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Air Dispersion Modeling Using AERMOD Software

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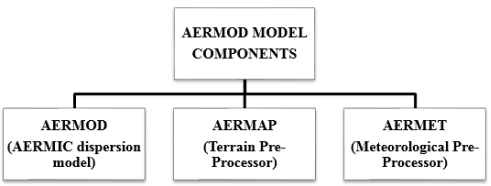
Abstract
Air pollution poses a significant threat to human health, environment and the quality of life of people throughout the world. Increasing industrialization and population, cause emission of Carbon Monoxide (CO), Sulphur dioxide (SO_2), oxides of Nitrogen (NO_x), Suspended Particulate Matter(PM_{10}, $PM_{2.5}$, $PM_{1.0}$), Hydrogen Sulphide(H_2S), Methane, Hydrocarbons(HC). The transport sector is the principal source of local air pollution in urban areas, because of the increased vehicular population, Vehicle Kilometers Travelled (VKT) and lack of infrastructure development. This paper deals with the assessment of the hourly and 24 hourly ground level concentration of PM_{10}, CO for line sources for winter season. An atmospheric dispersion model AERMOD 9.0.0 was used. In present study, meteorological data used are actual, however source data such as traffic volume count, etc. are assumed with some hypothesis to simulate the actual condition but the actual monitoring has not been carried out. The model outputs were compared with NAAQS, 2009 norms which shows that the study area fall under safe zone.
Keywords: Air Dispersion Modeling, Vehicular Pollution, Spatial Dispersion, AERMOD

Introduction

The air we breathe is a mixture of gases and small solid and liquid particles. Some substances come from natural sources while others are caused by human activities such as our use of motor vehicles, domestic activities, industry and business. Air pollution occurs when the air contains substances in quantities that could harm the comfort or health of humans and animals, or could damage plants and materials.

Air quality modeling is a mathematical tool used to predict and simulate the distribution and the behavior of air pollutants emitted to the atmosphere. It describes the causal relationship between emissions, meteorology, atmospheric concentrations, deposition, and other factors. Air pollution modeling, gives complete deterministic description of the air quality problem, including an analysis of factors and causes (emission sources, meteorological processes, and physical and chemical changes), and some guidance on the implementation of mitigation measures. Air pollution cannot be measured in every point for particular area because it requires a lot of money and time. Therefore, by the help of air pollution models, one can for example determine the suitable points for making pollution measurements. The purpose of these air pollution models is to quantitatively combine the effects of source strength and meteorology to describe the resulting ambient air pollution concentration. Source strength is affected by a number of variables including the size of the source, variable emission rates, and the efficiency of air pollution control equipment employed. Meteorology is affected by wind speed and direction, atmospheric stability, inversion height, and terrain features.

AERMOD (American Meteorological Society/Environmental Protection Agency Regulatory MODel) an atmospheric dispersion model based on atmospheric boundary layer turbulence structure and scaling concepts, including treatment of multiple ground-level and elevated point, area and volume sources. It handles flat or complex, rural or urban terrain and includes algorithms for building effects and plume penetration of inversions aloft. It uses Gaussian dispersion for stable atmospheric conditions (i.e., low turbulence) and non-Gaussian dispersion for unstable conditions (high turbulence). Algorithms for plume depletion by wet and dry deposition are also included in the model. AERMOD generates daily, monthly as well as annual concentrations of pollutants in ambient air. The model handles a variety of pollutant sources in a wide variety of settings such as rural and urban as well as flat and complex terrain. AERMOD models a system with three separate components as shown in figure.



It has two pre-processors AERMET and AERMAP. AERMET is a meteorological pre-processor that calculates meteorological parameters and passes them to AERMOD. AERMAP is a terrain pre-processor that calculates terrain elevations above mean sea level and passes them to AERMOD. It requires three kinds of input data such as emission (vehicles), geographical and meteorological data (hourly nine meteorological parameters). These hourly meteorological parameters include Wind Speed, Wind Direction, Ceiling Height, Rain Fall, Pressure, Humidity, Global Horizontal Radiation, Cloud Cover and Temperature.

