Air Quality Prediction Modelling and its Validation in the Near Field of Urban Roadway of Delhi, India

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Abstract: ***Automobile exhaust is considerably important source of increasing carbon monoxide (CO) concentration in atmosphere and mainly in the urban cities. Considering the complex geometry of roadways, intersections and roundabout in urban centres of Delhi,that leads to increased emission of vehicular pollution mainly CO concentration. The main objective of the study is to monitor and predict the CO level concentration at micro-scale with an adequate methodology that permits to understand source-receptor relationship and to develop a proper strategies and planning to reduce concentration of CO pollutant. In urban centres of Delhi, with the help of CALINE-4 air pollution modelling software and digital air meter device used for average continuous CO monitoring for morning and evening peak hours, non-peak hours for 3 receptor's location were done alongwith survey of peak traffic volume count for 14 hours on two weekdays and one weekend which includes peak hours and non-peak hours used for the prediction of concentration of CO level in air quality of road stretch of approx. 3.2 Km of Gurjar Samrat Mihir Bhoj Marg, NH 24 of recently constructed Meerut Expressway starting from intersection near Indraprastha Park (or Sarai Kaley Khan Bridge) to Akshardham setu in Delhi. Predicted values shows increase in CO concentration with increase in timings with increase in number of vehicles. Traffic survey shows drastic change in the category of vehicles during non-peak hours mainly goods vehicles and heavy passenger's vehicles. Monitoring results reflected increase in CO during non-peak hours expectedly due to presence of heavy vehicles and increase of background concentrations. The two different scenarios generated from the physical monitoring and from CALINE-4 software model has been compared. The prediction from the program has observed less values compared to the actual physical monitoring values, which shows the limitation of CALINE-4 software to an extent.***

Keywords: Carbon Monoxide, CALINE-4, Prediction, Monitoring

1. Introduction

Carbon monoxide concentrations are especially high in congested urban centers of Delhi. Carbon monoxide at higher concentration emitted by incombustion of vehicle fuel, seriously affect human aerobic metabolism. Carbon monoxide reacts with the haemoglobin of blood to give carboxyhemoglobin, thus reducing the capability of the blood to carry oxygen. Carbon monoxide is colourless, odourless & tasteless gas, which is nearly impossible to identify in atmosphere without using proper detector. Trace period of carbon monoxide is only 1-8hrs required frequent analysis of the CO sample. Concentration level of CO is determined by emissions of pollutants, transport & meteorological parameters of dispersion of pollutants by winds, chemical reactions amongst reactive gases and removal processes such as rain & surface deposition, with day to day changes in weather being the greatest factor affecting gradual increase of CO level in air qualities which are used to predict forecasts. Deteriorating air quality of Delhi has been addressed using CO level pollution modelling studies carried out for a representative urban road intersection by considering various traffic characteristics & complex geometry. As per the report submitted by Economic Survey of Delhi 2014-2015 traffic load in Delhi increasing gradually year by year shown in the figure 1.1. In which category of personal usage vehicles of car, jeep, motorcycle and scooter in the year of 2014-2015 increasing more in comparison of public transport and other passenger vehicles shown in the figure 1.2.

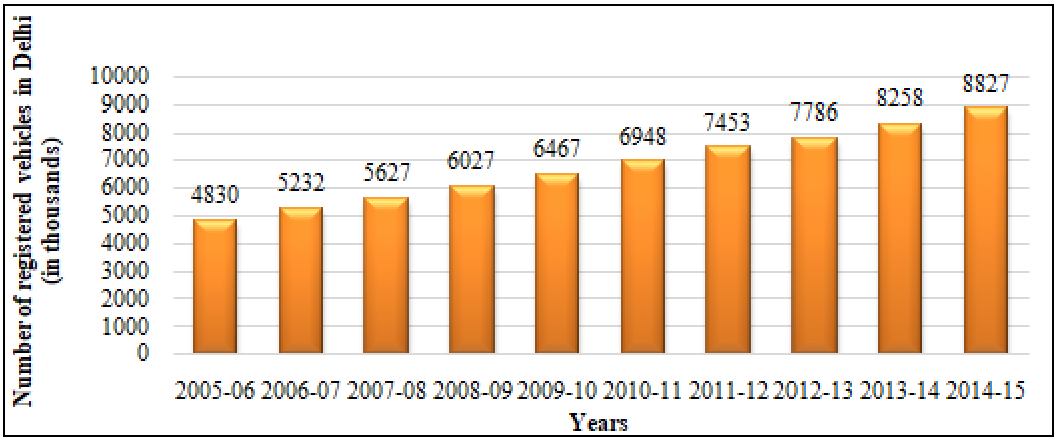

Figure 1.1: Number of registered vehicles in Delhi (Source: Economic Survey of Delhi 2014-2015)

