Draft Report On

AIR QUALITY MONITORING, EMISSION INVENTORY AND SOURCE APPORTIONMENT STUDIES FOR TEN CITIES IN THE STATE OF MAHARASHTRA

(NASHIK CITY)

for

Maharashtra pollution Control Board

By

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Indian Institute of Technology Bombay

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CSIR- National Environmental Engineering Research Institute

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Introduction

Chapter 1

Introduction

1.1 Preamble

Nashik city is situated on the banks of Godavari River, making it one of the holiest places for Hindus all over the world. Nashik has a rich historical past, as the mythology has it that, Lord Rama, the King of Ayodhya, made Nashik his abode during his 14 years in exile. At the same place, Lord Laxman, by the wish of Lord Rama, cut the nose of 'Shurpnakha' and thus city was named as 'Nasik'. Nashik is city of mythological, historical, social and cultural importance.

Nashik, the Headquarter of Nashik Administrative Division (comprising of Nashik, Ahmednagar, Nandurbar, Dhule and Jalgaon districts), is situated about 180 Kms; from Mumbai by the National Highway No.3, i.e. Mumbai- Agra Road which passes through the developed part of the city, while National Highway No. 50, i.e. Pune-Nashik road enters the city from Nashik-Road side and meets the Agra road near Dwarka Square. Nashik City lies on both side of the river Godavari, Panchavati lying across on left bank with Tapovan on side of it & the old Nashik on right bank. The main functional areas of the city are, the Nashik core area (the Nucleous), Satpur, Ambad Industrial areas and the second functional area is the Nashik–Pune road area with Nashik-Road railway station, supported by the industrial activities at Eklahara Thermal Power Plant, Railway Traction Factory etc. Satpur Industrial area is towards west. The MIDC Satpur Industrial Estate is mainly responsible for industrial and commercial growth of Satpur area. The Civic Administration area of 267.48 square kilometer (26747.75 hectars) is managed by Nashik Municipal Corporation.

The Nashik Municipal Corporation area is worked out on the basis of village wise revenue record. The Municipal Corporation area lies between 19^{o} 55' and 20^{o} 05' North Latitude and 73^{o} 41' and 73^{o} 54' East Longitude and is situated on eastern slope of the north-south of Sahayadri ranges. The city is bounded on north, by the northern boundary of villages Gangapur, Anandwali, Makhamalabad, Mhasrul, and Adgaon; on East, by the eastern boundary of villages Adgaon, Manur, Panchak, Chadegaon; on South by the northern boundary of river Darna, south boundary of part villages, Vihitgaon, Vadner, Pimpalgaon Khamb, south boundary of villages, Dadhegaon, Pathardi,; on West by western boundary of villages Chunchale, Satpur, Pimpalgaon–Bahula, and Gangapur. For the purpose of ascertaining the adequacy of the amenities, the city is divided into six sectors considering the character of the area. The study area of Nashik Municipal Corporation city limits with zoning structure is presented in **Table 1.1 and Figure 1.1**.

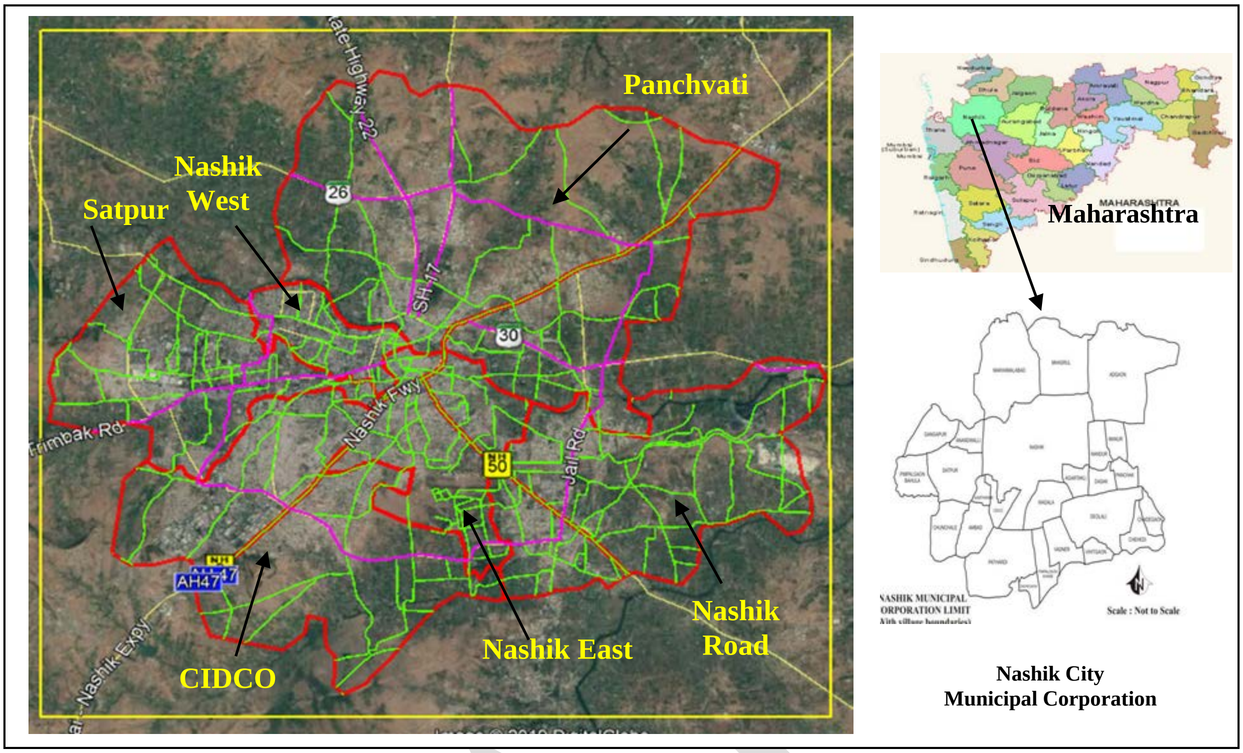

Figure 1.1 : Study Area (Nashik City Municipal Boundary)

Table 1.1 : Distribution Nashik City under Different Zone

Sector	Villages Included	Area (Hect.)
I	Makhamalabad, Mhasrul, Nashik (North).	6663.07
II	Adgaon, Nandur-Dasak, Manur	4146.77
III	Gangapur, Anandwali, Nashik (South) Agartakli.	4440.80
IV	Pimpalgaon Bahula, Satpur, Kamathwada, Ambad, Chunchale	3644.65
V	Pathardi, Wadala, Dadhegaon, Pimpalagaon Khamb(p), Vadner(p).	4162.57
VI	Dasak, Panchak, Chehedi, Chadegaon, Deolali, Vihitgaon(p)	3689.89
Total Area		**26747.75**

1.2 Population

On the basis of 2011 census figures, the population density of Nashik Municipal Corporation is 5556 persons per sq. km. The municipal corporation is divided into 61 wards. The highest gross density of 250.13 persons per hectare is in village Kamathwade. The lowest gross density of 4.22 persons per hectare is in village Dadhegaon. It is a fast developing area and has tremendous development potential in view of its advantageous situation of being located in Mumbai-Pune-Nashik Golden Triangle. This has made Nashik city an ideal place for location for new industrial and commercial establishments. As per the 2011 census, the total population of the entire area of Nashik Municipal Corporation, was 14,86,053 souls as against the 2001 census population of 10,77,236 souls, indicating the growth rate of 37.95% during 2001-2011 decade. Similarly, population for 1991 was 7,33,000 souls indicating decadal growth of 46.96%. **Table 1.2** shows decadal population growth.

With rapid industrialization and building construction activities during the past few years many hutment colonies have come up in the corporation area particularly near the industrial establishments and other work centres. There are about 168 slums consisting of about 42,742 huts with population of about 2,14,769 souls in the year 2014. In the year 2011, there were 131 slums consisting of 35,597 hutments with population of about 1,79,225 souls. This population constitutes near about 14.45% of the total population of the corporation area. The following tables show the details of slums and the details of ownership of lands.

Table 1.2 : Population Growth of the Nashik City and Slum Population Distribution

Year	Population	Decennial variation	Percentage Variation
1991	733000	--	--
2001	1077236	344236	46.96
2011	1486053	408817	37.95

Division	No of Slums	No of Hutments	Slum Population			Status	
			Private land	Govt. land	NMC land	Declared	Undeclared
Nashik East	25	6479	21670	1920	8805	9	16
Nashik West	16	3686	16790	210	1520	6	10
Panchavati	46	10390	19952	5965	26276	15	31
Nashik Road	44	8150	28634	12320	0	18	26
CIDCO	19	6252	18910	12350	0	2	17
Satpur	18	7785	11720	23127	4000	6	12
			117676	56492	40601		
Total	**168**	**42742**			**214769**	**56**	**112**

The above information shows that slum population is considerable in size and number. Across the six divisions, Panchvati has the highest number of slums i.e. 27.38% of the total slum population. Slums are mainly concentrated in the core of the city, along the banks of river Godavari and Nasardi, in canal alignment area and along the railway track. The slums are mostly built on private and government lands.

1.3 Climate

The climate in Nashik is quite pleasant and moderate. The year in Nashik could be divided into four seasons. The cold season from December to February, followed by the hot season from March to

May and the monsoon from June to September followed by the post monsoon season during October to November. The annual average rainfall is around 600 to 700 mm, the maximum reported in June and July months. The minimum Temperature reported in January around 4-5^{o}C and maximum in May around 45-40^{0}C. The area is very humid during the south- west monsoon season. In the post monsoon, in cold and summer season, air is generally dry. The summer season is the driest period of the year with relative humidity between 30 and 35% in the afternoons. The sky is heavily clouded during the monsoon season. During rest of the year, the sky is mostly clear or lightly clouded.

The winds are generally light to moderate with some strengthening in the wind force during the latter part of the summer season and in the monsoon season. In the post monsoon season, winds are light and variable in direction, north easterly in the morning and easterly in the afternoon. In the cold season, winds blow from directions between south- west and north-west in morning and between north and east in the afternoons. In the hot season, winds are from directions south-west and north-west. Some of the storms and depressions from the Arabian Sea in the latter half of summer and post monsoon season affect the area causing widespread rain. Thunderstorms occur in the latter half of the hot season and in the post monsoon season.

1.4 Air Quality of Nashik City

In Nashik district MPCB is carrying out monitoring at 8 different locations viz. (Residential : Old BJ Market, Girna Water Tank, RTO Colony, NMC Nashik and SRO Office), (Industrial : MIDC Jalgaon and MIDC Satpur) and one at Nashik CAAQMS station (Commercial). The annual averages of criteria pollutants with respect to NAAQM Standards are presented in **Figure 1.2 a to d**.

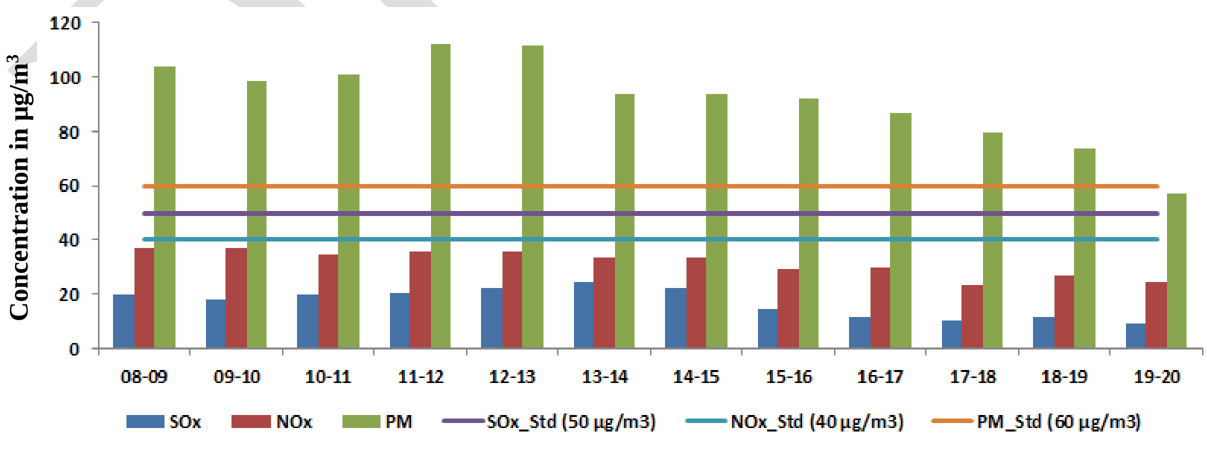

Figure 1.2a : Trend of Annual Average Concentrations of Criteria Pollutant in Nashik City

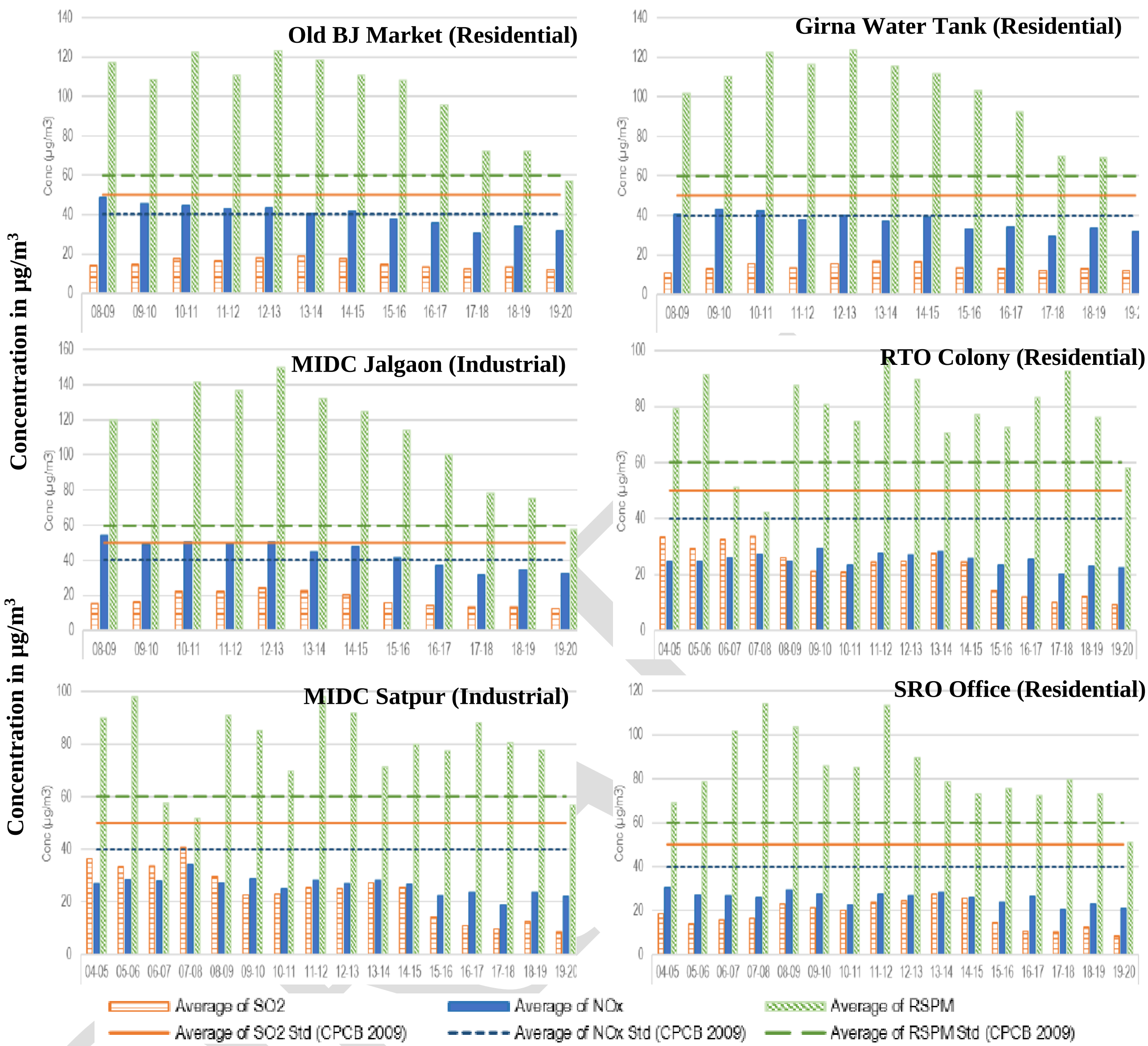

Figure 1.2b (Contd..) : Trend of Annual Concentrations at Different Monitoring Locations in Nashik City

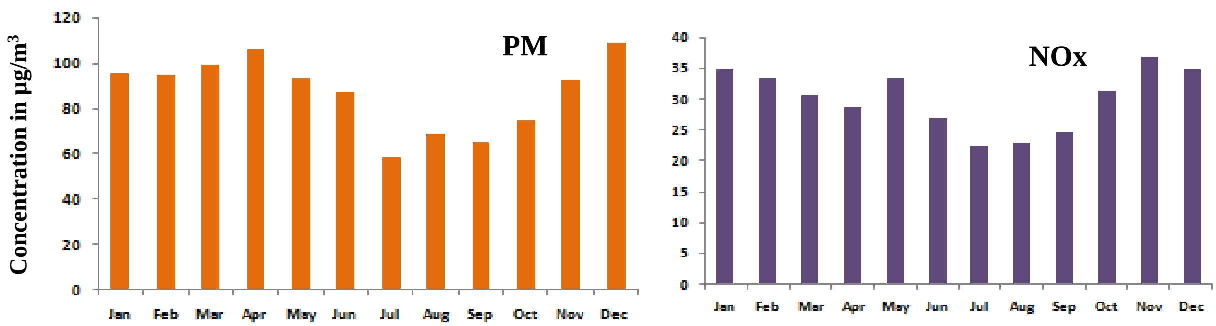

Figure 1.2c (Contd..) : Monthly Variation Trends for PM_{10}, and NOx (2019-20)

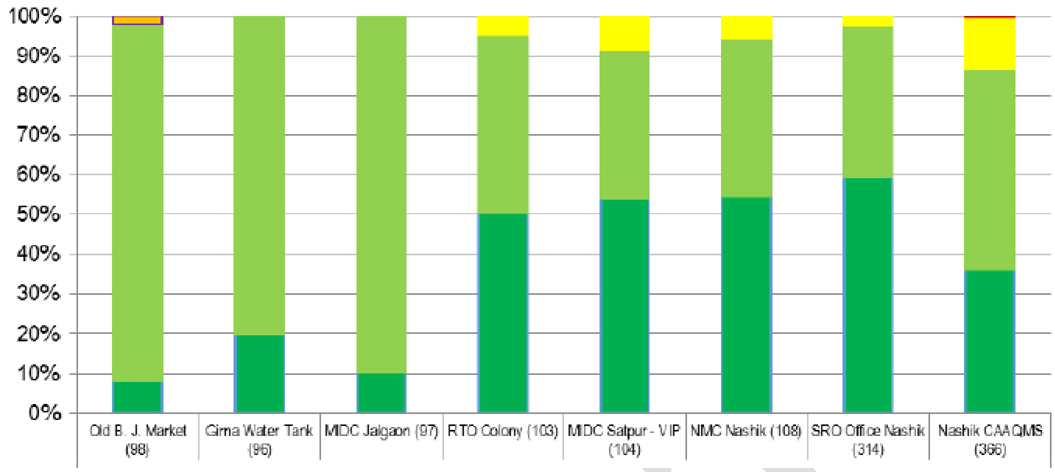

Figure 1.2d (Contd..) : Percentage Occurrence of Composite AQI of AQQMS in Nashik (2019-20)

In recent report was prepared by TERI -'Air Quality Status of Maharashtra' during 2019-2020 shows that the average PM concentration of Nashik City is around 92 µg/m^3, which is higher than the CPCB annual standards of 60 µg/m^3, as the vehicular and industrial impacts are more. While the NOx concentrations were below the annual standard, the NOx concentration is around 31.8 µg/m^3. The overall low average concentration of SO_2 is observed i.e 17 µg/m^3 at Nashik city,

The decadal annual averages from 2008 to 2020 of RSPM at residential sites shows that, the concentration of 51 to 124 µg/m^3 for RSPM, whereas for NOx it was 20 to 48 µg/m^3 and for SO_2 it gives 8 to 28 µg/m^3. Among them Old BJ Market, Girna Water Tank and SRO Office are represent as higher concentrations. The industrial site MIDC Satpur and Jalgaon, the RSPM ranging from 57 to 150 µg/m^3, similarly NOx moves around 19-54 µg/m^3 and SOx gives 9-30 µg/m^3. At Nashik CAAQMS station average PM and NOx concentration is reported around 66 and 21 µg/m^3 respectively. Average AQI represents around 30% as moderate and 40% are satisfactory for the Nashik City. The overall reduction of pollutant was observed after monsoon (July to September) and it was higher at winter.

In the past the study was undertaken by MPCB with NEERI i.e. 'Air Quality Data Assessment and Interpretation through Statistical Analysis' in 2011-2013 shows that :

- At SRO Office, Nashik, the concentrations shows annual exceedance of RSPM is about 90% and maximum concentration is 253 µg/m^3 in winter. AQI varied between unhealthy in winter, and moderate to unhealthy for sensitive group in other months.

- At RTO site, RSPM was reported to be higher in the range between 180 - 250 µg/m^3. Percent exceedance for RSPM was observed to range between 50 to 60% during that period. The AQI varied between moderate to unhealthy for sensitive groups.
- At Satpur, being an industrial site, the RSPM concentrations were found to be higher with annual exceedance of RSPM being 60-70%. AQI were reported as moderate to unhealthy for sensitive group.
- At NMC site, the percent exceedance of RSPM ranged between 60-70%. Highest concentration of RSPM was observed to be 282 µg/m^3 in winter. But all other parameters were reported to be within the permissible limits in the study period. The AQI varied between moderate to unhealthy for sensitive groups.
- Overall, Nashik district shows no significant change in air quality. As city is moving towards urbanization, control options should be implemented to control the increase the pollution levels

1.5 Objective of the Study

Nashik is one of the CPCB listed cities of India in which the RSPM levels are non-complaint with the NAAQS. In response, it has directed respective SPCBs to develop action plans and implement these as control measure over the coming years. A strategic action plan can only be devised on the basis of assessment of individual sources, their emission load, metrological conditions and level of exposure at individual level.

The main objectives of the projects are :

- To measure baseline air pollutants (Particulate Matter) in different parts of the city which include “hot spots” and kerbside locations.
- To develop emissions inventory various pollutants in the city.
- To conduct source apportionment study of PM.
- Suggest action plan based on various options delineated in the Six City Study of MoEF-CC or any relevant workable options. To prioritize the source categories for evolving city-specific air pollution management strategies/plan.
- To assess the impact of sources on ambient air quality under different management/ interventions/control options and draw a roadmap of short and long term measures as a part of action plan suggested

Among all the criteria air pollutants, particulate matter has emerged as the most critical pollutant in almost all urban areas of the country. Thus the main focus of this study was on characterization and source apportionment of particulate matter.

Chapter 2

Air Quality Monitoring

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Air Quality Monitoring

2.1 Monitoring Sites

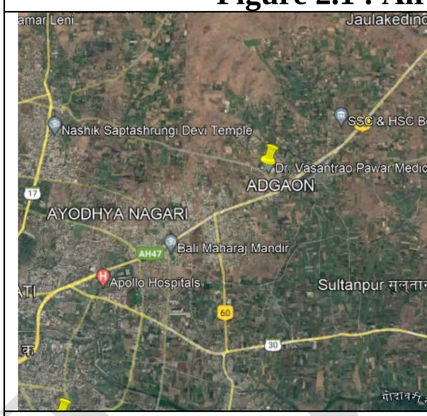
Population density, climatology, topography, and other factors all have a role in air quality monitoring design and assessment. The monitoring stations were chosen on the basis of region demography, consideration of activities and standard sampling procedure. Three sampling sites were chosen as representative of the Nashik city area. Of these, one site was selected as control site (Vasantrao Pawar Hospital) against RTO Colony Water Tank (Residential) and Taran Talav (Commercial/ Kerb). The study area and site characteristics are depicted in **Figure 2.1.**

Vasantrao Pawar Hospital (Background) : The site is on the outskirts of Adgaon's north-eastern suburbs. The sampling apparatus was placed on an elevated platform of a hospital at a height of 2 meters above the ground. Agriculture fields were within a one-kilometer radius of the sampling site, with minimal ongoing activity. The Mumbai Agra National Highway and Adgaon Road are two prominent roadways in the area. There were no industrial activities in these locations.

RTO Colony Water Tank (Residential) : The location selected is a residential sector in the city's centre, with heavy day to day activity.. The sampling instrument was installed at a height of 1.5 meters from ground on the terrace near the water tank. The majority buildings and societies near this site are residential. There are numerous commercial shopping malls, housing societies, and luxurious hotel facilities in the area, resulting in heavy traffic congestion at intersections at peak hours. The location is connected to the city's centre; the main thorough fares include Trambakeshwar Road, Panchvati Road, Peth Road, Dindori Road, Mumbai Nashik Old Agra Road, Chatrapati Shivaji Maharaj Udhan Pool, which see a lot of traffic. MPCB is also monitoring city air quality near Golf Club Nashik as part of the national ambient air quality programme.

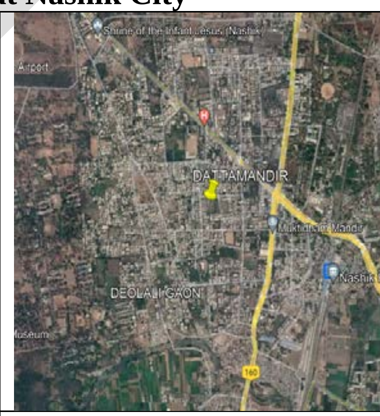
Taran Talav (Commercial /Kerb Side): The location is located on the south east, near the Nashik Pune Road. At a height of 3 meters above the ground, the sample apparatus was mounted. Nashik Railway Station and Gandhi Nagar Airport were close to the location. Near the site, there are residential blocks and mixed-land use pattern of activity. The location is connected roads Nashik Pune Road, Jail Road, Byloo Chowk, and other feeder roads, because of which there is heavy traffic around in the area. The state transport as well as municipal public bus services operate on these busy highways. There are various commercial and institutional structures in the surrounding region, as well as government office buildings. There are various businesses, hotels & restaurants, open eat outs, and other commercial activity on nearby roads, resulting in noticeable traffic during peak hours. Near the location, road construction was going on at the time of monitoring.

Figure 2.1 : Air Quality Monitoring Locations at Nashik City



Vasantrao Pawar Hospital (Background)

RTO Colony Water Tank (Residential)



Taran Talav (Commercial/ Kerb Side)

2.2 Measurement and Frequencies

Air quality pollutants were monitored as per the CPCB guide lines and chemical speciation methodologies adopted is given in **Table 2.1.** Portable air samplers (Airmetric) were used to sample $PM_{2.5}$ and PM_{10}. Four ARM samplers were collated at every sampling site to sample $PM_{2.5}$ and PM_{10}, each on two filter substrates (Teflon and Quartz). These samplers have been used widely for ambient air monitoring in several studies *(Chow et al., 2002; Ho et al., 2004)* tested MiniVol for its performance against the Federal Reference Method (FRM) sampler, and found that there was no statistical difference in the mass concentrations as measured by both the instruments.

The flow rate of 5.0 lpm was found to be suitable as it would collect about 7.2 m^3 of air in 24 hours, and the total mass of sample would be in the range of 720 to 1080 µg (based on the average ambient concentration of PM_{10} and $PM_{2.5}$ is 114.9 and 79.3 µg/m^3 respectively reported for Nashik).The mass of samples collected over a specified duration includes two main considerations: i) adequate mass collection for gravimetric as well as chemical analysis, and ii) prevention of overloading of the filter that could lead to excessive pressure drop across the filter. The sampling instrument has a constant flow control system, and an elapsed time totalizer. 24 hourly air qualities were monitored at each site for 10 days during winter 2021. Mass closures for all sites have been carried out as per protocol given in Data Validation Workbook: Session 4- Particulate Matter.

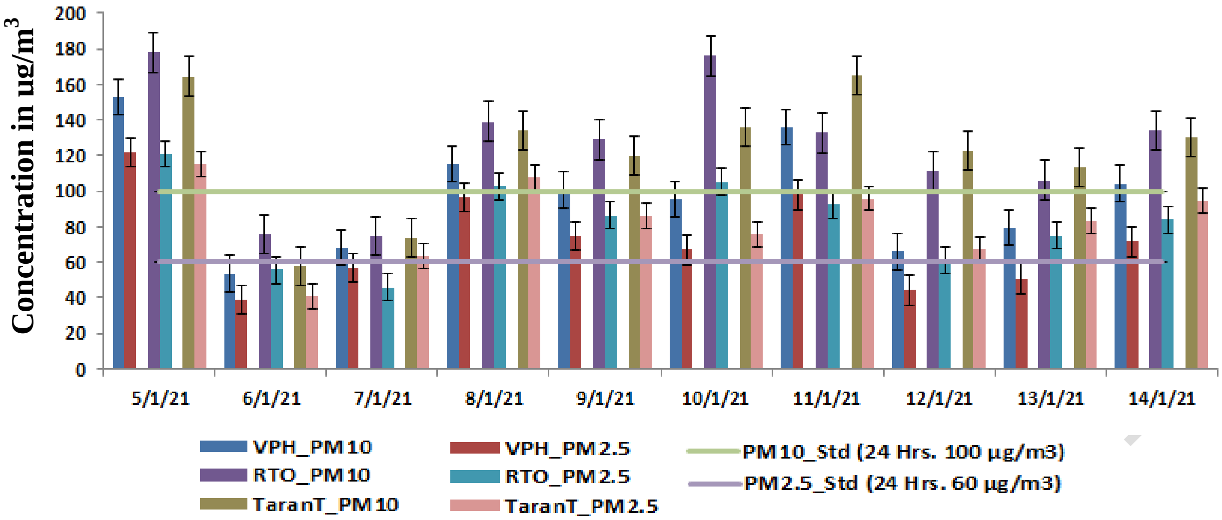
Table 2.1 : Target Physical and Chemical Components (groups) for Characterization of Particulate Matter for Source Apportionment

	PM_{10}	**$PM_{2.5}$**	**OC/E**	**Element /Ions**
Sampling Instrument	Air Metric MiniVol Portable Sampler		Particulate collected on Quartz filter	Particulate collected on PTFE Filter paper
Sampling Principle	Filtration of aerodynamic sizes with a size cut by impaction			
Flow Rate	5 LPM	5 LPM	5 LPM	5 LPM
Sampling Period	24 Hourly Filter Change			
Sampling Frequency	Total 10 days; using Quartz and PTFT Filter Simultaneously	Total 10 days; using Quartz and PTFT Filter	Total 10 days; using Quartz and PTFT Filter Simultaneously	Total 10 days; using Quartz and PTFT Filter Simultaneously
Analytical Instrument	Electronic Balance	Electro nic	OC/EC Analyzer	Ion Chromatography
Minimum Reportable Value	5 µg/m^3	5 µg/m^3	0.2 µg/ 0.5 cm^2 Punch	NA

Components	**Required Filter Matrix**	**Analytical Methods**
PM_{10} / $PM_{2.5}$	Teflon or Nylon filter paper. Pre and post exposure conditioning of filter paper is mandatory	Gravimetric
Elements (Na, Mg, Al, Si, P, S, Cl, Ca, Br, V, Mn, Fe, Co, Ni, Cu, Zn, As, Ti, Ga, Rb, Y, Zr, Pd, Ag, In, Sn, La Se, Sr, Mo, Cr, Cd, Sb, Ba, Hg, and Pb)	Teflon filter paper	ICP- AES or ICP-MS Or ED XRF
Ions (Na^+, NH_4^+, K^+, Mg_2^+, Ca_2^+, F^-, Cl^-, NO_2^-, NO_3^-, SO_4^{2-})	Teflon filter paper (Same teflon filter paper can be utilized if ED-XRF is used for elements analysis)	Ion chromatography with conductivity detector
Carbon Analysis (OC, EC and Carbonate Carbon)	Quartz filter. Prebaking of quartz filter paper at 600 ºC is essential	TOR/TOT method

2.3 Monitoring Results

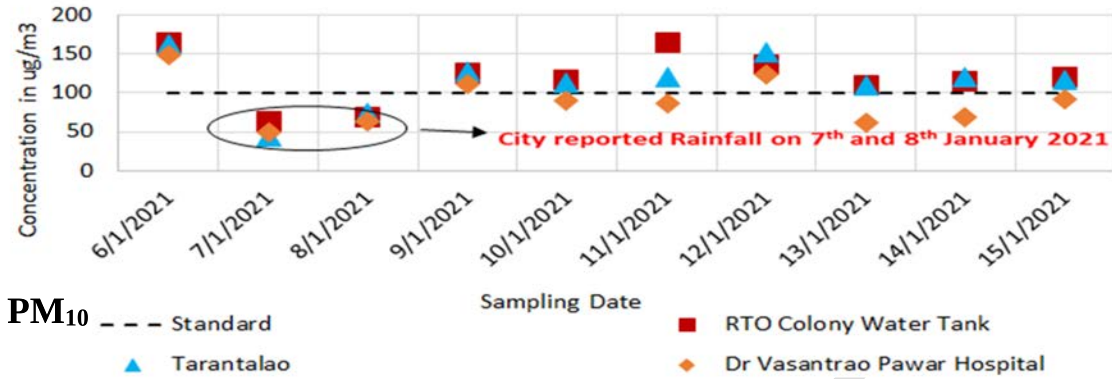
The particulate matter concentration compared with NAAQM Standard and $PM_{2.5}$ and PM_{10} is presented in of **Figure 2.2.**

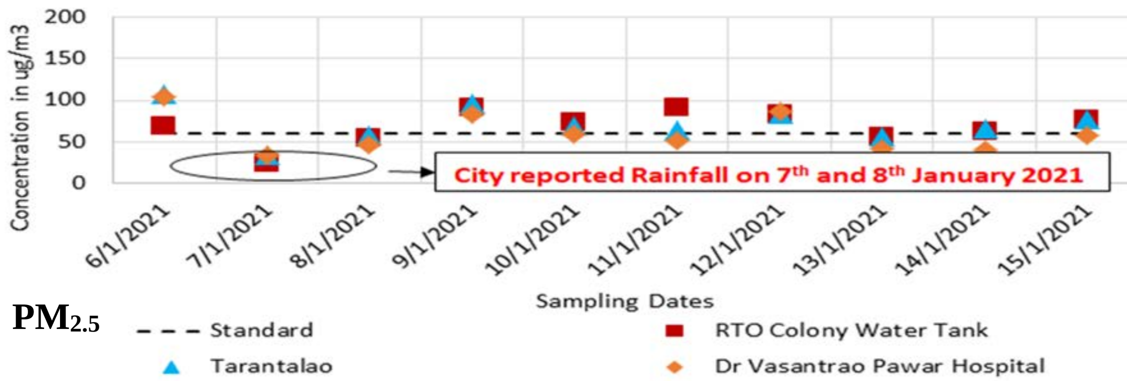


VPH -Vasantrao Pawar Hospital; RTO -RTO Colony Water Tank; TarnT -Taran Talav

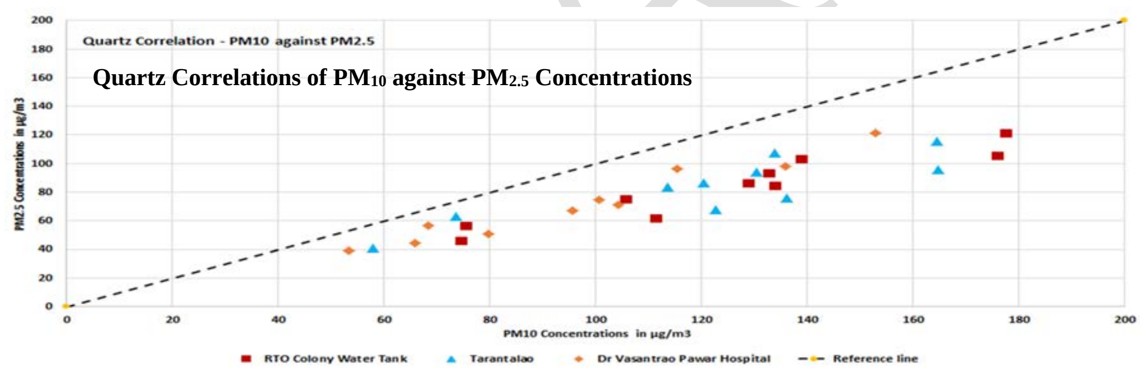
Figure 2.2 : PM_{10} and $PM_{2.5}$ Concentrations with respect to NAAQM Std.

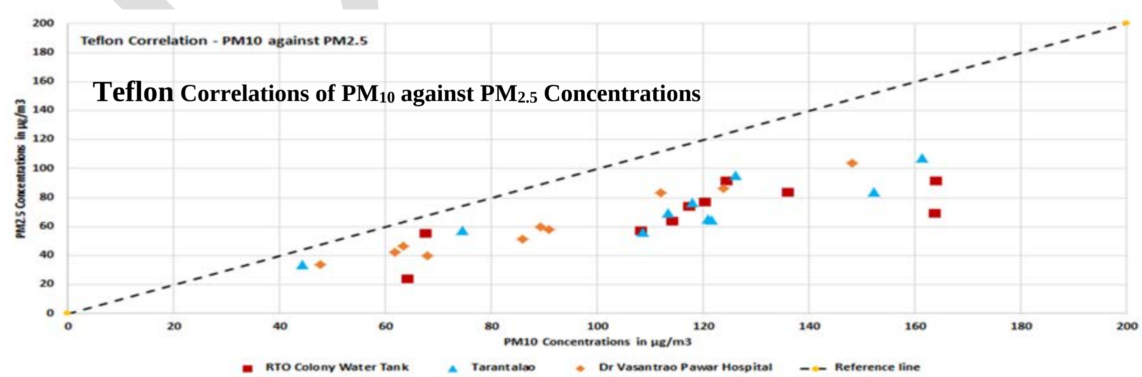
The PM_{10} concentration at Vasantrao Pawar Hospital (Background site) was observed to be in the range of 53.5 to 153 µg/m^3 (Avg. 97.2 µg/m^3), whereas; it was 39.1 to 121.7 for $PM_{2.5}$ (Avg. 72 µg/m^3). The $PM_{2.5}/PM_{10}$ ratio provides characteristics of particle pollution since fine particles ($PM_{2.5}$) and coarse particles ($PM_{2.5-10}$) are often created by multiple sources. $PM_{2.5}/PM_{10}$ ratio at background site is 0.74. PM_{10} concentration for the residential site (RTO Colony Water Tank) was in the range of 74.7 to 177.7 µg/m^3 (Avg. 125.7 µg/m^3), whereas $PM_{2.5}$ ranged between 45.8 to 120.8 µg/m^3 (Avg. 82.9 µg/m^3). The $PM_{2.5}/PM_{10}$ ratio was found to be around 0.65. The Commercial/ Kerbside Taran Talav, PM_{10} concentration was observed in the range of 57.9 to 164.8 µg/m^3 (Avg. 121.8 µg/m^3) and 40.8 to 115.5 µg/m^3 (Avg. 83 µg/m^3) for $PM_{2.5}$. The $PM_{2.5}/PM_{10}$ ratio was calculated to be around 0.68. The 24 hourly average concentrations of PM_{10} and $PM_{2.5}$ exceeded CPCB NAAQM Standards of 100 µg/m^3 for PM_{10} and 60 µg/m^3 for $PM_{2.5}$ at all the sites. Overall average $PM_{2.5}/PM_{10}$ ratio was found to be 0.6 to 0.7, indicating the predominance of coarse particulate matter. The correlation between PM_{10} and $PM_{2.5}$ had R^2 value of 0.83, indicating nearly similar sources for PM_{10} and $PM_{2.5}$. During sampling days (6 to 8/1-21) significant variance was reported in the gravimetric analysis, as the study area had witnessed rainfall. The Teflon and Quartz Correlations of PM_{10} against $PM_{2.5}$ concentrations are presented below. The graphical compositional comparisons of $PM_{2.5}$ vs PM_{10} for all species are shown in **Figure 2.3.**



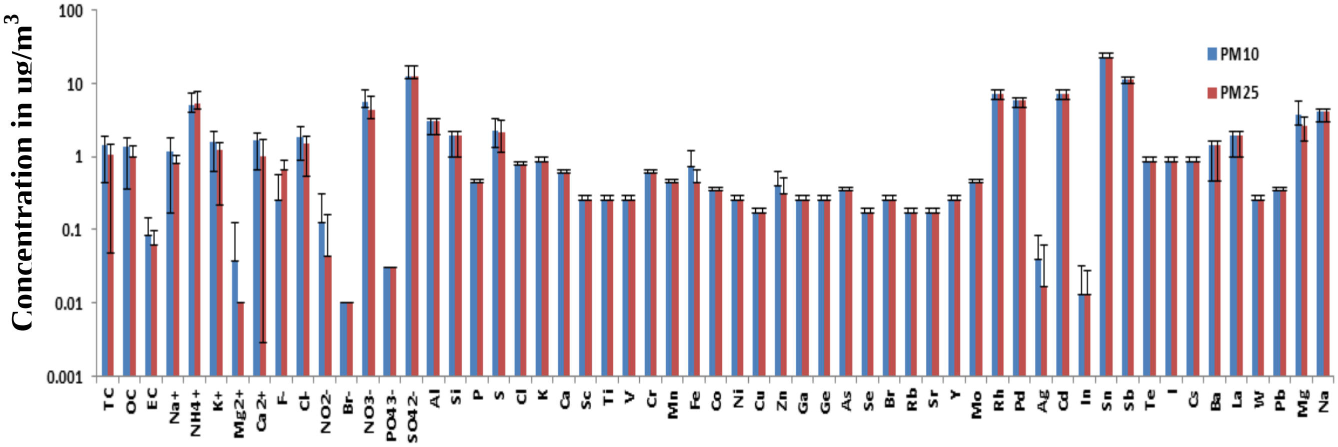


Drastic Change in the Gravimetric Due to City Witness Rainfall

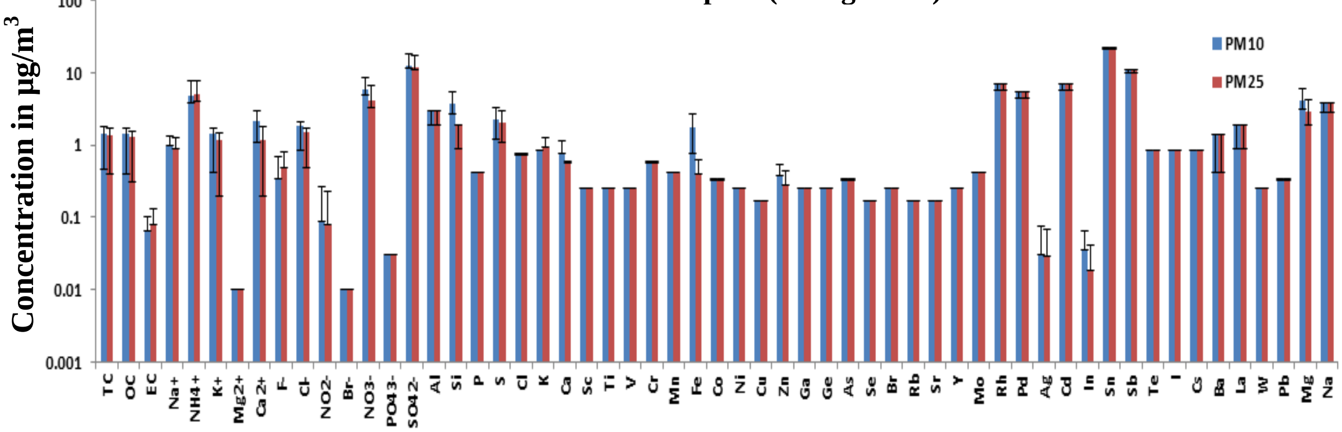




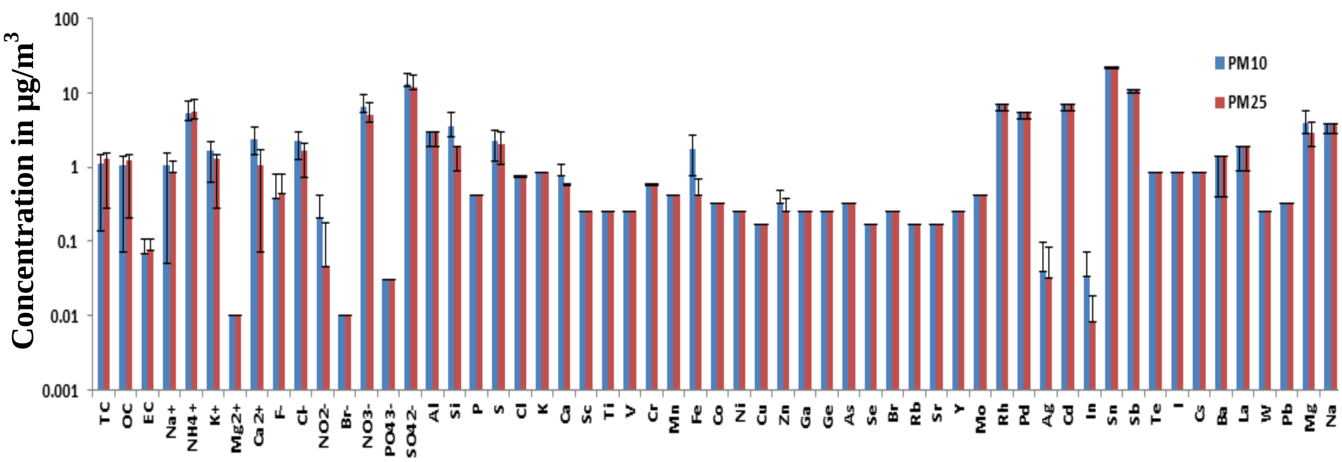
Teflon and Quartz Correlations of PM_{10} against $PM_{2.5}$ Concentrations



Vasantrao Pawar Hospital (Background)



RTO Colony Water Tank (Residential)



Taran Talav (Commercial /Kerb Side)

Figure 2.3 : Compositional Comparison of Species Concentrations in PM_{10} and $PM_{2.5}$

2.3.1 Mass Closure of PM_{10} and $PM_{2.5}$

The PM_{10} and $PM_{2.5}$ samples were analyzed for 46 elements and 12 ions species for a total of 30 samples. The mass reconstruction procedure used in the present study was based on PM Data Analysis Workbook, USA.

Material Balance Equation

Geographical [(1.89 x Al) + (2.14 x Si) + (1.4 x Ca) + (1.43 x Fe)]

Organic Carbon (1.4 x OC) + Elemental Carbon

+ Anions (Cl^-, SO_4^{2-}, NO_3^-,…) + Cations (Na^+, K^+, $NH4^+$,…)

+ Trace Elements (Excluding geological) +Unidentified

Interpretation for Mass Closure

Vasantrao Pawar Hospital (Background): - The major chemical component of the sample at this site was Crustal and Non-crustal elements, which accounted for 12.2% and 20% of total PM_{10} mass, respectively. Anion accounted for 21.2% of the total coarse particulate mass. Amongst the anions, contribution from sulfate is maximum (13%), followed by nitrate (5.9%), this is probably due to secondary aerosol, road dust etc. Cations make up to 9.9% of the total PM_{10} concentration. The ammonia is present in the fraction of 5.2%, while calcium, sodium and potassium is around 1 to 2%. The organic matter accounts for 15.7% of the total mass and elemental carbon is found only to be marginal, this may be due to anthropogenic activities near the monitoring site. Unidentified portion in PM_{10} was 21%, which may be due to volatilization of organic matter and nitrates **(Figure 2.4)**.

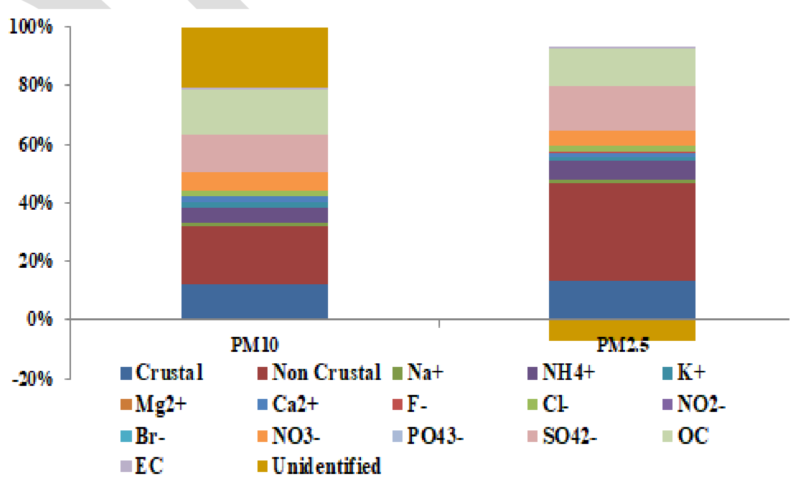


Figure 2.4 : Percent Contribution to Mass in PM_{10} and $PM_{2.5}$ at Vasantrao Pawar Hospital (Background)

Percent contribution of Crustal and Non-crustal elements in $PM_{2.5}$ is found to be around 15.8% and 38.9%, respectively. Anions and cations contribute 26.4% and 11.7%, respectively of the total $PM_{2.5}$. Sulfate (17.3%) and nitrate (6%) and chlorides (2.1%) form the major proportions in Anions, whereas ammonia (7.5%), and calcium, sodium and potassium (around 1 to 2%) are the major proportions in Cation. The organic matter accounts for 15.3% of the total. Negative percent -8.2% in $PM_{2.5}$ indicates that the sum of identified species exceeded the measured mass. This is due to particle bound water and other analytical uncertainties *(Rees et al., 2004)*.

RTO Colony Water Tank (Residential) : The Crustal and Non-crustal elements in the sample of monitoring site accounted for 13.5% and 24.6% in PM_{10}, respectively. The anion contribution in the sample was about 16.7% of the total coarse PM_{10} mass (sulphate 10.2%, nitrate 4.7% and chloride 1.5%), whereas, 7.5% was cations (ammonia 3.9% and calcium 1.7%). The organic matter accounted for 12.5% of the total mass and elemental carbon is found to be marginal. The emissions from commercial and residential activities in the area and contribution probably due to secondary aerosol, road dust etc. are the major source near the sampling point.

$PM_{2.5}$ was composed of 13.2% of Crustal elements and 31.7% of Non-crustal elements. Anion and cation contribution in total $PM_{2.5}$ mass was found to be 22% and 10.1%, respectively. 14.4% of Sulfate; 5.1% of nitrate and chlorides 1.8% are highest contributing source in Anions, whereas 6.2% of ammonia and calcium, sodium and potassium (around 1 to 2%) are highest in Cation. The organic matter is accounting for about 17.8% of the total mass. Unidentified portion in PM_{10} and $PM_{2.5}$ was around 25.1% and 5.1% respectively, which may due to volatilization of organic matter and nitrates **(Figure 2.5)**.

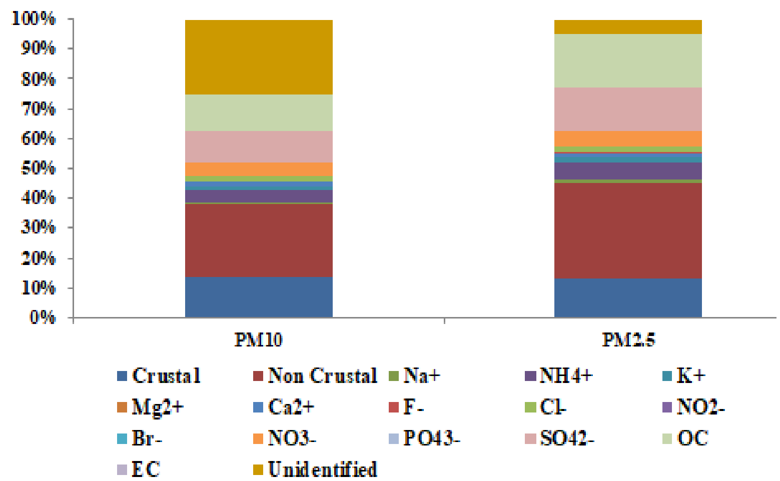


Figure 2.5 : Percent Contribution to Mass in PM_{10} and $PM_{2.5}$ at RTO Colony Water Tank (Residential)

Taran Talav (Commercial /Kerb Side) : The site is a busy commercial area with interconnected traffic junctions viz. Nashik Pune Road, Jail Road, Byloo Chowk, and other feeder roads, there is heavy traffic around this location. This resulted in resuspension of dust contributing 13.8% for Crustal and 21.8% of Non-crustal elements in PM_{10} of the total mass. Anions in PM_{10} account for 18.3% of the total coarse particulate mass in which sulphate is 10.7%, nitrate is around 5.3%; whereas Cations make up around 8.5% (ammonia 4.3%, calcium and potassium 1 to 2%) from rest of the total PM_{10}. The organic matter is accounting for about 9.9% and elemental carbon is negligible. This contribution is probably due to secondary aerosol, road dust and extensive vehicular movement. Unidentified portion in PM_{10} was 27.6%, which may due to volatilization of organic matter and nitrates.

In $PM_{2.5}$, Crustal and Non-crustal elements was around 13.2% and 25.8%, respectively. Anions and cations contribute 23.4% and 10.5% of the total $PM_{2.5}$. Sulfate 14.7% and nitrate 6.1% are the highest portions in Anions, whereas ammonia 6.7% and calcium and potassium 1 to 2% are higher in Cation. The organic matter account for 16.3% of the total mass. Unidentified portion in PM_{10} was 10.6%, which may due to volatilization of organic matter and nitrates **(Figure 2.6)**.

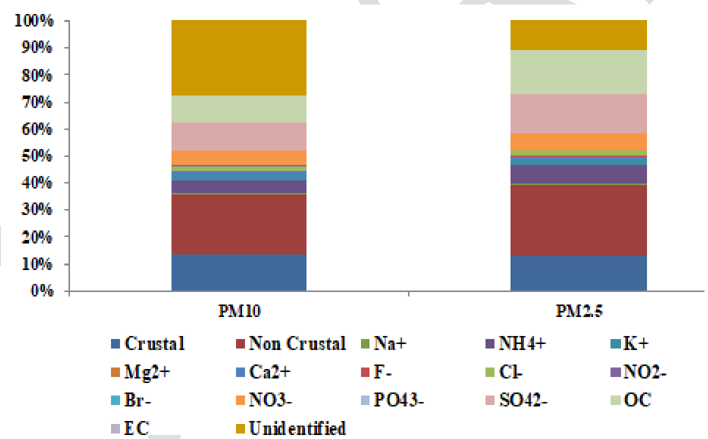


Figure 2.6 : Percent Contribution to Mass in PM_{10} and $PM_{2.5}$ at Taran Talav (Commercial /Kerb Side)

Chapter 3

Emission Inventory

Chapter 3

Emission Inventory

3.1 Nashik City Emission Inventory

As the city is overwhelming expanding and population and vehicular growth is increasing day by day. As also CPCB has listed the non-attainment of PM standards in Nashik city. The identification of pollutant loads and to prepare the strategic action for plan for controlling them is the need of the hour. Emissions inventory is the first exercise, under that identification and quantification of various sources are necessary to link them with the existing air quality levels measured at certain locations as well as predict air quality for whole region. It helps in assessing the impact of additional nearly sources in and around the region and also to evaluate the control strategies for certain emission sources. Air pollution sources are broadly categorized as area (domestic and fugitive combustion type emission sources viz. domestic, bakeries, crematoria etc.), industrial (point) sources and vehicular (line) sources. Emission inventory of different sources of air pollution has been prepared for 2 Km x 2 Km sizes for whole of Nashik city for accurately identify and quantify emissions from different sources **(Figure 3.1)**. Emission inventory has been prepared in terms of five major pollutants, viz. PM_{10}, SO_2, NOx, CO and HC.

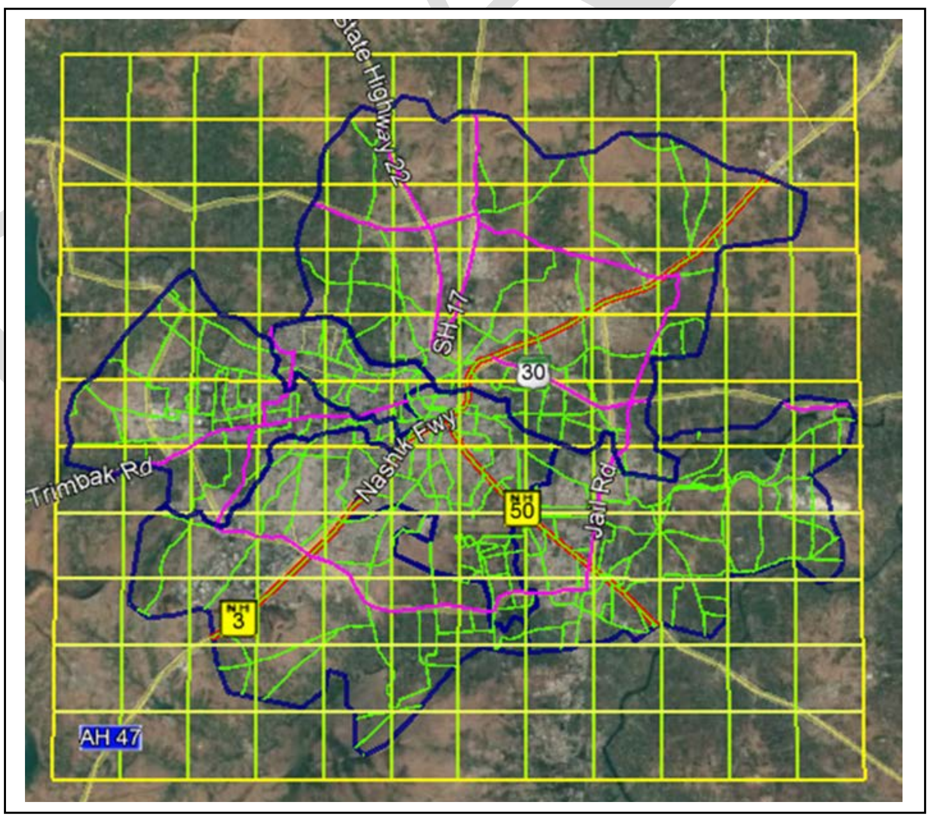


Figure 3.1 : 2 Km X 2 Km Grid Distribution Map of Nashik City

3.2 Area Source

Area sources are sources with relatively dispersed emissions over large areas and lead to proportionately constant source contributions over space but can have very large temporal changes in emissions. They are often collection of similar units within a geographic area. Though emissions from individual area sources are relatively small, collectively their emissions can be of concern - particularly where large numbers of sources are located in heavily populated areas. Area sources include the following groups, viz. bakeries, hotels/restaurants, crematories, construction activity, domestic cooking, open eat outs, paved/unpaved road dust, open burning of solid waste. In subsequent sections, these sources have been described along with the methodologies delineated for load estimation. Data on area source activities were collected from various Government and Non-Government departments/agencies. The required information was collected through interviews with the concerned authorities/ persons in respective activities. In addition, fuel consumption data and related information were obtained through primary surveys of residences, hotels, restaurants, crematoria etc in the study zones (2 Km x 2 Km area). Area source emissions are calculated by multiplying an established emissions factor referring in the CPCB 6 cities inventory report (emissions per unit of activity) by the appropriate activity or activity surrogate responsible for generating emissions.

3.2.1 Bakery

Bakery industry is mainly concentrated in the state of Andhra Pradesh, Maharashtra, West Bengal, Karnataka and Uttar Pradesh, out of which more than 60% of bakery is accounted to be unorganized. Being an essential item in urban areas, bakeries mainly operate from the midst of the city. An initial survey was arranged city wide to assess bakery related activities taking place in the jurisdictions of the city. There are 53 large and medium scale bakeries spread all across 6 divisions of the city. Considering the operation of bakeries, it was observed the fuel consumption pattern is of mixed nature. There have been reported cases of unorganized bakeries comprising small bakery units, cottage and household type manufacturing, characterized by low levels of packing and distribution mainly in neighboring areas. These small time bakeries operate mainly on outdated combustion technologies and traditional methods of manufacturing baked goods that utilize solid fuels in large quantity without any control measures for emission. Consumption of wood as fuel in bakery processes is one of the major source for PM emission loads from bakeries. Through survey it was observed, mostly bakeries operate for 12-16 hours per day and the peak season of business is in December and January month. Being a semi-urban region, the fuel consumption in the bakeries was low as compared to other metro and urban cities. About 2405 kg of wood, 93 kg of coal and 240 kg of LPG is being used on the daily basis in the bakeries of Nashik City. Data regarding bakeries in each ward was obtained from NMC, Public Health Department and ground level survey. The study area was divided into array of 2 Km x 2 Km grid to quantify the average fuel consumption and their subsequent emission across region. The number of bakeries operating division wise as NMC is given in **Table 3.1**. Based on the previous estimates it was found that most of the bakeries use about 90% firewood and remaining 10% diesel. Some of the bakeries also use electric ovens and PNG, however to a very limited extent. But the data for the same is not being accounted or managed by any regulatory body. In our study, fuel that came into survey was taken into account for emission load.

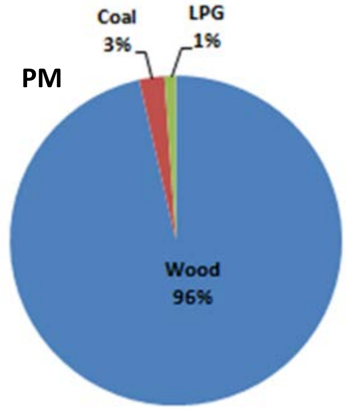
Table 3.1 : Divisions wise Wood and Diesel Consumption in Bakeries

Divisions	LPG	Wood	Coal
Satpur	20.53	1040	73.75
Nashik East	9.58	585	18.90
CIDCO	132.95	780	--
Panchvati	40.13	--	--
Nashik Road	31.87	--	--
Nashik West	3.19	--	--
Total (kg/day)	**238.25**	**2405**	**92.65**

Emission Estimations:

Emissions (kg/d) = No. of Bakeries x Fuel Consumption (kg/d) x Emission Factor
Number of registered bakeries with NMC = 53
Wood consumption in a day = 2405 kg/d
Emission factor used are listed **Annexure I**
Emission Factor for Wood Burning = 17.3 (kg/t) (PM_{10})
Emission from wood burning (PM_{10}) = 2405 x 17.3 = 43.21(kg/d)

In similar way emission for others pollutants have been estimated as given in **Table 3.2**. Out of the total PM emission load 44.82 kg/day from bakeries is mostly i.e. 96% is contributed by wood. The bakery activities in the region of Satpur (42.21%), CIDCO (30.75%), and Nashik East (23.51%) contribute the most towards the final emission loads. The lowest PM emission load is from Nashik West i.e 0.007 kg/day. 80% of NOx is from wood combustion in bakery processes of the region, where 11% is contributed from LPG consumption.



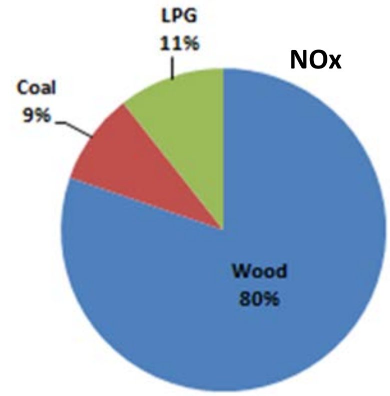


Table 3.2 : Emission Loads from Bakeries for all Divisions

Divisions	Wood (Kg/day)						
	PM_{10}	$PM_{2.5}$	SO_x	NO_x	HC	CO	CO_2
CIDCO	13.49	5.396	0.16	1.01	89.31	98.51	1326.0
Nashik East	10.29	4.116	0.12	0.77	68.14	75.16	1011.6
Nashik Road	1.43	0.572	0.02	0.11	9.45	10.42	140.2
Satpur	17.99	7.196	0.21	1.35	119.08	131.35	1768.0
Total (Kg/day)	43.21	17.284	0.50	3.25	285.97	315.44	4245.9
	LPG (Kg/day)						
CIDCO	0.28	0.28	0.05	0.24	0.01	0.03	228.14
Nashik East	0.02	0.02	0.00	0.02	0.00	0.00	16.43
Nashik Road	0.07	0.07	0.01	0.06	0.00	0.01	54.69
Nashik West	0.007	0.007	0.001	0.006	0.000	0.001	5.48
Panchvati	0.08	0.08	0.02	0.07	0.00	0.01	68.86
Satpur	0.04	0.04	0.01	0.04	0.00	0.01	35.23
Total (Kg/day)	0.50	0.50	0.10	0.43	0.02	0.06	408.83
	Coal (Kg/day)						
CIDCO	0.23	0.09	0.25	0.08	0.01	0.47	
Nashik East	0.89	0.36	0.98	0.29	0.04	1.84	
Total (Kg/day)	1.11	0.44	1.23	0.37	0.05	2.31	
	Total (Kg/day)						
CIDCO	14.00	5.77	0.46	1.33	89.33	99.01	1554.14
Nashik East	11.20	4.50	1.10	1.08	68.18	77.00	1028.03
Nashik Road	1.50	0.64	0.03	0.17	9.45	10.43	194.89
Nashik West	0.01	0.01	0.00	0.01	0.00	0.00	5.48
Panchavati	0.08	0.08	0.02	0.07	0.00	0.01	68.86
Satpur	18.03	7.24	0.22	1.39	119.08	131.36	1803.23
Total (kg/day)	**44.82**	**18.23**	**1.83**	**4.05**	**286.04**	**317.81**	**4654.63**
Total (Tons/day)	**0.045**	**0.018**	**0.002**	**0.004**	**0.286**	**0.318**	**4.655**

3.2.2 Crematoria

The fiery dissolution of the body is considered as death rite in Hindu religion**.** Existing cremation grounds of city are located along the bank of rivers or nallahs. There are total 51 sites at different locations covering an area of 27.88 Hectares of land. Burial grounds are located at different locations, specifically in old Nashik area. There are total 20 sites covering an area of 9.64 Hectares of land. These facilities seem to be inadequate considering the present and incremental future population of the city. There are 25 registered wood-based crematoriums in the NMC jurisdiction. As per the assumption from previous studies and in consultation with NMC the average wood requirement for burning a dead body is about 300 Kg and additives like kerosene, cow-dung or camphor. In this study, emission from wood and kerosene is considered. Emission from this category of Area source release major pollutants like PM_{10}, CO, HC, SO_2, and NO_x**.** Data regarding number of death crematmated on wood in each ward was obtained from NMC's Public Health Department as well as wood and kerosene consumption is reported in **Table 3.3.**

Table 3.3 : Division Wise Distribution of Registered Hindu Deaths and Respective Fuel Consumption (2016-17)

Divisions	Registered Deaths (2016-2017)	Wood Consumption (TPD)	Kerosene Consumption (kg/day)
CIDCO	2842	2.3	38.93
Nashik East	2190	1.8	30.00
Nashik Road	1076	0.9	14.74
Nashik West	97	0.08	1.33
Panchavati	2488	2.0	34.08
Satpur	485	0.39	6.64
Total	**9178**	**7.5**	**125.73**

Emission Estimations:

Emission (TSP) =No. of Hindu Death /yr * wood required per body (kg) * emission factor
And Number of Hindu Death /yr* fuel used (kerosene -liters) * emission factor
Total Number of registered deaths =9178 (deaths/yr)

Emission factor for wood burning, kerosene and electric crematoria are listed in **Annexure I.**
Emission Factor (PM_{10}) Wood Consumption = 17.3 (kg/t)
Emission Factor (SPM) Kerosene = 1.95 (kg/t)
Emission Factor (PM_{10}) Kerosene = 0.61 (kg/t)

Emission (PM_{10}) from wood burning = 9178 (deaths/yr) * 0.3 (t) * 17.3 (kg/t) = 47.66 (ton/yr)

[Average kerosene consumption /body =5 liters*0.81 (density in kg/l) = 4.05 (kg) =0.00405 (T)]

Emission (PM) from Kerosene burning = 9178 (deaths/yr) * 0.00405 (T) * 1.95 (SPM) (kg/t) + 0.61 (PM) (kg/t) = 9.1(ton/year)

In similar way division-specific contribution from each zone was calculated for different pollutant and is presented in **Table 3.4.** Along with emissions from fuel consumptions, body burn emissions are also calculated.

The PM, NO_x and SO_x emission load from fuel consumption at crematorium of Nashik City is 130.6, 17.8 and 3.3 kg/day, respectively. The emission load from CIDCO and Panchavati region is highest, contributing 40.4 kg/day and 35.4 kg/day of PM, respectively. An initial survey revealed that none of the crematorium had any emission control measures for the pyres.

Issues

- Hindu cremation processes vary substantially due to the quantity and type of wood used and type of pyres prepared which need proper attention.

Table 3.4 : Emission Loads from Crematoria for all Divisions

Divisions	Wood (kg/day)							Kerosene (kg/day)					
	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	HC	CO_2	PM_{10}	$PM_{2.5}$	SO_2	NO_2	CO	HC
CIDCO	40.4	27.5	0.5	3.0	295.0	267.5	3971.0	0.04	0.03	0.13	0.08	2.0	0.60
Nashik East	31.1	21.2	0.4	2.3	227.3	206.1	3060.0	0.03	0.02	0.10	0.06	1.5	0.47
Nashik Road	15.3	10.4	0.2	1.1	111.7	101.3	1503.5	0.01	0.01	0.05	0.03	0.7	0.23
Nashik West	1.4	0.9	0.0	0.1	10.1	9.1	135.5	0.00	0.00	0.00	0.00	0.1	0.02
Panchavati	35.4	24.1	0.4	2.7	258.3	234.1	3476.4	0.03	0.02	0.11	0.07	1.7	0.53
Satpur	6.9	4.7	0.1	0.5	50.3	45.6	677.7	0.01	0.00	0.02	0.01	0.3	0.10
Total	**130.5**	**88.7**	**1.5**	**9.8**	**952.8**	**863.7**	**12824.1**	**0.12**	**0.08**	**0.41**	**0.26**	**6.4**	**1.95**

Divisions	Body Burn (kg/day)					
	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	NVOC
CIDCO	0.0002	0.0001	0.42	2.40	1.10	0.101222
Nashik East	0.0002	0.0001	0.33	1.85	0.85	0.078
Nashik Road	0.0001	0.0001	0.16	0.91	0.42	0.038323
Nashik West	0.000007	0.000005	0.01	0.08	0.04	0.003455
Panchavati	0.0002	0.0001	0.37	2.10	0.96	0.088614
Satpur	0.0000	0.0000	0.07	0.41	0.19	0.017274
Total	**0.00071**	**0.00041**	**1.36**	**7.75**	**3.56**	**0.33**

Table 3.4 (Contd..) : Emission Loads from Crematoria for all Divisions

Divisions	Total Emission (kg/day)						
	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	HC	NVOC
CIDCO	40.4	27.5	1.0	5.5	298.1	268.1	0.101
Nashik East	31.2	21.2	0.784	4.2	229.7	206.6	0.078
Nashik Road	15.3	10.4	0.385	2.1	112.9	101.5	0.038
Nashik West	1.4	0.9	0.034	0.188	10.2	9.1	0.003
Panchavati	35.4	24.1	0.891	4.8	261.0	234.7	0.089
Satpur	6.9	4.7	0.173	0.941	50.9	45.7	0.017
Total (kg/day)	**130.6**	**88.8**	**3.3**	**17.8**	**962.7**	**865.7**	**0.327**
Total (Tons/day)	**0.131**	**0.089**	**0.003**	**0.018**	**0.963**	**0.866**	**0.0003**

3.2.3 Open Eat outs

In India, the national policy for urban street vendors /hawker notes that street vendors constitute approximate 2% of the population of a metropolis, while the number in region in Nashik is low compared to Mumbai, Pune or Navi Mumbai. This informal sector even though being small in size, contribute emission load on large area because of the variable fuel consumption pattern for their operations and absence of any control measures for these emissions. On the basis of primary survey, the fuel preference for open eat out in Nashik is LPG, followed by diesel and coal. The average consumption of fuel per day is approximately 1.7 ton/day of LPG, 19.3 kg/day of kerosene and 40 kg/day of coal in open eat out activities. Average operating hours of street vendors is 12 hours. Data regarding number of street vendors is not available since it is considered as illegal operation. Therefore, a questionnaire survey was carried out to collect necessary data for the estimation of emission load from this source. These numbers have been verified by visiting representative areas where these eat outs are prevalent. Distribution of open eats outs and their respective fuel consumption is presented in **Table 3.5**.

Assumption

- Fuel use pattern was estimated on the basis of primary survey which involved consultations with operators, municipal authorities and vendors.

Table 3.5 : Divisions wise Distribution of Open Eat outs and Their Fuel Consumption

Divisions	No of Open Eat-outs	Fuel Consumption (kg/day)		
		LPG	Kerosene	Coal
CIDCO	108	271.3	9.5	32
Nashik Road	64	215.47	8	--
Nashik West	102	301.72	2	--
Satpur	70	136.07	--	8
Panchavati	172	514.4	--	--
Nashik East	104	241.63	--	--
Total	**620**	**1698.68**	**19.5**	**40**

Emission Estimates

Total emissions = Emissions from kerosene burning + LPG burning + Coal burning

Emission from kerosene burning (PM) per day
= Number of street vendors operating on kerosene x fuel consumption per day x emission factor
= 19.5/ 1000 x 0.61x0.06 =0.0006 kg/d
Emission from LPG burning (PM) per day
= Number of street vendors operating on LPG x fuel consumption per day x emission factor
= 1698.68/ 1000 x 2.10 = 1.15 kg/d
Emission from Coal burning (PM) per day
= Number of street vendors operating on Coal x fuel consumption per day x emission factor
= 40 /1000 x 20 = 0.48 kg/d

Ward-specific contribution of the pollutant emission load is represented in **Table 3.6.**

The number of illegal and unorganized open eat outs is concentrated in region adjoining to industrial and commercial clusters. Accounting the commercial and mixed activities in and around CIDCO and Panchavati, the likelihood of floating population is high. Thus, the emission load from these wards is maximum and lowest from Nashik Road. PM emission load is mainly contributed by LPG 71% and, whereas NOx is contributed by LPG 94%.

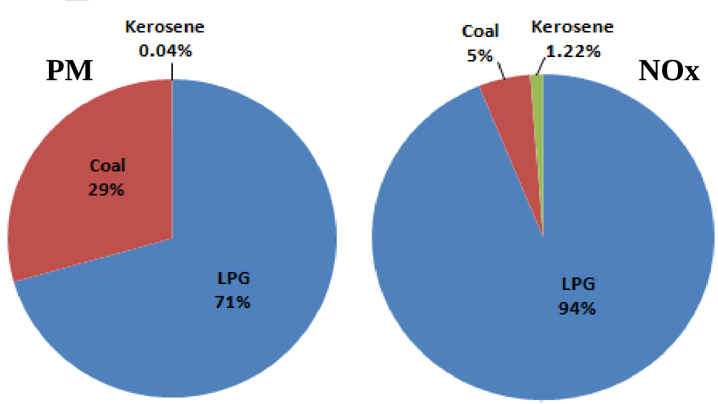


Table 3.6 : Emission Loads from Open Eat outs for all Divisions

Divisions	LPG (kg/day)						
	PM_{10}	$PM_{2.5}$	SO_2	NO_x	HC	CO	CO_2
CIDCO	0.18	0.18	0.11	0.68	0.02	0.07	465.1
Nashik East	0.16	0.16	0.10	0.60	0.02	0.06	414.6
Nashik Road	0.15	0.15	0.09	0.54	0.02	0.05	369.7
Nashik West	0.21	0.21	0.12	0.75	0.02	0.08	517.7
Panchavati	0.35	0.35	0.21	1.29	0.04	0.13	882.7
Satpur	0.09	0.09	0.05	0.34	0.01	0.03	233.5
Total (Kg/day)	**1.14**	**1.14**	**0.67**	**4.20**	**0.12**	**0.42**	**2883.4**
	Kerosene (kg/day)						
CIDCO	0.001	0.013	0.03	0.02	0.15	0.48	
Nashik Road	0.001	0.011	0.03	0.02	0.12	0.41	
Nashik West	0.000	0.003	0.01	0.00	0.03	0.10	
Total (Kg/day)	**0.002**	**0.027**	**0.06**	**0.04**	**0.30**	**0.99**	
	Coal (kg/day)						
CIDCO	1.61	0.02	0.43	0.13	0.02	0.80	
Satpur	0.40	0.00	0.11	0.03	0.00	0.20	
Total (Kg/day)	**2.01**	**0.02**	**0.54**	**0.16**	**0.02**	**1.00**	
	Total (kg/day)						
CIDCO	1.79	0.22	0.57	0.82	0.00	1.35	465.09
Nashik EAST	0.16	0.16	0.10	0.60	0.02	0.06	414.64
Nashik ROAD	0.15	0.16	0.11	0.56	0.14	0.46	369.74
Nashik WEST	0.21	0.21	0.13	0.76	0.05	0.18	517.75
Panchavati	0.35	0.35	0.21	1.29	0.04	0.13	882.71
Satpur	0.49	0.09	0.16	0.37	0.01	0.23	233.49
Total (Kg/day)	**3.15**	**1.19**	**1.28**	**4.40**	**0.26**	**2.41**	**2883.42**
Total (Tons/day)	**0.003**	**0.001**	**0.001**	**0.004**	**0.0003**	**0.002**	**2.8**

** Kerosene and Coal some zones are not estimated*

3.2.4 Hotel & Restaurants

There are around 400 hotels registered with the NMC License department. Ward-wise break up is presented in **Table 3.7**. It was observed that the large number of tea stalls/snack corners/fast food centers, which have fuel consumption almost same as a hotel, could be more than twice the registered number and remains unaccountable. In addition, institutions and organizations have their own canteen/hotels within their premises and their fuel consumption patterns are unknown. Hotels and Restaurants use LPG cylinders and coal for their operation. LPG commercial cylinders of 19 kg are used for cooking and coal is used in the tandoor bhattis. The tandoors are operated mostly in unsafe confined or open areas without any proper ventilation or control measures. The primary survey of Hotels and Restaurants gave an average LPG consumption of 2-5 cylinder for 3-7 days, coal consumption of 5 kg per hotel/restaurant was considered for the estimation of emission load.

The total LPG consumption of hotels in the city is around 2140.3 kg/day and that of coal was around 1.4 ton/day.

Table 3.7 : Division wise Number of Hotels & Restaurants and their Fuel Consumption: 2016-17 (Registered under NMC)

Divisions	No of Hotels	LPG (Kg/day)	Coal (Kg/day)
CIDCO	81	464.3	405
Nashik East	45	313.5	225
Nashik Road	12	90.67	60
Nashik West	104	494	7
Panchawati	75	363.5	375
Satpur	75	414.2	365
TOTAL	**392**	**2140.3**	**1437**

Emission Estimations

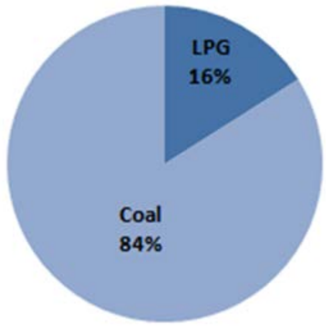
- Emission Load from LPG
  Since LPG burning doesn't comprise of coarse particles, an assumption that only $PM_{2.5}$ particles are present in the LPG emissions is made and considered as PM.
  Total emissions ($PM_{2.5}$) due to LPG burning in Hotels
  = Number of Hotels x LPG consumption (Tons/day) x Emission Factor (Kg/MT) **(Annexure I)**
  Total $PM_{2.5}$ emissions due to LPG burning in Hotels
  = 2140.3 x 2.1 Kg/MT = 3.50 Kg/Day
  However, for calculation purposes, it has been referred to as PM_{10}.
- Emission Load from Coal
  Total emissions (PM) due to coal burning in Hotels
  = No. of Hotels x Coal consumption (Tons/day) x Emission Factor (Kg/MT)
  = 392 x 5/1000 Tons/day x 20 kg/MT = 23.5 Kg/Day

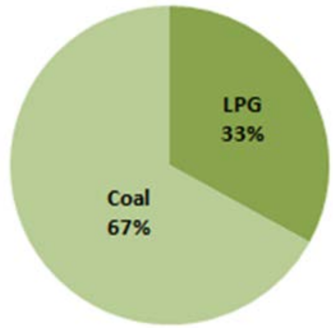
Zone specific contribution of the pollutant emission load is given in **Table 3.8.** The number of hotels in the region is less as compared to any urban setting. Being a holistic as well tourist spot, there has been increase in the number of hotels being registered in the region. Considering commercial and industrial zone of the city, most hotels are located in the region of Nashil West, CIDCO, Panchavati and Satpur. 392 hotels of Nashik city emit 27.9 kg/day of PM load and 11.6 kg/day of NO_x within the jurisdiction of the city. The major contributor is coal which gives 84% of PM and 67% of NOx.

Issues

- Domestic cylinders are also consumed in the commercial sector illegally for which data was not easily available.

PM





NOx

Table 3.8 : Emission Loads from Hotels & Restaurants for all Divisions

Divisions	LPG (kg/day)						
	PM_{10}	$PM_{2.5}$	SO_2	NO_x	HC	CO	CO_2
CIDCO	0.98	0.98	0.19	0.84	0.03	0.12	796.7
Nashik East	0.66	0.66	0.13	0.56	0.02	0.08	538.0
Nashik Road	0.19	0.19	0.04	0.16	0.01	0.02	155.6
Nashik West	1.04	1.04	0.20	0.89	0.04	0.12	847.7
Panchawati	0.76	0.76	0.15	0.65	0.03	0.09	623.8
Satpur	0.85	0.85	0.16	0.73	0.03	0.10	697.2
Total (Kg/day)	**4.48**	**4.48**	**0.85**	**3.84**	**0.15**	**0.54**	**3659.0**
	Coal (kg/day)						
CIDCO	4.86	3.30	5.39	1.62	0.20	10.09	
Nashik East	2.70	1.84	2.99	0.90	0.11	5.61	
Nashik Road	0.72	0.49	0.80	0.24	0.03	1.50	
Nashik West	6.26	4.26	6.94	2.08	0.26	13.01	
Panchawati	4.50	3.06	4.99	1.50	0.19	9.35	
Satpur	4.38	2.98	4.85	1.46	0.18	9.10	
Total (Kg/day)	**23.42**	**15.93**	**25.96**	**7.79**	**0.98**	**48.64**	
	Total (kg/day)						
CIDCO	5.84	4.28	5.57	2.45	0.24	10.21	796.7
Nashik East	3.36	2.49	3.12	1.46	0.14	5.69	538.0
Nashik Road	0.91	0.68	0.83	0.40	0.04	1.52	155.6
Nashik West	7.30	5.30	7.14	2.97	0.30	13.13	847.7
Panchawati	5.26	3.82	5.13	2.15	0.21	9.44	623.8
Satpur	5.23	3.83	5.02	2.19	0.21	9.20	697.2
Total (Kg/day)	**27.90**	**20.41**	**26.81**	**11.63**	**1.13**	**49.18**	**3659.0**
Total (Tons/day)	**0.03**	**0.02**	**0.03**	**0.01**	**0.001**	**0.05**	**3.7**

3.2.5 Domestic Sector

The Nashik City jurisdiction was categorized into 6 divisions for the study. Attributing to the demography of the region and standard of living of the population, the fuel consumption pattern is varied at individual level. As non-slum population is more organized considering their source of income, their primary domestic fuel is LPG. Due to the recent policy change from the government, the consumption of LPG has grown in slum areas. Along with LPG, slum population use locally available resources such as wood, coal, kerosene etc. The recent infrastructural changes brought by the oil companies, has made PNG an easily available domestic fuel in urban areas. This type of infrastructure is still not in place in these regions.

Around 15% of total population is found in 42742 household of slum region in Nashik City **(Table 3.9).** Panchvati has the highest number of slums i.e. 24.30% of the total slum population. Slums are mainly concentrated in the core of the city, along the banks of river Godavari and Nasardi, in canal alignment area and along the railway track. The slums are mostly built on private and government lands. In the year 2011, there were 131 slums consisting of 35,597 hutments with population of about 1,79,225 souls. This population constitutes near about 14.45% of the total population of the corporation area. **Table 3.10** shows the highest non slum population of 426510 is found in the region of CIDCO. The average LPG consumption in slums of the Nashik City for the day was estimated to be around 179.26 tons.

Table 3.9 : Division wise Slum Distribution

Divisions	Slums Population	% of total Slum Pop.	Area Sq. M	Density of Population	Number of Hutments	% of Hutments
Nashik East	32395	15.10	2,31,713	14	6,479	15.16
Nashik West	18520	8.60	1,08,745	17	3,686	8.62
Panchavati	52193	24.30	4,60,127	11	10,390	21.31
Nashik Road	41554	19.30	5,47,520	08	8,150	19.07
CIDCO	31260	14.30	4,58,610	07	6,252	14.63
Satpur	38847	18.60	3,46,576	11	7,785	18.21
Total	**214769**	**100**	21,53,291	**10**	42,742	**100**

***Source – NMC ESR Report 2016-17*

Based on the survey, it was observed that the consumption of kerosene, coal or wood as secondary fuel is prevalent in slum population. As per the inventory of the DSO office, Nashik, the monthly consumption of kerosene is about 12000 liters for 27172 eligible ration holders of the region. The wood and coal consumption as fuel in the region were estimated to be around 26.58 ton/day and 3.85 ton/day, respectively. The number of members in a slum household and non-slum household is assumed to be 6 and 5 respectively. Ward wise fuel consumption viz. LPG -Cylinder consumption and Slum and Non-slum kerosene consumption is presented in **Table 3.10**. Ward wise LPG cylinders consumption data is obtained from State Level Oil Coordination Committee (SLOC).

