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Caline–4 Model Validation in the Nearfield of Bahadur Shah Zafar Marg, New Delhi, India

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ABSTRACT
Rapid growth in the number of vehicles and vehicle activity makes this particularly true in cities in developing countries. It is generated due to incomplete combustion of the fuel in automobiles. It is observed to be as high as 70% of the total pollutants at urban environment, especially, in the near fields of urban roadways and intersections. Therefore, in present study, an attempt has been made to validate the air quality model (Caline – 4) through monitored and predicted CO concentrations. A typical urban roadway Bahadur Shah Zafar Marg containing highest traffic volume, heterogeneous traffic composition along with typical traffic flow conditions has been selected for validation of Caline – 4 model. The air quality (carbon monoxide) monitoring and prediction has been carried out as per standard procedure. The predicted values of average hourly concentration CO have been observed to be very close to monitored CO concentration irrespective of location. The values of statistical parameters in terms of mean, Index of Agreement (IA), Normalized Mean Square Error (NMSE), Pearson's correlation coefficient (COR), the Fractional Bias and the Factor-of-Two (F2) have been found to be very close to ideal model performance. The values of statistical parameters chosen for the model validation showed good correlation between monitored and predicted values of 1 hourly average CO at various locations of approaching roads forming intersection. Statistical analysis results concluded that the line source model, CALINE – 4 under predicts the CO concentrations at various locations of road. This will help a lot to the authority for proper planning, designing and policy matter.
Keywords: CO Monitoring, CO Prediction, Caline – 4, Statistical Analysis, Model Validation

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I. INTRODUCTION

Carbon monoxide is a local pollutant in that high concentrations are found only very near the source. The major source of carbon monoxide, a colorless, odorless, poisonous gas, is automobile traffic. In urban environment, CO is the one of the dominated pollutant among the traffic generated criteria pollutants (Mukherjee and Viswanathan, 2001). Motor vehicle emissions are a significant source of urban air pollution (Colvile et al., 2001; Health Effects Institute, 2009 and 2010). Rapid growth in the number of vehicles and vehicle activity makes this particularly true in cities in developing countries (Riley, 2002; Schipper et al., 2009). It is generated due to incomplete combustion of the fuel in automobiles. It is observed to be as high as 70% of the total pollutants at urban environment, especially, in the near fields of urban roadways and intersections. This may be due to heavy traffic on the road (Riley, 2002; Schipper et al., 2009) as well as closely spaced high-rise buildings on either side of the roadways causing built up of pollutant. The most affected group of peoples is the urban inhabitants residing in close vicinity of the urban roadways and intersections (junctions) as well as the pedestrians. The CO concentrations monitoring and modeling studies concerning vehicular pollution near roadways and major intersections in many cities (Bogo, 1999; Moseholm, 1996) have reported in the literature. Several air quality models exist for evaluating roadside air quality (Gokhale and Khare, 2004). However, many of the models are too complex to be operated routinely given the simplicity of the available meteorological and traffic data (Dirks et al., 2003). A few models widely used for evaluating the dispersions at roadside, are for example, the GM (Chock, 1978), the GFLSM (Luhar and Patil, 1989), the CALINE-4 (Benson, 1992), the CAR-FMI (Harkonen et al., 1996) and at street canyons, the OSPM (Berkowicz, 2000; Palmgren et al., 1999) model. The validation of air quality model considering localized conditions is foremost important prior to predictions and such studies seemed lacking for Delhi environment. Therefore, an attempt has been made to validate the air quality model (Caline – 4) through monitored and predicted CO concentrations.

II. MATERIALS AND METHOD

Various steps of methodology adopted in this study such as site selection, monitoring instrumentation and procedure, secondary data and collection, its analysis and prediction procedure have been described in the subsequent sections.

2.1 Site Selection

A typical urban roadway Bahadur Shah Zafar Marg has been selected for validation of Caline – 4 model. It has been located at latitude of $77^{0}\ 21^{/}\ 32^{//}$ N and longitude of $28^{0}\ 38^{/}\ 55^{//}$ E. It contains highest traffic volume, heterogeneous traffic composition along with typical traffic flow conditions. It is typically ventilated (the buildings surrounded the roads have typical characteristics, i.e., variable heights, widths and lengths as well as shapes). The selected urban road and monitoring/modeling locations have been shown in Fig. 1 as follows:

(i) Bahadur Shah Zafar Road (Delhi Gate Side) – Monitoring Locations, 1 and 2
(ii) Bahadur Shah Zafar Road (India Gate Side) – Monitoring Locations, 3 and 4

