Air Quality Prediction Modeling for Badarpur to NHPC Chowk Faridabad, Delhi-NCR, India using Caline 4

Pintu Kumar[1], Syed Khursheed Ahmad[2], Saurabh Kumar Garg[3], Shivani[3]

[1]M.Tech. Student
[2]Professor and HoD
[3]M.Tech. Student
[1-3]Dept. of Civil Engineering, Al-Falah University, Dhauj, Faridabad

---***---

Abstract - *The primary cause of urban air pollution is traffic emissions. While new technologies to control the level of pollution are being implemented, the number of vehicles without changing road conditions is rising, especially on congested urban roads, causing high-level emissions in the vicinity of roadways. The dispersion modelling exercise will provide optimal orientation of the intersection to minimise the trapping of contaminants, which can be applied at the planning stage, taking into account the gravity of the situation. The goal of this research is to conduct a dispersion modelling study with the CALINE 4 model to determine the levels of air pollution from road transport sources and to predict the distance & dispersion pattern and their impacts. For the present study, Badarpur to NHPC Chowk Faridabad was selected as the study location. The amount of traffic in this road consists of vehicles, two wheelers, three wheelers, Car, MAV, LCV and buses. Cars make up roughly 46 percent and motorized two wheelers makes 41 percent of the total traffic on the study road. The minimum percentage of MAV due to no entry of MAV vehicle in Delhi due to no entry hours. By using the emission factors and corresponding deterioration factors, the weighted emission factor was determined. Micro-meteorology data was collected from wunderground website at Indira Gandhi International Airport Station Delhi. These meteorological data as needed for model application of Caline 4. The study and monitoring of Particulate Matter 10 (PM_{10}), Sulphur Di-oxide (SO_2), Nitrogen dioxides (NO_2) and Carbon Monoxide (CO) was carried out at three (3) monitoring stations located very close to the study road.*

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

1. INTRODUCTION

Growing demand of transport due to economic growth has caused a boom in Delhi (Capital City of India) in the number and use of motor vehicles. In urban environments, pollutants such as respirable particulate matter (RPM), especially $PM_{2.5}$, nitrogen dioxide (NO_2), carbon monoxide (CO) and hydrocarbons (HC), are directly emitted by vehicles. Urban inhabitants are the most affected group, especially the population residing in the vicinity of urban roads as well as pedestrians. On urban roadways, where ventilation is inadequate, the situation continues to deteriorate.

The CPCB has estimated that the share of automotive emissions in air pollution of Delhi has risen to 72 percent over the years.

The primary source of urban air pollution is traffic emissions. While new technologies to control the level of pollution are being implemented, the number of vehicles without changing road conditions, especially on congested urban roads is causing high-level emissions in the vicinity of roadways. The dispersion modelling exercise will provide optimal orientation of the intersection to minimise the trapping of contaminants, which can be applied at the planning stage, taking into account the gravity of the situation. In the context of the location of the study, the scope of the present study is to carry out air dispersion modelling with the Caline 4 model.

Analysis of the viability and applicability of the dispersion model has always been a matter of high interest among scientists. Many scholars around the world have performed numerous studies on the viability of a specific model of dispersion. Some of the studies went one step forward and developed their own mathematical models for pollutant dispersion assessment. Karim and Matsui (1998) and Karim et al, in a report. (1998) developed a computer model to classify street canyons and vehicle wake effects on the transport of air pollution from urban roads to their micro environments consisting of wind distributions, emission dispersion and modified Gaussian equation. (1998) developed a computer model to classify street canyons and vehicle wake effects on the transport of air pollution from urban roads to their micro environments consisting of wind distributions, emission dispersion and modified Gaussian equation.

In his research, Baijayanta Kumar Majumdar (2009) presents that CALINE 4 offers many advantages over other models and is chosen as the basis model for the creation of a modified line source model for an area. Niraj Sharma (2013) conducted the performance assessment research of the CALINE 4 model to predict concentrations of carbon monoxide (CO) along an urban highway corridor passing through Together with Rajni Dhyani (2013), carbon monoxide (CO) concentrations along an urban highway corridor passing through the city of Delhi also compared CALINE 4 model predictions between flat and hilly terrain along two Solan District road corridors in the state of Himachal Pradesh (India). Studies show that the Caline 4 model remains unanswerable for complex terrain algorithms such as a hilly stretch, and the concentration is also expected by the model.

In this study, Chadetrik Rout (2015) found that the predicted results of Caline 4 are satisfactorily in agreement with the monitored value.

