Plant Archives Vol. 23, No. 2, 2023 pp.315-319 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2023.v23.no2.054

AIR QUALITY MODELING FOR RITHALA METRO TO MADHUBAN CHOWK, DELHI USING CALINE4

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(Date of Receiving : 18-07-2023; Date of Acceptance : 28-09-2023)

ABSTRACT

Traffic emissions remain the predominant source of urban air pollution. Despite the introduction of new technologies to regulate pollution levels, the increasing number of vehicles, especially in congested urban areas, continues to cause high emissions near roadways. To address this issue, dispersion modeling exercises can be conducted to determine the optimal orientation of intersections and reduce pollutant trapping. In this study, Rithala Metro to Madhuban Chowk Road was selected as the study location. The traffic volume at the study location includes bus, cars, three-wheelers, and two-wheelers. Two wheelers and Cars constituting the majority of the total traffic volume and cover almost approximately 41% and 38% respectively of the total traffic. Bus represents the smallest percentage, with only 2% of the total vehicle count.

Monitoring stations were set up on both side of the road to measure CO concentrations. The pollutant levels were found to be within prescribed standards. The model was run using a Multi-Run/Worst Case approach, and the monitoring results were slightly higher than the modeled values since the model only considered traffic as the pollution source. The higher monitoring values can be attributed to long-term deposition of carbon monoxide in the atmosphere and horizontal movement of gaseous pollutants from nearby emitters such as DG sets, parking areas, and commercial activities.

***Keywords*:** Urban Roadway, Carbon Monoxide, Air Quality Monitoring, Air Quality Prediction Modeling, CALINE 4

Introduction

The rising demand for transportation driven by economic growth has led to a significant increase in the number and usage of motor vehicles in Delhi, the capital city of India. As a result, pollutants like respirable particulate matter (RPM), especially $PM_{2.5}$, nitrogen dioxide (NO2), carbon monoxide (CO), and hydrocarbons (HC) are directly emitted by vehicles in the urban environment. This poses a major concern for urban inhabitants, particularly those residing near urban roadways and pedestrians. The situation worsens at congested urban roadways where ventilation is inadequate.

According to the CPCB, the share of automobile emissions in Delhi's air pollution has risen to 72 percent over the years. While new technologies have been introduced to regulate pollution levels, the continuous increase in the number of vehicles without modifications to road conditions exacerbates emissions in the vicinity of roadways.

Given the severity of the situation, conducting a dispersion modeling exercise using the Caline 4 model is crucial to determine the optimal orientation of intersections and reduce pollutant trapping, which can be implemented during the planning stage. The scope of the present study is to undertake Air Dispersion Modeling using the Caline 4 model in the context of the study location.

Various researchers worldwide have analyzed the feasibility and applicability of dispersion models. Some have even developed their own mathematical models to assess pollutant dispersion. For example, Karim and Matsui (1998) and Karim *et al.* (1998) developed a computer model that considers wind distributions, emission dispersion, and modified Gaussian equations to identify street canyon and vehicle wake effects on air pollution transport in urban areas.

In Baijayanta Kumar Majumdar's study (2009), it is highlighted that CALINE 4 offers several advantages over other models and is selected as the base model for developing a modified line source model for a city. Niraj Sharma (2013) evaluated the performance of CALINE 4 in predicting carbon monoxide (CO) concentrations along an urban highway corridor in Delhi. Rajni Dhyani (2013) compared CALINE 4 model predictions between flat and hilly terrains along two road corridors in Solan District, Himachal Pradesh (India). The studies revealed that the CALINE 4 model struggles with complex terrain algorithms like hilly stretches, leading to under predicted concentrations.

On the other hand, Chadetrik Rout (2015) found that CALINE 4's predicted results were in satisfactory agreement with the monitored values.

Materials and Method

Rithala metro to Madhuban Chowk road has been selected as the study location for the present study. The present road is in 4 lane configuration and circle provides the crossing. Figure 1 present the traffic pattern and land use along the selected site.

Road is surrounded by the mix land use. The average elevation of the study location is 240m above MSL.

Considering the scope of the present study, two (2) monitoring stations were set-up on either side of the road at 50m distance from the center point of the road and monitoring of Carbon Monoxide (CO) was undertaken. The purpose of these stations is to determine the temporal and spatial distribution of the pollutant. Air quality monitoring was carried continuously for 5 days starting from Saturday i.e. 12-11-2022 to Wednesday i.e. 16-11-2022.

The numbers of vehicles were counted at an hourly basis for all the categories. The count was taken for the monitoring period as of Ambient Air Quality Monitoring Period. The count was taken from 0900 hrs to 1700 hrs.