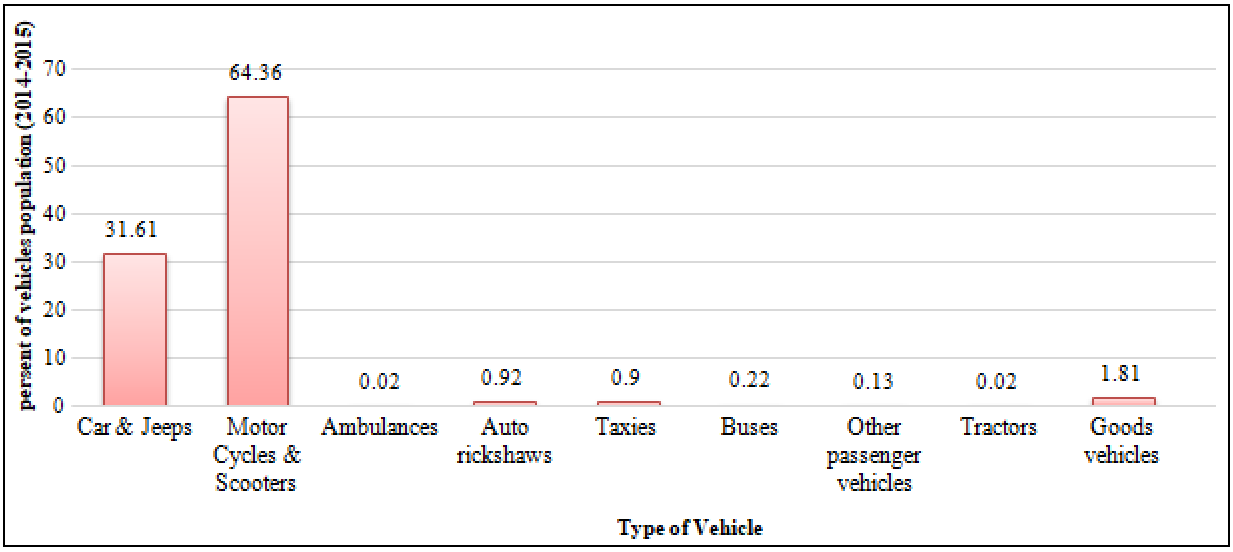

Figure 1.2: Vehicles population scenario in 2014-2015(Source: Economic Survey of Delhi 2014-2015)

The carbon monoxide levels have always been the target of investigation in most monitoring and modelling studies concerning vehicular pollution near roadways and major intersection in all over the world. Dimitris Potoglou and Pavlos (2005) suggested integrated urban model design for Hamilton, Canada to estimate the CO level concentration employing a dispersion model and spatial data analysis for an approach to provide framework for impact assessment of land-use and transport policies on traffic flows, emissions, and pollutant (i.e. CO) concentration, enabling the evaluation of population exposure to traffic related pollution. Ashok Luhar and R.S.Patil (1989) conducted study in Bombay, India which gives good results of a line source of relatively finite in length which is relatively infinite by using General Motor (GM) model and General Finite Line Source Model (GFLSM) COconcentration prediction model which requires more authentic and comprehensive data base for a finite line source.On major intersections of Delhi by GFLSM which shows accuracy in the predicted model and monitored values (Rajeev Kumar et. al, 2016). Jie Lin and Y.E.Ge (2006) used a discrete traffic kinematic wave model based on Cell Transmission (CT) recipe formulated by Danganzo (1994, 1995) in which every cell is modeled as a finite line source (FLS) positioned normal to wind direction which shows when traffic is less during peak and off-peak hours CT predicts higher CO concentrations. Tennyson Daniel and Rajesh Kumar.M (2013) conducted a study of seasonal variation CO centration with the help of CALINE 4 which shows average minimum CO concentration of 0.03 ppm in summer and average maximum CO centration of 6.396 ppm in winter season.

2. Materials and Method

This section describes the methodology adopted for present study which includes site description alongwith reconnaissance survey referring evolution of study area and meteorological conditions, receptor's location, traffic data estimation, average weighted emission factors, CO monitoring techniques and analysis. The detail description has been given in subsequent sections.

2.1 Site Description

Delhi has high volume of traffic all around and due to this increased traffic over the roads.Air quality of Delhi is getting worse day by day; in recent past government has introduced various bypass road and expressways to bypass Delhi traffic. Recently, Eastern Peripheral Expressway and Delhi-Meerut Expressway have been open for the traffic considering bypassing the heavy commercial traffic from Delhi. Delhi-Meerut expressway has been planned to provide high speed access to Delhi from the adjoining cities. The expressway starts from Outer Ring Road at Sarai Kale Khan and passes through Akshardham Bridge, Gazipur, Ghaziabad to Meerut. The part of stretch has been selected for the study is 3.2 Km length starts from Sarai Kale Khan Bridge to Akshardham Bridge. The stretch is varies from 12 to 18 lanes and consist a major bridge over Yamuna river. The stretch has no signals and a grade separated junction at Khel Gaon. The stretch has heavy traffic movement mostly the commuters travelling for regular works trips between Delhi-Ghaziabad-Noida during peak hours and commercial vehicles during non-peak hours.

Evolution of the study area over the last two decades shown in the figure 2.1(a), 2.1(b) and 2.1(c), referring the necessity of study prevailing air quality scenario.

Figure 2.1(a): Arial view of the site in the year 2001

Figure 2.1(b): Arial view of the site in the year 2010

Figure 2.1(c): Arial view of the site in the year 2018

Meteorological and terrain parameters play an important role in the dispersion phenomenon of the contaminants present in the atmosphere. The emissions from a region mainly depend upon the prevalent meteorological conditions. The impact level can vary due to meteorological parameters like wind speed, wind directions, pressure, temperature, relative humidity, etc. Air pollution can be controlled at its source but in some cases, reduction in emissions is direct function of geographical locations and existing meteorological conditions.

