Using ISCST3 and the Line Source Approach to Model the Air Quality Impacts associated with Pollutants emitted from Mobile Sources of Diesel Transportation for Barbosa Lima Sobrinho Thermal Power Plant.

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Luciana N. Loureiro
Andréa Moreira
Ana Regina Rosa
Paulo César de C. Barbosa
PETROBRAS - CENPES/PDEDS/AMA
Ilha do Fundão – Rio de Janeiro, RJ.
lloureiro@petrobras.com.br

Eduardo Sabóia
PETROBRAS / UTE Barbosa Lima Sobrinho.
Rod. Presidente Dutra km 200 – Seropédica RJ.

Silvio de Oliveira
SECA – Sistema de Estudos Climáticos e Ambientais Ltda
Av. Brig. Faria Lima 1478 cj. 910 – São Paulo, SP.
seca@seca-ambiental.com.br

ABSTRACT

The present paper summarizes an atmospheric dispersion modeling study applied in the highways used by HDV (heavy duty vehicles) in the transportation of diesel oil from Duque de Caxias Distribution Terminal (TEDUC) to Barbosa Lima Sobrinho (BLS) Thermal Power Plant. As requested by the local state environmental agency, some modeling scenarios were built in order to assess the air quality impact associated with HDV traffic enhancement (estimated to be about 24 vehicles per hour in the two directions) in the arteries connecting Terminal and Thermal Plant. The approach used was the line source type, targeting the description of the sources of interest involved, which were Washington Luiz Road, Brazil Avenue and Presidente Dutra Road. These have been segmented in sections to assure that the emissions of pollutants are from line sources. The meteorological data, emission inventory of pollutants and others variables related with line source modeling were used on air quality simulations for the pollutants: NO_X, CO, TPS, SO_2 and THC (total hydrocarbons), using the ISCST3 (Industrial Source Complex Short Term – version 3). Basically, three scenarios (Increment, Background and Background plus Increment) were built. The pollutants from mobile sources are emitted near the ground into an area with very low-level mechanical turbulence due to vehicle motion. In the simulation worst meteorological conditions were taken into consideration for dispersion purposes, thus conducting to the highest possible concentrations, which only occur in critical situations. In the final of study, highest concentrations simulated in the model were then compared with the current Brazilian Air Quality Standards, showing that the additional impact in the background air quality in the model domain was minimum.

INTRODUCTION

The environmental agencies generally request Air Quality Impact Assessments to issue permits for implementation and upgrades or processes modifications of industrial plants. The Barbosa Lima Sobrinho (BLS) Thermal Power Plant in Seropedica, Rio de Janeiro, was originally conceived and licensed to burn natural gas exclusively, but due to recent market constraints it was retrofitted to allow the use of diesel oil. Considering the particular occasions when diesel is burnt instead of gas, the power plant will be supplied by tank trucks. Having this scenario in mind the local state environmental agency requested an air quality impact study, associated with HDV traffic enhancement (estimated to be about 24 vehicles per hour considering both directions) in the highways used in the diesel oil transport from Duque de Caxias Distribution Terminal (TEDUC) to Barbosa Lima Sobrinho (BLS) Thermal Power Plant. USEPA ISCST3 model (Industrial Source Complex Short Term – version 3 - 1995) is accepted by environmental agencies world wide as to estimate environmental concentration of pollutants, in a plume released by emissions sources. Considering the sources located in specified coordinates (x, y, z), this model evaluates the incremental contribution of sources in terms of pollutants concentrations distributions in the model domain, considering local topography, meteorological conditions for defined periods of time. The approach used was the line source type, targeting the description of the highways involved, which were Washington Luiz Road, Brazil Avenue and President Dutra Road.

The highways were segmented in sections and treated as line sources. Three Scenarios were modeled: Background (considering the local current fleet), Increment (covering exclusively tank trucks used to transport diesel oil from TEDUC to BLS Thermal Power Plant) and Background plus Increment (the local current fleet plus the additional tank trucks used in the previous scenario). Pollutants emission rates (in g/s) were calculated as the product of the number of HDV (tank trucks) per hour running in each highways section times the distance (km) times the specific emission factor for Rio de Janeiro Metropolitan Area (RJMA) (g/km). The emission factors used in the current were retrieved from Table 2.