Table 3.10 : Division wise Fuel Consumption in Domestic Sector

Divisions	No of Slums	Slum Population	Non slum Population	LPG ton/day	Wood ton/day	Coal ton/day
CIDCO	6298	31490	426510	56.90	7.71	0.57
Nashik East	6928	34800	153714	22.38	3.48	0.62
Nashik Road	7898	40204	228723	32.33	4.81	0.71
Nashik West	3444	17315	174290	23.60	3.28	0.31
Panchavati	10389	52113	188313	28.18	4.55	0.94
Satpur	7785	38847	99734	15.84	2.75	0.70
Total	**42742**	**214769**	**1271284**	**179.3**	**26.58**	**3.85**

**Kerosene Consumption – 12000 lit/month*

Emission Estimation

- Emission Load from LPG
  Total emissions (PM) from LPG burning for domestic cooking
  = Number of LPG cylinders consumed x Capacity of the cylinder (14.6 Kg)
  x Em. Factor (Kg/MT) = 179.3 x 1000 x 2.1/1000 kg/d= 376.44 Kg/Day

  Census data was obtained from Census 2001, Percentage of Slum population from each ward is calculated according to *(Dr.D.P.Singh, Slum Population in Mumbai: Part I, Population – ENVIS Centre IIPS, Vol.3, No.1, March, 2006)*

  Total consumption of Kerosene in city = 326.86 kg/day

  Total emissions (PM) from kerosene burning per day in a household = number of households x kerosene consumption (tons/day) x emission factor (Kg/MT)
  Total emissions (PM) from kerosene burning per day in a slum household
  = 0.326 x 0.61 g/Kg = 0.199 Kg/day

All $PM_{2.5}$ emissions are estimated to be in terms of PM_{10}. Domestic emission load from LPG, wood, coal and kerosene with respect to their pollutants have been estimated and their zone wise distribution is presented in **Table 3.11.**

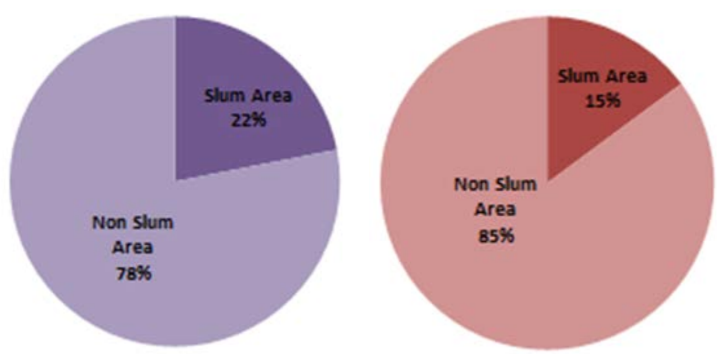


Table 3.11 : Emission Loads from Domestic Sector (Slum & Non Slums) for all Divisions

Sector	LPG Slum (Kg/day)						
	PM_{10}	$PM_{2.5}$	SO_2	NO_2	HC	CO	CO_2
CIDCO	5.3	5.3	1	4.6	0.2	0.6	4348.2
Nashik East	5.9	5.9	1.1	5	0.2	0.7	4783.1
Nashik Road	6.7	6.7	1.3	5.7	0.2	0.8	5452.8
NASHIK West	2.9	2.9	0.6	2.5	0.1	0.3	2377.8
Panchavati	8.8	8.8	1.7	7.5	0.3	1.1	7172.6
Satpur	6.6	6.6	1.3	5.6	0.2	0.8	5374.8
Total (Kg/d)	**36.2**	**36.2**	**7**	**30.9**	**1.2**	**4.3**	**29509.3**
	Coal Slum (Kg/day)						
CIDCO	6.8	4.6	7.5	2.3	0.3	14.1	
Nashik East	7.5	5.1	8.3	2.5	0.3	15.5	
Nashik Road	8.5	5.8	9.5	2.8	0.4	17.7	
NASHIK West	3.7	2.5	4.1	1.2	0.2	7.7	
Panchavati	11.2	7.6	12.4	3.7	0.5	23.3	
Satpur	8.4	5.7	9.3	2.8	0.4	17.5	
Total (Kg/d)	**46.1**	**31.3**	**51.1**	**15.3**	**2.1**	**95.8**	
	Kerosene Slum (Kg/day)						
CIDCO	0.03	0.02	0.20	0.10	0.90	3.00	
Nashik East	0.03	0.02	0.20	0.10	1.00	3.30	
Nashik Road	0.04	0.03	0.20	0.20	1.10	3.70	
NASHIK West	0.02	0.01	0.10	0.10	0.50	1.60	
Panchavati	0.05	0.03	0.30	0.20	1.50	4.90	
Satpur	0.04	0.03	0.20	0.10	1.10	3.70	
Total (Kg/d)	**0.20**	**0.14**	**1.20**	**0.80**	**6.10**	**20.20**	
	Wood Slum (Kg/day)						
CIDCO	16.3	11.1	0.2	1.2	108.2	119.3	1606.0
Nashik East	18.0	12.2	0.2	1.4	119.0	131.3	1766.6
Nashik Road	20.5	13.9	0.2	1.5	135.6	149.6	2014.0
NASHIK West	8.9	6.1	0.1	0.7	59.2	65.2	878.2
Panchavati	27.0	18.3	0.3	2.0	178.4	196.8	2649.2
Satpur	20.2	13.7	0.2	1.5	133.7	147.5	1985.2
Total (Kg/d)	**110.9**	**75.3**	**1.2**	**8.3**	**734.1**	**809.7**	**10899.2**
	Total Domestic Sector : Slum - (Kg/day)						
CIDCO	28.5	21.1	8.9	8.2	109.5	137.1	5954.2
Nashik East	31.3	23.2	9.8	9.0	120.5	150.8	6549.8
Nashik Road	35.7	26.4	11.2	10.2	137.4	171.9	7466.8
NASHIK West	15.6	11.5	4.9	4.5	59.9	75.0	3256.0
Panchavati	47.0	34.8	14.7	13.5	180.7	226.1	9821.8
Satpur	35.2	26.1	11.0	10.1	135.4	169.4	7360.0
Total (Kg/d)	**193.3**	**143.1**	**60.5**	**55.5**	**743.4**	**930.3**	**40408.6**

Table 3.11 (Contd..) : Emission Loads from Domestic Sector (Slum & Non Slums) for all Divisions

Sector	LPG Non Slum (Kg/day)						
	PM_{10}	$PM_{2.5}$	SO_2	NO_2	HC	CO	CO_2
CIDCO	114.2	114.2	21.8	97.9	3.9	13.7	93299.5
Nashik EAST	41.2	41.2	7.8	35.3	1.4	4.9	33625.1
Nashik ROAD	61.2	61.2	11.7	52.5	2.1	7.4	50033.4
NASHIK WEST	46.7	46.7	8.9	40.0	1.6	5.6	38126.1
Panchavati	50.4	50.4	9.6	43.2	1.7	6.1	41193.7
Satpur	26.7	26.7	5.1	22.9	0.9	3.2	21816.9
Total (Kg/d)	**340.3**	**340.3**	**64.8**	**291.7**	**11.7**	**40.8**	**278094.6**
	Wood Non Slum (Kg/day)						
CIDCO	117.0	79.6	1.4	8.8	774.7	854.5	11501.4
Nashik EAST	42.2	28.7	0.5	3.2	279.2	308.0	4145.1
Nashik ROAD	62.8	42.7	0.7	4.7	415.4	458.2	6167.8
NASHIK WEST	47.8	32.5	0.6	3.6	316.6	349.2	4700.0
Panchavati	51.7	35.1	0.6	3.9	342.0	377.3	5078.1
Satpur	27.4	18.6	0.3	2.1	181.1	199.8	2689.5
Total (Kg/d)	**348.9**	**237.2**	**4.0**	**26.2**	**2309.0**	**2546.9**	**34281.8**
	Total Domestic Sector : Non Slum - (Kg/day)						
CIDCO	231.2	193.8	23.1	106.7	778.6	868.2	104800.9
Nashik EAST	83.3	69.8	8.3	38.4	280.6	312.9	37770.2
Nashik ROAD	124.0	103.9	12.4	57.2	417.5	465.6	56201.2
NASHIK WEST	94.5	79.2	9.4	43.6	318.2	354.8	42826.1
Panchavati	102.1	85.6	10.2	47.1	343.8	383.3	46271.8
Satpur	54.1	45.3	5.4	24.9	182.1	203.0	24506.4
Total (Kg/d)	**689.2**	**577.6**	**68.9**	**317.9**	**2320.7**	**2587.8**	**312376.4**
	Total Domestic Sector : Slum +Non Slum - (Kg/day)						
CIDCO	259.6	214.8	32.0	114.9	888.2	1005.2	110755.1
Nashik EAST	114.8	93.1	18.1	47.4	401.1	463.7	44319.9
Nashik ROAD	159.7	130.3	23.6	67.4	554.8	637.4	63668.0
NASHIK WEST	110.0	90.7	14.3	48.1	378.2	429.6	46082.1
Panchavati	149.1	120.3	24.9	60.5	524.5	609.4	56093.6
Satpur	89.3	71.3	16.4	34.9	317.5	372.5	31866.4
Total (Kg/d)	**882.6**	**720.5**	**129.4**	**373.2**	**3064.1**	**3517.8**	**352784.9**
Total (Tons/d)	**0.9**	**0.7**	**0.1**	**0.4**	**3.1**	**3.5**	**352.8**

78% of PM emission load is contributed by non-slum population, while remaining 22% is emitted from domestic fuel combustion in slum areas. Region wise, domestic sector maximum emission of PM is from CIDCO (29.41%) area. The final emission load of PM from Domestic Sector is calculated to be 0.9 tons/day and that NO_X is 0.4 ton/day.

3.2.6 Open Burning

It is estimated that solid waste generated in small, medium and large cities and towns in India is about 0.1 kg, 0.3-0.4 kg and 0.5 kg per capita per day respectively. Rapid urbanization combined with development will double the solid waste generation. Semi urban centers generate disproportionately high mixed waste, sometimes creating unrest around the way they are disposed. Most of the waste is sent to landfills, or worse, to open dumps, raising concerns about air pollution, social unrest, and impact on poverty and so on. Open burning is one of the major contributors in Area Sources. Open burning is an illegal method of burning solid waste; materials commonly disposed of in this manner include municipal waste, auto body components, wood refuse, small scale industrial refuse and leaves. Owning to Kumbhela that take place every 12 years in the city, the Municipal Corporation has operational SWM system in place. The Nashik Municipal Corporation is collecting around 600 MT of municipal solid waste per day. All the waste from different areas are collected and transported to MSW facility at Pathardi which is 15 Km from core area. The bio hazardous waste generated by hospitals in the city is treated at 1000^o C in an incinerating plant located near Kannamwar Bridge (near core area). With better collection and transportation measures, the collection efficiency should increase. It is estimated that the projected quantity of municipal solid waste will be 1200 TPD by the year 2031. Analysis of city waste carried revealed 47% easily compactable materials, 31% nonbio-degradable and 22% other waste. These, last 2 components have become a major cause of concern. These materials are a negative contributor to the processing plant efficiency and rapidly exhaust available land for land filling. Mounting heaps of high volume of low density waste is common scene around each compost plant. As the open burning cases often get unreported and data for the same is missing, it was assumed that about 4% of the total solid waste is burnt in the wards containing solid waste landfill sites as given in **Table 3.12**. The quantity of ward wise solid waste generated was obtained from NMC, solid waste management division.

Table 3.12 : Ward wise MSW Generation and Amount of Open Burning Cases

Wards	MSW in Ton	Open Burning
CIDCO	110.30	4.28
Nashik East	106.90	3.19
Nashik Road	102.40	4.10
Nashik West	79.67	4.69
Panchavati	117.23	4.41
Satpur	67.63	2.71
Total (MTD)	**584.13**	**23.37**

Emission Estimation

Total emissions (PM) from open burning of solid waste
= Amount of solid waste generated (tons) x percentage of solid waste burnt x emission factor (Kg/MT) = [584.13 (tons) x 4% (non dumping site)] x 8 (Kg/MT) = **23.37 Kg/Day.**

In similar way emission for others pollutants have been estimated and their ward wise distribution is presented in **Table 3.13**. It was estimated that the highest emission load was contributed mainly from Panchavti, CIDCO and Nashik East areas. Mainly being industrial area and less populated, contribution of Satpur towards final emission load across all categories is lowest. Total 186.9 kg/day of PM load is released within the city limits from open burning of waste in wards and landfill site. Contribution of CO emission load is highest across all wards towards final emission load, followed by HC.

Table 3.13 : Ward Emission Load from Open Burning (kg/d)

Wards	PM_{10}	$PM_{2.5}$	SOx	NOx	HC	CO
CIDCO	35.3	24.0	2.2	13.2	94.9	185.3
Nashik East	34.2	23.3	2.1	12.8	91.9	179.6
Nashik Road	32.8	22.3	2.0	12.3	88.1	172.0
Nashik West	25.5	17.3	1.6	9.6	68.5	133.8
Panchavati	37.5	25.5	2.3	14.1	100.8	197.0
Satpur	21.6	14.7	1.4	8.1	58.2	113.6
Total (Kg/d)	**186.9**	**127.1**	**11.7**	**70.1**	**502.4**	**981.3**
Total (Tons/d)	**0.19**	**0.13**	**0.01**	**0.07**	**0.50**	**0.98**

Issues: Refuse burning refers to common burning of street litter and leaves, although little is known about the magnitude of the practice. No documented data on rate of burning, area of dump, unauthorized activity of the rag pickers are available. Landfill sites burning do not come under any of the seven sampling sites representing 2 Km x 2 Km area.

3.2.7 Road Dust Resuspension

Total constructed road length within corporation area is 1610.14 Kms, out of which cement concrete roads are 205.57 Kms, asphalted 1173.20 Kms and metalled 114.75 Kms**.** 96% of the total road was considered as paved, while remaining was accounted as unpaved**.** As motor vehicle moves over road surface, it leads to resuspension of dust from unpaved roads or settled dust from the paved surface by the turbulent wake of the vehicle and emitted as particulate matter. Emissions are estimated as a function of the silt loading of the paved surface and mean weight of the vehicles traveling over the surface. Data source such as road length, vehicle km traveled and depot, truck terminal was obtained from NMRDA, NMC and RTO, Nashik and primary survey of some roads for vehicle counting.

Major portion of this constitute the vehicle population in city. It is observed that increase in the vehicle population in every year is remarkable.

- **Emission Estimates for Paved Road Dust**

Vehicle Weight –Nashik*

Vehicle Count 2017		**%Vehicle Count (A)**	**Avg.Weight (kg) (B)**	**Veh. Weight by % (A*B) (kg)**
2 W	179370	0.33	175	58.2
3 W	60211	0.11	450	50.3
HDDV	143593	0.27	20000	5326.8
Cars	155957	0.28	1425	412.2
Total	**539131**			**5.8**

** Strengthening Environmental Management at the State Level (Cluster) Component E- Strengthening Environmental Management at West Bengal Pollution Control Board, TA No. 3423-IND, Asian Development Bank, Nov. 2005*

Annual /Long Term Avg. E. Factor E = (k (sL/2)^0.65 (W/3)1.5-C) (1-P/4N)
E= particulate emission factor (having units matching the units of k)
k= particle size multiplier for particle size range and units of interest
sL= road surface silt loading (grams per square meter) (g/m^2)
W= average weight (tons) of the vehicles traveling on the road
P= No. of wet days with at least 0.254 mm of precipitation during avg. period
C= Break and tire wear correction ($PM_{2.5}$=0.1005, PM_{10}=0.1317)
N = No. of days in averaging period (365 /year, 30/monthly, 91/seasonal);
Values of k (g/vkt) PM2.5 -1.1, PM10-4.6

EF (PM10) = (k (sL/2)0.65 (W/3)1.5-C) (1-P/4N)
= (4.6*((0.531/2)^0.65)*((5.8/3)^1.5)-0.1317)*((1-120/(4*365)))= **1.936 g/vkt**

EF (PM2.5) = (k (sL/2)0.65 (W/3)1.5-C) (1-P/4N)
= =(1.1*((0.531/2)^0.65)*((5.8/3)^1.5)-0.1005)*((1-120/(4*365))) **= 0.399 g/vkt**

For VKT – calculate: lb/vmt to gms/vkt =0.98 (VKT * 0.98)
VKT from all shifts * PM2.5 (EF) AND VKT from all shifts * PM10 (EF) = Emission load for paved Road Dust

Emission Estimation for Unpaved Dust

Annual /Long Term Avg. E. Factor, E = {([k (s/12)^a (S/30) ^d] /(m/0.5) ^c-C)} *(365-P)/ 365 E = size specific emission factor, (lb/vmt),
s = surface material silt content (%),
m= surface material moisture content (%),
S= mean vehicle speed (mph);
k = particle size multiplier (lb/vmt),
P= No. of wet days with at least 0.254 mm of precipitation during avg. period
C= Break and tire wear correction (PM2.5=0.00036, PM10=0.00047) - lb/VMT
Public Roads- Constant k (lb/vmt) - PM2.5= 0.27, PM10=1.8;
a. PM2.5=1, PM10=1, b. PM2.5=0.2, PM10=0.2; c. PM2.5=0.5, PM10=0.5

EF (PM_{10}) = {([k (s/12)a (S/30)d] /(m/0.5)c-C)} *(365-P)/ 365
=(((1.8*(18.4/12)^1*(12.5/30)^0.5)/(6.65/0.5)^0.2-0.00047))*(365-120)/365
0.712384 lb/vmt = **200.821 g/vkt**

EF ($PM_{2.5}$) = {([k (s/12)^a (S/30) ^d] /(m/0.5) ^c-C)} *(365-P)/ 365
=(((0.27*(18.4/12)^1*(12.5/30)^0.5)/(6.65/0.5)^0.2-0.00036))*(365-120)/365
0.106663 lb/vmt = **30.06 g/vkt**

Emission Load

- Total **Paved** Dust Emission Load for Whole City =
  PM_{10}= 2805.8 Kg/d and $PM_{2.5}$= 579.2 Kg/d
- Total **Unpaved** Dust Emission Load for Whole City =
  PM_{10}= 12125.9 Kg/d and $PM_{2.5}$ = 1815.6 kg/d

Site-specific contribution of the pollutant emission load is given in **Table 3.14.**

Table 3.14 : Ward wise Emission Load from Paved and Unpaved Road Dust

Divisions	Paved Road (kg/day)		Unpaved Road (kg/day)	
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
CIDCO	128.4	622.2	402.6	2689.2
Nashik East	71.4	345.8	223.8	1494.7
Nashik Road	42.2	204.3	132.2	882.9
Nashik West	69.2	335.2	216.9	1448.6
Panchavati	221.2	1071.5	693.3	4630.7
Satpur	46.8	226.7	146.7	979.9
Total (Kg/day)	**579.2**	**2805.8**	**1815.6**	**12125.9**
Total (Tons/day)	**0.58**	**2.81**	**1.82**	**12.13**

* Values expressed as kg/d

PM emission load is highest at Panchavti and CIDCO, attributing to the highest VKT in these regions. Even though the emission load from Nashik Road ward is lowest, this region is still not developed as compared to other regions. Uncertainty with respect to all sites across whole city will be high as silt loadings can vary from place to place. The paved road dusts get resuspended and act as source due to vehicles movement and friction of tires with roads.

3.2.8 Building Construction

With a scope of being developed as smart city, there are drastic infrastructural developments taking place in Nashik. Real Estate sector is booming in the city. The handling and construction activities contribute towards fugitive dust particulate matter in large proportions. Particulate emissions are predominantly due to site preparation work, which may include scrapping, grading, loading, digging, compacting, lights duty vehicle travel and other operations. Data related to construction activity in past one year, was obtained from Building construction department of NMC. 214 construction and building related activities were reported with the department. The number of construction activities ward wise is given in **Table 3.15**.

Assumption

- The project duration was estimated at 8 months for building construction related activities.
- The area of influence of each construction activity was taken as per authorized by RERA registrations.

Table 3.15 : Ward Wise distribution of Construction Activities

Wards	Build Construction
CIDCO	107
Nasik East	23
Nasik Road	5
Nasik West	30
Panchavati	18
Satpur	31
Total	**214**

Emissions Estimation

For the purpose of estimating emissions, it is assumed that the fugitive dust emission is related to the acreage affected by construction

Step 1 -Total No. of construction activities in each region. This was obtained from RERA database.
Step 2 -Acres disturbed
Step 3 -Months of activity (Buildings construction activity = 8 months)
Step 4 -Acre x months of activity
Buildings construction activity = 8 x total number of acres disturbed
Step 5 -PM_{10} Tons /years = 1.2 x total number of acre – months
(AP42, Section 13.2.3.3– PM_{10} - 1.2 tones/ acres months)

Ward wise emission load of PM during construction activity is presented in **Table 3.16**.

Table 3.16 : Ward wise Emission Load of PM in acre months during Construction Activity

Wards	PM_{10}
CIDCO	1604.1
Nasik East	603.6
Nasik Road	71.6
Nasik West	555.2
Panchavati	136.1
Satpur	360.2
Total (Kg/day)	**3330.87**
Total (Ton/day)	**3.3**

Total Emission Load =3.3 tons /day

The total PM emission load was calculated to be around 3.3 tons/day from the building construction activity in the region. Site-specific contribution of the pollutant emission load was derived based on primary survey as CIDCO and Nashik East have maximum particulate emission load due to construction activity.

Issues

- The activity is assumed to occur 6 days a week with 8 hours duration of working hours
- The current methodology assumes that all construction operations emit the same levels of PM on per acre basis.
- The methodology assumes that construction dust emissions are directly proportional to the number of acres disturbed during construction. The estimates of acreage disturbed are limited in their accuracy, as explained above
- Emission due to vehicle movement during construction activity is not calculated

3.3. Line (Vehicular) Source

Nashik is one of the six revenue divisions that regulate Vidarbha region for its administrative purposes, with the institutional framework for overall planning at the district level. Nashik region covers almost 15530 Sq.Km of area in the state, out of which the Nashik Municipal Corporation covers an area of about 267.48 Sq.Km and includes 25 villages out of which Vihitgaon, Vadner and Pimpalgaon Khamb are partly included. NMC's Roads and Building Department is responsible for maintenance of Nashik's 1,049 Km of roads as well as its schools, public toilets, community temples and health clubs. Total constructed road length within corporation area is 1610.14 Kms, out of which cement concrete roads are 205.57 Kms, asphalted 1173.20 Kms and metalled 114.75 Kms.

The existing road pattern of the Nashik Corporation Area is almost radial one. Following are the details of roads and transport amenities in city jurisdiction.

Major Roadways : Nashik lies at the intersection of two major National Highway, NH-3 i.e Mumbai-Agra Road passes through the Nashik city, while NH-50 i.e. Pune - Nashik Road meets Mumbai-Agra Road in the central part of the city near Dwarka point. There are Four National Highways that run outwards in radial form viz Dharmpur-Peth-Nashik-Aurangabad (MSH-2), Nashik-Dindori (MSH-3), Adgaon-Girnare-Javhar (SH-28) and Nashik-Trimbak (SH-30). Adjoining to them are District roads i.e. Nashik Road-Deolali-Bhagur (MDR-26), Nashik-Anandwali-Dugaon (MDR-34) and Adgaon-Pimprisayyed (MDR-36). There is a flyover on Mumbai-Agra Highway from Pathardiphata to Aurangabad Naka to decongest nearby areas. There is necessity of other bypass roads to link National and State Highways. In absence of by-passes to the above important roads and also due to intermixing of local and transit traffic, the situation gets aggravated, resulting in congestion, delays and serious emissions

Minor Roadways : The North-South bond connectivity of the city is through two major roads, viz, a 24 mt Tilak road from ABB circle to Gangapur road and a 30 mt road from Satpur to Gangapur Road. While the east-west links mainly comprise of Mahatma Gandhi Road, Shivaji Road, Sharanpur road, College Road, Gangapur Road, etc. Numbers of bridges have been constructed on river Godavari, Valdevi, Nasardi at various locations. The Panchvati area is connected with the Nashik city by five bridges out of which four are for vehicular traffic. Ramsetu is high level cause way open to pedestrians only. Satpur area is flanking to Trimbak Road with Satpurgaothan to its south and the main Industrial complex of M.I.D.C. to its north. Nashik-Pune Road is the main feeder road for Nashik Road Deolali area. Jail-Road, Lam Road, Subhash Road etc. are the other important roads in this area. The village roads viz. Eklahare road, Pathardi Road, Untwadi Road serve the southern part of the Corporation area, while the Makhamalabad road, Makhamalabad-Mhasrul-Adgaon link etc. serve the northern part of the Corporation area.

Bus &Public Transport : Maharashtra State Road Transport Corporation operates city bus through its 2 depot i.e. Nashik I depot (N.D.Patel Road) and Nashik II depot (near old Adgaonnaka). Under Jawaharlal Nehru National Urban Renewal Mission (JNNURM), 100 buses are provided to Nashik City.

There are 6 intra city bus terminals in the city namely :

1. Old C.B.S. (Central Bus Station).
2. Mela Bus Station.
3. Nimani Bus Station.
4. Deolali Camp Bus Station.
5. Nashik Road Bus Station.
6. Satpur Bus Station.

There are four inter-city terminals in the city namely :

1. New Central Bus Station
2. Mahamarg Bus Station
3. Old Central Bus Station (Old C.B.S)
4. Mela Bus Station.

In 2013, the total numbers of buses were 241 which used ply on 508 different routes, covering route of 7728.4 kms. The number of passengers handled by the bus system at that time was near-about 145000 per day out of which 45000 are students. But these bus numbers are brought down to 110 in 2018. Apart from state transport, there is huge dependence on 3 wheelers and private vehicle aggregators for intermediate point transport within the city. The above figures of number of passenger handled, trips in city area shows that there is necessity of efficient mass transportation system.

Truck Terminal & Parking Facilities : Nashik being one of the important agriculture hubs, there is lot of wholesale and retailing of agricultural products that take place within the city, giving rise to influx of HDDV traffic. Terminal facility in the form of Truck Terminus for heavy vehicles is in existence at Adgaon and on Mumbai-Agra National Highway. Weigh Bridge facilities are available at Panchavati and Peth Road market center and also have auction centre within the complex.

The main bi-weekly bazaars in the town are held at Panchvati on the Bank of River Godavari on Wednesday and Saturday. Another weekly bazaar is in Deolali which function on Monday mainly involving sales of grocery and vegetables. Besides above bi-weekly markets, there are some daily markets in the town, like vegetable market on bank of river Godavari, general market at Ravivar Karanja, vegetable market at CIDCO, Shivaji Chowk, Gangapur road. Besides this, there are many small local vegetable markets which cater needs of local people of that area. The C.B.S. in Nashik city and the existing Nashik Road Bus Station outside the Railway Station are very heavily loaded and their location in the heart of developed locality offers no scope for making more space available for bus parking. At Pune- Nashik National Highway such type of truck terminus is presently absent and need to be provided.

Inadequate parking facility and inadequate norms for hospital, mangal karyalaya, public places make the people to park the vehicle on streets, which creates hindrances in regular traffic flow. Places like C.B.S., M.G. Road, Main Road, Canada Corner, College Road, Gangapur Road, Bytco point, Dwarka junction, where there are commercial developments, are facing a problem of parking which results in creation of chaotic condition. Shopping mall culture is also well developed in the city. Big Bazar at College Road and Nashik Road, Nashik Central mall at Trimbak Naka, City Centre mall at Untawadi, and Reliance mall at Gadkari Chowk are noticeable, while the parking facilities near these institutions are adequate.

There is an annual growth of 8-9% in number of vehicles registration in Nashik City RTO. The details regarding the number of vehicles on road in Nashik city is given in **Table 3.17**, which was 861459 in 2011. Major portion of this constitute the vehicle population in city, it is observed that increase in the vehicle population in every year is remarkable **(Figure 3.2)**.

The Mumbai-Pune-Nashik area will soon be developed as the Golden Triangle industrial belt of the state and occupy a prominent place on the world map of industries. With this infrastructural and organizational development, there will be tremendous increase in number of vehicles registration and related activities. Vehicles are the primary source of precursor emissions for $PM_{2.5}$ pollutants in the atmosphere of high traffic congestion zones. Considering, the rapid decadal growth of vehicles there is need to assess the emission load from line source, for which a strategic Emission inventory is required. Emissions inventories are an essential input to mathematical models that estimate air quality. The effect on air quality of potential regulatory actions can be predicted by applying estimated emissions reductions to emissions inventory data in air quality models. An emissions inventory includes estimates of the emissions from various pollution sources in a geographical area.

It should include all pollutants associated with the air quality problems in the area. All such factors are taken into account to estimate the emission load from Line Source in the City of Nashik Municipal Corporation.

Table 3.17 : Number of Vehicles on Road in Nashik City (2016-17)

Sr.	Category	Type	Year 16-17
1	2 wheelers	Motor Cycles	815599
2		Scooter	220350
3		Moped	54882
4	4 wheelers	Cars	155647
5		Jeep	26442
6		Station Wagon	94
7	Taxi	Taxi	5756
8	Autorickshaw	Autorickshaw	22229
9	Buses	Stage Carriage	950
10		Contract Carriage	1548
11		School Bus	945
12		Private Service Vehicle	203
13		Ambulance	639
14		Other	48
15	Other Heavy Vehicles	Trucks	13224
16		Tankers	838
17		Delivery Van (4 Wheeler)	30784
18		Delivery Van (3 Wheeler)	12937
19		Tractor	69030
20		Trailer	28751
21		Others	5944
		Total	**1466840**

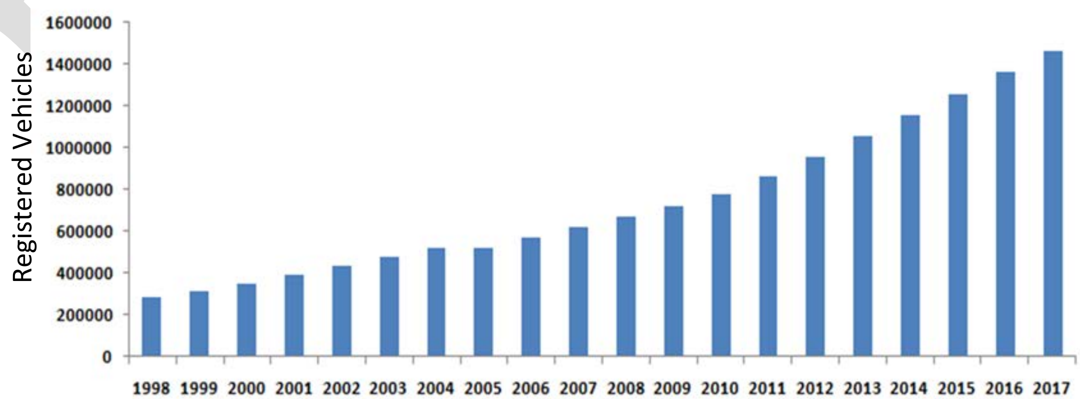


Figure 3.2 : Vehicular Growth at Nashik City

Source : RTO, Nashik Region

3.3.1 Primary Survey and Methodology

The methodology of study included preparation of vehicular emission by taking into consideration:

- Vehicle counts at representative major traffic junctions and congestion zones spread across the city limits
- Estimation of grid-wise road length.
- Estimation of VKT (Vehicle Kilometers Travelled) for different categories of vehicles.
- Selection of appropriate emission factors from the ARAI vehicle emission study.
- Preparation of emission inventory (grid-wise) and identification of major sources / hot spots in each grid.
- Emission growth projections.

Grid wise emission inventory preparation includes the following procedural steps:

- Division of study area into grids of 2 Km X 2 Km size
- Identification of major nodes which represent major traffic junctions
- Calculation of road length between the nodes and estimation of grid-wise road length
- Collection of data on number and type of vehicles traveling between nodes through field studies
- Estimation of vehicle kilometers (Km) traveled by each type of vehicle in each grid

$$VKTI = RLj * NI$$

Where, VKTI = Vehicle Km traveled by vehicle type I,
RLj= Road length in grid j
NI = Number of vehicles travelling between nodes for vehicle type I per day,

- Selection of appropriate emission factor for each type of vehicle
- Estimation of particulate matter emissions from each grid

$$PM_j = N * \sum_{J=1}^{m} VKT_I * EfI$$

Where, PMj= Particulate matter load in tones/year for grid j
N = Number of activity days in a year
EfI= Emission factor for a vehicle type I

- Projected emission inventory (with alternative control options) preparation

$$PM\ projected_j = N * \sum_{J=1}^{m} VKT_I * EfI * \eta_k$$

Where, PM Projected j = Projected particulate matter load in tones/year for grid j
η_k= Efficiency of control option K

3.3.2 Vehicle Count

To assess grid-wise vehicular emissions across city, vehicular counts on major traffic corridors and congestion zones as well as within the city internal-external roads were carried out. Road map of the city as given in **Figure 3.3,** which was used to determine the locations for the vehicle counting survey. For this purpose, the Nashik transportation network were divided into regions viz. CIDCO Nashik, Satpur, Nashik East, Nashik West, Nashik Road and Panchavati. Vehicular survey was carried out was carried out at each of the identified traffic junction to evaluate traffic movement in the city. Considering the demographics and radial road network of Nashik, around 31 monitoring locations were selected for the vehicular count assessment for a period of 24 hrs. The counting was continuously carried out considering peak and slack periods of the day representing the following time slots.

Shift	Traffic	Duration	No. of Hrs
I	Morning Peak	0700 to 1100	4
II	Afternoon Average	1100 to 1700	6
III	Evening Peak	1700 to 2200	5
IV	Night Average	2200 to 0700	9

Following categories of vehicles were covered in these counts:

Cars, Taxis, Heavy Duty Diesel Vehicles (HDDV) + Buses, Three Wheelers, 2 Wheelers

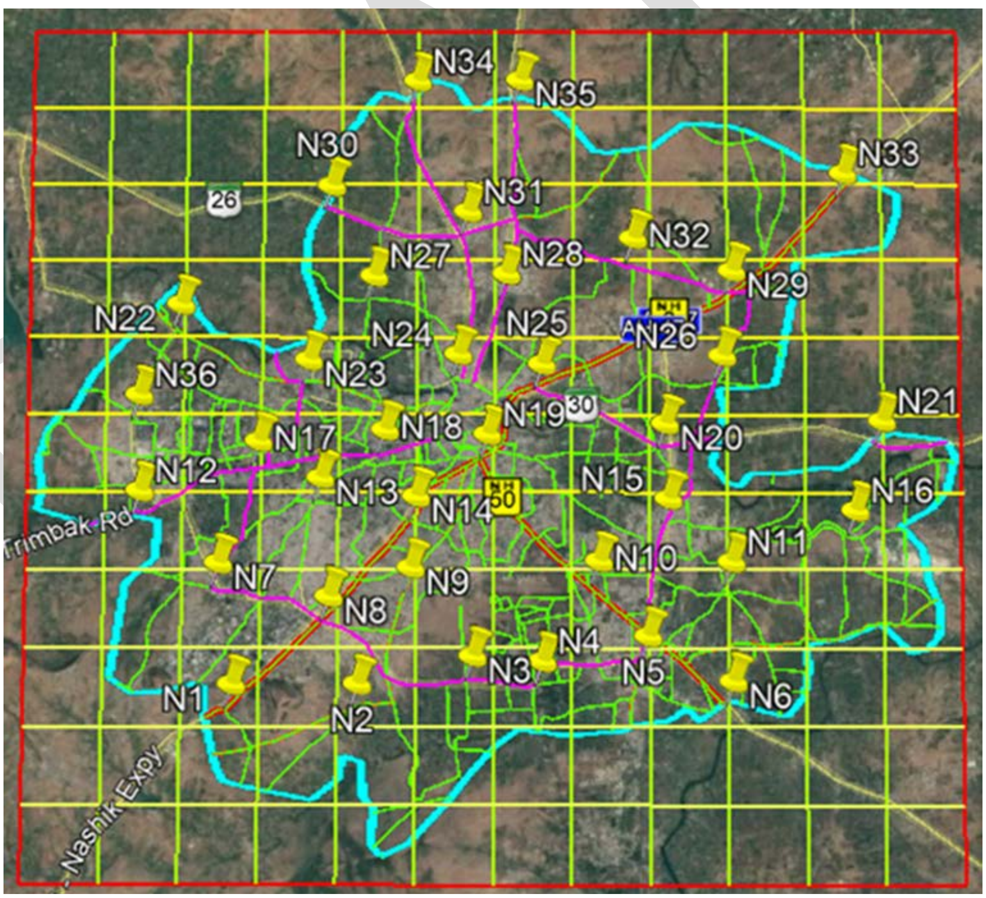


Figure 3.3 : 2 Km x 2 Km Grid-wise Distribution of City and 31 Vehicular Counting Survey Locations Selected Across Nashik City

3.3.3 Vehicle Kilometers Travelled (VKT) Estimation

Vehicle Kilometers Travelled (VKT) is an estimate for the distance travelled by all categories of vehicles between major nodes/traffic junctions within the region. Grid VKT is multiplied by the corresponding grid emission factors and summed over all grids to obtain total emissions. This approach is physically representative of realistic traffic conditions in each grid cell of the city. Major and minor roads were also covered to assess the emissions from vehicles traveling on internal roads **(Table 3.18)**.

Table 3.18 : Identified Roads/ Traffic Junctions around Monitoring Sites for Vehicle Counts

CIDCO Region			
1	Mumbai Nashik Express way	**2**	Pathardi Vadner Dumala road
3	Pathardi Gaulane Road	**4**	Mumbai Agra Highway
5	Rajeshwari Karyalay, Jail road	**6**	Ramkrushnanagar, Chunchale Road.
7	Mumbai Nashik Express way (Pathardi Phatard)	**8**	Pavannagar Road, Ambad
9	Pathardi Road-Indira Nagar Police Station		
Nashik East			
1	Pathardi to Vadner Dumala Road	**2**	Mumbai Nashik Express way, Indiranagar
3	Dwarka Circle		
Nashik Road			
1	Durga Chowk	**2**	Nashik Pune Road
3	Sinnar Phata, Eklahare	**4**	Nashik Pune Road
5	Jail Road, Shivaji Maharaj Chowk	**6**	Jail Road (Eklahare)
7	Odha Road	**8**	Durga Chowk
Nashik West			
1	Mayco Circle (Vedmandir Stop)	**2**	Gangapur Road, Jehan Circle
Panchavati			
1	Peth Road (Makhmalabadnaka)	**2**	Matori Bus Stand Road
3	Nashik Road	**4**	Peth road-Somnath Shinde Nagar
5	Mary Mhasrul	**6**	Mhasrul Aadgaon
7	Aurngabad Road	**8**	Peth Road-Gawalwadi
Satpur			
1	Trimbak Road	**2**	Trimbak Road-Satpur Police Station
3	Bardan Phata Chowk (Gangapur road)		

The percent distribution of vehicle count is shown in **Figure 3.4.** The vehicular kilometer travelled was calculated based on number vehicles multiply by road length for different types of vehicles in shifts which is shown in **Figure 3.5**.

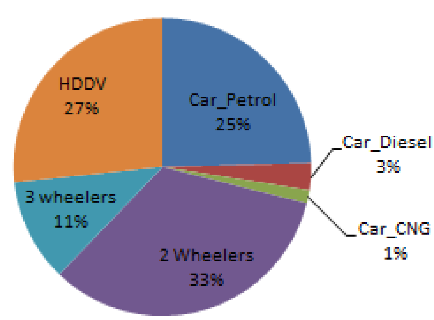


Figure 3.4 : Percent Distribution of Vehicle Count at Nashik City

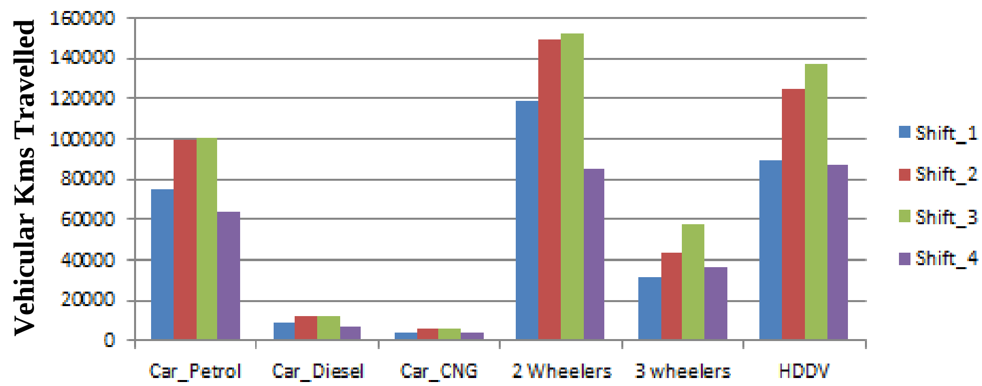


Figure 3.5 : Shift wise Vehicle Kms Travelled (VKT) for Different Categories of Vehicles

It was observed from the vehicular survey, that the percentage of two wheelers in terms of number as well as movement within the city is highest (over 33%) among the other categories, followed by HDDV (27%) and petrol cars (25%). Nashik being at the intersection of two Major highways, considerable amount of vehicular movement was observed in Shift I (0700 to 1100). The highest vehicular movement was evaluated in Shift II (1100 to 1700) & Shift III (1700 to 2200). As the provision of CNG and alternate fuel is limited in the region, huge dependency on 2-wheelers and private vehicles is evident for mobility across city. Nashik being one of the agricultural hubs, there is huge influx of HDDV within the city. Terminal facility in the form of Truck Terminus for heavy vehicles is in existence at few places in the region. An average VKT of 408834.4 (km/day) was estimated for all categories of vehicles travelling within city limits.

3.3.4 Emission Factors

Emission factors for different categories of vehicles along with variation with fuel were developed by ARAI in 2007. The summary of emission factor developed by ARAI is represented in **Table 3.19**.

Table 3.19 : Emission Factors Calculated by Automotive Research Association of India (ARAI)

Vehicular Emission Factors (Gm/Km)	Car Petrol Post 2005 Fuel BSII	Car Diesel Post 2005 Fuel BSII	Car CNG BSI, Post 2000, Fuel BSII	Two Wheeler Post 2005 4 Stroke Fuel BS II	Three Wheeler CNG Retro 25 Post 2000 Fuel BS II	CNG Buses Post 2000 Fuel BS II	Trucks Diesel Post 2000 Fuel BSII
PM	0.002	0.015	0.006	0.013	0.118	0.044	1.240
NOx	0.090	0.280	0.740	0.150	0.190	6.210	9.300
CO	0.840	0.060	0.060	0.720	0.690	3.720	6.000
HC	0.12	0.080	0.460	0.520	2.06	3.750	0.370

Factors used for emission load calculation Source: Air Quality Monitoring Project-
Indian Clean Air Programme (ICAP), The Automotive Research Association of India, 08, 2007

3.3.5 Whole Nashik City Vehicular Emission Inventory

Tailpipe emissions estimates were made from 2 Km x 2 Km grids with respect to the entire city taking ARAI emission factor for PM, NOx, CO and HC. SO_2 emissions are calculated based on VKT and sulphur content (Diesel 300 ppm and Gasoline 30 ppm) as SO_2 emission factor was not available. These estimates have been further used for grid wise projections, input to dispersion modeling and scenario generation.

Particulate matter is the solid form of fuel which is left behind after combustion. PM emission load within the city limit is largely contributed by mobile sources. Out of the total PM emission load of 3.709 tons/day, the highest contribution is from HDDV vehicles (95.41%) i.e, 3.528 tons/day. Followed by HDDV, about 0.128 tons/day of PM is from three wheelers. The emission load of PM is attributed to movement of Heavy Duty Diesel (HDD) Vehicle within the region. Considering the vehicular and industrial activities in the region, almost 64% of PM load is attributed from North and South region of the city. The maximum emission load is contributed from Panchavati (43%) and CIDCO (21%) region. The lowest PM emission load is calculated from cars operating on CNG, while region wise lowest PM emission load is lowest from Satpur region of Nashik city. The emission load from Nashik East, Nashik West and Nashik Road region contribute around 1.12 tons/day of PM in Total emission load. The emission load from 2 wheelers (0.0427 ton/day) is almost 10 times the emission load from Car operating on Petrol (0.0044 ton/day) and Diesel (0.00388 ton/day). While diesels are heavier oils which have large number of C bonds and are tough to break completely, this incomplete breaking appears as particulate matter. Petrol is more refined than diesel. The region wise PM emission load in a day with respect to its vehicular distribution is given in **Table 3.20 and Figure 3.6**.

Table 3.20 : PM Emission Load from Different Sector and Zones of Nashik City

Regions	Car_Petrol	Car_Diesel	Car_CNG	2 Wheelers	3 wheelers	HDDV	Total (TPD)
CIDCO	1.0	0.9	0.2	8.8	32.9	752.1	**0.80**
Nashik East	0.6	0.6	0.1	4.5	11.8	480.1	**0.50**
Nashik Road	0.3	0.2	0.05	3.7	13.4	205.5	**0.22**
Nashik West	0.7	0.6	0.1	4.5	14.2	381.9	**0.40**
Panchavati	1.3	1.2	0.2	17.7	44.8	1516.9	**1.58**
Satpur	0.5	0.4	0.1	3.6	11.3	192.2	**0.21**
Total (Kg/day)	**4.4**	**3.9**	**0.8**	**42.8**	**128.5**	**3528.8**	**3.71**

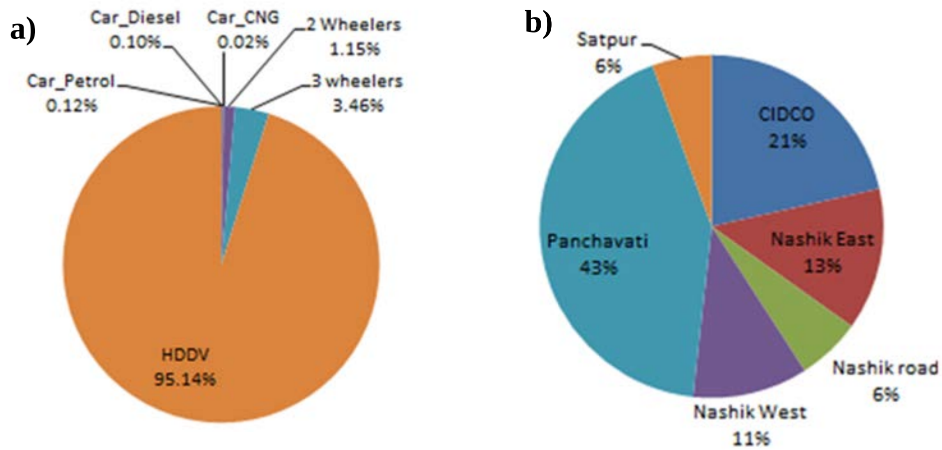


Figure 3.6 : Vehicular PM Emission Load in Nashik City
a) Vehicle Category-wise Distribution b) Region wise Distribution

NOx is produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. Out of the total, 27.497 ton/day of NOx, 96.25% of emission load is estimated from HDDV vehicles, followed by 2 wheelers (1.79%). The NOx emission load from 2 wheelers (0.493 ton/day) is almost equivalent to combined emission load from Car operating on Petrol (0.198 ton/day) and 3 wheelers (0.206 ton/day). The maximum contribution of NOx is from Panchavati region (42.75% i.e. 59.84 kg/d), followed by emission load from CIDCO (21.36% i.e. 47.21 kg/d) . NOx is forms when nitrogen reacts with oxygen at elevated temperatures. Diesel engines operate at a higher temperature and pressure than petrol engines. These conditions favour the production of NOx gases. The emission load from Satpur (5.58%) was calculated to be lowest among all the other regions, while the lowest NOx emission is found from car operating on diesel. The emission load from Nashik East (3.718 ton/day) and Nashik West (2.989 ton/day) is considerable in comparison with NOx load from Nashik Road (1.624 ton/day) and Satpur (1.535 ton/day). The contribution of emission loads from HDDV is highest for PM (95.13%), followed by NOx (96.25%). The region wise PM emission load in a day with respect to its vehicular distribution is given in **Table 3.21 and Figure 3.7**.

Table 3.21 : NOx Emission Load from Different Sector and Zones of Nashik City

Regions	Car_Petrol	Car_Diesel	Car_CNG	2 Wheelers	3 wheelers	HDDV	Total (TPD)
CIDCO	47.2	13.5	17.6	102.0	53.0	5640.6	**5.9**
Nashik East	28.3	8.0	10.5	51.9	19.1	3600.9	**3.7**
Nashik Road	11.7	3.4	4.5	42.3	21.5	1541.4	**1.6**
Nashik West	30.7	8.8	11.4	51.4	22.9	2864.5	**3.0**
Panchavati	59.8	18.5	24.2	204.3	72.1	11376.8	**11.8**
Satpur	20.4	5.9	7.7	41.4	18.3	1441.7	**1.5**
Total (Kg/day)	**198.1**	**58.1**	**75.8**	**493.3**	**206.8**	**26465.8**	**27.5**

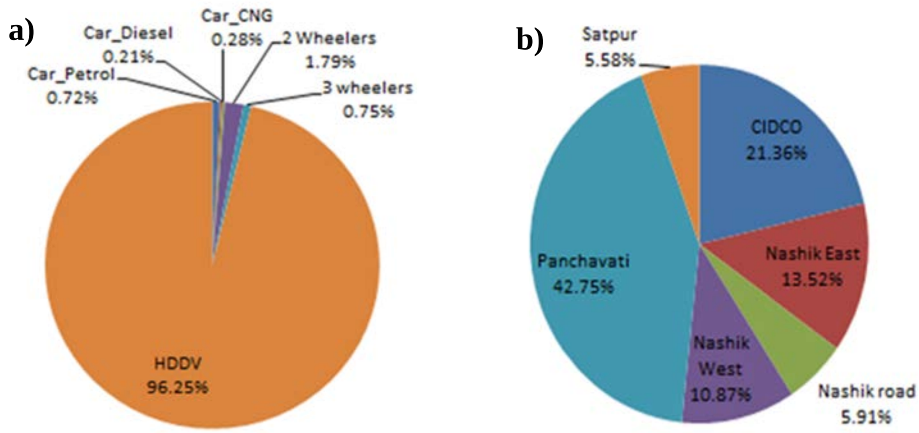


Figure 3.7 : Vehicular NOx Emission Load in Nashik City
a) Vehicle Category-wise Distribution b) Region wise Distribution

Sulfur dioxide is also present in motor vehicle emissions, as the result of fuel combustion. In the past, motor vehicle exhaust was an important, but not the main, source of sulfur dioxide in air. However, this is no longer the case. The highest SO_2 emission load was calculated from HDDV (94.51%) vehicles; region wise emission from Panchavati (42.38%) was estimated to be highest of all other region. The region wise PM emission load in a day with respect to its vehicular distribution is given in **Table 3.22 and Figure 3.8.**

Table 3.22 : SOx Emission Load from Different Sector and Zones of Nashik City

Regions	Car_Petrol	Car_Diesel	2 Wheelers	HDDV	Total (TPD)
CIDCO	0.0026	0.0031	0.0009	0.104	0.00011
Nashik East	0.0016	0.0018	0.0005	0.066	0.00007
Nashik Road	0.0007	0.0008	0.0004	0.028	0.00003
Nashik West	0.0017	0.0020	0.0005	0.053	0.00006
Panchavati	0.0033	0.0039	0.0018	0.210	0.00022
Satpur	0.0011	0.0013	0.0004	0.027	0.00003
Total (Kg/day)	**0.011**	**0.013**	**0.004**	**0.488**	**0.00052**

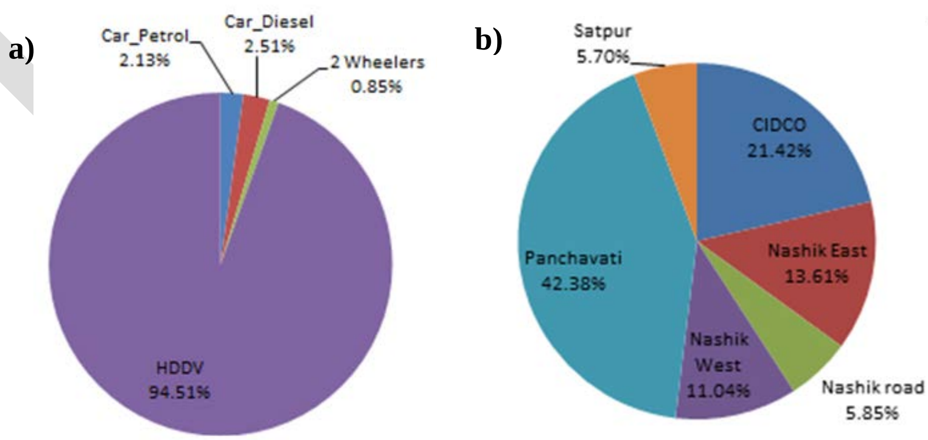


Figure 3.8 : Vehicular SOx Emission Load in Nashik City
a) Vehicle Category-wise Distribution b) Region wise Distribution

Motor vehicle fuel contains hydrocarbons, which are its primary source of energy. Any hydrocarbons emitted from a vehicle indicate unused fuel, which results from incomplete fuel combustion. This can be due to lesser amount of O2, incomplete mixing of fuel or lesser lapse time for the fuel to burn. Both petrol and diesel engine have considerable CO emissions. Out of the total 5.349 ton/day emission load of HC, the maximum contribution is from 3 wheelers (41.92%) followed by 2 Wheelers (31.96%) and HDDV (19.68%). Region wise, the lowest contribution of emission load for HC was calculated from Satpur (8.11%), while the highest load is from Panchavati (38.26%). Lowest emission load of 0.02 ton/day of HC was estimated from car operating on Diesel. Hydrocarbons are a major contributor to smog, which can be a major problem in urban areas. Prolonged exposure to hydrocarbons contributes to asthma, liver disease, lung disease, and cancer. The region wise HC emission load in a day with respect to its vehicular distribution is given in **Table 3.23 and Figure 3.9.**

Table 3.23 : HC Emission Load from Different Sector and Zones of Nashik City

Regions	Car_Petrol	Car_Diesel	Car_CNG	2 Wheelers	3 wheelers	HDDV	Total (TPD)
CIDCO	63.0	4.9	14.2	353.6	574.6	224.4	1.2
Nashik East	37.7	3.0	8.5	179.9	206.5	143.3	0.6
Nashik Road	15.6	1.2	3.52	146.7	233.2	61.3	0.5
Nashik West	40.9	3.2	9.2	178.1	248.5	114.0	0.6
Panchavati	79.8	6.3	18.0	708.3	781.8	452.6	2.0
Satpur	27.1	2.1	6.1	143.4	197.9	57.4	0.4
Total (Kg/day)	**264.1**	**20.7**	**59.6**	**1710.0**	**2242.5**	**1052.9**	**5.3**

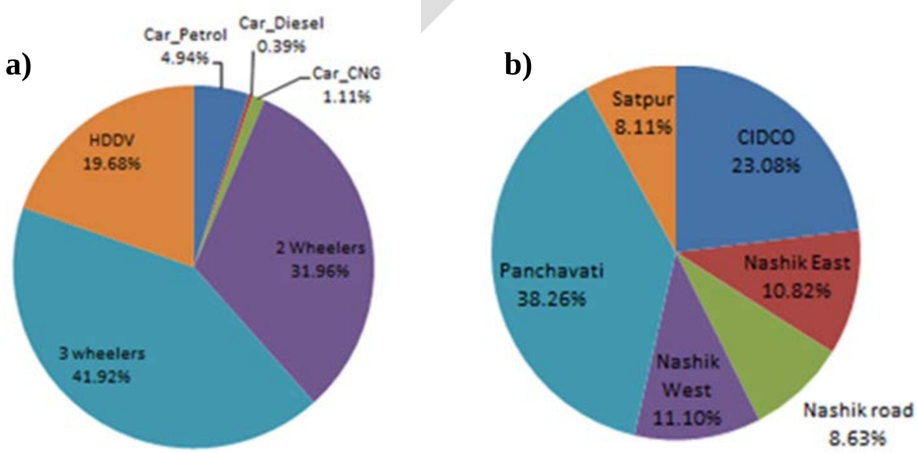
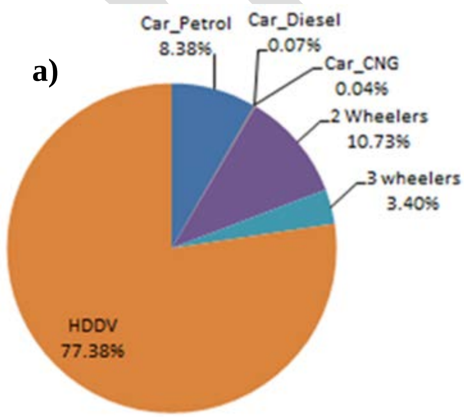


Figure 3.9 : Vehicular HC Emission Load in Nashik City
a) Vehicle Category-wise Distribution b) Region wise Distribution

Carbon monoxide (CO) a colorless, odorless, tasteless, and toxic air pollutant is produced in the incomplete combustion of carbon-containing fuels, such as gasoline, natural gas, oil, coal, and wood. This is due to insufficient air present to completely burn the fuel. The highest CO emission load of about 9.147 ton/day was estimated from Panchavati region (41.46%) and lowest from Nashik Road (6.28%) region. The emission load of CO from CIDCO region (4.767 ton/day) is almost half of the emission load from Panchavti region. Out of which 77.38% of CO load is contributed by HDDV vehicle category, followed by 2 wheelers (10.73%) and car operating on petrol (8.38%), while the lowest CO contributions is from car operating on CNG and Diesel. CO emission is common in petrol engine as it always operate close to stoichiometric conditions. While diesel engines are lean burn engines hence amount of CO emission from diesel engine is less compared to petrol. The total emission load of CO from Nashik city was calculated to be around 22.065 ton/day. The region wise HC emission load in a day with respect to its vehicular distribution is given in **Table 3.24 and Figure 3.10.**

Table 3.24 : CO Emission Load from Different Sector and Zones of Nashik City

Regions	Car_Petrol	Car_Diesel	Car_CNG	2 Wheelers	3 wheelers	HDDV	Total (TPD)
CIDCO	440.7	3.7	1.9	489.6	192.5	3639.1	**4.8**
Nashik East	263.8	2.2	1.1	249.0	69.2	2323.1	**2.9**
Nashik Road	109.4	0.9	0.46	203.2	78.1	994.5	**1.4**
Nashik West	286.3	2.4	1.2	246.6	83.2	1848.1	**2.5**
Panchavati	558.5	4.7	2.3	980.7	261.8	7339.9	**9.1**
Satpur	190.0	1.6	0.8	198.6	66.3	930.1	**1.4**
Total (Kg/day)	**1848.7**	**15.5**	**7.8**	**2367.6**	**751.1**	**17074.7**	**22.1**



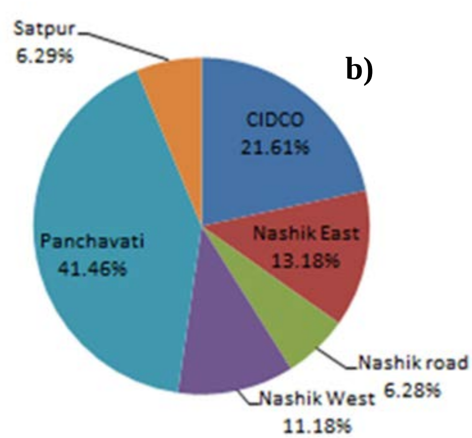


Figure 3.10 : Vehicular CO Emission Load in Nashik City
a) Vehicle Category-wise Distribution b) Region wise Distribution

Due to lot of agricultural products whole sale and retail trading at Panchavati and Industrial activities near CIDCO, the maximum emission load for PM and NOx is from these areas, where highest heavy duty vehicles movements are observed. Combined together, these two regions contribute around 64% of total PM and NOx emission loads. Out of which, the maximum emission load share is from 2 wheelers and HDDV vehicles. The region wise total emission load in a day with respect to its pollutants is given in **Table 3.25**.

Table 3.25 : Whole Nashik City Line Source Emission Load from Different Pollutant & Sector

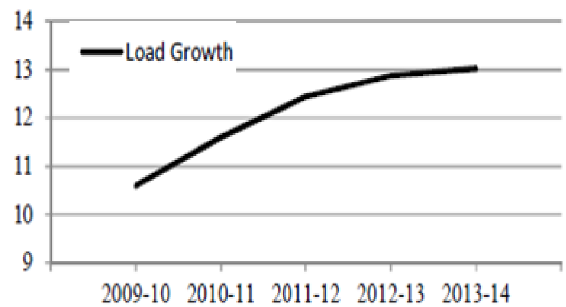
Regions	PM	NOx	SO_2	HC	CO
CIDCO	796.0	5873.9	0.05	1234.7	4767.4
Nashik East	497.7	3718.5	0.05	578.8	2908.5
Nashik Road	223.1	1624.9	0.05	461.7	1386.6
Nashik West	402.0	2989.6	0.05	593.9	2467.8
Panchavati	1582.1	11755.8	0.2	2046.7	9147.9
Satpur	208.1	1535.2	0.1	434.0	1387.3
Total (Kg/day)	**3709.0**	**27497.8**	**0.5**	**5349.8**	**22065.5**
Total (Tons/day)	**3.7**	**27.5**	**0.0005**	**5.4**	**22.1**

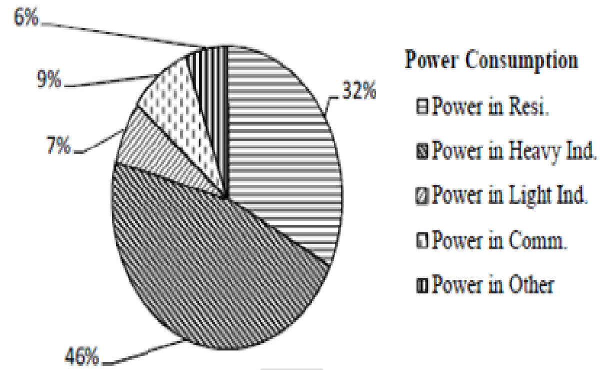
3.4 Point Sources

The state is gearing up for the rapid infrastructural as well as industrial development; likewise Nashik is changing its identify of being Holistic city and city of temple to an industrial hub. The decadal population growth is tremendous owing to this industrialization of the region. Supported by its climate, Nashik region always had potential agricultural production capacity. Nashik is called *"Wine City of India"* for its export quality grapes.

The Regional office of MPCB is functioning at Nasik since 1984. As of now there are five districts in its jurisdiction, namely Nasik, Ahmadnagar, Jalgaon, Dhule and Nandurbar. In the jurisdiction of Regional Office-Nasik there are about 9 Nos. of MIDC areas of which MIDC areas at Ambad, Satpur, Sinner, Palkhed, Dindori 'D+' zone, Vinchur and Malegaon MIDC are in Nasik district. The Maharashtra government has given its in-principle approval for an Rs.12,200 crore development project, known as the Golden Triangle Project, involving Mumbai, Pune and Nashik and equipping the region with world-class infrastructure and is on-going. Nashik had been growing very fast industrially, during the last few decades. It has seven industrial areas facilitating the industrial growth in the region, with a focus on engineering and automobiles. Industrial uses constituted around 15 % of the developed area which mainly cover Satpur M.I.D.C., Ambad M.I.D.C, Traction Factory, Brick kiln and group of small Industries along Godavari River. Besides this, there is sporadic industrial development comprising of sawmills, small scale industries, work-shops etc. spread all over the Corporation Area. In addition to above, there is Nashik Industrial Co-op Estate having an area of 135 hectares, established in 1962. There are about 6990 small scale, 27 medium scale and 131 large scale industrial units registered with DIC upto date. Majority of the Industries which came up in the city or Industrial areas are Automobiles, Engineering, Electrical, Electronics, Stationary manufacturing, Printing press components, Metal Arts, Steel and wooden Furniture, Fiber and plastic moldings, Pharmaceutical and medical equipment, Data processing etc.

To cater the power demand, the city is equipped with Eklahare Thermal Power Plant located in village Eklahare, near Nashik Road. From there, power is fed into the western division grid and subsequently distributed to substations and finally to households. It can be clearly observed from the figure, there is tremendous increase in the demand for power in the region. Out of the total power generated of 703 MW in 2013-2014, the maximum consumption is from Heavy Industries (46%). Compared to previous, load growth of 13.02 KW was observed form all the sector.





Nashik has micro, small, medium and large scale industries. While considering total number of industries in Nashik district, it can be analyzed that engineering industries are more in number. After this electrical and refrigeration industries are second and third on the list. Winery industries are the attraction of tourist for its quality, natural spot and celebration events. Coca cola, Crompton and greaves, Bosch, Everest, Kirloskar etc. are large scale industries in Nashik district. Nashik is home to one of India's largest multi-utility vehicle manufacturer, Mahindra & Mahindra Limited. Many micros, medium and small industries are doing their own production which is sold by them in the market or large scale organizations for their core product. Nashik district is growing by sense of industrial unit. It is not only contributing by the way of economy growth of Nashik district but also contributing in employment opportunities, social change and standard of living of the society. Nashik is a potential destination for engineering, food processing and biotechnology industries in the state. But along with this, there is also unchecked emission load emitted by these very industries on a large scale.

For proper estimate of emissions, the effectiveness of an existing control device applied in the industries are considered in the emission calculation. Emissions are estimated for pollutants such as PM_{10}, NOx, SO_2, CO and HC. In order to workout emission loads from industries due to burning of fossil fuel, information on fuel consumption in industries and the information on industries typology capacity etc. was obtained from Maharashtra Pollution Control Board (MPCB) for classification of industries viz. large, medium and small as well as red, orange and green categories.

According to MPCB, the polluting industries are classified as red (highly polluting), orange (moderately polluting) and green (low polluting) in nature. There are 3289 different categories of industries operates in Nashik district, out of that about 814 are the air polluting industries in Nashik.

Air Polluting Industries : 3289 Nashik District

Red			Orange			Green		
LSI	MSI	SSI	LSI	MSI	SSI	LSI	MSI	SSI
547	166	792	318	134	553	92	134	553

Air Polluting Industries : 814 Nashik

Red			Orange			Green		
LSI	MSI	SSI	LSI	MSI	SSI	LSI	MSI	SSI
110	39	296	38	24	206	13	7	81

Emission inventory from industries has considered working hours considered: for industries, MSI =16 hrs, LSI = 22 hrs, SSI = 12 hrs. 1 Barrel–159 lit, LSHS, FO is assumed to be residual oil. LDO and HSD are assumed to be distilled oil.

Stationary sources can be divided into two major subcategories, viz. point and area sources. Point sources are generally large emitters with one or more emission points at a permitted facility with an identified location. The emissions from point sources are generally calculated using emission factors obtained from direct measurements (e.g., source testing). EPA's document entitled, Compilation of Air Pollutant Emissions Factors (AP-42), or California Air Resource Board's material balance formulas are the major resources for emission factors of point sources. The simplest method of calculating emissions is to multiply the process rate (how much or how often an activity occurs) by an emissions factor (mass of air pollutant emitted per unit time of activity) and a control factor (percent of emissions not allowed to reach the atmosphere). Engineering, Automotive, Machinery etc. are the major point sources of emissions in Nashik region.

The fuel consumption pattern of industries reveals that the region of Nashik is highly depended on solid and fossil fuel for power usage and other processes. Exploration of alternative energy sources are yet not being explored to full capacity. As per the data furnished by the MPCB officials, the fuel consumption of all the air-pollution industries in the city is given in **Table 3.26 and Figure 3.11**. It can be observed that the most common fuels used in the industries of this region are coal, wood, bagasse or briquettes. The amount of diesel consumption in Green and Orange category industries is around 3 ton/hr, whereas that of Red category industry is 1.02 ton/hr.

Being an agricultural region, there is easy availability of briquettes, bagasse as fuel. The average daily consumption of bagasse and briquettes in heavy industry is much higher as compared to other fuels. The most significant pollutant emitted by bagasse-fired boilers is particulate matter, caused by the turbulent movement of combustion gases with respect to the burning bagasse and resultant ash. Emissions of sulfur dioxide (SO_2) and nitrogen oxides (NOx) are lower than conventional fossil fuels due to the characteristically low levels of sulfur and nitrogen associated with bagasse.

Table 3.26 :
Total Fuel Consumption from Industries in Nashik City Area

Fuel Category	TPD
Coal	1376.57
Bagasse	3140.37
Wood	151.76
Briquette	191.60
Diesel	109.15
FO	18.46
HSD	65.49
LDO	16.45
LSHS	7.92
LPG	6.46
NG	0.27

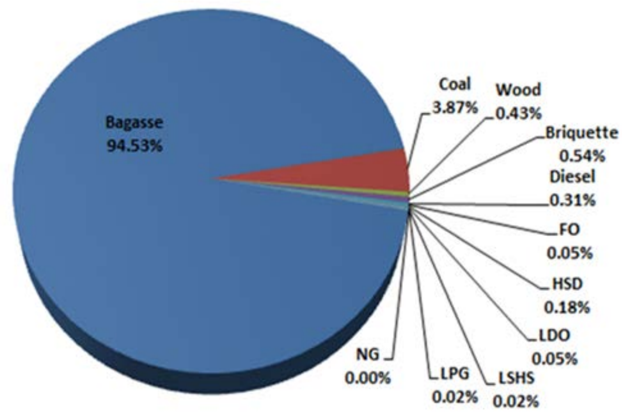


Figure 3.11 :
Percent Fuel Consumption from Air Polluting Industries in Nashik City Area

3.4.1 Approach/Methodology

Due to the wide variety of industrial processes, reliable determinations of industrial emissions have been found to depend on individual types of treatment. This is expensive and time-consuming, as it involves detailed study and testing of specific plants and processes. In this assessment, data on industrial emissions was obtained by means of consent agreements approved to the individual plants requesting information on processes, types and quantities of process exhaust, air cleaning equipment and fuel consumption. Frequently, the industries themselves do not have on-line data of this sort. Consequently, insufficient or incomplete results can be expected. From the data provided by MPCB, a total of 241 industries were identified as air polluting industries in Nashik region. Fuel consumption inventory of was formulated from the consent copies of industries authorized and verified by MPCB official. The gross emissions are estimated for all types of industries viz. LSI, MSI and SSI.

Emission factors published by TERI, New Delhi are used because the data on type of combustion equipment used for firing and other operating parameters like fuel quality, efficiency of boilers were not readily available with the industries in the region which are essential for the estimation of load. As per the regulation, many of the industries have installed control equipment after stringent action from MPCB officials in recent times. Emission factors, which have been applied to source data to yield emission data for SOx, NOx, HC, CO, particulates and so on, exist for a wide variety of industrial processes such as fuel burning, chemical production, manufacturing processes, and solvent usage. The emission load was calculated based on 90% reduction due to control equipment in industries for PM and SOx viz. bag filters, industrial scrubbers, electro static precipitator, use of low sulphur fuel oil, cylinder lubrication and for NOx 30% reduction was assumed on account of different technologies that are being used for reduction of NOx viz. Flue-gas recirculation, Hybrid SNCR/SCR technologies, reagents to reduce these emissions, humid air method, water injection and water emulsion, high scavenge pressure and compression ratio and selective catalytic reduction. The sulfur and ash content of the respective fuels were taken from the consent of respective industry, for those industries without any ash and sulfur details were calculated on the base of standard content percentage given in **Table 3.27**.

Total emissions were calculated and distributed into various wards in accordance with the actual location of industries. Site specific estimation for seven locations was based on survey of the locations as per MPCB records.

Table 3.27 : Emission Factors applied for Industrial Emissions

S. No.	Type of Fuel	Unit	S	Emission Factors (Kg/Unit)					
				TSP	SO_2	NO_x	HC	CO	Ash
1.	LSHS	KL	0.45	1.25*S + 0.38	19.25*S	7.5	0.12	0.63	
2.	FO	KL	4.0	1.25*S + 0.38	19.25*S	7.5	0.12	0.63	
3.	LDO	KL	1.8	0.25	17.25*S	2.75	0.12	0.63	
4.	HSD	KL	1.0	0.25	17.25*S	2.75	0.12	0.63	
5.	LPG/FG$^{\$\$}$	KL	0.02	0.072	0.01*S	2.52	0.07	0.43	
6.	NG	m^3	-	160 E-06	9.6 E-06	2800 E-06	48 E-06	272 E-06	
7.	Coal /Coke	MT	0.5*	6.5*A	19S	7.5	0.5	1.0	45
8.	Kerosene$^{\#\#}$	Kg/t	0.25	0.06	17S	2.5	--	--	--
For Power Plant**									
1.	LSHS	KL	0.45	1.25*S + 0.38	19.25*S	6.25	0.12	0.63	
2.	NG	m^3	-	160 E-06	9.6 E-06	2800 E-06	48 E-06	272 E-06	
3.	Coal	MT	0.15	6.5*A	19*S	7.5	0.5	1	6

Source: URBAIR Report, Bombay, 1992
A: Percentage ash in coal = 45% and S: Percentage Sulphur
Other than Power Plant, efficiency of Cyclone considered as 75%
* *Power plant
$$Emission Factors for LPG from Revised AP-42 (Ref. PMRAP, NEERI, 2003 (Table
Π Coal
A - % Ash: 2- 10% Avg. 6%, S - % Sulphur: 0.1 – 0.2%, Avg. 0.15%
ESP Eff. : 99.5%, FGD Eff. : 99%
Π LSHS Sulphur: 0.45%
Source:
a. Environmental effects of energy production, transformation and consumption in the National Capital Region submitted to the Ministry of Environment & Forest, by Tata Energy Research Institute (TERI), New Delhi, February 1992
b. Indian Oil Corporation Ltd, Vadodara

Density[b] of Fuels (Kg/m^3)

LSHS	943
FO	943
LDO, LPG	860
HSD	504

Baggase : Emission Factor Documentation for AP-42 Section 1.8, Bagasse Combustion in Sugar Mills, April, 1993 [PM10- 4.6, SO2-0.18, NO2-0.275, HC-0.0002515, CO -390 (g/km)]

3.4.2 Point Source (Industrial) Emission Load

The final total emission load includes contribution from air polluting industries out of the total 4162 industries established in Nashik region. CPCB categories industries into LSI, SSI and MSI type on the basis of initial capital investment made towards the establishment of the institution or organization. Based on the score of 'Range of Pollution Index', the industries were further classified into Red, Orange, Green and White category. While calculation the emission load, fuel consumption quantity, emission factor of respective fuel type, control equipment that are being used, operating hours etc., were taken into consideration. Most industrial point sources release pollution into the atmosphere through chimneys at a height sufficient to provide ample dilution before the pollutants reach ground level. However, certain meteorological conditions may prevent or reduce the effectiveness of this dispersion and pollutants may become trapped near the source and descend to ground level where they may cause poor air quality. For grid wise emissions estimation, the whole region of the city was divided into equal grids of 2 Km x 2 Km size and the wards were overlaid on these grids. The grid wise emissions from various industries in those wards have been estimated based on their actual locations. The industrial emission load from different pollutants and whole of Nashik city is given in **Table 3.28**.

Table 3.28 : Emission Load for Point Source from Different Pollutants

Category	PM_{10}	NOx	SOx	HC	CO
Red LSI	12397.1	9210.0	828.6	11966.2	722522.8
Red MSI	122.9	216.2	38.6	216.0	3045.3
Red SSI	212.0	156.2	65.5	1131.8	16722.6
Orange LSI	347.8	736.1	154.4	43.6	5302.7
Orange MSI	120.4	14.3	6.5	687.2	11590.9
Orange SSI	173.5	50.9	29.1	1091.2	16314.2
Green LSI	13.9	245.2	248.0	4.4	23.3
Green MSI	0.4	27.8	14.6	0.9	5.2
Green SSI	71.0	80.7	77.4	440.9	6534.6
Total (kg/day)	**13459.0**	**10737.5**	**1462.6**	**15582.2**	**782061.6**
Total (TPD)	**13.5**	**10.7**	**1.5**	**15.5**	**782.0**

Releases from point sources can include complex mixtures of substances and the pollutants released will be dependent on process input materials, type of process, etc. Taking all the type of industry into consideration, the emission load from MSI and LSI category is much more liable for regulation than emissions from LSI units. Large number of SSI and MSI set up in commercial and residential zone are accountable, considering units in industrial zone. Inventorization of their fuel consumption is not being maintained, as they are often left unsupervised from the regulatory end. The emission from

LSI units across all category contributed maximum load towards the final emission. LSI units were responsible for 94.8%, 84.2%, 94.9%, 78.1% and 93.4% share of emissions for PM, SO_2, NO_2, HC and CO respectively. The loads from RED category LSI units were highest attributing to quantity of their fuel consumption in various processes. The total emission load from MSI and SSI for PM is around 1.8 to 3.4%, whereas for NOx it is 2.4 to 2.7% respectively.

The percent contribution of emission load from fuel consumption is given in **Figure 3.12**. The emission load of PM is highest from burning of biomass, coal and wood as power source in different industrial process of Nashik region. The highest PM emission load was calculated from Bagasse (48.1%) [from 3140.37 TPD], followed by load from Coal (33.9%) [from 1376.57 TPD] and Wood (17.5%) [from 151.76 TPD] as fuel consumption. The Particulate matter (PM) emissions from large combustion plants burning solid fuels are often lower than emissions from smaller plants (per unit of energy input); the physical and chemical characteristics of the particulate matter also differ. This is because different combustion and abatement techniques are applied. Combustion of fuels can generate solid residues, which may be deposited within combustion chambers (furnace bottom ash) within the furnace, boiler surfaces or ducting (fly ash) or on heat exchanger surfaces (soot and fly ash). Coal and other fuels with significant ash content have the highest potential to emit particulate matter. The emission load of PM from RED-LSI units was alone calculated to be around 12.3 ton/day.

Nitrogen oxides are produced in the combustion process by at least two different mechanisms: one source is from the molecular nitrogen in the combustion air (thermal NOx), and the other is from the nitrogen in the fuel being burnt (fuel NOx). 83.78% of NOx is emitted from coal based industries [from 1376.57 TPD], followed by emission loads from Diesel (7.04%) [from 109.15 TPD) and Bagasse (3.5%) [from 3140.37 TPD]. While Red category industries contribute 94.9% of NOx emission load out of all LSI industries. The total emission for NOx is around 10737.5 kg/day and in terms of Tons/day it's 10.73.

Sulphur dioxide is found in many industrial gases emanating from plants involved in roasting, smelting and sintering sulphide ores, or gases from power plants burning high sulphur coal or fuel oils or other sulphurous ores or other industrial operations involved in the combustion of sulphur-bearing fuels, such as fuel oil. Out of the total SO_2 emission load of 10.7 ton/day, 45.88% is contributed by Diesel (from 109.15 TPD) as fuel consumption followed by coal 20.2% (from 1376.57 TPD) and Bagasse 14.5% (from 3140.37 TPD). RED LSI units contribute around 0.82 ton/day of SO_2 out of the total 1.46 ton/day emission load.

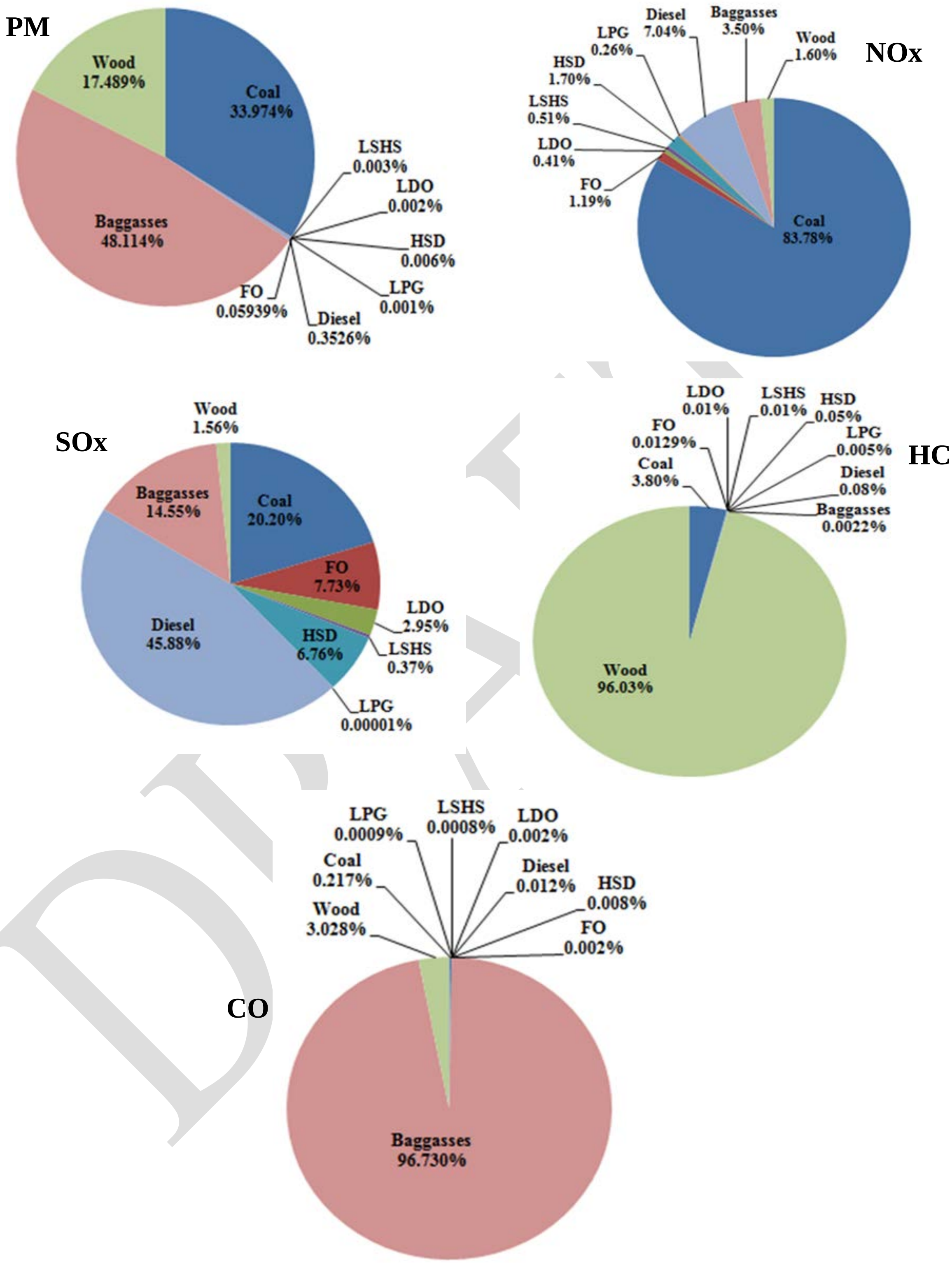


Figure 3.12 : Percent Distribution of Pollutant from Different Source Category (Nashik Industries)

Hydrocarbons are either evaporated from fuel or are remnants of fuel that did not burn completely. About 96.03% of HC is released from burning of wood in the industries. Followed by coal is highest, accounting at 3.8% share of total HC emission load. Around 15.5 ton/day of HC is released into the atmosphere of the Nashik region by the industries, out of which 11.96 ton/day of HC is emitted by RED LSI industries alone. And others ROG, MSI & SSI across all categories contributes around 3.6% of HC towards total emission load.

Out of the total 782.06 TPD of CO emission load, 96.7% of CO is produced by industries using Bagasse. Carbon monoxide is produced when organic materials, such as gasoline, coal, wood, and trash, are incompletely burned. 91.2% i.e, 722.52 TPD of CO is contributed from LSI category of industries. Emission from SSI and MSI are also highly accountable, emitting load of 14.6 TPD and 39.6 TPD, respectively

Very less amount of fuel consumption pattern was observed for FO, HSD, LDO, LSHS, and LPG/NG which reflect negligible amount of emission load for every pollutant. The low cost and easy availability fuel such as bagasse and wood are generally used in the industries giving more PM pollution load.

Data Constraints / Assumptions

- Emissions have been worked on the basis of fuel consumption only. The estimation of DG sets emission while load shading time is not worked out, as also the briquette because of its inadequate data and unidentified source and type.
- A wide variation in the data on fuel supplied to the industries as per survey and the data obtained from the consent forms of MPCB on fuel consumption is observed. This indicates some other source of fuel supply and consumption whose details are not available for estimating the point source emissions. It necessarily does not mean that the fuel supplied goes to industries alone.
- The surrounding industrial areas in Nashik Region is not taking for estimation as whole emission inventory is developed on the basis of city level.

3.5 Whole Nashik City Total Emission Load

Cumulating all the emission loads from significant sources viz., Area, Point and Line sources for Nashik city vide emission inventory was developed as shown in **Table 3.29**.

Table 3.29 : Nashik City wide Emission Load from All the Sources

Sector	PM	%	NOx	%	SOx	%	HC	%	CO	%
Bakeries	44.8	0.12	4.1	0.01	1.8	0.11	286.0	1.12	317.8	0.04
Hotels	27.9	0.08	11.6	0.03	26.8	1.64	1.1	0.00	49.2	0.01
Open Eatout	3.2	0.01	4.4	0.01	1.3	0.08	0.5	0.00	2.4	0.00
Crematorium	130.6	0.36	17.8	0.05	3.3	0.20	865.7	3.37	962.7	0.12
Slum - Domestic	193.4	0.53	55.5	0.14	60.6	3.70	743.5	2.90	930.2	0.11
Non Slum- Domestic	689.2	1.88	317.9	0.82	68.9	4.21	2320.7	9.05	2587.8	0.32
Open Burning	186.9	0.51	70.1	0.18	11.7	0.71	502.4	1.96	981.3	0.12
Building Const.	3330.9	9.07								
Total Area (A)	**4606.9**	**12.55**	**481.35**	**1.24**	**174.39**	**10.65**	**4719.78**	**18.40**	**5831.39**	**0.72**
Red LSI	12397.1	33.77	9210.0	23.79	828.6	50.60	11966.2	46.65	722522.8	89.20
Red MSI	122.9	0.33	216.2	0.56	38.6	2.36	216.0	0.84	3045.3	0.38
Red SSI	212.0	0.58	156.2	0.40	65.5	4.00	1131.8	4.41	16722.6	2.06
Orange LSI	347.8	0.95	736.1	1.90	154.4	9.43	43.6	0.17	5302.7	0.65
Orange MSI	120.4	0.33	14.3	0.04	6.5	0.40	687.2	2.68	11590.9	1.43
Orange SSI	173.5	0.47	50.9	0.13	29.1	1.78	1091.2	4.25	16314.2	2.01
Green LSI	13.9	0.04	245.2	0.63	248.0	15.15	4.4	0.02	23.3	0.00
Green MSI	0.4	0.00	27.8	0.07	14.6	0.89	0.9	0.00	5.2	0.00
Green SSI	71.0	0.19	80.7	0.21	77.4	4.73	440.9	1.72	6534.6	0.81
Total Point (B)	**13459.0**	**36.67**	**10737.5**	**27.73**	**1462.6**	**89.32**	**15582.2**	**60.75**	**782061.6**	**96.56**
Car_Petrol	4.4	0.01	198.1	0.51	0.011	0.0007	264.1	1.03	1848.7	0.23
Car_Diesel	3.9	0.01	58.0	0.15	0.013	0.0008	20.7	0.08	15.5	0.00
Car_CNG	0.8	0.00	75.8	0.20			59.6	0.23	7.8	0.00
2 Wheelers	42.7	0.12	493.3	1.27	0.004	0.00268	1710.0	6.67	2367.6	0.29
3 wheelers	128.5	0.35	206.8	0.53			2242.5	8.74	751.1	0.09
HDDV	3528.8	9.61	26465.8	68.36	0.488	0.0298	1052.9	4.10	17074.7	2.11
Total Line (C)	**3709.0**	**10.10**	**27497.8**	**71.02**	**0.52**	**0.0315**	**5349.8**	**20.86**	**22065.5**	**2.72**
Paved Rd. Dust	**2805.8**	**7.6**								
Unpaved Rd. D.	**12125.9**	**33.0**								
Total of Resuspension Dust 14931.7 kg/d (40.7 of Total PM)										
Total (A+B+C) Kg/day	**36706.6**		**38716.7**		**1637.5**		**25651.8**		**809958.5**	
Total Tons/Yr.	**13397.9**		**14131.6**		**597.7**		**9362.9**		**295634.9**	

** Values of Concentrations are in kg/d*

Percent contribution of pollutant due to different source categories for PM and NOx and percent distribution of all pollutant is presented in **Figure 3.13 and 3.14.**

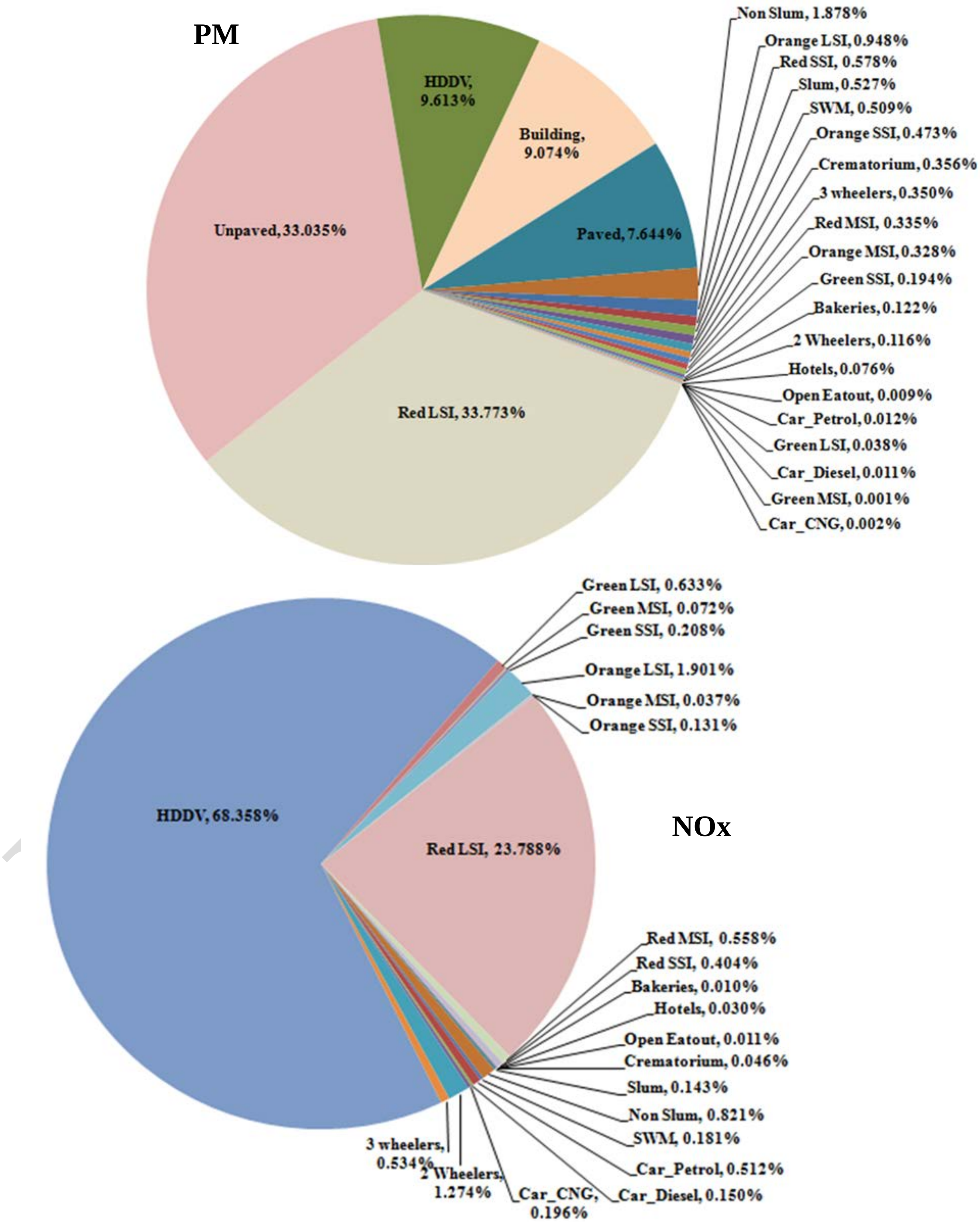
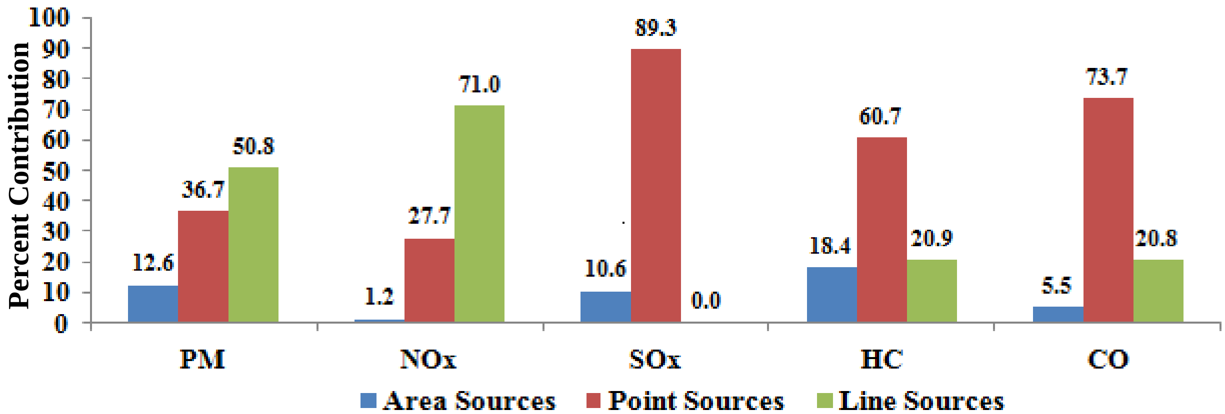


Figure 3.13 : Percent Contribution of PM and NOx from Different Sector in Nashik City

To devise an efficient air quality management framework, the estimation of a robust emission inventory is crucial.



