

*Draft Report On*

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

**(NAVI MUMBAI CITY)**

**for**



**Maharashtra pollution Control Board**

**By**



**&**



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**November, 2021**

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#### 1.1 Preamble

Navi Mumbai is a part of Konkan coast line and is located in center of MMR (Mumbai Metropolitan Region) with Thane creek on west side, while the Parsik hill ranges surrounded on east side, whereas region of Thane and Panvel region covers the North and South zone. The total area of Navi Mumbai Municipal Corporation (NMMC) is around 110 square Km. As per MRSAC (Maharashtra Remote Sensing Application Centre), area under NMMC's jurisdiction is broadly distributed under Built Up area (56%), Forests (24%) and Wetlands (12%) and the remaining area is covered under water bodies and agriculture. There are a total of 163 gardens and 80 open spaces which support the biodiversity of the city. Navi Mumbai's coastline has rich mangrove coverage, which spread over approximately 50 square Km.

In 1970, CIDCO (City & Industrial Development Corporation), a state public sector undertaking, was incorporated with purpose to plan, develop and maintain the city of Navi Mumbai under 'Companies Act' of 1956. CIDCO prepared development plan for Navi Mumbai covering 95 villages from Thane to Raigad district with an estimated area of 345 square Km. CIDCO has planned to develop 14 nodes in Navi Mumbai out of which 8 nodes were handed over to NMMC (Navi Mumbai Municipal Corporation) in 1991 for its maintenance.

The development of industrial belt in Navi Mumbai attracted a large population as it gave rise to employment opportunities. Further given the ease of connectivity to Mumbai, the city witnessed quick progress in term of urbanization. Navi Mumbai, in true terms has lived to its expectations of absorbing the population shock from the mega city of Mumbai which is evident from the fact that Navi Mumbai recorded a decadal population growth by more than 51% between 2001 and 2011.

This increase in population coupled with growth in industrial, educational hub, economic activities and infrastructure are the major driving forces for the growth of a city which exert pressure on the resources of the city like water, air and land. Some renowned facts of Navi Mumbai's are :

- Mahape's (Millennium Business Park) and Airoli Knowledge Park are the modern state of the art Software Park ideally located for many IT and BPO companies due to its vicinity near and are well connected road to other major metropolis like Thane and Mumbai.

- CBD Belapur is a chief business district of Mumbai after Vashi, Bandra-Kurla Complex, Nariman Point and Worli. CBD Belapur locations having several economic and government administrative and private companies' offices.
- Vashi is the leading node having big and famous malls like Centre One, Raghuleela mall and Inorbit mall, while some Hypermalls are also located at Koparkhairne and Nerul.
- The APMC market established at Vashi node of NMMC, spread across almost 8 hectares, is one of the biggest agricultural markets in Asia and has given a unique identity to the city. Agricultural produce from various parts of the country arrives at APMC which attracts a lot of wholesalers as well as retailers as it gets distributed to various suburbs of the city. The APMC has an estimated annual trade turnover of INR. 6000 crores, and generates employment for about 1 lakh people. APMC comprises of four markets divided into two phases - Phase-I has Market I for wholesale dealing of onion & potato and Market –II for fruit & vegetable, whereas Phase-II has Market-I as commodity market and Market-II is the grain, rice and oilseed market. The market has influx of major vehicles along with hustle and bustle of traders and floating population.
- The Trans Thane creek (TTC) Industrial area lies within the NMMC limits while the Taloja MIDC area lies in close proximity of NMMC area. The TTC industrial area accounts for more than 3000 industries while the Taloja industrial area consists of large, medium and small industrial units. Various types of processing industries including chemical, paper, and plastic and so on are located in these industrial areas.
- About 16% of total area in Navi Mumbai falls under MIDC (Maharashtra Industrial Development Corporation) zone. Various MNC's (Multi-National Companies) have their offices/branches in the city which makes this city an attractive business destination. It has various recreational and public places which makes it an ideal city for living.
- One of the well-known Jawaharlal Nehru Port Trust residence nearby the city have largest container port that handles around 60% of the country's containerized cargo.
- In terms of rail connectivity, Navi Mumbai has six rail corridors, 157 Km railway system and an independent mainline rail terminal connecting the city directly to Chhatrapati Shivaji Maharaj Terminus (town side) as well as western parts of Mumbai. The city also has good accessibility to Pune and Pimpri regions through road as well as rail transport. The NMMC area is served by 4 bus transport agencies operation between Mumbai-NMMC area, within NMMC area, Thane-NMMC area and surrounding areas. The road transport wing of Navi Mumbai includes connectivity from bus operators of BEST (BrihanMumbai Electric Supply and Transport),

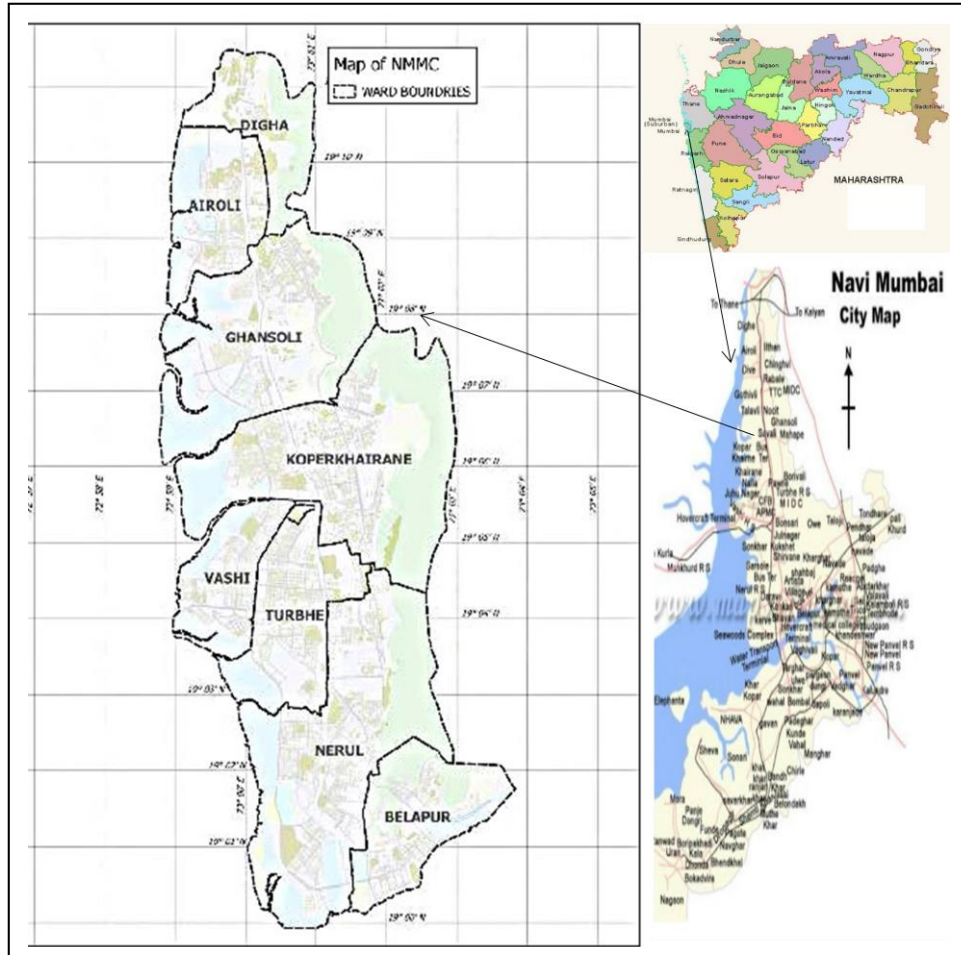
NMMT (Navi Mumbai Municipal Transport), KDMT (Kalyan- Dombivli Municipal Transport) and KMT (Khopoli Municipal Transport) which provide bus services to entire Navi Mumbai city as well as to certain parts of Mumbai, Thane, Kalyan, Dombivli, Badlapur, Taloja, Panvel and Uran.

- Many projects, like the Navi Mumbai Metro, trans-harbour link between Mumbai (Wadala) and Navi Mumbai (Ulwe), elevated corridor on Palm Beach road, as well as the ambitious international airport proposed near Panvel, are expected to enhance the connectivity as well as the status of the city.

The Navi Mumbai Municipal Corporation (NMMC) secured the first rank in the Cleanest Big City in the 10 to 40 lakh population category, but it slipped to the fourth position from the third last year in the overall ranking in the annual survey of cleanliness, Swachh Survekshan 2021. As per the annual Environment Status Report of Navi Mumbai Municipal Corporation, 2021 the EQI (Environmental Quality Index) improved by 0.63 percent, the QOLI (Quality of Life) by 0.64 percent, and the UII (Urban Infrastructure Index) by 0.65 percent in 2018-19. The overall improvement in EQI can be attributed to better air quality, particularly at traffic intersections, better solid waste management, a decrease in vector-borne diseases, the completion of road work in MIDC, enhanced public awareness of noise and solid wastes, and so on. The development of sanitary facilities, improved waste segregation at the source, improved operating efficiency of solid waste processing plants, and finished construction activities of roads and bridges inside Navi Mumbai city are all contributing to an increase in UII. In the current year, NMMC has calculated the EPI (Environment Performance Index), endorsed by MPCB for the sixth consecutive year. The calculator takes into consideration 65 data variables which are compared against the state level and national level benchmarks or averages as may be applicable. The EPI score for the NMMC area was determined to be 698.0 out of 944 and has registered an improvement of 0.64% as compared to the previous year owing to major initiatives undertaken to increase awareness related to environmental issues, public transport, effective segregation and management of solid waste, and development of roads.

The study area covers Navi Mumbai Municipal Corporation city limits. Jurisdiction of Navi Mumbai Municipal Corporation is spread over eight zones starting with Digha in north, Airoli, Ghansoli, Koparkhairane, Vashi, Turbhe, Nerul and Belapur in south. Each ward has its corresponding Ward Office to facilitate the civic amenities to the general population. The study area of Navi Mumbai Municipal Corporation city limits with zoning structure is presented in **Figure 1.1**.

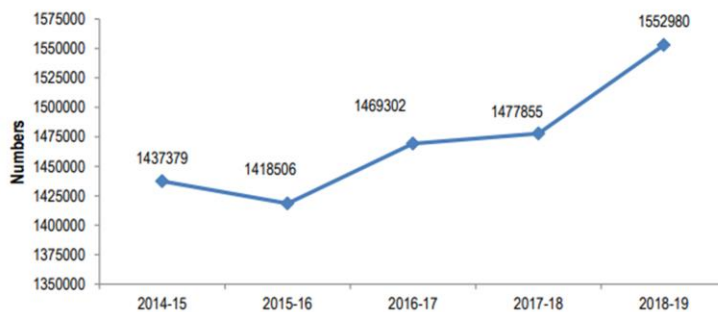




**Figure 1.1: Ward wise Jurisdiction of Navi Mumbai Municipal Corporation**

### Population

As per the Census of India 2011, the population in NMMC is 11,20,547, with population density of 10,315 persons per sq. km., and according to NMMC UHP Survey, 2018-19 the population of NMMC was estimated to be about 15,52,980. Population density is estimated to be 14,171 persons /sq.



**Figure 1.2 : Population Growth in Navi Mumbai** Source: UHP Survey, NMMC

Km. The development of industrial belt with job opportunities, higher income, civic lifestyle, and

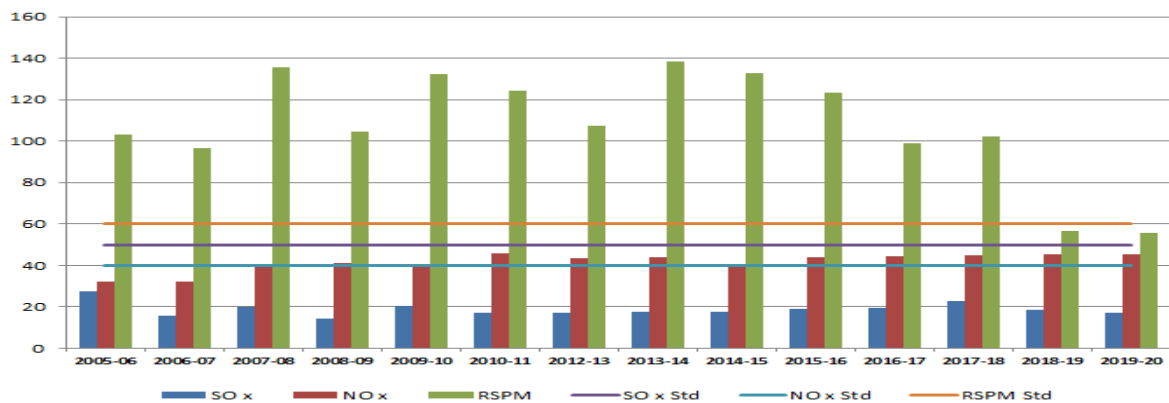
other facilities has led to migration of people into the city. The population growth for last 5 years for Navi Mumbai has been represented in **Figure 1.2**. Total number of 48,577 Slums in Navi Mumbai city has population of 207,645 residents. This is around 18.53% of total population of Navi Mumbai city (*census2011.co.in*). Since last 9 years, the city has witnessed over 21% rise in properties. In 2018-19, total number of properties rose to 3,10,222 from 3,09,841 in 2017-18. Residential sector holds major share of the properties (~82%) followed by commercial (~17%) and then MIDC commercial with least of 1% share.

## **Climate**

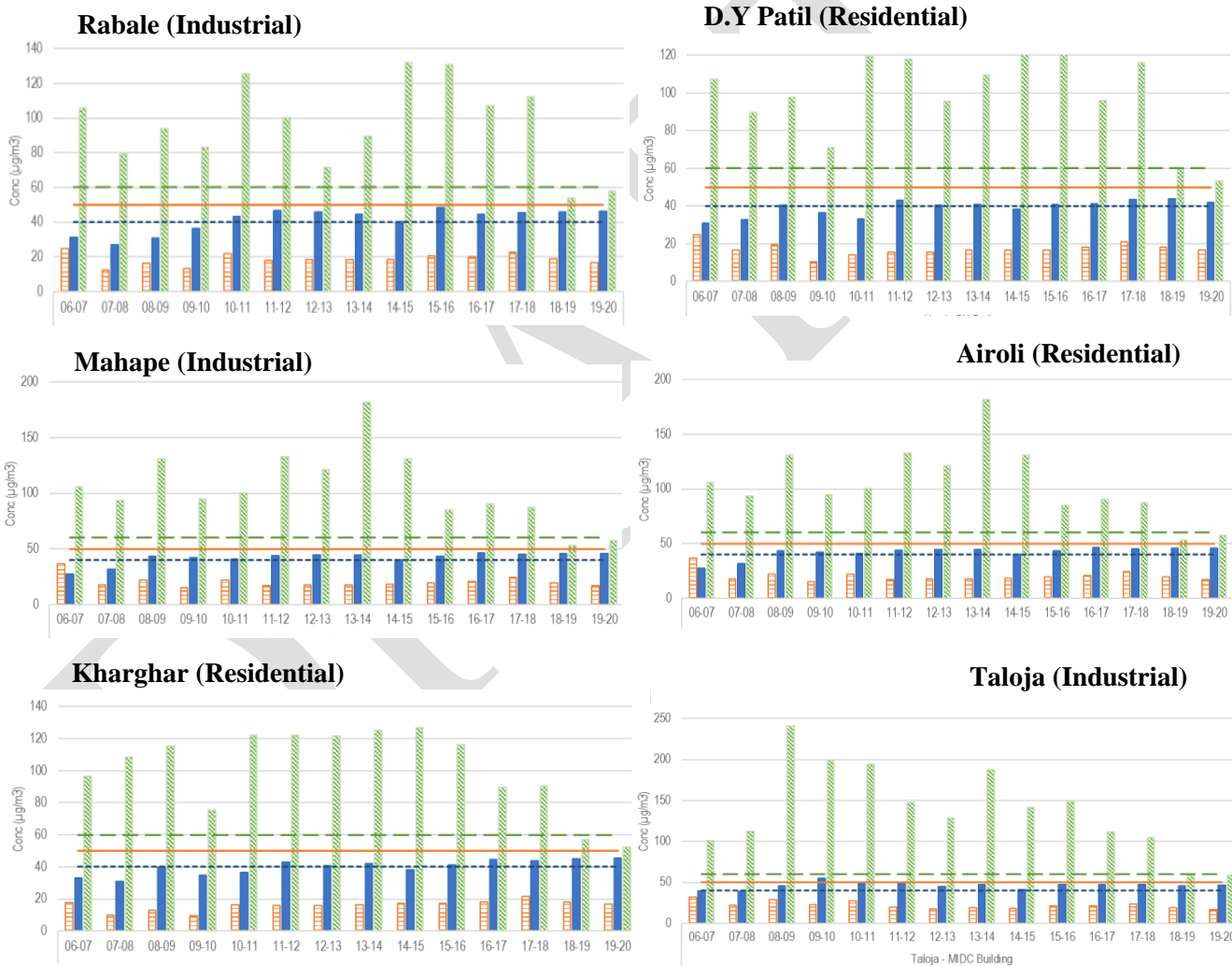
In terms of weather, temperature of the region varies from 22°C to 36°C. The area receives average annual rainfall of 2500-3000 mm and humidity is about 60-75 %. Navi Mumbai lies in the tropical climatic zone and has three seasons' summer, monsoon and winter. The annual temperature in Navi Mumbai varies from 22°C to 36°C while in summers the maximum temperature ranges between 36°C to 41°C and the minimum temperatures in winter ranges between 17°C to 20°C. Based on IMD's (Indian Meteorology Department) observations recorded at TBIA's (Thane Belapur Industry Association's) premises, the predominant wind direction in Navi Mumbai is southwest in monsoon and north-east during rest of the year.

## **1.2 Air Quality of Navi Mumbai City**

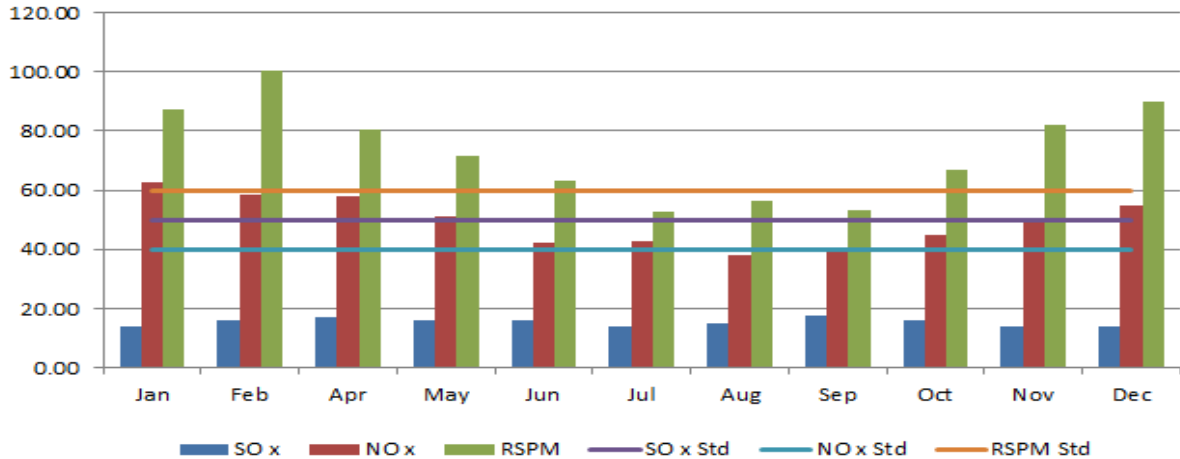
Ambient air quality is being monitored under National Ambient Air Monitoring Program (NAMP), coordinated by Central Pollution Control Board (CPCB) or SAMP (State Ambient Air Monitoring Program) stations. Presently 5 stations are operated under NAMP programme at Rabale, Nerul-DY Patil, Mahape, MPCB-Nirmal Bhavan, Kharghar-CIDCO Nodal Office and at Taloja-MIDC Building. The need for continuous ambient monitoring led to the establishment of CAAQMS (Continuous Ambient Air Quality Monitoring Stations) networks and is also being expanded throughout the country. At present there are 4 CAAQMS (Continuous Ambient Air Monitoring Stations) installed at Airoli, Koparkhairane, Turbhe, and Nerul taken care by NMMC. NMMC has also proposed installation of a CAAQMS at CBD-Belapur. The Municipal Corporation operates a mobile monitoring van which is deputed at various locations on the nodes of Navi Mumbai to monitor the air quality. The annual averages of criteria pollutants with respect to NAAQM Standards are presented in **Figure 1.3 a to d**.



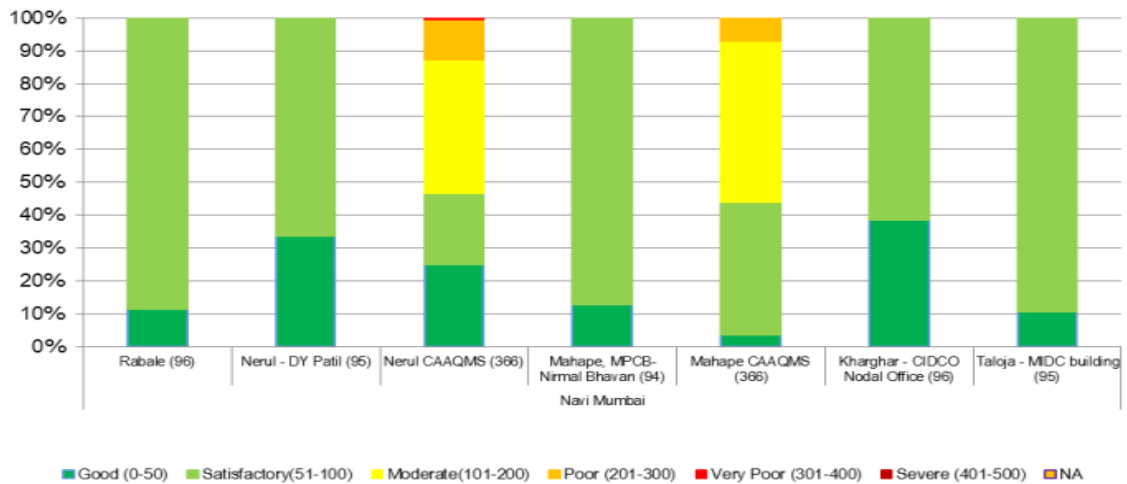
**Figure 1.3a : Trend of Annual Concentrations of Criteria Pollutant in Navi Mumbai City**



**Figure 1.3b (Contd..) : Trend of Annual Concentrations at Different Monitoring Locations in Navi Mumbai City (MPCB Sites) (2006-07 to 2019-20)**



**Figure 1.3c (Contd..) : Monthly Variation Trends for PM10, SOx, and NOx (2019-20)**



**Figure 1.3d (Contd..) : Percentage Occurrence of Composite AQI of AQQMS in Navi Mumbai (2019-20)**

From recent report of MPCB prepared by TERI - ‘Air Quality Status of Maharashtra’ during 2019-2020, the decadal analysis shows that the Annual PM concentration of Navi Mumbai City is around 71 to 136  $\mu\text{g}/\text{m}^3$ , which is mostly higher than the CPCB standards of 100  $\mu\text{g}/\text{m}^3$ , as construction, vehicular and industrial impacts were observed to be more. In the recent years considerable increase in annual average NOx Concentrations from 43  $\mu\text{g}/\text{m}^3$  to 55  $\mu\text{g}/\text{m}^3$  were noticed, which are higher than the prescribed annual average limit of 40  $\mu\text{g}/\text{m}^3$ . The concentration of SO<sub>2</sub> observed at Navi Mumbai city ranges from 15 to 37  $\mu\text{g}/\text{m}^3$ .

The decadal annual averages from 2007 to 2019 at residential (D.Y.Patil and Kharghar) sites has the concentration range from 75 to 130  $\mu\text{g}/\text{m}^3$  for RSPM, whereas for NOx it was 31-45  $\mu\text{g}/\text{m}^3$  and for SO<sub>2</sub> was 10-25  $\mu\text{g}/\text{m}^3$ . The industrial site at Mahape recorded highest annual PM concentration of 182  $\mu\text{g}/\text{m}^3$ . The Rabale industrial site also exceeds the CPCB standard limit with concentration of

PM ranging from 70 to 132  $\mu\text{g}/\text{m}^3$ . NO<sub>x</sub> concentration at industrial monitoring location was observed at around 31-45  $\mu\text{g}/\text{m}^3$  and SO<sub>x</sub> at 12-37  $\mu\text{g}/\text{m}^3$ .

In Navi Mumbai region 5 locations- Rabale, Nerul D.Y. Patil, Mahape MPCB Nirmal Bhawan Kharghar CIDCO Nodal Office and Talaja MIDC Building recorded all observations in the Good and Satisfactory categories. Moderate and Poor AQI was observed at Nerul CAAQMS (41% and 12%) and Mahape CAAQMS (49% and 7%). The AQI at Airoli (residential) represented as Good, whereas for Kharghar (residential) it was moderate to satisfactory. The downward trend of emission concentration was observed in monsoon.

### 1.3 Objective of the Study

CPCB has listed cities in India in which the RSPM levels are non-complaint with the NAAQS and has directed SPCBs to develop action plans and implement these to control air pollution in these cities; Navi Mumbai is one of them. There is a strong need for city-scale emission inventories to assess the types and sources of emission loads and to develop control measure as well for the development of pollution control strategies and policies.

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 of various air 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.

## **Air Quality Monitoring**

### **2.1 Monitoring Sites (Navi Mumbai)**

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. Six sampling sites were finalized as representative of the Navi Mumbai metropolitan area. Of these, one site was selected as control site (Maritime University), and two for Kerbside (Vashi Toll Naka and Vashi Plaza Traffic Intersection), others are Nerul (Residential), APMC-Kanda Batata Market (Commercial) and industrial site at Thane Belapur Road, Juinagar. The study area is presented in **Figure 2.1** and site characteristics are presented below.

**Maritime University (Background)** : Located at Seawoods, on further end of Palm Beach Road, the sampling instrument was installed in the premises of Maritime University at a height of about 1.5 m above the ground level. The location is on western boundary side of Navi Mumbai region and secluded in terms of activities as compared to other monitoring locations, hence selected as background location. The area around these locations is a well-planned neighborhood, with Nerul on the north, Panvel Creek on the south, Belapur CBD on the east, and Thane Creek on west. The NMMC Corporation building is across the street from the site, and there is seasonal sighting of flamingo's congregation in the nearby stream area of the location.

**Nerul- Sahakar Bazar (Residential Site)** : Nerul is a well-planned neighborhood that acts as a residential and business center in Navi Mumbai. As the city is accessible in terms of road connectivity, local market in Sector 1 of Nerul is visited by people from the vicinity as well as from Palm Beach Road, Vashi, Thane, and Belapur. The various activities at market, hotels, restaurants and, open eateries along with buzzing neighbourhood contribute in local emission load. The sampling instrument was installed on the terrace (first floor) of Sahakar Bazar building, about 3 m above the ground level.

**APMC Market (Commercial Site)**: The Agricultural Produce Market Committee (APMC) in Vashi was selected as commercial site location for monitoring. The samplers were installed at a height of about 1.5 m above the ground level near the security guard cabin of the market. At peak hours, the market area has heavy duty vehicles movement for loading-unloading of the goods. The monitoring station was installed near Kanda Batata Market. The market is at the interjection of

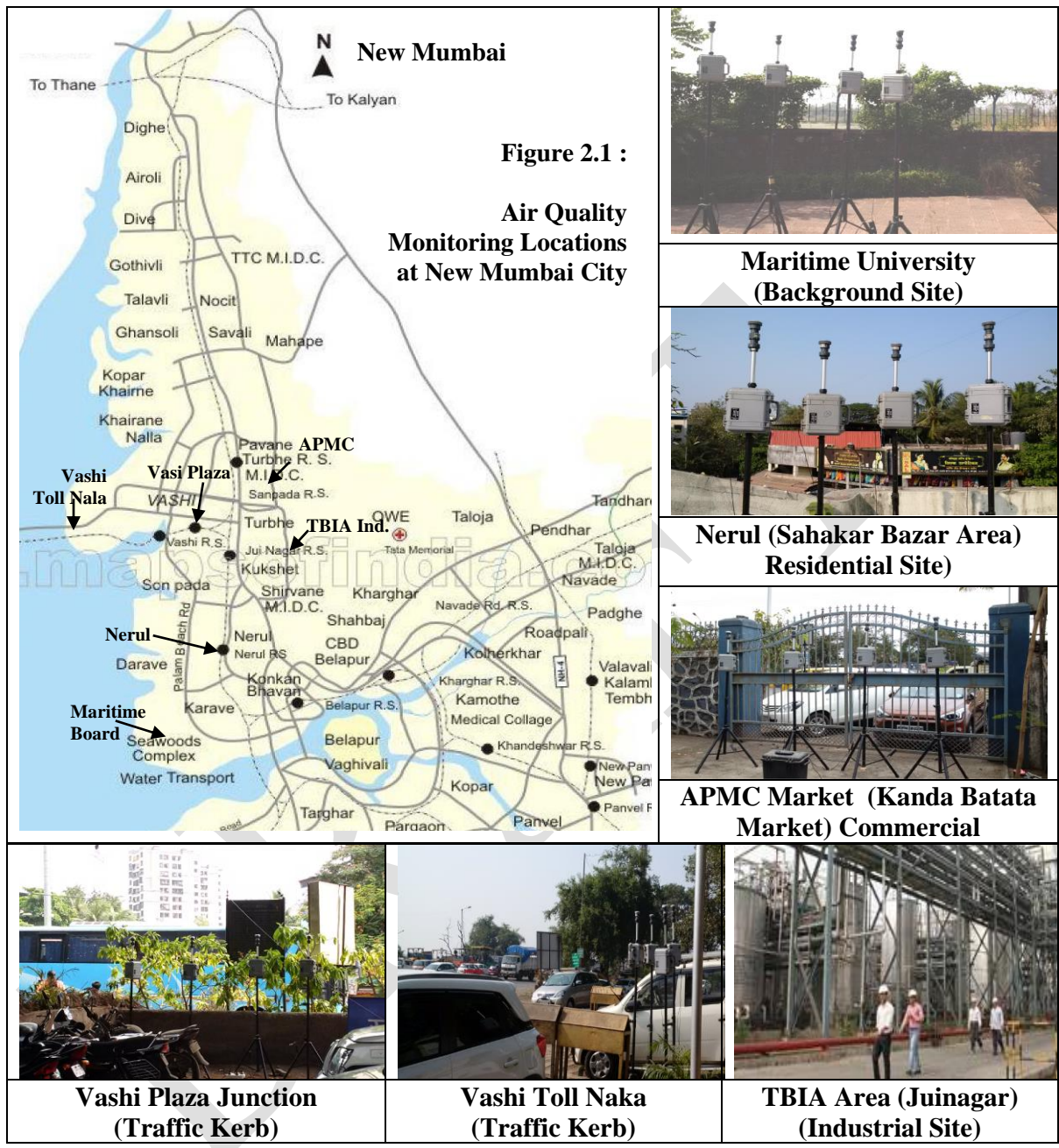
Thane Belapur Road, Vashi Bridge, and Turbhe Road. The surrounding region has residential buildings, small and medium hotels; open eateries, and frequent movement of public transportation as well as commercial and private vehicles along the route.

**Vashi Toll Plaza (Kerbside)** : This was a kerbside location and the samplers were installed on an elevated platform at a height of about 1.5 m from the ground level. The majority of NMMC's private as well as public transportation buses arrive at this intersection. The key routes in the area include Vashi Sanpada Road, APMC Market Road, Palm Beach Road, and others. Along the route are major commercial buildings like malls, restaurant, hotel and shops, institutions like hospitals and schools and so on. The traffic at this interjection is high as compared to other part of the city, as it serves link between Mumbai, Thane, Panvel and Pune.

**Vashi Toll Naka (Kerbside)** : The Vashi toll naka is located on the Vashi end of the Vashi creek bridge, which is 1837 meters long. This was a kerbside and the samplers were installed on an elevated footpath at a height of about 2 m from the ground level, near Vashi Traffic Office. It is a key entry point toll in Navi Mumbai. The kerbside location was chosen due to the huge volume of vehicles entering and exiting the city premises, particularly during peak hours. During idle and acceleration situations, which are common at toll plazas and traffic junctions, engine will release greater particle exhaust emissions.

**Juinagar, Thane-Belapur Road (Industrial)**: Industrial units of various categories which includes manufacturing units of chemicals, dyes, pharmaceuticals, petrochemicals, textile and engineering, are the main category of industries in NMMC. Besides this, the city is having well established Information Technology (IT) sector especially in Airoli, Ghansoli and Vashi node. Thane-Belapur is congested majorly with heavy duty and private vehicles at peak hours because it connects Navi Mumbai to Thane District. The monitoring station was installed in industrial premises near Juinagar on Thane-Belapur Road, on the top of a single story building at about 3 m height.





## 2.2 Measurement and Frequencies

Air quality was monitored as per the CPCB guidelines and chemical speciation methodologies adopted are given in **Table 2.1**. Portable air samplers (Airmetric) were used to sample PM<sub>2.5</sub> and PM<sub>10</sub>. Four samplers were collocated at every monitoring site to collect samples for PM<sub>2.5</sub> and PM<sub>10</sub>, each on two filter substrates (Teflon and Quartz). 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. The flow rate of 5.0 lpm was found to be suitable as it would collect about 7.2 m<sup>3</sup> of air in 24 hours, and the total mass of sample would be under 1500 µg (based on the average ambient concentration of PM<sub>10</sub> and PM<sub>2.5</sub> is 203 and 80 µg/m<sup>3</sup> respectively reported for Navi Mumbai). 24-hour air quality was monitored at each site for 10 days during winter 2018-19.

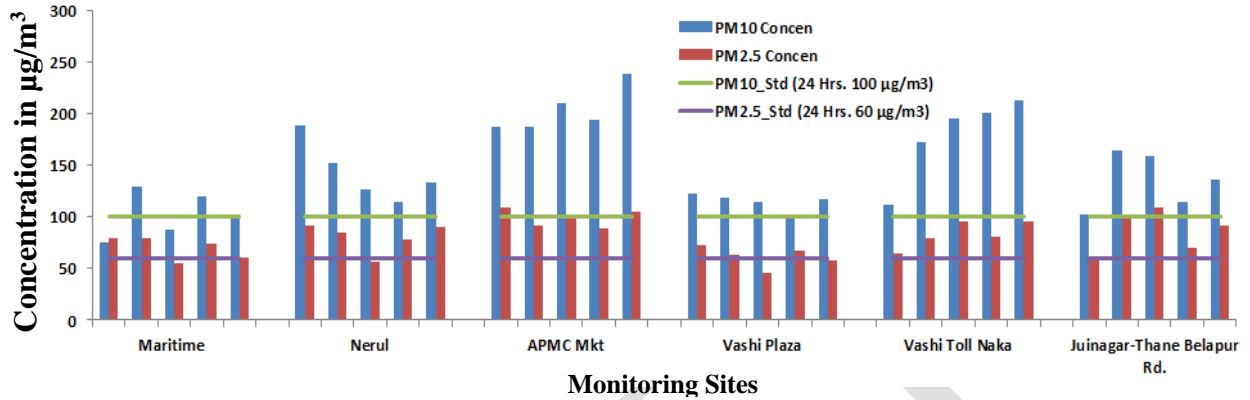
**Table 2.1 : Target Physical and Chemical Components (groups) for Characterization of Particulate Matter for Source Apportionment**

	PM <sub>10</sub>	PM <sub>2.5</sub>	OC/EC	Element /Ions
Sampling Instrument	Air Metric MiniVol Portable Sampler		Particulate collected on Quartz filter paper	Particulate collected on PTFE Filter paper
Sampling Principle	Inertial impaction			
Flow Rate	5 LPM			
Sampling Period	24-Hour			
Sampling Frequency	Total 10 days; using Quartz and PTFE Filter Simultaneously			
Analytical Instrument	Electronic Microbalance	Electronic Microbalance	OC/EC Analyzer	Ion Chromatography (Ions) and ED-XRF (Elements)
Minimum Reportable Value	5 µg/m <sup>3</sup>	5 µg/m <sup>3</sup>	0.2 µg/ 0.5 cm <sup>2</sup> Punch	NA

Components	Required Filter Matrix	Analytical Methods
PM <sub>10</sub> / PM <sub>2.5</sub>	Teflon (PTFE) 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 (PTFE) filter paper	ED-XRF
Ions (Na <sup>+</sup> , NH <sub>4</sub> <sup>+</sup> , K <sup>+</sup> , Mg <sup>2+</sup> , Ca <sup>2+</sup> , F <sup>-</sup> , Cl <sup>-</sup> , NO <sub>2</sub> <sup>-</sup> , NO <sub>3</sub> <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup> )	Teflon (PTFE) 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 °C is essential	TOR/TOT method

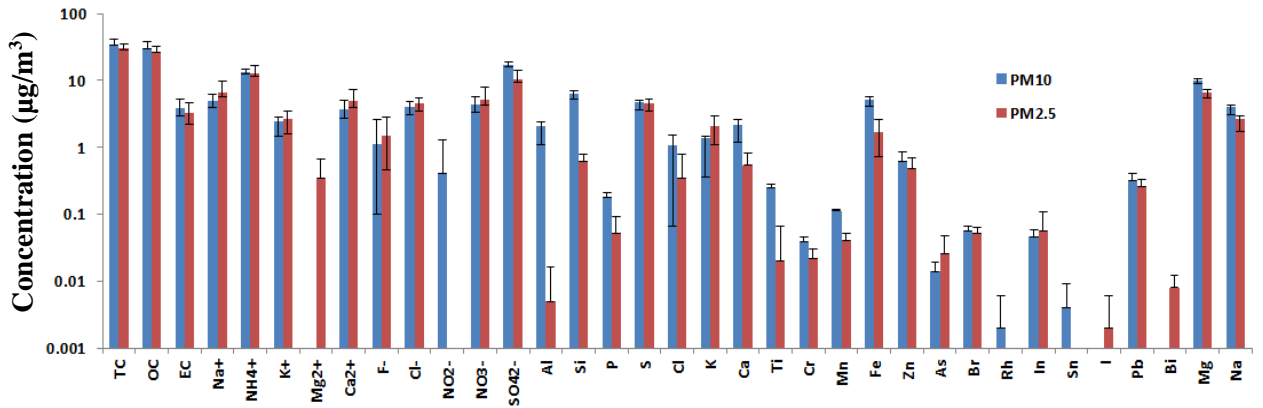
### 2.3 Monitoring Results

The particulate matter concentration compared with NAAQM Standard of PM<sub>2.5</sub> and PM<sub>10</sub> is presented in of **Figure 2.2**.

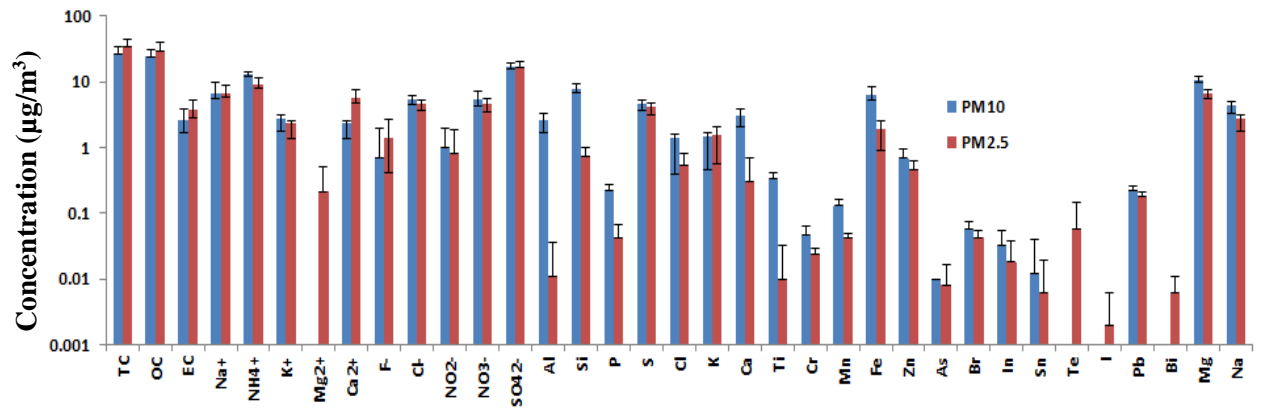


**Figure 2.2 : PM<sub>10</sub> and PM<sub>2.5</sub> Concentrations with respect to NAAQM Std**

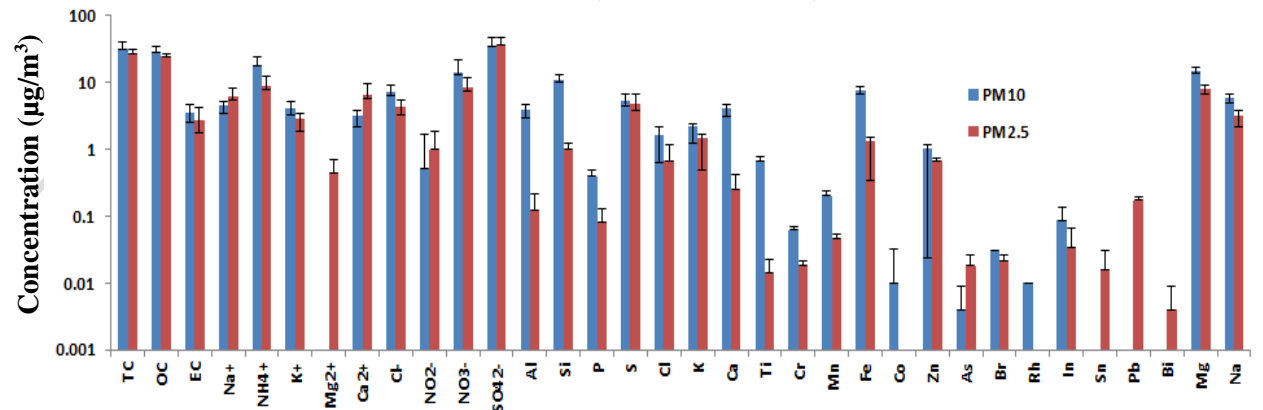
The PM<sub>10</sub> concentration at Maritime Board (Background site) ranges from 75.5 to 129.0 µg/m<sup>3</sup> (Avg. 103 µg/m<sup>3</sup>), whereas for PM<sub>2.5</sub> it was 55 to 80.1 (Avg. 69.8 µg/m<sup>3</sup>) for same location. PM<sub>2.5</sub>/PM<sub>10</sub> ratio is in the range of 0.5 to 0.7. The concentration range at Nerul (residential site) for PM<sub>10</sub> was from 114.2 to 189.5 µg/m<sup>3</sup> (Avg. 143.3 µg/m<sup>3</sup>), whereas PM<sub>2.5</sub> ranged from 56.6 to 91.5 µg/m<sup>3</sup> (Avg. 80.4 µg/m<sup>3</sup>). PM<sub>2.5</sub>/PM<sub>10</sub> ratio is in the range of 0.4 to 0.6 for the location. The concentrations at APMC Market (Commercial site) were in the range of 187.2 to 239.4 µg/m<sup>3</sup> (Avg. 203.9 µg/m<sup>3</sup>) and 89 to 108.7 µg/m<sup>3</sup> (Avg. 98.7 µg/m<sup>3</sup>) for PM<sub>10</sub> and PM<sub>2.5</sub> respectively, with PM<sub>2.5</sub>/PM<sub>10</sub> ratio of 0.4 to 0.5. At kerbside location Vashi Plaza, PM<sub>10</sub> concentration was found to be between 98.3 to 122.7 µg/m<sup>3</sup> (Avg. 114.3 µg/m<sup>3</sup>) and 46 to 72.5 µg/m<sup>3</sup> (Avg. 61.4 µg/m<sup>3</sup>) for PM<sub>2.5</sub>. Another kerbside at Vashi Toll Naka reported PM<sub>10</sub> concentration at the range of 112.5 to 213.2 µg/m<sup>3</sup> (Avg. 178.9 µg/m<sup>3</sup>) and for PM<sub>2.5</sub> concentration at range 65.1 to 95.9 µg/m<sup>3</sup> (Avg. 83.2 µg/m<sup>3</sup>). At both the sites PM<sub>2.5</sub>/PM<sub>10</sub> ratio is around 0.4. At Juinagar-Thane Belapur Rd. vicinity, PM<sub>10</sub> concentration at Industrial monitoring location was observed to be 103.2 to 164.5 µg/m<sup>3</sup> (Avg. 135.8 µg/m<sup>3</sup>) and 58.1 to 108.9 µg/m<sup>3</sup> (Avg. 85.4 µg/m<sup>3</sup>) for PM<sub>2.5</sub> with ratio of 0.6. The 24 hourly average concentrations of PM<sub>10</sub> and PM<sub>2.5</sub> exceeded at all the sites of the NAAQM CPCB Standards of 100 µg/m<sup>3</sup> for PM<sub>10</sub> and 60 µg/m<sup>3</sup> for PM<sub>2.5</sub>. The highest particulate matter concentrations were observed at APMC Mkt; followed by Vashi Toll Naka and Thane Belapur industrial area. Overall average PM /PM ratio was in the range of 0.4 to 0.7 indicating the predominance of coarse particulate matter. The correlation between PM<sub>10</sub> and PM<sub>2.5</sub> showed on R<sup>2</sup> value of 0.3 indicating merely similar sources for PM<sub>10</sub> and PM<sub>2.5</sub>. The graphical compositional comparison of PM<sub>2.5</sub> Vs PM<sub>10</sub> for all species are shown in **Figure 2.3**



Maritime Board (Background Site)



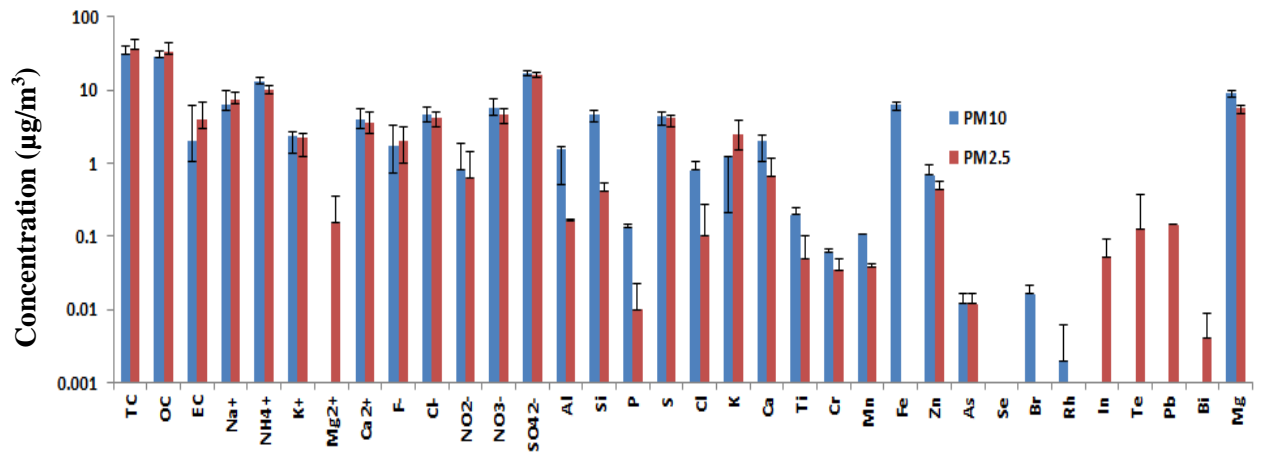
Nerul (Residential Site)



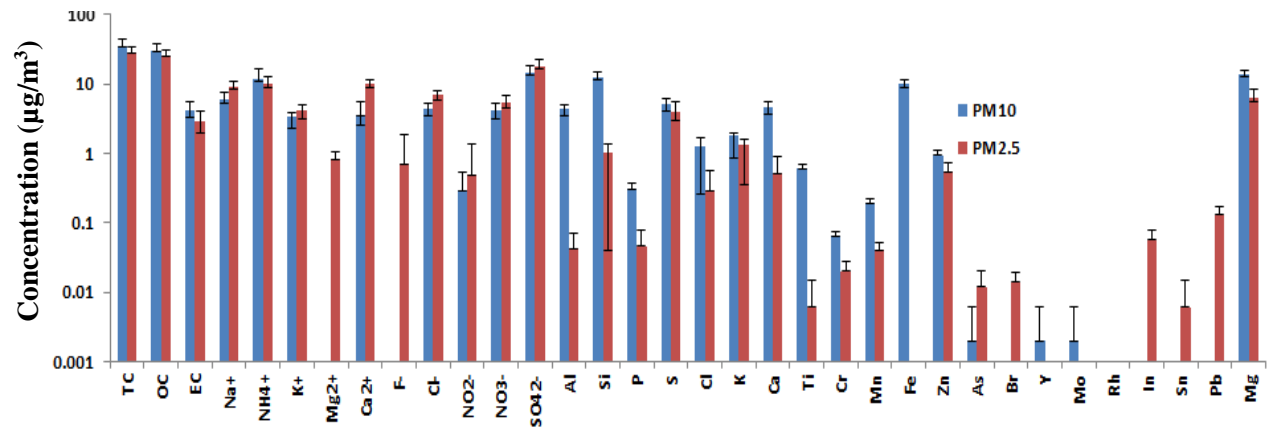
APMC Market (Commercial Site)

Chemical Species

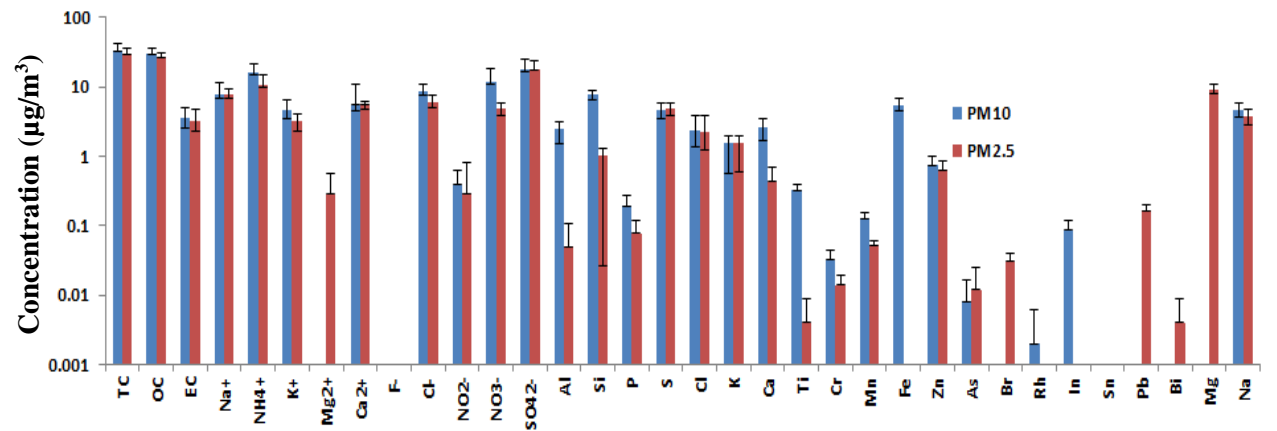
Figure 2.3 : Compositional Comparison of Species Concentrations in PM<sub>10</sub> and PM<sub>2.5</sub>



Vashi Plaza (Kerbside)



Vashi Toll Naka (Kerbside)



Junagar-Thane Belapur Road (Industrial Site)

Chemical Species

Figure 2.3 (Contd..) : Compositional Comparison of Species Concentrations in PM<sub>10</sub> and PM<sub>2.5</sub>

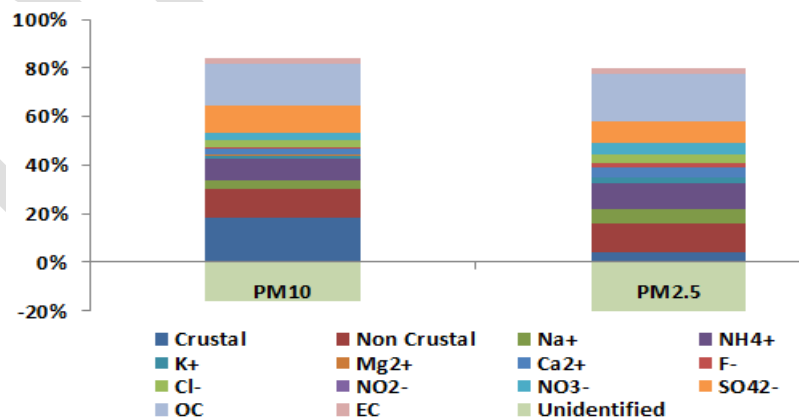
### 2.3.1 Mass Closure of PM<sub>10</sub> and PM<sub>2.5</sub>

The PM<sub>10</sub> and PM<sub>2.5</sub> samples were analyzed for 46 elements and 12 ions species for a total of 60 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<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, NO<sub>3</sub><sup>-</sup>,...) + Cations (Na<sup>+</sup>, K<sup>+</sup>, NH<sub>4</sub><sup>+</sup>,...)  
 + Trace Elements (Excluding geological + Unidentified)

**Maritime Board (Background):** The major chemical component of PM<sub>10</sub> is of Crustal and Non-crustal elements that account for 27.7% and 18.1%, respectively at this site. Anions account for 26.9% of the total coarse particulate mass. Amongst the anions, contribution from sulfate is maximum (17.1%), followed by nitrate and chloride (4%), which is probably due to secondary aerosol, road dust etc. Cations make up 24.9% of the total PM<sub>10</sub> concentration. Composition of Ammonia (13.5%), calcium and sodium (4 to 5%) are higher in Cation. The 25.8% organic matter and 3.9% of elemental carbon is probably due to anthropogenic activities near the monitoring site. The negative unidentified portion in PM<sub>10</sub> was -24.3% 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). (Figure 2.4)

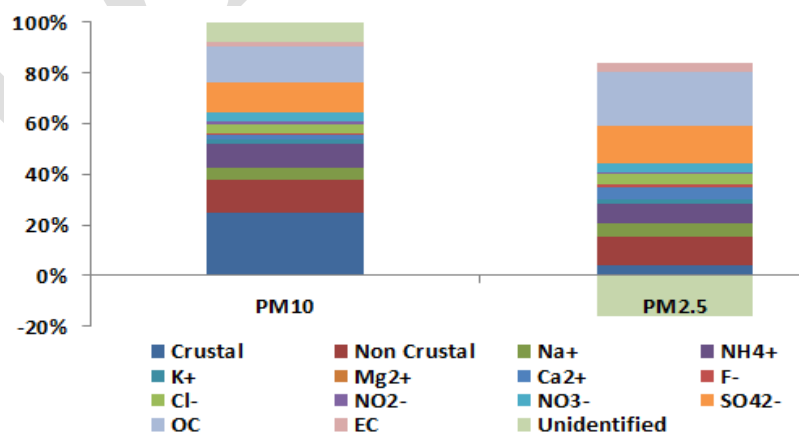


**Figure 2.4 : Percent Contribution to Mass in PM<sub>10</sub> and PM<sub>2.5</sub> at Maritime Board (Background Site)**

Percent contribution of Crustal and Non-crustal elements in PM<sub>2.5</sub> is around 4.5% and 13.8%, respectively. Anions and cations contribute 21.6% and 27.2% of the total PM<sub>2.5</sub>. Contribution of Sulfate (10.4%), nitrate and chlorides (4 to 5%) are high in Anions, whereas that of ammonia (12.6%), calcium (4.9%) and sodium (6.7%) are higher in Cation. The organic matter accounts for 22.5% and elemental carbon is 3.2% of the total concentration. Negative percent -23.1% in PM<sub>2.5</sub> indicates that water bound particle exceeded the sum of identified species in measured mass.

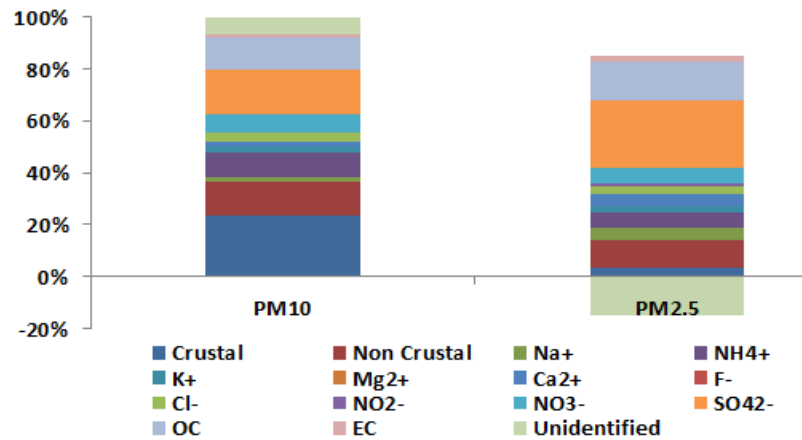
**Nerul (Residential Site) :** The Crustal and Non-crustal elements accounts for 35.2% and 19.4%, respectively in PM<sub>10</sub>. Anions account for 29.3% of the total coarse particulate mass (sulphate 16.9%, nitrate 5.3% and chloride 5.4%); whereas, Cations constitutes of up 25.2% (ammonia 13% and sodium 6.7%) of the total PM<sub>10</sub>. Out of the total concentration, 20.9% accounts for OC and 2.7% for elemental carbon. The impact of highly commercial and residential is visible in the results and maximum contribution is probably due to secondary aerosol, road dust etc. Unidentified portion in PM<sub>10</sub> was 10.7% which may due to volatilization of organic matter and nitrates.

PM<sub>2.5</sub> is found to be in Crustal and Non-crustal elements i.e. 4.8% and 13.2%, respectively. Anions and cations contribute 28.5% and 23.9% of the total PM<sub>2.5</sub> concentration. In anion, 17.1% sulfate and 4% chlorides & nitrate and 5.7% calcium and 8.9% ammonia in Cation, are of the highest composition. The organic matter accounts for 25.8%, and elemental carbon is around 3.8% of the total concentration. The unidentified negative contribution -19.4% of PM<sub>2.5</sub> indicates that the sum of identified species exceeded the measured mass. This is due to particle bound water and other analytical uncertainties (**Figure 2.5**).



**Figure 2.5 : Percent Contribution to Mass in PM<sub>10</sub> and PM<sub>2.5</sub> at Nerul (Residential Site)**

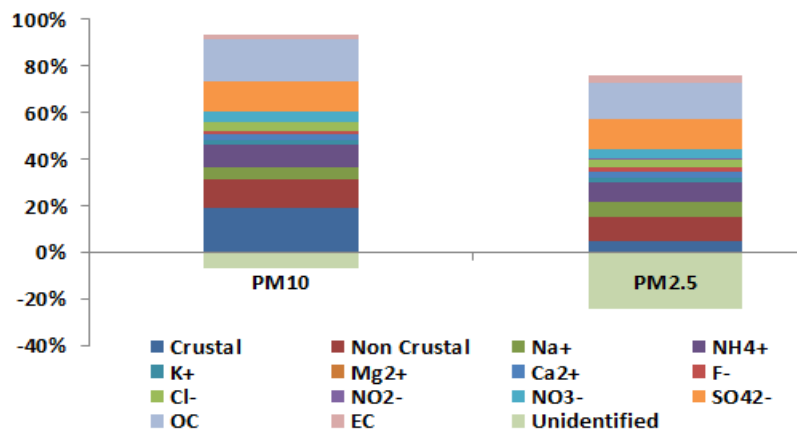
**APMC Mkt Yard:** The monitoring location being commercial market area and also because of heavy duty vehicle movements, the resuspension of dust is contributing 48% for Crustal and 26.2% of Non-crustal elements in PM<sub>10</sub> mass. Anions account for 57.6% of the total coarse particulate mass (sulphate 35.3%, nitrate 14.3% and chloride 7.5%); whereas Cations make up 31.4% (ammonia 18.8%, calcium 7.5% and sodium 4.5%) of the total PM<sub>10</sub>. The organic matter, accounting for 24.3% and elemental carbon is around 3.5%. The high contribution is probably due to secondary aerosol, road dust and extensive vehicular movement. Unidentified portion in PM<sub>10</sub> was 13% which may due to volatilization of organic matter and nitrates (**Figure 2.6**).



**Figure 2.6 : Percent Contribution to Mass in PM<sub>10</sub> and PM<sub>2.5</sub> at APMC Mkt (Commercial Site)**

PM<sub>2.5</sub> in Crustal and Non-crustal elements i.e. 4.6% and 15.4%, respectively. Anions and cations contribute 50.7% and 25.2% of the total PM<sub>2.5</sub>. Sulfate 37%; nitrate 8.5% and chlorides 4.3% are the major portion in Anions, whereas calcium 6.7% and ammonia 8.8% are highest in Cation. The organic matter accounts for 21.3%, and elemental carbon is around 2.8%. The unidentified negative contribution -21.3% of PM<sub>2.5</sub> indicates that the sum of identified species exceeded the measured mass.

**Vashi Plaza (Kerbside):** The major source identified at this location was heavy duty vehicle movement, idling of the vehicles at toll and traffic, and commercial activities. The 24.8% and 16.5% is contributed by Crustal and Non-crustal elements in PM<sub>10</sub> mass, respectively. Anions account for 29.7% of the total coarse particulate mass (sulphate 17%, nitrate and chloride 4 to 5%); whereas, Cations make up 25.7% of the total PM<sub>10</sub> (ammonia 13%, sodium 6.4% and calcium 3.9%). The organic matter accounts for 24.3% and elemental carbon is around 2%. The highly commercial activities and vehicular movement reflected the area for maximum contribution. Negative percent -8.8% in PM<sub>10</sub> indicates that the sum of identified species exceeded the measured mass (**Figure 2.7**).



**Figure 2.7 : Percent Contribution to Mass in PM<sub>10</sub> and PM<sub>2.5</sub> at Vashi Plaza (Kerbside)**

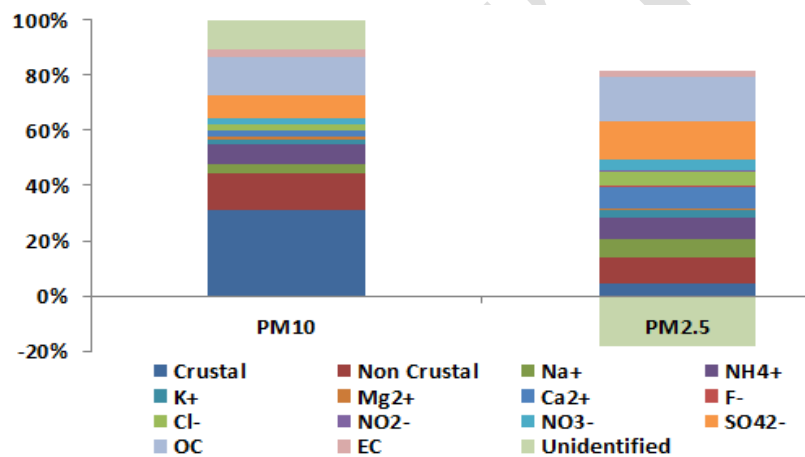
The Crustal (5.9%) and Non-crustal elements (12.5%) contributes for PM<sub>2.5</sub>. Anions and cations contribute 26.9% and 23.2% of the total PM<sub>2.5</sub>. Sulfate 15.7%, chlorides and nitrate 4% are highest in Anions, whereas, ammonia 10% and sodium 7% and calcium 4% are highest in Cation. The organic matter accounts for 18.2% and elemental carbon is around 3.9%. The negative discrepancy unidentified portion in PM<sub>10</sub> was -29.1% indicates that the sum of identified species exceeded the measured mass. This is due to particle bound water and other analytical uncertainties.

**Vashi Toll Naka (Kerbside):** This monitoring site is another major hotspot for traffic, heavy vehicular movement which results in resuspension of road dust. The 56% and 23.7% is contribution of Crustal and Non-crustal elements in PM<sub>10</sub> mass. Anions account for 23.1% of the total coarse particulate mass (sulphate 14.6%, nitrate and chloride 4%); whereas, Cations make up 27.1% of the total PM<sub>10</sub> (ammonia 12%, sodium 6% and calcium 3.5%). The organic matter accounts for 25.3% and elemental carbon is around 4.2%. The highly vehicular movement



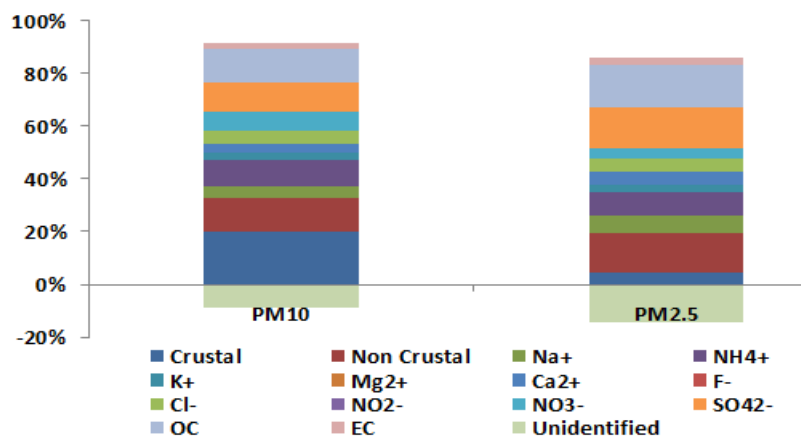
reflected the area for maximum contribution. Unidentified portion in PM<sub>10</sub> was 19.5% which may be due to volatilization of organic matter and nitrates (**Figure 2.8**).

The Crustal (5.6%) and Non-crustal elements (12.4%) contribute for PM<sub>2.5</sub>. Anions and cations contribute 31.4% and 33.9% of the total PM<sub>2.5</sub>. Sulfate 17.8%, chlorides 7% and nitrate 5.4% are high in Anions, whereas, ammonia, sodium and calcium are around 9%, and are higher in Cation. The organic matter accounts for 21.4% and elemental carbon is around 2.9%. The negative discrepancy unidentified portion in PM<sub>10</sub> was -24.4% indicates that the sum of identified species exceeded the measured mass. This is due to particle bound water and other analytical uncertainties.



**Figure 2.8 : Percent Contribution to Mass in PM<sub>10</sub> and PM<sub>2.5</sub> at Vashi Toll Naka (Kerbside)**

**Juinagar-Thane Belapur Rd. (Industrial Site) :** In TBIA belt, resuspension of dust due to anthropogenic activities and natural wind effect is the major cause. The Crustal and Non-crustal elements contribution is around 32.6% and 21% respectively to the PM<sub>10</sub> mass. Anions account for 38.1% of the total coarse particulate mass, whereas Cations make up 34% of the total PM<sub>10</sub>. The sulphate 17.9%, nitrate 11.7% and chloride 8.5% in anions, and ammonia 15.9%, calcium and potassium 4% sodium 7.8% in cations are the major contributors; as also the organic matter, accounting for 20.9%. The high contribution is probably due to secondary aerosol and road dust. Unidentified negative portion in PM<sub>10</sub> was -14.4% indicates that the sum of identified species exceeded the measured mass (**Figure 2.9**).



