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Dispersion Modelling of PM10 at Unsignalised Intersection using Caline4

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Abstract

Air Pollution caused due to human activities is one of the major problems in the whole world and India being third largest contributor for emission of green house gases. Thus to control the air pollution, monitoring for the various pollutants as CO, PM10, PM2.5, SOx and NOx were carried out by CPCB in India. In Surat the daily monitoring was carried out at twelve sampling stations all around the city. The Air Quality Index (AQI) was found to fairly harmful with high concentration of Particulate Matter (PM). PM10 is a complex mixture of dry solid fragments, droplets of .liquids or solid cores with coatings which being highly carcinogenic. Present study aims to study the dispersion of PM10 at unsignalised intersection on urban roads. The temporal variation of the PM10 was studied compared with the traffic volume. It was observed that morning peak shows high concentration of PM10 which goes on decreasing towards off peak then again increases in evening peak.

Keywords*: - Caline4, PM10, Dispersion*

INTRODUCTION

India a developing country is second highest in the road network around the whole world. The vehicular population in India is about 250 millions which also increases congestion and thus emissions. Millions of people get affected due to air pollution caused by human activities which causes great economic damage to ecosystems and society. India is the third largest in the emission of greenhouse gases after China and the United States. The severity of air pollution is so much that life expectancy among Indians on an average reduces by 3.4 years while among the residents of Delhi it reduces by almost 6.3 years. It was observed that more than 1 lakh children were died due to severe effect of air pollution in India (WHO). Particulate matter (PM) is a complex mixture tiny particle of metals, soot, soil, and dust which vary greatly in shape, size and chemical composition.

Particulates are highly carcinogenic and have been classified in Group I carcinogen because of their ability to penetrate deep into the lungs and bloodstreams. They can also cause permanent DNA mutations, heart attacks, and premature death. More than 80% of cities in India where air quality is monitored do not meet the standard of air quality prescribed by the Government of India. Various models have been applied for estimation , simulation and dispersion of gases such as Caline4 (Coats et al. 1980;Vincent et al. 2010;Xiugang Li, Xiaoguang Yang 2002;Yazdi et al. 2015;Zhang and Batterman 2010), MOBILE (Boriboonsomsin et al. 2006;Zhang and Batterman 2010), MOVES (Liu 2014;Xu 2018). (Xiugang Li, Xiaoguang Yang 2002) have studied the simulation of emissions at signalised intersection in China using Caline 4 software and found that the Caline 4 predicts good relation with the actual field data. Vincent et al. (2010) have studied the spatial and temporal variation and dispersion of highway generated air pollution in residential urban area using Caline 4 and found that the effect of pollution goes on decreasing away from the road Central Pollution Control Board (2015) have studied the pollution level of six mega cities with the use of IVE and action plans were taken for each city. Fallah-shorshani et al. (2017) have integrated Gaussian Puff and Street Canyon model for the simulation of NOx. Yazdi et al. (2015) have studied the vehicular emissions near the highway in Tehran using tunnel experimental campaign and modelling procedure using Caline 4, COPERT and found the emissions follow exponential decay pattern and are remaining up to 50-80% of the total in a distance between 100-150m from highway. Tennyson and Kumar (2016) have studied the carbon monoxide (CO) prediction and seasonal variation for Madhurai city in India and found Caline 4 to be predicting nearly equal values of actual data.

From the above literature the Caline 4 was found to be most appropriate for the study. The aim of the present research was to study the dispersion pattern of the primary pollutant PM10 in urban area. The study area was taken as an unsignalised intersection in city of Surat. Surat is the eighth largest city and ninth largest urban agglomeration in Gujarat, India. The city is located 284 kilometres, south of the state capital, Gandhinagar . The city centre is located on the Tapti River, close to Arabian Sea. The surat is located at 21°10′N 72°50′E. It has an average elevation of 13 meters. . The average maximum temperature in summer is 370C and in monsoon 320C and in winter it downs to 230C.