Site Description

The study area taken for the line and area source is the eastern region of Mumbai near kanjur dumping ground. The latitude and longitude of proposed site are 19° 07’37.96” 72°56’04.91”. The elevation of the study region is 14 m above the sea level.

The area taken for the study purpose is spread around 3.30 Square kilometres. The location of the study area is as shown in figure.

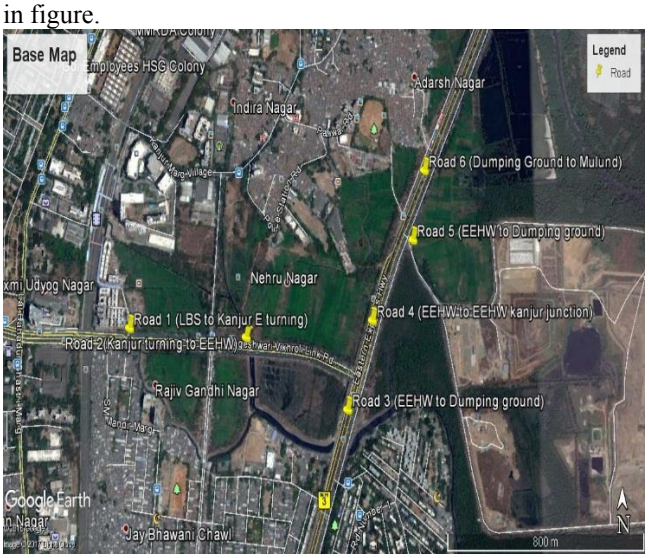


Figure 1 Site description for line source

METEOROLOGICAL DATA

The dispersion of pollutants along with meteorological conditions also depends upon the source characteristic (such as emission rate, exit velocity of gases, exit temperature of gases, stack height and stack diameter) included in the emission inventory. These data are essential requirement for source data of point source. With the help of UTM co-ordinates sampling sites and receptors were located and the parameters were set in the models pathways and models were successfully run and the GLC of pollutants including NO_2, SO_2 and PM_{10} for point source, NO_2 and CO for Line source and TSP for Area source were predicted for daily (24 h) and hourly time period. Meteorological conditions play a vital role in transport and dispersion of pollutants in the atmosphere. The hourly surface meteorological data viz. wind speed and direction and surface temperature required as input to the model were collected from the above mentioned site Meteorological station. This met information was converted to .Samson format from AERMET and is used by it to generate the WARPLOT which has the wind-rose plot of wind class shown in the picture it also prepares two files: .SFC and .PFL for the AERMOD.

Model Prediction For Winter Season

Based on hourly surface meteorological data and upper air data for period January 2015 to February 2015, wind rose was plotted based on the data processed in the pre-processors in order to present prevailing wind speeds and wind directions in the study area during 2015.

Figure shows the wind rose for the period between January 1, 2015 and February 28, 2015. According to figure, dominant wind direction were North West (NW), North (N), and West (W) with 42.80 % frequency of calm winds. Hence, this pictorial view showed the dispersion of pollutants was towards North West (NW), North (N), and West (W) side, the downwind distance up to which wind can cause pollutants to travel was further estimated with AERMOD along with pollutants concentrations.