Line Source also includes Paved + Unpaved Rd. Dust for PM

Figure 3.14 : Percent Contribution from All Sources for Whole of Nashik City

With its development Nashik has been witnessing migrations and settlement from the surrounding regions on large scale. It is the fourth largest city in terms of population. The various anthropogenic activities of more than 14.8 million population of the region form baseline for local level dispersion of the emission load. These sources include stationary area sources that are too small or too spread out to be classified as a point source. Although the population of Nashik city is same as that of Navi Mumbai, the contribution of Area sources alone accounts for 12.55% of the total PM emission load, while that of Navi Mumbai contributes only 1.9%. These emission loads can be attributed to dependency of local population on conventional biomass fuels. These ground level emission loads have adverse health impact over long-term exposure.

In Nashik city, PM is mainly contributed from road dust (40.6%) and tailpipe emissions of vehicular sources contribute 10.1%; followed by area sources (12.6%); whereas industrial sources contribution is around 36.7%.

The total PM_{10} emission load from Area Source was calculated to be 4.6 tons/day. The number of construction and building activities that are going in and around Nashik city is one of the major factor resuspension of road dust. There is lot of emissions while transport and handling of cement and other construction material. Hence, their contribution towards the final load is also significant. 72.3% of total Area source PM emission load is from Building and construction activity. Followed by building and construction activity, domestic fuel combustion contributes the most (11.5%) of PM emission load to the total area source emissions. Open burning of solid waste contributes 4.06% in the final PM load in the region. It is observed that the quantity of waste that is left un accounted or mismanaged from SWM system often ends up in open burning cases.

Consumption of domestic fuels, coal, kerosene etc at house hold level as well at commercial institutions like hotel, restaurants, open eat-outs, bakeries, crematorium etc are the contributory factor for the area sources. Apart from PM, the emission load of NOx is also estimated to be higher. Attributing to the population, currently the domestic fuel consumption emits the highest emission load across all the parameters of the total area source emission load.

Vehicles affect the concentrations of ambient airborne particles through exhaust emissions, but particles are also formed in the mechanical processes in the road-tire friction, brakes, and engine. Particles deposited on or in the vicinity of the road may be re-entrained, or resuspended, into air through vehicle-induced turbulence and shearing stress of the tires. Road dust has been acknowledged as an important source of urban PM_{10} particles in many parts of the world and its contribution can also be significant in the $PM_{2.5}$ size range. The PM emission load from paved road of Nashik was estimated to be 2.8 tons/day and 12.12 tons/day from unpaved roads. In the region of Nashik, 96% of roads were considered to be paved and remaining to be unpaved. Out of the total PM emission load, Road resuspension from both paved and unpaved contribute 40.6%.

Nashik is well connected to other cities of India via two national highways (NH3- Agra-Bombay National Highway & NH50- Nashik-Pune Highway) that pass right across the city. Along with regional level stationary sources, the emission load from mobile sources i.e, Line Source is also significant. The auto exhaust as well as dust emissions from these vehicles contribute lot of air pollution. The total PM emission load from vehicular sources is 3.7 tons/day and contributing 10.1% of total emission load. The maximum amount of emission load from total Line source is from Heavy Duty Diesel Vehicles (HDDV- 95.14%), followed by 3 wheelers (3.4%) and 2 wheelers (1.2%). There is lot of emissions due to transport, loading, unloading and handling of agro produces at Agro Produces Marketing Committee (APMC), where, there is huge transaction of agro products.

The total NOx emission load from Line Source is 27.5 tons/day and Area Sources is 0.48 tons/day. The among major contribution of NOx in Line source is also from Heavy Duty Diesel Vehicles (HDDV- 96.2%). In absence of an efficient public transport, there is dependency on private vehicles like 2 wheelers and intermediate point transport like 3 wheelers and 6 seaters within the city limits. The public transport of the region is not developed as compared to population migration and developmental changes that are expected in coming years. Out of total emission load nearly 68.3% of NOx is coming from HDDV transport vehicles.

Nashik had been growing very fast industrially, during the last few decades. There are about 6990 small scale, 27 medium scale and 131 large scale industrial units registered with DIC in 2011. There are 541 Air Polluting industries in area/cluster. Majority of the Industries which came up in the city or Industrial areas are Automobiles, Engineering, Electrical, Electronics, Stationary manufacturing, Printing press components, Metal Arts, Steel and wooden Furniture, Fiber and plastic moldings, Pharmaceutical and medical equipment, Data processing etc. The major players in Nashik include Mahindra and Mahindra, Schneider Electric, Siemens and Crompton Greaves. Major pollutants are TPM /SPM, SOx, NO_x, NH_3 and VOC. Among all sources, Point Source contributes 36.7% of PM and 27.7% of NOx load of the total final load for the city. There has been an increasing trend in consumption of fuels in industries of Nashik Industrial region. It can be observed that the most common fuels used in the industries of this region are coal, wood, bagasse or briquettes. The amount of diesel consumption in Green and Orange category industries is around 3 ton/hr, whereas that of Red category industry is 1.02 ton/hr. Considering huge fuel consumption in industry, the emission load from LSI was calculated to be 12.76 and 10.1 tons/day of PM and NOx, respectively and 0.7 tons/day of PM_{10} and 0.55 tons/day of NOx emission load from MSI and SSI. It was found out that the actual number of SSI and MSI differ from representative value. Inventorization of their fuel consumption is missing from the directory of all governing regulatory bodies. The Red LSI industries alone contribute 33.7% and 23.7% of PM and NOx respectively. As industrial percent emission of SO_2 is 89.3% the combustion of Basgasse, diesel, FO, HSD coal as fuel is one of the factor responsible for 95.12% of total SO_2 in final emission load.

The total 60.7% of HC percent contribution is coming from industries, whereas 18-20% is adding from area and line source. Consumption of wood in industries alone contribute 96%, as also bakeries, crematoria’s and non-slum domestic cooking share to area source. In line source 3 & 2 wheeler’s and HDDV are the major sources.

The total 73.7% of CO percent contribution is coming from industries, whereas 5-20% is adding from area and line source. Consumption of Bagasse in industries alone contribute 96.7%, as also line source, HDDV is the prominent sources.

Nashik is one of the most important and fastest growing cities in Maharashtra. Together with Mumbai and Pune, Nashik forms the Golden Triangle of Maharashtra. The development potential of Nashik city is certainly very high. These rapid changes put pressure on existing resources of the region, thereby attributing to impartial dispersal of developmental benefits to accommodating population. Besides the industries, there are other sources which are major contributors for pollution.

As mentioned above, the first Development Plan was sanctioned in the year 1993 and in the subsequent period, trend of urbanization, needs of urban population, mode of living, modes of transportation, industrialization, need of social and physical infrastructure, trend of migration, etc., have undergone many changes and therefore revision of Development Plan became necessary. Also provision of section 38 stipulates revision of Development Plan once in 20 years. As the speed of urbanization is very fast, Development Plan needs to be revised as and when required, to meet the aspirations of the citizens. Though the present revision is aimed at physical planning to achieve planned development, creation of social amenities rationally, etc.; it is also aimed to meet the changed aspirations of the citizens.

Chapter 4

Receptor Modelling & Source Apportionment

Chapter 4

Receptor Modelling & Source Apportionment

4.1 Source Apportionment Study Using EPA PMF v5.0

Positive matrix factorization (PMF) is a receptor modeling tool used for identification and quantification of sources and their contribution *(Norris et al., 2014)*. It is a multivariate statistical approach to factor analysis used for the source apportionment of atmospheric particulate matter *(Paatero and Hopke, 2003; Gupta et al., 2012; Das et al., 2015; Cesari et al., 2016; Habil et al., 2016; Sharma et al., 2016; Zong et al., 2016; Gadi et al., 2019)*. It requires concentration dataset of samples and associated uncertainty as inputs and gives several variables such as factor profiles, their contribution and error in modeling as output *(Polissar, 1998; Paatero and Hopke, 2003; Pakbin et al., 2011)*. The chemically speciated air samples can be assembled as a data matrix 'X' of i x j dimensions, in which i is the number of samples and j is the number of chemical species measured during analysis. It is based on chemical characterization of collected particles, are aimed to solve Eq 1.1.

$$x_{ij} = \sum_{k-1}^{p} g_{ik} f_{jk} + e_{ij} \qquad \text{...... Eq 1.1}$$

where p is the number of factors contributing to the atmospheric particulate matter, x_{ij} is the j^{th} compound concentration measured in the i^{th} sample, g_{ik} is the gravimetric concentration of the j^{th} element in material from the k^{th} source, and f_{kj} is the airborne mass concentration (mg/m^3) of material from the k^{th} source contributing to the i^{th} sample and e_{ij} is the residual for each species, difference between the measured and calculated amount.

PMF is a weighted least square problem in which a certain number of factors have to be determined in order to minimize an 'object function' as shown in Eq 1.2. Factor contributions and profiles are calculated by minimizing the object function 'Q' in the PMF model.

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} \left(\frac{x_{ij} - \sum_{k-1}^{p} g_{ik} f_{kj}}{u_{ij}} \right)^2 \qquad \text{........ Eq 1.2}$$

Where, u_{ij} is an estimate of uncertainty in the j^{th} variable in ith sample. Q is a significant parameter in the PMF model for which two values, Q (true) and Q (robust), are calculated in the model results. The apportionment technique relies on many trial attempts to arrive at an acceptable solution *(Reff et al., 2007; Jiang et al., 2015)*. More description with results analysis of the apportionment approach is included in Section 4.2; technical details can be found elsewhere *(Paatero and Hopke, 2003; Pakbin et al.,2011; Jiang et al., 2015)*.

4.2 Methodology

For the present study EPA PMF v.5.0 developed by US EPA (URL 1) was used. This model predicts the source profiles or fingerprints as Factors, relative contributions, and uncertainties for identification of sources and their positive contributions to ambient air pollution.

The study was carries out for representative samples of $PM_{2.5}$ and PM_{10} collected during winter, 2021 sampling campaign at 3 locations: RTO Colony Water Tank (Residential site), Taran Talao (Commercial/ Kerb Site) and Dr. Vasantrao Pawar Hospital (Background). The concentration and uncertainty data were obtained from the gravimetric analysis ($PM_{2.5}$ and PM_{10}); Elemental carbon and Organic carbon analysis; Elemental analysis by ED-XRF (46 elements: Na, Mg, Al, Si, P, S, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Rb, Sr, Y, Zr, Mo, Rh, Pd, Ag, Cd, Sn, Sb, Te, I, Cs, Ba, La, W, Au, Hg, Pb, Bi, Th and In); and Ionic Analysis (12 ions: Na^+, NH_4^+, Ca^{2+}, Mg^{2+}, F^-, Cl^-, NO_2^-, Br^-, NO_3^{2-}, PO_4^{3-} and SO_4^{2-}) for both PM_{10} and $PM_{2.5}$ for all sources as listed above.

EPA PMF requires 2 input files : ‘Concentration’ file and ‘Uncertainty’ file. The input file is prepared using concentration data set of samples and associated uncertainty and both these data sets should be in same format (csv or xls) with all the elements analysed for the study in same units ($\mu g/m^3$). The Concentration file is prepared by multiplying the concentration data as well as the uncertainty (i.e., standard deviation of analysis) obtained in $\mu g/cm^2$ with area of Filter paper (i.e., 11.9 cm^2 @ 39mm ϕ deposit area) from the ED -XRF and ionic analysis and then dividing the mass by the flow rate of Mini volume samplers (7.2 m^3, taking the sampling time as 24 hours @ 5 lpm. Here note that PMF works on non-negative aspect so if the concentration of any species is below detection limit or zero then that value needs to be replaced by 0.5 x Minimum Detection Limit (MDL) of that species. The MDL of all the elements is given in **Table 4.1**.

The uncertainty for measured values of elemental, ionic, gravimetric and EC-OC Analysis are calculated with Eq. 1.3 *(Norris et al., 2014).* This calculation includes field as well as analytical uncertainty. If the value of uncertainty is missing it can be replaced by 5/6 x MDL *(Norris et al., 2014).*

$$\text{Unc} = \sqrt{(conc\ of\ ion\ X\ 0.05)^2 + (Mdl * 0.5)^2)} \qquad \textbf{….Eq 1.3}$$

Where, Conc of ion = Concentration of ion, $\mu g/m^3$; Del relativity = Delta Relativity ~ 5%, Smp Unc = Sampling uncertainty ~5%; MDL = Minimum Detection Limit, $\mu g/m^3$

These two files are then used as input for EPA PMF v5.0 software. The model uses input files to display the summary of concentration data species in the form of minimum value, 25^{th}, 50^{th} and 75^{th} percentile value, maximum value and 'Signal to Noise' (S/N) ratio. Based on this ratio the species are assigned as strong, weak or bad, as error is minimum in strongest variable and maximum in weakest variable, those labelled bad are excluded from the analysis *(Paatero and Hopke, 2003; Jiang et al., 2015).* The Species having S/N ratio more than 3 are assigned Strong, ratio between 1 to 3 are assigned as weak and species with ratio less than 1 are assigned as bad species for running of the model. Species with 80% values below MDL are considered Bad species.

The model requires many trial and error attempts to arrive at the solutions. Thus, a wide range of factors (3-8 in number) were tried, and trial runs of 100 with a random start were attempted each time. The ratio Q_{true}/Q_{robust} has also been used to assess the modelled results. Q_{true} is estimated by considering entire data whereas Q_{robust} is estimated excluding outliers *(Waked et al., 2014).* This ratio when close to 1.0, signifies good solution and negligible influence of outlier whereas if ratio is greater than 1.5 indicates, non-negligible influence *(Waked et al., 2014; Jiang et al., 2015).* Hence for the present study the recommended protocol of convergence of all the runs and factors were selected for the cases where $Q_{robust} < 1.5\ Q_{true}$ *(Jiang et al., 2015: Zong et al., 2016; Gadi et al., 2019).* Also, the correlation coefficients (R^2) between measured and modelled metal concentration were checked for >0.80, which indicate better fit of the model to the measured data.

Table 4.1 : Minimum Detection Limit (MDL) of Target Analytes

Elements (a)	µg/cm^2	µg/m^3#	Elements (a)	µg/cm^2	µg/m^3#
Na	0.0876	0.211	Ag	0.0192	0.046
Mg	0.0414	0.1	Cd	0.0260	0.063
Al	0.0128	0.031	Sn	0.0488	0.118
Si	0.0050	0.012	Sb	0.0700	0.169
P	0.0134	0.032	Te	0.0866	0.209
S	0.0090	0.022	I	0.1176	0.283
Cl	0.0100	0.024	Cs	0.0040	0.01
K	0.0162	0.039	Ba	0.0092	0.022
Ca	0.0048	0.012	La	0.0054	0.013
Sc	0.0074	0.018	W	0.0060	0.014
Ti	0.0020	0.005	Au	0.0022	0.005
V	0.0042	0.01	Hg	0.0020	0.005
Cr	0.0020	0.005	Pb	0.0056	0.013
Mn	0.0110	0.026	In	0.0274	0.066
Fe	0.0102	0.025	Br	0.0010	0.002
Co	0.0044	0.011	Rb	0.0102	0.025
Ni	0.0030	0.007	Sr	0.0086	0.021
Cu	0.0050	0.012	Y	0.0090	0.022
Zn	0.0020	0.005	Zr	0.0100	0.024
Ga	0.0020	0.005	Mo	0.0104	0.025
Ge	0.0010	0.002	Rh	0.0108	0.026
As	0.0092	0.022	Pd	0.0126	0.03
Se	0.0010	0.002	**Ions (b)**	**PPM**	**µg/m^3#**
Ions (b)	**PPM**	**µg/m^3#**	NO_2^-	0.01	0.001
Na^+	0.008	0.001	Br^-	0.02	0.003
NH_4^+	0.009	0.001	NO_3^{2-}	0.02	0.003
K^+	0.02	0.003	NO_3^{2-}	0.06	0.008
Mg^{2+}	0.02	0.003	PO_4^{3-}	0.02	0.003
Ca^{2+}	0.03	0.004	SO_4^{2-}	0.02	0.008
F^-	0.002	0.0002	**EC-OC (c)**	**PPM**	**µg/m^3#**
Cl^-	0.005	0.001	EC	0.06	0.063
			OC	0.45	0.013

#Based on nominal air sampled @ 5LPM per sampling day

ED- XRF; (b) IC; (c)Based on DRI SOP for EC/OC (URL 2)

PMF can produce non-unique solutions because of many possible rotations of the solutions *(Paatero et al., 2002; Norris et al., 2014)*, also referred to as rotation ambiguity. Rotating a given solution and investigating how rotated solution fill the solution space is one way to minimize the number of solutions. F-peak, a parameter for rotation of solution, is controlled to ensure minimum change in Q to produce unique solution. F-peak values were varied between −3 and 3 and Q-values were monitored. The lowest Q-value indicated negligible presence of rotational ambiguity and thus solution at that F-peak was considered. The results are then check for mapping of the factors with respect to base model. Near to 100% mapping indicates that model is showing the efficiency of model results. If unmapped factors are more then, base factors and other parameters may need to be revised for getting better results. For the present work mapping of factors above 95% were accepted for all the cases.

Bootstrapping is a technique to estimate uncertainty in the solution by using series of dataset that are modified version of the original data *(Norris et al., 2014)*. Bootstrap runs indicated less than 5% variability in percentage of species. Minimum correlation value of 0.8 was selected with the default block size for every case. The above criteria, with reasonable control over numerous statistical parameters, substantiate that the solutions arrived were acceptable.

After matching all the criteria as described above, the model runs were considered for further analysis. The factor fingerprints, factor profiles and contribution obtained from these optimized runs were matched with the standard factor fingerprints and previous studies *(Maykut et al., 2003; Gupta et al., 2012; Patil et al., 2013; Sharma et al., 2016; Zong et al., 2016; Police et al., 2016; Jain et al., 2017; Mukherjee et at., 2018; Taghvaee et al., 2018; Garaga et al., 2020)* to identify the sources. Also, all the results from various run and error estimation were obtained in the form of datasheets which were used for further analysis to obtain percentage contributions of each source at receptor locations and percentage of elemental contribution from that source.

4.3 Results

The results of both cases for $PM_{2.5}$ & PM_{10} mentioned in Section 4.2 are presented in this section.

4.3.1 PM_{10}

After the EPA PMF run analysis, 5 factors were identified in the study location for PM_{10} Samples as shown below. The factor finger prints are shown in **Figure 4.1 (a and b)**. The final source contributions are shown in **Table 4.2**. Base factor profiles and their contributions for $PM_{2.5}$ and PM_{10} is presented in **Figure 4.2 (a to d).**

Factor 1: Fossil Fuel Combustion /Industrial

Factor 1 is identified as Fossil Fuel burning and industrial source, which accounted for contributions of 11.88%. Major proportions of NH_4^{-2}, Mg^{+2}, F^-, NO_3^{-2}, SO_4^{-2} and S (~21.6%, 30.8%, 85.3%, 18.1%, 16.3% and 17.4%) and Zn, Mg, Fe, Si and Ca^+ as minor indicators contributed to this source. Earlier studies reported that Fe, Zn and Mg are the indicators of the industrial emissions as these elements are greatly used in various industries like machinery, battery and electroplating purposes *(Taghvaee et al., 2018)*. Location of industrial regions in some of this study area could be the possible reason of this source. NH_4^{-2} along with SO_4^{2-} have been widely used as a marker of coal combustion in power plants *(Kumar et al., 2001; Patil et al., 2013; Rai et al, 2016; Sharma et al., 2016; Jain et al., 2018)*.

Factor 2: Construction Dust

Factor 2 is identified as Construction dust which accounted for contributions of 12.49%. Major proportions of EC, Na^+, Ca^+, NO_2^-, NO_3^{-2}, Ca (~29.1%, 22.6%, 13.1%, 86.4%, 14.8% and 12.7%) and minor species such as Ti and Si also contributed to this factor. Ca^{2+}, Mg, Si, Cl^- are major indicators of construction dust from cement and aggregate mixing *(Patil et al., 2013; Buyan, 2018; Jain et al., 2018; Keerthi et al., 2018, Garaga et al., 2020)*. Several Construction activities like infrastructure development projects and renovation of old structures was observed in and around the city contributing to this source.

Factor 3: Biomass Burning

Factor 3 biomass burning, accounted for 20.47%, with indicators of OC, EC, Na^+, K^+, Ca^+, Cl^-, Al, K and Ca, (~25%, 24.2%, 70.9%, 41.6%, 18.2%, 36.7%, 30.1%, 30.1% and 23%) and minor indicators such as Ti, Mn, Br, Pb and Na contributed to this factor. There have been many studies in the past suggesting that OC, K^+ and SO_4^{2-} are clear indicator of biomass burning. *(Shukla and Sharma, 2008; Police et al., 2016; Sharma et al., 2016; Jain et al., 2017; Mukherjee et at., 2018; Garaga et al., 2020)*.

Factor 4: Crustal Dust/ Road Dust

Factor 4 is represented by the significant levels OC, Ca^+, Cl^-, Al, Si, K, Ca, Ti, Mn, Fe and Zn (~28.4%, 60%, 25.6%, 31.3%, 67.4%, 31.3%, 63.3%, 31.3%, 31.3%, 70.5%, and 26.3%) contributing to about 26.94% of total PM_{10} pollution indicating by Crustal and Road dust. The wind-driven airborne dust from surface soils would have resulted in the considerable emissions of this factor. K, Mn, Si and Ca are good tracer of crustal dust (Kothai et al., 2008; Patil et al., 2013; Jain et al., 2017; Keerthi et al., 2018; Garaga et al., 2020) whereas substantial amount of paved road dust is being resuspended by vehicular movements which is indicated by minor markers such as Fe, Zn and Al are indicators of road dust re-suspension (Jain et al., 2017, Pawar et al., 2020). Road dust gets re-suspended due to natural gust of winds or moving objects like vehicles (Zhang, 2008; Kothai, 2011; Banerjee et al., 2015; Ashrafi et al., 2018). Since the study was done in dry conditions wind-blown dust has large influence on this source.

Factor 5: Secondary Aerosols/ Vehicular

Factor 5 is represented by the significant levels of OC, EC, NH_4^+, Mg^+, NO_3^{-2}, SO_4^{-2}, S, Zn, Mg (~31.4%, 29.9%, 68.2%, 42.7%, 51.8%, 57.3%, 60.9%, 52.3% and 60.3%) and minor indicators such as K^+, Ti, Mn, Br and Pb, Na contributing to 28.23% of total PM_{10} pollution which signifies secondary aerosol and vehicular factor. The studies indicated that NO_3^{2-}, NH_4^{2-} and SO_4^{2-} are major indicators for secondary aerosols *(Patil et al., 2013; Police et al.,2016; Sharma et al., 2016; Jain et al., 2017, Mukherjee et at., 2018; Garaga et al., 2020).* Emissions arising from road vehicles are generally contributed by a mixture of tailpipe emissions, and wear and tear of tyres. Zn is usually used as an additive in lubricating oil in two-stroke engines and is also a major trace metal component of wear and tear of tyres and Pb is the indicator of emission due to engines in vehicles *(Shukla and Sharma, 2008; Jain et al., 2017; Mukherjee et at., 2018, Pawar et al., 2020).* Also, EC, Br and OC were present in this factor indicating emissions from burning of fossil fuel from vehicles *(Jain et al., 2018; Keerthi et al., 2018).* The said major contributing metals are tracers of vehicular exhaust emissions as shown by various previous studies *(Gupta et al., 2012; Sharma et al., 2016; Jain et al., 2018; Keerthi et al., 2018; Jain et al., 2017; Pawar et al., 2020.*

4.3.2 $PM_{2.5}$

After the EPA PMF run analysis, 5 factors were identified in the study location for $PM_{2.5}$ samples as shown below. The factor finger prints are shown in **Figure 4.1 (a and c)**. The final source contributions are shown in **Table 4.2**. Base factor profiles and their contributions for $PM_{2.5}$ and PM_{10} is presented in **Figure 4.2 (a to d)**.

Factor 1: Vehicular / Road Dust

Factor 1 is identified as Vehicular and Road dust which accounted for contributions of 28.33%. Major fractions are OC, Mn, Fe, Zn, Pb, Mg and Na (~36.4%, 35.1%, 56.1%, 55.4%, 35.1%, 34.7% and 35.1%) and minor species such as Si, Br, Mo, K^+ and Cl^- are contributing to this factor. Emissions from road vehicles are generally caused by a combination of exhaust emissions and tyre wear and tear. Zn is commonly employed as a lubricant additive in two-stroke engines and is also a major trace metal component of tyre wear and tear, whereas Pb is a measure of emissions from automobiles' engines *(Shukla and Sharma, 2008; Jain et al., 2017; Mukherjee et at., 2018, Pawar et al., 2020).* Al, Si, K and OC are major indicators of resuspended Road dust, whereas Zn and Fe are deposited by vehicular emissions which are resuspended due to wind-driven airborne dust from surface soils and paved roads *(Gupta et al., 2011; Rai et al., 2016; Zong et al., 2016; Buyan, 2018).*

Factor 2: Fossil Fuel Combustion/ Industrial

Factor 2 represented as Fossil Fuel Combustion and Industrial source, which accounted for contributions of 19.47%. OC, Na^{+}, F^{-}, Cl^{-}, Si and K (~17.4%, 32.27%, 89.3%, 20.7%, 25.1% and 35.6%) are the major contributors and minor indicators are Mn, Br, Mo, Pb and Na. Earlier studies reported that Fe, Cr and Al are the indicators of the industrial emissions as these elements are greatly used in various industries like machinery, battery and electroplating purposes *(Taghvaee et al., 2018).* As major contributing factor representing Fluoride as a source. Fluoride source originating from industry, domestic heating *(Lewandowska A. et al., 2013)*. S, Fe, Cl^{-} along with SO_4^{2-} have been widely used as a marker of Fossil fuel combustion *(Kumar et al., 2001; Patil et al., 2013; Rai et al, 2016; Sharma et al., 2016; Jain et al., 2018)*. The modal could not differentiate these sources as there were many overlapping species.

Factor 3: Secondary Aerosols

The Factor 3 contributes 19.27% of total $PM_{2.5}$, which is represented by Secondary Aerosol. The fraction of NH_4^{+}, NO_3^{-2}, SO_4^{-2} and S are the dominant (~63.8%, 59.5%, 59.4% and 59.6%) and other species contributes around 17 to 34% from K^{+}, Cl^{-}, Fe, Zn and Mg. The studies indicated that NO_3^{2-}, NH_4^{2-} and SO_4^{2-} are major indicators for secondary aerosols *(Patil et al., 2013; Police et al.,2016; Sharma et al., 2016; Jain et al., 2017, Mukherjee et at., 2018; Garaga et al., 2020).* This is a background source which is contributing at all locations of the study area

Factor 4: Biomass Burning

Factor 4 was identified as Biomass burning by the significant levels of OC, Na^{+}, K^{+}, Ca^{+}, NO_3^{-2}, SO_4^{-2} and K (~24.5%, 50.7%, 23.8%, 29.5%, 33.9%, 21.2% and 30%) contributed to 21.42% of total $PM_{2.5}$ emissions. Minor indicators are NH_4^{+}, Mn, Br, Mo, Pb, Na and Si. There have been many studies in the past suggesting that K^{+} and SO_4^{2-} is clear indicator of biomass burning. *(Shukla and Sharma, 2008; Police et al., 2016; Sharma et al., 2016; Jain et al., 2017; Mukherjee et at., 2018; Garaga et al., 2020).* It is a known fact that biomass is a widely used energy source as well as there is issue of illegal litter burning in India which has resulted in the nominal contributions of biomass burning in this location.

Factor 5: Crustal and Construction Dust

Factor 5 represented as Crustal and Construction Dust by the significant levels of OC, Ca^{+}, NO_3^{-2}, Si, Mn and Na (~14.8%, 68.9%, 51.6%, 10.8%, 10.8% and 10.8%) contributing to 11.51% of total $PM_{2.5}$ emissions. Minor indicators are Cl^{-}, Br, Ti, Mo, Fe and Pb. Ca, Ti and Fe are major indicators of crustal dust/ soil as per previous studies *(Kothai et al., 2008; Sharma et al., 2016; Jain et al., 2017; Mukherjee et al., 2018; Pawar et al., 2020)*. Ca^{2+}, Mg, Cl^- are major indicators of construction dust from cement and aggregate mixing *(Patil et al., 2013; Buyan, 2018; Jain et al., 2018; Keerthi et al., 2018, Garaga et al., 2020)*. Several Construction activities like infrastructure development projects and renovation of old structures was observed in and around the city contributing to this source.

Table 4.2: Percentage Source Contribution for Nashik

Most likely source(s)	% PM_{10}	Most likely source(s)	% $PM_{2.5}$
Fossil Fuel Combustion /Industrial	11.88	Fossil Fuel Combustion/ Industrial	19.47
Construction Dust	12.49	Crustal and Construction Dust	11.51
Biomass Burning	20.47	Biomass Burning	21.42
Crustal Dust/ Road Dust	26.94	Vehicular / Road Dust	28.33
Secondary Aerosols/ Vehicular	28.23	Secondary Aerosols	19.27

4.4 Positive Matrix Factor Analysis Conclusion

After PMF analysis, five factors were identified contributing to both fraction of the PM. The contribution of Fossil Fuel Combustion /Industrial is around (11-19%), whereas Crustal and Construction Dust (11-12%), Biomass burning (20-21%), Resuspension Road Dust (26-28%) and in $PM_{2.5}$ Secondary Aerosol contributes (19.3%). In PM_{10} Secondary Aerosols and Vehicular source contribute (28%) as co-exist, modal could not differentiate the sources due to many overlapping species. Both source categories were found to be contributing almost the same for both $PM_{2.5}$ and PM_{10} Pollution.

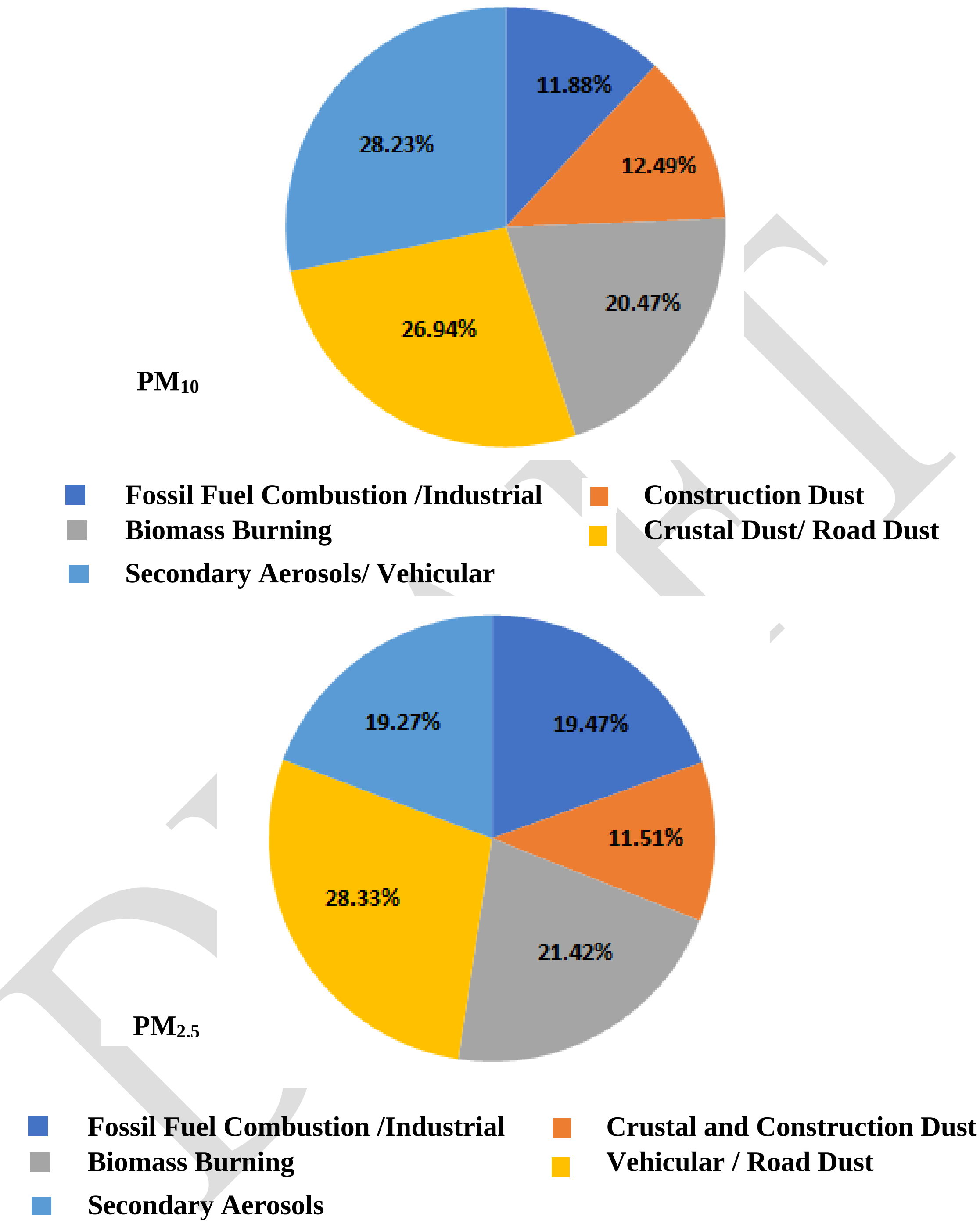
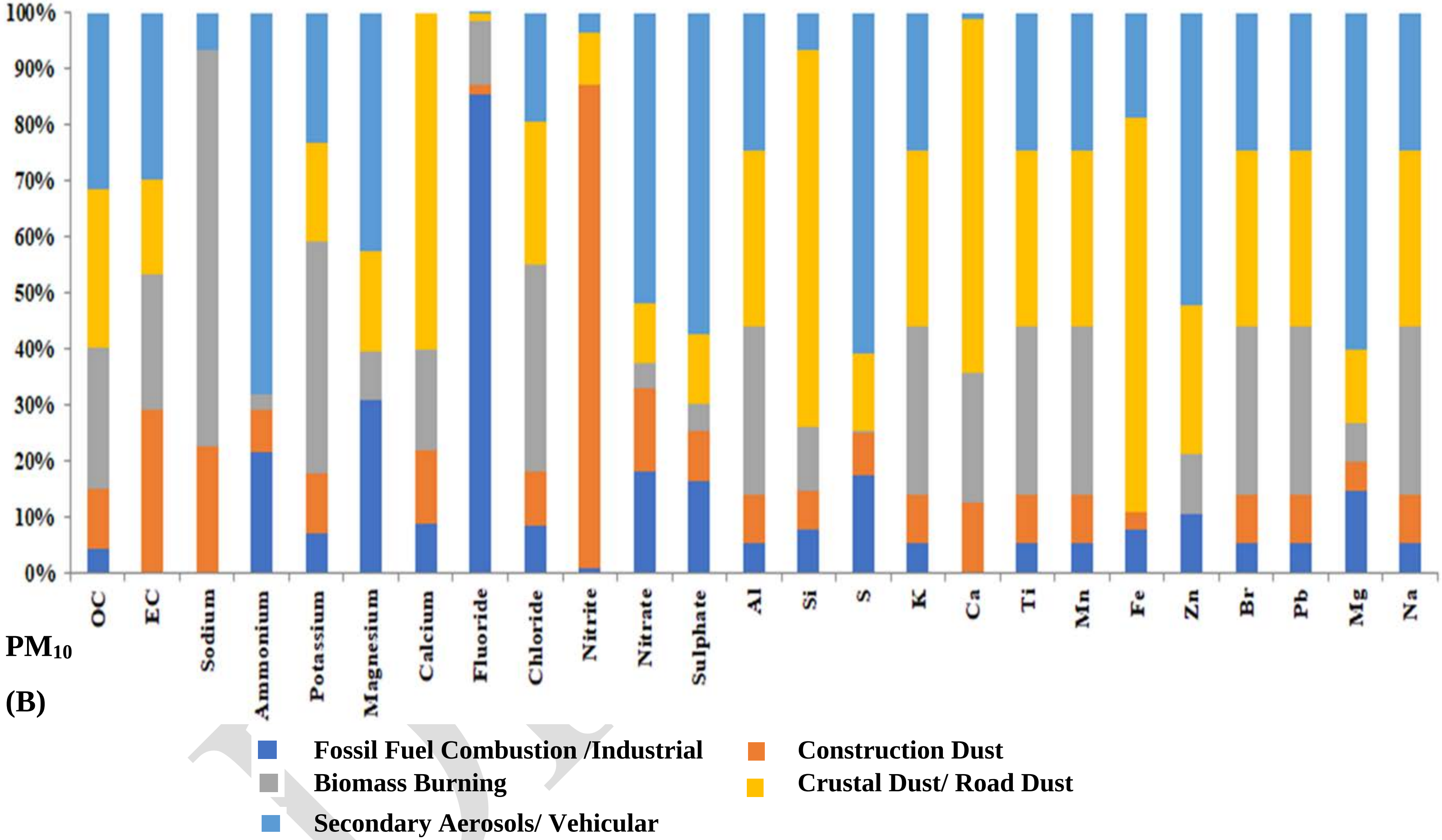


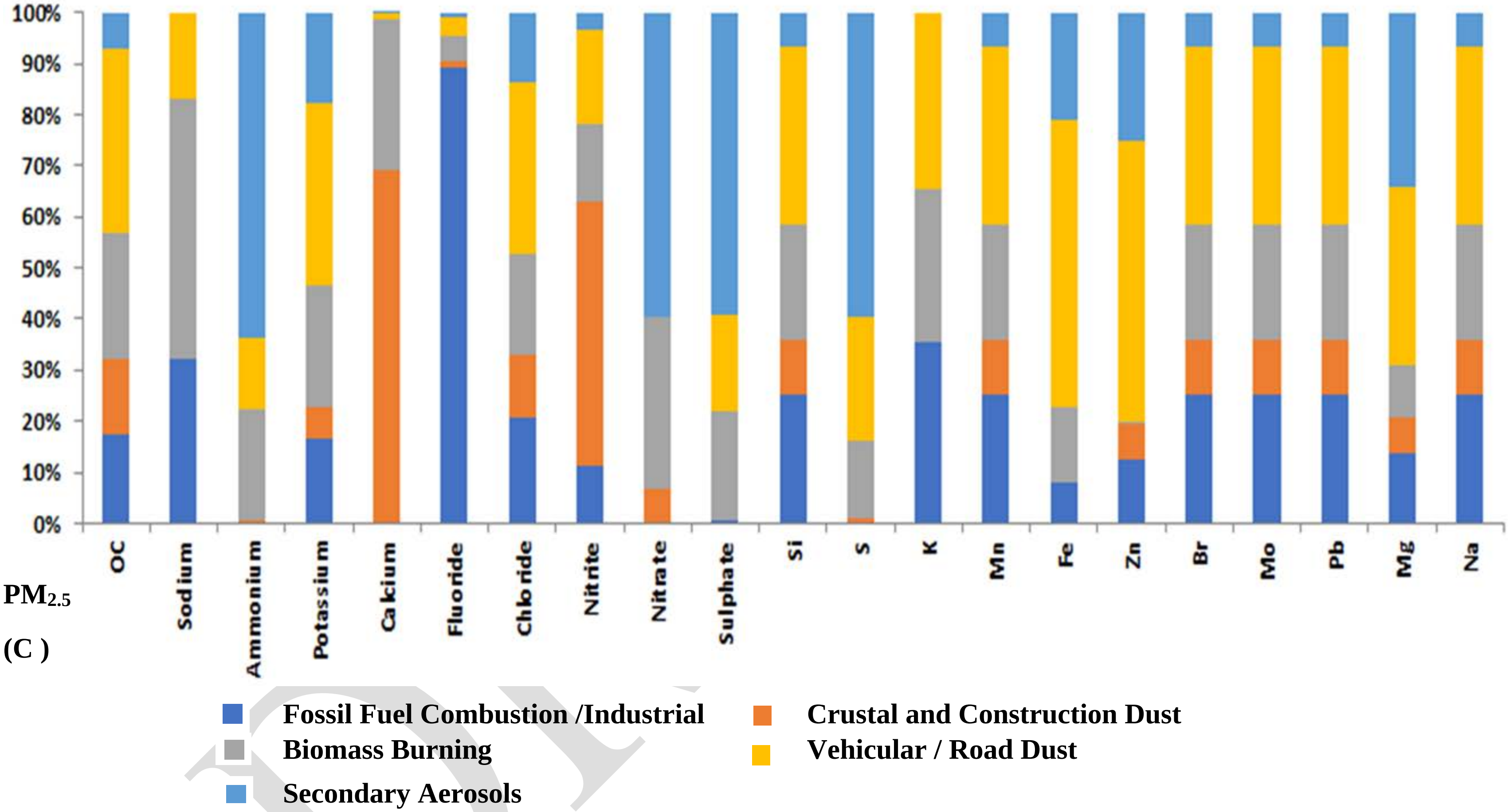
Figure 4.1: A) Percentage Contribution of Sources & Factor Fingerprints for B) PM_{10} C) $PM_{2.5}$ for Nashik



PM_{10}

(B)

Figure 4.1: A) Percentage Contribution of Sources & Factor Fingerprints for B) PM_{10} C) $PM_{2.5}$ for Nashik



$PM_{2.5}$

(C)

Figure 4.1: A) Percentage Contribution of Sources & Factor Fingerprints for B) PM_{10} C) $PM_{2.5}$ for Nashik

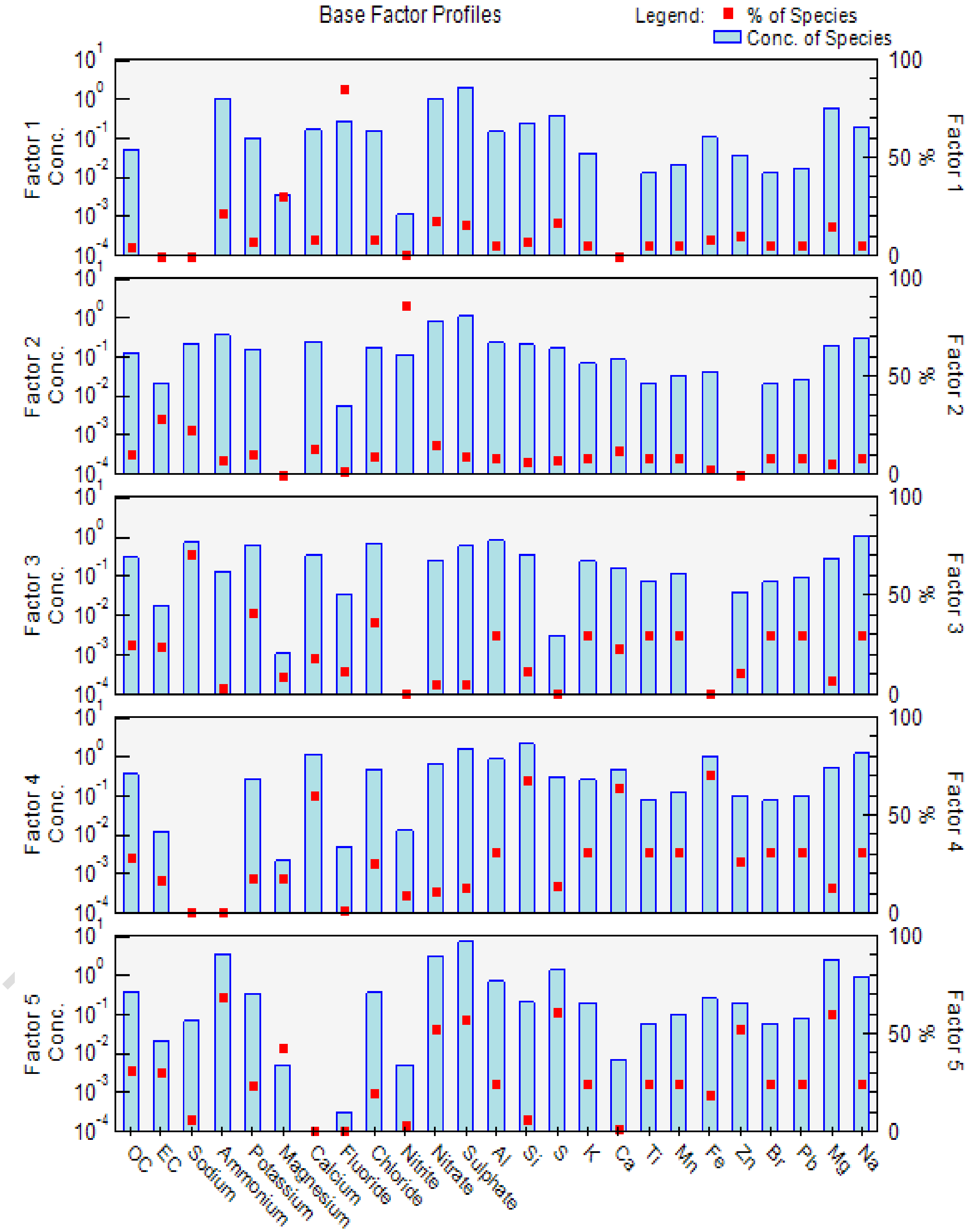


Figure 4.2 a : PM_{10} Base Factor Profiles

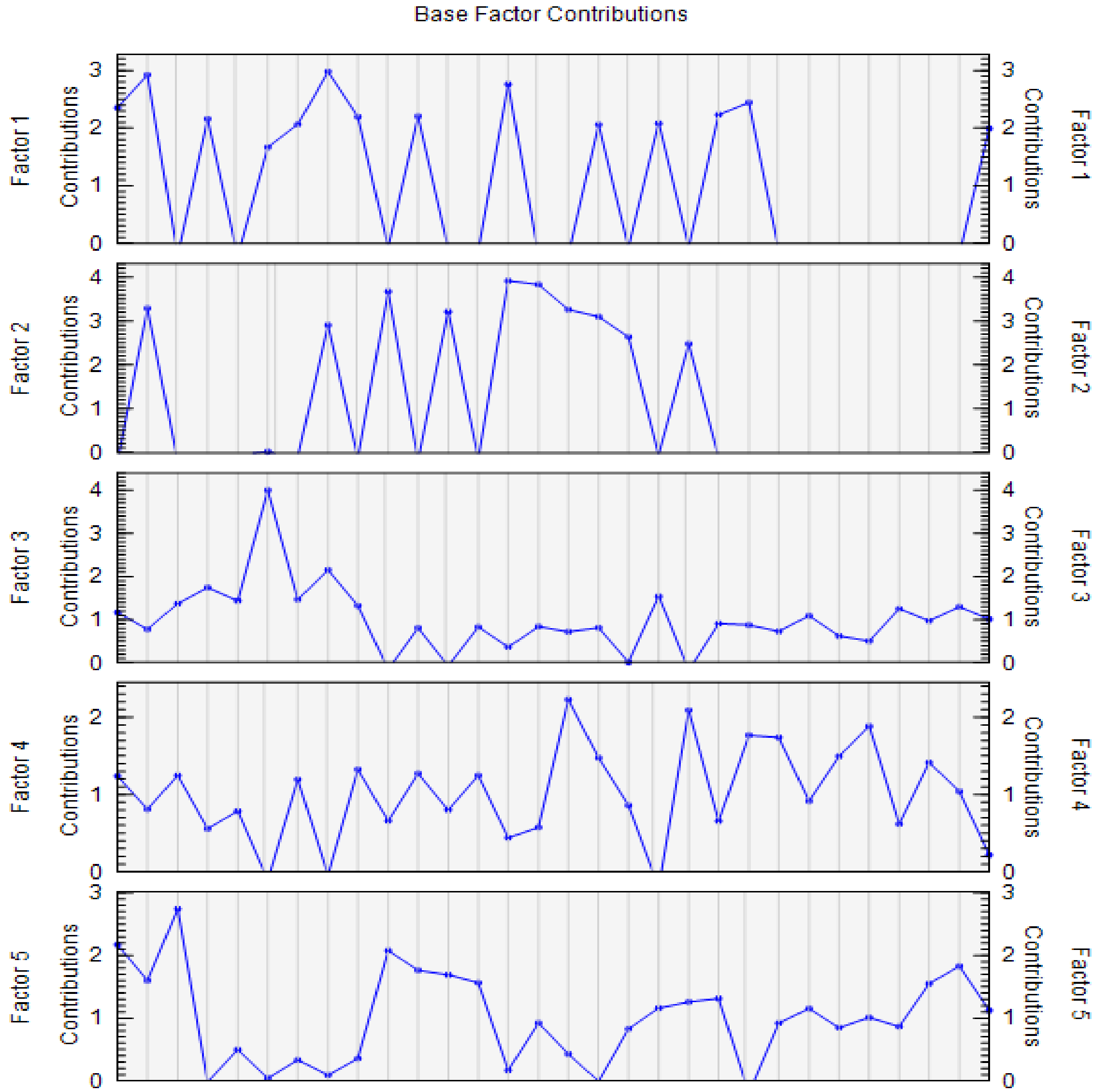


Figure 4.2 b : PM_{10} Base Factor Contributions

	Predominant Factors	% Contribution	Factor Name
Factor 1	NH_4^{-2}, Mg^{+2}, F^-, NO_3^{-2}, SO_4^{-2}, S	11.88	Fossil Fuel Combustion /Industrial
Factor 2	EC, Na^+, Ca^+, NO_2^-, NO_3^{-2}, Ca	12.49	Construction Dust
Factor 3	OC, EC, Na^+, K^+, Ca^+, Cl^-, Al, K, Ca	20.47	Biomass Burning
Factor 4	OC, Ca^+, Cl^-, Al, Si, K, Ca, Ti, Mn, Fe, Zn	26.94	Crustal Dust/ Road Dust
Factor 5	OC, EC, NH_4^+, Mg^+, NO_3^{-2}, SO_4^{-2}, S, Zn, Mg,	28.23	Secondary Aerosols/ Vehicular

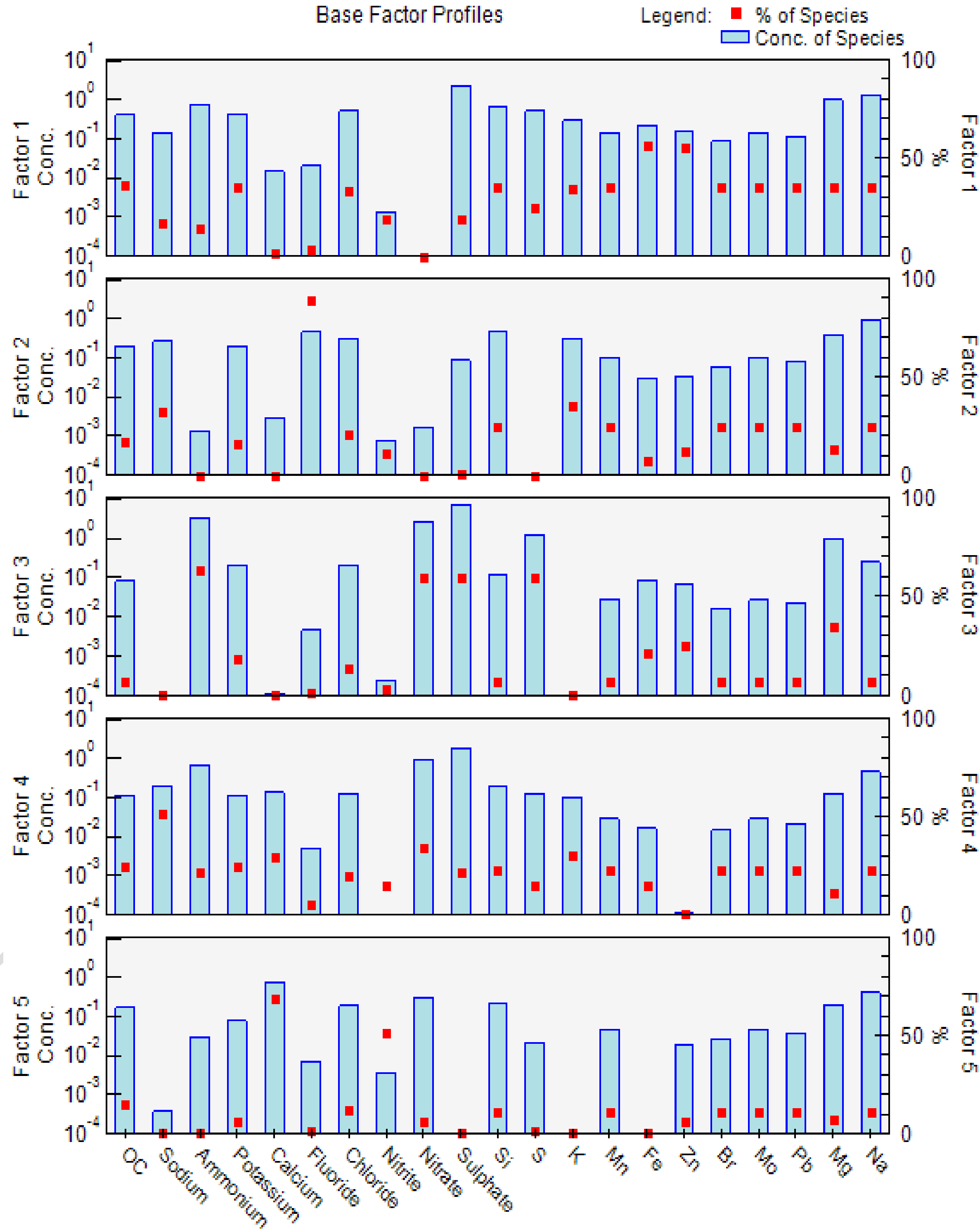


Figure 4.2 c : $PM_{2.5}$ Base Factor Profiles

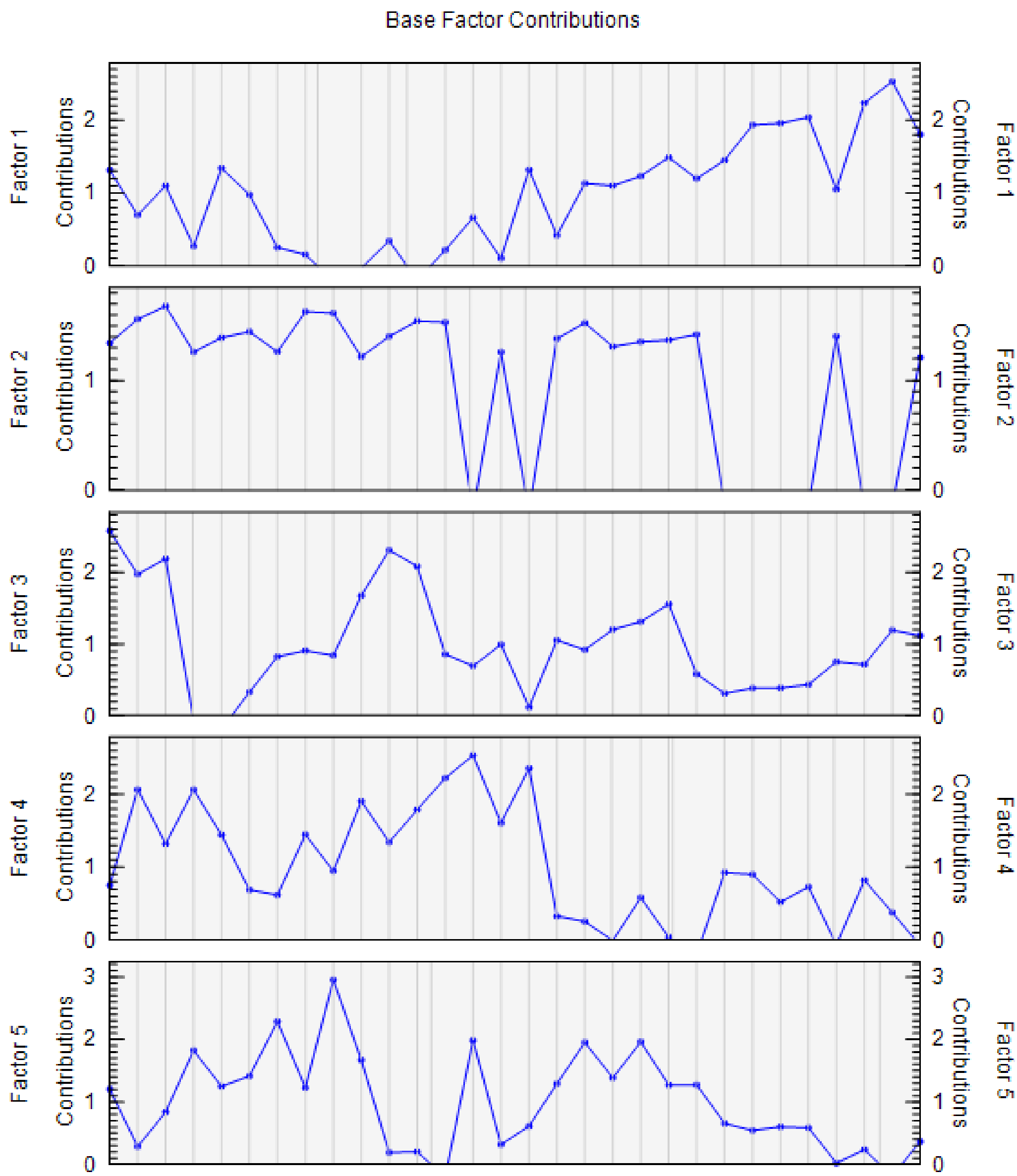


Figure 4.2 d : $PM_{2.5}$ Base Factor Contributions

	Predominant Factors	% Contribution	Factor Name
Factor 1	OC, Mn, Fe, Zn, Pb, Mg, Na	19.47	Fossil Fuel Combustion/ Industrial
Factor 2	OC, Na^+, F^-, Cl^-, Si, K	11.51	Crustal and Construction Dust
Factor 3	NH_4^+, NO_3^{-2}, SO_4^{-2}, S	21.42	Biomass Burning
Factor 4	OC, Na^+, K^+, Ca^+, NO_3^{-2}, SO_4^{-2}, K	28.33	Vehicular / Road Dust
Factor 5	OC, Ca^+, NO_3^{-2}, Si, Mn, Na	19.27	Secondary Aerosols

4.5 Emission Inventory and Source Apportionment

Emission inventory is a thorough accounting of air pollutant emissions sources and amounts emitted into the air as a result of a certain process in a specific geographic location over a specific time period. The process of relating a source emission (an activity sector or a region) to the ambient air concentration of a pollutant is known as source apportionment (SA).

Industrial : Among all sources, point source contributes 36.7% of the total PM emission load and 27.7% of NOx load from the total load of the city. The amount of diesel consumption in Green and Orange category industries is around 3 ton/hr, whereas that of Red category industry is 1.02 ton/hr. The emission load of PM from RED-LSI units was estimated to be around 12.3 ton/day. Considering huge fuel consumption in industry, the emission load from LSI was calculated to be 12.76 and 10.1 tons/day of PM and NOx, respectively and 0.7 tons/day of PM_{10} and 0.55 tons/day of NOx emission load from MSI and SSI. The Red LSI industries contribute 33.7% and 23.7% of PM and NOx, respectively. The highest PM emission load was calculated from Bagasse (48.1%) [from 3140.37 TPD], followed by load from Coal (33.9%) [from 1376.57 TPD] and Wood (17.5%) [from 151.76 TPD] as fuel consumption.

The 83.78% of NOx is emitted from coal-based industries [from 1376.57 TPD], followed by emission loads from combustion of Diesel (7.04%) [from 109.15 TPD) and Bagasse (3.5%) [from 3140.37 TPD]. Red category industries contribute 94.9% of NOx emission loads out of all LSI industries. The total NOx emission is around 10737.5 kg/day i.e, 10.73 TPD. Out of the total emission load, SO_2 is estimated to be around 10.7 ton/day The contribution of industrial source in SO_2 emission is around 89.3%, from the combustion of Basgasse, diesel, FO, HSD coal as fuel.

The results are well corroborated with apportionment of particulate matter; the overall factor emphases industrial source contributions of 11.88 percent in PM_{10} sample load, compared to 19.47 percent in $PM_{2.5}$. In PM_{10}, significant indicators such as NH_4^{-2}, Mg^{+2}, F^-, NO_3^{2-}, SO_4^{2-} and S was found in concentrations of 16-85%. In $PM_{2.5}$ the indicators of OC, Na^+, F^-, Cl^-, Si and K are the dominant contributors in the range of 17 to 89%. The other minor indicators are Zn, Mg, Fe, Si, Ca^+, Mn, Br, Mo, Pb and Na. Machinery, battery, smelting and electroplating industries emit Fe, Zn, Mg, Cd, Mn and Cr. As also, Cd, Cl^-, Mg, SO_4^{2-} and Br are emitting from incinerator /furnaces and industrial combustion. NH_4^{-2} along with SO_4^{2-} have been widely used as a marker of coal combustion. The overall all trace indictors and emission loads prominence the industrial fossil fuel burning is high in Nashik region.

Vehicular Source: As per emission inventory, the vehicular sector contributes around 3.7 tons/day and contributes 10.1% of the total emission load. The PM emission load from 3 wheelers is 128.5 kg/d and from 2 wheelers is 42.7 kg/d. Out of the total, 27.497 ton/day of NOx, 96.25% (26465.8 kg/d) of emission load is estimated from HDDV vehicles, followed by 2 wheelers (1.79%, 493.3 kg/d). The NOx emission load from 2 wheelers (0.493 ton/day) is almost equivalent to combined emission load from Car operating on Petrol (0.198 ton/day) and 3 wheelers (0.206 ton/day). There is lot of emissions due to transport, loading, unloading and handling of agro produces at Agro Produces Marketing Committee (APMC), where, there is huge transaction of agro products.

The overall source contribution of vehicular emission factor is around 28% in both the PM fractions. The vehicular factor dominant species are OC, EC, SO_4^{-2}, Mn, Fe, Zn, Pb, Mg and Na ranging from 34 to 56% in PM load. The minor tracer indicators found are NO_3^-, NH_4^{3-}, Br and S. Vehicles emissions are majorly mixture of tailpipe emissions, exhaust, wear and tear of tires, brakes, brake lining and exhaust system, and also different additives in the fuel. Zn and Pb is indicator of additive in lubricating oil in two-stroke engines as also component of wear and tear of tyres. Also, EC, SO_4^{2-} and OC were present in this factor indicating emissions from burning of fossil fuel from vehicles. The said major contributing metals are tracers of vehicular exhaust emissions as shown by various previous studies. The influencing vehicular traffic supports the source characterization

Road dust is an important source of urban PM_{10} and contributes significantly. The PM emission load from paved road of Nashik was estimated to be 2.8 tons/day and 12.12 tons/day from unpaved roads. In the region of Nashik, 96% of roads were considered to be paved and remaining to be unpaved. Out of the total PM emission load, Road resuspension from both paved and unpaved contribute 40.6% of the total PM emission load.

As per source characteristics, the resuspended road dust and wind blowing dust contributes 26 to 28%, from both the fractions. The major indicators OC, Ca^+, Cl^-, Al, Si, Mg, Pb, Ti, Fe and Zn were contributing around 28 to 63% to the total. The minor trace indictors are SO_4^{2-}, Na^+, Mn, NO_2^-, K^+ and Cl^-. Al, Si and SO_4^{2-} are the major indicators of resuspended road dust, whereas Zn and Fe are deposited by vehicular emissions which are resuspended due to wind-driven airborne dust from surface soils and paved roads. The Unpaved and Paved Road dusts get resuspended and act as source due to vehicles movement and friction of tires with roads.

Area Source: The total PM_{10} emission load from Area Source was calculated to be 4.6 tons/day. Among area source, dominant source is building and construction activity which contribute around 72.3% to PM emission load, followed by domestic fuel combustion (19.5%). Open burning of solid waste contributes 4.05% in the final PM load. It is observed that the quantity of waste that is left un accounted or mismanaged from SWM system often ends up in open burning cases. Consumption of domestic fuels, coal, kerosene etc at house hold level as well at commercial institutions like hotel, restaurants, open eat-outs, bakeries, crematorium etc are the contributory factor for the area sources. Apart from PM, the emission load of NOx is also estimated to be higher.

As per the PMF matrix factorization, biomass burning/ wood combustion and as well minor contribution from waste burning and construction/crustal/soil dust are the prominent sources. The biomass burning factor, accounted for 20 to 22% in both the PM fraction. Major tracers are OC, EC, Na^+, K^+, Ca^+, Cl^-, NO_3^{-2} and SO_4^{2-} which accounts for around 25 to 41% of the total load. The past studies suggesting that OC, K^+ and SO_4^{2-} are clear indicator of biomass burning and NH_4^{3-} is an indicator of Wood Combustion. The crustal and construction dust tracer contributes 11 to 13% in both the fractions, the major indicators are Ca, Na^+, Ti and Si ranging around 12 to 86%. As per previous studies Ca, K and Mg are the major indicators of crustal and soil dust. As per characterization, secondary aerosols factor are mixed source which accounted for 20 to 25% in both the fraction. The traces viz. $NH4^+$, NO_3^{2-}, SO_4^{2-} and S are contributing around 50 to 60%. The different studies indicated that NH_4^{3-}, NO_3^{2-} and SO_4^{2-} are major species of secondary aerosols. These secondary ions are derived from gas to particle conversion processes involving photo-chemical reaction of gaseous precursors such as SO2 and NOx which are largely emitted from local and regional sources. Since these are background pollutant sources, they are found in all samples for entire study duration.

4.6 Past Studies

- **National Clean Air Programme (NCAP) for Indian Cities: Review and Outlook of Clean Air Action Plans**. Ganguly et. al., 2020. Atmospheric Environment: X, Volume 8, 100096

NCAP, launched in 2019, is India's flagship program for better air quality in 122 cities. The Nashik is one of the non-attainment cities of Maharashtra. As per CPCB and urban emission data sets analysis of source contribution from different sectors indicate that all transport (road, rail, aviation, and shipping) - gives 12.1%, residential 6.6%, Industries (without brick kilns) 15.8%, dust (construction and resuspension due to vehicle movement) accounted for 13.2%, open waste burning

8.7%, diesel generator sets 3.6%, brick manufacturing 0.9% and outside/regional contribution is around 39.1%. Transport and road dust together cover 30%, followed by industries, which needs to address by policy interventions. The institutional and administrative arrangements for ensuring inter-departmental and regional alignment in air pollution mitigation strategies are absent.

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Chapter 5

Dispersion Modelling

Chapter 5

Dispersion Modelling of Nashik

Air quality dispersion modeling exercise was undertaken with a view to delineate the immediate sources and their impact on measurement locations. Dispersion modeling tool (AERMOD model) was also used for the whole city air quality scenario generation for different emission loads of PM and NOx. The existing scenario model runs were undertaken to establish the dispersion pattern of pollutants due to local meteorology and emission from all possible sources. Model runs also provide an idea about missing sources or additional sources which may have been accounted for earlier. The scenarios for different seasons, locations and sources have been generated to bring out the contributions and their variability. The comparison of concentrations for the scenario has been carried out by considering the highest ten concentrations.

5.1 Description of AERMOD Model

The AMS/ EPA Regularity Model (AERMOD, EPA 2004) are a steady-state plume model. AERMOD was developed in collaboration between the USEPA and the American Meteorological Society (AMS). Air quality model provides a mathematical prediction of ambient concentration of pollutants using simulation of physical and chemical processes of atmosphere, affecting air pollutants and determining the dispersion, reaction and behaviour of pollutants. The model is capable to assess the pollutant concentrations from number of sources and considers the dispersion of pollutants from stationary sources for a short-range (up to 50 Km). In the stable boundary layer (SBL), it assumes the concentration distribution to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function. The convective boundary layer is the lower troposphere layer in contact with the ground heated by the sun and moves by the wind. The convective phenomena and wind causes significant air mixing with horizontal and vertical turbulences. The model is capable of accepting single station data assuming that the weather status is horizontally homogenous over the study area.

Additionally, in the CBL, AERMOD treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates into the elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate. The

AERMOD model is applicable to rural and urban areas, flat and complex terrain, surface and elevated releases, and multiple sources (including, point, area and volume sources).

The modelling system of AERMOD contains an air dispersion model processor, a meteorological data pre-processor called AERMET, and a terrain data pre-processor called AERMAP. The AERMET meteorological pre-processor program provides the meteorological data as the basic input data in AERMOD. AERMET presents two types of meteorological data files consisting of surface scalar parameters and vertical profiles of meteorological data. AERMET uses the steady hourly surface and upper air meteorological observations to develop the meteorological inputs for AERMOD through calculating the hourly boundary layer parameters such as the Monin-Obukhov length, sensible heat flux, surface friction velocity, convective velocity scale, temperature scale and mixing height. AERMAP facilitates the generation of hill heights scales for AERMOD. The details of AERMOD model and its application guide have been presented in EPA, 2004.

5.2 Application of AERMOD for Air Quality Management

Air quality management studies have been done across the World using AERMOD. In China, it was applied for near future air quality simulation using change in emissions based on proposed development plan to predict the concentration for the industrial city, Xuanwei of Yunan province (Ma *et al.*, 2013). The impact of emission control policy was studied for the five year (2011-2015) plan for Xuanwei. Emission reduction scenarios were prepared for the emission control policy for SO_2, NOx and PM_{10}. Emission inventory was built based on general investigation of pollution sources and pollutant source monitoring report (2008). This included the industrial plant and six important factories around the city. In this case, average meteorological data in same time period was to be used to predict the future air quality. One way ANOVA test was used to show effectiveness of the emission control policy. Spatial contour plots helped to identify the high concentration regions, which required the attention of the special environmental supervisors. Gulia *et al.*, 2015 used AERMOD to appraise the air quality surrounding the heritage site of Amritsar. Amritsar is a tourist place and religious heritage complex which is crowded during festivals. Free open kitchens operate next to the heritage structure to provide free meals to the visitors. Apart from this, coal based tandoor, diesel generators, local industries and vehicle movement are main source of emission. In this study conducted to predict concentration from June to September 2012, AERMOD was used. Various management options were discussed to decrease pollution levels at the heritage site. Recently in 2010, air quality monitoring, emission inventory and source apportionment study for Indian Cities were conducted by CPCB and MoEF-CC. Dispersion modelling is an important component of the study that was used for projecting air quality profiles (iso-concentrations plots) of the city, under different scenarios viz. business as usual, future projections with implementations of control options, etc. It was also used to evaluate efficacy of various control options for evolving city-specific action plans for air quality improvements.

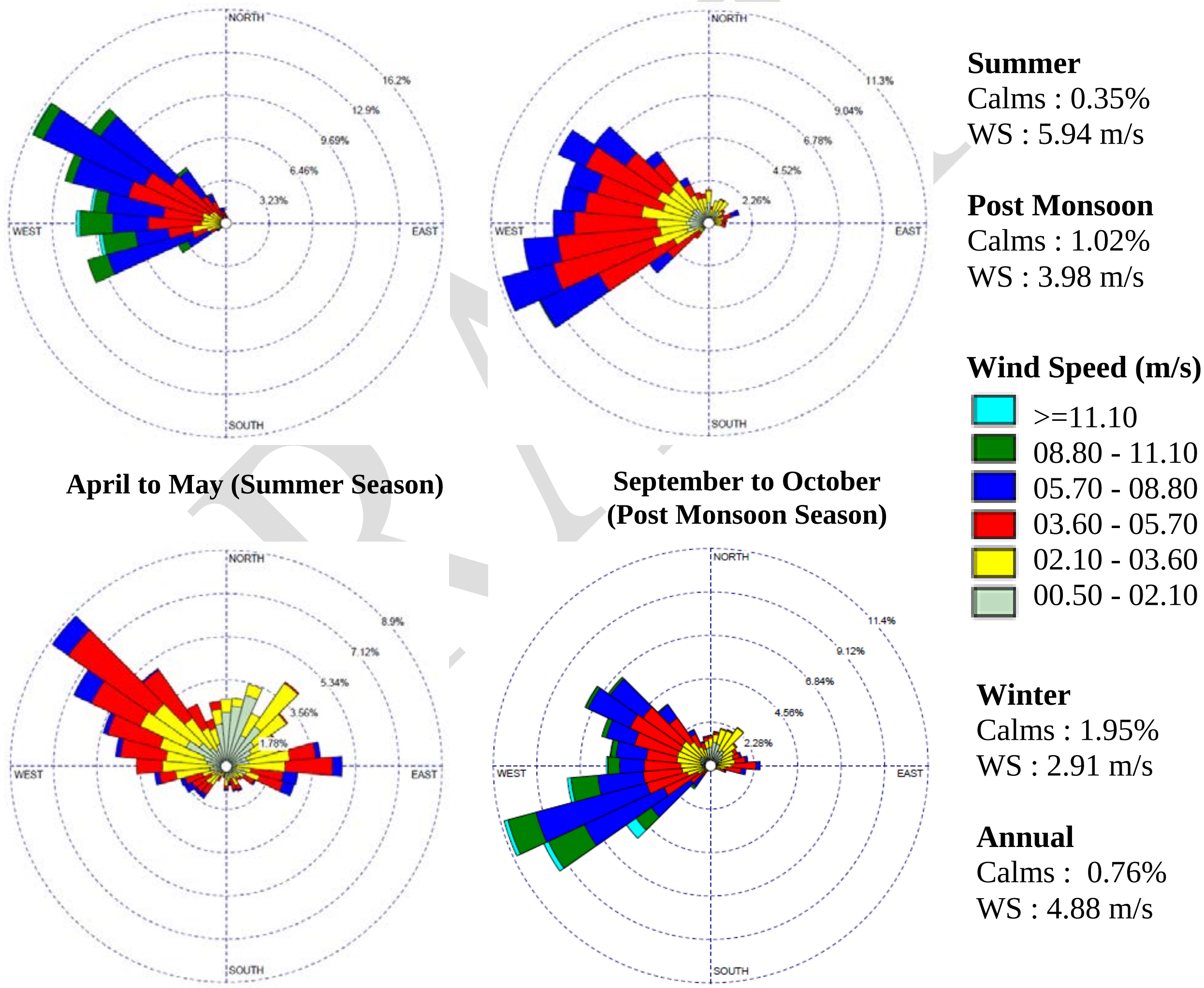
Meteorological data required for AERMET includes upper air and onsite data. The requirement of meteorological data for air quality modelling can be accomplished by either onsite monitoring or meteorological modelling. The onsite meteorological measurement in Nashik is limited to surface measurement and limited upper air data is available at IMD station. Therefore, meteorological model can help to generate onsite meteorological data to use in air quality models. Meteorological and air quality models have been applied in many studies with several objectives and addressed various scientific research questions across the world.

Meteorological models calculate three-dimensional gridded meteorology using mathematical equations to simulate atmospheric processes like the variation in temperature, wind direction and speed over time. The main purpose of the meteorological model is to forecast and simulate the weather parameters. In the early nineties, mesoscale meteorological models were developed. Mesoscale is an intermediate scale between those of weather systems and of microclimates, on which storms and other phenomena occur. The mesoscale meteorological modelling system was upgraded to the fifth generation of mesoscales meteorological model by Penn State University and National Center for Atmospheric Research which is commonly referred to as MM5 (1994).

Weather Research and Forecasting Model (WRF) was developed as an evolutionary successor to the MM5 model and incorporates current state-of-the-science atmospheric physics improvements. WRF use 1 Km by 1 Km gridded land use to estimate surface properties (surface boundary conditions). It also uses the pre-processed wind field for the global weather simulations to obtain the initial time boundary condition at t=0 and at other times as well.

Regarding low wind conditions, the majority of meteorological data is collected from airport met stations. An airports primary concern is high wind speeds which may affect aircraft. Therefore, low wind speeds are often not recorded with sufficient accuracy for air dispersion modelling purposes. This is of particular concern for air dispersion modelling because low wind speeds often result in higher concentrations. The WRF models avoid this issue as all wind speeds are calculated with equal accuracy. The uncertainties of meteorological model create negative impact to air quality model simulation (Sistla *et al.*, 1996). Significant errors have still been observed during the routine assessment of the performance of the next generation air quality models despite having made use of the advanced techniques for data collection and numerical modelling with high computational abilities *(Russell and Dennis, 2000)*.

Hourly meteorological data has been collected from Lakes Environmental for 2016 which includes both surface and upper air data and considered as representative for whole Nashik city. The Albedo, Bowen ratio and Surface roughness length were set to default, as 0.2075, 1.625 and 1 respectively. Wind roses of summer, post-monsoon, winter seasons and annual of Nashik city are presented in **Figure 5.1**.



April to May (Summer Season)

September to October (Post Monsoon Season)

December to January (Winter Season)

Annual

Figure 5.1 : Wind Rose of the Winter and Summer for the Study Area (Nashik)

Annual windrose shows, the predominant direction is from WSW (9 to 11%), W (9%) and WNW(7%); in WSW direction wind speed mostly is in the range 8.8 to 11.1 m/s or less. In W and

WNW direction predominant wind speed is in the ramge of 5.7 to 8.8 m/s. The average wind speed observed is around 4.88% and calm condition is 0.76%. During December to January (winter season) the predominant directions are blowing from NW (7 to 8%) and moving towards E (3 to 10%) or less, inclining towards NE. The predominant wind speeds are 3.6 to 5.7 m/s in NW direction, whereas as Easting speed is around 2.1 to 3.6 m/s. The average wind speed observed is 2.91 m/s and calm condition is around 1.95%. During Post Monson and Summer seasons the predominant wind directions are blowing from mostly the same way i.e. NNW to W and some part in WSW. The wind speed moves around 3.6 -5.7 m/s to 5.7 -8.8 m/s in summer and 5.7 -8.8 m/s to 8.8 to 11.1 m/s in post monsoon. The average wind speed in summer season was 5.94 m/s, whereas it was 3.98 m/s in post monsoon. Calm condition for both the seasons are around 0.35 to 1.02% respectivley.

5.2.1 Terrain Data

The terrain is characterized by the AERMIC terrain pre-processor (AERMAP) which also generates elevations for receptor grids. Gridded terrain data are used to model the area, where the gridded elevation data is made available to AERMAP in the form of a Digital Elevation Model (DEM) data and all sources (Area–wards, Line –vehicular and Point –industry), are presented in **(Figure 5.2)**.

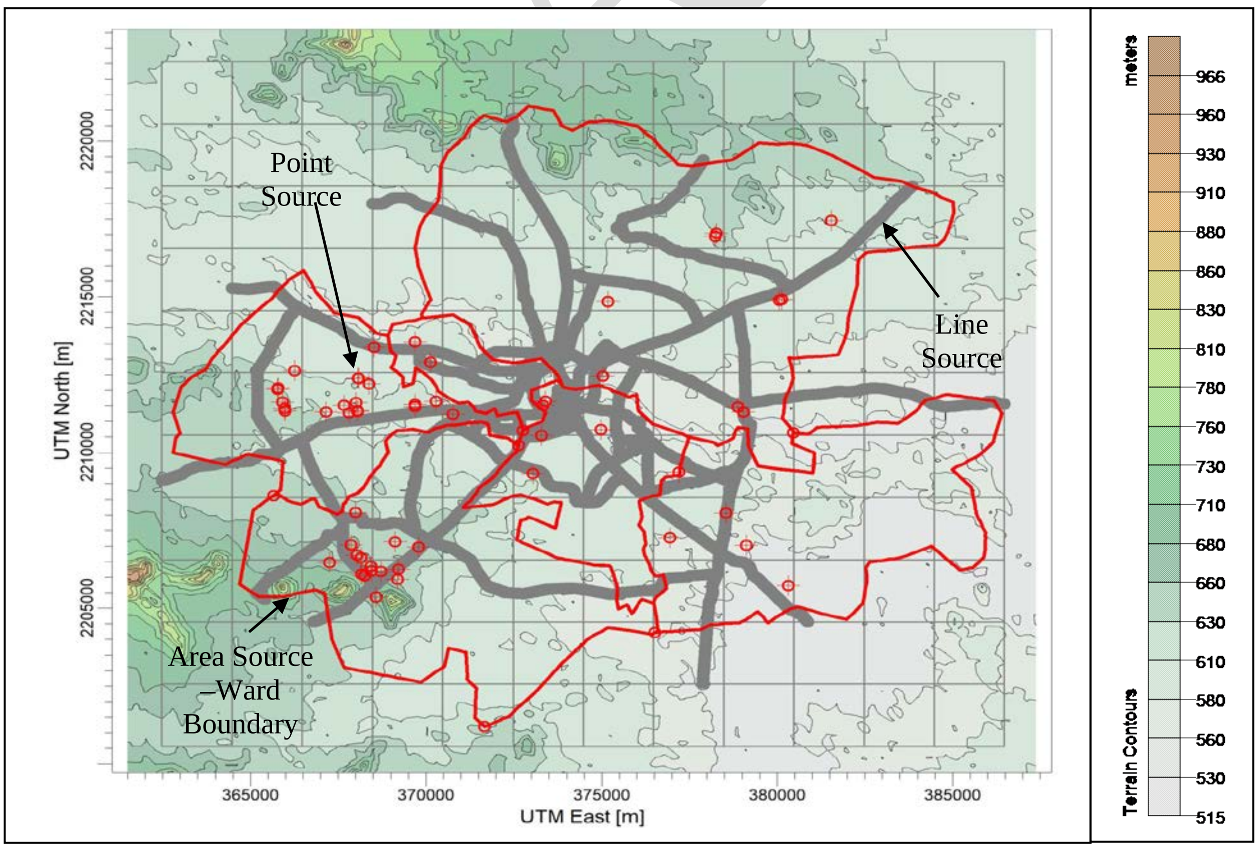


Figure 5.2 : AERMAP Digital Elevation Model (DEM) Data for Nashik City

This data also proves useful when the associated representative terrain influence height has to be calculated for each receptor location. Thus, elevations for all sources viz. line sources, point sources, area sources, both discrete receptors and receptor grids are computed by the terrain pre-processor. SRTM3 - Shuttle Radar Topography Mission (SRTM) 3 with resolution of 30 m was used as Terrain Data for running the model.

A uniform Cartesian grid receptor covering 22 x 24 Km^2 of the study area was considered as input in the AERMOD model. The model was set to simulate the 24-h ground level concentrations (GLC) of at the selected receptor network. The number sources as an input to the model was considered for different source category i.e. Area, Line, Industry and Resupension Dust are given in **Table 5.1 and Figure 5.2.**

Table 5.1 : Summary of Type and Number of Sources

Emission Source	Modelled Source Type	Number of Sources
Area sources	Area sources including bakery, crematoria, building construction, hotels and Restaurants, domestic sector, open burning, open eatouts	6 Nashik Municipal Wards
Vehicles	Line Volume (Major & Arterial Roads), connecting State & National Highways	94 Roads
Major Industries with stack heights more than 10m	Point (Red, Orange, Green), LSI Industries	61 Stacks
Industries which include Medium and small scale industries with less than 15m stacks	Area Polygon [Red, Orange, Green] MSI 14 and SSI 18	32 Wards
Road dust	Line Volume on each road	94 Roads

5.2.2 Model Simulations

The modelling exercise was carried out for PM_{10} and NOx for three seasons as well as for annual, by making use of meteorological data and emission loads and other related inputs for area, line and point sources. Meteorological inputs were put in AERMET. Based on the emission load discussed eelier, the future estimation were worked out.

5.2.3 Model Performance for PM

Table 37 indicates that the average PM_{10} concentration observed at 7 monitoring locations ranged from 90 to 133 µg/m^3 during the winter season. The predicted concentrations at these sites ranged from 19 to 31 µg/m^3. Likewise during the post monsoon season the average concentrations observed at represented ambient air quality monitoring sites ranged from 49 to 108 µg/m^3. The predicted average PM_{10} concentrations at these sites during post monsoon ranged from 16 to 41 µg/m^3. The summer season observed concentration gives as 73 to 114 for observed, whereas for predicted it is 24 to 53 µg/m^3. The annual concentration differs from 64 to 98 µg/m^3 for observed, whereas it is 39 to 97 µg/m^3 for predicted. The factor of 2 (FAC2) value is most commonly used to assess the performance of the air quality models. It is defined as the ratio of predicted to observed concentration and varied between 0.1 to 1.5. All the predicted values were lying within FAC2. Variations in are presented in **Table 5.2 and Figure 5.3**.

Table 5.2 : Observed and Predicted Seasonal Variation of Average PM_{10} Concentrations (µg/m^3) with their Ratio

	Observed Concentration (µg/m^3) #				**Predicted Concentration (µg/m^3)**			
	Sum	**PostMon**	**Win**	**Ann**	**Sum**	**PostMon**	**Win**	**Ann**
Old BJ Mkt.	122	94	90	95	53	40	30	96
Girna Water Tank	114	92	90	92	48	39	31	95
RTO Colony	73	72	125	83	33	16	14	68
NMC Nashik	89	108	133	98	30	18	19	39
SRO Office	86	49	88	75	24	15	11	59
Nashik CAAQMS	94	72	72	64	54	41	32	97
MIDC Satpur	97	82	126	88	46	18	21	82
Ratio of Predicted to Observed Concentration								
Old BJ Mkt.	0.4	0.4	0.3	1.0				
Girna Water Tank	0.4	0.4	0.3	1.0				
RTO Colony	0.5	0.2	0.1	0.8				
NMC Nashik	0.3	0.2	0.1	0.4				
SRO Office	0.3	0.3	0.1	0.8				
Nashik CAAQMS	0.6	0.6	0.4	1.5				
MIDC Satpur	0.5	0.2	0.2	0.9				

Sum –Summer, PostMon- Post Monsooon, Win –Winter, Ann - Annual
 # Observed Concentration (Air Quality Status of Maharashtra 2016-17, MPCB

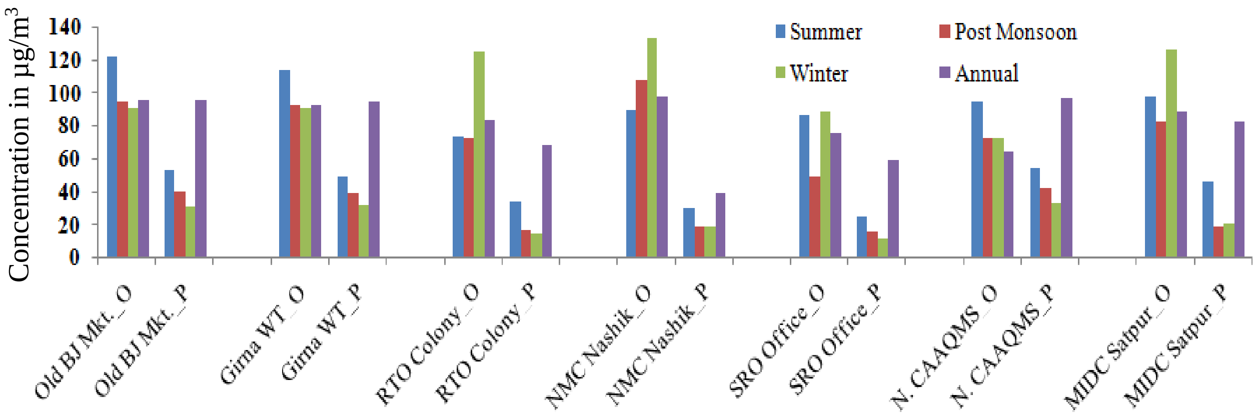


Figure 5.3 : Observed and Predicted Concentration for All Seasons (PM - µg/m^3)

From modeling results discrete cartesian location where identified based on monitoring locations of pollution control and the difference where match for observed and predicted concentrations. It has been observed that less prediction is reflected at all the sites in all seasons, whereas prediction for annual indicated that in Old BJ Mkt and Girna Water Tank the observed and predicted were almost similar, whereas it is exceeding in Nashik CAAQMS site. The less prediction in all seasons shows the meteorological effect i.e. the wind speed is almost 3 to 5 m/s over a period. The 24 hourly concentrations gets dispersed due to wind speed and reflect less concentrations, the effect of PM reporting in observed concentrations is high due to local /regional impact.