**Figure 2.9 : Percent Contribution to PM<sub>10</sub> and PM<sub>2.5</sub> at TBIA (Industrial Site)**

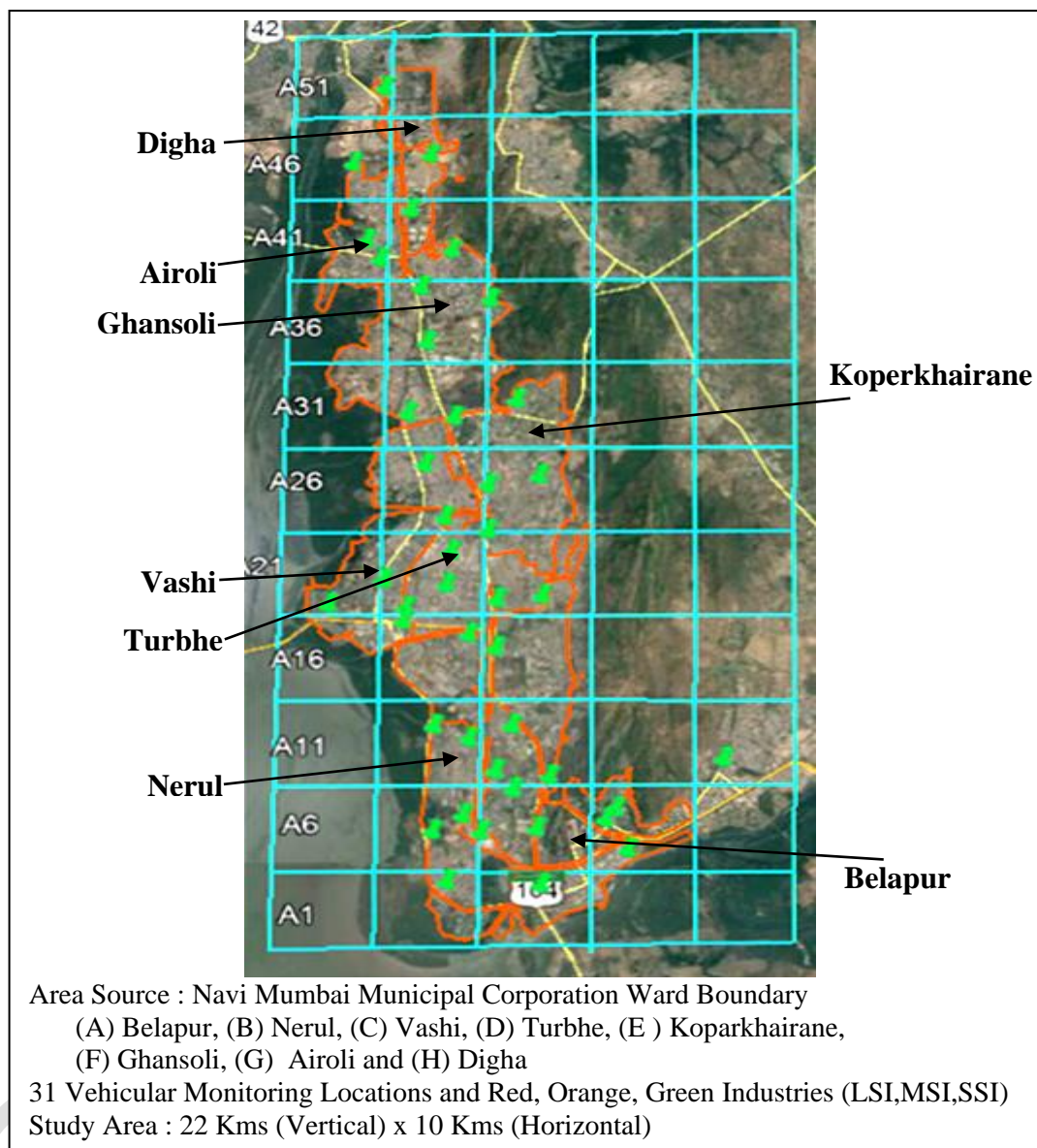
Crustal and Non-crustal elements influence in PM<sub>2.5</sub> is around 5.2% and 18%. Anions and cations contribute 29% and 27.7% of the total PM<sub>2.5</sub>. Sulfate 18.3%, nitrate and chlorides 4 to 6% are high in Anions, whereas ammonia 10.6%, sodium 7.9% and calcium 5.7% are higher in Cation, as also organic matter, accounting for 19.2%. Negative unidentified portion -16.9% in PM<sub>2.5</sub> is identified due to particle bound water and other analytical uncertainties.

### 3.1 Preamble

As the city is expanding in terms of commerce and infrastructure development, there is increase in the rate of population and vehicular growth in the city. With this, there is increase in the level of anthropogenic activities in the region which contribute to overall emission load of the city. The unchecked increasing emission load of the region might lead to several health complexions in the general population. The identification of pollutant loads and to prepare the strategic action plan for controlling them is the need of the hour. Quantitative emissions estimates supplied by an inventory enable policymakers and the general public gains a better knowledge of actual emissions and raise awareness. Emission inventories are increasingly considered essential tools for a wide range of environmental measures, management of chemicals as well as the prevention of air pollution.

An emissions factor is a representative variable that attempts to link the amount of a pollutant emitted to the level of activity associated with that pollutant's emission. Emissions data when geographically and temporally distributed can be utilized as input data for atmospheric transport and dispersion models. After verification using ground monitoring data and/or data from satellite observations, the resulting air concentration and dispersion estimations derived by modeling will be critical information for air quality management decision-making. The key emission sources can be identified, emission reduction priorities can be established, and any data gaps that need to be filled can be discovered through this approach. An emission inventory can be used to forecast future emissions based on expected socio-economic indicators (e.g. population increase, economic growth, changes in energy usage per unit activity), lower emission factors (e.g. better control methods), fuel switching, and so on. Future emissions projections are crucial for determining emissions targets. One of the most important dimensions that characterize emission inventories is the spatial resolution of emission data. Inventory with high spatial resolution is required for micro scale or local scale assessments. Low spatial resolution inventories are sufficient for estimating background concentration.

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 Navi Mumbai for accurately identify and quantify emissions from different sources (**Figure 3.1**). mission inventory has been prepared in terms of five major pollutants, viz. PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>x</sub>, CO and HC.



**Figure 3.1: 2 Km X 2 Km Grid Distribution Map of Navi Mumbai City**

### 3.2 Area Sources

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. The emission load for volatile organic compound (VOC) emissions and particulate matter (PM) from area source accounts more proportion as compared to point and line sources. VOC significantly contribute towards the formation of ground level ozone. Area sources include the following groups, viz. bakeries, hotels/restaurants, crematories,

construction activity, garages, domestic cooking, open eat outs, paved/unpaved road dust, solid waste dumping ground and refuse burning. Area source emissions are calculated by multiplying an established emissions factor (emissions per unit of activity) by the appropriate activity or activity surrogate responsible for generating emissions. Population is one of the more commonly used activity surrogates for area sources. In subsequent sections, these sources have been described along with the methodologies delineated for load estimation.

### 3.2.1 Bakery

About 60% of bakery industry in India is unorganized, being an essential item in urban areas, bakeries mainly operate from the midst of a city. According to NMMC, there are 8 bakeries in Navi Mumbai region, spread across 5 wards. To suffice the demands of Navi Mumbai's population for bakery products, the number of bakeries is few. 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 use outdated technologies and traditional methods of manufacturing baked goods that utilize solid fuels in large quantity. Wood burning is the main source of pollution from bakeries. Mostly bakeries operate for 16 hours in a day and the peak season of business is December and January. An initial survey with baker association pointed out that on average bakeries has 2 wood based operating ovens and the average amount of wood consumed per oven is 250 kg/day. Diesel consumption for oven operating is about 60 liters/day. Data regarding bakeries in each ward was obtained from NMMC, Public Health Department. 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 regions (**Table 3.1**). Based on the local survey and estimates it was found that most of the bakeries use about 90% firewood and remaining 10% diesel. However, it was found only wood is being used as the fuel for ovens in these regions. 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 inventoried to maintain such records. In our study, emission from wood consumption of these bakeries is taken into account.

#### **Emission Estimations:**

Emissions (kg/d) = No. of Bakeries x Fuel Consumption (kg/d) x Emission Factor

Number of registered bakeries with NMMC = 8

Wood consumption in a day = 250 (kg/d/oven) x 2 Ovens = 500 kg/d

Emission factor used are listed **Annexure I**

Emission Factor for Wood Burning = 17.3 (kg/t) (PM<sub>10</sub>)

Emission from wood burning (PM<sub>10</sub>) = 8 x 500 x 17.3 = 69.2 (kg/d)

**Table 3.1 : Fuel Consumption and Emission Loads from Bakeries for all Wards**

Ward	Wood Bakeries	Wood Consu. (Kg/day)	Emission Load (Kg/day)							
			PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	HC	CO	CO <sub>2</sub>	
Belapur - A	2	1000	17.3	11.8	0.2	1.3	114.5	126.3	1700.0	
Vashi – C	1	500	8.7	5.9	0.1	0.7	57.3	63.2	850.0	
Turbhe – D	3	1500	26.0	17.7	0.3	2.0	171.8	189.5	2550.0	
Koparkhairane -E	1	500	8.7	5.9	0.1	0.7	57.3	63.2	850.0	
Ghansoli - F	1	500	8.7	5.9	0.1	0.7	57.3	63.2	850.0	
<b>Total</b>	<b>8</b>	<b>4000</b>	<b>Kg/d</b>	<b>69.2</b>	<b>47.1</b>	<b>0.8</b>	<b>5.2</b>	<b>458.0</b>	<b>505.2</b>	<b>6800.0</b>
			<b>T/Yr</b>	<b>25.3</b>	<b>17.2</b>	<b>0.3</b>	<b>1.9</b>	<b>167.2</b>	<b>184.4</b>	<b>2482.0</b>

As there are 3 bakeries registered in Ward -D, the emission load for all the parameters from Ward D is highest, followed by Ward A. Total PM<sub>10</sub> load emission from bakeries comes around 69.2 kg/d. The other major pollutant reflected as HC and CO<sub>2</sub> as there is wood burning activity.

### 3.2.2 Crematoria

Hindus consider a fiery dissolution of the body as death rites for cremation. According to NMMC there are around 27 Hindu crematoria in the city. Of these, 25 are wood based and 2 are electrically operated by NMMC or privately owned. As per the assumption from previous studies and in consultation with NMMC, the average wood requirement for burning a dead body is about 300 kg and 3 liters (2.43 kg) of kerosene. Emission from this category of Area source release major pollutants like PM<sub>10</sub>, CO, HC, SO<sub>2</sub>, and NO<sub>x</sub>. Data regarding crematoria in each ward was obtained from NMMC's Public Health Department. The number of crematoria operating wards wise and number of Hindu deaths reported in each ward as per NMMC is given in **Table 3.2**. The wood and diesel consumption of crematorium for each ward is represented in **Table 3.3**.

**Table 3.2 : Ward Wise Distribution of Crematoria and Registered Hindu Deaths (2018-19)**

Ward /Name	Crematoria Locations	Wood	Electric	Bodies incarcerated at Wood Crematorium	Bodies incarcerated at Electric Crematorium
<b>A Belapur</b>	Belapur	1	--	314	--
	Devale	1	--	39	--
	Karave	1	--	243	--
	Darave	1	--	76	--
<b>B Nerul</b>	Juinagar_Sarsole	1	--	578	--
	Nerul Gaon	1	--	34	--
	Sector 2_Shirvane	1	1	24	9

**Table 3.2 (Contd.): Ward Wise Distribution of Crematoria & Registered Hindu Deaths**

Ward /Name	Crematoria Locations	Wood	Electric	Bodies incarcerated at Wood Crematorium	Bodies incarcerated at Electric Crematorium
<b>C Vashi</b>	VashiGaon	1	--	41	--
	Juhu Gaon	1	--	18	--
	Kopari Gaon	1	--	9	--
<b>D Turbhe</b>	Sector 19 Turbhe	1	1	215	67
	Sector 5 Sanpada	1	--	39	--
	Sector 23 Juipada	1	--	3	--
<b>E Koparkhairane</b>	Mukti Dham	1	--	395	--
	Vakunta Dham	1	--	22	--
	Bonkode	1	--	26	--
	Pawane Gaon	1	--	11	--
	Mahape Gaon	1	--	22	--
	Advali Butavali	1	--	5	--
<b>F Ghansoli</b>	Rabale Gaon	1	--	111	--
	Talavali Gaon	1	--	11	--
	Gothivali	1	--	11	--
	Ghansoli Gaon_1	1	--	66	--
	Ghansoli Gaon_2	1	--	17	--
<b>G Airoli</b>	Divagaon	1	--	174	--
	Airoli Gaon	1	--	412	--
<b>H Digha</b>	Digha 3 Nos.	3	--	365	--
<b>Total</b>		<b>25</b>	<b>2</b>	<b>3281</b>	<b>76</b>

-- Crematoria is not present in the respective ward

**Table 3.3 : Ward Wise Distribution of Bodies Burnt and Wood and Kerosene Consumption**

Ward	Number of Bodies burnt in Wood Crematoria	Number of Bodies burnt in Electric Crematoria	Total Wood Consumption (kg)	Total Kerosene Consumption (kg)
A	672	--	201600	1632.96
B	636	9	190800	1545.48
C	68	--	20400	165.24
D	257	67	77100	624.51
E	481	--	144300	1168.83
F	216	--	64787	525
G	586	--	175800	1424
H	365	--	109500	887
<b>Total</b>	<b>3281</b>	<b>76</b>	<b>984287</b>	<b>7973</b>

**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

Number of Registered death in Navi Mumbai = 3357

Total dead bodies in fire wood crematoria = 3281 (deaths/yr)

Total dead bodies in fire wood crematoria = 76 (deaths/yr)

Emission factor for wood burning, kerosene and electric crematoria are listed in **Annexure I**.

Emission Factor (PM<sub>10</sub>) Wood Consumption = 17.3 (kg/t)

Emission Factor (SPM) Kerosene = 1.95 (kg/t)

Emission Factor (PM<sub>10</sub>) Kerosene = 0.61 (kg/t)

Emission Factor Electric crematoria = 0.000025 (kg/body)

Emission (PM<sub>10</sub>) from wood burning = 3281 (deaths/yr) \* 0.3 (t) \* 17.3 (kg/t) = 17028.4 (kg/yr)

[Average kerosene consumption /body = 3 liters \* 0.81 (density in kg/l) = 2.43 (kg) = 0.00243 (T)]

Emission (PM) from Kerosene burning = 3281 (deaths/yr) \* 0.00243 (T) \* 1.95 (SPM) (kg/t)

\* 0.61 (PM) (kg/t) = 4.86 (kg/year)

Emission (PM<sub>10</sub>) from Electric burning = 76 (deaths/yr) \* 0.000025 (kg/t) = 0.0019 (kg/yr)

In similar way emission for others pollutants and their ward wise distribution have been estimated and presented in **Table 3.4**. Along with emissions from fuel consumptions, body burn emissions are also accounted for. Crematoria related emissions load were majorly estimated from Ward A (Belapur) and Ward B (Nerul) as number of reported is high in a year.

**Table 3.4 : Total Emission Estimates for Crematoria**

Wards	Total Crematoria Emissions /yr.							
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	HC	CO	CO <sub>2</sub>	NVOC
<b>A</b>	3488.7	2372.3	83.4	473.1	23123.0	25658.1	342720	8.7
<b>B</b>	3301.8	2245.2	79.4	450.6	21884.3	24284.8	324360	8.3
<b>C</b>	353.0	240.1	8.4	47.9	2339.8	2596.4	34680	0.9
<b>D</b>	1334.2	907.3	35.5	201.6	8844.0	9822.1	131070	3.3
<b>E</b>	2497.1	1698.0	59.7	338.7	16550.8	18365.4	245310	6.3
<b>F</b>	1121.1	762.4	26.8	152.0	7430.9	8245.6	110138	2.8
<b>G</b>	3042.2	2068.7	72.7	412.6	20163.8	22374.5	298860	7.6
<b>H</b>	1894.9	1288.5	45.3	257.0	12559.3	13936.3	186150	4.7
<b>Kg/day</b>	<b>46.7</b>	<b>31.7</b>	<b>1.1</b>	<b>6.4</b>	<b>309.3</b>	<b>343.2</b>	<b>4584.4</b>	<b>0.1</b>
<b>Ton./year</b>	<b>17.0</b>	<b>11.6</b>	<b>0.4</b>	<b>2.3</b>	<b>112.9</b>	<b>125.3</b>	<b>1673.3</b>	<b>0.04</b>



**Table 3.4 (Contd.) : Fuel wise Emission Estimates for Crematoria**

Wards	Wood Emissions /yr.							Electric Emissions /yr.					
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	HC	CO	CO <sub>2</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	HC	CO
<b>A</b>	3487.7	2371.6	40.3	262.1	23083.2	25462.1	342720	--	--	--	--	--	--
<b>B</b>	3300.8	2244.6	38.2	248.0	21846.6	24098.0	324360	0.0002	0.0002	0.490	2.772	0.117	1.269
<b>C</b>	352.9	240.0	4.1	26.5	2335.8	2576.5	34680	--	--	--	--	--	--
<b>D</b>	1333.8	907.0	15.4	100.2	8828.0	9737.7	131070	0.0017	0.0011	3.6448	20.6360	0.8710	9.4470
<b>E</b>	2496.4	1697.5	28.9	187.6	16522.4	18225.1	245310	--	--	--	--	--	--
<b>F</b>	1120.8	762.2	13.0	84.2	7418.1	8182.6	110138	--	--	--	--	--	--
<b>G</b>	3041.3	2068.1	35.2	228.5	20129.1	22203.5	298860	--	--	--	--	--	--
<b>H</b>	1894.4	1288.2	21.9	142.4	12537.8	13829.9	186150	--	--	--	--	--	--
<b>Kg/day</b>	<b>46.7</b>	<b>31.7</b>	<b>0.5</b>	<b>3.5</b>	<b>308.8</b>	<b>340.6</b>	<b>4584.4</b>	<b>5.21E-06</b>	<b>3.54E-06</b>	<b>1.13E-02</b>	<b>6.41E-02</b>	<b>2.71E-03</b>	<b>2.94E-02</b>
<b>Ton./year</b>	<b>17.0</b>	<b>11.6</b>	<b>0.2</b>	<b>1.3</b>	<b>112.7</b>	<b>124.3</b>	<b>1673.3</b>	<b>1.90E-06</b>	<b>1.29E-06</b>	<b>4.13E-03</b>	<b>2.34E-02</b>	<b>9.88E-04</b>	<b>1.07E-02</b>

Wards	Kerosene Emissions /yr.						Body Burn Emissions/yr					
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>x</sub>	NO <sub>x</sub>	HC	CO	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>x</sub>	NO <sub>x</sub>	HC	CO
<b>A</b>	1.00	0.68	6.53	4.08	31.03	101.24	0.02	0.01	36.56	206.98	8.74	94.75
<b>B</b>	0.94	0.64	6.18	3.86	29.36	95.82	0.02	0.01	34.60	195.89	8.27	89.68
<b>C</b>	0.10	0.07	0.66	0.41	3.14	10.24	0.00	0.00	3.70	20.94	0.88	9.59
<b>D</b>	0.38	0.26	2.50	1.56	11.87	38.72	0.01	0.00	13.98	79.16	3.34	36.24
<b>E</b>	0.71	0.48	4.68	2.92	22.21	72.47	0.01	0.01	26.17	148.15	6.25	67.82
<b>F</b>	0.32	0.22	2.10	1.31	9.97	32.54	0.01	0.00	11.75	66.51	2.81	30.45
<b>G</b>	0.87	0.59	5.70	3.56	27.06	88.29	0.01	0.01	31.88	180.49	7.62	82.63
<b>H</b>	0.54	0.37	3.55	2.22	16.85	54.99	0.01	0.01	19.86	112.42	4.75	51.47
<b>Kg/day</b>	<b>0.01</b>	<b>0.01</b>	<b>0.09</b>	<b>0.05</b>	<b>0.42</b>	<b>1.35</b>	<b>0.0002</b>	<b>0.0002</b>	<b>0.5</b>	<b>2.8</b>	<b>0.1</b>	<b>1.3</b>
<b>Ton./year</b>	<b>0.005</b>	<b>0.003</b>	<b>0.032</b>	<b>0.020</b>	<b>0.151</b>	<b>0.494</b>	<b>0.0001</b>	<b>0.0001</b>	<b>0.2</b>	<b>1.0</b>	<b>0.04</b>	<b>0.5</b>

**Issues**

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

### 3.2.3 Open Eat-outs

In India, the national policy for urban street vendors /hawkers notes that street vendors constitute approximate 2% of the population of a metropolis. Municipal Corporation /government consider street vendors as encroachers, but this forms an important unorganized sector of business and livelihood. This informal sector even though being small in size, contribute emission load on large area because of the fuel consumption for their operations and absence of any control measures for these emissions. On the basis of primary survey, 40% of the vendors use kerosene as fuel followed by LPG-50% and coal-about 10%. The average consumption of kerosene per day is approximately 8 liters, 4 kg/day of LPG and 10 kg/day of coal for cooking purpose. 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 in NMMC jurisdiction. Therefore, NMMC regularly takes action on street vendors and the data is documented. Based on the data of areas of such action taken on number of street vendors by NMMC (License Department), fuel consumption pattern was quantified. It was found that there are considerable amount of open eat-outs and hawkers operating at Ward -D (Turbhe), where the floating population is concentrated around industrial areas. These number have been checked by visiting representative 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 : Ward wise Distribution of Open Eat-outs**

Wards	Street Vendors	S. Vendors Operated on Kerosene	S. Vendors Operated on LPG	S. Vendors Operated on Coal	Kerosene Consumption (litres)	LPG Consumption (kg)	Coal Consumption (kg)
A	28	11	14	3	90	56	28
B	32	13	16	3	102	64	32
C	57	23	29	6	182	114	57
D	263	105	132	26	842	526	263
E	74	30	37	7	237	148	74
F	19	8	10	2	61	38	19
G	65	26	33	7	208	130	65
H	34	14	17	3	109	68	34
<b>Total</b>	<b>572</b>	<b>229</b>	<b>286</b>	<b>57</b>	<b>1830</b>	<b>1144</b>	<b>572</b>

## Emission Estimates

Per capita consumption for each type of fuel is taken as

For Kerosene – 8 lits/stall/day, For LPG – 4 kg /day, For Coal – 10 kg/day

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

= 229 x 8 x 0.81 (density)/ 1000 x 0.61x 0.06 =0.0543 kg/d

Emission from LPG burning (PM) per day

= Number of street vendors operating on LPG x fuel consumption per day x emission factor

= 286 x 4 / 1000 x 2.10 = 2.4 kg/d

Emission from Coal burning (PM) per day

= Number of street vendors operating on Coal x fuel consumption per day x emission factor

= 57 x 10 /1000 x (20 EF SPM) x 0.6 (EF PM)= 6.84 kg/d

Emission for others pollutants and Ward-specific contribution have been estimated, and is presented in **Table 3.6**.

**Table 3.6 : Fuel wise Emission Load from Open Eat-out**

Wards	SPM	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>x</sub>	NO <sub>x</sub>	HC	CO
	Kerosene Emissions (kg/d)						
A	0.004	0.003	0.002	0.293	0.183	1.391	4.539
B	0.005	0.003	0.002	0.335	0.209	1.590	5.188
C	0.009	0.005	0.004	0.596	0.373	2.832	9.241
D	0.041	0.025	0.017	2.751	1.719	13.067	42.638
E	0.012	0.007	0.005	0.774	0.484	3.677	11.997
F	0.003	0.002	0.001	0.199	0.124	0.944	3.080
G	0.010	0.006	0.004	0.680	0.425	3.229	10.538
H	0.005	0.003	0.002	0.356	0.222	1.689	5.512
<b>KG/Day</b>	<b>0.090</b>	<b>0.055</b>	<b>0.037</b>	<b>5.983</b>	<b>3.739</b>	<b>28.419</b>	<b>92.734</b>
<b>Tons/Yr</b>	<b>0.033</b>	<b>0.020</b>	<b>0.014</b>	<b>2.184</b>	<b>1.365</b>	<b>10.373</b>	<b>33.848</b>

Wards	LPG Emissions (kg/d)						
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>x</sub>	NO <sub>x</sub>	HC	CO	CO <sub>2</sub>
A	0.12	0.12	0.02	0.10	0.004	0.01	96.10
B	0.13	0.13	0.03	0.12	0.005	0.02	109.82
C	0.24	0.24	0.05	0.21	0.008	0.03	195.62
D	1.10	1.10	0.21	0.95	0.038	0.13	902.62
E	0.31	0.31	0.06	0.27	0.011	0.04	253.97
F	0.08	0.08	0.02	0.07	0.003	0.01	65.21
G	0.27	0.27	0.05	0.23	0.009	0.03	223.08
H	0.14	0.14	0.03	0.12	0.005	0.02	116.69
<b>KG/Day</b>	<b>2.40</b>	<b>2.40</b>	<b>0.46</b>	<b>2.06</b>	<b>0.082</b>	<b>0.29</b>	<b>1963.10</b>
<b>Tons/Yr</b>	<b>0.88</b>	<b>0.88</b>	<b>0.17</b>	<b>0.75</b>	<b>0.030</b>	<b>0.11</b>	<b>716.53</b>

**Table 3.6 (Contd..) : Fuel wise Emission Load from Open Eat Out**

Wards	Coal Emissions (kg/d)						Total Open Eatout Emissions (kg/d)						
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>x</sub>	NO <sub>x</sub>	HC	CO	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>x</sub>	NO <sub>x</sub>	HC	CO	CO <sub>2</sub>
<b>A</b>	0.3	0.2	0.4	0.1	0.01	0.7	0.46	0.35	0.69	0.40	1.41	5.25	96.10
<b>B</b>	0.4	0.3	0.4	0.1	0.02	0.8	0.52	0.40	0.79	0.45	1.61	6.00	109.82
<b>C</b>	0.7	0.5	0.8	0.2	0.03	1.4	0.93	0.71	1.40	0.81	2.87	10.69	195.62
<b>D</b>	3.2	2.1	3.5	1.0	0.13	6.6	4.29	3.27	6.46	3.72	13.24	49.32	902.62
<b>E</b>	0.9	0.6	1.0	0.3	0.04	1.8	1.21	0.92	1.82	1.05	3.72	13.88	253.97
<b>F</b>	0.2	0.2	0.3	0.1	0.01	0.5	0.31	0.24	0.47	0.27	0.96	3.56	65.21
<b>G</b>	0.8	0.5	0.9	0.3	0.03	1.6	1.06	0.81	1.60	0.92	3.27	12.19	223.08
<b>H</b>	0.4	0.3	0.5	0.1	0.02	0.8	0.55	0.42	0.84	0.48	1.71	6.38	116.69
<b>kg/day</b>	<b>6.9</b>	<b>4.7</b>	<b>7.6</b>	<b>2.3</b>	<b>0.29</b>	<b>14.3</b>	<b>9.32</b>	<b>7.11</b>	<b>14.05</b>	<b>8.08</b>	<b>28.79</b>	<b>107.28</b>	<b>1963.10</b>
<b>Ton/year</b>	<b>2.5</b>	<b>1.7</b>	<b>2.8</b>	<b>0.8</b>	<b>0.10</b>	<b>5.2</b>	<b>3.40</b>	<b>2.59</b>	<b>5.13</b>	<b>2.95</b>	<b>10.51</b>	<b>39.16</b>	<b>716.53</b>

Accounting the commercial and mixed activities in and around Ward D & E, the likelihood of floating population is high. The number of illegal and unorganized open eat outs in this region is highest as compared to other wards. Thus, the emission load from these wards is maximum and lowest from Ward A (Belapur) and Ward F (Ghansoli). CO & HC are the major other contributors to total emission load from open eat outs.

**Issues**

- Fuel consumption given by street vendor during primary survey may not be very reliable
- The actual number of street vendors could be high /low than the estimated depending upon time, season and locations.

### 3.2.4 Hotels & Restaurants

Information of hotels and restaurant was obtained directly from License Department of NMMC. There are around 1166 Hotels registered with the NMMC License department. Ward-wise break up is presented in **Table 3.7**. During the discussions with the authorities, it was concluded that the large proportion actual number of tea stalls/snack corners/fast food centers 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 are used for cooking and coal is used in the tandoor bhattis, which are often operated in open or without any efficient control measures. The primary survey of Hotels and Restaurants gave an average LPG consumption of 2 Cylinders (19 kg capacity) and coal consumption of 8 kg per hotel/restaurant as per the survey. The total LPG consumption of hotels in the city is around 44308 kg/day.

**Table 3.7 : Ward wise Number of Hotels & Restaurants and their Fuel Consumption (Registered under NMMC : 2018-19)**

Name	Registered Hotels & Restaurants	LPG Consumption (Kg)	Coal Consumption (Kg)
A	188	7144	1504
B	210	7980	1680
C	197	7486	1576
D	178	6764	1424
E	195	7410	1560
F	60	2280	480
G	130	4940	1040
H	8	304	64
<b>Total</b>	<b>1166</b>	<b>44308</b>	<b>9328</b>

#### Emission Estimations

- Emission Load from LPG

Since LPG burning doesn't comprise of coarse particles, an assumption that only PM<sub>2.5</sub> particles are present in the LPG emissions is made and considered as PM.

Total emissions (PM<sub>2.5</sub>) due to LPG burning in Hotels

= Number of Hotels x LPG consumption (Tons/day) x Emission Factor (Kg/MT) (**Annexure I**)

Total PM<sub>2.5</sub> emissions due to LPG burning in Hotels

= 1166 x (2 x 19/1000 Tons/day) x 2.1 Kg/MT = 93.05 Kg/Day

However, for calculation purposes, it has been referred to as PM<sub>10</sub>.

The emission load calculated for different fuel pattern and their ward distribution is presented in **Table 3.8**.

- 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)

= 1166 x 8/1000 Tons/day x 20 kg/MT (EF SPM) x 0.6 (PM) = 111.94 Kg/Day

**Table 3.8 : Fuel wise Distribution of Emission Load from Hotel and Restaurants**

Wards	LPG Emission (kg/d)							Coal Emission (kg/d)					
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>2</sub>	HC	CO	CO <sub>2</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>2</sub>	HC	CO
A	15.0	15.0	2.9	12.9	0.51	1.8	12259.1	18.0	12.3	20.0	6.0	0.75	37.5
B	16.8	16.8	3.2	14.4	0.57	2.0	13693.7	20.2	13.7	22.3	6.7	0.84	41.9
C	15.7	15.7	3.0	13.5	0.54	1.9	12846.0	18.9	12.9	21.0	6.3	0.79	39.3
D	14.2	14.2	2.7	12.2	0.49	1.7	11607.0	17.1	11.6	18.9	5.7	0.71	35.5
E	15.6	15.6	3.0	13.3	0.53	1.9	12715.6	18.7	12.7	20.7	6.2	0.78	38.9
F	4.8	4.8	0.9	4.1	0.16	0.6	3912.5	5.8	3.9	6.4	1.9	0.24	12.0
G	10.4	10.4	2.0	8.9	0.36	1.2	8477.0	12.5	8.5	13.8	4.1	0.52	25.9
H	0.6	0.6	0.1	0.5	0.02	0.1	521.7	0.8	0.5	0.9	0.3	0.03	1.6
<b>Kg/day</b>	<b>93.0</b>	<b>93.0</b>	<b>17.7</b>	<b>79.8</b>	<b>3.19</b>	<b>11.2</b>	<b>76032.5</b>	<b>111.9</b>	<b>76.1</b>	<b>124.1</b>	<b>37.2</b>	<b>4.66</b>	<b>232.5</b>
<b>Ton/Yr</b>	<b>34.0</b>	<b>34.0</b>	<b>6.5</b>	<b>29.1</b>	<b>1.16</b>	<b>4.1</b>	<b>27751.9</b>	<b>40.9</b>	<b>27.8</b>	<b>45.3</b>	<b>13.6</b>	<b>1.70</b>	<b>84.8</b>

	Total Emission Hotel and Restaurants (Kg/d)						
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>2</sub>	HC	CO	CO <sub>2</sub>
A	33.1	27.3	22.9	18.9	1.3	39.3	12259.10
B	36.9	30.5	25.5	21.1	1.4	43.9	13693.68
C	34.6	28.6	24.0	19.8	1.3	41.2	12845.98
D	31.3	25.8	21.6	17.9	1.2	37.2	11607.02
E	34.3	28.3	31.3	15.0	1.3	40.7	12715.56
F	10.5	8.7	7.3	6.0	0.4	12.5	3912.48
G	22.9	18.9	15.8	13.0	0.9	27.2	8477.04
H	1.4	1.2	1.0	0.8	0.1	1.7	521.66
<b>Kg/day</b>	<b>205.0</b>	<b>169.2</b>	<b>149.4</b>	<b>112.4</b>	<b>7.9</b>	<b>243.6</b>	<b>76032.53</b>
<b>Ton/Yr</b>	<b>74.8</b>	<b>61.7</b>	<b>54.5</b>	<b>41.0</b>	<b>2.9</b>	<b>88.9</b>	<b>27751.87</b>

Nerul is an up market residential and commercial node in Navi Mumbai, and the number of registered hotel is highest in this area. The emissions attributed to these sources are highest from Ward B (Nerul), followed by Ward C (Vashi). Next highest emissions are from Ward E, A, D, G, F and H, respectively as residential block have also witness the Hotels/ Restaurants. About 205 kg/day of PM<sub>10</sub> is being released from these area sources, while PM<sub>2.5</sub> is released in the concentration of 169 kg/day. HC, NO<sub>x</sub> and SO<sub>x</sub> are also higher contributing to the total emission load. [Issues : Domestic cylinders are also consumed in the commercial sector illegally for which data was not easily available].

### 3.2.5 Domestic Sector

There are 8 wards under Navi Mumbai Municipal Corporation. The fuel usage pattern of slum and non-slum population is different. As non-slum population is more organized considering source of income, their primary domestic fuel is LPG. The recent infrastructural changes brought by the oil companies, has made PNG an easily available domestic fuel. The total number of gas agencies distributing LPG across city is 22, with 14590 subscriptions per agencies. Mahanagar Gas Ltd. is the major shareholders for the supply of LPG in the city. In the year 2016-17, numbers of LPG connections 3,20,980 were registered with the gas agencies of the city. The average LPG consumption of the Navi Mumbai for the day was estimated to be around 156210 Kg/d, while that of PNG consumption was found to be 3335.2 Kg/day. Out of the total population of 1.5 million, the highest slum population is found in Ward F- Ghansoli and the lowest is in Ward A- Belapur. Based on the survey, it was observed that the consumption of kerosene in slum population is prevalent. Average kerosene consumption by a slum household is about 25 Liters/month and average kerosene consumption by a non-slum household is 3 Liters/month. 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 3.9**. Ward wise LPG cylinders consumption data is obtained from State Level Oil Coordination Committee (SLOC).

**Table 3.9 : Ward wise Fuel Consumption in Domestic Sector**

Ward	Area	LPG Consumption (kg/day)	PNG Consumption (kg/day)	Slum Kerosene Consumption (lit/d)	Non Slum Kerosene Consumption (lit/d)
A	Belapur	7100	152	2321	1337
B	Nerul	35502	758	8553	4929
C	Vashi	14201	303	4464	2572
D	Turbhe	21301	455	6752	3891
E	Koparkhairane	28402	606	6998	4032
F	Ghansoli	21301	455	8811	2962
G	Airoli	14201	303	4204	2759
H	Digha	14201	303	5953	1593
<b>Total</b>		<b>156210</b>	<b>3335.2</b>	<b>3335</b>	<b>48057</b>

**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)

= 156210 x 2.1/1000 kg/d= 328.04 Kg/Day (**Annexure I**)

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*)

Number of Household was calculated on the assumption that there are 6 members from one slum-household and 5 members in non -slum household

Kerosene consumption per slum household = 25 liters/month = 0.833Liters/day

Kerosene consumption per non-slum household = 3liters/month = 0.1 Liters/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

= 48056.83 (l/d) x 0.61 g/Kg = 23.95 Kg/day

Total emissions (PM) from kerosene burning per day in a non-slum household

= 24075 x 0.61 g/Kg = 14.68 Kg/day

In case of LPG/PNG consumption, all PM<sub>2.5</sub> emissions are estimated to be in terms of PM<sub>10</sub>.

Domestic emission load from LPG, PNG and kerosene with respect to their pollutants have been estimated and their ward wise distribution is presented in **Table 3.10**.



**Table 3.10 : Fuel wise Distribution of Emission Load from Domestic Sector**

Wards	LPG Emissions (Kg/d)							PNG Emissions (Kg/d)					
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	VOC	CO	CO <sub>2</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	HC	CO
<b>A</b>	14.91	14.91	2.8	357.9	14.3	50.1	341163	0.00001	0.00001	0.000001	0.00042	0.00001	0.00004
<b>B</b>	74.55	74.55	14.2	1789.3	71.6	250.5	1705816	0.00007	0.00005	0.000007	0.00212	0.00004	0.00021
<b>C</b>	29.82	29.82	5.7	715.7	28.6	100.2	682326	0.00003	0.00002	0.000003	0.00085	0.00001	0.00008
<b>D</b>	44.73	44.73	8.5	1073.6	42.9	150.3	1023490	0.00004	0.00003	0.000004	0.00127	0.00002	0.00012
<b>E</b>	59.64	59.64	11.4	1431.5	57.3	200.4	1364653	0.00006	0.00004	0.000006	0.00170	0.00003	0.00016
<b>F</b>	44.73	44.73	8.5	1073.6	42.9	150.3	1023490	0.00004	0.00003	0.000004	0.00127	0.00002	0.00012
<b>G</b>	29.82	29.82	5.7	715.7	28.6	100.2	682326	0.00003	0.00002	0.000003	0.00085	0.00001	0.00008
<b>H</b>	29.82	29.82	5.7	715.7	28.6	100.2	682326	0.00003	0.00002	0.000003	0.00085	0.00001	0.00008
<b>Kg/d</b>	<b>328.04</b>	<b>328.04</b>	<b>62.5</b>	<b>7873</b>	<b>314.9</b>	<b>1102.2</b>	<b>7505591</b>	<b>0.00033</b>	<b>0.00022</b>	<b>0.00003</b>	<b>0.00934</b>	<b>0.00016</b>	<b>0.00091</b>
<b>T/year</b>	<b>119.74</b>	<b>119.74</b>	<b>22.8</b>	<b>2873.6</b>	<b>114.9</b>	<b>402.3</b>	<b>2739541</b>	<b>0.00012</b>	<b>0.00008</b>	<b>0.00001</b>	<b>0.00341</b>	<b>0.00006</b>	<b>0.00033</b>

Wards	Kerosene Emissions from Slums (Kg/d)					Kerosene Emissions from Non Slums (Kg/d)					Total Kerosene Emissions from Slum + Non Slums (Kg/d)				
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	CO	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	CO	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	CO
<b>A</b>	1.16	0.79	7.59	4.74	117.59	0.67	0.45	4.37	2.73	67.76	1.83	1.24	11.96	7.47	185.35
<b>B</b>	4.26	2.90	27.96	17.47	433.34	2.46	1.67	16.11	10.07	249.70	6.72	4.57	44.07	27.54	683.04
<b>C</b>	2.23	1.51	14.59	9.12	226.17	1.28	0.87	8.41	5.26	130.33	3.51	2.38	23	14.38	356.5
<b>D</b>	3.37	2.29	22.07	13.79	342.10	1.94	1.32	12.72	7.95	197.13	5.31	3.61	34.79	21.74	539.23
<b>E</b>	3.49	2.37	22.87	14.30	354.52	2.01	1.37	13.18	8.24	204.29	5.5	3.74	36.05	22.54	558.81
<b>F</b>	4.39	2.99	28.80	18.00	446.41	1.48	1.00	9.68	6.05	150.05	5.87	3.99	38.48	24.05	596.46
<b>G</b>	2.10	1.42	13.74	8.59	212.99	1.38	0.94	9.02	5.64	139.78	3.48	2.36	22.76	14.23	352.77
<b>H</b>	2.97	2.02	19.46	12.16	301.59	0.79	0.54	5.21	3.25	80.69	3.76	2.56	24.67	15.41	382.28
<b>Kg/d</b>	<b>23.95</b>	<b>16.29</b>	<b>157.08</b>	<b>98.17</b>	<b>2434.72</b>	<b>12.00</b>	<b>8.16</b>	<b>78.69</b>	<b>49.18</b>	<b>1219.72</b>	<b>35.95</b>	<b>24.45</b>	<b>235.77</b>	<b>147.35</b>	<b>3654.44</b>
<b>T/year</b>	<b>8.74</b>	<b>5.95</b>	<b>57.33</b>	<b>35.83</b>	<b>888.67</b>	<b>4.38</b>	<b>2.98</b>	<b>28.72</b>	<b>17.95</b>	<b>445.20</b>	<b>13.12</b>	<b>8.93</b>	<b>86.05</b>	<b>53.78</b>	<b>1333.87</b>

**Table 3.10 (Contd.) : Fuel wise Distribution of Emission Load from Domestic Sector**

Wards	Total Domestic Emissions (Kg/d)						
	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	VOC (HC)	CO	CO <sub>2</sub>
<b>A</b>	16.7	16.2	14.8	365.3	14.3	235.4	341163.2
<b>B</b>	81.3	79.1	58.3	1816.9	71.6	933.5	1705816.1
<b>C</b>	33.3	32.2	28.7	730.1	28.6	456.7	682326.4
<b>D</b>	50.0	48.3	43.3	1095.3	42.9	689.5	1023489.7
<b>E</b>	65.1	63.4	47.4	1454.0	57.3	759.2	1364652.9
<b>F</b>	50.6	48.7	47.0	1097.6	42.9	746.8	1023489.7
<b>G</b>	33.3	32.2	28.4	730.0	28.6	453.0	682326.4
<b>H</b>	33.6	32.4	30.3	731.1	28.6	482.5	682326.4
<b>Kg/d</b>	<b>364.0</b>	<b>352.5</b>	<b>298.3</b>	<b>8020.4</b>	<b>314.9</b>	<b>4756.7</b>	<b>7505590.9</b>
<b>T/year</b>	<b>132.9</b>	<b>128.7</b>	<b>108.9</b>	<b>2927.4</b>	<b>114.9</b>	<b>1736.2</b>	<b>2739540.7</b>

Domestic sector maximum emission of PM is from Ward B Nerul area (i.e 81.3 kg/d). Both kerosene and LPG emissions are high in Ward B as compared to other wards (where higher population 3,08,044 reflect). Ward E Koparkhairane has the next maximum emission of PM (65.1 kg/d) (as population 252015 is high). Total PM load is around 364 kg/d. The NO<sub>x</sub> emission is high 8020 kg/d as LPG cylinders consumption is high 156210 kg/d. The other major pollutant reflected as CO, HC, and SO<sub>2</sub>, CO<sub>2</sub>.

### 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. Urban centres generate disproportionately high 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. As these open burning cases often get unreported and data for the same is missing, it was assumed that about 1% of the total solid waste generated in each ward is openly burnt and about 4% of the total solid waste is burnt in the wards containing solid waste landfill sites as given in **Table 3.11**. The quantity of ward wise solid waste generated was obtained from corporation, solid waste management division.

**Table 3.11 : Ward wise & Landfill Site, Solid Waste Generation and Their Open Burnt Percent Contribution**

Wards	Region	Solid waste generation in Tonnes	Open Burning
A	Belapur	36.36	0.36
B	Nerul	134.00	1.34
C	Vashi	69.94	0.70
D	Turbhe	105.79	1.06
E	Koparkhairane	109.63	1.10
F	Ghansoli	92.03	0.92
G	Airoli	73.18	0.73
H	Digha	53.29	0.53
<b>TOTAL (MTD)</b>		<b>674.21</b>	<b>6.74</b>

Landfill Sites	Solid Waste at Landfill Site	Open Burning (4%)
<b>Turbhe</b>	725	29

### 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) = [674.21 (tons) x 1% (non dumping site) + 725 (Landfill site) x 4%] x 8 (Kg/MT) = **285.9 Kg/Day.**

In similar way emission for others pollutants have been estimated and their ward wise distribution is presented in **Table 3.12**. It was estimated that the highest emission load was contributed mainly from Nerul, Koparkhairane and Turbhe Ward. Being less populated, contribution of Digha to emission load across all categories is lowest. Total 285 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 and landfill site towards final emission load, followed by HC.

**Table 3.12 : Ward Emission Load from Open Burning (Kg/d)**

Wards	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	HC	CO
A	2.91	1.98	0.18	1.09	7.82	15.27
B	10.72	7.29	0.67	4.02	28.81	56.28
C	5.60	3.80	0.35	2.10	15.04	29.37
D	8.46	5.75	0.53	3.17	22.74	44.43
E	8.77	5.96	0.55	3.29	23.57	46.04
F	7.36	5.01	0.46	2.76	19.79	38.65
G	5.85	3.98	0.37	2.20	15.73	30.74
H	4.26	2.90	0.27	1.60	11.46	22.38
<b>Total Kg/d</b>	<b>53.94</b>	<b>36.68</b>	<b>3.37</b>	<b>20.23</b>	<b>144.95</b>	<b>283.17</b>
<b>Total T/yr</b>	<b>19.69</b>	<b>13.39</b>	<b>1.23</b>	<b>7.38</b>	<b>52.91</b>	<b>103.36</b>

**Table 3.12 (Contd..) : Emission Load from Landfill Open Burning(kg/d)**

Wards	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	NO <sub>x</sub>	HC	CO
<b>Turbhe</b>	232	157.76	14.5	87	623.5	1218
<b>Total Kg/d</b>	<b>232</b>	<b>157.76</b>	<b>14.5</b>	<b>87</b>	<b>623.5</b>	<b>1218</b>
<b>Total T/yr</b>	<b>84.68</b>	<b>57.58</b>	<b>5.29</b>	<b>31.76</b>	<b>227.58</b>	<b>444.57</b>

**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 x2 Km area.

### 3.2.7 Building Construction

Real Estate sector is booming in the city. With a scope of being developed as planned city, there are drastic infrastructural changes taking place in Navi Mumbai. 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 NMMC. 117 construction and building related activities were reported with the department. The number of construction activities ward wise is given in **Table 3.13**.

#### Assumption

- The project duration was estimated as 18 months for new buildings, 6 months for addition /alteration.
- The area of influence of each construction activity was taken as 0.5 acres for new building and 0.2 acres for addition /alteration. This was the most prevalent areas noticed during the primary. However, some places sizes vary more than the above mentioned values.

**Table 3.13 : Ward Wise distribution of Construction Activities**

Wards	Build Construction	New Building	Alteration/ Addition
<b>A</b>	5	2	3
<b>B</b>	6	1	5
<b>C</b>	3	3	2
<b>D</b>	4	2	2
<b>E</b>	7	4	3
<b>F</b>	7	1	6
<b>G</b>	21	15	7
<b>H</b>	4	3	1
<b>Total</b>	60	31	29

## 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 NMMC.

Step 2 – Acres disturbed

For new buildings, = 0.5 acres are disturbed per activity

For addition / alteration = 0.2 acres per activity are disturbed

Step 3 – Months of activity

New buildings = 18 months, Addition / alteration = 6 months

Step 4 – Acre –months of activity

For new building = 18 x total number of acres disturbed

For addition / alteration = 6 x total number of acres disturbed

Step 5 – PM<sub>10</sub> Tons /years = 1.2 x total number of acre – months

(AP42, Section 13.2.3.3– PM<sub>10</sub> - 1.2 tones/ acres months)

Ward wise emission load of PM during construction activity is presented in **Table 3.14**.

**Table 3.14 : Ward wise Emission Load of PM in acre months during Construction Activity**

Wards	New Building (Kg/day)	Alteration (Kg/day)
A	40	24
B	20	40
C	60	16
D	40	16
E	80	24
F	20	48
G	300	56
H	60	8

**Total Emission Load = 310.98 tones /year**

**(New Building = 620 kg/day, alternation building = 232 kg/day)**

The number of construction and building project are on rise along the Thane-Belapur Road, due to upcoming and establishment of commercial and IT hubs around the regions. The highest PM emission load was calculated from the area of Airoli Wards G.

### 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

### 3.2.8 Road Dust (Paved & 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 MMRDA, NMMC and RTO, Navi Mumbai and primary survey of some roads for vehicle counting.

#### • Emission Estimates for Paved Road Dust

##### Vehicle Weight –Navi Mumbai \*

Vehicle Count 2017	%Vehicle Count (A)	Avg.Weight (kg) (B)	Veh. Weight by % (A*B) (kg)
2 W	13172	0.41	175
3 W	8075	0.25	450
HDDV	2232	0.07	20000
Cars	8521	0.27	1425
Total	32000	1	2.0

\* 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

#### Emission Estimation for Paved Dust

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<sub>2.5</sub>=0.1005, PM<sub>10</sub>=0.1317)

N = No. of days in averaging period (365 /year, 30/monthly, 91/seasonal);

Values of k (g/vkt) PM<sub>2.5</sub> -1.1, PM<sub>10</sub>-4.6

# EF (PM<sub>10</sub>) =  $(k (sL/2)^{0.65} (W/3)^{1.5-C} (1-P/4N))$

=  $(4.6 * ((0.505/2)^{0.65} * ((2/3)^{1.5} - 0.1317) * ((1-120/(4*365)))) = 0.818 \text{ g/vkt}$

# EF (PM<sub>2.5</sub>) =  $(k (sL/2)^{0.65} (W/3)^{1.5-C} (1-P/4N))$

=  $(1.1 * ((0.752/2)^{0.65} * ((2/3)^{1.5} - 0.1005) * ((1-120/(4*365)))) = 0.198 \text{ g/vkt}$

For VKT – calculate:  $lb/vmt \text{ to } gms/vkt = 0.98 (VKT * 0.98)$

VKT from all shifts \* PM<sub>2.5</sub> (EF) AND VKT from all shifts \* PM<sub>10</sub> (EF) = Emission 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 (PM<sub>2.5</sub>=0.00036, PM<sub>10</sub>=0.00047) - lb/VMT  
Public Roads- Constant k (lb/vmt) - PM<sub>2.5</sub>= 0.27, PM<sub>10</sub>=1.8;  
a. PM<sub>2.5</sub>=1, PM<sub>10</sub>=1, b. PM<sub>2.5</sub>=0.2, PM<sub>10</sub>=0.2; c. PM<sub>2.5</sub>=0.5, PM<sub>10</sub>=0.5

$$EF (PM_{10}) = \{([k (s/12)^a (S/30)^d] / (m/0.5)^{c-C})\} * (365-P) / 365$$

$$= (((1.8 * (12/12)^1 * (12.5/30)^{0.5}) / (6.65/0.5)^{0.2-0.00047}) * (365-120)) / 365$$

0.464488 lb/vmt = 130.93 g/vkt

$$EF (PM_{2.5}) = \{([k (s/12)^a (S/30)^d] / (m/0.5)^{c-C})\} * (365-P) / 365$$

$$= (((0.27 * (12/12)^1 * (12.5/30)^{0.5}) / (6.65/0.5)^{0.2-0.00036}) * (365-120)) / 365$$

0.069479 lb/vmt = 19.58 g/vkt

**Emission Load**

- Total **Paved** Dust Emission Load for Whole City =  
PM<sub>10</sub>= **3283.5 Kg/d** and PM<sub>2.5</sub>= 794.4 Kg/d
- Total **Unpaved** Dust Emission Load for Whole City =  
PM<sub>10</sub>= **8020 Kg/d** and PM<sub>2.5</sub> = 1199.6 Kg/d

**Emission Load**

Total Paved Dust Emission Load for Whole City : **PM= 11303.3 Kg/d**

Site-specific contribution of the pollutant emission load is given in **Table 3.15**.

**Table 3.15 : Ward wise Emission Load from Paved & Unpaved Road Dust**

Ward	Region	Paved Roads		Unpaved Roads	
		PM <sub>2.5</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	PM <sub>10</sub>
<b>A</b>	<b>Belapur</b>	122.6	506.6	185.1	1237.3
<b>B</b>	<b>Nerul</b>	169.4	700.0	255.8	1709.8
<b>C</b>	<b>Vashi</b>	184.1	761.0	278.0	1858.7
<b>D</b>	<b>Turbhe</b>	87.8	362.9	132.6	886.3
<b>E</b>	<b>Koparkhairane</b>	57.7	238.4	87.1	582.2
<b>F</b>	<b>Ghansoli</b>	62.6	258.9	94.6	632.4
<b>G</b>	<b>Airoli</b>	59.5	246.0	89.9	601.0
<b>H</b>	<b>Digha</b>	50.7	209.8	76.6	512.3
<b>Total (kg/day)</b>		794.4	3283.5	1199.6	8020.0
<b>Total (Tons/yr)</b>		290.0	1198.5	437.9	2927.3

\* Values expressed as kg/d

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

### 3.3. Line (Vehicular) Source

A counter magnet for Mumbai, Navi Mumbai has been developed as a planned city by City and Industrial Development Corporation (CIDCO) to meet the infrastructural needs of a modern metropolis. It has been developed as an independent, fully self-contained metro city. Navi Mumbai has a robust infrastructure, is well connected to other parts of the state and country. Navi Mumbai's CIDCO boasts of a 650 Km-long road network that connects nodes and neighbouring towns, besides 5 major bridges, 8 flyovers, 15 road-over bridges and a couple of foot-over bridges. The Palm Beach Marg, a 10 Km and six lane road connects Vashi to CBD Belapur running parallel to the Thane creek. The road transport wing of Navi Mumbai includes connectivity from bus operators of Navi Mumbai Municipal Transport (NMMT), BrihanMumbai Electric Supply and Transport (BEST), Kalyan- Dombivali Municipal Transport (KDMT) and Khopoli Municipal Transport (KMT) which provide bus services to entire Navi Mumbai city as well as to & fro from certain parts of Mumbai, Thane, Kalyan, Dombivli, Badlapur, Taloja, Panvel and Uran. The number of operational buses under NMMT was 390 in the year 2015-16. As per the data records of NMMT, the average number of passengers travelling per month by NMMT buses is around 55,37,375. The distance travelled by buses per day is on an average 281.1 Km. The Trans-harbor and Harbor lines of central railways pass through the municipal region of Navi Mumbai with total 12 stations connecting to other parts of Mumbai. Auto rickshaws provide inter as well as intra nodal public transport across the city. Taxis operating from designated taxi stands provide the means to travel to further destinations. Taxis charge a fixed rate approved by the R.T.O. details of which can be found on popular local transit apps of the city. Navi Mumbai has the largest container terminal in India, Jawaharlal Nehru Port at Nhava Sheva near Uran. It is well connected by road and rail, and handles approximately 56.13% of India's container traffic. The Chatrapati Shivaji International Airport, 30 Km away, is the nearest airport to the city. The Navi Mumbai Metro is an under construction rapid transit system in Navi Mumbai. A network of as many as six lines have been planned of which four lines will be constructed by CIDCO in the Navi Mumbai south region, the second and third line of the metro system will be constructed by NMMC and MMRDA respectively.

With the increasing infrastructural changes being implemented in the city from the government, there is a mass migration of population towards Navi Mumbai. Growing population led to increase in the number of registered vehicles at RTO across city. At the population density of 10,315 persons /sq.Km, the office/ region wise growth of vehicle in the city was 11% in 2016-17 as compared to 2015-16. Trend of vehicle growth is presented in **Table 3.16 and Figure 3.2**.



**Table 3.16 : Trend of Vehicular Growth in Navi Mumbai**

**a) Office/ Region wise Growth of Vehicles as on 31<sup>st</sup> March 2009-10 to 2016-17**

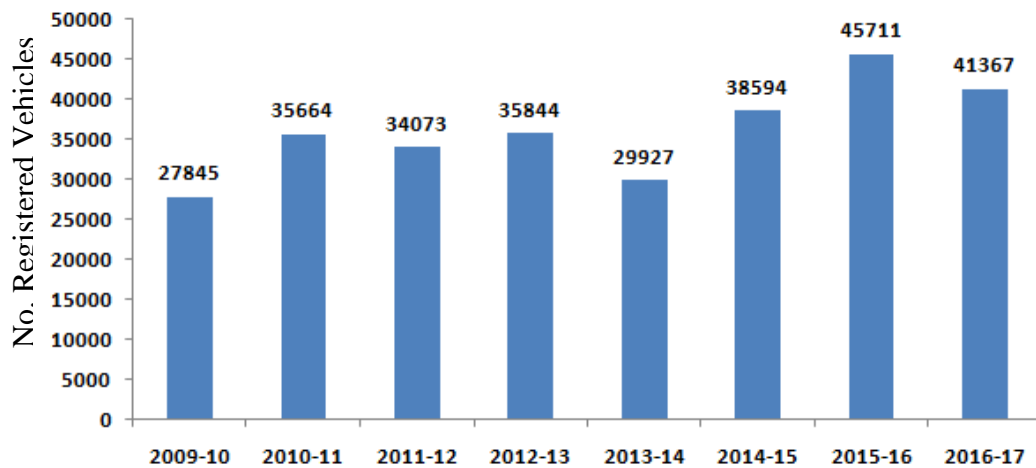
Name of the office/region	2009-10	2010-11	% Growth	2011-12	% Growth	2012-13	2013-14	% Growth
Vashi – New Mumbai	202252	231449	14.44	257831	11.4	275275	301731	9.62
	2014-15	% Growth	2015-16	% Growth	2016-17	% Growth		
	310959	3.06	351620	13.08	392987	11.76		

**b) Office / Region wise Yearly Registration of Vehicles & Their Growth (2012-13 to 2016-17)**

Name of the office/region	2012-13	2013-14	% Growth	2014-15	% Growth	2015-16	% Growth	2016-17	% Growth
Vashi – New Mumbai	35844	29927	-16.51	38594	28.96	45711	18.44	41367	-9.5

**c) Category wise Number of Registered Vehicles in Navi Mumbai (2017 to 2018)**

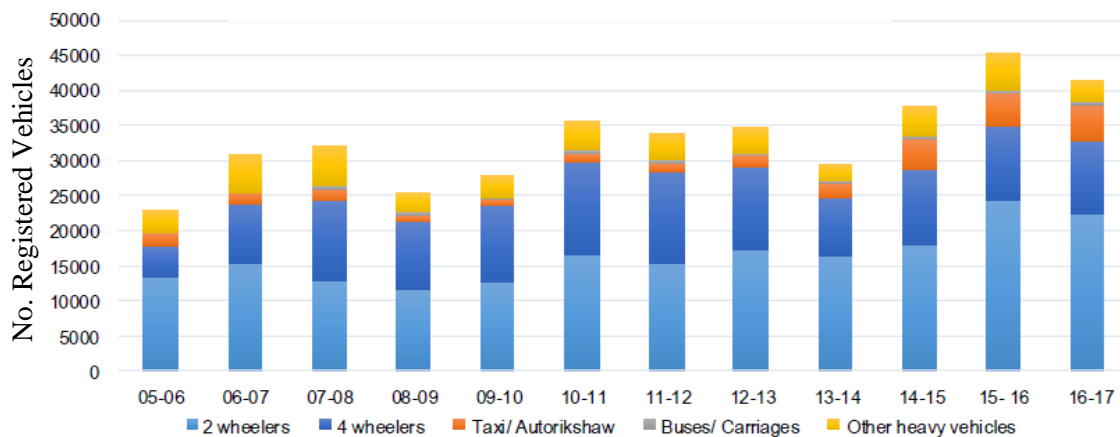
Sr	Category	Financial Year		% Growth
		2015-16	2016-17	
1	Motor Cycles	24404	22535	-7.7
2	Scooter	0	0	0
3	Moped	0	0	0
4	Cars	10805	10343	-4.3
5	Jeep	0	2	--
6	Station Wagon	0	0	0
7	Taxis Meter Fitted	203	2560	1161.1
8	Luxury Tourist Cabs	1763	644	-63.5
9	Auto rickshaw	2445	1944	-20.5
10	Stage Carriage	44	109	147.7
11	Contract Carriage	334	158	-52.7
12	School Bus	143	36	-74.8
13	Private Service Vehicle	11	13	18.2
14	Ambulance	18	14	-22.2
15	Other (Arti/Multi.Veh.)	364	28	-92.3
16	Trucks	2751	1001	-63.6
17	Tankers	267	256	-4.1
18	Delivery Van ( 4 Wheeler)	284	397	39.8
19	Delivery Van ( 3 Wheeler)	1866	967	-48.2
20	Tractor	0	37	0
21	Trailer	0	278	0
22	Others	9	45	400
	<b>Total</b>	<b>45711</b>	<b>41367</b>	<b>-9.5</b>



**Figure 3.2 : Vehicular Growth at Navi Mumbai City**

Source : RTO, Navi Mumbai Region & NMMC ESR -2016-17

The variation in different type of registered vehicles over a period of time is depicted in **Figure 3.3**.



**Figure 3.3 : Trend of Registered Vehicles in Navi Mumbai**

Source : RTO, Navi Mumbai Region & NMMC ESR -2016-17

### 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

$$VKTI = RL_j * NI$$

Where, VKTI = Vehicle Km traveled by vehicle type I,

RL<sub>j</sub>= 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

$$PM_j = N * \sum_{I=1}^m VKT_I * E_{fI}$$

Where, PM<sub>j</sub>= Particulate matter load in tones/year for grid j

N = Number of activity days in a year

E<sub>fI</sub>= Emission factor for a vehicle type I

- Projected emission inventory (with alternative control options) preparation

$$PM \text{ projected } j = N * \sum_{I=1}^m VKT_I * E_{fI} * \eta_k$$

Where, PM Projected j = Projected particulate matter load in tones/year for grid j

η<sub>k</sub>= Efficiency of control option K

### 3.3.2 Vehicle Count

In order to estimate the actual grid-wise vehicular emissions across city, vehicular counts on major traffic corridors and congestion zones as well as within the city were carried out. Road map of the city as given in **Figure 3.4** was used to determine the locations for the vehicle counting survey. For this purpose, the Navi Mumbai transportation network were divided into different parts (i) Western transportation network along Thane Creek (ii) Eastern Corridor transportation network from Belapur to Thane and (iii) Internal transportation network spread across sectors of wards of study area.

Manual counting of the traffic movement was carried out at each of the identified traffic junction for a whole day. Around 31 monitoring locations were selected for the vehicular count assessment, taking suggestions of RTO-Navi Mumbai into consideration. 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



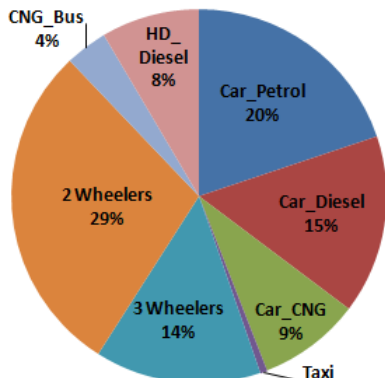
**Figure 3.4 : 2 Km x 2 Km Grid-wise Distribution of City and 31 Vehicular Counting Survey Locations Selected Across Navi Mumbai City**

### 3.3.3 Vehicle Kilometers Traveled (VKT) Estimation

Temporal and spatial vehicle emissions are determined by the emission factors and distributions of Vehicle Kilometers Traveled (VKT). Percent vehicle count distribution is given in **Figure 3.5**. Major and minor roads were also covered to assess the emissions from vehicles traveling on internal roads among settlements **Table 3.17**.

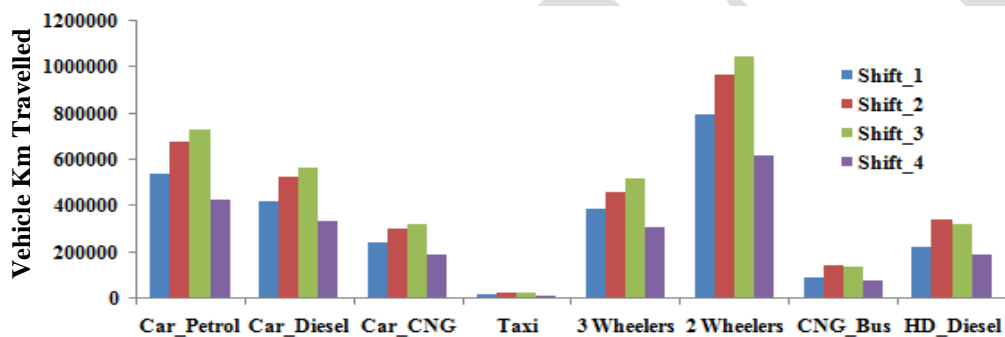
**Table 3.17 : Identified Roads/ Traffic Junctions around Monitoring Sites for Vehicle Counts**

<b>Turbhe Transportation Department</b>			
<b>Sr.</b>	<b>Congestion Zone/Junction</b>	<b>Sr.</b>	<b>Congestion Zone/Junction</b>
1	Sterling College Chowk, Near Hawre Mall	10	Indiranagar Circle, Turbhe
2	Ruparel Circle	11	Savita Chemical, Turbhe
3	Nerul Railway Station Chowk	12	Turbhe Store Cut
4	Shiwaji Chowk, Nerul	13	Sanpada Police Station Chowk
5	Nerul Post Office Chowk	14	Sanpada Junction
6	L.P Circle	15	Turbhe Under bridge Chowk
7	Shani Mandir Chowk, Nerul	16	Shivaji Maharaj Statue Chowk
8	Shani Mandir Kaman Chowk, Nerul	17	Moraj Circle
9	Turbhe Naka	18	Shalimar Chowk, Turbhe MIDC
<b>Koparkhairane Transportation Department</b>			
<b>Sr.</b>	<b>Congestion Zone/Junction</b>	<b>Sr.</b>	<b>Congestion Zone/Junction</b>
1	Koparkhairane D-Mart Chowk	4	Varisht Chowk
2	Teen Taki Chowk	5	Kalash Garden Chowk
3	MSEB Chowk		
<b>Seawoods Transportation Department</b>			
<b>Sr.</b>	<b>Congestion Zone/Junction</b>	<b>Sr.</b>	<b>Congestion Zone/Junction</b>
1	Moraj Chowk – Palm Beach Rd	7	Sec 50 Chowk – Palm Beach Rd
2	Saarsale Chowk – Palm Beach Rd	8	Sawla Chowk
3	Varzani Chowk – Palm Beach Rd	9	Sanjay Joshi Chowk
4	T.S. Chanakya Chowk – Palm Beach Rd	10	Seawoods Station Chowk
5	Akshar Chowk – Palm Beach Rd	11	Nerul Station Chowk
6	NIR Chowk – Palm Beach Rd		
<b>Vashi Transportation Department</b>			
<b>Sr.</b>	<b>Congestion Zone/Junction</b>	<b>Sr.</b>	<b>Congestion Zone/Junction</b>
1	Vashi Plaza Chowk	5	Opp. Vijay Dairy Chowk, Sec. 28
2	Sambhaji Chowk	6	Rajmata Chowk, Sec. 17
3	Apna Bazar Chowk	7	Mahatma Phule Chowk, Sec. 17
4	Shivaji Chowk	8	Noor Masjid Chowk, Sec. 9
<b>APMC Transportation Department</b>			
<b>Sr.</b>	<b>Congestion Zone/Junction</b>	<b>Sr.</b>	<b>Congestion Zone/Junction</b>
1	Annapurna Chowk	5	Bonkode Chowk
2	Areja Chowk	6	Mathadi Bhavan Chowk
3	MSEB	7	Dakshata Station Chowk
4	Kopri Signal		



**Figure 3.5 : Percent Vehicle Count Distribution in Navi Mumbai**

Vehicle Kilometers Traveled (VKT) estimation by each type of vehicle in each grid per day was estimated by using length of roads between major nodes/traffic junctions from Navi Mumbai Region Map as also length in each grid (**Figure 3.6**). Road length in each grid and number of vehicles (of different types) plying in the same are taken into account while estimating vehicle kilometer traveled in each grid by the respective vehicle.



