

# **Prediction of Air Pollutant Dispersion from Point and Line Sources and Validation of ISCST3 and CALINE4 Model Data with Observed Values in the Industrial Area of Mysuru**

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**ABSTRACT:** Ambient Air Quality (AAQ) has been monitored over a period of 8 months from November, 2016 to June, 2017, considering winter, summer and monsoon seasons at three identified locations along the highway passing through industrial area of Mysuru city, India. The number of 2W vehicles were found to be maximum (13620 nos./d) followed by 4W (4654 nos./d), HDV (2410 nos./d) and LDV (2024 nos./d). During weekdays the peak traffic volumes were observed at 08:00–10:00 hours and 17:00–20:00 hours. All the monitored pollutant concentrations were found to be well within National Ambient Air Quality Standard (NAAQS) in all the seasons, except during winter season PM<sub>10</sub> and PM<sub>2.5</sub> at receptor R1 were found to be exceeding the NAAQS. The comparison between observed values with Industrial source complex short term model 3 (ISCST3) and California line source model 4 (CALINE4) predictions showed ISCST3 model prediction found to be good agreement with observed NO<sub>x</sub> and SO<sub>2</sub> concentration, however, CALINE4 model prediction was good agreement with observed PM<sub>10</sub> concentration. It was also observed that, NO<sub>x</sub> and PM<sub>10</sub> was contributing ~86% and ~68% from line sources and ~14% and ~32% from point sources, respectively, however, SO<sub>2</sub> was contributing ~67% from point sources and ~33% from line sources. The statistical analysis of ISCST3 model was found to be within the acceptable values, indicating a good agreement with the observed pollutant concentrations.

**KEYWORDS:** ISCST3, CALINE4, Emission inventory, Source contribution, Statistical analysis, Q-Q plots.

## **I. INTRODUCTION**

Continuous and rapid growth in population, urbanization, industrialization and transportation in India, in recent years have caused tremendous damage to the environment [49]. The major sources of air pollution in urban areas are due to traffic emissions and point source industrial emissions [3,39]. Sources of PM<sub>2.5</sub>, NO<sub>x</sub> and SO<sub>2</sub> include biogenic, geogenic and anthropogenic local and long-range emissions and secondary formations within the atmosphere [12,19,20,21,26,33]. The emission from industries and vehicles are typically composed of a mixture of NO and NO<sub>2</sub> [41]. Various studies have been conducted to segregate different category of vehicles and to identify the peak traffic

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hours. Most of the studies reveal that, maximum traffic densities were found between 08:00–11:00 hours and 17:00–20:00 hours with maximum of 2W and 4W followed by LDVs and HDVs [13,14,15,38,43]. The traffic fleet such as, type of vehicle, fuel category and engine technology could vary within different cities in a state and age profile of different category of vehicles is important to calculate accurate emission factors [13,14,15,42,43]. However, air pollutants concentrations at road intersections have observed to vary in minutes due to the influence of traffic signal lights [16,27,50], which inevitably increases the complexity of pollutant predictions. Many researchers have conducted statistical analysis [17,25,28,30,43,46] of the air pollutant dispersion models and Q-Q plots [29,31,36,41,48] to validate the model predictions with the observed pollutant concentrations. In India, not much work have been done on the adverse impacts of air pollution associated with the transportation to the natural environment, despite reported by many investigators that, air pollution in mega cities contribute from automobiles ranging from 40–80% of total air pollution [3,7,23,31,38]. Hence, the aim of the present study is to monitor ambient air pollutant concentrations and to predict the ambient air quality for point and line sources using ISCST3 and CALINE4 dispersion models. An attempt has been made to check the model accuracy using statistical analysis by comparing the model predicted values with the observed concentrations and to determine the contribution of air pollutants individually from vehicular and industrial emissions.

## II. STUDY AREA

Mysore district is one of the tourist destination, in Karnataka, India, with a population of about 10.25 lakhs. In the present study, highway (3.3 km length) passing through the industrial area of Mysuru (12°20' N longitude and 76°35' E latitude) has been considered for ambient air quality monitoring. The study area (Figure 1) is located in the North-Western part of the Mysuru city, India, where Hebbal industrial area is located Northern part and residential area is located Southeast part of the study area. The road geometry of the study area shows marginal variation in the elevation among all the monitoring locations. Three monitoring stations at an interval of 1 km have been selected for Ambient Air Quality Monitoring (AAQM). The monitoring stations located near to Seshadripuram College (R1), Weigh Bridge (R2), V-LEAD Institute (R3), Prema Fuel Station (R4), Dexter Logistics (R5) and JSS Urban Haat (R6) were considered. Further, study area was comprised of 3000 m x 1500 m (for CALINE4 with 3 different coordinates, as model prediction capability is only upto 500 m) and 3000 m x 3000 m (for ISCST3) with 100 m x 100 m grids.



Fig. 1. Google map of the study area for ISCST3 and CALINE4 models along with the stretch of highway with point and line sources selected for the study and the established ambient air quality monitoring stations.

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## III. MATERIALS AND METHODS

Contribution of air pollutants such as, PM<sub>10</sub>, NO<sub>x</sub> and SO<sub>2</sub> from point and line sources in the industrial area of Mysuru has been calculated by preparing a comprehensive emission inventory or emission factor data.

### Emission inventory

The emission inventory comprises of listing and description of air pollutant sources including quantification of emitted pollutants [3,7,18]. In order to determine the contribution of air pollutant sources, emission data were collected from November, 2016 to June, 2017, which is being considered as winter, summer and monsoon seasons.

### Industrial emission

The Hebbal industrial area is located Northern part of the study area, where most of the industries come under red category. Four major industries with eleven stacks have been considered in the present study based on the wind direction and topography, which can effect on the residential area located South-Eastern part of the study area. The selected industries are as follows: Hindustan Unilever Ltd. (HUL) with seven major stacks; J.K. Tyre radial plant with two major stacks; Mysore Polymers & Rubber Products Pvt. Ltd. (MYPOL) and Automotive Axles Ltd. with one major stack. The emission characteristics of eleven major stacks were collected from the Karnataka State Pollution Control Board (KSPCB), Mysuru, India. The stack characteristics for HUL, MYPOL, J.K.Tyre plant and Automotive Axles Ltd. are shown in Table 1.

Table 1 :Stack inventory data obtained for Hindustan Unilever Ltd., MYPOL, J.K.Tyre plant and Automotive Axles Ltd. Mysuru (Source: KSPCB - Mysuru).

Stacks	Emission rate (g/s)		
	PM <sub>10</sub>	NO <sub>x</sub>	SO <sub>2</sub>
Stack 1 (HUL)	5.2	0.809	0.367
Stack 2 (HUL)	0.135	0.12	0.02
Stack 3 (HUL)	0.098	0.22	0.02
Stack 4 (HUL)	0.25	0.164	0.53
Stack 5 (HUL)	0.318	0.239	0.116
Stack 6 (HUL)	0.201	0.124	0.040
Stack 7 (HUL)	0.044	0.13	0.01
Stack 8 (J.K.Tyres plant-1)	5.025	0.856	0.324
Stack 9 (J.K. Tyres plant-2)	0.767	0.368	0.138
Stack 10 (MYPOL)	1.305	0.141	0.058
Stack 11 (Automotive axles)	0.321	0.15	0.08

### Vehicular emission

A traffic count study was conducted using CCTV camera installed at the monitoring locations. Automotive Research Association of India (ARAI), Government of India, New Delhi, is responsible for developing Emission Factor for different types and categories of vehicles such as, 2 wheelers (2W), 3 wheelers (3W), 4 wheelers (4W) which comprised of cars, Light Duty Vehicles (LDVs) and Heavy Duty Vehicles (HDVs), which is, based on mass emission tests conducted on limited number of in-use vehicles covering different engine technologies, types of vehicle, types of fuels, etc. (ARAI, 2008) [2]. Emission factors along with total number of vehicles per hour are used to calculate Weighted Emission Factor (WEF) developed by US-EPA, as calculated by [15,43,46].

$$WEF = ((EF_1 * V_1) + (EF_2 * V_2) + (EF_3 * V_3) + (EF_4 * V_4)) / (\Sigma V) \quad (1)$$

Where, EF = Emission factor for different category of vehicles, V = volume of different category of vehicles. In the present study air pollutant load, i.e., WEF in g/mile was calculated using ARAI standards. The calculated emission inventories were used as inputs for CALINE4 and ISCST3 dispersion models.

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## Micro-meteorology

Dispersion of air pollutants depend upon meteorological data such as, wind velocity, wind direction, temperature, relative humidity and precipitation. The hourly meteorological data was collected from the website [www.wunderground.com](http://www.wunderground.com). Hourly meteorological data was used to plot monthly variation of all the meteorological parameters (Figure 2). Maximum temperature was found to be 37°C in the month of April, 2017 (summer season) and a minimum temperature of 15°C was noticed in the month of January, 2017 (winter season). The average temperature was varying from 24°C to 28°C during the study period. Further, a maximum relative humidity (RH) was found to be 96% in the month of January and March, 2017 and a minimum relative humidity of 19% was noticed during the month of February, 2017. However, maximum precipitation was observed during the month of May (35 mm) followed by June and April, 2017. Wind speed of 7.77 m/s was noticed in the month of June, 2017 (monsoon season) and a minimum wind speed of 0.55 m/s was noticed in the month of December, 2016 and January, 2017 (winter season). The average wind speeds were varying from 2.22 m/s to 3.889 m/s during the study period. The annual windrose plot shown in Figure 3 indicates that, predominant wind was blowing from East direction during winter season and from West-South-West direction during summer and monsoon seasons.