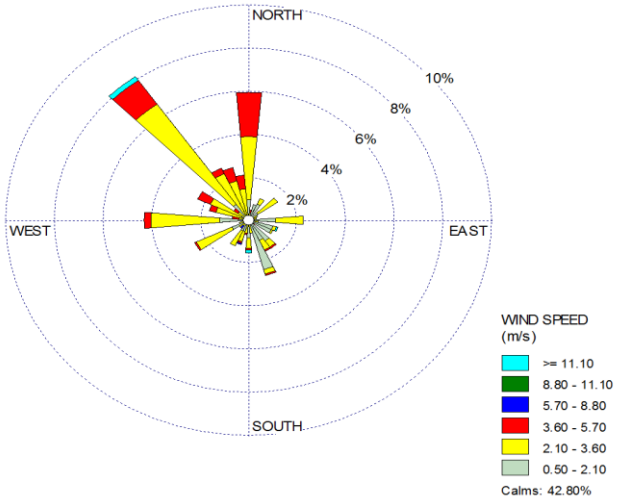


Figure 2 Winter Wind Rose Diagram (January-February)

Emission factors of vehicles obtained from ARAI, 2008 is given in Table1.

Table 1 Emission factors of Indian vehicles used in the study

Pollutant	Trucks diesel post 2000 Fuel BSII	CNG Buses post 2000 Fuel BS II	Car Petrol post 2005 Fuel BSII	Car diesel post 2005 (MIDC) Fuel BSII	Car CNG BSI, Post 2000, Fuel BSII	Three wheeler CNG retro 25 post 2000 Fuel BS II	Two wheeler post 2005 (4 stroke) fuel BS II
NO_x	9.300	6.210	0.090	0.28	0.74	0.19	0.15
CO	6.000	3.720	0.840	0.060	0.060	0.690	0.720

Thus, from Table it is observed that the primary emission from vehicles is NOx and CO. Therefore modelling for line sources was carried out for NOx and CO only.

To calculate emission from vehicles, vehicle counts are carried out on main roads under different classes of vehicles given in Table. The total no of cars and taxies (yellow and black taxies) are counted. Then from parking lots the number of CNG, Petrol and diesel cars are counted. Based on this counting actual number of diesel, petrol and CNG cars in the road are found out.

Hot Emission of line source in gm/s=

$$\frac{\text{(emission factor in gm/km * length in km * no of vehicles in 1 hour)}}{3600}$$

24 hours of the day was divided into morning pick hour from 8 to 11. Afternoon from 12 to 5pm Evening peak hour from 6

to 11pm and night 6pm to 7 am. Table gives the vehicle counts under different categories of vehicles.

Table 2 Vehicle count on Road 1 to Road 6 from 8 to 11 am

Road	8-11am (4hrs)						
	Truck diesel	CNG Bus	Car Petrol	Car diesel	Car CNG	Three wheeler CNG	Two wheeler
Road 1	45	560	680	500	660	780	550
Road 2	50	545	640	480	640	760	520
Road 3	46	750	540	500	600	650	540
Road 4	43	650	680	500	680	440	670
Road 5	47	0	10	12	16	10	16
Road 6	48	750	576	555	725	643	580

Table 3 Vehicle count on Road 1 to Road 6 from 12 to 5 pm

Road	12 -05pm (6hrs)						
	Truck diesel	CNG Bus	Car Petrol	Car diesel	Car CNG	Three wheeler CNG	Two wheeler
Road 1	80	170	480	530	480	550	480
Road 2	76	165	430	412	470	550	510
Road3	85	134	360	435	450	570	505
Road4	90	154	420	350	550	630	520
Road 5	200	0	10	8	10	8	6
Road6	100	150	360	435	500	580	480

Table 4 Vehicle count on Road 1 to Road 6 from 6 to 10 pm

Road	6pm-10pm (5 hrs)						
	Truck diesel	CNG Bus	Car Petrol	Car diesel	Car CNG	Three wheeler CNG	Two wheeler
Road 1	230	600	765	743	650	876	743
Road 2	190	650	600	676	700	750	743
Road 3	190	680	850	790	650	780	765
Road 4	290	700	760	750	760	650	743
Road 5	300	0	16	10	10	23	12
Road 6	295	750	800	860	850	880	732

Table 5 Vehicle count on Road 1 to Road 6 from 11pn to 7am

Road	11pm to 7am (9hr)						
	Truck diesel	CNG Bus	Car Petrol	Car diesel	Car CNG	Three wheeler CNG	Two wheeler
Road 1	110	70	180	190	225	380	230
Road 2	105	55	175	210	185	350	310
Road 3	110	86	280	220	223	375	267
Road4	120	90	270	230	210	425	321
Road 5	220	0	18	12	10	19	20
Road6	195	78	280	230	220	440	300

Spatial Dispersion of Pollutants for Winter Season

The predicted hourly monthly ground level concentration of NO_2 is 395 µg/m^3 with coordinates (x=283140.40m, y=2115826.74m) for winter season.

