IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 1 Ver. I (Jan- Feb. 2015), PP 83-87
www.iosrjournals.org

Modeling Carbon Monoxide Concentrations near Urban Road Corridors in New Delhi Using CALINE-4

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Abstract: *Assessing carbon monoxide (CO) concentrations adjacent to urban roadways is essential for protecting public health and supporting informed environmental management. This study focuses on measuring and simulating hourly CO levels along two major traffic corridors in New Delhi—Deen Dayal Upadhyaya Marg and Indraprastha Marg—using field observations and the CALINE-4 dispersion model. CO concentrations were monitored at four roadside locations with a portable electrochemical analyzer between 8:00 AM and 8:00 PM. Traffic characteristics, emission factors, and meteorological parameters were compiled from field surveys and institutional sources and used as model inputs. Model outputs were compared with observed concentrations to evaluate performance. Results indicate that CALINE-4 successfully reproduced temporal trends but generally underestimated measured CO levels.*
Keywords: *Carbon monoxide, Urban air quality, Traffic emissions, CALINE-4, Dispersion modeling*

I. Introduction

Rapid urbanization and increasing vehicular traffic have intensified air quality challenges in Indian cities. Carbon monoxide, primarily emitted from incomplete combustion in vehicle engines, is a key pollutant in roadside environments. Continuous monitoring of CO at every urban location is neither feasible nor cost-effective, making dispersion modeling a valuable alternative for estimating pollutant levels.

Several line-source dispersion models have been developed worldwide to predict traffic-related air pollution. Among these, CALINE-4 has been recommended for Indian urban conditions due to its adaptability and moderate data requirements. The present study applies CALINE-4 to simulate CO concentrations near two heavily trafficked roads in New Delhi and evaluates model predictions against observed data.

II. Materials and Methods

2.1 Study Area and Monitoring Locations

The investigation was conducted along Deen Dayal Upadhyaya Marg and Indraprastha Marg in New Delhi. These corridors experience high traffic volumes with mixed vehicle categories and are bordered by buildings of varying heights, creating complex dispersion conditions. Two monitoring sites were selected on each road, positioned approximately 150 m from major intersections.

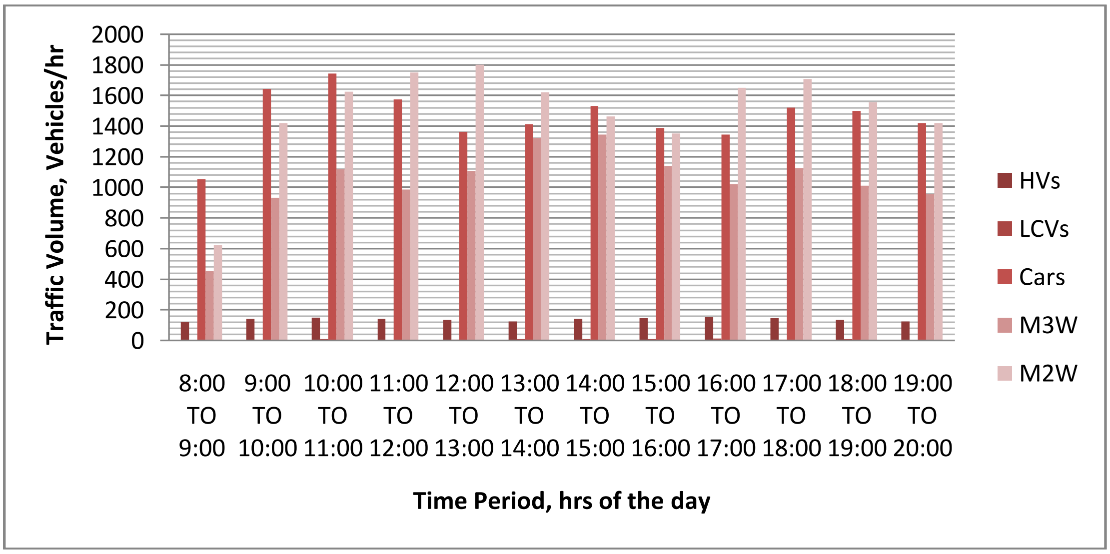

Fig.: Average hourly variation of traffic volume at DeenDayalUpadhya Marg

2.2 CO Monitoring Instrumentation

CO concentrations were measured using a portable electrochemical carbon monoxide monitor capable of detecting levels from 0.1 to 99 ppm. Ambient air diffuses through the sensor inlet to the electrochemical cell, where CO concentration is determined in real time.