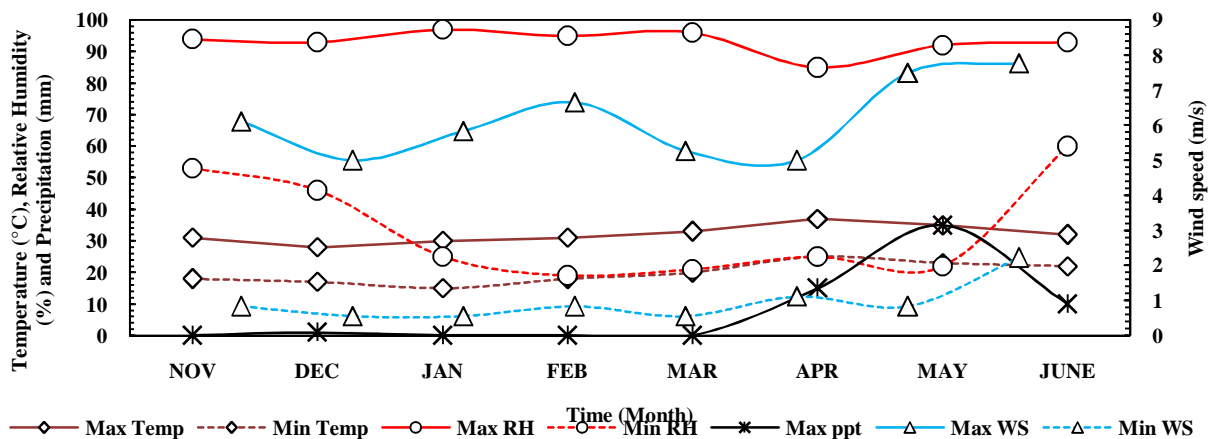


Fig. 2. Monthly variation of meteorological factors at Mysuru from November, 2016 to June, 2017.

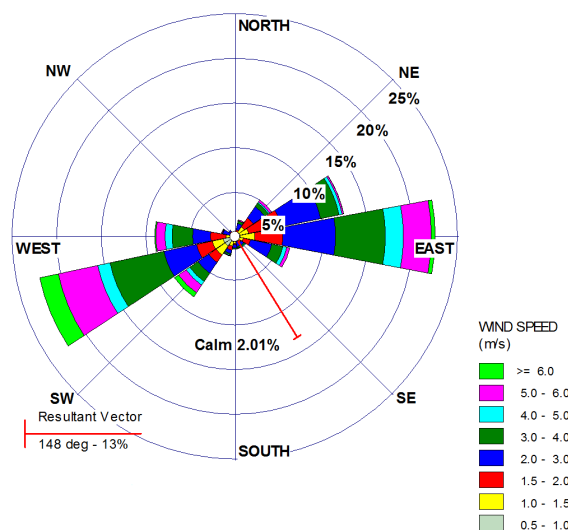


Fig. 3. Annual windrose plot over Mysuru city from November, 2016 to June, 2017.

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## Ambient air quality monitoring (AAQM)

Ambient air quality has been monitored over a period of 8 months from November, 2016 to June, 2017, considering winter, summer and monsoon seasons. The AAQM was conducted for 8 hours from 10.00 am to 06.00 pm for pollutants such as, PM<sub>10</sub>, PM<sub>2.5</sub>, NO<sub>x</sub> and SO<sub>2</sub>. Analysis of NO<sub>x</sub> and SO<sub>2</sub> were carried out as per Indian Standards IS:5182 (Part 6 (BIS, 2006) [10] and Part 2 (BIS, 2001) [8]). Gravimetric technique was used to analyse PM<sub>10</sub> concentrations as per IS:5182 Part 23 (BIS, 2006) [9].

## Ambient air quality modeling

In order to predict the ambient air quality at selected receptor points, ISCST3 and CALINE4 Gaussian plume dispersion models were used. ISCST3 model was used to predict point and line source emissions for PM<sub>10</sub>, NO<sub>x</sub> and SO<sub>2</sub>, however, CALINE4 model was used to predict the emission (PM<sub>10</sub> and NO<sub>x</sub>) from line sources.

## ISCST3 dispersion model

ISCST3 model is based on Gaussian plume dispersion model, which is the simplified form of the three-dimensional transmission-distribution equation. ISCST3 can calculate the ground level pollutant concentrations for annually, daily and hourly basis using area-specific hourly meteorological data [1,40]. ISCST3 dispersion model uses polar or cartesian co-ordinates for receptor grid; can calculate for point, area and volume sources considering wet and dry deposition, which account for terrain and building downwash considerations [24]. ISCST3 Gaussian plume model for predicting downwind pollutant concentrations from point and line sources can be described by

$$C = (Q_p / \pi u \sigma_y \sigma_z) * \exp((-1/2)(y/\sigma_y)^2) * \exp((-1/2)(H/\sigma_z)^2) \quad (\text{For point source}) \quad (2)$$

$$C = (2Q_L / (\sqrt{2\pi} * u \sigma_z)) * \exp((-1/2)(H/\sigma_z)^2) \quad (\text{For line source}) \quad (3)$$

Where, C is the downwind pollutant concentration ( $\mu\text{g}/\text{m}^3$ ),  $Q_p$  is the point source emission rate (g/s),  $Q_L$  is line source pollutant emission rate ( $\text{g}/\text{m}^2\text{s}$ ),  $\sigma_y$  and  $\sigma_z$  = lateral and vertical dispersion coefficients (m) based on stability class, u = average wind speed at pollutant release height (m/s), H = effective height above ground of emission source (m) and y is distance at cross wind direction (m).

## CALINE4 dispersion model

CALINE4 is a line source Gaussian-based dispersion model developed by the California Department of Transportation used to estimate CO, NO<sub>x</sub> and particulates concentration levels within 500 m of roadways [5,6]. It represents a line source as a series of finite length elements each oriented perpendicular to the wind. The length of each element is determined based on its distance from the receptor of interest. The model uses Pasquill Gifford categories to characterize the stability of the atmosphere [4]. It employs a mixing zone concept to characterise pollutant dispersion over the roadway due to vehicles plying on the road corridor [15].

## Model performance evaluation

Statistical analysis were carried out to evaluate the model performance or model predictions with the ambient air monitored pollutant concentrations. Absolute Bias (AB), Fractional Bias (FB), Normal Mean Square Error (NMSE), Root Mean Square Error (RMSE), Index of Agreement (d), Factor of Two (FAC2) and Person's Correlation (R) were calculated. The performance of the model can be acceptable if,  $0 \leq \text{RMSE} \leq +1$  [46];  $-0.5 \leq \text{FB} \leq +0.5$ ;  $-0.5 \leq \text{NMSE} \leq +0.5$ ,  $+0.4 \leq d \leq +1$  [32] and  $+0.5 \leq \text{FAC2} \leq +2$  [28].

## IV. RESULTS AND DISCUSSION

### Traffic volume studies

The vehicular emissions are one of the major sources of air pollution in the study area. To estimate the contribution of pollutants from vehicular exhaust into the ambient air, the numbers of vehicles passing through the study area during the monitoring days were determined by installing CCTV camera at Seshadripuram College, Mysuru, India. The total number of vehicles have been counted with help of external hard drive having the record of 7 days x 24

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hours of traffic flow in .mp4 format. The traffic variation near to Seshadripuram College is presented in Figure 4. 2W vehicles were found to be maximum (13620 nos./d) followed by 4W (4654 nos./d), HDV (2410 nos./d) and LDV (2024 nos./d). However, a maximum 2Ws of 1100 nos. vehicles were noticed at 19:00 h followed by 4W (373 nos. at 08:00 h), HDV (225 nos. at 11:00 h) and LDV (162 nos. at 09:00 h). However, Dhyani et al. (2017) and Sharma et al. (2013) showed that, traffic flow was dominated by 4W, followed by 2W, 3W and HDVs at a highway in Delhi city, India [14,43]. During weekdays the peak traffic volumes were observed during 08:00–10:00 hours (morning peak hours) and 17:00–20:00 hours (evening peak hours). Dhyani et al. (2017), Khare et al. (2012) and Sharma et al. (2013) have also observed the peak traffic hours between 08:00–11:00 hours and 18:00–20:00 hours in Delhi, India, which found to be very similar observation made in the present study [14,30,43].

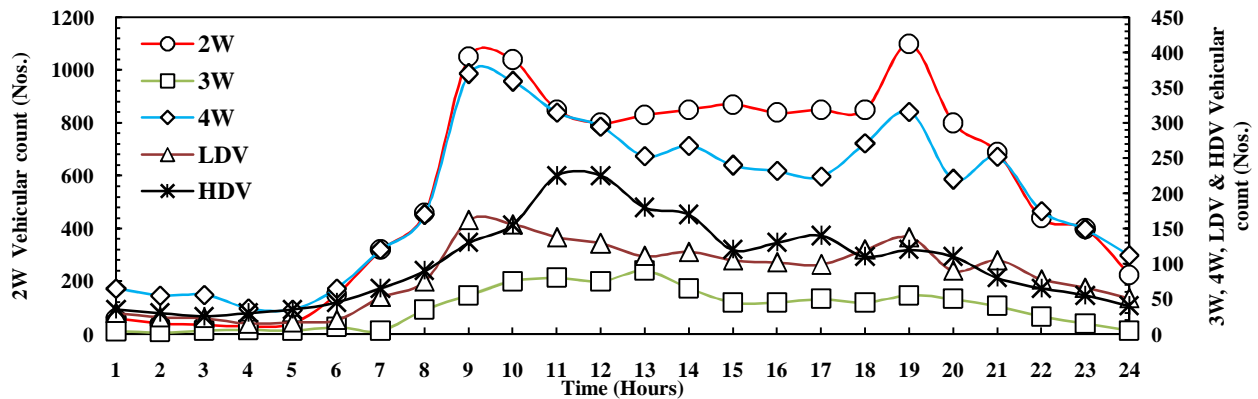


Fig. 4. Traffic variations during weekdays near Seshadripuram College.