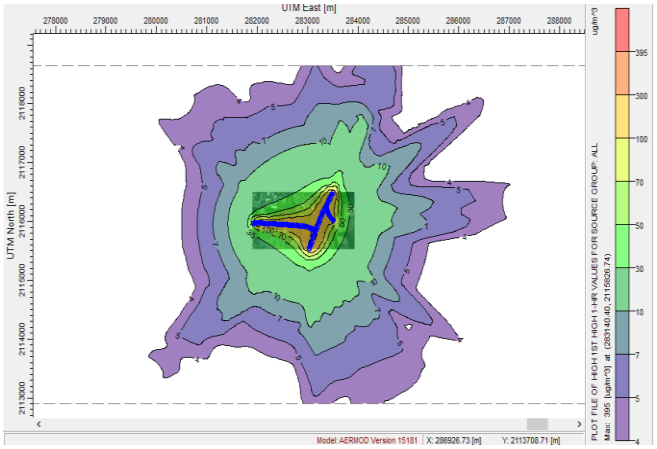


Figure 3 Contour plots of Ist Highest 1 hourly values for NO_2 for vehicles (line sources)

The predicted 24 hourly monthly ground level concentration of NO_2 is 47.07µg/m^3 with coordinates (x=283140.40m, y=2115826.74m) for winter season

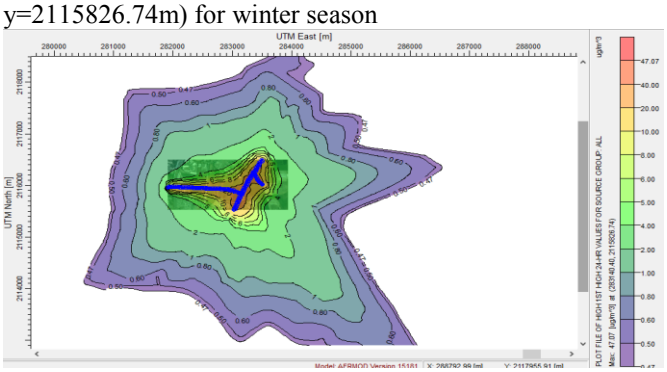


Figure 4 Contour plots of Ist highest 24 hourly values for NO_2 for vehicles (line sources)

The predicted hourly monthly ground level concentration of CO is 1353µg/m^3 with coordinates (x=283355.63m, y=2116122.92m) for winter season

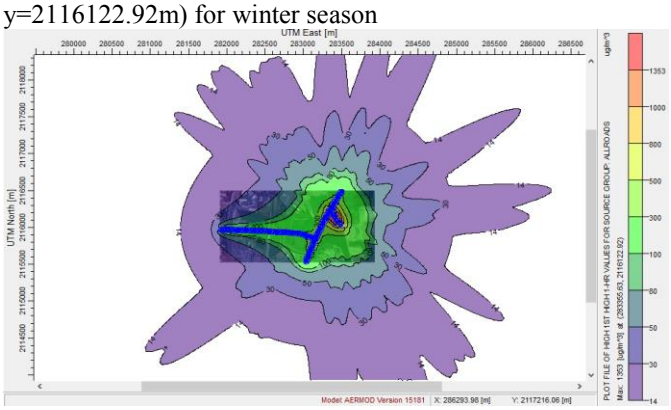


Figure 5 Contour plots of Ist Highest 1 hourly values for CO for vehicles (line sources)

The predicted 24 hourly monthly ground level concentration of CO is 365µg/m^3 with coordinates (x=283355.63m, y=2116172.92m) for winter season.