THE MODEL

The line source approach was used following the Guidance Integrated Urban Air Toxics Strategy (USEPA, 1999) in order to study the atmospheric dispersion of pollutants from mobile sources (vehicles) along Washington Luis Road, Brazil Avenue and President Dutra Road, thus enabling the calculations of concentrations distributions in the area of interest due to mobile sources on traffic roads. The mixing turbulent height close to surface is a direct function of the local traffic, which causes the mechanical plus thermal movement of the air parcels next to the road and the instantaneous turbulent dispersion of pollutants emitted by vehicle tail pipe at the ground level along the road. The figure 1 shows this process.

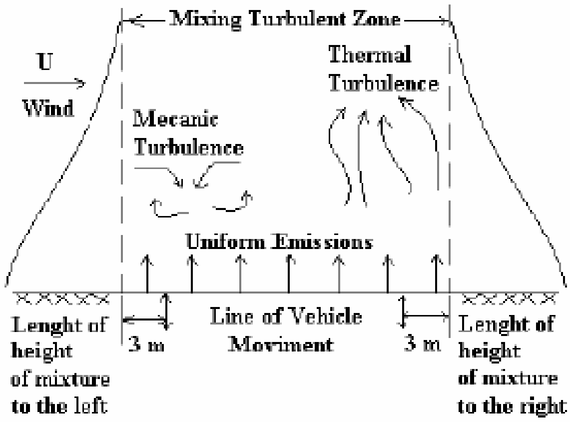

Figure 1 – Illustration of the road cross section and the mixing turbulent effects in vehicle emissions at ground level for line source approach.

The model input data are length, width of traffic road and emission height. In order to simulate a linear source, the ISCST3 User's Guide recommends using several volume sources equally distributed in space along the roadway length. The spacing between individual sources should be equal to the width of the roadway, or as an acceptable approximation, twice the width of the roadway. To estimate a number of N emission volumes (length of line source divided by width) over the line source the model uses sequential computational algorithm that divide extension of traffic road per width according to figure 2.

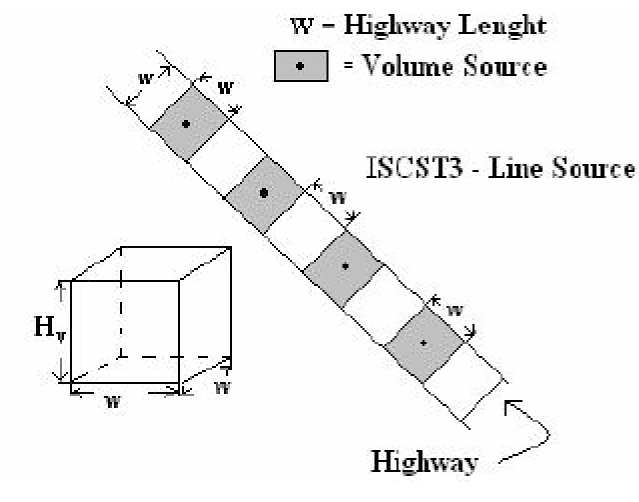

Figure 2 – Distribution of Volume Sources along the line source to simulate the pollutant dispersion

METHODOLOGY

To assess the impact of diesel transportation the approach adopted was to combine well known atmospheric dispersion methodologies together with a customized emissions inventory. The following information was input to the model:

- Topographic profile
- Local meteorology
- Vehicle emissions in different scenarios
- Road physical characteristic
- Hourly profile of traffic distribution on the highways
- Vehicle Emissions factors (customized for RJMA)

AREA OF STUDY

Trajectory

The average distance run by the tank trucks supplying diesel to BLS Thermal Power Plant covers Grids I and III, is showing in Figure 3.