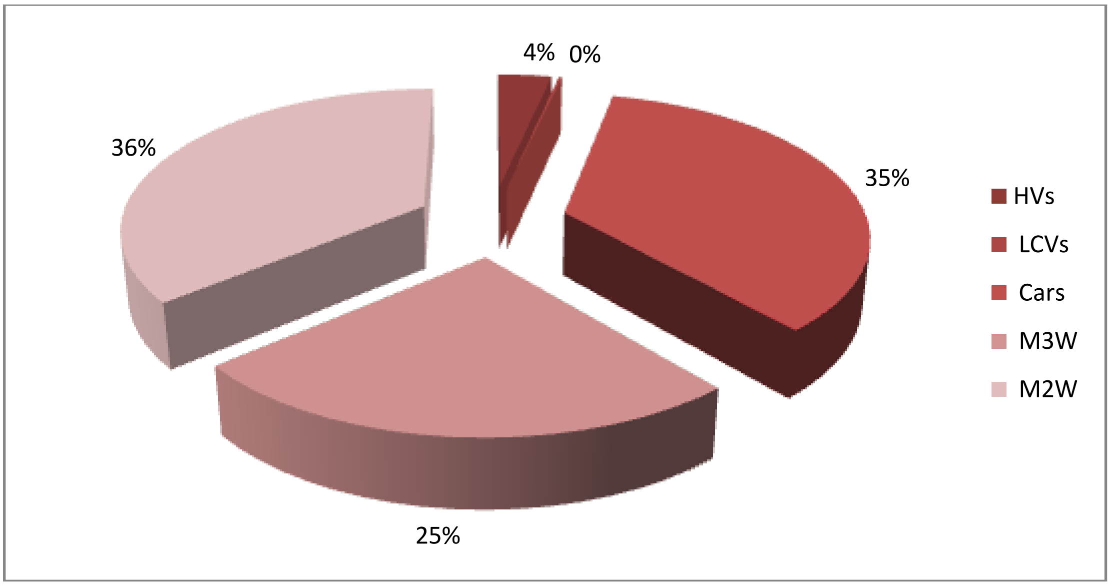

Fig: Average traffic composition at DeenDayalUpadhya Marg

2.3 Monitoring Procedure

Measurements were carried out between 8:00 AM and 8:00 PM at all selected locations. Readings were recorded manually at three-minute intervals due to the absence of onboard data logging, and hourly averages were subsequently calculated. Monitoring on Deen Dayal Upadhyaya Marg was conducted in April 2011, while measurements on Indraprastha Marg took place in March 2011.