**Figure 3.6 : Vehicle Km Travelled by Different Categories of Vehicles**

Considering peak office hours, VKT were higher in morning during 8 am to 12 pm and in evening during 6 pm to 10 pm. It was observed that the overall VKT of 2 wheelers was highest in all the shifts, followed by Petrol Cars. There is an average annual increase of 10% in the number of registration for 2 wheelers, as per RTO, Navi Mumbai. The VKT was highest in Shift 3 (1700 hrs. to 2200 hrs.), followed by in Shift 2 (1100 hrs. to 1700 hrs.). The VKT of taxis and CNG buses is lowest compared to other categories of vehicle in the study, as the number of CNG operated Bus fleet by the corporation is minimum and dependency on 3 wheelers for point to point transit is more. An average VKT of 1496605 Km/day was estimated for all categories of vehicles travelling within city limits. As observed from the **Figure 3.5**, the movement of 2 wheelers (29%) were more followed by Private owned petrol cars (20%), diesel operated cars (15%) and 3 wheelers (14%) in vehicular count survey at different location across city jurisdiction.

### 3.3.4 Vehicular 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 3.18**.

**Table 3.18 : Emission Factors Calculated by Automotive Research Association of India (ARAI)**

<b>Vehicular Emission Factors (Gm/Km)</b>	<b>Car Petrol Post 2005 Fuel BSII</b>	<b>Car Diesel Post 2005 Fuel BSII</b>	<b>Car CNG BSI, Post 2000, Fuel BSII</b>	<b>Two Wheeler Post 2005 4 Stroke Fuel BS II</b>	<b>Three Wheeler CNG Retro 25 Post 2000 Fuel BS II</b>	<b>CNG Buses Post 2000 Fuel BS II</b>	<b>Trucks Diesel Post 2000 Fuel BSII</b>
PM	0.002	0.015	0.006	0.013	0.118	0.044	1.240
NO <sub>x</sub>	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 Ward wise Vehicle 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, NO<sub>x</sub>, CO and HC. SO<sub>2</sub> emissions are calculated based on VKT and sulphur content (Diesel 300 ppm and Gasoline 30 ppm) as SO<sub>2</sub> 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 emission of PM, 25.67% of emissions are from Ward C-Vashi, contributing 838.4 Kg/day of PM. The lowest PM emission load was found at Ward H- Digha (4.14%). Emission load of PM from Ward A (Belapur) & B (Nerul) is also considerable from other wards of Navi Mumbai. Out of the total PM emission load of 3266.4 Kg/day from the line source, load contributed by Belapur ward is 474.5 Kg/day and that of Nerul was 756.4 Kg/day. Almost all categories of vehicular load for PM are observed at Vashi among them heavy duty and 3 wheelers are impacting more. CNG Buses are also contributing 40.5 Kg/d as their percent contribution is less 1.24%. The Heavy duty diesel vehicles contribute 81.55% (2663.8 Kg/d) to the total load followed by 3 wheelers 12% (394.8 Kg/d). As heavy duty vehicles are more plying (approx 2148235 VKT) on industrial belt of Thane Belapur are as well as movement from Sion Panvel Highway. The emission load from 2 wheelers (88.90 Kg/d; i.e. 2.7%) is almost 10 times the emission load from Car operating on Petrol (9.48 Kg/d; i.e. 0.29%) and half of

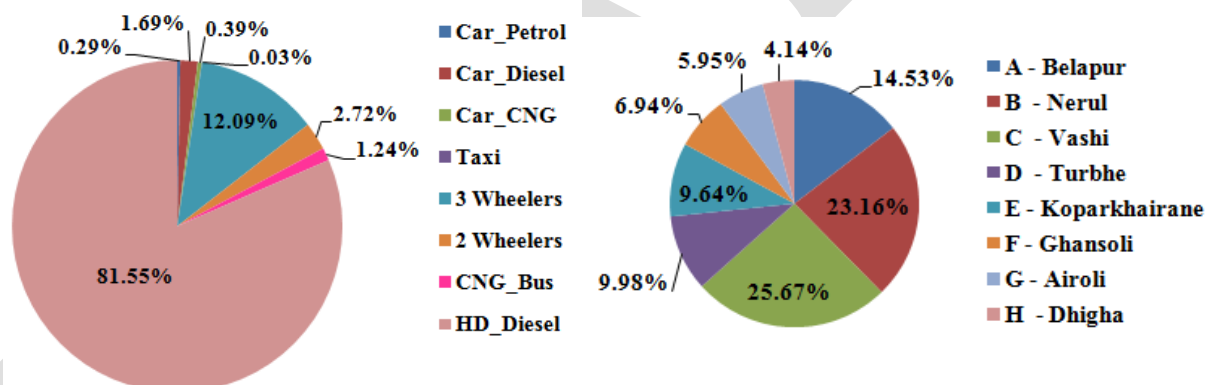


Car Diesel (55.3 Kg/d; i.e. 1.7%) to the total load. As diesels are heavier oils which have large number of ‘C - bonds and are tough to break completely, this incomplete breaking appears as particulate matter. Petrol is more refined than diesel. The region wise PM emission load in a day with respect to its vehicular distribution is given in **Table 3.19** and **Figure 3.7**.

**Table 3.19 : PM Vehicular Emission Load from Different Sector and Zones of Navi Mumbai City**

Wards	Car Petrol	Car Diesel	Car CNG	Taxi	3 Wheelers	2 Wheelers	CNG Bus	Heavy Duty Diesel Veh.	Total Kg/day
A	1.60	9.4	2.1	0.11	36.4	11.7	6.2	407.0	474.5
B	2.37	13.8	3.2	0.22	54.9	18.6	9.9	653.5	756.4
C	2.36	13.8	3.1	0.48	111.9	21.9	10.3	674.6	838.4
D	0.72	4.2	1.0	0.04	55.6	8.4	3.8	252.4	326.1
E	0.61	3.6	0.8	0.04	34.2	6.3	4.0	265.2	314.7
F	0.80	4.6	1.1	0.04	30.3	7.9	2.7	179.3	226.7
G	0.65	3.8	0.9	0.02	34.5	7.9	2.2	144.4	194.3
H	0.36	2.1	0.48	0.02	37.0	6.3	1.3	87.5	135.2
<b>Kg/day</b>	<b>9.48</b>	<b>55.29</b>	<b>12.64</b>	<b>0.97</b>	<b>394.79</b>	<b>88.90</b>	<b>40.51</b>	<b>2663.81</b>	<b>3266.4</b>
<b>Tones/Yr</b>	<b>3.46</b>	<b>20.18</b>	<b>4.61</b>	<b>0.36</b>	<b>144.10</b>	<b>32.45</b>	<b>14.79</b>	<b>972.29</b>	<b>1192.2</b>

Wards : A-Belapur; B-Nerul; C-Vashi; D-Turbhe; E-Koparkhairane; F-Ghansoli; G-Airoli; H-Digha



**Figure 3.7 : Percent Contribution Vehicle Categories and Ward wise Emission Load Distribution of PM (Kg/d) in Navi Mumbai**

NOx is produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. The total NOx emission load for all the wards of the city is 30494.5 kg/day. The highest percentage contribution of NOx concentration was at Ward C-Vashi (25.42%), followed by Nerul (24.23%). The lowest NOx emission load was from Digha (3.59%). Ward A, B and C comprises of more than 65% share of total emission of NOx load from the city. With 65.52% the emission load of NOx concentration is highest from Heavy Duty Vehicles; the load of NOx from CNG Buses is second largest (18.75%); followed by Car CNG 5.11%. The 2 and 3 wheelers contribution is around 3.36% and 2.08% respectively as also Car Diesel 3.38%. While the emission

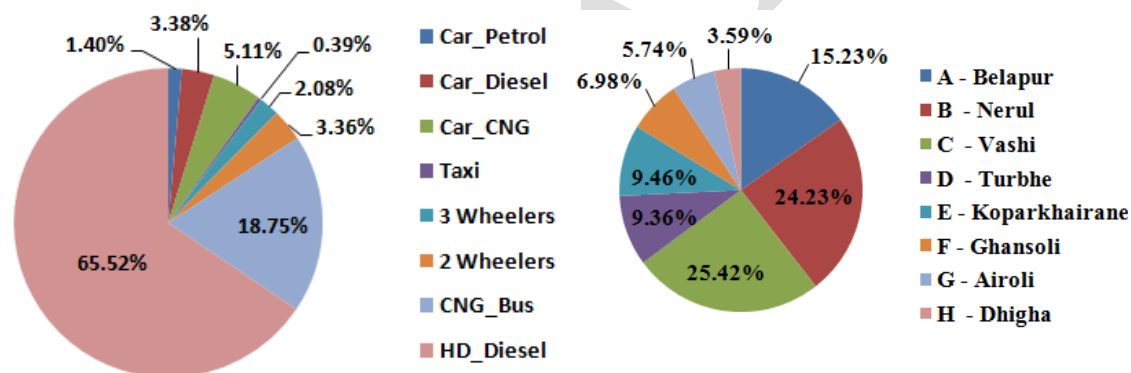


from Taxi for NO<sub>x</sub> is lowest (0.39%). This low concentration is attributed to number of taxis registered in the city (Taxis Meter Fitted – 2560, Luxury/Tourist Vehicles – 644; 2016-17). The region wise PM emission load in a day with respect to its vehicular distribution is given in **Table 3.20 and Figure 3.8**.

**Table 3.20 : NO<sub>x</sub> Vehicular Emission Load from Different Sector and Zones of Navi Mumbai City**

Wards	Car Petrol	Car Diesel	Car CNG	Taxi	3 Wheelers	2 Wheelers	CNG Bus	Heavy D. Diesel Veh.	Total Kg/day
A	72.2	174.7	263.9	13.1	58.6	135.5	873.5	3052.3	4643.8
B	106.7	258.2	389.9	27.5	88.3	214.2	1402.6	4901.2	7388.5
C	106.3	257.1	388.3	59.7	180.2	252.3	1447.9	5059.3	7751.1
D	32.3	78.2	118.1	5.1	89.6	96.3	541.7	1892.8	2854.2
E	27.6	66.7	100.8	5.0	55.1	72.7	569.1	1988.6	2885.6
F	35.8	86.7	131.0	5.2	48.8	90.7	384.8	1344.6	2127.7
G	29.3	71.0	107.2	1.9	55.5	90.9	310.0	1083.1	1749.0
H	16.2	39.3	59.3	2.5	59.6	73.1	187.9	656.6	1094.6
<b>Kg/day</b>	<b>426.5</b>	<b>1032.0</b>	<b>1558.5</b>	<b>120.0</b>	<b>635.7</b>	<b>1025.7</b>	<b>5717.4</b>	<b>19978.6</b>	<b>30494.5</b>
<b>Tones/Yr</b>	<b>155.67</b>	<b>376.68</b>	<b>568.87</b>	<b>43.82</b>	<b>232.02</b>	<b>374.39</b>	<b>2086.84</b>	<b>7292.19</b>	<b>11130.5</b>

Wards : A-Belapur; B-Nerul; C-Vashi; D-Turbhe; E-Koparkhairane; F-Ghansoli; G-Airoli; H-Digha



**Figure 3.8 : Percent Contribution Vehicle Categories and Ward wise Emission Load Distribution of NO<sub>x</sub> (Kg/d) in Navi Mumbai**

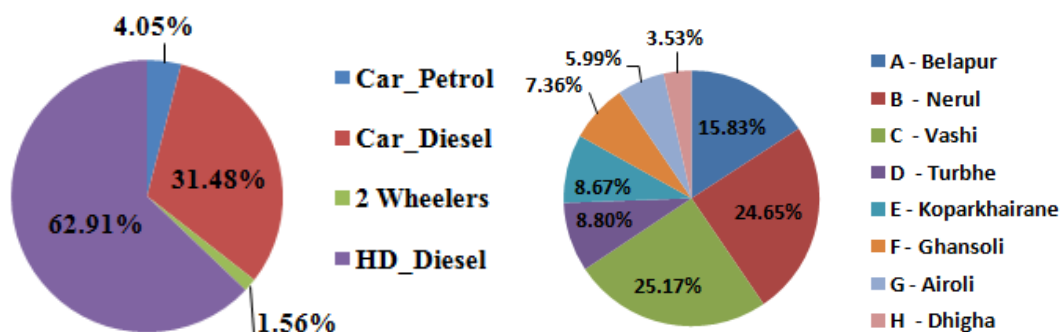
Sulfur dioxide is also present in motor vehicle emissions, as the result of fuel combustion. In the past, motor vehicle exhaust was an important, but not the main, source of sulfur dioxide in air. The emission load of city of SO<sub>2</sub> from different category of vehicle was estimated to be around 0.585 kg/day. The highest emission load of SO<sub>2</sub> was found from Ward C- Vashi (25.17%), followed by emission load of Ward B- Nerul (24.65%). This emission load can be attributed to the presence of commercial activities engaging around APMC market. The maximum SO<sub>2</sub> load was emitted by HDD Vehicle (62.91%) and lowest from 2 wheelers (1.56%). The diesel operated car in the city contributes on an average of 0.184 kg/day (i.e. 31.48%) of SO<sub>2</sub> emission load.

The region wise PM emission load in a day with respect to its vehicular distribution is given in Table 3.21 and Figure 3.9.

**Table 3.21 : SO<sub>x</sub> Vehicular Emission Load from Different Sector and Zones of Navi Mumbai City**

Wards	Car Petrol	Car Diesel	2 Wheelers	Heavy Duty Diesel Veh.	Total Kg/day
A	0.004	0.031	0.001	0.056	0.093
B	0.006	0.046	0.002	0.090	0.144
C	0.006	0.046	0.002	0.093	0.147
D	0.002	0.014	0.001	0.035	0.052
E	0.002	0.012	0.001	0.037	0.051
F	0.002	0.015	0.001	0.025	0.043
G	0.002	0.013	0.001	0.020	0.035
H	0.001	0.007	0.001	0.012	0.021
<b>Kg/day</b>	<b>0.024</b>	<b>0.184</b>	<b>0.009</b>	<b>0.368</b>	<b>0.585</b>
<b>Tones/Yr</b>	<b>0.009</b>	<b>0.067</b>	<b>0.003</b>	<b>0.134</b>	<b>0.214</b>

Wards : A-Belapur; B-Nerul; C-Vashi; D-Turbhe; E-Koparkhairane; F-Ghansoli; G-Airoli; H-Digha



**Figure 3.9 : Percent Contribution Vehicle Categories and Ward wise Emission Load Distribution of SO<sub>x</sub> (Kg/d) in Navi Mumbai**

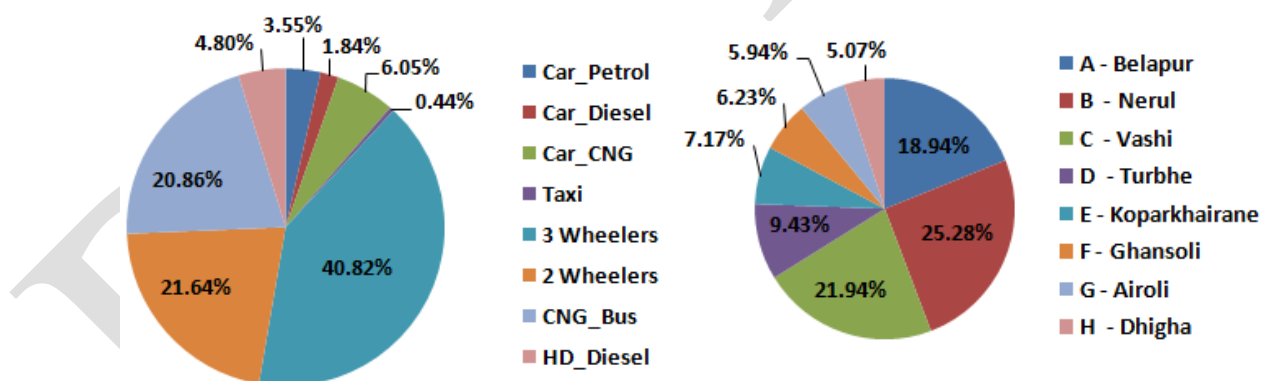
Motor vehicle fuel contains hydrocarbons, which are its primary source of energy. Any hydrocarbons emitted from a vehicle indicate unused fuel, which results from incomplete fuel combustion. This can be due to lesser amount of O<sub>2</sub>, incomplete mixing of fuel or lesser lapse time for the fuel to burn. As for the concentration of HC, the highest emission load was calculated at Ward B- Nerul (25.28%) and the lowest was found at Ward H- Digha (5.08%), while Ward A & C contributes around 41% of emission load. As also vehicular movement around Ward C- Vashi is often found to be high, the percent is more i.e. 22%. The HC emission load of the city is largely contributed by the 3 wheelers and 2 wheelers i.e around 41% and 22% respectively. Heavy duty diesel vehicles are not impacting much as emission factor for HC is 0.37 gms/km, whereas it is 2.06 gm/km for 3 wheeler and 3.75 gm/km for CNG buses. Maharashtra itself accounts for almost 10% of the overall three-wheeler market annually in the country. According to industrial reports, the three-

wheeler market is likely to cross the major milestone of 1 million units in production in the next couple of years, with domestic market crossing its previous peak of 5.5 lakh units per annum to about 6-7 lakh units. Passenger carrying three-wheelers will be crossing a critical half a million mark in the domestic market by 2019-2020. Following emissions from 3 wheelers CNG Buses contributes (20.86%). The total HC emission load of the city is 10863.7 kg/day. The region wise PM emission load in a day with respect to its vehicular distribution is given in **Table 3.22** and **Figure 3.10**.

**Table 3.22 : HC Vehicular Emission Load from Different Sector and Zones of Navi Mumbai City**

Wards	Car Petrol	Car Diesel	Car CNG	Taxi	3 Wheelers	2 Wheelers	CNG Bus	Heavy D. Diesel Veh.	Total Kg/day
A	95.1	49.3	162.0	8.0	632.6	467.7	522.5	120.3	2057.5
B	120.4	62.4	205.1	13.3	851.6	647.0	688.0	158.4	2746.2
C	70.7	36.7	120.5	20.0	1162.2	457.4	419.7	96.6	2383.8
D	23.1	12.0	39.4	2.0	551.1	180.0	176.3	40.6	1024.6
E	20.3	10.5	34.6	1.5	343.1	128.6	195.3	45.0	779.0
F	24.6	12.7	41.8	1.7	280.8	168.5	119.1	27.4	676.6
G	20.1	10.4	34.3	0.6	296.3	173.9	88.8	20.5	644.9
H	11.2	5.8	19.0	0.8	316.8	128.4	56.1	12.9	551.0
<b>Kg/day</b>	<b>385.5</b>	<b>199.9</b>	<b>656.8</b>	<b>47.9</b>	<b>4434.6</b>	<b>2351.4</b>	<b>2265.9</b>	<b>521.7</b>	<b>10863.7</b>
<b>Tones/Yr</b>	<b>140.7</b>	<b>73.0</b>	<b>239.7</b>	<b>17.5</b>	<b>1618.6</b>	<b>858.3</b>	<b>827.0</b>	<b>190.4</b>	<b>3965.3</b>

Wards : A-Belapur; B-Nerul; C-Vashi; D-Turbhe; E-Koparkhairane; F-Ghansoli; G-Airoli; H-Digha



**Figure 3.10 : Percent Contribution Vehicle Categories and Ward wise Emission Load Distribution of HC (Kg/d) in Navi Mumbai**

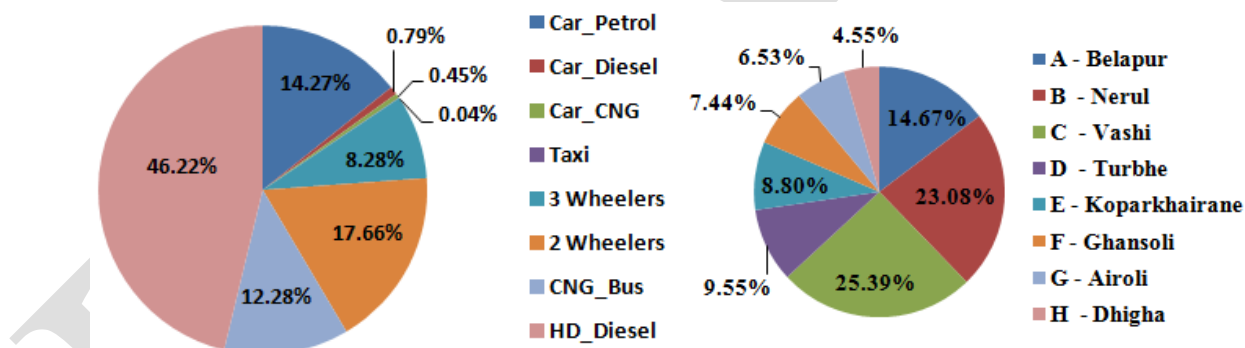
Carbon monoxide (CO) a colorless, odorless, tasteless, and toxic air pollutant is produced in the incomplete combustion of carbon-containing fuels, such as gasoline, natural gas, oil, coal, and wood. This is due to insufficient air present to completely burn the fuel. At 25.39%, the CO emission load was estimated highest at Ward C- Vashi, followed by Ward B-Nerul (23.08%), Ward A-Belapur (14.67%) and lowest at Ward H-Digha (4.55%). Ward A, B and C contribute almost 63% of total emission load of CO. This CO emission load is emitted maximum from Heavy Duty vehicles i.e.,

around 46.22% (i.e. 12889.4 kg/d). The cumulative CO emission load of the city was estimated to be 27885.9 kg/day. Whereas emission load from 2 wheelers is around 4923.5 kg/day, contributing 17.66% of total load, followed by emission from Petrol Cars stands around 14.27%. The lowest emission load was found from vehicle category of Taxis (0.04%). The region wise PM emission load in a day with respect to its vehicular distribution is given in **Table 3.23** and **Figure 3.11**.

**Table 3.23 : CO Vehicular Emission Load from Different Sector and Zones of Navi Mumbai City**

Wards	Car Petrol	Car Diesel	Car CNG	Taxi	3 Wheelers	2 Wheelers	CNG Bus	Heavy D. Diesel Veh.	Total Kg/day
A	673.9	37.4	21.4	1.3	212.8	650.4	523.3	1969.2	4089.6
B	995.8	55.3	31.6	2.7	320.7	1028.1	840.2	3162.1	6436.5
C	991.8	55.1	31.5	5.6	654.4	1210.9	867.3	3264.1	7080.7
D	301.7	16.8	9.6	0.47	325.3	462.5	324.5	1221.2	2661.9
E	257.4	14.3	8.2	0.48	200.0	349.1	340.9	1283.0	2453.3
F	334.6	18.6	10.6	0.50	177.4	435.4	230.5	867.5	2074.9
G	273.9	15.2	8.7	0.18	201.7	436.2	185.7	698.8	1820.2
H	151.5	8.4	4.8	0.24	216.4	351.0	112.6	423.6	1268.6
<b>Kg/day</b>	<b>3980.6</b>	<b>221.1</b>	<b>126.4</b>	<b>11.4</b>	<b>2308.5</b>	<b>4923.5</b>	<b>3424.9</b>	<b>12889.4</b>	<b>27885.9</b>
<b>Tones/Yr</b>	<b>1452.9</b>	<b>80.7</b>	<b>46.1</b>	<b>4.2</b>	<b>842.6</b>	<b>1797.1</b>	<b>1250.1</b>	<b>4704.6</b>	<b>10178.3</b>

Wards : A-Belapur; B-Nerul; C-Vashi; D-Turbhe; E-Koparkhairane; F-Ghansoli; G-Airoli; H-Digha



**Figure 3.11 : Percent Contribution Vehicle Categories and Ward wise Emission Load Distribution of CO (Kg/d) in Navi Mumbai**

Besides ward wise vehicle emission inventory as presented earlier, the data collected for vehicle counts and road lengths were used to prepare city emission inventory. Methodology described earlier remains same; however, the estimates have been made for 2 Km x 2 Km grids with respect to the entire city. These estimates have been further used for grid wise projections, input to dispersion modeling and scenario generation. **Table 3.24** presents the total emission loads as per different vehicle categories.

**Table 3.24 : Total Emission Load from Different Categories of Vehicle for Navi Mumbai**

	<b>PM</b>	<b>SO<sub>x</sub></b>	<b>NO<sub>x</sub></b>	<b>HC</b>	<b>CO</b>
2 Wheelers	88.9	0.009	1025.7	2351.4	4923.5
3 Wheelers	394.8	--	635.7	4434.6	2308.5
Car Petrol	9.5	0.024	426.5	385.5	3980.6
Car Diesel	55.3	0.184	1032.0	199.9	221.1
Car CNG	12.6	--	1558.5	656.8	126.4
Taxi	1.0	--	120.0	47.9	11.4
HD Diesel	2663.8	0.368	19978.6	521.7	12889.4
CNG Bus	40.5	--	5717.4	2265.9	3424.9
<b>Total (Kg/day)</b>	<b>3266.4</b>	<b>0.585</b>	<b>30494.5</b>	<b>10863.7</b>	<b>27885.9</b>
<b>Total (Tons/Yr.)</b>	<b>1192.2</b>	<b>0.214</b>	<b>11130.5</b>	<b>3965.3</b>	<b>10178.4</b>

\* Values are in kg/day

Considering the distribution of vehicles on the basis of their fuel consumption, the categories wise vehicle registered in the city are as follows. It can be observed that the proportion of CNG operated vehicle in the city is low as compared to diesel and petrol based vehicles.

**Office-wise No. of Diesel, Petrol, LPG & CNG Motor Vehicles Newly Registered  
During 31<sup>st</sup> March, 2016**

<b>Name of the office/region</b>	<b>Diesel</b>	<b>Petrol</b>	<b>LPG</b>	<b>CNG</b>	<b>Others</b>	<b>Total</b>
<b>Vashi - New Mumbai</b>	113283	212623	385	25298	31	351620

Emission from different categories of cars is considerable. The percent distribution of pollutant gives highest emission of PM i.e. 82%, whereas 66% and 63% of NO<sub>x</sub> and SO<sub>x</sub> and 46% of CO is mainly contributing from HDDV. The NO<sub>x</sub> contribution in a day is around 19978.6 kg, followed by CNG operated vehicles (5717.4 kg/d). HDDV also dominate PM<sub>10</sub> emission load with about 2663.8 kg/d followed by 3 Wheelers with a load of 394.8 kg/d towards the final emission load. Even for CO, HD vehicles were major contributor at 12889.4 kg/day of emissions. Whereas, the percentage of emission load from HD vehicles of HC (4.80%) is low. The Agricultural Produce Market Committee (APMC) market, Asia's largest market, located at Vashi has pulled in huge truck traffic in the area which is the prominent reason for the reflecting the pollution load.

The emission load of PM and CO from CNG operated car is lower than the Diesel and Petrol cars, whereas the emission load for NO<sub>x</sub> and HC is higher as compared to other two categories of cars. Three wheelers on the other hand give highest HC, followed by CO, NO<sub>x</sub>; whereas 2 wheelers give higher contribution of CO followed by HC. Similar trend was observed for CNG buses and also contribute NO<sub>x</sub> substantially. Shift wise total emission varies considerably according to vehicle category wise. It has been seen that most of the places, evening peak hours are extended late in the night and therefore, night emissions load are also high.

### 3.4 Point (Industrial) Sources

In terms of absorbing the incremental population shock from the mega city of Mumbai, Navi Mumbai recorded a decadal population growth by more than 51% between 2001 and 2011. The population of NMMC (Navi Mumbai Municipal Corporation) area was estimated to be about 14.69 lakhs 2016–17 which was 1.4% more compared to last year as per the survey data of UHPs (Urban Health Posts), Health department NMMC. The development of industrial belt in Navi Mumbai attracted a large population as it gave rise to employment opportunities. This increase in population brought growth in medium and small scale industrial establishments, educational hub, economic activities and infrastructure, in turn exerting pressure on the resources of the city. This thrust alters the normal state of the resources either in terms of resource availability (land and water supply) or pollution loads (water and air pollution).

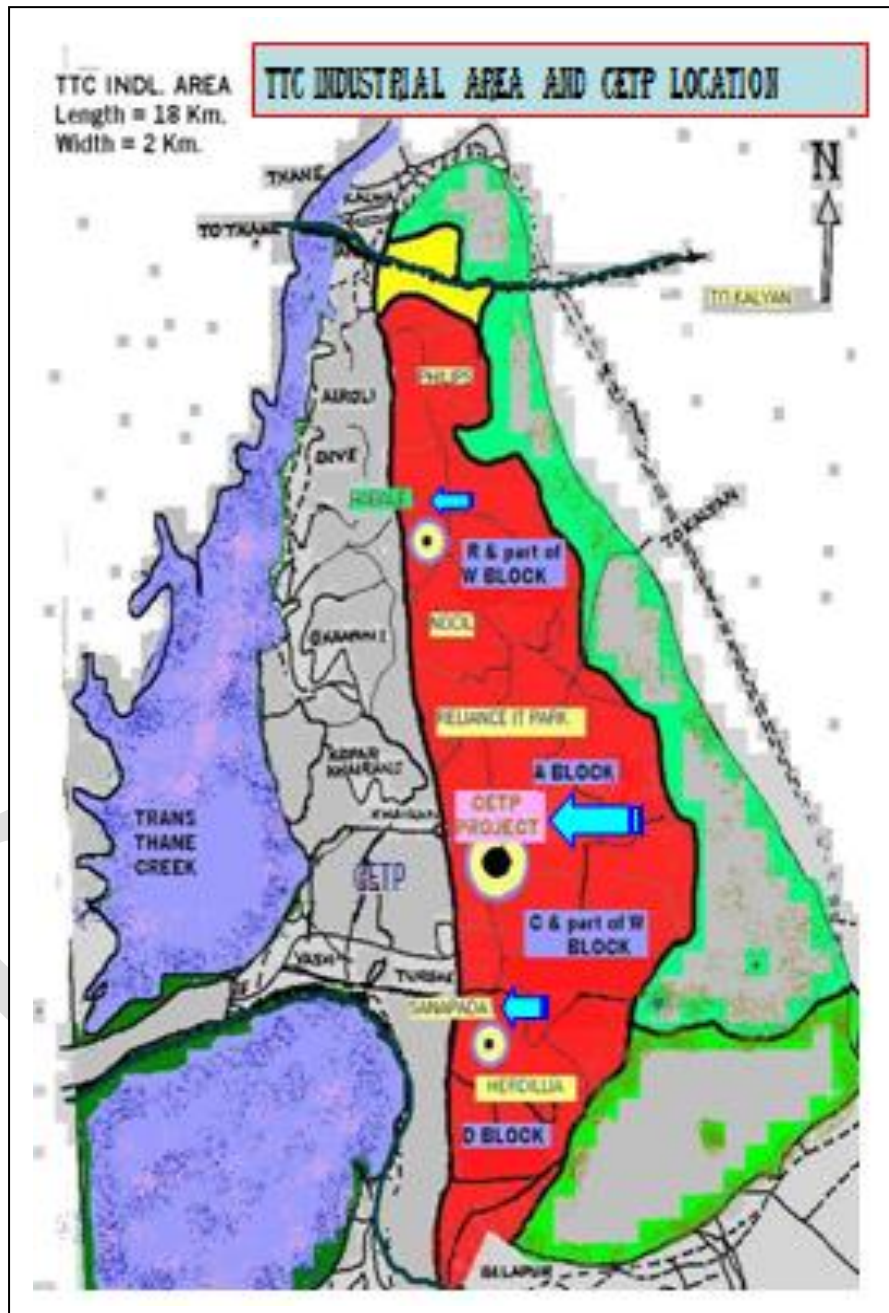
The industrial sector under NMMC jurisdiction is regulated by Maharashtra Pollution Control Board (MPCB) & Maharashtra Industrial Development Corporation (MIDC). The city development and infrastructure is jointly managed by NMMC and CIDCO. The core sector of Navi Mumbai mainly comprises of Residential Cluster, Residential & Industrial Cluster and Industrial Cluster (TTC Industrial, MIDC Area). MIDC has established an industrial estate at Thane Belapur Road, Navi Mumbai in the year 1963, known as Trans Thane Creek (TTC) which is located at Thane-Belapur Road (**East:** Parsik Hill Range; **West:** Thane Municipal Area; **North:** Residential Area; **South:** Thane Belapur Rd, and Navi Mumbai Township). The total area of the industrial estate is 27 Sq.kms and about 16% of total area in Navi Mumbai falls under MIDC zone (**Figure 3.12**).

The Trans Thane creek (TTC) Industrial area and Taloja MIDC are main industrial zones in Navi Mumbai. The Trans Thane creek (TTC) Industrial area lies within the NMMC limits while the Taloja MIDC area lies in close proximity of NMMC area. The TTC industrial area accounts for more than 3000 industries while the Taloja industrial area consists of large, medium and small industrial units. Various types of processing industries including chemical, dyes, dye- intermediates, bulk drugs, pharmaceuticals, textile auxiliaries, pesticides, petrochemicals, engineering units, paper, plastic and so on are located in these industrial areas.

Some of the well-known industries in these areas include Balmer Lawrie & Co. Ltd., Reliance Paper Products, E Merck (I) Ltd., Hindustan Lever Ltd. and Pidilite Industries Ltd, Pfizer, Lubrizol India Ltd., Polyolefins Industries Ltd., Herdillia Chemicals Ltd., BASF (India) Ltd., Star Chemicals, Indofil Chemicals Ltd., and Phoenix Chemical Works are located in this area.



Apart from industrial units, there exists a CBD (Central Business District) located at Belapur spreads over 575 hectare which has been developed to house various corporate as well as government and administrative institutions. The area is known to account for country's most prominent IT- BPO establishments. Employments observed in CBD Belapur are around 32% while 37% jobs are IT- BPO establishments located in Vashi.



**Figure 3.12 : Industrial Area of Navi Mumbai Region**

As per MPCB, Navi Mumbai had aggregate Comprehensive Environmental Assessment of Industrial Cluster in December 2009 having CEPI Score of 73.77, which improvised to 56.48 as on March 2017. There are 241 Air Polluting industries in area/cluster. Major pollutants are TPM/SPM, SO<sub>2</sub>, NO<sub>x</sub>, NH<sub>3</sub>, Cl<sub>2</sub>, and VOC from pesticide and bulk drug units.

At present there are 4 CAAQMS (Continuous Ambient Air Monitoring Stations) installed at Airoli, Koparkhairane, Turbhe, and Nerul. NMMC has also proposed installation of a CAAQMS at CBD-Belapur. NMMC operates a mobile monitoring van which is deputed at various locations in the nodes of Navi Mumbai to monitor the air quality. As per NMMC ESR 2016-17, the Air Quality Index was non-polluting for more than half year at Koparkhairne and Turbhe and for less than 10% of observation day's air pollution quality was recorded in 'Poor' or 'Very Poor' category.

The regions of Turbhe and Koparkhairne were observed to be polluted under Moderate to Very poor category for particulate matter. 15% of observations were seen under Poor category followed by 3% under Severe category for PM<sub>2.5</sub> (RSPM) more than 50% observation were noted under Moderate category for PM<sub>10</sub> (SPM) for these region as per ESR. This can be attributed to due presence of TTC industrial belt within NMMC limits.

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. Examples include food processing facilities, oil production and refinery facilities, steam generators, boilers, process heaters, glass manufacturing, etc. 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). Chemical, oil refineries, petrochemical, fuel-based power plant, textiles, fertilizer and other industries are the major point sources of emissions in Navi Mumbai region.

The status of different types of industries with their grading 'Red (highly polluting), Orange (moderately polluting) and Green (low polluting)' based on labour employed and consumption of water, fuel and power under Maharashtra Pollution Control Board Regional office of Navi Mumbai is given in **Table 3.25**.



**Table 3.25 : Category wise Different Types of Industries located in TTC MIDC Area**

Category	LSI	MSI	SSI	Total
RED	42	27	549	620
ORANGE	20	13	436	469
GREEN	5	7	2091	2103
<b>Total</b>	<b>69</b>	<b>47</b>	<b>2529</b>	<b>3192</b>

As per ‘Environmental Status and Revised Action Plan for Prevention and Control of Pollution of Industrial Cluster -Navi Mumbai’ prepared by MPCB -2016-17’ the most highly polluting industries are given in **Table 3.26 a & b**.

**Table 3.26 a : List of Highly Polluting Industries in TTC MIDC Area**

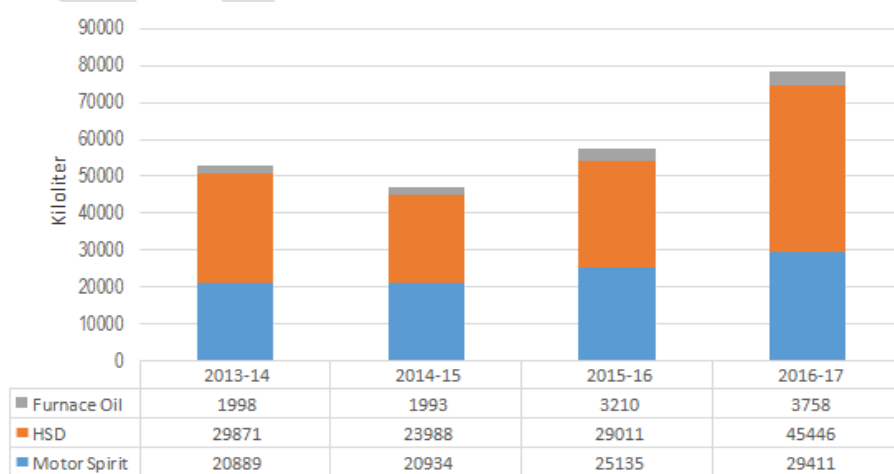
Sr.	Industries Name	Industry Type
1.	M/s. Sandoz Pvt.Ltd., Plot No. D-31/32, TTC, MIDC, Turbhe, Navi Mumbai	Basic Drugs & Pharma Mfg.
2.	M/s. Hemmo Pharmaceutical Pvt. Ltd., Plot No.C-43, TTC, MIDC Pawane, Navi Mumbai	Basic Drugs & Pharma Mfg.
3.	M/s. Modepro India Pvt. Ltd., Plot No. D-16/2, TTC, MIDC Pawane, Navi Mumbai	Basic Drugs & Pharma Mfg.
4.	M/s. R.P.G. Life Science Ltd. Plot No. 25& 25A, TTC, MIDC Pawane, Navi Mumbai	Basic Drugs & Pharma Mfg.
5.	M/s. Zydus Takeda Health Care Ltd., Plot No. C-4, TTC MIDC, Thane Belapur Road, Navi Mumbai 400705	Basic Drugs & Pharma Mfg.
6.	M/s. Zoeitus Plot No. 16, TTC MIDC Indl., Turbhe Navi Mumbai	Basic Drugs & Pharma Mfg.
7.	M/s. S.I.Group India Ltd. Plot No.2, TTC, MIDC Turbhe, Navi Mumbai	Basic Drugs & Pharma Mfg.
8.	Padarsh Pharmaceuticals Pvt.Ltd., Plot No.C-45/1, TTC MIDC, Pawane, Navi Mumbai	Basic Drugs & Pharma Mfg.
9.	Paramount Chemical Industries, Plot No.C-384, TTC MIDC, Pawane, Navi Mumbai	Basic Drugs & Pharma Mfg.
10.	Paras Organics Pvt. Ltd., Plot No.D-119, TTC, MIDC Shirvane, Navi Mumbai	Basic Drugs & Pharma Mfg.
11.	Great Pacific Exports Pvt. Ltd., Plot No. D-5/8, TTC MIDC, Shirvane, Navi Mumbai	Basic Drugs & Pharma Mfg.
12.	NGL Fine Chem Limited Plot No. W-142, TTC MIDC Khiarane, Navi Mumbai	Basic Drugs & Pharma Mfg.
13.	Deepa Chemicals, Plot No. W-20, TTC, MIDC Pawane, Navi Mumbai	Dyes and Dye Intermediates
14.	Reliance Life Sciences Pvt. Ltd., Plot No. R-282. MIDC Rabale, Thane Belapur Road, Navi Mumbai	Basic Drugs & Pharma Mfg.
15.	Indoco Remedies Ltd., R-104, MIDC Rabale, Thane Belapur Road, Navi Mumbai	Basic Drugs & Pharma Mfg.
16.	Maharashtra Polybutens Ltd., R-104, MIDC Mahape, Thane Belapur Road, Navi Mumbai	Petrochemical

**Table 3.26 b : Summarized Status of Compliance of Category Industries in TTC- MIDC Area**

Category of Industry	Total	No. of Operational and Complying Units	No. of Operational and Non Complying Units.	Closed Units
Basic Drugs & Pharmaceuticals Mfg.	17	13	0	4
Dyes & Dye Intermediate	1	1	0	
Pesticide Formulation & Mfg.	2	0	0	2
Petrochemical	2	1	1	
<b>Total</b>	<b>22</b>	<b>15</b>	<b>1</b>	<b>6</b>

Fossil fuel used by the industries for boilers or manufacturing process remains the single potential source of discharging emissions into the atmosphere from their stacks. For proper estimate of emissions, the effectiveness of an existing control device must be applied in the emission calculation. Emissions are estimated for pollutants such as SPM, PM<sub>10</sub>, CO, HC, SO<sub>2</sub> and NO<sub>x</sub>. 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).

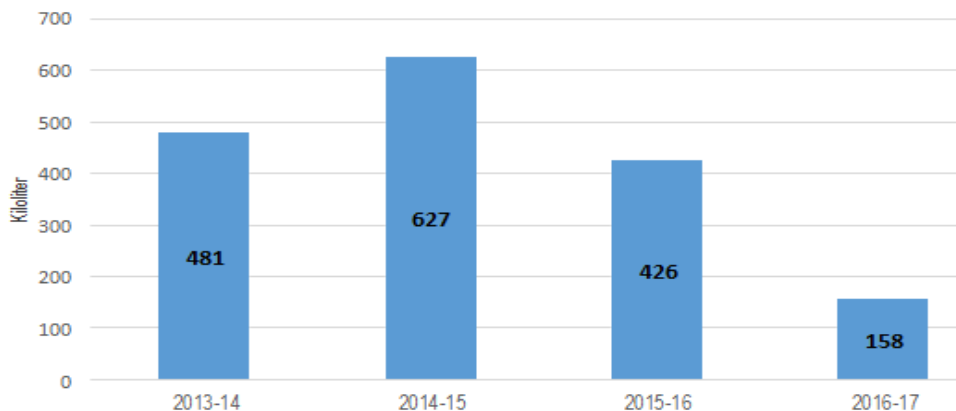
Two main grades of diesel fuel are marketed in India, High Speed Diesel (HSD) and Light diesel oil (LDO). The former is a 100% distillate fuel while the latter is a blend of distillate fuel with a small proportion of residual fuel. It was observed that there is huge demand for petroleum products like Furnace oil and HSD in industries too. In 2016-17, the total petroleum sale within Navi Mumbai is noted to be around 78 thousand Kiloliters (KL) (**Figure 3.13**).



**Figure 3.13 : Trend in Sale of Petrol, Diesel and Furnace Oil in NMMC Area by HPCL**

*Source : HPCL*

The sale in Navi Mumbai has grown by 37% as compared to previous year 2015-16. In the year 16-17, the sale of HSD has increased by 57%, followed by Motor Spirit and Furnace oil by 17% as compared to previous year. The decrease in LDO is seen by 63% as compared to last year (**Figure 3.14**).



**Figure 3.14 : Trend in Sale of LDO in NMMC Area in NMMC Area by HPCL**

*Source : HPCL*

### 3.4.1 Approach/Methodology

From the data furnished by MPCB, a total of 241 industries were identified as air polluting industries in Navi Mumbai region. Data for Fuel consumption such as Furnace Oil (FO), Light Diesel Oil (LDO), Low Sulphur Heavy Stock (LSHS), and Compressed Natural Gas (CNG), by the industries in the Navi Mumbai area has been obtained from MPCB (**Table 3.27**). The gross emissions are estimated for all types of industries viz. LSI, MSI and SSI. Accounting to the number of MSI and SSI establishment, emission from the fuel consumption is considerable as from LSI.

**Table 3.27 : Fuel Consumption from Industries ( TPD)**

	FO	LSHS	LDO	HSD	NG	Coal	LPG	Wood	Diesel	CNG	PNG
<b>Red_All</b>	347.4	0.0	135.2	94.4	1434.8	764.1	931.6	0.6	64.7	2.6	22.8
<b>Orange_All</b>	12.5	1.4	16.5	1054.5	0.0	7.0	0.0	0.0	30.8	0.0	112.8
<b>Green_All</b>	2.2	0.0	0.9	13.0	0.0	0.0	0.4	0.0	21.3	0.0	0.0
<b>Total (TPD)</b>	<b>362.0</b>	<b>1.4</b>	<b>152.6</b>	<b>1161.8</b>	<b>1434.8</b>	<b>771.1</b>	<b>931.9</b>	<b>0.6</b>	<b>116.9</b>	<b>2.6</b>	<b>135.6</b>

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.

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.

As per the regulation, many of the industries have installed control equipment after stringent action from MPCB officials in recent times. The emission load was calculated based on 90% reduction due to control equipments in industries for PM and SO<sub>x</sub> viz. bag filters, industrial scrubbers, electro static precipitator, use of low sulphur fuel oil, cylinder lubrication and for NO<sub>x</sub> 30% reduction was assumed by way of different technologies for reduction of NO<sub>x</sub> 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 was taken from the consent of respective industry, for those industries without any ash and sulfur content is calculated based on **Table 3.28**.

**Table 3.28 : Emission Factors applied for Industrial Emissions**

S. No.	Type of Fuel	Unit	S	Emission Factors (Kg/Unit)					
				TSP	SO <sub>2</sub>	NO <sub>x</sub>	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 <sup>\$\$</sup>	KL	0.02	0.072	0.01*S	2.52	0.07	0.43	
6.	NG	m <sup>3</sup>	-	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 <sup>##</sup>	Kg/t	0.25	0.06	17S	2.5	--	--	--
<b>For Power Plant**</b>									
1.	LSHS	KL	0.45	1.25*S + 0.38	19.25*S	6.25	0.12	0.63	
2.	NG	m <sup>3</sup>	-	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:**

- 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
- Indian Oil Corporation Ltd, Vadodara

**Density<sup>b</sup> of Fuels (Kg/m<sup>3</sup>)**

LSHS	943
FO	943
LDO	860
LPG	504
HSD	860

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.

Total estimation load was calculated on the basis of fuel consumption required for the different process in the industries. 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. Total emissions were calculated and distributed into various wards in accordance with the actual location of industries. 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. The industrial emission load from different pollutants and whole of Navi Mumbai city is given in **Table 3.29**.

**Table 3.29 : Emission Load for Point Source from Different Pollutants**

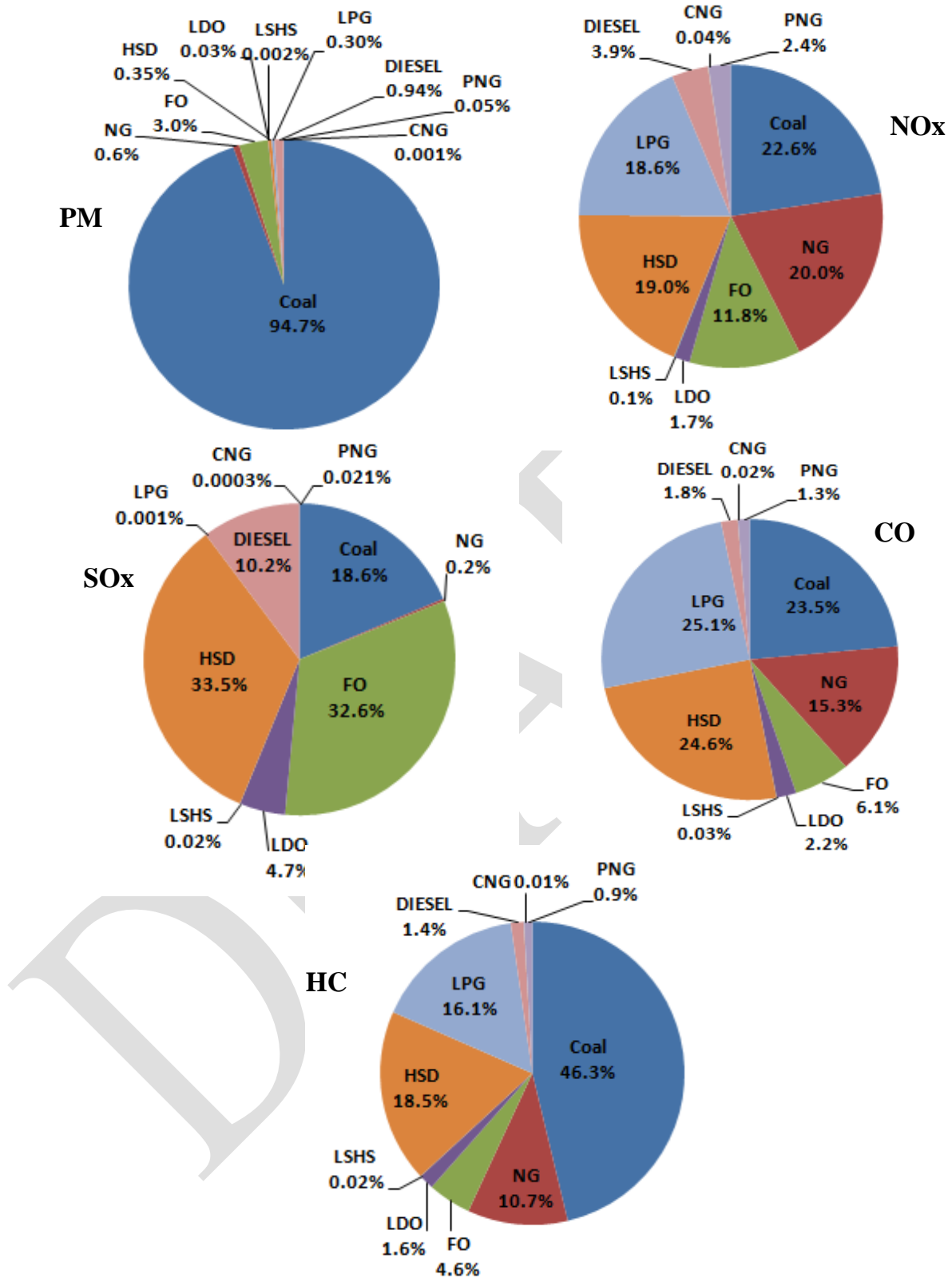
<b>Category</b>	<b>PM<sub>10</sub></b>	<b>SO<sub>x</sub></b>	<b>NO<sub>x</sub></b>	<b>HC</b>	<b>CO</b>
Red LSI	4212.9	3497.4	12368.4	608.8	2198.6
Red MSI	32.6	293.3	353.1	9.8	43.0
Red SSI	120.9	652.3	887.9	29.0	112.4
Orange LSI	24.3	2091.2	3592.6	143.2	754.4
Orange MSI	4.0	86.5	89.7	2.2	11.4
Orange SSI	16.2	68.4	93.6	3.3	11.5
Green LSI	1.8	49.5	63.8	2.0	10.7
Green MSI	0.1	2.5	2.4	0.0	0.2
Green SSI	4.8	82.9	81.1	1.4	7.2
<b>Total (kg/day)</b>	<b>4417.6</b>	<b>6824.1</b>	<b>17532.7</b>	<b>799.6</b>	<b>3149.3</b>
<b>Total (TPD)</b>	<b>4.42</b>	<b>6.82</b>	<b>17.53</b>	<b>0.80</b>	<b>3.15</b>

The emission load from all Red Category Polluting Industries are higher 4366.5, 4443.1 and 13609.5 kg/d for PM, NO<sub>x</sub> and SO<sub>x</sub> respectively, whereas total all category Orange and Green industries emission load reflect as 0.05, 2.38 and 3.92 kg/d. The Red category emission load is mainly reflected by mostly fuel consumption from (Coal 764, FO 347, LDO 135 and HSD 94 TPD) as also NO<sub>x</sub> and HC is reflected by (NG 1434, LPG 931 and PNG 22 TPD). The all LSI contribution to PM load is

around 96% and other pollutants in the range of 83 to 94%, whereas all MSI percent emission load is around 0.8 to 2.5%, except SO<sub>x</sub> 5.6% and SSI percent emission load is around 3.2 to 6.1% except SO<sub>x</sub> 11.8%; among them SO<sub>x</sub> and NO<sub>x</sub> are the major. The Orange and Green category fuel consumption is higher for HSD 1067, Diesel 52 and FO 15 TPD which shows the SO<sub>x</sub> and NO<sub>x</sub> emission. Overall substantial amount of NO<sub>x</sub> comes from fossil fuel combustion utilities. Considering the NO<sub>x</sub> emission loads certain action measures will be required in future context to control the emissions. The percent contribution of emission load from fuel consumption is given in **Figure 3.15**.

The contribution of the PM<sub>10</sub> emission load can be attributed towards the consumption of fossil fuel like coal. The total emission load of PM<sub>10</sub> was calculated to be around 4.42 tons/day. Out of which the load contributed by coal was highest by 94.7% (771 TPD), followed by FO 3% (362 TPD). 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 4212.9 kg/day. While calculating emission load for PM and SO<sub>x</sub>, 90% reductions are considered, as we assuming industries are taking precautions to control dust by way of bag filters, industrial scrubbers, electro static precipitator etc.

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 NO<sub>x</sub>), and the other is from the nitrogen in the fuel being burnt (fuel NO<sub>x</sub>). 22.6% of NO<sub>x</sub> is emitted from coal based industries [from 771.1 TPD], followed by NG, 20% as Red category is single source (fuel 1434.8 TPD for NG); as also 18% to 19% emitted by burning of fuel like LPG and HSD respectively, approximately 1000 TPD each is the source. Another input is from FO (362 TPD) gives 12% emission, the LDO and Diesel are the minor sources as there fuel source is around 100-150 TPD. The Red LSI contributes 71% and Orange LSI share 20%, and others are 9% to the total emission load. We assume that industries are implementing reduction technologies such as Flue-gas recirculation, Hybrid SNCR/SCR, reagents to reduce these emissions, high scavenge pressure and compression ratio and selective catalytic reduction etc. so as the calculation are worked out on the basis of 30% reduction in total load, else the NO<sub>x</sub> load will be higher.



**Figure 3.15 : Percent Distribution of Pollutant from Different Source Category (Navi Mumbai Industries)**

Sulphur dioxide is found in many industrial gases emanating from plants involved in roasting, smelting and sintering sulphide ores, or gases from furnaces 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. The total SO<sub>x</sub> emission is around 6.82 TPD, and is mainly contributing from FO and HSD i.e. 32.6% and 33.5% respectively as their fuel consumption is around (362 TPD and 1162 TPD). FO is mainly used by Red industries, whereas HSD is by Orange. The other contributors are Coal 18.6% and Diesel 10.2%, the least contribution is from LDO 4.7%. The Red LSI contribute 51% and Orange LSI share 31%, others are 18% to the total emission load.

Hydrocarbons are either evaporated from fuel or are remnants of fuel that did not burn completely. About 46% of HC is released from burning of coal in the industries; HSD is also contributing 18.5% as fuel consumption from all categories is 1161.8 TPD. The LPG and NG are cleaner fuel as compared to solid fuels but HC is contributing some extent i.e. 16% and 10% respectively to the total emission. The percent contribution from sector The Red LSI contributes 76% and Orange LSI share 18%, and others are 5% to the total emission load. Out of the total 3149 TPD of CO emission load around 25% is coming from LPG, Coal and HSD each categories of fuel. Carbon monoxide is produced when organic materials, such as gasoline, coal, wood, and trash, are incompletely burned. 70% is mainly contributing from Red LSI and 24% is from Orange LSI. The percent contribution of CO emission i.e. 3.9% and 1.7% from SSI and MSI are very negligible emission load.

Very less amount of fuel consumption pattern was observed for FO, LDO, LSHS and CNG/PNG which reflect negligible amount of emission load. The MSI and SSI Industries are also using the low cost and easy availability fuel such as briquette and wood which add up the emission load. The overall emission contributing areas are Pawane, Turbhe, Rabale, Koparkhairane, Mahape, Sanpada and Ghansoli, where mostly number of industries operates in TTC belt.

#### **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 (Taloja Belt) in Navi Mumbai Region are not taking for estimation as whole emission inventory is developed on the basis of city level.



### 3.5 Whole Navi Mumbai City Total Emission Load

Cumulating all the emission loads from significant sources viz., Area, Point and Line sources for Navi Mumbai city wide emission inventory was developed as shown in **Table 3.30**.

**Table 3.30 : Navi Mumbai City wide Emission Load from All the Sources**

Sector	PM	%	NOx	%	SOx	%	HC	%	CO	%
Bakeries	69.2	0.33	5.2	0.01	0.8	0.01	458.0	3.38	505.2	1.31
Crematorium	46.7	0.22	6.4	0.01	1.1	0.02	309.3	2.28	343.2	0.89
Open Eatout	9.3	0.04	8.1	0.01	14.1	0.19	28.8	0.21	107.3	0.28
Hotels & Res.	205.0	0.98	112.4	0.20	149.4	2.04	7.9	0.06	243.6	0.63
Domestic Sect.	364.0	1.75	8020.4	14.25	298.3	4.08	314.9	2.32	4756.7	12.36
Open Burning	285.9	1.37	107.2	0.19	17.9	0.24	768.5	5.67	1501.2	3.90
Building Const.	852.0	4.09	5.2	0.01	0.8	0.01	458.0	3.38	505.2	1.31
<b>Total Area (A)</b>	<b>1832.12</b>	<b>8.80</b>	<b>8259.7</b>	<b>14.67</b>	<b>481.5</b>	<b>6.59</b>	<b>1887.39</b>	<b>13.93</b>	<b>7457.2</b>	<b>19.37</b>
Red LSI	4212.9	20.24	12368.4	21.97	3497.4	47.87	608.8	4.49	2198.6	5.71
MSI & SSI-ROG	204.7	0.98	5164.2	9.17	3326.6	45.53	190.9	1.41	950.8	2.47
<b>Total Point (B)</b>	<b>4417.6</b>	<b>21.22</b>	<b>17532.6</b>	<b>31.15</b>	<b>6824.0</b>	<b>93.40</b>	<b>799.7</b>	<b>5.90</b>	<b>3149.4</b>	<b>8.18</b>
2 Wheelers	88.9	0.43	1025.7	1.82	0.01	0.0001	2351.4	17.35	4923.5	12.79
3 wheelers	394.8	1.90	635.7	1.13			4434.6	32.73	2308.5	6.00
Car_Petrol	9.5	0.05	426.5	0.76	0.02	0.0003	385.5	2.84	3980.6	10.34
Car_Diesel	55.3	0.27	1032.0	1.83	0.18	0.0025	199.9	1.48	221.1	0.57
Car_CNG	12.6	0.06	1558.5	2.77			656.8	4.85	126.4	0.33
Taxies	1.0	0.00	120.0	0.21			47.9	0.35	11.4	0.03
HDDV	2663.8	12.79	19978.6	35.49	0.37	0.0050	521.7	3.85	12889.4	33.49
CNG Buses	40.5	0.19	5717.4	10.16			2265.9	16.72	3424.9	8.90
<b>Total Line (C)</b>	<b>3266.4</b>	<b>15.69</b>	<b>30494.4</b>	<b>54.18</b>	<b>0.6</b>	<b>0.01</b>	<b>10863.7</b>	<b>80.17</b>	<b>27885.8</b>	<b>72.44</b>
<b>Paved Rd. Dust</b>	<b>3283.5</b>	<b>15.77</b>								
<b>Unpaved Rd.D.</b>	<b>8020.1</b>	<b>38.52</b>								
Total of Resuspension Dust 11303.7 kg/d (55.74% of Total PM)										
<b>Total (A+B+C) Kg/day</b>	<b>20819.8</b>		<b>56286.7</b>		<b>7306.1</b>		<b>13550.8</b>		<b>38492.4</b>	
<b>Total Tons/Yr.</b>	<b>7599.2</b>		<b>20544.6</b>		<b>2666.7</b>		<b>4946.0</b>		<b>14049.7</b>	

\* 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 3.16 and 3.17**. To devise an efficient air quality management framework, the estimation of a robust emission inventory is crucial.

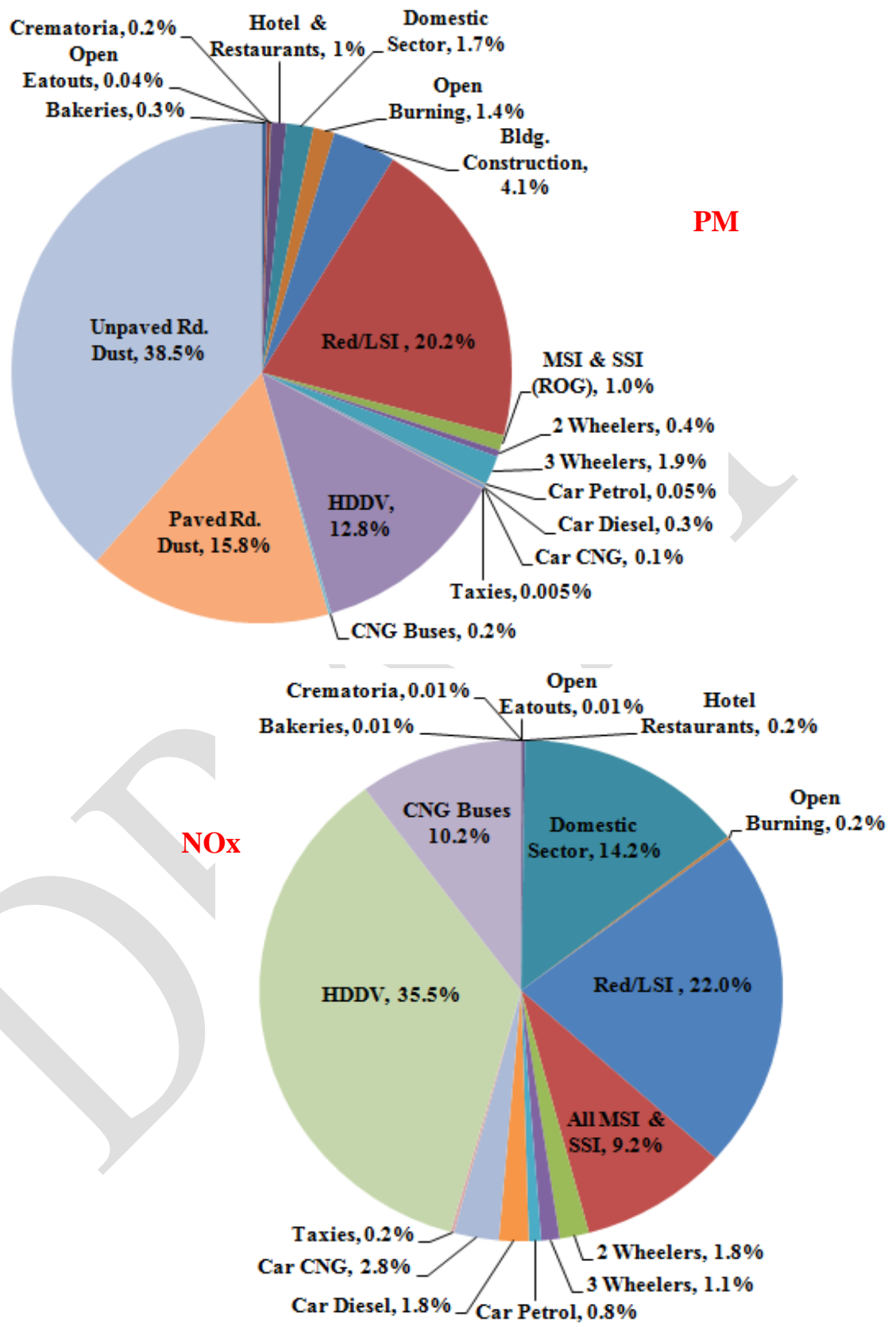
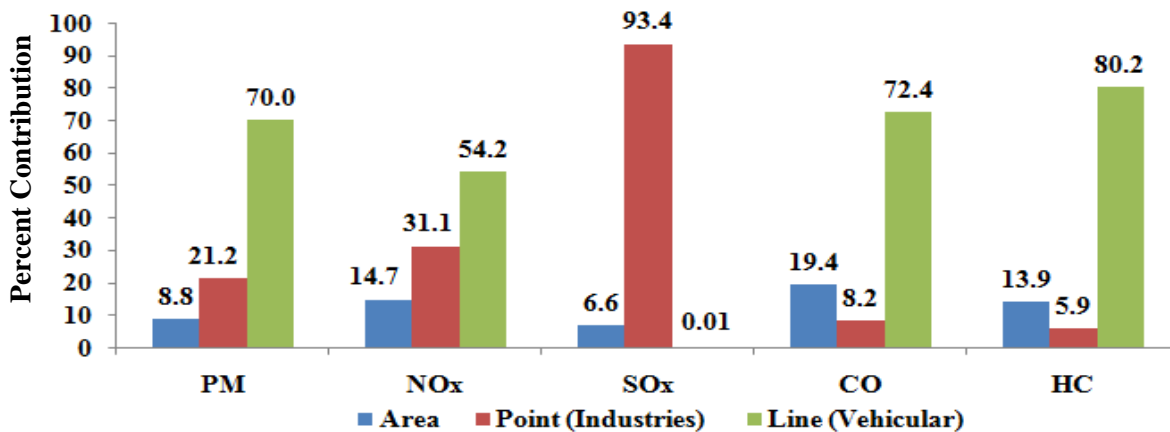


Figure 3.16 : Percent Contribution of PM and NOx from Different Sector in Navi Mumbai



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

**Figure 3.17 : Percent Contribution from All Sources for Whole of Navi Mumbai**

In Navi Mumbai city, PM is mainly contributed from collective sources of road dust and vehicular sector i.e. 70%; among road dust Paved dust share 15.77% and unpaved 38.52% (both 54.29%) and tailpipe emissions of vehicular sources contribute 15.69%. The second largest percent contribution is from industrial source (21.2%), whereas area source share is 8.8%. Among the total area source i.e. 1832 kg/day domestic sector reflect 1.75% and construction activities 4.09% followed open burning 1.37% and hotels and restaurants 1% to the total emission load. Negligible percent contribution is observed from bakeries, crematoria and open eatouts. The total industrial load comes around 4417.6 kg/d and amongst them all Red LSI is the highest contributors 20.24% (4212.9 kg/d). The Orange, Green and Red (MSI and SSI) is very less impactive i.e. 1% (204.7%). The fuel consumption of Red industries (Coal 764, NG 4134, FO 347, LDO 135, HSD 94, and Diesel 64 TPD) is the main source, whereas only 1054 TPD of HSD is observed Orange Industries. All other fuels from all sector i.e. MSI, SSI are in the range of 2 to 21 TPD resulting less pollution. The vehicular sector gives 3266.4 kg/d to the total load, the percent contribution from heavy duty is more 12.79 (2663.8 kg/day), the major vehicular movement of Thane Belapur Road, Sion Panvel Highway, way to JNPT -Uran Road are the influencing point, the APC Market and industrial transportation gives the momentum to transport sector. Because of the heavy movements of vehicles the re-suspension of dust shows the high volume of load. The other category of vehicles viz. 3 wheelers, 2 wheelers, all cars, CNG buses are only gives 2.89%. The total PM load of the city gives around 20819.8 Kg/d and yearly accounts to 7599.2 tones/year.