The study of air direction in urban areas can help to understand the flow of pollutants and their respective impact/ predicted values to fetch the planning for controlling pollution concentration in the atmosphere.The greater the wind speed, the greater is the turbulence which helps in the natural process of rapid and complete dispersion of the air polluting contaminants. The CO concentration increases with decrease in temperature but decreases with increase in relative humidity.

For this study, three receptors were positioned to observe the predicted specific pollutants concentration at various observing points at the stretch. The coordinates of receptors in x and y axis used for site geometry to run Caline-4 model.

2.2. Traffic Data Estimation

Traffic volume comprises each two category passenger and goods vehicles which are further classified into four categories i.e. Heavy Commercial Vehicles, Light Commercial Vehicles, Car, Two wheelers and Three wheelers which includes 2-axel trucks, 3-axel trucks and 4-6 axels; Govt. Bus, Pvt. Bus, School/College Bus, Mini Buses, Mini LCV, Tractor and Trailer, LCV (6 Tyre); Pvt. Cars/Vans/Jeeps and Taxi; 2-Wheelers, Auto, Goods Auto.

The major percentage of about 91%found from all three days of traffic volume in the form of about 66% comprises of Cars & Jeeps and 25 % comprises of 2 wheelers. Percentage traffic volume composition for 3 days have been analysedfor peak hours (morning & evening) and non-peak hours from Figure 2.2(a), 2.2(b) and 2.2(c).

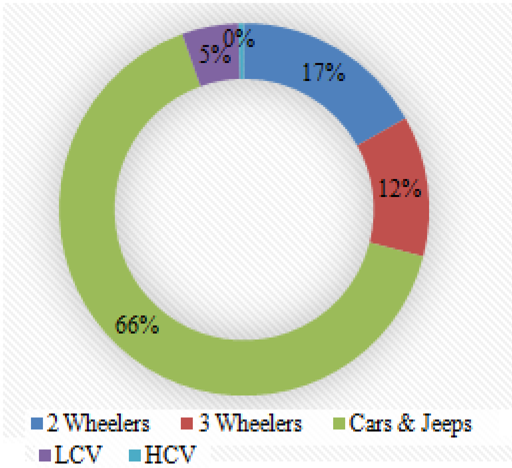

Figure 2.2 (a): Traffic Volume Composition (in percentage) from Day 1

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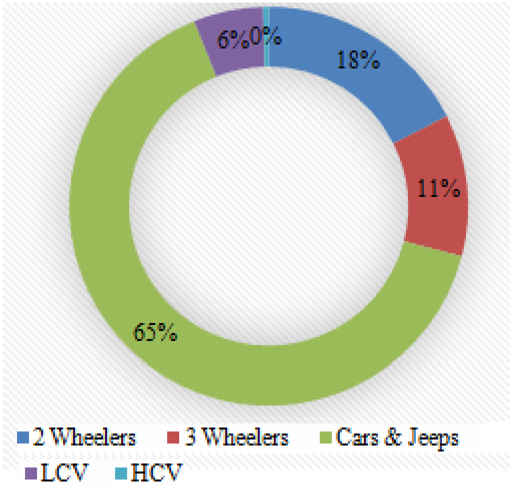

Figure 2.2(b): Traffic Volume Composition (in percentage) from Day 2

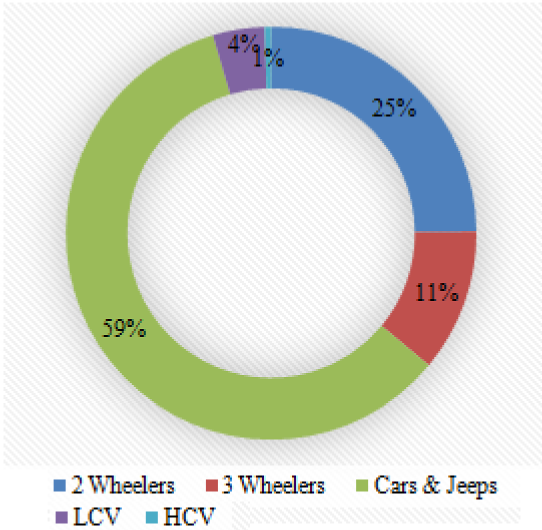

Figure 2.2 (c): Traffic Volume Composition (in percentage) from Day 3

The above figures2.2 (a), 2.2 (b) and 2.2(c) indicates the composition of traffic in the volume count of consecutive 3 days (including 2 weekday & 1 weekend) which is slight different from the previous vehicular scenario of Economic Survey of Delhi 2014-2015. The chart indicates the majority of the traffic comprises of cars followed by two wheeler and three wheeler.

Thus to estimate the emissions of the air pollutants loads from the different vehicle class alongwith the emission factors and appropriate deterioration factors published by the CPCB should be consider.