METHODOLOGY

The California Line Source Model (Caline 4) is a line source Gaussian model which was developed by California Department of Transportation (Caltrans). The Caline 4 was used to estimate the dispersion of the pollutants such as Carbon Monoxide (CO), Particulate Matter (PM) and Nitrogen Oxides (NOx) for around 500m the links using receptors. The Caline 4 is applicable for suburban, rural and Central Business District (CBD) areas and urban areas by changing the aerodynamic coefficient. The inputs for the Caline4 were ambient temperature, base pollutants, ambient velocity and stability class as meteorological parameters. The traffic volume, link size, link type, link height, emission factors and receptors position were given as inputs for traffic characteristics. The base data for the present study was used from the dataset obtained from Gujarat Pollution Control Board (GPCB) for last four years. The model for dispersion was formed for each temporal variation.

Data Collection

For the present study the data was collected at an unsignalised intersection in Surat city on 27th September, 2018. The videographic data was collected for one hour in morning peak, off peak and evening peak. The meteorological data was obtained by meteorological department. The data was analysed using AVIDEMUX software on a large screen as shown in Figure 1. The Table 1 depicts the traffic volume count and weighted emission factors for morning peak, off peak and evening peak respectively.

The Caline 4 was used for dispersion modelling with the input data as shown in Table 2.The Caline4 was provided with only 20receptors. So to increase the data points the receptors are used in each quadrant, 20 at a time as shown in Figure 2.

Figure: 1 Traffic Volume Count at Unsignalised Intersection, Surat

Table 1 Traffic Volume and Emission Factors for each link

	Traffic Volume (Veh Per hour)			Emission Factor (g/km)		
	Morning Peak	**Off Peak**	**Evening Peak**	**Morning Peak**	**Off Peak**	**Evening Peak**
Northbound to Southbound	3398	2934	4173	0.80735	0.7783	0.78086
Southbound to Northbound	2179	1844	2234	0.85025	0.77407	0.88699
Eastbound to Westbound	731	654	1163	0.80735	0.7783	0.78086
Westbound to Eastbound	487	436	776	0.85025	0.77407	0.88699

Table 2 Base data for Caline4 for morning peak, off peak and evening peak

	Time	**Temperature**	**Wind direction (from North)**	**Speed(m/s)**	**Base PM10 µg/ m^3**	**Base PM2.5 µg/ m^3**	**Base Nox µg/ m^3**
Morning	9AM-10AM	28^0C	120^0	1.66667	81.05	26.05	18.09
OFF	1PM-2PM	37^0C	210^0	1.66667	81.05	26.05	18.09
Evening	6PM-7PM	34^0C	290^0	1.94444	81.05	26.05	18.09

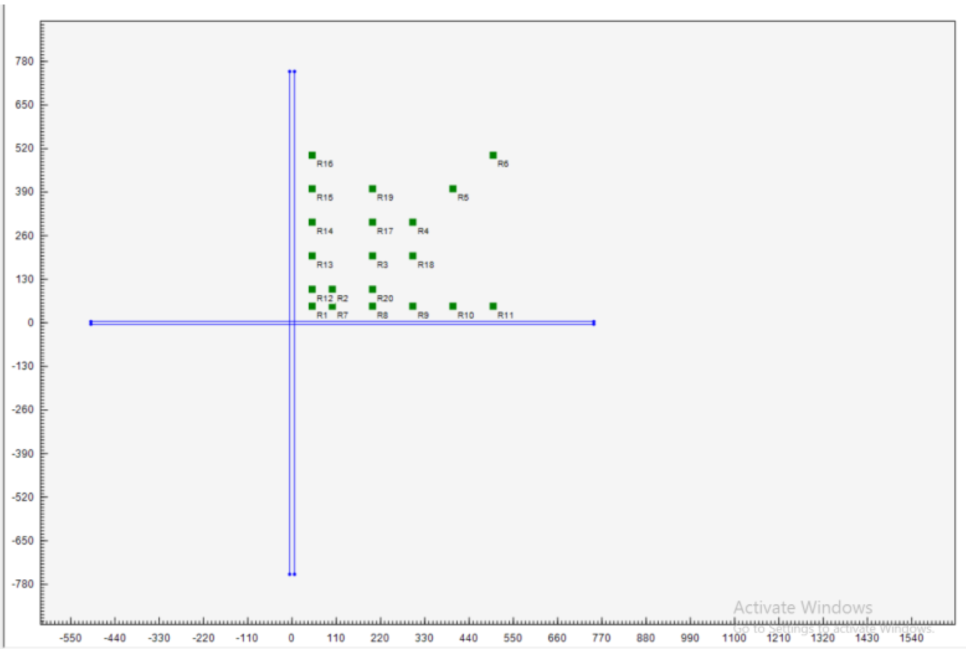

Fig. 2 Receptor Position in Caline4 for North East (NE)

