Impact assessment on air quality due to widening of a highway by using CALINE software

U. S. Kulkarni & H. A. Keshwani
Fine Envirotech Engineers, Mumbai, India

Abstract

A complete assessment of the impacts caused due to widening of a National Highway on the air, water and soil environment in the nearest vicinity and 10 kms study area has been carried out and results presented. The Pune–Solapur National Highway-9 from km 144.00 to km 249.00 chainage has to be widened from existing 2 lane carriageway to 4/6 lane carriageway. The said project has been accorded Environmental Clearance from the Ministry of Environment and Forests (MoEF), Govt. of India, in the month of September 2011. The baseline study of the site comprising ambient air, noise, surface/ ground water, soil, land-use, ecological biodiversity and socio-economic factors of the area in 10 kms from the proposed widening site was carried out. Since the proposed project is a highway project, major air pollutants from the widening shall be vehicular exhaust emission from the increased traffic. This being a line source can be predicted through CALINE software. Study of ambient level of existing carbon monoxide (CO) concentration has been carried out in the EIA report. Predicted increased levels of air pollutant CO for worst-case scenario was projected based on the existing baseline data. The input parameters required for the CALINE software such as, traffic volume, meteorological parameters (wind speed, wind direction, stability class, mixing height), emission parameters, road geometry, terrain type, background pollutant concentration and receptor location are incorporated after carrying out site-specific study. The maximum concentration of Carbon Monoxide (CO) was found to be in the southwest direction of the proposed development. This ground level concentration of CO is very meagre and even after summing up with the existing ambient air level shall cause very negligible impact on the existing ambient air of the study area as assessed from the software results. Moreover, it is planned that vehicles plying in the area shall

WIT Transactions on Ecology and The Environment, Vol 157, © 2012 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/AIR120051

be fitted with the EURO engines complying with the emission standards of India so as to reduce emissions during operational phase of the highway after widening. The detailed impact assessment as well as mitigation measures and the environmental management plan for the proposed project have been prepared.

Keywords: NHAI, vehicular emission, CALINE 4 software, AAQM, traffic density, receptors, line source model, impact assessment, results & discussion.

1 Introduction

National Highway Authority of India (NHAI) under National Highway Development Project (NHDP) Phase III has proposed to develop 4/6 laning of Pune to Solapur section of NH-9 from km. 144.00 to km 249.00 in the state of Maharashtra. The stretch of the 2 lane highway starting at 144.400 km at Bhima River ends at 249.00 km at Solapur. The existing length is 104.600 km. There is one congested area where bypass/ realignments have been proposed. Realignment is proposed on left side near Solapur at km 241+300 to km 249+000 chainages. The environmental clearance of the said project has been availed from the Ministry of Environment and Forests (MoEF), Govt. of India in the month of September 2011.

The project extends from latitude 18°18'N to 17°18'N and longitude 73°33'E to 76°30'E. At an altitude of 500.4m to 642.4m above mean sea level.

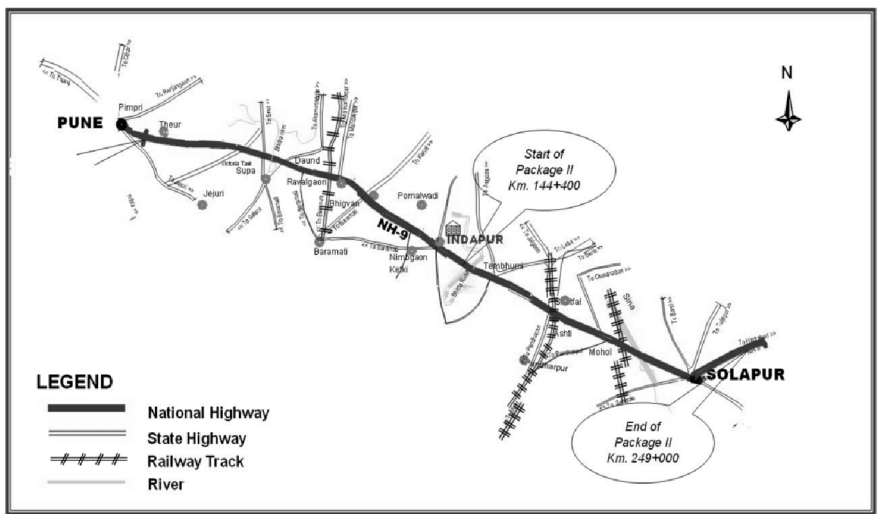

Figure 1: Project location map.