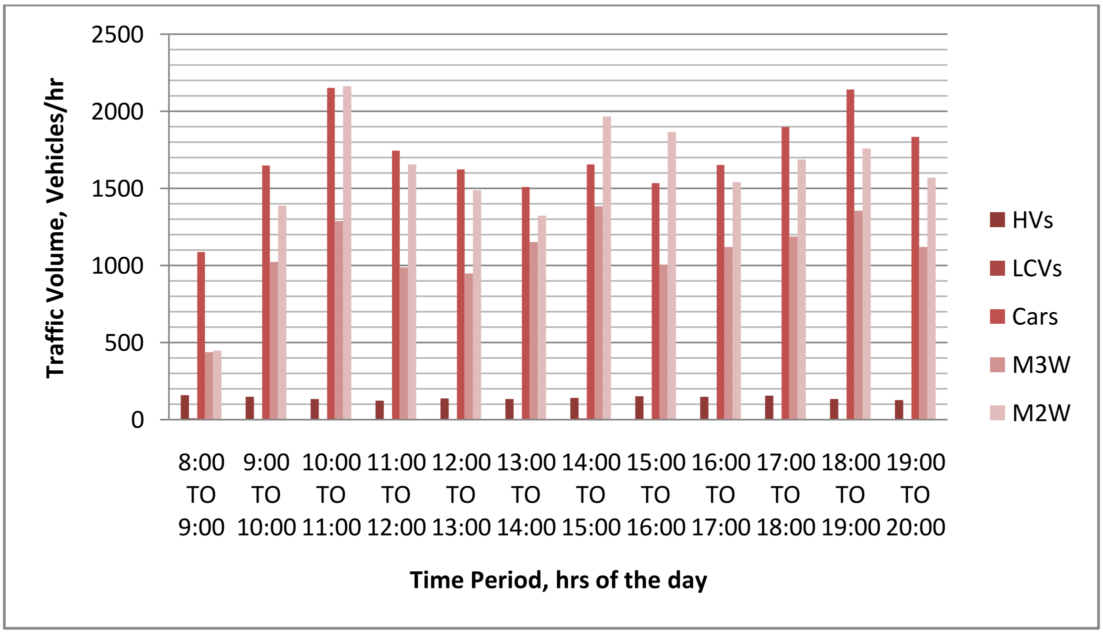

Fig.: Average hourly variation of traffic volume at Indraprastha Road

2.4 Meteorological Data

Meteorological parameters—including wind speed, wind direction, temperature, atmospheric stability, and mixing height—were obtained from the India Meteorological Department and the Central Road Research Institute. Monthly datasets were processed to derive representative daily averages for use in the dispersion model.

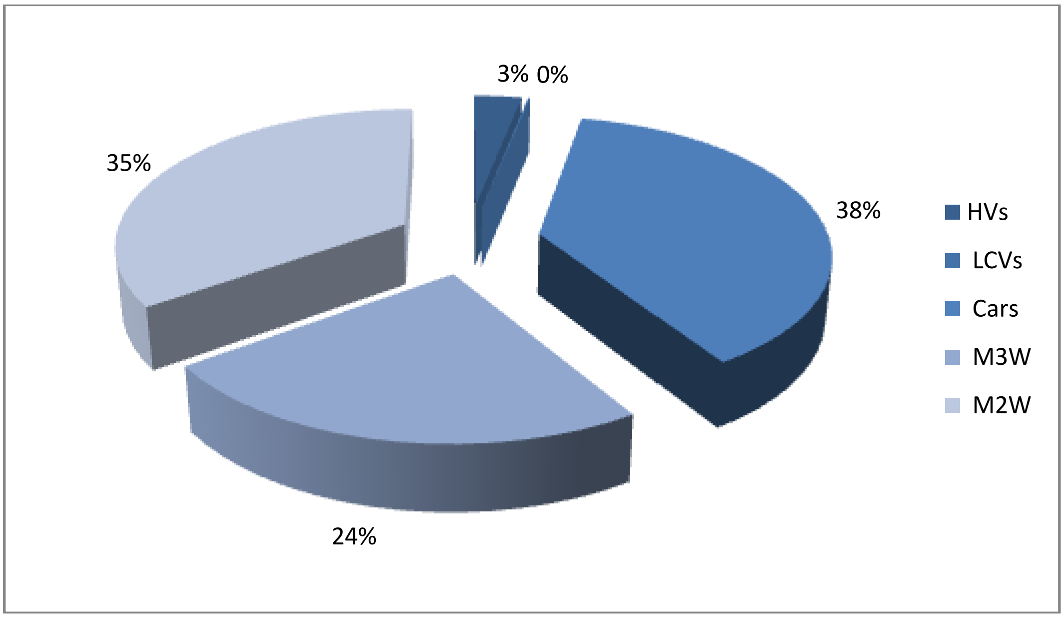

Fig.: Average traffic composition at Indraprastha Road

2.5 Traffic Data Collection

Traffic volume and composition were determined through manual counts conducted hourly from 8:00 AM to 8:00 PM. Vehicles were classified into heavy vehicles, light commercial vehicles, cars, three-wheelers, and two-wheelers. Vehicle age distribution and emission factors were sourced from published CRRI reports.