The total NOx load of the city gives around 56286.7 kg/d and yearly accounts to 20544.6 tones/year. The NOx contribution mainly reflects by vehicular source i.e 54.2% (30494.4 kg/d) and secondly by industrial 31.1% (17532.6 kg/d). Among industries Red LSI contributes (12368.4 kg/day) 21.97%, and from Orange, Green and Red, all MSI & SSI categories (5164.2 kg/day) shares 9.17%. The

35.49% i.e. 19978.6 kg/d alone comes from HDDV vehicles followed by 5717.4 kg/d (10.16%) is from CNG Buses. Approximately 1000 to 1500 kg/d is coming from 2 Wheelers, Car Diesel and Car CNG collectively and gives 6.42% to the vehicular NO<sub>x</sub>. The 3 Wheelers are also gives 635 kg/d i.e. 1.13% to the total NO<sub>x</sub>. The area source percent contribution is 14.67% (8259.6 kg/d) and entire mainly reflected by domestic sector (8020.4 kg/d) the residential consumption of LPG is around 156210 which reflect the highest contribution.

The 6824 kg/day of SO<sub>x</sub> emission is mainly from industries i.e. around 93.4%. Out of this 3497.4 kg/day and 3326.6 kg/day comes from Red LSI industries and all MSI & SSI (R,O,G) industries and contributing 47.87% and 45.33% respectively. Only 6.59% shares come from area source among them domestic sector is higher 4.08% (i.e. 298.3 kg/d). For vehicles SO<sub>x</sub> emissions are calculated based on sulphur content (Diesel 300 ppm and Gasoline 30 ppm) which reflect 0.37 (kg/d) from HDDV, 0.18 from Car Diesel.

The total CO from all sources comes around 38492.3 (kg/d). The line source contribute 72.44% (27885.8 kg/d) among them 33.49% comes from HDDV, whereas 12.79% is from 2 Wheelers. The second highest contribution is from area source 12.36% (4756.7 kg/d) in domestic sector followed by open burning i.e 3.90% (1501.2 kg/d). The total industrial sector gives 8.18%, Red LSI gives 5.71% (2198.6 kg/d) and all MSI and SSI (ROG) gives 2.47% (950.8 kg/d). The total hydrocarbon emission is 13550.79 kg/d; the vehicular source contributes substantially i.e. 80% (10863.7 kg/d); and the major operators are 3 wheelers 32.73% (4434.6 kg/d) followed by 2 wheelers and CNG Buses i.e. 17.35% and 16.72% respectively. Only 5.9% is coming from industries among Red LSI once comes around 608.8 kg/d. The area source gives 14% to the total emission load, around 4-5% is coming mostly from bakeries, crematoria, domestic sector and open burning.

It is important to note that high load contribution does not necessarily lead to high ambient contribution of a particular source at the receptor site. This is due to the fact that emission distribution in atmosphere depends upon multitude of factors such as local meteorology, location, height of release, atmospheric removal processes and diurnal variation. Further, it is equally important that fine particles which constitute higher fractions of toxics are mostly released at ground level sources such as vehicles, refuse burning, bakeries-crematoria, road side eateries, airport and railways ground operations etc. Since mass based emission inventories do not provide the complete picture of real contributions at the levels of exposure, it is pertinent to use chemical analysis data with appropriate dispersion and receptor models.

## Receptor Modelling &amp; 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  $i \times j$  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:

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

where  $p$  is the number of factors contributing to the atmospheric particulate matter,  $x_{ij}$  is the  $j^{\text{th}}$  compound concentration measured in the  $i^{\text{th}}$  sample,  $g_{ik}$  is the gravimetric concentration of the  $j^{\text{th}}$  element in material from the  $k^{\text{th}}$  source, and  $f_{kj}$  is the airborne mass concentration ( $\text{mg}/\text{m}^3$ ) of material from the  $k^{\text{th}}$  source contributing to the  $i^{\text{th}}$  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.

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

Where,  $u_{ij}$  is an estimate of uncertainty in the  $j^{\text{th}}$  variable in  $i^{\text{th}}$  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 carried out for representative samples of PM<sub>2.5</sub> and PM<sub>10</sub> collected during November, 2019, sampling campaign at 6 locations: Maritime University, Nerul, APMC Mkt, Vashi Plaza, Vasai Toll Naka, TBIA Ind. area Juinagar. The concentration and uncertainty data were obtained from the gravimetric analysis (PM<sub>2.5</sub> and PM<sub>10</sub>); 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<sup>+</sup>, NH<sub>4</sub><sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, F<sup>-</sup>, Cl<sup>-</sup>, NO<sub>2</sub><sup>-</sup>, Br<sup>-</sup>, NO<sub>3</sub><sup>2-</sup>, PO<sub>4</sub><sup>3-</sup> and SO<sub>4</sub><sup>2-</sup>) for both PM<sub>10</sub> and PM<sub>2.5</sub> for all sources as listed above.

EPA PMF requires 2 input files: 'Concentration' files 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 (µg/m<sup>3</sup>). The Concentration file is prepared by multiplying the concentration data as well as the uncertainty (i.e., standard deviation of analysis) obtained in µg/cm<sup>2</sup> with area of Filter paper (i.e., 11.9 cm<sup>2</sup> @ 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<sup>3</sup>, taking the sampling time as 24 hours @ 5lpm. 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).

$$\text{Unc} = \sqrt{(\text{conc of ion} \times 0.05)^2 + (\text{Mdl} * 0.5)^2} \quad \text{.....Eq 1.3}$$

Where, Conc of ion = Concentration of ion, µg/m<sup>3</sup>; Del relativity = Delta Relativity ~ 5%,  
Smp Unc = Sampling uncertainty ~5%; MDL = Minimum Detection Limit, µg/m<sup>3</sup>

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<sup>th</sup>, 50<sup>th</sup> and 75<sup>th</sup> 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  $Q_{\text{true}}/Q_{\text{robust}}$  has also been used to assess the modelled results.  $Q_{\text{true}}$  is estimated by considering entire data whereas  $Q_{\text{robust}}$  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).

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

Elements (a)	$\mu\text{g}/\text{cm}^2$	$\mu\text{g}/\text{m}^3\#$	Elements (a)	$\mu\text{g}/\text{cm}^2$	$\mu\text{g}/\text{m}^3\#$
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	Se	0.0010	0.002
Co	0.0044	0.011	Br	0.0010	0.002
Ni	0.0030	0.007	Rb	0.0102	0.025
Cu	0.0050	0.012	Sr	0.0086	0.021
Zn	0.0020	0.005	Y	0.0090	0.022
Ga	0.0020	0.005	Zr	0.0100	0.024
Ge	0.0010	0.002	Mo	0.0104	0.025
As	0.0092	0.022	Rh	0.0108	0.026
Pd	0.0126	0.03	<b>Ions (b)</b>	<b>PPM</b>	<b><math>\mu\text{g}/\text{m}^3\#</math></b>
<b>Ions (b)</b>	<b>PPM</b>	<b><math>\mu\text{g}/\text{m}^3\#</math></b>	NO <sub>2</sub> <sup>-</sup>	0.01	0.001
Na <sup>+</sup>	0.008	0.001	Br <sup>-</sup>	0.02	0.003
NH <sub>4</sub> <sup>+</sup>	0.009	0.001	NO <sub>3</sub> <sup>2-</sup>	0.02	0.003
K <sup>+</sup>	0.02	0.003	NO <sub>3</sub> <sup>2-</sup>	0.06	0.008
Mg <sup>2+</sup>	0.02	0.003	PO <sub>4</sub> <sup>3-</sup>	0.02	0.003
Ca <sup>2+</sup>	0.03	0.004	SO <sub>4</sub> <sup>2-</sup>	0.02	0.008
F <sup>-</sup>	0.002	0.0002	<b>EC-OC (c)</b>	<b>PPM</b>	<b><math>\mu\text{g}/\text{m}^3\#</math></b>
Cl <sup>-</sup>	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)

Hence for the present study the recommended protocol of convergence of all the runs and factors were selected for the cases where  $Q_{\text{robust}} < 1.5 Q_{\text{true}}$  (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.

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; Taghvaei *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 for both cases of  $PM_{2.5}$  &  $PM_{10}$  mentioned in Section 1.2 are explained below.

#### 4.3.1 $PM_{10}$

After the EPA PMF run analysis, 6 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<sub>2.5</sub> and PM<sub>10</sub> is presented in **Figure 4.2 (a to b)**.

#### **Factor 1: Resuspended Road Dust/ Wind Blown Dust /Construction Dust**

Factor 1 was identified by the significant levels of Al, Ti, P, Si, Ca, Mg, K and NO<sub>3</sub><sup>-</sup> (~8%, 0.8%, 0.5%, 21%, 8%, 14%, 3% and 2.6%) and minor indicators such as Fe, Zn, and SO<sub>4</sub><sup>2-</sup> that contributed to 28.5% of total PM<sub>10</sub> emissions. Al, Si and SO<sub>4</sub><sup>2-</sup> 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**

Factor 2 was identified by significant levels of Br, As, Pb, EC, OC, F<sup>-</sup>, SO<sub>4</sub><sup>2-</sup> and S (~0.3%, 0.06%, 1%, 1.2%, 7.9%, 0.01%, 27.86%, and 8.6%) with minor indicators such as Cr, K, Fe and Pb contributed to 12.8% of total PM<sub>10</sub> emissions. F<sup>-</sup>, Cl and Fe along with SO<sub>4</sub><sup>2-</sup> have been widely used as a marker of coal combustion in industrial plants as well as in some studies as Fossil fuel combustion (Kumar *et al.*, 2001; Patil *et al.*, 2013; Rai *et al.*, 2016; Sharma *et al.*, 2016; Jain *et al.*, 2018).

#### **Factor 3: Secondary Aerosol / Marine Aerosols**

Factor 3 is identified as Secondary and Marine aerosols which accounted for 11.8% of total PM<sub>10</sub> contribution. Major and minor indicators are NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, NH<sub>4</sub><sup>+</sup>, (~ 10.76%, 38.9% and 10.13%) with Cl<sup>-</sup>, Na<sup>+</sup>, OC, (~2.98%, 0.69% and 2.8%). The studies indicated that NH<sub>4</sub><sup>3-</sup>, NO<sub>3</sub><sup>2-</sup> and SO<sub>4</sub><sup>2-</sup> are major indicators for secondary aerosols and Na<sup>+</sup> and Cl<sup>-</sup> are indicators of Marine source (Patil *et al.*, 2013; Police *et al.*, 2016; Sharma *et al.*, 2016; Jain *et al.*, 2017; Mukherjee *et al.*, 2018; Garaga *et al.*, 2020). As Navi Mumbai is located in the vicinity of Mumbai which is a coastal city the impact of Marine and Secondary aerosols as background source is justified.

#### **Factor 4: Industrial Emissions**

Factor 4 was identified as Industrial emissions with the presence of tracers, such as As, Cr, Zn, Cl<sup>-</sup>, Fe, P, Mn and S (~0.03%, 0.11%, 1.59%, 1.89%, 15.15%, 0.37%, 0.2%, and 6.08%) with minor indicators such as Cr, Cd, Na<sup>+</sup>, Mg, Br, OC and Pb suggest the source of Industrial emissions contributed to about 16.4%. of total PM<sub>10</sub> pollution. Earlier studies reported that Fe, Cr and Mn are the indicators of the industrial emissions as these elements are greatly used in various industries like machinery, battery and electroplating purposes (Taghvaei *et al.*, 2018). As and S is a major indicator of metal Smelting and coal combustion (Kumar *et al.*, 2001; Shukla & Sharma, 2008; Police *et al.*, 2016, Rai *et al.*, 2016). Cl<sup>-</sup>, Mg, SO<sub>4</sub><sup>2-</sup> and Br are indicators of industries combustion at plant as well as Cl<sup>-</sup> and Cd is also a major indicator of incinerator (Rai *et al.*, 2016, Sharma *et al.*, 2016; Jain *et al.*, 2017). Major industrial pocket in the study area could be the possible reason of industrial source.

### **Factor 5: Biomass Burning**

Factor 5 is identified as Biomass burning which accounted for contributions of 14.6%. Major proportions of  $\text{Cl}^-$ ,  $\text{K}^+$ , EC, OC,  $\text{NH}_4^+$  and  $\text{SO}_4^{2-}$  (~4.73%, 2.45%, 0.2%, 1.6%, 2.62% and 8.7%). Fe, Mg, and  $\text{Na}^+$  as minor indicators contributed to this source. There have been many studies in the past suggesting that OC,  $\text{K}^+$  and  $\text{SO}_4^{2-}$  are clear indicator of biomass burning and  $\text{NH}_4^+$  is an indicator of Wood Combustion (Shukla and Sharma, 2008; Police *et al.*, 2016; Sharma *et al.*, 2016; Jain *et al.*, 2017; Mukherjee *et al.*, 2018; Garaga *et al.*, 2020).

### **Factor 6: Vehicular Emissions**

Factor 6 accounted for 15.7%, with major indicators such as EC, OC, Fe, Mn, Zn and Pb (~1%, 6.8%, 15.24%, 0.2%, 1% and 0.24%) and minor indicators are Mg,  $\text{NO}_3^-$ ,  $\text{NH}_4^+$ ,  $\text{SO}_4^{2-}$ , Br and S. 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 al.*, 2018, Pawar *et al.*, 2020). Also, EC,  $\text{SO}_4^{2-}$  & 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<sub>2.5</sub>**

After the EPA PMF run analysis, 7 factors were identified in the study location for PM<sub>2.5</sub> 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<sub>2.5</sub> and PM<sub>10</sub> are presented in **Figure 4.2 (c to d)**.

### **Factor 1 : Industrial Emissions**

Factor 1 was identified as Industrial emissions with the presence of tracers, such as As,  $\text{SO}_4^{2-}$ , Fe, P, Pb, Mg, Mn, OC and Zn (~0.17%, 48.5%, 7.04%, 0.2%, 0.5%, 12.52%, 0.1, 1.7%, % and 0.6%) with minor indicators such as Cr, Cd,  $\text{Na}^+$ , Ca, V and  $\text{Mg}^{2+}$  suggest the source of Industrial emissions contributed to about 13.2%. of total PM<sub>2.5</sub> pollution. Earlier studies reported that Fe, Cr and Mn are the indicators of the industrial emissions as these elements are greatly used in various industries like machinery, battery and electroplating purposes (Taghvaei *et al.*, 2018). Cd, Mn, Fe is a major indicator of metal Smelting and coal combustion (CMB Manual, 2004, Kumar *et al.*, 2001; Shukla & Sharma, 2008; Police *et al.*, 2016, Rai *et al.*, 2016).  $\text{Cl}^-$  and Cd is also a major indicator of incinerator (Rai *et al.*, 2016, Sharma *et al.*, 2016; Jain *et al.*, 2017). Major industrial pocket in the study area could be the possible reason of industrial source.

### **Factor 2 : Resuspended Road Dust/ Wind Blown Dust**

Factor 2 was identified by significant levels of Ti, Si, Fe, Ca and Mg (~0.2%, 10.51%, 6.64%, 0.3% and 28.46%) and minor indicators such as Al, Na<sup>+</sup>, Mn, Zn and NO<sub>2</sub><sup>-</sup> contributed to 11.5% of total PM<sub>2.5</sub> emissions. 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 3: Vehicular Emissions /Secondary Aerosol**

Factor 3 accounted for 19.3% of total PM<sub>2.5</sub> emissions with major and minor indicators such as NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup>, OC, EC, SO<sub>4</sub><sup>2-</sup>, Mn, Pb, Zn and Fe (~10.62%, 10.17%, 6.15%, 0.78%, 33.76%, 0.08%, 0.03%, 0.95% and 3.97%). 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 al.*, 2018, Pawar *et al.*, 2020). 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).

### **Factor 4 : Marine Aerosols**

Factor 4 is identified as Marine aerosols which accounted for contributions of 10.7% of total PM<sub>2.5</sub> emissions. Major proportions indicated as Cl<sup>-</sup>, Br, Na<sup>+</sup>, Mg and K (~13.7%, 0.15%, 1.4%, 27.47% and 3.5%). The Na<sup>+</sup> and Cl<sup>-</sup> are indicators of Marine source (Patil *et al.*, 2013; Police *et al.*, 2016; Sharma *et al.*, 2016; Jain *et al.*, 2017, Mukherjee *et al.*, 2018; Garaga *et al.*, 2020). As Navi Mumbai is located in the vicinity of Mumbai which is a coastal city the impact of Marine and Secondary aerosols as background source is justified.

### **Factor 5 : Secondary Aerosols**

Factor 5 accounted for 21.9% of Secondary Aerosols which mainly contributes by Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, EC, OC, SO<sub>4</sub><sup>2-</sup>, and NH<sub>4</sub><sup>+</sup> (~5.9%, 11.31%, 5.20%, 0.64%, 30.86%, and 5.69%). The studies indicated that NO<sub>3</sub><sup>2-</sup> and SO<sub>4</sub><sup>2-</sup> are major indicators for secondary aerosols and Na<sup>+</sup> and Cl<sup>-</sup> are indicators of Marine source (Patil *et al.*, 2013; Police *et al.*, 2016; Sharma *et al.*, 2016; Jain *et al.*, 2017, Mukherjee *et al.*, 2018; Garaga *et al.*, 2020).

### **Factor 6 : Construction Dust**

Factor 6 is identified as crustal dust which accounted for 11.1% of total PM<sub>2.5</sub> contributions. Major indicators of this source are Ca, K, Ti, Mg, Si, Al and Fe (~6.43%, 7.08%, 0.02%, 15.04%, 1.5%, 0.02% and 1.57%). Ca, K and Mg are major indicators of crustal dust/ soil as per previous studies

reported (Kothai *et al.*, 2008; Sharma *et al.*, 2016; Jain *et al.*, 2017; Mukherjee *et al.*, 2018; Pawar *et al.*, 2020).

#### Factor 7 : Fossil Fuel Combustion/ Biomass Burning

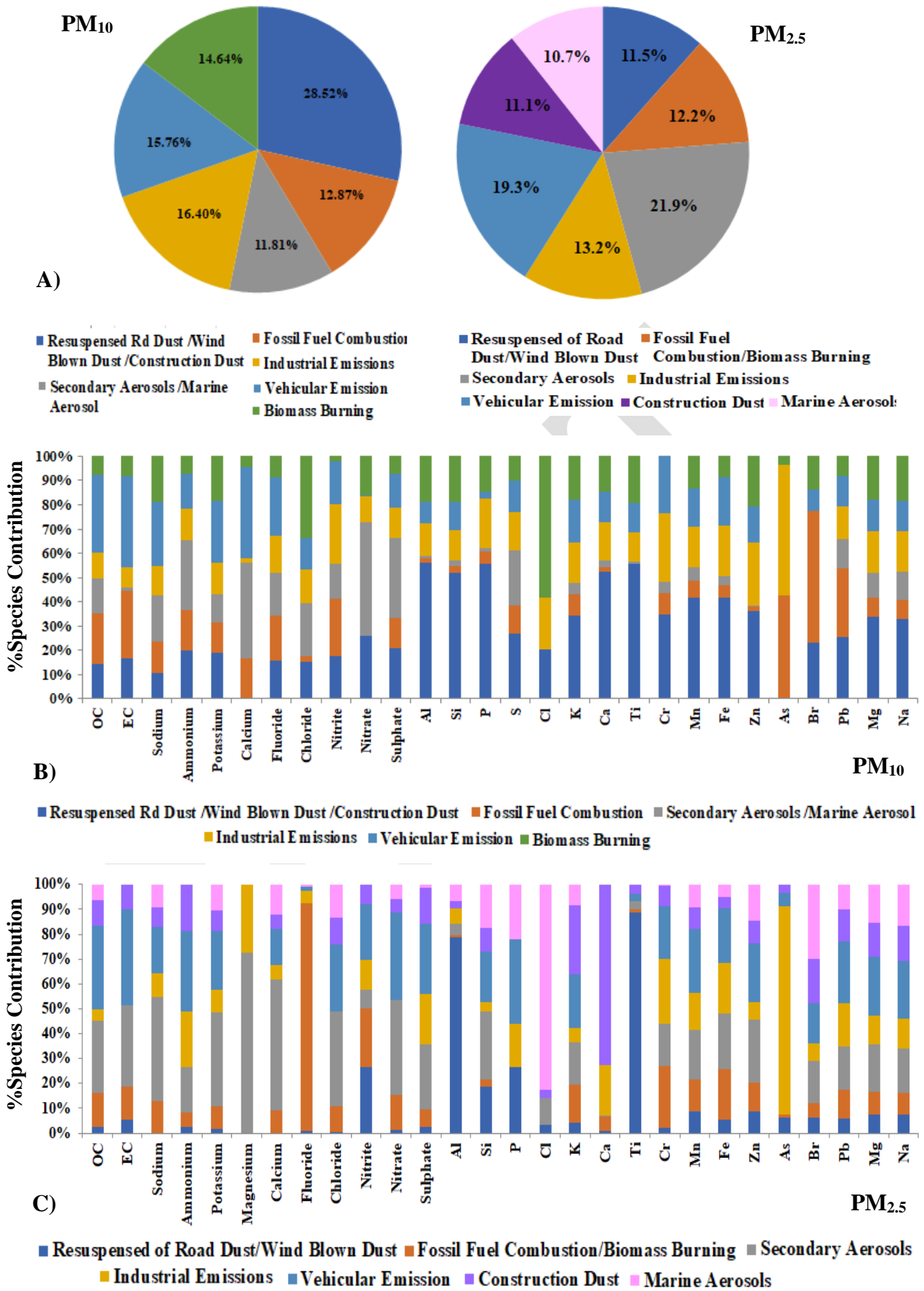
Factor 7 was identified by the significant levels of K, EC, OC, Cl<sup>-</sup>, Pb, Br and SO<sub>4</sub><sup>2-</sup> (~5.23%, 0.8%, 6.5%, 4.25%, 0.4%, 0.024% and 22.73%). with minor indicators such SO<sub>4</sub><sup>2-</sup>, Ca, and Fe contributed to 12.2% of total PM<sub>2.5</sub> emissions. F<sup>-</sup>, Fe, Cl<sup>-</sup> along with SO<sub>4</sub><sup>2-</sup> have been widely used as marker of coal combustion in power plants as well as in some studies as Fossil fuel combustion (Kumar *et al.*, 2001; Patil *et al.*, 2013; Rai *et al.*, 2016; Sharma *et al.*, 2016; Jain *et al.*, 2018). There have been many studies in the past suggesting that K<sup>+</sup> and SO<sub>4</sub><sup>2-</sup> are clear indicator of biomass burning whereas NH<sub>4</sub><sup>3-</sup> is a major indicator of wood combustion and Br is an indicator of combustion (Shukla and Sharma, 2008; Police *et al.*, 2016; Sharma *et al.*, 2016; Jain *et al.*, 2017; Mukherjee *et al.*, 2018; Garaga *et al.*, 2020). Biomass/ wood are used as low-cost fuel contributing to ambient air pollution.

**Table 4.2: Percentage Source Contribution for Navi Mumbai**

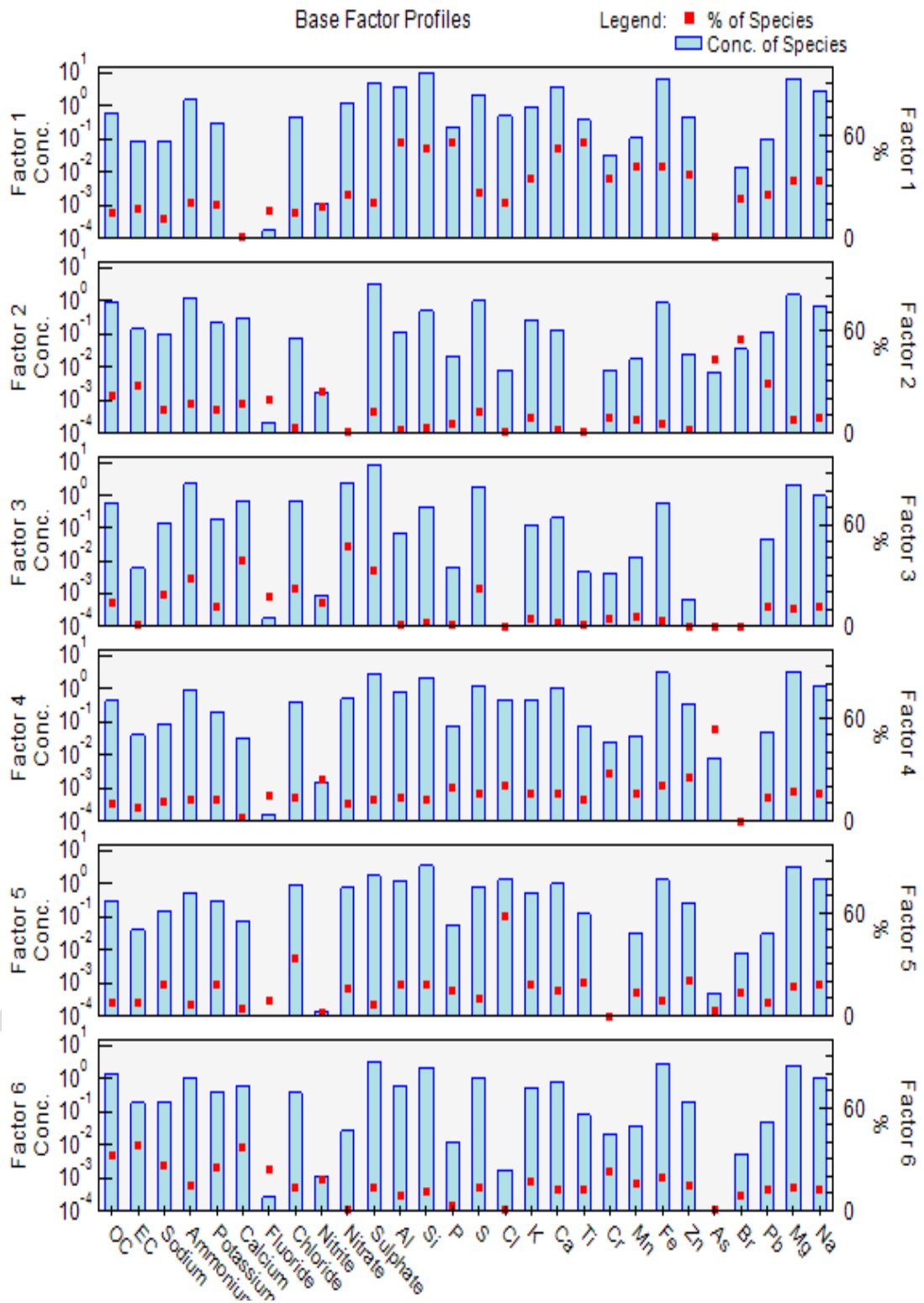
Most likely source(s)	%Contribution	
	PM <sub>10</sub>	PM <sub>2.5</sub>
Resuspended of Road dust/ Wind Blown Dust	28.5	11.5
Fossil Fuel Combustion	12.8	12.2
Secondary Aerosol /Marine aerosol	11.8	21.9
Industrial Emissions	16.4	13.2
Biomass Burning	14.6	--
Vehicular Emission	15.7	19.3
Marine Aerosol	--	10.7
Construction Dust	--	11.1

#### 4.4 PMF Conclusion

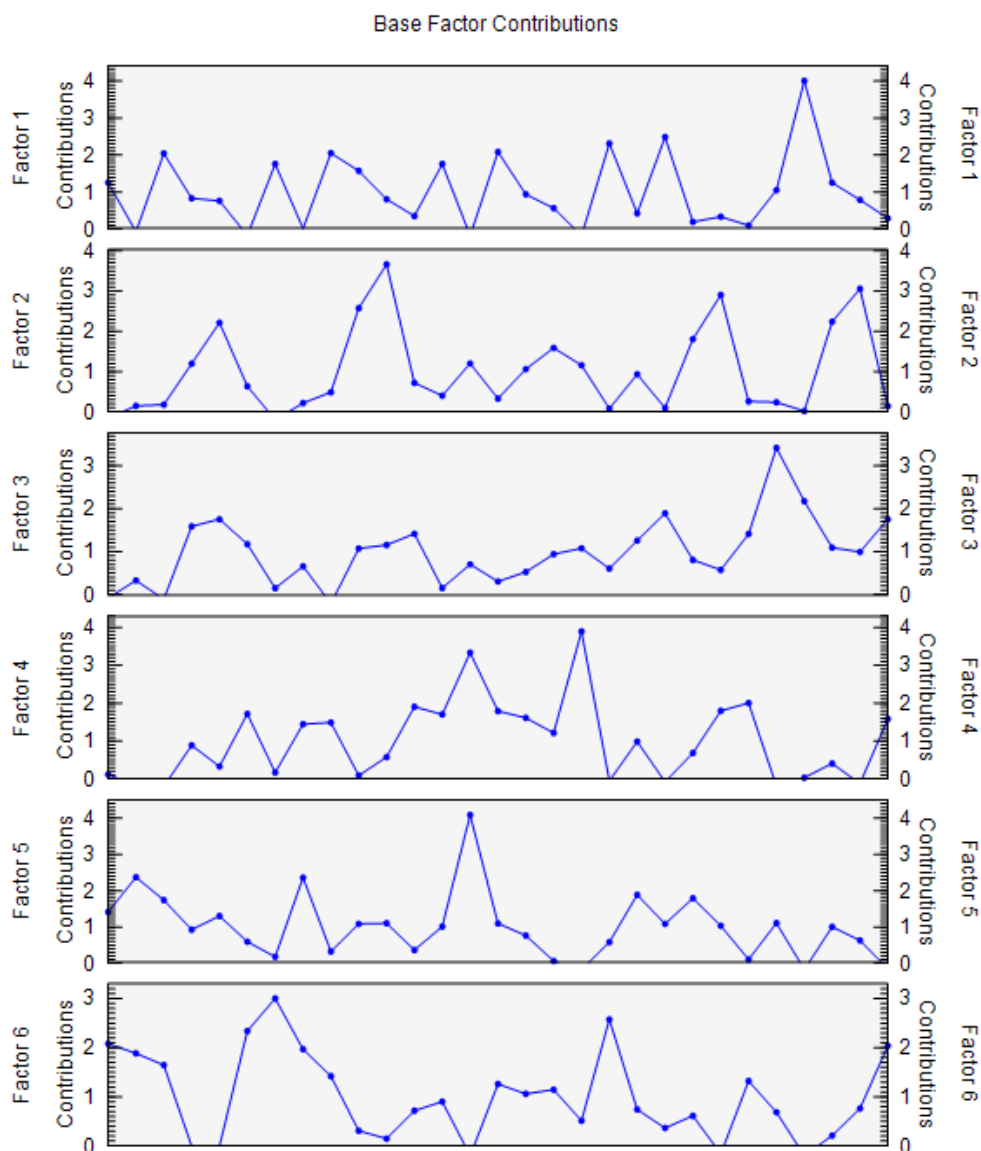
After PMF analysis, six factors for PM<sub>10</sub> and seven factors for PM<sub>2.5</sub> were identified. The major contributors from both the fractions for PM pollution ranges as Resuspended of Road dust/ Wind Blown Dust (11-28%), vehicular emission (15-19%), secondary and marine aerosol (11-21%), fossil fuel combustion (12%) and industrial emission (13-16%) and others are biomass (14%), marine aerosol (10%) and construction dust (11%). Both source categories were found to be contributing almost the same for both PM<sub>2.5</sub> and PM<sub>10</sub> Pollution.



**Figure 4.1: A) Percentage Contribution of Sources & Factor Fingerprints for B) PM<sub>10</sub> C) PM<sub>2.5</sub> for Navi Mumbai**

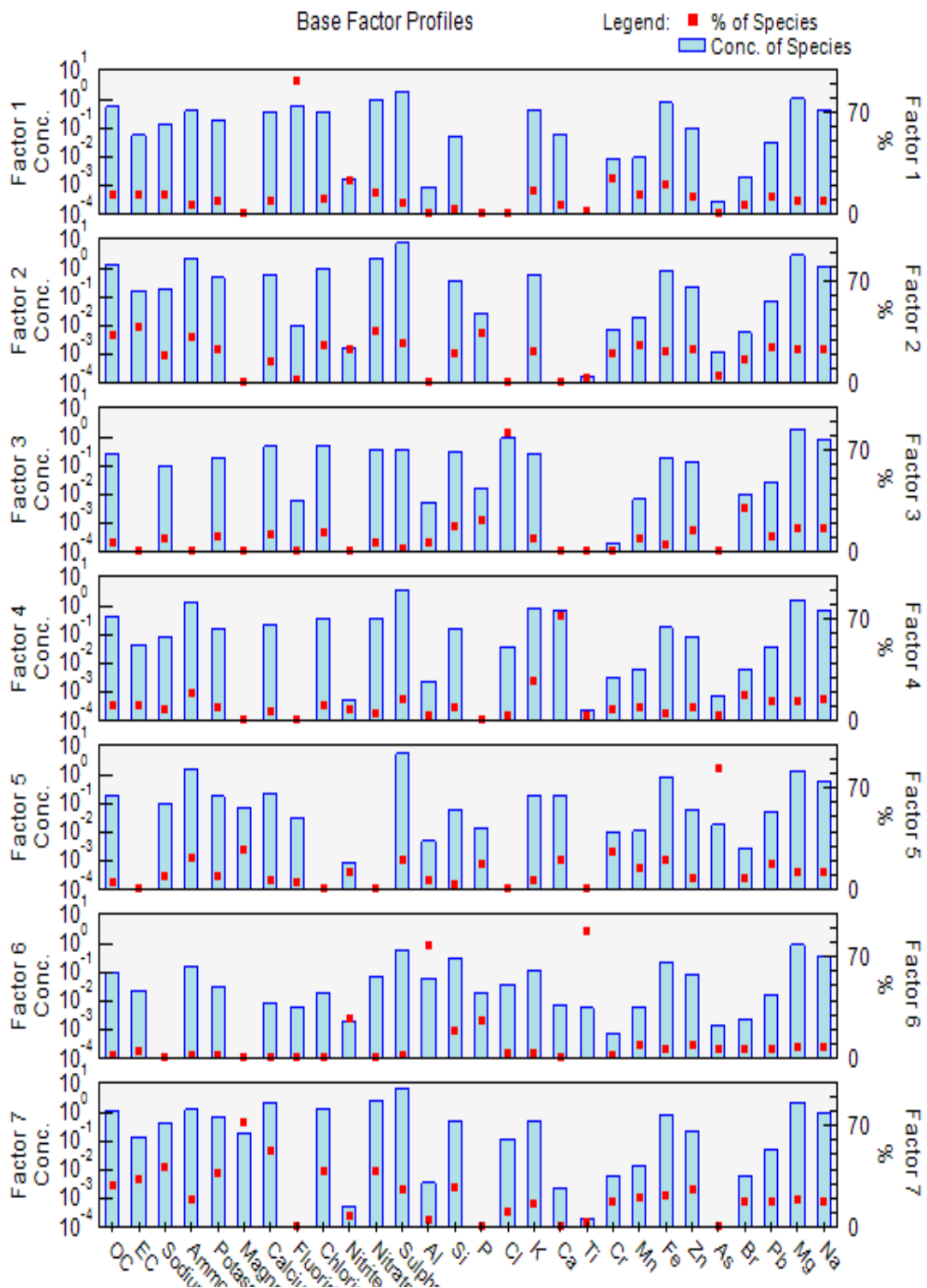


**Figure 4.2 a : PM<sub>10</sub> Base Factor Profiles**



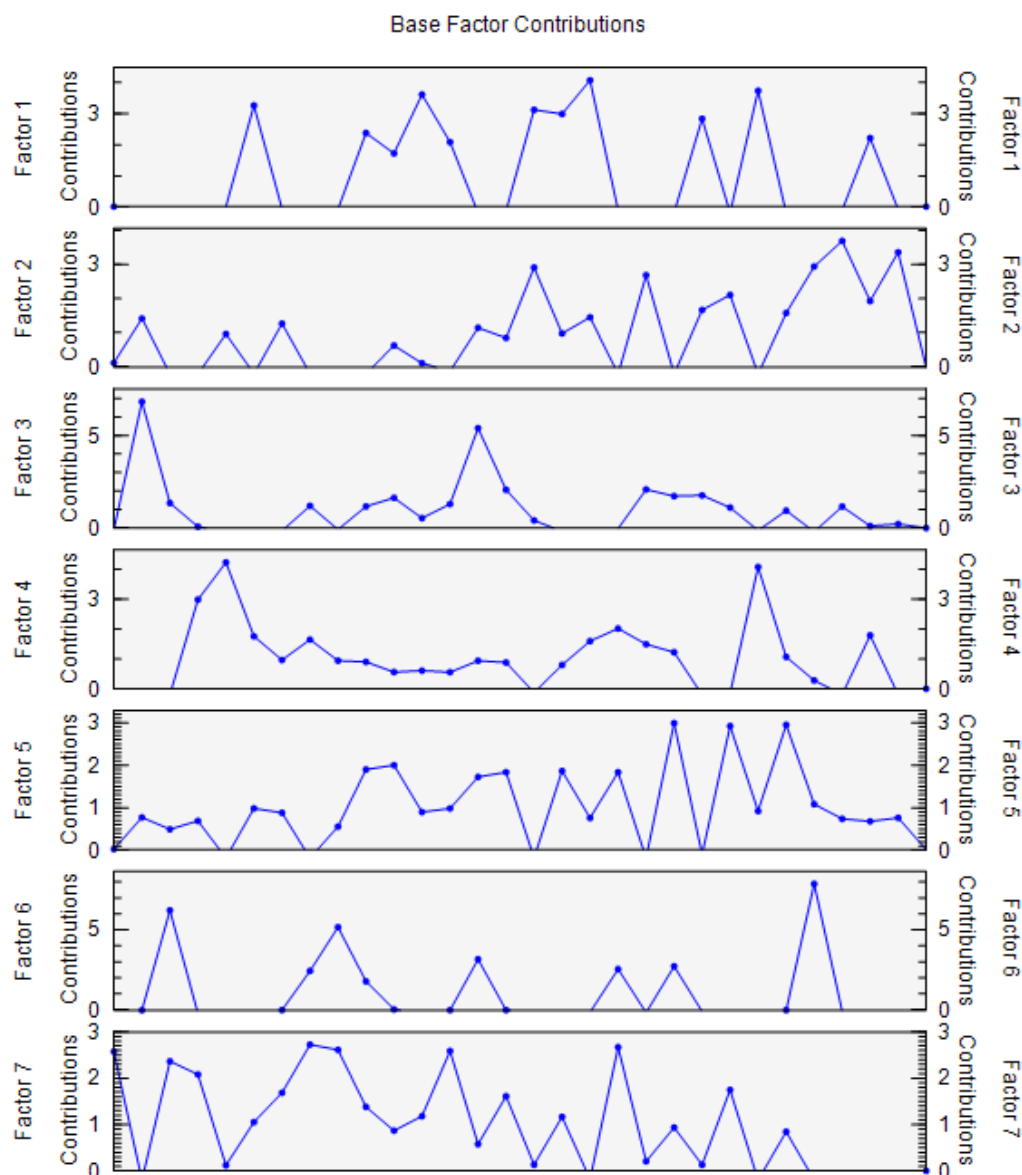
**Figure 4.2 b : PM<sub>10</sub> Base Factor Contributions**

	<b>Predominant factors</b>	<b>% Contribution</b>	<b>Factor Name</b>
Factor 1	Al, Ti, P, Si, Ca, Mg, K, NO <sub>3</sub> <sup>-</sup>	28.5	Resuspended of Road Dust/ Wind Blown Dust/ Construction Dust
Factor 2	As, Pb, EC, OC, F <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup> , S	12.8	Fossil Fuel Combustion
Factor 3	NO <sub>3</sub> <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup> , NH <sub>4</sub> <sup>+</sup> Cl <sup>-</sup> , Na <sup>+</sup> , OC	11.8	Secondary Aerosol /Marine Aerosol
Factor 4	As, Cr, Zn, Cl <sup>-</sup> , Fe, P, Mn, S	16.4	Industrial Emissions
Factor 5	Cl <sup>-</sup> , K <sup>+</sup> , EC, OC, NH <sub>4</sub> <sup>+</sup> , SO <sub>4</sub> <sup>2-</sup>	14.6	Biomass Burning
Factor 6	EC, OC, Fe, Mn, Zn, Pb	15.7	Vehicular Emission



**Figure 4.2 c : PM<sub>2.5</sub> Base Factor Profiles**





**Figure 4.2 d : PM<sub>2.5</sub> Base Factor Contributions**

	<b>Predominant Factors</b>	<b>% Contribution</b>	<b>Factor Name</b>
Factor 1	As, SO <sub>4</sub> <sup>2-</sup> , Fe, P, Pb, Mg, Mn, OC, Zn	13.2	Industrial Emissions
Factor 2	Ti, Si, Fe, Ca, Mg	11.5	Resuspended Road Dust/Wind Blown Dust
Factor 3	NO <sub>3</sub> <sup>-</sup> , NH <sub>4</sub> <sup>+</sup> , OC, EC, SO <sub>4</sub> <sup>2-</sup> , Mn, Pb, Zn, Fe	19.3	Vehicular Emission
Factor 4	Cl <sup>-</sup> , Br, Na <sup>+</sup> , Mg, K	10.7	Marine Aerosols
Factor 5	Cl <sup>-</sup> , NO <sub>3</sub> <sup>-</sup> , EC, OC, SO <sub>4</sub> <sup>2-</sup> , NH <sub>4</sub> <sup>+</sup>	21.9	Secondary Aerosols
Factor 6	Ca, K, Ti, Mg, Si, Al, Fe	11.1	Construction Dust
Factor 7	K, EC, OC, Cl <sup>-</sup> , Pb, Br, SO <sub>4</sub> <sup>2-</sup>	12.2	Fossil Fuel Combustion/ Biomass Burning

#### 4.5 Emission Inventory and Source Apportionment

Emission inventory is a comprehensive listing by sources of air pollutant emissions and amount of air pollutants released into air as a result of a specific process in a particular geographic region during a specific time period. Source apportionment (SA) is the technique which relates a source emission (an activity sector or an area) to the ambient air concentration of a pollutant.

**Industrial Source:** The entire industrial emission load is about 4417.6 kg/d, with the Red LSI group of industries accounting for 20.24 percent (4212.9 kg/d), or 96 percent of total industrial emissions, primarily due to fossil fuel combustion such as coal. The overall emission load from coal was the highest (94.7 percent, or 771 TPD), followed by FO at 3%. (362 TPD). LDO (152.6 TPD), HSD 1161.8 TPD, and Diesel (116.9 TPD) are some of the other fuels used, and they all contribute significantly to the total PM load from industry. The significant amount of particulate matter emission comes from coal and other fuels with a high ash content. Industrial gases containing sulphur dioxide, are primarily emitted from smelting and furnaces. unit Total SO<sub>x</sub> emissions are over 6.82 TPD, with 32.6 percent and 33.5 percent coming from FO (362 TPD) and HSD (1162 TPD), respectively. MSI and SSI Industries also use low-cost, readily available fuels like briquettes and wood, which adds to the overall emission burden from point sources. About 46% of HC is discharged through coal combustion, and 18.5 percent is emitted from the industries' 1161.8 Tonne per Day of HSD combustion.

The results are well corroborated with apportionment of particulate matter; the overall factor emphasizes industrial source contributions of 16.4 percent in PM<sub>10</sub> sample load, compared to 13.2 percent in PM<sub>2.5</sub> sample load. In PM<sub>10</sub>, Factor Profiles (% of species sum) of the significant indicators such as As, Cr, Zn, Cl<sup>-</sup>, Fe, P, Mn, and S was found in concentrations ranging from 17 to 54 %. In PM<sub>2.5</sub> the indicators of As, SO<sub>4</sub><sup>2-</sup>, Fe, P, Pb, Mg, Mn, OC and Zn are the dominant contributors in the range of 15 to 84%. The other Factor Profiles (% of species sum) of the minor indicators are Cd, Na<sup>+</sup>, V, Mg, Br, OC and Pb. Machinery, battery and electroplating industries emit Fe, Cr and Mn. Also, As, S Cd, Mn and Fe are the source of smelting and coal combustion industries. Cl<sup>-</sup>, Mg, SO<sub>4</sub><sup>2-</sup> and Br are indicators of industrial combustion, and Cl<sup>-</sup> and Cd are emitting from incinerator /furnaces.

Another factor, fossil fuel combustion contributes 12.8% and 12.2% of PM<sub>10</sub> and PM<sub>2.5</sub> emission load, respectively. The Factor Profiles (% of species sum) of the predominant species Br, As, Pb, EC, OC, F<sup>-</sup>, SO<sub>4</sub><sup>2-</sup> and S are in the range of (~12 to 54%) in PM<sub>10</sub>, whereas (~10 to 16%) of K, EC, OC, Cl<sup>-</sup>, Pb, Br and SO<sub>4</sub><sup>2-</sup> are the major species in PM<sub>2.5</sub>. The Factor Profiles (% of species sum) of the minor indicators are Cr, Fe, SO<sub>4</sub><sup>2-</sup>, Ca, and Fe. In studies reported, F<sup>-</sup>, Cl<sup>-</sup> and Fe along with SO<sub>4</sub><sup>2-</sup> have been widely used as a marker of coal combustion in industrial plants. The overall all trace

indicators and emission loads prominence the industrial fossil fuel burning is high in Navi Mumbai.

**Vehicular Source:** As per emission inventory the vehicular sector contributes around 3266.4 kg/d of PM to the total city load, the percent contribution from heavy duty vehicles is highest i.e. 12.79 (2663.8 kg/day). The Heavy duty diesel vehicles contribute around 81.55% (2663.8 Kg/d) of PM emission load, followed by 3 wheelers i.e., 12% (394.8 Kg/d) of the total load estimated. Traffic of heavy duty vehicles is observed (approximately 2148235 VKT) on industrial belt of Thane Belapur as well as to and fro movement of vehicle on Sion Panvel Highway. The emission load from 2 wheelers (88.90 Kg/d; i.e. 2.7%) is almost 10 times the emission load from Car operating on Petrol (9.48 Kg/d; i.e. 0.29%) and almost half of Car Diesel (55.3 Kg/d; i.e. 1.7%). The main source of NO<sub>x</sub> contribution is vehicular source i.e. 54.2% (30494.4 kg/d). 35.49% of NO<sub>x</sub> emission load is estimated from HDDV vehicles followed by 5717.4 kg/d (10.16%) from CNG Buses. 2 Wheelers, Car Diesel and Car CNG collectively and gives 6.42%.

The vehicular Factor Profiles (% of species sum) of the dominant species are EC, OC, Fe, Mn, Zn and Pb, ranging from 13 to 38% in PM<sub>10</sub> sample load, whereas NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup>, OC, EC, SO<sub>4</sub><sup>2-</sup>, Mn, Pb, Zn and Fe ranging from 22 to 38% was found in PM<sub>2.5</sub> sample load. The minor tracer indicators found are Mg, NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>3-</sup>, SO<sub>4</sub><sup>2-</sup>, Br and S. The overall source contribution of vehicular emission factor is around 15.7% and 19.3% in PM<sub>10</sub> and PM<sub>2.5</sub>, respectively. 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<sub>4</sub><sup>2-</sup> & 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.

The resuspended road dust and wind blowing dust contributes 28.5% from PM<sub>10</sub> and 11.5% in PM<sub>2.5</sub> sample load. The Factor Profiles (% of species sum) of the major indicators Al, Ti, P, Si, Ca, Mg, K and NO<sub>3</sub><sup>-</sup> were contributing around (26 to 56%) in PM<sub>10</sub>, whereas Ti, Si, Fe, Ca and Mg were in the range of around 6 to 89%. The minor trace indicators are Zn, SO<sub>4</sub><sup>2-</sup>, Na<sup>+</sup>, Mn and NO<sub>2</sub><sup>-</sup>. Al, Si and SO<sub>4</sub><sup>2-</sup> 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. The percent contribution of this source in overall city estimated emission load from unpaved road is observed to be 38.5% (8020.1 kg/d), while that from paved road is around 15.8% (3283.5 kg/d).

**Area Source:** The estimated emission of the city shows total area source contribution of around 1832 kg/day, amongst which emission from domestic sector is estimated to be 364 kg/d, 46.7 kg/d

from crematorium and 69.2 kg/d from bakeries.

As per the study, unorganized and illegal open eat outs uses 10 kg/d of coal and wood as a fuel source and contribute 9% to open eatouts. Total 285 kg/day of PM load is released from open burning of waste in wards limits of NMMC and landfill site.

As per the PMF matrix factorization, biomass burning/ wood combustion and as well minor contribution of waste burning and construction/crustal/soil dust are the prominent sources. The biomass burning factor, accounted for 14.6% in PM<sub>10</sub> sample load. Factor Profiles (% of species sum) of the Major tracers are Cl<sup>-</sup>, K<sup>+</sup>, EC, OC, NH<sub>4</sub><sup>+</sup> and SO<sub>4</sub><sup>2-</sup> which accounts for around 18 to 33% of the total load. The minor indicators are Fe, Mg, and Na<sup>+</sup>. The past studies suggesting that OC, K<sup>+</sup> and SO<sub>4</sub><sup>2-</sup> are clear indicator of biomass burning and NH<sub>4</sub><sup>3-</sup> is an indicator of Wood Combustion. The construction dust tracer of contributes 11.1% in PM<sub>2.5</sub> the major indicators are Ca, K, Ti, Mg, Si, Al and Fe ranging around 9 to 72%. As per previous studies Ca, K and Mg are the major indicators of crustal and soil dust.

As per characterization, secondary and marine aerosols factor are mixed source which accounted for 11.8% of total PM<sub>10</sub> sample load. Whereas, secondary aerosol factor is 21.9% and marine aerosol factor is 10.7% in PM<sub>2.5</sub>, are separate factors. The Factor Profiles (% of species sum) of the traces viz. NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, NH<sub>4</sub><sup>+</sup> are contributing around 29 to 47% and Cl<sup>-</sup>, Na<sup>+</sup>, OC ranges from 14 to 22% in PM<sub>10</sub>. The markers in PM<sub>2.5</sub> are Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, EC, OC, SO<sub>4</sub><sup>2-</sup>, and NH<sub>4</sub><sup>+</sup> which are in the range of 18 to 38% for secondary aerosol. The different studies indicated that NH<sub>4</sub><sup>3-</sup>, NO<sub>3</sub><sup>2-</sup> and SO<sub>4</sub><sup>2-</sup> are major species of secondary aerosols and Na<sup>+</sup> and Cl<sup>-</sup> are indicators of Marine source. As Navi Mumbai is located in the vicinity of coastal city, Mumbai and also has creek in its surrounding, the impact of Marine and secondary aerosols are found as definite background source.

#### 4.6 Past Studies for Source Apportionment

- *Source Apportionment of Coarse and Fine Particulate Matter at Navi Mumbai, India*  
Kothai et al., *Aerosol and Air Quality Research* 8(4):423-436, DOI:10.4209/aaqr.2008.07.0027

Atmospheric particulate matter in two size fractions 2.5-10 µm and ≤ 2.5 µm were collected on nuclepore polycarbonate filter papers and were analysed for elements using NAA and EDXRF. Varimax rotated factor analysis identified five major sources contributing to coarse and fine particulate mass. FA-MLR technique is applied to apportion the sources. Source apportionment studies showed maximum contribution of the coarse fraction was from sea salt (35%) and crustal (25%) sources. A considerable amount of the mass was also contributed from industrial (14%), vehicular (10%) and fugitive emissions (7%). These results also showed the percentage contribution of soil, two-stroke emission with fugitive dust, industrial emission, motor vehicles and sea salt to the

average fine mass concentration was 3%, 18%, 23%, 29% and 9%, respectively. The contribution of each source to their constituent elements also has been determined using the same technique.

- *Chemical Characterization and Source Identification of Particulate Matter at an Urban Site of Navi Mumbai, India. Kothai et al., Aerosol and Air Quality Research, 11: 560–569, 2011*

Particulate matter samples were collected using a dichotomous sampler at a residential area of Vashi situated in Navi Mumbai, India during the period of 2008. The sampler facilitates the simultaneous collection of atmospheric particulates in coarse and fine size fractions. The filter samples collected were analysed for trace elements using Proton Induced X-ray Emission (PIXE) technique. The particulate matter trends show higher concentration during winter season compared to other seasons. High concentrations of elements related to soil and sea salt were found in the coarse fraction of particulate matter. Enrichment Factor (EF) analysis with respect to Fe showed enrichment of Cu, Cr, and Mn only in the fine fraction suggesting their origin from anthropogenic sources. The EF value was observed to be maximum for As, Pb and Zn in the fine particulates. However, crustal and marine derived elements showed very low EF values indicating their origin from soil and sea salt respectively. The Principal Component Analysis (PCA) based multivariate studies identified soil, sea salt and combustion as common sources for coarse and fine particles. Additionally a source contributing to coarse fraction Br concentration as well as an industrial and Se source contributing to fine fraction particles has been identified.

In our study Positive matrix factorization (PMF) is a receptor modeling tool was used for identification and quantification of sources and their apportionment of atmospheric particulate matter. After PMF analysis seven factors were identified contributing to both PM<sub>2.5</sub> and PM<sub>10</sub> pollution. The contribution of vehicular pollution (19%) & Marine Aerosols (22%) are dominated in PM<sub>2.5</sub> size range, followed by Industrial and fossil Fuel combustion emissions (12 to 13%), Resuspended Road dust and biomass burning is 11%. As the case of PM<sub>10</sub>, Resuspension of road and windblown dust (22%) and Industrial emissions (17%) contributing dominate source. Vehicular sector and marine aerosol contribute around 12 to 13% each. Biomass wood combustion is around 16% and incinerator and fossil fuel gives 9-10% contribution.

There are limited numbers studies reported for emission inventory and source apportionment for Navi Mumbai city. The prominent sources identified are resuspension dust crustal elements, fossil fuel combustion, industrial and vehicular emission and marine aerosols, wherein increasing contribution of emission load from anthropogenic source is further deteriorating AQI of the city.

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#### URL

- URL 1: EPA PMF v5.0 Software link: <https://www.epa.gov/air-research/positive-matrix-factorization-model-environmental-data-analyses>
- URL 2: DRI EC-OC Manual : [https://www.epa.gov/sites/production/files/2018-10/documents/csn\\_improvea\\_model2015\\_2-231r0\\_053118\\_508comp-dri.pdf](https://www.epa.gov/sites/production/files/2018-10/documents/csn_improvea_model2015_2-231r0_053118_508comp-dri.pdf)
- URL 3 : US EPA Speciates : <https://www.epa.gov/air-emissions-modeling/speciate-0>



## **Dispersion Modelling**

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 NO<sub>x</sub>. 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) is 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<sub>2</sub>, NO<sub>x</sub> and PM<sub>10</sub>. 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 Navi Mumbai 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).

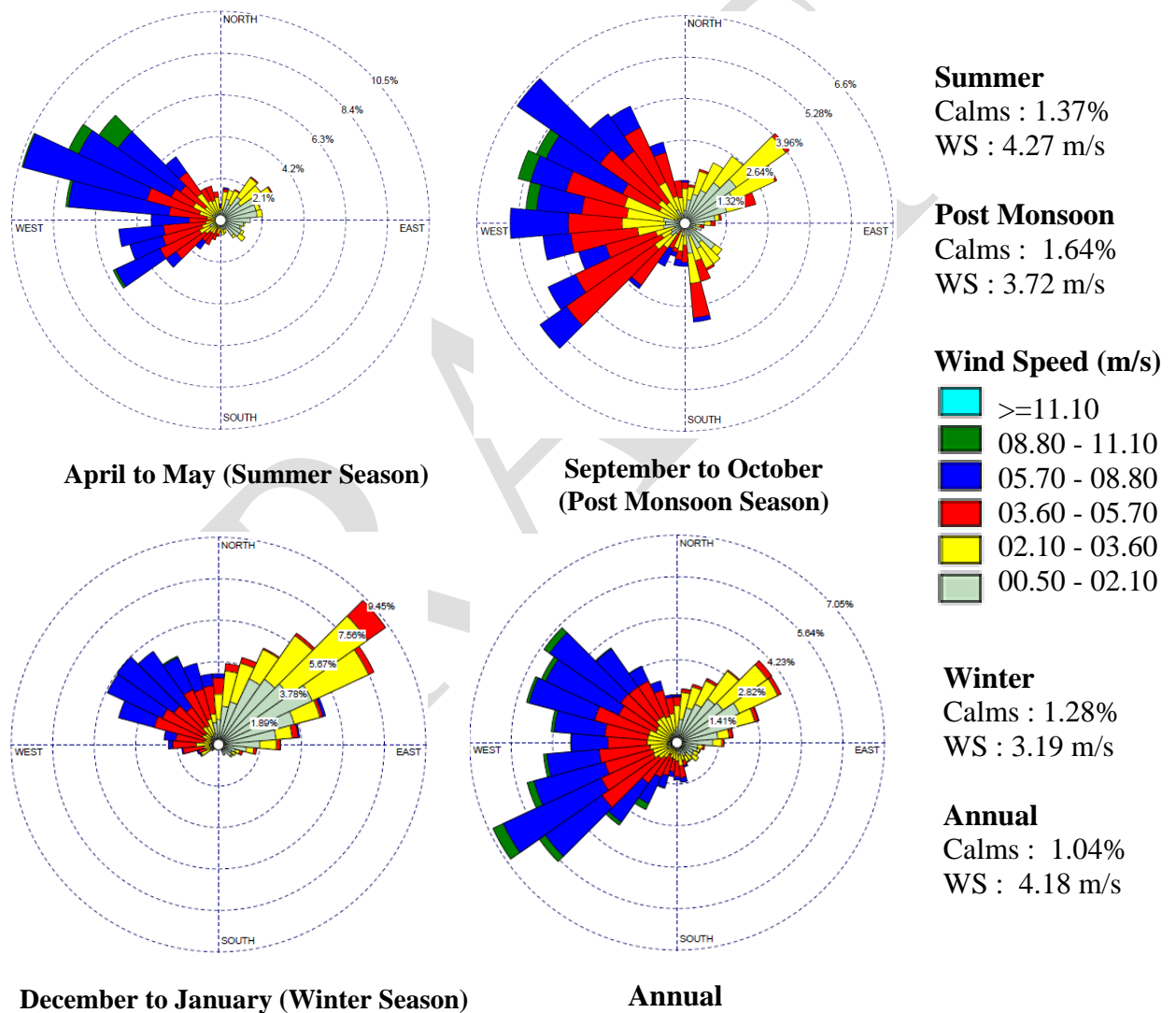
**Weather Research and Forecasting Model (WRF)** was developed as an evolutionary successor to the MM5 model and incorporates current state-of-the-science atmospheric physics improvements. WRF use 1 Km by 1 Km gridded land use to estimate surface properties (surface boundary conditions). It also uses 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 Navi Mumbai city. The Albedo, Bowen ratio and Surface roughness length were set to default, as 0.2075, 1.625 and 1 respectively. Wind roses of December to January (winter season) and March to April (summer season) of Mumbai are presented in **Figure 5.1**.



**Figure 5.1 : Wind Rose of the Winter and Summer for the Study Area (Navi Mumbai)**

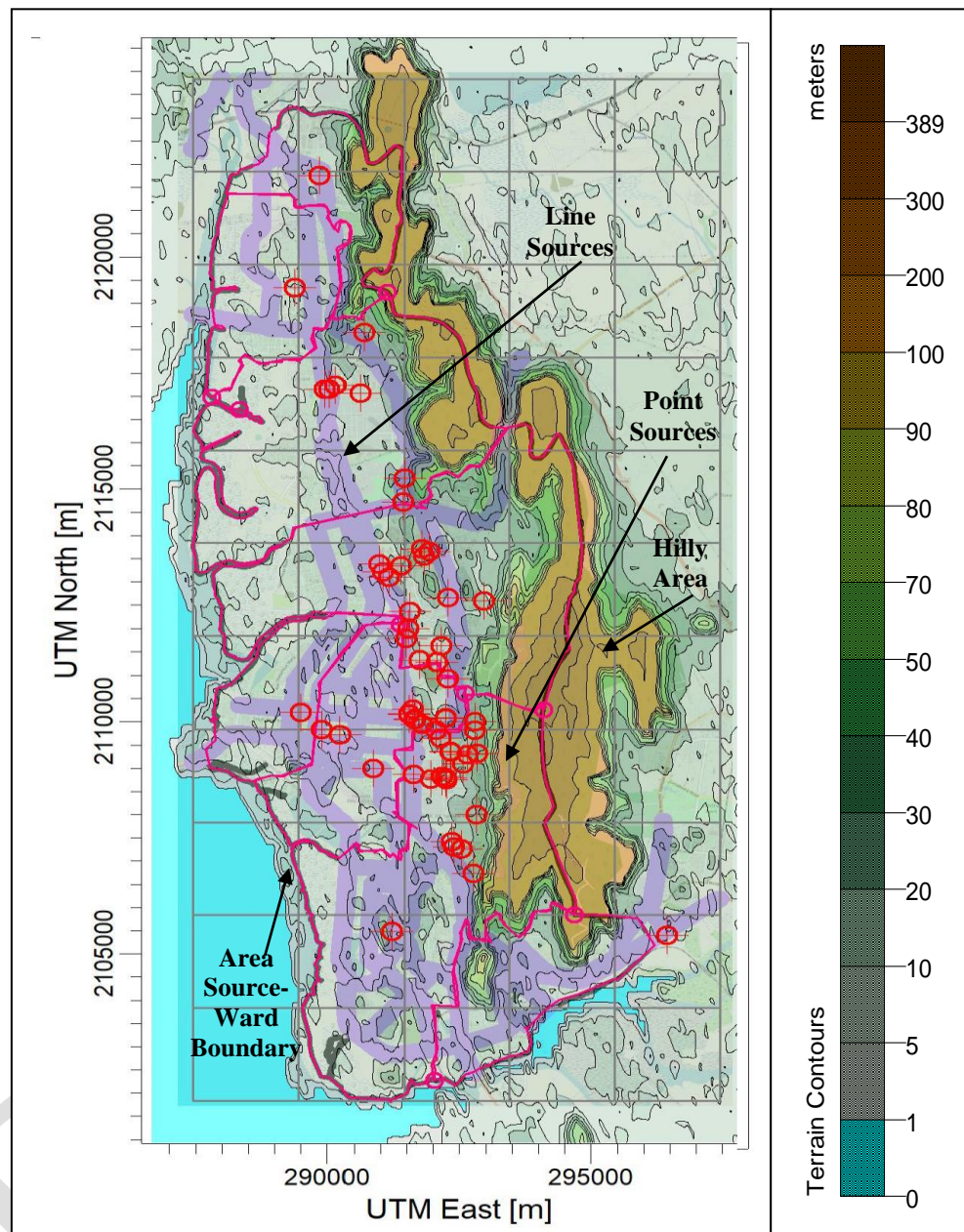
Annual windrose shows, the predominant direction is from WSW (7%), WNW (5%); in WSW direction wind speed mostly is in the range 5.7 to 8.0 m/s or less. In WNW direction predominant wind speed is in the range of 2.1 to 3.6 m/s. Calm condition is around 1.04%. Average wind speed is 4.18 m/s. During December to January (winter season) the predominant directions are blowing from NE (9.5%), N (3.7%) or less and WNW (5.67%). The predominant wind speeds are 2.1 to 3.6 m/s in NE direction, whereas N is 3.6 to 5.7 m/s and in WNW direction shows, it is around 5.7 to 8.8 m/s or less. Calm condition is around 1.28%. Average wind speed is 3.19 m/s. During Post Monsoon the predominant wind directions are blowing mostly from WNW, W and WSW, the wind speed is moving from 3.6 to 5.7 m/s. Average wind speed is 3.72 m/s and calm condition is 1.64%. In Summer seasons the predominant wind directions are blowing from WNW towards W and some part inclined towards WSW, the wind speed moves around 5.7- 8.8 m/s. Average wind speed is 4.27 m/s and calm condition is 1.37%.

### 5.3 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 and Table 5.1**. 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 both discrete receptors and receptor grids are computed by the terrain pre-processor.