5.2.4 Existing Scenario Concentration Contours for PM_{10}

The models were run for annually and all seasons for different source group combinations **(Table 5.1)**. The iteration for different source groups were estimated and presented in **Table 5.3** for PM concentrations. The annual and seasonal 24 hourly average concentrations at grid points were plotted for all the source group is presented in **Figures 5.4 through 5.7**. The sector wise distribution (area, line, point, resuspended dust) of all the seasons for PM is presented in **Annexure 2**.

Table 5.3 : Predicted PM Concentrations for Different Source Group for Nashik City

Sources Group	Summer	Post Monsoon	Winter	Annual
All Group	58.3	70.2	173.0	118.0
Area Source	3.79	4.29	19.8	9.76
Line Source	6.18	5.53	25.9	12.1
Point Source (LSI)	14.8	35.9	14.8	17.7
Point Source (MSI)	0.208	0.200	1.13	0.496
Point Source (SSI)	0.441	0.431	2.41	1.12
Resuspension Dust	52.5	63.1	143.0	103.0

- Concentrations in µg/m^3

Observations

- The all group annual impact of PM concentrations 118 µg/m^3 shows that it is exceeding the CPCB standard, which is also, reflected worse in winter 173 µg/m^3. In other seasons, summer and post monsoon the average observed concentrations are 80 to 90 µg/m^3, predicted are 58-70 µg/m^3 which are within the standards limits.
- The maximum 24 hourly predicted concentration due to all sources in winter was 173 µg/m^3. The pockets of high concentration are observed close to major traffic junctions in central part of the city viz. Panchavati (Peth Road, Nashik, Aurngabad Road); CIDCO (Mumbai Nashik Express Highway, Mumbai Aagra Highway, Pathardi are); Nashik East (Dwarka Circle); Nashik West (Mayco Circle, Gangapur Road), where major vehicle movements were observed. The State and National Highways are impacted more having HDDV vehicles influence are noticed. Whereas, the predicted concentration due to re-suspended dust is more, i.e. 143 µg/m^3 and Tailpipe emission from Vehicles is 25.9 µg/m^3. The daily resuspension of dust contribution around 40.6% from paved and unpaved road to the total load i.e (12125.9 kg/d) and vehicular contribute 10% having load of 3709 kg/d.
- The maximum 24 hourly predicted concentration due to area sources was 19.8 µg/m^3 in winter. The overall impact of areas source is due to domestic cooking, open burning and domestic DG sets which almost similar in all wards. Building construction is also one of the growing sector. Area source contributing 12% to the city emission load i.e. 4606.9 kg/d.
- Industries are located mainly at MIDC Satpur, Nashik West, CIDCO and some parts of panchvati wards, where impact is reflected. The Red LSI contributing highest i.e. 12397 kg/d to the total emission. The maximum 24 hourly predicted concentration due to Industries was 35.9 µg/m^3 for LSI category in post monsoon, but annually it was 17.7 µg/m^3. Very negligible values were reported from MSI and SSI categories of industries. The percent emission load from industries indicates 36% and almost 33% is coming from Red LSI.

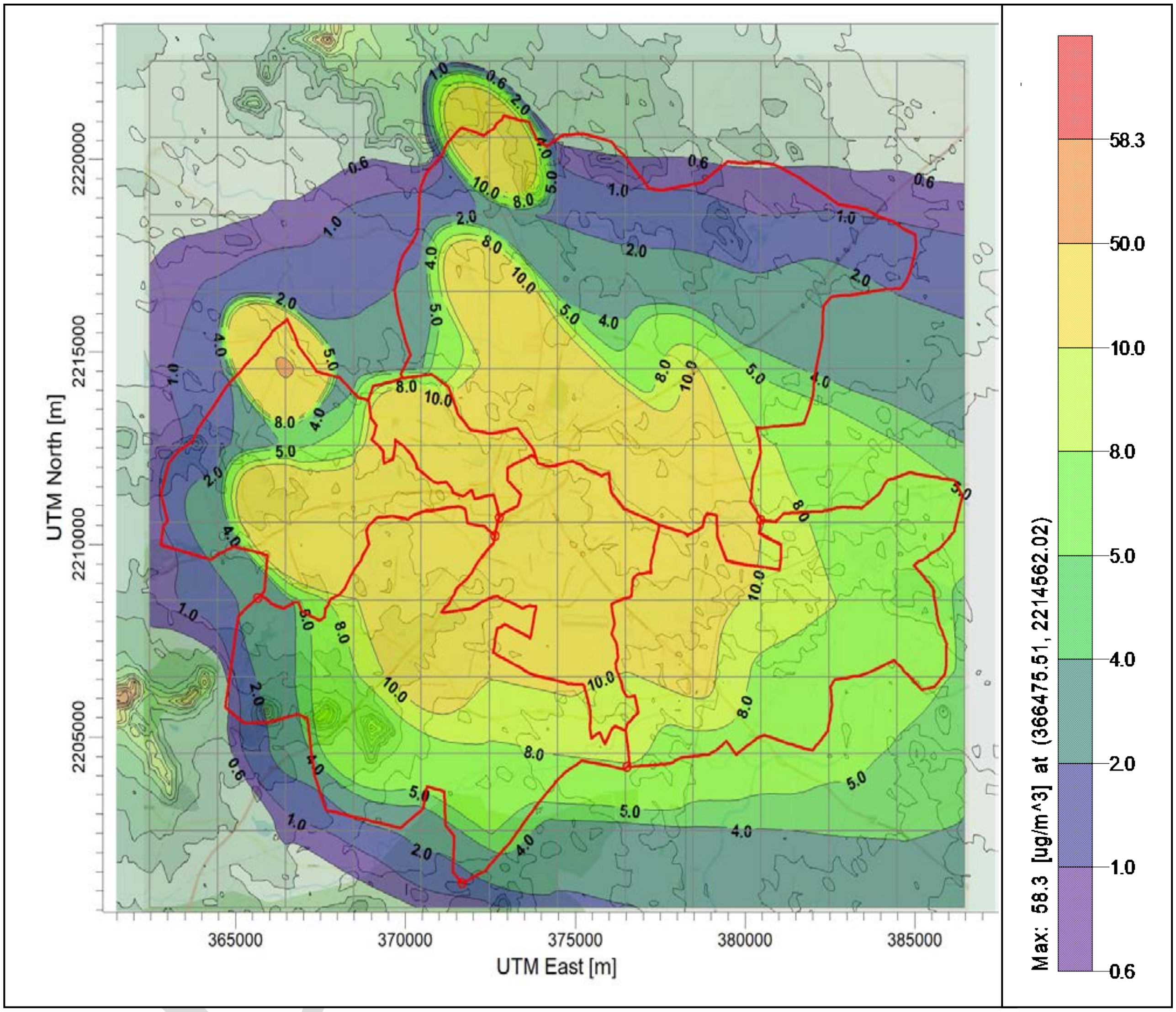


Figure 5.4 : Isopleths of PM Due to All Sources -Summer Season (Nashik City)

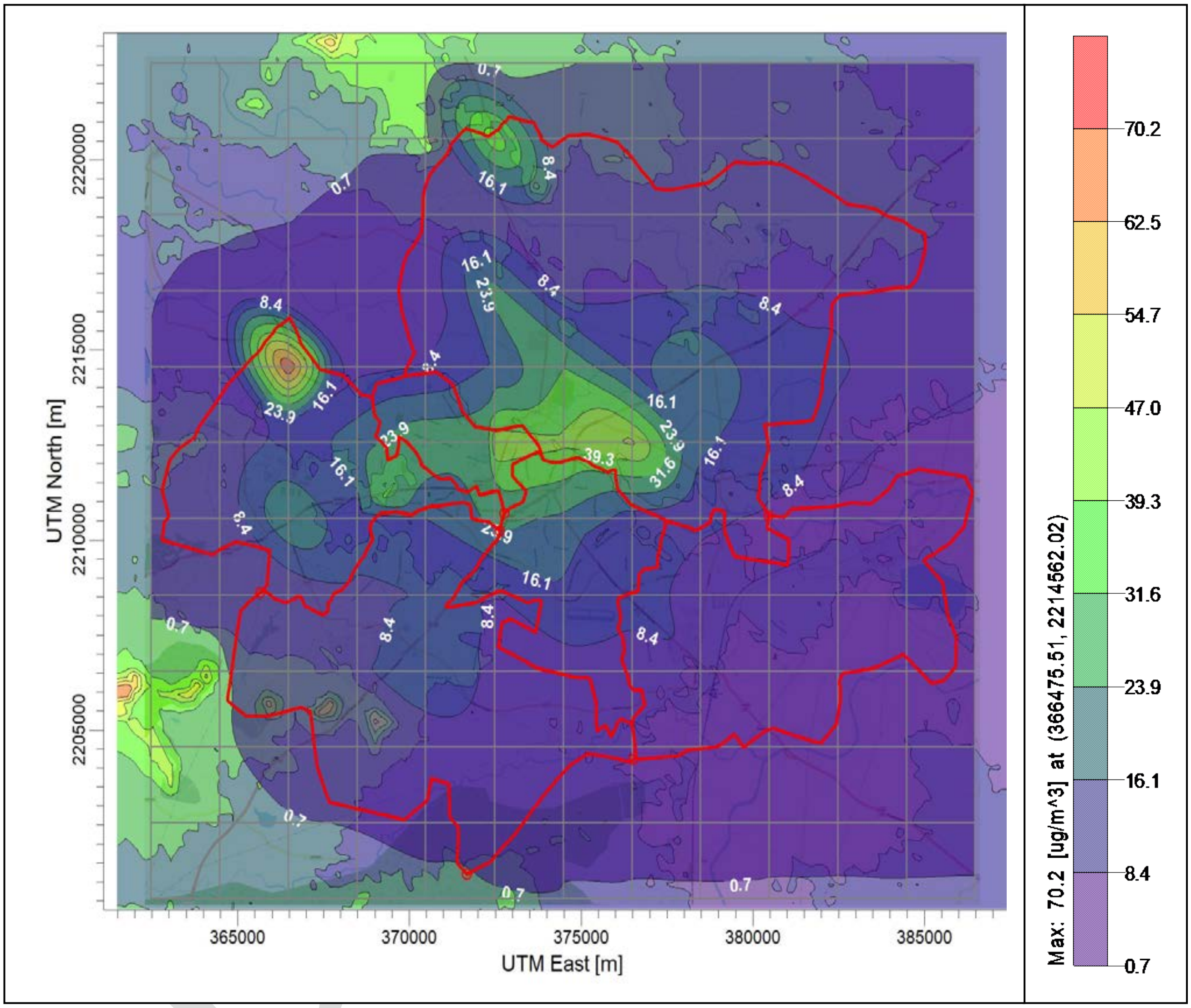


Figure 5.5 : Isopleths of PM Due to All Sources -Post Monsoon Season (Nashik City)

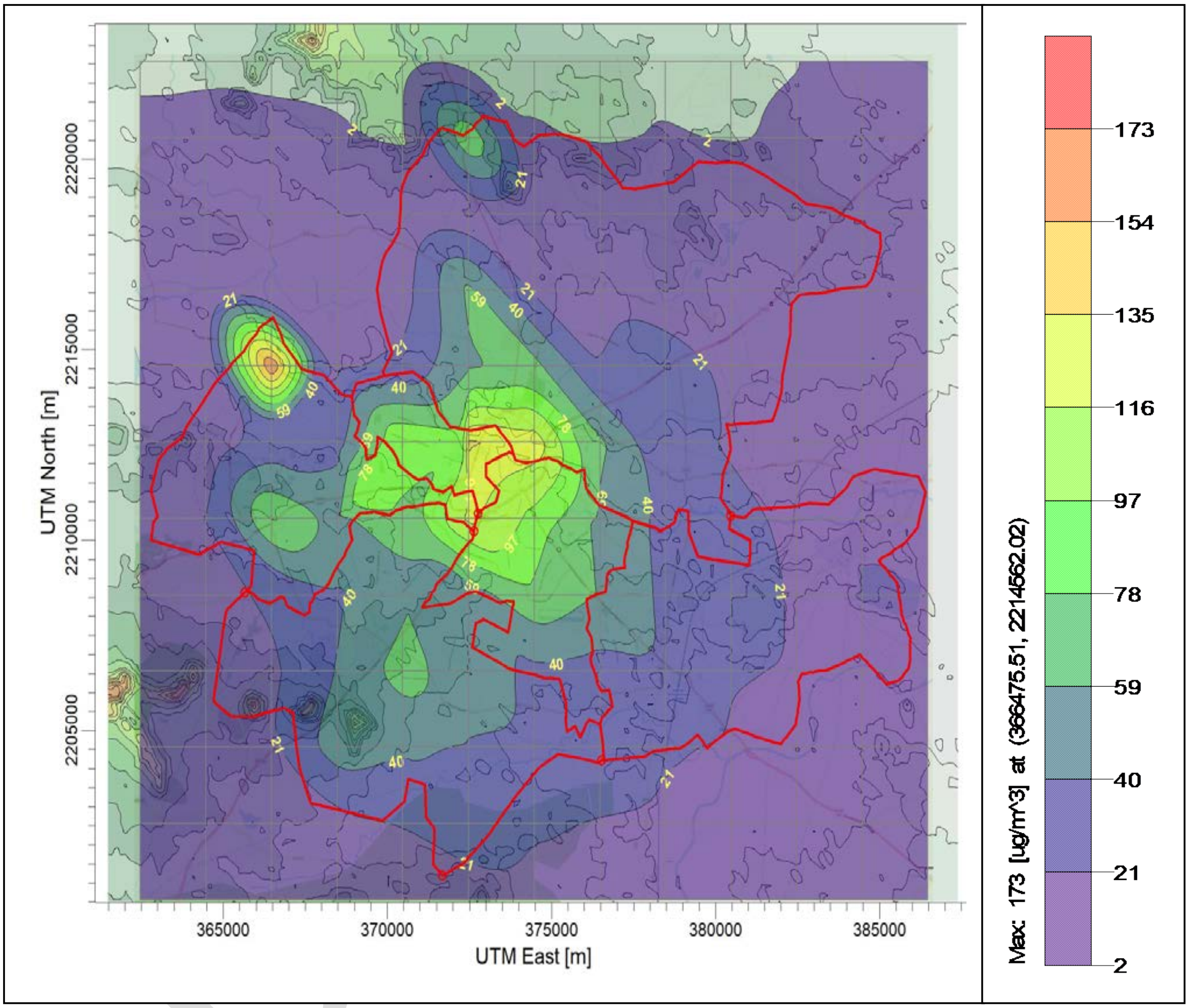


Figure 5.6 : Isopleths of PM Due to All Sources -Winter Season (Nashik City)

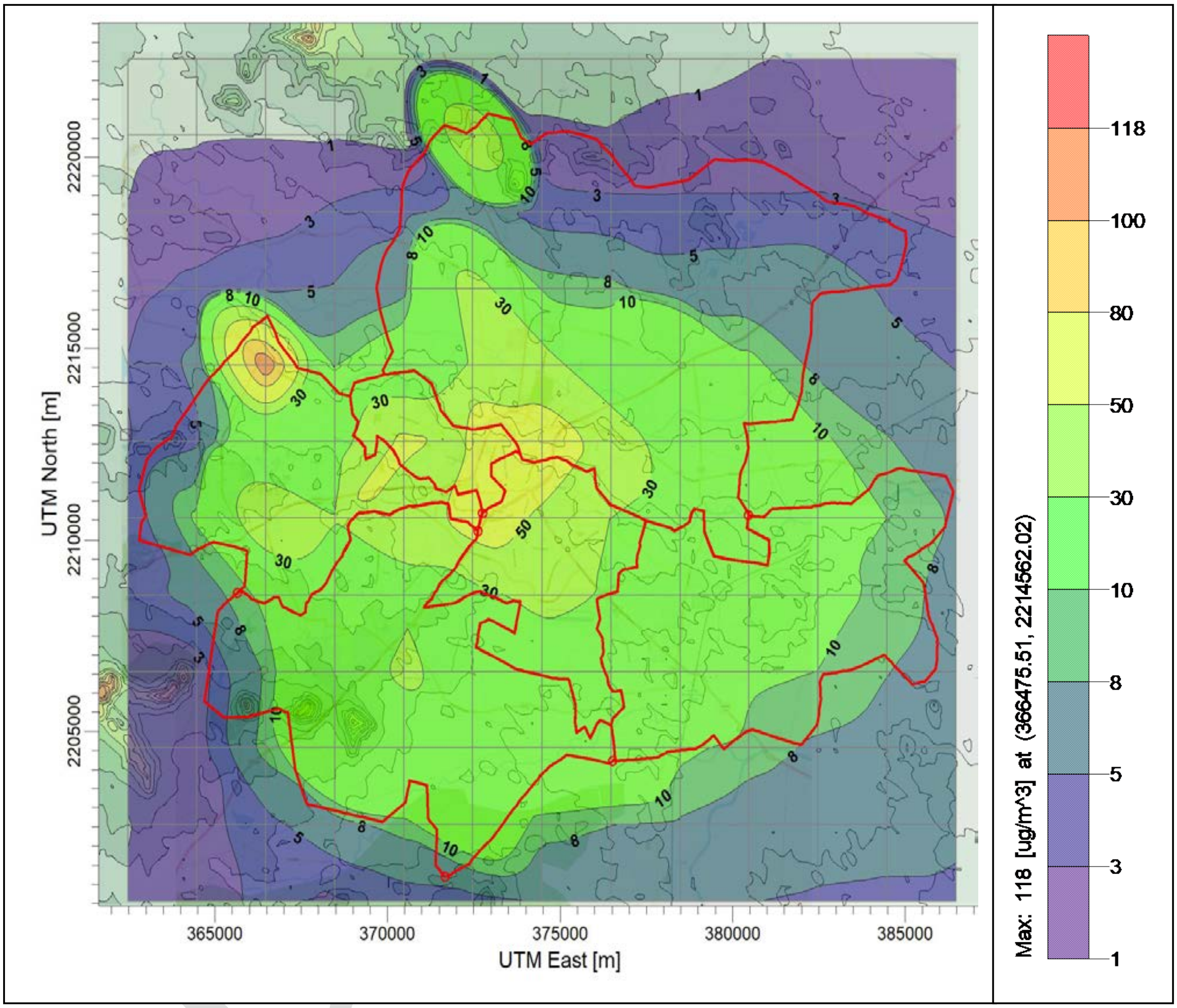


Figure 5.7 : Isopleths of PM Due to All Sources -Annual (Nashik City)

5.2.5 Model Performance for NOx

As in the case of PM_{10}, the modelling exercise was carried out for NOx for all seasons. **Table 5.4** indicates that the average NOx concentration observed at 7 monitoring locations ranged from 25 to 67 µg/m^3 during the winter season. The predicted concentrations at these sites ranged from 8 to 20 µg/m^3. Likewise during the summer season the average concentrations for observed sites ranges from 12 to 43 µg/m^3 and the predicted concentrations ranges from 19 to 54 µg/m^3. The post monsoon season observed and predicted reflected as 29 to 46 µg/m^3 to 7 to 49 µg/m^3 respectively. The annual concentration differs from 24 to 36 µg/m^3 for observed, whereas it is 36 to 93 µg/m^3 for predicted. The factor of 2 (FAC2) value is most commonly used to assess the performance of the air quality models. It is defined as the ratio of predicted to observed concentration and varied between 0.3 to 1.0. All the predicted values were lying within FAC2. Variations in are presented in **Figure 5.8**.

Table 5.4 : Observed and Predicted Seasonal Variation of Average NOx Concentrations (µg/m^3) with their Ratio

	Observed Concentration (µg/m^3) #				**Predicted Concentration (µg/m^3)**			
	Sum	**PostMon**	**Win**	**Ann**	**Sum**	**PostMon**	**Win**	**Ann**
Old BJ Mkt.	43	35	35	36	54	31	17	93
Girna Water Tank	39	34	34	34	52	33	17	93
RTO Colony	28	29	28	25	34	11	12	59
NMC Nashik	27	33	27	26	19	15	13	36
SRO Office	30	32	25	26	24	7	8	43
Nashik CAAQMS	12	46	67	33	23	49	19	75
MIDC Satpur	26	29	25	24	52	17	20	60
Ratio of Predicted to Observed Concentration								
Old BJ Mkt.	1.3	0.9	0.5	2.6				
Girna Water Tank	1.3	1.0	0.5	2.7				
RTO Colony	1.2	0.4	0.4	2.3				
NMC Nashik	0.7	0.5	0.5	1.4				
SRO Office	0.8	0.2	0.3	1.6				
Nashik CAAQMS	1.9	1.1	0.3	2.3				
MIDC Satpur	2.0	0.6	0.8	2.5				

Sum –Summer, PostMon- Post Monsooon, Win –Winter, Ann - Annual
 # Observed Concentration (Air Quality Status of Maharashtra 2016-17, MPCB

From predicted modeling results discrete cartesian location where identified, which where match with observed concentrations. It has been observed that seasonal ratios were with the factor of 2, but the annual predictions are almost exceeding the factor ratio except at NMC Nashik and SRO Office Sites. At NMC Nashik and SRO Office the predicted concentrations are below the observed in summer season and during post monsoon season, OBJ Mkt and CAAQMS sites, the observed and predicted are similar, but all other locations predicted are below the observed. In winter seasons all station are showing predicted values below the observed, but opposite scenario is notice that all the predicted values are much higher than the observed for Annual prediction. Estimation of emission load from vehicular sector and industries are reflected NOx dispersion.

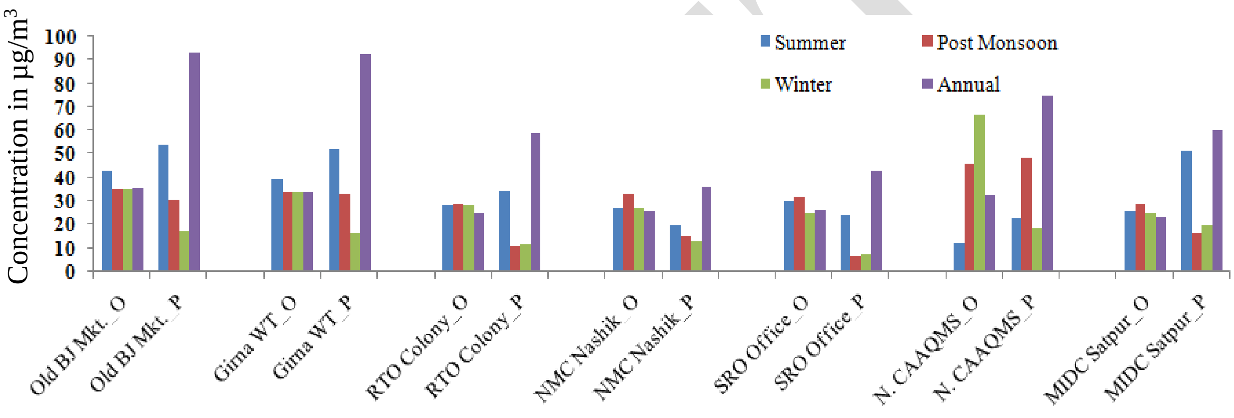


Figure 5.8 : Observed and Predicted Concentration for All Seasons (NOx - µg/m^3)

5.2.6 Existing Scenario Concentration Contours for NOx

The models were run for annually and all seasons for different source group combinations **(Table 5.1)**. The iteration for different source groups were estimated and presented in **Table 5.5** for NOx concentrations. The annual and seasonal 24 hourly average concentrations at grid points were plotted for all the source group is presented in **Figures 5.9 through 5.12.** The sector wise distribution (area, line, point, resuspended dust) of all the seasons for NOx is presented in **Annexure 3**.

Table 5.5 : Predicted NOx Concentrations for Different Source Group for Nashik City

Sources Group	Summer	Post Monsoon	Winter	Annual
All Group	48.70	44.50	155.1	92.90
Area Source	0.370	0.447	1.46	0.883
Line Source	46.56	42.90	151.2	89.50
Point Source (LSI)	12.80	8.55	4.46	6.26
Point Source (MSI)	0.252	0.266	0.960	0.548
Point Source (SSI)	0.290	0.344	1.17	0.682

- Concentrations in $\mu g/m^3$

Observations

- The all group annual impact of NOx concentrations for whole city shows that it is exceeding predicted values than the observed. The Old BJ Mkt and Girna Water Tank area are exceeding the CPCB standard, otherwise all other sites concentrations are below the standard. The ratio is coming in the range of 0.3 to 1.3 in all the seasons, but exceeding the factor of 2 in annual except at NMC Nashik and SRO Office i.e. 1.4 to 1.6 and others are represented by 2.3 & above.
- The maximum 24 hourly predicted concentration due to all sources in winter was 155.1 $\mu g/m^3$, and vehicular source impact is more showing 151.1 $\mu g/m^3$. The concentrations are reflected in central part of the city i.e. Panchavati (Peth Road, Nashik, Aurngabad Road); CIDCO (Mumbai Nashik Express Highway, Mumbai Aagra Highway, Pathardi are); Nashik East (Dwarka Circle); Nashik West (Mayco Circle, Gangapur Road), where major vehicle movements were observed. From emission inventory it is estimated that vehicular emission load is 27497.8 kg/d in Nashik city for NOx, which is 71% of the total emission load from all source.
- The maximum 24 hourly predicted concentration due to area sources was 1.46 $\mu g/m^3$ in winter. The overall impact of areas source is due to domestic cooking and hotels and open burning which almost similar in all wards.
- Industries are located mainly at MIDC Satpur, Nashik West, CIDCO and some parts of panchvati wards, where impact is reflected. The maximum 24 hourly predicted concentration due to industries ranging from 4.46 to 12.80 $\mu g/m^3$ for LSI categories, mostly from Red categories. Summer is the highest concentration and annual average shows the concentration of 6.26 $\mu g/m^3$. Very negligible values were reported for MSI & SSI category and maximum was observed at winter SSI 1.17 $\mu g/m^3$. The total load of 10737.5 kg/d for NOx was observed and it represents 27.7% of the total emission load from all sources. Among them 9210 kg/d contributing 23% is from Red category.

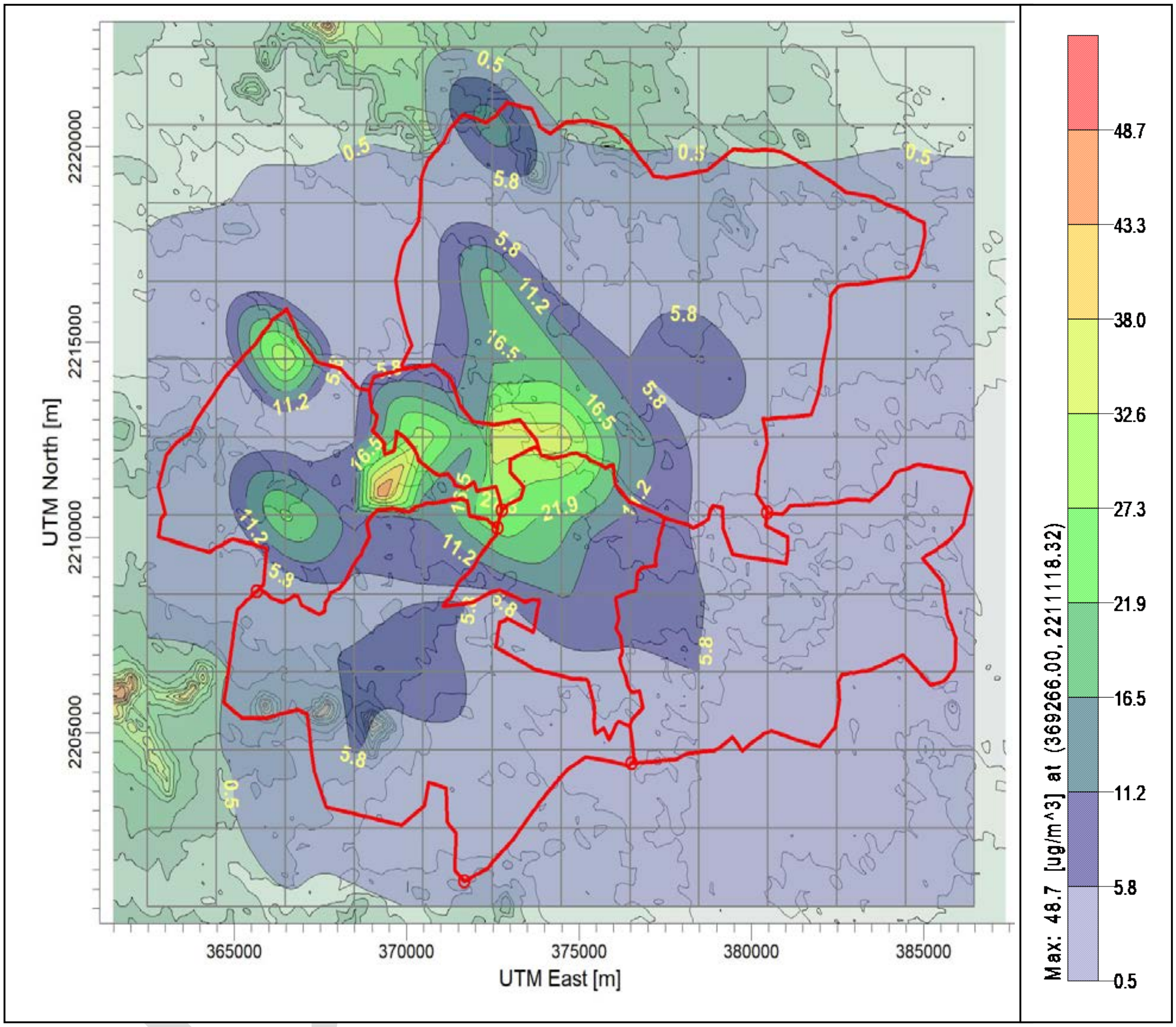


Figure 5.9 : Isopleths of NOx Due to All Sources -Summer Season (Nashik City)

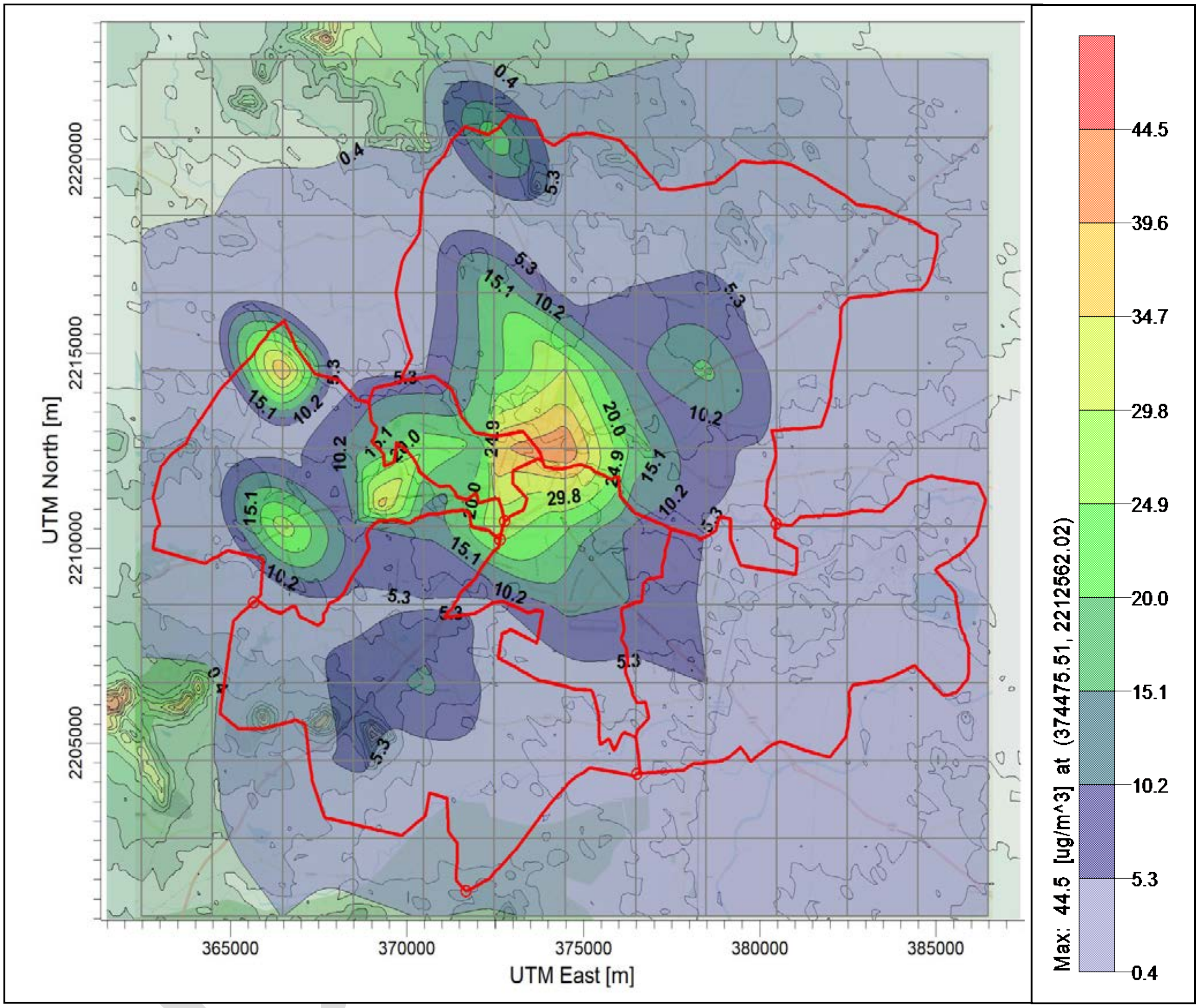


Figure 5.10 : Isopleths of NOx Due to All Sources -Post Monsoon Season (Nashik City)

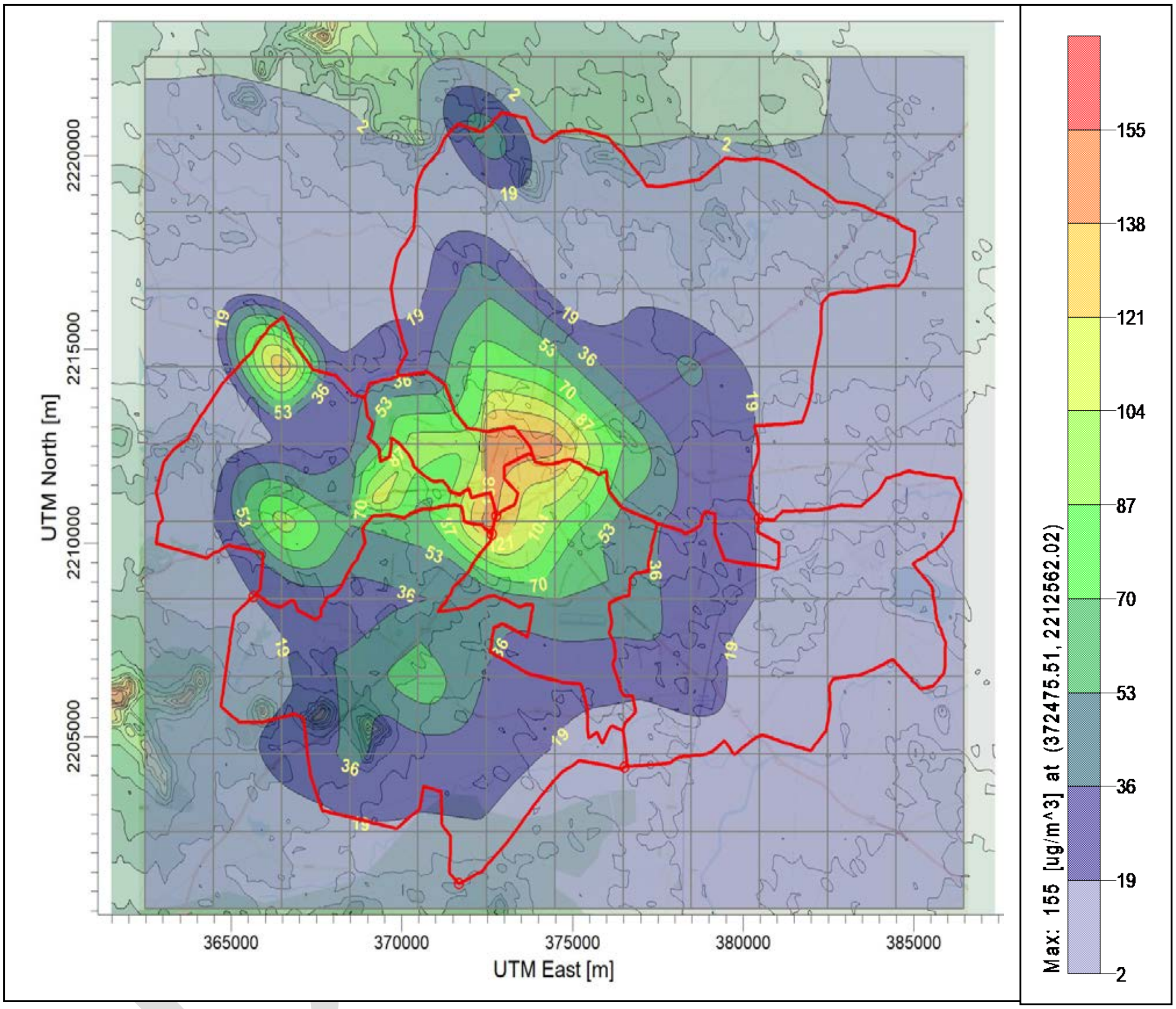


Figure 5.11 : Isopleths of NOx Due to All Sources -Winter Season (Nashik City)

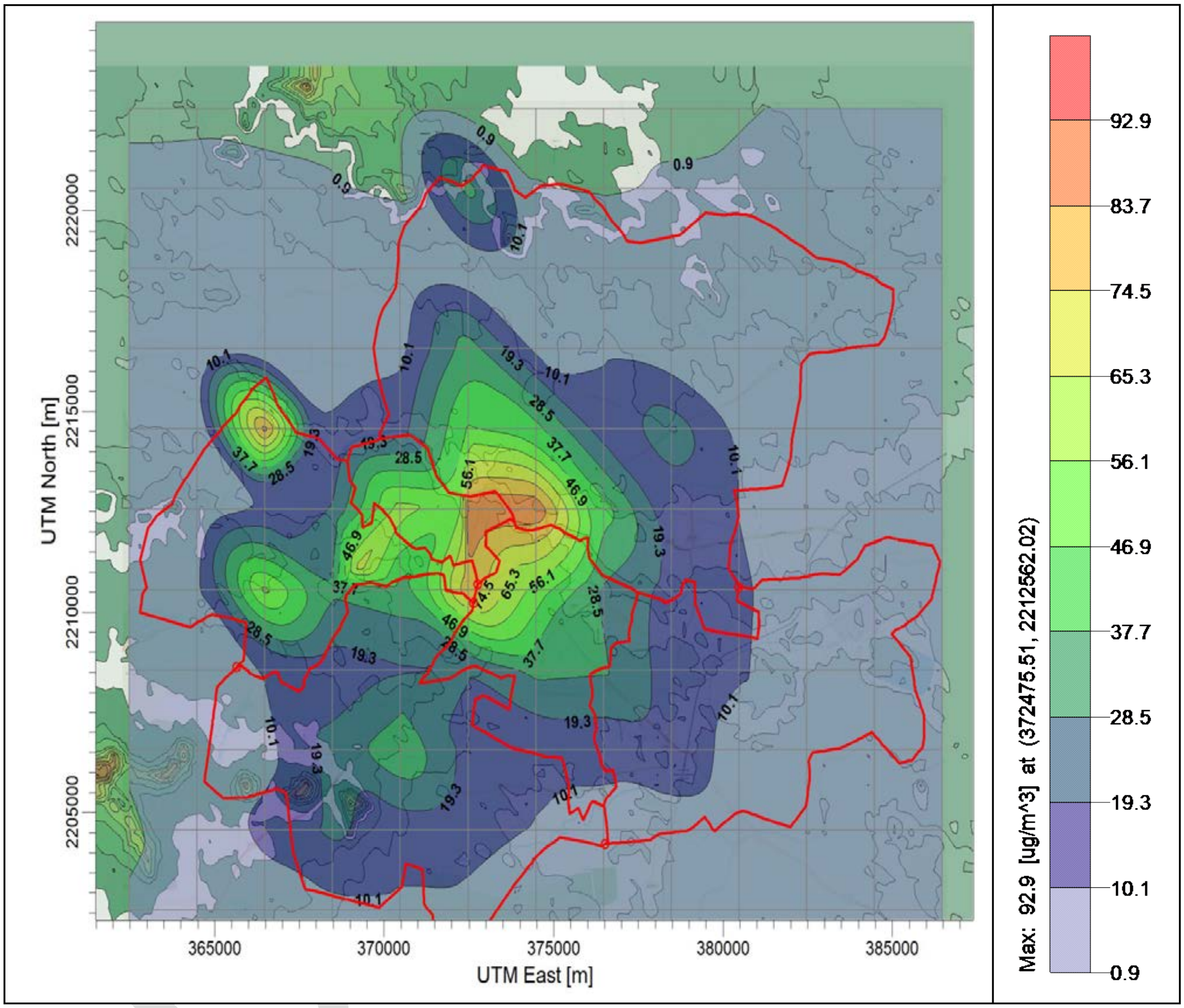


Figure 5.12 : Isopleths of NOx Due to All Sources -Annual (Nashik City)

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Chapter 6

Emission Reduction Action Plan for Mumbai

Chapter 6

Emission Reduction Action Plan for Nashik

Nashik is the fourth largest city, and third largest urban area, in the state of Maharashtra. The Nashik Municipal Corporation (NMC) is the authority responsible planning and service provision for the Nashik Metropolitan Area. Headed by a Municipal Commissioner, NMC utilizes eleven departments to carry out civic operations. NMC's Roads and Building Department is responsible for maintenance of Nashik's 1,049 Km of roads and other amenities. The Nashik Municipal Corporation covers an area of about 267.48 Sq.Km and includes 25 villages out of which Vihitgaon, Vadner and Pimpalgaon Khamb are partly included. The municipal corporation is divided into 61 wards. Nasik today is a tremendously busy industrial centre.

According to the 2011 census, Nashik has a population of 1.48 million as against the 2001 census population of 10,77,236 indicating the growth rate of 37.95% during 2001-2011 decade. With increasing migration to urban areas, Nashik's population is estimated to rise to nearly 4 million by 2030. On the basis of 2011 census figures, the population density of Nashik Municipal Corporation is 5556 persons per Sq. Km.

With rapid industrialization and building construction activities during the past few years many hutment colonies have come up in the Corporation area particularly near the industrial establishments and other work centres. There are about 168 slums consisting of about 42,742 huts with population of about 2,14,769 souls in the year 2014. This population constitutes near about 14.45% of the total population of the Corporation area. The Central & State Government and the Nashik Municipal Corporation have initiated various projects to decrease the number of slums and for the betterment of living conditions of slum dwellers.

The PMC, however, has been unable to meet forecasted demands for housing, commercial and industrial space, resulting in large scale unauthorized development, and areas with non- conforming land uses.

There are many sources of particulate matter emission impacting the ambient air quality of the city of Nashik; however the major ones are resuspended dusts, industries and vehicles. Some industrial uses traditional fuel viz. bagasse and brequittee as low cost and its availability. The industrial emission inventory shows impact on the ambient air quality is low due to emissions at a higher elevation, providing high dilution and dispersion.

The city is witnessing rapid motorization, tremendous increase over a period of last 10 years, along with increased congestion and pollution. The mobile (line) source emissions are not only dependent upon the number of vehicles registered but also on the actual number plying on the roads, speed of movement and the conditions of vehicles besides many other factors. Vehicle kilometer travelled for the city has been showing consistent increase; however, at some junctions the traffic congestion is so high that VKT rise is ironically not so high but emission is high. Saturation traffic situation where average speed goes on decreasing, the VKT may not increase as vehicles are not crossing a point for a long time. Increased levels of vehicular activity and resulting high levels of air pollution have led to active anti air pollution campaign by the nongovernmental organization (NGO) and judiciary.

The area sources which emit at ground level also have significant impact on the PM levels in the atmosphere; however it could be more localized, particularly from the sources such as bakeries, crematories, construction, garbage burning etc. Some of these sources can have significant local impact on the ambient air quality for a shorter duration. Overall a city growth pattern indicates that domestic fuel has become cleaner, bakeries, crematoria, construction/ demolition situation have not changed so much. Refuse burning has increase and road dust related emissions have also shown grown up.

The action plan presented later therefore, makes an attempt to delineate strategies on the basis of understanding of the PM and NOx sources and their possible contribution to the ambient and kerb side air quality. Each of the strategies will have to be looked at from the point of view of its impact level in terms of reduction in PM and NOx emissions (low, medium, high); its feasibility from implementation and administrative point of view (easy, moderately difficult and difficult); financial viability (low, medium and high costs) besides issues relating to their long and short term impacts.

6.1 Area Source - Reduction Strategy

Area sources are mainly domestic sources of fuel (coal, wood, kerosene, LPG) burning, trash/MSW combustion, bakeries, hotels/restaurants etc. and resuspension of dust. Based on the survey and assessment, following recommendations emerge to curb area source emissions:

- From the data provided by Mahangar gas, Nashik region had been supplied with around 62.5 TMT of packed LPG. Consumption of solid fuel is high in Nashik, which contribute to the emission on a large extent. Fuel Gas Organizations and ULB should take initiative to sensitize people from the slum and non-slum to make the shift from conventional domestic fuel (LPG, Kerosene, wood). Provision of PNG should also be explored. HPCL is enhancing its storage capacity of Existing LPG bottling Plant from 1390 MT to 2000 MT at Nashik LPG Plant, Malegaon MIDC Industrial area Sinnar. The distance between project site and Nashik city is 25 KM which will be helpful for domestic fuel supply.

- The data for the usage of domestic fuel in slum and non-slum area is not readily available. Inventorization of LPG quantity from supply agencies should be maintained.
- Nashik being a tourist attraction place, there is increase in number of hotels and dhabas along the highways. On survey it was found that there were 392 registered hotels in Nashik region with consumption of LPG of 2140 kg/day and coal around 1.4 Ton/day. These hotels and dhabas should be regulated to use LPG for its cooking purposes. Traditional wood/coal based tandoors of restaurants as fuel should be replaced by LPG/electrically operated tandoors.
- Similarly usage of LPG by small hotels/ restaurants and roadside tea /snack stalls should also be encouraged. Subsequent concession should be provided. 620 eat out found in survey had fuel consumption of 1698 Kg/day of LPG and 40 kg/day of coal, respectively.
  - No license is issued to the hawkers on prominent roads. Instead the licenses are given to them where there is low traffic. The strict vigilance from time to time is necessary to observer whether rules are followed or not.
  - Permission must be granted in the vacant places in residential areas, so that they do not cause disturbance on the road.
  - The hawker's zone is created in public places like garden, play grounds, hospitals, bus stand, religious places and big hectic squares.
- With 53 bakeries in the region, the emissions from the stacks of bakeries should be regulated and emission control devices such as bag filter, scrubbers etc should be installed. These bakeries can be made to operate on electric or LPG.
- There are around 25 wood operated crematorium under NMC jurisdiction. For increasing population, existing facilities of cremation and burial ground is not sufficient. All crematoria should be installed with efficient pyres and chimneys for release of emissions. Bodies related emissions from the pyre can be reduced by installing efficient PM control measures such as bag filters or cyclones. Further, a study involving usage of LPG burners in closed furnace like electrical crematoria may be explored as substitute to existing practices.
- Building construction / demolition codes need to be formulated with specific reference to PM control. There were around 214 new building constructions and alteration activities being carried out all over the region in 2017, which emitted PM load of 3.3 ton/day in the region.

Operational measures to be made compulsory and building permissions should be revoked if the norms are not met by the organization.

- There is Poor pedestrian infrastructure in Nashik. RUBs / ROBs / Footpaths, Pedestrian crossing etc. are necessary for proper transport system. Provision should be made from Corporation with appropriate fiscal measures.
- In all there are existing 144 gardens, having area 98.87 hectares. Out of which 22 are of bigger size. This works out to be 0.58 sq.m. per person which is less. There are 32 playgrounds having 64.21 hectares area out of which 17 are of bigger size. This works out to be 0.38 sq.m. per person which is less. Green Belt Development can be done along the banks of river with provision of cycle track and recreational spots. For the population of 2026 year, total 49 sites for park are necessary.
- Open Trash Burning is common in Nashik, especially in the season of winter. NMC should take required regulatory measures to abolish the practice of open burning of waste within the city.

The Nashik Municipal Corporation is collecting about 501 MT of municipal solid waste per day. All the waste from different areas are collected and transported to MSW facility at Pathardi which is 15 km from core area. The bio hazardous waste generated by hospitals in the city is treated at 1000°C in an incinerating plant located near Kannamwar Bridge (near core area). With better collection and transportation measures, the collection efficiency should increase. It is estimated that the projected quantity of municipal solid waste will be 1200 TPD by the year 2031.

The present emission load from area source is around 4606.9 kg/day which contribute 12.5% of the total emission load for Nashik city. With the implementation of the short and long term scenarios, the total reduction in particulate matter from area sources would be more than 37% (**Table 6.1)**.

Table 6.1 : Emission Reduction Action Plan for Area Source

Area Sources	Short Term-2019	Long Term-2022	Action required
Domestic	50% of slums to use LPG/ PNG 75% abolishment of solid fuel use	100% of slum to use LPG/ PNG 100% abolishment of solid fuel use	Proper dispensing and easy availability of cylinder to the consumer of slum population should be made. Increase the infrastructure and availability of LPG/PNG to whole of Nashik region. Ensure proper ventilation reforms to be implemented in kitchens through periodic information dissemination of indoor air quality via seminars street plays and workshops.
Hotel & Restaurants	50% of coal/wood to be replaced by LPG	75% of coal/wood to be replaced by LPG	Around 1.5 tons of coal is being used daily by hotel and restaurants in Nashik. Hotels & Restaurants should be regulated for their operation and maintenance of chimneys. Designated areas should be designed for the coal and wood based operations within the premises. Options of fuel shift should be implanted in phase wise. 75% replacement of coal/wood consumption would bring down emission load of PM to7 kg/day and NOx to 2.9 kg/day.
Open Eat outs	Since these operations are illegal, they are difficult to quantify. An effective redressal system towards their total number and fuel consumption should be made.		If we restrict the activities with proper rehabilitation or their conversion from traditional fuels to clean fuels, then per unit /day reduction of PM- 1.62, and NOx – 3.22 kg/day can be achieved, considering emissions from 620 vendors and eat outs.
Bakeries	25% LPG /NG 25% Electric	50% LPG /NG 75% Electric	Clean fuels like LPG/NG or electricity can be attempted for bakery operations. Initial incentives and rebate should be provided for the conversion from traditional fuel. There are illegal and unaccounted small and mid-scale bakeries that have significant contribution to final emission load. They should be taken in confident by the regulatory bodies for their accountability, inventeriozation of their fuel consumption and conversion of their existing facilities. This will require change in current baking practices for which a separate study involving techno-economic feasibility is recommended.
If consumption of wood in a bakery is considered to be 500 kg/day, then emission load of pollutants are PM - 8.65 kg/d, CO - 63.15 kg/d, NOx -0.65 kg/d, HC-57.25 kg/d and if we manage to replace the wood quantity by other fuel i.e only 100 kg/days of wood is being used, there will be 80% reduction in load, with final emission per 100 kg will be PM -1.73 kg/d, CO -12.6 kg/day, NOx- 0.13 kg/d and HC - 11.4 kg/d. This conversion can be towards natural gas, as emissions from them are relatively much less than solid fuels.			

Table 6.1 (Contd..) : Emission Reduction Action Plan for Area Source

<table>
<tr><th>Area Sources</th><th>Short Term-2019</th><th>Long Term-2022</th><th>Action required</th></tr>
<tr><td>Crematoria</td><td>50% Electric</td><td>75% Electric</td><td>There are sentiments involved in the activities that are carried out in crematorium. Still all crematoria should be provided with efficient pyres and chimneys with bag filters for release of emissions through stacks at appropriate height.
Further, a study involving usage of NG burners in a closed furnace like electrical crematoria may be explored as substitute to existing practices. This will require participation of social organizations for increasing the awareness about need to change from the traditional methods. Concept like Green Crematoria should be explored.</td></tr>
<tr><td colspan="4">Similarly, for wood consumption of 300 kg/body cremation at crematoria is replaced by electric or gas cremation, an overall PM-5.19, CO-37.89, NOx -0.39, HC -34.35 and CO2 – 510 kg/yr of emission load reduction can be achieved per unit cremation.</td></tr>
<tr><td>Open & Landfill Burning</td><td>100% immediate and stringent redressal of open burning cases
100% control of Landfill burning events</td><td>Feasibility study for establishment of Waste to energy plant facility</td><td>It has been observed that the unaccounted or mismanaged waste from SWM system, often are reported into road side open burning cases. Nashik City region has a daily average SW generation of 501 MT, out of which 52.88% is bio-degradable and remaining is non-biodegradable. The maximum solid waste generation is from Panchavati division. The APMC accounts considerable amount of the total solid waste generated in the city. Assessing the demography, an efficient and strategic SWM plan should be implanted for the region. Also at the landfill site, surveillance facility and response team should be brought in place</td></tr>
<tr><td colspan="4">If we restrict the activities of open and landfill burning we can reduce pollutant load per Tonne by PM -8, CO- 42, HC -21.5 kg/t</td></tr>
</table>

Table 6.1 (Contd..) : Emission Reduction Action Plan for Area Source

Area Sources	Short Term-2019	Long Term-2022	Action required
Bldg. & Road Construction	50% control on dust emission	75% control on dust emission	Building construction/demolition codes need to be used with specific reference to PM control. UTTIPEC design manual has been recently created by Delhi Development authority for uniform roadside, drains, footpath and related design. The same should be adopted for all future design for roads and pathways. Road construction/repair uses wood for melting tar, this technology needs to be abolished as over a large period of time, emissions are high.
Paved & Unpaved Road Dust	Paving : 75% control on dust Unpaving: 15% of remaining road if any	Paving : 100% control on dust Unpaved : 100% of remaining road if any	85% of roads were considered to be paved. Pavement of road should be made wall to wall, especially the shoulders. The silt on partially paved shoulders of road are re-entrained, or resuspended, into air through vehicle-induced turbulence and shearing stress of the tires. A Road dust suspension is an increasing concern in terms of being a source of atmospheric PM. Better sweeping management system should be implemented. NMC should implement usage of mechanical sweepers for resuspension control activities such as frequent sweeping, sprinkling of roads and collection of dust. A strategic plan should be devised so as to cover larger area of region. This will help in effective management of manual sweeping labors in other activities and to cover areas which are inaccessible with vehicles. Feasibility study for road construction material that can be used in the region so as to control resuspension should be initiated. Local resources should be considered as priority.

6.2 Line Source - Reduction Strategy

Roads : The existing road pattern of the Nashik Corporation Area is almost radial one. The National Highway No.3, Mumbai-Agra Road passes through the Nashik city, while National Highway No.50 i.e. Pune - Nashik Road meets Mumbai-Agra Road in the central part of the city near Dwarka point. Four State Highways, Dharmpur-Peth-Nashik-Aurangabad (MSH-2), Nashik-Dindori (MSH-3), Adgaon Girnare-Javhar (SH-28) and Nashik-Trimbak (SH-30) run outwards in radial form. Also there are three Major District Roads i.e. Nashik Road-Deolali-Bhagur (MDR-26), Nashik-Anandwali-Dugaon (MDR-34) and Adgaon-Pimpri sayyed (MDR-36). In absence of by-passes to the above important roads and also due to intermixing of local and transit traffic, the situation gets aggravated, resulting in congestion, delays and serious accidents. To avoid this congestion, the flyover on Mumbai-Agra Highway from Pathardi phata to Aurangabad Naka is constructed and is in operation. Numbers of bridges have been constructed on river Godavari, Valdevi, Nasardi at various locations. There is necessity of other bypass roads to link National and State Highways. Existing and new colonies are being connected to the arterial link roads and ring roads by improving the road infrastructure. The existing road infrastructure is about 1974 Kms consisting of Cement road of 262 Kms, B.T. Roads of 1282 Kms and W.B.M Roads of 430 Kms.

Presently, most public transport in Nashik comprises bus services operated by the Maharashtra State Road Transportation Corporation (MSRTC). The remaining trips are made via privately owned and operated shared autorickshaws. The public transport in the city is of substandard quality. Buses are overcrowded during peak hours and their speed is dropping by the day due to traffic congestion. As a result, the number of personal motor vehicles is growing at 7 per cent per annum. If this growth continues, The Institute for Transportation and Development Policy (ITDP) estimates that the number of trips made by personal motorized modes will double over the next 10 years. Accommodating this increase in personal motor vehicle use will be difficult. Even if all of Nashik’s main roads are transformed to include elevated corridors on top, there won’t be enough capacity to meet 2023 demand. Recently, Nashik Municipal Corporation has taken over the City Bus Service to control the increasing traffic problems.

Reduction strategies addressing both technical and non-technical issues presented here take into consideration the current ambient air quality standards; exhaust emission standards, emission inventory, vehicular population composition, infrastructure availability and the techno-economic feasibility in Nashik Region.

The discussion has been presented in following order:

- Improvement in fuel quality and alternate fuels
- Improvement in vehicle related components/technologies (After-exhaust treatment techniques and retrofitment)
- Synchronization of traffic signals
- Inspection & Maintenance programme
- Transport planning and traffic management
- Other options including phasing out old vehicles, revision of emission standards
- Encourage public transport, encourage non-motorized transport and
- Reduce dust resuspension

Many potential emission reduction options have been considered based on viability in the city and the major issues are pertaining to the overall vehicular sector emission reduction have been discussed in **Table 6.2**.

Looking into scenario the Regional Transport officer in collaboration with ULB and private and PPP entity should be directed to give information about the time bound strategy to control the vehicular pollution and traffic management for:

- Banning out-dated vehicles of age more than 15 years.
- P.U.C. check of auto-rickshaws to be done periodically and ensure that adulterated fuel is not being used. Remote Sensing technology can be utilized for PUC monitoring.
- The district has 319 petrol pumps, including 74 in the city. Oil companies such as HPCL, BPCL and IOC supply fuel, both petrol and diesel, through 200 tankers daily to pumps across the district. A single tanker includes fuel worth Rs 8 lakh on an average. Accordingly, the total fuel supply in the district is estimated at Rs 16 crore per day. Better quality fuel by adopting stricter fuel supply & dispensing system along with Chemical marker system to keep check on adulterations in fuel.
- Concession/ rebates by NMC for erection of CNG fuel. Conversion of existing public transport buses/tempos/mini buses to CNG fuel operation.
- The electrical countdown mechanism has to be implemented at major traffic intersections, which will help in switching on and off vehicles. Proper routing of the vehicles to avoid congestion.
- Adoption of standard emission regulation BS-V and BS-VI in line with EURO-V & EURO-VI for all categories. The benefit of BS-V and BS-VI in PM are 1% and 2.5% of total PM respectively. Similarly the NOx benefits with BSV and BSVI are 7.5 & 14.6%, respectively.

- Need to frame legislation for the Retro-fitment of new engine/Emission Control Devices (Diesel Particulate Filter (DPF) /Diesel Oxidation Catalyst (DOC) particularly to heavy duty vehicles that could help in major reduction of PM. Cost sharing and subsidy by the agencies will help in immediate provision.
- Hybrid buses can be introduced in fleet of Public buses. Biodiesel (B5/B10:5–10% blends) should be considered as a fuel option for public transport. Promotion of electric public transport. Battery Operated transport vehicles providing point to point service can also be initiated.
- I&M (Inspection and Maintenance) of old vehicles: Promotion of proper maintenance of vehicles. Use of 2T oil in excess is to be avoided. All private vehicles should be subjected to proper assessment and fitness tests through I&M centres. All autos and buses shall also be subjected to I&M tests Implementation of penalties should be laid on vehicles if found exceeding the emission limits. Set up a mechanism of Inspection and Maintenance programme for all vehicles in the district through RTO with automated system assessment. The I &M center should also test all vehicles for their in-built emission tests.
- In 2013, the total numbers of buses were 241 which used to ply on 508 different routes, covering route of 7728.4 Kms. The number of passengers handled by the bus system at that time was near-about 145000 per day out of which 45000 are students. But these bus numbers are brought down to 110 in 2018. Apart from state transport, there is huge dependence on 3 wheelers and private vehicle aggregators for intermediate point transport within the city.
- Management of Intermediate Public Transport - IPT (auto rickshaws / shared auto rickshaws / taxis) can be done considering the travel demand management. Widening of roads approaching towards mass transit stations.
- Prepare a traffic dispersal model for efficient mobility and Mass Rapid Transit connectivity. Facilitate safe and convenient movement for pedestrian (Subways/ FOBs/ Footpaths including Skywalks).
- As per the provisions of 73 (3), Central Govt. can restrict and limit number of contract carriers in the cities / towns were heavy population is not less than 5 lakhs. Accordingly, Maharashtra Govt. has issued notification restricting number of contract carriers in the city of Mumbai, Thane, Pune, Nagpur, Solapur, Nashik, Aurangabad etc., the provision of Act & Rules need to be reviewed and amended suitably in the light of increasing population & urbanization of these cities. Traffic of heavy goods vehicles may be routed outside city area by creating by-passes & ring roads before entry and exit of the city.

- NMC, RTO, MSRDC & MIDC should collaborate to formulate time bound design and construction of under passes, flyovers and widening of roads to control the traffic jams and congestion along Highway and pre-determined junctions passing through core of the city. All buses (STC/PVT/PPP/School/Airport) in the city should be regulated to run only on clean fuels (LPG or CNG) or clean diesel of 10 ppm sulphur with particulate trap for exhaust.
- Promotion of non-motorized transport (NMT). Bicycle sharing schemes should be introduced in the city. Provision of cycle parking facilities at mass transit (BRT/Metro) stations should be made. Provision of City E rickshaw can be initiated. Allocation of designated space for idling/ parking of cycle rickshaws will curb traffic congestion.
- Promotion of use of pool car system, sharing of vehicles, utilization of public transport and use of bicycles for short distances.
- Sweeping of the roads should be done regularly. Vacuum suction pumps for sucking of road dust can be utilized.
- Finally, awareness programme should be undertaken with no vehicle day and assessment for air pollution to share the benefits among the general population. Mass awareness should be done at local level by the way of advertisements on local TV channels, theatres and at public stations like bus stops, libraries etc.

Parking : Free on-street parking is the norm in Nashik. Double parking is common, especially in busy commercial areas such. Parked vehicles often occupy one or more lanes of the carriageway. This reduction in effective width often results in congestion and traffic jams. Congestion from poorly managed parked vehicles not only reduces carriageway widths, but it also hampers the mobility of all vehicles (especially public transport), increasing travel times and emissions secondary to vehicle idling. It has been observed that the traffic police do not have sufficient vehicles or personnel to enforce parking restrictions. Provision of public parking is required at the places like C.B.S., M.G.Road, Main Road, Canada Corner, College Road, Gangapur Road, Bytco point, Dwarka junction etc.

On street parking Measures :

- The safety and efficiency of the road shall be maintained through effective on street parking restrictions and management options. On street parking spaces shall be designed as per IRC:SP:12:2015.

- Carrying capacity of the road shall be taken into consideration while allotting on street parking spaces. Options such as restricting parking at all times on all mobility corridors shall be explored.
- Areas up to 50 m from intersections on all arms and other critical locations shall be kept free from parking and other encroachments.
- Parking shall be prohibited up to 3 metres on both sides of pedestrian crossings with appropriate road markings showing boundary of parking lots and 'No parking zone'.
- Opinion of traffic police and local stakeholders shall be necessary while designating parking spaces. Parking and halting (including auto rickshaws) shall be prohibited up to 20 metres prior to the bus stop and 15 metres after the bus stop.
- Lots for bicycle parking shall be provided in the on street parking lots at suitable locations as recommended in Bicycle plan for Nashik.
- Any type of commercial activity (goods vehicles) or vehicles indulging in commercial activity shall not be permitted in designated parking lots.
- Parallel parking configuration shall be adopted for all three-wheeled and four-wheeler vehicles including motor cars, light commercial vehicles (LCV), buses and trucks.
- Perpendicular parking configuration shall be adopted for motorized two wheelers as well as bicycles. Only single lane parking shall be allowed for any on street parking lots

Off street parking structures

- Private sector's investment shall be encouraged for creating multi story parking structures.
- Cost of land, construction of built space, operation and maintenance shall be recovered from the users using such facility.
- The capacity of off street parking block shall be dependent on the carrying capacity of the adjoining street and not on FSI permissibility or availability of built up space.
- Design of multi storey parking spaces and standards. Off street parking spaces shall be designed to comply with design standards, including dimensional and circulation requirements. IRC:SP:12:2015, NBCC,BSI standards shall be adopted.
- Multi Storey parking structure shall have proper access road and separate entry and exit ramps for vehicle movement to all floors.

Table 6.2 : Emission Reduction Action Plan for Line Source

Line Sources	Short Term-2019	Mid Term-2022	Long Term-2024	Action required
Reduction Emission per Unit of Fuel				
Fuel Adulteration	Strict Banning of Fuel Adulteration-50%	Strict Banning of Fuel Adulteration-80%	Strict Banning of Fuel Adulteration-100%	There is significant contribution from adulterated fuel as compared to clean fuel. There seem to be a loop hole in distribution system of pure fuel to the end customers. Ministry of petroleum has constituted anti adulteration cell for preventing the malpractices of fuel adulteration. A local level body should be developed for the periodic vigilance and fair distribution in the region. At petrol pumps, facility should be provided for identification of fuel adulteration by way of marker. Oil companies should use colour codes on the tanker transporting the fuel, regular testing of the fuel before it is filled in the bunks and after. Promotion of better lubricants. Oil companies should also put their own manpower and machineries in checking effectively their products being sold from their outlets. (e.g. BPCL's Pure for Sure; HPCL's Club HP and IOC's Q & Q etc., which are being carried out in, limited way. Economic measures such as removing the disparity in petrol, diesel and kerosene prices will be required to remove incentives for such large scale malpractices Fines and cancellation of license are some of the stringent tools.
CNG/ LPG	Privately operated Vehicles viz. OLA, Uber and other contract buses, public transport should be converted - 30%	Privately operated Vehicles viz. OLA, Uber and other contract buses, public transport should be converted - 50%	Privately operated Vehicles viz. OLA, Uber and other contract buses, public transport should be converted - 75%	In 2013, the total numbers of buses were 241 which used ply on 508 different routes, covering route of 7728.4 Kms. But these bus numbers are brought down to 110 in 2018. Apart from state transport, there is huge dependence on 3 wheelers and private vehicle aggregators for intermediate point transport within the city. Buses run either on Diesel or CNG. All can be converted to CNG phase wise. Private aggregator vehicles from institution, schools and services should be regulated to convert to CNG/LPG. Incentives for fast paced successful implementation. Incentive for new owners to buy CNG/LPG vehicles. Developed infrastructure for easy availability of fuel station for CNG/LPG refueling and availability of subsidiary kits for such conversion to the older vehicles.

Table 6.2 (Contd..) : Emission Reduction Action Plan for Line Source

Line Sources	Short Term-2019	Mid Term-2022	Long Term-2024	Action required
Reduction Emission per Unit of Fuel				
New Vehicle Standards Sulphur Reduction	Currently BS-IV standards are in operation	Implement BS- VI from 2020 -50% (adopt progressive increment)	Implement BS- VI from 2025 -75% (adopt progressive increment)	Sulphur specification for petrol and diesel will be reduced 50 times from a level of 50 ppm for BS-IV fuel to 10 ppm in BS-VI. Cities in the national capital region like Noida, Ghaziabad, Gurugram and Faridabad as well as 13 major cities, including Mumbai, Chennai, Bengaluru, Hyderabad and Pune, will switch over to Euro-VI grade fuel from January 1 next year. Rest of the country will follow suit from April 2020. The cleaner fuel should cost around 50 paise a litre more. There presently exists no better fuel than this anywhere in the world. Oil refineries will need to invest Rs.30,000 crore in upgrading petrol and diesel quality to meet cleaner fuel specifications by 2020. A strategic plan should be devised for its successful implantation across all levels. Vehicle manufacture should be taken in confidence for the respective modification of engines.
Reduction Emission per Unit of Vehicle/Congestion				
Banning of 15 year Old Commercial Vehicle	50% banning	70% banning	100% banning	Encouragement by provision of incentives in form of scrap value, tax rebate, and transferrable discount rewards for new vehicles and registrations. All the existing and newly vehicles should go through inspection and certification every two years. Corporation and metropolitan authority should demark designated places and system facility for scrapping vehicles, as such there is no provision in the city. According to reports, the government has set up a central depository called 'VAHAN' to store data relating to all vehicles. A city level depository of all the vehicles should be made by the administrative bodies in collaboration with traffic and RTO bodies, which can be linked to the central depository with appropriate information technology structure. This can help the city administration for the monitoring and management for future perusal.
Synchronization of traffic signals Sensor Based -Real time tracking	Major & minor roads, excluding feeder roads (or about 35% of the all arterial roads)	Major & minor roads, excluding feeder roads (or about 65% of the all arterial roads)	Major & minor roads, excluding feeder roads (or about 80% of the all arterial roads)	There are significant emissions at signals and congestion zones, especially because of hot and cold start due to unsynchronized and delayed traffic signals. Pre-feasibility study should be undertaken for some hotspots. Detail study should be worked out on signaling network with sensor based monitoring and apply fuzzy logic, mathematical model gives the real time picture.

Table 6.2 (Contd..) : Emission Reduction Action Plan for Line Source

Line Sources	Short Term-2019	Mid Term-2022	Long Term-2024	Action required
Reducing Fuel Consumption Per Unit Distance				
Share of Electric vehicles in Total City Fleet	Two wheeler: 15%, 3 wheeler: 15% Public transport buses -20%	Two wheeler: 30%, 3 wheeler: 30% Public transport buses -40%	Two wheeler: 60%, 3 wheeler: 60% Public transport buses -80%	The government is focusing on creating charging infrastructure and policy framework so that by 2030, more than 30 percent of vehicles are electric vehicles. The flagship program to boost electric technologies in India is the Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME) scheme from the Central Government, launched in April 2015. The FAME scheme offers a subsidy on the retail price of passenger cars. These subsidies range as follows: for electric vehicles, from INR 60,000 to INR 1,34,000. Subsidies are also available for two-wheelers, three-wheelers, light-commercial vehicles, buses, and for retrofit kits. (presently only two wheeler models appear to be taking advantage of the scheme) The Central Government of India and some state governments, provide tax incentives that treat hybrid and electric vehicles preferentially over conventional technologies. The administration should devise some incentives and rebate at local level. For example, the Central Government of India levies an excise duty of up to 30% on conventional car technologies while electric vehicles are subjected to flat duties of 6%. In the national FY 2016-17 budgets, the Central Government of India also subjected conventional motor vehicles to an infrastructure cess ranging from 1% to 4% of the vehicle price and exempted electric vehicles from this cess. The Ministry of Heavy Industries recently gave its approval to the introduction of EV-based public transportation systems in 11 cities across the country. Nashik city can be assessed at regional levels at their own capacity. The life-cycle emissions intensity of electric vehicles in India is poised for substantial reductions in alignment with India's post 2020 climate action plans. Improvement of efficiencies in the power generation sector and its distribution should also be recognized as a priority. There are 24 two-wheeler models, all battery-operated electric, registered to receive demand incentives under the FAME scheme.

Table 6.2 (Contd..) : Emission Reduction Action Plan for Line Source

Line Sources	Short Term-2019	Mid Term-2022	Long Term-2024	Action required
Reducing Fuel Consumption Per Unit Distance				
Share of Hybrid vehicles in Total City Fleet	(Gasoline powered four-wheelers only) – 10%	(Gasoline powered four-wheelers only) – 20%	Gasoline powered four-wheelers only) – 30%	Hybrids with efficient internal-combustion engines and other non-polluting power trains will contribute to a cleaner environment. The flagship program to boost hybrid technologies in India is the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) scheme from the Central Government, launched in April 2015. The FAME scheme offers a subsidy on the retail price of passenger cars. These subsidies range as follows: for mild hybrids, from INR 11,000 (USD 165) to INR 24,000 (USD 360); for strong hybrids, from INR 59,000 (USD 885) to INR 71,000 (USD 1,065); Subsidies are also available for two-wheelers, three-wheelers, light-commercial vehicles, buses, and for retrofit kits. The Central Government of India and some state governments, provide tax incentives that treat hybrid and electric vehicles preferentially over conventional technologies. The administration should devise some incentives and rebate at local level. For example, the Central Government of India levies an excise duty of up to 30% on conventional car technologies while hybrid vehicles are subjected to flat duties of 12.5%. In the national FY 2016-17 budgets, the Central Government of India also subjected conventional motor vehicles to an infrastructure cess ranging from 1% to 4% of the vehicle price and exempted hybrid vehicles from this cess. Hybrid buses hold potential to gain significantly under FAME, as the allocations available cover a significant portion of the technology costs.

Here are some of the subsidiary benefits from government and emission reduction study conducted at Delhi explained with examples for various hybrid/electric models available in the market.

Passenger Cars Currently Eligible for Demand Incentives Under FAME Scheme

Vehicle	Technology	Segment[25]	Curb Weight (kg)	Length (mm)	Displacement (cc)	Price Range (INR Lakhs)[26]	Gasoline Equivalent Fuel Consumption (liter/100Km)	Life-Cycle CO2 e Emissions (Tonnes /5 Yrs.)
Maruti Ciaz SHVS	Mild Hybrid (Diesel)	Midsize	1,115	4,490	1,248	8 to 10.5	3.98	6.73
Maruti Ertiga SHVS	Mild Hybrid (Diesel)	Utility Vehicle (UV1)	1,235	4,265	1,248	7.5 to 9.5	4.55	7.71
Toyota Camry Hybrid	Strong Hybrid (Gasoline)	Premium	1,635	4,850	2,494	28 to 32	5.22	8.12
Mahindra E2O	Battery Operated Electric	Mini	830	3,280	NA	4.5 to 7.5	0.86	5.06
Mahindra eVerito	Battery Operated Electric	Midsize	1,140	4,277	NA	9.5 to 10	1.47	9.94

Fuel Consumption Savings of Models Under FAME Scheme Compared with Base Models

Technology	Hybrid/ Electric Model (BEER Fuel Efficiency Star Rating	Non-Hybrid /Non Electric Base Model (BEE Fuel Efficiency Star Rating)	Gasoline Equivalent Fuel Consumption Reduction over Base Model
Diesel –Based Mild Hybrid	Maruti Ciaz, VDI SHVS (5 Star)	Maruti Ciaz, VDI (5 Star)	7%
Diesel –Based Mild Hybrid	Maruti Ertiga, VDI SHVS (5 Star)	Maruti Ertiga, VDI (4 Star)	15%
Gasoline Based Strong Hybrid	Toyota Camry, Hybrid (5 Star)	Toyota Camry, At 2.5 L (2 – Star)	32%
Battery Operated Electric	Mahindra E-Vertio D2 (5 Star)	Mahindra Verito D2 (4 Star)	68%
Battery Operated Electric	Mahindra E2Om (5 Star)	--	--

Fuel Consumption Limits for Two-Wheelers Under FAME Scheme Compared with Non-Electric Benchmark

	Maximum Speed (kmph)	Maximum Power Output (w)	Gasoline Equivalent Fuel Consumption (t/100 Km)	Life Cycle CO2 Emission (tons/5 Yrs.)
Low speed Electric Scooters	25	250	< 0.51	< 3.04
High Speed Electric Scooters	45-55	1,500 – 1,800	< 0.82	< 4.86
Honda Activa 3G	82	5.966	1.5	2.33

Source: International Council on Clean Transportation

Table 6.2 (Contd..) : Emission Reduction Action Plan for Line Source

Line Sources	Short Term-2019	Mid Term-2022	Long Term-2024	Action required
Reducing Fuel Consumption Per Unit Distance				
Inspection and Maintenance	New I&M regulations (30% population of vehicles of a RTO region)	New I&M regulations (50% population of vehicles of a RTO region)	Full compliance - 100%	The Vahan-nagari area should be developed for I&M which is equipped with state-of-the-art testing set-up for all the types of emission as well as fitness testing. The test design should have the basis of engine and overall vehicles fitness (roadworthiness). Set up a mechanism of Inspection and Maintenance programme for all vehicles in the district through RTO with automated system assessment. Implementation of penalties should be laid on vehicles if found exceeding the emission limits. The I &M center should also test all vehicles for their in-built emission tests. All private vehicles should be subjected to proper assessment and fitness tests through I&M centers. All autos and buses shall also be subjected to I&M tests. On-road emission tests for vehicles plying on Indian roads will be mandatory once the Bharat Stage VI norm kicks in from 2020, for which testing agency Automotive Research Association of India (ARAI) is developing a unified test cycle. The European Commission will begin conducting these tests on new models from September 2017 and on new vehicles by 2019. India, however, will begin collecting data through these tests from 2020 and set permissible limits for emissions by 2024.
Ban of odd /even vehicles	It is feasible to take trail for commercial / office areas – 20%	Identified interlinking roads and traffic hotspots and implement for trail road - 20%	Identified interlinking roads and traffic hotspots and implement for trail road - 50%	A trial run should be arranged to study the impact. Alternate arrangements should be made to bolster public transport. All private vehicles even having registration numbers issued by neighboring states will have to follow the odd-even number formula.

Environment Pollution (Prevention and Control) Authority (EPCA) for Delhi NCR for submitted a "Report of assessment of Pollution Under Control (PUC) Programme in Delhi and NCR: Recommendations for improvement to ensure pollution from in-use vehicles is under control" to Supreme court. Some of the measures can be followed as recommendation for existing PUCs of the city:

EPCA states that without a robust system of emissions monitoring and compliance, the investments in emission monitoring of on-road vehicles as well as advanced emissions control systems in new vehicles to meet tighter emissions standards, can go waste and negate air pollution control efforts in our cities. Management of emissions from on-road vehicles will require an integrated approach to ensure all generations of vehicles -old and new remain low emitting for as long as the vehicles are on the road.

This will require strengthening of the PUC systems for all on-road vehicles - Bharat stage (BS) I to IV generations of vehicles combining both physical tests as well as On-board Diagnostic (OBD) tests. This will also require appropriate emissions monitoring system for the new generation of BSVI vehicles to come within three years. PUC will not be the relevant programme for that genre of vehicles. The BSVI standards and regulations have already provided for real driving emissions testing when vehicles move on the road. But the roadmap for its implementation needs to be charted quickly to allow Delhi and NCR to be prepared in time.

Simultaneously, the newly amended Motor Vehicle Act and Rules has given the opportunity to implement emissions recall programme so that the vehicle manufacturers can be held responsible for any manufacturing defect that increase on-road emissions. Both EPCA and Auto Fuel Policy committee had recommended emissions recall programme in 2003. Thus, addressing all the three element of the programme, PUC both physical testing and OBD testing; real driving emissions testing for in-use compliance; and manufacturer responsibility for manufacturing defects, are the critical steps to get a robust system to keep vehicles low emitting on roads. This is needed for both consumers as well as manufacturers' responsibility. In view of this the following recommendations are made:

1. Limit the numbers of PUC centres, upgrade them and bring them under strong supervision and quality control:
   The current practice of allowing mushrooming of small time and numerous PUC centres in refuelling stations across the NCR must be stopped. It is more important to limit their numbers, upgrade their capacity to carry out proper credible and authentic testing and bring them within a strong accountability framework

2. For improving compliance with the PUC programme, MoRTH and state transport departments should do the following:
   2.1 Ensure 100 per cent compliance by linking annual vehicle insurance with PUC certificates. Annual vehicle insurance cannot be obtained without all the requisite PUC certificates. Currently, PUC certificates need to be obtained every quarter in Delhi and every six months in the NCR. This periodicity of PUC certification can be made uniform across Delhi and NCR later only after PUC norms and oversight systems have been adequately upgraded and made stringent. Issue of authentic certificates must be ensured based on authentic and credible tests.

   2.2 Introduce automatic online network for transmission of PUC data to the central server to minimize manual interference and allow proper analysis of data for remote auditing of PUC centres. Adopt uniform and standardized data recording and reporting format and uniform software across Delhi NCR. Mandate periodic analysis of data to refine enforcement and for monitoring and submission of compliance report every six months. Software used in different make of testing equipment across NCR needs to be standardized to prevent fake values. MoRTH needs to develop the standardized protocol for uniform application across Delhi-NCR.

   2.3 Mandate pre-payment of PUC fees before the tests are conducted. No test should be conducted without taking the fee in advance. The software should be modified accordingly.

   2.4 Strengthen inspection of the PUC centres for quality control and strengthen the licensing programme to ensure proper calibration, authentic tests; annual maintenance contact for the maintenance of all testing equipment and accessories; training of operators, calibration of equipment etc are carried out. Make quality audit of centres and calibration quarterly. Introduce annual third party inspection of PUC centres immediately. State Pollution Control Boards with guidance from Central Pollution Control Board should coordinate this.

   2.5 Phase in big centralized emissions testing centres capable of conducting automatic and upgraded tests for commercial vehicles on a priority basis. Delhi already has Burari vehicle inspection and fitness centre in Delhi for commercial vehicles. The commercial vehicles visit it for annual vehicle fitness and roadworthiness tests. This needs to be upgraded for high level of automatic emissions testing so that operators and vehicle drivers do not come in contact to influence the test results and credible and upgraded tests are conducted. MoRTH is also setting up centralized inspection centres in NCR as in Rohtak. These should be aligned to firm up the roadmap. Add more such centres as needed.

2.6 Introduce well equipped mobile test centres and a programme to check visibly polluting vehicles:
   - In addition to stationery testing centres, mobile units are also needed for surprise checks as well as to catch the visibly polluting vehicles on road. There should be appropriate penalty for visibly polluting vehicles.
   - Enforce stringent penalty for PUC centres for non-compliance and malpractices.

3. For improving the effectiveness of the PUC tests and inspection, MoRTH should do the following:

3.1 Tighten the PUC emissions norms for pre-Bharat Stage IV vehicles: Analysis of large data set on actual emissions concentration tested in large number of PUC centres in Delhi and UP has also brought out that the actual observed emissions values of pre-Bharat Stage IV vehicles are significantly lower than their prescribed norms. In most cases 80 per cent lower than the limits. These norms cannot identify at least 15 to 20 per cent grossly polluting vehicles in the on-road fleet. Nearly all vehicles pass the tests. Due to poor recording of failed tests and due to very lax norms the overall failure rate in Delhi is 4.69 per cent. For the diesel vehicles tested, the failure rate stands at 1.68 per cent, compared to 5.18 per cent for petrol vehicles and 4.65 per cent for all other fuel categories requires urgent attention and action. In UP NCR cities, the overall failure rate is abysmally low, at 0.49 per cent – 0.39 per cent in two-wheelers and 0.59 per cent in four wheelers. The MoRTH needs to tighten the PUC standards for the pre-Bharat Stage IV emissions standards. This will also help to weed out very old non-compliant vehicles and speed up fleet renewal based on improved standards.

3.2 Overhaul emissions tests and tighten norms for diesel vehicles: The review of available data shows that the smoke density tests – the only test that is carried out in diesel vehicles is very lax for the pre Bharat Stage IV diesel vehicles. More than 80 per cent of vehicles tested show smoke density levels that are below the norm prescribed for the Bharat Stage IV vehicles. Therefore, the current norms for Bharat Stage IV norms should be made uniform for the pre-Bharat Stage IV vehicles as well. This can be further weed out the very old and polluting vehicles and speed up fleet renewal.

Moreover, as explained earlier globally smoke tests are being upgraded with more advanced test procedures to make these tests more rigorous and effective. MoRTH may review those advanced testing procedures and provide a roadmap for the introduction of these tests in the large centralized testing centres for commercial vehicles quickly.

3.3 Make lambda test for petrol cars mandatory across NCR: Lambda testing for petrol cars equipped with three way catalytic converters – introduced in BSII-III level is already mandatory in Delhi as per the MORTH 2004 notification, but not in NCR. Lambda value represents the air to fuel ratio. It is important to maintain the optimum ratio for proper functioning of the catalytic converters that play a crucial role in cleaning up the exhaust gases from petrol cars. It is not possible to directly test the efficacy of the catalytic converters. That is why it is important to ensure that the operative systems in the vehicles needed for its optimum performance are maintained. Lambda is an indicator of that. Such tests will require upgradation of the test equipment from two gas analysers to four gas analyzers capable of doing lambda testing. Petrol cars are already tested for carbon monoxide, hydrocarbon based on two speeds. If done along with lambda measurement, the test procedures for petrol cars can become more robust and effective. As the MoRTH has already provided for lambda tests in its 2004 notification, the concerned state governments need to issue orders for implementation in the NCR.

3.4 Integrate OBD with inspection and maintenance programme: The MoRTH needs to develop the protocol for implementation of OBD for vehicle inspection programme that will be implemented by the state governments. This will complement the physical testing.10 It is also important to detail out how this will be operationalized at the ground level and how the transport department will implement this programme.

3.5 Detail out the strategy for advanced real driving emissions monitoring of new generation vehicles to come with BSVI emissions standards in 2020: Any roadmap for improving vehicle inspection programme at this juncture will have to keep in view the dramatic transition in emissions control technologies within a short span of three years when BSVI emissions standards will be enforced. The current PUC is not designed to address those vehicle technologies. The notification of MoRTH on BSVI standards has already provided for the introduction of Real Driving Emissions Test Procedures and Standards based on portable emissions monitoring system to monitor emissions as vehicles move on the road. This is needed to ensure that all the advanced emissions control devices that to be fitted in the new vehicles will continue to perform effectively in real world conditions.

This has become necessary in view of the rapid deterioration in emissions noted in new Euro VI vehicles in Europe and the US and also to prevent use of defeat devices to cheat emissions standards. The data available from Europe shows that the actual NOx emissions from Euro VI diesel cars can be as bad or worse than a Euro I diesel car as on-road emissions can be as higher as upto 16 times higher than their certification level EPCA strongly believes that as India is now making this crucial transition to a very advanced genre of vehicles proactive and preventive policies and systems should be put in place to these advanced systems continue to perform efficiently on road and for emissions to all generation of vehicles remain low emitting during their useful lifetime. MoRTH along with the state governments of the NCR-Delhi need to put in place the systems for introduction of Real Driving Emissions testing for BSVI vehicles.

Table 6.2 (Contd..) : Emission Reduction Action Plan for Line Source

Line Sources	Short Term-2019	Mid Term-2022	Long Term-2024	Action required
Reducing Fuel Consumption Per Unit Distance				
Retrofitment of Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter in HDDV	Retrofitting devices- 50% conversion for HDDV in city registered vehicles	Retrofitting devices- 75% conversion for HDDV in city registered vehicles	Retrofitting devices- 1000% (Excluding the heavy duty city outside vehicles)	A pilot study is required to test the need and efficacy of emission control device and retrofitting it in the older vehicles As retrofitment of emission control devices also needs a certain levels of fitness of the vehicle, it would be desirable to follow the norm after developing the same through the inspection and certification procedures. It will be helpful to Maharashtra State Transport Corporation, Old contract buses and carriers. Impose restriction of truck movement in the city for plying without retrofitment to HDDV vehicles (base on age and engine type). Tighter diesel fuel standards particularly for Sulphur to bring down its level up to 50 ppm. Differential taxation to those with and without after treatment devices. On August 16, 2017, the government of India, in consultation with the Bureau of Energy Efficiency (BEE), published final fuel efficiency standards for commercial heavy-duty vehicles (HDVs). The regulations are aimed at reducing fuel consumption and greenhouse gas (GHG) emissions from diesel-powered trucks and buses with a gross vehicle weight (GVW) of 12 tonnes or greater.