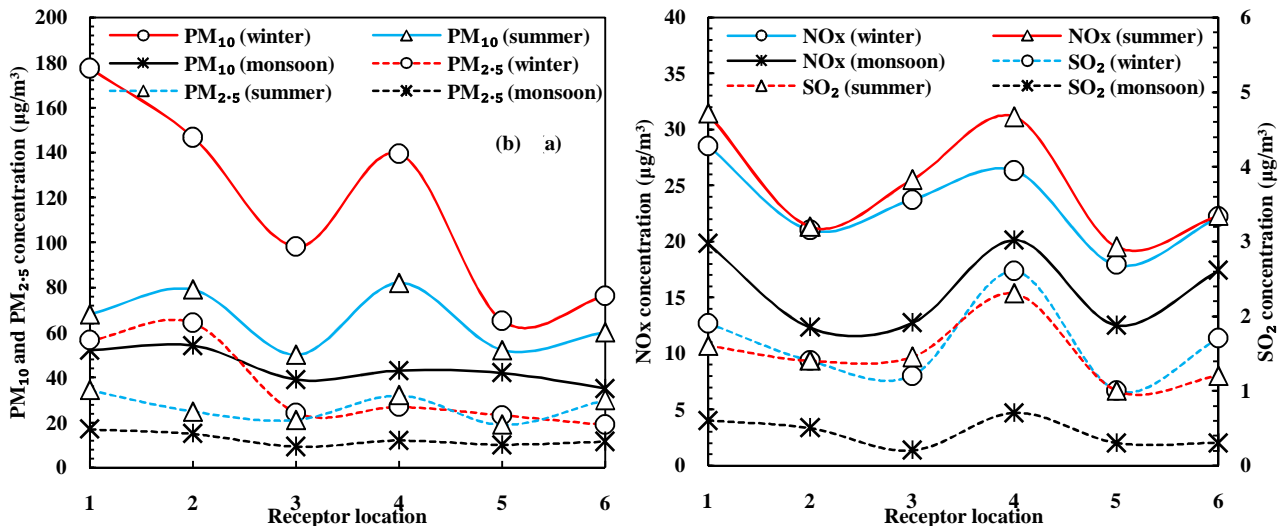


Fig. 5. Seasonal variation of observed (a)  $PM_{10}$  and  $PM_{2.5}$ , (b)  $NO_x$  and  $SO_2$  concentrations at different receptor locations.

## Ambient air quality monitoring (AAQM)

Ambient air quality has been monitored to estimate the total pollutant concentrations arising from various sources such as, point, area and line sources including the background concentration in the study area. The AAQM have been conducted from December, 2016 to June, 2017 for winter, summer and monsoon seasons over a period of 8 hours from 10:00 am to 06:00 pm for the pollutants such as,  $PM_{10}$ ,  $PM_{2.5}$ ,  $NO_x$  and  $SO_2$ . Dispersion of air pollutants depend on the various meteorological factors which influence the AAQ [35]. Meteorological data such as, wind speed, wind direction, temperature, relative humidity, stability class, MMD and precipitation were collected during the

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ambient air quality monitoring days and used in air quality model studies. The observed concentration of PM<sub>10</sub>, PM<sub>2.5</sub> and NO<sub>x</sub>, SO<sub>2</sub> during winter, summer and monsoon seasons at different receptor locations are made shown in Figures 5 (a-b). From the winter plots (Figure 5a) it was observed that, PM<sub>10</sub> and PM<sub>2.5</sub> was exceeding at receptor locations R1 and R2. The reason for higher concentration achieved due to less wind speed (2 – 8 km/h), which leads to calm atmospheric condition. During winter season, the average temperature was found to be 19°C, due to which the pollutants dispersion in the atmosphere was low. Bhanarkar et al. (2005), Banerjee et al. (2011) and Prakash et al. (2015, 2016) also reported pollutant concentrations were found to be more during winter due to low wind speeds compared to summer season [3,7,37,38]. The concentration of NO<sub>x</sub> during winter season was found to be more at receptor R1 and R2 due to stable atmospheric condition and more number of vehicles during experimental day compared to receptor locations R3 – R6. As the number of vehicle increases, concentration of CO, NO<sub>x</sub> and PM<sub>10</sub> in the atmosphere also increases due to vehicular exhaust emission [44,45,47]. Further, R1 was located downwind to J.K. Tyres Radial plant, as wind was blowing from E (90°) and ENE (68°) towards W (270°), WSW (248°) and SW (225°). However, SO<sub>2</sub> concentration was found to be more near Prema Fuel Station (R4) as the place was located near J.K. Tyres radial plant and fuel station. Pollutant concentrations were found to be minimum at receptor locations R5 and R6, though the places were having maximum vehicular density during the AAQ monitored day, due to very unstable atmospheric condition (wind speed > 24 km/h). Unstable condition favours to more initial dilution and dispersion of air pollutants, hence, leads to lower ground level pollutant concentration. Further, R5 and R6 was located upwind direction of J.K. Tyres, HUL and Automotive Axles for winter season.

During summer season (Figure 5b) NO<sub>x</sub> concentration was found to be more compared to winter and monsoon seasons. This may be due to increase in fleet movement of vehicles in summer holidays (~15000–18000 vehicles/8h) compared to winter season (~13000–15000 vehicles/8h). This could be also due to the photochemical reaction within the atmosphere which helped to produce more NO<sub>x</sub> during summer season [37]. PM<sub>10</sub> concentrations at receptor R1 to R4 were found to be more because of frequent fluctuation in wind direction from SW and W towards NE and E. However, pollutant concentration at receptor R5 and R6 was found to be minimum, due to the precipitation just before the ambient air monitoring. Further, pollutants such as, PM<sub>10</sub>, PM<sub>2.5</sub> and SO<sub>2</sub> were found to be within NAAQS. Pollutant concentrations were found to be minimum during monsoon season compared to winter and summer seasons. This may be due to the precipitation which scavenged all the air pollutants from atmosphere to the ground level. However, Prakash et al. (2015, 2016) have also reported a minimum air pollutant concentration during monsoon season due to precipitation [37].

## Comparisons of ISCST3 and CALINE4 model predictions with observed values

ISCST3 and CALINE4 models have been used to predict NO<sub>x</sub>, SO<sub>2</sub> and PM<sub>10</sub> concentrations at selected receptor points and are presented in Figure 6. ISCST3 (combined point and line sources) model prediction found to be better than CALINE4 model for predicting NO<sub>x</sub> concentration during winter season (Figure 6a) and showed a good agreement with the observed values. The reason for low performance of CALINE4 model was mainly due to CALINE4 can predict pollutant concentration upto 500 m of downwind distances [6]. Moreover, the emission factors were calculated based on the types of vehicles, however, the age profile of vehicles and acceleration of the vehicles were not considered. According to Sharma et al. (2013) CALINE 4 model should not be used in urban environmental conditions, where roadside air quality is influenced by industrial, thermal power plants and urban street canyons which play a vital role in determining the resultant pollutant concentrations [43]. Further, ISCST3 prediction for SO<sub>2</sub> during winter season was found to be close to observed values. However, none of the models prediction for PM<sub>10</sub> was in good agreement with the observed values (Figure 7a). Both the models were under-predicting the PM<sub>10</sub> concentration. The reason may be due to the fact that, during winter season PM<sub>10</sub> concentration was found to be more and some fugitive emissions such as, contribution from area sources and road side dusts were not considered into the models. Benson (1992) has reported that, dispersion models do not perform well under low wind conditions [6]. Accuracy of the model predictions mainly dependent on input data to the model. Emission data may have uncertainties in magnitude and variation in hourly meteorological data may influence the final model output. Further, ISCST3 model predictions of NO<sub>x</sub> and SO<sub>2</sub> concentrations for summer season (Figure 6b) were found to be good agreement with the measured concentrations. It was observed that, ISCST3 prediction was very close to the observed values.