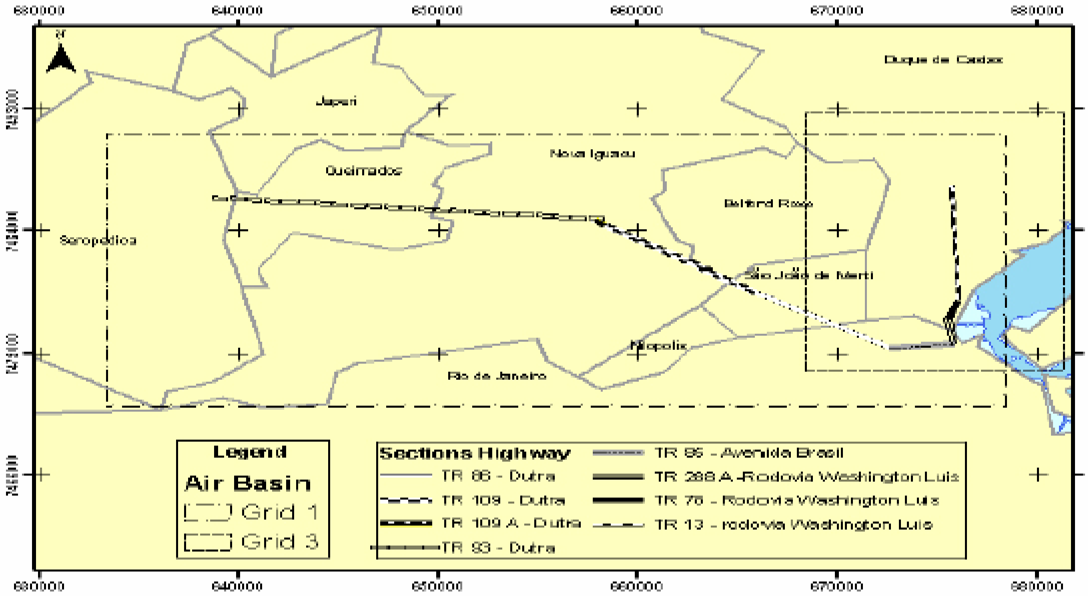

Figure 3 – Tank trucks Trajectory.

Terrain irregularities were identified and plotted on two grids covered by the trucks trajectory, which was split into eight sections due to the need to picture the differences between the roads being modeled, such as lengh, width and traffic flow. The topography was incorporated using digital information with the specific coordinates (UTM) of each road section, both for Grid I and III, as shown in Figures 4 and 5.

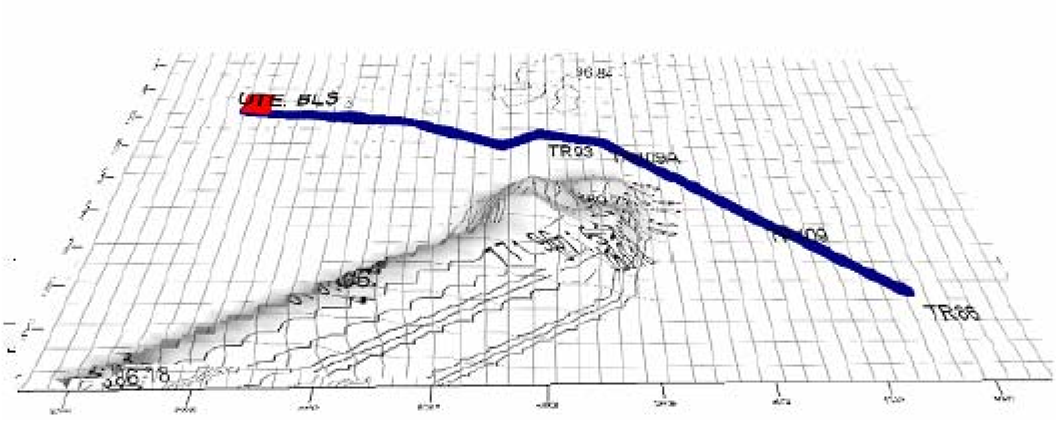

Figure 4 – Grid I Topography for the 45 Km X 20 km area.