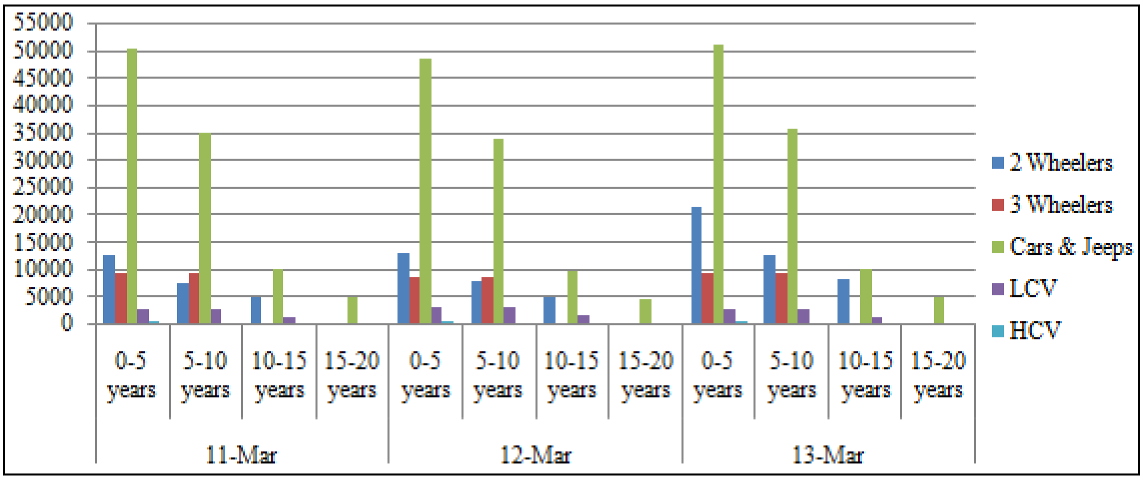

Figure 2.3: Estimated percentage of age group for total number of vehicles

Total number of vehicles on Day 1, Day2 and Day 3are 153968, 150181 and 153968 respectively in which percentage share of vehicles of age group 0-5 years more for 2 wheelers, Cars & Jeeps and HCV category of vehicles. But in case of 5-10 years age group vehicles, the percentage share isslight decrease in case of all categories of vehicles as per the above figure 2.3.

2.3 Average Weighted CO Emission Factor

The weighted emission factor can be calculated by using the emission factors and corresponding deterioration factors. Average weighted emission factors was calculated by emerging all categories of vehicles for pollution load of CO on hourly basis for Day 1, Day2 and Day3 as shown in figure 2.4.

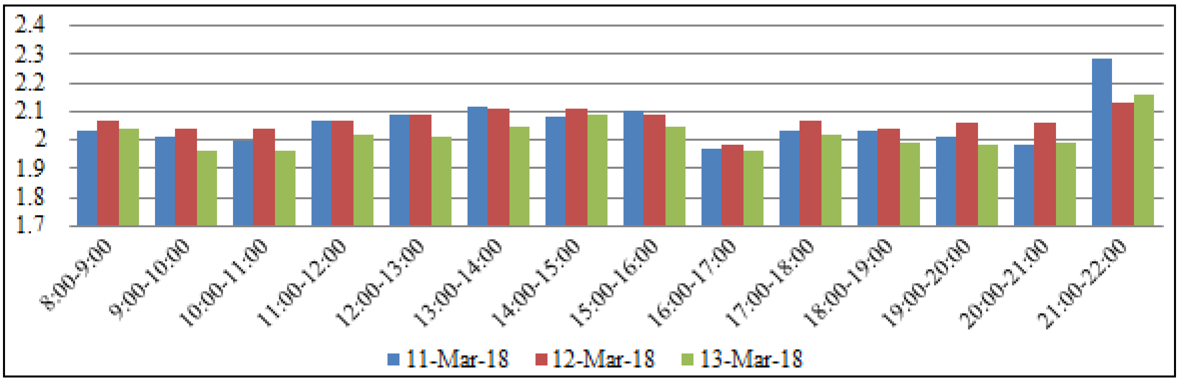

Figure 2.4: Average Weighted Emission Factor on Day1, Day2 and Day3

The calculated average weighted CO emission factor represents a slight increase in CO emission factor during non-peak hours for day as well as night times.

2.4 Sampling Procedure and Frequency

Combined field CO monitoring results of three receptors location 'A' near Sarai Kale Khan Bridge, receptor location 'B' near Khel Goan Road and receptor location 'C' near Akshardham Bridge are taken with the help of digitalmonitoring air meter device. Three consecutive days were selected for the monitoring during peak hours (morning and evening) alongwith the non-peak hours (afternoon) for all the receptor's locations.

2.5 Sampling Analysis and Parameters considered

CALINE-4 model was run by providing the inputs of the Job Parameters (such as mean sea level, aerodynamic roughness coefficient, etc.), Link Geometery (such as X and Y coordinates, link height, mixing zone width), Link Activity (such as traffic volume, emission factor), Run Conditions (such as wind speed, wind direction, wind direction standard deviation, atmospheric stability class, mixing height, ambient temperature, ambient pollutant concentration) and Receptor List (such as X and Y coordinates).

3. Results and Discussion

This section describes the results and discussions of combined field monitoring results, CO prediction results and comparison of CO emission data of model's predicted values and field observations. The detail description has been given in subsequent sections.

3.1 Combined Field Monitoring Results

Combined field CO monitoring results of three receptors location 'A' near Sarai Kale Khan Bridge, receptor location 'B' near Khel Goan Road and receptor location 'C' near Akshardham Bridge are shown in figure3.1(a), 3.1(b) and 3.1(c) for three days including one non-working on 11/03/18 (Sunday) and two working days on 12/03/18 (Monday) and 13/03/18(Tuesday) with the help of protable CO monitoring device at three receptors locations on peak hour (morning and evening) and non-peak hours (afternoon).