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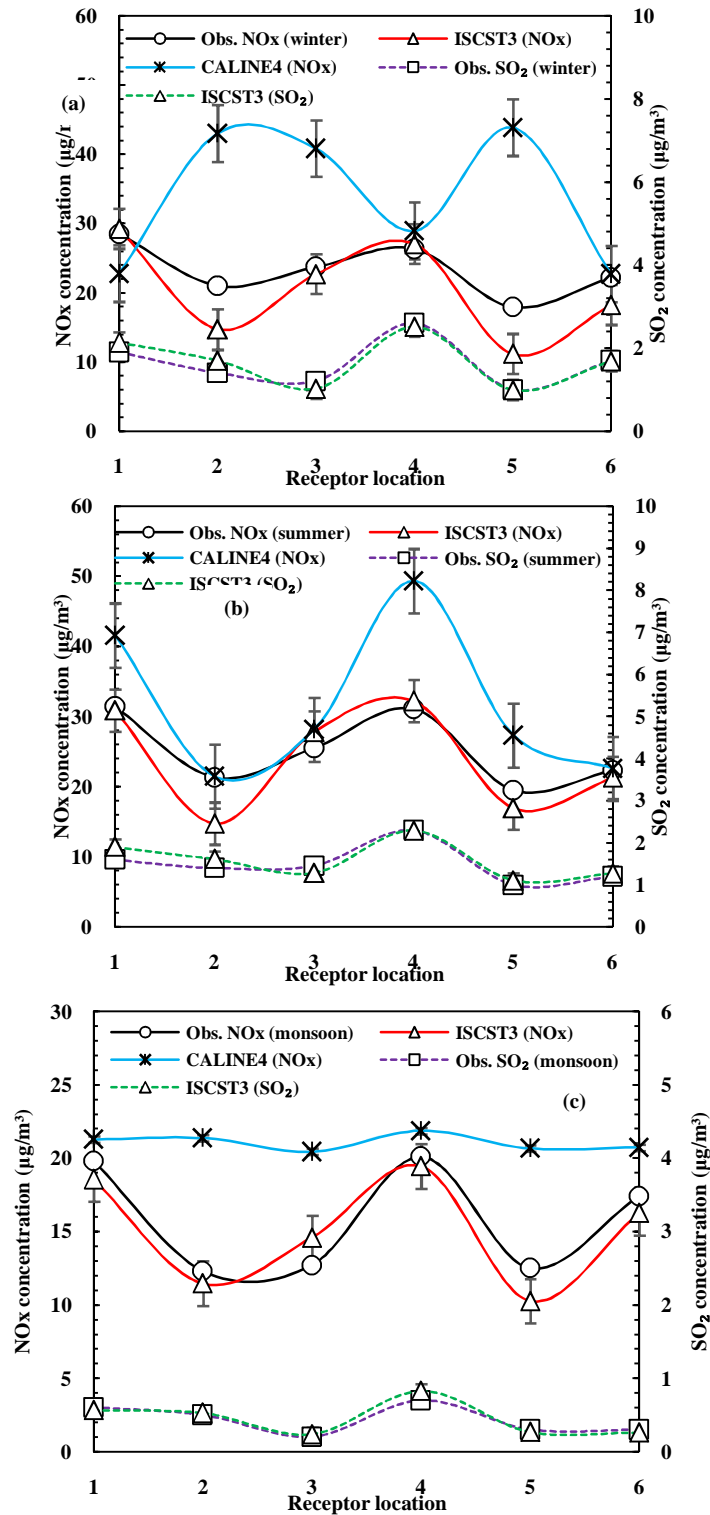


Fig. 6. Comparison between observed and predicted NO<sub>x</sub> and SO<sub>2</sub> concentrations during (a) winter, (b) summer and (c) monsoon seasons.



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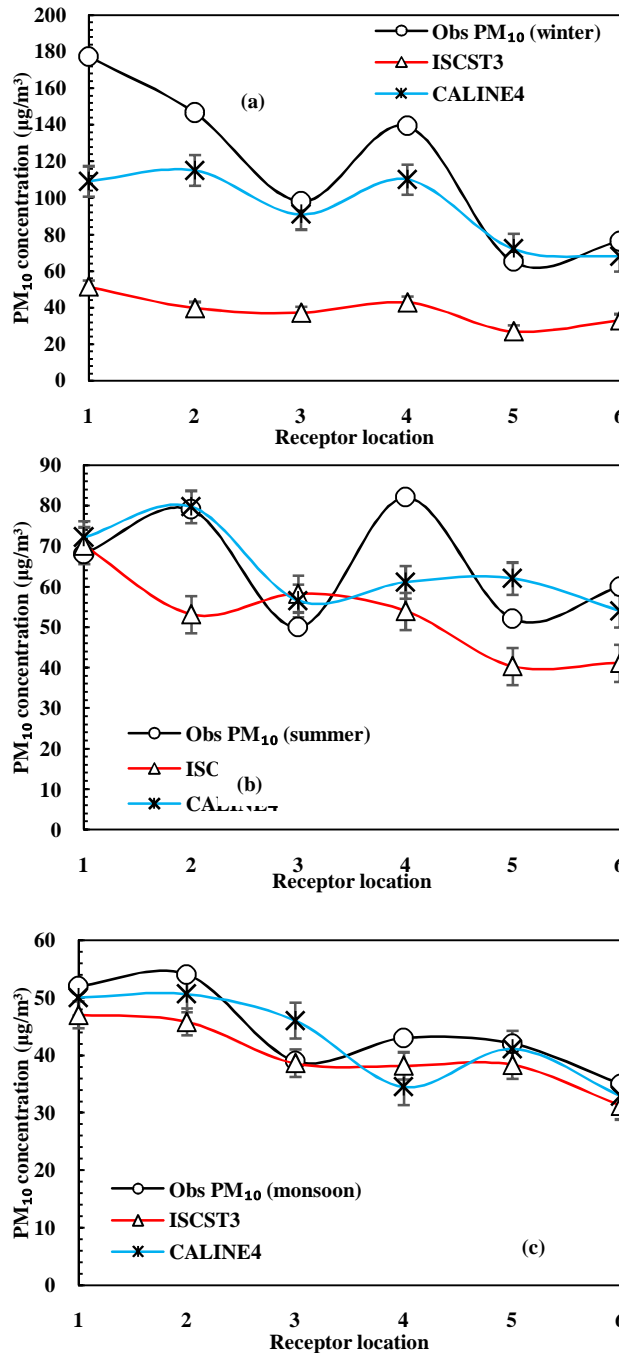


Fig. 7. Comparison between observed and predicted PM<sub>10</sub> concentrations during (a) winter, (b) summer and (c) monsoon seasons.

However, CALINE4 model was over predicting NO<sub>x</sub> concentration (Figures 6b-c) in all receptor points. This may be due to the input parameters into the CALINE4 model was very limited and it predicts NO<sub>x</sub> concentration in ppm which further has to be converted into µg/m<sup>3</sup>. It was also observed that, CALINE4 model was not applicable at lower pollutant concentration and model accuracy was found to be upto two decimal points. PM<sub>10</sub> prediction (Figure 7b) by both the

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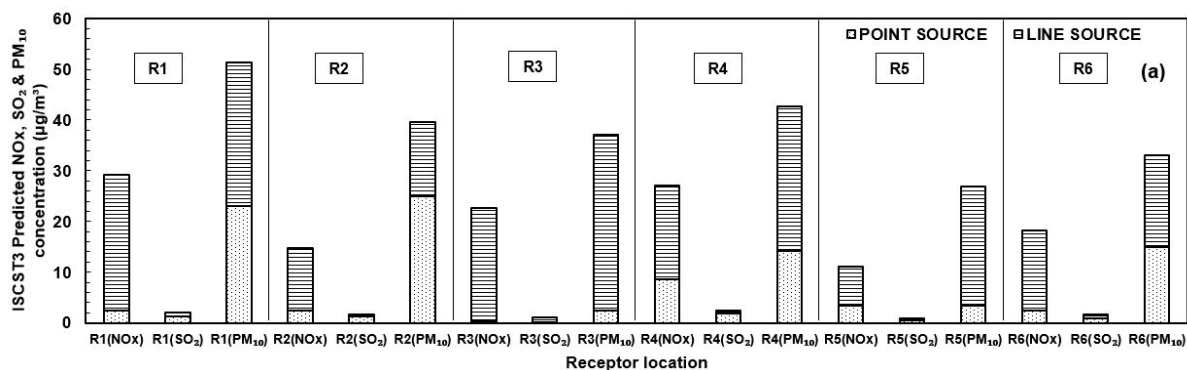
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models were satisfactory during summer season. CALINE4 model prediction was found to be better than ISCST3 for predicting PM<sub>10</sub> concentration. The reason of lower performance by ISCST3 may be due to considering only 11 stacks in the study area, insufficient input data for area source emissions, and hourly variation of wind speeds and wind directions. However, ISCST3 model predictions for NO<sub>x</sub> and SO<sub>2</sub> during monsoon season (Figure 6c) were found to be good agreement with the measured concentrations, while, CALINE4 model was over predicting NO<sub>x</sub> concentration at all the receptor points (Figure 6c). Khare et al. (2012) and Heist et al. (2013) have reported higher version models such as, ADMS, AERMOD and ISCST3 performance was better than lower version models such as, CALINE3 CALINE4, GFLSM and DFLSM [28,30].