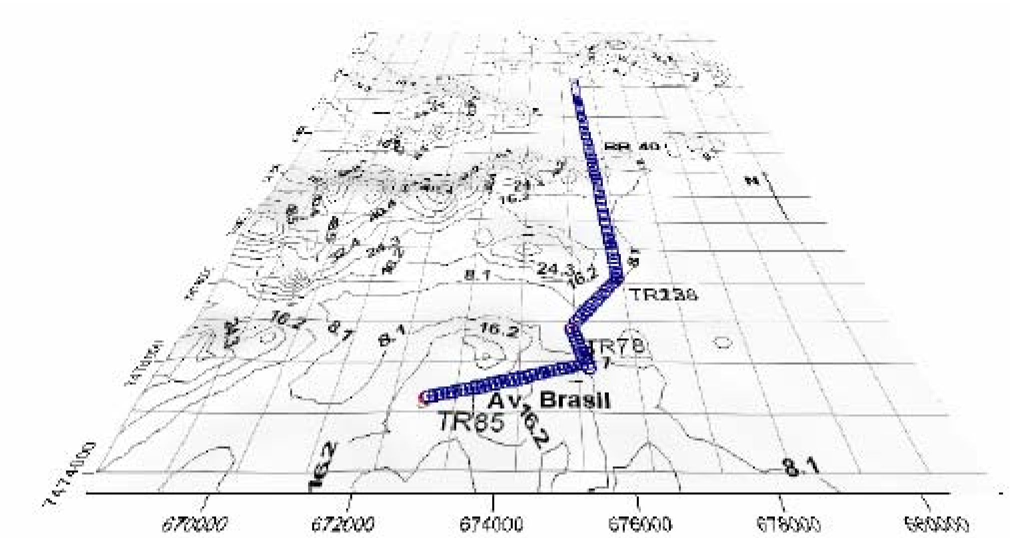

Figure 5 – Grid III Topography for 13 Km X 19 km area

In each grid the nominal road widths and the average emission source height (or the distance from the ground) were used to calculate the initial plume vertical dimension (óy), described in equation 1.

$ó_y$ = *(average height of emission up to ground) / 2.15* (Equation 1)

Meteorological Data

Simulations were performed in two different grids in order to assimilate the automatic measurements of two microclimate monitoring stations located in the vicinities of TEDUC (Police station) and the BLS Thermal Power Plant station. The wind roses generated are illustrated in Figures 6 and 7.

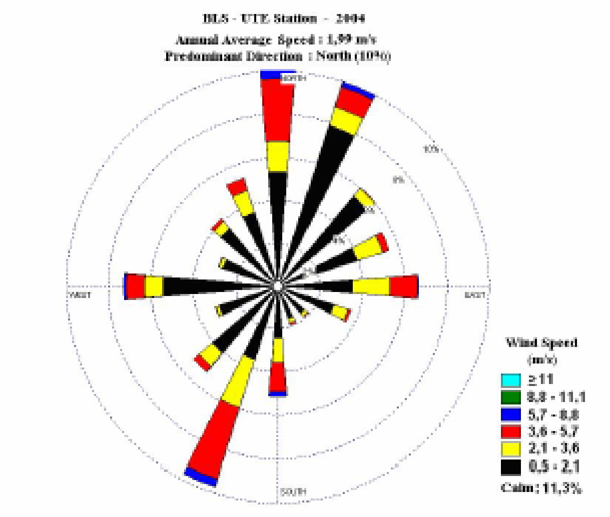

Figure 6 – Wind Rose from BLS- Thermal Power Plant meteorological station.

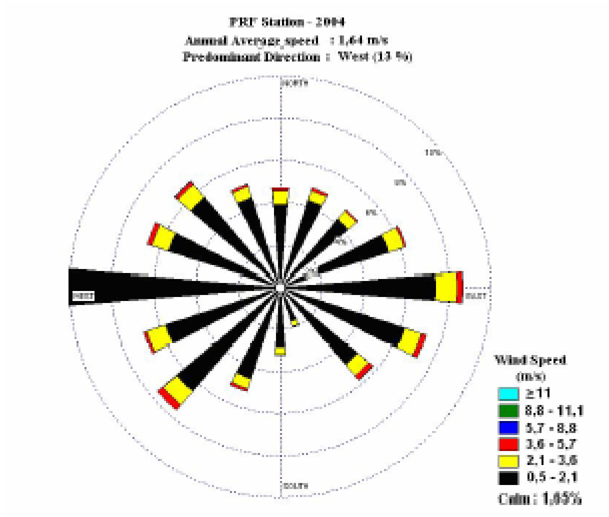

Figure 6 – Wind Rose from BLS- Thermal Power Plant meteorological station.

STUDIED SCENARIOS

In order to assess the impact of diesel transportation, three scenarios were built:

- Background Scenario - considering only the current local vehicle emissions in the highways of interest;
- Increment Scenario - considering only tank trucks emissions;
- Combined Scenario - considering the Increment + Background Scenarios

INPUT DATA

Pollutant emissions for each highway section were calculated considering number of lines, width of lines, section extention and the official vehicle counting stratified by vehicle type(light and heavy duty). Additionaly the vehicles were classified by fuel type gasohol (misture of automotive gasoline and ethanol 25%w) for LDV fleet and diesel for HDV fleet. Table 1 summarizes the main characteristics of the sections being modeled.

Table 1: Characterization of sections.