2 Description of the project

The proposed project shall require additional 270 Ha of Land for the widening. The raw materials for the same shall be acquired from three aggregate quarries,

11 borrow areas and single sand quarry. The total water requirement of the proposed project comes to 987 m^3/day. The total cost of the project comes to 835 Crores INR (4175 Million USD.)

2.1 Existing traffic scenario [1]

The daily average traffic of the existing highway has been depicted in table 1. It was found that approximately 7678 number of average daily vehicles ply at chainage 170+ 700, 7357 number of average daily vehicles at ply at chainage 201 + 000 and 10600 number of average daily vehicles ply at chainage 234 + 10600 as per the traffic analysis report for the said project. The traffic load on the highway is projected to reach around 10386 Passenger Car per Unit (PCU) in 2009, 11450 PCU by 2011 and 12022 PCU by 2012.

Table 1: Existing traffic scenario on highway.

Section	Average Daily Traffic (ADT) for year 2005 (Vehicles/Day)
Ch.170+700	7678
Ch.201+000	7357
Ch.234+200	10600

3 Baseline environmental status

The existing baseline environmental status of the area was studies to carry out the impact assessment of the proposed widening. The study was carried out at 9 villages in the area of 10 kms around the project site in order to establish baseline environmental data [2].The various locations selected are given Table 2 and the parameters studied during environmental survey at these locations are indicated in Table 3.

Table 2: Environmental study area.

Sr. No.	Study Location	Distance from Highway
1.	Tembhurni	0.2 km
2.	Shetfal	0.12 km
3.	Mohol	0.15 km
4.	Modnimb	0.1 km
5.	Kaegaon	5.56 km
6.	Solapur	0.4 km

Table 3: Parameters studied.

Sr. No	Parameters	
1.	Air	PM_{10}, $PM_{2.5}$, SO_X, NO_X, CO
2.	Water	pH, DO, PO4 NO3 & heavy metals etc.
3.	Noise	Noise Levels

3.1 Wind

Onsite Meteorological data for the proposed project was carried out and Wind rose diagram for the same was obtained.

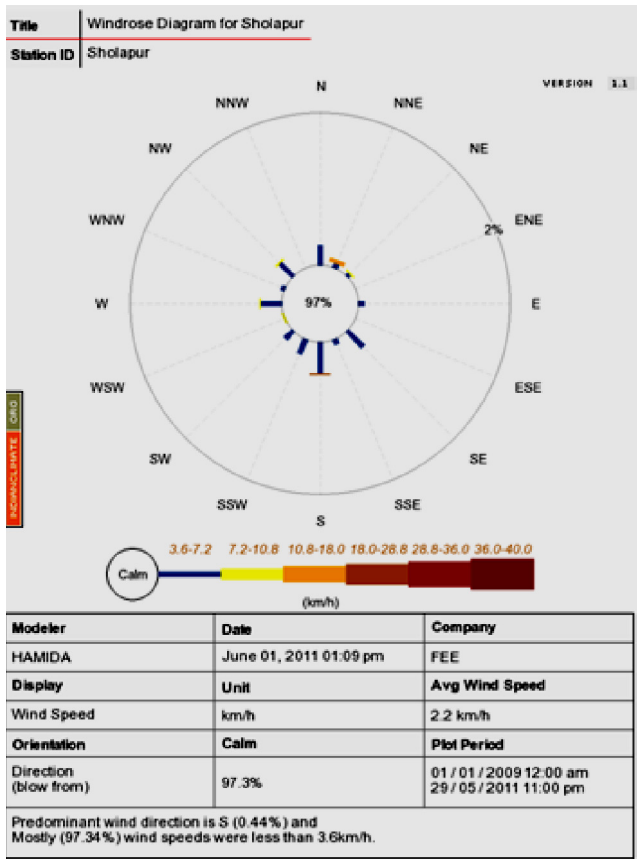

Figure 2: Wind rose diagram of Solapur [3].