On August 16, 2017, the government of India, in consultation with the Bureau of Energy Efficiency (BEE), published final fuel efficiency standards for commercial heavy-duty vehicles (HDVs). The regulations are aimed at reducing fuel consumption and greenhouse gas (GHG) emissions from diesel-powered trucks and buses with a gross vehicle weight (GVW) of 12 tonnes or greater. The new standards include two phases of regulatory compliance. Phase 1 goes into effect April 1, 2018, while Phase 2 is effective beginning April 1, 2021. The regulatory classes affected by this rule are as follows (Vahan Sewa, 2017) :

- Category M3: motor vehicles for the carriage of passengers, comprising nine or more seats in addition to the driver's seat with GVW exceeding 5 tonnes
- Category N3: motor vehicles for the carriage of goods with GVW exceeding 12 tonnes

Although, the M3 regulatory subclass includes vehicles 5 tonnes and above, the rule applies only to vehicles greater than 12 tonnes GVW. Tables 1 and 2 summarize the limit value equations for all of the subcategories within the M3 and N3 vehicle classifications.

Table 1 : Stringency Equations for Phase 1 (Effective April 1, 2018)

Vehicle Category	Gross Vehicle Weight (tones)	Axie Configuration	Equation	Fuel Consumption (l/100 Km)	
				Value at lower weight limit	Value at upper weight limit
40 Kilometer per hour					
N3 Rigid Vehicles	12.0- 16.2	4 x 2	Y=0.362X + 10.327	14.7	16.2
	16.2- 25.0	6 x 2	Y=0.603X + 6.415	16.2	21.5
	16.2- 25.0	6 x 4	Y=0.723X + 4.482	16.2	22.6
	25.0- 31.0	8 x 2	Y=0.527X + 8.333	21.5	24.7
	25.0- 31.0	8 x 4	Y=0.928X – 0.658	22.5	28.1
	31.0- 37.0	10 x 2	Y=0.960X – 5.100	24.7	30.4
N3 Tractor Trailers	35.2- 40.2	4 x 2	Y=0.986X – 7.727	27.0	31.9
	40.2- 49.0	6 x 2	Y=0.628X – 6.648	31.9	37.4
	40.2- 49.0	6 x 4	Y=1.255X – 18.523	31.9	43.0
M3 Vehicles	12.0 and above	4 x 2 & 6 x 2	Y=0.509X – 11.062	17.2	
60 Kilometer per hour					
N3 Rigid Vehicles	12.0- 16.2	4 x 2	Y=0.788X + 9.003	18.5	21.8
	16.2- 25.0	6 x 2	Y=0.755X + 9.546	21.8	28.4
	16.2- 25.0	6 x 4	Y=1.151X + 3.122	21.8	31.9
	25.0- 31.0	8 x 2	Y=0.650X + 12.160	28.4	32.3
	25.0- 31.0	8 x 4	Y=0.968X + 7.692	31.9	37.7
	31.0- 37.0	10 x 2	Y=0.960X + 5.100	24.7	30.4
N3 Tractor Trailers	35.2- 40.2	4 x 2	Y=0.208X + 32.198	39.5	40.6
	40.2- 49.0	6 x 2	Y=0.628X + 15.298	40.5	46.1
	40.2- 49.0	6 x 4	Y=1.342X + 13.390	40.6	52.4
M3 Vehicles	12.0 and above	4 x 2 & 6 x 2	Y=0.199X + 19.342	21.7	

** Source: International Council On Clean Transportation*

The standards are represented in an equation based on GVW and axle configuration, providing normalized values of fuel consumption in liters per hundred kilometers (l/100 km). The regulations are a minimum performance requirement, similar to the existing Bharat Stage (BS) emission norms.

Table 2. Stringency Equations for Phase 2 (Effective April 1, 2021)

Vehicle Category	Gross Vehicle Weight (tones)	Axie Configuration	Equation	Fuel Consumption (l/100 Km)	
				Value at lower weight limit	Value at upper weight limit
40 Kilometer per hour					
N3 Rigid Vehicles	12.0- 16.2	4 x 2	Y=0.329X + 9.607	13.6	14.9
	16.2- 25.0	6 x 2	Y=0.523X + 6.462	14.9	19.5
	16.2- 25.0	6 x 4	Y=0.673X + 4.032	14.9	20.9
	25.0- 31.0	8 x 2	Y=0.430X + 8.780	19.5	22.1
	25.0- 31.0	8 x 4	Y=0.732X + 2.558	15.7	20.1
	31.0- 37.0	10 x 2	Y=0.963X – 7.753	22.1	27.9
N3 Tractor Trailers	35.2- 40.2	4 x 2	Y=0.826X – 3.165	25.9	30.0
	40.2- 49.0	6 x 2	Y=0.630X + 4.732	20.6	26.1
	40.2- 49.0	6 x 4	Y=1.008X – 10.480	30.0	38.9
M3 Vehicles	12.0 and above	4 x 2 & 6 x 2	Y=0.659X + 6.582	17.2	
60 Kilometer per hour					
N3 Rigid Vehicles	12.0- 16.2	4 x 2	Y=0.600X + 9.890	17.1	19.6
	16.2- 25.0	6 x 2	Y=0.515X + 11.271	19.6	24.6
	16.2- 25.0	6 x 4	Y=0.932X + 4.515	19.6	27.8
	25.0- 31.0	8 x 2	Y=0.382X + 14.598	24.2	26.4
	25.0- 31.0	8 x 4	Y=1.318X – 5.148	27.8	35.7
	31.0- 37.0	10 x 2	Y=1.043X – 5.913	26.4	32.7
N3 Tractor Trailers	35.2- 40.2	4 x 2	Y=0.260X + 27.888	37.0	38.3
	40.2- 49.0	6 x 2	Y=0.236X + 28.838	38.3	40.4
	40.2- 49.0	6 x 4	Y=0.563X + 15.728	38.4	43.3
M3 Vehicles	12.0 and above	4 x 2 & 6 x 2	Y=0.340X + 14.300	18.4	

* *Source: International Council On Clean Transportation*

To demonstrate compliance, each vehicle model and configuration is required to meet the fuel consumption levels shown in Tables 1 and 2. This stands in contrast to the fuel consumption and greenhouse gas standards in the United States and Canada, which are based on sales-weighted averaging.

For evaluating the performance of the vehicles, manufacturers are required to use a Constant Speed Fuel Consumption (CSFC) driving cycle. This means that the fuel consumption is measured over a set speed without any transient behavior. In this particular regulation, the CSFC test is run at two separate speeds one at 40 km/h, and the other at 60 km/h. The CSFC testing has been used in India as part of the vehicle certification process for several years *(Sharpe & Delgado, 2015)*. The CSFC cycle is different from the regulatory cycles adopted in HDV standards for other countries.

The efficiency standards are required for both vehicle manufacturers and importers. The conformity-of-production test will be undertaken by MoRTH once every two years. The CSFC testing and reporting also needs to be done at least once before April 1, 2020. There is no such requirement before Phase 1 goes into effect April 1, 2018, because the standards reflect averages found in HDV baseline testing between 2014 and 2015.

As per internal government records, the Phase 1 stringency for each vehicle subcategory represents the average fuel consumption from CSFC testing. Thus, starting April 1, 2018, for every segment of the market, the maximum allowable fuel consumption is equal to the average fuel consumption from the baseline testing campaign. The Phase 2 stringency represents the 20th percentile of the baseline testing data, meaning that 20% of the baseline vehicles had fuel consumption levels lower than the limit curve.

Fuel Consumption Stringency : Phase 1 to Phase 2

Assuming equal weighting for the two test cycles, an estimated fuel-consumption reduction from Phase 1 to Phase 2 can be calculated as shown in Table 3. The average stringency is calculated using sales weighting, which comes from data that was acquired from Segment Y Automotive Intelligence for the year 2013-2014.

Table 3: Required reduction in fuel consumption from Phase 1 to Phase 2 and market shares by vehicle category in fiscal year 2013-14

	GVW Bin (tones)	Axie Configuration	Required Fuel- Consumption Reduction Between Phase1 and Phase 2	Market Share
Rigid Truck	12.0- 16.2	4 x 2	8.2 %	23.3 %
	16.2- 25.0	6 x 2	10.7 %	13.9 %
	16.2- 25.0	6 x 4	9.6 %	16.8 %
	25.0- 31.0	8 x 2	13.3 %	12.9 %
	25.0- 31.0	8 x 4	8.9 %	6.5 %
	31.0- 37.0	10 x 2	11.5 %	0.5 %
Tractor-Trailers	35.2- 40.2	4 x 2	5.4 %	8.9 %
	40.2- 49.0	6 x 2	7.2 %	0.0 %
	40.2- 49.0	6 x 4	10.0 %	2.6 %
Bus	12.0 and above	All Configuration	15.5 %	14.5 %
Sales weighted average stringency			10.4 %	

** Source: International Council On Clean Transportation*

The Phase 1 to Phase 2 stringency analysis shows that transit buses face the largest reduction in fuel consumption from 2018 to 2021 at 15.5%. The fleet-wide fuel-consumption reduction from Phase 1 to Phase 2 is estimated at 10.4%. This is calculated on a vehicle-population weighted average and therefore is not necessarily representative of the overall fuel savings that will be achieved as a result of the regulation. This is due to the difference in fuel consumption that the different vehicle configuration may have. For example, changing the stringency of for a tractor-trailer by 1% will not have the same result as changing the value for a rigid truck. Because the regulation applies only to trucks and buses greater than 12 tonnes GVW, a significant percentage of the HDV market in India is not subject to these standards. Sales data from Segment Y provides evidence that nearly half of the HDV market is less than 12 tonnes and thus is not covered by this regulatory program.

Truck Terminal : Terminal facility in the form of Truck Terminus for heavy vehicles is in existence at Adgaon. Truck Terminus is partly developed on Mumbai-Agra National Highway and is functioning. At Pune-Nashik National Highway such type of truck terminus is presently absent and need to be provided. The C.B.S. in Nashik city and the existing Nashik Road Bus Station outside the Railway Station are very heavily loaded and their location in the heart of developed locality offers no scope for making more space available for bus parking.

The growing traffic needs in the city would also call for proper traffic management measures along with traffic signal with area co-ordination traffic signals etc. Due to rapid growth of auto-rickshaws and two-wheelers and lack of proper traffic control, the road accidents are prevalent in the city.

- The inner city roads are congested particularly during the morning and evening peak hours. The comprehensive area traffic control plans need to be prepared for the congested area.
- The wholesale market like Gole Colony and Main road may need to be suitably relocated by making reservation in the land use plan.
- The national and state highways passing through the city function as major arterial roads. In the absence of an effective by pass, intermixing of regional traffic and city traffic takes place, especially on the national highway. This adds to the traffic congestion on the highway in the city area. Thus, there is a need to segregate inter-city and intra-city traffic, may be by providing service roads or by constructing effective by pass links.
- There should be planned and designated bus stops that reduce traffic congestion and accidents.
- Footpath should be built on every road of the city. The widening and maintenance of the roads should be undertaken in an effective manner.
- The road marking such as Zebra Crossings would be essential, particularly, at the intersection where there is significant pedestrian- vehicle conflict.
- Inadequate street lighting also undermines the safety and convenience on the city road. This situation needs to improve.
- Efficiency, energy, environment and equity should be taken into account while solving traffic and transportation problem.

Table 6.2 (Contd..) : Emission Reduction Action Plan for Line Source

Line Sources	Short Term-2019	Mid Term-2022	Long Term-2024	Action required
Reduce Vehicle Distance Travelled				
Regulating Road Site Parking	Road site parking to be reduced by 50% (On street parking spaces as per IRC: SP: 12:2015.)	Road site parking to be reduced by 75%	Road site parking to be reduced by 100%	Currently, parking in city is either free or priced very low. Increased parking cost, if coupled with the parking locations, so that they are as far as the bus and the rail stops, will make public transportation an attractive option Parking on roads should be regulated along with a rule to allow purchase of vehicles only if parking place is available. Municipal corporation should define designated space in the localities and develop elevated pay and park zones. Higher parking fee for longer period of time. Diversion of non-destined traffic especially the trucks trough by-pass roads. Major haul trucks with heavy loads should not be left to pass through the main city; instead a Truck Terminal can be established at outskirt of city. Construction of multi storied parking complexes. Pay and Park Schemes on major roads and mass transit stations. Road side parking should be regulated on internal roads.
Encourage Public Transport	Increase Public Transport - 20% Which reflect 10% VKT reduction from private vehicles.	Increase Public Transport - 50% Which reflect 40% VKT reduction from private vehicles	Increase Public Transport - 75% Which reflect 60% VKT reduction from private vehicles	Efficient public transport can be achieved by way of providing better frequency to reduce congestion during peak period, better bus quality in terms of sitting as well as standing space The public transport should be cross-supported directly from the personalized vehicles either being purchased newly or older one running on the road. Funds generated from measures such as higher car user charges, higher parking charges, high registration fees, higher taxes on private mode of transport etc. should be directly transferred to them to achieve the low cost, better comfort, better frequency and faster travel. Diesel or any fuel used for public transport should be sold at lower price to keep the bus fare lower. Exclusive bus lanes should be identified. There is a need to undertake a project to demonstrate effectiveness of such system in Nashik city at one or two road stretches Management of Intermediate Public Transport - IPT (auto rickshaws / shared auto rickshaws / taxis) can be done considering the travel demand management. One way traffic movement on few roads. Widening of roads approaching towards mass transit stations.

Buses are critical as spine of city mobility- 40-60% of daily trips. These allow greater flexibility to allow more efficient geographical coverage and score high on space efficiency. Buses move people in most cost-effective way and emit a lot less per person.

Yet city have Inadequate and unreliable services, poor fleet utilization, under-utilization of passenger carrying capacity, no route rationalization and poor geographical and population coverage, operated kilometer are much less than scheduled kilometer and no dedicated right of way for buses.

Bus numbers of the state transport corporations are extremely inadequate and dwindling over time. According to the bus transport guidelines of the Ministry of Urban Development framed with support from Asian Development Bank states that a city should ideally have at least 60 buses per lakh of population. Estimating this number for cities is extremely difficult as in most cities public transport buses are operated by both state owned city transport corporations and private agencies.

For example for one km of travel a car consumes nearly five times more energy than a 52-seater bus with an average load factor of 82 percent. The corresponding consumption factor for two-wheeler is 2.6. The comparative fuel costs of a car and two wheelers are 11.8 and 6.8 times respectively for the same distance. Besides, the major issues are that a car occupies 38 times more road space compared to a bus for a kilometer of travel. Two wheelers space requirement is even higher at 54 times that of a bus*.

Further, the emission from a two wheeler equivalent to a bus could add 27 percent higher, whereas the cars would cause 17 percent more pollution. The age of the bus can be of no major concern, when we compare the benefits that it could give in term of fuel savings, emission and safety.

Report of the Expert Committee on Auto Fuel Policy, Chapter 15, Government of India, 2002

Promotion of NMT

The vehicle ownership in India is low as compared to foreign countries and also traditional mixed-use design of the cities makes the majority share of trips by walk or cycle. In big cities with higher population density, in the absence of dedicated Non-Motorized Transport infrastructure (NMT), people owning two-wheelers and cars are encouraged to use their vehicles, even for walk-able distances. In the context of growing cities, the measures to improve air quality should include NMT policies as an integral part.

Non-Motorized Sectors

Cycle Track : To contribute to the sustainable development of the city, provision of dedicated 3 m. wide cycle track along all nallas having width more than 6 m, can be developed. Municipal Corporation should look after the procurement of required lands and its construction. In addition to this, 6 m. wide cycle track can be developed in the Nashik bank canal land. The development of this cycle track can be done by public-private participation or from the funds of Municipal Corporation. In addition to this, provision of cycle track shall be made in green belt proposed along river sides.

Green Belt Development : The Green Belt along the banks of Godavari, Nasardi, Valdevi and Darna Rivers can be developed. This belt shall be a use for plantation, cycle track, recreation, etc. which will protect the erosion of the river banks and also enhance the environment.

- Conservation and development of green belts on the road side in order to increase beauty
- Improvements of Footpaths
- Periodic manicure of tree planted on roads.
- Improvement of Traffic island & junctions.
- Awareness to citizens to keep city clean through slogans, messages, media etc.
- Maintenance of public utility buildings and Monuments.
- Total use of open land for green belt development
- Arranging the seminar/awareness programme at school & college levels.

<u>Congestion Pricing</u>

Some economic measures should also be designed to force the use of public transport. One such measure is the congestion pricing where the motorists are charged to use a network of roads during periods of the peak hours. Its purpose is to reduce automobile (mostly car) use during peak congestion periods, thereby easing traffic and encouraging commuters to walk, bike, or take mass transit rail/bus as an alternative.

Congestion pricing programs were successfully implemented in Singapore, London, and Stockholmb *(Eliasson, 2009; Menon and Guttikunda, 2010; Litman, 2011)*. On average, in London, congestion pricing is estimated to have reduced 20-30% of the downtown passenger car traffic and promote the non-motorized transport, whereas Stockholm experienced an immediate reduction of at least 20% in the daily car use. In Singapore, the average traffic speeds increased by at least 15 km/h. In all three cities, 10-20% reduction in eCO2 emissions was estimated, along with health benefits of reducing air pollution

Increased Parking Cost

With increasing costs for private vehicles linked with their usage (fuel and other operational expenses), it is possible to achieve a shift to public transport, if combined with the provision of an adequate, reliable, and safe public transportation. One such measure is the increased parking cost. Currently, parking in most cities is either free or priced very low. Increased parking cost, if coupled with the parking locations, so that they are as far as the bus and the rail stops, will make public transportation an attractive option *(Barter, 2012; CSE, 2012).*

Car Specific Taxes

According to International Energy Agency IEA's World Energy Outlook (WEO) report, in the new policies scenario, passenger car ownership will grow from less than 20 vehicles per 1,000 inhabitants today to 175 cars per 1,000 people in 2040, and overall road passenger vehicle activity will increase more than six-times. While the congestion pricing and parking policies target reduced vehicle usage, some countries have used regulatory measures to reduce the growth of private vehicles. For instance, a Chinese national regulation enacted in September, 2008, raised taxes on big cars and reduced on smaller ones. Car owners with engines above 4-L capacity have to pay a 40% tax; 15%-25% for cars with engines above 3-L capacity; and 1%-3% for cars with engines below 1-L capacity. China also introduced a policy to limit the number of licenses issued every year, where the license plates are auctioned in the cities of Beijing, Shanghai, and Guangzhou. Similar to congestion pricing, for the time being, such measures are difficult to implement under democratic political context of India.

Action on Vehicle Technology and Fuels

In urban landscape clean air action on vehicles and mobility is the weakest. Even though vehicles are one of the most rapidly growing sources of pollution local action has remained the minimal. Emissions standards for vehicles and fuel quality are common across cities. However, it is also important to know that the central government has issued notification to leap directly to Euro VI emissions standards in 2020. This has serious implications for the implementation and compliance strategies at city level. Bharat Stage VI will bring in new genre of technology and fuel that will be subjected to a new compliance regime for the first time in the country. For the first time monitoring of real world emissions with portable monitoring system along with in-service compliance regulations will be implemented to keep an eye on real world emissions. Real driving emissions (RDE) testing will be included as an additional requirement for vehicle certification. Emissions measurements will be carried out with the help of Portable Emission Measurement System (PEMS) and onwards in-service conformity factor will be applied to ensure that emissions from vehicles remain within the stated margin. This can prevent emissions cheating and use of sub standards emissions control or defeat devices as was done by Volkswagen. However, adoption of more advanced on-board diagnostic system has been delayed until 2023. Cities will have to develop a compliance programme to integrate these emissions control approaches within this time frame for successful implementation.

Since 01 September 2017, Real Driving Emissions (RDE) has become mandatory with specific pollutant limits for new light duty vehicle approvals in Europe. This year, European Commission will finalize the RDE 4th package, with which, Europe will consolidate the most stringent approach worldwide for light duty vehicles emissions regulation. The new approach of RDE in measuring vehicle emissions during on-road driving is rapidly being adopted by many other countries. There is already a substantial diversity arising in the local applications of RDE, some examples are given below this is not a complete list of those intending to apply RDE in future, nor does it contain a comprehensive list of all the differences in comparison to the European application:

India is developing its own RDE -currently investigations are running regarding driving speeds, conditions and potential limits as well as on the robustness of the measurement equipment under Indian driving conditions.

6.2.1 Clean Air Fund

Prioritization of Public Transport on Roads: Once, more and more people get used to personalized transport, it would be very difficult to bring them back into the fold of public transport users. The fact that personal vehicles are occupying more and more space on the road; it is felt necessary that disincentive mechanism should be developed for personal vehicle owners. There are many methods of carrying out this task, however, financial and space constraints can achieve the balance. The efficiency of the public transport can be maintained only if priority is given to the public transport vehicles. Some of the suggestions are:

In Nashik City Bus lane, there is need to find out gaps and exclusive bus lanes should be introducing base on point to point service. If one wishes to see higher bus utilization, it also has to see correspondingly higher service levels. This could be achieved by way of providing better frequency to reduce congestion during peak period, better bus quality in terms of sitting as well as standing space. Those vehicles which may travel in bus lanes will need to pay a sum to get the benefits

Cost of Bus Ride: The cost of the bus fare has been increasing at a steady pace. This is seen as a very common practice when there is an increase in the diesel cost announced by the Government. What it leads to is that the bus fare for two-four persons becomes almost equivalent to either the auto fare or attractive enough to own a private two or four wheeler. In such a situation, it shows that increasing bus fare and purchasing power is becoming the main responsible agent for higher private vehicles purchase. The other reason, such as better roads with flyovers (faster travel) makes it attractive for private vehicle ownership.

Public transport fare pricing, therefore, should not only be dependent upon the actual cost, but on some other sources of income. Modalities and options which can be adopted for no increase in bus fares are presented below:

- The public transport should be cross-supported directly from the personalized vehicles either being purchased newly or older one running on the road.
- An Air Quality Fund could be created which will have sources of funds coming from measures such as higher car user charges, higher parking charges, high registration fees, higher taxes on private mode of transport etc. should be directly transferred to them to achieve the low cost, better comfort, better frequency and faster travel.
- Diesel or any fuel used for public transport should be sold at lower price to keep the bus fare lower. The losses can be recovered from car-users.
- Certain areas of business district or identified regions of high congestion, free bus services can be provided. The cost can be recovered from parking, congestion and high fuel costs charged to personal vehicles. (For example Pilot feasibility study may be carried out in Hotspots)
- All shopping centres (malls) must be asked to provide their own free service to nearest train and bus routes so that congestion due to their activities is reduced further. Alternately, all cars must pay an additional fee besides parking charges as congestion fee when they enter the mall. All such charges should be pooled and shared with the public transport company.
- All malls and institutions attracting outside car visitors levy a Rs. 10 per hour charges. This can either go to PMT or the fund

- Administration : Insurance cost should be inclusive of congestion charge every six months, buy sticker worth congestion charges. Annual insurance time each vehicle can pay a sum of Rs.500 extra, which can go to the fund. Collection responsibility will be with the insurance company.
- Vehicle manufacturers selling vehicles in state of Maharashtra must pay a ONE TIME air pollution tax towards the CAF

The key is that all such charges thus collected should be managed as Clean Air Fund and should be passed on the public transport company, which could not only take care of its operational costs but also addresses other issues such as: Lower cost to passenger, Better bus quality, Faster services and Adequate growth in bus population for more people.

Emission reduction from transport sector can also be achieved by forming a ‘Clean Air Fund’ in co-operation with public private partnership which can operate on following guidelines:

Example of how a small levy can bring additional revenue as part of **Clean Air Fund :**

Vehicle Km Travel in a Day for Nashik City (2017)

	2 Wheelers	3 Wheelers	Car CNG	Car Petrol	Car Diesel	HDDV
VKT	3288367	1088602	129463	2200879	258927	2845787
Cost (Rs.)	1644183	544300.9	64732	2200879	258927	2845787
Rate Rs./Km	0.5	0.5	0.5	1	1	1

Total Collection about Rs. 75,58,810 per day

The current VKT growth of the city ranges between 2-5% depending upon the region of the city. Awareness programmes for policy makers, people, drivers-mechanic, traffic police, health professionals, academicians etc. will bring the importance of better air quality. Land use and transport planning need to be looked at seriously for future sustainability of the cities. In dense cities conglomerate of NMC, public transport saves valuable space and energy compared to private transport, and can make a healthy profit at the same time. But cities need to nurture their public transport by giving then some priority on the road over cars. If buses are always caught in traffic then a vicious cycle begins, with bus riders abandoning public transport and adding to the traffic jams. Various case studies from other places also indicate the importance of sustainable transportation. Strong leadership and governance brings radical change in achieving sustainable development of the city. The authorities responsible for the development of transport need to develop Integrated Environment Management Systems (IEMS). The goal of achieving a balanced development of the region through proper land use planning, strengthening of infrastructure facilities and formulates policies and programmes that help in preserving the environment for sustainable development.

6.3 Point Sources - Reduction Strategy

Nashik had been growing very fast industrially, during the last few decades. There are some major industrial activities on the out skirt of Nashik city, such as Hindustan Aeronautics Ltd. at Ozar, Thermal power station at Eklahare, Sinnar M.I.D.C., Five Star Industrial Estate at Sinnar, which can directly or indirectly influence the working population as well as trade and commerce activities of the city. Industrial development within city limit is also noteworthy which has directly or indirectly increased the working population, as well as Trade and Commerce. Some of them are Currency and Security Press, Govt. of India, Crompton Greaves, M.I.C.O., V.I.P., CEAT, Mahindra and Mahindra, Railway Traction Factory. Besides this, there is sporadic Industrial development comprising of sawmills, small scale industries, work-shops etc. spread all over the Corporation Area. M.I.D.C has developed an Industrial Area in Satpur over an area of 635.76 hectares, Ambad over an area of 515.50 hectares and Sinner over an area of 51.067 hectares. In addition to above, there is Nashik Industrial Co-op Estate having an area of 135 hectares, established in 1962. There are about 6990 small scale, 27 medium scale and 131 large scale industrial units registered. Majority of the Industries which came up in the city or Industrial areas are Automobiles, Engineering, Electrical, Electronics, Stationary manufacturing, Printing press components, Metal Arts, Steel and wooden Furniture, Fiber and plastic moldings, Pharmaceutical and medical equipment, Data processing etc. All the above units, more or less, have contributed directly or indirectly in pushing up the trade and commerce activity in the city.

Thermal Power Plant : Eklahare Thermal Power Plant located in village Eklahare, near Nashik Road, caters to the power demand. From there, power is fed into the western division grid and subsequently distributed to substations and finally to households. In line with the guide lines issued by Central Electricity Authority (CEA), MAHAGENCO plans to install energy efficient 1 x 660 MW coal based super-critical thermal unit at Nashik as replacement project.

- The data for fuel consumption pattern in the industries of Nashik is not updated. There are large numbers of medium scale industries established within the city limit as well as in MIDCs. Inventorisation of fuel consumption of prominent industries should be maintained with inclusion of technological gaps.
- Nashik district and circumferential area earmarked for development and industrialization should be grouped under a Nashik Metropolitan Development Authority and MIDC for better planning and administration. The fuel (vehicular and industry) of corresponding quality in this area should be ensured. Similarly, national level decision of controlling sulfur content of these industrial fuels will yield good results (present sulfur content: FO 4%, LDO 1.8%)

- Majority of the industries of Nashik are of engineering or manufacturing nature. There is dire need for the identification of low cost and advanced cleaner technology for these industries. Use of air pollution monitoring devices (Continuous Environment Monitoring System) and other in-situ emission reduction devices should be made mandatory in their premises. Some units having coal fired boilers are proposed to improve efficiency of the wet scrubber and to stick for eco-friendly fuels.
- Use of fossil based fuel is high in Nashik's Industrial area. Industries should adopt natural gas or renewable resources as fuel for their operations. Use of FO, LSHS, LDO, and Bagasse should be regulated. Provision for supply of LPG or PNG should be explored.
- Industries should adopt stack emission norms beyond those prescribed by CPCB Industries/power plants, which should be followed by regular QA/QC & performance audit.
- Power Shedding is a common phenomenon in Nashik MIDC area, which gave rise to number of D.G sets in the vicinity. To control the emission from the D.G set, their stack should be regulated according to the standards prescribed. Control equipment installation should be made mandatory. Provision of continuous supply should be made.
- All the bulk drug and pesticides manufacturing units should be proposed to improve efficiency of their VOC scrubbers. Some units having coal fired boilers are proposed to improve efficiency of the wet scrubber and to stick for eco-friendly fuels. Solvent distillation Units should be directed to establish waste solvent recovery unit. The chemical and dyes units should improve their scrubbers and dust collectors.
- Energy Conservation Scheme should be encouraged in the industries that are not economically capable towards shifting cleaner fuel use or advanced cleaner technologies. Air polluting industries can improve their ECS by increasing efficiency of their scrubbers and changing to eco-friendly fuels.
- NMC, MIDC & MPCB should survey for the identification of illegal SSI and their levels of operation and their contribution in each of the grids in the city. Need for regulations for such units.

With the implementation of the short and long term scenarios, the total reduction in particulate matter from point sources would be 54% and 98% respectively **(Table 6.3)**.

Table 6.3 : Emission Reduction Action Plan for Point Source

Point Sources	Short Term-2019	Long Term-2022	Action Plan
RED CATEGORY FO – 14.5 tpd LDO – 3.6 tpd Coal – 1154.8 tpd Wood – 111.2 tpd Diesel – 22.4 tpd Briquette -74.8 tpd Bagasse – 2831.3 tpd **ORANGE CATEGORY** HSD –29.5 tpd Coal –77.9 tpd Wood –15.5 tpd Diesel & Briquette – 9.4 tpd Bagasse - 34.4 tpd **GREEN CATEGORY** LDO -2.5 tpd HSD- 8.1 tpd Wood – 3.6 tpd Briquette – 48 tpd Diesel -35.3 tpd Consumption are major contributors towards PM and NOx emission loads from this category	Shift to cleaner fuels in both the category of industries– 50% of FO, LSHS, HSD to LDO, Coal & Others to NG	Shift to cleaner fuels – 100% All types of fuel to Natural gas	There are around 1000 Air Polluting industries in area/cluster. The emission load of PM is highest from burning of biomass, coal and wood as power source in different industrial process of Nashik region. The highest PM emission load was calculated from Bagasse (48.1%), followed by Coal (33.9%) and Wood (17.4%), whereas highest NOx emission load is from Coal (83.8%). While Indian coal has a low sulfur content in comparison with other coals, ash levels are reported to be quite high and can contribute to coarse PM emissions. A requisition should be made to Mahanagar Gas Co. for commissioning of pipeline for the supply across the region. The civic regulatory bodies should intervene to make sure it is facilitated at all levels of demography, management and organizational scale. Identification of low cost and advanced cleaner technology for air pollution control with policy intervention at specific zones. Feasibility of changing combustion technology to facilitate usage of gaseous fuels may be undertaken with financial incentives. All the bulk drug and pesticides manufacturing units are being proposed to improve efficiency of their VOC scrubbers. All the Hazardous Air Polluting Units should be directed to install Leak detection & repair system (LDAR) as safety as well control measure. Fuel consumption in DG set operation in industrial should be regulated with stringent surveillance and made to follow stack emission standards with installation of efficient air control equipment. The dependency on DG set on power cut should be replaced by conventional source of energy. Industries should adopt stringent stack emission norms beyond those prescribed by CPCB Industries with periodic audits like QA/QC of units from both the parties.

Table 6.3 (Contd..) : Emission Reduction Action Plan for Point Source

Point Sources	Short Term-2019	Long Term-2022	Action Plan
Red, Orange & Green fuel consumption from industries at Nashik City	Shift to cleaner fuels in both the category of industries– 50% of FO, LSHS, HSD to LDO, Coal & Others to NG	Shift to cleaner fuels – 100% All types of fuel to Natural gas	Inventorisation of prominent industries with technological gaps and detailed feasibility study is required as dispersion of pollution with modeling and formulate land can be used to devise regulatory policy. Energy Conservation Scheme should be encouraged in the industries that are not economically capable towards shifting to eco-friendly fuel use or advanced clean technology. The number of illegal MSI and SSI are left unaccountable. Their identification and consent to operation should be provided with proper regulations. Stringent regular monitoring should be initiated by the authority. Industries should be regulated to install air monitoring devices within their premises and same data should be regularly submitted to MPCB. Inter organizational stakeholder meetings and workshop should be held industry wise, so as to collaboratively devise measures that can be adopted within their operation and process. Fiscal measures can be shared on mutual understanding. NMC should make arrangements for provision of land to Industrial Authorities for the development of green zone in and around industrial region of Nashik MIDC areas
One tree will offset an average about 10 kg of CO_2 each year. According to this we will need 500 million additional trees in 2020 and 1200 million trees in 2051.			

6.4 Management

There are five AAQM locations covered under SAMP at SRO Office, KTHM College, MIDC Satpur, RTC Colony and NMC Nashik office. The Air Quality Index (AQI) of period January to February 2018 shows AQI is satisfactory (51-100) to moderate (101-200). The average concentration of SO_2, NOx and RSPM during this period was 7.04 $\mu g/m^3$, 22.47 $\mu g/m^3$ and 106.72 $\mu g/m^3$, respectively. The dominant parameter are Particulate matter & CO, attributed to growing vehicular traffic and construction projects as well as commercial and infrastructure development including road construction etc. A strategic approach towards Hierarchical and structured managerial system for efficient implementation should be initiated with information exchange to SPCB/CPCB (of monitoring devices).

There is a lack of collaborative policy initiative among the administrations and organization with regard to air quality improvement. These sources could be State Pollution Control Board, Regional Transport Office, Nashik Municipal Corporation, CIDCO, MIDC, Oil Companies, Anti-Adulteration Cell, and representative from ULB and NGOs, school and colleges. As and when, it is felt by the apex body that particular information desired is either site specific or city specific it can commission studies/ investigate on its own. Monitoring and regulatory agencies will provide all the information on monitoring to this body for data assimilation and dissemination. Regulatory framework, if needs can be communicated to the apex body for starting the initiative for policy formation.

Nashik stands at a crossroad in its history and development. With suitable urban interventions at this stage, it can avoid the pitfalls of cities of similar characteristics and can set high standards for other cities to follow. The city has the potential to become a global commercial and cultural centre that affords its citizens immense benefits in the form of jobs, opportunities, and improved quality of life. For this opportunity to become a reality, the city will have to develop adequate infrastructure and services to facilitate development and improve the quality of life of all its citizens, both rich and poor.

All reductions planned will only reduce emissions from manmade sources; however, natural background and dust would continue to remain in the atmosphere. The benefits computed in the process described above will not only yield PM and NOx related pollution reduction but also co-benefit of other pollutants (SOx, VOCs, HC, CO etc.) reductions as well. One of the other major co-benefits of these options (adoption of mass transport, use of cleaner fuel, efficient combustion etc) will provide large scale greenhouse gas reduction. Nashik as a big metro city will provide the impetus of overall mitigation of GHG.

Chapter 7

Reduction Strategies for Emission Control

Chapter 7

Reduction Strategies for Emission Control

Based on emission inventory results of all the sources viz. industrial, area and vehicular obtained under the present study, the subsequent sections will discuss the possible strategies for pollution reduction. The focus on reduction discussed will be mainly for PM and NOx as these pollutants are cause of concern. Other pollutants will also reduce with the adoption of strategies discussed here. Additional benefits should be taken as co benefits.

7.1 Area Source Control Options and Analysis

It is observed that the total particulate matter emissions from area sources, particularly due to building and construction activity is high, followed by emission from domestic consumption of fuels, which can be attributed to dependency on conventional solid and fossil fuel in slum population. The emission loads from the fuel consumption at crematorium and due to open burning cases are almost same. The area sources though called area sources, are limited to small regions and therefore, their impact does not seem to be wide ranging and across the city. Hence, the efforts should focus on finding out appropriate technology/management options, particularly on conversion to natural gas in much more cost effective way. Other sectors also need large scale adoption of cleaner practices. The control scenarios as part of management plans for expected pollution load reduction due to area sources are given in **Table 7.1.**

Table 7.1 : Area Source Emission Scenario with Control Options

Source	Present Emissions	PM Control Options	
		2012	2017
Bakeries	44.8	25% LPG /NG 25% Electric	50% LPG /NG 75% Electric
Crematoria	130.63	50% Electric	75% Electric
Open Eat outs	3.2	Since these operation is illegal, difficult to quantify. Measures related to fuel change should be incorporated. Reductions on 25-50% conversion of existing coal, wood, kerosene etc. based eateries are estimated.	
Hotel & Restaurants	27.9	50% of coal to replace by LPG	75% of coal to replace by LPG
Slums Domestic Non Slum Domestic.	193.4 689.2	50% of slums to use LPG/ PNG 50% of remaining non slums to use LPG/ PNG	100% of the remaining slum to use LPG/ PNG 100% of remaining non slums to use LPG/ PNG
Open & Landfill	186.9	50% open burning	100%
Bldg. Construction	3330.9	50% control on dust emission	75% control on dust emission

As part of management plans the anticipated sector-wise particulate matter emission loads reduction is presented in **Table 7.2**.

Table 7.2 : Anticipated Reduction in Particulate Matter : Area Sources

	Existing	**% Contri-bution**	**BAU 2020 (5.5% Growth)**	**BAU 2025 (7.0% Growth)**	**Expected Emissions (Short Term) 2020**	**Expected Emissions (Long Term), 2025**
Bakeries	44.9	0.97	47.3	50.6	36.4	20.6
Crematoria	130.63	2.84	137.9	145.4	70.1	37.6
Open Eat-outs	3.15	0.07	3.32	3.56	2.75	2.91
Hotel Restaurants	27.9	0.61	28.3	29.0	14.1	14.5
Domestic Sector -Slum	193.4	4.20	157.5	181.1	128.4	113.6
Domestic Sector -Non Slum	689.2	14.96	786.8	904.9	708.0	566.0
Open Burning	186.9	4.06	200.0	215.0	100.0	53.7
Construction Activity	3330.9	72.30	3664.0	4163.6	1832.0	2081.8
Total	**4606.98**		**5025.12**	**5693.16**	**2891.75**	**2890.71**
Reduction w.r.t BAU 2018					**37.23%**	**37.5%**

With the implementation of the short and long term scenarios, the overall total reduction in particulate matter from area sources would be around 37%, whereas at individual sources around 45-50% of reduction can be achieved in 2020 from crematoria, hotels & restaurants, open burning, and construction activities, whereas same percent will represent in 2025 for bakeries, hotels & restaurants and domestic sector –slums sectors. Major impact will be observed for crematoria and open burning almost 70%in 2025. The domestic slum emission will be more as LPG supply will boost up along with the population and numbers of replacement of cylinders and also consumption of wood and kerosene reduction, the growth of 3% will be observed in 2020, whereas using control option the reduction of 17% will notice in 2025.

7.2 Point Source Pollution Reduction Strategies

The strategies for abatement of emissions from point sources include cleaner fuel substitution, change in basic production processes, and pollution abatement through flue gas treatment modifications of exit gas characteristics besides shifting of industries outside the city premises. The point sources emission inventory prepared indicates that some Red LSI and Orange and Green MSI are the major sources. The strategies are recommended for the following two broad sectors i.e. all Red groups (LSI, MSI and SSI); another all Orange and Green (LSI, MSI and SSI); for short term 2 yrs. (upto 2020) and long term 5 yrs. (upto 2025).

Point Source Control Options and Analysis

Nashik had been growing very fast industrially, during the last few decades. It has seven industrial areas facilitating the industrial growth in the region, with a focus on engineering and automobiles. It was observed that the most common fuels used in the industries of this region are coal, wood and bagasse or briquettes. The Red LSI fuel consumption is around 1154.8 tpd of Coal, 111.2 tpd of Wood, 2831.3 tpd of Bagasse and 74.8 tpd of Briquette, whereas from Orange industries it was 77.9 tpd of Coal, 15.5 tpd of Wood and 34.4 tpd of Bagasse. The PM emission load of 12397.1 kg/d was observed from all Red category, whereas it was 641.7 kg/d from all Orange categories, the total PM percent coming around 36.7% from all industries. The emission of NOx percentage from all industries around 27.7% and all LSI (R,O,G) industries contribute 10191.3 kg/d, whereas MSI, SSI emits in the range of 250-270 kg/d of NOx. **Table 7.3** presents the fuel switch options for short and long term scenarios.

The control options were derived on the basis of emission inventory estimated for all categories of industries. The replacement with alternative fuel was suggested on the basis of respective calorific value of each fuel. The calorific value is energy contained in a fuel, determined by measuring the heat produced by the complete combustion of a specified quantity of it. The calorific value considered for the inter conversion of fuel for reduction strategies were: 45.00 MJ/kg (FO), 44.38 MJ/kg (LSHS), and 49.57 MJ/kg (HSD), 43.96 MJ/kg (LDO), 30.20 MJ/kg (Coal), 50.03 MJ/kg (Natural Gas), 16.0 MJ/kg (Wood) and 46.1 MJ/kg (LPG), respectively. After implementing short and long term control options, the reduction emission load is depicted in **Table 7.4 a to c** for PM and **Table 7.5 a to c** for NOx.

Table 7.3 : Point Source Strategies for Short and Long Term

Point Sources Category	Major PM Emission Contributor	Control Strategies	
		Short Term (2012)	**Long Term (2017)**
Red, Orange and Green Category (LSI/MSI/SSI)	Coal, Wood, Bagasse are the major source contributors towards PM emissions	• Shift to cleaner fuels i.e. LSHS, FO, Coal, Wood, Bagasse to Light Diesel Oil (LDO) and then to NG • Combustion technology up gradation for fuel change.	• Shift in cleaner fuels from LDO & coal to Natural Gas (NG). • Combustion technology improvement with fuel change. Feasibility of conversion of thermal power production to gas based system. • Industrial development (expansion) should be based on cleaner gaseous fuel with no net increase in emissions.

Table 7.4 : Point Source Emission Scenario Before & After Control Strategies: Short & Long Term Scenarios for PM

A. For Red (LSI/MSI/SSI) for PM

	Present PM Emissions			PM Emissions After Control Strategies					
				Short Term (2020)			**Long Term (2025)**		
	Fuel type	**Qty. (TPD)**	**Emission (Kg/day)**	**Fuel Type**	**Qty. (TPD)**	**Emission (Kg/day)**	**Fuel Type**	**Qty. (TPD)**	**Emission (Kg/day)**
1.	**FO**	14.46	7.01	**LDO (100%)**	14.8	0.215	**LDO**	688.44	10.01
2.	**LSHS**	7.25	0.362	**LDO (100%)**	7.33	0.106	**NG (m^3/d)**	1913.34	38.27
3.	**LDO**	3.59	0.052	**LDO**	3.59	0.052	**LPG**	3.86	0.06
4.	**HSD**	4.59	0.067	**LDO (100%)**	5.18	0.075			
5.	**NG (m^3/d)**	0.247	0.0049	**NG (m^3/d)**	0.247	0.0049			
6.	**Coal**	1154.76	4278.40	**NG (50%)**	956.54	19.13			
7.	**LPG**	2.66	0.038	**LPG**	3.46	0.0494			
8.	**Wood**	111.17	1923.28	**Wood (-50%)**	55.59	961.64			
9.	**Diesel**	22.38	10.85	**LDO (100%)**	22.91	0.333			
10.	**Bagasse**	2831.31	6512.02	**LDO (50%)**	317.05	4.61			
				Coal (50%)	577.38	2139.20			
				Bagasse (50%)	1415.66	3256.01			
Total (kg/d)			**12732.08**	**Total (kg/d)**		**6381.43**			**48.34**
				Reduction (%)		**49.87%**	**Reduction (%)**		**99.62%**

B. For Orange (LSI/MSI/SSI) for PM

	Present PM Emissions			PM Emissions After Control Strategies					
				Short Term (2020)			Long Term (2025)		
	Fuel Type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)
1.	**FO**	0.89	0.43	**LDO (100%)**	0.907	0.0132	**LDO**	56.77	0.83
2.	**LDO**	4.99	0.0726	**LDO**	4.99	0.0726	**NG (m3/d)**	128.97	2.06
3.	**HSD**	29.49	0.429	**LDO (100%)**	33.25	0.483	**LPG**	0.0085	0.00012
4.	**Coal**	77.85	288.44	**NG m3/d) (50%)**	64.48	1.03			
5.	**LPG**	0.0059	8.37E-05	**LPG**	0.0076	0.000109			
6.	**Wood**	15.52	268.47	**Wood (-50%)**	7.76	134.24			
7.	**Diesel**	9.45	4.58	**LDO (100%)**	9.67	0.1406			
8.	**Bagasse**	34.44	79.21	**LDO (50%)**	3.85	0.0561			
				Coal (50%)	38.92	144.22			
				Bagasse (50%)	17.22	39.61			
			Total (kg/d)			**Total (kg/d)**			
			641.64		**Total (kg/d)**	**319.86**	**Total (kg/d)**		**2.89**
					Reduction (%)	**50.14%**	**Reduction (%)**		**99.54%**

C. For Green (LSI/MSI/SSI) for PM

	Present PM Emissions			PM Emissions After Control Strategies					
				Short Term (2020)			Long Term (2025)		
	Fuel Type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)
1.	**FO**	0.677	0.3282	**LDO (100%)**	0.692	0.0101	**LDO**	49.34	0.72
2.	**LDO**	2.52	0.0366	**LDO**	2.52	0.0366	**NG (m^3/d)**	0.0397	0.000636
3.	**HSD**	8.12	0.118	**LDO (100%)**	9.16	0.1332	**LPG**	2.58	0.037
4.	**Coal**	0.024	0.0889	**NG (50%)**	0.0198	0.00032			
5.	**LPG**	1.78	0.0253	**LPG**	2.31	0.033			
6.	**Wood**	3.6	62.28	**Wood (50%)**	1.8	31.14			
7.	**Diesel**	35.28	17.11	**LDO (100%)**	36.12	0.5249			
				Coal (50%)	0.012	0. 044			
		Total (kg/d)	**79.98**		**Total (kg/d)**	**31.93**	**Total (kg/d)**		**0.75**
					Reduction (%)	**60.09**	**Reduction (%)**		**99.06%**

D. Total Industrial Emissions in Mumbai Before & After Control Strategies

	Sector	Present PM Emissions (kg/d)	Emissions After Control Strategies (kg/d)	
			Short Term	Long Term
A.	**Red**	12732.08	6381.43	48.34
B.	**Orange**	641.64	319.86	2.89
C.	**Green**	79.98	31.93	0.75
	Total (kg/d)	**2622.79**	**1189.55**	**40.64**
		% Reduction	**54.64%**	**98.45%**

Shift in cleaner fuel based on equivalent heat input estimation.

Table 7.5 : Point Source Emission Scenario Before & After Control Strategies: Short & Long Term Scenarios for NOx

A. For Red (LSI/MSI/SSI) for NOx

	Present NOx Emissions			NOx Emissions After Control Strategies					
				Short Term (2020)			Long Term (2025)		
	Fuel type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)
1.	**FO**	14.46	114.99	**LDO (100%)**	14.8	47.33	**LDO**	688.44	2201.41
2.	**LSHS**	7.26	57.71	**LDO (100%)**	7.32	23.43	**NG (m^3/d)**	1913.34	6696.70
3.	**LDO**	3.59	11.49	**LDO**	3.59	11.49	**LPG**	3.86	19.30
4.	**HSD**	4.59	14.68	**LDO (100%)**	5.18	16.55			
5.	**NG (m^3/d)**	0.247	0.86	**NG (m^3/d)**	0.247	0.86			
6.	**Coal**	1154.76	8660.73	**NG (50%)**	956.54	3347.92			
7.	**LPG**	2.66	13.31	**LPG**	3.46	17.30			
8.	**Wood**	111.17	144.52	**Wood (-50%)**	55.59	72.26			
9.	**Diesel**	22.38	177.98	**LDO (100%)**	22.9	73.25			
10.	**Bagasse**	2831.31	389.31	**LDO (50%)**	317.05	1013.82			
				Coal (50%)	577.38	4330.37			
				Bagasse (50%)	1415.65	194.65			
Total (kg/d)			**9585.58**	**Total (kg/d)**		**9149.22**			**8917.40**
				Reduction (%)		**4.55%**	**Reduction (%)**		**6.97%**

B. For Orange (LSI/MSI/SSI) for NOx

	Present NOx Emissions			NOx Emissions After Control Strategies					
				Short Term (2020)			Long Term (2025)		
	Fuel Type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)
1.	FO	0.89	7.052	LDO (100%)	0.908	2.90	LDO	56.77	181.53
2.	LDO	4.99	15.97	LDO	4.99	15.97	NG(m^3/d) (100%)	128.97	361.13
3.	HSD	29.49	94.30	LDO (100%)	33.25	106.34	LPG	0.0085	0.042
4.	Coal	77.85	583.88	NG (m^3/d) (50%)	64.49	180.57			
5.	LPG	0.0059	0.029	LPG	0.0076	0.038			
6.	Wood	15.52	20.17	Wood (-50%)	7.76	10.09			
7.	Diesel	9.45	75.14	LDO (100%)	9.67	30.92			
8.	Bagasse	34.44	4.73	LDO (50%)	3.86	12.33			
				Coal (50%)	38.92	291.94			
				Bagasse (50%)	17.22	2.37			
Total (kg/d)			801.29	Total (kg/d)		653.47	Total (kg/d)		542.71
				Reduction (%)		18.44%	Reduction (%)		32.27%

C. For Green (LSI/MSI/SSI) for NOx

	Present NOx Emissions			NOx Emissions After Control Strategies					
				Short Term (2020)			Long Term (2025)		
	Fuel Type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)	Fuel Type	Qty. (TPD)	Emission (Kg/day)
1.	FO	0.68	5.38	LDO (100%)	0.69	2.22	LDO	49.34	157.78
2.	LDO	2.52	8.06	LDO	2.52	8.06	NG (m^3/d)	0.0398	0.11
3.	HSD	8.12	25.98	LDO (100%)	9.16	29.29	LPG	2.58	12.88
4.	Coal	0.024	0.18	NG (50%)	0.0199	0.0557			
5.	LPG	1.78	8.88	LPG	2.31	11.54			
6.	Wood	3.60	4.68	Wood (50%)	1.8	2.34			
7.	Diesel	35.28	280.6	LDO (100%)	36.12	115.49			
				Coal (50%)	0.012	0.09			
Total (kg/d)			333.78	Total (kg/d)		169.08	Total (kg/d)		170.77
				Reduction (%)		49.33%	Reduction (%)		48.83%

D. Total Industrial Emissions in Mumbai Before & After Control Strategies

	Sector	Present NOx Emissions (kg/d)	Emissions After Control Strategies (kg/d)	
			Short Term	Long Term
A.	**Red**	9585.58	9149.22	8917.40
B.	**Orange**	801.29	653.47	542.71
C.	**Green**	333.78	169.08	170.77
	Total (kg/d)	**10720.65**	**9971.77**	**9630.88**
		% Reduction	**6.99%**	**10.17%**

Shift in cleaner fuel based on equivalent heat input estimation.

The above short and long term strategies for different sectors, if implemented effectively would reduce the PM emissions from 12732.08 kg/d to 6381.43 kg/d (i.e. about 50%) and 48.34 kg/d (i.e 99.6%), respectively for RED category industries, Similar trend was observed for Orange and Green categories of industries for PM. The overall short term reduction from all categories is around 54.6% and for long term it will be 98.4%. The emphases were made for the conversion of conventional fossil, solid and liquid fuel to natural gas or LDO.

As per current scenario the total emission of NOx is around 9585.58 kg/d from Red industries, if action plan implemented in time bound period, reduction for NOx is around 50% (9149.22 kg/d) in short term and 99% (8917.40 kg/d) in long term can be achieved for Red categories of industries. Similar trend was observed for Orange and Green categories of industries for NOx. The overall short and long term reduction is not observed substantially for NOx, it is reported 6.9% in short term and 10.1% in long term respectively. Conversion of heavy sulphur fuel to natural gas, will probably increase the overall NOx emission.

7.3 Vehicular Sources Reduction Strategies

Vehicles are the primary source of precursor emissions for $PM_{2.5}$ pollutants in the atmosphere of high traffic congestion zones. Considering, the rapid decadal growth of vehicles there is need to assess the emission load from line source, for which a strategic reduction measures should be devised to control the emission load from this category. One of the major contributors to Particulate Matter (PM) and NOx emissions in Nashik region is vehicular exhaust. As per RTO data, 2017 the registered vehicles of 2 wheelers is around 10.9 lakhs, whereas cars are around 1.87 lakhs, 3 wheelers of about 0.22 lakhs and heavy duty vehicles (trucks, buses, tempos, etc.) reported as 1.65 lakhs. The two-wheelers still enjoying the lion's share. The total PM and NOx emission load from this vehicles is measured to be 3.71 and 27.5 tons /day, among the polluted vehicles HDDV is the major source. The most prominent sources of vehicle particulate emissions are diesel driven and two-stroke petrol driven vehicles.

Based on the results of emission inventory, specific strategies need to be ranked out of wide variety of reduction options available. Reduction strategies option selection was based on much iteration with a view to achieve significant change in load, take into consideration the current ambient air quality standards; exhaust emission standards, emission inventory, vehicular population composition, infrastructure availability and the techno-economic feasibility in Nashik Region. The Mumbai-Pune-Nashik area will soon be developed as the Golden Triangle industrial belt of the state and occupy a prominent place on the world map of industries. With this infrastructural and organizational development, there will be tremendous increase in number of vehicles registration and related activities.

The discussion has been presented in following order:

- Improvement in vehicle related components/technologies
- Improvement in fuel quality and alternate fuels
- After-exhaust treatment techniques and retro fitment
- Transport planning and traffic management
- Inspection & Maintenance programme
- Other options including phasing out old vehicles, revision of emission standards, anti-smoke campaign, upgraded PUC

As there are considerable differences in emission control options required for diesel and petrol driven vehicles, for new and in-use vehicles; it will be appropriate to address them separately. This approach will also help in planning and implementing the specific control options and also assessing their contributions towards emission reduction.

Factors Effecting Vehicle Emissions

1. Vehicle/Fuel Characteristics

- Engine type and technology-two stroke, four stroke; diesel, otto, wankel, other engines; fuel injection, turbo charging, and other engine design features; type of transmission system
- Exhaust, crankcase, and evaporative emission control systems in place-catalytic converters, exhaust gas recirculation, air injection, stage II and other vapor recovery systems
- Engine mechanical condition and adequacy of maintenance
- Air conditioning, trailer towing, and other vehicle appurtenances
- Fuel properties and quality-contamination, deposits, sulfur, distillation characteristics, composition (e.g., aromatics, olefin content) additives, oxygen content, gasoline octane, diesel cetane
- Alternative fuels such as CNG, LPG, Bio Diesel
- Deterioration characteristics of emission control equipment
- Deployment and effectiveness of inspection/maintenance (I/M) and anti-tampering (ATP) program

2. Fleet Characteristics

- Vehicle mix (number and type of vehicles in use)
- Vehicle utilization (kilometers per vehicle per year) by vehicle type
- Age profile of the vehicle fleet
- Traffic mix and choice of mode for passenger/goods movements
- Emission standards in effect and incentives/disincentives for purchase of cleaner vehicles
- Adequacy and coverage of fleet inspection maintenance programs

3. Operating Characteristics

- Vehicle use patterns-number and length of trips, number of cold starts, speed, loading, aggressiveness of driving behaviour
- Degree of traffic congestion, capacity and quality of road infrastructure, and traffic control systems
- Transport demand management programs

Source: Faiz and others 1995; Faiz and Aloisi de Larderal 1993

As per recent emission standards for BS IV and BS VI norms across all category of vehicles, and its implementation will yield the maximum reduction of PM and NO_x emission **(Table 7.6)**. The stipulated CO emission for diesel vehicles is 0.50 g/km and for petrol it is 1.0 g/km, whereas NO_x is regulated at 0.08 g/km for diesel and 0.06 g/km for petrol, while particulate matter (PM) is set at 0.005 g/km for both in BS VI. We should see a substantial drop in air pollutants, especially for diesel car vehicles, as current BS IV figures are 0.25 g/km for NO_x and 0.025 g/km for PM. Similarly HDDV reduction will possible from 3.5 g/km to 0.4 g/km in BS VI for NOx and 0.02 to 0.01 g/km for PM.

Table 7.6 : Emission Factors for BS IV and BS VI

Emission Factor for BS IV fuel	PM	NO_x	CO	HC
Car Petrol Car	0.002	0.08	1	0.1
Car Diesel Car	0.025	0.25	0.5	0.3
CNG Car/Taxi (LMV)	0.006	0.08	1	0.1
Two wheeler	0.013	0.79	1.403	0.39
Three wheeler	0.0425	0.38	0.38	2.06
Heavy Duty Diesel Vehicles	0.02	3.5	1.5	0.46

Emission Factor for BS VI fuel	PM	NO_x	CO	HC
Car Petrol Car	0.005	0.06	1	0.1
Car Diesel Car	0.005	0.08	0.5	0.17
CNG Car/Taxi (LMV)	0.005	0.06	1	0.1
Two wheeler	0.0045	0.06	1	0.1
Three wheeler	0.025	0.1	0.22	0.1
CNG Buses	0.01	0.46	4	0.16
Heavy Duty Diesel Vehicles	0.01	0.4	1.5	0.13

* Values in g/km Source: *https://www.transportpolicy.net/region/asia/india/*

TransportPolicy.net is collaboration between the International Council on Clean Transportation and DieselNet. On 19 Feb 2016, the Ministry of Road Transport and Highways (MoRTH) issued a draft notification of Bharat Stage (BS) VI emission standards. The standards, as proposed, will take effect throughout the country for all light-duty and heavy-duty vehicles as well as two and three wheelers manufactured on or after 1 Apr 2020. The draft proposal specifies mass emission standards, type approval requirements, and on-board diagnostic (OBD) system and durability levels for each vehicle category.

Additional provisions in the draft proposal include:

- Adoption of more stringent WHSC and WHTC test cycles
- Off-cycle emissions testing requirements and in-service conformity testing for type approval
- Specifications for Portable Emissions Measurement System (PEMS) demonstration testing at type approval. The proposed BS VI regulation establishes an important precedent for leap frogging from Euro IV-equivalent directly to Euro VI-equivalent motor vehicle emissions standards.

The World Harmonized Transient Cycle (WHTC) test is a transient engine dynamometer schedule defined by the proposed global technical regulation (GTR) developed by the UN ECE GRPE group. The GTR is covering a world-wide harmonized heavy-duty certification (WHDC) procedure for engine exhaust emissions. The proposed regulation is based on the world-wide pattern of real heavy commercial vehicle use.

a. test is performed on an engine dynamometer operated through a sequence of 13 speed and load conditions
b. a hot start steady state test cycle
c. transient test cycle with both cold and hot start requirements

Prior to 2010, emissions were tested using the ECE R49[a] test cycle. After 2010, for Bharat III and IV, the ESC (European Stationary Cycle) and ETC (European Transient Cycle) test cycles were used. BS VI will require the application of WHSC[b] (World Harmonized Stationary Cycle) and WHTC[c] (World Harmonized Transient Cycle) test cycles.

The option selection was based on much iteration with a view to achieve significant change in load and consequent reduced emission contribution. For calculation of BaU scenario for vehicle projections the average decadal registered vehicle growth was considered as 5.5% in 2020 and 6.2%

in 2025. The estimation of emission loads for new emission standards i.e. BS- IV and BS- VI was also calculated for comparison with BaU scenario. **Table 7.7** presents options which are likely to achieve desired results based on earlier discuss action plan **(Table 6.3)** for line source as also those which are relevant to Nashik city.

Table 7.7 : Vehicular Source Control Options

Scenario	PM		NOx	
BAU 2018	**3709.04**		**27497.82**	
BAU 2020 (5.5% growth)	**3951.2**		**29293.4**	
BAU 2025 (6.2% growth)	**4252.7**		**31528.5**	
Complete implementation of BS – IV norms by 2020	**157.6 (96.0%)**		**13208.6 (54.9%)**	
Complete Implementation of BS – VI norms by 2025	**82.1 (98.1%)**		**1599.4 (94.9%)**	
	PM	**NOx**	**PM**	**NOx**
<u>Conversion vehicles to CNG/LPG</u> ▪ 2020- Privately operated Vehicles viz. OLA, Uber and other contract buses, public transport should be converted -50% ▪ 2025-Privately operated Vehicles viz. OLA, Uber and other contract buses, public transport should be converted -75%	**2445.5 (38.1%)**	**17967.2 (38.7%)**	**1821.8 (57.2%)**	**13234.4 (58.0%)**
<u>Banning of 15 year Old Commercial Vehicle</u> ▪ 2020-70% banning ▪ 2025-100% banning Encouragement by provision of incentives in form of scrap value.	**2103.7 (46.8%)**	**15903.4 (45.7%)**	**1389.5 (67.3%)**	**10109.5 (67.9%)**
<u>Synchronization of traffic signals</u> ▪ 2020-Major & minor roads, excluding feeder roads (or about 65% of the all arterial roads) ▪ 2025-Major & minor roads, excluding feeder roads (or about 80% of the all arterial roads)	**1958.0 (50.4%)**	**14412.7 (50.8%)**	**1368.8 (67.8%)**	**9991.0 (68.3%)**
<u>Share of Electric vehicles in Total City Fleet</u> ▪ 2020-Two wheeler: 10%; 3 wheeler and Taxi: 10% and Public transport buses -10% ▪ 2025-Two wheeler: 10%; 3 wheeler and Taxi: 10% and Public transport buses -20%	**2429.3 (38.5%)**	**17941.2 (38.8%)**	**1805.5 (57.5%)**	**13241.1 (58.0%)**
<u>Encourage Public Transport</u> ▪ 2020-Increase Public Transport -50% ▪ 2025-Increase Public Transport -75%	**1687.8 (57.3%)**	**12394.2 (57.7%)**	**1932.5 (54.6%)**	**14076.4 (55.4%)**
<u>Retrofitment of Diesel Oxidation Catalyst (DOC) 4wheeler public transport (BSII)</u> ▪ 2020-50% conversion ▪ 2025-100% conversion	**2482.6 (37.2%)**	**18228.1 (37.8%)**	**1709.9 (59.8%)**	**12405.2 (60.7%)**

* Emission load in kg/day

Table 7.7 (Contd..) : Vehicular Source Control Options

Scenario	PM		NOx	
BAU 2018	**3709.04**		**27497.82**	
BAU 2020 (5.5% growth)	**3951.2**		**29293.4**	
BAU 2025 (6.2% growth)	**4252.7**		**31528.5**	
Complete implementation of BS – IV norms by 2020	**157.6 (95.8%)**		**13208.6 (52.0%)**	
Complete Implementation of BS – VI norms by 2025	**82.1 (97.8%)**		**1599.4 (94.2%)**	
Retrofitment of Diesel particulate filter in 4 Wheelers Public Transport (BS II) ▪ 2020 -50% conversion ▪ 2025-100% conversion	**1319.8 (66.6%)**	**9557.6 (67.4%)**	**1420.5 (66.6%)**	**10286.9 (67.4%)**
Reduce Dust Resuspension (Unpaved Dust as on 2018- **12125.9** kg/day) ▪ 2020-Paving of all road 45% wrt BaU 2018 ▪ 2025-Paving of all road 90% wrt BaU 2020	**6280.5 (48.2%)**		**4305.8 (64.5%)**	
Banning Odd/Even Vehicles on Particular Day	**1920.3 (51.4%)**	**13738.6 (53.1%)**	**2007.3 (52.8%)**	**15480.5 (50.9%)**

* Emission load in kg/day

As it was observed from the vehicular survey, that the percentage of two wheelers in terms of number as well as movement within the city is highest (over 33%) among the other categories, followed by HDDV (27%) and petrol cars (25%). Out of the total PM emission load of 3.71 tons/day, the highest contribution is from HDDV vehicles (95.41%) i.e, 3.52 tons/day. Followed by HDDV, 2 and there wheelers emission contribution is more. The emission load of PM is attributed to movement of Heavy Duty Diesel (HDD) Vehicle within the region. Considering the vehicular and industrial activities in the region, almost 64% of PM load is attributed from North and South region of the city. As it can be observed, the complete implementation of BS VI and BS VI norms across all category of vehicles yield the maximum reduction of PM and NOx emission. For BS VI, the stipulated CO emissions for diesel vehicles is 0.50 g/km and for petrol is 1.0 g/km, NOx is regulated at 0.080 g/km for diesel and 0.060 g/km for petrol, while particulate matter (PM) is set at 0.005 g/km for both. We should see a substantial drop in air pollutants, especially for diesel vehicles, as current BS IV figures are 0.25 g/km NOx for and 0.025 g/km PM. The reduction of 96% (i.e. 157.6 kg/d) from 3951.2 kg/day after implementation of BS-IV, similarly 98% (i.e. 82.1 kg/d) from 1599.4 kg/day after implementation of BS-VI.

About 50-60% of PM and NOx reduction can be achieved on short term basis with respect to public transport, retrofitment of diesel particulate filter, banning of odd/even vehicles and synchronization of traffic with strategic and technology based management options. Whereas in long term, almost all options are giving reduction of about 50-60%. The CNG conversion can achieve the result of 38-58% of reduction in both emissions scenario. The paving of road will probably reduce the road dust emission by 48% in 2020 and 64% in 2025. If want substantially results collective efforts need to be implemented, and emphasis should be given to ease of access to public, techno feasible infrastructure.

Chapter 8

Prioritization of Management/ Control Options

Chapter 8

Prioritization of Management/Control Options

Management options for each sectors need to be prioritized with a view to understand the issue of implementation. Implementations are highly influenced not only by the idea of the improvement alone but also by the nature of the recommendations, fiscal and administrative barriers, effectiveness, implementing agencies and acceptance from large group of stakeholders. Prioritization issues are also driven by the comparative account of short term and long term implementation dilemma. Low cost with high effectiveness, low cost with shorter implementation period shall be a better option when compared with high effectiveness with high costs or long implementation period. Some of these considerations have been used here to prioritize the options in each case of vehicular, industrial and area sources.

8.1 City wise Dispersion Modeling for Selected Options for Future Scenario

A very comprehensive set of options have been examined for the purpose of understanding the issue of urban air pollution reduction and are given in **Table 8.1.** The dispersion run was carried out for many scenarios and based on options, where the effectiveness of PM and NOx reductions were significant, those were selected and included for the model run. For the successful implementation of the control measures, it is very important to categories them according to need of mitigation required. In order to achieve maximum reduction in emission loads, it is essential to prioritize selected control option, taking into account their respective sources and demography of the region. Out of the all devised control measures, few were selected according to the sources, their fuel consumption and feasibility. The implementation of these control measures were considered to be applied in stages, cumulatively across all the identified sources of the region. 2020 is considered short term measures, where for industrial and area sources the listed control measures were implemented and that for vehicles, 1 to 6 were selected **(Priority I)**. The selected control measures for point and area sources for short term 2020 are further aggressively implemented during the long term stage 2025 **(Priority II)**, so as to cover the aspects which weren't possible in short term stage. Considering their tremendous number growth, for vehicles sources, option 1 to 11 were applied with point and line source measures. The control options were compared with the Business as Usual Scenario considering the growth of vehicles and activities within the area sources, no changes will be assumed for industrial growth in Nashik city. The annual predicted concentrations for different sources in BaU and control option scenario are presented in **Table 8.2** and **Table 8.3** for PM and NOx.

Table 8.1 : Summary of Options used for City Based Model Run

Category		Control Options	Scenario 2020	Scenario 2025
Vehicle Sources	1	New Vehicle Standards	Complete implementation of BS - IV	Complete Implementation of BS - VI
	2	CNG/ LPG	Privately operated Vehicles viz. OLA, Uber, contract buses, public transport converted -50%	Privately operated Vehicles viz. OLA, Uber, contract buses, public transport converted-75%
	3	Electric vehicles	Two wheeler: 10%; 3 wheeler and Taxi: 10% and Public transport buses -10%	Two wheeler: 10%; 3 wheeler and Taxi: 10% and Public transport buses -20%
	4	Synchronization of traffic	Major & minor roads, excluding feeder roads (or about 65% of the all arterial roads)	Major & minor roads, excluding feeder roads (or about 80% of the all arterial roads)
	5	Public Transport	Increase Public Transport-50%	Increase Public Transport -75%
	6	Ban or scrapping -15 year old Veh.	70% banning	100% banning
	7	Ban of odd / even vehicles	50% reduction private vehicles	50% reduction private vehicles
	8	Retrofitment of DOC- 4 wheeler Public Transport	50% conversion (BSII)	100% conversion
	9	Retrofitment of DPF-4 wheelers public transport	50% conversion (BSII)	100% conversion
	10	Share of Hybrid vehicles in Total City Fleet	Gasoline powered four-wheelers only -20%	Gasoline powered four-wheelers only- 30%
	11	Inspection and Maintenance	New I&M regulations (50% population)	Full compliance -100%
Industrial Sources		Shifting of Fuel	Red, Orange & Green Industries (LSI, MSI & SSI) 50% fuel FO, LSHS, HSD to LDO; Coal & Others to NG	100% [Low Fuel i.e LDO to Nearly all to NG]
Area Sources		Domestic	25% of slums to use LPG/ PNG 50% of non slum to use LPG/PNG	50% of slum to use LPG 100% same
		Hotel & Rest.	50% of coal use to LPG	75% of coal use to LPG
		Open Eat outs	Since these operation is illegal, difficult to quantify	
		Bakeries	25% LPG, 25% Electric	50% LPG, 25% Electric
		Crematoria	50% Electric	75% Electric
		Open Burning	50% control on open burning	100% control on open burning
		Landfill Burning	100% control of Landfill burning	100% control of Landfill burning
		Bldg. Constr.	50% control on dust emission	50% control on dust emission
		Unpaved Rd.Dust	Paving of all road 75%	Paving of all road 100%

Though some of the options were selected on the basis of PM reduction potential, their possible co-benefits in reducing NOx and other pollutants were also considered during the process of prioritizing. The options considered are based on the discussion presented earlier in action plan, describing the city specific situation and its possible impacts on air quality. Model runs for the whole city included the major control options from all the three sources (Area, Line and Point). The model run's iso-contours maps for PM and NOx in BaU 2020, BaU 2022 and after implementation of Preferred Option I (i.e. options 1 to 6 for vehicles, and all options for industries and area) scenario's in 2020 and Preferred Option II (i.e. options 1 to 11 for vehicles and all options for industries and area) 2025 are given in **Figures 8.1 through 8.8.**

Table 8.2 : Comparison of PM_{10} Concentrations BaU With Preferred Option I (2020) & Preferred Option II (2025)

Sources Group	BaU 2018	BaU 2020	BaU 2025	Preferred Option I -2020	Preferred Option II -2025
All Group	117.65	125.24	128.07	60.61	30.10
Area Source	9.76	10.30	11.02	5.24	2.59
Line Source	12.11	12.90	14.03	6.64	3.30
Point Source (LSI)	17.68	17.68	17.68	9.00	4.15
Point Source (MSI)	0.49	0.50	0.50	0.25	0.12
Point Source (SSI)	1.12	1.12	1.12	0.57	0.26
Resuspension Dust	102.92	109.64	112.18	53.05	26.36

- Concentrations in $\mu g/m^3$

Table 8.3 : Comparison of NOx Concentrations BaU With Preferred Option I (2020) & Preferred Option II (2025)

Sources Group	BaU 2018	BaU 2020#	BaU 2025	Preferred Option I -2020	Preferred Option I -2025
All Group	92.90	98.89	107.21	55.19	43.21
Area Source	0.88	0.93	1.00	0.52	0.40
Line Source	89.49	95.33	103.60	53.23	41.75
Point Source (LSI)	6.26	6.26	6.26	3.46	2.52
Point Source (MSI)	0.55	0.55	0.55	0.30	0.22
Point Source (SSI)	0.68	0.68	0.68	0.38	0.27

- Concentrations in $\mu g/m^3$

The annual predicted 24 hourly average concentrations were compared with the BaU scenarios considering the future growth and after implementation of preferred option for 2020 and 2025 for both PM and NOx is presented in **Figure 8.9 and 8.10** respectively.

A) Predicted Scenario for PM

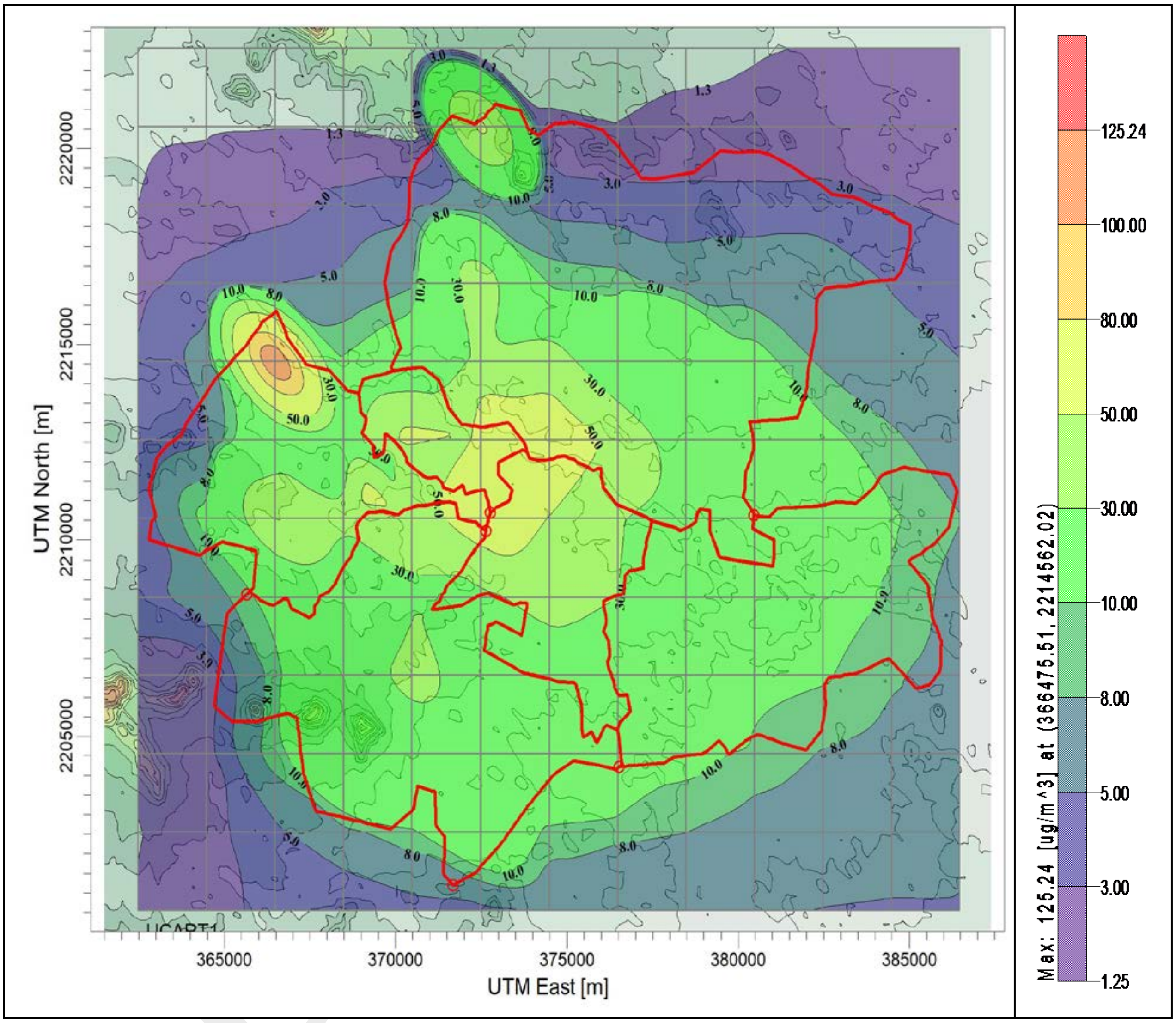

Figure 8.1 : Isopleths of PM Due to All Source– BaU 2020 (Nashik City)

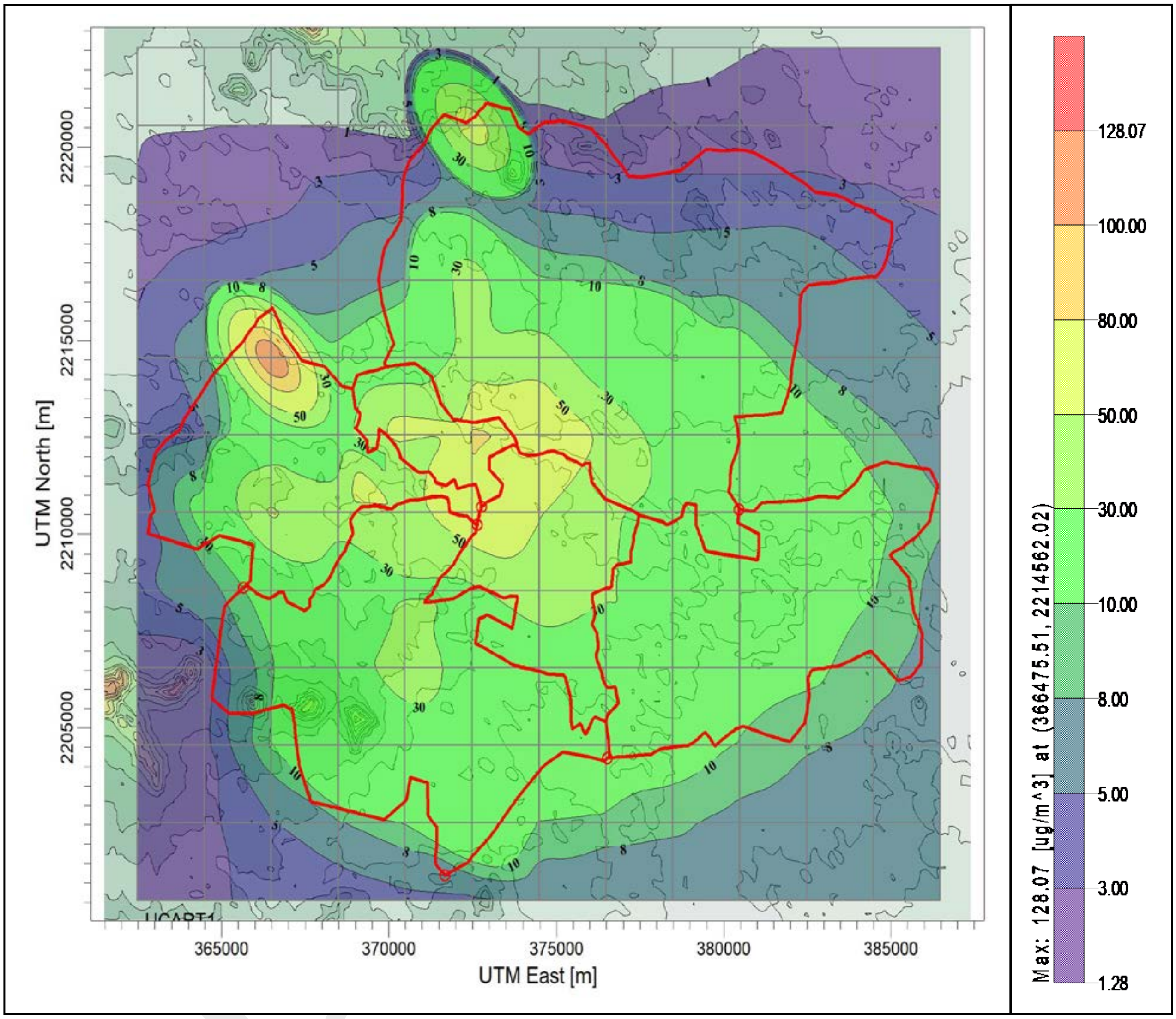

Figure 8.2 : Isopleths of PM Due to All Source– BaU 2025 (Nashik City)

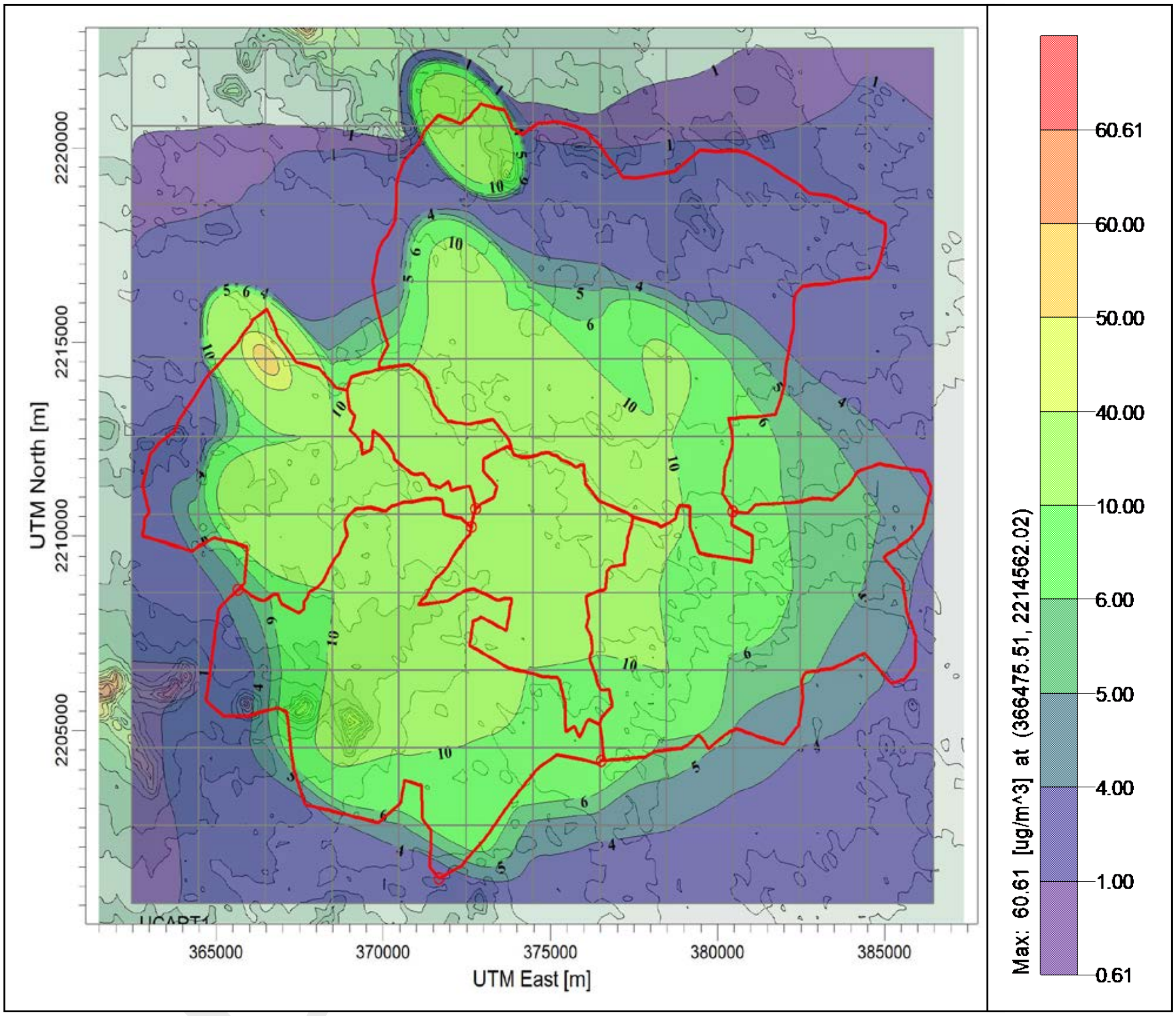

Figure 8.3 : Isopleths of PM Due to All Source– Preferred Options I - 2020 (Nashik City)

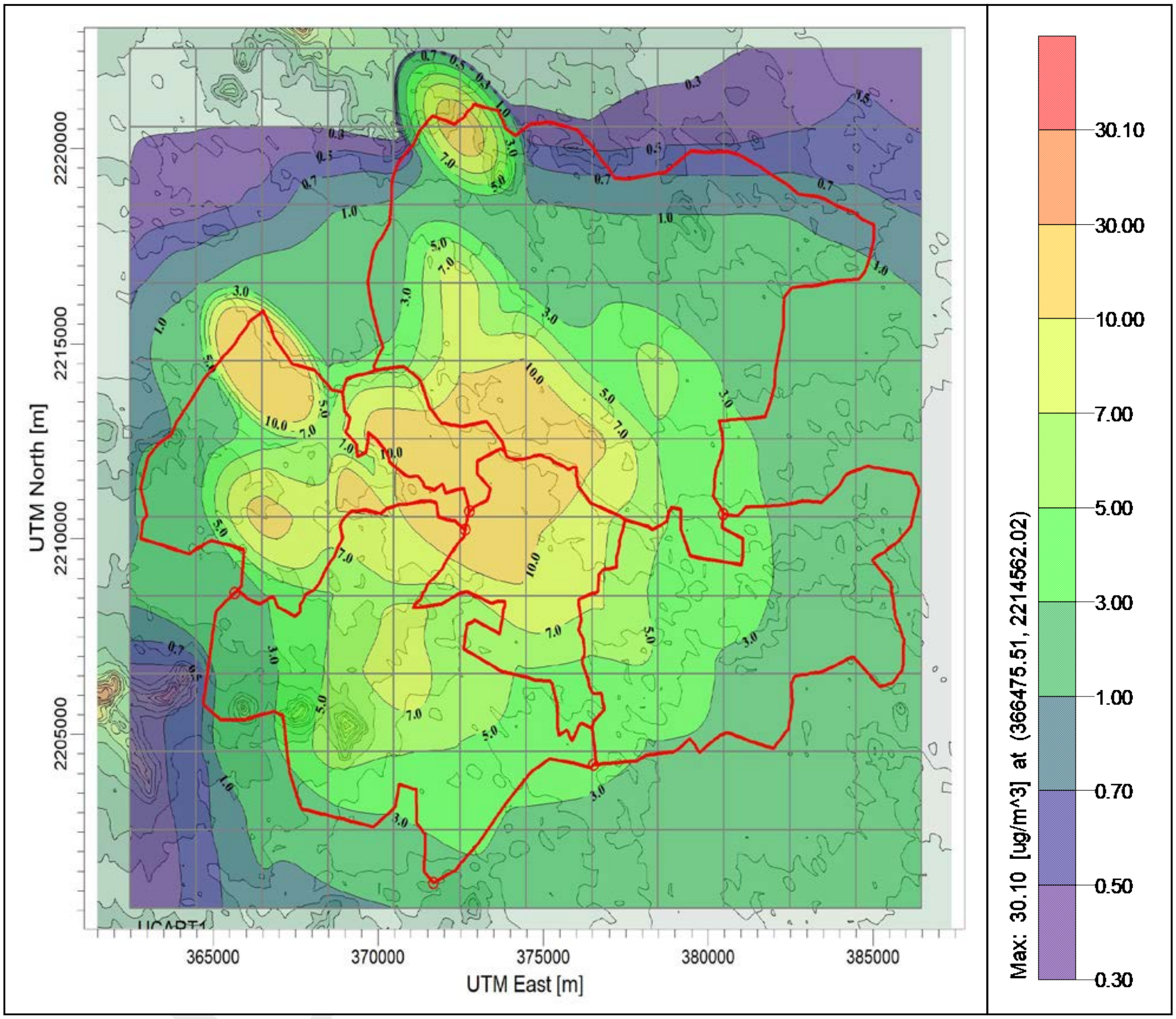

Figure 8.4 : Isopleths of PM Due to All Source– Preferred Options II - 2025 (Nashik City)