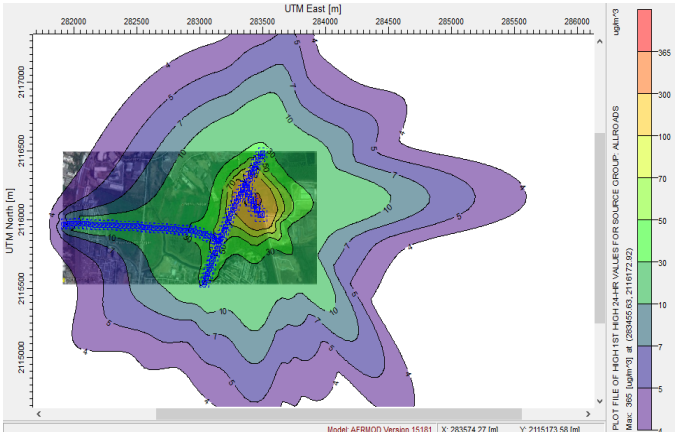


Figure 5 Contour plots of Ist highest 24 hourly values for CO for vehicles (line sources)

Result And Disscussion

By comparing the concentration of revised National Ambient Air Quality Standards and the results obtained from predicted ground level concentration of line sources it can be found that the predicted values of the result are not exceeding the standard values and the area taken under the study cannot be considered as highly concentrated region and it falls under safe zone.

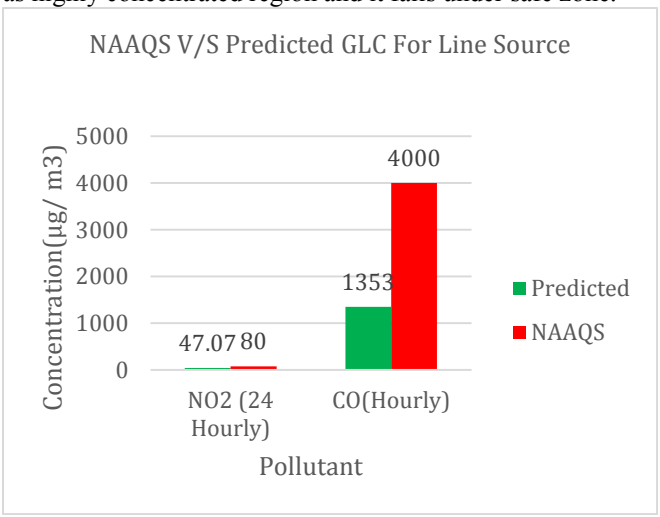


Figure 7 NAAQS V/S Predicted GLC For Line Source

Conclusion

There are several models for air dispersion modeling namely AERMOD, CALPUFF, CALINE, ISCST3 etc. AERMOD model is one of the state of art model which was used here for modeling of air pollutant like NO_2, CO from vehicular emission of urban area.

Meteorological parameters like wind, rain, temperature, cloud cover and relative humidity etc. plays significant role in dispersion of these kinds of pollutants.

GLC are mostly high during winter season as compared to other season due to stable atmospheric conditions.

The study region taken for the study falls under safe region.

AERMOD 9.0.0 Model output suggest that pollutants concentration in ambient air are within acceptance limits as per NAAQS 2009 norms.

From manual of US EPA it can be said that AERMOD software is more accurate in predicting values at ground level concentration.

Limitation Of The Research Work

In the present study, meteorological data used are actual, however source data such as traffic volume count are assumed with some hypothesis to simulate the actual condition but not the actual monitored data.

The present model prepared is not validated for actual site condition.

More effective results can be obtained by using terrain complex and building downwash tools of AERMOD.

Total traffic counting is done on the basis of total vehicle travelled irrespective of taking the direction in which vehicle travelled.

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