Traffic volume comprises of Bus, Car, Three wheelers and Two wheelers. The numbers of vehicles were counted at an hourly basis for all the categories. The composition of traffic volume across different days during the monitoring period is presented in Figure 2 below.

The weighted emission factor was calculated by using the emission factors and corresponding deterioration factors. The weighted emission factor of specified pollutant (gm/km/vehicles) can be estimated as the composite sum of the product of vehicles nos. in specific age group, deterioration factor and emission factor of pollutant divided by total nos. of vehicles recorded. The weighted emission factor was found varying from 2.04 to 2.20 gm/mile/vehicle.

Micro-meteorology data as requisite for model application of Caline 4 includes hourly Wind Speed, Direction, Ambient Temperature, etc. were collected form wunder weather's website for Indira Gandhi International Airport Station. Mixing height was extracted for post-monsoon season from Atlas of Hourly Mixing Height and Assimilative Capacity of Atmosphere in India published by India Meteorological Dept., Govt. of India.

Results and Discussion

Carbon Monoxide concentration was assessed by using NDIR method. Spatial and temporal variation of the Carbon Monoxide across the monitoring stations and monitoring period is presented in Table below and further graphically presented in subsequent figures. The concentration of Carbon Monoxide found varying between 1.20 to 1.80 and 1.30 to 1.70 mg/m^3 on Right side and Left side respectively. The spatial distribution of Carbon Monoxide was found varying from 1.20 to 1.70 mg/m^3.

The spatial and temporal variations of the Ambient Air Quality Parameters are presented in Figure 3, 4 and 5 respectively.

All the input parameters have been gathered and incorporated in the various tabs on individual input screens for Job Parameters, Rub Conditions, Link Geometry, Link activity and receptors positions. Since the model is window based therefore after incorporation of parameters the run command has been given and the output file has been saved. The model has been run for 8 hourly data (multi run scenario) based on climatological data downloaded from weather underground's website.

The model was run considering the Multi run / Worst case approach. In this approach model itself estimate the wind direction for worst case scenario pollution load assessment. This approach negates the variation of prediction due to wind angle.

Conclusions

The spatial distribution of Carbon Monoxide (CO) ranged from 1.2 to 1.8 mg/m^3, while the predicted concentrations were in the range of 0.03 to 0.04 mg/m3. The monitored results were consistently higher than the model's predictions. These higher monitored values can be attributed to the long-term deposition of CO in the atmosphere and horizontal transport of the pollutant from nearby sources, such as DG sets, parking areas, and commercial activities. The comparison between the predicted CO concentrations and the monitored values indicates that the Caline-4 model underestimates the pollution levels, as it solely considers traffic as the pollution source.

Further, since vehicles contribute significantly to the total air pollution load in most urban areas vehicular pollution control deserves top priority. A practical strategy should be devised that reduces both emissions and congestion, using a mixed set of instruments, which are dictated by command and control, and/ or the market-based principles.