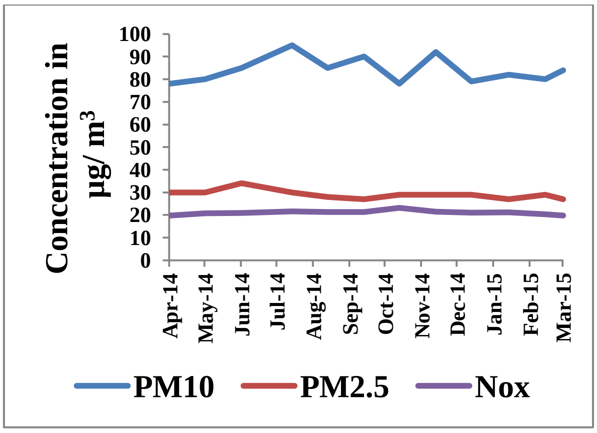

Fig. 3(a) Variation of PM10, PM2.5 and NOx for Year 2014-2015

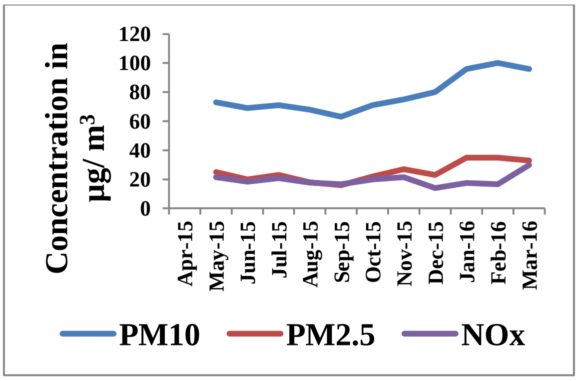

Fig. 3(b) Variation of PM10, PM2.5 and NOx for Year 2015-2016

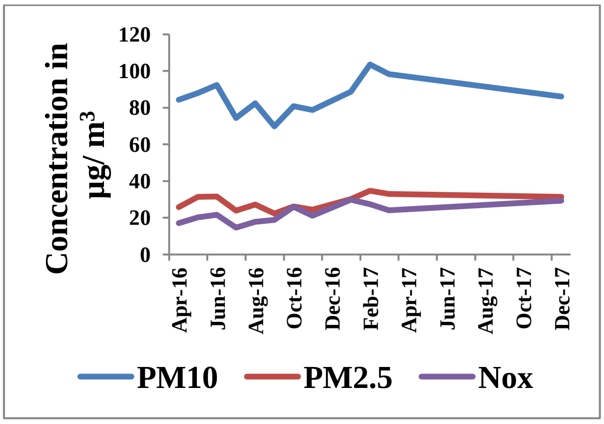

Fig. 3(c) Variation of PM10, PM2.5 and NOx for Year 2016-2017

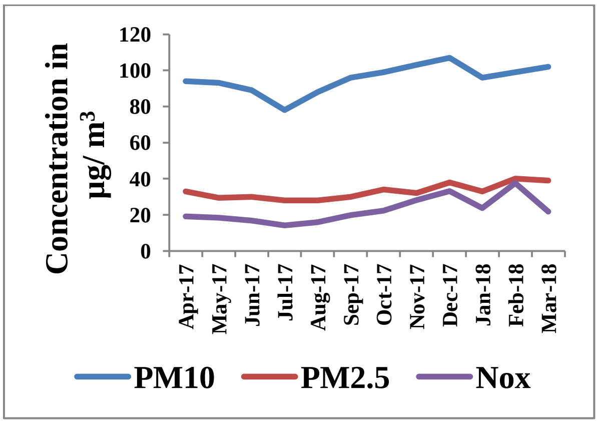

Fig. 3(d) Variation of PM10, PM2.5 and NOx for Year 2017-2018

Fig. 3 Variation of PM10, PM2.5 and NOx for last four year

The Figure 3 shows the yearly variation of three constituent pollutants for last four years as obtained from GPCB. The figure shows that there was large variation in PM10. The least value was found to be 63 µg/ m3 and maximum of about 107 µg/ m3. The concentration of PM 2.5 was within range of 16 µg/ m3 to 40 µg/ m3 and that of NOx it was found to be 9.4 µg/ m3 to 21 µg/ m3. The maximum values were occurred in the year of 2017-2018 as shown in Figure 3(d). The annual average for PM 10 was violating the prescribed standards by Central Pollution Control Board (CPCB). The annual average values for PM2.5 and NOx were within the limits given by CPCB

The variation in concentration with respect to season was also checked for base data. Figure 4 depicts the seasonal variation in pollutants. It was found that there is overall increase in concentration per year for all three constituents. The PM10 concentration shows its maximum value in the season of summer as 101 µg/ m3. This value occurs may be due to blowing of wind and lot of alteration in environment as pressure zones. The base data also shows that the PM2.5 has maximum value of 38 µg/ m3 in season of summer. Contrary the NOx shows the maximum value of 27 µg/ m3 in month of winter. This may be due to stagnant environment helps the pollutant to stay within the environment which gets accumulates in the space