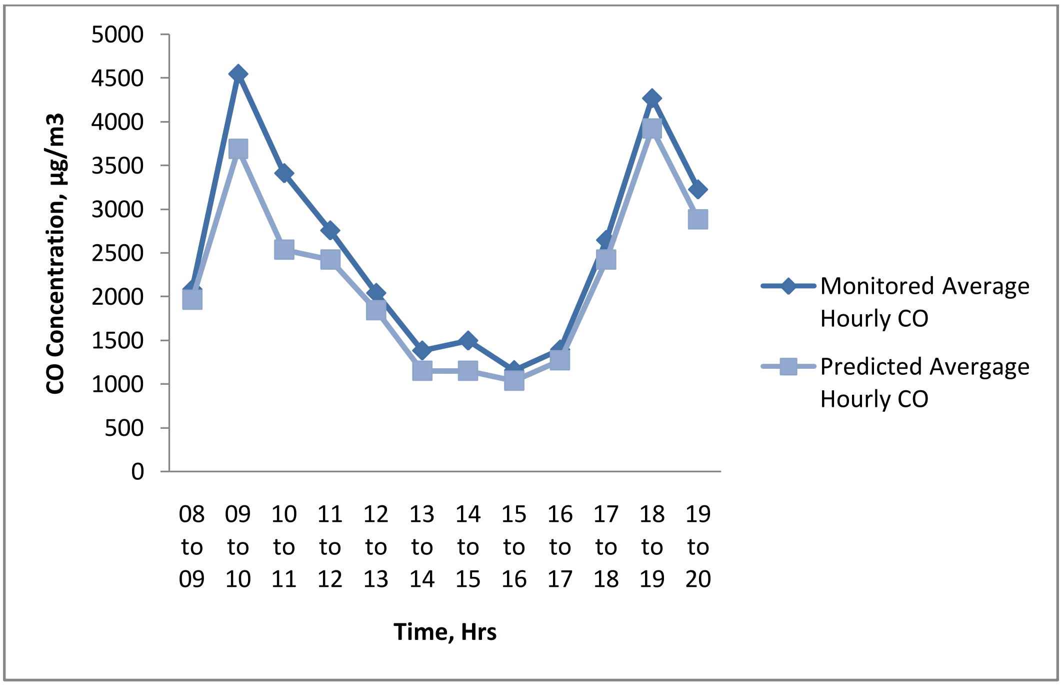

Fig.: Comparative monitored and predicted average hourly CO concentration at location 1

2.6 Emission Factor Estimation

Average emission factors for each vehicle category were calculated by incorporating age-related deterioration factors. Composite emission factors were then derived by weighting category-specific emission factors by observed traffic composition. These composite values were converted into the units required for CALINE-4 simulations.