3.2 Air quality

As a part of the environmental impact analysis (EIA) studies air quality was monitored at all the 5 villages coming along the national highway to be widened. The proposed national highway crosses many villages. The impact on air quality due to the proposed development of the highway shall affect these nearby villages the most and thus they are selected for the Baseline data. The baseline ambient air quality data of the region has been monitored during the period of March 2011-May 2011 [2].

3.2.1 Selection of monitoring stations [2]

The stations selected for air monitoring are villages that are in the vicinity or intersecting the highway depending upon the prominent wind direction and receptor sensitivity.

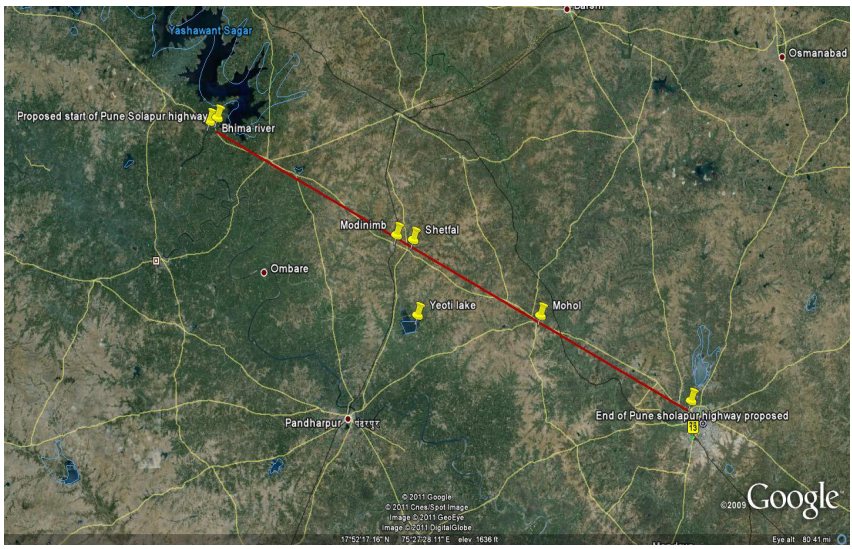

Figure 3: Google image showing sampling location in the study area.

3.2.2 Monitoring methodology

Monitoring of ambient air quality was carried out as per Central Pollution Control Board (CPCB) guidelines. The analysis of various air parameters were carried out using Indian Standards. The methods used for analysis as stipulated by CPCB are presented in table 4 and results in table 5. As per the observations PM_{10} is found to be slightly high but within the normal permissible standards at Solapur, Kaegaon and Tembhurni whereas other parameters such as $PM_{2.5}$, SO_2, and NO_X were found to be within the permissible limits at all the locations of monitoring within the stretch of the highway. Here μm refers to microns and mg/m^3 refers to microgram per cubic meter.

Table 4: Ambient Air Quality Monitoring Standards [4].

Pollutant	Time Weighted Average	Concentration in Ambient Air		Methods as per Indian Standards (IS)
		Industrial, Residential, Rural and other areas	Ecologically Sensitive areas notified by Central Government	
Sulphur Dioxide (SO_2) ($\mu g/m^3$)	Annual Average* 24 hours**	50 80	20 80	IS 5182 Part II.
Oxides of Nitrogen (NOx) ($\mu g/m^3$)	Annual Average* 24 hours**	40 80	30 80	IS 5182 Part VI.
Particulate Matter (Size less than 10μm) or PM_{10} $\mu g/m^3$)	Annual Average* 24 hours**	60 100	60 100	IS 5182 (Part- 23)
Particulate Matter (Size less than 2.5μm) or $PM_{2.5}$ $\mu g/m^3$	Annual Average* 24 hours**	40 60	40 60	Gravimetric Method
Carbon Monoxide (CO) mg/m^3	8 hours** 1 hour**	02 04	02 04	IS 5182 Part10.

**Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform levels.*
***24 hourly or 08 hourly or 01 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.*

Table 5: Ambient air quality monitoring data.

Location ID	Locations	Parameters (24 hourly values)				(8 hour values)
		PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_X ($\mu g/m^3$)	CO ($\mu g/m^3$)
1	Tembhurni	47.2–56.4	14.6–17.32	5.57–6.98	7.56–10.72	0.4
2	Shetfal	39.7–45.5	11.4–13	4.88–5.35	7.21–10.42	0.3
3	Mohol	50.4–51.2	17.8–22.1	6.12–5.98	8.44–11.24	0.5
4	Modnimb	48–53.2	15.5–20.2	6.61–7.91	7.73–11.89	0.41
5	Kegaon	51.2–57.1	19.23–25.4	5.1–6.11	8.45–12.17	0.2
6	Solapur	55.4–59.1	22.1–28.7	6.49–7.45	9.07–13.69	0.7
7	Permissible Limits	100	60	80	80	2

4 Prediction of impacts

Prediction of impacts on air environment for the proposed project has been carried out using a line source model CALINE 4. Since the proposed project is of highway widening, the existing highway traffic has been calculated and the proposed traffic has been projected for year 2012 at various junctions of the said highway. The impacts during various phases of the proposed project on the air environment are given below.

4.1 Preconstruction phase

Pre-construction phase activities such as site clearance, tree cutting, movement of worker and materials, construction work, construction of haul roads for movement of aggregates and filling materials shall generate negligible amount of dust. Thus particulate matter shall be the predominant pollutant during this phase. Water sprinkling and covering of transportation trucks are the appropriate mitigation measures that will be employed during this stage to reduce the pollution level to acceptable limit.

4.2 Construction phase

The important activities during the construction phase that may affect the air quality are identified as heating and mixing of aggregate with bitumen in asphalt mix plant resulting in the emission of gaseous pollutants like SO_2, NO_X, CO and CO_2, material storage, transportation and handling of construction materials such as sand, fly ash, (if used), earth from borrow pits, aggregates from stone quarries and stone crushing operations resulting in the increase of SPM values, construction and other allied activities, operation of concrete batching plants etc resulting in emission of gaseous pollutants and particulate matter.

4.3 Operational phase

During operational stage air pollution generation from vehicular movements on highway are primarily confined to emissions from diesel-powered heavy vehicles and volatile organic carbon emission from vehicular tyres. Besides this there will be gaseous emissions such as CO_2, HC (Hydrocarbon), NO_X and CO from the vehicles plying on the road. PM emissions due to dust flying on the road as well as small amount from the vehicular emission will also impact the air quality of the area. Air quality modelling for CO and NO_x was done to access the impacts arising from gaseous emissions on surrounding environment. The PM predication cannot be carried out since the software does not support the prediction of particulate matter as a whole, moreover emission co-efficient for the particulate matter of different sizes has not been devised. The said prediction was done using CAlifornia LINE Source Dispersion Model (CALINE4) [5].

5 CAlifornia LINE source dispersion model (CALINE4) modelling

CL4 is a graphical windows-based user interface, designed to ease data entry and increase the on-line help capabilities of CALINE-4 [5]. The CL4 setup program is self-contained, so the user only needs to complete a single installation step. The original CALINE4 executable files are copied to the CL4 program directory.

5.1 Input requirement

The highway dispersion model requires the following data as input - traffic parameters such as traffic volume (hourly and peak)**,** meteorological parameters: (wind speed, wind direction, stability class, mixing height), emission parameters (expressed in grams/distance travelled), road geometry (road width, median width, and length), type of terrain (urban or rural, flat or hilly)**,** background concentration of pollutants and receptor location.

5.2 Emission factor

The emission factor used in this study is given in table below.

Table 6: Emission factors for criteria pollutant [6].