2. MATERIALS AND METHOD

For the current report, Badarpur to NHPC Chowk Faridabad was selected as the research location. The road receives traffic from Prahladpur, Meethapur (Delhi), Gurukul basti, Sarai road, Sector-37, and NHPC Sectror-33 (Faridabad). The present road is configured for 6 lanes and provided for signal-free traffic by flyover & service lane. The Land use of the study road is surrounded by mix of shopping complex, restaurants, petrol pumps and Multiplex. The study location's average elevation is 210 m above MSL.

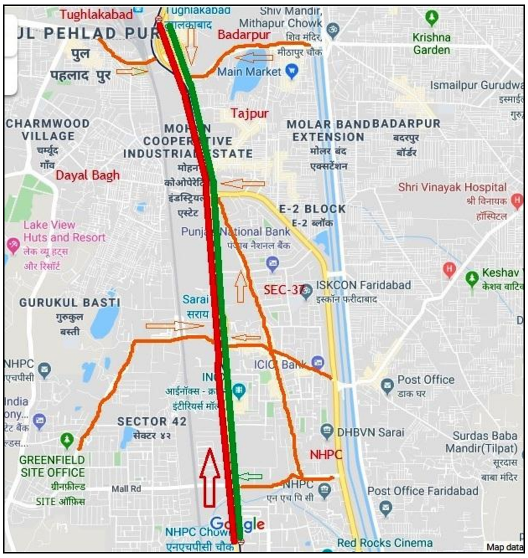
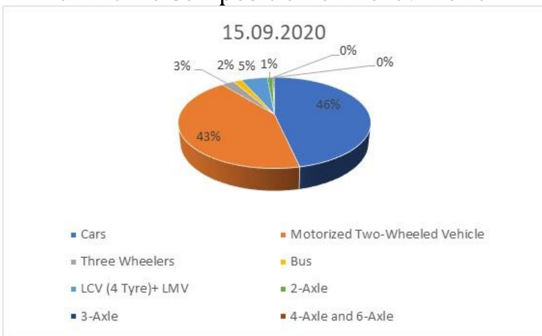


Fig -1: Description of Study Area

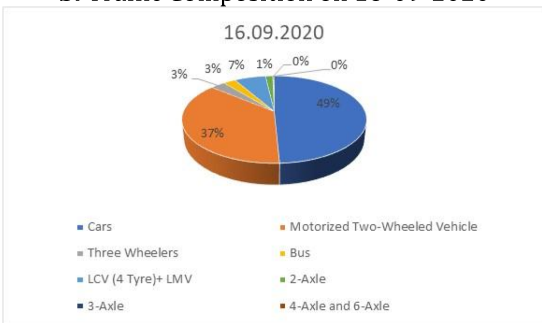
The monitoring and analysis of Particulate Matter 10 (PM_{10}), Sulphur Di-oxide (SO_2), Nitrogen Oxides (NO_X) and Carbon Monoxide (CO) was carried out at three (3) monitoring stations located very close to the study road. 8 hourly monitoring, covering the time from 9 am to 5 pm, was carried out. Starting from Tuesday, i.e. 15-09-2020 to Saturday, i.e. 19-09-2020, air quality monitoring was carried out continuously for 5 days.

The amount of traffic in this road consists of vehicles, two wheelers, three wheelers, Car, MAV, LCV and buses. Cars make up roughly 46 percent and motorized two wheelers makes 41 percent of the total traffic on the study road. The minimum percentage of MAV due to no entry of commercial vehicle *(except taxi)* in Delhi due to no entry hours. Traffic Nos. were found from Badarpur to NHPC Chowk and NHPC Chowk to Badarpur respectively, ranging from 14304 to 24915 and 13497 to 23957. The composition of traffic volume across different days during the monitoring period is presented in figure below.