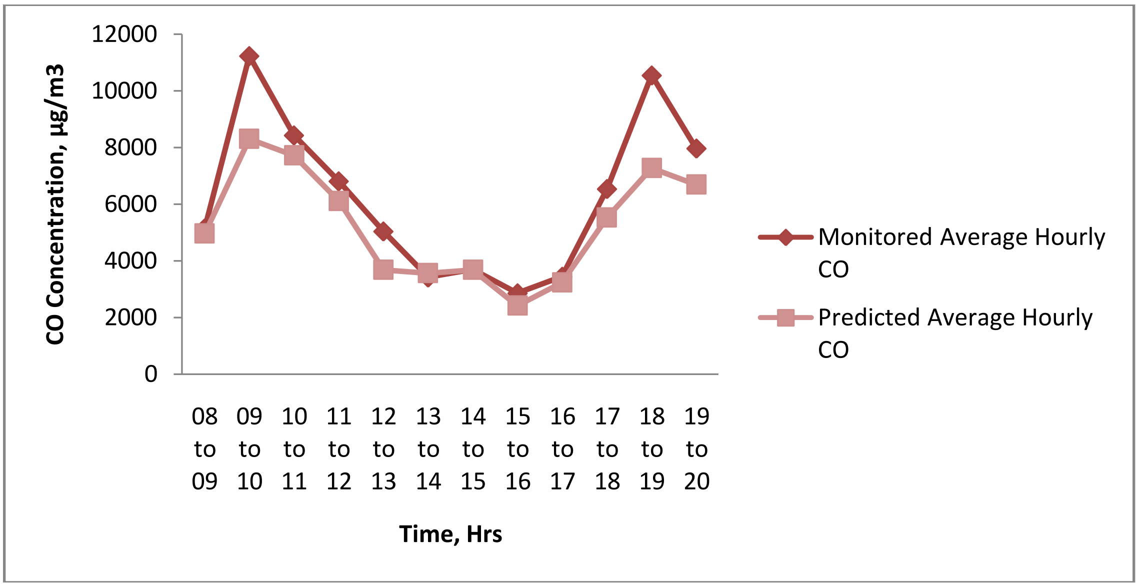

Fig.: Comparative monitored and predicted average hourly CO concentration at location 2

2.7 CALINE-4 Model Application

CALINE-4 was used to estimate hourly CO concentrations at predefined receptor locations. Model inputs included traffic volume, composite emission factors, roadway geometry, and meteorological conditions. Simulations were performed for representative days during the monitoring months.

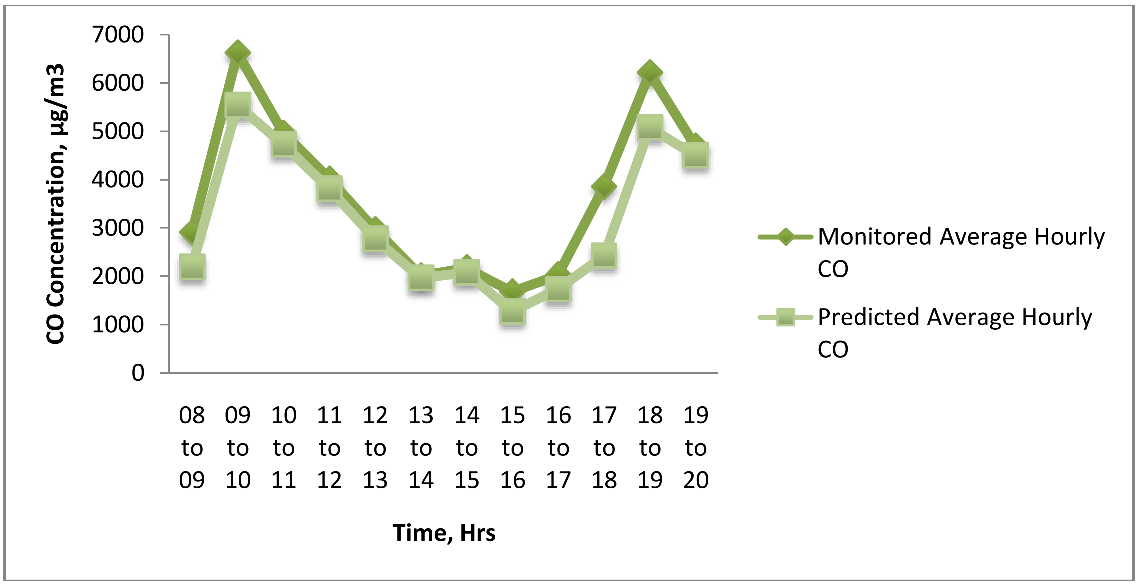

Fig.: Comparative monitored and predicted average hourly CO concentration at location 3

III. Results and Discussion

3.1 CO Levels at Deen Dayal Upadhyaya Marg

Both observed and modeled CO concentrations displayed clear morning and evening peaks corresponding to traffic patterns. While CALINE-4 reproduced the general temporal variation, predicted values were consistently lower than measured concentrations, indicating underestimation by the model.