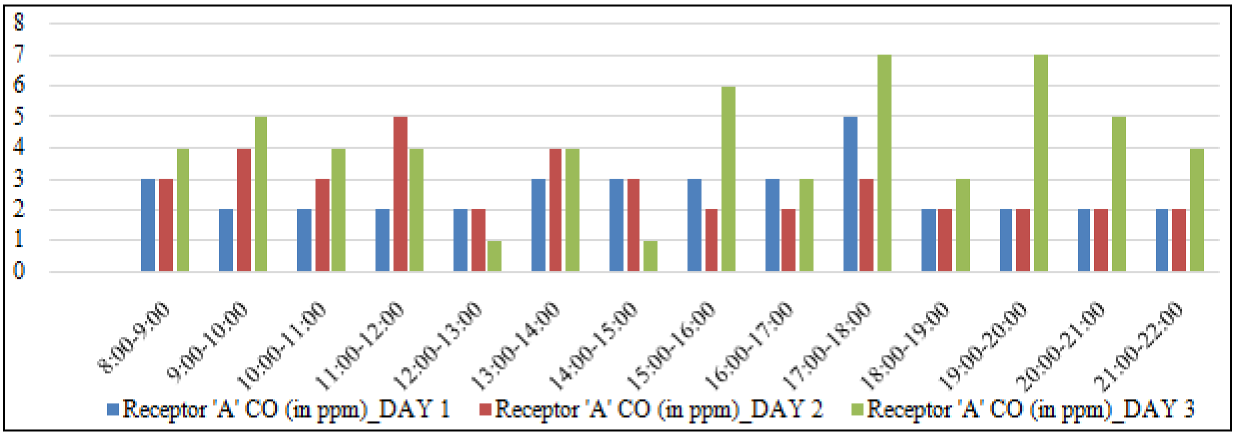

Figure 3.1(a): Monitored CO level at receptor location 'A' for 3 days

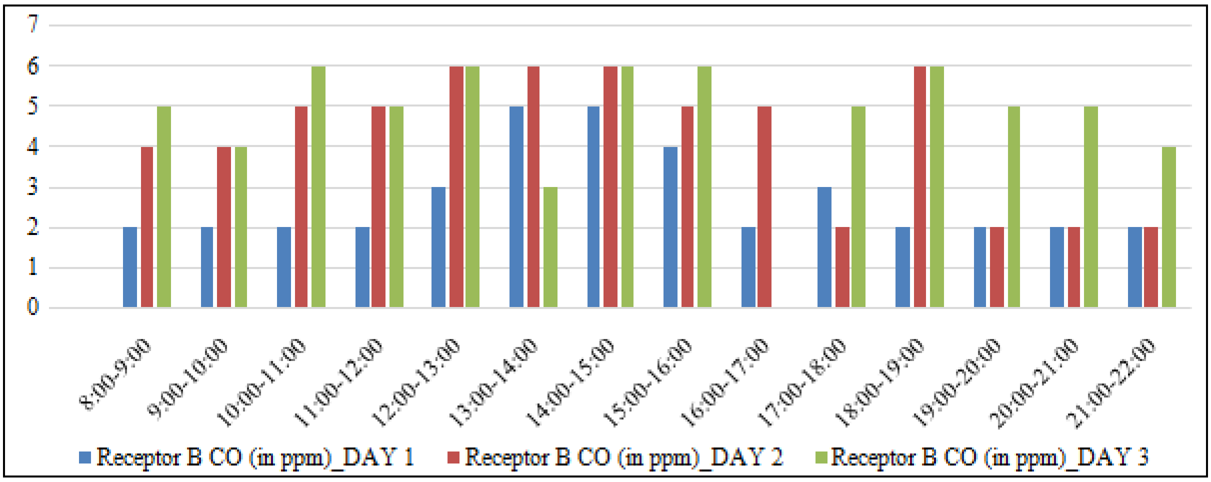

Figure 3.1(b): Monitored CO level at receptor location 'B' for 3 days

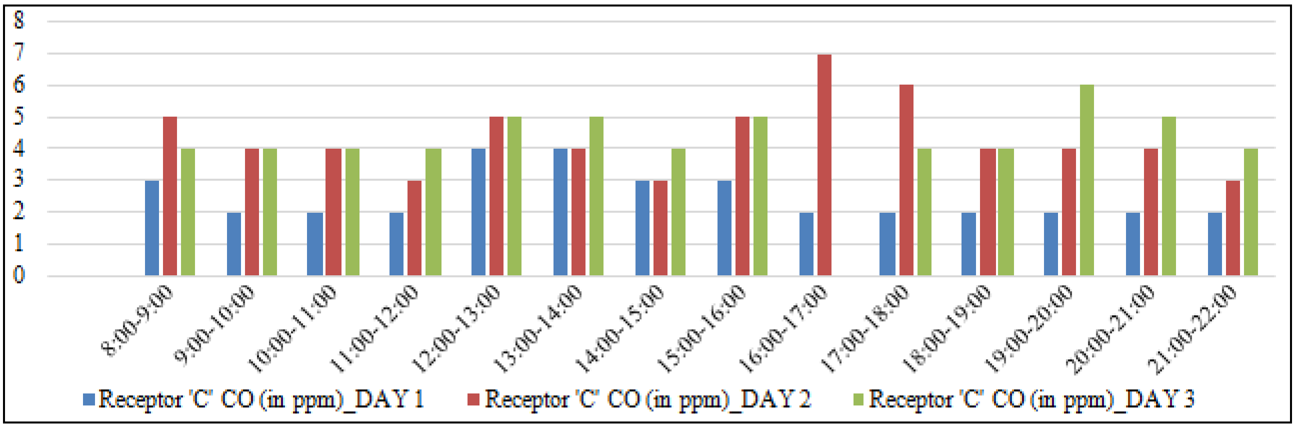

Figure 3.1(c): Monitored CO level at receptor location 'C' for 3 days

The observed CO emission is more in weekdays as compared with the weekends. The CO concentration varies high fluctuations due to traffic congestion during monitoring as shown in the figures3.1(a), 3.1(b) and 3.1(c).