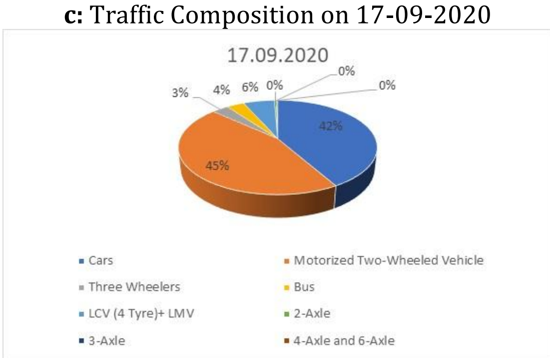
a: Traffic Composition on 15-09-2020



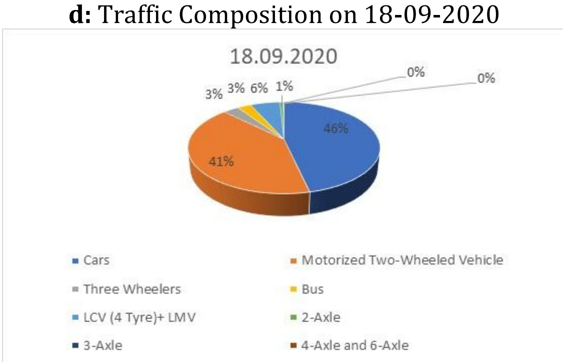
b: Traffic Composition on 16-09-2020



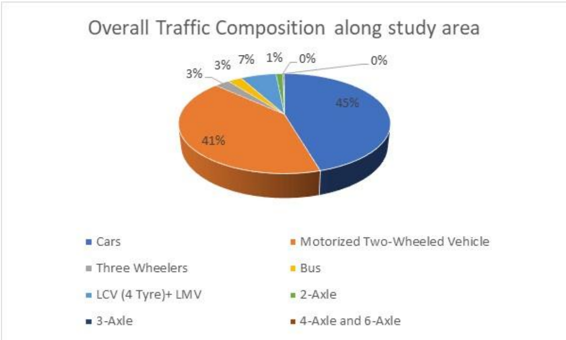
c: Traffic Composition on 17-09-2020



d: Traffic Composition on 18-09-2020



e: Traffic Composition on 19-09-2020



f: Overall Traffic Composition

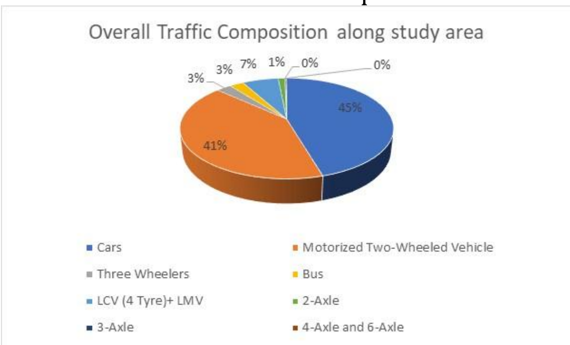
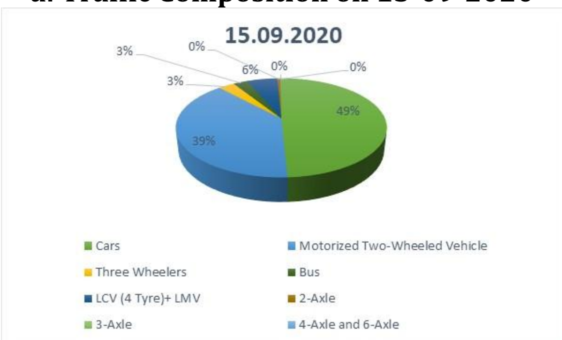
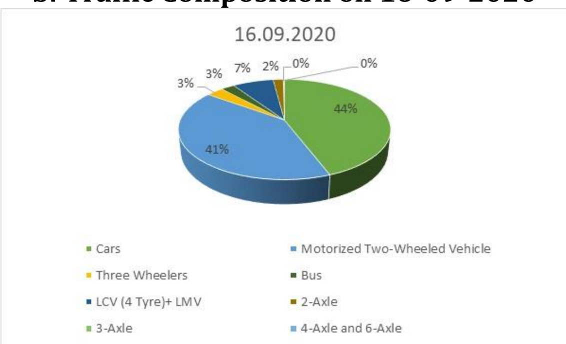