A) Predicted Scenario for NOx

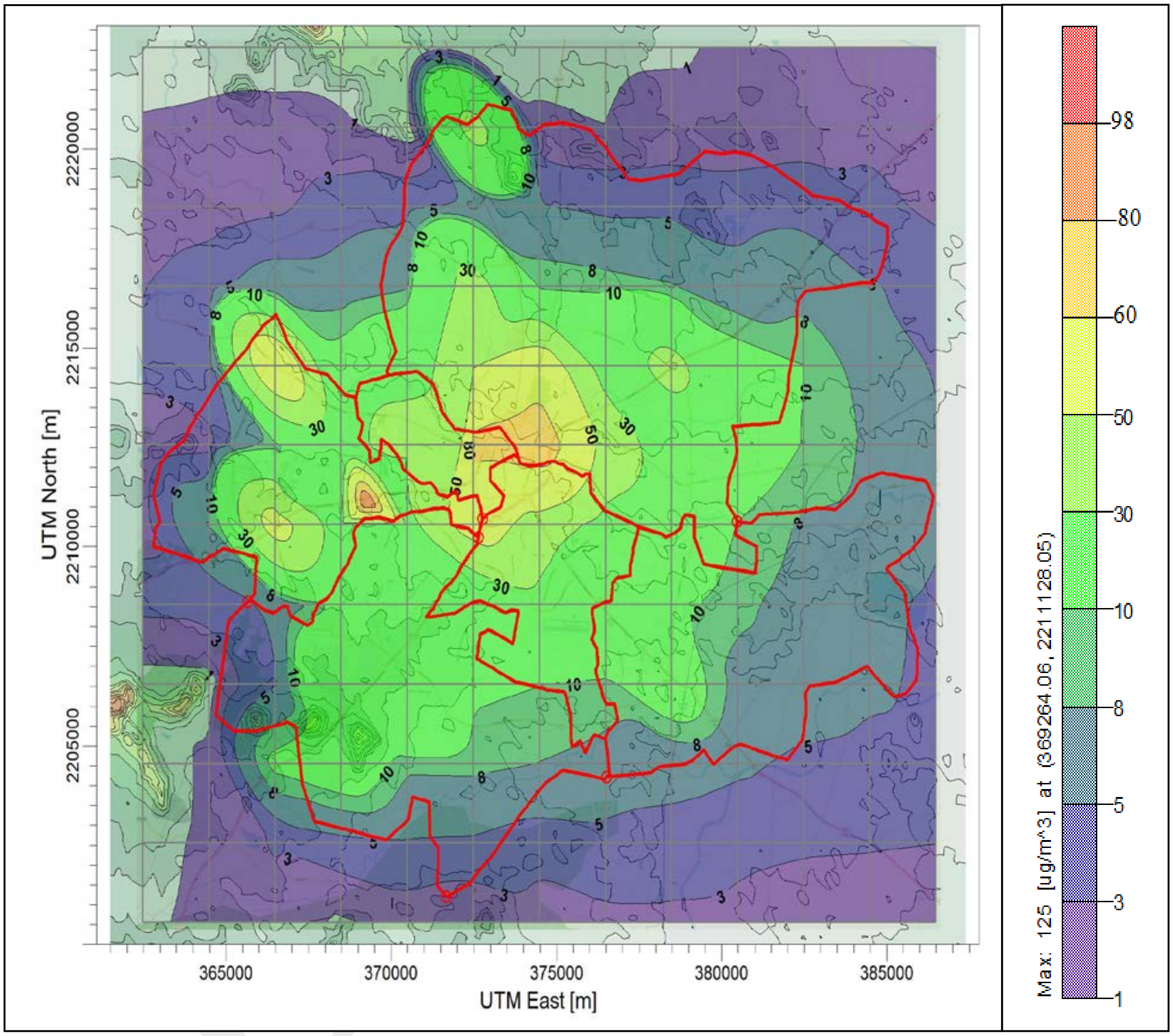

Figure 8.5 : Isopleths of NOx Due to All Source– BaU 2020 (Nashik City)

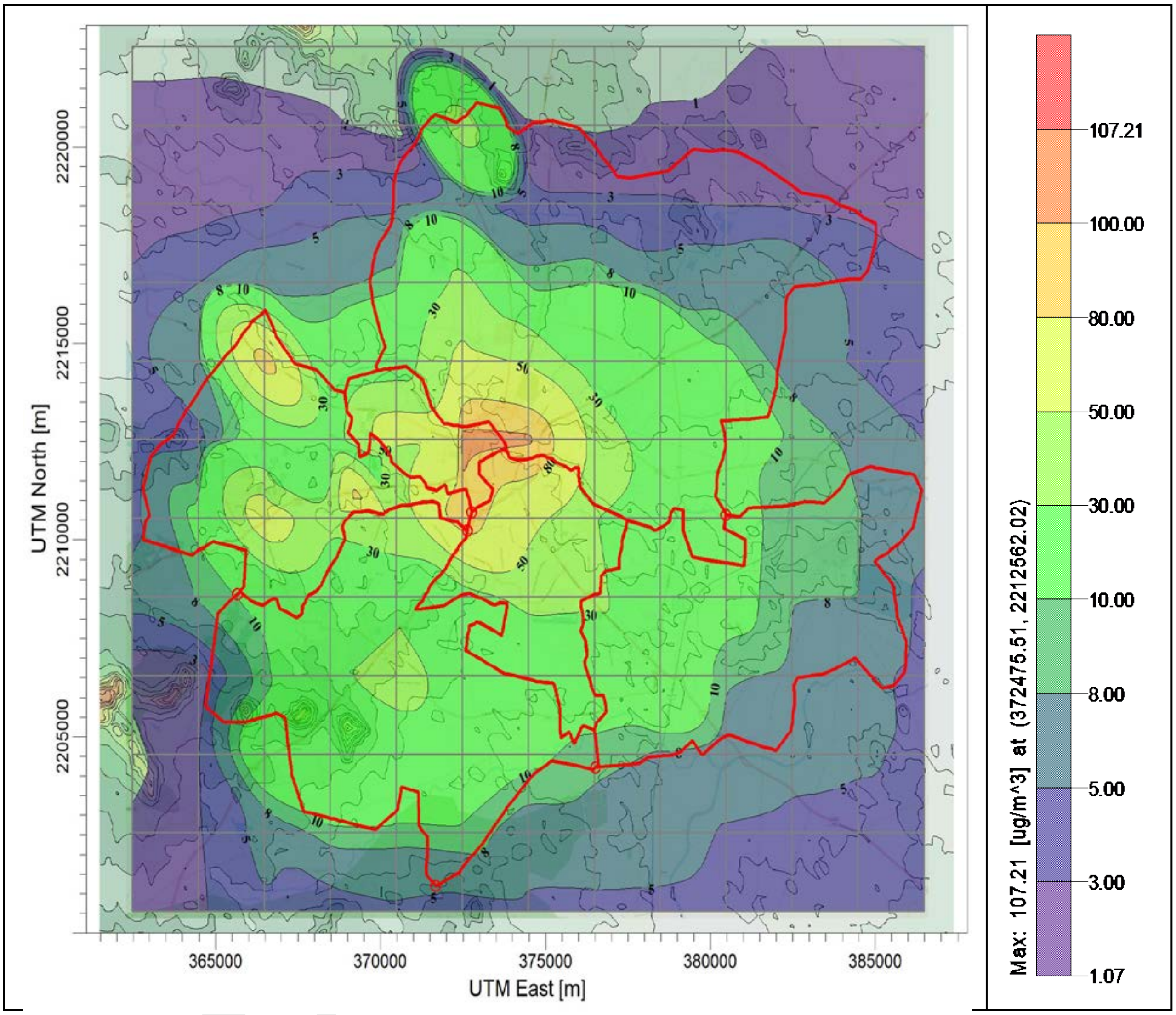

Figure 8.6 : Isopleths of NOx Due to All Source– BaU 2025 (Nashik City)

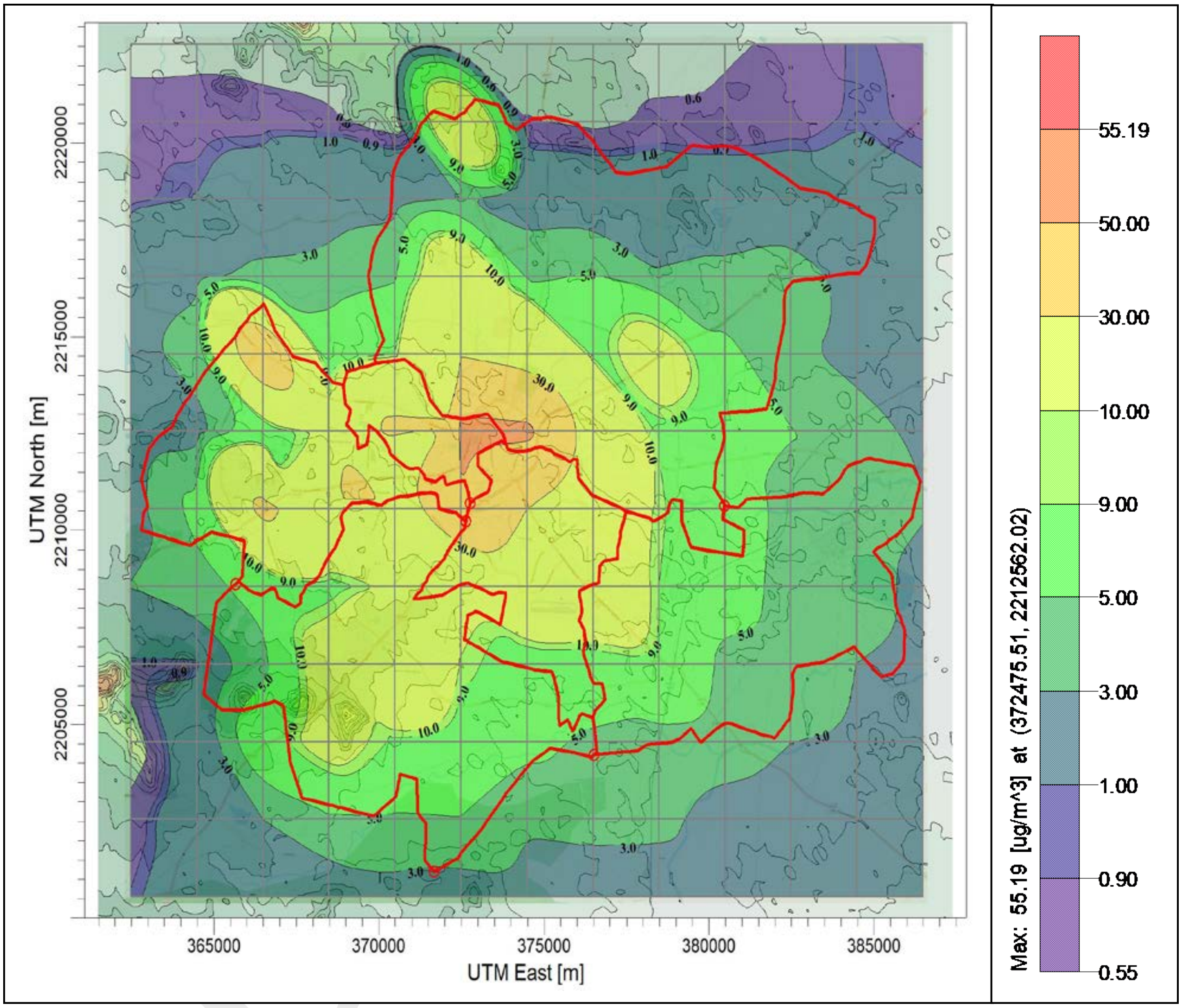

Figure 8.7 : Isopleths of NOx Due to All Source– Preferred Options I - 2020 (Nashik City)

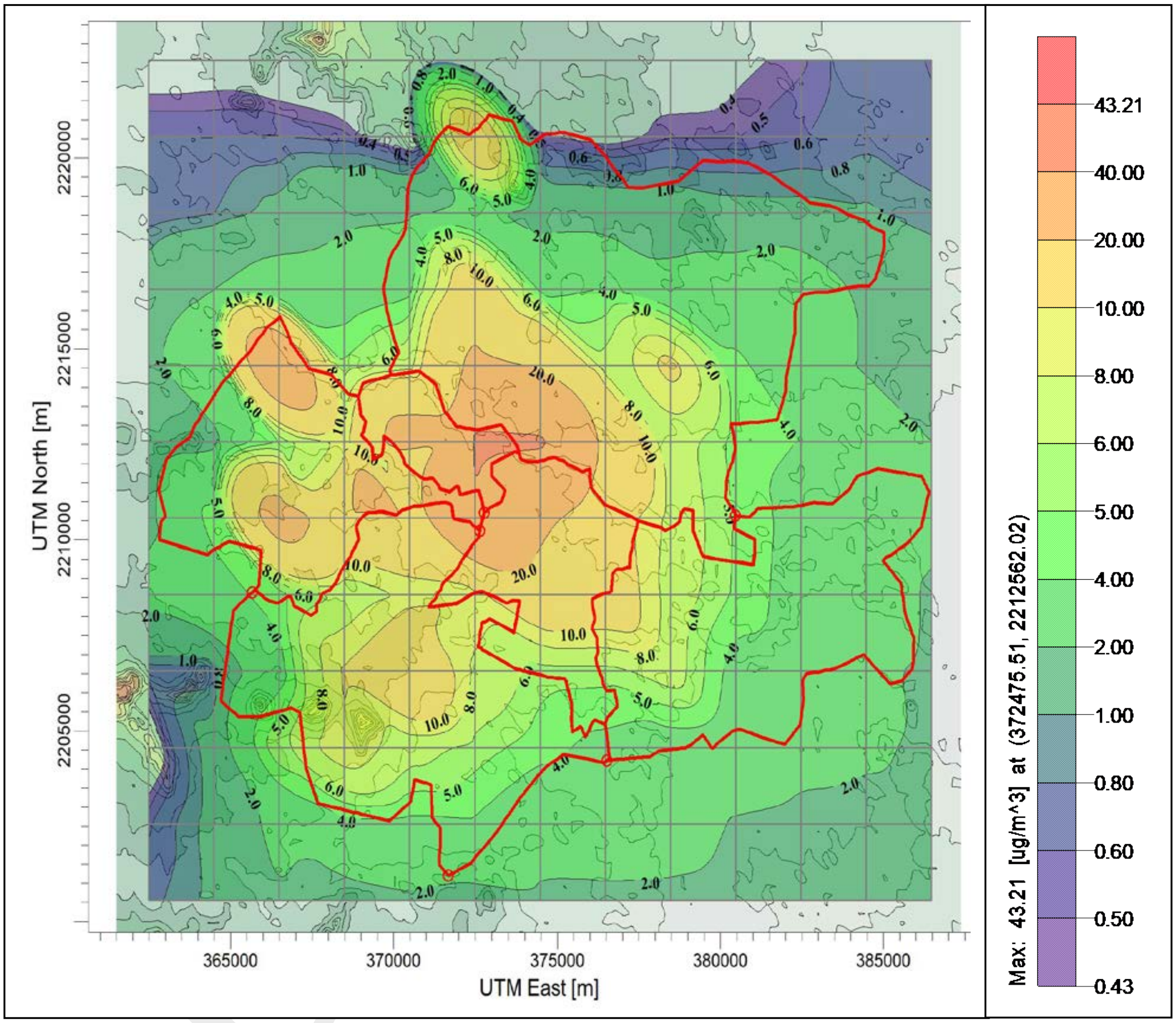

Figure 8.8 : Isopleths of NOx Due to All Source– Preferred Options II - 2025 (Nashik City)

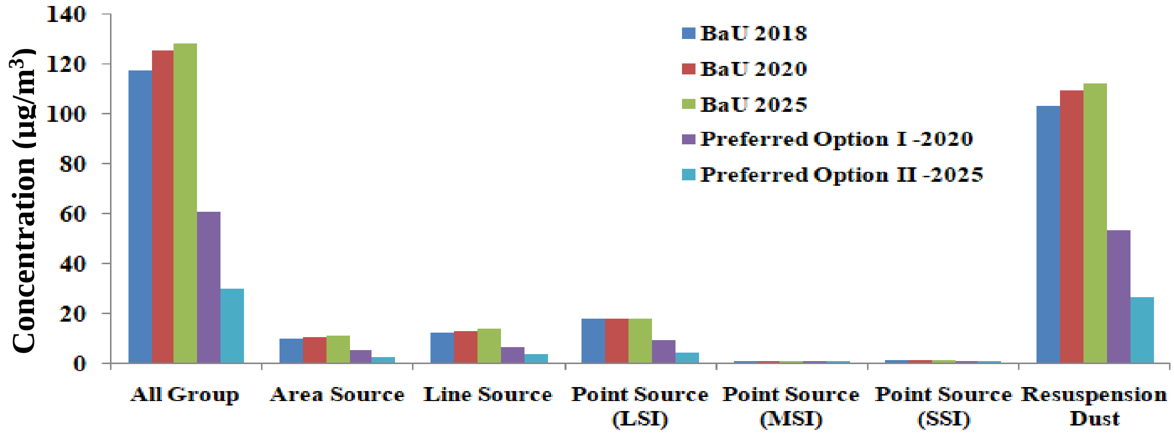

Figure 8.9 : PM Scenario Compared with BaU of 2018 for Preferred Option I (2020) and Preferred Option II (2025)

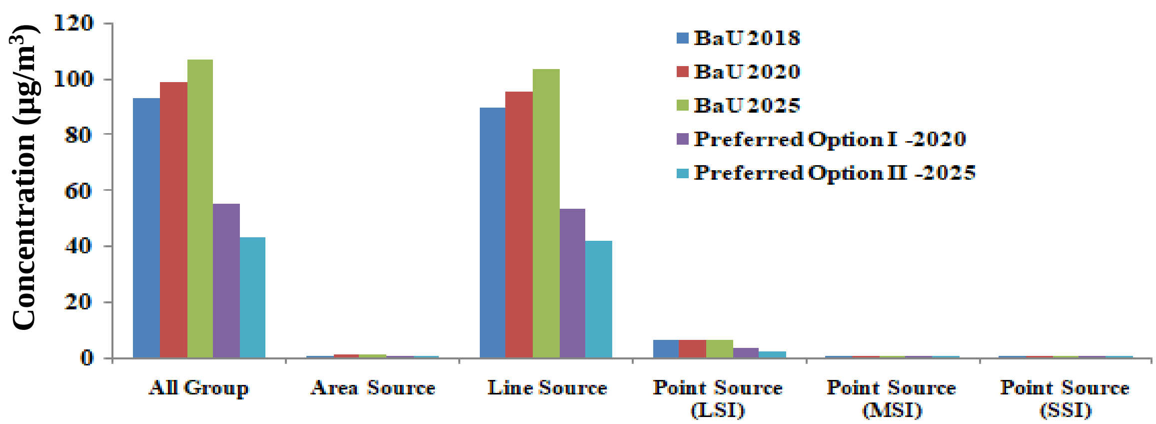

Figure 8.10 : NOx Scenario Compared with BaU of 2018 for Preferred Option I (2020) and Preferred Option II (2025)

If we compared with the all source group for BaU 2018, the concentrations of PM range around 117.65 µg/m^3 and that will increase upto 125.24 µg/m^3 in 2020 and 128.07 µg/m^3 in 2025, if the growth factor is liner. However, the Preferred Option I is applied (control measures for area, industrial source and vehicles 1 to 6 scenarios) the predicted concentrations will be coming down to 60.61 µg/m^3, whereas for Preferred Option II (all vehicles scenarios 1 to 11; industrial and area sources) it is coming around 30.10 µg/m^3. That means the reduction can be observed upto 48% in short term and 70% in long term as per dispersion modeling, which is also coming line with reduction option calculation without modeling upto 40% to 50% in short term and long term as discussed earlier in reduction strategies for control option chapter.

The other source contributions such as area source increases from 9.76 to 11.02 µg/m^3 from 2018 to 2025 as liner growth, after control option implementation, as preferred option I (2020) and II (2025) it will decreases upto 5.24 µg/m^3 to 2.59 µg/m^3 in 2020 and 2025 respectively. As compared to preferred options, line source also decreases from 12.11 µg/m^3 to 6.64 µg/m^3 in 2020 and 3.30 µg/m^3 in 2025, and if we not considered any preferred option the BaU 2025 concentration may reaches upto 14.03 µg/m^3 for line source. The both dispersion modeling and reduction control option for line source gives the reduction upto 40% to 60% in short and long term respectively. The pockets of high concentration are observed close to major traffic junctions in central part of the city viz. Panchavati (Peth Road, Nashik, Aurngabad Road); CIDCO (Mumbai Nashik Express Highway, Mumbai Aagra Highway, Pathardi are); Nashik East (Dwarka Circle); Nashik West (Mayco Circle, Gangapur Road), where major vehicle movements were observed. Nashik is well connected to other cities of India via two national highways (NH3- Agra-Bombay National Highway & NH50- Nashik-Pune Highway) that pass right across the city. The total PM emission load from vehicular sources is 3.7 tons/day and contributing 10.1% of total emission load. The maximum amount of emission load from total Line source is from Heavy Duty Diesel Vehicles (HDDV- 95.14%), followed by 3 wheelers (3.4%) and 2 wheelers (1.2%). There is lot of emissions due to transport, loading, unloading and handling of agro produces at Agro Produces Marketing Committee (APMC), where, there is huge transaction of agro products.

The industrial source will give substantial impact as they are located mainly at MIDC Satpur, Nashik West, CIDCO and some parts of panchvati wards which reflect pollution in the city of Nashik. Point Source contributes around 36.7% (i.e. 13459.0 kg/d) of total PM emission load (i.e. 36706.6 kg/d from all sources). Among them Red LSI alone contribute highest 33.7% (i.e 12397 kg/d). The Red LSI contributing highest i.e. to the total emission. As per dispersion modeling the percentage contribution of LSI i.e. 17.68% for all BaU, if we consider no growth scenario. If implement the shifting fuel quality from fossil fuel to NG in preferred options the reduction observed as 9.0 µg/m^3 in 2020 and 4.15 µg/m^3 in 2025. The dispersion modeling for preferred options gives reduction upto 49% in 2020 and 76% in 2025, whereas without dispersion modeling reduction option calculations gives 54% in short term and 94% in long term for industrial source.

The resuspension of dust contribution around 40.6% to the total load of all sources, from paved road it comes around 7.6% (i.e. 2805.8 kg/d) and unpaved road 33% (i.e 12125.9 kg/d). The vehicular contribute 10% having load of 3709 kg/d, which means natural dust is more. The same is reflected in dispersion modeling, for BaU 2018 and gives concentration of 102.92 µg/m^3 out of 117.65 µg/m^3 from all source group. If we considered the preferred options I and II (i.e. pavement and widening of unpaved roads, vehicular resupension, controlling road constructions and building activities) it will bring down the concentrations upto 53.05 µg/m^3 in short term and 26.36 µg/m^3 in long term, which will reduce the concentrations upto 48% to 74% as per dispersion modeling, similar percent is noticed without the dispersion modeling.

In current scenario, the concentrations of emission is exceeding the CPCB standard i.e. 100 µg/m^3 for PM, is mainly due to resuspension of dust. We compare the standard with individual sources (area, point and line) then preferred option will definitely reduce the emission below the CPCB standard, as also the respension of dust will be reduce. Anthropogenic activities like construction, vehicular resupension will be managed, but natural dust remains and concentrations will be noticed above the standard.

In case of NOx the predicted ground level concentrations for all source group for BaU 2018, the concentrations of NOx range around 92.90 µg/m^3 and that will increase upto 98.89 µg/m^3 in 2020 and 107.21 µg/m^3 in 2025, if the growth factor is liner. After running the Preferred Option I and II the predicted concentrations goes down upto 55.19 µg/m^3 and 43.21 µg/m^3 in short and long term respectively. The reduction is coming upto 43 -53% in both the cases.

The other source contributions for NOx will also decrease viz. area source i.e. 0.88 µg/m^3 (2018) to 0.52 to 0.40 µg/m^3 in 2020 and 2025. Vehicular source is the major contributor, out of 92.90 µg/m^3 from all sources, the line source share approx 96% i.e. 89.49 µg/m^3. Predicted line source also decreases upto 53.23 µg/m^3 in 2020 and 41.75 µg/m^3 in 2025; and if we not considered any preferred option the concentration may reaches upto 95.33 to 103.60 µg/m^3 for line source in BaU 2020 and BaU 2025 respectively. The dispersion modeling gives reduction upto 40% to 50% and without dispersion modeling reduction control option for line source gives the reduction upto 50% to 60% in short and long term respectively. If rigorous BS-VI scenario will be implemented then NOx reduction can be achieved upto 94%. The hotspot for major traffic junctions will not change the concentrations range which is in between 90 to 105 µg/m^3.

The industry share is coming around 27% (i.e. 10737.5 kg/d) of the total NOx (38716.7 kg/d), As per BaU 2018 and no growth scenario, concentration for dispersion modeling gives 6.26 µg/m^3, which is further reduces upto 3.46 to 2.55 µg/m^3, if we implement conversion of fuels to NG. The dispersion modeling for preferred options gives the reduction upto 40-45% in short term and long term, whereas without dispersion modeling reduction will not observed for the both the years in industrial source. The all group annual impact of NOx concentrations shows that, it is exceeding the CPCB 24 hourly standard of 80 µg/m^3 among all the sources vehicular source is highest.

8.2 Prioritizing Technical Measures

Based on the framework of each sector delineated in possible action plan has been discussed in respect to their effectiveness, barriers to implementation and administrative issues. These options have also been considered for their co-benefits with regard to other pollutants adding values to the action planned. Nashik city specific measures at national as well as local levels have also been finalized after interactions in various meetings. Implementing agencies roles and responsibilities finally take the process further. These agencies are likely to have direct and indirect role in implementation. **Table 8.4** presents the considerations in prioritizing various measures for vehicular, industrial and area sources, respectively.

Table 8.4 : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Pollution reduction	Barriers to implementation	Administrative /regulatory	Qualifiers (Co-Benefit)	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit Fuel Used						
S reduction in diesel	Technically feasible and being implemented	Moderate. Reported elsewhere 2000 to 300 ppm reduction in S leads to 2.5- 13% reduction in PM #	High cost. Being planned by Refineries as per the Auto Fuel Policy. The cost is in the range of 15000/35000 crores based on the levels of S	Improvement in emission standards as well as legislation for stringent fuel standards for S, Phasing out the subsidies on diesel. Bringing diesel cost at par in a state/centre	The S reduction will not only reduce the PM but also lead to correspondingly lower SO_2 emission leading to lower ambient SO_2 and sulphate. It will also allow better functioning of exhaust after treatment devices.	Oil companies, Ministry of Petroleum, vehicle manufacturer
Reduce fuel adulteration	Better quality fuel by adopting stricter fuel supply and dispensing system (e.g. Pure for Sure etc.) Chemical marker system	Reduced adulteration will lead to reduced PM (difficult to quantify). Effectiveness is moderate as marker system has not been seen as a primary means to reduce PM	Present system of Anti Adulteration cell function needs major improvement in terms of higher manpower and spread. Presently one office at Mumbai looks after three states of western region. Success of marker system shall be highly dependent upon the joint working relation of Oil companies and AAC.	The current fuel specifications are too broad and therefore checking of conventional parameters such as density etc. does not reflect the adulteration. Finer fuel specifications are needed for implementation. Oil companies themselves can be proactive in proposing these values, which can be checked easily in any laboratory. They also need to be more accountable.	One of biggest advantage of non-adulteration shall be longer engine life besides the emission reduction for PM as well as CO and HC. The catalytic converter shall be active for its entire lifetime.	Anti-Adulteration Cell, Oil Companies, Vehicle owners

 # Source (Air Quality Monitoring, Emission Inventory and Source Apportionment Studies for Indian Cities, February, 2011, CPCB, and Air pollution from motor vehicles, Faiz Asif, Weaver C.S. and Walsh M.P., The World Bank, Washington, D.C., 1996)

Table 8.4 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Pollution reduction	Barriers to implementation	Administrative /regulatory	Qualifiers (Co-Benefit)	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit Fuel Used						
Alternative fuels	Technical infrastructure in Nashik for dispensing CNG/LPG is not effective its need to be improve	High, more than 90% reduction in PM can be achieved compared to diesel #	Can be applicable mainly for vehicles, which are supposed to ply within the city. Applicable to only local public transport, Buses /taxies, auto etc.	Incentive by the government authorities to private vehicle owners to shift to CNG/LPG.	Will lead to substantial reduction in CO and HC emission, however, NOx values may go up	Mahanagar Gas, Oil Companies marketing LPG, Local Government
Phase out of grossly polluting vehicles	No major technical problem	High, Estimate suggest 25% of these vehicle may contribute 75% of total emission $	Poor Inspection system both for emission as well as vehicle. New legislation may require changes in Motor Vehicles Act	New legislation needed for improved Inspection certification system, better testing facility.	Better compliance will lead to reduction of other pollutants as well. It will also lead to less pressure on complying vehicles	Transport Commissioner Office, Ministry of Road Transport and Highway

Source (Air pollution from motor vehicles, Faiz Asif, Weaver C.S. and Walsh M.P., The World Bank, Washington, D.C., 1996)

$ Source (Impact of Better Traffic Management, South Asia Urban Air Quality Management, Briefing Note No. 5, ESMAP, The World Bank, 2002)

Table 8.4 (Contd...) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Pollution reduction	Barriers to implementation	Administrative /regulatory	Qualifiers (Co-Benefit)	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit distance travelled						
Congestion reduction	Improvement of roads, new roads, scientifically planned traffic management Connectivity of nodes to major highways, intercity transport	High emission due to fuel burning at idle or slow moving traffic	Road quality improvement is a matter of technology and quality of work carried out. Inter disciplinary approach within nodal agencies for future expansion of city.	Better planning and training in traffic management Road construction norms to be evolved and implemented	It will reduce traffic junction hotspot of all the pollutants It will also reduce continuous source of dust	NMC, Nashik Metropolitan Urban Region, MSRDC, State Government Transport police, other agencies.
Standards for new and In-use vehicles	No technical issue with new vehicles. For in-use old vehicles, technical feasibility needs to be established	Implementation of BSIV- BSVI norms- vehicles emission reduction can be substantial	The process of in-use vehicles standards may take time as they need to be revised at central level. Inadequate infrastructure and manpower at local levels could be other major barriers.	After the legislation is in place, provision of strict penalty leading to cancellation of vehicle registration.	As the old vehicle population is substantial, the standards will bring in the much needed control on emissions of all types	MoRTH, Transport Office Govt. Maharashtra, Automobile Companies & Fuel Suppliers
Introduction of new technology vehicles	New technology based vehicles emit less per unit distance travelled Electric and Hybrid vehicles	High compared to grossly polluting, moderate with respect to in-use vehicles. It can be mostly use for Public transport	Emphasis to allow only a type of technology to be permitted may meet with resistance from manufacturer as well as buyer. (e.g. rule to allow only 4 stroke vehicle to be registered)	This needs to be backed with proper legislation. Else charge higher registration fee or subject them to carry out more frequent I&C test. Electric vehicles for grossly polluting high VKT vehicles are a good option. It needs regulatory push	It will lead to better compliance from on-road emission test and overall improvement in emission of all the pollutants. Electric vehicles provide localized benefits of no air pollution	MNRE, MoRTH, Transport Office Govt. Maharashtra, Automobile Companies

Table 8.4 (Contd...) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Pollution reduction	Barriers to implementation	Administrative /regulatory	Qualifiers (Co-Benefit)	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit distance travelled						
Retrofitment of new engine/ Emission control device	Experience of other countries suggests that it can be feasible. However, in Indian scenario, a pilot retrofit programme to evaluate the efficacy needs to be undertaken. A pilot project was conducted in Pune with USEPA, USTDA and NEERI	Engine replacement could lead to major reduction of PM. Emission control devices available (DPF, DOC) can remove PM upto 90%	Availability of new engines for retrofit. Vehicle manufacturers need to come forward. For Emission control devices, there are innumerable agencies. Govt initiative for cost sharing for its implementation.	Presently no legislation. Need to frame one including a mechanism by which the system can be evaluated by an appropriate agency.	All the heavy duty in-use vehicles. Truck and heavy tourist vehicles entering into the city boundary will be restricted. High levels of compliance expected.	Truck Association, Transport Office Govt. Maharashtra, vehicle manufacturer, MoRTH, MSRDC
Higher usage of Public Transport	Dedicated bus lane, better buses, low cost of travel, faster travel etc. Inter-linkages of nodes development with surrounding cities.	Effectiveness is high as less and less road space will be occupied by private vehicles, faster movement of public transport in comfort shall lead to low emissions	Feasibility to be established for bus lane. Finances for better buses Measures to reduce the cost of travel by way of cross financing.	Local level planning in coordination with all the authorities involved in Nashik Mahanagar Parivahan Mahamandal Limited (NMPML), Urban Planners, and City Development Planers	Future growth of the city will entirely depend upon the levels of public transport availability. Cheaper and faster mode of public transport will lead to higher per capita efficiency.	Rainbow BRT Park & Ride Facilities at Nashik phata-Wakad Corridor and MSRTC Greater Nashik Metro or Metro NEO, Nashik Municipal Corporation, MSRDC Transport Office Govt. Maharashtra

Table 8.4 (Contd...) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Vehicles

Actions	Technical Issue	Effectiveness for Pollution reduction	Barriers to implementation	Administrative /regulatory	Qualifiers (Co-Benefit)	Local/ National Stakeholders
Strategy : Vehicles: Emission Reduction per unit distance travelled						
Decrease Private vehicles on Road	Vehicle manufactures and holding of private ownership vehicle is the major issue	Less private vehicles on road, high road space utilization	Awareness matched with better public transport. Need for barriers for buying a car	Higher parking charges, high registration fees, higher car user charges, sale linked with parking availability.	Private vehicles owners should must own their own garages, less parking on the roads, less congestion	Transport Office Govt. Maharashtra, RTO, PMC, Nashik Metropolitan Urban Region
Strategy : Vehicles: Emission Reduction -Awareness						
Training and Awareness programme for car owners, public transport operators, drivers and mechanics	On use of alternative fuel, Inspection and certification, adulteration of fuels, use of public transport, less usage of private vehicles	May lead to 5-10% reduction of emission.	Resources for awareness and training, bringing the different groups together	Structure for such programme should be developed and integrated into legislation.	Savings by way of improved vehicle maintenance and operation	RTO, Transport Commissioner Off., NMC, Nashik Metropolitan Urban Region, Other institutions/ NGO involved in awareness campaign

Table 8.4 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Industries

Actions	Technical Issue	Effectiveness for Pollution reduction	Barriers to implementation	Administrative /regulatory	Qualifiers] (Co-Benefit)	Local/ National Stakeholders
Strategy : Industries: Emission Reduction per unit Fuel Used						
S reduction in fuel	This process is currently on, however, the fuel S reduction is mainly for Medium and Small Scale industries	Many industries are shifting fuel from fossil fuel to NG, PNG, CNG Bigger industries needs to take care for Coal, HSD, LSHS, and FO	Industrial growth is not progressive in Nashik, the Medium and Small Scale LSI, Orange industries need to be pressed upon	MPCB can specify the S levels for the fuel being used	Implementation of barriers viz. bag filters, industrial scrubbers, electro static precipitator, use of low sulphur fuel oil will leads to control PM, SOx and pollutants	MPCB, Industries
Combustion Processes	Change in combustion technology will be needed for shifting from coal/oil to natural gas	Moderate	Finances to change the process technology.	Administrative and regulatory incentive and tax rebate for changing technology.	It will lead to lower emission of CO and HC	MPCB, Industries
Alternate Fuel	Large no of small scale industries are using Bagasse /Wood, FO and HSD	Industry should get cleaner fuel viz. NG, PNG. Shifting of heavy fuel ie. FO, HSD, Diesel to LDO and low sulphur and ash. The higher percentage of use of cleaner fuel will resulted in better air quality in the city	Easy availability and infrastructural improvement	More allocation of NG/LPG to the industrial sector through MGL/GAIL/ Govt. of India	Better air quality in terms of SO_2, CO and HC will be achieved.	Mahanagar Gas, MPCB

Table 8.4 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution - Industries

Actions	Technical Issue	Effectiveness for Pollution reduction	Barriers to implementation	Administrative /regulatory	Qualifiers (Co-Benefit)	Local/ National Stakeholders
Strategy : Industries: Emission Reduction by Industrial Policy and Standards						
Promoting Cleaner Industries	Use of cleaner production processes	Large scale shift shall result in major PM reduction	Finances to carry out these changes	State as well as central government can provide incentives to carry out the necessary change	It will lead to sustainable existence of industries within the city. Also lead to other pollutants reduction High level emission shall have lower PM and other gaseous pollutants	MoEF, CPCB, MPCB, MNRE Electrical and auxiliary industries
Fugitive Emission control	Industrial process improvement better operation and maintenance	For localized region, very effective, particularly for industries with fine particles raw material or products. Brick Kilns, DG Sets, Agriculture Pumps needs to be controlled	Monitored data is scarce and therefore how and where to undertake the action will be limited	MPCB can work on the identification of hotspots, standards and compliance system should be developed for fugitive emission	Local area air quality improvement could be highly effective.	MPCB, Industries, CPCB

Table 8.4 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Area Source

Actions	Technical Issue	Effectiveness for Pollution reduction	Barriers to implementation	Administrative /regulatory	Qualifiers (Co-Benefit)	Local/ National Stakeholders
Strategy : Area Sources: Mixed sources and varied strategies						
Improve fuel used for domestic purposes	LPG/PNG major domestic fuel, however kerosene is still a major source in low income group/ better stoves or change in fuel to LPG	Likely to improve indoor air quality	Lack of finance to low income group, particularly in slums	Administrative mechanism to be evolved to provide low cost clean fuel to slum dwellers	It would alleviate large section of population with high indoor pollution of other sources leading to lower disease burden and better quality of life	Central and State Govt., MoPNG, Mahanagar Gas
Bakeries /crematoria	Electric/LPG source based bakeries needing changes in design. Many crematoria have electric system, but need to convert all the other into electric system	Local grid based PM can be reduced.	Awareness to bakeries that the quality can still be maintained with electric or LPG ovens. Similarly, despite electric crematoria being available, people prefer using wood based pyres	Strict monitoring of emissions from bakeries and crematoria, Stack monitoring	Reduction in PM as well as odour will take place and is likely to improve the local air quality	NMC and Nashik Metropolitan Urban Region, MPCB
Biomass/trash burning, landfill waste burning	Better control on collection and disposal at the respective sites. Trash burning and Landfill waste burning needs proper technology driven site management	Local area can have substantial reduction in PM. Very high effectiveness to adjoining grids (city connecting with agriculture field)	Awareness and local control. Apathy to take urgent action. No burning day vow to be taken by NMC and	Nashik Metropolitan Urban Region and Nashik Municipal Regional Wards offices needs to address this issues	High level improvement in local area ambient air quality not only for PM but other pollutants	NMC, MPCB, Nashik Metropolitan Urban Region

Table 8.4 (Contd..) : Considerations in Prioritizing Technical Measures for Addressing Urban Air Pollution – Area Source

Actions	Technical Issue	Effectiveness for Pollution reduction	Barriers to implementation	Administrative /regulatory	Qualifiers (Co-Benefit)	Local/ National Stakeholders
Strategy : Area Sources: Mixed sources and varied strategies						
Resuspension	Vehicle movement related resuspension can be reduced by having better paved roads, regular sweeping and spray of water.	Highly effective for kerb-side air quality	Awareness and will to implement	Norms for road construction to be framed and implemented	Roadside as well population within the distance of about 200-300 m from the road will have low exposure of PM leading to better sense of well being	NMC, Nashik Metropolitan Urban Region, MSRDC, MSRTC
Illegal SSI	Level of problem not well known. Need to understand what are the levels of operation and their contribution in each of the grids in the city	Local area improvement can be moderately good	Knowledge of the problem	Need for strict rules of such units and identification by MPCB/DIC and NMC	It will lead to large scale reduction of fire accidents as well as minimization of wastewater problem	MPCB, DIC, NMC
Construction	Construction activities which involve demolition, digging, construction, vehicle movement etc. need information on how to minimize the dust	Large scale improvement in local area is expected.	Emphasis on better construction practices and management plan for air emission and its control by the implementing agencies	Penalty system to be employed by the local authorities for violating the best construction practices for air pollution control.	Spillage on road and further re-suspension of dust can be minimized	NMC, Nashik Metropolitan Urban Region, Builders Association

The options discussed are also detailed with regard to action to be taken up at city, state or central levels. The **Table 8.5** delineate the prioritize action plan components with ranking for vehicles, industries and area sources.

Table 8.5 : Prioritization of Action Components for Ranking

Types	Components
Vehicular Sector	
Fuel Related	1. Alternative Fuel CNG/LPG 2. Prevent fuel adulteration 3. Sulphur reduction
Vehicle Technology related	1. Replacement of commercial diesel vehicles to CNG/LPG 2. Conversion of private diesel cars to CNG/LPG 3. Electric vehicles for high VKT vehicles 4. Phase out of older vehicles 5. Stringent Emission standards for new vehicles (Bharat IV and VI) 6. Retrofitment of catalytic converter & diesel oxidation catalyst -older vehicles 7. Retrofitment of older vehicles with Bharat Stage III engines with DOC
In-Use vehicle	1. Improvement and compliance system in existing PUC 2. Inspection and identification of highly polluting vehicles 3. Augmentation of manpower and related infrastructure for Inspection and Certification
Policy and Public Processes	1. Prioritization of public transport on roads (bus lanes, better buses, low cost of travel, faster travel, accessibility of transport viz. BRTS, Metro Rail). 2. Affordable public transport (cross-support from charges collected for higher car use charges, higher parking charges, higher registration costs, higher taxes on private mode of transport, low fuel cost for public transport 3. Incentive/subsidy for voluntary inspection and maintenance of vehicles 4. Incentive/subsidy to phase out grossly polluting vehicles 5. Drivers and Mechanics Training programmes 6. Public awareness on use of alternate fuel (CNG/LPG), adulteration of fuels, benefits of various maintenance measures.
Road and Traffic Control	1. Improvement of roads, (Inter linkages and Bypass Roads etc. State and National Highways) 2. Interstate transport vehicles viz. tourist and goods vehicles needs to be ply outside the city area, restricted entry into the city 3. Transportation planning and better road maintenance 4. Pavement improvement and better sweeping for less resuspension 5. Road Congestion –encroachment etc. 6. Traffic Management: signal synchronization, one way, pedestrian plaza

Table 8.5 (Contd..) : Prioritization of Action Components for Ranking

Types	Components
Industrial Sector	
Fuel Related	1. Change of FO, HSD, LSHS, Coal to NG 2. Change of fuel such as Bagasse and Wood to Alternative Fuel
Technology related	1. Clean combustion technology 2. High efficiency control technology 3. Clean process technology
Fugitive and other emissions	1. Industry specific plans 2. Compliance monitoring design for fugitive emissions
Area Sector	
Fuel Related	1. LPG/ CNG & Low sulfur fuel for bakeries, crematoria 2. PNG/ LPG for domestic fuel in place of kerosene
Biomass /landfill burning	1. Open burning viz. biomass, trash burning need to urgently managed in big organizations premises landscape areas 2. Landfill burning management 3. Open eatout burning of coal /kerosene to be regulated
Construction / demolition of buildings	1. Norms for building construction / demolitions 2. Regulation and compliance monitoring 3. Material movement control 4. Construction machineries use and its management
Road Construction/ Repairs	1. Road quality norms to be revisited (Refer : UTTIPEC design manual created by Delhi Development Authority for uniform roadside, drains, footpath and related design) 2. Use road repair technologies and consider life of road warranties 3. Stoppage of wood burning for tar melting or re-surfacing of the road
Public Awareness	1. Public awareness programme to empower citizens to report small sources but highly prevalent 2. Dissemination of information to public addressing system

All the above actions have been rated on the basis four criteria viz.

- Effectiveness - Ease of implementation - Cost implications - Time frame

These criteria should not be considered as firm numbers as many of these cannot be easily quantified. The ranking carried out here therefore is of subjective in nature; however, these are based on relevant facts and analysis of their effectiveness. For example an action plan with "low cost" in Fuel Related category may not be same as in Technology Related "low cost".

The prioritization of various options in all three categories have addressed mostly all the major reduction in the overall pollutants load reduction combined with ambient air quality improvement. However, many of these measures still may not lead to resolving very small area high concentration points which could be due to short term but high emission or high activity for a limited period and limited area. Such hot spots in the city of Nashik could exist when a local road is dug up and/or being repaired, construction and demolition of buildings, biomass and refuse burning, industries short term emissions etc. All of such activities can be controlled and regulated through local efforts and constant vigil on the part of citizen, pollution control agency and respective responsible implementing agency.

One of the biggest issues for large metro city is land use pattern, which indirectly drives the growth pattern of the city and consequent vehicle increase. Migration of people within the state from nearby districts, due to climate conditions, searching for the jobs, development of city as a infrastructural availability and better livelihood had changed the city growth profile and living structure. Frequent change in floor space index (allowing more built up per unit area) leads to large scale increase in vehicle ownership and their presence on road. Better air quality planning for the city also needs appropriate transport planning which is linked with land use.

All reductions planned will only reduce emissions from manmade sources; however, natural background and dust would continue to remain in the atmosphere.

The benefits computed in the process described above will not only yield PM and NOx related pollution reduction but also co benefit of other pollutants (SO_2, VOCs, HC, CO etc) reductions as well. One of the other major co-benefits of these options (adoption of mass transport, use of cleaner fuel, efficient combustion etc) will provide large scale green house gas reduction. Nashik as growing metro city will provide the impetus of overall mitigation of GHG. The benefits of air quality improvement plan suggested and delineated above again will not yield desired results if the adjoining urban centers do not adopt measures suggested, as the objectives of clean air cannot be kept limited to the political boundary of Nashik City, when it is in close proximity of major urban centers and developing regions.

ANNEXURE - 1

Emission Factors

(Area, Line and Point Sources)

Annexure 1

Emission Factors

A) Area Source

Bakery

Emission Factor for Wood Burning (kg/t)
PM_{10} = 17.3, SO_2 = 0.2, NOx = 1.3, CO =126.3, HC = 114.5 (VOC as HC)
*$PM_{2.5}$ /PM_{10} ratio considered was =0.68
http://www.epa.gov/ttn/chief/ap42/index.html (Sec. 1.9, pp. 1.10.4, Table 1.9.1)
(Rakesh Kumar and Abba Elizabeth., 2003), VOC to HC - lb/ton - kg/ton*
Emission Factor for Diesel Burning (kg/kiloliters)
SPM= 0.25, PM_{10} =60% of SPM, $PM_{2.5}$ =40% of SPM, CO= 0.63, SO_2 =17.25S,
NOx = 2.75, HC = 0.12, (Sulfur content = 0.35%) - automobile euro norms
(TERI, Environmental Effects of Energy Production
Transportation and Consumption in NCR, New Delhi, 1992)

Crematoria
Emission factors for wood burning (kg/t)
PM_{10}=17.3, SO_2 = 0.2, NOx 1.3, CO =126.3, HC =114.5 (VOC as HC)
*$PM_{2.5}$ /PM_{10} ratio considered was =0.68
http://www.epa.gov/ttn/chief/ap42/index.html (Sec. 1.9, pp. 1.10.4, Table 1.9.1)
Emission Factor Kerosene (kg/t)
SPM =1.95, PM_{10} =0.61, SO_2 =4, NOx =2.5, CO=62, HC =19
URBAIR, Working Group 1992 - Kerosene, Residential Emission Factor - Electric (kg/ body)
Emission Factor Electric (kg/body)
PM_{10} =0.000025, SO_2 = 0.0544, NOx =0.308, CO =0.141, NVOC =0.013
*$PM_{2.5}$ /PM_{10} ratio considered was =0.68
http://www.naei.org.uk/emissions/selection.php
Body burning was separately calculated based on emission factor electric crematoria

Open Eat Outs
Emission factor for LPG
PM_{10} =2.10, SO_2 = 0.40, NOx = 1.8, CO= 0.25, HC as VOC=0.07
Assessment of Sources of Air, Water and Land Pollution – A Guide to Rapid Source Inventory Techniques and their Use in Formulating Environmental Control Strategies – Part one – Rapid Inventory Techniques in Environmental Pollution by A.P. Economopolous, WHO, Geneva, 1993
Particulate emission LPG considered as $PM_{2.5}$
Emission factor for Kerosene : SPM=0.06, PM_{10}=0.61, SO_2 =4, NOx =2.5, CO = 62
Urban Air Quality Management Strategy in Asia – Greater Mumbai Report edited by Jitendra J. Shah and Tanvi Nagpal, World Bank Technical Paper No. 381, 1997
Emission factor for Coal : SPM =20, SO_2 = 13.3, NOx =3.99, CO=24.92, HC =0.5
Environmental effects of energy production, transformation and consumption in the National Capital Region submitted to the Ministry of Environment & Forest, by Tata Energy Research Institute (TERI), New Delhi, February 1992

Domestic Cooking
Emission Factor for LPG : PM=2.1, CO =0.252, SO_2 = 0.4, NOx = 1.8, VOC = 0.072
Emission Factor for Kerosene : PM_{10}=0.61, SO_2 =4, NOx =2.5, CO = 62
Assessment of Sources of Air, Water and Land Pollution – A Guide to Rapid Source Inventory Techniques and their Use in Formulating Environmental Control Strategies – Part one – Rapid Inventory Techniques in Environmental Pollution by A.P. Economopolous, WHO, Geneva, 1993

Hotels & Restaurants
Emission factor for LPG
PM_{10} =2.10, SO_2 = 0.40, NOx = 1.8, CO= 0.25, HC as VOC=0.07
Assessment of Sources of Air, Water and Land Pollution – A Guide to Rapid Source Inventory Techniques and their Use in Formulating Environmental Control Strategies – Part one – Rapid Inventory Techniques in Environmental Pollution by A.P. Economopolous, WHO, Geneva, 1993
Particulate emission LPG considered as PM2.5
Emission factor for Coal : SPM =20, SO_2 = 13.3, NOx =3.99, CO=24.92, HC =0.5
Environmental effects of energy production, transformation and consumption in the National Capital Region submitted to the Ministry of Environment & Forest, by Tata Energy Research Institute (TERI), New Delhi, February 1992

Open Burning
Emission Factor (kg/MT) PM_{10} = 8, $PM_{2.5}$ =5.44, CO=42, SO_2=0.5000,NOx= 3, VOC= 21.5
A Guide to Rapid Source Inventory Techniques and their Use in Formulating Environmental Control Strategies – Part one – Rapid Inventory Techniques in Environmental Pollution by A.P. Economopolous, WHO, Geneva, 1993

Aircrafts
Emission factor domestic flight
PM10=0.99*, CO =11.8, SOx =0.8, NOx =8.3, VOC=0.5
Emission factor international flight
PM10=0.99*, CO =6.1, SOx =1.6, NOx =26, VOC=0.2
** A Guide to Rapid Source Inventory Techniques and their Use in Formulating Environmental Control Strategies – Part one – Rapid Inventory Techniques in Environmental Pollution by A.P. Economopolous, WHO, Geneva, 1993*
Other emission factors are taken from
www.ecotourism.org/onlineLib/Uploaded/ … Airplanes emissions. PDF
PM2.5/PM10 = 0.92
Preparation of Fine Particulate Emission Inventories -Student Manual, APTI Course 419B, Sec. 4.2.1, pg-4.7

Marine Vessels
Emission factors *(kg/t fuel consumed)*: PM_{10} =1.03, CO =1.85, SO_2 =11, NOx= 10, VOC as HC = 0.83, Density of diesel = 0.86 (HSD) *UK-Shipping international-Fuel oil*

Paved & Unpaved Dust
Paved Road Dust : $PM_{2.5}$ = 0.39, PM_{10}= 1.93
** Strengthening Environmental Management at the State Level (Cluster) Component E- Strengthening Environmental Management at West Bengal Pollution Control Board, TA No. 3423-IND, Asian Development Bank, Nov. 2005 (Table 12, Page 23) USEPA AP42 Paved, Section 13.2.1.4 Motor Transport Statistics, Transport Commissioner Office, Mumbai* Silt loading estimate -0.531 gm/m2 (*Kolkata ADB report –Table 13, page 23) Break and tire wear correction – (USEPA AP42 Paved, Section 13.2.1.4, Table 13.2.1.2) Wet days = 120, (IMD, Mumbai)

Emission factor for industrial and vehicular sources are given in respective chapters

B) Line (Vehicular) Source

Emission Factors Calculated by Automotive Research Association of India (ARAI)

Vehicular Emission Factors (Gm/Km)	Car Petrol Post 2005 Fuel BSII	Car Diesel Post 2005 Fuel BSII	Car CNG Post 2000, Fuel BSII	Two Wheeler Post 2005 4 Stroke Fuel BS II	Three Wheeler CNG Retro 25 Post 2000 Fuel BS II	CNG Buses Post 2000 Fuel BS II	Trucks Diesel Post 2000 Fuel BSII
PM	0.002	0.015	0.006	0.013	0.118	0.044	1.240
NOx	0.090	0.280	0.740	0.150	0.190	6.210	9.300
CO	0.840	0.060	0.060	0.720	0.690	3.720	6.000
HC	0.12	0.080	0.460	0.520	2.06	3.750	0.370

Factors used for emission load calculation Source: Air Quality Monitoring Project-Indian Clean Air Programme (ICAP), The Automotive Research Association of India, 08, 2007

* Emission Factors for BS IV and BS VI are given below :

Emission Factors for BS IV and BS VI

Emission Factor for BS IV fuel	PM	NO_x	CO	HC
Car Petrol Car	0.002	0.08	1	0.1
Car Diesel Car	0.025	0.25	0.5	0.3
CNG Car/Taxi (LMV)	0.006	0.08	1	0.1
Two wheeler	0.013	0.79	1.403	0.39
Three wheeler	0.0425	0.38	0.38	2.06
Heavy Duty Diesel Vehicles	0.02	3.5	1.5	0.46

Emission Factor for BS VI fuel	PM	NO_x	CO	HC
Car Petrol Car	0.005	0.06	1	0.1
Car Diesel Car	0.005	0.08	0.5	0.17
CNG Car/Taxi (LMV)	0.005	0.06	1	0.1
Two wheeler	0.0045	0.06	1	0.1
Three wheeler	0.025	0.1	0.22	0.1
CNG Buses	0.01	0.46	4	0.16
Heavy Duty Diesel Vehicles	0.01	0.4	1.5	0.13

* Values in g/km Source: *https://www.transportpolicy.net/region/asia/india/*

TransportPolicy.net is collaboration between the International Council on Clean Transportation and DieselNet. On 19 Feb 2016, the Ministry of Road Transport and Highways (MoRTH) issued a draft notification of Bharat Stage (BS) VI emission standards. The standards, as proposed, will take effect throughout the country for all light-duty and heavy-duty vehicles as well as two and three wheelers manufactured on or after 1 Apr 2020. The draft proposal specifies mass emission standards, type approval requirements, and on-board diagnostic (OBD) system and durability levels for each vehicle category.

Additional provisions in the draft proposal include:

- Adoption of more stringent WHSC and WHTC test cycles
- Off-cycle emissions testing requirements and in-service conformity testing for type approval
- Specifications for Portable Emissions Measurement System (PEMS) demonstration testing at type approval. The proposed BS VI regulation establishes an important precedent for leap frogging from Euro IV-equivalent directly to Euro VI-equivalent motor vehicle emissions standards.

The World Harmonized Transient Cycle (WHTC) test is a transient engine dynamometer schedule defined by the proposed global technical regulation (GTR) developed by the UN ECE GRPE group. The GTR is covering a world-wide harmonized heavy-duty certification (WHDC) procedure for engine exhaust emissions. The proposed regulation is based on the world-wide pattern of real heavy commercial vehicle use.

a. test is performed on an engine dynamometer operated through a sequence of 13 speed and load conditions
b. a hot start steady state test cycle
c. transient test cycle with both cold and hot start requirements

Prior to 2010, emissions were tested using the ECE R49[a] test cycle. After 2010, for Bharat III and IV, the ESC (European Stationary Cycle) and ETC (European Transient Cycle) test cycles were used. BS VI will require the application of WHSC[b] (World Harmonized Stationary Cycle) and WHTC[c] (World Harmonized Transient Cycle) test cycles.

C) Point (Industry) Source

Emission Factors applied for Industrial Emissions

S. No.	Type of Fuel	Unit	S	Emission Factors (Kg/Unit)					
				TSP	SO_2	NO_x	HC	CO	Ash
1.	LSHS	KL	0.45	1.25*S + 0.38	19.25* S	7.5	0.12	0.63	
2.	FO	KL	4.0	1.25*S + 0.38	19.25* S	7.5	0.12	0.63	
3.	LDO	KL	1.8	0.25	17.25* S	2.75	0.12	0.63	
4.	HSD	KL	1.0	0.25	17.25* S	2.75	0.12	0.63	
5.	LPG/FG[$$]	KL	0.02	0.072	0.01*S	2.52	0.07	0.43	
6.	NG	m^3	-	160 E-06	9.6 E-06	2800 E-06	48 E-06	272 E-06	
7.	Coal /Coke	MT	0.5*	6.5*A	19S	7.5	0.5	1.0	45
8.	Kerosene[##]	Kg/t	0.25	0.06	17S	2.5	--	--	--
For Power Plant**									
1.	LSHS	KL	0.45	1.25*S + 0.38	19.25* S	6.25	0.12	0.63	
2.	NG	m^3	-	160 E-06	9.6 E-06	2800 E-06	48 E-06	272 E-06	
3.	Coal	MT	0.15	6.5*A	19*S	7.5	0.5	1	6

Source: URBAIR Report, Bombay, 1992
A: Percentage ash in coal = 45% and S: Percentage Sulphur
Other than Power Plant, efficiency of Cyclone considered as 75%
* *Power plant
[$$]Emission Factors for LPG from Revised AP-42 (Ref. PMRAP, NEERI, 2003 (Table 3.2)
Π Coal
A - % Ash: 2- 10% Avg. 6%, S - % Sulphur: 0.1 – 0.2%, Avg. 0.15%
ESP Eff. : 99.5%, FGD Eff. : 99%
Π LSHS Sulphur: 0.45%
Source:
a. Environmental effects of energy production, transformation and consumption in the National Capital Region submitted to the Ministry of Environment & Forest, by Tata Energy Research Institute (TERI), New Delhi, February 1992
b. Indian Oil Corporation Ltd, Vadodara

Density[b] of Fuels (Kg/m^3)

LSHS	943
FO	943
LDO	860
LPG	504
HSD	860

Baggase : Emission Factor Documentation for AP-42 Section 1.8, Bagasse Combustion in Sugar Mills, April, 1993 [PM10- 4.6, SO2-0.18, NO2-0.275, HC-0.0002515, CO - 390 (g/km)]

ANNEXURE - 2

ISOPLETS OF PM :

All Categories- (a)Area, (b) Line, (c) Resuspension of Dust, (d) Point –LSI, MSI & SSI

&

For All Season (Summer, Post Monsoon, Winter and Annual)

(Nashik City)

A) AREA SOURCE – ALL PM

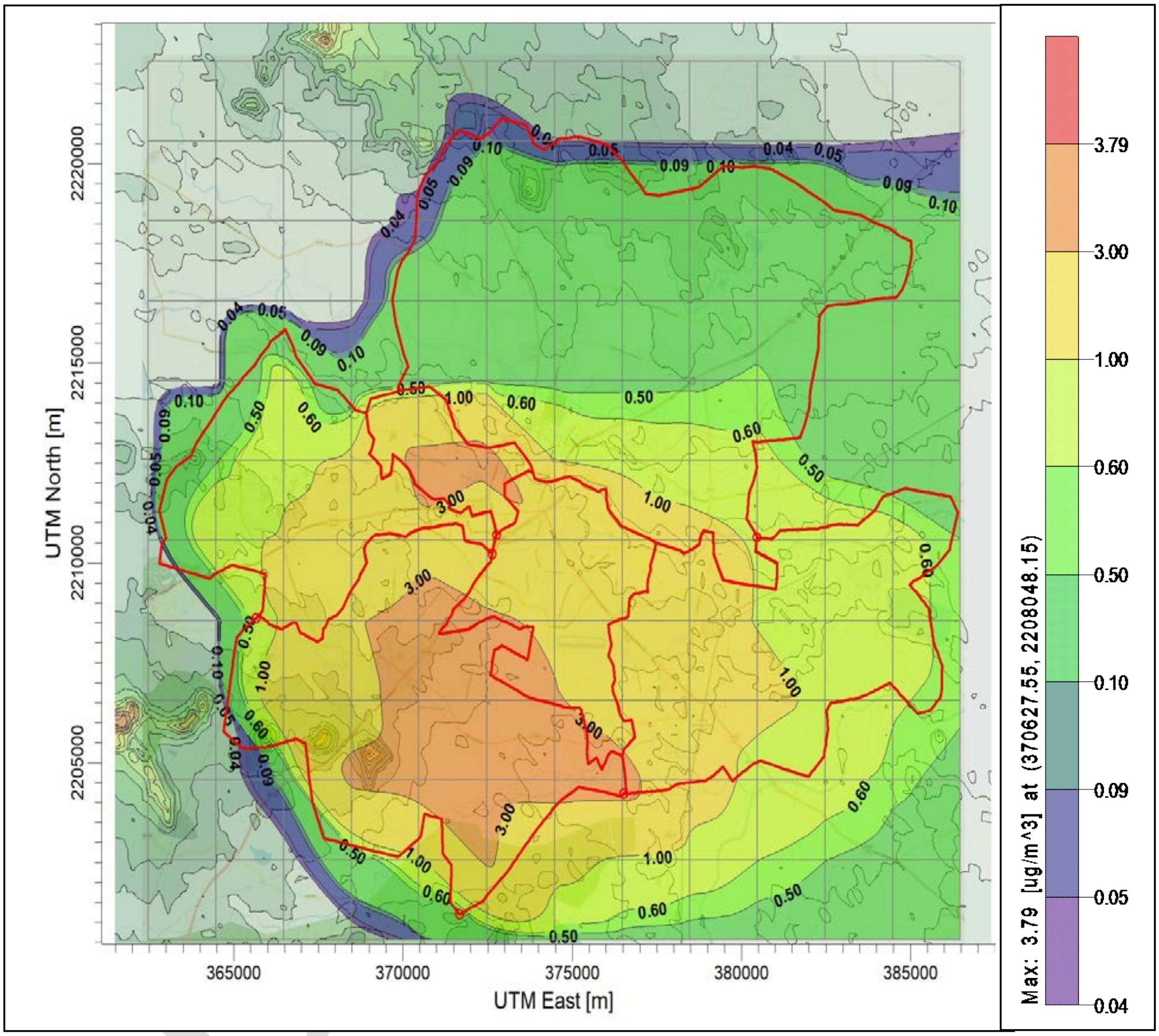

Figure P1: Isopleths of PM Due to Area Sources –Summer Season (Nashik City)

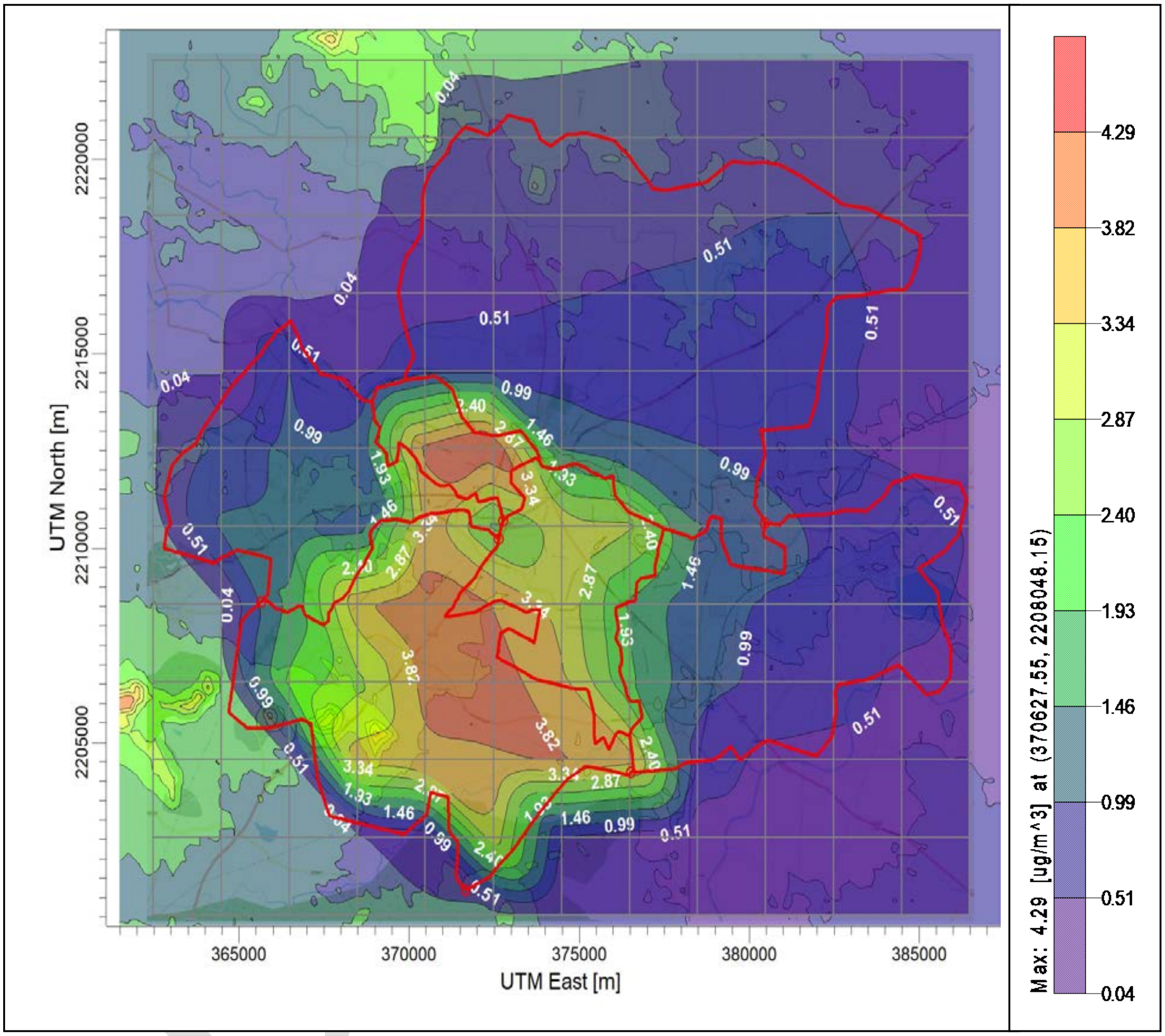

Figure P2 : Isopleths of PM Due to Area Sources – Post Monsoon Season (Nashik City)

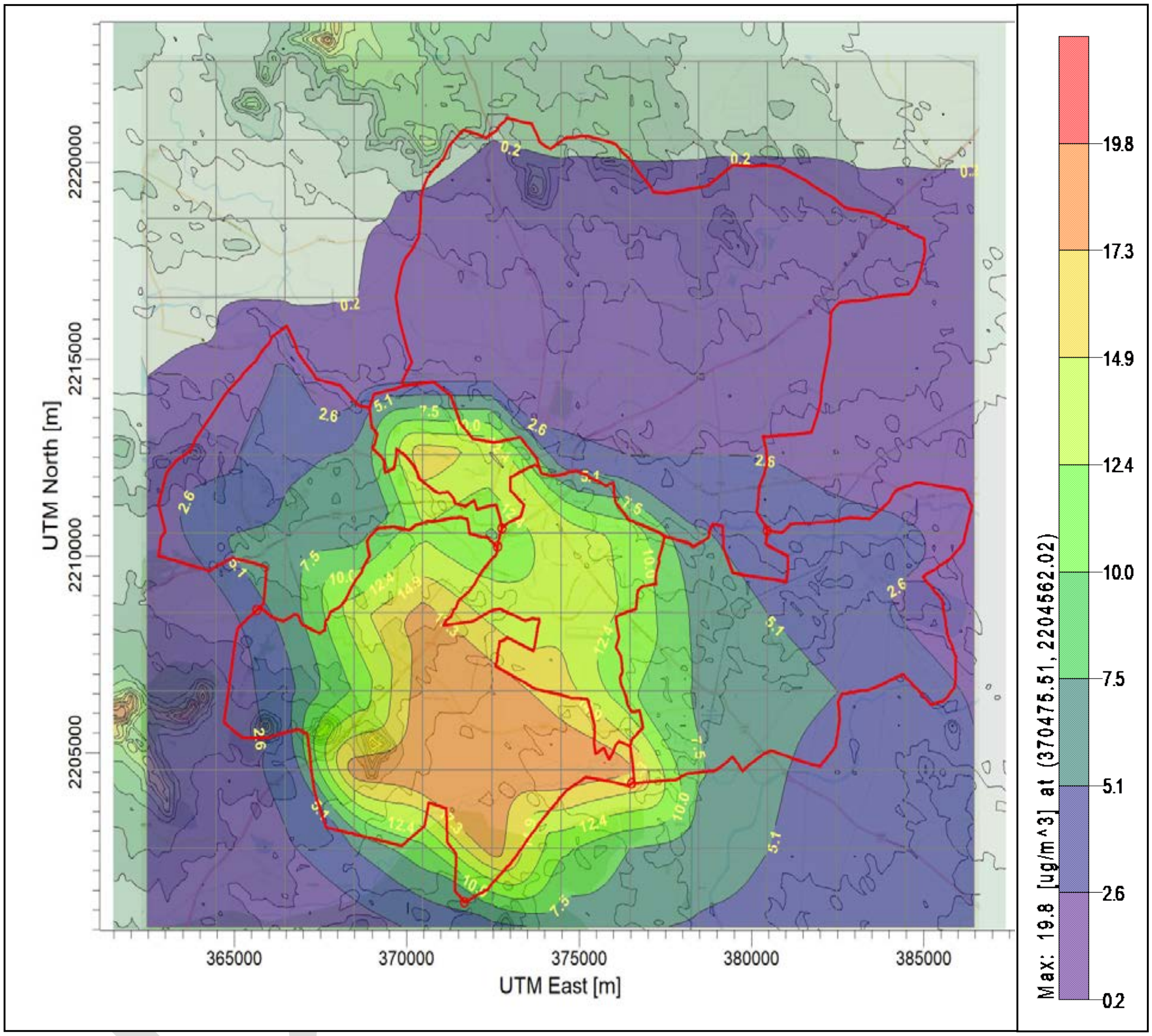

Figure P3 : Isopleths of PM Due to Area Sources – Winter Season (Nashik City)

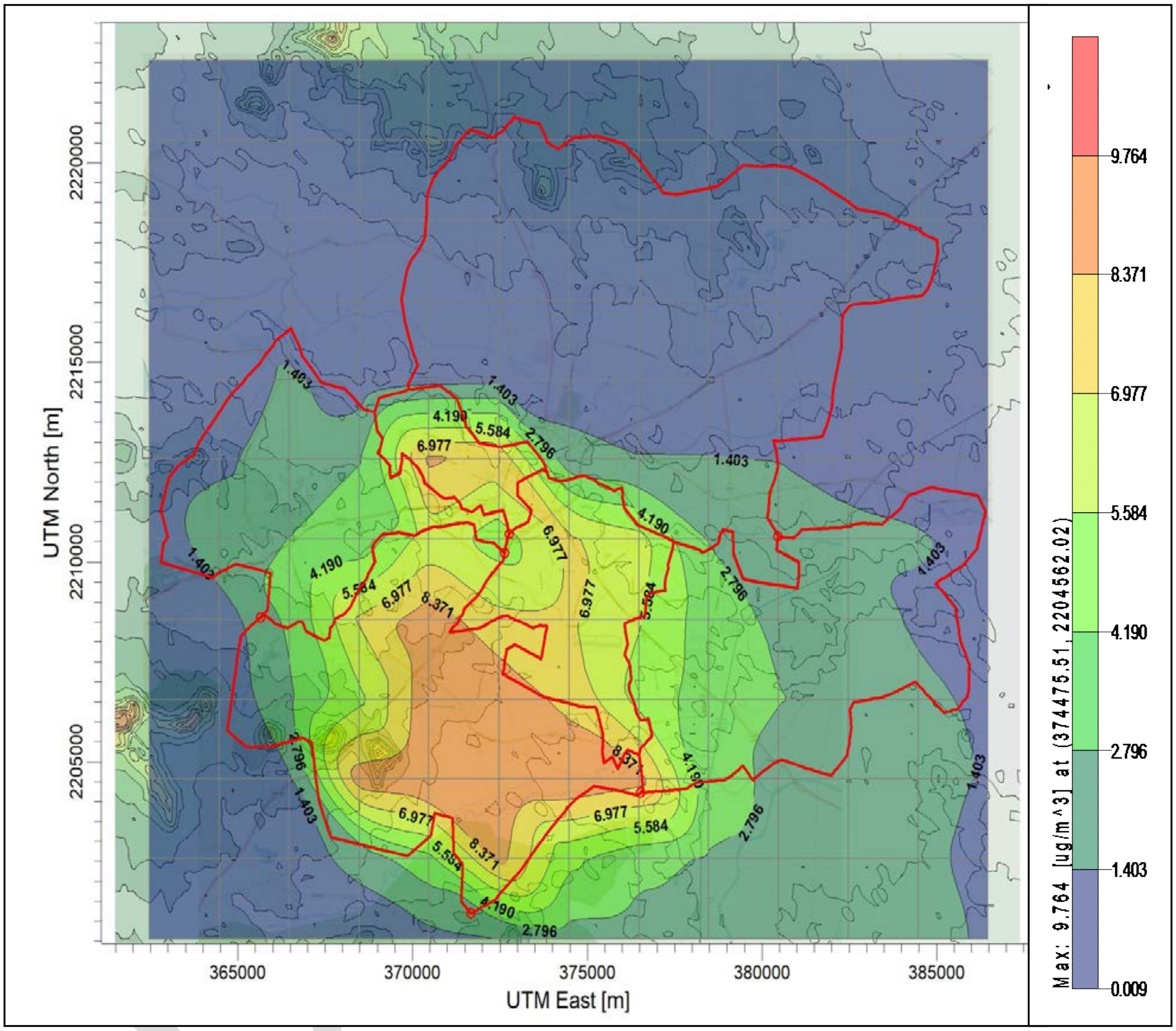

Figure P4 : Isopleths of PM Due to Area Sources – Annual (Nashik City)

B) LINE SOURCE – ALL PM

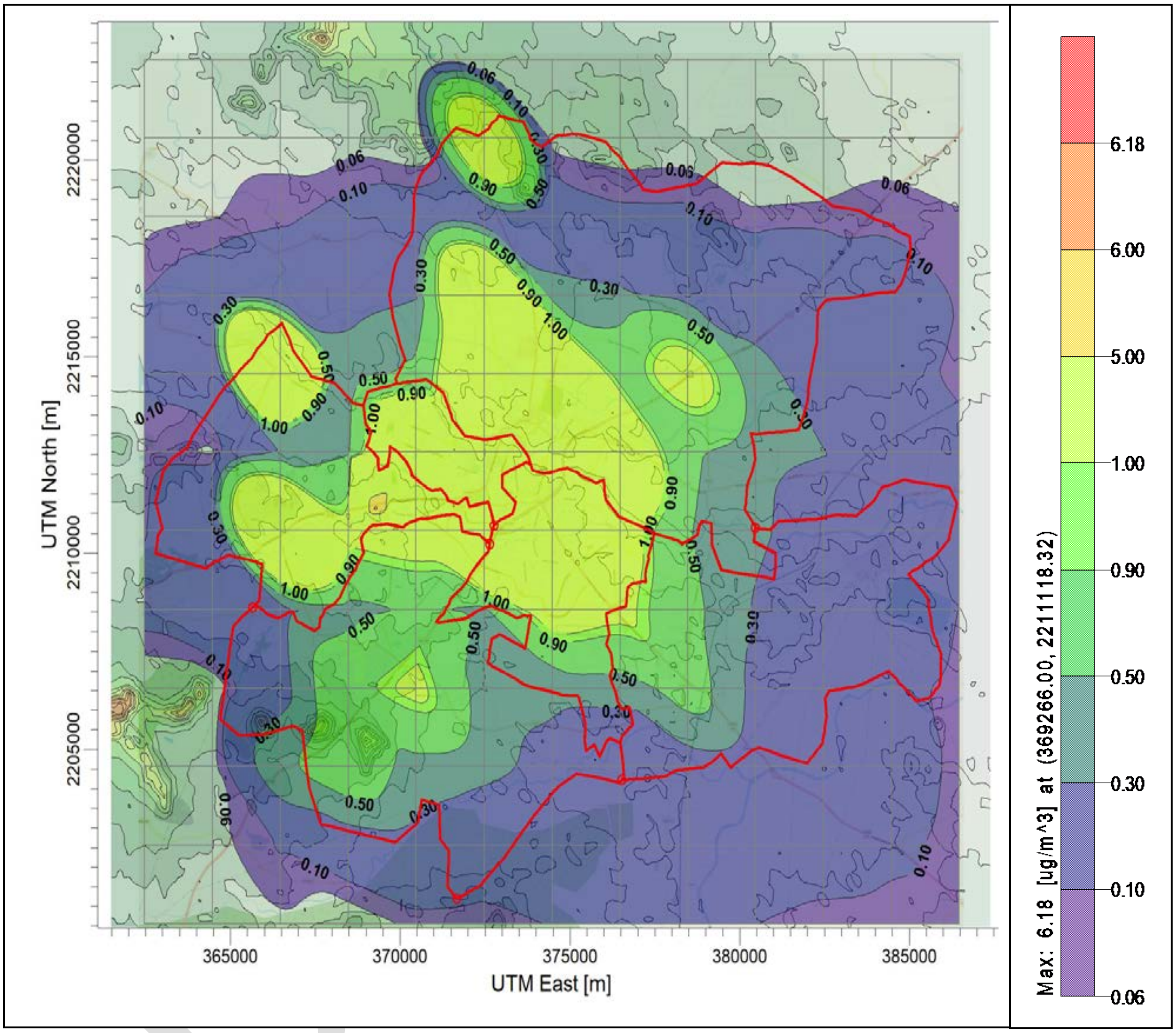

Figure P5 : Isopleths of PM Due to Line Sources – Summer Season (Nashik City)

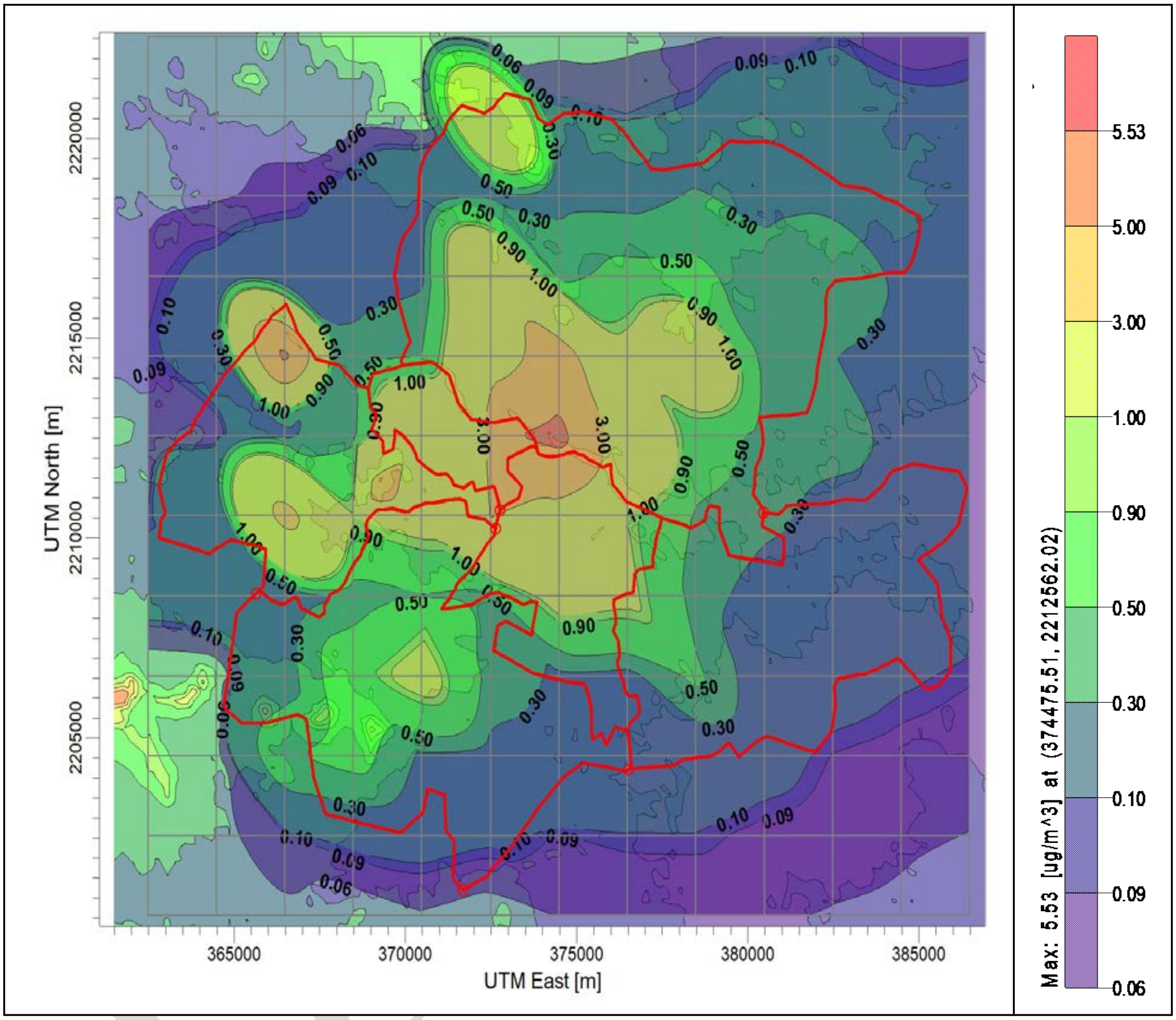

Figure P6 : Isopleths of PM Due to Line Sources – Post Monsoon Season (Nashik City)

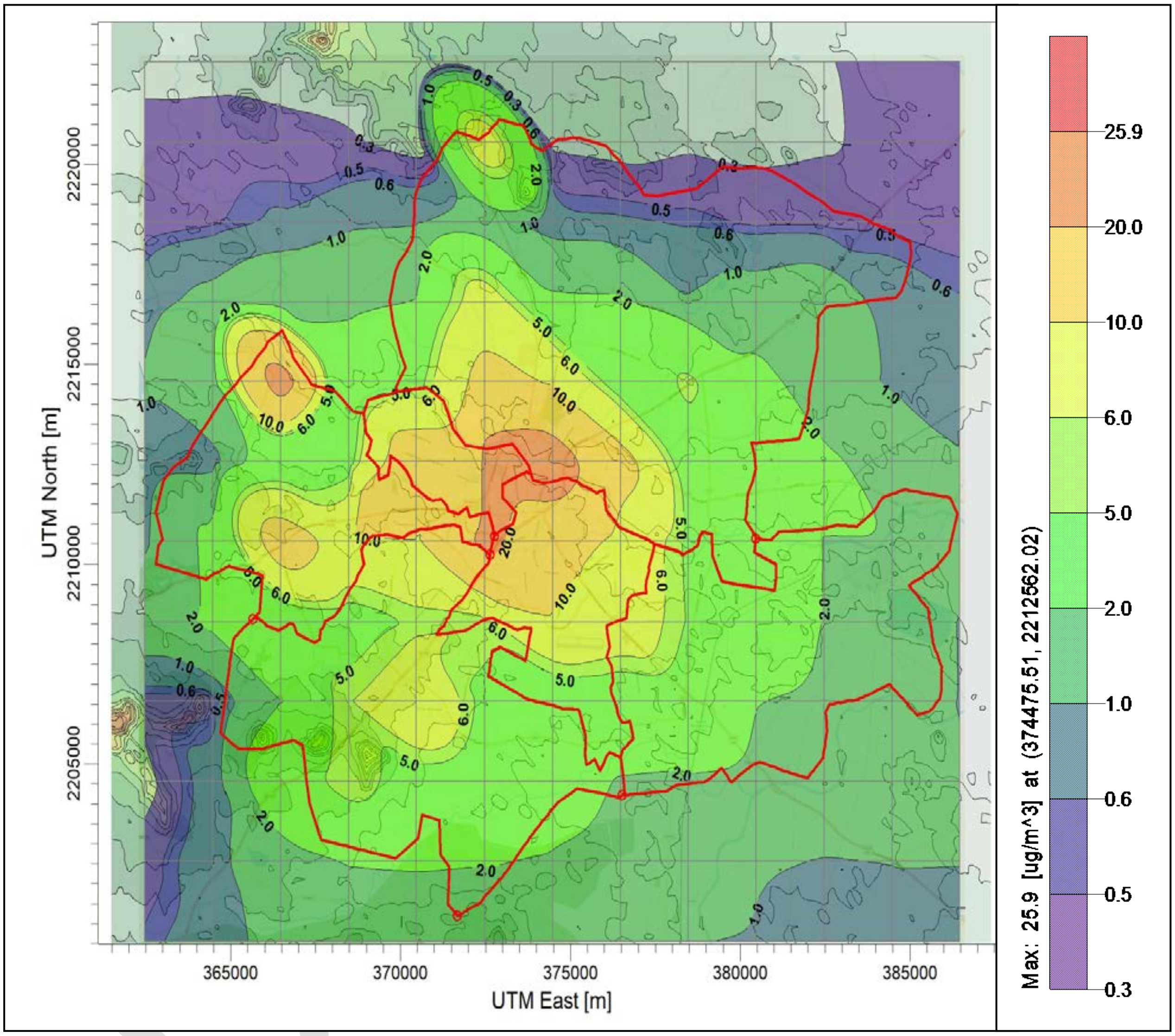

Figure P7 : Isopleths of PM Due to Line Sources – Winter Season (Nashik City)

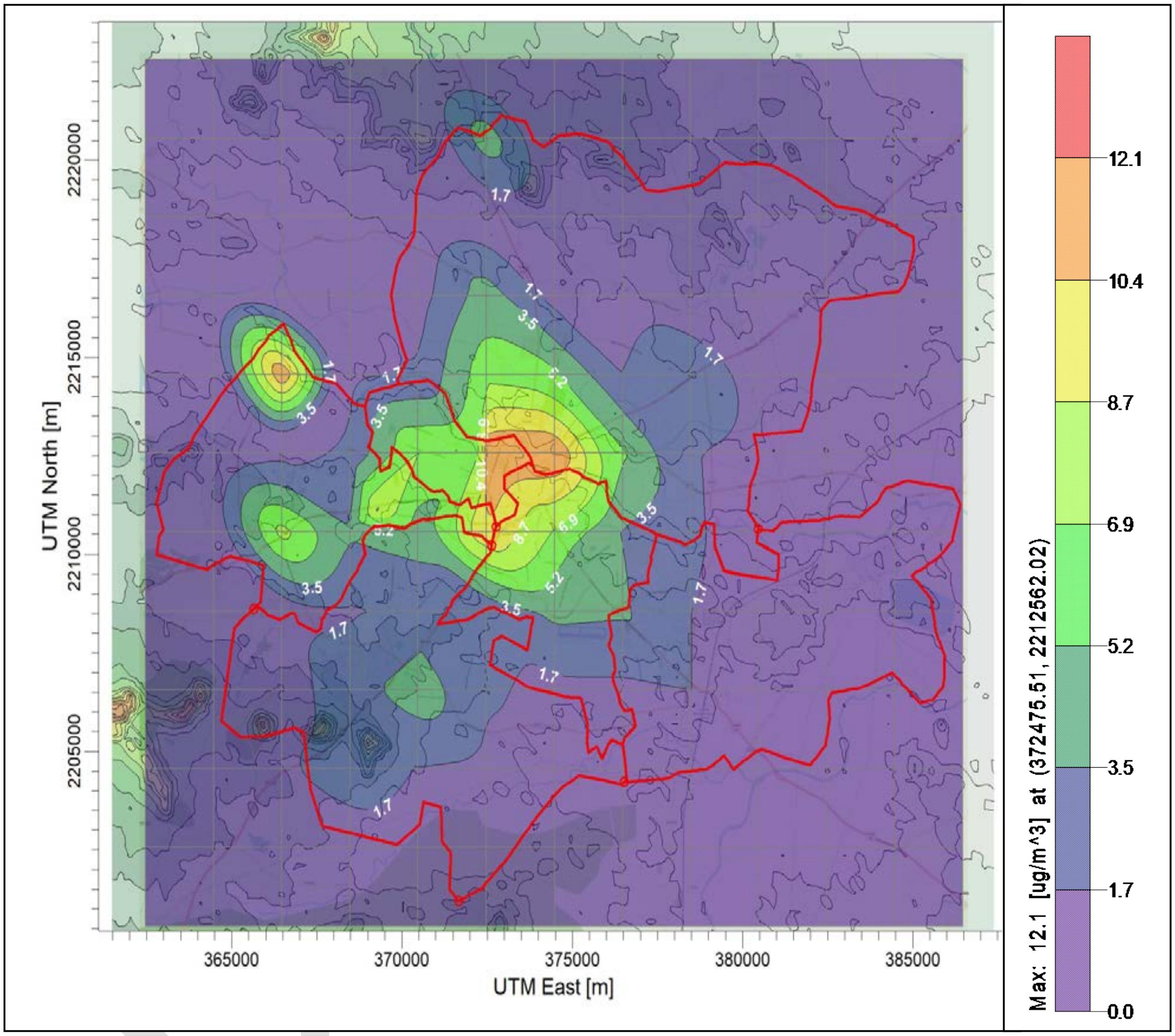

Figure P8 : Isopleths of PM Due to Line Sources – Annual (Nashik City)