**Table 5.1 : Summary of Type and Number of Sources**

Emission Source	Modelled Source Type	Number of Sources
Area sources	Area sources includes bakery, crematoria, building construction, hotels & Restaurants, domestic sector, open burning, open eatouts	8 Navi Mumbai Municipal Wards
Vehicles	Line Volume (Major & Arterial Roads, connecting State & National Highways)	72 Roads
Major Industries with stack heights more than 10m	Point	97 Stacks
Industries which include Medium and small scale industries with less than 15m stacks	Area (MSI 8 and SSI 8)	16 Ind
Road dust	Line Volume on each road	72 Roads



**Figure 5.2 : AERMAP Digital Elevation Model (DEM) Data for Navi Mumbai**

SRTM3- Shuttle Radar Topography Mission (SRTM) 3 with resolution of 90 m was used as Terrain Data for running the model. A uniform Cartesian grid receptor covering 22 (h) x 10 (w) Km<sup>2</sup> of the study areas 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.

## 5.4 Model Simulations

The modelling exercise was carried out for PM<sub>10</sub> and NO<sub>x</sub> 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 earlier, the future estimation were worked out.

### 5.4.1 Model Performance for PM

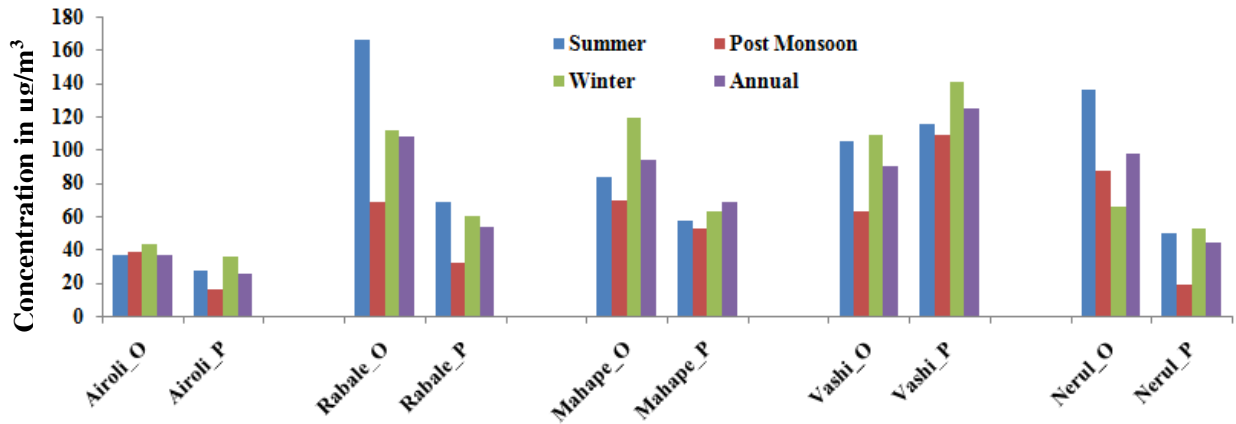
**Table 5.2** shows the average PM<sub>10</sub> concentration observed at 5 monitoring locations, which was observed in the range of 43 to 119 µg/m<sup>3</sup> during winter season, averaging to about 89 µg/m<sup>3</sup>. The predicted dispersion concentrations at these sites ranged from 35 to 140 µg/m<sup>3</sup>. Likewise, during the summer season the average concentrations observed at monitoring sites was about 105 µg/m<sup>3</sup>. The predicted average PM<sub>10</sub> concentrations at these sites during summer ranged from 26 to 115 µg/m<sup>3</sup>. Whereas in post monsoon season, concentrations varied between 38 to 87 µg/m<sup>3</sup>; with an average of about 65 µg/m<sup>3</sup>. The predicted concentrations at these sites ranged from 15 to 108 µg/m<sup>3</sup>. The annual concentration differs from 36 to 107 µg/m<sup>3</sup> for observed, whereas it is 24 to 124 µg/m<sup>3</sup> 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 0.2 to 1.7. All the predicted values were lying within FAC2. Variations in are presented in **Figure 5.3**.

**Table 5.2 : Seasonal PM<sub>10</sub> Average Concentrations (µg/m<sup>3</sup>) of the 24 Hourly Model Simulations**

	Observed Concentration (µg/m <sup>3</sup> ) #				Predicted Concentration (µg/m <sup>3</sup> )			
	Summer	Post Monsoon	Winter	Annual	Summer	Post Monsoon	Winter	Annual
Airoli	36.2	38.5	43.3	36.4	26.9	15.6	35.8	24.9
Rabale	165.5	68.5	111.4	107.8	68.2	32.3	60.4	53.6
Mahape	83.5	69.5	119.2	93.5	56.9	52.4	62.8	68.2
Vashi	105.4	62.5	109.1	89.8	115.2	108.6	140.9	124.6
Nerul	136.4	87.5	65.5	97.3	49.7	18.3	52.6	43.8
Ratio of Predicted to Observed Concentration								
Airoli	0.7	0.4	0.8	0.7				
Rabale	0.4	0.5	0.5	0.5				
Mahape	0.7	0.8	0.5	0.7				
Vashi	1.1	1.7	1.3	1.4				
Nerul	0.4	0.2	0.8	0.5				

Sum – Summer, PostMon- Post Monsoon, Win – Winter, Ann - Annual

# Observed Concentration (Air Quality Status of Maharashtra 2018-19, MPCB)



**Figure 5.3 : Observed and Predicted Concentration for All Seasons (PM - µg/m<sup>3</sup>)**

From modeling results discrete cartesian location were identified based on pollution control sampling points, and the difference where match for observed and predicted concentrations. It has been observed that less prediction is reflected at Rabale and Nerul sites in all seasons, whereas over prediction indicated in Vashi Site. The Mahape site also reflects little less prediction, impact is observed in summer season, whereas Airoli near to observed and predicted, except post monsoon. The less prediction in all seasons shows the meteorological effect i.e. the wind speed is almost 3.7 to 4.2 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.

#### 5.4.2 Existing Scenario Concentration Contours for PM<sub>10</sub>

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 depicted Annexure 2 and ground level concentration of 10<sup>th</sup> concentrations is presented in Annexure 3.

**Table 5.3 : Predicted PM Concentrations for Different Source Group for Navi Mumbai City**

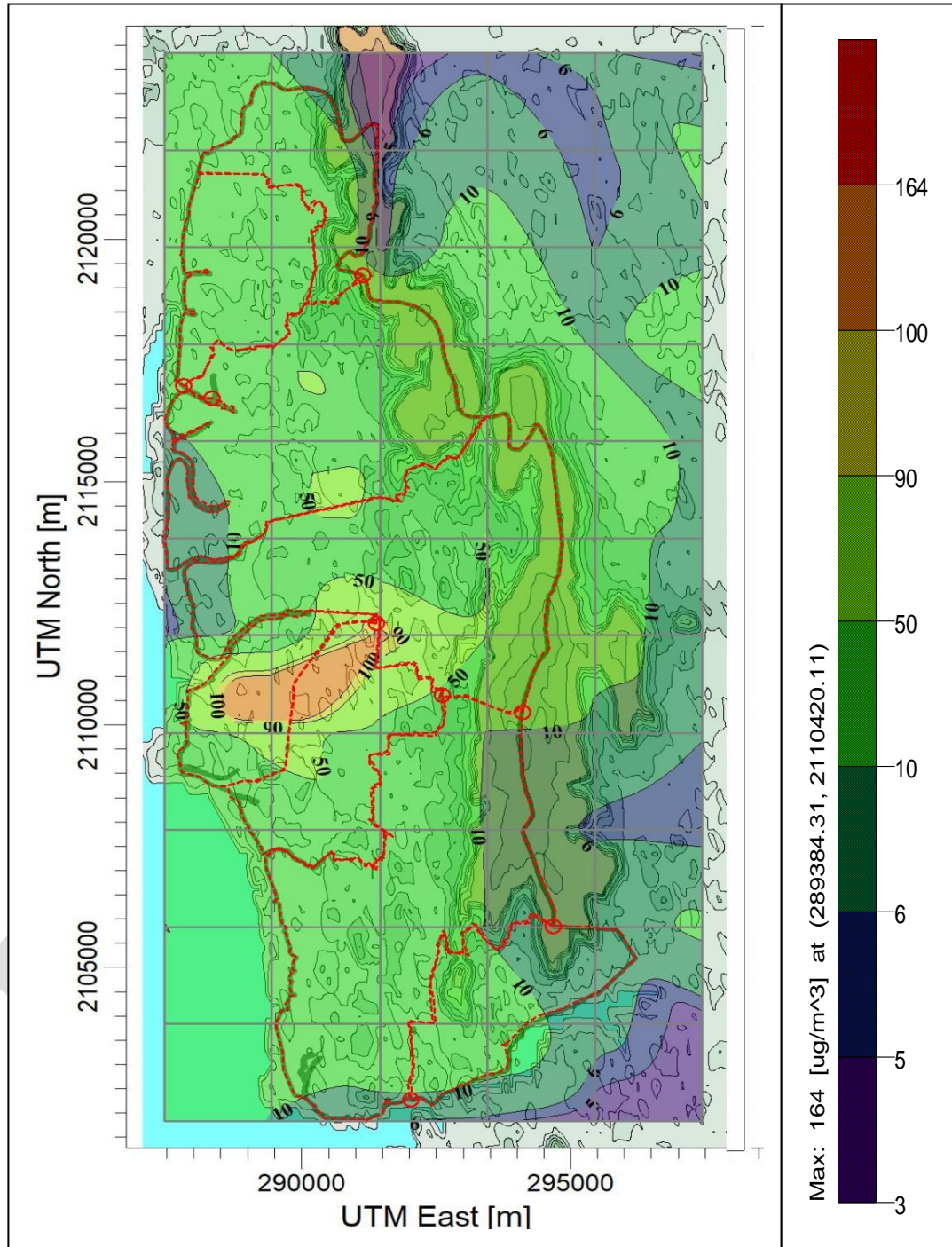
Sources Group	Summer	Post Monsoon	Winter	Annual
All Group	164.2	133.4	236.1	182.4
Area Source	5.3	4.8	6.5	5.7
Line Source	18.7	17.1	23.2	20.4
Point Source (LSI)	48.5	57.6	166.2	65.2
Point Source (MSI)	0.270	0.225	0.304	0.275
Point Source (SSI)	1.11	0.951	1.56	1.16
Resuspension Dust	136.3	124.2	168.1	148.3

- Concentrations in µg/m<sup>3</sup>

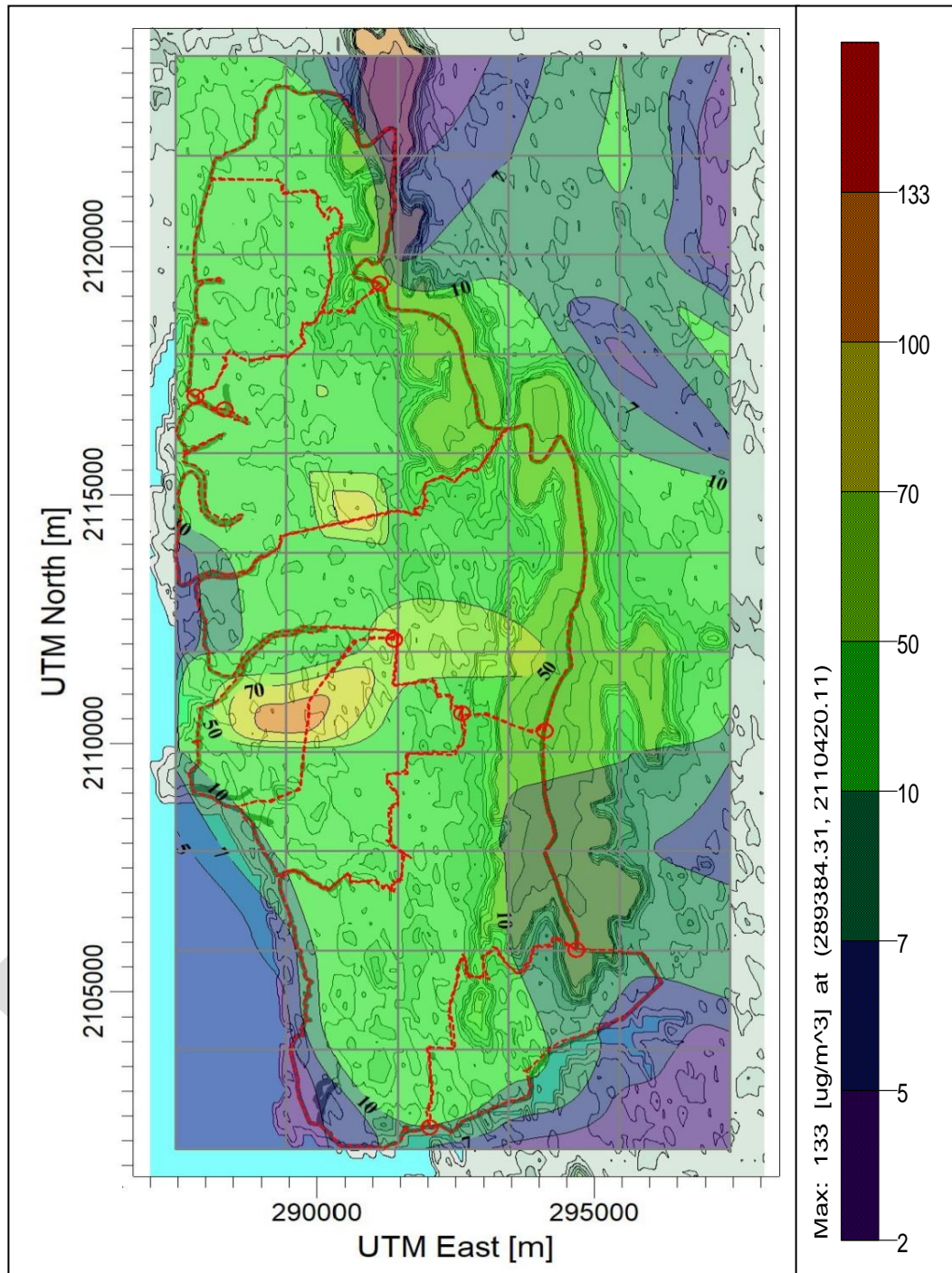


## Observations

- The average annual concentration of dispersed PM emission load from all the sources exceeds the CPCB standard, which is also observed in summer and further deteriorates in winter.
- The maximum 24 hourly predicted concentration from all the sources in winter was around 236  $\mu\text{g}/\text{m}^3$ . Whereas, the predicted concentration due to re-suspended dust is 168  $\mu\text{g}/\text{m}^3$  and Tailpipe emission from Vehicles is 23.2  $\mu\text{g}/\text{m}^3$ . The pockets of high concentration are observed close to major traffic junctions in central part of the city i.e near Vashi and Pawane area, where major interlinkages or roads viz. Thane Belapur and Sion Panvel Highway exist. Due to APMC market and industrial connectivity, approx 2148235 VKT movement was observed for Heavy Duty Vehicles. Amongst the total emission of PM from vehicular sector, 25.67% of emissions are from Ward C-Vashi, contributing 838.4 Kg/day of PM. The Heavy Duty vehicles contribute 12.8% of the total PM load. Due to heavy vehicular movements, resuspension of dust is also higher. The Annual average PM from dispersion of emission load from all the sources is around 182  $\mu\text{g}/\text{m}^3$ , and in summer and post monsoon the concentration ranges between 133 to 164  $\mu\text{g}/\text{m}^3$ .
- The maximum 24 hourly predicted dispersed concentration due to area sources was 6.51  $\mu\text{g}/\text{m}^3$  in winter season. The overall impact of areas source is due to domestic cooking and DG sets (commercial/industrial), which are almost similar in all the wards. Building construction is also one of the prominent sources, contributing around 4.1% of the total emission of PM.
- Industries are located mainly at Thane Belapur Road, MIDC area, Mahape, Rabale, and Pawane. The annual maximum 24 hourly predicted concentration due to industries is 65.2  $\mu\text{g}/\text{m}^3$ , which is highest in winter i.e. 166  $\mu\text{g}/\text{m}^3$ , and moves around 48 to 57  $\mu\text{g}/\text{m}^3$  in summer and post monsoon for LSI category of industries. Red LSI contributes 20% to the total PM emission load (ie. 4212.9 Kg/d).
- The resuspension of dust is major issue in the study area, the overall concentrations was in the range of 124 to 168  $\mu\text{g}/\text{m}^3$  for all seasons. The resuspension of dust from unpaved road contributes around 38.5% and that from paved road is around 15.8% to the total estimated PM load in the city.

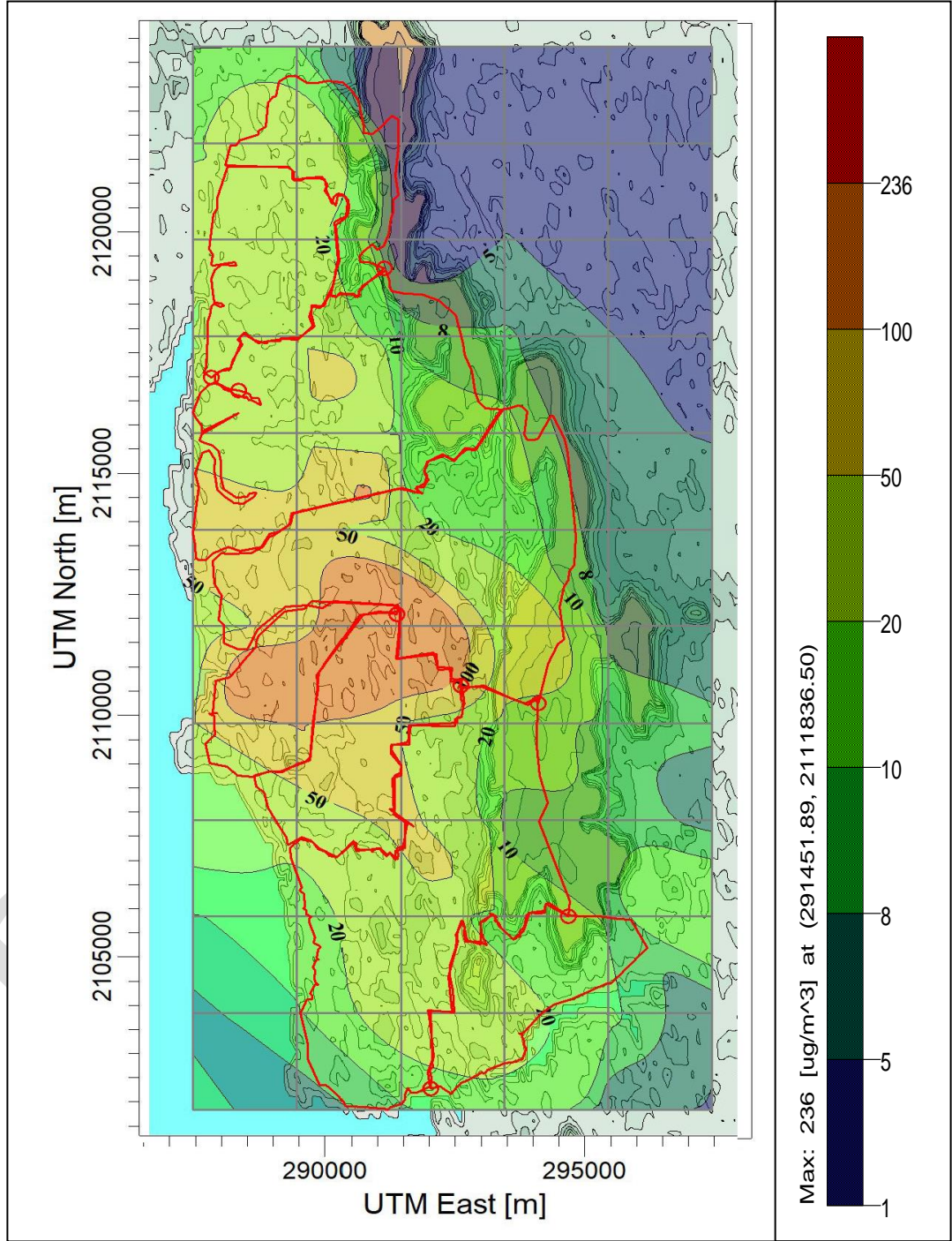


**Figure 5.4 : Isopleths of PM Due to All Source– Summer Season (Navi Mumbai City)**

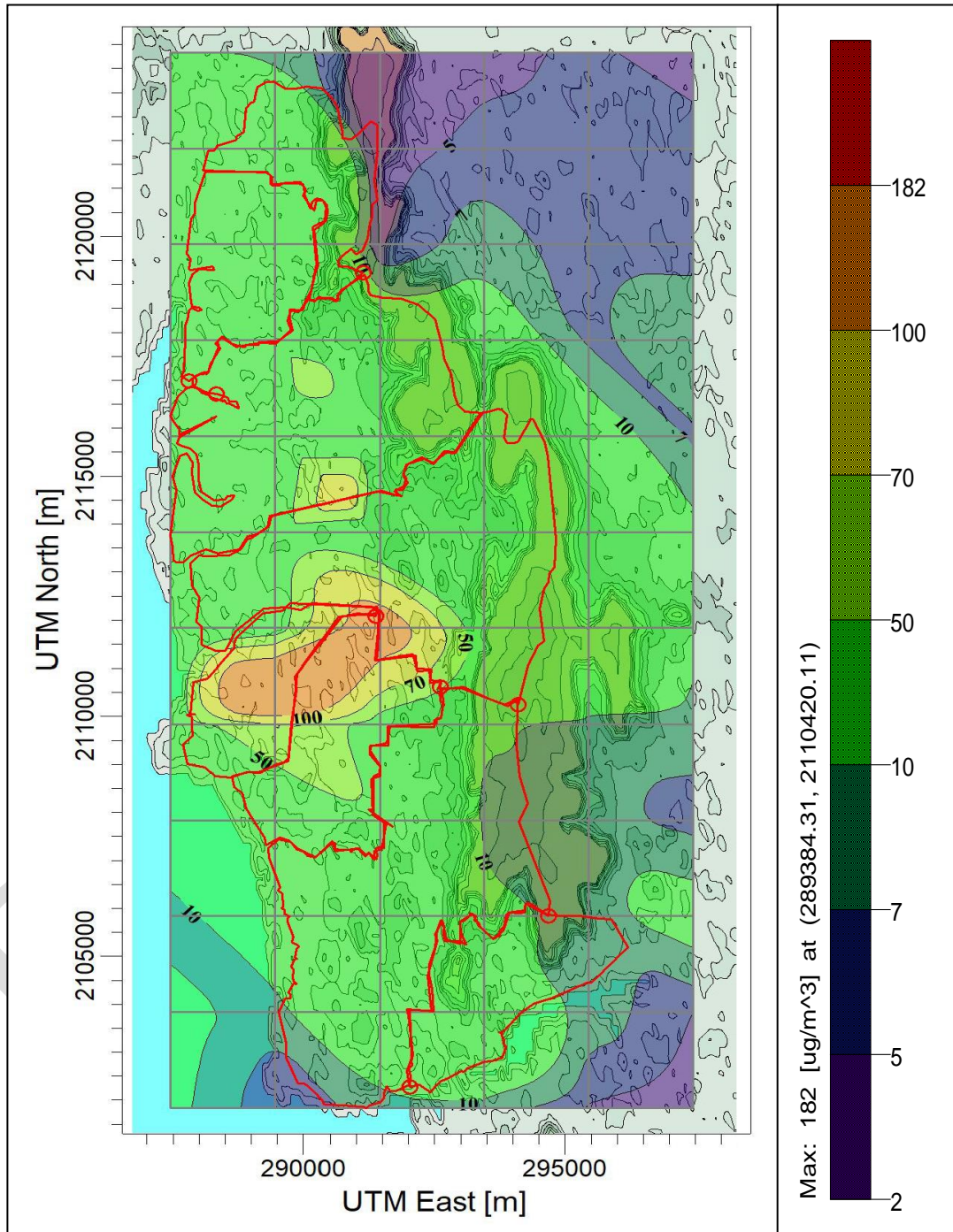


**Figure 5.5 : Isopleths of PM Due to All Source– Post Monsoon Season (Navi Mumbai City)**





**Figure 5.6 : Isopleths of PM Due to All Source– Winter Season (Navi Mumbai City)**



**Figure 5.7 : Isopleths of PM Due to All Source– Annual (Navi Mumbai City)**

### 5.4.3 Model Performance for NOx

As for PM<sub>10</sub>, the modelling exercise was also carried out for NOx for all seasons. **Table 5.4** shows the average NOx concentration observed at 5 monitoring locations which were in the range of 31 to 55 µg/m<sup>3</sup> during the winter season, with an average of about 42 µg/m<sup>3</sup>. The predicted dispersion concentrations at these sites were in the range of 42 to 59 µg/m<sup>3</sup>. Likewise during the summer season, the average concentrations observed at monitoring sites ranged from 45 to 58 µg/m<sup>3</sup> with an average of about 51 µg/m<sup>3</sup>. The predicted average NOx dispersion concentrations at these sites during summer ranged from 20 to 54 µg/m<sup>3</sup>; whereas, in post monsoon season concentrations varied between 34 to 47 µg/m<sup>3</sup>, with an average of about 42 µg/m<sup>3</sup>. The predicted dispersion concentrations at these sites ranged from 26 to 54 µg/m<sup>3</sup>. The annual concentration differs from 41 to 45 µg/m<sup>3</sup> (averaging about 43 µg/m<sup>3</sup>) for observed concentration, whereas, it is 38 to 58 µg/m<sup>3</sup> (with an average of about 51 µg/m<sup>3</sup>) for predicted values. 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 0.5 to 1.8. All the predicted values were lying within FAC2. Variations in are presented in **Figure 5.8**.

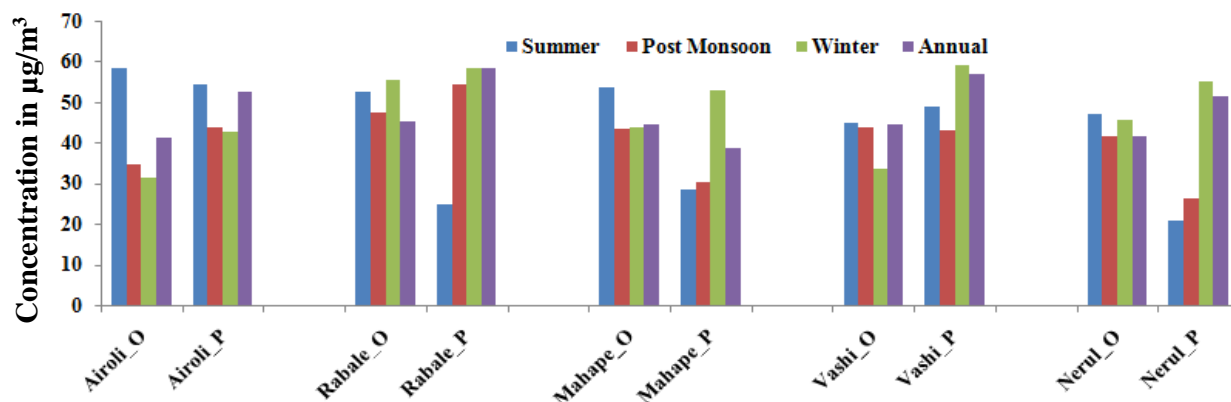
**Table 5.4 : Seasonal NOx Average Concentrations (µg/m<sup>3</sup>) of the 24 Hourly Model Simulations**

	Observed Concentration (µg/m <sup>3</sup> ) #				Predicted Concentration (µg/m <sup>3</sup> )			
	Summer	Post Monsoon	Winter	Annual	Summer	Post Monsoon	Winter	Annual
Airoli	58.2	34.7	31.2	41.2	54.2	43.7	42.5	52.6
Rabale	52.4	47.5	55.5	45.1	24.8	54.2	58.4	58.4
Mahape	53.5	43.5	43.7	44.6	28.4	30.4	52.7	38.6
Vashi	45.0	43.8	33.7	44.6	48.7	43.1	59.2	56.9
Nerul	47.1	41.5	45.5	41.4	20.6	26.4	55.1	51.4
Ratio of Predicted to Observed Concentration								
Airoli	0.9	1.3	1.4	1.3				
Rabale	0.5	1.1	1.1	1.3				
Mahape	0.5	0.7	1.2	0.9				
Vashi	1.1	1.0	1.8	1.3				
Nerul	0.4	0.6	1.2	1.2				

*Sum –Summer, PostMon- Post Monsoon, Win –Winter, Ann - Annual*

*# Observed Concentration (Air Quality Status of Maharashtra 2018-19, MPCB)*

From modeling results discrete cartesian location where identified based on pollution control sampling points, and the difference where match for observed and predicted concentrations. It has been observed that annual over prediction is noticed at all the sites except Mahape.



**Figure 5.8 : Observed and Predicted Concentration for All Seasons (NOx - µg/m³)**

For summer season, the ratio at Airoli and Vashi is similar, predicted concentration was nearer to observed, whereas for Rabale, Mahape and Nerul it is under predicted. The values in winter are over predicted at all the sites except Rabale. In post monsoon season, Vashi is similar and Airoli and Rabale are over predicted Mahape. The values at Nerul are less predicted for NOx concentrations. The percentage vehicular share and industrial emission load resulted in higher prediction of NOx as well as the local /regional impact as a source. The less prediction reflect due to meteorological effect i.e. the wind speed is almost 3.7 to 4.2 m/s over a period. The 24 hourly concentrations get's dispersed due to wind speed. The Vashi intersection (vehicular and industrial) area and Rabale industrial area are the most influential area.

#### 5.4.4 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 4 and ground level concentration of 10<sup>th</sup> concentrations is presented in Annexure 5.

**Table 5.5 : Predicted NOx Concentrations for Different Source Group for Navi Mumbai**

Sources Group	Summer	Post Monsoon	Winter	Annual
All Group	182.3	178.2	269.6	206.2
Area Source	16.6	16.4	23.0	18.5
Line Source	153.2	150.1	212.1	169.0
Point Source (LSI)	37.8	38.8	153.2	91.3
Point Source (MSI)	2.1	2.1	3.3	2.2
Point Source (SSI)	7.1	6.8	9.8	7.8

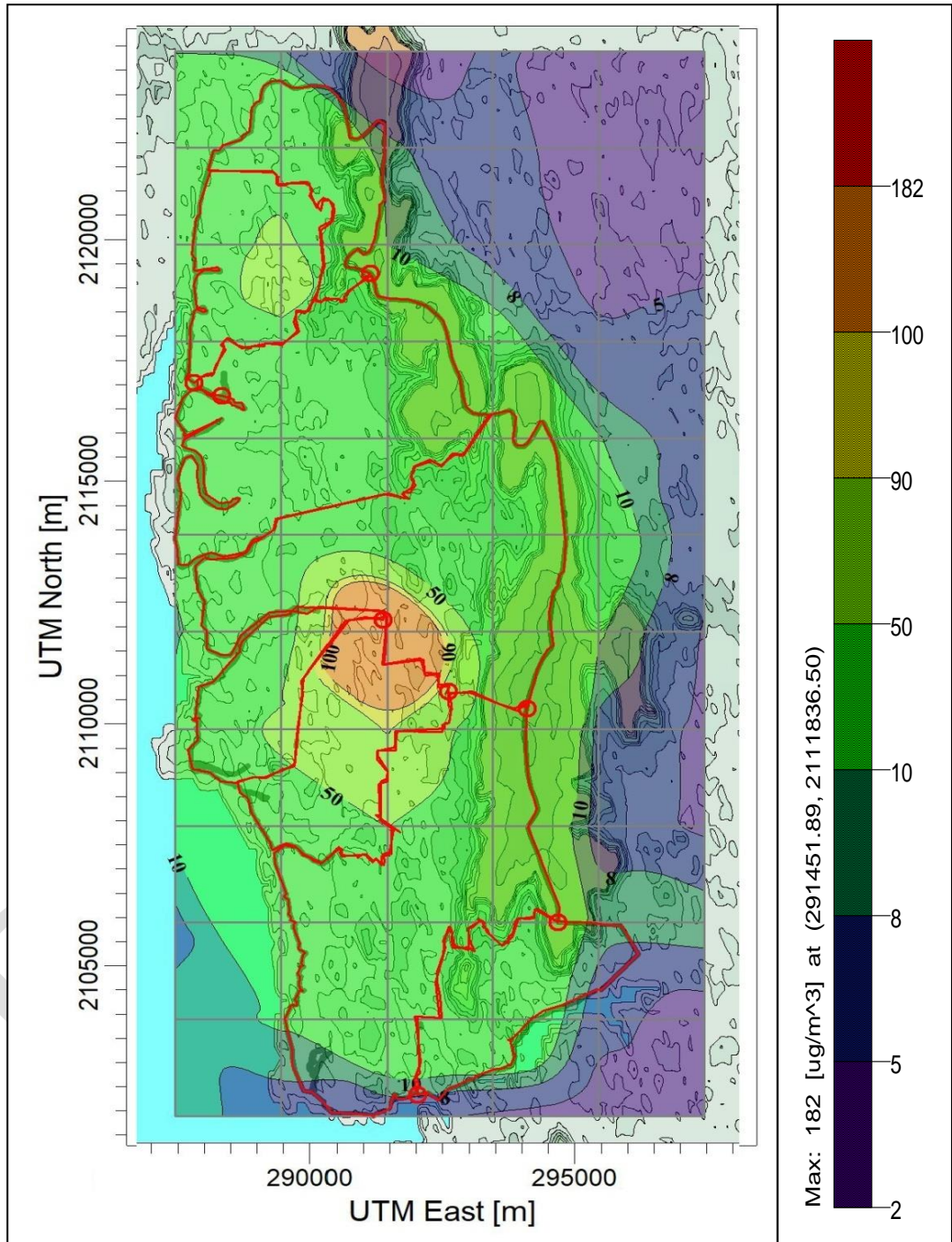
- Concentrations in µg/m<sup>3</sup>



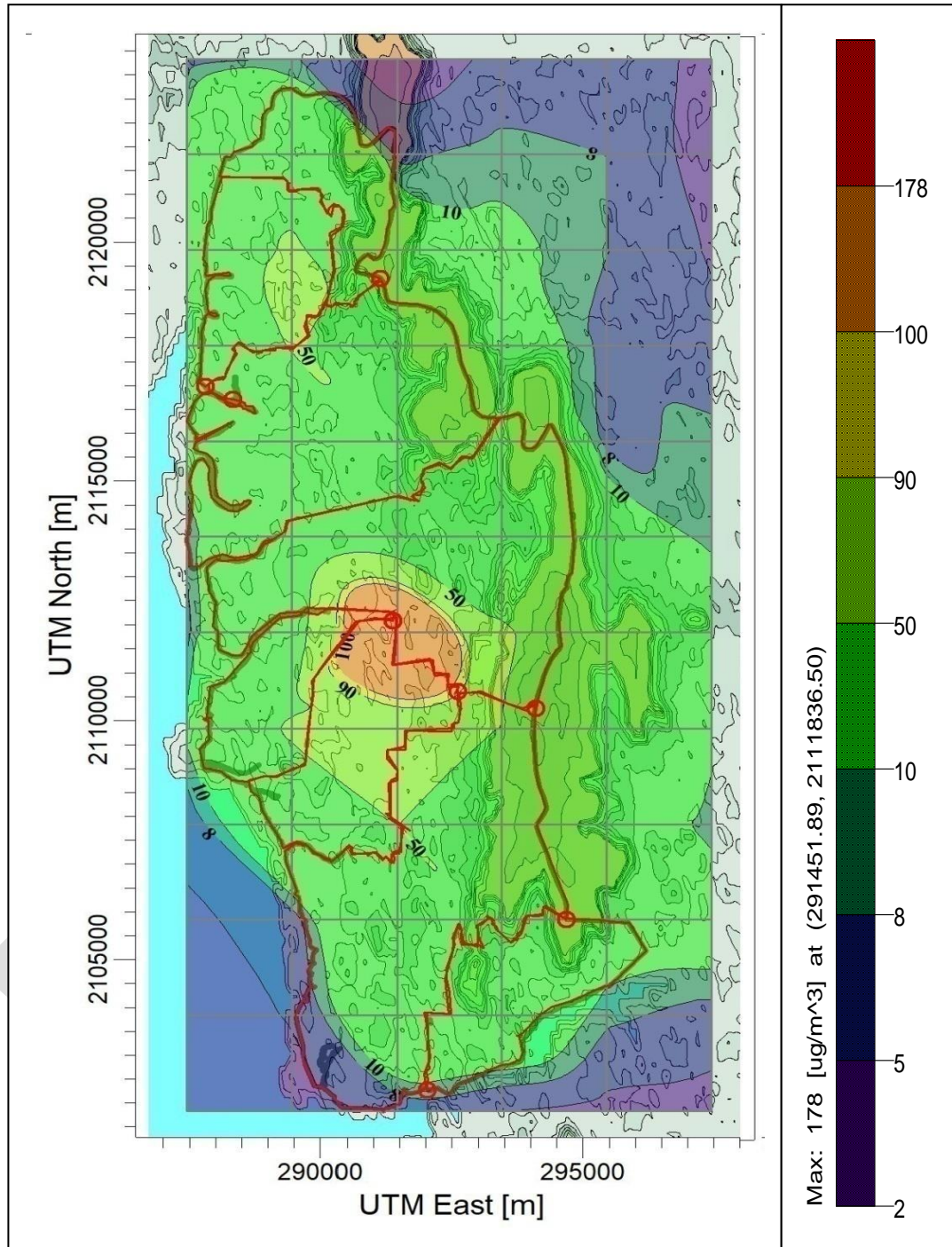
## Observations

- The average annual concentration of dispersed PM emission load from all the sources exceeds the CPCB standard, which is also observed in summer and further deteriorates in winter. The observed and predicted ratio is highest in winter and worst in Vashi and nearby area.
- The maximum 24 hourly predicted concentration due to all sources in winter was  $269 \mu\text{g}/\text{m}^3$ , where maximum is from Tailpipe emission from Vehicles and Red LSI i.e. 212 and is  $153 \mu\text{g}/\text{m}^3$ , respectively. The pockets of high concentration are observed close to major traffic junctions in central part city i.e near Vashi and Pawane area, where major interlinkages or roads viz. Thane Belapur and Sion Panvel Highway exist. The NOx vehicular emission is higher at Vashi area, i.e. around 7751 Kg/d. Due to APMC market and industrial connectivity of roads, approx 2148235 VKT movement was observed for Heavy Duty Vehicles. The NOx vehicular emission is around 30494 Kg/d out of which 19978 Kg/d is coming from HDDV i.e. 35.4% of total emission load from all the sources, whereas Red LSI alone contributes 12368 Kg/d i.e. 21.9% of the total NOx emission load. The Annual predicted concentration of NOx is  $206 \mu\text{g}/\text{m}^3$ , whereas summer and post monsoon it is ranging from 170 to  $180 \mu\text{g}/\text{m}^3$ . Amongst them, the dispersed emission form line source is in the range of 150 to  $212 \mu\text{g}/\text{m}^3$  and that from Red LSI varies between 38 to  $91 \mu\text{g}/\text{m}^3$ . Industries are located mainly at Thane Belapur Road, MIDC area, Mahape, Rabale, and Pawane, where impact is noticed.
- The maximum 24 hourly predicted concentration due to area sources was  $23 \mu\text{g}/\text{m}^3$  in winter. The overall impact of areas source is due to domestic cooking and DG sets (commercial/ industrial), which is spatially distributed over all wards. The NOx percent contribution from domestic sector is 14% of the total city emission load.
- The dispersed concentration of NOx from medium scale industrial sources is predicted in the range of 2.16 to  $3.36 \mu\text{g}/\text{m}^3$ , similarly from small scale industries the concentration was found to be in the range of 6.8 to  $9.8 \mu\text{g}/\text{m}^3$ . The concentration in winter is the highest i.e.  $9.85 \mu\text{g}/\text{m}^3$ .



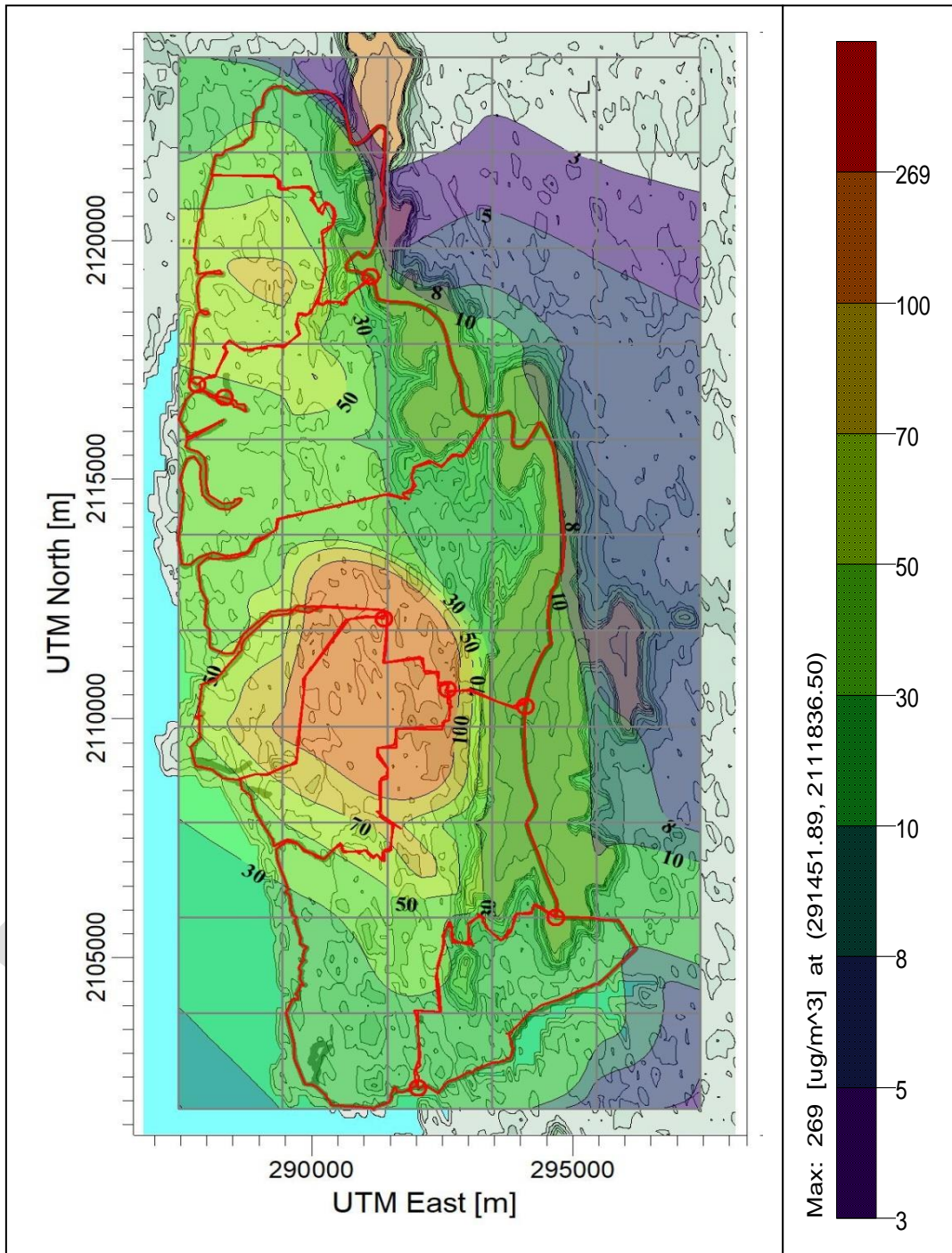


**Figure 5.9 : Isopleths of NOx Due to All Source– Summer Season (Navi Mumbai City)**

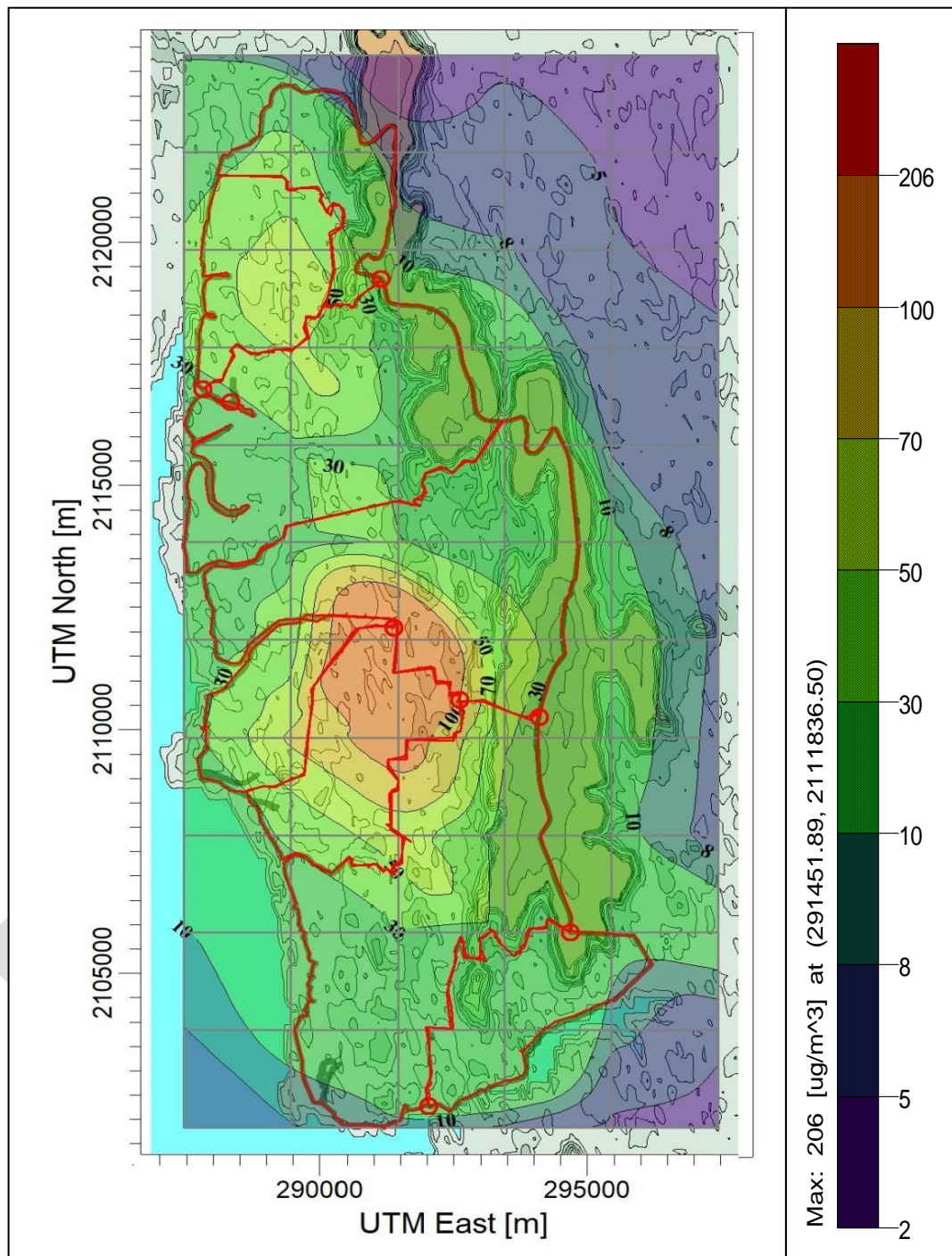


**Figure 5.10 : Isopleths of NO<sub>x</sub> Due to All Source– Post Monsoon Season (Navi Mumbai City)**





**Figure 5.11 : Isopleths of NO<sub>x</sub> Due to All Source– Winter Season (Navi Mumbai City)**



**Figure 5.12 : Isopleths of NO<sub>x</sub> Due to All Source– Annual (Navi Mumbai City)**

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### Emission Reduction Action Plan for Navi Mumbai

For city administrators, regulating air pollution is the primary concern and accurate knowledge of the source contributions is vital to developing an effective air quality management program. The action plan presented later therefore, makes an attempt to delineate strategies on the basis of understanding of the PM and NO<sub>x</sub> 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 NO<sub>x</sub> 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. With the implementation of these action plan the total reduction in particulate matter from area sources would be more than 37% (**Table 6.1**).

#### 6.1 Area Source

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. From the estimation of emission inventory, contribution of regional ground level emission load of PM<sub>10</sub> is 1.83 tons/day and from road resuspension is 11.3 tons/day out of the total PM<sub>10</sub> emission load. Out of the total area source emission, the most contribution is from domestic and household consumption of fuels and construction activity. The same trend was observed for NO<sub>x</sub> emission load. This can be attributed to recent settlement and migration of huge population towards the region and inclination of new building and construction project in and around the region. Based on the survey and assessment, following points emerge to curb area source emissions:

- Inventorization of LPG quantity from supply agencies should be maintained.
- Mahanagar Gas Ltd. and ULB should take initiative to sensitize people from the slum & non slum to make the shift from conventional domestic fuel (LPG, Kerosene, wood) to Piped Natural Gas (PNG).

- Development of roads - Navi Mumbai is interconnected by Asphalt /Cement roads however; internal roads in MIDC area require improvement. There are internal roads of 95 Km in TTC MIDC area, Navi Mumbai Municipal Corporation authority informed that 98% construction work of internal roads in MIDC area is completed and the remaining work will be completed at the earliest. Dusty materials such as sand and cement should be kept covered. City pathways and footpath design needs a norm. 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.
- Resuspension of dust can be minimized through regular sweeping and application of treated sewage for road side bioswale system, which will not only keep the kerb-side green but also help in arresting air pollution. Appropriate barricading of the under construction site to avoid dispersion of the dust and particulate matter in the ambient air. Water spraying on the tires of trucks and vehicles at the entry/exit point of construction as well as industrial sites. Constructing a water pit at the entry/exit points of the construction site to avoid dispersion of particulate matter through movement of trucks while entering and exiting the site.
  - Navi Mumbai also faces pressures from mining and quarrying activities. A total of 80 leases have been provided in 5 different regions of the city which account to a total area of 823988 sq.m (0.82 sq.km). Two years back there are over 200 quarries in NMMC area (Nerul-106, Turbhe-92, Koparkhairane- 8, and Digha-3). The operators were permitted to carry out mining activities in the area till the year 2016 (September 2016). An approved period of lease for existing sites for stone mining and quarrying has been over. As per ESR Report prepared by NMMC, air pollution with high RSPM level can be observed in the area near the mining sites. In view of land degradation due to stone quarrying in NMMC, restoration of these areas is a challenge for NMMC, it needs to construct and barricading using of curb stones for preventing access of vehicle for illegal dumping and trespassers. Towards this NMMC has proposed actions for restoration of abandoned quarries and protection of hills by using them as follows :
    - Use of abandoned quarries for Rainwater harvesting
    - Planting trees for restoration of land under abandoned quarries
    - Abandoned quarries can be restored by sanitary land filling with innocuous inorganic wastes, especially construction debris by adopting suitable slopes from stability angle and with due compaction.
    - Stone quarries and crushing units were identified as one of main source for particulate matter as per a survey study was carried out by NEERI & IIT under MPCB, 2015. Post

- the survey action against 24 defaulting units, was taken out of which 19 stone crushers units have taken steps towards improvement of air pollution control system by installing dust suppression system, water sprinkling arrangement & metal road.
- Use of Sweeping machines for vacuum suction of dust/fine particles at Palm Beach road, Thane-Belapur and other major roads to reduce air pollutants. Number of quarries are closed which has resulted in decline of particulate matter within the Navi Mumbai municipal limits.
  - In the year 2016-17, the daily average MSW was 725 Metric Tonnes (MT) which has increased by about 30 tons as compared to the last year. The major share of about 92% (672 MT) of the total waste is generated from residential NMMC has achieved more than 60% waste segregation at source through various awareness drives. The presence of APMC (Agriculture Produce Marketing Committee) right within the city is also a major source of solid waste, and accounts to about 7.1% (51.69 MT) of the total solid waste generated in the city. Presence of all these solid waste management, there may be open burning activities would happen in the city, so in our report we assumed that 1% waste from each ward and 4% at landfill site may be openly burnt. As per NMMC official there was not reported any open burning activities, so the quantum of open burning waste may be differ.
  - Under Swachh Bharat Abhiyaan, NMMC is in the process of establishing a 300 tons/day capacity C&D recycling plant at its Turbhe Landfill facility. Around 5 acres of areas has been reserved to construct the facility on a PPP (Public Private Partnership) basis. The plant shall segregate the waste into sand, metals and stone dust and also use part of it to manufacture paver blocks/tiles. Policy level modifications/interventions are under discussion to decide (i) arrangement on levying of charges for collection of C&D waste and (ii) strategizing mainstreaming of usage of the products for usage in the construction sector.
  - For the current year 2016-17, the residential properties mark the highest recording 82% of total 3,07,710 properties. This is followed by commercial buildings with 17% share and MIDC commercial with least of 1% share. These entire resource loads on environment in future will reflect the different activities of area sources and emission load as well.
  - Thus trees play a vital role in regulating the city's environment and helps maintain proper balance. NMMC has carried out tree plantations in every block consecutively as per the requirement, out of the total trees present in the city 1.14 Lakhs (1,14,931) have been planted on road dividers. As per the provisional figures, the total tree count of the city is around 8.5 Lakhs.

*Source: Environmental Status Report (2016-17), NMMC*



**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	100% of slum to use LPG/ PNG	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 Navi Mumbai region. Ensure proper ventilation reforms to be implemented in kitchens through periodic information dissemination of indoor air quality.
Hotel & Restaurants	50% of coal to replace by LPG	50% of coal to replace by LPG	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.
Open Eat outs	Since these operations are illegal, they are difficult to quantify. An effective redressal system towards their total no. 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- 0.12, and NOx- 0.039 kg/day can be achieved, considering the large number of 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.
<p><i>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.</i></p>			

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

Area Sources	Short Term 2019	Long Term 2022	Action required
Crematoria	50% Electric	75% Electric	<p>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.</p> <p>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.</p>
<p><i>Similarly, for wood consumption of 300kg/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.</i></p>			
Open & Landfill Burning	<p>100% immediate and stringent redressal of open burning cases</p> <p>100% control of Landfill burning events</p>	<p>Feasibility study for establishment of Waste to energy plant facility</p>	<p>It has been observed that the unaccounted or mismanaged waste from SWM system, often are reported into road side open burning cases. The waste generated from the residential sector highest quantity (108.58 MT/day) of waste was generated and collected from Turbhe node. The APMC accounts to about 7.1% (51.69 MT) 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.</p>
<p><i>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</i></p>			

**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	99.5% 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. A total of 1317 Km length of road is swept everyday an average one sweeper sweeps 700 running meters of road length. NMMC has 8 mechanical sweepers for efficient sweeping of roads. About 196.16 Km road is swept by the sweeping machines per day, which is very low. A strategic plan should be devised so as to cover larger area of region. This will help in effective management of 2646 manual sweeping labors in other resuspension control activities such as frequent sweeping, sprinkling of roads and collection of dust. Feasibility study for road construction material that can be used in the region so as to control resuspension should be initiated.

## 6.2 Point Source

As per MPCB, Navi Mumbai had aggregate Comprehensive Environmental Assessment of Industrial Cluster in December 2009 having CEPI Score of 73.77, which improvised to 56.48 as on March 2017. There are 541 Air Polluting industries in area/cluster. Major pollutants are TPM/SPM, SO<sub>2</sub>, NO<sub>x</sub>, NH<sub>3</sub>, Cl<sub>2</sub>, and VOC from pesticide and bulk drug units. All the Air polluting industries have provided emission control systems as required i.e. Dust collectors, Scrubbers, and Stack of sufficient height. The number of D.G sets in the region is very high and emissions from their stacks are accountable. A recent report prepared by MPCB, 2017 '*Environmental Status and Revised Action Plan for Prevention and Control of Pollution of Industrial Cluster of Navi Mumbai*', highlighted some of the facts and action under taken by the board as :

- Total 69 industries have changed their fuel pattern and are using PNG as fuel from LDO/FO and the remaining 13 industries using coal as fuel has been directed to switch over for use of PNG. However because of economic viability out these 13 units 11 has upgraded ECS (Energy Conservation Scheme) and provided Bag filter and ventury scrubbers. Work is in progress for remaining 2 units.
- M/s. Mahanagar Gas Ltd. is lying down gas pipeline, which is to be commissioned in the next year. All the industries are proposed to use natural gas soon after commissioning of Gas supply. 17 industries have changed their fuel pattern and are using CNG as fuel.
- Presently, 16 industries identified as a Hazardous air pollutant emitting units. They should be issued directions to install Leak detection & repair system (LDAR) within 6 months. Presently, 10 industries are installed with LDAR.
- All the bulk drug and pesticides manufacturing units should be proposed to improve efficiency of their VOC scrubbers. Total 16 industries have been identified to install VOC analyzer. Out of this 10 industries have installed VOC analyzer system. 2 units are not in operation. And remaining 4 units has been directed for compliance.
- Air pollution control measures adopted in the 458 industrial units with respect to efficiency, operation, maintenance and implementation along with up- gradation of air pollution control equipment's. Online display system implemented at all Large and medium scale industries. 15 units had updated PCS and their performance is under vigilance.

- Repairing of internal roads & proper maintenance of the same, there are internal roads of 95 Km in TTC MIDC area. NMMC authority informed that 98% construction work of internal roads in MIDC area is completed and the remaining work will be completed at the earliest.
- It needs to be inventories of prominent industries with inclusion of technological gaps.
- Industries should adopt stack emission norms prescribed by CPCB for Industries, which should be followed by regular QA/QC and performance audit.
- Use of Furnace Oil should be regulated. The chemical and dyes units should improve their scrubbers and dust collectors.
- NMMC, 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. Needs to regulate 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 6.2**).

**Table 6.2 : Emission Reduction Action Plan for Point Source**

Point Sources	Short Term 2019	Long Term 2022	Action Plan
<p>Red (LSI) FO (347 TPD), LDO (135 TPD) HSD (94 TPD) Diesel (65 TPD) Coal(764 TPD), LPG 931 TPD), NG (1434 TPD) And CNG &amp; PNG (25 TPD) are the major contributors towards PM and NOx emission loads</p>	<p>Shift to cleaner fuels in both the category of industries - 50% of FO, LSHS, HSD to LDO, Coal &amp; Others to NG</p>	<p>Shift to cleaner fuels - 100% All types of fuel to Natural gas</p>	<p>There are 541 Air Polluting industries in area/cluster.</p> <p>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. Mahanagar Gas Co. already started 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.</p> <p>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.</p>
<p>Red, Orange and Green (MSI &amp; SSI) FO (15 TPD), LDO (17 TPD), HSD (1068 TPD) Diesel (52 TPD) and PNG (113 TPD) are the major contributors towards PM and NOx emission loads</p>			<p>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.</p> <p>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.</p> <p>Identification of low cost and advanced cleaner technology for air pollution control with policy intervention at specific zones.</p>

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

Point Sources	Short Term 2019	Long Term 2022	Action Plan
Red (LSI) & Red, Orange and Green (MSI & SSI)	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	<p>Feasibility of changing combustion technology to facilitate usage of gaseous fuels may be undertaken with financial incentives.</p> <p>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.</p> <p>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.</p> <p>Only 6 out of 16 Hazardous Air Polluting Units are yet to install Leak detection &amp; repair system (LDAR). They have been directed by MPCB for the installation within next 6 months.</p> <p>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.</p> <p>NMMC has agreed for provision of land to Industrial Authorities for the development of green zone in and around industrial region of Navi Mumbai</p>
<p><i>One tree will offset an average about 10 kg of CO<sub>2</sub> each year. According to this we will need 500 million additional trees in 2020 and 1200 million trees in 2051.</i></p>			

### 6.3 Line Source

The presences of increased truck traffic in the area apart from construction activity are the reasons for the increased pollution. The Agricultural Produce Market Committee (APMC) market, Asia's largest market, has pulled in huge truck traffic in the area as well from industries truck to and pro movements. The number of vehicles has increased above estimates here and there is no check on their emissions. As per RTO, the vehicle population in Navi Mumbai is around 41,367 ('thousand) for the year 2016-17 and the year wise growth in number of registration of vehicle is observed to be in the range of 11%. As per current study the emission from vehicular source is calculated to be around 3.27 Tonnes/day for PM. The line source vehicular emission contributes around 16% of the total city load. Heavy Duty vehicles contributing 13% of total vehicular emissions of PM. While, emission due to resuspension is about 16% for paved roads and 39% for unpaved roads. The NO<sub>x</sub> share from vehicular sector is 54% and 70-80% for CO and HC.

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:

- Synchronizing traffic line strategy to phase out of the old commercial vehicles say more than 15 years old, most of which are diesel driven. Stringent Emission standards for the new vehicle in line with Bharat Stage VI Emission Standards should be adopted.
- Need to frame legislation for the Retro-fittment of new engine/Emission Control Devices (Diesel Particulate Filter (DPF) /Diesel Oxidation Catalyst (DOC) that could help in major reduction of PM. Cost sharing by the agencies will help in immediate provision of retrofitment devices.
- Better quality fuel by adopting stricter fuel supply and dispensing system along with Chemical Marker system to keep check on adulterations in fuel. The current fuel specification are too board and therefore, analysis of conventional parameters does not reflect adulteration. Finer fuel specifications are needed for implementation. Success of marker system shall be highly dependent upon the collaboration of Oil Companies and Anti Adulteration Cell. Fiscal Measures for development of alternative fuel technology.
- Conversion of existing public transport buses/tempos/mini buses to CNG fuel operation. Concession/rebates by NMMC for erecting CNG fuel.
- Hybrid buses can be introduced in NMMT's fleet of buses. Biodiesel (B5/B10:5 – 10% blends) should be considered as a fuel option. Promotion of electric public transport. Battery Operated transport vehicles providing point to point service can also be initiated.



- Prepare a traffic dispersal model for efficient mobility & connectivity and should be undertaken by regulatory bodies like NMMC, RTO, MIDC and Departments of Police. Develop North-South road links in the suburbs including Mass Rapid Transit connectivity. Appropriate quality and smooth surface roads should be developed. Facilitate safe and convenient movement for pedestrian (Subways/ FOBs/ Footpaths including Skywalks).
- NMMC operates bus services in Navi Mumbai as well as to certain parts of Mumbai, Thane, Kalyan, Dombivli, Badlapur, Taloja, Panvel and Uran. NMMC operates a total of 475 buses on 77 routes with some special services covering total route length for all the services is 1895 Km, which needs to improve as a public transport and better connectivity.
- Being the IT hub, the contract carriers are mainly operated in north of Navi Mumbai. As per the provisions of 73 (3), Central Govt. can restrict and limit number of contract carriers in the cities / towns where heavy population is not less than 5 lakhs. Traffic of heavy goods vehicles may be routed outside city area by creating by-passes & ring roads before entry and exit of the city
- NMMC, RTO, MSRDC & MIDC should collaborate to formulate time bound design and construction of underpasses, fly-overs and widening of roads to control the traffic jams and congestion along Thane - Belapur and Mumbai - Pune Highway and pre-determined junctions. 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.
- To provide easy access and infrastructure to commuters travelling from Mumbai towards Thane- Belapur and Panvel-Pune. Currently, Navi Mumbai International Airport is under construction at Ulwe Kopar-Panvel in Maharashtra which is 35 Km far from existing Chhatrapati Shivaji International Airport, Mumbai; which will increase the traffic movement. A comprehensive mobility plan needs to be drawn looking into the future demand.
- Finally, awareness programme should be undertaken with no vehicle day and assessment for air pollution to share the benefits among the general population.

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 6.3**.