### Individual pollutant contribution from point and line sources

The distribution of pollutants from point and line sources predicted by ISCST3 model during winter, summer and monsoon seasons at each receptor points are shown in Figures 8 (a-c). Maximum NO<sub>x</sub> concentration during winter season found to be 20 – 30 µg/m<sup>3</sup> near to receptor locations R1 and R4 followed by 15 – 25 µg/m<sup>3</sup> near R2, R3, R5 and R6. The reason for higher concentration obtained at R1 and R4 was due to these receptors were located downwind to the major sources of pollution from HUL, J.K. Tyres radial plant and also due to the higher vehicular density during AAQM days. PM<sub>10</sub> concentration during winter season found to be 45 – 55 µg/m<sup>3</sup> near to the receptors R1 and R4 followed by 35 – 45 µg/m<sup>3</sup> near the receptor locations R2 and R3. Pollutant concentrations were found to be more during winter season due to calm atmospheric condition and minimum during monsoon season (Figure 8c) due to unstable atmospheric condition (wind speed > 24 km/h). From Figures 8 (a-c), it is observed that, NO<sub>x</sub> and PM<sub>10</sub> was contributing more from the line sources than point sources. However, SO<sub>2</sub> was contributing more from the point sources. A similar result was also observed by Bhanarkar et al. (2005), Kansal et al. (2011) and Prakash et al. (2016) [7,29,38]. It was observed that, the dominant source of NO<sub>x</sub> and PM<sub>10</sub> at all receptors over the study area was from vehicular emissions (vehicular exhaust) in all the seasons. NO<sub>x</sub> was contributing on an average ~86% (Figure 9a) from line sources and ~14% from point sources. Further, PM<sub>10</sub> was contributing ~68% (Figure 9c) from line sources and ~32% from point sources. However, model results showed, SO<sub>2</sub> was contributing around 67% (Figure 9b) from point sources and ~33% from line sources. Indeed, it was observed that, NO<sub>x</sub> and PM<sub>10</sub> was mainly contributed from line sources and SO<sub>2</sub> was mainly contributed from point sources. Bhanarkar et al. (2005) have reported that, industrial sources account for 77% and 68% of the total emissions of SO<sub>2</sub> and NO<sub>2</sub>, respectively, in the Jamshedpur region, whereas, vehicular emissions contributed to about 28% of the total NO<sub>2</sub> emissions [7]. Further, Kansal et al. (2011) stated that, line sources were contributing ~58% of total NO<sub>x</sub> and PM<sub>10</sub> pollution, whereas, point sources (Thermal power plants) were contributing only ~30% of NO<sub>x</sub> and PM<sub>10</sub> pollution in Delhi city, India [29].



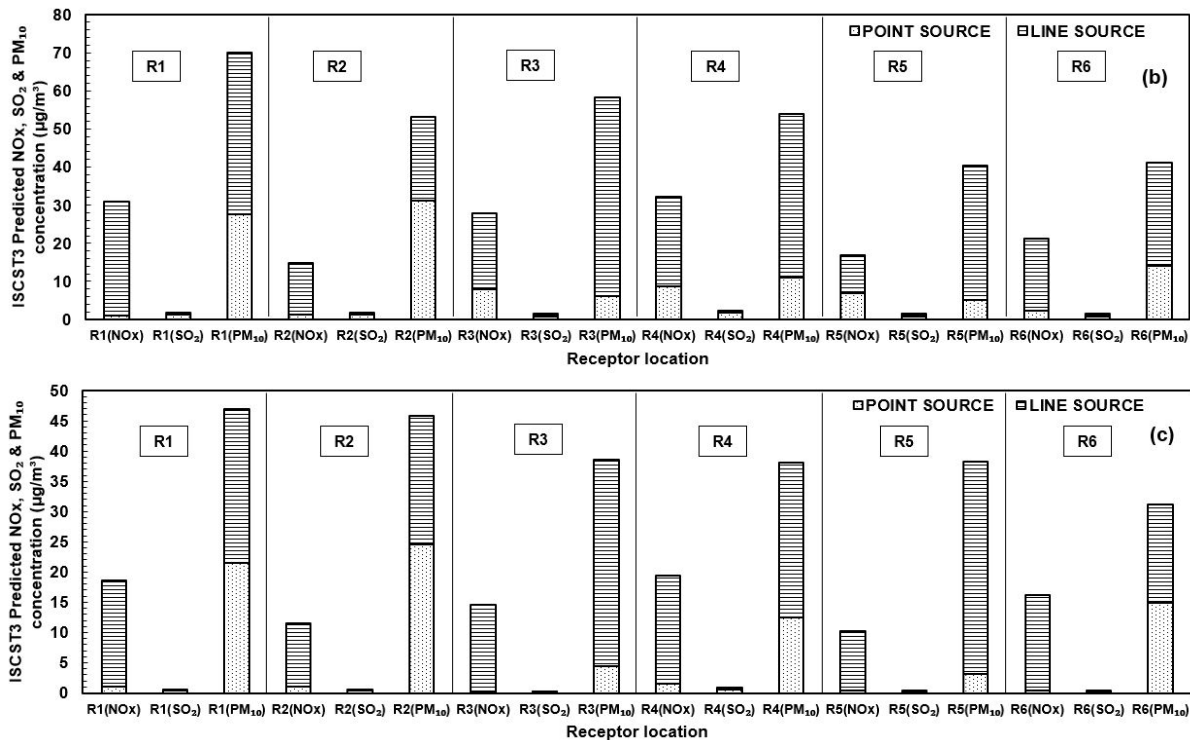


Fig. 8. ISCST3 model predicted pollutant concentrations at different receptor points in the study area during (a) winter, (b) summer and (c) monsoon seasons for distributed point and line sources.

#### Performance evaluation of ISCST3 and CALINE4 models

Statistical analysis was carried out to evaluate the model performance / model prediction with the field monitored values. The results of the statistical analysis of observed and monitored data for winter, summer and monsoon seasons are presented in Table 2. During winter season, FB value obtained from ISCST3 model (FB = 0.127) for NOx was found to be satisfactory compared to the FB value obtained by CALINE4 model (FB = - 0.365). The positive FB value indicates ISCST3 model was under-predicted NOx concentration and the negative FB value indicates, CALINE4 model was over-predicted NOx concentration during winter season. Further, FB value produced by CALINE4 model (FB = 0.219) for PM<sub>10</sub> concentration was satisfactory when compared to ISCST3 (FB = 1.011), infact, ISCST3 model estimated FB value for PM<sub>10</sub> was not within the acceptable range ( $-0.5 \leq \text{FB} \leq +0.5$ ; [32]). This may be due to insufficient data inputs or influence of other meteorological factors at the study area, which result in the difference between the observed and predicted concentrations. Goud et al. (2015) reported that, performance of CALINE4 model based on NMSE, FB, MG and R for prediction of PM<sub>2.5</sub> was well within the limits [22]. In the present study, NOx concentration estimated from ISCST3 model was found to be better (NMSE = 0.016; FAC2 = 1.135) than CALINE4 model (NMSE = 0.138; FAC2 = 0.691). Further, SO<sub>2</sub> concentration estimation by ISCST3 model during winter season had low AB (- 0.037), FB (- 0.022), RMSE (0.015) and high d (0.973) and R (0.951) values.

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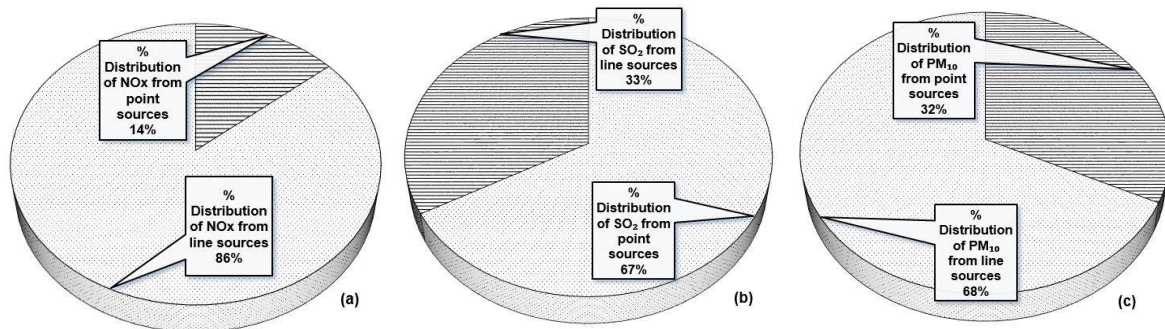


Fig. 9. Average seasonal contribution of (a) NO<sub>x</sub>, (b) SO<sub>2</sub> and (c) PM<sub>10</sub> from point and line sources in the study area.

Table 2: Statistical analysis for observed and modeled data for winter, summer and monsoon seasons.

Models	Pollutants	AB	FB	NMSE	RMSE	FAC2	d	R
			(- 0.7 to + 0.7)	(- 0.5 to + 0.5)		(0.5 to 2)	(0.4 to 1)	
<b>Winter season</b>								
ISCST3	PM <sub>10</sub>	78.658	1.011	1.374	32.112	3.046	0.139	0.950
	NO <sub>x</sub>	2.770	0.127	0.016	1.131	1.135	0.836	0.987
	SO <sub>2</sub>	- 0.037	- 0.022	0.000	0.015	0.978	0.973	0.951
CALINE4	PM <sub>10</sub>	23.100	0.219	0.048	9.431	1.246	0.713	0.919
	NO <sub>x</sub>	- 10.40	- 0.365	0.138	4.246	0.691	- 0.552	0.696
ISCST3	PM <sub>10</sub>	- 55.72	- 0.840	0.858	22.749	0.408	0.123	0.800
vs CALINE4	NO <sub>x</sub>	- 13.17	- 0.486	0.251	5.377	0.609	- 0.710	0.663
<b>Summer season</b>								
ISCST3	PM <sub>10</sub>	12.335	0.209	0.044	5.036	1.233	0.299	0.285
	NO <sub>x</sub>	1.219	0.050	0.002	0.498	1.051	0.925	0.941
	SO <sub>2</sub>	- 0.084	- 0.055	0.003	0.034	0.947	0.954	0.932
CALINE4	PM <sub>10</sub>	0.917	0.014	0.000	0.374	1.014	0.708	0.578
	NO <sub>x</sub>	- 6.550	- 0.230	0.054	2.674	0.794	0.670	0.896
ISCST3	PM <sub>10</sub>	- 11.41	- 0.195	0.038	4.662	0.822	0.413	0.448
vs CALINE4	NO <sub>x</sub>	- 7.769	- 0.279	0.079	3.171	0.755	0.713	0.845
<b>Monsoon season</b>								
ISCST3	PM <sub>10</sub>	4.327	0.103	0.011	1.766	1.109	0.851	0.956
	NO <sub>x</sub>	0.707	0.046	0.002	0.289	1.047	0.954	0.972
	SO <sub>2</sub>	-0.013	- 0.030	0.001	0.005	0.970	0.977	0.931
CALINE4	PM <sub>10</sub>	1.650	0.038	0.001	0.674	1.039	0.861	0.937
	NO <sub>x</sub>	-5.254	- 0.285	0.083	2.145	0.750	0.095	0.588
ISCST3	PM <sub>10</sub>	-2.677	- 0.065	0.004	1.093	0.937	0.876	0.984
vs CALINE4	NO <sub>x</sub>	-5.961	- 0.330	0.112	2.434	0.717	0.068	0.495