Fig. 1: Description of urban Roads and monitoring locations

2.2 CO Monitoring Instrument and Procedure

The CO detector (Model, CO–84) is a portable Carbon Monoxide Detector/ Monitor. In fact, it is a electrochemical cell assembly. A perforated cap at the top end allows the surrounding atmosphere to diffuse in and reach the active part of the cell. The Carbon Monoxide Detector has been especially designed to detect the CO and indicate its concentration at any time. This portable Carbon Monoxide Detector has capability to detect the carbon monoxide level from 0.1 ppm to 99 ppm. The CO concentration has been monitored at selected locations from 8:00 AM to 8:00 PM using portable online CO monitor. Initially, the Instrument has been pre-calibrated and then, used for CO monitoring at various preselected locations. Since, the instrument did not have data acquisition system/storage system; the data have been manually recorded at 3 minute intervals and averaged.

On Bahadur Shah Zafar Road (Delhi Gate Side) – Monitoring Locations, 1 and 2, the CO Monitoring has been carried out from March 18 to April 02, 2011. At each location, 242 samples have been collected with an interval of 3 minutes. Thereafter, 1 hourly average and 8 hourly average concentration of CO has been evaluated for each location.

Bahadur Shah Zafar Road (India Gate Side) – Monitoring Locations, 3 and 4, the CO Monitoring has been carried out from April 20 to May 04, 2011. At each location, 242 samples have been collected with an interval of 3 minutes. Thereafter, 1 hourly average and 8 hourly average concentration of CO has been evaluated for each location.

2.3 Meteorological Parameters – Collection and Analysis

The meteorological data including wind speed, wind direction, temperature, atmospheric stability and mixing height have been collected from Meteorological Department of India, Mausam Bhawan, New Delhi – 110003 and CRRI, New Delhi (through personal communication). Furthermore, the representative one day average meteorological data has been evaluated from one month data and used as model input.

2.4 Traffic Parameters – Collection and Analysis

The traffic volume in terms of vehicles/hour and traffic composition has been collected in the month of April, 2011. The traffic volume comprised of Bus and Trucks (HVs), Light Carriage Vehicles (LCVs), Cars, Three Wheelers (M3W) and Two Wheelers (M2W). The numbers of vehicles have been counted manually at an hourly basis for all the categories. The traffic counts have been performed from 8:00AM to 8:00 PM continuously. The vintage of vehicles and their corresponding emission factors for different categories of vehicles have been collected published report of CRRI (Central Road Research Institute). The traffic data have been analyzed using MS Excel spread sheet and composite emission factor has been evaluated.

2.5 Traffic Volume and Composition towards Delhi Gate side on April, 2011

The average traffic volume varied at different hours of the day along with various categories of vehicles. The heavy vehicles have their maximum numbers (156) at 9:00 AM to 10:00

AM, however, minimum (113) at 7:00 to 8:00 PM. The light carriage vehicles have their maximum numbers (11) at 2:00 PM to 3:00 PM, however, minimum (2) at 11:00 to 12:00 AM. The cars have their maximum numbers (1954) at 2:00 PM to 3:00 PM, however, minimum (1039) at 8:00 to 9:00 AM. The Three Wheelers (M3W) have their maximum numbers (1354) at 1:00 PM to 2:00 PM, however, minimum (401) at 8:00 to 9:00 AM. The Two Wheelers (M2W) have their maximum numbers (2145) at 6:00 PM to 7:00 PM, however, minimum (588) at 8:00 to 9:00 AM.

2.6 Traffic Volume and Composition towards India Gate side on April, 2011

The average traffic volume varied at different hours of the day along with various categories of vehicles. The heavy vehicles have their maximum numbers (146) at 3:00 PM to 4:00 PM, however, minimum (109) at 7:00 to 8:00 PM. The light carriage vehicles have their maximum numbers (9) at 9:00 AM to 10:00 AM, however, minimum (2) at 7:00 to 8:00 PM. The cars have their maximum numbers (1625) at 5:00 PM to 6:00 PM, however, minimum (850) at 8:00 to 9:00 AM. The Three Wheelers (M3W) have their maximum numbers (1325) at 1:00 PM to 2:00 PM, however, minimum (421) at 8:00 to 9:00 AM. The Two Wheelers (M2W) have their maximum numbers (1896) at 10:00 AM to 11:00 AM, however, minimum (488) at 8:00 to 9:00 AM.