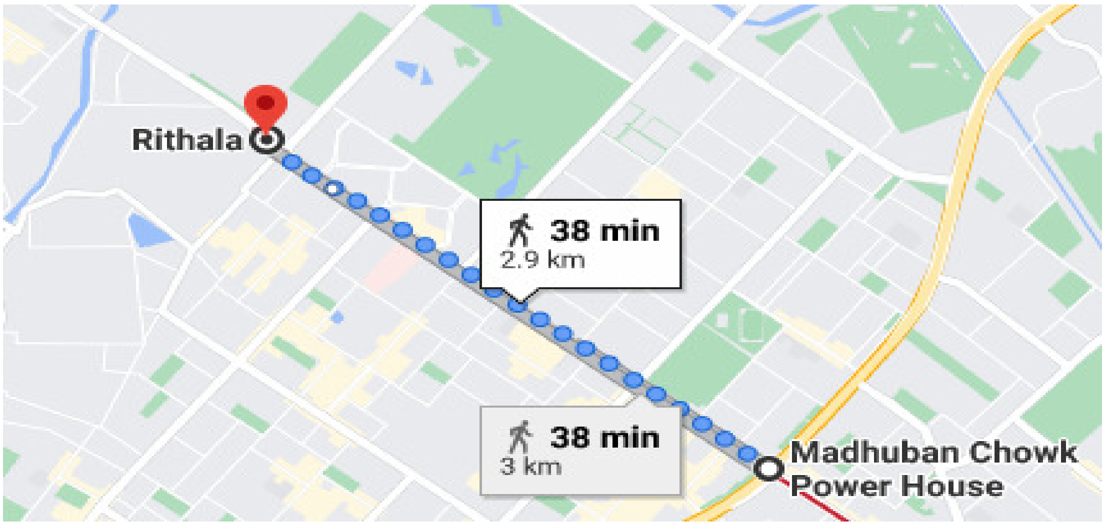

Fig. 1 : Description of Study Area

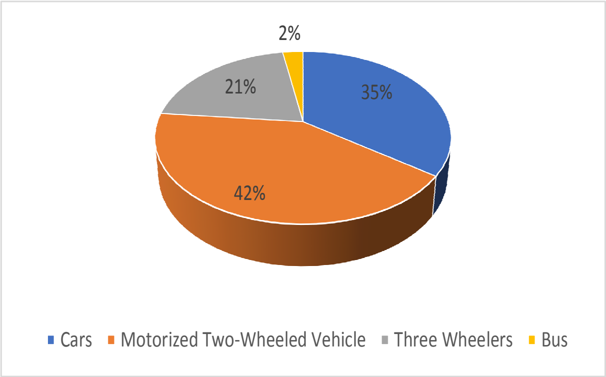

Fig. 1a: Traffic Composition on 12-11-2022

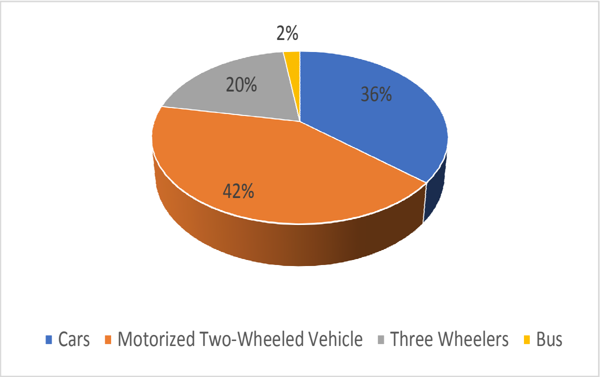

Fig. 1b: Traffic Composition on 13-11-2022

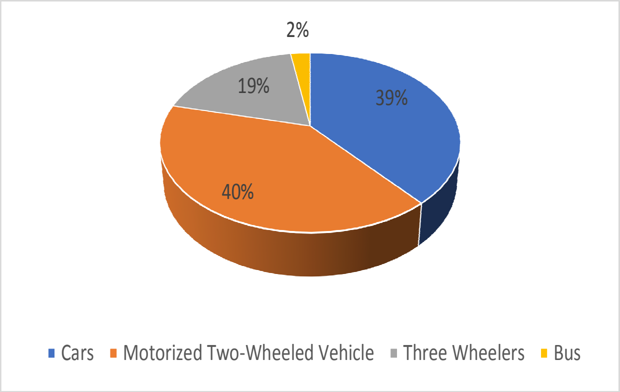

Fig. 1c: Traffic Composition on 14-11-2022

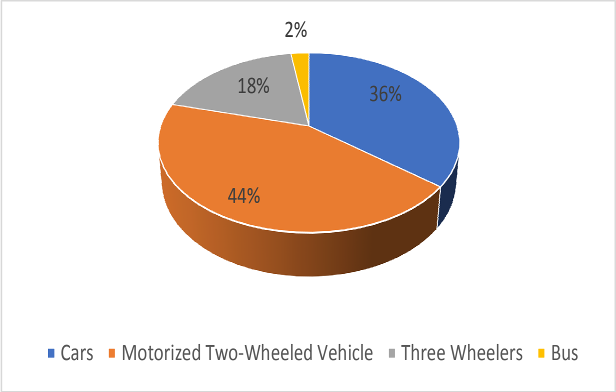