**Table 6.3 : Emission Reduction Action Plan for Line Source**

Line Sources	Short Term- 2019	Mid Term- 2022	Long Term- 2024	Action required
<b>Reduction Emission per Unit of Fuel</b>				
Fuel Adulteration	Strict Banning of Fuel Adulteration- 50%	Strict Banning of Fuel Adulteration- 80%	Strict Banning of Fuel Adulteration- 100%	<p>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.</p> <p>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.</p> <p>At petrol pumps, facility should be provided for identification of fuel adulteration by way of marker</p> <p>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.</p> <p>Promotion of better lubricants.</p> <p>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 &amp; Q etc., which are being carried out in, limited way.</p> <p>Economic measures such as removing the disparity in petrol, diesel and kerosene prices will be required to remove incentives for such large scale malpractices</p> <p>Fines and cancellation of license are some of the stringent tools.</p>
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%	<p>NMMC has a fleet of both AC (82) and Non AC (398) buses in its inventory. Buses run either on Diesel or CNG. All can be converted to CNG phase wise.</p> <p>Private aggregator vehicles from institution, schools and services should be regulated to convert to CNG/LPG. Incentives for fast paced successful implementation.</p> <p>Incentive for new owners to buy CNG/LPG vehicles.</p> <p>Developed infrastructure for easy availability of fuel station for CNG/LPG refueling and availability of subsidiary kits for such conversion to the older vehicles.</p>

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

Line Sources	Short Term- 2019	Mid Term- 2022	Long Term- 2024	Action required
<b>Reduction Emission per Unit of Vehicle /Congestion</b>				
Banning of 15 year Old Commercial Vehicle	50% banning	70% banning	100% banning	<p>Encouragement by provision of incentives in form of scrap value, tax rebate, and transferrable discount rewards for new vehicles and registrations.</p> <p>All the existing and newly vehicles should go through inspection and certification every two years.</p> <p>Corporation and metropolitan authority should demark designated places and system facility for scrapping vehicles, as such there is no provision in the city.</p> <p>According to reports, the government has set up a central depository called 'VAHAN' to store data relating to all vehicles.</p> <p>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.</p>
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)	<p>There are significant emissions at signals and congestion zones, especially because of hot and cold start due to unsynchronized and delayed traffic signals.</p> <p>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.</p>
New Vehicle Standards (Sulphur Reduction)	Currently BS-IV standards are in operation	Implement BS- VI from 2020 -50% (adopt progressive increment)	Implement from 2020 -75% (adopt progressive increment)	<p>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.</p>

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

Line Sources	Short Term- 2019	Mid Term- 2022	Long Term- 2024	Action required
<b>Reducing Fuel Consumption Per Unit Distance</b>				
Share of Electric vehicles in Total City Fleet	Two wheeler: -15%, 3 wheeler and Taxi: - 15% Public transport buses -20%	Two wheeler: -30%, 3 wheeler and Taxi: -30% Public transport buses -40%	Two wheeler: -60%, 3 wheeler and Taxi: - 60% Public transport buses -80%	<p>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 &amp; Electric Vehicles (FAME) scheme from the Central Government, launched in April 2015.</p> <p>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. There are 24 two-wheeler models, all battery-operated electric, registered to receive demand incentives under the FAME scheme.</p> <p>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.</p> <p>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%.</p> <p>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.</p> <p>The Ministry of Heavy Industries recently gave its approval to the introduction of EV-based public transportation systems in 11 cities across the country. These include Delhi, Mumbai, Ahmedabad, Bengaluru, Jaipur, Lucknow, Hyderabad, Indore, Kolkata, Jammu and Guwahati. Same can be assessed at regional levels at their own capacity.</p> <p>While the FAME scheme provides incentives for all market segments, presently only two wheeler models appear to be taking advantage of the scheme.</p> <p>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.</p>

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

Line Sources	Short Term- 2019	Mid Term- 2022	Long Term- 2024	Action required
<b>Reducing Fuel Consumption Per Unit Distance</b>				
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%	<p>Hybrids with efficient internal-combustion engines and other non-polluting power trains will contribute to a cleaner environment.</p> <p>The flagship program to boost hybrid technologies in India is the Faster Adoption and Manufacturing of (Hybrid &amp;) Electric Vehicles (FAME) scheme from the Central Government, launched in April 2015.</p> <p>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.</p> <p>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.</p> <p>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%.</p> <p>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.</p> <p>While the FAME scheme provides incentives for all market segments, presently only passenger car models appear to be taking advantage of the scheme.</p> <p>Hybrid buses hold potential to gain significantly under FAME, as the allocations available cover a significant portion of the technology costs</p>

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 <sup>25</sup>	Curb Weight (kg)	Length (mm)	Displacement (cc)	Price Range (INR Lakhs) <sup>26</sup>	Gasoline Equivalent Fuel Consumption (liter/100Km)	Life-Cycle CO <sub>2</sub> 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 CO <sub>2</sub> 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 6.3 (Contd..) : Emission Reduction Action Plan for Line Source**

Line Sources	Short Term- 2019	Mid Term- 2022	Long Term- 2024	Action required
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%	<p>In MMR, there are 219 Nos. of PUC centres for Petrol, 56 Nos. for diesel &amp; 244 Nos. for petrol &amp; diesel. Overall, 8% of vehicles come for inspection and failure rate is 1%. The Vahan-nagari area should be developed for I&amp;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).</p> <p>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 &amp; 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&amp;M centers. All autos and buses shall also be subjected to I&amp;M tests.</p> <p>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.</p> <p>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.</p>
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%	<p>A trial run should be arranged to study the impact.</p> <p>Alternate arrangements should be made to bolster public transport.</p> <p>All private vehicles even having registration numbers issued by neighboring states will have to follow the odd-even number formula.</p>

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 contract 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.<sup>10</sup> 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 NO<sub>x</sub> 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 6.3 (Contd..) : Emission Reduction Action Plan for Line Source**

Line Sources	Short Term-2019	Mid Term-2022	Long Term-2024	Action required
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)	<p>A pilot study is required to test the need and efficacy of emission control device and retrofitting it in the older vehicles</p> <p>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</p> <p>It will be helpful to Maharashtra State Transport Corporation, Old BEST buses, Contract carriers.</p> <p>Impose restriction of truck movement in the city for plying without retrofitment to HDDV vehicles (base on age and engine type).</p> <p>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.</p> <p>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).</p> <p>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.</p>

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 (tonnes)	Axie Configuration	Equation	Fuel Consumption (l/100 Km)	
				Value at lower weight limit	Value at upper weight limit
<b>40 Kilometer per hour</b>					
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
N3 Tractor Trailers	31.0- 37.0	10 x 2	$Y=0.960X - 5.100$	24.7	30.4
	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
M3 Vehicles	40.2- 49.0	6 x 4	$Y=1.255X - 18.523$	31.9	43.0
	12.0 and above	4 x 2 & 6 x 2	$Y=0.509X - 11.062$	17.2	
<b>60 Kilometer per hour</b>					
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
N3 Tractor Trailers	31.0- 37.0	10 x 2	$Y=0.960X + 5.100$	24.7	30.4
	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
M3 Vehicles	40.2- 49.0	6 x 4	$Y=1.342X + 13.390$	40.6	52.4
	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
<b>40 Kilometer per hour</b>					
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	
<b>60 Kilometer per hour</b>					
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 20<sup>th</sup> 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**

	<b>GVW Bin (tonnes)</b>	<b>Axle Configuration</b>	<b>Required Fuel- Consumption Reduction Between Phase1 and Phase 2</b>	<b>Market Share</b>
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.

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

Line Sources	Short Term- 2019	Mid Term- 2022	Long Term- 2024	Action required
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%	<p>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.</p> <p>Municipal corporation should define designated space in the localities and develop elevated pay and park zones. Higher parking fee for longer period of time.</p> <p>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 recently vacated Vashi Octroi check post. 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.</p>
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	<p>NMMC has a fleet of both AC (82) and Non AC (398) buses in its inventory.</p> <p>It 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</p> <p>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.</p> <p>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 Navi Mumbai at one or two road stretches</p> <p>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.</p>



Buses are critical as spine of city mobility, 40-60 per cent 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.

### **Congestion Pricing**

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 Stockholm (*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 eCO<sub>2</sub> 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.

## Indian Diesel Specification required meeting Bharat Stage II, III, & IV Emission Norms

Characteristics	Unit	Bharat Stage II	Bharat Stage III	Bharat Stage IV	Bharat Stage VI <sup>†</sup>
Implementation date		2001 (selected cities), 2005 (nationwide)	2005 (selected cities), 2010 (nationwide)	2010 (selected cities), 2017 (nationwide)	2020 <sup>†</sup> (nationwide)
Ash, max	% mass	0.01	0.01	0.01	0.01
Carbon Residue (Ramsbottom) on 10% residue, max <sup>†</sup>	% mass	0.3	0.3	0.3	0.3
Cetane Number (CN), min	–	48*	51	51	51
Cetane Index (CI), min	–	46*	46	46	46
Distillation 95% vol. Recovery at °C, max	°C	–	360	360	370
Flash point Abel, min	°C	35	35	35	35
Kinematic Viscosity @ 40 °C	cst	2.0-5.0	2.0-5.0	2.0-4.5	2-4.5
Density @ 15 °C	Kg/m <sup>3</sup>	820-860 (820-870)*	820-845	820-845	820-860
Total Sulfur, max	mg/kg	500	350	50	10
Water content, max	mg/kg	0.05% vol	200	200	200
Cold filter plugging point (CFPP)					
a) Summer, max	°C	18	18	18	18
b) Winter, max	°C	6	6	6	6
Total contaminations, max	mg/kg	–	24	24	24
Oxidation stability, max	g/mg <sup>3</sup>	–	25	25	25
Polycyclic Aromatic Hydrocarbon (PAH), max	% mass	–	11	11	11
Lubricity, corrected wear scar diameter (wsd 1,4) @ 60 °C, max	µm (microns)	460	460	460	460
Copper Strip corrosion for 3 hrs @ 50 °C	Rating	Not worse than No. 1	Class I	Class I	Class I

Notes:† Proposed fuel quality

### 6.3.1 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 Navi Mumbai 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 Navi Mumbai City (2017)**

	<b>Car Petrol</b>	<b>Car Diesel</b>	<b>Car CNG</b>	<b>Taxis</b>	<b>2 Wheelers</b>	<b>3 Wheelers</b>	<b>CNG Buses</b>	<b>HDDV</b>
VKT	3577059	2782157	1589804	120716	5146496	2488842	692858	1616669
Rate Rs./Km	1	1	0.5	0.5	0.5	0.5	0.5	1
Cost (Rs.)	3577059	2782157	794902	60358	2573248	1244421	346429	1616669

**Total Collection about Rs. 1,29,95,242 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 NNMC, 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 them 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.

### ***Are Cities Monitoring of Impact of Action?***

Air quality monitoring also needs to get linked with assessment of impact of action taken. Very few cities have made such efforts to demonstrate the change.

- The Karnataka State Pollution Control Board has assessed the impact of the monthly bus day scheme that was introduced by the Bangalore Metropolitan Transport Corporation (BMTC) in 2010. Monitoring is carried out on the stretch of Bus day route.
- Similarly, West Bengal Pollution Control Board has assessed the impact of phase out of old vehicles on PM<sub>2.5</sub> in 2009. That shows significant drop in the levels as a result of this intervention.

This is the maturity that is needed in air quality governance.

### **6.3.2 Non Motorized Sectors**

**Cycle Track :** To contribute to the sustainable development of the city, provision of dedicated 3 m. wide cycle track along all road pathways 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 Navi Mumbai open land. The development of this cycle track can be done by public-private participation or from the funds of Municipal Corporation.

**Green Belt Development :** The Green Belt along the road like Pam Beach Road across the city 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.

Air quality can be improved through the use of trees and shrubs. Leaves filter the air by removing dust and other particulates in addition to specific plants which can also reduce gaseous pollutants. A green belt with pollutant tolerance trees act as mitigating air pollution in an effective manner by filtering, intercepting and absorbing pollutants. Plant species that will be considered for air pollution and dust control are given below:

<i>Dracena deremensis</i> (Dracena)	<i>Butea monosperma</i> (Phalas)
<i>Colocassia esculenta</i> (Green Taro, Arvi)	<i>Mangifera indica</i> (Aam)
<i>Scindapsus aures</i> (Golden Pothos)	<i>Anthocephalus cadamba</i> (Kadamba)
<i>Chlorophytum comosum</i> (Spider Plant, Musli)	<i>Chamaedorea seifrizii</i> (Bamboo Palm)
<i>Nerium oleander</i> (Oleander, Kaner)	<i>Ficus virens</i> (White Fig)
<i>Thevetia peruviana</i> (Yellow Oleander)	<i>Ficus religiosa</i> (Peepal)
<i>Hibiscus rosa-sinensis</i> (China Rose, Jaswand)	<i>Spathodea campanulata</i> (African Tulip Tree)
<i>Bougainvillea glabra</i>	<i>Psidium guajava</i> (Peru)
(Bougainvillea, Booganvel)	
<i>Plumaria rubra</i> (Plumeria)	<i>Terminalia arjuna</i> (Arjun)
<i>Cassia fistula</i> (Amaltas)	<i>Bombax ceiba</i> (Silk Cotton Tree)
<i>Cassia siamia</i>	

Green belt development can attenuate the sound levels during the operation of the facilities. The following species can be planted within the facilities to reduce the noise levels.

<i>Tectona grandis</i> (Teak)	<i>Butea monosperma</i> (Phalas)
<i>Azadirachta indica</i> (Neem)	<i>Dalbergia Sissoo</i> (Indian rosewood, Shisham)
<i>Syzygium cumini</i> (Jamun)	<i>Tamarindus indica</i> (Imli)

#### 6.4 Stone Crushers

Quarrying is being done for at least last 30 years in west side of the Parsik hill ranges. Till March 2017, there were 74 active quarries out of 94 quarries. Quarries in Navi Mumbai have been shut since April 1, 2017. Thane Collector office has allowed only 3 quarries in Navi Mumbai to operate as a special case, from where BMC can source raw materials for road works. During mining, crushing and transportation activity lot of dust was getting resuspended in the air. The roads outside the quarry are unpaved roads. Following measures can be adopted to control on/off-site emission and resuspension from Quarry site:

- Stringent Fugitive emission management practices and regulation should be implemented



- Most of the quarries have provided sprinkler system for dust suppression however, improvements are required. Use of water sprinklers should be made compulsory at the quarrying sites. All these units will be proposed to install efficient emission control system. Provision of chemical spray for dust suppression with R & D lab can be done.
- Trucks carrying the crushed stone material for transportation should be covered.
- Quarrying sites and activities should be regulated with strict vigilance as per the norms laid by CPCB and MPCB.
- Constructing a water pit at the entry/exit points of the construction site to avoid dispersion of particulate matter through movement of trucks while entering and exiting the site. Spraying of water on the tires of the truck and vehicles at the entry/exit of construction site.
- Tree plantation in and around the quarrying site.

### **6.5 Management -Stakeholders**

There are three AAQM locations covered under NAMP at Nerul, Mahape and Rabale. These station being monitored since 2006. Navi Mumbai Municipal Corporation has set up two CAAQM stations at Vashi and Airoli. These stations are in operation for the last three years. The Air Quality Index (AQI) of period April to March 2017 shows AQI is satisfactory (51-100) to moderate (101-200). In November, 2016 Air quality at Turbhe & Koparkhairane is poor due to particulate matter and temperature inversion phenomenon in the winter season. The dominant parameter are Particulate matter and CO, attributed to growing vehicular traffic and construction projects as well as commercial and infrastructure development including road construction etc. Hierarchical and structured managerial system for efficient implementation should be introduced with data linkage 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 policy initiatives can be sustained and kept up-to-date only if there is an apex body, which from time to time gets feedback from various sources. These sources could be State Pollution Control Board, Regional Transport Office, Navi Mumbai Municipal Corporation, Truck Association for Navi Mumbai, CIDCO, MIDC, TBIA, MMRDA, 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.

It is not just sufficient to measure air pollutant concentrations and assess their sources and their apportionment. It is equally important to disseminate that information to the public through various channels such as web / mobile application, information boards in public spaces as well sharing important studies conducted on air pollution with the public. This ensures public awareness of the issues and can help build ground up pressure on the concerned agents to address the problem.

MPCB & TBIA should take initiative in creating awareness program at various schools, colleges, public places, etc. through road shows, posters, banners, hand bills and various programs etc. Most of the actions can be done by adapting and reinforcing existing actions for a more integrated, comprehensive and effective approach to combating Air pollution. Other actions focus on identified gaps in our study response so far that requires new activities, the discovery of new knowledge and the creation of new partnerships. The action plan will strengthen collaboration and surveillance, will reduce data gaps and allow for the sharing of best practices within the city jurisdiction. It will create more synergies and coherence between different policies according to our study. The action plan will thus support the stakeholders in delivering innovative, effective and sustainable responses to Air Pollution.

## 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 NO<sub>x</sub> 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 and large quantity of PNG with LPG at domestic level. The emission loads from the fuel consumption at crematorium and bakeries are almost same. The emission from other area sources is limited to few regions e.g open burning. 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 Emission	PM Control Options	
		2019	2022
Bakeries	69.2	25% LPG /NG; 25% Electric	50% LPG /NG; 75% Electric
Crematoria	46.7	50% Electric	75% Electric
Open Eat outs	9.3	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	204.9	50% of coal to replace by LPG	75% of coal to replace by LPG
Domestic Sec. Slums /Non Slum	363.9	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	285.9	50% open burning	100%
Bldg. Construction	852.0	50% control on dust emission	75% control on dust emission

With the implementation of the short and long term scenarios, the overall total reduction in particulate matter from area sources would be around 33 to 38%, whereas at individual sources 50-70% of reduction can be achieved. Anticipated sector-wise particulate matter emission loads are given in **Table 7.2** below.

**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	69.2	3.8	73.0	78.1	54.8	29.3
Crematoria	46.7	2.5	49.2	51.9	24.6	13.2
Open Eatouts	9.3	0.5	9.8	10.5	7.4	7.6
Hotel Restaurants	204.9	11.2	208.1	213.3	141.3	145.8
Domestic sector	363.9	19.9	389.5	447.9	368.4	373.4
Open Burning	285.9	15.6	306	328.8	153.0	82.2
Construction Activity	852.0	46.5	937.2	954.3	468.6	477.1
<b>Total</b>	<b>1831.9</b>		<b>1972.8</b>	<b>2084.8</b>	<b>1217.4</b>	<b>1128.5</b>
<b>Reduction w.r.t BAU 2018</b>					<b>33.54%</b>	<b>38.4%</b>

## 7.2 Point Source Pollution Reduction Options

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 power plant, some chemical industries and partly operated stone crushers are the major sources. The strategies mainly considered are based on cleaner fuel substitution as well as closing/shifting of industries outside the city region. The strategies are recommended for the following broad sectors i.e under short (5 yrs) and long (10 yrs) term scenarios. Industrial PM Emissions from Red, Orange and Green (LSI, MSI and SSI) category.

### Point Source Control Options and Analysis

The industrial sector has been steadily declining in the city due to shifting development priorities and market forces. Likewise, there is huge demand for petroleum products like Furnace oil and HSD in industries too. In 2016-17 the total petroleum sale within Navi Mumbai is noted to be around

78 thousand Kiloliters (KL). There is increasing trend in shifting towards better fuel option. As per the consent, industries in Navi Mumbai currently use Coal, HSD, FO, NG as their main fuel for operation (771, 1162, 362 and 1434 TPD, respectively). The emission load of PM from RED-LSI units was alone estimated to be around 4212.9 kg/day and that of NO<sub>x</sub> was 12368.4 Kg/d. The percent emission load calculation for PM and NO<sub>x</sub> in Red LSI is around 21%, whereas that for MSI and SSI (ROG) is 1% (PM) and 9% (NO<sub>x</sub>). **Table 7.3** presents the fuel switch options and their corresponding emission loads in each case. An attempt has been made to align the use of clean fuel in the city for improving the air quality.

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.

**Table 7.3 : Point Source Strategies for Short and Long Term**

Point Sources Category	Major PM Emission Contributor	Control Options	
		Short Term (2019)	Long Term (2022)
Red, Orange and Green Category (LSI/MSI/SSI)	FO, HSD & Coal major contributors towards PM emissions	<ul style="list-style-type: none"> <li>Shift to cleaner fuels i.e. LSHS, FO, HSD, Coal, Diesel to Light Diesel Oil (LDO)</li> <li>Combustion technology up gradation for fuel change.</li> </ul>	<ul style="list-style-type: none"> <li>Shift in cleaner fuels from LDO &amp; Coal to Natural Gas (NG)</li> <li>Combustion technology improvement with fuel change</li> <li>Feasibility of conversion of thermal power production to gas based system.</li> <li>Industrial development (expansion) should be based on cleaner gaseous fuel with no net increase in emissions.</li> </ul>

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 NO<sub>x</sub>.

**Table 7.4 : Point Source Emission Scenario Before & After Control Options:  
(Short & Long Term Scenarios for PM)**

**A. For Red (LSI/MSI/SSI)**

Sr.	Present PM Emissions			PM Emissions After Control Options					
	Fuel type	Quantity (TPD)	Emissions (Kg/day)	Short Term (2020)			Long Term (2025)		
				Fuel Type	Quantity	Emissions (Kg/day)	Fuel Type	Quantity	Emissions (Kg/day)
1.	FO	347.4	128.48	LDO (100%)	333.9	4.90	LDO	621.52	9.03
2.	LSHS	0.00396	0.0004	LDO (100%)	0.004	0.000058	NG (m <sup>3</sup> /d)	2692.6	53.79
3.	LDO	135.2	1.11	LDO	135.2	1.11	LPG	931.6	13.25
4.	HSD	94.4	1.21	LDO (100%)	102.6	1.50	CNG (m <sup>3</sup> /d)	2.6	0.035
5.	NG (m <sup>3</sup> /d)	1434.8	28.39	NG (m <sup>3</sup> /d)	1434.8	28.39	PNG (m <sup>3</sup> /d)	22.8	0.320
6.	Coal	764.1	4169.58	NG (50%)	628.9	12.60			
7.	LPG	931.6	13.25	LPG	931.6	13.25			
8.	Diesel	64.6	24.06	LDO (100%)	60.7	0.90			
9.	CNG	2.6	0.035	CNG	2.6	0.035			
10.	PNG	22.8	0.320	PNG	22.8	0.320			
				Coal	379.6	1910.4			
	<b>Total (Kg/d)</b>		<b>4366.44</b>	<b>Total (Kg/d)</b>	<b>1973.41</b>		<b>Total (Kg/d)</b>		<b>76.43</b>
				<b>Reduction (%)</b>		<b>54.81</b>	<b>Reduction (%)</b>		<b>98.25</b>

**B. For Orange (LSI/MSI/SSI)**

Sr.	Present PM Emissions			PM Emissions After Control Options					
	Fuel type	Quantity (TPD)	Emissions (Kg/day)	Short Term (2020)			Long Term (2025)		
				Fuel Type	Quantity	Emissions (Kg/day)	Fuel Type	Quantity	Emissions (Kg/day)
1.	FO	12.5	3.65	LDO (100%)	12.75	0.123	LDO	1251.26	12.12
2.	LSHS	1.4	0.066	LDO (100%)	1.45	0.014	NG(m <sup>3</sup> /d) (100%)	11.6	0.15
3.	LDO	16.5	0.23	LDO	16.5	0.23	PNG	112.8	2.068
4.	HSD	1054	13.90	LDO (100%)	1189.03	11.52			
5.	Coal	7.0	12.98	NG (m <sup>3</sup> /d) (50%)	5.8	0.077			
6.	Diesel	30.8	11.43	LDO (100%)	31.5	0.30			
7.	PNG	112.8	2.068	PNG	112.8	2.068			
				Coal (50%)	3.5	6.49			
	<b>Total (Kg/d)</b>		<b>44.32</b>	<b>Total (Kg/d)</b>	<b>20.82</b>		<b>Total (Kg/d)</b>		<b>14.33</b>
				<b>Reduction (%)</b>		<b>53.02</b>	<b>Reduction (%)</b>		<b>67.65</b>

### C. For Green (LSI/MSI/SSI)

Sr.	Present PM Emissions			PM Emissions After Control Options					
				Short Term (2020)			Long Term (2025)		
	Fuel type	Qty. (TPD)	Emissions (Kg/day)	Fuel Type	Qty.	Emissions (Kg/day)	Fuel Type	Qty.	Emissions (Kg/day)
1.	FO	2.2	0.53	LDO (50%)	1.10	0.01	LDO	39.52	0.2873
2.	LDO	0.9	0.01	LDO	0.9	0.01	LPG	0.33	0.0047
3.	HSD	13.0	0.17	LDO (50%)	7.30	0.05			
4.	LPG	0.33	0.00	LPG	0.33	0.00			
5.	Diesel	21.3	6.01	LDO (50%)	10.91	0.08			
				FO (50%)	1.08	0.26			
				HSD (50%)	6.48	0.08			
				Diesel (50%)	10.66	3.07			
	<b>Total (Kg/d)</b>		<b>6.71</b>	<b>Total (Kg/d)</b>		<b>3.56</b>	<b>Total (Kg/d)</b>		<b>0.29</b>
				<b>Reduction (%)</b>		<b>46.96</b>	<b>Reduction (%)</b>		<b>95.65</b>

### D. Total Industrial Emissions in Navi Mumbai Before & After Control Options

Sector		Present PM Emissions (Kg/d)	Emissions After Control Options (Kg/d)	
			Short Term	Long Term
<b>A.</b>	<b>RED</b>	4366.44	1973.41	76.43
<b>B.</b>	<b>ORANGE</b>	44.32	20.82	14.34
<b>C.</b>	<b>GREEN</b>	6.72	3.56	0.29
<b>Total (Kg/d)</b>		<b>4417.48</b>	<b>1999.65</b>	<b>261.10</b>
		<b>% Reduction</b>	<b>54.73</b>	<b>94.08</b>

\* 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 4366.44 kg/d to 1973.41 kg/d (i.e. about 55%) and 76.43 kg/d (i.e. 98%), respectively for RED category industries, About the Orange categories, PM reduction for short term is 20% and long term is 14%. Very negligible impact for green category, as fuel quantities are considerably less. The overall short term reduction from all categories is around 54.7% and for long term it will be 97.9%. The emphases were made for the conversion of conventional fossil, solid and liquid fuel to natural gas or LDO.

**Table 7.5 : Point Source Emission Scenario Before & After Control Options:  
(Short & Long Term Scenarios for NOx)**

**A. For Red (LSI/MSI/SSI)**

Sr.	Present NOx Emissions			NOx Emissions After Control Options					
	Fuel type	Quantity (TPD)	Emissions (Kg/day)	Short Term (2020)			Long Term (2025)		
				Fuel Type	Quantity	Emissions (Kg/day)	Fuel Type	Quantity	Emissions (Kg/day)
1.	FO	347.4	2008.06	LDO (100%)	333.9	1067.56	LDO	621.52	1829.74
2.	LSHS	0.00396	0.02	LDO (100%)	0.004	0.012	NG (m <sup>3</sup> /d)	2692.6	7904.61
3.	LDO	135.2	239.84	LDO	135.2	239.84	LPG	931.6	3254.01
4.	HSD	94.4	215.19	LDO (100%)	102.6	328.23	CNG (m <sup>3</sup> /d)	2.6	6.14
5.	NG (m <sup>3</sup> /d)	1434.8	3502.35	NG (m <sup>3</sup> /d)	1434.8	3502.35	PNG (m <sup>3</sup> /d)	22.8	55.93
6.	Coal	764.1	3934.24	NG (50%)	628.9	2201.13			
7.	LPG	931.6	3254.01	LPG	931.6	3254.01			
8.	Diesel	64.6	394.66	LDO (100%)	60.7	194.11			
9.	CNG	2.6	6.14	CNG	2.6	6.14			
10.	PNG	22.8	55.93	PNG	22.8	55.93			
				Coal	382.05	1967.12			
		<b>Total (Kg/d)</b>	<b>13610.44</b>		<b>Total (Kg/d)</b>	<b>12816.43</b>		<b>Total (Kg/d)</b>	<b>13050.43</b>
					<b>Reduction (%)</b>	<b>5.83</b>		<b>Reduction (%)</b>	<b>(-) 1.83</b>

**B. For Orange (LSI/MSI/SSI)**

Sr.	Present NOx Emissions			NOx Emissions After Control Options					
	Fuel type	Quantity (TPD)	Emissions (Kg/day)	Short Term (2020)			Long Term (2025)		
				Fuel Type	Quantity	Emissions (Kg/day)	Fuel Type	Quantity	Emissions (Kg/day)
1.	FO	12.5	60.0	LDO (100%)	12.75	27.18	LDO	1251.26	2691.3
2.	LSHS	1.4	10.49	LDO (100%)	1.45	3.1	NG(m <sup>3</sup> /d) (100%)	11.6	27.1
3.	LDO	16.5	50.62	LDO	16.5	50.62	PNG	112.8	361.90
4.	HSD	1054	3079.02	LDO (100%)	1189.03	2543.7			
5.	Coal	7.0	26.28	NG (m <sup>3</sup> /d) (50%)	5.8	13.55			
6.	Diesel	30.8	187.58	LDO (100%)	31.5	67.28			
7.	PNG	112.8	361.90	PNG	112.8	361.90			
				Coal (50%)	3.5	13.14			
		<b>Total (Kg/d)</b>	<b>3775.89</b>		<b>Total (Kg/d)</b>	<b>3080.47</b>		<b>Total (Kg/d)</b>	<b>3080.3</b>
					<b>Reduction (%)</b>	<b>18.41</b>		<b>Reduction (%)</b>	<b>18.42</b>



### C. For Green (LSI/MSI/SSI)

Sr.	Present NOx Emissions			NOx Emissions After Control Options					
				Short Term (2020)			Long Term (2025)		
	Fuel type	Qty. (TPD)	Emissions (Kg/day)	Fuel Type	Qty.	Emissions (Kg/day)	Fuel Type	Qty.	Emissions (Kg/day)
1.	FO	2.2	8.61	LDO (50%)	1.10	1.77	LDO	39.52	63.19
2.	LDO	0.9	1.37	LDO	0.9	1.37	LPG	0.33	1.65
3.	HSD	13.0	37.02	LDO (50%)	7.30	11.68			
4.	LPG	0.33	1.65	LPG	0.33	1.65			
5.	Diesel	21.3	98.61	LDO (50%)	10.91	17.46			
				FO (50%)	1.08	4.30			
				HSD (50%)	6.48	18.51			
				Diesel (50%)	10.66	49.35			
	<b>Total (Kg/d)</b>		147.26	<b>Total (Kg/d)</b>		106.09	<b>Total (Kg/d)</b>		64.84
				<b>Reduction (%)</b>		<b>27.96</b>	<b>Reduction (%)</b>		<b>55.97</b>

### D. Total Industrial Emissions in Navi Mumbai Before & After Control Options

Sector		Present NOx Emissions (Kg/d)	Emissions After Control Options (Kg/d)	
			Short Term	Long Term
<b>A.</b>	<b>RED</b>	13610.44	12816.43	13050.43
<b>B.</b>	<b>ORANGE</b>	3775.89	3080.47	3080.30
<b>C.</b>	<b>GREEN</b>	147.26	106.09	64.84
<b>Total (Kg/d)</b>		<b>17533.59</b>	<b>16002.99</b>	<b>16195.57</b>
		<b>% Reduction</b>	<b>8.73</b>	<b>7.63</b>

\* Shift in cleaner fuel based on equivalent heat input estimation.

As per emission inventory, the total emission load of NOx from Red industries was estimated to be around 13610.4 kg/d. If action plan is implemented, the reduction in NOx is not significant, as the conversion to Natural Gas, CGN & PNG will increase the emission load of nitrogen dioxides. NOx reduction of only 5.8% (12816.43 Kg/d) is estimated in short term (as most of the conversion are to LDO, 50% coal still will be in use). But this fuel switch will increase the emission load of NOx in long term by 1.8% (13050.4 Kg/d). NOx emission from Orange categories of industries is 3775.89 Kg/d and also cannot change the dynamics much. Their emission load is around 18% (~ 3080 Kg/d) in both short term and long term control measures. The Green category of industries does not use much of NG, their basic conversion of fuel will be from FO, HSD, Diesel to LDO and NG. The 147.26 Kg/d of emission load from Green category will be reduced by 27% in short term and 56% in long term. The overall NOx emission load (i.e. 17533.59 Kg/d) will not reduce in quantum. The short term reduction is about 8.7%, whereas long term reduction is estimated to be around 7.6%. Conversion of heavy sulphur fuel to natural gas, will probably increase the overall NOx emission load to the total.

### 7.3 Vehicular Sources Reduction Options

One of the major contributors to Particulate Matter (PM) and NO<sub>x</sub> emissions in Navi Mumbai region is vehicular exhaust. There is an average annual increase of 10% in the number of registration for 2 wheelers, as per RTO, Navi Mumbai. As per vehicular counting survey the total VKT of 18014601 Km/day was estimated for all categories of vehicles travelling within city limits, the movement of 2 wheelers percent is around 29%, whereas, private owned petrol cars (20%), diesel operated cars (15%), 3 wheelers (14%) and HDDV vehicles comes around 13% at different location across city jurisdiction. The percent emission load of PM is 16% and NO<sub>x</sub> 54% from line source amongst the all categories of emission load of Navi Mumbai.

The most prominent sources of vehicle particulate emissions are diesel driven and two-stroke petrol driven vehicles. Vehicles are the primary source of precursor emissions for PM<sub>2.5</sub> pollutants in the atmosphere of high traffic congestion zones. Based on the results of emission inventory, specific strategies need to be ranked out of wide variety of reduction options available. Reduction strategies 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 Navi Mumbai Region.

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 retrofitment
- 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<sub>x</sub> 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<sub>x</sub> 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<sub>x</sub> 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 NO<sub>x</sub> and 0.02 to 0.01 g/km for PM.

**Table 7.6 : Emission Factors for BS IV and BS VI**

<b>Emission Factor for BS IV fuel</b>	<b>PM</b>	<b>NO<sub>x</sub></b>	<b>CO</b>	<b>HC</b>
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

<b>Emission Factor for BS VI fuel</b>	<b>PM</b>	<b>NO<sub>x</sub></b>	<b>CO</b>	<b>HC</b>
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<sup>a</sup> 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<sup>b</sup> (World Harmonized Stationary Cycle) and WHTC<sup>c</sup> (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 3.7% in 2020 and 7.7%

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 Navi Mumbai city.

**Table 7.7 : Vehicular Source Control Options**

\* Emission load in kg/day

Scenario	PM		NOx	
	PM	NOx	PM	NOx
<b>BAU 2018</b>	<b>3266.4</b>		<b>30494.5</b>	
<b>BAU 2020</b>	<b>3511.4</b>		<b>32781.6</b>	
<b>BAU 2025</b>	<b>3774.7</b>		<b>35240.2</b>	
Complete implementation of BS – IV norms by 2019	<b>462.0 (86.8%)</b>		<b>22996.1 (29.9%)</b>	
Complete Implementation of BS – VI norms by 2025	<b>223.3 (94.1%)</b>		<b>3169.8 (91.0%)</b>	
Control Options	2020		2025	
	PM	NOx	PM	NOx
<b><u>Conversion vehicles to CNG/LPG</u></b> 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%	2346.5 <b>(33.2%)</b>	23769.5 <b>(27.5%)</b>	1898.3 <b>(49.7%)</b>	20738.0 <b>(41.2%)</b>
<b><u>Banning of 15 year Old Commercial Vehicle</u></b> 2020-70% banning 2025-100% banning Encouragement by provision of incentives in form of scrap value.	2047.9 <b>(41.7%)</b>	21754.9 <b>(33.6%)</b>	1522.6 <b>(59.7%)</b>	18267.8 <b>(48.2%)</b>
<b><u>Synchronization of traffic signals</u></b> 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)	1882.9 <b>(46.4%)</b>	19286.0 <b>(41.2%)</b>	1437.2 <b>(61.9%)</b>	15983.5 <b>(54.6%)</b>
<b><u>Share of Electric vehicles in Total City Fleet</u></b> 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%	2310.0 <b>(34.2%)</b>	23400.8 <b>(28.6%)</b>	1862.4 <b>(50.7%)</b>	19874.1 <b>(43.6%)</b>
<b><u>Share of Hybrid vehicles in Total City Fleet</u></b> 2020- Gasoline powered four-wheelers only) – 20% 2025- Gasoline powered four-wheelers only) – 30%	2577.0 <b>(26.2%)</b>	25681.4 <b>(21.7%)</b>	2123.2 <b>(43.8%)</b>	22359.1 <b>(36.6%)</b>
<b><u>Encourage Public Transport</u></b> 2020-Increase Public Transport -50% 2025-Increase Public Transport -75%	2333.6 <b>(33.5%)</b>	23769.5 <b>(27.5%)</b>	1884.0 <b>(50.1%)</b>	20832.3 <b>(40.9%)</b>
<b><u>Retrofitment of Diesel Oxidation Catalyst (DOC) 4wheeler public transport (BSII)</u></b> 2020-50% conversion 2025-100% conversion	1619.9 <b>(53.9%)</b>	19078.7 <b>(41.8%)</b>	1507.6 <b>(60.1%)</b>	17753.4 <b>(40.9%)</b>

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

Scenario	PM		NOx	
<b>BAU 2018</b>	<b>3266.4</b>		<b>30494.5</b>	
<b>BAU 2020</b>	<b>3511.4</b>		<b>32781.6</b>	
<b>BAU 2025</b>	<b>3774.7</b>		<b>35240.2</b>	
Complete implementation of BS – IV norms by 2019	<b>462.0 (86.8%)</b>		<b>22996.1 (29.9%)</b>	
Complete Implementation of BS – VI norms by 2025	<b>223.3 (94.1%)</b>		<b>3169.8 (91.0%)</b>	
Control Options	2020		2025	
	PM	NOx	PM	NOx
<b><u>Retrofitment of Diesel particulate filter in 4 wheelers public transport (BS II)</u></b> 2020 -50% conversion 2025-100% conversion	2366.4 <b>(32.6%)</b>	24194.0 <b>(26.2%)</b>	1927.7 <b>(48.9%)</b>	21387.5 <b>(39.3%)</b>
<b><u>Reduce Dust Resuspension</u></b> (Resuspension Dust as on 2018- 11303.7 <b>kg/day</b> ) 2020-Paving of all road 75%; 2025- 100%	8500.4 <b>(24.8%)</b>		5222.3 <b>(53.8%)</b>	
<b>Banning odd/even vehicles on particular day</b>	1689.0 <b>(51.9%)</b>	15767.9 <b>(51.9%)</b>	1653.3 <b>(56.2%)</b>	15787.6 <b>(55.2%)</b>

Out of the total PM emission load of 3.27 tons/day, the highest contribution is from HDDV vehicles (81.5%) i.e, 2.7 tons/day. Followed by HDDV, 3 and 2 wheelers, car diesel and CNG Buses emission contribution is more. The emission load of PM attributed to movement of Heavy Duty Diesel (HDD) Vehicles within the region mostly from North and South region. 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 PM observed to be 86.8% (i.e. 462 Kg/d) from 3511.4 Kg/day after implementation of BS-IV, likewise 94% (i.e. 223.3 Kg/d) from 3774.7 Kg/day after implementation of BS-VI. Similarly, NOx reduction can possible upto 30% after implementation of BS IV, whereas drastic reduction can possible i.e. 91% after BS VI.

About 50-60% of PM and NOx reduction can be achieved on short term basis with respect to public transport, 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 30-40% of reduction in both emissions scenario. The change of Electric vehicles and Hybrid vehicles in long term gives better results (40-50%). Among retrofitment, if technology of DOC will used in HDDV vehicles, then reduction can possible for PM around 50-60%. The paving of road will probably reduce the road dust emission by 25% in 2020 and 54% 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.

### 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 prioritized 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 NO<sub>x</sub> 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 2022 (**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 Navi Mumbai 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 NO<sub>x</sub>.

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

Category		Control Options	Scenario 2012	Scenario 2017
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]
			Power Plant : Coal to NG -50%	100% 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%	
	Ports	Awareness and Management		
	Airports	Awareness and Better Inventory		
	Railways	100% on electric	100% on electric	



Though some of the options were selected on the basis of PM reduction potential, their possible co-benefits in reducing NO<sub>x</sub> 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 NO<sub>x</sub> 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<sub>10</sub> 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	182.4	193.8	206.3	117.3	70.6
Area Source	5.7	6.1	6.5	3.7	2.2
Line Source	20.4	21.9	23.6	13.3	8.1
Point Source (LSI)	65.2	65.2	65.2	39.5	22.3
Point Source (MSI)	0.27	0.27	0.27	0.16	0.09
Point Source (SSI)	1.16	1.16	1.16	0.71	0.40
Resuspension Dust	148.3	159.6	171.6	96.6	58.7

- Concentrations in  $\mu\text{g}/\text{m}^3$

**Table 8.3 : Comparison of NO<sub>x</sub> 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	206.2	218.9	233.0	131.6	141.3
Area Source	18.5	19.5	20.8	11.7	12.6
Line Source	169.0	181.7	195.2	109.2	118.4
Point Source (LSI)	65.9	65.9	65.9	39.6	39.9
Point Source (MSI)	2.2	2.3	2.19	1.35	1.37
Point Source (SSI)	7.8	7.9	7.87	4.7	4.8

- Concentrations in  $\mu\text{g}/\text{m}^3$

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 NO<sub>x</sub> is presented in **Figure 8.9 and 8.10** respectively.

A) Predicted Scenario for PM

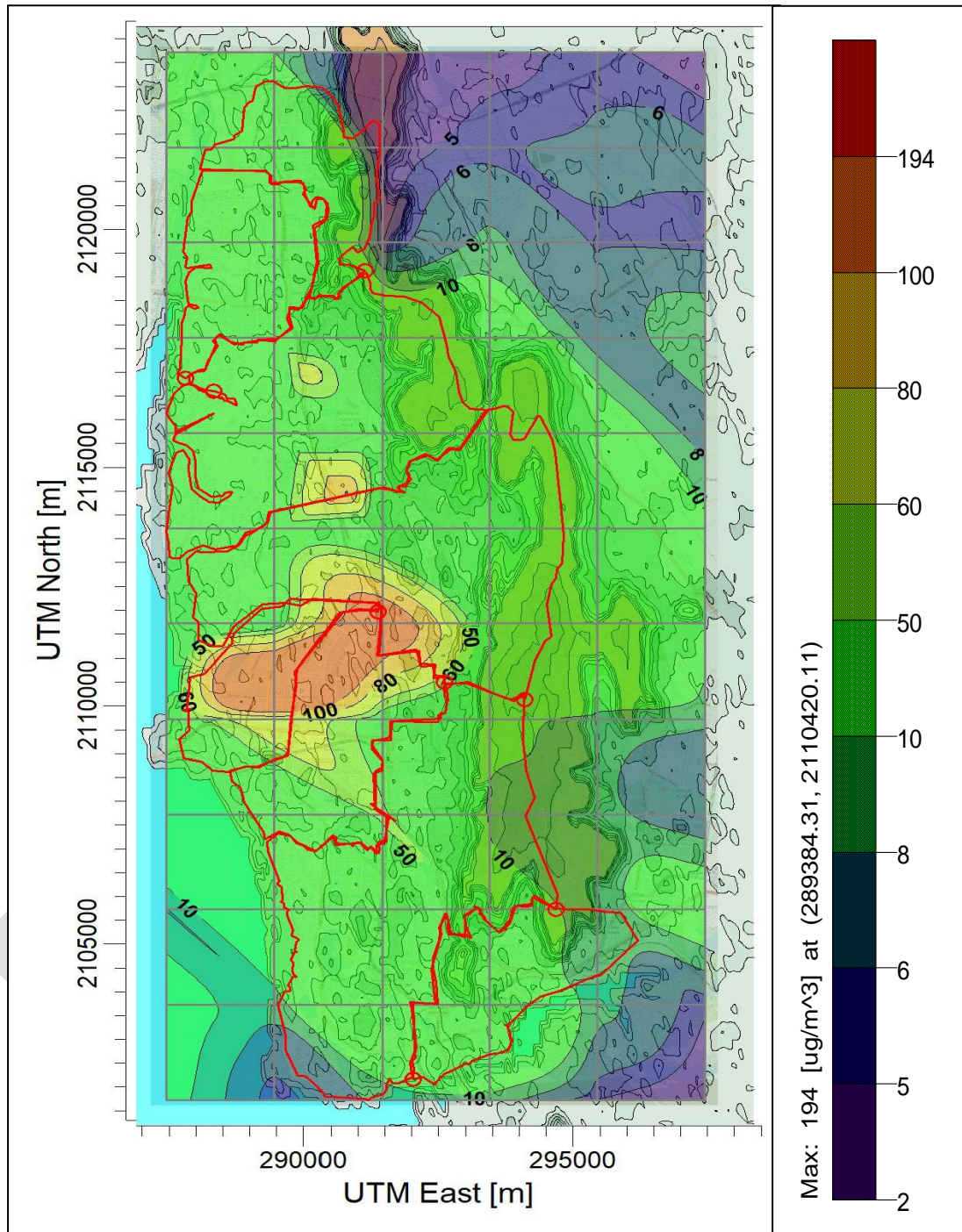
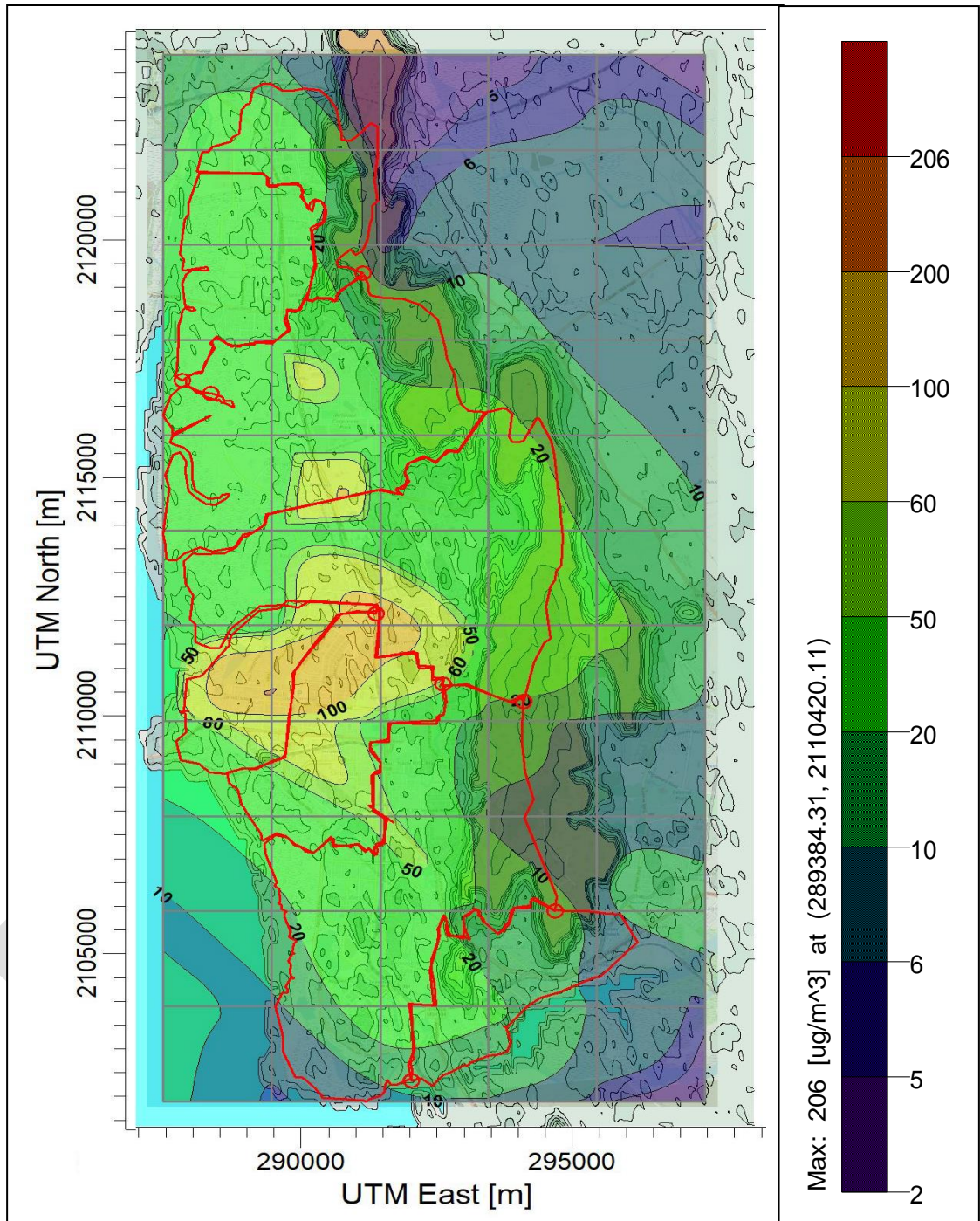
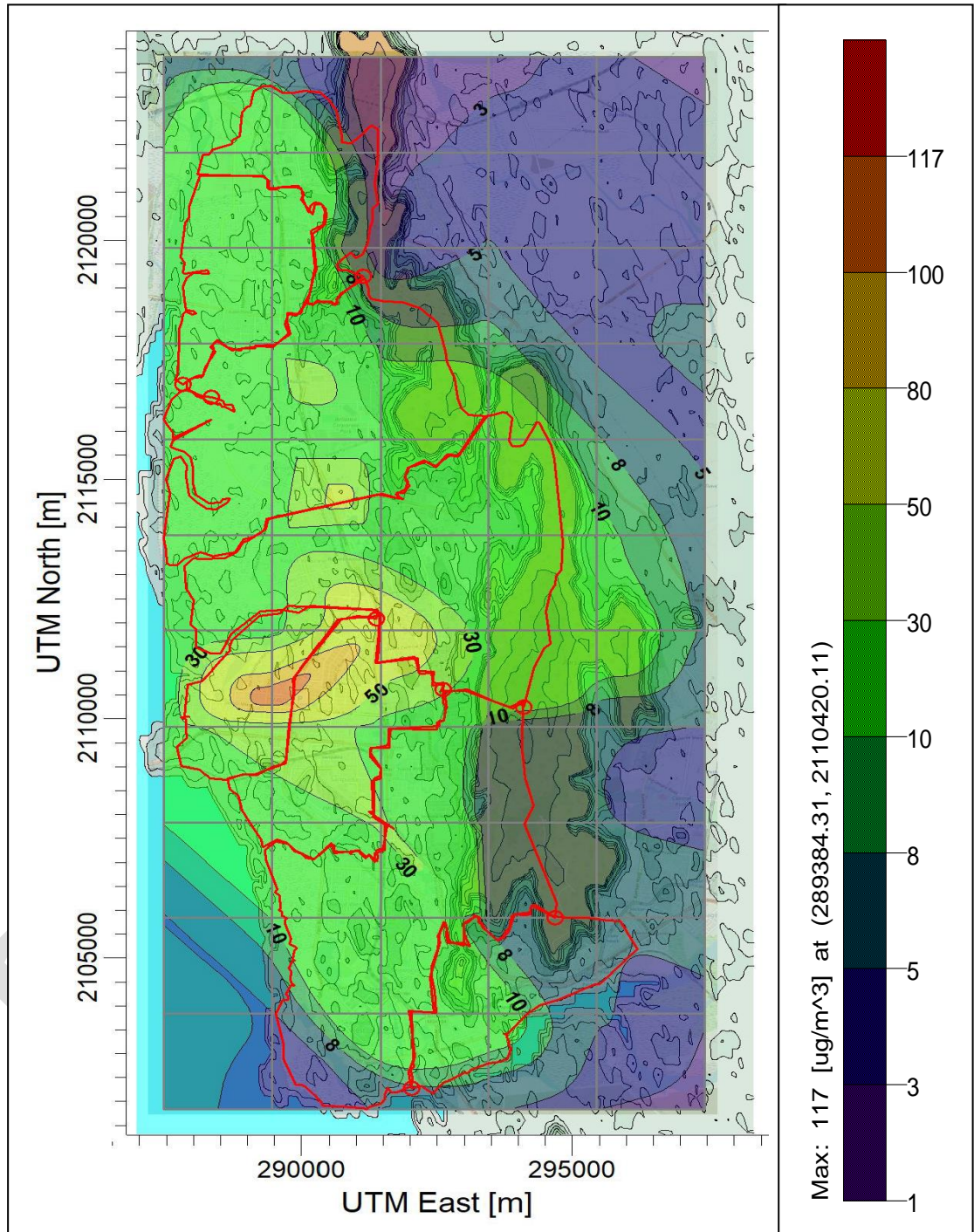


Figure 8.1 : Isopleths of PM Due to All Source– BaU 2020 (Navi Mumbai City)

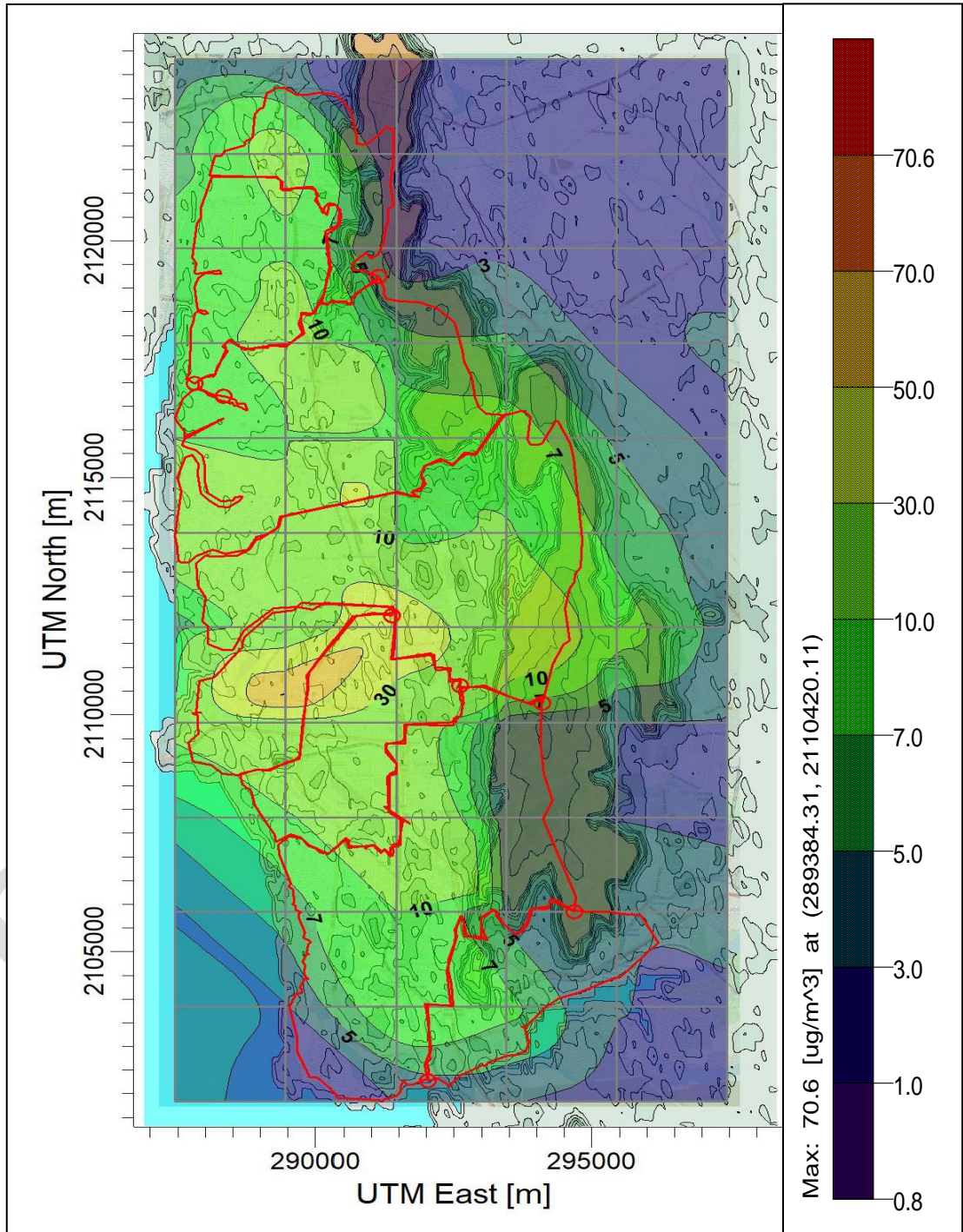


**Figure 8.2 : Isopleths of PM Due to All Source– BaU 2025  
(Navi Mumbai City)**





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



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



A) Predicted Scenario for NOx

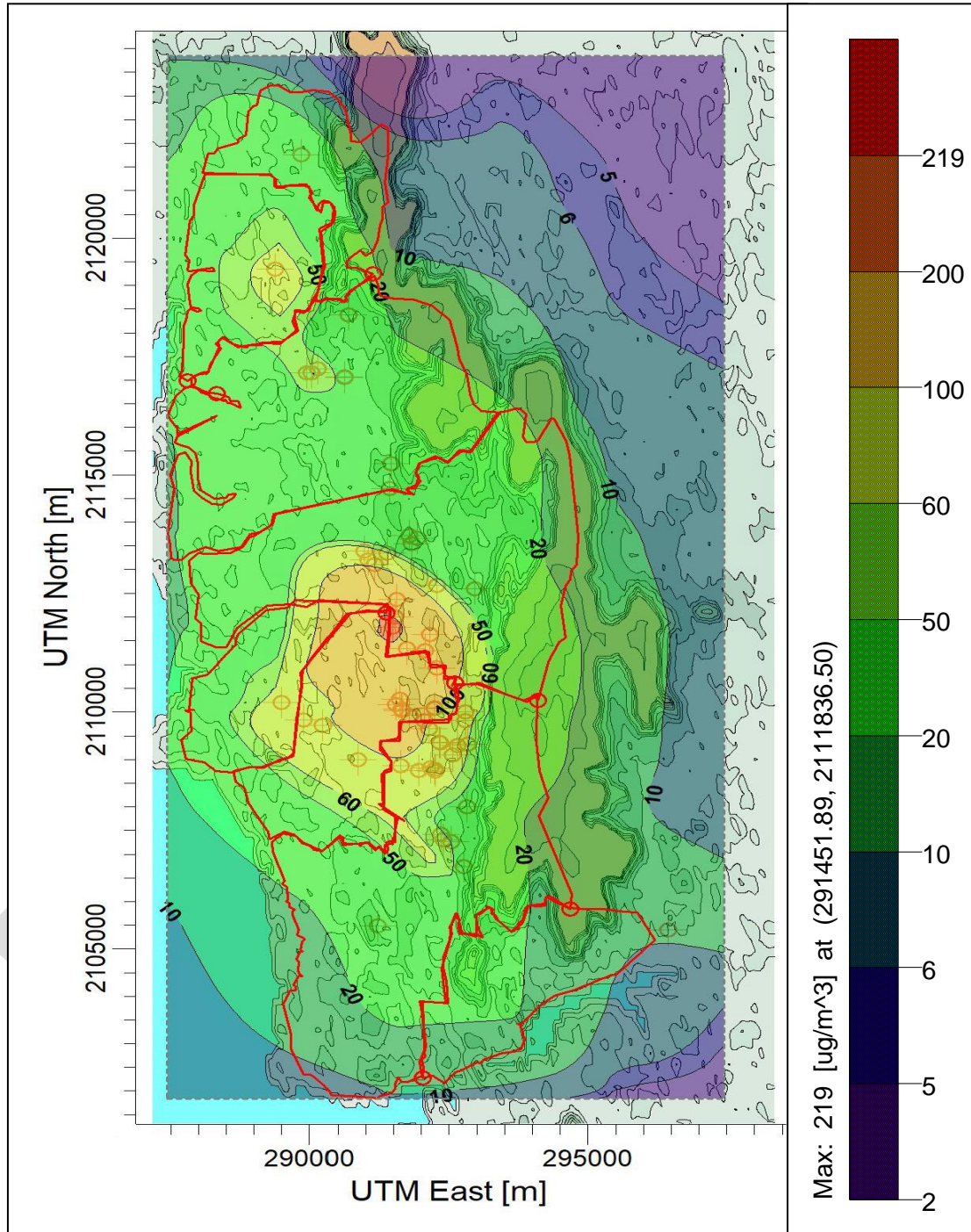
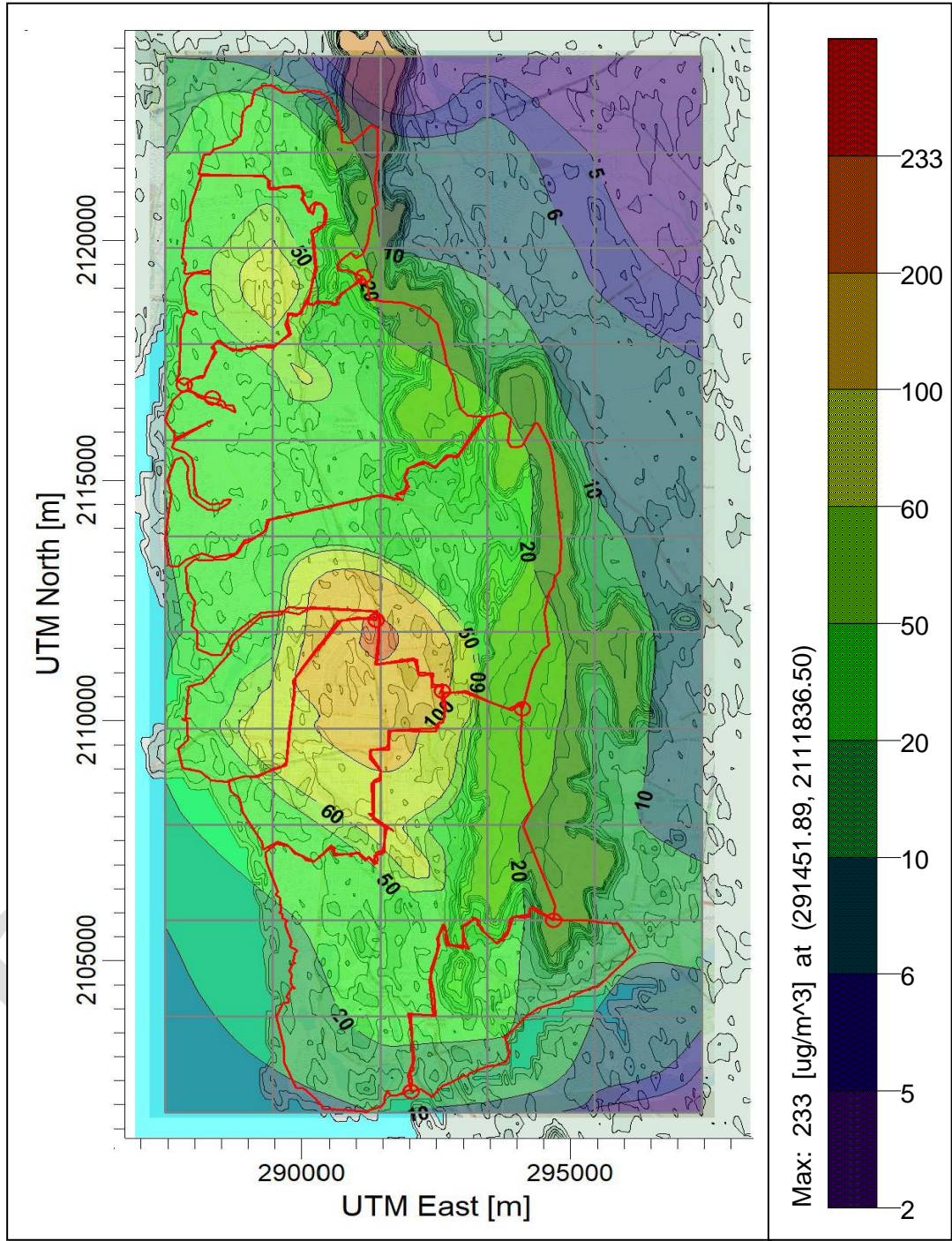
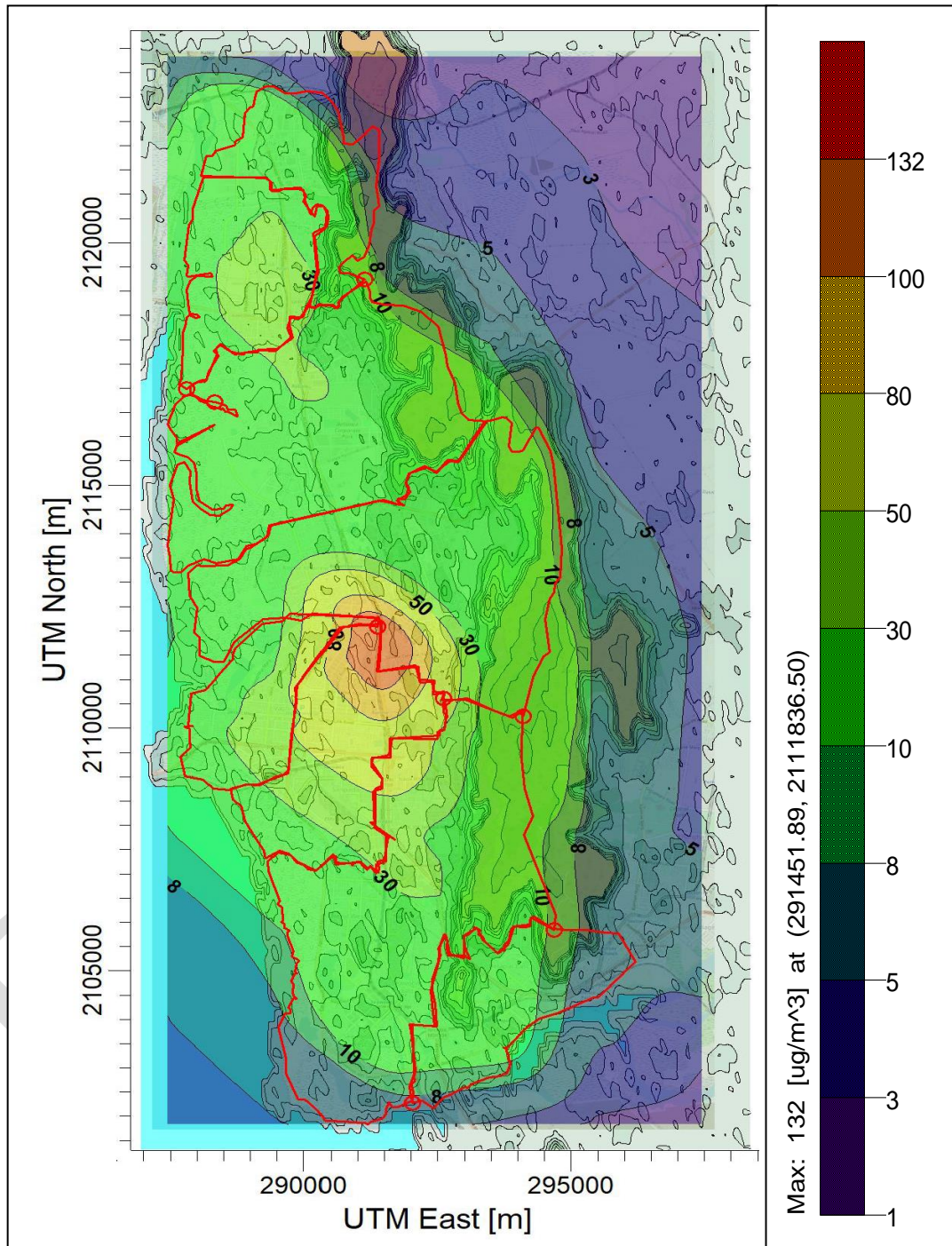


Figure 8.5 : Isopleths of NOx Due to All Source– BaU 2020 (Navi Mumbai City)



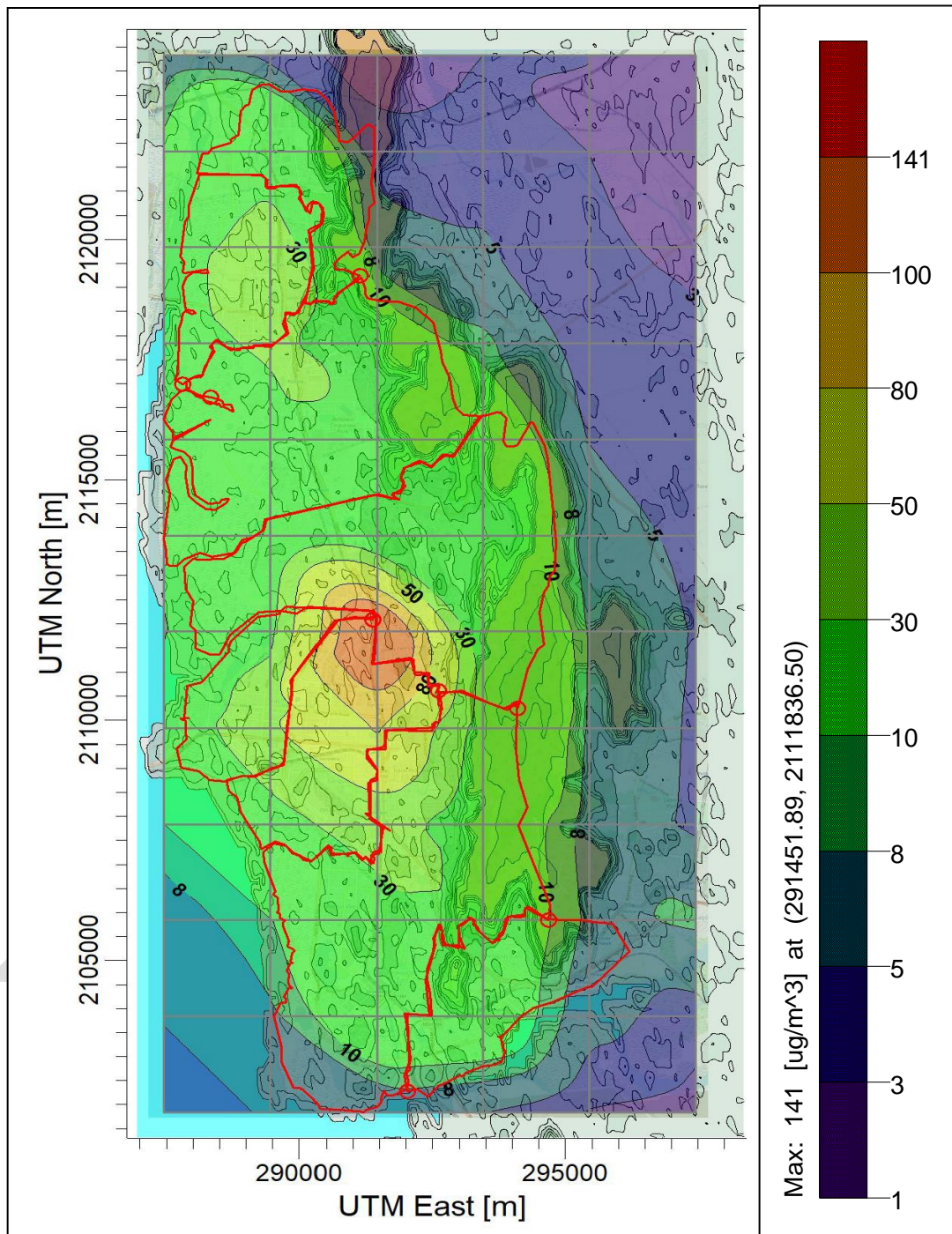
**Figure 8.6 : Isopleths of NOx Due to All Source– BaU 2025  
(Navi Mumbai City)**



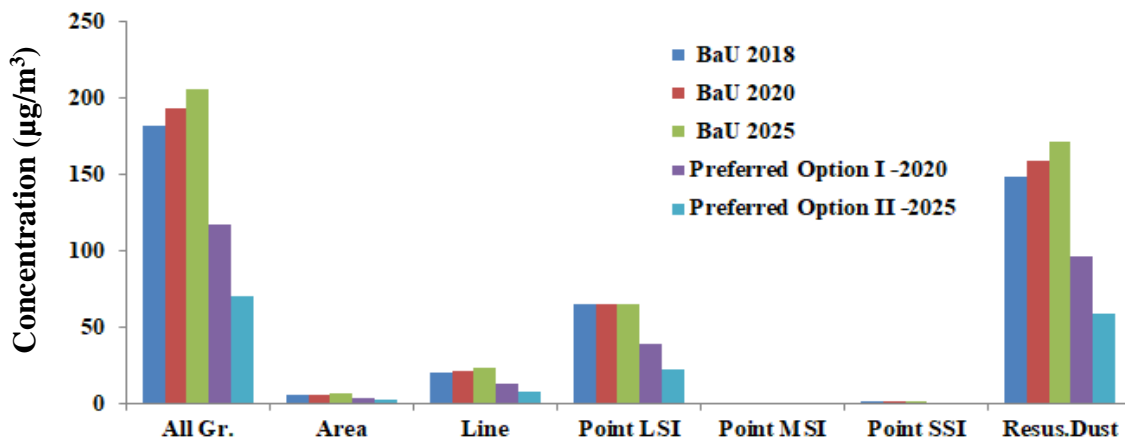


**Figure 8.7 : Isopleths of NO<sub>x</sub> Due to All Source– Preferred Options I - 2020 (Navi Mumbai City)**

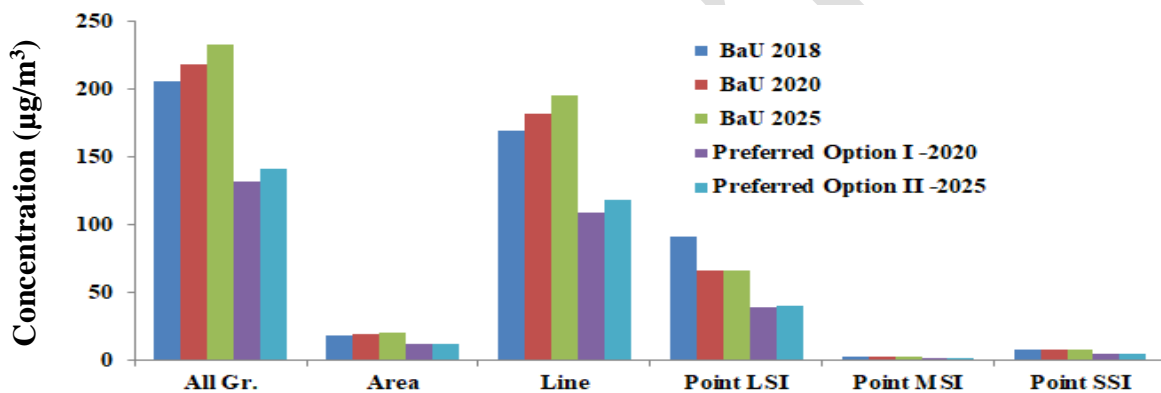




**Figure 8.8 : Isopleths of NOx Due to All Source– Preferred Options II - 2025 (Navi Mumbai City)**



**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  $182.4 \mu\text{g}/\text{m}^3$  and that will increase upto  $193.8 \mu\text{g}/\text{m}^3$  in 2020 and  $206.3 \mu\text{g}/\text{m}^3$  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  $117.3 \mu\text{g}/\text{m}^3$ , whereas for Preferred Option II (all vehicles scenarios 1 to 11; industrial and area sources) it is coming around  $70.6 \mu\text{g}/\text{m}^3$ . That means the reduction can be observed upto 36% in short term and 61% in long term as per dispersion modeling, which is also coming line with reduction option calculation without modeling upto 40% in short term and 50% long term as discussed earlier in reduction strategies for control option chapter.