3.2 CO Levels at Indraprastha Marg

Similar trends were observed at Indraprastha Marg, with peak CO levels occurring during high traffic periods. Model predictions followed the observed diurnal pattern but underestimated absolute concentration levels, particularly during peak hours.

The underprediction may be attributed to uncertainties in emission factors, simplified representation of complex urban geometry, and limitations in capturing local dispersion effects under stable atmospheric conditions.

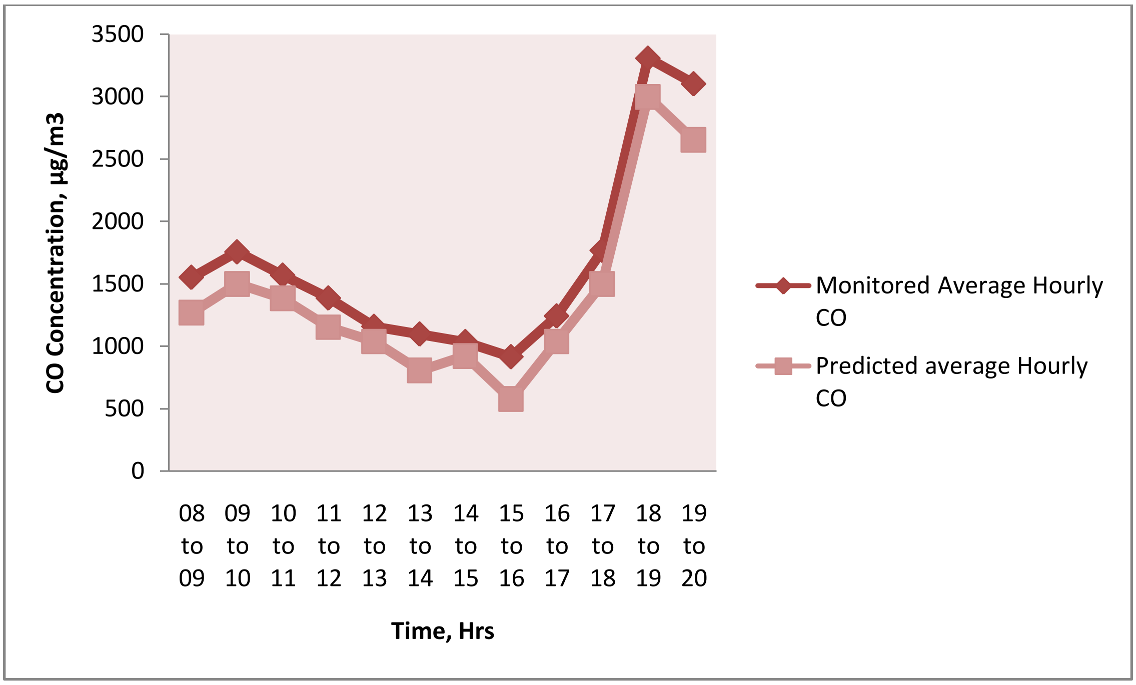

Fig.: Comparative monitored and predicted average hourly CO concentration at location 4

IV. Conclusions

This study demonstrates that CALINE-4 is effective in capturing the temporal variation of traffic-related CO concentrations along urban roads in New Delhi. However, the model tends to underestimate observed concentrations. Morning peaks were generally higher than evening peaks, likely due to reduced atmospheric dispersion during early hours. Improved representation of vehicle emissions, roadside geometry, and localized meteorological conditions may enhance model accuracy. Despite its limitations, CALINE-4 remains a useful screening tool for urban air quality assessment and management.

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