2.7 Evaluation of Average Emission Factor/Composite Emission Factor

The pollutant CO emitted from the tail pipe of the automobiles has been estimated on the basis of vehicle – kms travelled by different age group and categories of vehicles. The average emission factor for CO for different categories of vehicles has been calculated by using the emission factors and corresponding deterioration factors. Thereafter, the composite emission factor has been estimated considering vintage of vehicles plying on the road. Initially, average emission factor has been evaluated for different categories of vehicles including appropriate deterioration factor as mentioned in “transport fuel quality for the year 2006 to 2010 (CRRI)”. The evaluated average and composite emission factors, of different categories of vehicles, have been used in Caline – 4 model for predictions.

2.8 CO PREDICTION PROCEDURE

Prediction of CO concentration at various receptor locations of intersection has been carried out using CALINE-4 model. Initially, relevant information necessary for model run such as traffic volume, composite emission factor and meteorological parameters as well as train conditions have been collected. Thereafter, input files as per model requirement have been prepared and the model run has been performed. The average hourly CO concentration has been obtained at pre-defined receptor locations of Bahadur Shah Zafar Marg as an output. The CO concentration predictions have been carried out for the months of March and April, 2011.

III. RESULTS AND DISCUSSION

3.1 Validation of Caline 4 Model for Predicted CO Concentration at Delhi Gate Side

The values of mean, IA, NMSE, R, FB and the F2 for monitored and predicted CO concentration at Delhi Gate (location 1) have been given in Table 1 and Fig. 2. The value of IA has been found to be 0.93, which is very close to 1.0. This shows perfect agreement between monitored and predicted conc. of CO.

Table 1: Values of statistical parameters for monitored and predicted concentrations of CO

Parameters	Monitored CO	Predicted CO	Range
Mean	3061	2442	-
Index of Agreement (IA)	1.00	0.93	0.0 – 1.0
NMSE	0.00	0.05	0.0 – 1.0
Pearson's Correlation (R)	1.00	0.90	+1 to – 1.0
Fractional Bias (FB)	0.00	-0.09	+2 to – 2
F2	100%	79.80	100%

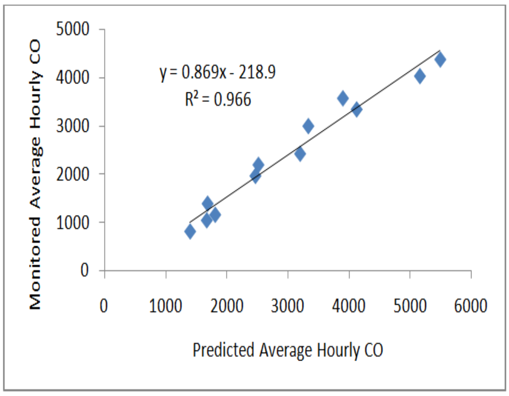

Fig. 2: Correlation between monitored and predicted average hourly CO concentration at location 1

The value of NMSE has been evaluated to be 0.05, which denotes better model performance. The value of Correlation Coefficient, R gives quantitative relation between monitored and predicted results. It has been has been found to be (0.90), close to unity, which implies good model performance. The value of fractional bias (FB) ranges from + 2 to – 2 and has ideal value zero for an ideal model. The value of FB been evaluated to be – 0.09, which is very close to zero, indicates better performance of model. The ideal value for the Factor-of-Two (F2) should be 1 (100%). The calculated value of F2 has been found to be 79.80%, shows good correlation among monitored and predicted values.

The values of mean, IA, NMSE, R, FB and the F2 for monitored and predicted CO concentration at Delhi Gate (location 2) have been given in Table 2 and Fig 3. The value of IA has been found to be 0.94, which is very close to 1.0. This shows perfect agreement between monitored and predicted concentrations of CO. The value of NMSE has been evaluated to be 0.03, which denotes better model performance. The value of Correlation Coefficient, R gives quantitative relation between monitored and predicted results.

Table 2: Values of statistical parameters for monitored and predicted concentrations of CO

Parameters	Monitored CO	Predicted CO	Range
Mean	5844	5212	–
Index of Agreement (IA)	1.00	0.94	0.0 – 1.0
NMSE	0.00	0.03	0.0 – 1.0
Pearson's Correlation (R)	1.00	0.89	+1 to – 1.0
Fractional Bias (FB)	0.00	-0.12	+ 2 to – 2
F2	100%	89.19	100%

It has been has been found to be (0.89), close to unity, which implies good model performance. The value of fractional bias (FB) ranges from + 2 to – 2 and has ideal value zero for an ideal model. The value of FB been evaluated to be – 0.12, which is very close to zero, indicates better performance of model. The ideal value for the Factor-of-Two (F2) should be 1 (100%). The calculated value of F2 has been found to be 89.19%, shows good correlation among monitored and predicted values.