Fig. 1d: Traffic Composition on 15-11-2022

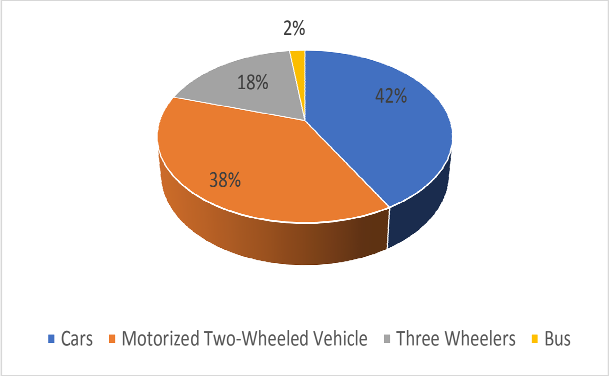

Fig. 1e: Traffic Composition on 16-11-2022

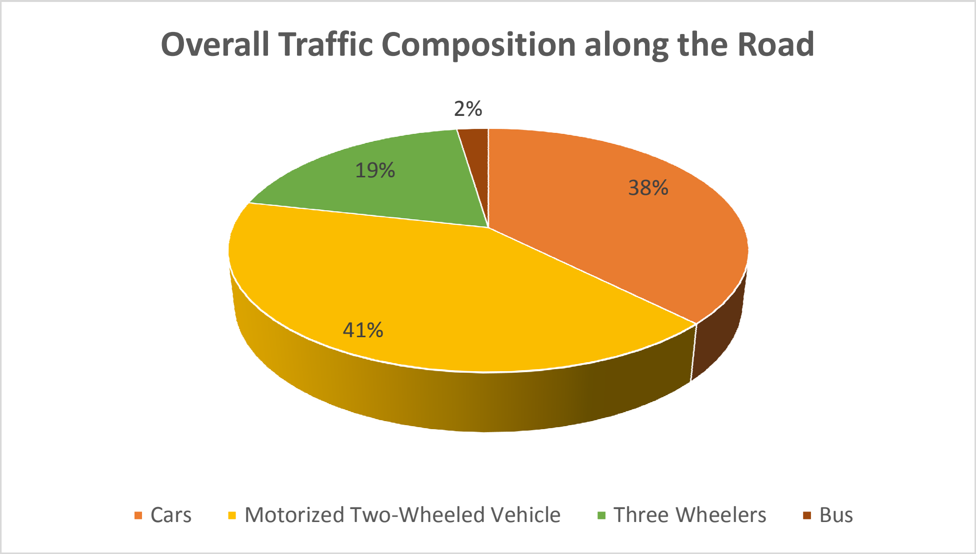

Fig. 2 : Overall Traffic Composition along the Road

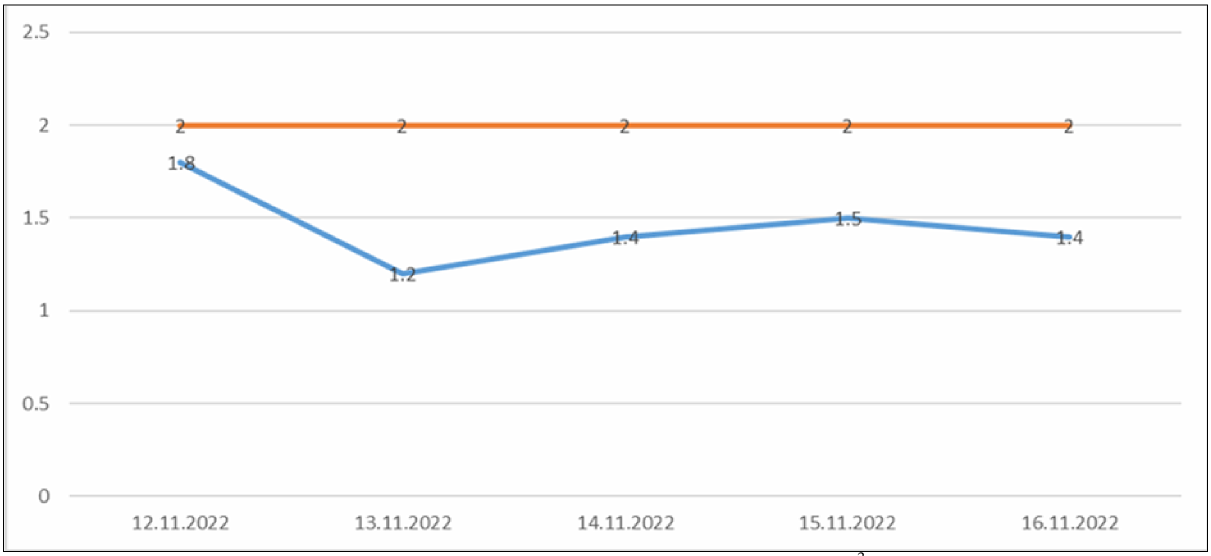

Fig. 3: Temporal Distribution of Carbon Monoxide (CO) Concentration in mg/m^3 at Right side Monitoring Station