Grid	Section of Highway	Distance (m)	Number of roadways	Width (m)	Area (m^2)	Start of section		End of section	
						Coordinate X	Coordinate Y	Coordinate X	Coordinate Y
I	TR 86 – Dutra Road	16873	4	12	202473	672536	7475482	665891	7479567
	TR 109 – Dutra Road	3537	4	12	42444	665891	7479567	658375	7484372
	TR 109 A – Dutra Road	1942	4	12	23300	658375	7484372	657927	7484762
	TR 93 – Dutra Road	24041	4	12	288498	654927	7484762	638296	7486354
III	TR 85 – Brasil Avenue	2603	14	42	109322	672536	7475482	675823	7475695
	TR 228 A – Washington Luis Road	1449	4	12	17389	675823	7475695	675486	7477586
	TR 78 – Washington Luis Road	985	14	42	41388	675486	7477586	676020	7478966
	TR 13 – Washington Luis Road	9497	4	12	113969	676020	7478966	675647	7487288

Local Current Fleet

Data covering current fleet information were retrieved from the official mobile source inventory of environmental agency of Rio de Janeiro (FEEMA).

Average Number of vehicles by hour

The loading tank trucks terminal, TEDUC, operates 5 days per week (Monday to Friday) for 24 hours; the preferential schedule for trucks´ loading is 4:00 pm to 2:00 am. So, total preferential period for the trucks loading is 10 hours. Equation 2 shows the calculation of the average number of vehicles running per hour in each traffic roads direction.

$$V = C/K \quad \text{(Equation 2)}$$

Where:

V (k) = average volume per day, in function of K
C= Total consumption of diesel oil for thermal power plant operation (m^3/day)
K= Number of weekdays available for tank truck loading (considering a week of 7 days).

So,

V = 2500/ (5/7) = 3500 m^3 /day (loading in 5 days of week)

Nv = V / (Cap X p) (Equation 3)

Where:

Nv= average number of tank truck per hour
V (k) = average volume per day
Cap = Capacity of each tank truck (m_3)
p= total available hours per day for loading tank trucks

Nv = 3500/(30X 10) = 11,667 vehicles/h ~ 12 vehicles/h (24 vehicles/h considering departue and return).

The final number of vehicles was rounded up to 12 in each direction and added up to the current local fleet, considering the hours of tank truck loading (between 4:00 pm - 2:00 a.m.).
24 vehicles per hour were used to calculate the emission rates in the Increment Scenario. For Background Scenario, the local current fleet data was supplied by FEEMA. In the Combined Scenario the emission rate were calculated per highway sections, after the addition of the 12 diesel tank trucks to local current fleet in each dierection, for the times slot of 4:00 pm - 2:00 a.m. (preferencial period).

Emissions Vehicles Rate for each sections

Vehicle emission rates were calculated for each pollutant p resorting to Equation 4.

Ep= N X d X Fp **(**Equation 4)

Where:

Ep →Average emission mass for defined time period (g/period)
N → Number of vehicles that transit in the section for a certain period of time (1/period)
d → average running distance per vehicle (km)
Fp→Average emission factor from fleet to each pollutant (g/km) (see **Table 2**)

Table 2: Emissions factors adopted

Emission Sources	Pollutant / Fuel	CO (g/km)	HC (g/km)	NOx (g/km)	SOx (g/km)	TPS (g/km)
Flushing Pipe	Gasoline	14,00	2,40	0,85	0,20	0,08
	Ethanol	18,60	2,00	1,40	-	-
	Diesel Oil	17,80	2,90	13,00	1,13	0,81
Carter and Evaporative Emission	Gasoline	-	2,10	-	-	-
	Ethanol	-	1,60			
Tire	All	-	-	-	-	0,07

Source: Adapted by DETRAN & FEEMA, 2001

Proporcionality Factor

ISCST3 can discretize the emissions of each pollutant per hour. In this study it was done by means of proportionality factors applied on a reference emission (the peak traffic or maximum emission level) thus generating an hourly emission profile. The maximum hourly emissions were calculated for each pollutant and for each section of the highways. The hourly proportionality factors were estimated based upon fleet size and vehicle type considerations.