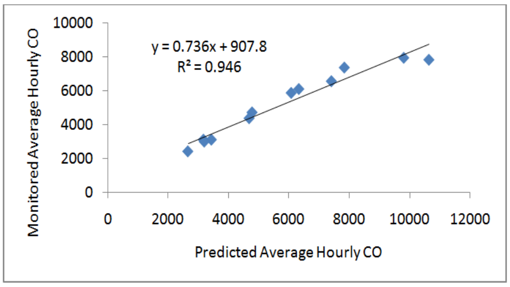

Fig. 3: Correlation between monitored and predicted average hourly CO concentration at location 2

3.2 Validation of Caline 4 Model for Predicted CO Concentration at India Gate Side

The values of mean, IA, NMSE, R, FB and the F2 for monitored and predicted CO concentration at India Gate (location 3) have been given in Table 3 and Fig. 4. The value of IA has been found to be 0.97, which is very close to 1.0. This shows perfect agreement between monitored and predicted concentrations of CO. The value of NMSE has been evaluated to be 0.02, which denotes better model performance. The value of Correlation Coefficient, R gives quantitative relation between monitored and predicted results. It has been has been found to be (0.91), close to unity, which implies good model performance. The value of fractional bias (FB) ranges from + 2 to – 2 and has ideal value zero for an ideal model. The value of FB been evaluated to be – 0.18, which is very close to zero, indicates better performance of model. The ideal value for the Factor-of-Two (F2) should be 1 (100%). The calculated value of F2 has been found to be 88.85%, shows good correlation among monitored and predicted values.

Table 3: Values of statistical parameters for monitored and predicted concentrations of CO

Parameters	Monitored CO	Predicted CO	Range
Mean	2456	2182	–
Index of Agreement (IA)	1.00	0.97	0.0 – 1.0
NMSE	0.00	0.02	0.0 – 1.0
Pearson's Correlation (R)	1.00	0.91	+1 to – 1.0
Fractional Bias (FB)	0.00	-0.18	+ 2 to – 2
F2	100%	88.85	100%

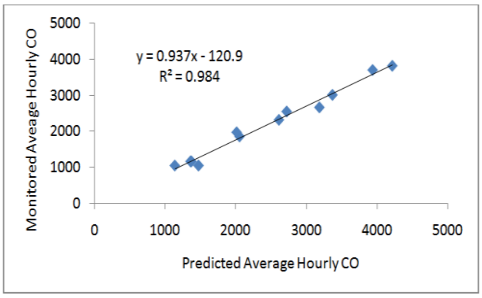

Fig. 4: Correlation between monitored and predicted average hourly CO concentration at location 3

The values of mean, IA, NMSE, R, FB and the F2 for monitored and predicted CO concentration at India Gate (location 4) have been given in Table 4 and Fig. 5. The value of IA has been found to be 0.96, which is very close to 1.0. This shows perfect agreement between monitored and predicted concentrations of CO. The value of NMSE has been evaluated to be 0.02, which denotes better model performance. The value of Correlation Coefficient, R gives quantitative relation between monitored and predicted results. It has been has been found to be (0.89), close to unity, which implies good model performance. The value of fractional bias (FB) ranges from + 2 to – 2 and has ideal value zero for an ideal model. The value of FB been evaluated to be – 0.24, which is very close to zero, indicates better performance of model. The ideal value for the Factor-of-Two (F2) should be 1 (100%). The calculated value of F2 has been found to be 90.57%, shows good correlation among monitored and predicted values.

Table 4: Values of statistical parameters for monitored and predicted concentrations of CO

Parameters	Monitored CO	Predicted CO	Range
Mean	5149	4664	-
Index of Agreement (IA)	1.00	0.96	0.0 – 1.0
NMSE	0.00	0.02	0.0 – 1.0
Pearson's Correlation (R)	1.00	0.89	+1 to – 1.0
Fractional Bias (FB)	0.00	-0.24	+2 to – 2
F2	100%	90.57	100%

The predicted hourly concentration of CO using Cal3QHCR and Caline – 4 for the month of February shows similar trends of CO concentration variation as discussed in the case of measured CO concentration. The values of predicted CO concentrations by Cal3QHCR have been found to be 2440 μg/m^3 as evening peak, 2214 μg/m^3 as morning peak and 1839 μg/m^3 as afternoon peak. However, Caline – 4 predicted the highest level of CO concentration (2536 μg/m^3) in evening (peak value) followed by morning peak (2285 μg/m^3) and afternoon peak (1881 μg/m^3). It is evident that both models have under predicted in comparison of measured values of CO in the month of February, 2009. The comparison of measured and prediction results show better performance of Caline – 4 than that of Cal3QHCR in all cases of CO concentration predictions. Ganguli et al. (2006) have reported the under prediction of CO concentration by Caline – 4 and GLSM in their studies.