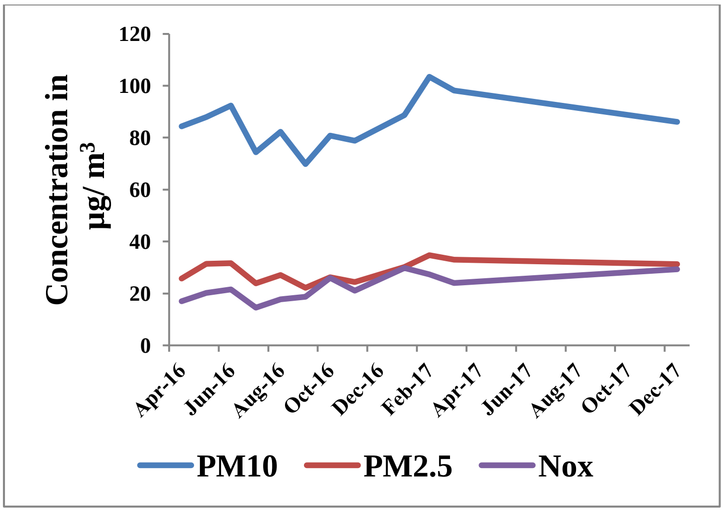

Fig. 4(a) Variation of pollutants in Mansoon season

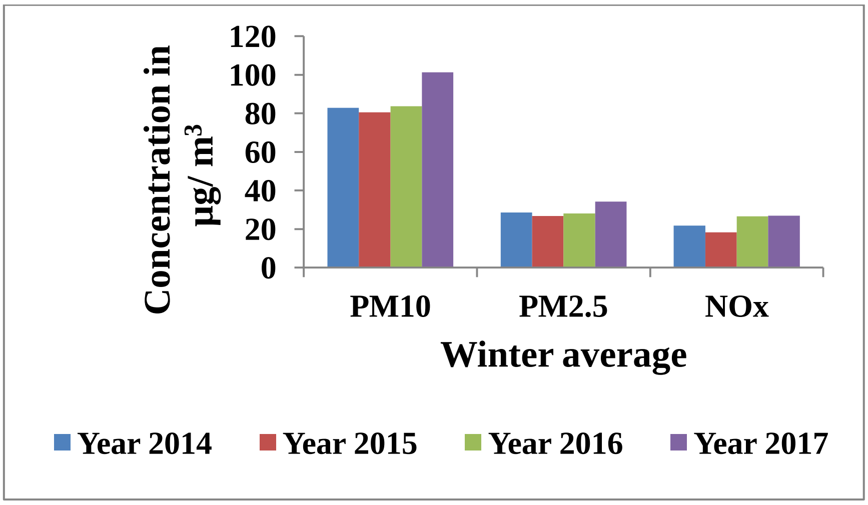

Fig. 4(b) Variation of pollutants in winter season

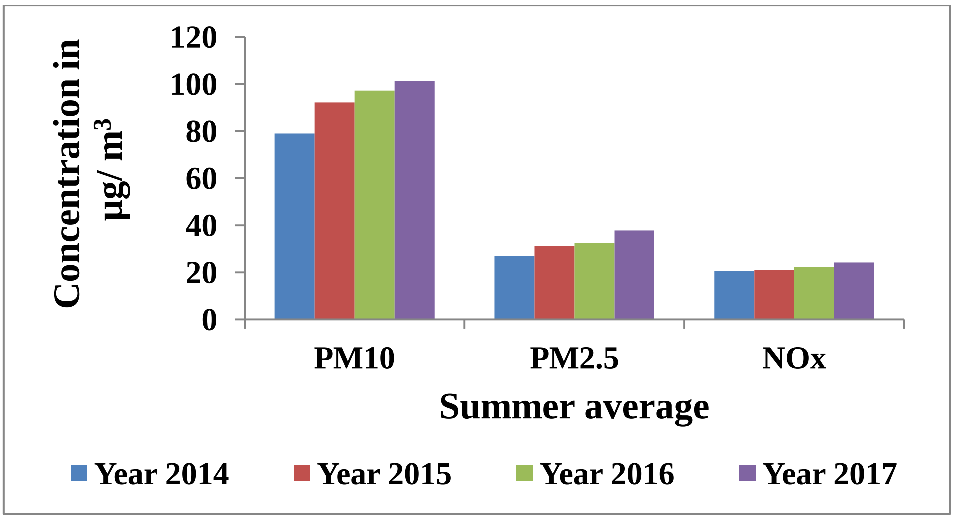

Fig. 4(c) Variation of pollutants in summer season

Fig. 4 Seasonwise variation of pollutants

The Figure 5 depicts the variation in pollutants with respect to comparison in season within a year. It was observed that the year 2014 shows the decreasing trend for PM10 and PM2.5 from monsoon to summer. But from the 2014 onwards the maximum concentration was obtained in season of summer that is increasing trend from monsoon to summer. But the NOx shows the peak in winter as discussed earlier in Figure 4.