3.2. Carbon Monoxide Prediction Results

CALINE-4 model run for the data of three consecutive days for 14 hours monitoring volume of vehicles. Average weighted factor calculated based onthe vehicles categories according to their average age in years and their percentage share on the roads.

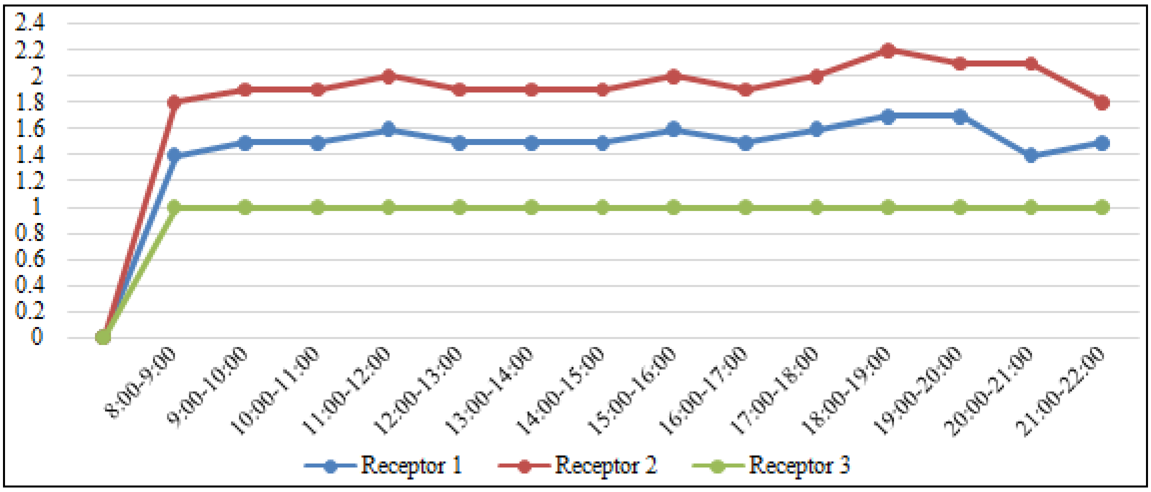

Figure 3.2(a): Predicted Values of CO Concentration for different receptor locations on Day1

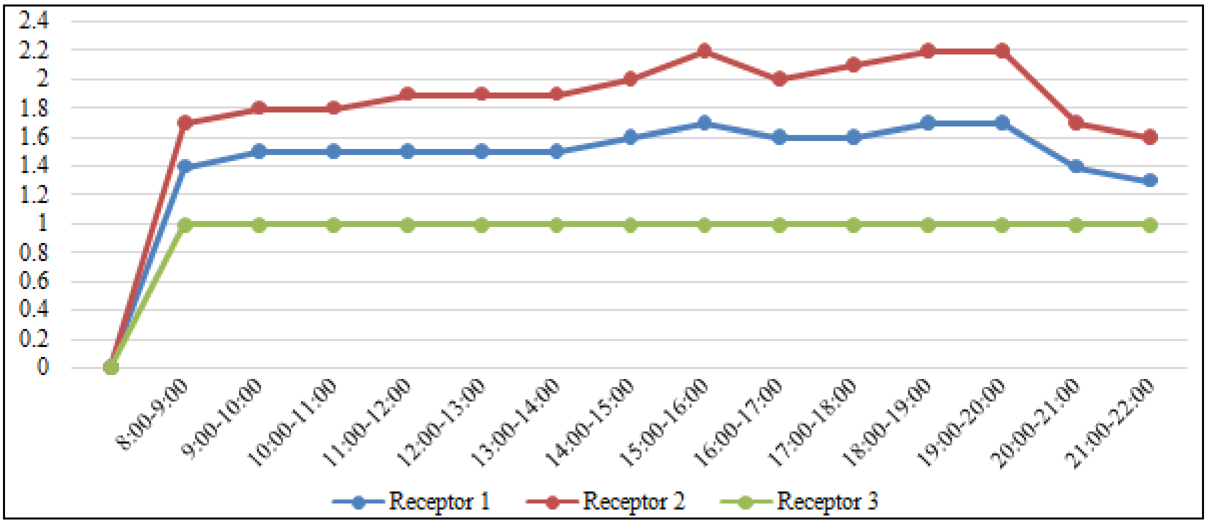

Figure 3.2(b): Predicted Values of CO Concentration for different receptor locations on Day2