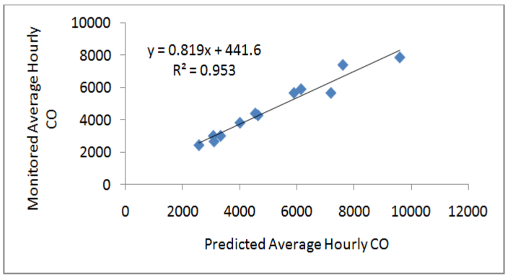

Fig. 5: Correlation between monitored and predicted average hourly CO concentration at location 4

IV. CONCLUSIONS

The highest average hourly concentration of predicted CO has been found to be towards Delhi Gate and the lowest average hourly concentration of predicted CO has been found to be at India Gate side. This may be due to more ventilated road towards India Gate side than Delhi gate side. The predicted values of average hourly concentration CO have been observed to be very close to monitored CO concentration irrespective of location. However, the predicted values show slightly under prediction of Caline–4 model. The values of statistical parameters in terms of mean, Index of Agreement (IA), Normalized Mean Square Error (NMSE), Pearson's correlation coefficient (COR), the Fractional Bias and the Factor-of-Two (F2) have been found to be very close to ideal model performance. The values of statistical parameters chosen for the model validation showed good correlation between monitored and predicted values of 1 hourly average CO at various locations of preselected road. Statistical analysis results concluded that the line source model, CALINE – 4 under predicts the CO concentrations at various locations of road.

REFERENCES

[1]. **Benson, P.E (1992)**, A review of the development and application of the CALINE 3 and 4 models. Atmos. Environ., Vol. 26B (3), pp. 379 – 390

[2]. **Berkowicz, R. (2000),** OSPM—a parameterised street pollution model. Environmental Monitoring and Assessment, Vol. 65, pp. 323–331

[3]. **Bogo, H., Negri, R.M., San Roman, E., (1999),** Continuous measurement of gaseous pollutants in Buenos Aires city, Atmos. Environ., Vol 33, pp. 2587 – 2598

[4]. **Chock, D.P. (1978),** A simple line source model for dispersion near roadways, Atmospheric Environment, Vol. 12, pp. 823–829.

[5]. **Colvile, R.N., Hutchinson, E.J., Mindel, J.S., Warren, R.F. (2001),** The transport sector as a source of air pollution, Atmos. Environ., Vol. 35, pp. 1537-1565.

[6]. **Dirks, K.N., Johns, M.D., Hay, J.E., Sturman, A.P. (2003),** A semi empirical model for predicting the effect of changes in traffic flow patterns on carbon monoxide concentrations, Atmospheric Environment, Vol. 37, pp. 2719–2724

[7]. **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.

[8]. **Harkonen, J. (2002),** Regulatory Dispersion Modelling of Traffic-originatedPollution. Finnish Meteorological Institute, Contributions No. 38, FMI-CONT-38. University Press, Helsinki, 103pp.

[9]. **Health Effects Institute (2009),** Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects. Health Effects Institute, Boston, MA. Special Report 17.

[10]. **Health Effects Institute, (2010),** Outdoor Air Pollution and Health in the Developing Countries of Asia: A Comprehensive Review. Health Effects Institute, Boston, MA. Special Report 18.

[11]. **Luhar, A.K, Patil, R.S, (1989),** A general finite line source model for vehicular pollution prediction, Atmos. Environ., Vol. 23, pp. 555 – 562.

[12]. **Mukherjee, P., Viswanathan, S. (2001),** Carbon monoxide modeling from transportation sources. Chemos., Vol. 45, pp. 1071- 1083

[13]. **Palmgren, F., Berkowicz, R., Ziv, A., Hertel, O. (1999),** Actual Car fleet emissions estimated from urban air quality measurements and street pollution models, Science of the Total Environment, Vol. 235, pp. 101–109

[14]. **Riley, K. (2002),** Motor vehicles in China: the impact of demographic and economic changes, Population & Environment, Vol. 23, pp. 479-494

[15]. **Schipper, L., Banerjee, I., Ng, W.S. (2009),** Carbon dioxide emissions from land transport in India. Transportation Research Record, 2114, pp. 28-37.

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