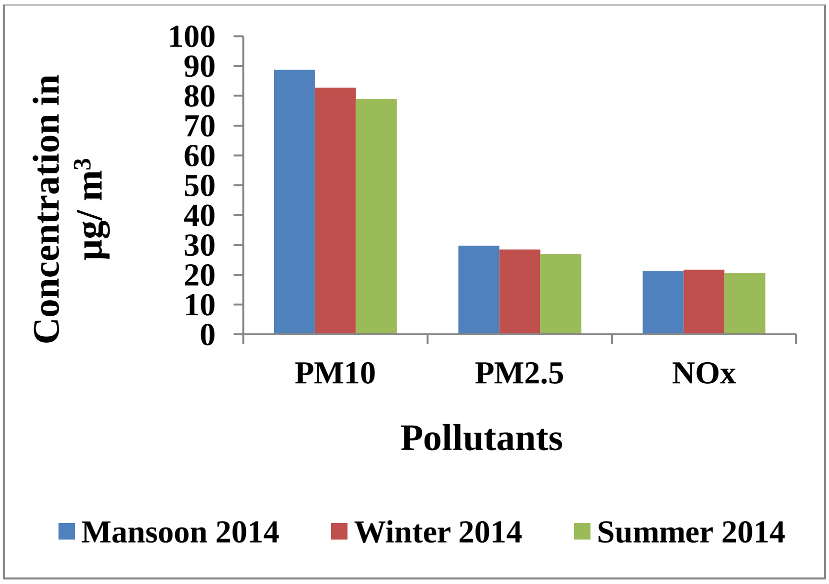

Fig.5 (a) Seasonal variation of pollutants Year 2014 Fig.5

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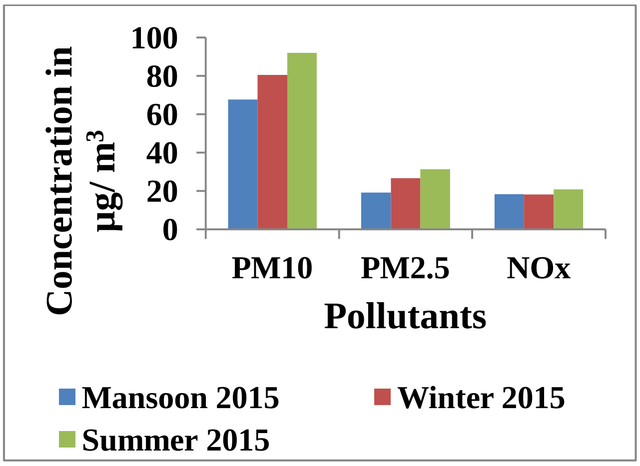

Fig.5 (b) Seasonal variation of pollutants Year 2015

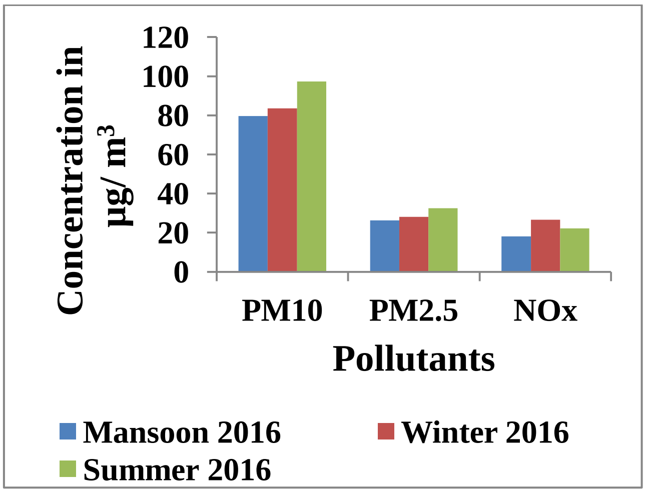

Fig.5 (c) Seasonal variation of pollutants Year 2016

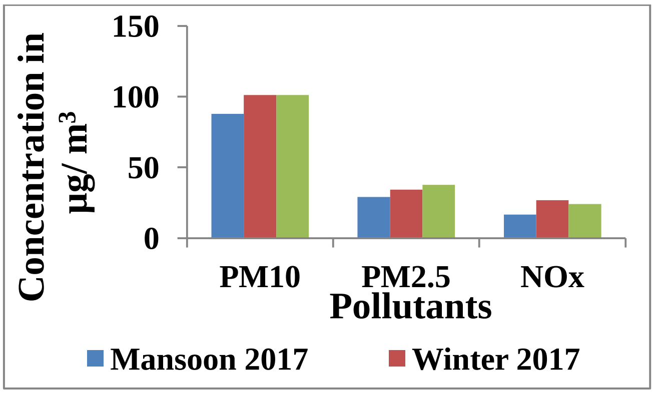

Fig.5 (d) Seasonal variation of pollutants Year 2017

RESULTS

The Caline 4 model gives the predicted emissions for PM10 and PM2.5 as shown in Figure 6. The results shows that the PM10 concentration was maximum in morning peak of about 114.40 µg/ m3 and minimum of about 85.80 µg/ m3. It may be due to low wind speed and less temperature which formed the calm environment for accumulation of pollutants. Figure 6 (a) shows that the concentration of PM10 pollutants was high near the road surface and it goes on decreasing as distance from road increases and it decreases upto 25 % of initial value. It was observed that at a particular region (-250,500) in Figure 6 (a) the concentration was high as the wind direction accumulates the pollutants at that point. Hence, it may be conclude that the green belt should be there for dispersion when wind direction is about South East (SE). Figure 6 (b) shows the dispersion of PM10 for Off peak time and it was found that the concentration was lower than both morning peak and evening peak. The concentration was high at the intersection and some dispersion occurs towards the South West (SW) due to prevailing wind. Figure 6 (c) depicts the dispersion of PM10 for evening peak which shows maximum dispersion in North West (NW) that is in direction of wind.