C) RESUSPENSION DUST– ALL PM

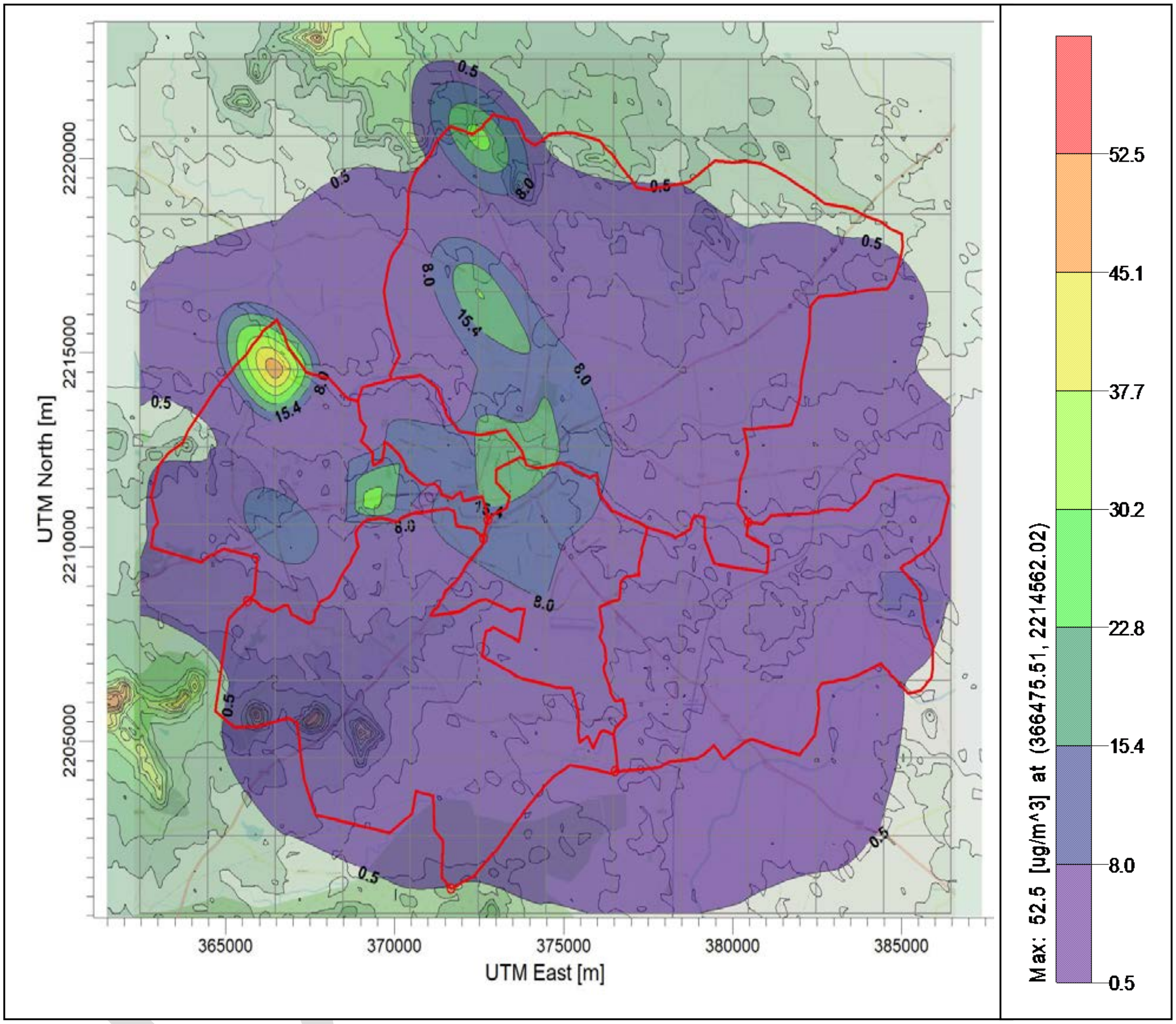

Figure P9 : Isopleths of PM Due to Resuspension Dust– Summer Season (Nashik City)

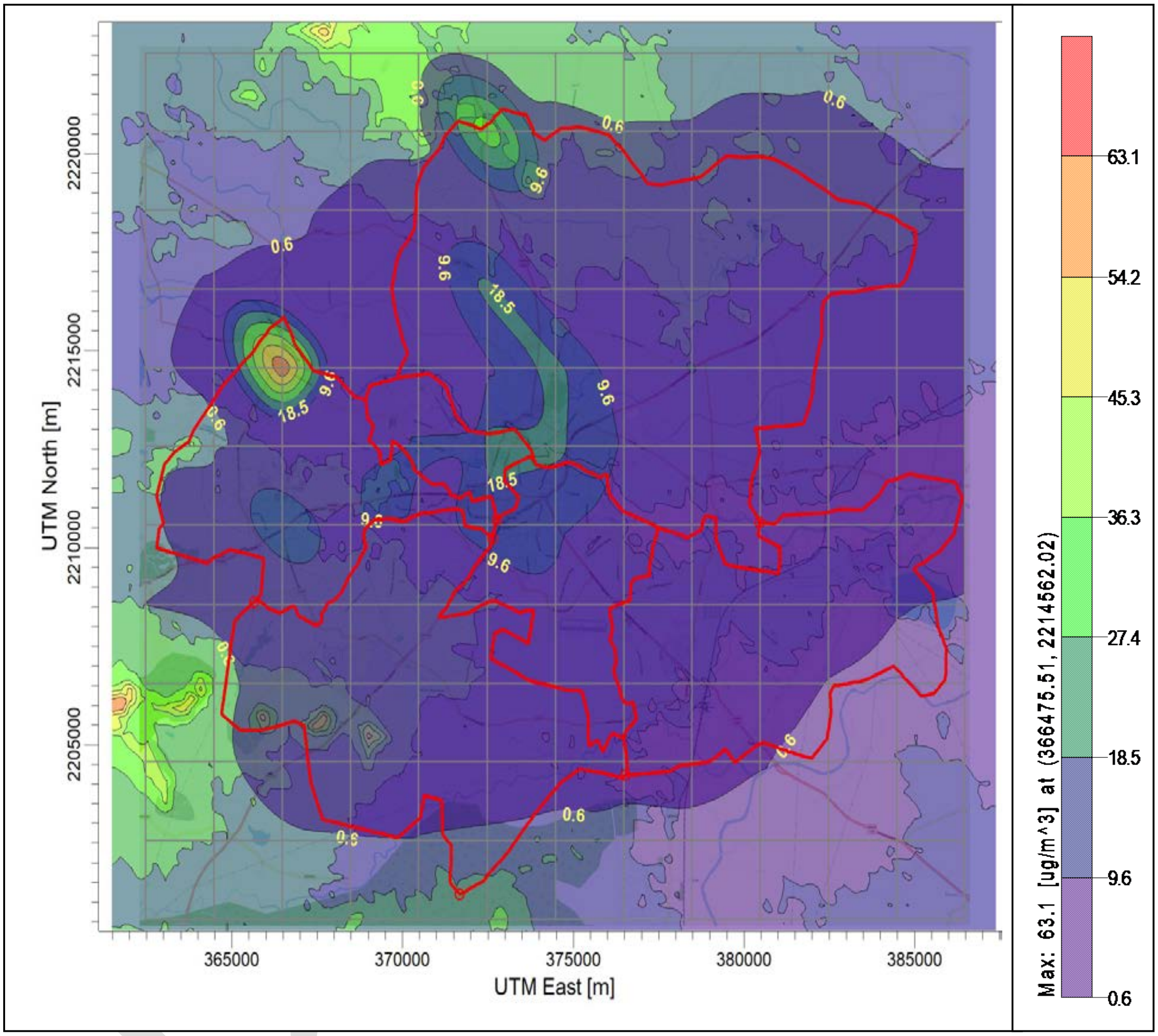

Figure P10 : Isopleths of PM Due to Resuspension Dust– Post Monsoon Season (Nashik City)

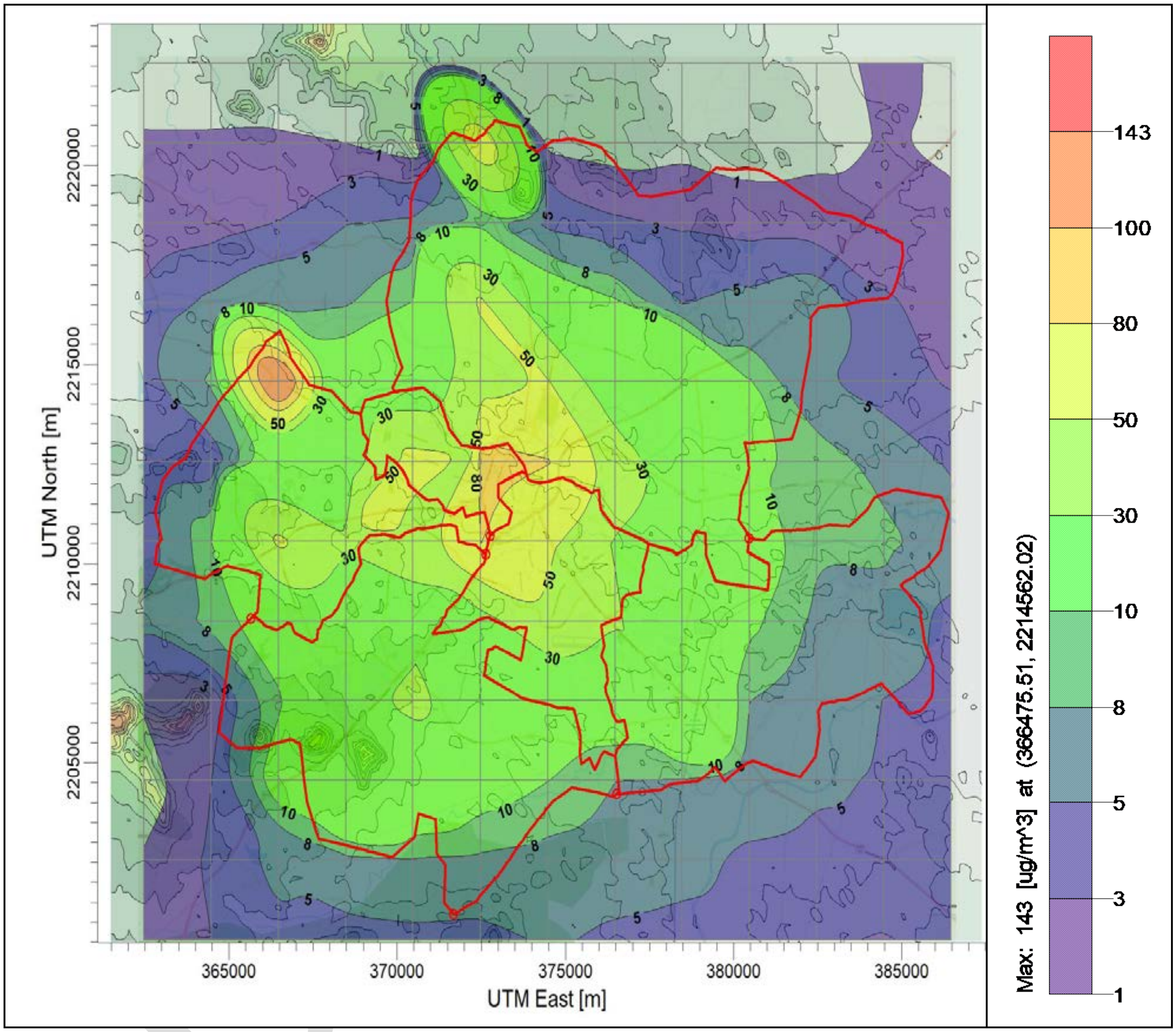

Figure P11 : Isopleths of PM Due to Resuspension Dust– Winter Season (Nashik City)

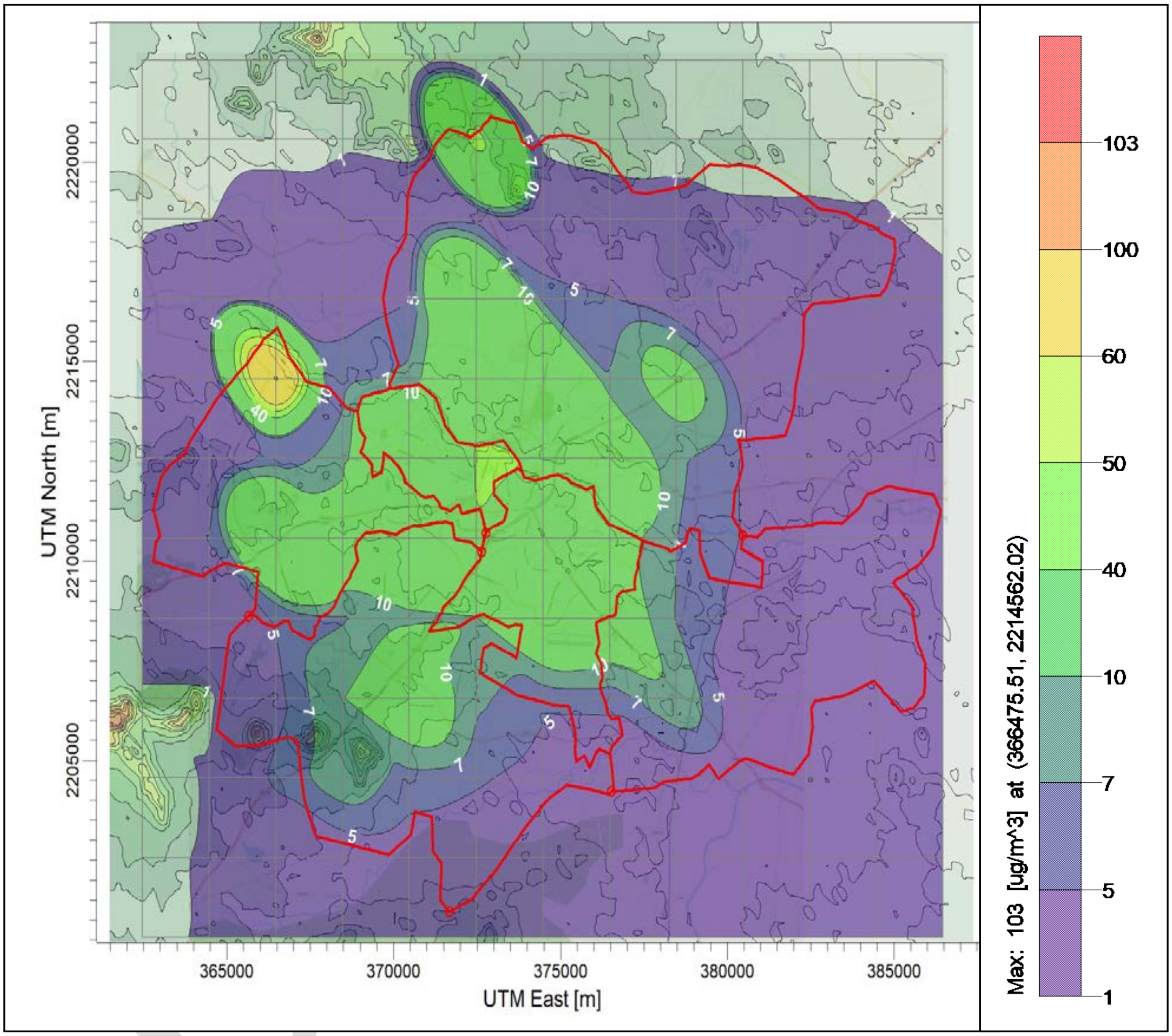

Figure P12 : Isopleths of PM Due to Resuspension Dust– Annual (Nashik City)

D) POINT SOURCE – LSI PM

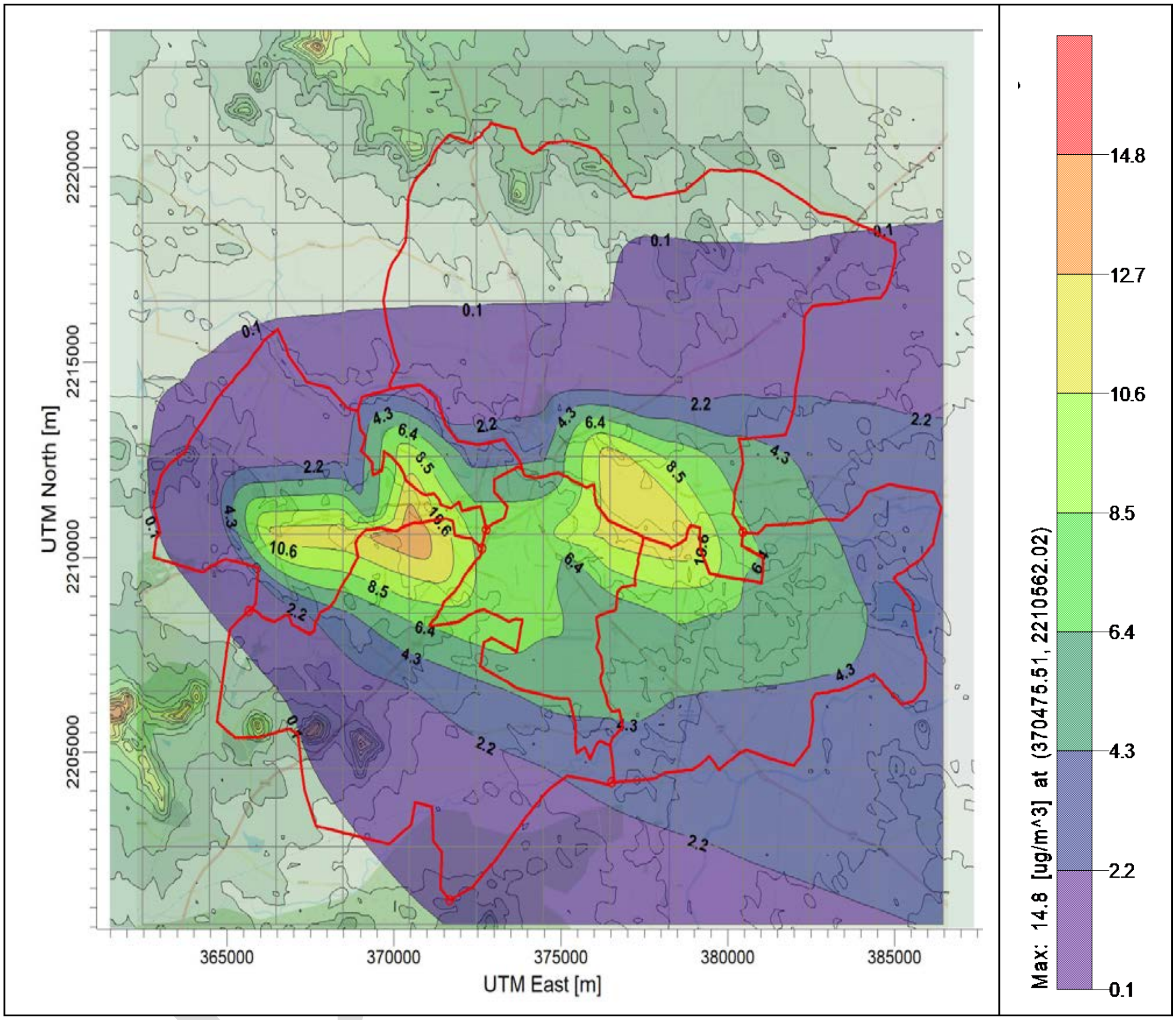

Figure P13 : Isopleths of PM Due to Point Sources (LSI) – Summer Season (Nashik City)

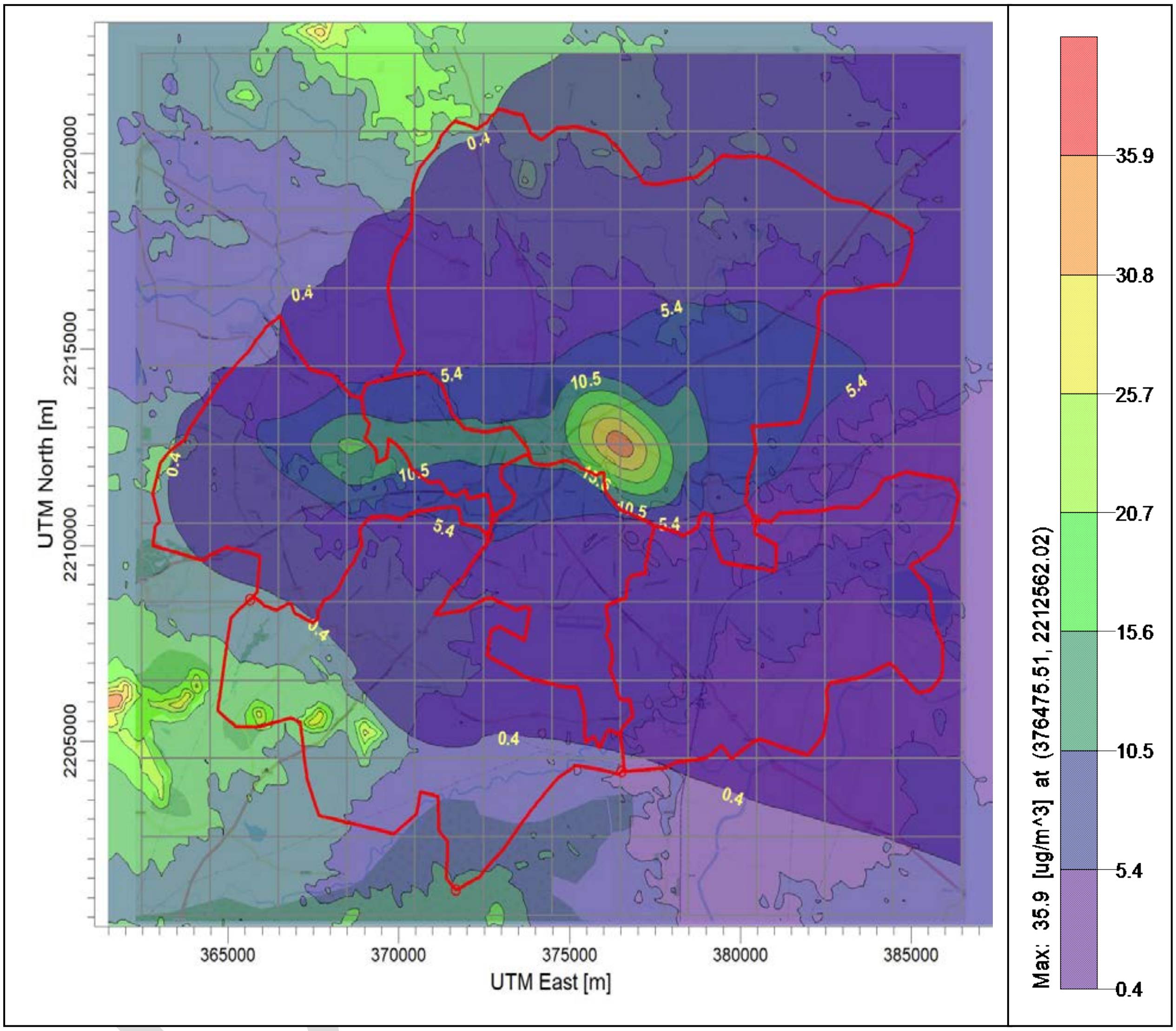

Figure P14 : Isopleths of PM Due to Point Sources (LSI) – Post Monsoon Season (Nashik City)

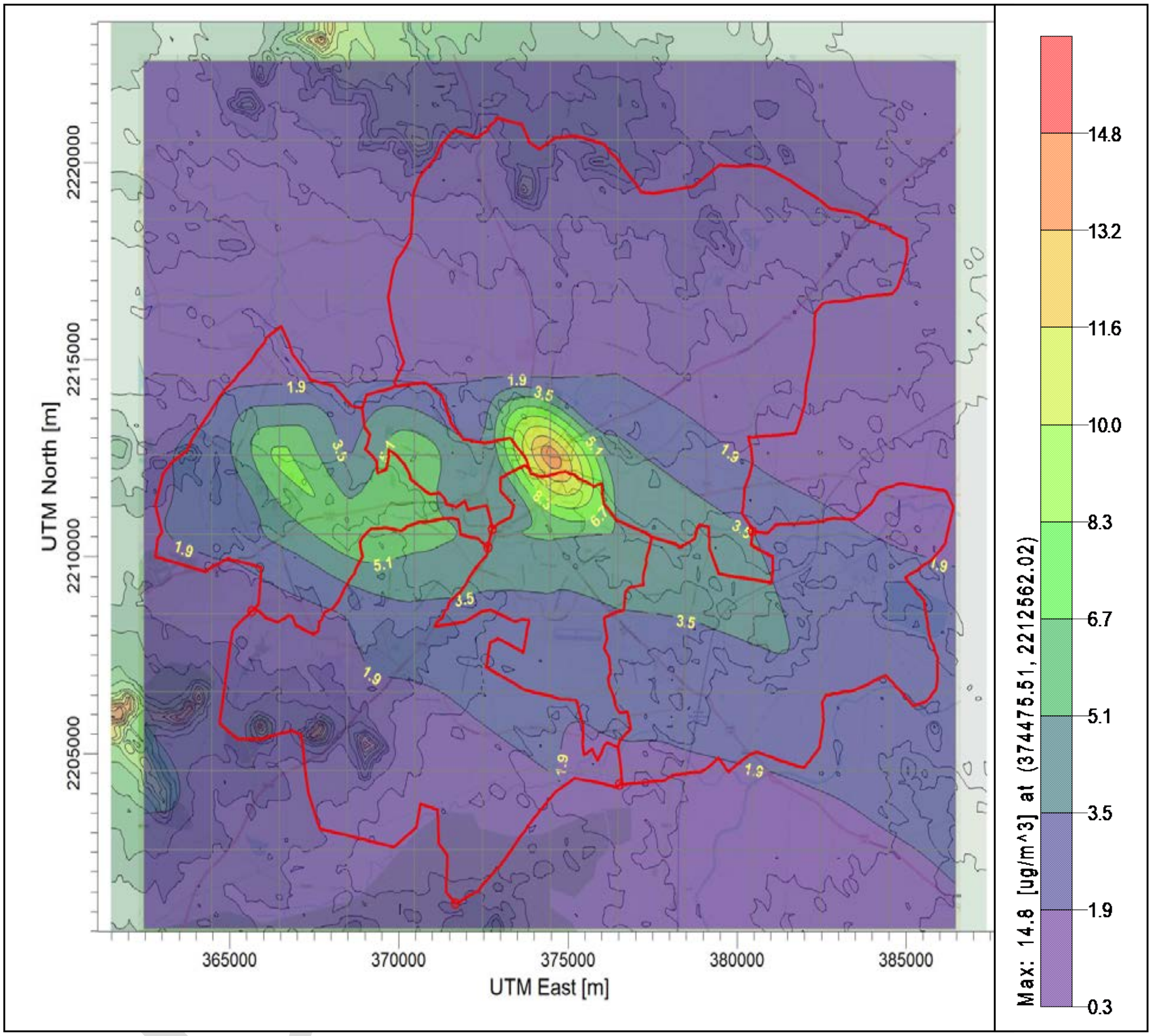

Figure P15 : Isopleths of PM Due to Point Sources (LSI) – Winter Season (Nashik City)

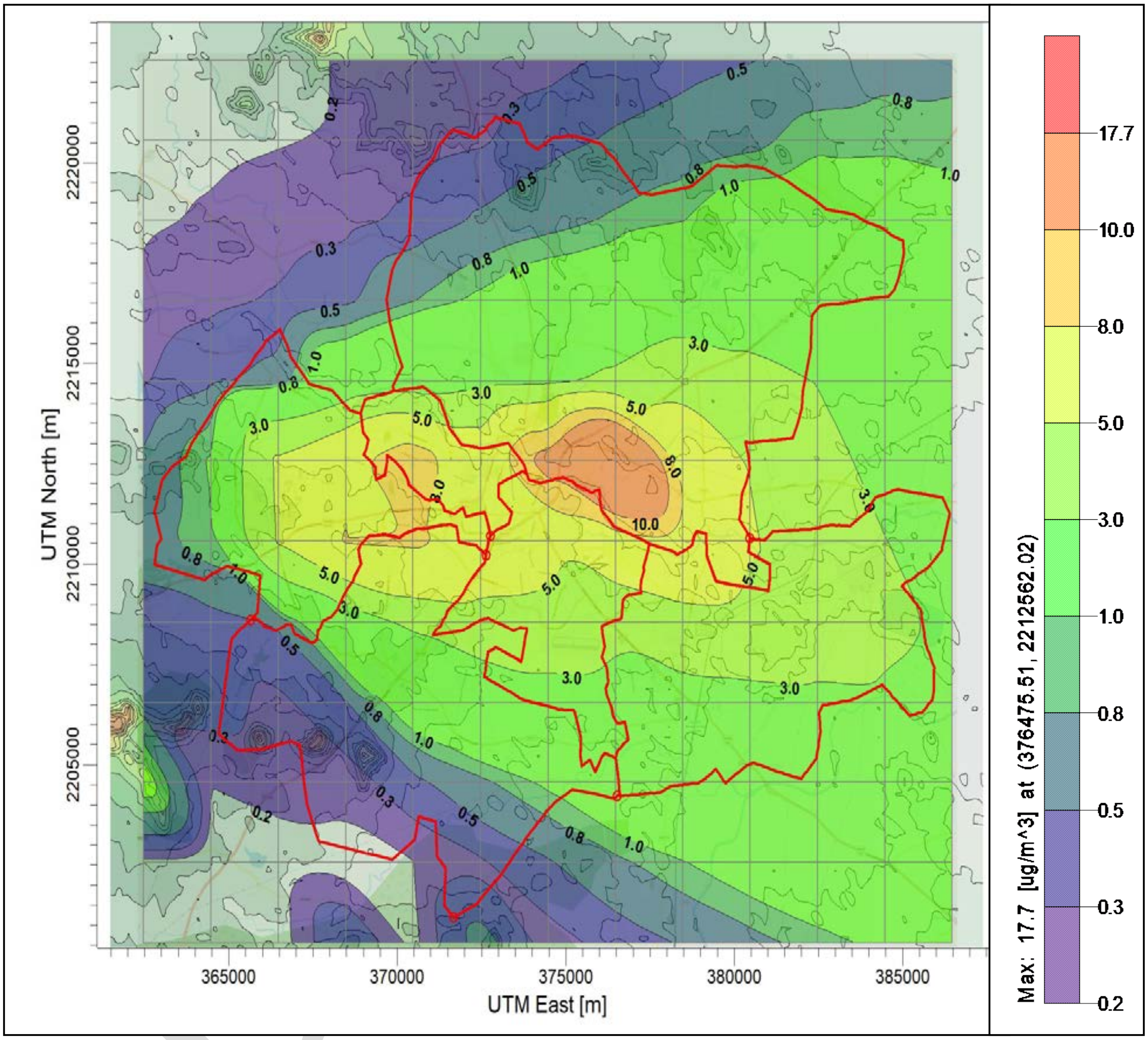

Figure P16 : Isopleths of PM Due to Point Sources (LSI) – Annual (Nashik City)

E) POINT SOURCE – MSI PM

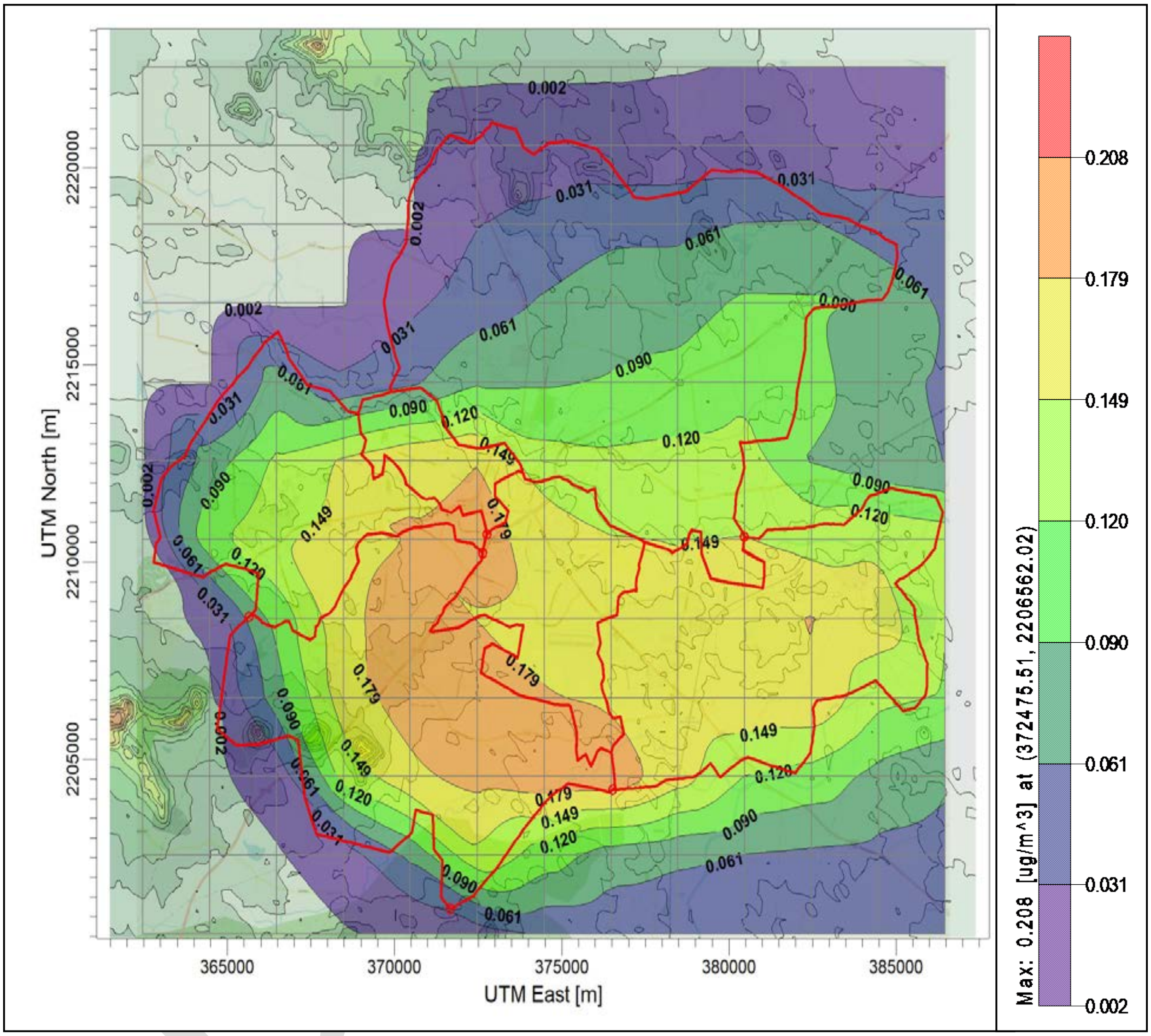

Figure P17 : Isopleths of PM Due to Point Sources (MSI)– Summer Season (Nashik City)

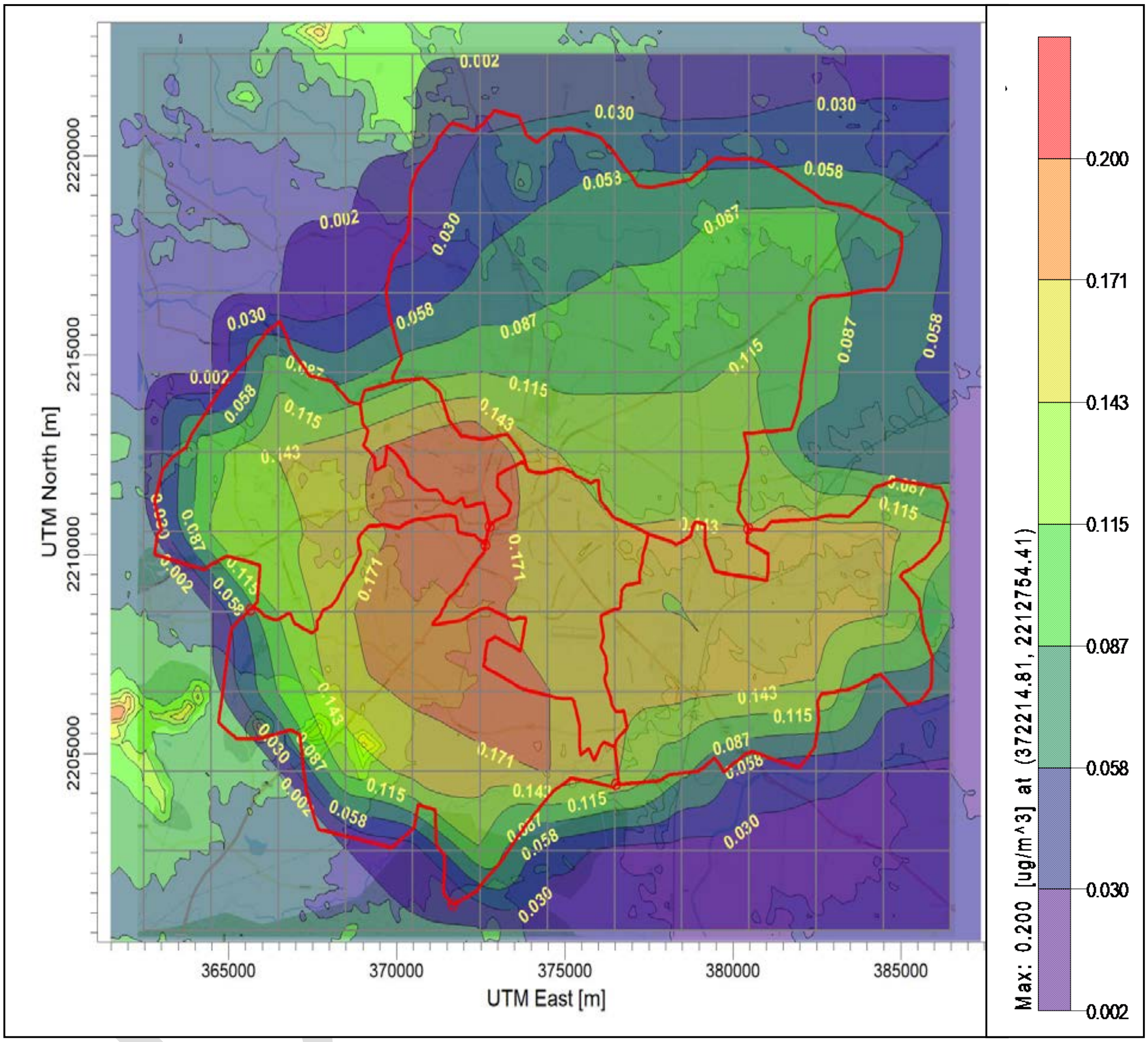

Figure P18 : Isopleths of PM Due to Point Sources (MSI)– Post Monsoon Season (Nashik City)

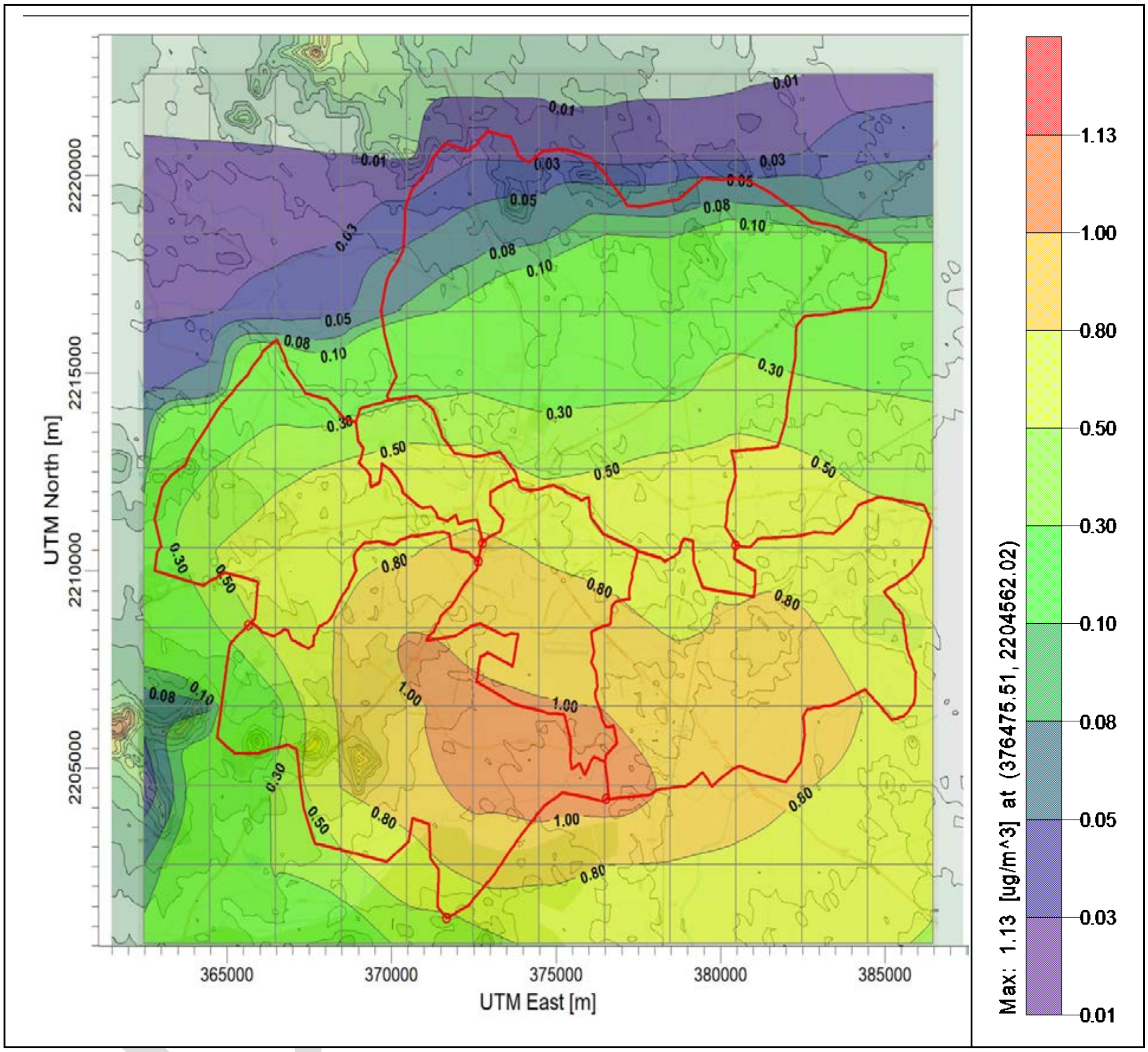

Figure P19 : Isopleths of PM Due to Point Sources (MSI) – Winter Season (Nashik City)

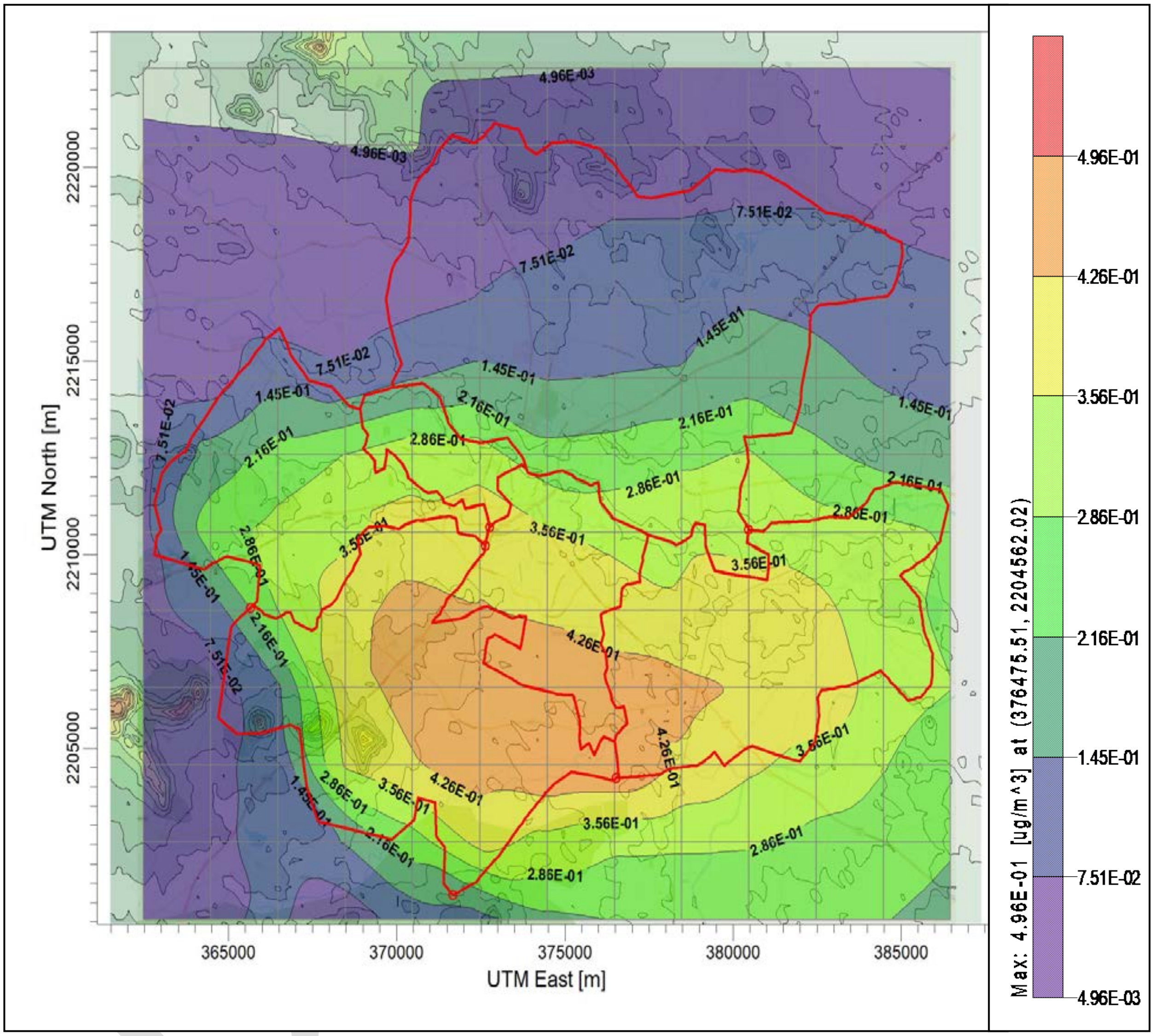

Figure P20 : Isopleths of PM Due to Point Sources (MSI) – Annual (Nashik City)

F) POINT SOURCE – SSI PM

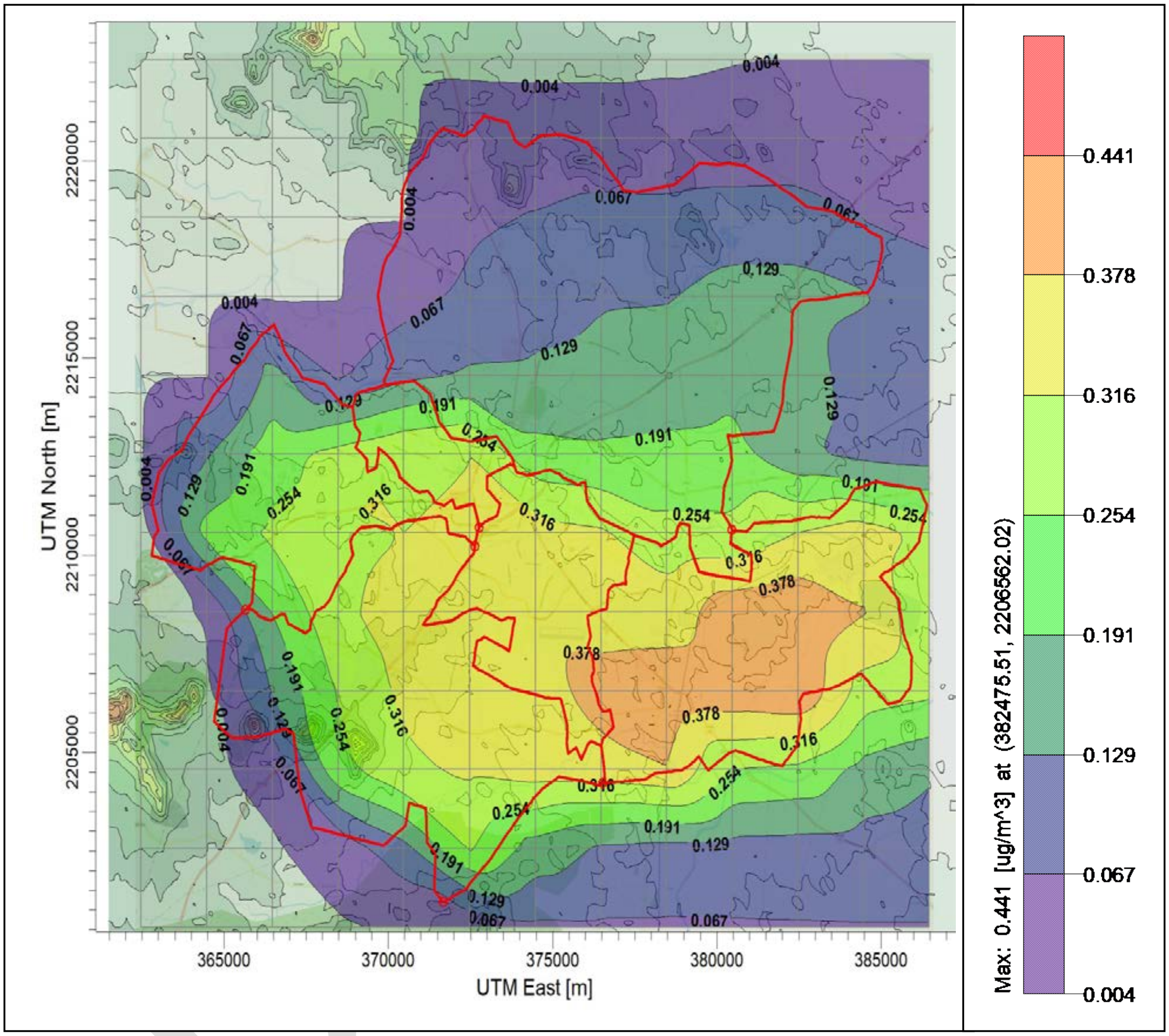

Figure P21 : Isopleths of PM Due to Point Sources (SSI) – Summer Season (Nashik City)

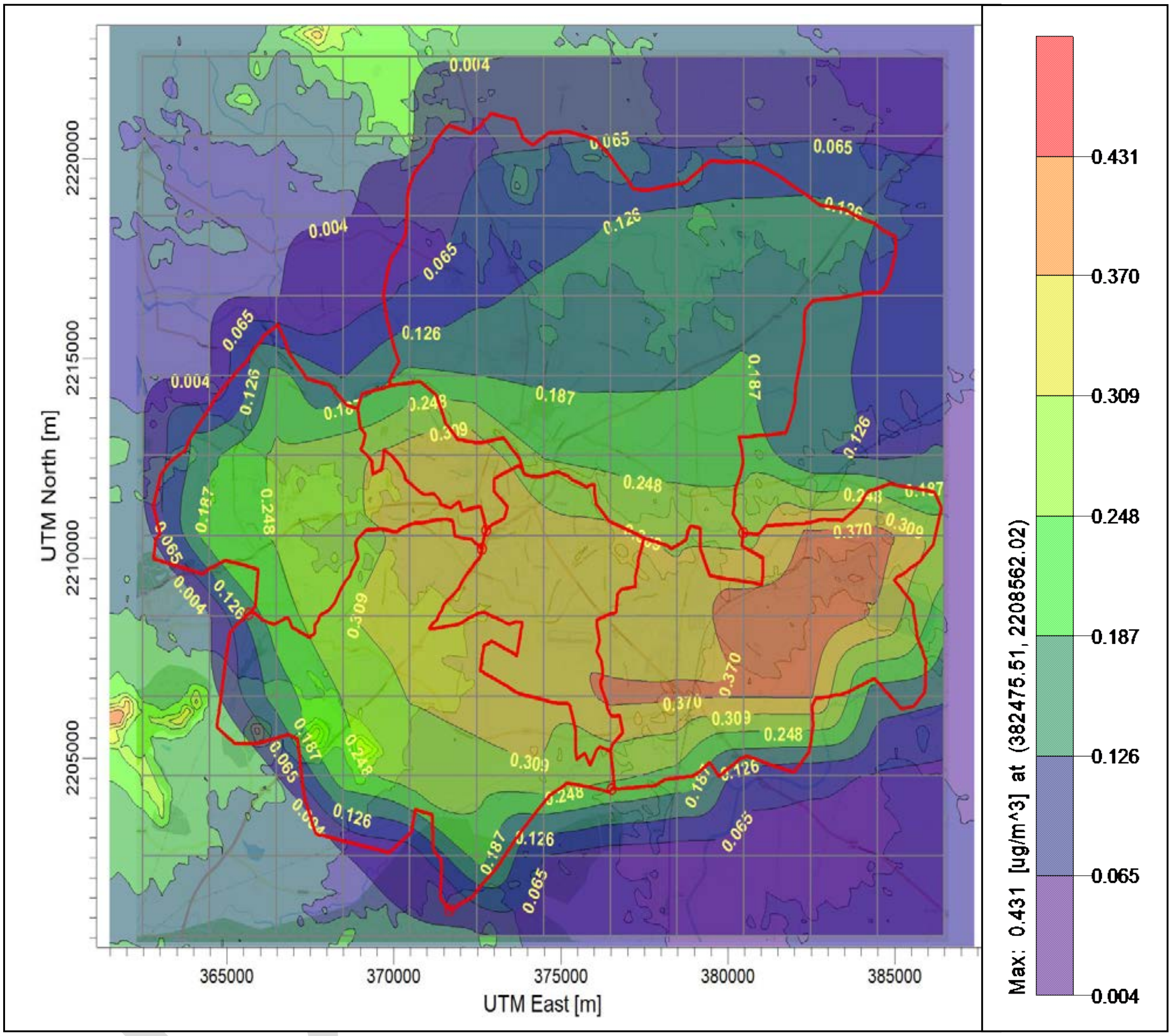

Figure P22 : Isopleths of PM Due to Point Sources (SSI) – Post Monsoon Season (Nashik City)

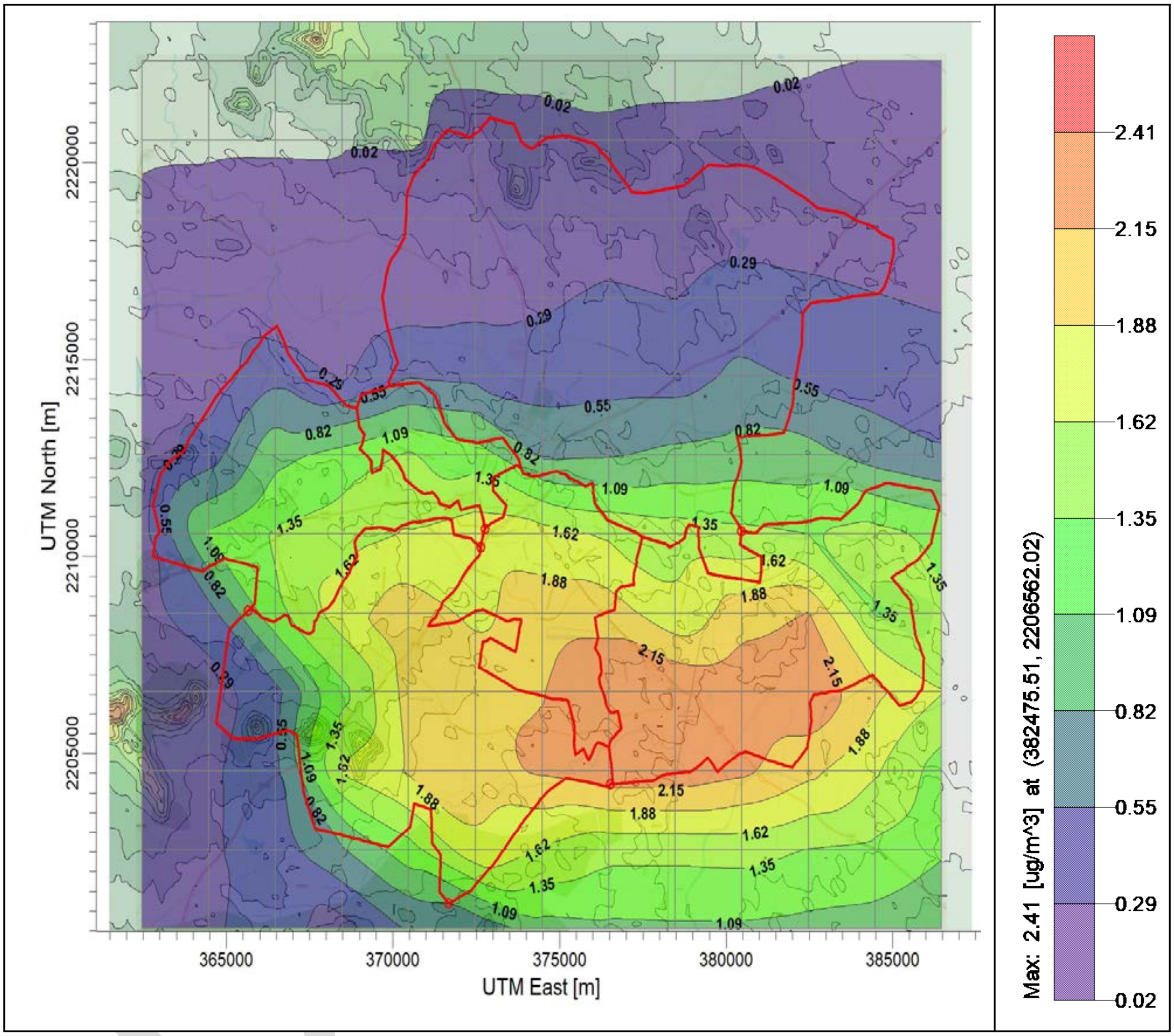

Figure P23 : Isopleths of PM Due to Point Sources (SSI) – Winter Season (Nashik City)

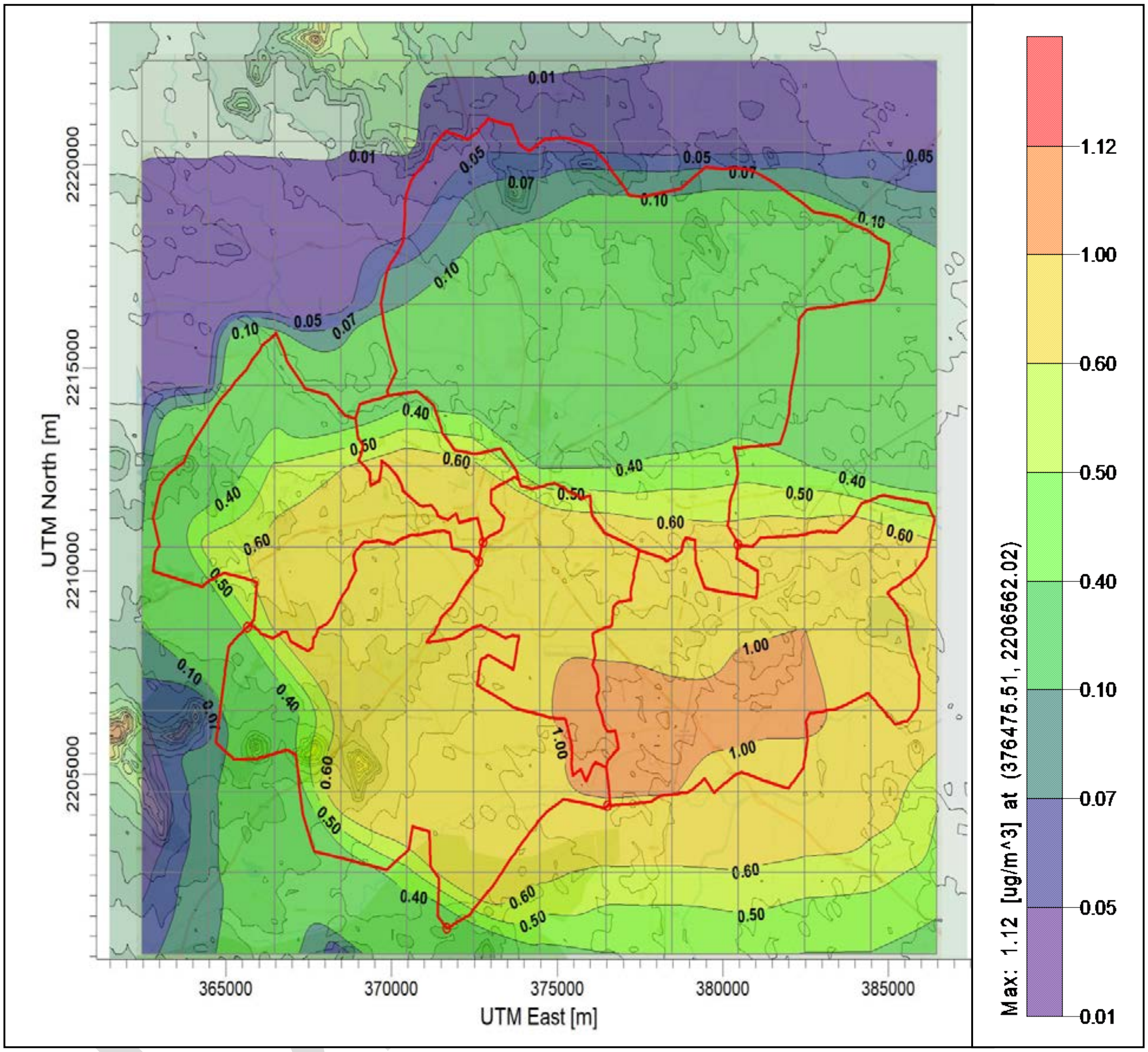

Figure P24 : Isopleths of PM Due to Point Sources (SSI) – Annual (Nashik City)

ANNEXURE – 3

Maximum Ten Concentrations of PM_{10} (Annual) BaU 2018, 2020, 2025 and Preferred Option I -2020, Preferred Option II – 2025

Nashik City

Annexure 3

A) Maximum Ten Occurrences of PM_{10} Concentrations in BaU 2018 at Nashik City (Annual)

Annual - All Source – BaU 2018			
	X length,m	Y length,m	Concentration µg/m^3
1st	366475.51	2214562.02	417.01
2nd	366475.51	2214562.02	291.07
3rd	366475.51	2214562.02	174.54
4th	366475.51	2214562.02	101.90
5th	366475.51	2214562.02	69.13
6th	366475.51	2214562.02	60.98
7th	366475.51	2214562.02	59.77
8th	366475.51	2214562.02	53.47
9th	366475.51	2214562.02	51.19
10th	366475.51	2214562.02	49.02
Avg.	366475.51	2214562.02	117.65

Annual - Area Source – BaU 2018			
	X length,m	Y length,m	Concentration µg/m^3
1st	374475.51	2204562.02	43.09
2nd	370475.51	2204562.02	24.09
3rd	368475.51	2204562.02	16.95
4th	372475.51	2206562.02	9.02
5th	370627.55	2208048.15	4.98
6th	372208.92	2212740.26	4.44
7th	370627.55	2208048.15	4.28
8th	370627.55	2208048.15	4.23
9th	370627.55	2208048.15	4.01
10th	372475.51	2206562.02	3.73
Avg.	374475.51	2204562.02	9.76

Annual – Point Source (LSI) – BaU 2018			
	X length,m	Y length,m	Concentration µg/m^3
1st	376475.51	2212562.02	53.31
2nd	376475.51	2212562.02	43.09
3rd	376475.51	2212562.02	35.88
4th	376475.51	2212562.02	25.61
5th	376475.51	2212562.02	20.41
6th	376475.51	2212562.02	11.33
7th	374475.51	2212562.02	9.82
8th	374475.51	2212562.02	8.97
9th	374475.51	2212562.02	8.40
10th	370475.51	2212562.02	6.01
All Avg.	376475.51	2212562.02	17.68

Annual – Point Source (MSI) – BaU 2018			
	X length,m	Y length,m	Concentration µg/m^3
1st	376475.51	2212562.02	0.51
2nd	376475.51	2212562.02	0.48
3rd	376475.51	2212562.02	0.48
4th	376475.51	2212562.02	0.44
5th	376475.51	2212562.02	0.16
6th	376475.51	2212562.02	0.15
7th	374475.51	2212562.02	0.17
8th	374475.51	2212562.02	0.15
9th	374475.51	2212562.02	0.14
10th	370475.51	2212562.02	0.16
Avg.	376475.51	2212562.02	0.24

Annual – Point Source (SSI) – BaU 2018			
	X length,m	Y length,m	Concentration µg/m^3
1st	380475.51	2204562.02	4.88
2nd	376475.51	2204562.02	3.05
3rd	376475.51	2206562.02	1.95
4th	382475.51	2208562.02	1.47
5th	382475.51	2208562.02	0.51
6th	382475.51	2208562.02	0.50
7th	382475.51	2208562.02	0.49
8th	382475.51	2208562.02	0.48
9th	382475.51	2208562.02	0.44
10th	382475.51	2206562.02	0.41
Avg.	376475.51	2206562.02	1.12

A) Maximum Ten Occurrences of PM_{10} Concentrations in BaU 2018 at Nashik City (Annual) (Contd..)

Annual – Line Source – BaU 2018			
	X length,m	**Y length,m**	**Concentration µg/m^3**
1st	374475.51	2212562.02	47.87
2nd	372475.51	2210562.02	33.46
3rd	372475.51	2212562.02	24.87
4th	369264.06	2211128.05	13.73
5th	369264.06	2211128.05	6.96
6th	369264.06	2211128.05	6.89
7th	369264.06	2211128.05	6.78
8th	369264.06	2211128.05	6.47
9th	369264.06	2211128.05	6.14
10th	369264.06	2211128.05	6.02
Avg.	372475.51	2212562.02	12.11

Annual – Resuspended Dust– BaU 2018			
	X length,m	**Y length,m**	**Concentration µg/m^3**
1st	366475.51	2214562.02	363.16
2nd	366475.51	2214562.02	254.18
3rd	366475.51	2214562.02	152.31
4th	366475.51	2214562.02	88.29
5th	366475.51	2214562.02	60.83
6th	366475.51	2214562.02	53.90
7th	366475.51	2214562.02	52.82
8th	366475.51	2214562.02	47.19
9th	366475.51	2214562.02	45.17
10th	366475.51	2214562.02	43.31
Avg.	366475.51	2214562.02	102.92

B) Maximum Ten Occurrences of PM_{10} Concentrations in BaU 2020 at Nashik City (Annual)

Annual - All Source – BaU 2020			
	X length,m	Y length,m	Concentration µg/m^3
1st	366475.51	2214562.02	444.07
2nd	366475.51	2214562.02	309.94
3rd	366475.51	2214562.02	185.76
4th	366475.51	2214562.02	108.38
5th	366475.51	2214562.02	73.57
6th	366475.51	2214562.02	64.91
7th	366475.51	2214562.02	63.63
8th	366475.51	2214562.02	56.92
9th	366475.51	2214562.02	54.50
10th	366475.51	2214562.02	52.18
Avg.	366475.51	2214562.02	125.24

Annual - Area Source – BaU 2020			
	X length,m	Y length,m	Concentration µg/m^3
1st	374475.51	2204562.02	45.46
2nd	370475.51	2204562.02	25.42
3rd	368475.51	2204562.02	17.88
4th	372475.51	2206562.02	9.52
5th	370627.55	2208048.15	5.25
6th	372208.92	2212740.26	4.69
7th	370627.55	2208048.15	4.52
8th	370627.55	2208048.15	4.46
9th	370627.55	2208048.15	4.23
10th	372475.51	2206562.02	3.93
Avg.	374475.51	2204562.02	10.30

Annual – Point Source (LSI) – BaU 2020			
	X length,m	Y length,m	Concentration µg/m^3
1st	376475.51	2212562.02	53.31
2nd	376475.51	2212562.02	43.09
3rd	376475.51	2212562.02	35.88
4th	376475.51	2212562.02	25.61
5th	376475.51	2212562.02	20.41
6th	376475.51	2212562.02	11.33
7th	374475.51	2212562.02	9.82
8th	374475.51	2212562.02	8.97
9th	374475.51	2212562.02	8.40
10th	370475.51	2212562.02	6.01
All Avg.	376475.51	2212562.02	17.68

Annual – Point Source (MSI) – BaU 2020			
	X length,m	Y length,m	Concentration µg/m^3
1st	380475.51	2204562.02	1.82
2nd	376475.51	2204562.02	1.47
3rd	370627.55	2208048.15	0.95
4th	382475.51	2208562.02	0.64
5th	370475.51	2208562.02	0.23
6th	370475.51	2208562.02	0.23
7th	370475.51	2208562.02	0.22
8th	370475.51	2208562.02	0.22
9th	370475.51	2208562.02	0.20
10th	372475.51	2206562.02	0.19
Avg.	376475.51	2204562.02	0.50

Annual – Point Source (SSI) – BaU 2020			
	X length,m	Y length,m	Concentration µg/m^3
1st	380475.51	2204562.02	4.88
2nd	376475.51	2204562.02	3.05
3rd	376475.51	2206562.02	1.95
4th	382475.51	2208562.02	1.47
5th	382475.51	2208562.02	0.51
6th	382475.51	2208562.02	0.50
7th	382475.51	2208562.02	0.49
8th	382475.51	2208562.02	0.48
9th	382475.51	2208562.02	0.44
10th	382475.51	2206562.02	0.41
Avg.	376475.51	2206562.02	1.12

B) Maximum Ten Occurrences of PM_{10} Concentrations in BaU 2020 at Nashik City (Annual) (Contd..)

Annual – Line Source – BaU 2020			
	X length,m	Y length,m	Concentration µg/m^3
1st	374475.51	2212562.02	51.00
2nd	372475.51	2210562.02	35.65
3rd	372475.51	2212562.02	26.50
4th	369264.06	2211128.05	14.63
5th	369264.06	2211128.05	7.41
6th	369264.06	2211128.05	7.34
7th	369264.06	2211128.05	7.22
8th	369264.06	2211128.05	6.89
9th	369264.06	2211128.05	6.54
10th	369264.06	2211128.05	6.41
Avg.	372475.51	2212562.02	12.90

Annual – Resuspended Dust– BaU 2020			
	X length,m	Y length,m	Concentration µg/m^3
1st	366475.51	2214562.02	386.87
2nd	366475.51	2214562.02	270.77
3rd	366475.51	2214562.02	162.26
4th	366475.51	2214562.02	94.06
5th	366475.51	2214562.02	64.80
6th	366475.51	2214562.02	57.42
7th	366475.51	2214562.02	56.27
8th	366475.51	2214562.02	50.27
9th	366475.51	2214562.02	48.12
10th	366475.51	2214562.02	46.14
Avg.	366475.51	2214562.02	109.64

C) Maximum Ten Occurrences of PM_{10} Concentrations in BaU 2025 at Nashik City (Annual)

Annual - All Source – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	366475.51	2214562.02	445.19
2nd	366475.51	2214562.02	306.35
3rd	366475.51	2214562.02	189.58
4th	366475.51	2214562.02	114.06
5th	366475.51	2214562.02	77.92
6th	366475.51	2214562.02	68.63
7th	366475.51	2214562.02	67.25
8th	366475.51	2214562.02	60.12
9th	366475.51	2214562.02	57.53
10th	366475.51	2214562.02	55.18
Avg.	366475.51	2214562.02	128.07

Annual - Area Source – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	374475.51	2204562.02	48.64
2nd	370475.51	2204562.02	27.20
3rd	368475.51	2204562.02	19.13
4th	372475.51	2206562.02	10.18
5th	370627.55	2208048.15	5.62
6th	372208.92	2212740.26	5.02
7th	370627.55	2208048.15	4.83
8th	370627.55	2208048.15	4.78
9th	370627.55	2208048.15	4.53
10th	372475.51	2206562.02	4.21
Avg.	374475.51	2204562.02	11.02

Annual – Point Source (LSI) – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	376475.51	2212562.02	53.31
2nd	376475.51	2212562.02	43.09
3rd	376475.51	2212562.02	35.88
4th	376475.51	2212562.02	25.61
5th	376475.51	2212562.02	20.41
6th	376475.51	2212562.02	11.33
7th	374475.51	2212562.02	9.82
8th	374475.51	2212562.02	8.97
9th	374475.51	2212562.02	8.40
10th	370475.51	2212562.02	6.01
All Avg.	376475.51	2212562.02	17.68

Annual – Point Source (MSI) – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	380475.51	2204562.02	1.82
2nd	376475.51	2204562.02	1.47
3rd	370627.55	2208048.15	0.95
4th	382475.51	2208562.02	0.64
5th	370475.51	2208562.02	0.23
6th	370475.51	2208562.02	0.23
7th	370475.51	2208562.02	0.22
8th	370475.51	2208562.02	0.22
9th	370475.51	2208562.02	0.20
10th	372475.51	2206562.02	0.19
Avg.	376475.51	2204562.02	0.50

Annual – Point Source (SSI) – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	380475.51	2204562.02	4.88
2nd	376475.51	2204562.02	3.05
3rd	376475.51	2206562.02	1.95
4th	382475.51	2208562.02	1.47
5th	382475.51	2208562.02	0.51
6th	382475.51	2208562.02	0.50
7th	382475.51	2208562.02	0.49
8th	382475.51	2208562.02	0.48
9th	382475.51	2208562.02	0.44
10th	382475.51	2206562.02	0.41
Avg.	376475.51	2206562.02	1.12

C) Maximum Ten Occurrences of PM_{10} Concentrations in BaU 2025 at Nashik City (Annual) (Contd..)

Annual – Line Source – BaU 2025			
	X length,m	**Y length,m**	**Concentration µg/m³**
1st	374475.51	2212562.02	54.01
2nd	372475.51	2210562.02	38.39
3rd	372475.51	2212562.02	28.93
4th	369264.06	2211128.05	16.08
5th	369264.06	2211128.05	7.97
6th	369264.06	2211128.05	7.91
7th	369264.06	2211128.05	7.70
8th	369264.06	2211128.05	7.48
9th	369264.06	2211128.05	7.21
10th	369264.06	2211128.05	7.11
Avg.	372475.51	2212562.02	14.03

Annual – Resuspended Dust– BaU 2025			
	X length,m	**Y length,m**	**Concentration µg/m³**
1st	366475.51	2214562.02	388.36
2nd	366475.51	2214562.02	267.62
3rd	366475.51	2214562.02	165.56
4th	366475.51	2214562.02	99.09
5th	366475.51	2214562.02	68.67
6th	366475.51	2214562.02	60.73
7th	366475.51	2214562.02	59.50
8th	366475.51	2214562.02	53.11
9th	366475.51	2214562.02	50.81
10th	366475.51	2214562.02	48.80
Avg.	366475.51	2214562.02	112.18

D) Maximum Ten Occurrences of PM_{10} Concentrations after Implementation of Control Options (Preferred Option I -2020) at Nashik City (Annual)

Annual All Source Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m³
1st	366475.51	2214562.02	210.62
2nd	366475.51	2214562.02	144.95
3rd	366475.51	2214562.02	89.75
4th	366475.51	2214562.02	54.03
5th	366475.51	2214562.02	36.89
6th	366475.51	2214562.02	32.48
7th	366475.51	2214562.02	31.83
8th	366475.51	2214562.02	28.45
9th	366475.51	2214562.02	27.22
10th	366475.51	2214562.02	26.11
Avg.	366475.51	2214562.02	60.61

Annual Area Source Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m³
1st	374475.51	2204562.02	23.14
2nd	370475.51	2204562.02	12.94
3rd	368475.51	2204562.02	9.10
4th	372475.51	2206562.02	4.84
5th	370627.55	2208048.15	2.67
6th	372208.92	2212740.26	2.39
7th	370627.55	2208048.15	2.30
8th	370627.55	2208048.15	2.27
9th	370627.55	2208048.15	2.15
10th	372475.51	2206562.02	2.00
Avg.	374475.51	2204562.02	5.24

Annual Point Source (LSI) Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m³
1st	376475.51	2212562.02	27.14
2nd	376475.51	2212562.02	21.93
3rd	376475.51	2212562.02	18.26
4th	376475.51	2212562.02	13.04
5th	376475.51	2212562.02	10.39
6th	376475.51	2212562.02	5.77
7th	374475.51	2212562.02	5.00
8th	374475.51	2212562.02	4.56
9th	374475.51	2212562.02	4.28
10th	370475.51	2212562.02	3.06
All Avg.	376475.51	2212562.02	9.00

Annual Point Source (MSI) Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m³
1st	380475.51	2204562.02	0.93
2nd	376475.51	2204562.02	0.75
3rd	370627.55	2208048.15	0.48
4th	382475.51	2208562.02	0.33
5th	370475.51	2208562.02	0.12
6th	370475.51	2208562.02	0.11
7th	370475.51	2208562.02	0.11
8th	370475.51	2208562.02	0.11
9th	370475.51	2208562.02	0.10
10th	372475.51	2206562.02	0.10
Avg.	376475.51	2204562.02	0.25

Annual Point Source (SSI) Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m³
1st	380475.51	2204562.02	2.48
2nd	376475.51	2204562.02	1.55
3rd	376475.51	2206562.02	0.99
4th	382475.51	2208562.02	0.75
5th	382475.51	2208562.02	0.26
6th	382475.51	2208562.02	0.25
7th	382475.51	2208562.02	0.25
8th	382475.51	2208562.02	0.24
9th	382475.51	2208562.02	0.22
10th	382475.51	2206562.02	0.21
Avg.	376475.51	2206562.02	0.57

D) Maximum Ten Occurrences of PM_{10} Concentrations after Implementation of Control Options (Preferred Option I -2020) at Nashik City (Annual) (Contd..)

Annual Line Source Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m^3
1st	374475.51	2212562.02	25.54
2nd	372475.51	2210562.02	18.15
3rd	372475.51	2212562.02	13.68
4th	369264.06	2211128.05	7.61
5th	369264.06	2211128.05	3.77
6th	369264.06	2211128.05	3.74
7th	369264.06	2211128.05	3.64
8th	369264.06	2211128.05	3.54
9th	369264.06	2211128.05	3.41
10th	369264.06	2211128.05	3.36
Avg.	372475.51	2212562.02	6.64

Annual Resuspended Dust Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m^3
1st	366475.51	2214562.02	183.66
2nd	366475.51	2214562.02	126.56
3rd	366475.51	2214562.02	78.30
4th	366475.51	2214562.02	46.86
5th	366475.51	2214562.02	32.48
6th	366475.51	2214562.02	28.72
7th	366475.51	2214562.02	28.14
8th	366475.51	2214562.02	25.12
9th	366475.51	2214562.02	24.03
10th	366475.51	2214562.02	23.08
Avg.	366475.51	2214562.02	53.05

E) Maximum Ten Occurrences of PM_{10} Concentrations after Implementation of Control Options (Preferred Option II -2025) at Nashik City (Annual)

Annual All Source Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m³
1st	366475.51	2214562.02	104.62
2nd	366475.51	2214562.02	71.99
3rd	366475.51	2214562.02	44.55
4th	366475.51	2214562.02	26.80
5th	366475.51	2214562.02	18.31
6th	366475.51	2214562.02	16.13
7th	366475.51	2214562.02	15.80
8th	366475.51	2214562.02	14.13
9th	366475.51	2214562.02	13.52
10th	366475.51	2214562.02	12.97
Avg.	366475.51	2214562.02	30.10

Annual Area Source Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m³
1st	374475.51	2204562.02	11.43
2nd	370475.51	2204562.02	6.39
3rd	368475.51	2204562.02	4.50
4th	372475.51	2206562.02	2.39
5th	370627.55	2208048.15	1.32
6th	372208.92	2212740.26	1.18
7th	370627.55	2208048.15	1.14
8th	370627.55	2208048.15	1.12
9th	370627.55	2208048.15	1.06
10th	372475.51	2206562.02	0.99
Avg.	374475.51	2204562.02	2.59

Annual Point Source (LSI) Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m³
1st	376475.51	2212562.02	12.53
2nd	376475.51	2212562.02	10.13
3rd	376475.51	2212562.02	8.43
4th	376475.51	2212562.02	6.02
5th	376475.51	2212562.02	4.80
6th	376475.51	2212562.02	2.66
7th	374475.51	2212562.02	2.31
8th	374475.51	2212562.02	2.11
9th	374475.51	2212562.02	1.97
10th	370475.51	2212562.02	1.41
All Avg.	376475.51	2212562.02	4.15

Annual Point Source (MSI) Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m³
1st	380475.51	2204562.02	0.43
2nd	376475.51	2204562.02	0.35
3rd	370627.55	2208048.15	0.22
4th	382475.51	2208562.02	0.15
5th	370475.51	2208562.02	0.05
6th	370475.51	2208562.02	0.05
7th	370475.51	2208562.02	0.05
8th	370475.51	2208562.02	0.05
9th	370475.51	2208562.02	0.05
10th	372475.51	2206562.02	0.05
Avg.	376475.51	2204562.02	0.12

Annual Point Source (SSI) Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m³
1st	380475.51	2204562.02	1.15
2nd	376475.51	2204562.02	0.72
3rd	376475.51	2206562.02	0.46
4th	382475.51	2208562.02	0.35
5th	382475.51	2208562.02	0.12
6th	382475.51	2208562.02	0.12
7th	382475.51	2208562.02	0.11
8th	382475.51	2208562.02	0.11
9th	382475.51	2208562.02	0.10
10th	382475.51	2206562.02	0.10
Avg.	376475.51	2206562.02	0.26

E) Maximum Ten Occurrences of PM_{10} Concentrations after Implementation of Control Options (Preferred Option II -2025) at Nashik City (Annual) (Contd..)