Chart - 1: Traffic Composition Badarpur To NHPC Chowk

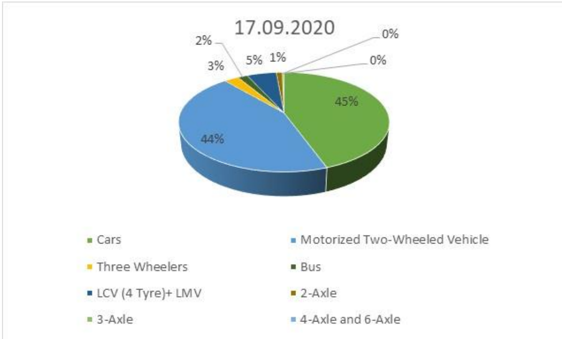
a: Traffic Composition on 15-09-2020



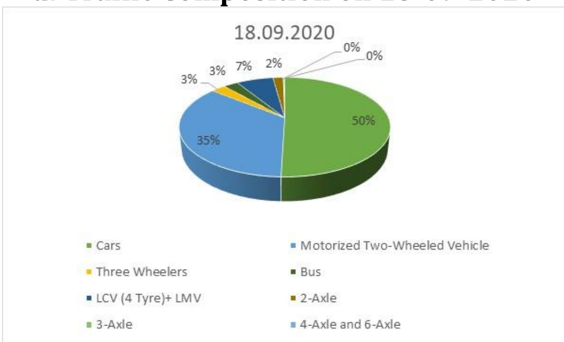
b: Traffic Composition on 16-09-2020



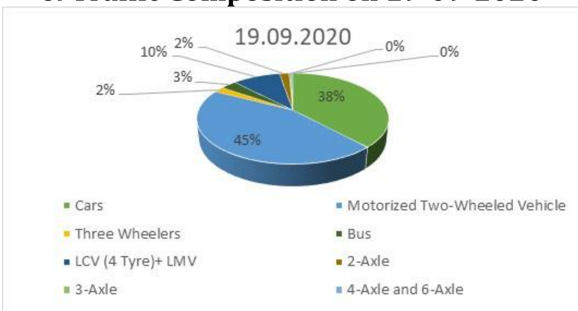
c: Traffic Composition on 17-09-2020



d: Traffic Composition on 18-09-2020



e: Traffic Composition on 19-09-2020



f: Overall Traffic Composition

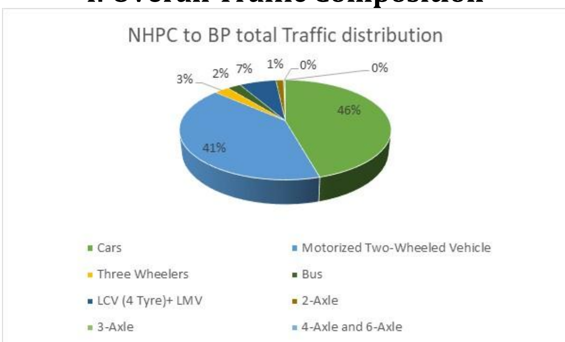


Chart - 2: Traffic Composition NHPC Chowk to Badarpur

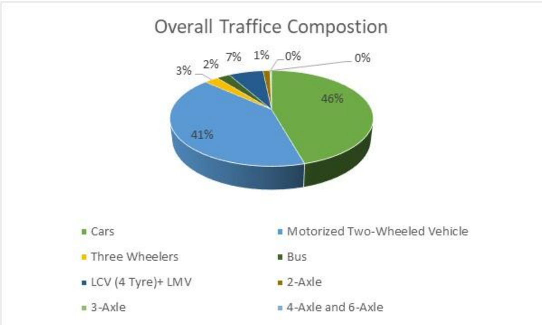


Chart - 3: Overall Traffic Composition in Study Road

Using the emission factors and corresponding deterioration factors, the weighted emission factor was calculated. The weighted emission factor of the specified pollutant (gm / km / vehicles), i.e. EW can be calculated as the cumulative amount of the vehicle product Nos. in the particular age group, pollutant deterioration factor and emission factor divided by the total number of vehicles registered. Varying from 2.27 to 2.41 gm / mile / vehicle, the weighted emission factor was found. Micro-meteorology data as needed for Caline 4 model application including hourly wind speed, direction, ambient temperature, etc. were collected from the Indira Gandhi International Airport Station website of wunderweather. Mixing height was extracted from the Atlas of Hourly Mixing Height and Assimilative Capacity of Atmosphere in India published by India Meteorological Dept. for post-monsoon season Around India.

3. RESULTS AND DISCUSSION

Considering the Covid 19 pandemic scenario, the limited commercial activities are supporting the satisfactory level of ambient air pollutant.

The concentration of Particulate matter 10 was found varying from 74 to 92 µg/m3 in respect to the prescribed National Ambient Air Quality Standards of 100 µg/m3 for residential areas. The concentration of SO2 and NO2 were found varying from 5.2 to 8.2 µg/m3 and 16.9 to 24.3 µg/m3 respectively in respect to residential NAAQS limit of 80 µg/m3. The spatial distribution of Carbon Monoxide was found varying from 0.42 to 0.76 mg/m3 in respect to 8 hourly NAAQS of 2 mg/m3. The spatial and temporal variation of the Ambient Air Quality Parameters are presented in Figures below.