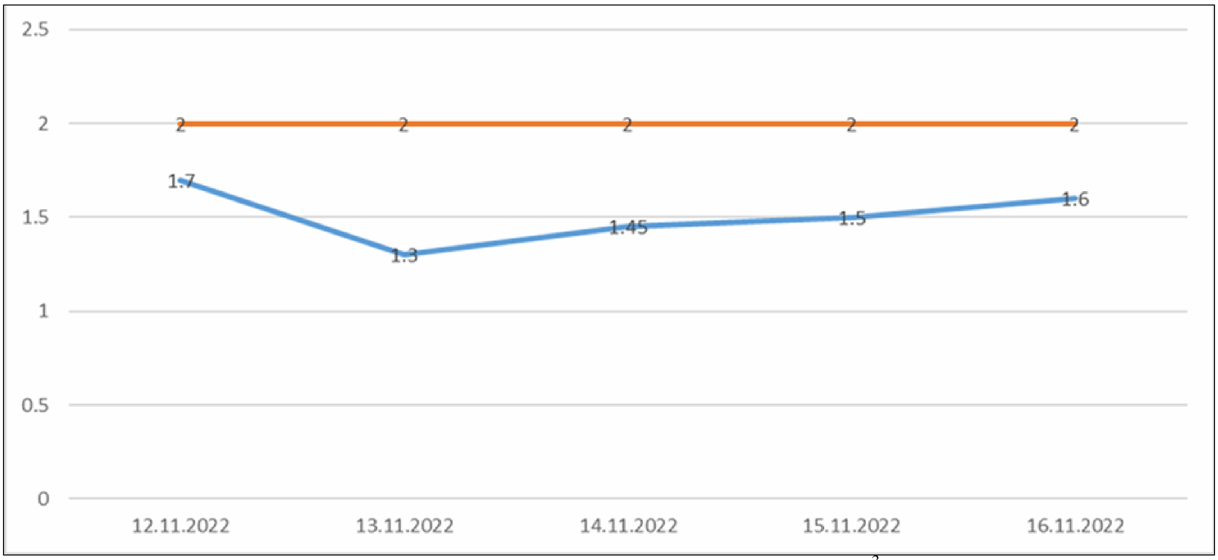

Fig. 4 : Temporal Distribution of Carbon Monoxide (CO) Concentration in mg/m^3 at Left side Monitoring Station

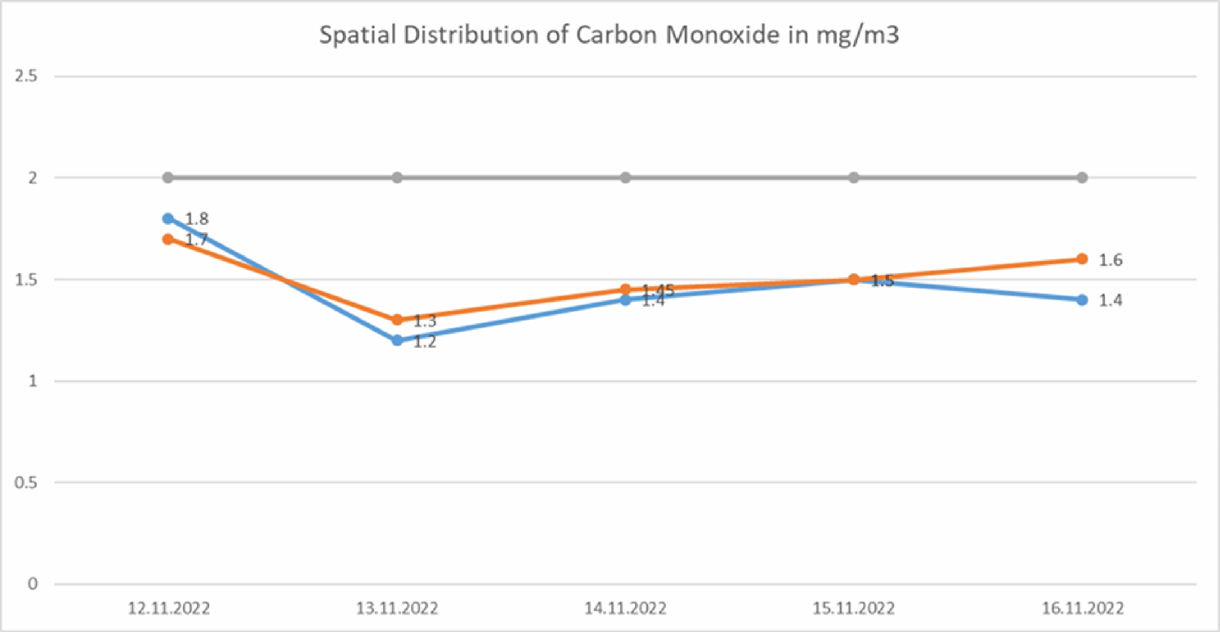

Fig. 5 : Spatial Distribution of Carbon Monoxide (CO) Concentration (mg/m^3)

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