The results obtained during summer and monsoon seasons (Table 2) were very similar to the results obtained during winter season, except during summer and monsoon studies, model predictions were improved. This may be due to more significant data input to the models. FB value produced by CALINE4 model (FB = 0.014) during summer season for PM<sub>10</sub> was satisfactory when compared to ISCST3 model (FB = 0.209). The positive FB value indicates both CALINE4 and ISCST3 models were under-predicted the PM<sub>10</sub> concentrations. PM<sub>10</sub> prediction by CALINE4 had lower FB, NMSE and higher d and R value compared to ISCST3 model. Further, FB value produced by CALINE4 (FB = 0.038) during monsoon season for PM<sub>10</sub> was found to be satisfactory compared to the FB values obtained by ISCST3 model (FB = 0.103). However, CALINE4 estimated d (0.861) and R (0.937) values were closer to ISCST3 calculations (d = 0.851; R = 0.956). It was observed that, ISCST3 model predictions for SO<sub>2</sub> was satisfying all the statistical values and found to be good correlation with observed values. Gulia et al. (2015) reported that, ISCST3 model performance

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was better than AERMOD and ADMS-Urban [25]. Finally, Statistical analysis between the model predictions, showed significant variation between ISCST3 and CALINE4 model. Negative FB was indicating CALINE4 model predictions for NO<sub>x</sub> and PM<sub>10</sub> values were more than ISCST3 predictions. Further, NMSE and FAC2 values were not within the limit. This may be due to ISCST3 model was higher version model and also due to the limitations of CALINE4 model predictions.

## Q-Q Plots for ISCST3 and CALINE4 model predictions with observed pollutant concentrations

In the present study quantile - quantile or Q-Q plots for modeled and measured NO<sub>x</sub>, SO<sub>2</sub> and PM<sub>10</sub> concentrations combined winter, summer and monsoon seasons are made shown in Figure 10. The “factor-of-two” or FAC2 plot was used to assess model performance. If, 75% of the data sets fall within the FAC2 envelop, the model results are considered good in predicting true values [4,11,34,48]. From Figure 10a, it was observed that, all the points were fitted within the FAC2, which indicates a good correlation was achieved by ISCST3 model for predicting NO<sub>x</sub> concentration. The R<sup>2</sup> value for NO<sub>x</sub> was found to be 0.8543, which also indicates a good correlation with the observed values. The SO<sub>2</sub> concentration (Figure 10b) prediction by ISCST3 model showed all points were closely fitted to 1:1 line. The R<sup>2</sup> value was found to be 0.9603, which also indicates a good correlation with the measured concentrations. Further, the Q-Q plot of ISCST3 model and observed PM<sub>10</sub> concentration (Figure 10c) showed only 66.66% of data fell within FAC2, which does not fall within the acceptable 75% envelope. It was found that, ISCST3 model was under-predicting the PM<sub>10</sub> concentrations, because PM<sub>10</sub> was contributed from area sources and road side dusts which were not considered into the model input data. The Q-Q plot of CALINE4 model prediction for NO<sub>x</sub> concentration (Figure 10d) showed all the points were within FAC2 and the R<sup>2</sup> value was found to be 0.2727, which represents a poor prediction capability by CALINE4 model. The reason for low performance of CALINE4 was mainly due to CALINE4 can predict pollutant concentration upto 500 m of downwind distances [6]. However, from Figure 10e, it was observed that, all the points were within FAC2 for PM<sub>10</sub> prediction. The R<sup>2</sup> value was found to be 0.8797, indicating a good correlation of CALINE4 model prediction with the observed values. Wang et al. (2014) have reported that, CAL3QHC and CALINE4 model predictions were better for PM<sub>2.5</sub> when compared to gaseous pollutant such as CO [46]. Yura and Niemeier (2007) have reported that, CALINE4 model predictions with suburban condition resulted 80% of data within FAC2, whereas, with urban condition resulted only 56.4% within FAC2 [48]. In the present investigation, Q-Q plots for NO<sub>x</sub> and PM<sub>10</sub> (Figures 10f-g) between the model predictions showed a very poor correlation, though 75% of the points were within the FAC2. The R<sup>2</sup> values for NO<sub>x</sub> and PM<sub>10</sub> were found to be 0.1328 and 0.0228, respectively.

## V. CONCLUSIONS

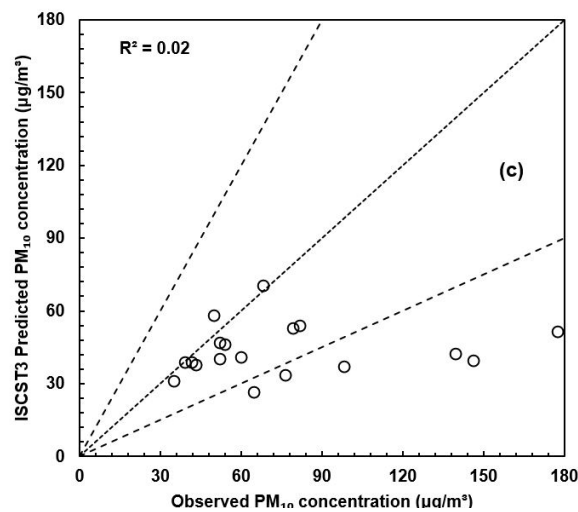
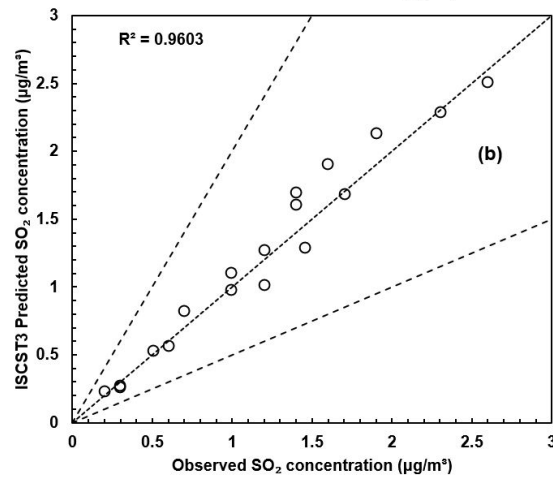
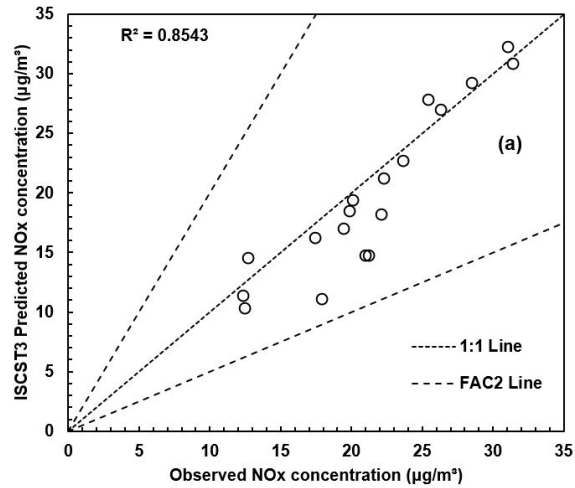
The ambient air quality monitoring (AAQM) of pollutants such as, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub> and NO<sub>x</sub> during winter, summer and monsoon seasons were carried at identified locations over a period of 8 months from November, 2016 to June, 2017. Traffic count studies showed, the number of 2W vehicles were found to be maximum followed by 4W, HDV, LDV and 3W. During weekdays the peak traffic volumes were observed between 08:00–10:00 hours and 17:00–20:00 hours. The AAQM results reveal during winter season PM<sub>10</sub> concentration was exceeded at receptor R1 (177.3 µg/m<sup>3</sup>) and R2 (146.6 µg/m<sup>3</sup>), and PM<sub>2.5</sub> was exceeding at receptor R1 (64.2 µg/m<sup>3</sup>), which may be due to low ambient temperature (15°C), low wind speeds (2–8 km/h) and high relative humidity (93%). NO<sub>x</sub> and SO<sub>2</sub> concentrations in the ambient air were found to be within the NAAQS of 80 µg/m<sup>3</sup> at all the receptor locations. Further, during monsoon season, pollutant concentrations in the ambient air were found to be minimum due to the occurrence of precipitation.