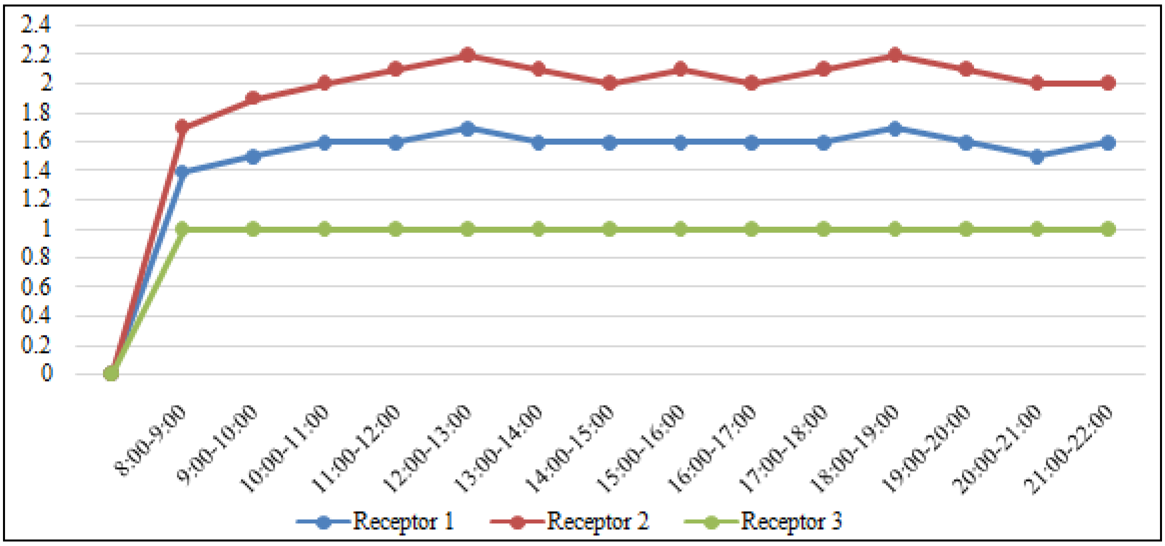

Figure 3.2(c): Predicted Values of CO Concentration for different receptor locations on Day3

The observed CO emission is more in Receptor's 2 as compared with other receptors shown in the figures3.2(a), 3.2(b) and 3.2(c).