Table 3 Descriptive statistics for PM10 output for morning peak, off peak and evening peak

	Morning peak	**Off Peak**	**Evening Peak**
Mean	96.15 µg/ m^3	92.64 µg/ m^3	95.00 µg/ m^3
Minimum	87.00 µg/ m^3	86.00 µg/ m^3	85.80 µg/ m^3
Maximum	114.40 µg/ m^3	103.30 µg/ m^3	106.90 µg/ m^3
Standard Deviation	6.58	5.06	6.16
Skewness	0.44	0.48	0.53

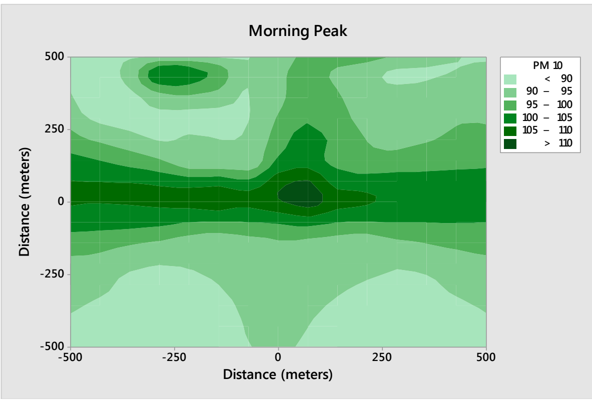

Fig.6 (a) Morning Peak variation in Dispersion of PM10

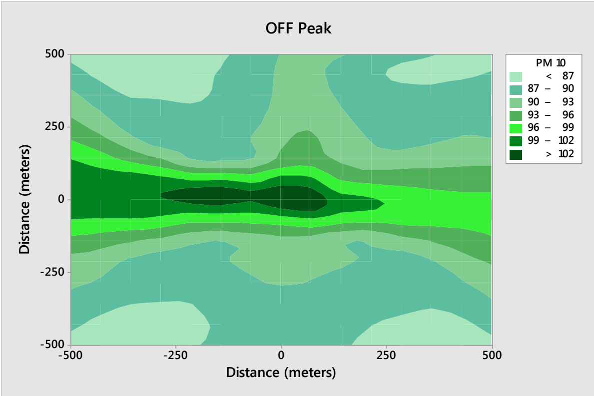

Fig.6 (b) Off Peak variation in Dispersion of PM10

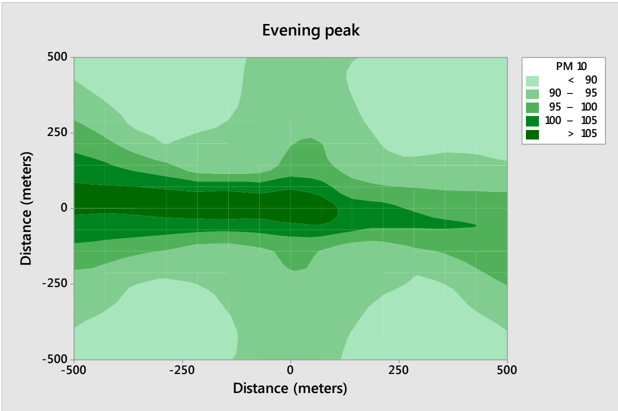

Fig.6 (c) Evening Peak variation in Dispersion of PM10

Fig. 6 Temporal variation in Dispersion of PM10

CONCLUSIONS

The air pollution is one of the major problems in the present condition and vehicular exhaust is a major source for emission. The health hazards due to air pollutions cause lung cancer, respiratory diseases and even death. Many times the pollutants in calm environment with fog forms poisonous smog which is more harmful to health and also for driving purpose. Thus the present study aims to study the dispersion at unsignalised intersection for PM10 with the use of Caline4 software developed by Caltrans. The traffic volume was collected using video graphic data and base data was obtained by GPCB. The model was developed with 20 receptors in each quadrant. The results show that the concentration of PM10 was high in morning peak and found to be low in off peak. It was also found that dispersion was function of wind direction and its speed. Furthermore, the concentration of pollutants was found to be goes on decreasing as distance from source that is link goes on increasing.

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