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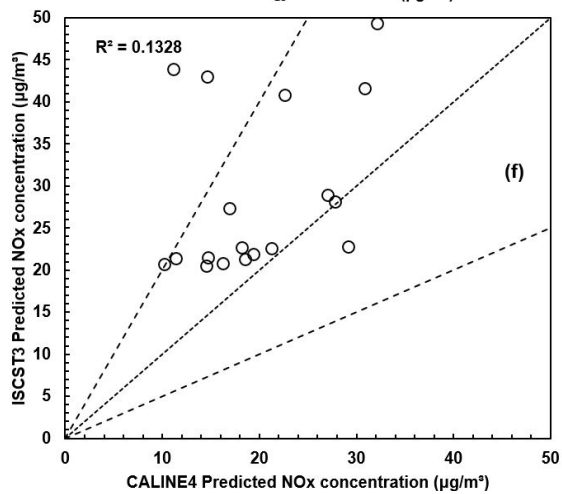
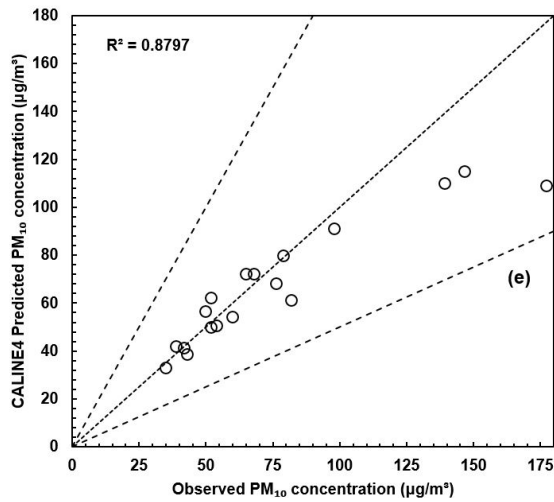
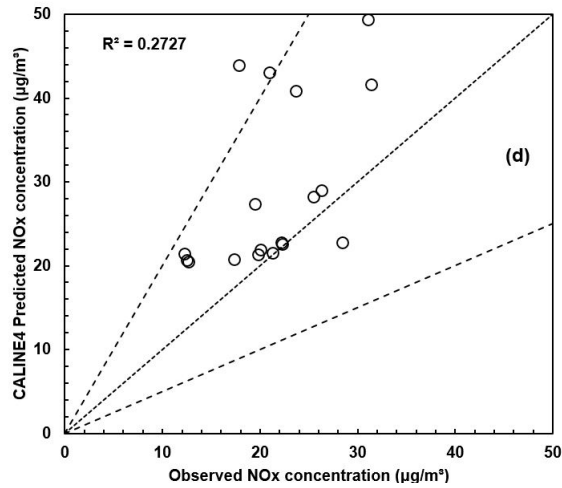


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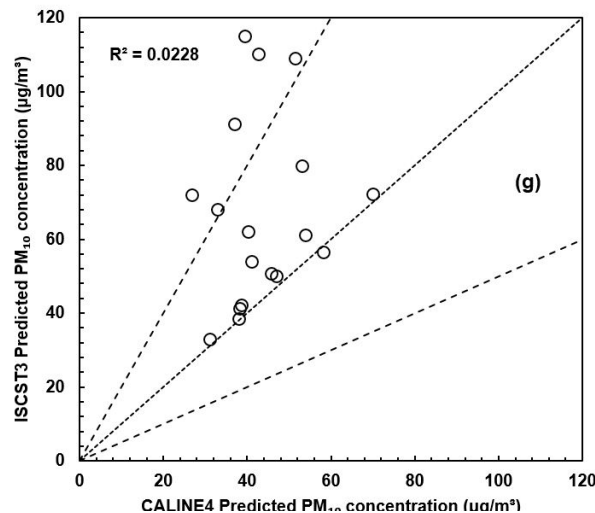


Fig. 10. Q-Q plots for (a) ISCAST3 prediction vs obs. NO<sub>x</sub> conc. (b) ISCAST3 prediction vs obs. SO<sub>2</sub> conc. (c) ISCAST3 prediction vs obs. PM<sub>10</sub> conc. (d) CALINE4 prediction vs obs. NO<sub>x</sub> conc. (e) CALINE4 prediction vs obs. PM<sub>10</sub> conc. (f) ISCAST3 vs CALINE4 predicted NO<sub>x</sub> conc. (g) ISCAST3 vs CALINE4 predicted PM<sub>10</sub> conc.

The dominant source of NO<sub>x</sub> and PM<sub>10</sub> at all receptor locations was found to be vehicular emissions. NO<sub>x</sub> and PM<sub>10</sub> were contributing ~86% and ~68% from line sources and ~14% and ~32% from point sources, respectively. However, SO<sub>2</sub> was contributing around ~67% from point sources and ~33% from line sources. The comparison between ambient air quality monitored values with ISCAST3 and CALINE4 model predicted values showed, ISCAST3 model prediction was in good agreement with observed NO<sub>x</sub> and SO<sub>2</sub> concentration and CALINE4 model prediction showed a good agreement with observed PM<sub>10</sub> concentration. Statistical analysis of ISCAST3 model for AB, FB, NMSE, RMSE and d values were found to be within the acceptable limits, indicating a good agreement with the observed pollutant concentrations. Further, Q-Q plot of CALINE4 prediction for PM<sub>10</sub> concentration showed a good correlation with the measured values.

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## REFERENCES

- [1] Abril, G.A., Wannaz, E.D., Mateos, A.C. and Pignata, M.L., "Bio-monitoring of airborne particulate matter emitted from a cement plant and comparison with dispersion modelling results", *Atmos Environ*, Vol. 82, pp. 154, 2014.
- [2] ARAI, "Draft Report on Emission Factor Development for Indian Vehicles, Report Submitted to CPCB/MOEF as a Part of Ambient Air Quality Monitoring and Emission Source Apportionment Study", Automotive Research Association of India, Pune, India, 2008.
- [3] Banerjee, T., Barman, S.C. and Srivastava, R.K., "Application of air pollution dispersion modeling for source-contribution assessment and model performance evaluation at integrated industrial estate – Pantnagar", *Environmental Pollution*, Vol. 159, pp. 865-875, 2011.
- [4] Benson, P.E., "Caline4: A Dispersion Model for Predicting Air Pollutant Concentrations near Roadways", California Department of Transportation, Sacra-mento, CA, USA, 1984.
- [5] Benson, P.E., "CALINE 4: A Dispersion Model for Predicting Air Pollutant Concentrations near Roadways", California Department of Transportation, Sacra-mento, CA, USA, 1989.
- [6] Benson, P.E., "A Review of the Development and Application of the CALINE3 and 4 Models", *Atmospheric Environment*, Vol. 26, pp. 379-390, 1992.
- [7] Bhanarkar, A.D., Goyal, S.K., Sivacoumar, R. and Rao, C.V.C., "Assessment of contribution of SO<sub>2</sub> and NO<sub>2</sub> from different sources in Jamshedpur region, India", *Atmospheric Environment*, Vol. 39, pp. 7745-7760, 2005.



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(A High Impact Factor & UGC Approved Journal)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 9, September 2017