3.3 Comparison of CO Emission Data of Model's Predicted Values and Field Observations

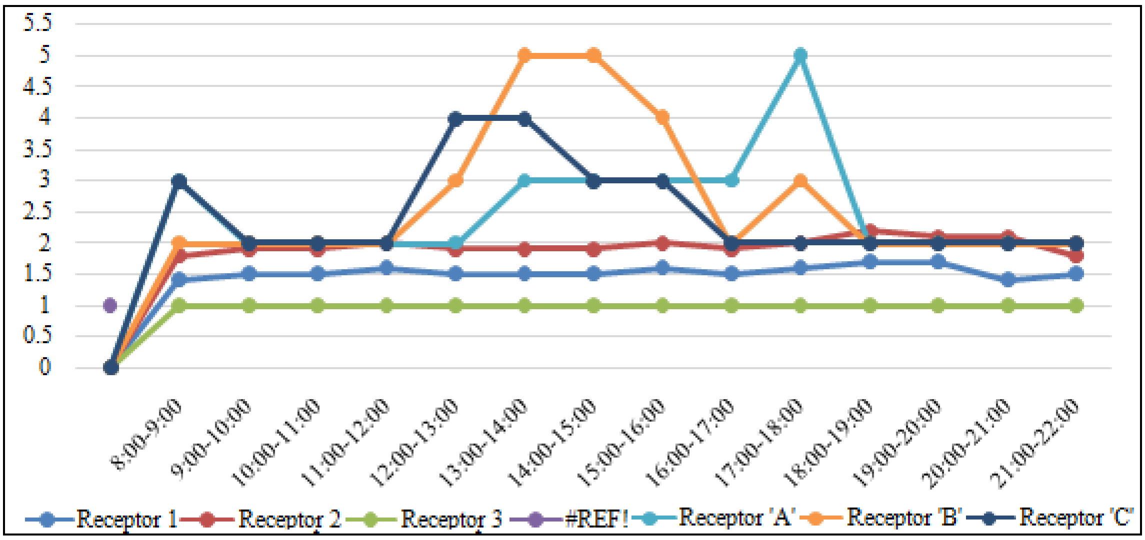

Figure 3.3(a): Comparative analysis of monitored and predicted CO on Day 1

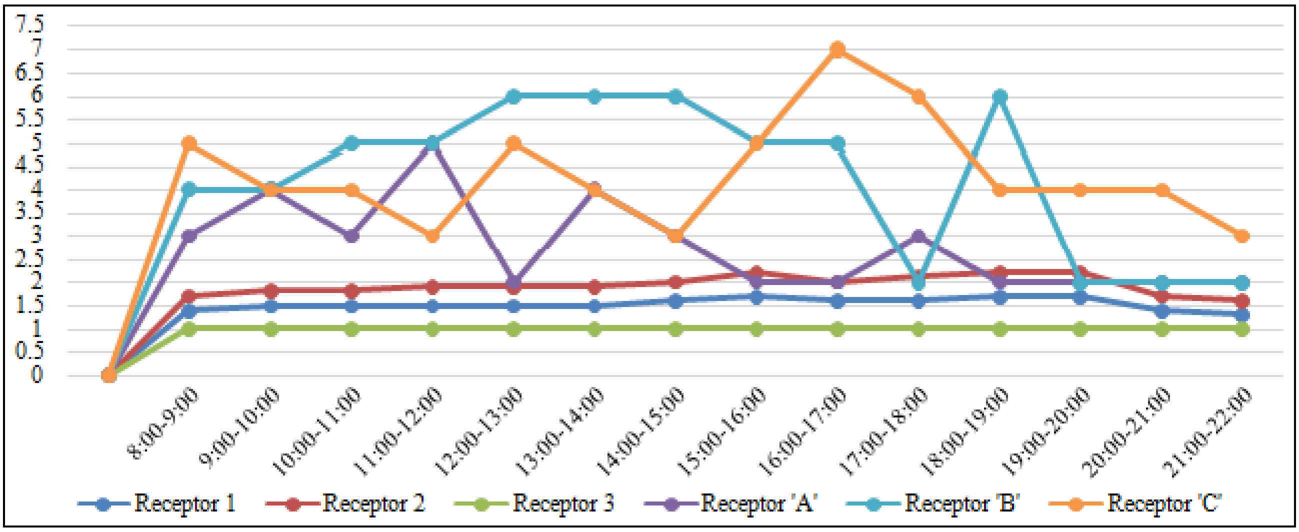

Figure 3.3(b): Comparative analysis of monitored and predicted CO on Day 2

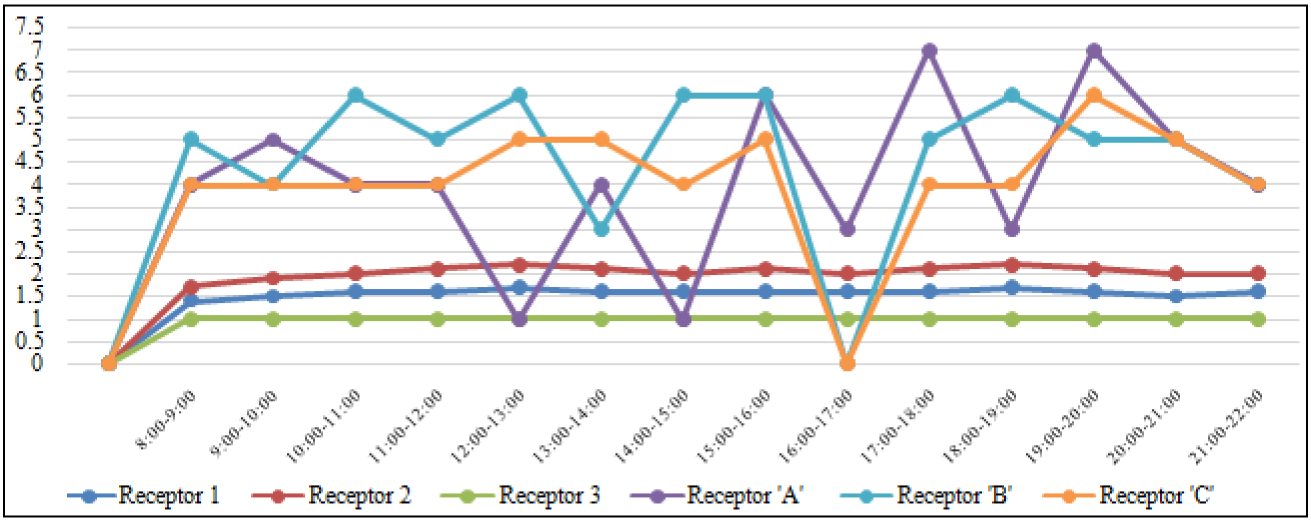

Figure 3.3(c): Comparative analysis of monitored and predicted CO on Day 3

The observed CO emission monitoring values are more than predicted values of CALINE-4 mainly due to congestion in traffic at monitoring location shown in the figures3.3(a), 3.3(b) and 3.3(c).

4. Conclusions

As per the result, the experiments stated that the quality of air is worse from the desired and there is vast scope for improvement, which would necessitate focussed attention by the authorities. It is a grave situation as times and both short as well as long term measure needs to be taken up considering the future growth of vehicular traffic. Since vehicles contribute significantly to the total air pollution load in most urban areas, vehicular pollution control deserves top priority. Both the scenarios generated from the physical monitoring and from CALINE-4 software model have been compared. CALINE-4 software is the advanced technology based program developed by the California Department of Transportation and it works on vital parameters than its predecessors. The working principle of this program is based on the line source model and accuracy of the input data. The performance of the software required pre-requisite input of meteorological data, traffic counts and emission norms for more accurate predictions with least error. The prediction from the program observes less values compared to the actual physical monitoring values, which shows the limitation of CALINE-4 software to an extent. Predicted values in weekdays are more than weekend values with increase in the duration of time in three consecutive days. Emission factor calculated for input to prediction models are slightly high during non-peak hours. CO concentration level is more in receptor's location 1 as compared to other receptor's locations. 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. Monitored values show change in the level of CO concentration due to increase in the total number of vehicles mainly heavily polluting vehicles such as public transport and goods vehicles. During non-peak hours CO concentration were slightly higher than the peak hour's concentrations.CO monitor device used for the field observations. Few values are high as expected due to congestion and increase in the number of heavy vehicles during monitoring. In practice, continuous CO monitoring could be expensive.

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