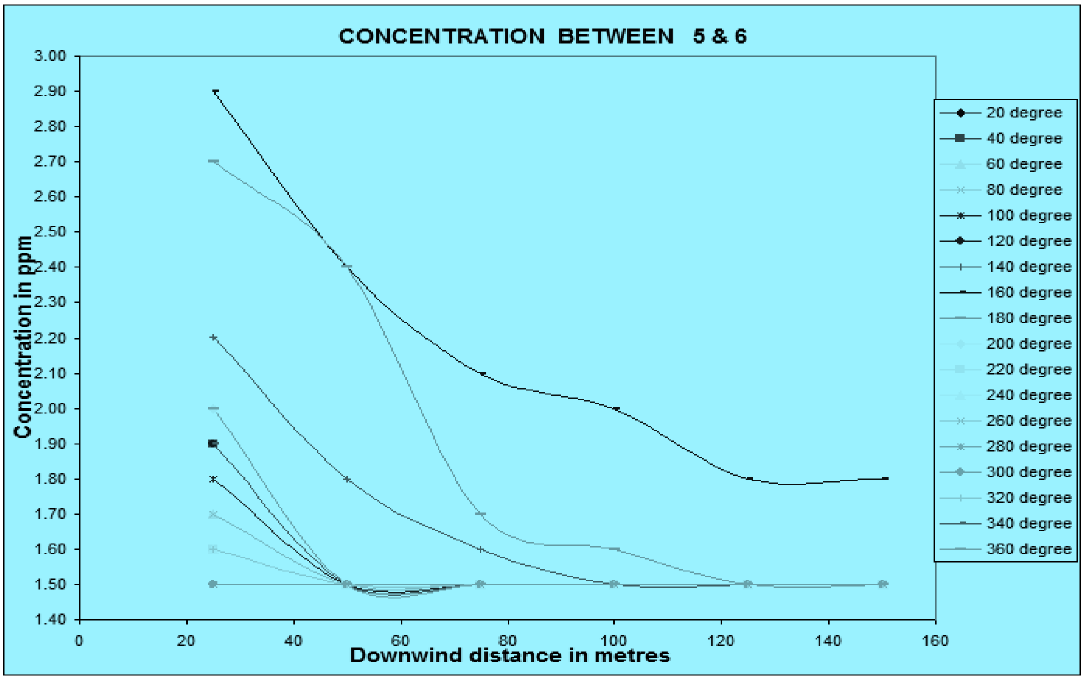

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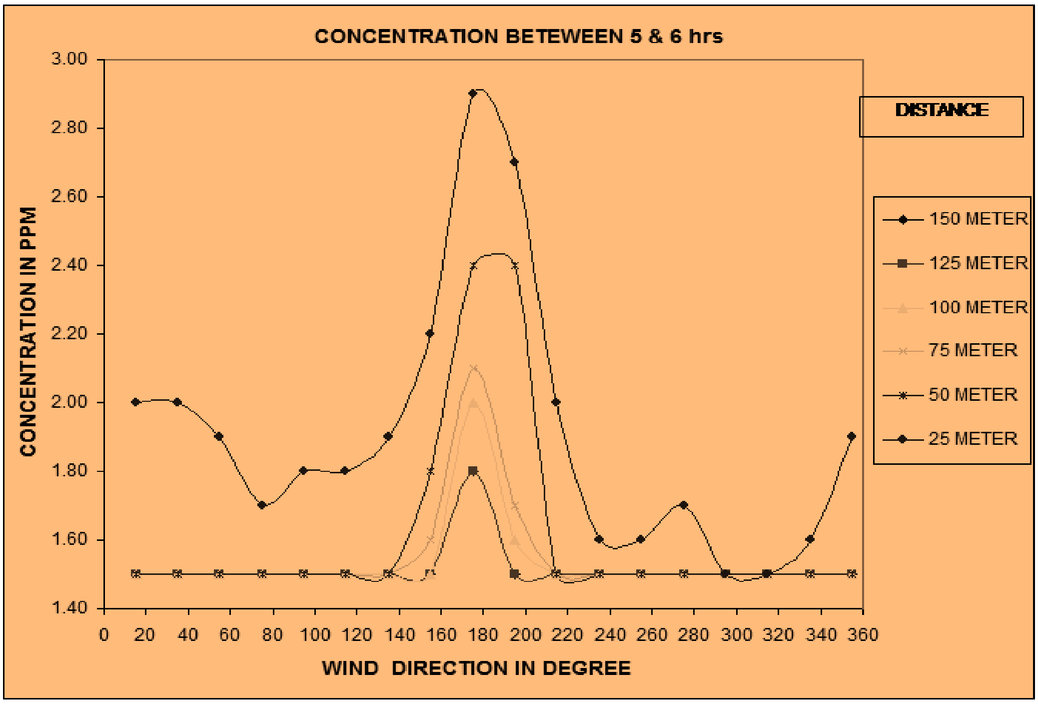

Fig.: CO Concentration with wind flow direction and downwind distances

IV. CONCLUSIONS

This study demonstrates the applicability of the CALINE-4 model for predicting CO concentrations at non-signalized roadway intersections. Under existing traffic conditions at the selected intersection, predicted CO levels remained within national ambient air-quality standards, even during peak traffic periods. Although the model tended to overpredict concentrations, the level of agreement with monitored data was satisfactory.

Meteorological conditions, traffic composition, and intersection geometry were found to significantly influence pollutant dispersion and concentration levels. The results highlight the usefulness of dispersion modelling as a planning and assessment tool for traffic management, roadway design, and air-quality mitigation strategies. Further improvements in intersection-level air-quality modelling would benefit from more detailed representation of vehicle operating modes and localized meteorological effects.

REFERENCES

[1]. Claggett, M., Miller, T.L. (1979), Final Report: Carbon monoxide monitoring and line source model evaluation for an urban freeway and urban intersection, prepared for the Illinois Environmental Protection Agency, Springfield, IL.

[2]. Claggett, M, Shrock, J, Noll, K.E (1981) Carbon monoxide near an urban intersection, Atmos. Environ., Vol. 15, pp. 1633-1642.

[3]. Gokhale, S. and Khare, M. (2004), A review of deterministic, stochastic and hybrid vehicular exhaust emission models, International Journal of Transport Management, Vol. 2, pp. 59-74.

[4]. Gokhale, S., and Khare, M. (2005), A hybrid model for predicting carbon monoxide from vehicular exhausts in urban environments, Atmospheric Environment, Vol. 39, pp. 4025–4040.

[5]. Kho, F. W. L., Law, P. L., Ibrahim, S. H., and Sentian, J. (2007), Carbon monoxide levels along roadway. Int. J. Environ. Sci. Tech., Vol. 4, pp. 27-34.

[6]. Schattanek, G., Kahng, J., Stratou, T. Braverman, T.N. (Eds.), (1990), EPA User's Guide to CAL3QHC - A modeling methodology for predicting pollutant concentrations near roadway intersections, USEPA.

[7]. Tippichai, A., Klungboonkrong, P., Pan-Aram, R. and Wongwises, P. (2005), Prediction of CO concentrations from road traffic at signalized intersections using CAL3QHC model: the KhonKaen case study, Songklanakarin, J. Sci. Technol., Vol. 27(6), pp. 1285-1298