The other source contributions such as area source increases from  $5.7$  to  $6.5 \mu\text{g}/\text{m}^3$  from 2018 to 2025 as liner growth, after control option implementation, as preferred option I (2020) and II (2025) it will decreases from  $3.7 \mu\text{g}/\text{m}^3$  to  $2.2 \mu\text{g}/\text{m}^3$  in 2020 and 2025 respectively. Line source also decreases from  $20.4 \mu\text{g}/\text{m}^3$  to  $13.3 \mu\text{g}/\text{m}^3$  in 2020 and  $8.1 \mu\text{g}/\text{m}^3$  in 2025, and if we not

considered any preferred option the BaU 2025 concentration may reach upto  $23.6 \mu\text{g}/\text{m}^3$  for line source. The both dispersion modeling and reduction control option for line source gives the reduction upto 30% to 50% in short and long term respectively. The pockets of high concentration are observed close to major traffic junctions in central part city i.e near Vashi and Pawane area, where major interlinkages or roads viz. Thane Belapur and Sion Panvel Highway exist. Due to APMC market and industrial connectivity, approx 2148235 VKT movement was observed for Heavy Duty Vehicles. Amongst the total emission of PM from vehicular sector, 25.67% of emissions are from Ward C-Vashi, contributing 838.4 Kg/day of PM. The Heavy Duty vehicles contribute 12.8% of the total PM load. At discrete cartesian location at highest concentrations reported at Vashi area and Pawane area.

The industrial source will not give any impact as there is no growth scenario in the city of Navi Mumbai, the concentrations of is coming around  $65.2 \mu\text{g}/\text{m}^3$  which will further, reduces upto  $39.5 \mu\text{g}/\text{m}^3$  in 2020 and  $22.3 \mu\text{g}/\text{m}^3$  in 2025, if we shifting fuel quality from fossil fuel to NG. The dispersion modeling for preferred options gives reduction upto 40% in 2020 and 66% in 2025, whereas without dispersion modeling reduction option calculations gives 54% in short term and 94% in long term for industrial source.

As we are observed from emission inventory 50% contribution is from resuspension of dust i.e. (39% Unpaved and 16% Paved), which is also reflected in dispersion modeling for BaU 2018 and gives concentration of  $148.3 \mu\text{g}/\text{m}^3$  out of  $182.4 \mu\text{g}/\text{m}^3$  from all source group. If we considered the preferred options I and II (i.e. pavement and widening of unpaved roads, vehicular resuspension, controlling road constructions and building activities) it will bring down the concentrations upto  $96.6 \mu\text{g}/\text{m}^3$  in short term and  $58.7 \mu\text{g}/\text{m}^3$  in long term, which will reduce the concentrations upto 30% to 50% as per dispersion modeling, similar percent is noticed without the dispersion modeling calculations.

In current scenario, the concentrations of emission is exceeding the CPCB standard i.e.  $100 \mu\text{g}/\text{m}^3$  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 resuspension of dust will be reduce. Anthropogenic activities like construction, vehicular resuspension will be managed, but natural dust remains and concentrations will be noticed above the standard.

In case of NO<sub>x</sub> the predicted ground level concentrations for all source group for BaU 2018, the concentrations of NO<sub>x</sub> range around 206.2 µg/m<sup>3</sup> and that will increase upto 218.9 µg/m<sup>3</sup> in 2020 and 233 µg/m<sup>3</sup> in 2025, if the growth factor is liner. After running the Preferred Option I and II the predicted concentrations goes down upto 131.6 µg/m<sup>3</sup> and 141.3 µg/m<sup>3</sup> in short and long term respectively. The reduction is not substantial it is coming upto 31 -36% in both the cases.

The other source contributions for NO<sub>x</sub> will also decrease viz. area source i.e. 18.5 µg/m<sup>3</sup> (2018) to 11.7 to 12.6 µg/m<sup>3</sup> in 2020 and 2025. Vehicular source is the major contributor, out of 206.2 µg/m<sup>3</sup> from all sources, the line source share 80% i.e. 169 µg/m<sup>3</sup>. Predicted line source also decreases from 169 µg/m<sup>3</sup> to 109.2 µg/m<sup>3</sup> in 2020 and 118.4 µg/m<sup>3</sup> in 2025; and if we not considered any preferred option the concentration may reaches upto 181.7 to 195.2 µg/m<sup>3</sup> for line source in BaU 2020 and BaU 2025 respectively. The both dispersion modeling and reduction control option for line source gives the reduction upto 30% to 40% in short and long term respectively. If rigorous BS-VI scenario will be implemented then NO<sub>x</sub> reduction can be achieved upto 91%. The hotspot for major traffic junctions will not change the concentrations range which is in between 40 to 195 µg/m<sup>3</sup>.

The industry will also share the major role in NO<sub>x</sub>, out of 206.2 µg/m<sup>3</sup> the point source gives (65.91) µg/m<sup>3</sup> i.e. (31)% in BaU 2018, conversion of fuels to NG will increase the NO<sub>x</sub> emission. With no growth scenario and partly shifting of fuel the concentration of 2020 and 2025 will comes around 65.9 µg/m<sup>3</sup>, and if the preferred option I and II considered the concentrations decreases upto 39.6 to 39.9 µg/m<sup>3</sup>. The dispersion modeling for preferred options gives the reduction upto 40% in short term and long term, whereas without dispersion modeling reduction would 8 to 9% for the both the years for industrial source. The all group annual impact of NO<sub>x</sub> concentrations shows that, it is exceeding the CPCB 24 hourly standard of 80 µg/m<sup>3</sup> 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. Navi Mumbai 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
<b>Strategy : Vehicles: Emission Reduction per unit Fuel Used</b>						
<b>S reduction in diesel</b>	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 <sub>2</sub> emission leading to lower ambient SO <sub>2</sub> and sulphate. It will also allow better functioning of exhaust after treatment devices.	Oil companies, Ministry of Petroleum, vehicle manufacturer
<b>Reduce fuel adulteration</b>	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
<b>Strategy : Vehicles: Emission Reduction per unit Fuel Used</b>						
<b>Alternative fuels</b>	Technical infrastructure in Navi Mumbai for dispensing CNG/LPG is fairly good and is improving	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
<b>Phase out of grossly polluting vehicles</b>	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
<b>Strategy : Vehicles: Emission Reduction per unit distance travelled</b>						
<b>Congestion reduction</b>	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	NMMC, MMRDA, MMRCL, CIDCO, MSRDC, State Government Transport police, other agencies.
<b>Standards for new and In-use vehicles</b>	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
<b>Introduction of new technology vehicles</b>	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
<b>Strategy : Vehicles: Emission Reduction per unit distance travelled</b>						
<b>Retrofitment of new engine/ Emission control device</b>	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. The APC market movements of truck entering into the city boundary will restricted, if control measures are not taken. High levels of compliance expected.	Truck Association, Transport Office Govt. Maharashtra, vehicle manufacturer, MoRTH, MSRDC
<b>Higher usage of Public Transport</b>	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 MUTP, CIDCO, Urban Planners, and City Development Planers, Metro Rail Corporation.	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.	NMMT, BEST, KDMT , KMT NMMC, MMRDA, MSRDC, MMRCL, 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
<b>Strategy : Vehicles: Emission Reduction per unit distance travelled</b>						
<b>Decrease Private vehicles on Road</b>	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 own their own garages, less parking on the roads, less congestion	Transport Office Govt. Maharashtra, RTO, NMMC, MMRDA
<b>Strategy : Vehicles: Emission Reduction -Awareness</b>						
<b>Training and Awareness programme for car owners, public transport operators, drivers and mechanics</b>	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., NMMC, MMRDA, CIDO, 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
<b>Strategy : Industries: Emission Reduction per unit Fuel Used</b>						
<b>S reduction in fuel</b>	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 Navi Mumbai, 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
<b>Combustion Processes</b>	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
<b>Alternate Fuel</b>	Large no of industries are using NG and LPG	The higher percentage of use of cleaner fuel has already 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 <sub>2</sub> , 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
<b>Strategy : Industries: Emission Reduction by Industrial Policy and Standards</b>						
<b>Promoting Cleaner Industries</b>	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 Pharmaceutical, Refineries,
<b>Fugitive Emission control</b>	Industrial process improvement better operation and maintenance	For localized region, very effective, particularly for industries with fine particles raw material or products. High efficiencies can be achieved for quarries.	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
<b>Strategy : Area Sources: Mixed sources and varied strategies</b>						
<b>Improve fuel used for domestic purposes</b>	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
<b>Bakeries /crematoria</b>	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	MMRDA, NMMC and MPCB
<b>Biomass/trash burning, landfill waste burning</b>	Better control on collection and disposal at the respective sites. Landfill waste burning needs proper technology driven site management	Local area can have substantial reduction in PM. Very high effectiveness to adjoining grids	Awareness and local control. Apathy to take urgent action. No burning day vow to be taken by NMMC	NMMC needs to address this issues	High level improvement in local area ambient air quality not only for PM but other pollutants	NMMC, MPCB, MMRDA

**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
<b>Strategy : Area Sources: Mixed sources and varied strategies</b>						
<b>Resuspension</b>	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	NMMC, CIDCO, MSRDC, MMRDA
<b>Illegal SSI</b>	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 BMC	It will lead to large scale reduction of fire accidents as well as minimization of wastewater problem	MPCB, DIC, NMMC
<b>Construction</b>	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	NMMC, MMRDA, CIDCO 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**

<b>Types</b>	<b>Components</b>
<b><i>Vehicular Sector</i></b>	
Fuel Related	<ol style="list-style-type: none"> <li>1. Alternative Fuel CNG/LPG</li> <li>2. Sulphur reduction</li> <li>3. Prevent fuel adulteration</li> </ol>
Vehicle Technology related	<ol style="list-style-type: none"> <li>1. Stringent Emission standards for new vehicles (Bharat IV and VI)</li> <li>2. Electric vehicles for high VKT vehicles</li> <li>3. Conversion of private diesel cars to CNG/LPG</li> <li>4. Fuel Efficiency standards</li> <li>5. Replacement of commercial diesel vehicles to CNG/LPG</li> <li>6. Retrofitment of catalytic converter &amp; diesel oxidation catalyst -older vehicles</li> <li>7. Phase out of older vehicles</li> <li>8. Retrofitment of older vehicles with Bharat Stage III engines with DOC</li> </ol>
In-Use vehicle	<ol style="list-style-type: none"> <li>1. Improvement and compliance system in existing PUC</li> <li>2. Inspection and identification of highly polluting vehicles</li> <li>3. Augmentation of manpower and related infrastructure for Inspection and Certification</li> </ol>
Policy and Public Processes	<ol style="list-style-type: none"> <li>1. Prioritization of public transport on roads (bus lanes, better buses, low cost of travel, faster travel, accessibility of transport).</li> <li>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</li> <li>3. Incentive/subsidy for voluntary inspection and maintenance of vehicles</li> <li>4. Incentive/subsidy to phase out grossly polluting vehicles</li> <li>5. Drivers and Mechanics Training programmes</li> <li>6. Public awareness on use of alternate fuel (CNG/LPG), adulteration of fuels, benefits of various maintenance measures.</li> </ol>
Road and Traffic Control	<ol style="list-style-type: none"> <li>1. Improvement of roads</li> <li>2. Transportation planning and better road maintenance</li> <li>3. Pavement improvement and better sweeping for less resuspension</li> <li>4. Road Congestion –encroachment etc.</li> <li>5. Traffic Management: signal synchronization, one way, pedestrian plaza</li> </ol>

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

<b>Types</b>	<b>Components</b>
<b><i>Industrial Sector</i></b>	
Fuel Related	1. Change of coal to NG 2. Change of LSHS to LDO
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
<b><i>Area Sector</i></b>	
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 to be stopped 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. Inclusion of road construction related burning in rules

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 Navi Mumbai 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. 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 NO<sub>x</sub> related pollution reduction but also co benefit of other pollutants (SO<sub>2</sub>, 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. Navi Mumbai 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 Navi Mumbai, when it is in close proximity of major urban centers.*



# **ANNEXURE - 1**

## **Emission Factors**

**(Area, Line and Point Sources)**

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## Annexure 1

### Emission Factors

#### A) Area Source

##### **Bakery**

###### Emission Factor for Wood Burning (kg/t)

PM<sub>10</sub> = 17.3, SO<sub>2</sub> = 0.2, NO<sub>x</sub> = 1.3, CO = 126.3, HC = 114.5 (VOC as HC)

\*PM<sub>2.5</sub> /PM<sub>10</sub> 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<sub>10</sub> =60% of SPM, PM<sub>2.5</sub> =40% of SPM, CO= 0.63, SO<sub>2</sub> =17.25S,

NO<sub>x</sub> = 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<sub>10</sub>=17.3, SO<sub>2</sub> = 0.2, NO<sub>x</sub> 1.3, CO =126.3, HC =114.5 (VOC as HC)

\*PM<sub>2.5</sub> /PM<sub>10</sub> 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<sub>10</sub> =0.61, SO<sub>2</sub> =4, NO<sub>x</sub> =2.5, CO=62, HC =19

URBAIR, *Working Group 1992 - Kerosene, Residential Emission Factor - Electric* (kg/ body)

###### Emission Factor Electric (kg/body)

PM<sub>10</sub> =0.000025, SO<sub>2</sub> = 0.0544, NO<sub>x</sub> =0.308, CO =0.141, NVOC =0.013

\*PM<sub>2.5</sub> /PM<sub>10</sub> 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<sub>10</sub> =2.10, SO<sub>2</sub> = 0.40, NO<sub>x</sub> = 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<sub>2.5</sub>

Emission factor for Kerosene : SPM=0.06, PM<sub>10</sub>=0.61, SO<sub>2</sub> =4, NO<sub>x</sub> =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<sub>2</sub> = 13.3, NO<sub>x</sub> =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<sub>2</sub> = 0.4, NO<sub>x</sub> = 1.8, VOC = 0.072

Emission Factor for Kerosene : PM<sub>10</sub>=0.61, SO<sub>2</sub> =4, NO<sub>x</sub> =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<sub>10</sub> =2.10, SO<sub>2</sub> = 0.40, NO<sub>x</sub> = 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<sub>2</sub> = 13.3, NO<sub>x</sub> =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<sub>10</sub> = 8, PM<sub>2.5</sub> =5.44, CO=42, SO<sub>2</sub>=0.5000,NO<sub>x</sub>= 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

PM<sub>10</sub>=0.99\*, CO =11.8, SO<sub>x</sub> =0.8, NO<sub>x</sub> =8.3, VOC=0.5

Emission factor international flight

PM<sub>10</sub>=0.99\*, CO =6.1, SO<sub>x</sub> =1.6, NO<sub>x</sub> =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/ ...](http://www.ecotourism.org/onlineLib/Uploaded/...) Airplanes emissions. PDF

PM<sub>2.5</sub>/PM<sub>10</sub> = 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<sub>10</sub> =1.03, CO =1.85, SO<sub>2</sub> =11, NO<sub>x</sub>= 10, VOC as HC = 0.83, Density of diesel = 0.86 (HSD) *UK-Shipping international-Fuel oil*

**Paved & Unpaved Dust**

Paved Road Dust : PM<sub>2.5</sub> = 0.39, PM<sub>10</sub>= 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/m<sup>2</sup> (\*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)**

<b>Vehicular Emission Factors (Gm/Km)</b>	<b>Car Petrol Post 2005 Fuel BSII</b>	<b>Car Diesel Post 2005 Fuel BSII</b>	<b>Car CNG Post 2000, Fuel BSII</b>	<b>Two Wheeler Post 2005 4 Stroke Fuel BS II</b>	<b>Three Wheeler CNG Retro 25 Post 2000 Fuel BS II</b>	<b>CNG Buses Post 2000 Fuel BS II</b>	<b>Trucks Diesel Post 2000 Fuel BSII</b>
PM	0.002	0.015	0.006	0.013	0.118	0.044	1.240
NO <sub>x</sub>	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

<b>Emission Factor for BS IV fuel</b>	<b>PM</b>	<b>NO<sub>x</sub></b>	<b>CO</b>	<b>HC</b>
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

<b>Emission Factor for BS VI fuel</b>	<b>PM</b>	<b>NO<sub>x</sub></b>	<b>CO</b>	<b>HC</b>
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.

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

Prior to 2010, emissions were tested using the ECE R49<sup>a</sup> 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<sup>b</sup> (World Harmonized Stationary Cycle) and WHTC<sup>c</sup> (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 <sub>2</sub>	NO <sub>x</sub>	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 <sup>\$\$</sup>	KL	0.02	0.072	0.01*S	2.52	0.07	0.43	
6.	NG	m <sup>3</sup>	-	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 <sup>##</sup>	Kg/t	0.25	0.06	17S	2.5	--	--	--
<b>For Power Plant**</b>									
1.	LSHS	KL	0.45	1.25*S + 0.38	19.25*S	6.25	0.12	0.63	
2.	NG	m <sup>3</sup>	-	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:

- 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
- Indian Oil Corporation Ltd, Vadodara

#### Density<sup>b</sup> of Fuels (Kg/m<sup>3</sup>)

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, SO<sub>2</sub>-0.18, NO<sub>2</sub>-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**

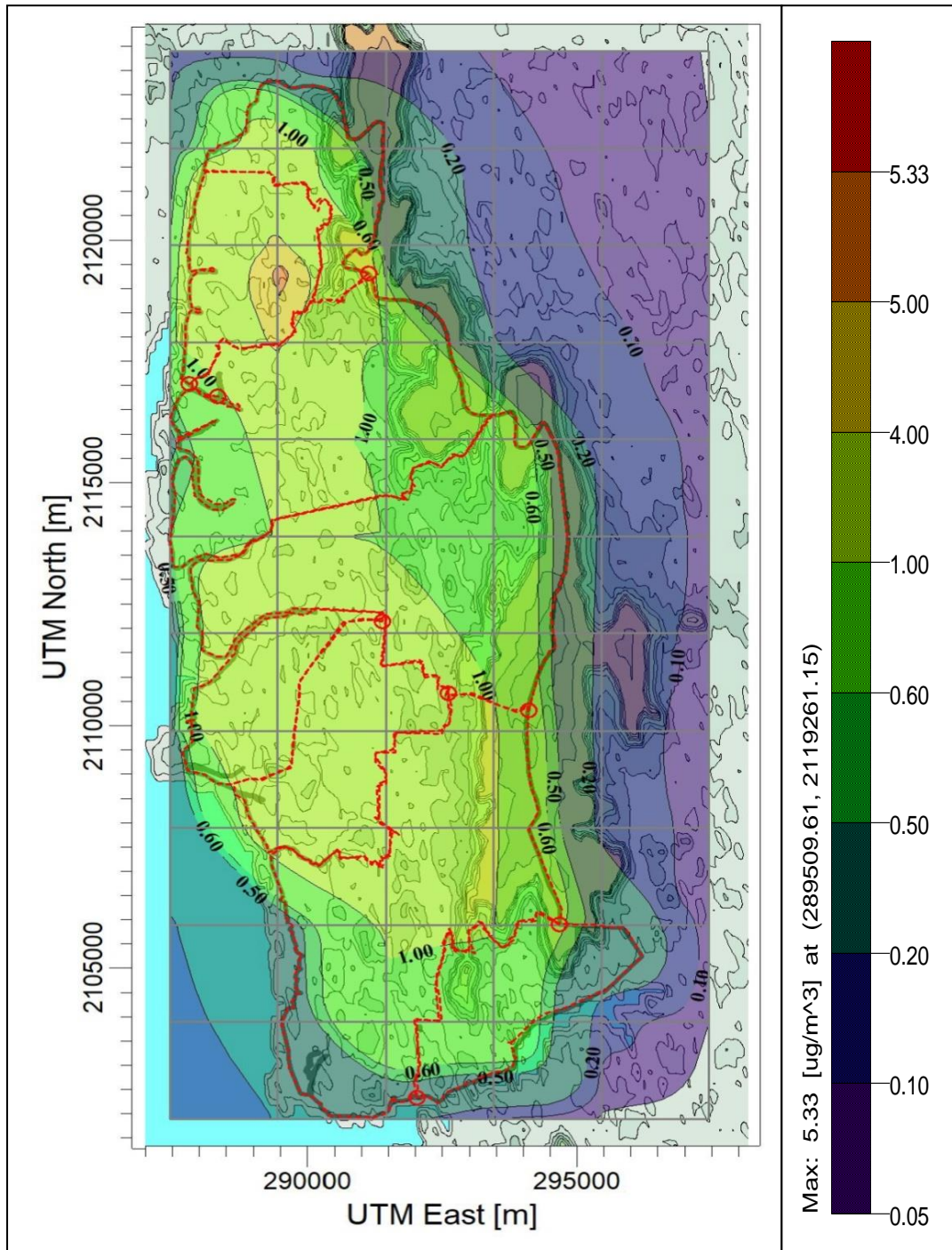
**&**

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

**(Navi Mumbai City)**

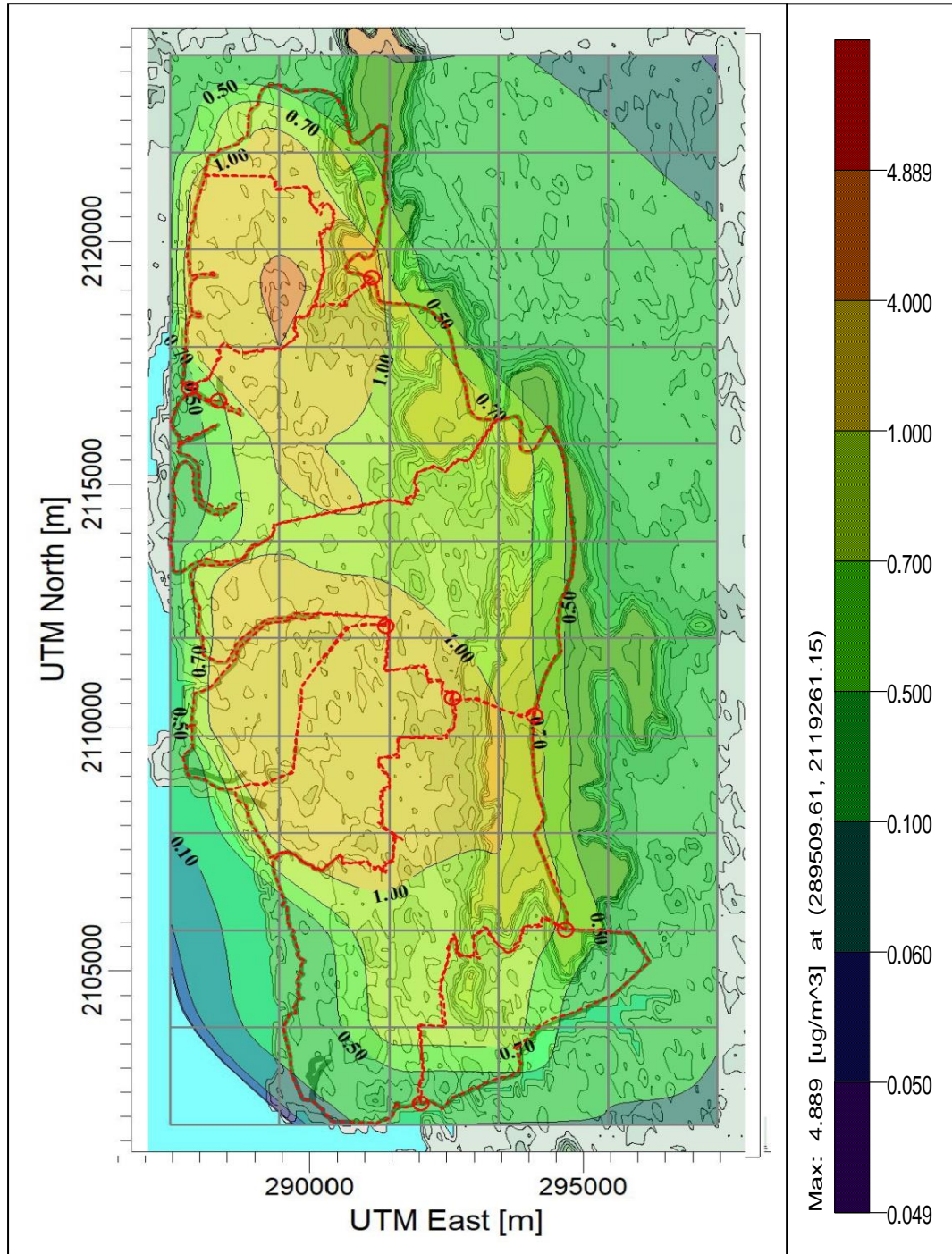
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### A) AREA SOURCE – ALL (PM)

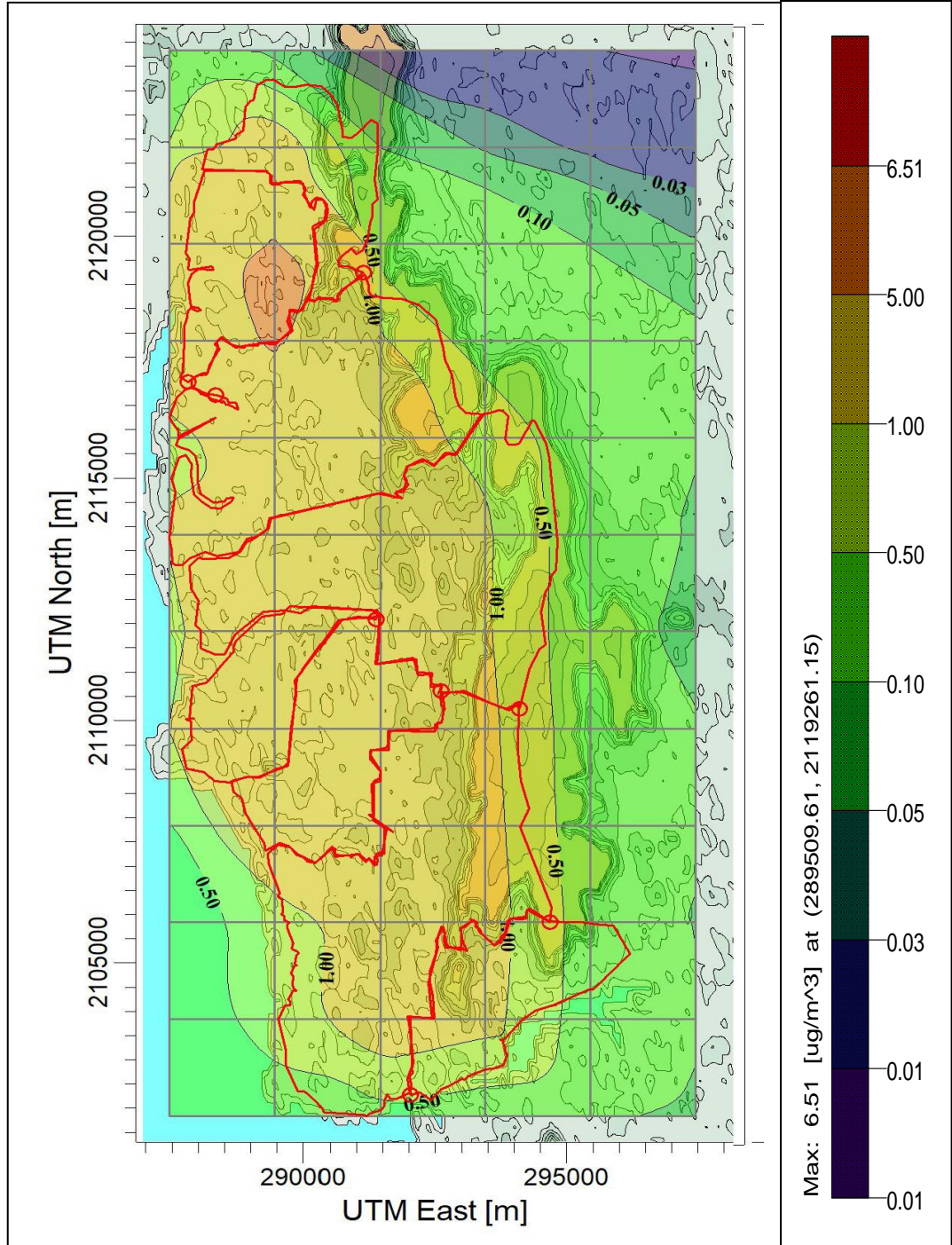


**Figure P1: Isopleths of PM Due to Area Sources – Summer Season (Navi Mumbai City)**



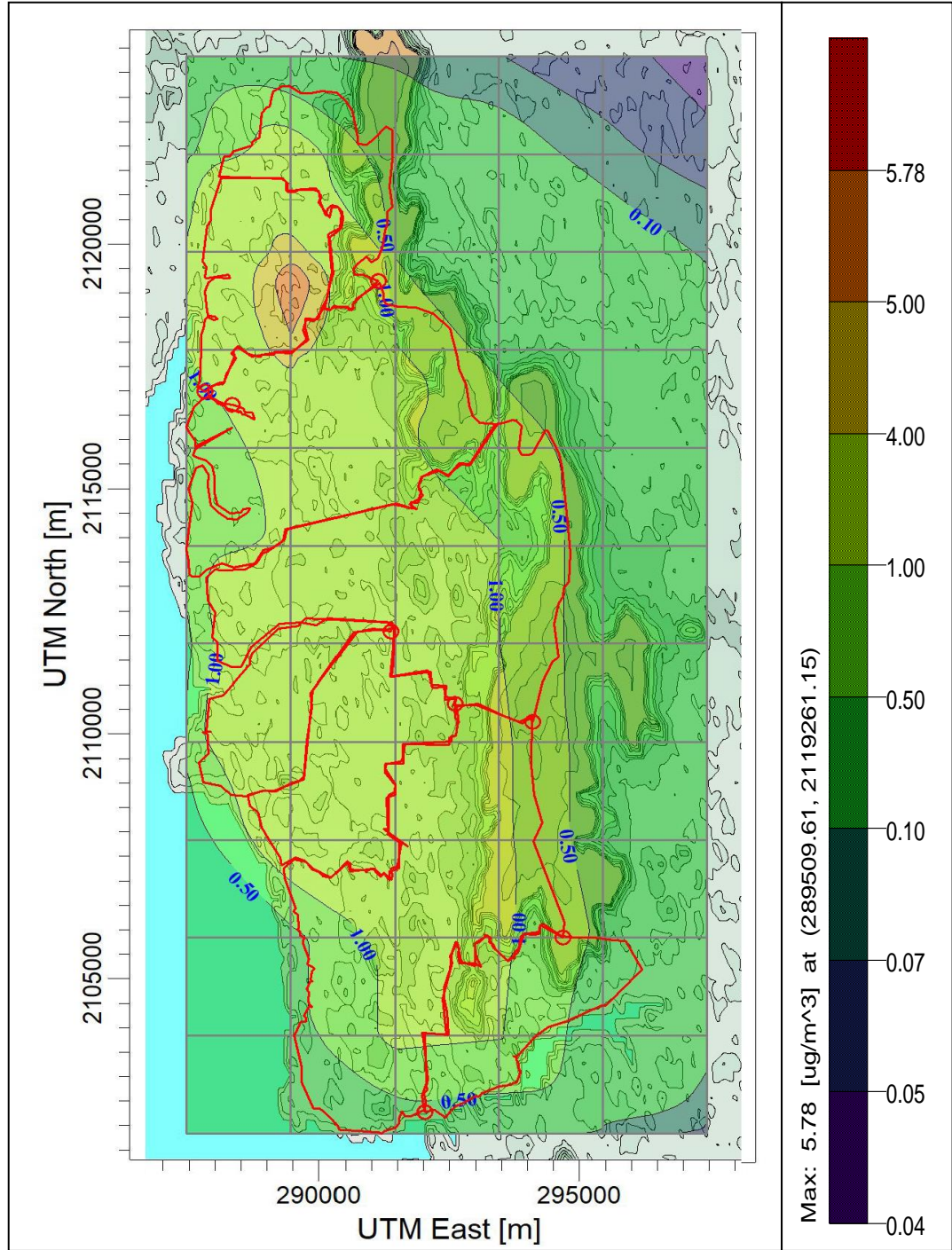


**Figure P2 : Isopleths of PM Due to Area Sources – Post Monsoon Season (Navi Mumbai City)**



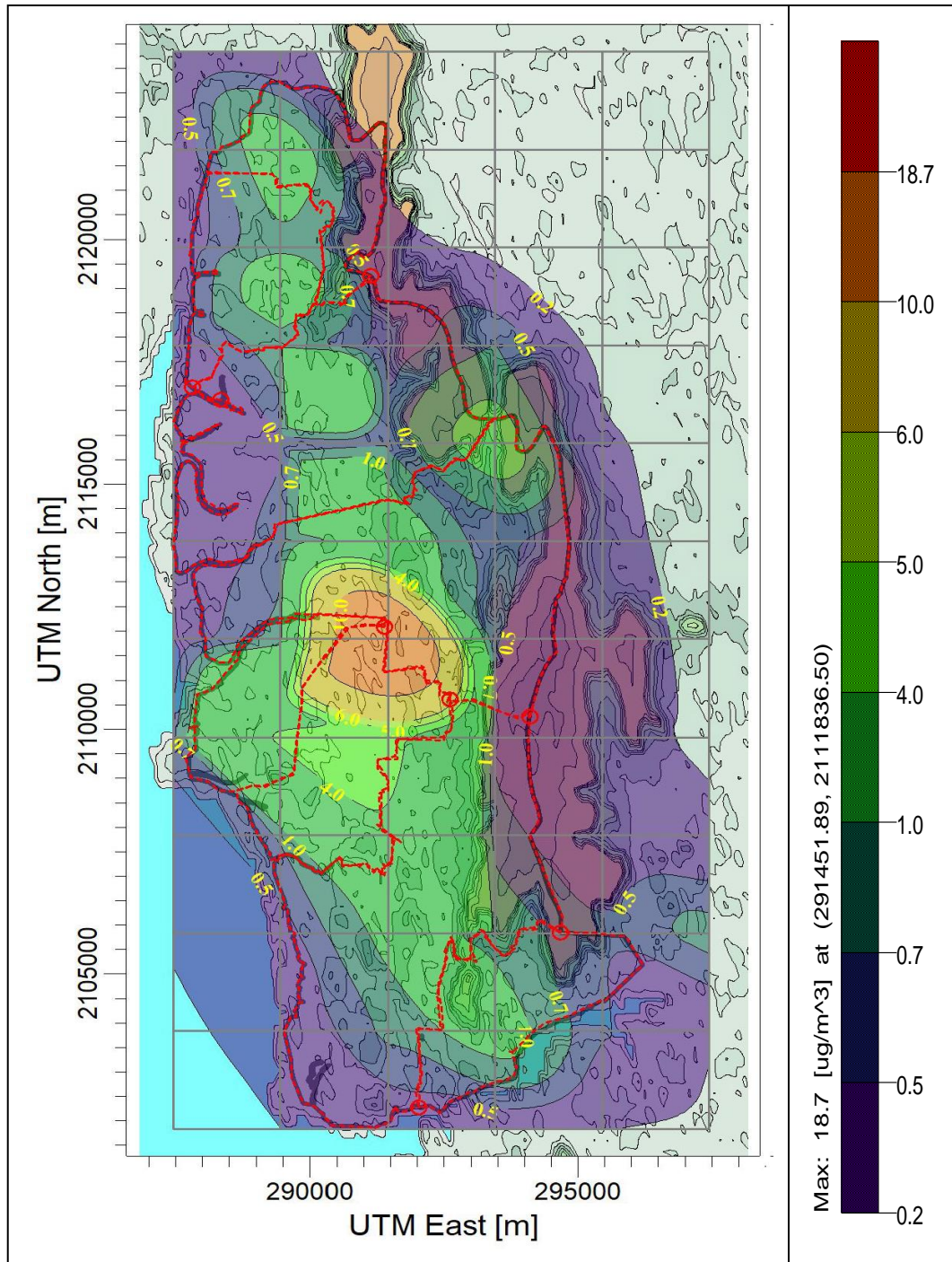
**Figure P3 : Isopleths of PM Due to Area Sources – Winter Season  
(Navi Mumbai City)**





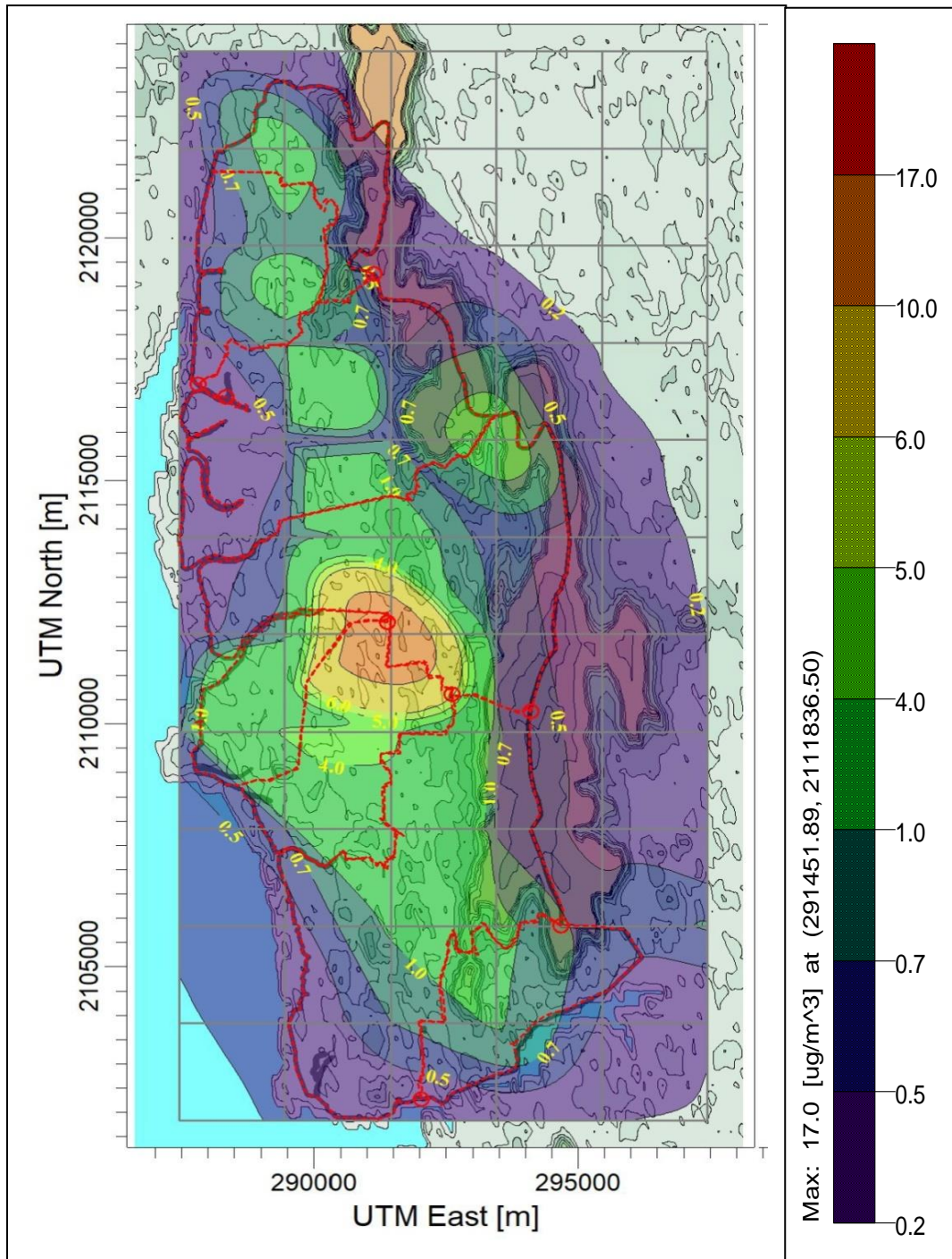
**Figure P4 : Isopleths of PM Due to Area Sources – Annual (Navi Mumbai City)**

## B) LINE SOURCE – ALL (PM)

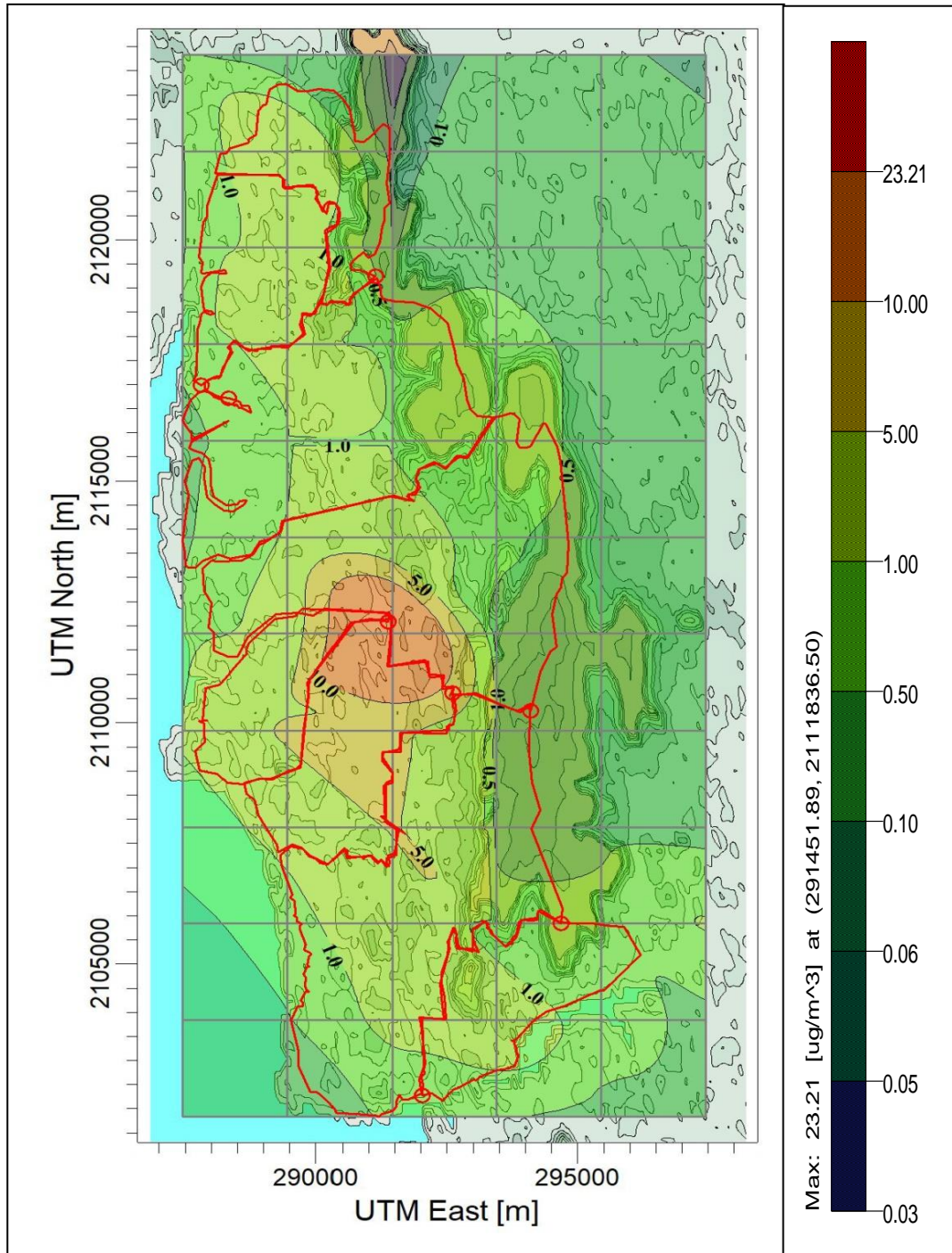


**Figure P5 : Isopleths of PM Due to Line Sources – Summer Season  
(Navi Mumbai City)**



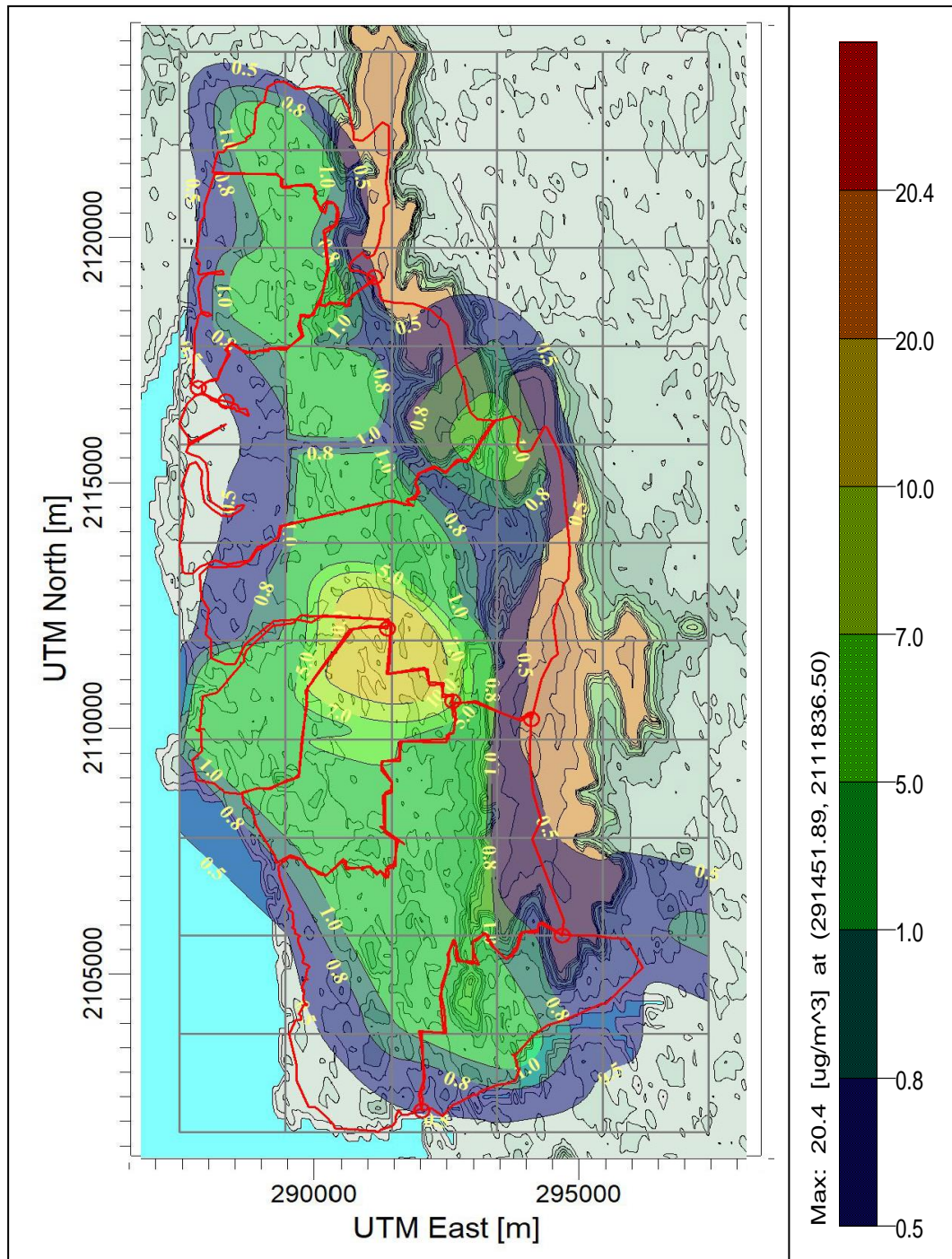


**Figure P6 : Isopleths of PM Due to Line Sources – Post Monsoon Season (Navi Mumbai City)**



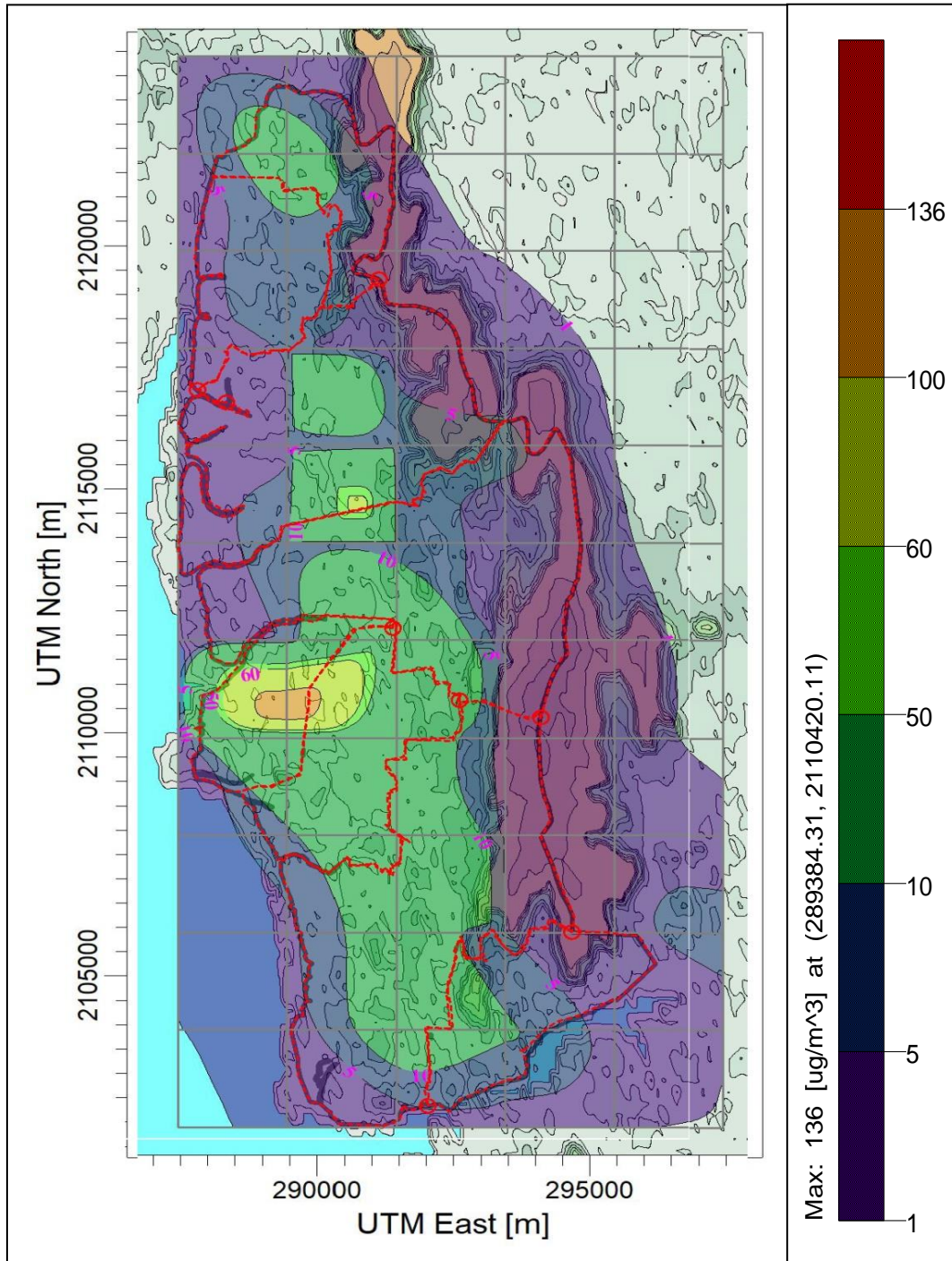
**Figure P7 : Isopleths of PM Due to Line Sources – Winter Season  
(Navi Mumbai City)**





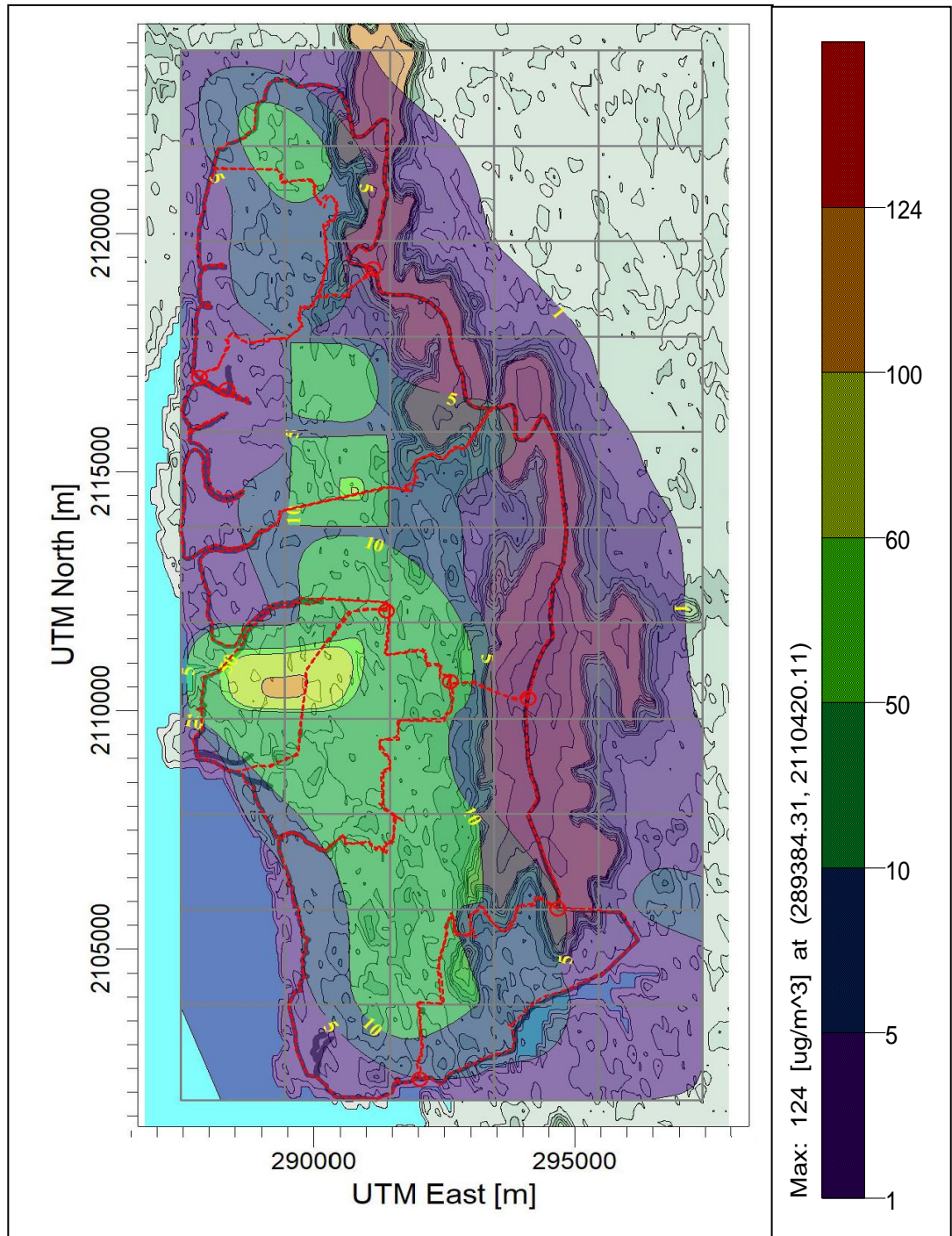
**Figure P8 : Isopleths of PM Due to Line Sources – Annual (Navi Mumbai City)**