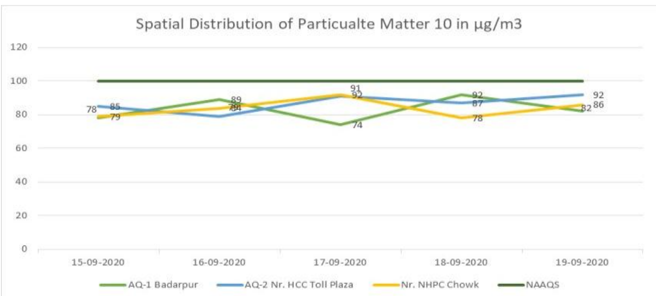


Chart - 4: Temporal and Spatial Distribution of Particulate Matter 10 in $\mu g/m^3$

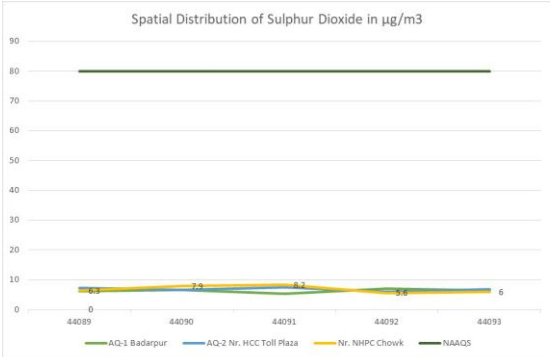


Chart - 5: Temporal and Spatial Distribution of Sulphur Dioxide in $\mu g/m^3$

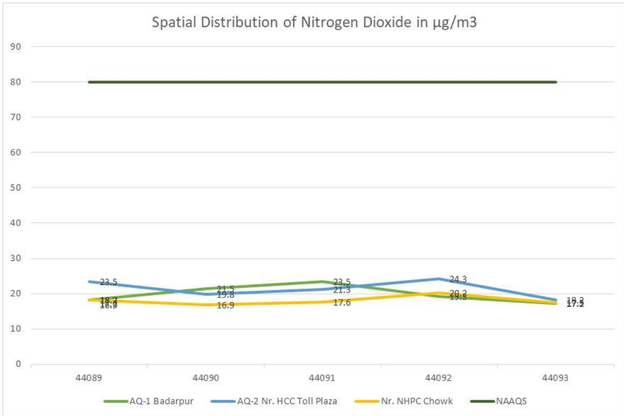


Chart - 6: Temporal and Spatial Distribution of Nitrogen Dioxide in $\mu g/m^3$

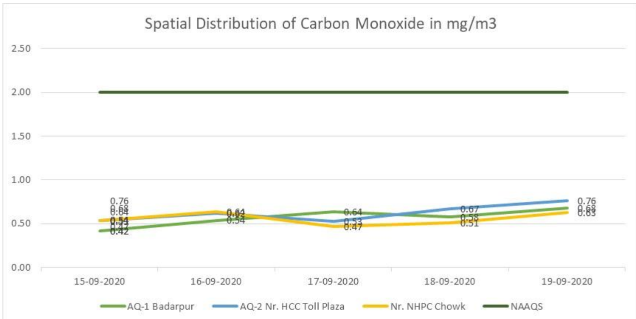


Chart - 7: Temporal and Spatial Distribution of Carbon Monoxide in mg/m^3

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

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

4. CONCLUSIONS

Predicted results have clear indication that the CO concentration varies significantly with downwind distance from the running traffic and atmospheric conditions. The predicted results were found varying from 0.06 mg/m^3 to 0.15 mg/m^3 across the receptors. The variation in the predicted concentration is observed due to traffic scenario, distance of the receptors from the traffic point, width of mixing zone and most importantly the meteorological scenario. Calm weather condition supports the least dispersion, which results in higher concentration near to roadways. Scenario was observed in the modeling study undertaken for Saturday i.e. 19th September, 2020. On this day traffic was the least in number, however, calm condition didn't support dispersion of the pollutant. Therefore, highest ever predicted concentration were observed on this day.

The spatial distribution of Carbon Monoxide was found varying from 0.42 to 0.76 mg/m^3 in comparison to the predicted concentration of 0.06 to 0.15 mg/m^3. The monitoring results were slightly higher than the modelled value. Higher values of the monitoring can be concluded as due to long term deposition of the Carbon Monoxide in the atmosphere and horizontal movement of the gaseous pollutant from the nearby emitters like DG set, Parking areas, commercial activities, etc. as Caline 4 model capability is limited for assessment of traffic generated emission only.