Annual Line Source Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	374475.51	2212562.02	12.69
2nd	372475.51	2210562.02	9.02
3rd	372475.51	2212562.02	6.80
4th	369264.06	2211128.05	3.78
5th	369264.06	2211128.05	1.87
6th	369264.06	2211128.05	1.86
7th	369264.06	2211128.05	1.81
8th	369264.06	2211128.05	1.76
9th	369264.06	2211128.05	1.69
10th	369264.06	2211128.05	1.67
Avg.	372475.51	2212562.02	3.30

Annual Resuspended Dust Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	366475.51	2214562.02	91.27
2nd	366475.51	2214562.02	62.89
3rd	366475.51	2214562.02	38.91
4th	366475.51	2214562.02	23.29
5th	366475.51	2214562.02	16.14
6th	366475.51	2214562.02	14.27
7th	366475.51	2214562.02	13.98
8th	366475.51	2214562.02	12.48
9th	366475.51	2214562.02	11.94
10th	366475.51	2214562.02	11.47
Avg.	366475.51	2214562.02	26.36

ANNEXURE - 4

ISOPLETS OF NOx:

All Categories- (a)Area, (b) Line, (c) Resuspension of Dust, (d) Point –LSI, MSI & SSI

&

For All Seasons (Summer, Post Monsoon, Winter and Annual)

(Nashik City)

A) AREA SOURCE – ALL NOX

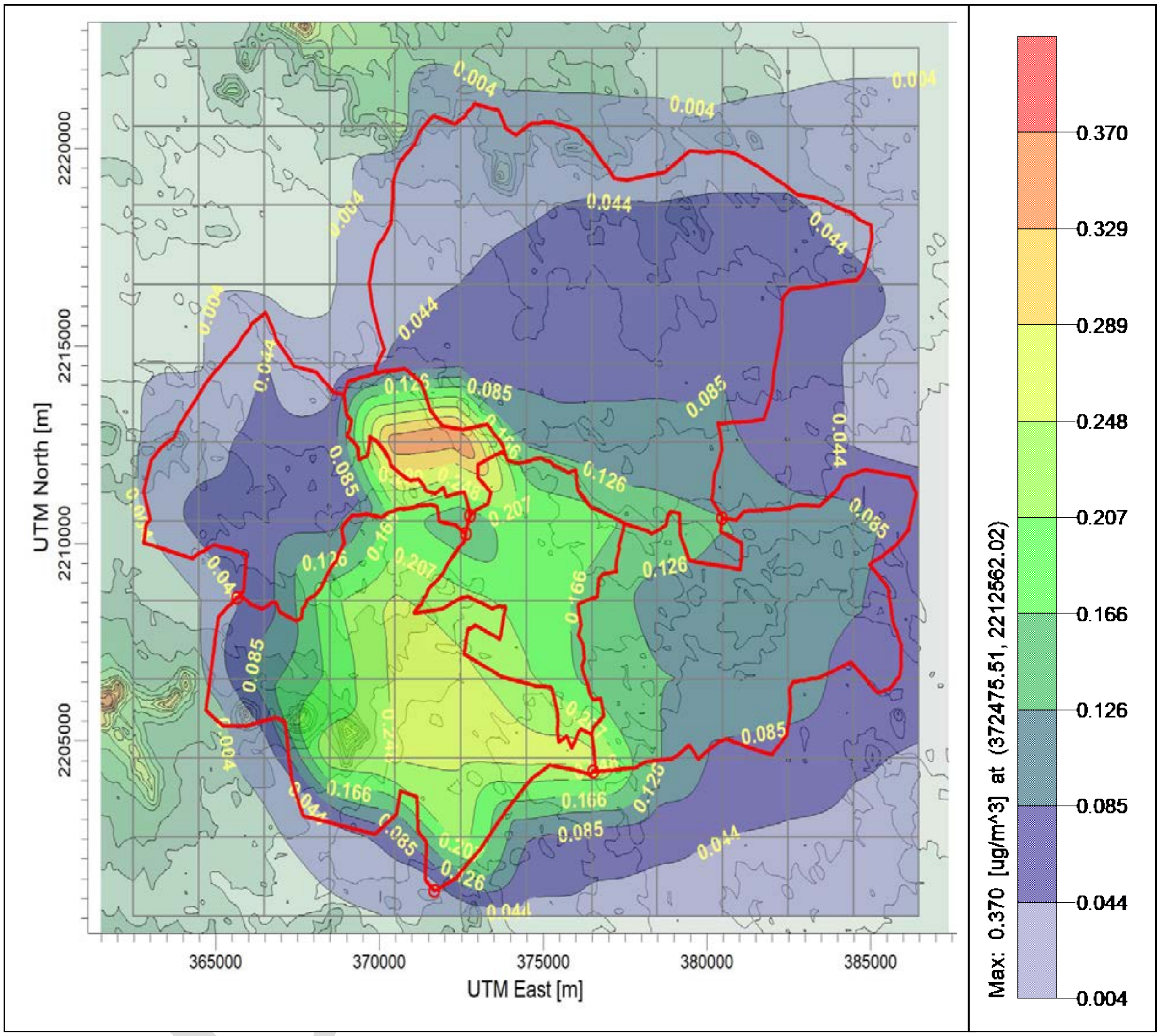

Figure N1 : Isopleths of NOx Due to Area Sources– Summer Season (Nashik City)

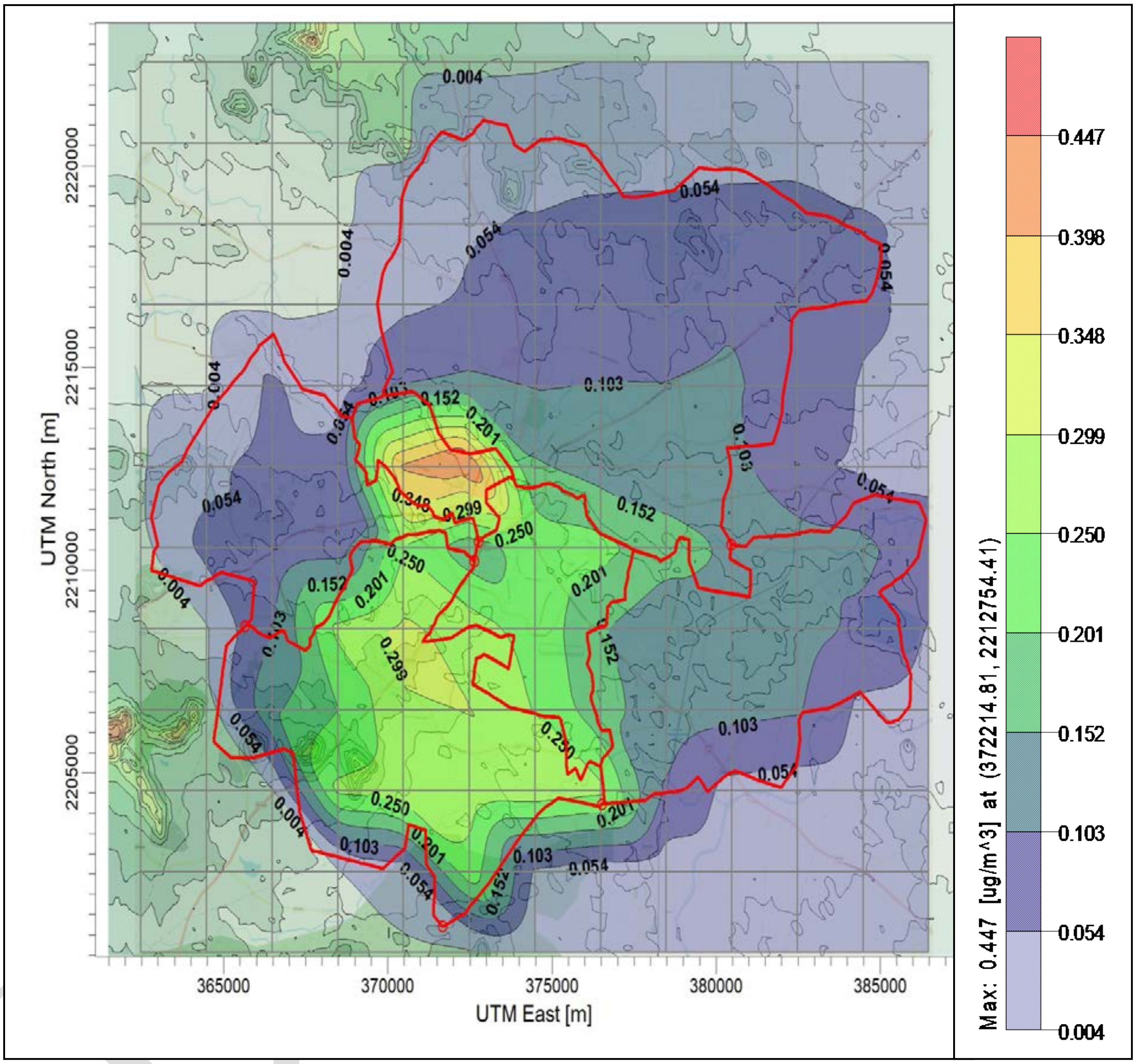

Figure N2 : Isopleths of NOx Due to Area Sources– Post Monsoon Season (Nashik City)

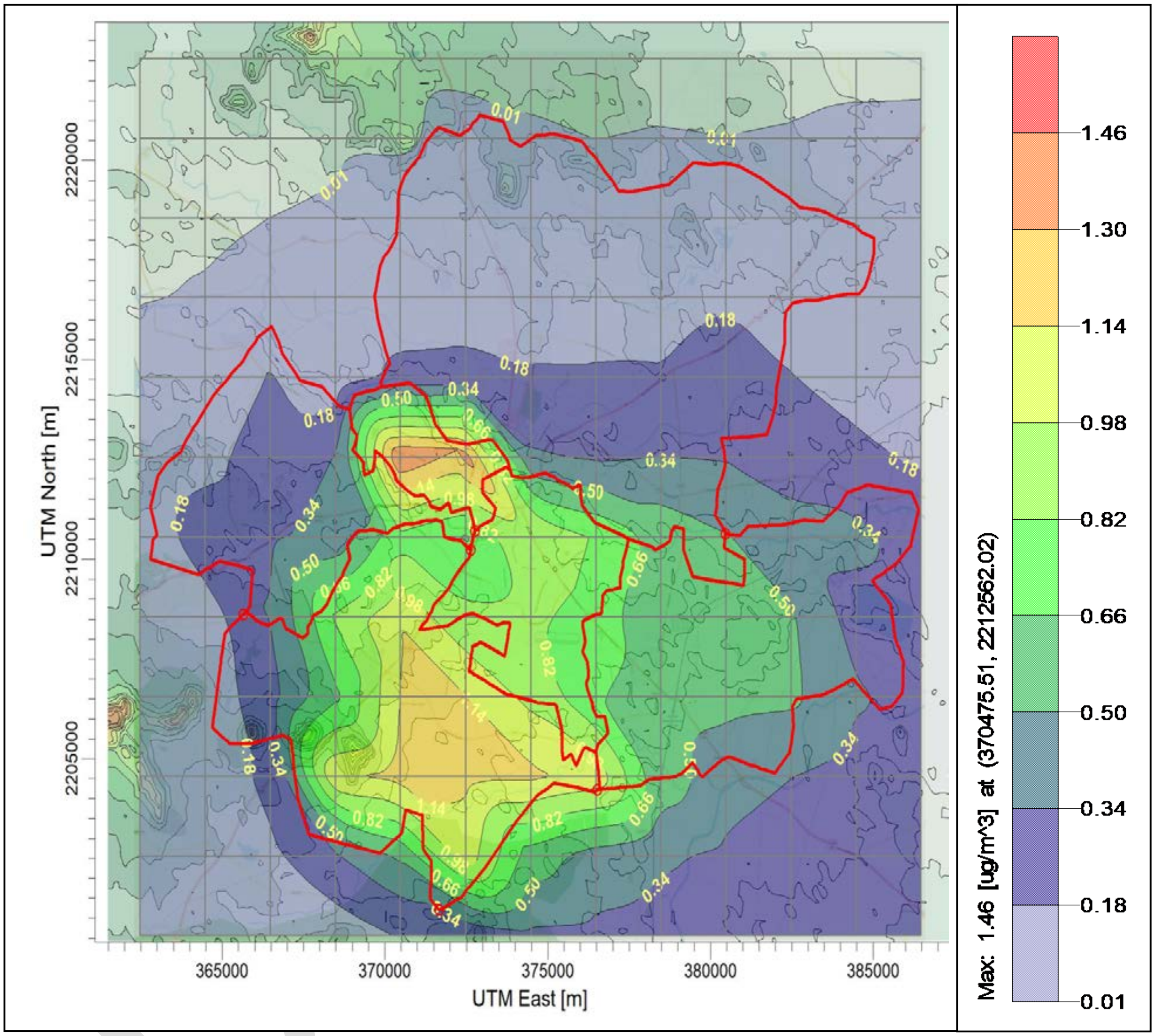

Figure N3 : Isopleths of NOx Due to Area Sources– Winter Season (Nashik City)

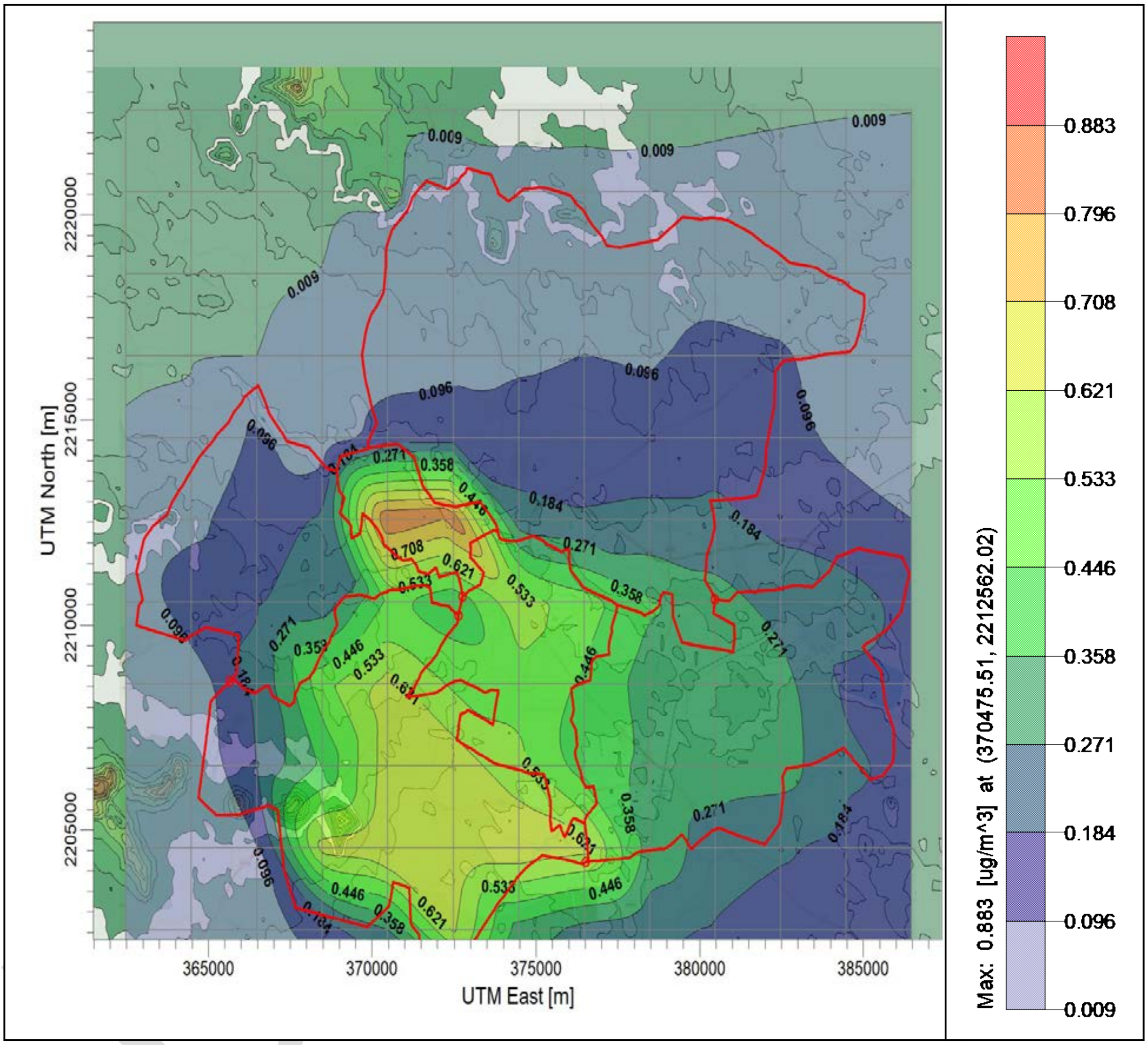

Figure N4 : Isopleths of NOx Due to Area Sources– Annual (Nashik City)

B) LINE SOURCE – ALL NOX

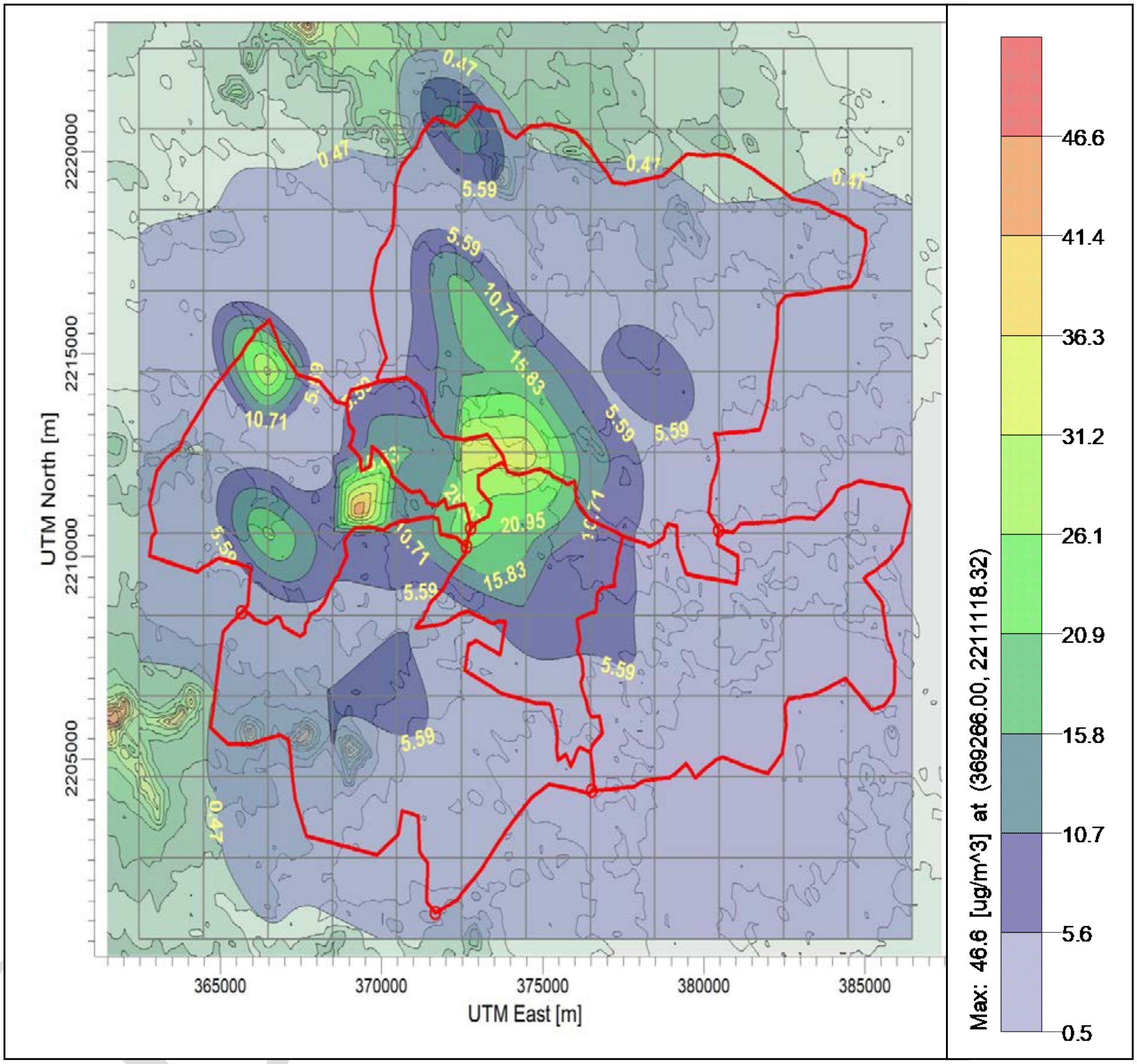

Figure N5 : Isopleths of NOx Due to Line Sources– Summer Season (Nashik City)

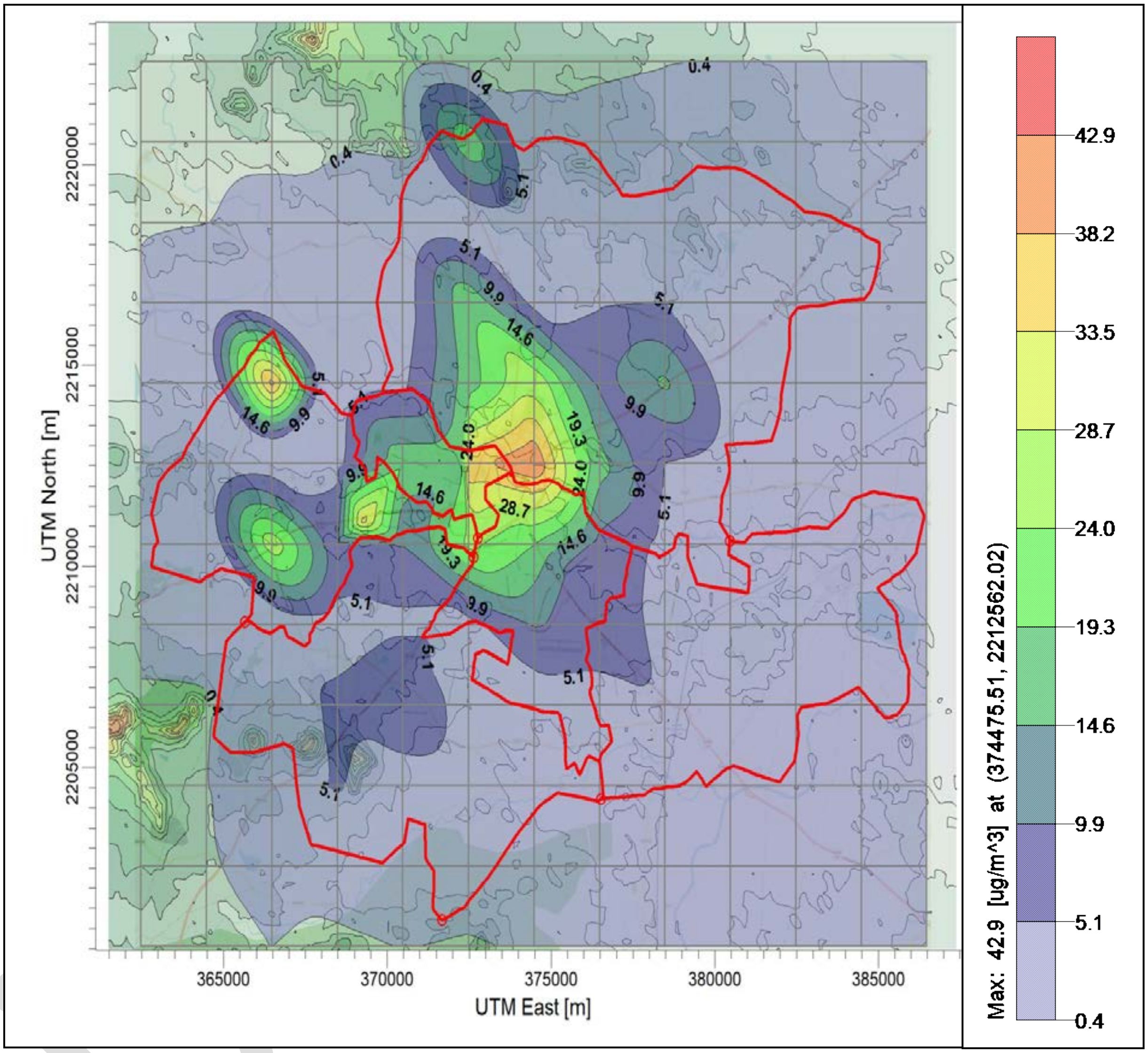

Figure N6 : Isopleths of NOx Due to Line Sources– Post Monsoon Season (Nashik City)

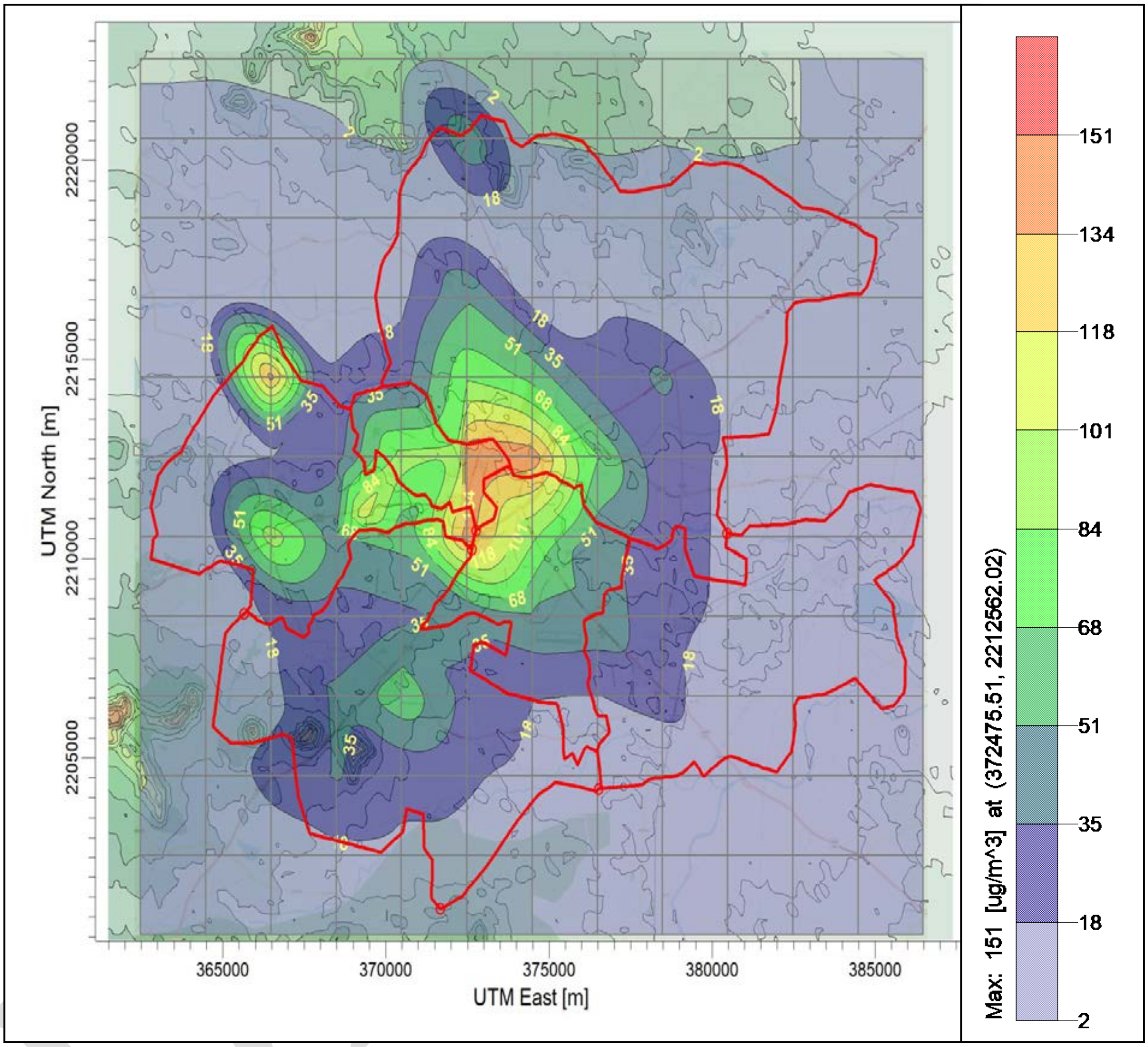

Figure N7 : Isopleths of NOx Due to Line Sources– Winter Season (Nashik City)

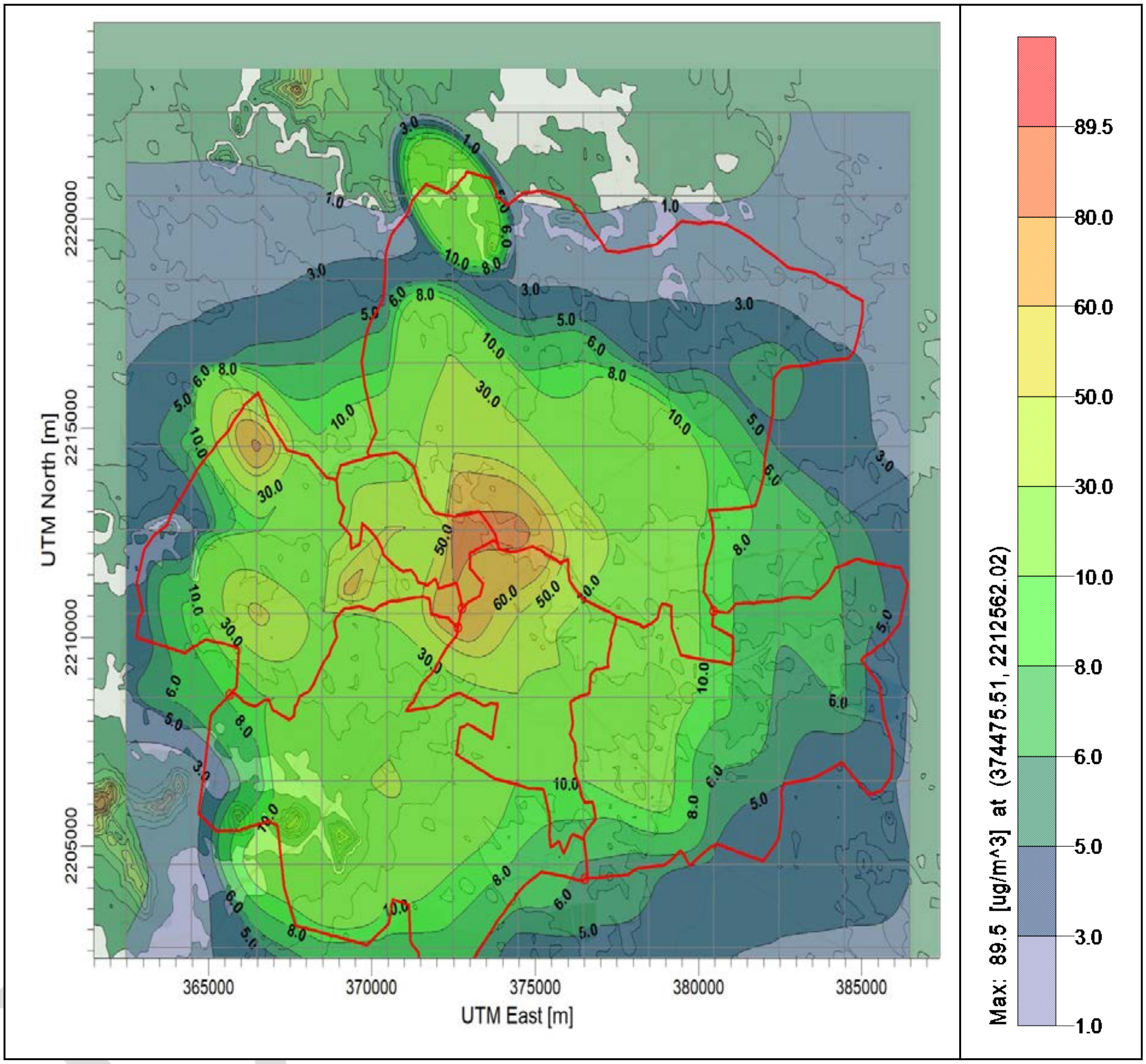

Figure N8 : Isopleths of NOx Due to Line Sources– Annual (Nashik City)

C) POINT SOURCE (LSI) – ALL NOX

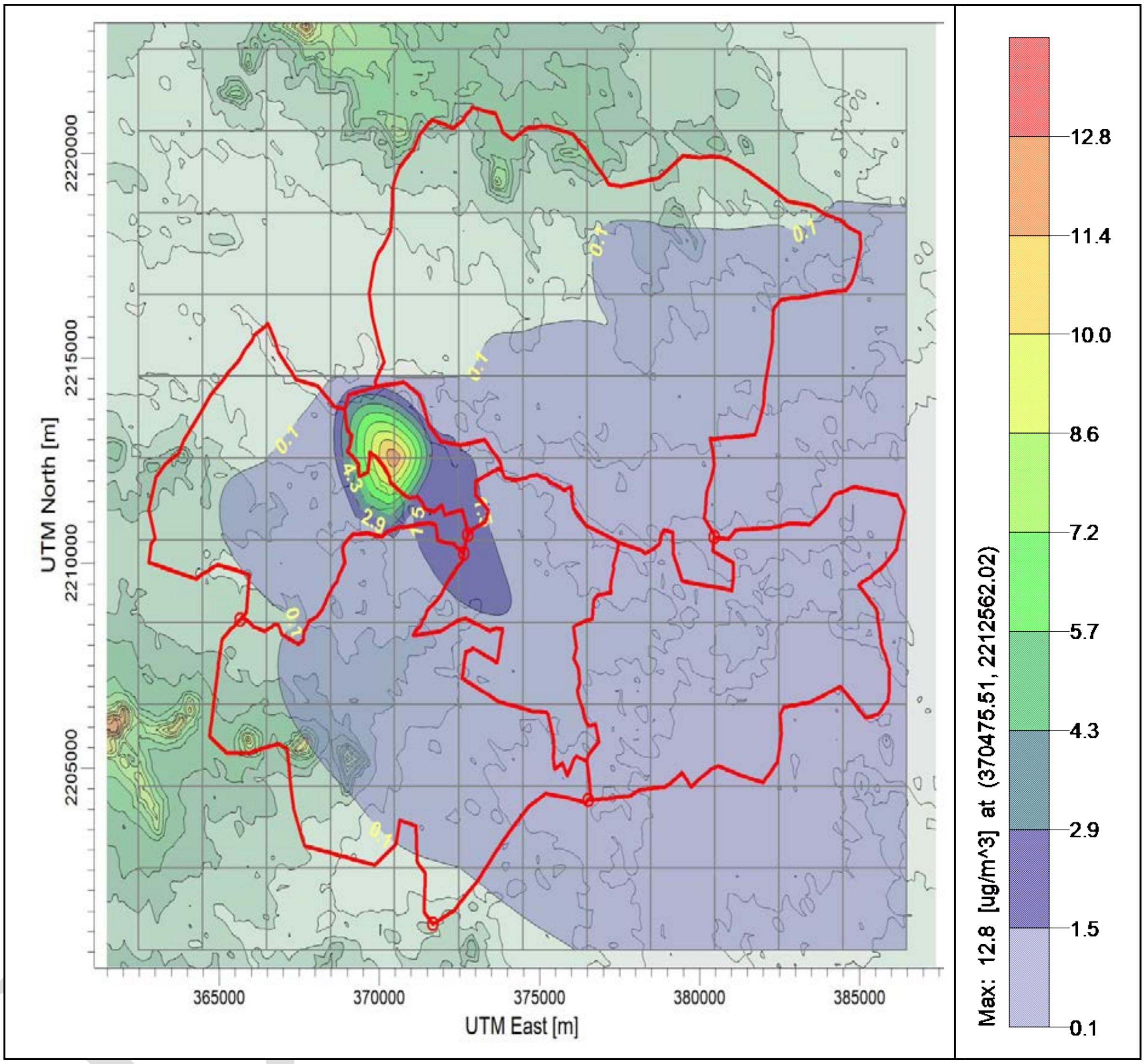

Figure N9 : Isopleths of NOx Due to Point Sources (LSI)– Summer Season (Nashik City)

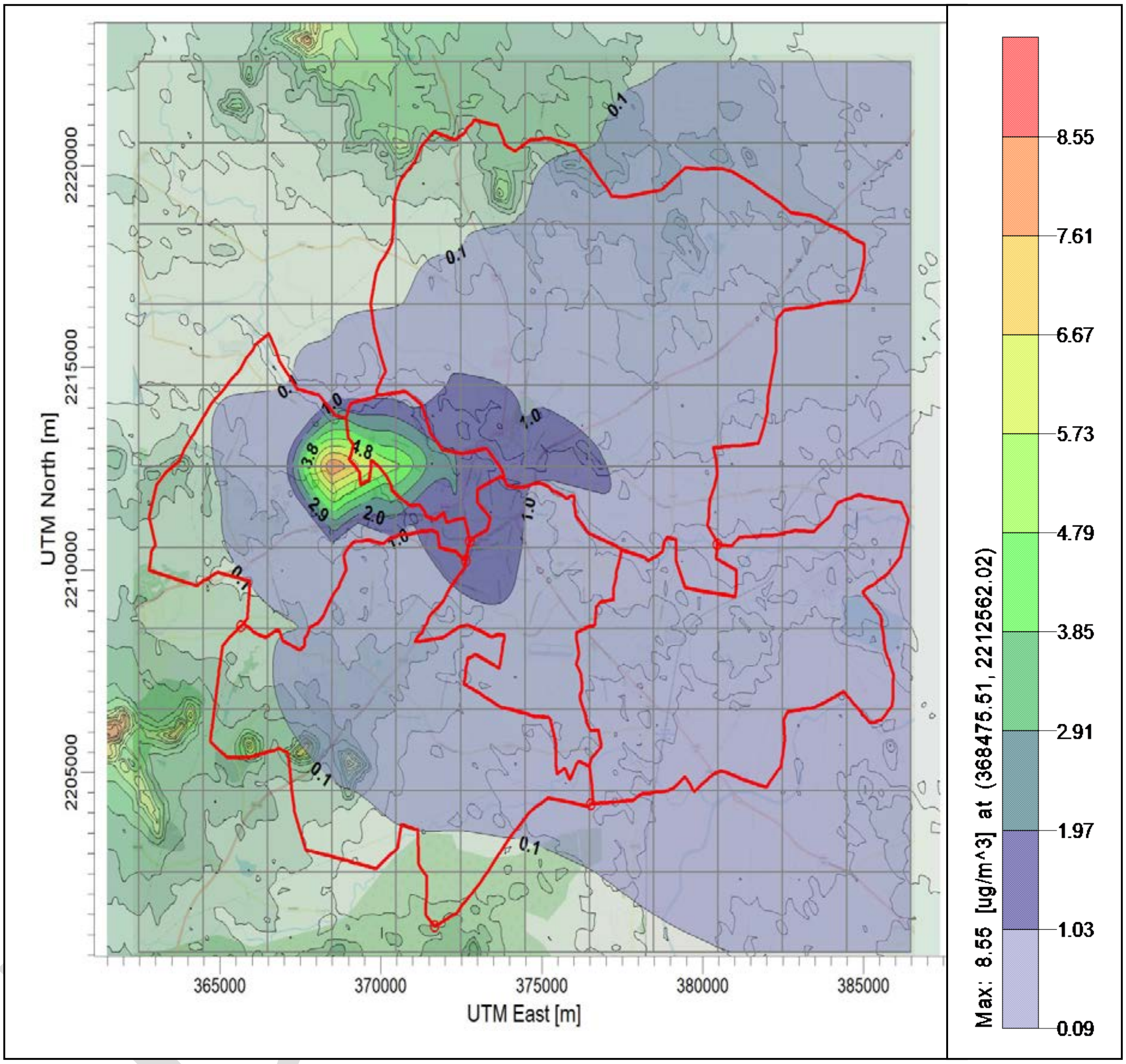

Figure N10 : Isopleths of NOx Due to Point Sources (LSI)– Post Monsoon Season (Nashik City)

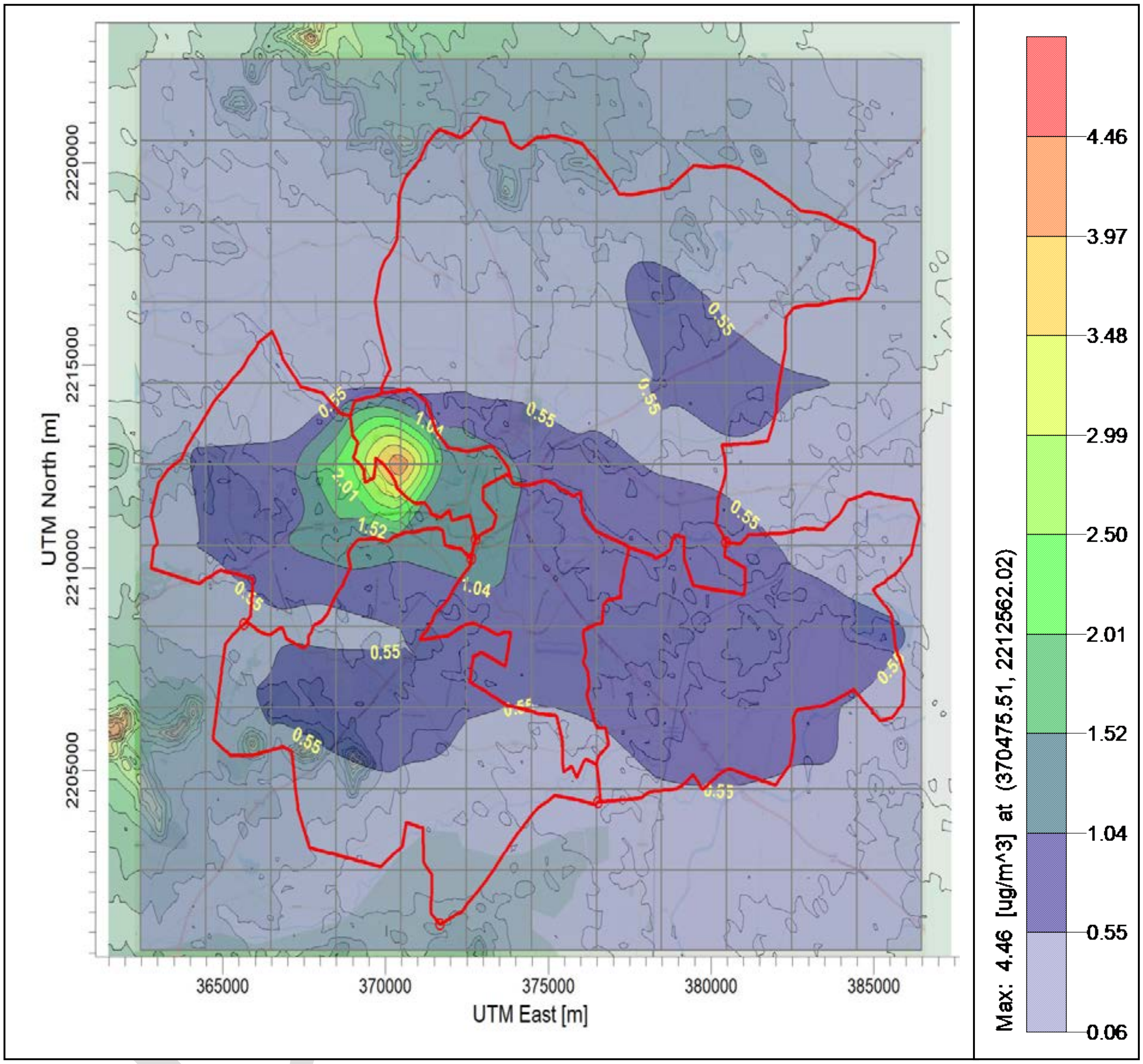

Figure N11 : Isopleths of NOx Due to Point Sources (LSI)– Winter Season (Nashik City)

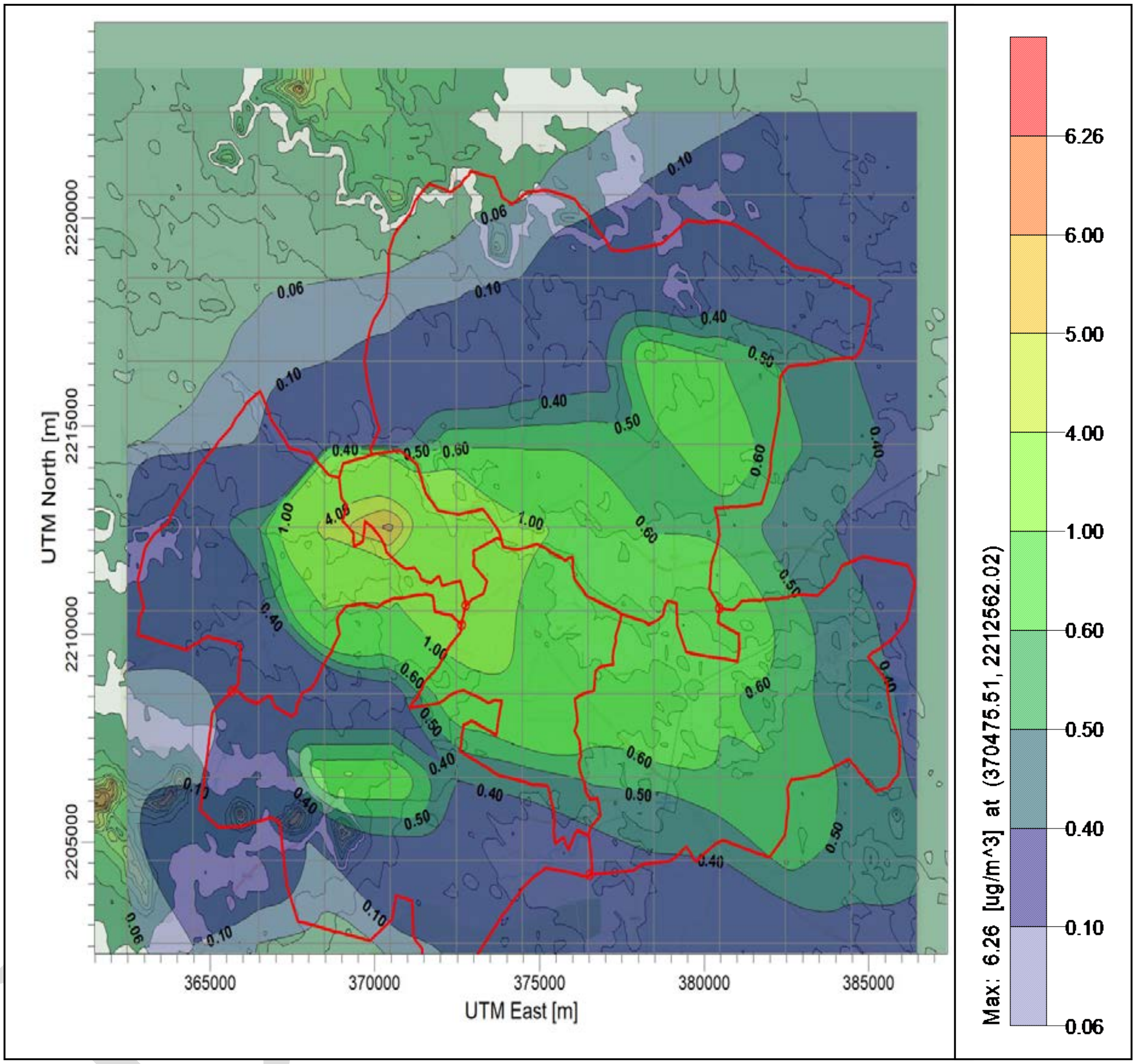

Figure N12 : Isopleths of NOx Due to Point Sources (LSI)– Annual (Nashik City)

D) POINT SOURCE (MSI) – ALL NOX

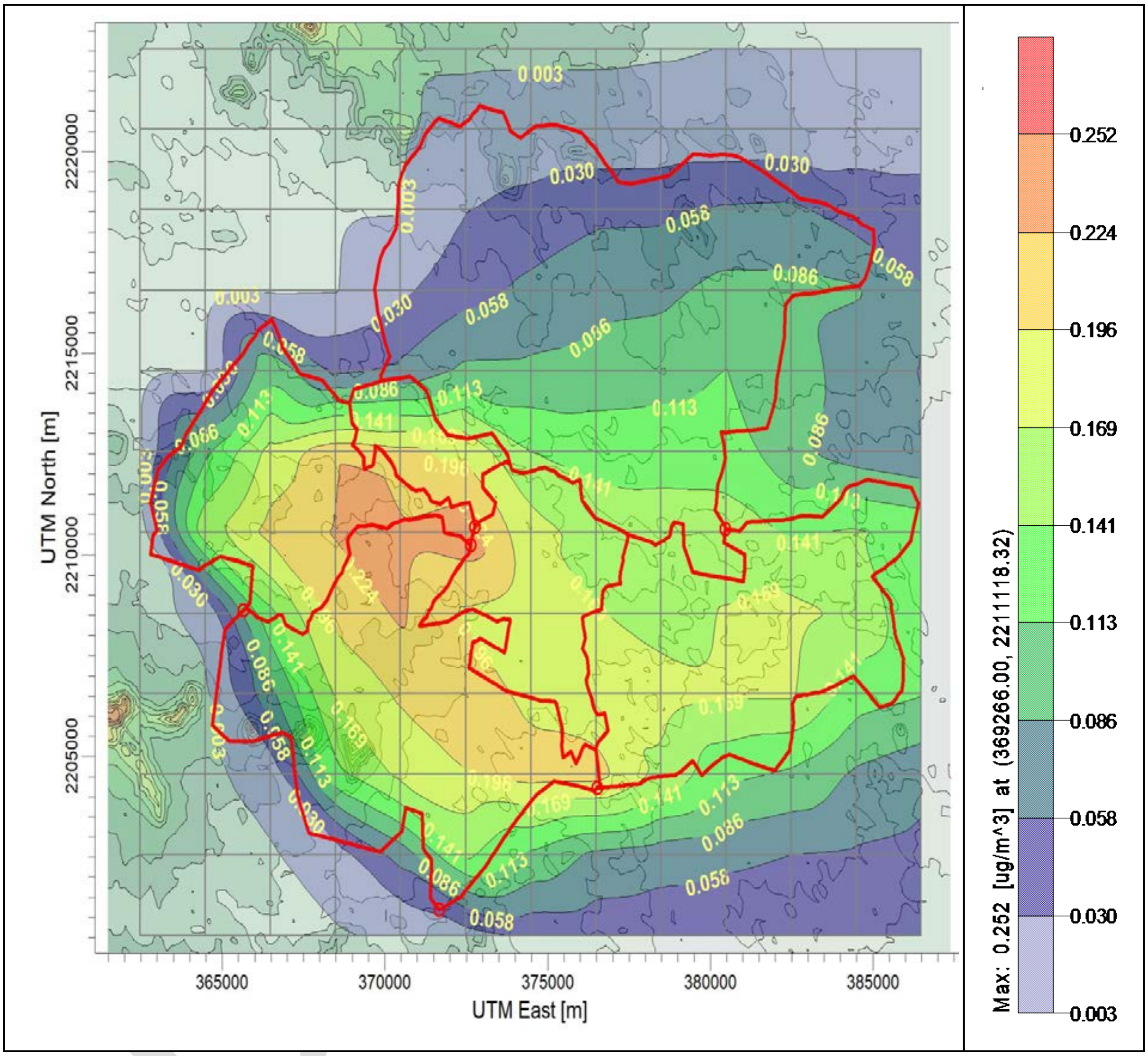

Figure N13 : Isopleths of NOx Due to Point Sources (MSI)– Summer Season (Nashik City)

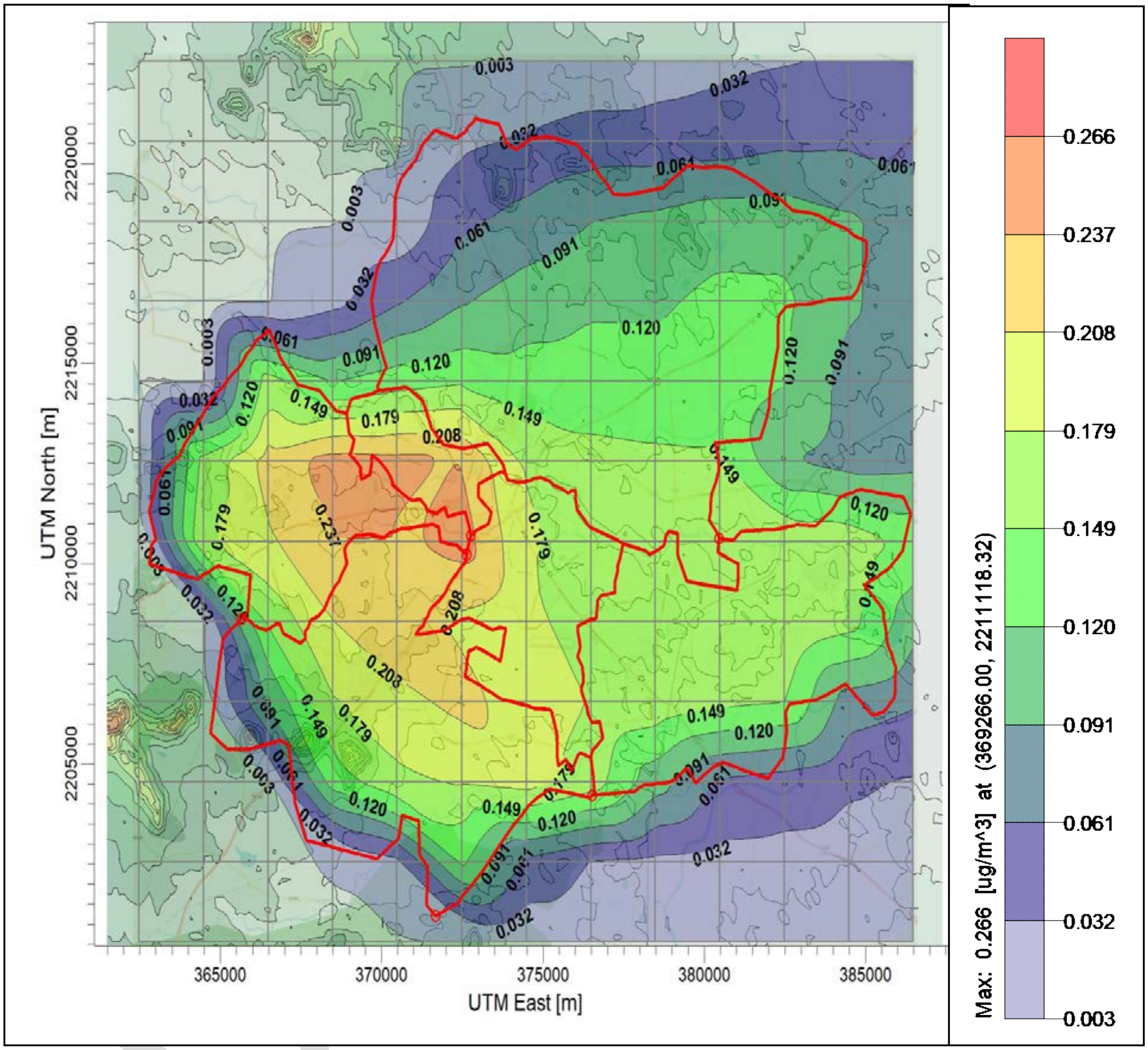

Figure N14 : Isopleths of NOx Due to Point Sources (MSI)– Post Monsoon Season (Nashik City)

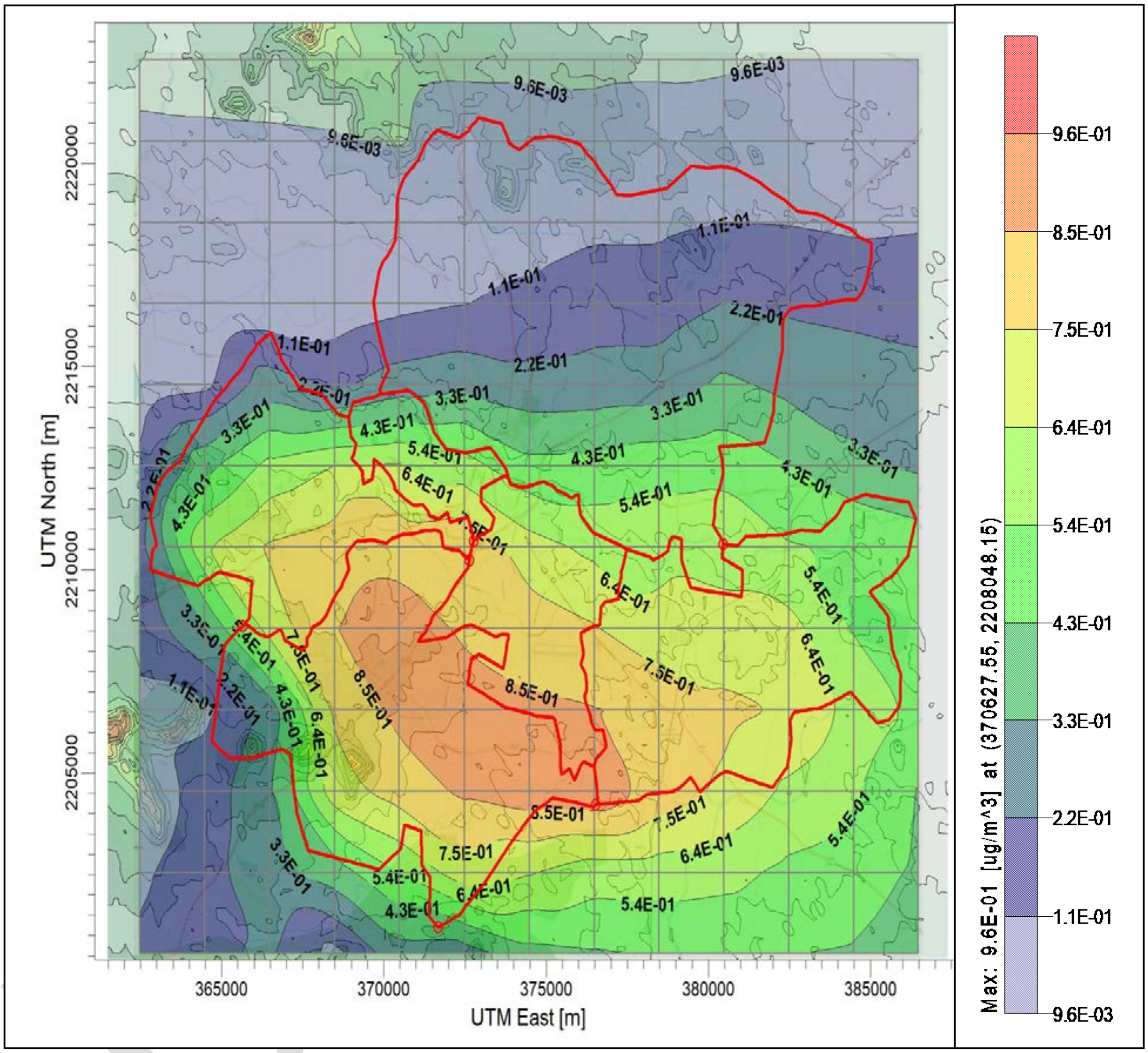

Figure N15 : Isopleths of NOx Due to Point Sources (MSI)– Winter Season (Nashik City)

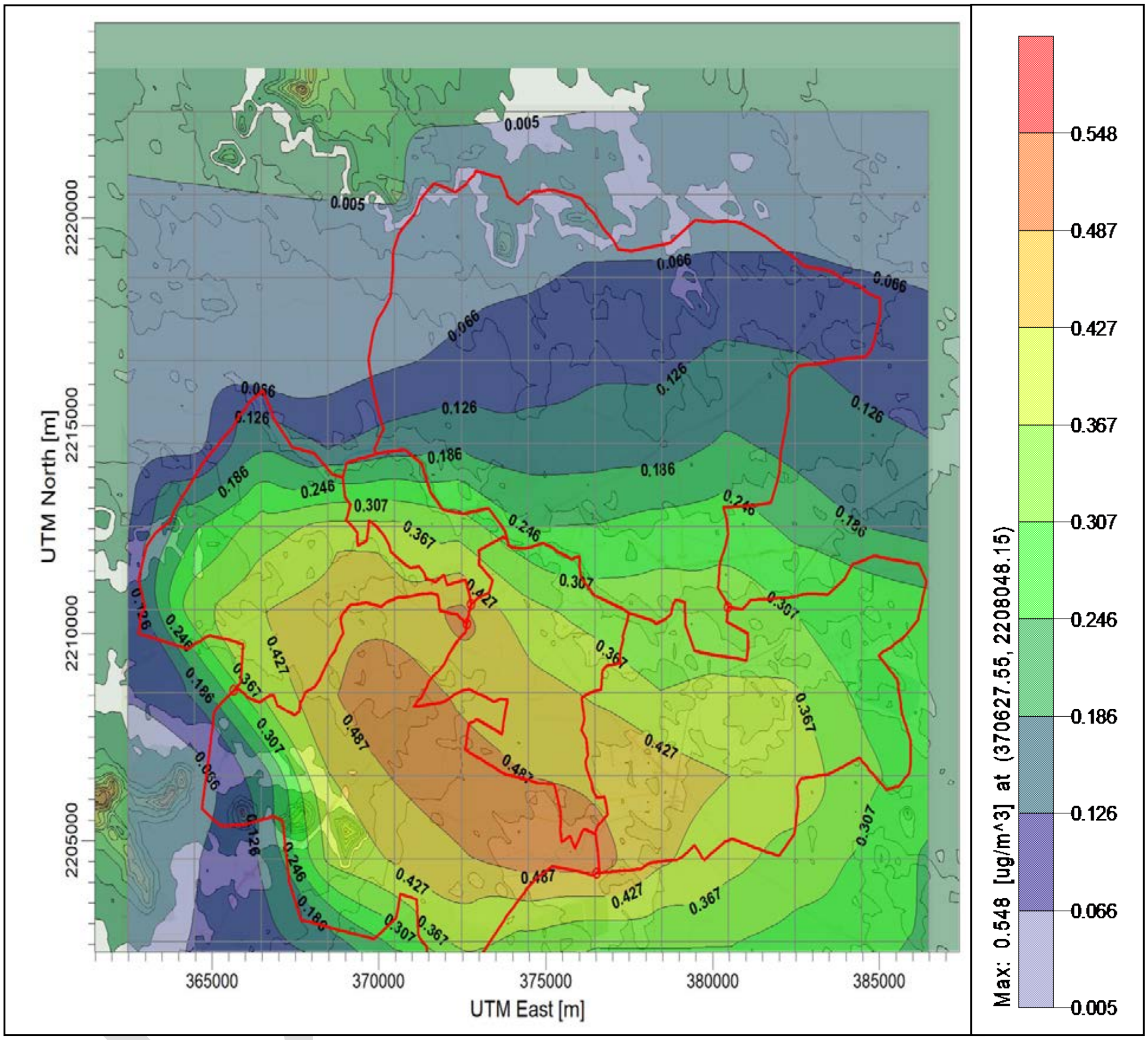

Figure N16 : Isopleths of NOx Due to Point Sources (MSI)– Annual Season (Nashik City)

E) POINT SOURCE (SSI) – ALL NOX

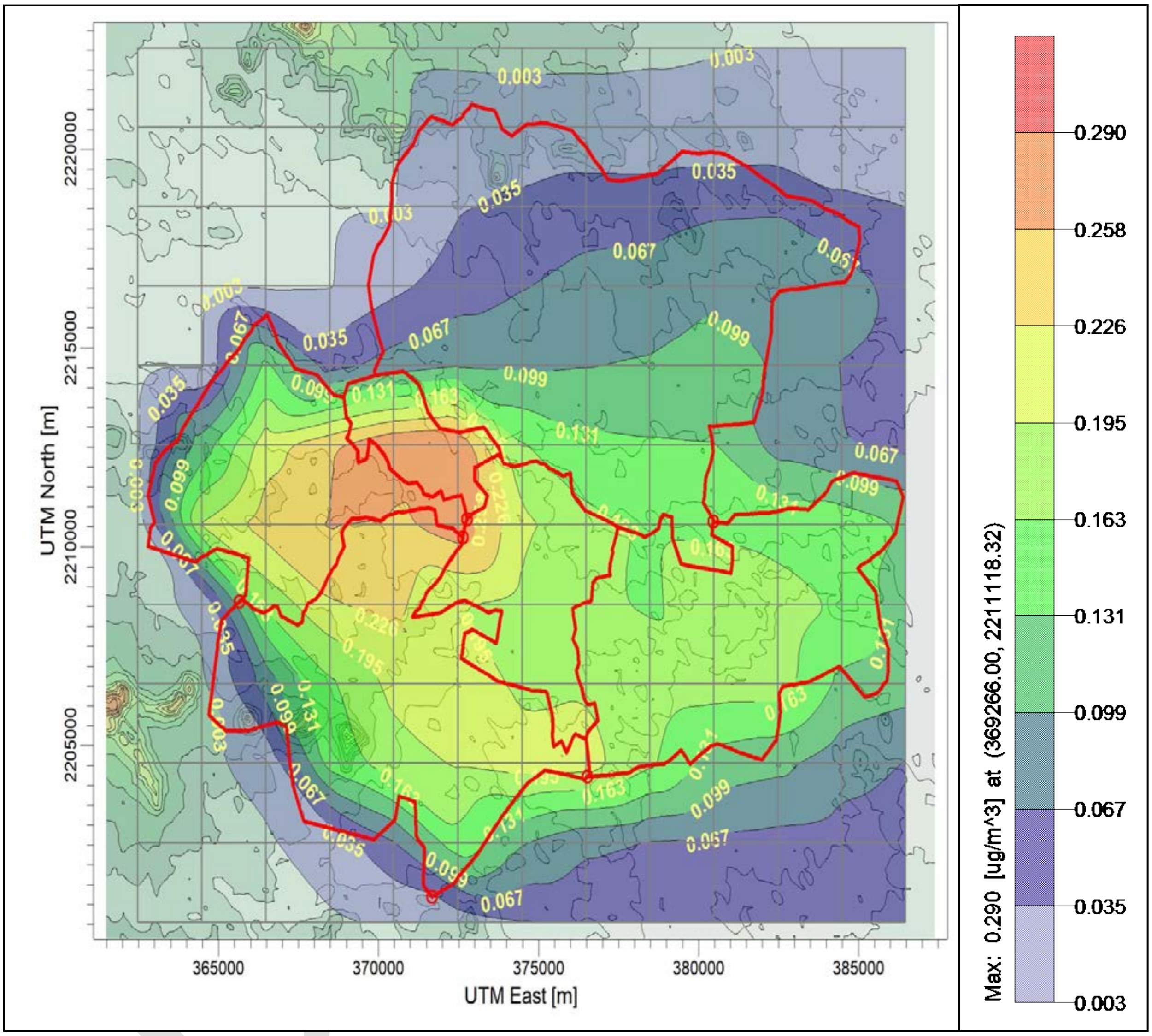

Figure N17 : Isopleths of NOx Due to Point Sources (SSI)– Summer Season (Nashik City)

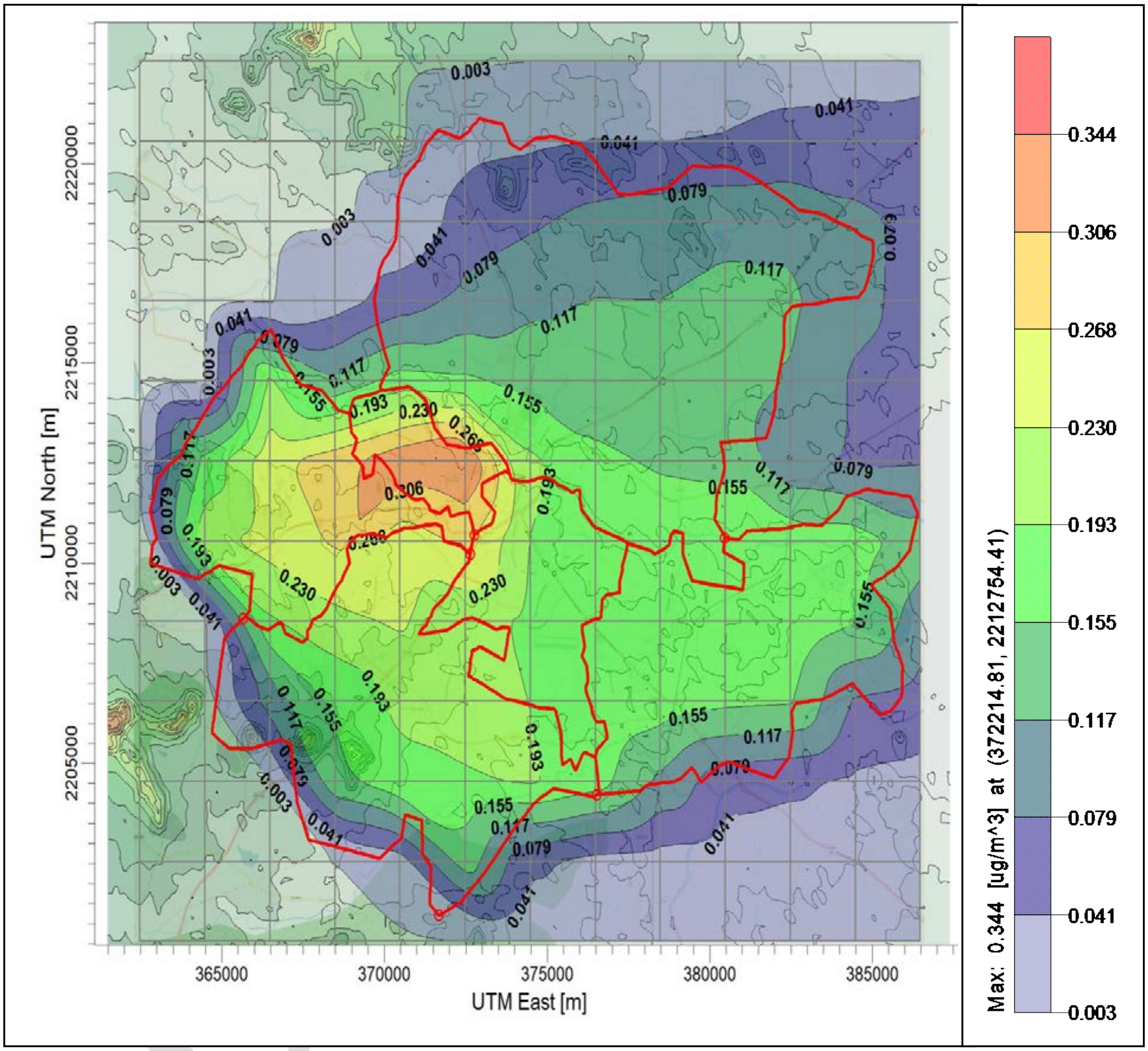

Figure N18 : Isopleths of NOx Due to Point Sources (SSI)– Post Monsoon Season (Nashik City)

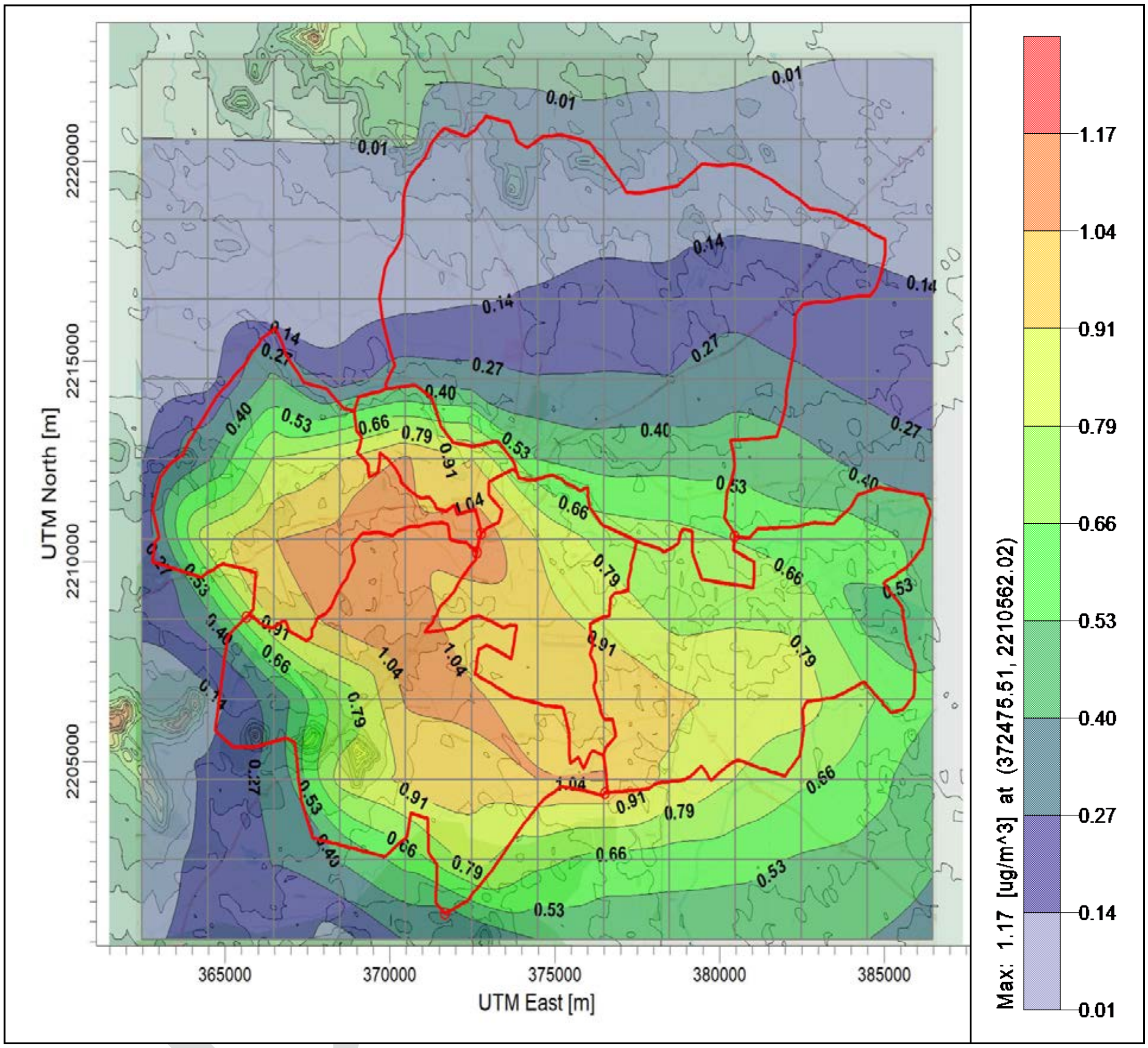

Figure N19 : Isopleths of NOx Due to Point Sources (SSI)– Winter Season (Nashik City)

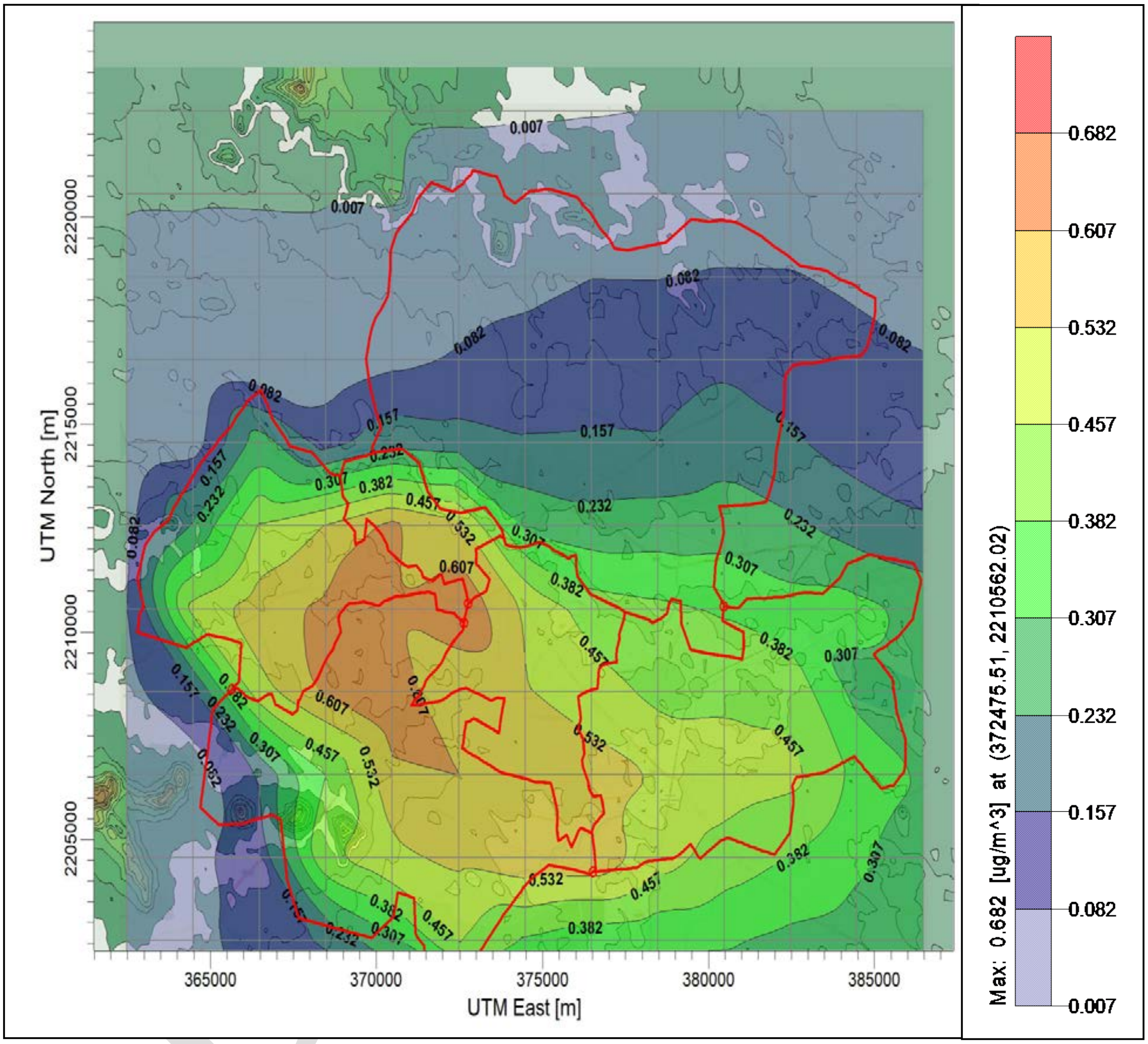

Figure N20 : Isopleths of NOx Due to Point Sources (SSI)– Annual (Nashik City)

ANNEXURE – 5

Maximum Ten Concentrations of NOx (Annual) BaU 2018, 2020, 2025 and Preferred Option I -2020, Preferred Option II – 2025

Nashik City

Annexure 5

A) Maximum Ten Occurrences of NO_X Concentrations in BaU 2018 at Nashik City (Annual)

Annual - All Source – BaU 2018			
	X length,m	Y length,m	Concentration $\mu g/m^3$
1st	374475.51	2212562.02	356.63
2nd	372475.51	2210562.02	255.34
3rd	372475.51	2212562.02	188.71
4th	369264.06	2211128.05	107.22
5th	369264.06	2211128.05	54.84
6th	369264.06	2211128.05	54.45
7th	369264.06	2211128.05	53.47
8th	369264.06	2211128.05	51.25
9th	369264.06	2211128.05	48.37
10th	369264.06	2211128.05	47.65
Avg.	372475.51	2212562.02	92.90

Annual - Area Source – BaU 2018			
	X length,m	Y length,m	Concentration $\mu g/m^3$
1st	370475.51	2212562.02	3.34
2nd	370475.51	2212562.02	1.97
3rd	370475.51	2212562.02	1.58
4th	372208.92	2212740.26	0.89
5th	372208.92	2212740.26	0.50
6th	372208.92	2212740.26	0.46
7th	372208.92	2212740.26	0.44
8th	372208.92	2212740.26	0.41
9th	372475.51	2212562.02	0.39
10th	372475.51	2212562.02	0.36
Avg.	370475.51	2212562.02	0.88

Annual – Line Source – BaU 2018			
	X length,m	Y length,m	Concentration $\mu g/m^3$
1st	374475.51	2212562.02	354.89
2nd	372475.51	2210562.02	250.90
3rd	372475.51	2212562.02	184.03
4th	369264.06	2211128.05	104.14
5th	369264.06	2211128.05	52.76
6th	369264.06	2211128.05	52.28
7th	369264.06	2211128.05	51.41
8th	369264.06	2211128.05	49.09
9th	369264.06	2211128.05	46.55
10th	369264.06	2211128.05	45.67
Avg.	374475.51	2212562.02	89.49

Annual - Point Source (LSI)– BaU 2018			
	X length,m	Y length,m	Concentration $\mu g/m^3$
1st	370475.51	2212562.02	16.41
2nd	370475.51	2212562.02	15.24
3rd	370475.51	2212562.02	10.46
4th	370475.51	2212562.02	8.98
5th	370475.51	2212562.02	4.96
6th	370475.51	2212562.02	4.70
7th	370475.51	2212562.02	3.69
8th	370475.51	2212562.02	3.66
9th	370475.51	2212562.02	2.40
10th	370475.51	2212562.02	1.99
Avg.	370475.51	2212562.02	6.26

Annual – Point Source (MSI) – BaU 2018			
	X length,m	Y length,m	Concentration $\mu g/m^3$
1st	380475.51	2204562.02	1.97
2nd	376475.51	2204562.02	1.53
3rd	368475.51	2208562.02	1.03
4th	369264.06	2211128.05	0.78
5th	369264.06	2211128.05	0.28
6th	369264.06	2211128.05	0.28
7th	369264.06	2211128.05	0.28
8th	369264.06	2211128.05	0.27
9th	369264.06	2211128.05	0.25
10th	369264.06	2211128.05	0.23
Avg.	370627.55	2208048.15	0.55

Annual – Point Source (SSI) – BaU 2018			
	X length,m	Y length,m	Concentration $\mu g/m^3$
1st	370627.55	2208048.15	2.90
2nd	368475.51	2208562.02	1.74
3rd	366475.51	2210562.02	1.36
4th	372475.51	2212562.02	0.94
5th	372208.92	2212740.26	0.37
6th	372208.92	2212740.26	0.35
7th	372208.92	2212740.26	0.34
8th	372208.92	2212740.26	0.32
9th	372475.51	2212562.02	0.32
10th	369264.06	2211128.05	0.27
Avg.	372475.51	2210562.02	0.68

B) Maximum Ten Occurrences of NO_X Concentrations in BaU 2020 at Nashik City (Annual)

Annual - All Source – BaU 2020			
	X length,m	Y length,m	Concentration µg/m³
1st	374475.51	2212562.02	206.57
2nd	372475.51	2210562.02	150.37
3rd	372475.51	2212562.02	112.64
4th	369264.06	2211128.05	64.38
5th	369264.06	2211128.05	32.24
6th	369264.06	2211128.05	31.98
7th	369264.06	2211128.05	31.14
8th	369264.06	2211128.05	30.36
9th	369264.06	2211128.05	29.12
10th	369264.06	2211128.05	28.80
Avg.	372475.51	2212562.02	55.19

Annual - Area Source – BaU 2020			
	X length,m	Y length,m	Concentration µg/m³
1st	370475.51	2212562.02	1.95
2nd	370475.51	2212562.02	1.15
3rd	370475.51	2212562.02	0.92
4th	372208.92	2212740.26	0.52
5th	372208.92	2212740.26	0.29
6th	372208.92	2212740.26	0.27
7th	372208.92	2212740.26	0.26
8th	372208.92	2212740.26	0.24
9th	372475.51	2212562.02	0.23
10th	372475.51	2212562.02	0.21
Avg.	370475.51	2212562.02	0.52

Annual – Line Source – BaU 2020			
	X length,m	Y length,m	Concentration µg/m³
1st	374475.51	2212562.02	205.59
2nd	372475.51	2210562.02	147.89
3rd	372475.51	2212562.02	110.01
4th	369264.06	2211128.05	62.67
5th	369264.06	2211128.05	31.04
6th	369264.06	2211128.05	30.83
7th	369264.06	2211128.05	30.00
8th	369264.06	2211128.05	29.16
9th	369264.06	2211128.05	28.11
10th	369264.06	2211128.05	27.70
Avg.	372475.51	2212562.02	53.23

Annual - Point Source (LSI)– BaU 2020			
	X length,m	Y length,m	Concentration µg/m³
1st	370475.51	2212562.02	9.08
2nd	370475.51	2212562.02	8.43
3rd	370475.51	2212562.02	5.78
4th	370475.51	2212562.02	4.97
5th	370475.51	2212562.02	2.74
6th	370475.51	2212562.02	2.60
7th	370475.51	2212562.02	2.04
8th	370475.51	2212562.02	2.03
9th	370475.51	2212562.02	1.33
10th	370475.51	2212562.02	1.10
Avg.	370475.51	2212562.02	3.46

Annual – Point Source (MSI) – BaU 2020			
	X length,m	Y length,m	Concentration µg/m³
1st	380475.51	2204562.02	1.09
2nd	376475.51	2204562.02	0.84
3rd	368475.51	2208562.02	0.57
4th	369264.06	2211128.05	0.43
5th	369264.06	2211128.05	0.16
6th	369264.06	2211128.05	0.15
7th	369264.06	2211128.05	0.15
8th	369264.06	2211128.05	0.15
9th	369264.06	2211128.05	0.14
10th	369264.06	2211128.05	0.13
Avg.	370627.55	2208048.15	0.30

Annual – Point Source (SSI) – BaU 2020			
	X length,m	Y length,m	Concentration µg/m³
1st	370627.55	2208048.15	1.60
2nd	368475.51	2208562.02	0.96
3rd	366475.51	2210562.02	0.75
4th	372475.51	2212562.02	0.52
5th	372208.92	2212740.26	0.21
6th	372208.92	2212740.26	0.19
7th	372208.92	2212740.26	0.19
8th	372208.92	2212740.26	0.17
9th	372475.51	2212562.02	0.17
10th	369264.06	2211128.05	0.15
Avg.	372475.51	2210562.02	0.38

C) Maximum Ten Occurrences of NO_X Concentrations in BaU 2025 at Nashik City (Annual)

Annual - All Source – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	374475.51	2212562.02	401.94
2nd	372475.51	2210562.02	292.40
3rd	372475.51	2212562.02	218.96
4th	369264.06	2211128.05	125.09
5th	369264.06	2211128.05	62.59
6th	369264.06	2211128.05	62.09
7th	369264.06	2211128.05	60.46
8th	369264.06	2211128.05	58.93
9th	369264.06	2211128.05	56.55
10th	369264.06	2211128.05	55.90
Avg.	372475.51	2212562.02	107.21

Annual - Area Source – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	370475.51	2212562.02	3.77
2nd	370475.51	2212562.02	2.23
3rd	370475.51	2212562.02	1.78
4th	372208.92	2212740.26	1.00
5th	372208.92	2212740.26	0.57
6th	372208.92	2212740.26	0.51
7th	372208.92	2212740.26	0.50
8th	372208.92	2212740.26	0.46
9th	372475.51	2212562.02	0.44
10th	372475.51	2212562.02	0.41
Avg.	370475.51	2212562.02	1.00

Annual – Line Source – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	374475.51	2212562.02	400.14
2nd	372475.51	2210562.02	287.83
3rd	372475.51	2212562.02	214.11
4th	369264.06	2211128.05	121.98
5th	369264.06	2211128.05	60.42
6th	369264.06	2211128.05	60.00
7th	369264.06	2211128.05	58.39
8th	369264.06	2211128.05	56.76
9th	369264.06	2211128.05	54.71
10th	369264.06	2211128.05	53.91
Avg.	372475.51	2212562.02	103.60

Annual - Point Source (LSI)– BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	370475.51	2212562.02	16.41
2nd	370475.51	2212562.02	15.24
3rd	370475.51	2212562.02	10.46
4th	370475.51	2212562.02	8.98
5th	370475.51	2212562.02	4.96
6th	370475.51	2212562.02	4.70
7th	370475.51	2212562.02	3.69
8th	370475.51	2212562.02	3.66
9th	370475.51	2212562.02	2.40
10th	370475.51	2212562.02	1.99
Avg.	370475.51	2212562.02	6.26

Annual – Point Source (MSI) – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	380475.51	2204562.02	1.97
2nd	376475.51	2204562.02	1.53
3rd	368475.51	2208562.02	1.03
4th	369264.06	2211128.05	0.78
5th	369264.06	2211128.05	0.28
6th	369264.06	2211128.05	0.28
7th	369264.06	2211128.05	0.28
8th	369264.06	2211128.05	0.27
9th	369264.06	2211128.05	0.25
10th	369264.06	2211128.05	0.23
Avg.	370627.55	2208048.15	0.55

Annual – Point Source (SSI) – BaU 2025			
	X length,m	Y length,m	Concentration µg/m^3
1st	370627.55	2208048.15	2.90
2nd	368475.51	2208562.02	1.74
3rd	366475.51	2210562.02	1.36
4th	372475.51	2212562.02	0.94
5th	372208.92	2212740.26	0.37
6th	372208.92	2212740.26	0.35
7th	372208.92	2212740.26	0.34
8th	372208.92	2212740.26	0.32
9th	372475.51	2212562.02	0.32
10th	369264.06	2211128.05	0.27
Avg.	372475.51	2210562.02	0.68

D) Maximum Ten Occurrences of NO_X Concentrations after Implementation of Control Options (Preferred Option I -2020) at Nashik City (Annual)

Annual - All Source Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m³
1st	374475.51	2212562.02	379.64
2nd	372475.51	2210562.02	271.81
3rd	372475.51	2212562.02	200.88
4th	369264.06	2211128.05	114.14
5th	369264.06	2211128.05	58.38
6th	369264.06	2211128.05	57.96
7th	369264.06	2211128.05	56.92
8th	369264.06	2211128.05	54.56
9th	369264.06	2211128.05	51.49
10th	369264.06	2211128.05	50.72
Avg.	372475.51	2212562.02	98.89

Annual - Area Source Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m³
1st	370475.51	2212562.02	3.52
2nd	370475.51	2212562.02	2.08
3rd	370475.51	2212562.02	1.67
4th	372208.92	2212740.26	0.94
5th	372208.92	2212740.26	0.53
6th	372208.92	2212740.26	0.49
7th	372208.92	2212740.26	0.46
8th	372208.92	2212740.26	0.43
9th	372475.51	2212562.02	0.41
10th	372475.51	2212562.02	0.38
Avg.	370475.51	2212562.02	0.93

Annual – Line Source Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m³
1st	374475.51	2212562.02	378.04
2nd	372475.51	2210562.02	267.27
3rd	372475.51	2212562.02	196.04
4th	369264.06	2211128.05	110.93
5th	369264.06	2211128.05	56.20
6th	369264.06	2211128.05	55.69
7th	369264.06	2211128.05	54.76
8th	369264.06	2211128.05	52.29
9th	369264.06	2211128.05	49.59
10th	369264.06	2211128.05	48.65
Avg.	372475.51	2212562.02	95.33

Annual Point Source (LSI) Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m³
1st	370475.51	2212562.02	16.41
2nd	370475.51	2212562.02	15.24
3rd	370475.51	2212562.02	10.46
4th	370475.51	2212562.02	8.98
5th	370475.51	2212562.02	4.96
6th	370475.51	2212562.02	4.70
7th	370475.51	2212562.02	3.69
8th	370475.51	2212562.02	3.66
9th	370475.51	2212562.02	2.40
10th	370475.51	2212562.02	1.99
Avg.	370475.51	2212562.02	6.26

Annual Point Source (MSI) Preferred Option I-2020			
	X length,m	Y length,m	Concentration µg/m³
1st	380475.51	2204562.02	4.10
2nd	376475.51	2204562.02	3.19
3rd	368475.51	2208562.02	2.15
4th	369264.06	2211128.05	1.63
5th	369264.06	2211128.05	0.58
6th	369264.06	2211128.05	0.58
7th	369264.06	2211128.05	0.58
8th	369264.06	2211128.05	0.56
9th	369264.06	2211128.05	0.52
10th	369264.06	2211128.05	0.48
Avg.	370627.55	2208048.15	1.15

Annual Point Source (SSI) Preferred Option I-2020			
	X length,m	Y length,m	Concentration µg/m³
1st	370627.55	2208048.15	2.90
2nd	368475.51	2208562.02	1.74
3rd	366475.51	2210562.02	1.36
4th	372475.51	2212562.02	0.94
5th	372208.92	2212740.26	0.37
6th	372208.92	2212740.26	0.35
7th	372208.92	2212740.26	0.34
8th	372208.92	2212740.26	0.32
9th	372475.51	2212562.02	0.32
10th	369264.06	2211128.05	0.27
Avg.	372475.51	2210562.02	0.68

E) Maximum Ten Occurrences of NO_X Concentrations after Implementation of Control Options (Preferred Option II -2025) at Nashik City (Annual)

Annual - All Source Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m³
1st	374475.51	2212562.02	161.98
2nd	372475.51	2210562.02	117.84
3rd	372475.51	2212562.02	88.24
4th	369264.06	2211128.05	50.41
5th	369264.06	2211128.05	25.23
6th	369264.06	2211128.05	25.02
7th	369264.06	2211128.05	24.37
8th	369264.06	2211128.05	23.75
9th	369264.06	2211128.05	22.79
10th	369264.06	2211128.05	22.53
Avg.	372475.51	2212562.02	43.21

Annual - Area Source Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m³
1st	370475.51	2212562.02	1.52
2nd	370475.51	2212562.02	0.90
3rd	370475.51	2212562.02	0.72
4th	372208.92	2212740.26	0.40
5th	372208.92	2212740.26	0.23
6th	372208.92	2212740.26	0.21
7th	372208.92	2212740.26	0.20
8th	372208.92	2212740.26	0.18
9th	372475.51	2212562.02	0.18
10th	372475.51	2212562.02	0.17
Avg.	370475.51	2212562.02	0.40

Annual – Line Source Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m³
1st	374475.51	2212562.02	161.26
2nd	372475.51	2210562.02	116.00
3rd	372475.51	2212562.02	86.29
4th	369264.06	2211128.05	49.16
5th	369264.06	2211128.05	24.35
6th	369264.06	2211128.05	24.18
7th	369264.06	2211128.05	23.53
8th	369264.06	2211128.05	22.87
9th	369264.06	2211128.05	22.05
10th	369264.06	2211128.05	21.73
Avg.	372475.51	2212562.02	41.75

Annual Point Source (LSI) Preferred Option II-2025			
	X length,m	Y length,m	Concentration µg/m³
1st	370475.51	2212562.02	6.61
2nd	370475.51	2212562.02	6.14
3rd	370475.51	2212562.02	4.21
4th	370475.51	2212562.02	3.62
5th	370475.51	2212562.02	2.00
6th	370475.51	2212562.02	1.89
7th	370475.51	2212562.02	1.49
8th	370475.51	2212562.02	1.48
9th	370475.51	2212562.02	0.97
10th	370475.51	2212562.02	0.80
Avg.	370475.51	2212562.02	2.52

Annual Point Source (MSI) Preferred Option II-2025			
	X length,m	Y length,m	Concentration µg/m³
1st	380475.51	2204562.02	0.79
2nd	376475.51	2204562.02	0.62
3rd	368475.51	2208562.02	0.42
4th	369264.06	2211128.05	0.32
5th	369264.06	2211128.05	0.11
6th	369264.06	2211128.05	0.11
7th	369264.06	2211128.05	0.11
8th	369264.06	2211128.05	0.11
9th	369264.06	2211128.05	0.10
10th	369264.06	2211128.05	0.09
Avg.	370627.55	2208048.15	0.22

Annual Point Source (SSI) Preferred Option II-2025			
	X length,m	Y length,m	Concentration µg/m³
1st	370627.55	2208048.15	1.17
2nd	368475.51	2208562.02	0.70
3rd	366475.51	2210562.02	0.55
4th	372475.51	2212562.02	0.38
5th	372208.92	2212740.26	0.15
6th	372208.92	2212740.26	0.14
7th	372208.92	2212740.26	0.14
8th	372208.92	2212740.26	0.13
9th	372475.51	2212562.02	0.13
10th	369264.06	2211128.05	0.11
Avg.	372475.51	2210562.02	0.27