RESULTS

Atmospheric dispersion of NO_X, CO, MP, SO_2 and THC was calculated using the Gaussian model ISCST3,in order to assess the air quality impact associated with HDV traffic enhancement in the highways used for the transportation of diesel. The modeling philosophy was to consider the worst meteorological conditions possible thus enabling the construction of sufficiently robust outputs and maximum concentration forcasts. Spatial distribution of the modeled concentrations was performed for each grid and each scenario using ISCST3 default visualizer. The estimated concentrations were compared with the respective air quality standards. Tables 3, 4 and 5 summarize ISCST3 main results.

Table 4 - First maximum concentrations for Grids I and III on increment scenario.

	Grid I (1st maximum) - incremental scenario						Grid III (1st maximum) - incremental scenario					
Pollutants	CO (µg/m³)	HC (µg/m³)	TPS (µg/m³)	NO_x (µg/m³)	NO_2* (µg/m³)	SO_2 (µg/m³)	CO (µg/m³)	HC (µg/m³)	TPS (µg/m³)	NO_x* (µg/m³)	NO_2 (µg/m³)	SO_2 (µg/m³)
1h	73,7			53,8	19,9		16,1			12,4	4,6	
8h	51,8						12,7					
3h		10,5						2,5				
24h			1,0			1,1			0,3			0,3
Annual			0,3	3,7	1,4	0,3			0,1	0,8	0,3	0,1

Table 5 - First maximum concentrations for Grid I on background scenario and background + increment scenario.

	Grid I (1st maximum) -background scenario						Grid I (1st maximum) - background + incremental scenario					
Pollutants	CO (µg/m³)	HC (µg/m³)	TPS (µg/m³)	NO_x (µg/m³)	NO_x* (µg/m³)	SO_2 (µg/m³)	CO (µg/m³)	HC (µg/m³)	TPS (µg/m³)	NO_x* (µg/m³)	NO_2 (µg/m³)	SO_2 (µg/m³)
1h	2003,9			802,3	296,9		2029,6			852,5	315,4	
8h	1145,8						1200,5					
3h		356,8						367,7				
24h			18,1			24,0			19,6			25,1
Annual				76,7	28,4	7,4			6,1	80,3	29,7	7,8

Table 6 - First maximum of concentrations for Grid III on background scenario and background + incremental scenario.

	Grid III (1st maximum) -background scenario						Grid III (1st maximum) - background + incremental scenario					
Pollutants	CO (µg/m³)	HC (µg/m³)	TPS (µg/m³)	NO_x (µg/m³)	NO_x* (µg/m³)	SO_2 (µg/m³)	CO (µg/m³)	HC (µg/m³)	TPS (µg/m³)	NO_x* (µg/m³)	NO_2 (µg/m³)	SO_2 (µg/m³)
1h	4635,7			954,7	353,2		4635,7			965,8	357,3	
8h	2622,7						2632,7					
3h		1148,5						1157,4				
24h			30,6			38,5			30,9			38,9
Annual			5,9	74,4	27,5	7,5			5,9	75,1	27,8	7,6

CONCLUSION

The Gaussian model ISCST3 was used to study the atmospheric dispersion of mobile sources along Washington Luis Road, Brazil Avenue and President Dutra Road applying line source approach in highways used for diesel transportation. The main conclusion are summarized as follows:

- Different wind patterns in Grids I and III affect pollutant dispersion in the local atmospheres.
- In Grid I wind flows from west (W) to east (E), with speed between 0,5 and 3,6 m/s.
- In Grid III the prevaling wind direction is from southwestern south (SSO) to Northeast north (NNE) with speeds between 0,5 and 5,7 m/s. Therefore, Grid I is less favorable to atmospheric dispersion than Grid III.

- Ambient concentration levels measured automatically at the surface air quality stations located at BLS and TEDUC shown that on average for the current scenario maximum pollution levels
- are below the respective air quality standards, as regulated by CONAMA Resolution No 03/1990
- Considering the Increment Scenario the simulations shown that the contribution of diesel truck emissions are negligible; for the worst case the modeled concentration levels are one order of magnitude smaller than the current air quality standards for all the pollutants studied.

- Therefore the use of tank trucks for the transportation of diesel to BLS Thermal Plant does not contribute to significant pollution levels and has no associated impacts in the local atmosphere, as compared to the current air quality standards, based upon the physical dispersion studies.

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KEY WORDS

Atmospheric Dispersion Model, Vehicles, Mobile sources, Highways, line source type, Background, emission rates, Carbon Monoxide (CO), Nitrogen Oxides (NOx), Sulfur Dioxide (SO_2), Total Suspended Particles (TPS) and Total Hydrocarbons (THC).