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

REFERENCES

[1] Humaib Nasir, Kirti Goyal and Dolonchapa Prabhakar (2016), 'Review of Air Quality Monitoring: Case Study of India'.

[2] C. P. Kaushik, Ravindra Khaiwal, Krishan Yadav, Surender Mehta and A. K. Haritash (2006), 'Assessment of Ambient Air Quality in Urban Centres of Haryana (India) in Relation to Different Anthropogenic Activities and Health Risks'.

[3] Lakshmi Rajagopalan and Sarah Lamothe (2015), 'Urban Air Pollution Data in India: Gaps Between Regulations and Reality'

[4] Pallavi Pant & Raj M. Lal & Sarath K. Guttikunda & Armistead G. Russe & Ajay S. Nagpure & Anu Ramaswami & Richard E. Peltier (2018), 'Monitoring particulate matter in India: recent trends and future outlook'

[5] Umesh Chandra and Kamal Jain (2013), 'Web Based Ambient Air Quality Monitoring System for Delhi'.

[6] Laura E. Venegas and Nicolás A. Mazzeo (2013), 'A Method for Selection of Background Air Quality Monitoring Sites in an Urban Area'

[7] R. Angle Consulting (2014), 'Ambient Air Quality Objectives'

[8] Xingzhe Xie, Ivana Semanjski, Sidharta Gautama, Evaggelia Tsiligianni, Nikos Deligiannis, Raj Thilak Rajan, Frank Pasveer and Wilfried Philips (2017), 'A Review of Urban Air Pollution Monitoring and Exposure Assessment Methods'

[9] Mogesh Naidoo and Mark Zunckel (2018), 'Overview of ambient air quality monitoring in South Africa'

[10] Sadheesh Sellamuthu (2018), 'Assessment of Ambient Air Quality Monitoring and Modelling in Coimbatore City'

[11] Baijayanta Kumar Majumdar, Amit Dutta, Shibnath Chakraborty and Subhabrata Ray (2009), 'Assessment of vehicular pollution in Kolkata, India, using CALINE 4 model'

[12] Niraj Sharma, Sunil Gulia, Rajni Dhyani and Anil Singh (2013), 'Performance evaluation of CALINE 4 dispersion model for an urban highway corridor in Delhi'

[13] Niraj Sharma, Sunil Gulia, Rajni Dhyani and Anil Singh (2013), 'Performance evaluation of CALINE 4 model in a hilly terrain – a case study of highway corridors in Himachal Pradesh (India)'

[14] Rout Chadetrik, Gulia Sunil and Saini Mukesh (2015), 'Air Quality Prediction along a Highway Corridor under Mixed Traffic Condition'

[15] Md M Karim, Hiroshi Matsui and Randall Guensler (1998), 'A mathematical model of wind flow, vehicle wake, and pollutant concentration in urban road microenvironments. Part II: Model results'

[16] Validation of air pollution dispersion modeling for the road transport sector under Irish conditions (2000-LS-6.3-M1)

[17] Performance evaluation of air quality dispersion models at urban intersection of an Indian city: A case study of Delhi city

[18] Mayer, H., Air pollution in cities. Atmospheric Environment (1999), pp. 4029- 4037

[19] Sharma, N., Chaudhry, K.K. and Rao, C.V.C., Vehicular pollution modeling in India. Journal of the Institution of Engineers (India), (2005), pp. 46-63

[20] Badami, M. G., Urban transport policy as if people and the environment mattered: Pedestrian accessibility the first step. Economic & Political Weekly, EPW Vol. XLIV (33), 2009

[21] CPCB, Status of vehicular pollution control program in India, Program Objective Series/PROBES/136/2010

BIOGRAPHIES

Pintu Kumar has 12+ years of progressive experience in the field of Environment, Risk/Hazard and Social Impact Assessment (ESIA) Studies, formulation of Environment & Social Management and Monitoring Plan / Framework (ESMMP / ESMF), Environment and Social Audit & Due diligence (ESDD), Preparation of Environment and Social Action Plan (ESAP), Air Dispersion Modeling, Risk Assessment Modeling, Noise Modeling, carrying capacity assessment, preparation of Forest Diversion Proposals, Wildlife Clearance / NoC Proposal, etc.