S. No	Pollutant	Emission factor (g/km/PCU)
1.	CO	13.00
2.	NOx	2.00

5.3 Traffic density

A detailed study of the traffic density along the project road as well as the predicted traffic scenario till year 2012. Maximum hourly PCU for the years is projected in Table 7.

Table 7: Projected Traffic (PCU).

Year	2009	2011	2012
Package-II	10386	11450	12022

The project Traffic for year 2012 has been considered for impact prediction.

5.4 Meteorological data

For this study, worst-case meteorological input of low wind speed (2 m/s), ambient temperature 35^0C and stability class F was considered.

5.5 Receptors

A total of 3 receptors near the said highway were selected for prediction of ground level concentrations due to the existing and proposed traffic on the project road.

5.6 Results and discussion

The increase in traffic due to the proposed project shall directly impact vehicular emission pollutants such as CO, NO_x (Oxides of Nitrogen), PM_{10}, HC and SO_2. The predicted maximum ground level concentration (GLC) for CO and NO_2 (Oxides of Nitrogen in terms of Nitrogen Dioxide) was derived with help of CALINE-4 software. The prediction for CO was conducted for 8-hourly concentration (conc.) and for NO_2 was conducted for 24-hourly concentration. The output result of the software is given below. A graphical representation of the same has been depicted in figure.4. As per the graph in figure 4, it has been observed that there will be slight increase in CO levels after the said project, due to the increase in vehicular traffic of the highway. NO_2 does not have significant environmental baseline concentration in terms of $\mu g/m^3$ (microgram per cubic meter) which comes to a very negligible value when converted to ppm (parts per million). The input unit for Caline Software being in ppm, the 0.007 ppm value of NO_2 gets nullified and simulation indicates extremely low values that cannot be effectively predicted. Hence, the predicted NO_2 concentration shows no prominent increase after the proposed project thus the impact is negligible.

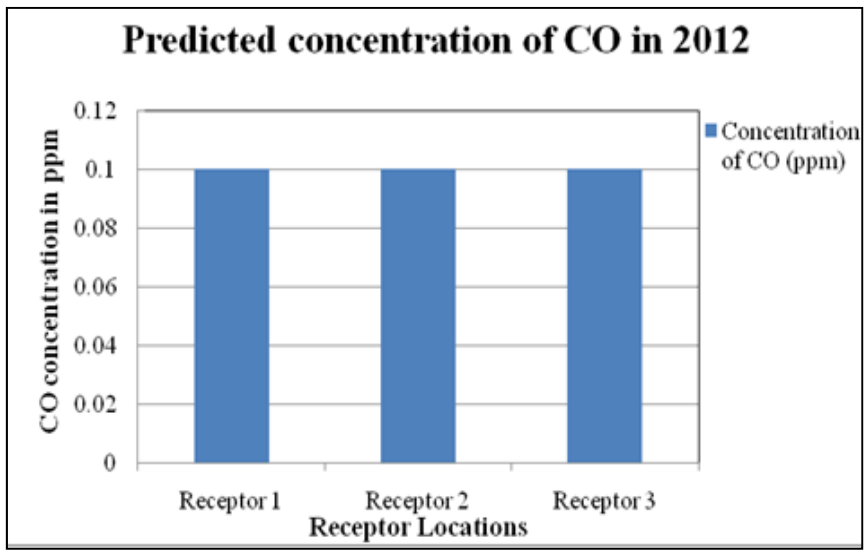

Figure 4: Prediction of CO concentration in worst case scenario for the year 2012.

Particulate Matter being the major pollutant amongst them, it is important to address predicted PM_{10} concentration from the said project, however the Emission factor for PM_{10} is not available (Total Suspended particle emission factor is available), moreover the conversion of PM_{10} from $\mu g/m^3$ to ppm is not possible since we cannot obtain Molecular weight of particulate matter as a whole. Thus prediction of concentration for Particulate Matter cannot be addressed through Caline Software. It is envisaged that the other pollutants such as HC, SO_2 will also show some increase in concentration after the said project, however it will be very negligible and adhere to the standard limits. Adequate preventive measures have to be planned to counter this aspect. The provision of greenbelt around the roads as well as on the road median shall result in a localized cushioning of air pollution. This would also help in curbing the ill effects of CO emission.