- [8] BIS, "Methods for Measurement of Air Pollution: Part 2 Sulphur Dioxide, Cyclonic Flow Technique", Bureau of Indian Standard, New Delhi, 2001.
- [9] BIS, "Methods for Measurement of Air Pollution: Part 23 Respirable Suspended Particulate Matter (PM<sub>10</sub>), Cyclonic Flow Technique", Bureau of Indian Standard, New Delhi, 2006.
- [10] BIS, "Methods for Measurement of Air Pollution: Part 6 Oxides of Nitrogen, Cyclonic Flow Technique", Bureau of Indian Standard, New Delhi, 2006.
- [11] Chen, H., Bai, S., Eisinger, D., Niemeier, D. and Claggett, M., "Modeling Uncertainties and Near-Road PM<sub>2.5</sub>: A Comparison of CALINE4, CAL3QHC and AERMOD", Department of Civil and Environmental Engineering, University of California-Davis, Davis, CA, 2008.
- [12] de Gouw, J.A., Brock, C.A., Atlas, E.L., Bates, T.S., Fehsenfeld, F.C., Goldan, P.D., Holloway, J.S., Kuster, W.C., Lerner, B.M., Matthew, B.M., Middlebrook, A.M., Onasch, T.B., Peltier, R.E., Quinn, P.K., Senff, C.J., Stohl, A., Sullivan, A.P., Trainer, M., Warneke, C., Weber, R.J. and Williams, E.J., "Sources of particulate matter in the Northeastern United States in summer: 1. Direct emissions and secondary formation of organic matter in urban plumes", *Journal of Geophysical Research & Atmospheres*, Vol. 113, pp. 1-19, 2008.
- [13] Dhyani, R. and Sharma, N., "Sensitivity Analysis of CALINE4 Model under Mix Traffic Conditions", *Aerosol and Air Quality Research*, Vol. 17, pp. 314-329, 2017.
- [14] Dhyani, R., Sharma, N. and Maity, A.K., "Prediction of PM<sub>2.5</sub> along urban highway corridor under mixed traffic conditions using CALINE4 model", *Journal of Environmental Management*, Vol. 198, pp. 24-32, 2017.
- [15] Dhyani, R., Singh, A., Sharma, N. and Gulia, S., "Performance evaluation of CALINE 4 model in a hilly terrain – a case study of highway corridors in Himachal Pradesh (India)", *Int. J. Environment and Pollution*, Vol. 52, pp. 244-262, 2013.
- [16] Galatioto, F. and Zito, P., "Traffic Parameters Estimation to Predict Road Side Pollutant Concentrations using Neural Networks", *Environmental modeling & assessment*, Vol. 14, pp. 365-374, 2009.
- [17] Ganguly, R., Broderick, B.M. and O'Donoghue, R., "Assessment of a General Finite Line Source Model and CALINE4 for Vehicular Pollution Prediction in Ireland", *Environ Model Assess*, Vol. 14, pp. 113-125, 2009.
- [18] Gargava, P. and Aggarwal, A.L., "Emission inventory for an industrial area of India", *International Journal of Environmental Studies*, Vol. 55, pp. 299-304, 1999.
- [19] Gibson, M.D., Heal, M.R., Bache, D.H., Hursthouse, A.S., Beverland, I.J., Craig, S.E., Clark, C.F., Jackson, M.H., Guernsey, J.R. and Jones, C., "Using mass reconstruction along a four-site transect as a method to interpret PM<sub>10</sub> in West-Central Scotland, United Kingdom", *Journal of the Air & Waste Management Association*, Vol. 59, pp. 1429-1436, 2009a.
- [20] Gibson, M.D., Heal, M.R., Li, Z., Kuchta, J., King, G.H., Hayes, A. and Lambert, S., "The spatial and seasonal variation of nitrogen dioxide and sulfur dioxide in Cape Breton Highlands National Park, Canada and the association with lichen abundance", *Atmospheric Environment*, Vol. 64, pp. 303-311, 2013a.
- [21] Gibson, M.D., Kundu, S. and Satish, M., "Dispersion model evaluation of PM<sub>2.5</sub>, NO<sub>x</sub> and SO<sub>2</sub> from point and major line sources in Nova Scotia, Canada using AERMOD Gaussian plume air dispersion model", *Atmospheric Pollution Research*, Vol. 4, pp. 157-167, 2013b.
- [22] Goud, B.S., Savadatti, S. and Prathibha, D., "Application of CALINE4 Model to Predict PM<sub>2.5</sub> Concentration at Central Silk Board Traffic Intersection of Bangalore City", *International Journal of Civil Engineering and Technology (IJCIET)*, Vol. 6, pp. 191-200, 2015.
- [23] Goyal, S.K., Ghatge, S.V., Nema, P. and Tamhane, S.M., "Understanding urban vehicular pollution problem via-a-vis ambient air quality-case study of a megacity, Delhi, India", *Environmental Monitoring and Assessment*, Vol. 119, pp. 557-569, 2006.
- [24] Goyal, S.K. and Rao, C.V.C., "Assessment of atmospheric assimilation potential for industrial development in an urban environment: Kochi (India)", *Science of the Total Environment*, Vol. 376, pp. 27-39, 2007.
- [25] Gulia, S., Shrivastava, A., Nema, A.K. and Khare, M., "Assessment of Urban air quality around a heritage site using AERMOD: A case study of Amritsar city, India", *Environ Model Assess*, Vol. 6, pp. 599-608, 2015.
- [26] Harrison, R.M., Deacon, A.R., Jones, M.R. and Appleby, R.S., "Sources and processes affecting concentrations of PM<sub>10</sub> and PM<sub>2.5</sub> particulate matter in Birmingham (UK)", *Atmospheric Environment*, Vol. 1, pp. 4103-4117, 1997.
- [27] He, H.D. and Lu, W.Z., "Urban Aerosol Particulates on Hong Kong Roadside: Size Distribution and Concentration Levels with Time", *Stochastic Environmental Research and Risk Assessment*, Vol. 26, pp. 177-187, 2012.
- [28] Heist, D., Vlad, I., Perry, S., Snyder, M., Venkatram, A., Hood, C., Stocker, J., Carruthers, D., Arunachalam, S. and Chris, O.R., "Estimating near-road pollutant dispersion: A model inter-comparison", *Transportation Research*, Vol. 25, pp. 93-105, 2013.
- [29] Kansal, A., Khare, M. and Sharma, C.S., "Air quality modelling study to analyse the impact of the World Bank emission guidelines for thermal power plants in Delhi", *Atmospheric Pollution Research*, Vol. 2, pp. 99-105, 2011.
- [30] Khare, M., Nagendra, S. and Gulia, S., "Performance evaluation of air quality dispersion models at urban intersection of an Indian city: a case study of Delhi city", *WIT Transactions on Ecology and The Environment*, Vol. 157, pp. 249-259, 2012.
- [31] Krishna, R.T.V.B.P.S., Reddy, M.K., Reddy, R.C. and Singh, R.N., "Assimilative capacity and dispersion of pollutants due to industrial sources in Visakhapatnam bowl area", *Atmospheric Environment*, Vol. 38, pp. 6775-6787, 2004.
- [32] Kumar, A., Dixit, S., Varadarajan, C., Vijayan, A. and Masuraha, A., "Evaluation of the AERMOD dispersion model as a function of atmospheric stability for an urban area", *Environmental Progress*, Vol. 25, pp. 141-151, 2006.
- [33] La Spina, A., Burton, M. and Salerno, G.G., "Unravelling the processes controlling gas emissions from the central and northeast craters of Mt. Etna", *Journal of Volcanology and Geothermal Research*, Vol. 198, pp. 368-376, 2010.
- [34] Liu, X.Z. and Frey, H.C., "Modeling of in Vehicle Human Exposure to Ambient Fine Particulate Matter", *Atmos. Environ*, Vol. 45, pp. 4745-4752, 2011.
- [35] Manju, N., Balakrishnan, R. and Mani, N., "Assimilative capacity and pollutant dispersion studies for the industrial zone of Manali", *Atmospheric Environment*, Vol. 36, pp. 3461-3471, 2002.
- [36] Mazzeo, N.A. and Venegas, L.E., "Hourly NO<sub>x</sub> Concentrations and Wind Direction in the Vicinity of a Street Intersection", *International Journal of Environment and Pollution*, Vol. 48, pp. 96-104, 2012.
- [37] Prakash, B.M., Mahadevaswamy, M., Mahesh, S. and Sharadhini, S.R., "Air Quality Assessment along the Highway Due to Vehicular Emissions and Validation of Air Quality Monitored Data with the CALINE4 Model", *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 4, pp. 8369-8376, 2015.

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- [38] Prakash, B.M., Mahadevaswamy, M., Mahesh, S. and Vishala, N., "Prediction of Air Pollutants Dispersion Emitted from Point and Line Sources along the Highway Passing Through Industrial Area of Mysuru - AERMOD and CALINE4 Models", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, pp. 14497-14508, 2016.
- [39] Quinn, M.J., "Factors affecting blood lead concentration in the U.K. Results of the EEC blood lead surveys", Int. J. Epidemiol, Vol. 14, pp. 420-431, 1985.
- [40] Rashidi, A.M.S., Nassehi, V. and Wakeman, R.J., "Investigation of the efficiency of existing air pollution monitoring sites in the state of Kuwait", Environ Pollut, Vol. 138, pp. 219, 2005.
- [41] Seangkiatiyuth, K., Surapipith, V., Tantrakarnapa, K. and Lothongkum, A.W., "Application of the AERMOD modeling system for environmental impact assessment of NO<sub>2</sub> emissions from a cement complex", Journal of Environmental Sciences, Vol. 23, pp. 931-940, 2011.
- [42] Sharma, N. and Gangopadhyay, S., "Methodology for estimation of vehicular emission load along an urban corridor", Proceedings of National Conference on Sustainable Urban Transportation: Issues and Management Strategies, pp.78-84, 2007.
- [43] Sharma, N., Gulia, S., Dhyani, R., and Singh, A., "Performance evaluation of CALINE 4 dispersion model for an urban highway corridor in Delhi", Journal of Scientific and Industrial Research, Vol. 72, pp. 521-530, 2013.
- [44] Sivacoumar, R., "Vehicular pollution near highways in Chennai city", Indian Journal of Environmental Protection, Vol. 20, pp. 592-596, 2000.
- [45] Sivacoumar, R. and Thanasekaran, K., "Line source model for vehicular pollution prediction near roadways and model evaluation through statistical analysis", Environmental Pollution, Vol. 104, pp. 389-395, 1999.
- [46] Wang, D., Wang, Z. and Zhong, R.P., "Performance Evaluation of CAL3QHC and CALINE4 for Short-Term Simulation of Fine Particulate Matter and Carbon Monoxide Concentrations at a Road Intersection", Transportation Research Board, 2014.
- [47] Whiteside, L., "The 2004 year vehicle classification data at the I-75 PTR 9799", 2006.
- [48] Yura, E.A., Kear, T. and Niemeier, D., "Using CALINE Dispersion to Assess Vehicular PM<sub>2.5</sub> Emissions", Atmos. Environ, Vol. 41, pp. 8747-8757, 2007.
- [49] Zafar, S.I., "A Review of Transport and Urban Air Pollution in Pakistan", J. Appl. Sci. Environ. Manage, Vol. 11, pp. 113-121, 2007.
- [50] Zito, P., Chen, H.B. and Bell, M.C., "Predicting Real-time Roadside CO and NO<sub>2</sub> Concentrations using Neural Networks", IEEE Transactions on Intelligent Transportation Systems, Vol. 9, pp. 514-522, 2008.