Table 8: Model output results.

Sr. No	Receptor	Degrees	Predicted conc. of CO		Predicted conc. of NOx	Conc./Link (ppm)		
			(ppm)	(mg/m^3)	(ppm)	A	B	C
1.	Receptor 1	114	0.1	0.114	0	0.0	0.0	0.0
2.	Receptor 2	114	0.1	0.114	0	0.0	0.0	0.0
3.	Receptor 3	145	0.1	0.114	0	0.0	0.0	0.0

6 Observation

The baseline concentration for Carbon Monoxide (CO), Oxides of Nitrogen as Nitrogen dioxide (NO_2) have been monitored, the predicted concentration of CO and NO_2 for the worst case scenario due to the proposed widening project have been derived to be 0.1ppm (0.114 $\mu g/m^3$) for CO and 0ppm for NO_2. The negligible value of NO_2 simulation can be credited to the non-significant value of baseline NO_2 concentration which further decreases when converted into ppm making it difficult to be predicted through the Caline software. As discussed earlier the PM_{10} simulation cannot be carried out since its emission co-efficient does not exist. The total maximum concentration in ambient air for CO for the proposed 4/6 laning of existing 2-Lane highway stretch from Bhima river to Solapur of NH-9 that has been predicted is given in table 9. The results show that the predicted concentration of the proposed area shall conform to the standard

limits as per National Ambient Air Quality Standards (NAAQS) by Ministry of Environment and Forests (MoEF), Govt. of India.

Table 9: Maximum ambient air concentration of Carbon Monoxide (CO) predicted to increase after the proposed project.

Location	Baseline Concentration in Ambient Air	Maximum predicted GLC (ground level concentration)		Maximum Concentration in Ambient Air After starting of the proposed project	Permissible Limits [1]
	(µg /m3)	8 hr Worst Case Concentration		(mg / m^3)	(µg / m^3)
	[A]	(mg /m^3)	Direction	[A+B]	
		[B]	(°)		
Tembhurni	0.4	0.114	114	0.5	2
Shetfal	0.3	0.114	114	0.4	2
Mohol	0.5	0.114	114	0.6	2
Modnimb	0.41	0.114	114	0.51	2
Kegaon	0.2	0.114	114	0.3	2
Solapur	0.7	0.114	114	0.8	2

7 Conclusion

It may be noted that the concentration of Carbon Monoxide (CO) as predicted through CALINE software in worst case scenario is the maximum predicted value for the proposed development. The actual values shall not exceed this limit. However the predicted maximum ambient air concentration of CO value after the proposed project shall conform the standard permissible limits of National Ambient Air Quality Standards (NAAQS), dated 18th November, 2009 [1]. Therefore, it can be concluded that the said section of NH-9 shall have no major impact on air pollution as predicted from above modeling studies. The said case was presented at the Ministry of Environment and Forests (MoEF), Govt. of India on 22nd September, 2011 and received Environmental Clearance from the Expert Appraisal Committee.

References

[1] Pre-feasibility report for "widening of Pune-Solapur National Highway under NHDP Phase-III.
[2] As per EIA Notification under Environmental Protection Rules, 1986 published under ministry of Environment and Forests (MoEF), dated 14th September, 2006 and amended on 16th November, 2009.
[3] Software WRPlot View from Lakes Environment at http://www.weblakes.com/.
[4] Schedule VII, Rule 3(3b) "National Ambient Air Quality Standards" in Ministry of Environment and Forest's (MoEF) Notification under Gazette of India at New Dehli on 16th November, 2009.

[5] CAlifornia LINE Source Dispersion Model (CALINE4) by the California Department of Transportation (Caltrans).
[6] Gurjar *et al* (2004). "Emission estimates and trends (1990-2000) for megacity Dehli and implications". Atmospheric Environment, 38, pp. 5663-5681.