### C) RESUSPENSION DUST- ALL (PM)

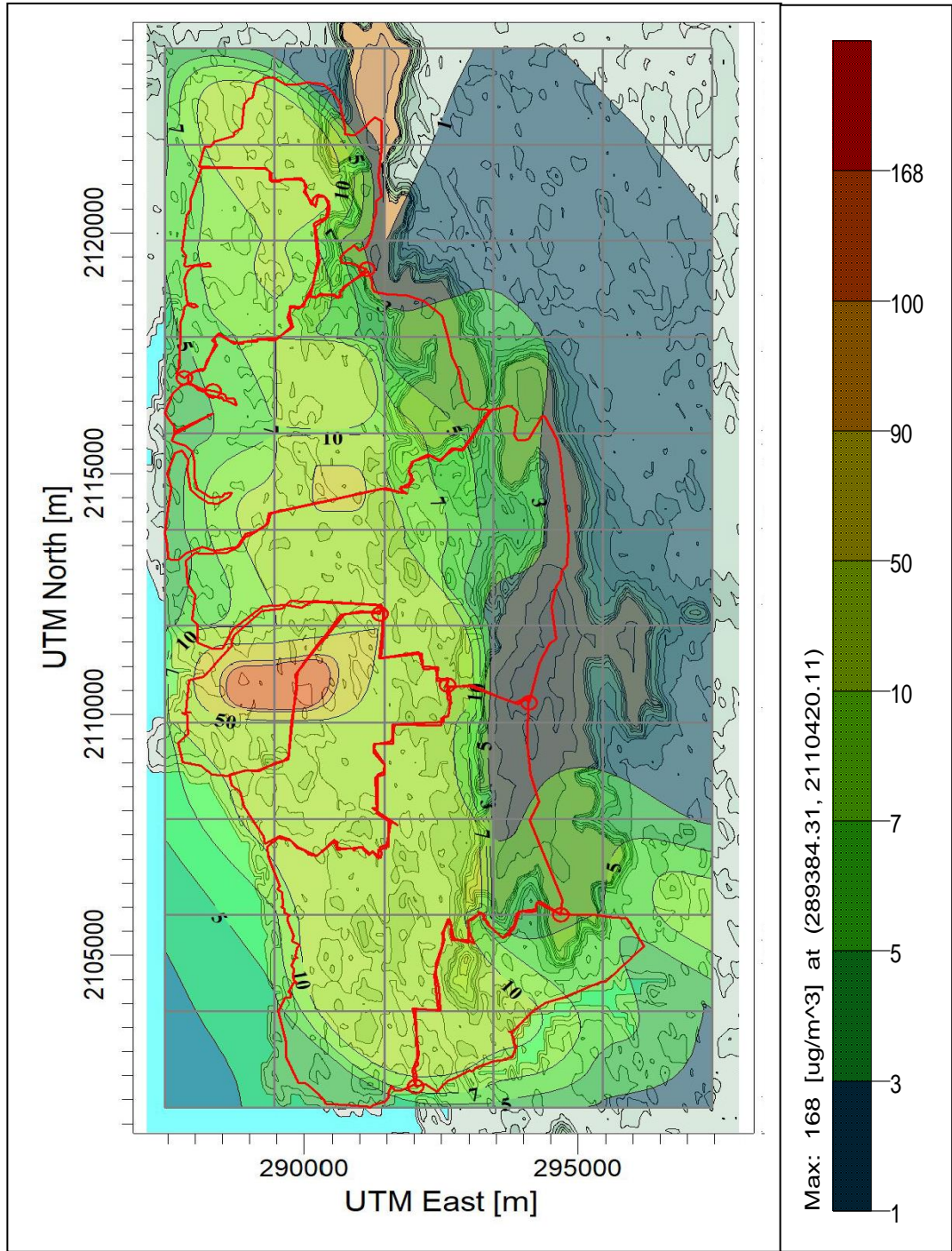


**Figure P9 : Isopleths of PM Due to Resuspension Dust- Summer Season (Navi Mumbai City)**



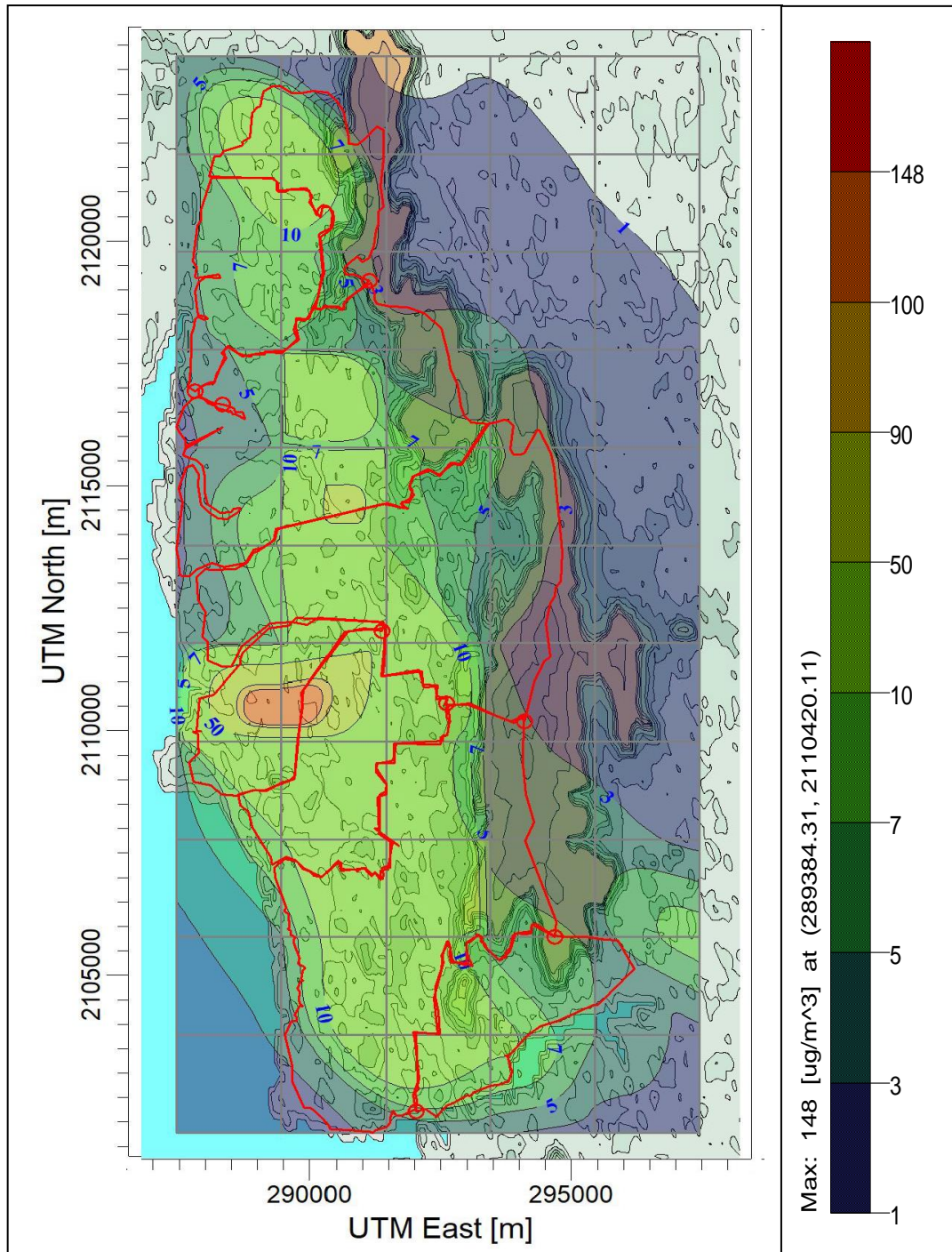


**Figure P10 : Isopleths of PM Due to Resuspension Dust– Post Monsoon Season (Navi Mumbai City)**



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





**Figure P12 : Isopleths of PM Due to Resuspension Dust– Annual (Navi Mumbai City)**

### D) POINT SOURCE – LSI (PM)

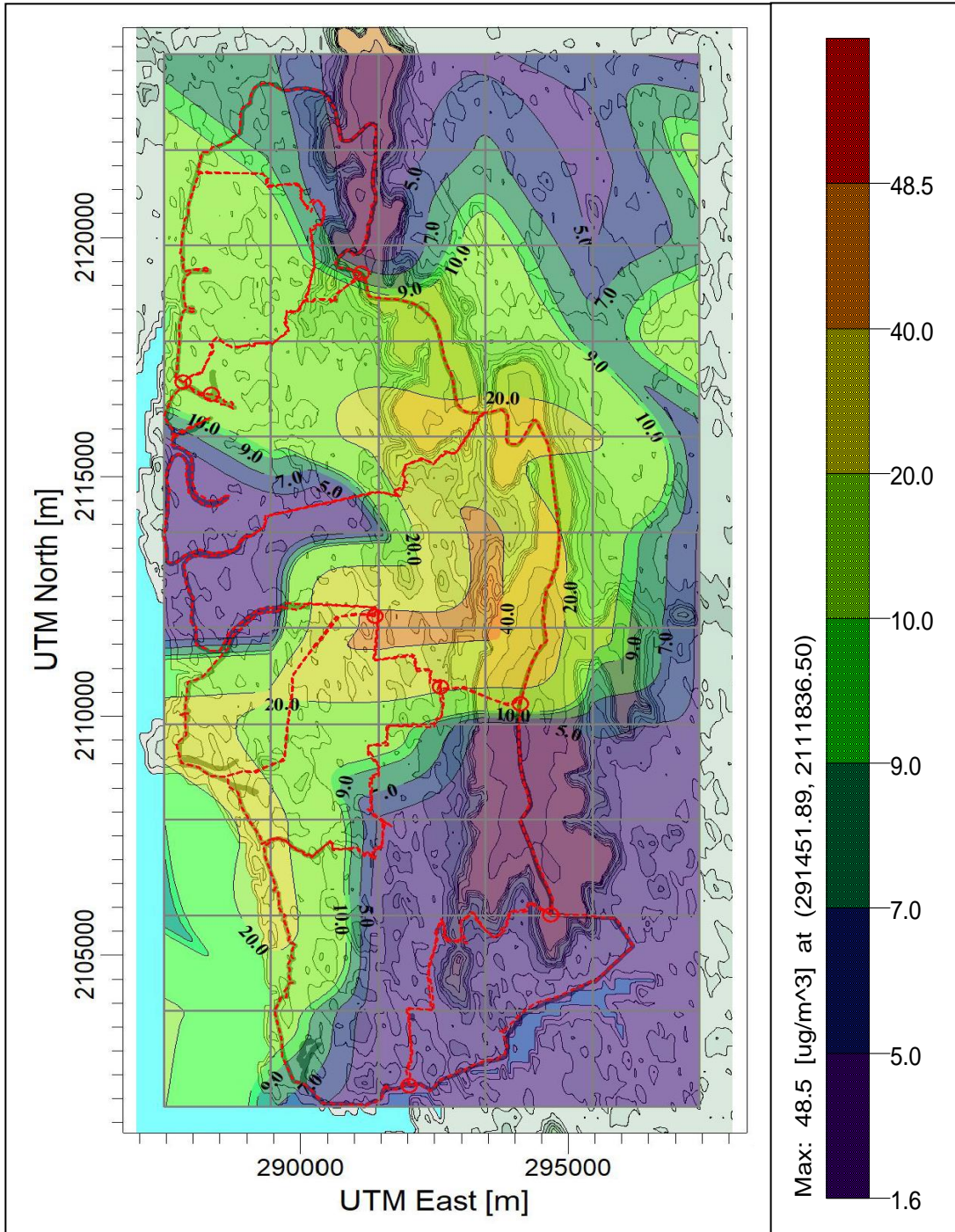
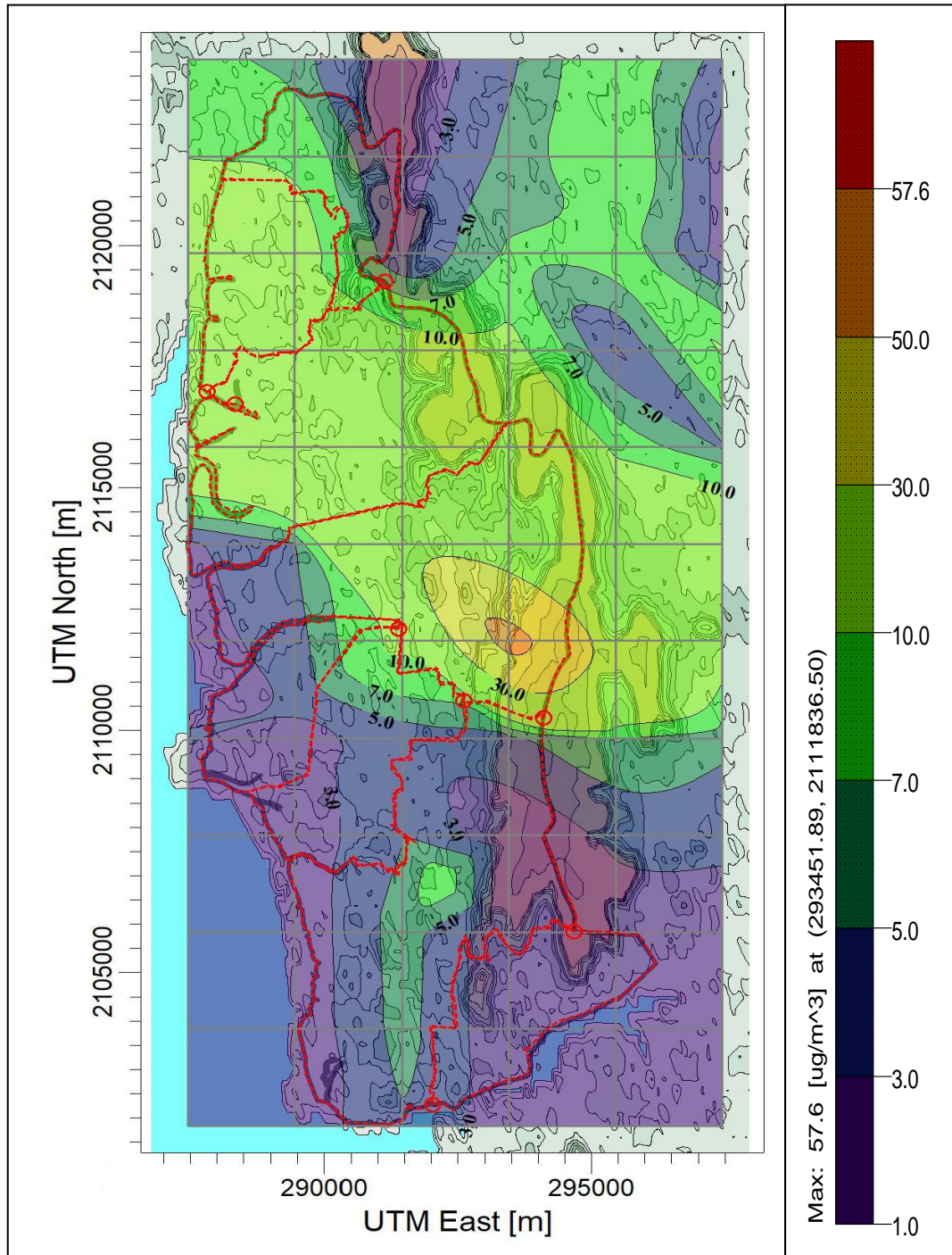
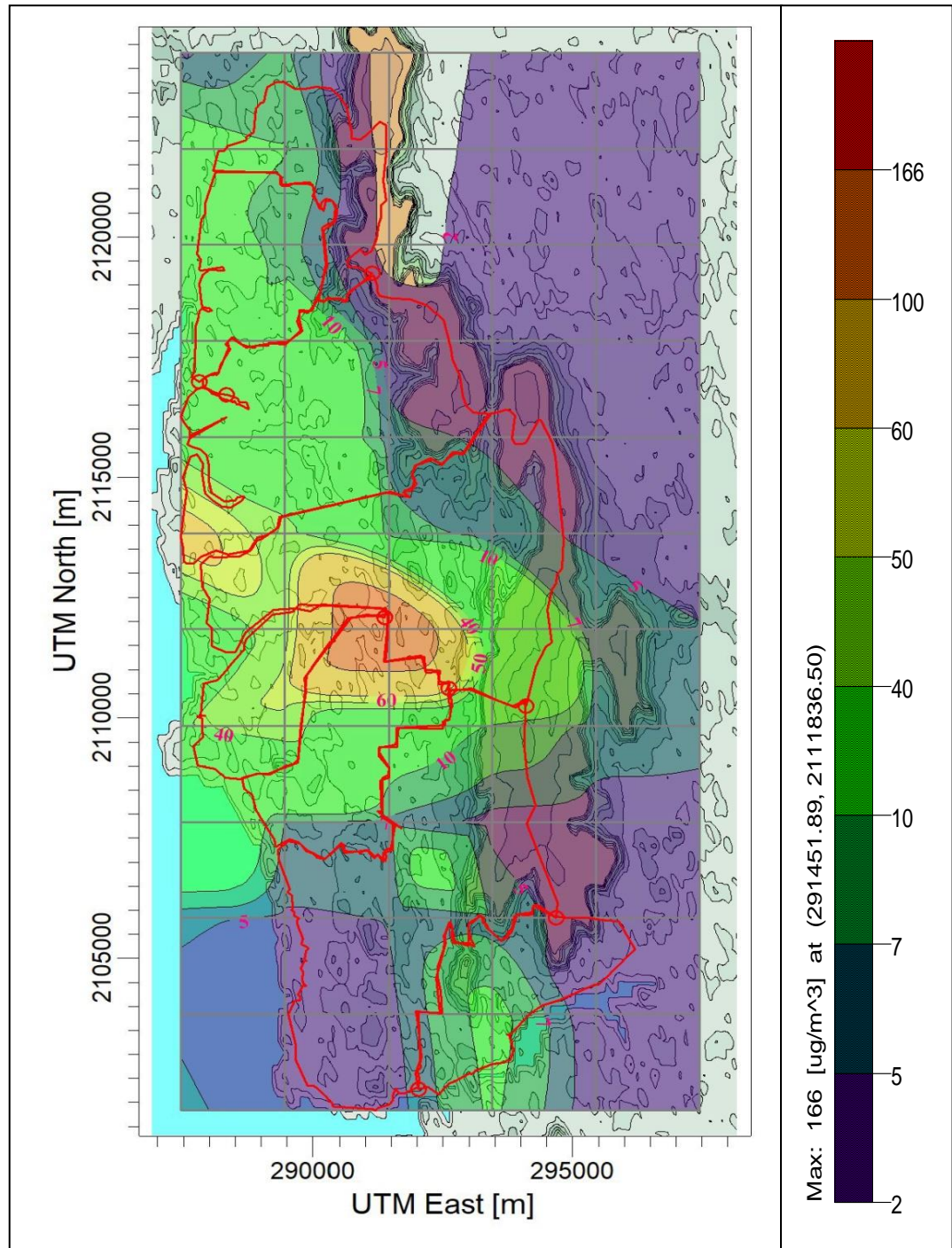


Figure P13 : Isopleths of PM Due to Point Sources (LSI) – Summer Season (Navi Mumbai City)



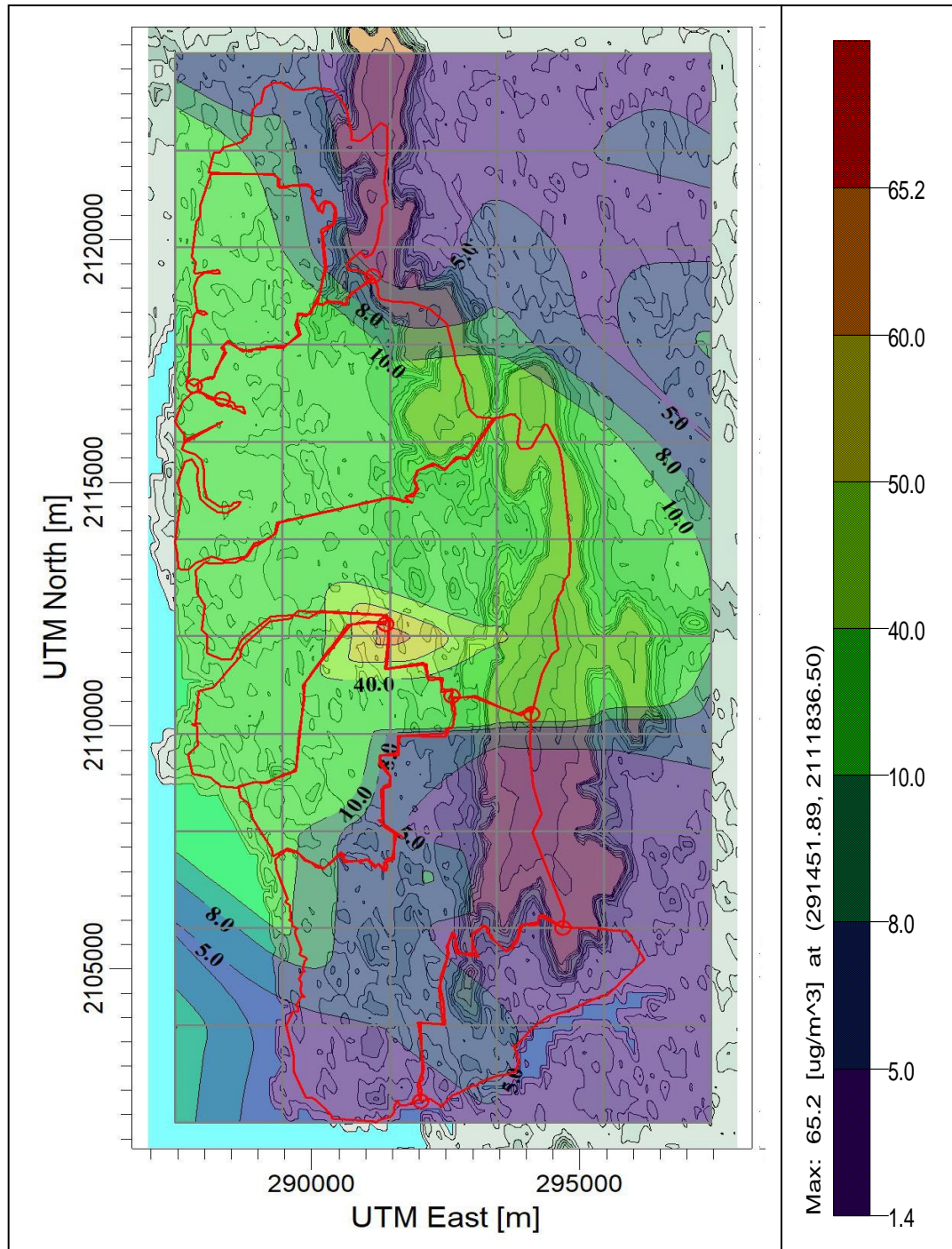


**Figure P14 : Isopleths of PM Due to Point Sources (LSI) – Post Monsoon Season (Navi Mumbai City)**



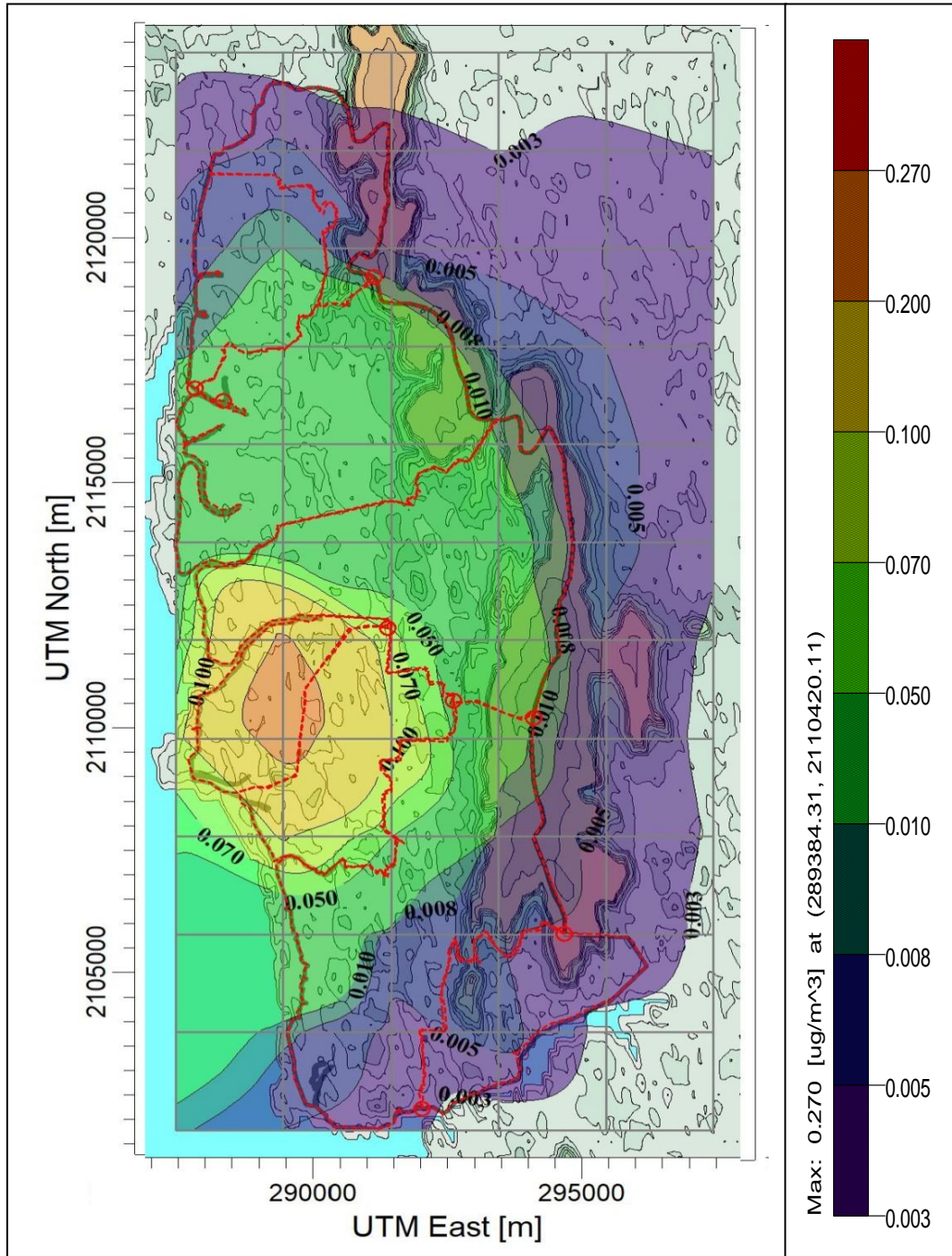
**Figure P15 : Isopleths of PM Due to Point Sources (LSI) – Winter Season (Navi Mumbai City)**





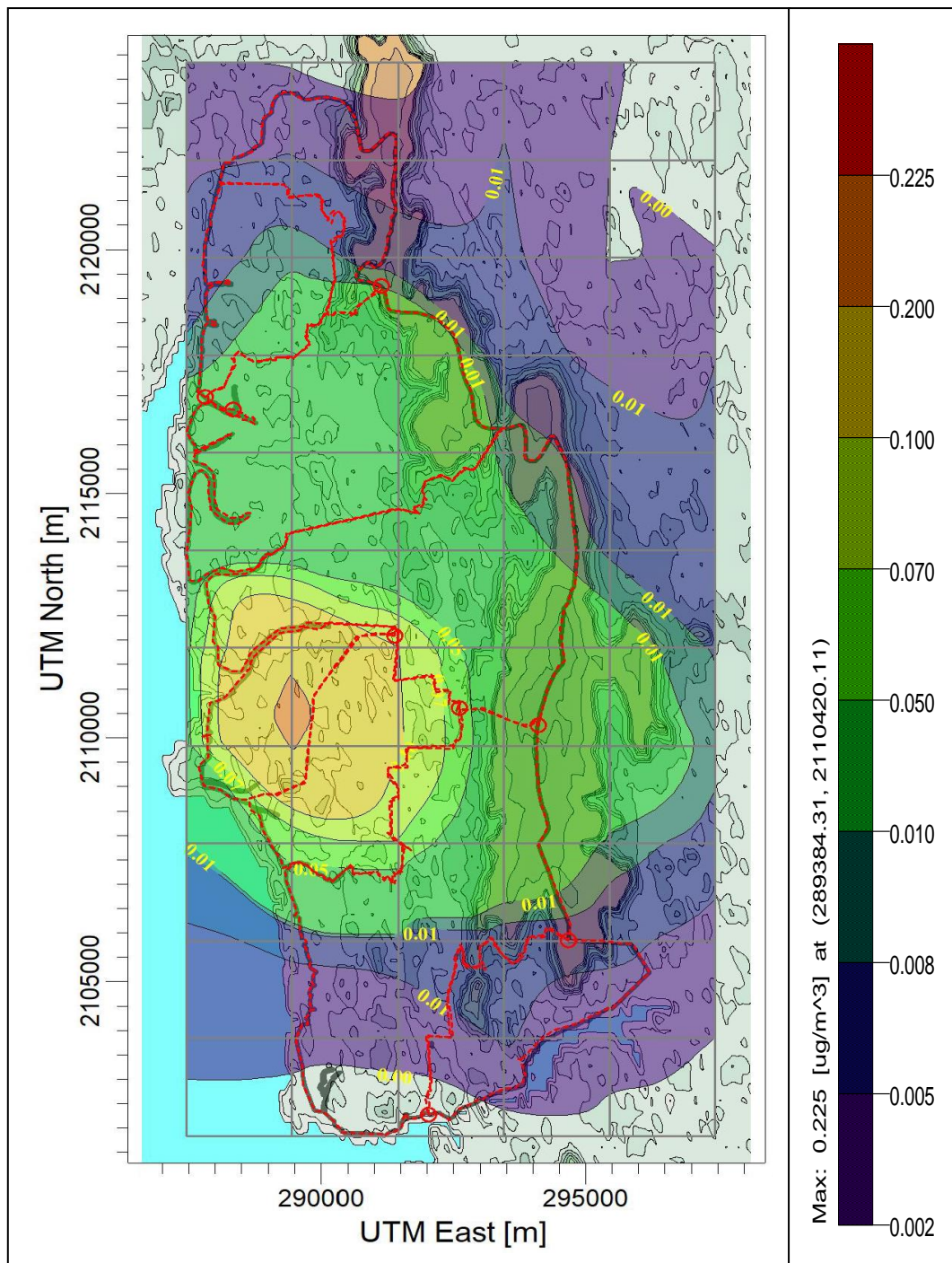
**Figure P16 : Isopleths of PM Due to Point Sources (LSI) – Annual (Navi Mumbai City)**

### E) POINT SOURCE – MSI (PM)

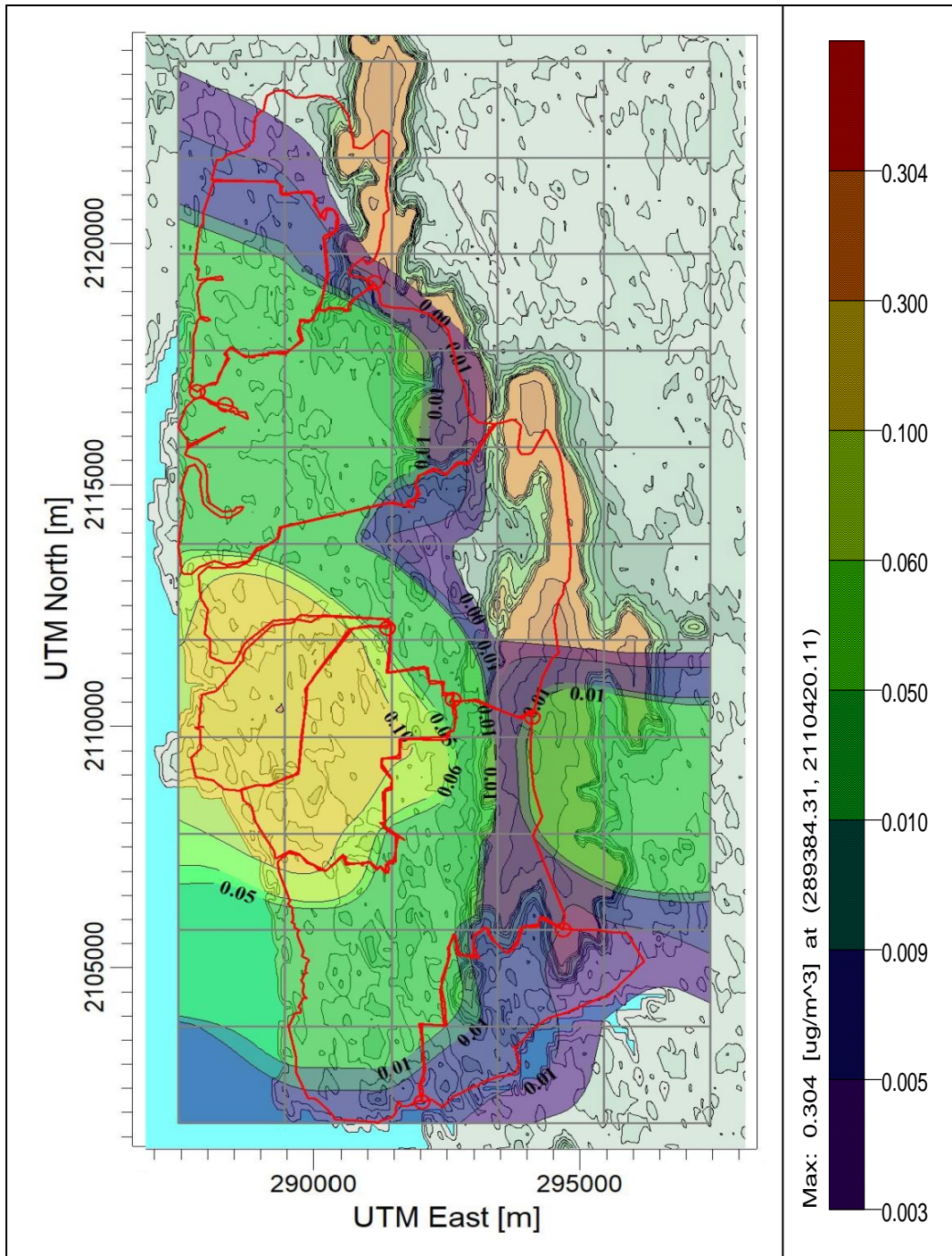


**Figure P17 : Isopleths of PM Due to Point Sources (MSI)– Summer Season (Navi Mumbai City)**



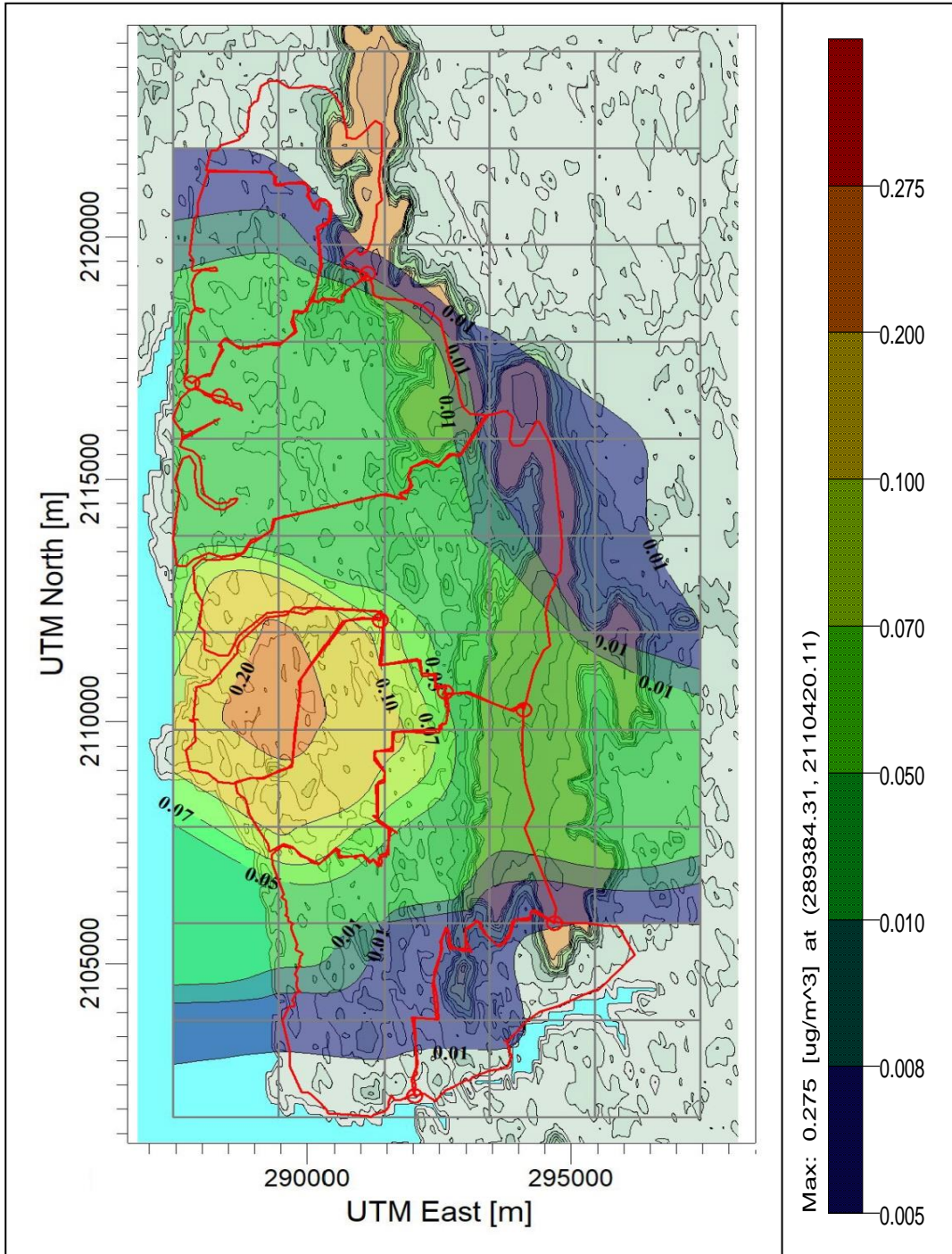


**Figure P18 : Isopleths of PM Due to Point Sources (MSI)– Post Monsoon Season (Navi Mumbai City)**



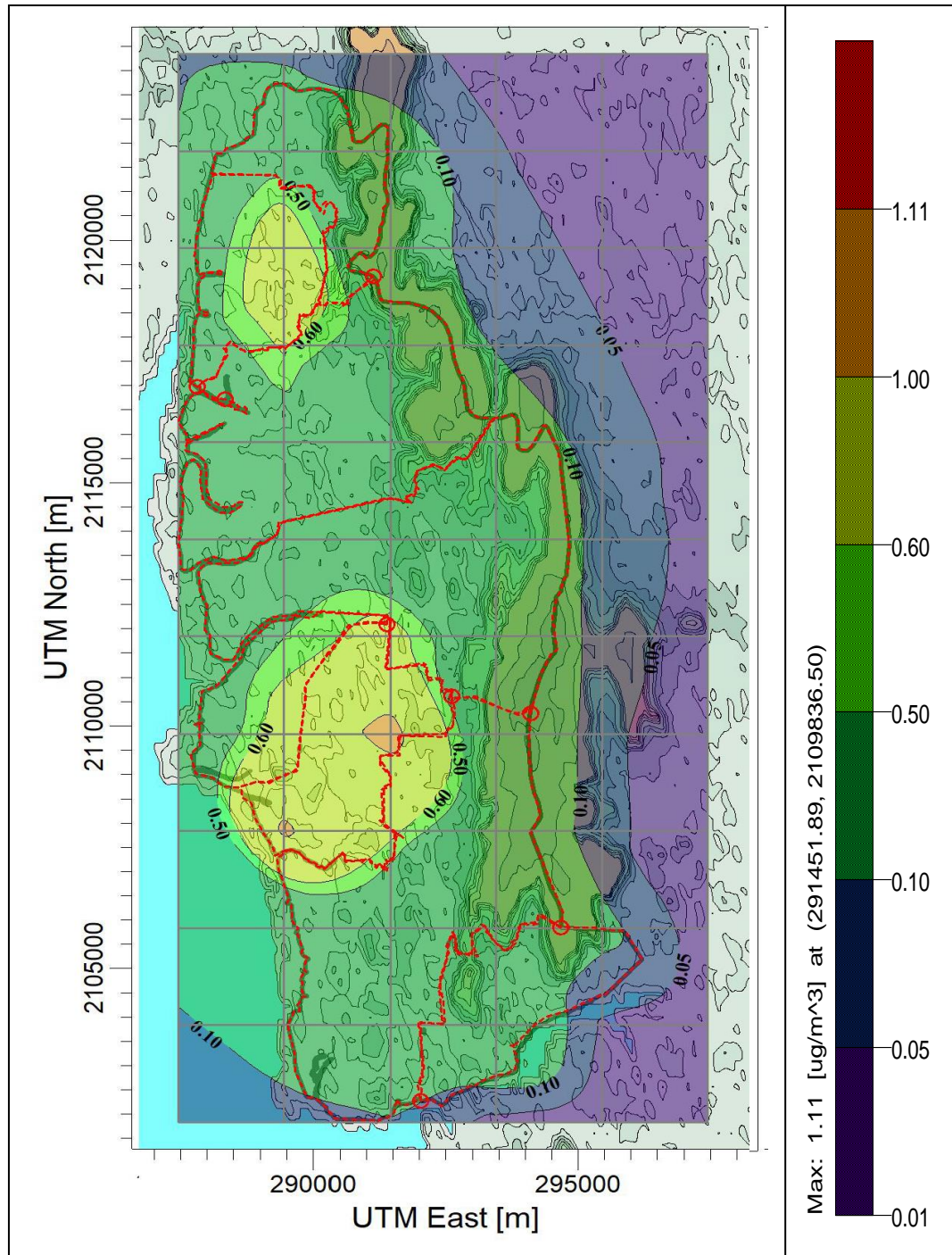
**Figure P19 : Isopleths of PM Due to Point Sources (MSI) – Winter Season (Navi Mumbai City)**





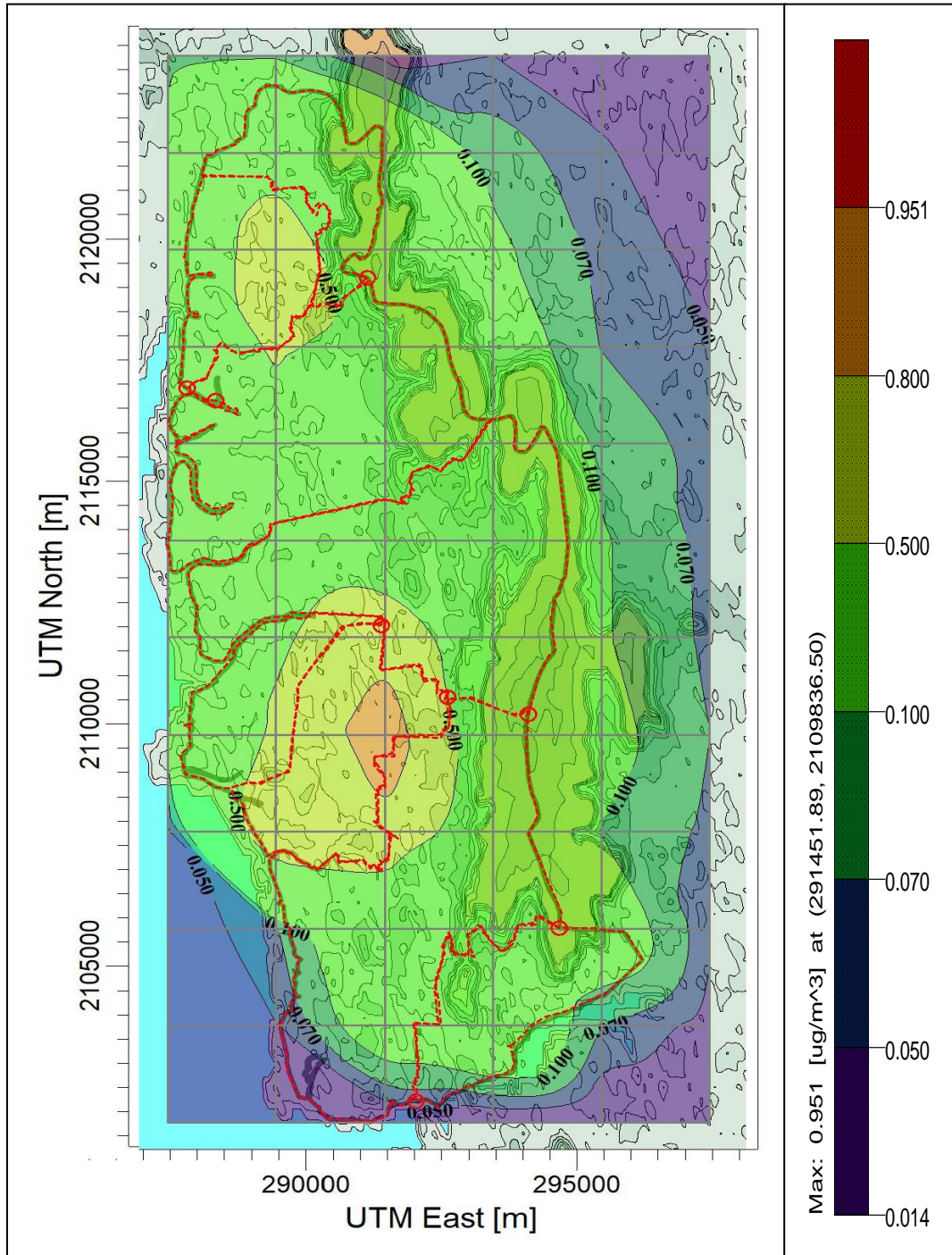
**Figure P20 : Isopleths of PM Due to Point Sources (MSI) – Annual (Navi Mumbai City)**

## F) POINT SOURCE – SSI (PM)

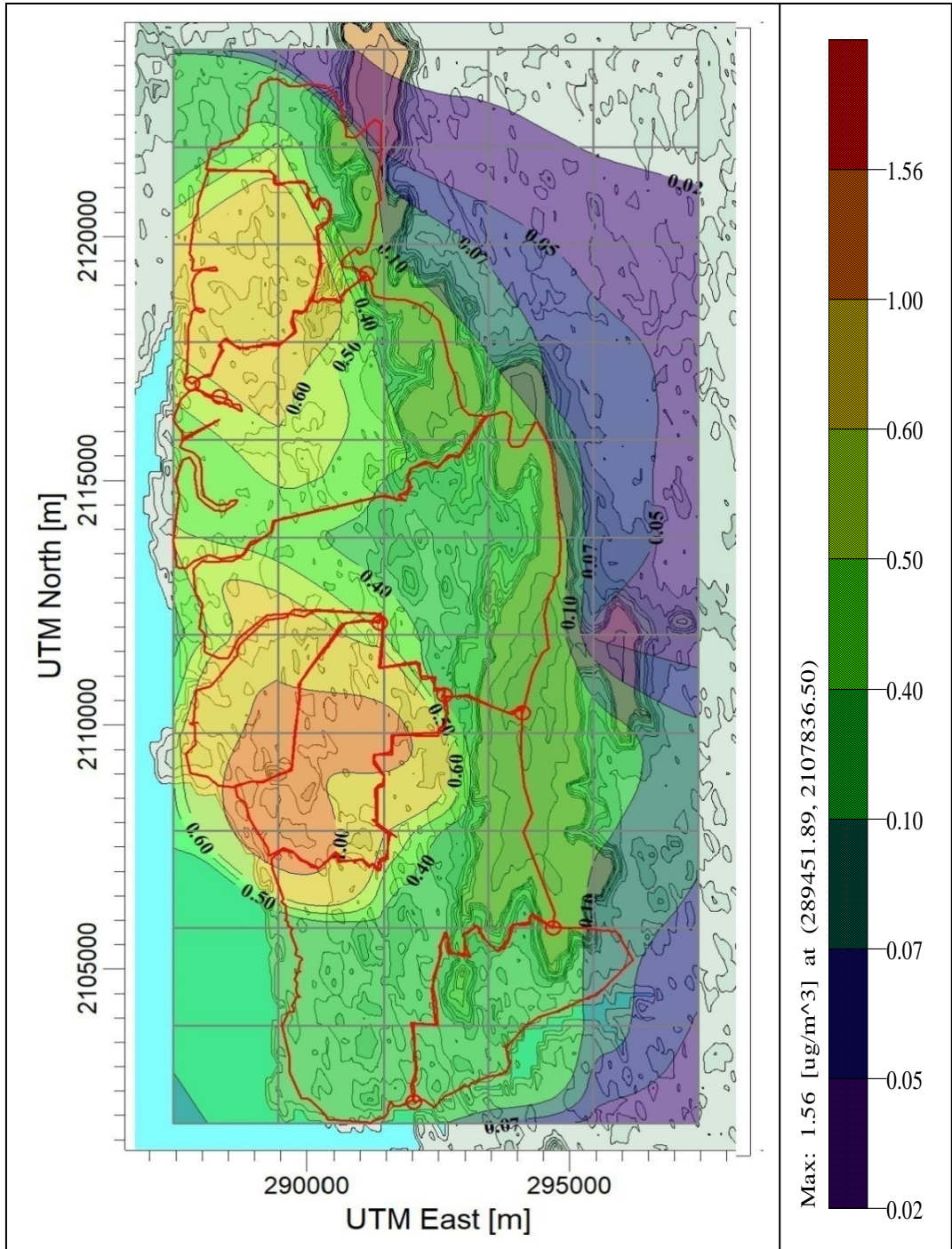


**Figure P21 : Isopleths of PM Due to Point Sources (SSI) – Summer Season (Navi Mumbai City)**



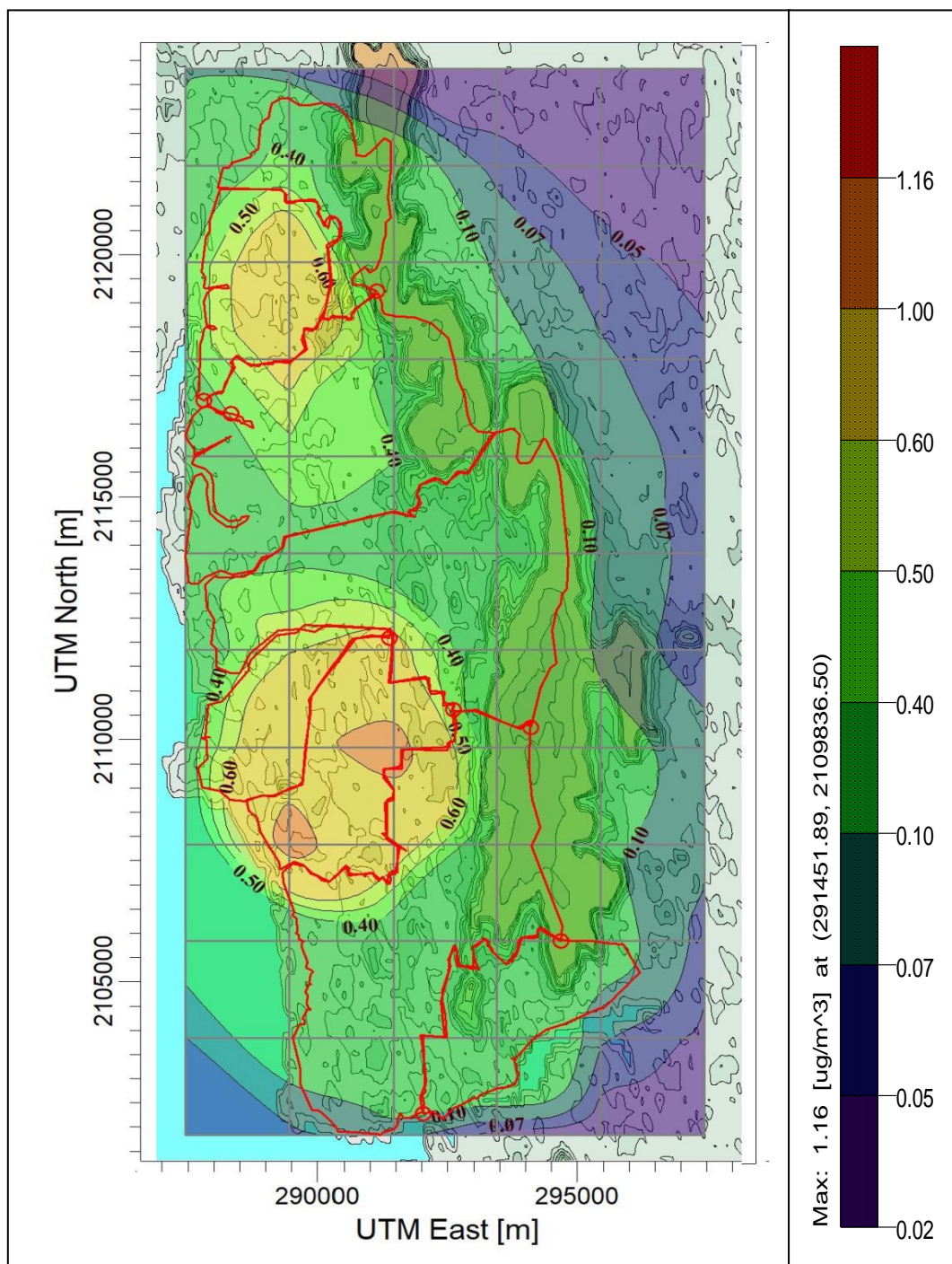


**Figure P22 : Isopleths of PM Due to Point Sources (SSI) – Post Monsoon Season (Navi Mumbai City)**



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





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



## **ANNEXURE – 3**

**Maximum Ten Concentrations of PM<sub>10</sub> (Annual) BaU 2018, 2020,  
2025 and Preferred Option I -2020, Preferred Option II – 2025**

**Navi Mumbai City**

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### Annexure 3

#### A) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations in BaU 2018 at Navi Mumbai City (Annual)

Annual - All Source – BaU 2018				Annual - Area Source – BaU 2018			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289384.31	2110420.11	403.85	1 <sup>st</sup>	289509.61	2119261.15	11.76
2 <sup>nd</sup>	289384.31	2110420.11	362.90	2 <sup>nd</sup>	289509.61	2119261.15	10.66
3 <sup>rd</sup>	289384.31	2110420.11	288.79	3 <sup>rd</sup>	289509.61	2119261.15	9.01
4 <sup>th</sup>	289384.31	2110420.11	268.29	4 <sup>th</sup>	289509.61	2119261.15	7.54
5 <sup>th</sup>	289384.31	2110420.11	217.17	5 <sup>th</sup>	289509.61	2119261.15	7.17
6 <sup>th</sup>	289384.31	2110420.11	216.81	6 <sup>th</sup>	289509.61	2119261.15	7.07
7 <sup>th</sup>	289384.31	2110420.11	208.22	7 <sup>th</sup>	289509.61	2119261.15	6.27
8 <sup>th</sup>	289384.31	2110420.11	189.61	8 <sup>th</sup>	289509.61	2119261.15	5.61
9 <sup>th</sup>	289384.31	2110420.11	167.45	9 <sup>th</sup>	289509.61	2119261.15	5.24
10 <sup>th</sup>	289384.31	2110420.11	148.81	10 <sup>th</sup>	289509.61	2119261.15	4.71
Avg.	289384.31	2110420.11	182.25	Avg.	289509.61	2119261.15	5.78

Annual – Point Source (LSI) – BaU 2018			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	389.65
2 <sup>nd</sup>	287451.89	2113836.50	192.65
3 <sup>rd</sup>	291451.89	2111836.50	174.99
4 <sup>th</sup>	291451.89	2111836.50	115.07
5 <sup>th</sup>	293451.89	2111836.50	76.83
6 <sup>th</sup>	291451.89	2111836.50	72.51
7 <sup>th</sup>	293451.89	2111836.50	58.97
8 <sup>th</sup>	293451.89	2111836.50	35.51
9 <sup>th</sup>	293451.89	2111836.50	34.38
10 <sup>th</sup>	293451.89	2111836.50	29.26
All Avg.	291451.89	2111836.50	65.22

Annual – Point Source (MSI) – BaU 2018				Annual – Point Source (SSI) – BaU 2018			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289384.31	2110420.11	0.64	1 <sup>st</sup>	289451.89	2107836.50	3.25
2 <sup>nd</sup>	289384.31	2110420.11	0.49	2 <sup>nd</sup>	289451.89	2109836.50	2.21
3 <sup>rd</sup>	289384.31	2110420.11	0.41	3 <sup>rd</sup>	289451.89	2107836.50	1.90
4 <sup>th</sup>	289384.31	2110420.11	0.40	4 <sup>th</sup>	289451.89	2107836.50	1.90
5 <sup>th</sup>	289384.31	2110420.11	0.39	5 <sup>th</sup>	289451.89	2107836.50	1.84
6 <sup>th</sup>	289384.31	2110420.11	0.35	6 <sup>th</sup>	289451.89	2107836.50	1.74
7 <sup>th</sup>	289384.31	2110420.11	0.33	7 <sup>th</sup>	289451.89	2107836.50	1.34
8 <sup>th</sup>	289384.31	2110420.11	0.27	8 <sup>th</sup>	291451.89	2109836.50	1.23
9 <sup>th</sup>	289384.31	2110420.11	0.25	9 <sup>th</sup>	291451.89	2109836.50	1.11
10 <sup>th</sup>	289384.31	2110420.11	0.24	10 <sup>th</sup>	291451.89	2109836.50	0.94
Avg.	289384.31	2110420.11	0.28	Avg.	291451.89	2109836.50	1.16

**A) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations in BaU 2018 at Navi Mumbai City (Annual) (Contd..)**

<b>Annual – Line Source – BaU 2018</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	291451.89	2111836.50	42.07
<b>2<sup>nd</sup></b>	291451.89	2111836.50	36.96
<b>3<sup>rd</sup></b>	291451.89	2111836.50	31.81
<b>4<sup>th</sup></b>	291451.89	2111836.50	26.89
<b>5<sup>th</sup></b>	291451.89	2111836.50	26.86
<b>6<sup>th</sup></b>	291451.89	2111836.50	24.68
<b>7<sup>th</sup></b>	291451.89	2111836.50	22.90
<b>8<sup>th</sup></b>	291451.89	2111836.50	19.24
<b>9<sup>th</sup></b>	291451.89	2111836.50	19.11
<b>10<sup>th</sup></b>	291451.89	2111836.50	16.20
<b>Avg.</b>	291451.89	2111836.50	20.44

<b>Annual – Resuspended Dust– BaU 2018</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	289384.31	2110420.11	304.78
<b>2<sup>nd</sup></b>	289384.31	2110420.11	271.87
<b>3<sup>rd</sup></b>	289384.31	2110420.11	229.92
<b>4<sup>th</sup></b>	289384.31	2110420.11	196.30
<b>5<sup>th</sup></b>	289384.31	2110420.11	192.45
<b>6<sup>th</sup></b>	289384.31	2110420.11	178.75
<b>7<sup>th</sup></b>	289384.31	2110420.11	163.65
<b>8<sup>th</sup></b>	289384.31	2110420.11	140.36
<b>9<sup>th</sup></b>	289384.31	2110420.11	137.53
<b>10<sup>th</sup></b>	289384.31	2110420.11	118.39
<b>Avg.</b>	289384.31	2110420.11	148.49

**B) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations in BaU 2020 at Navi Mumbai City (Annual)**

Annual - All Source – BaU 2020				Annual - Area Source – BaU 2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	433.72	1 <sup>st</sup>	289509.61	2119261.15	12.41
2 <sup>nd</sup>	289384.31	2110420.11	386.73	2 <sup>nd</sup>	289509.61	2119261.15	11.25
3 <sup>rd</sup>	289384.31	2110420.11	306.78	3 <sup>rd</sup>	289509.61	2119261.15	9.51
4 <sup>th</sup>	289384.31	2110420.11	276.00	4 <sup>th</sup>	289509.61	2119261.15	7.96
5 <sup>th</sup>	289384.31	2110420.11	232.47	5 <sup>th</sup>	289509.61	2119261.15	7.57
6 <sup>th</sup>	289384.31	2110420.11	231.80	6 <sup>th</sup>	289509.61	2119261.15	7.45
7 <sup>th</sup>	289384.31	2110420.11	220.96	7 <sup>th</sup>	289509.61	2119261.15	6.62
8 <sup>th</sup>	289384.31	2110420.11	203.52	8 <sup>th</sup>	289509.61	2119261.15	5.92
9 <sup>th</sup>	289384.31	2110420.11	178.16	9 <sup>th</sup>	289509.61	2119261.15	5.53
10 <sup>th</sup>	289384.31	2110420.11	159.73	10 <sup>th</sup>	289509.61	2119261.15	4.97
<b>Avg.</b>	289384.31	2110420.11	193.82	<b>Avg.</b>	289509.61	2119261.15	6.10

Annual – Point Source (LSI) – BaU 2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	389.65
2 <sup>nd</sup>	287451.89	2113836.50	192.65
3 <sup>rd</sup>	291451.89	2111836.50	174.99
4 <sup>th</sup>	291451.89	2111836.50	115.07
5 <sup>th</sup>	293451.89	2111836.50	76.83
6 <sup>th</sup>	291451.89	2111836.50	72.51
7 <sup>th</sup>	293451.89	2111836.50	58.97
8 <sup>th</sup>	293451.89	2111836.50	35.51
9 <sup>th</sup>	293451.89	2111836.50	34.38
10 <sup>th</sup>	293451.89	2111836.50	29.26
<b>All Avg.</b>	291451.89	2111836.50	65.22

Annual – Point Source (MSI) – BaU 2020				Annual – Point Source (SSI) – BaU 2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289384.31	2110420.11	0.64	1 <sup>st</sup>	289451.89	2107836.50	3.25
2 <sup>nd</sup>	289384.31	2110420.11	0.49	2 <sup>nd</sup>	289451.89	2109836.50	2.21
3 <sup>rd</sup>	289384.31	2110420.11	0.41	3 <sup>rd</sup>	289451.89	2107836.50	1.90
4 <sup>th</sup>	289384.31	2110420.11	0.40	4 <sup>th</sup>	289451.89	2107836.50	1.90
5 <sup>th</sup>	289384.31	2110420.11	0.39	5 <sup>th</sup>	289451.89	2107836.50	1.84
6 <sup>th</sup>	289384.31	2110420.11	0.35	6 <sup>th</sup>	289451.89	2107836.50	1.74
7 <sup>th</sup>	289384.31	2110420.11	0.33	7 <sup>th</sup>	289451.89	2107836.50	1.34
8 <sup>th</sup>	289384.31	2110420.11	0.27	8 <sup>th</sup>	291451.89	2109836.50	1.23
9 <sup>th</sup>	289384.31	2110420.11	0.25	9 <sup>th</sup>	291451.89	2109836.50	1.11
10 <sup>th</sup>	289384.31	2110420.11	0.24	10 <sup>th</sup>	291451.89	2109836.50	0.94
<b>Avg.</b>	289384.31	2110420.11	0.28	<b>Avg.</b>	291451.89	2109836.50	1.16

**B) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations in BaU 2020 at Navi Mumbai City (Annual) (Contd..)**

<b>Annual – Line Source – BaU 2020</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	291451.89	2111836.50	45.23
<b>2<sup>nd</sup></b>	291451.89	2111836.50	39.73
<b>3<sup>rd</sup></b>	291451.89	2111836.50	34.20
<b>4<sup>th</sup></b>	291451.89	2111836.50	28.90
<b>5<sup>th</sup></b>	291451.89	2111836.50	28.88
<b>6<sup>th</sup></b>	291451.89	2111836.50	26.53
<b>7<sup>th</sup></b>	291451.89	2111836.50	24.62
<b>8<sup>th</sup></b>	291451.89	2111836.50	20.68
<b>9<sup>th</sup></b>	291451.89	2111836.50	20.54
<b>10<sup>th</sup></b>	291451.89	2111836.50	17.42
<b>Avg.</b>	291451.89	2111836.50	21.98

<b>Annual – Resuspended Dust– BaU 2020</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	289384.31	2110420.11	327.64
<b>2<sup>nd</sup></b>	289384.31	2110420.11	292.27
<b>3<sup>rd</sup></b>	289384.31	2110420.11	247.17
<b>4<sup>th</sup></b>	289384.31	2110420.11	211.03
<b>5<sup>th</sup></b>	289384.31	2110420.11	206.88
<b>6<sup>th</sup></b>	289384.31	2110420.11	192.15
<b>7<sup>th</sup></b>	289384.31	2110420.11	175.92
<b>8<sup>th</sup></b>	289384.31	2110420.11	150.89
<b>9<sup>th</sup></b>	289384.31	2110420.11	147.84
<b>10<sup>th</sup></b>	289384.31	2110420.11	127.27
<b>Avg.</b>	289384.31	2110420.11	159.63

**C) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations in BaU 2025 at Navi Mumbai City (Annual)**

Annual - All Source – BaU 2025				Annual - Area Source – BaU 2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289384.31	2110420.11	448.06	1 <sup>st</sup>	289509.61	2119261.15	13.28
2 <sup>nd</sup>	289384.31	2110420.11	412.46	2 <sup>nd</sup>	289509.61	2119261.15	12.03
3 <sup>rd</sup>	289384.31	2110420.11	326.18	3 <sup>rd</sup>	289509.61	2119261.15	10.17
4 <sup>th</sup>	289384.31	2110420.11	284.32	4 <sup>th</sup>	289509.61	2119261.15	8.51
5 <sup>th</sup>	289384.31	2110420.11	248.98	5 <sup>th</sup>	289509.61	2119261.15	8.10
6 <sup>th</sup>	289384.31	2110420.11	247.96	6 <sup>th</sup>	289509.61	2119261.15	7.98
7 <sup>th</sup>	289384.31	2110420.11	234.71	7 <sup>th</sup>	289509.61	2119261.15	7.08
8 <sup>th</sup>	289384.31	2110420.11	218.54	8 <sup>th</sup>	289509.61	2119261.15	6.33
9 <sup>th</sup>	289384.31	2110420.11	189.71	9 <sup>th</sup>	289509.61	2119261.15	5.92
10 <sup>th</sup>	289384.31	2110420.11	171.51	10 <sup>th</sup>	289509.61	2119261.15	5.31
<b>Avg.</b>	289384.31	2110420.11	206.31	<b>Avg.</b>	289509.61	2119261.15	6.53

Annual – Point Source (LSI) – BaU 2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	389.65
2 <sup>nd</sup>	287451.89	2113836.50	192.65
3 <sup>rd</sup>	291451.89	2111836.50	174.99
4 <sup>th</sup>	291451.89	2111836.50	115.07
5 <sup>th</sup>	293451.89	2111836.50	76.83
6 <sup>th</sup>	291451.89	2111836.50	72.51
7 <sup>th</sup>	293451.89	2111836.50	58.97
8 <sup>th</sup>	293451.89	2111836.50	35.51
9 <sup>th</sup>	293451.89	2111836.50	34.38
10 <sup>th</sup>	293451.89	2111836.50	29.26
<b>All Avg.</b>	291451.89	2111836.50	65.22

Annual – Point Source (MSI) – BaU 2025				Annual – Point Source (SSI) – BaU 2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289384.31	2110420.11	0.64	1 <sup>st</sup>	289451.89	2107836.50	3.25
2 <sup>nd</sup>	289384.31	2110420.11	0.49	2 <sup>nd</sup>	289451.89	2109836.50	2.21
3 <sup>rd</sup>	289384.31	2110420.11	0.41	3 <sup>rd</sup>	289451.89	2107836.50	1.90
4 <sup>th</sup>	289384.31	2110420.11	0.40	4 <sup>th</sup>	289451.89	2107836.50	1.90
5 <sup>th</sup>	289384.31	2110420.11	0.39	5 <sup>th</sup>	289451.89	2107836.50	1.84
6 <sup>th</sup>	289384.31	2110420.11	0.35	6 <sup>th</sup>	289451.89	2107836.50	1.74
7 <sup>th</sup>	289384.31	2110420.11	0.33	7 <sup>th</sup>	289451.89	2107836.50	1.34
8 <sup>th</sup>	289384.31	2110420.11	0.27	8 <sup>th</sup>	291451.89	2109836.50	1.23
9 <sup>th</sup>	289384.31	2110420.11	0.25	9 <sup>th</sup>	291451.89	2109836.50	1.11
10 <sup>th</sup>	289384.31	2110420.11	0.24	10 <sup>th</sup>	291451.89	2109836.50	0.94
<b>Avg.</b>	289384.31	2110420.11	0.28	<b>Avg.</b>	291451.89	2109836.50	1.16

**C) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations in BaU 2025 at Navi Mumbai City (Annual) (Contd..)**

<b>Annual – Line Source – BaU 2025</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	291451.89	2111836.50	48.62
<b>2<sup>nd</sup></b>	291451.89	2111836.50	42.71
<b>3<sup>rd</sup></b>	291451.89	2111836.50	36.76
<b>4<sup>th</sup></b>	291451.89	2111836.50	31.07
<b>5<sup>th</sup></b>	291451.89	2111836.50	31.05
<b>6<sup>th</sup></b>	291451.89	2111836.50	28.52
<b>7<sup>th</sup></b>	291451.89	2111836.50	26.47
<b>8<sup>th</sup></b>	291451.89	2111836.50	22.23
<b>9<sup>th</sup></b>	291451.89	2111836.50	22.08
<b>10<sup>th</sup></b>	291451.89	2111836.50	18.72
<b>Avg.</b>	291451.89	2111836.50	23.62

<b>Annual – Resuspended Dust– BaU 2025</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	289384.31	2110420.11	352.21
<b>2<sup>nd</sup></b>	289384.31	2110420.11	314.19
<b>3<sup>rd</sup></b>	289384.31	2110420.11	265.70
<b>4<sup>th</sup></b>	289384.31	2110420.11	226.85
<b>5<sup>th</sup></b>	289384.31	2110420.11	222.40
<b>6<sup>th</sup></b>	289384.31	2110420.11	206.56
<b>7<sup>th</sup></b>	289384.31	2110420.11	189.11
<b>8<sup>th</sup></b>	289384.31	2110420.11	162.20
<b>9<sup>th</sup></b>	289384.31	2110420.11	158.93
<b>10<sup>th</sup></b>	289384.31	2110420.11	136.81
<b>Avg.</b>	289384.31	2110420.11	171.60



**D) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations after Implementation of Control Options (Preferred Option I -2020) at Navi Mumbai City (Annual)**

Annual All Source Preferred Option I -2020				Annual Area Source Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	262.60	1 <sup>st</sup>	289509.61	2119261.15	7.51
2 <sup>nd</sup>	289384.31	2110420.11	234.15	2 <sup>nd</sup>	289509.61	2119261.15	6.81
3 <sup>rd</sup>	289384.31	2110420.11	185.74	3 <sup>rd</sup>	289509.61	2119261.15	5.76
4 <sup>th</sup>	289384.31	2110420.11	167.10	4 <sup>th</sup>	289509.61	2119261.15	4.82
5 <sup>th</sup>	289384.31	2110420.11	140.75	5 <sup>th</sup>	289509.61	2119261.15	4.58
6 <sup>th</sup>	289384.31	2110420.11	140.34	6 <sup>th</sup>	289509.61	2119261.15	4.51
7 <sup>th</sup>	289384.31	2110420.11	133.78	7 <sup>th</sup>	289509.61	2119261.15	4.01
8 <sup>th</sup>	289384.31	2110420.11	123.22	8 <sup>th</sup>	289509.61	2119261.15	3.58
9 <sup>th</sup>	289384.31	2110420.11	107.86	9 <sup>th</sup>	289509.61	2119261.15	3.35
10 <sup>th</sup>	289384.31	2110420.11	96.71	10 <sup>th</sup>	289509.61	2119261.15	3.01
<b>Avg.</b>	289384.31	2110420.11	117.35	<b>Avg.</b>	289509.61	2119261.15	3.69

Annual Point Source (LSI) Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	235.92
2 <sup>nd</sup>	287451.89	2113836.50	116.64
3 <sup>rd</sup>	291451.89	2111836.50	105.95
4 <sup>th</sup>	291451.89	2111836.50	69.67
5 <sup>th</sup>	293451.89	2111836.50	46.52
6 <sup>th</sup>	291451.89	2111836.50	43.90
7 <sup>th</sup>	293451.89	2111836.50	35.70
8 <sup>th</sup>	293451.89	2111836.50	21.50
9 <sup>th</sup>	293451.89	2111836.50	20.82
10 <sup>th</sup>	293451.89	2111836.50	17.72
<b>All Avg.</b>	291451.89	2111836.50	39.49

Annual Point Source (MSI) Preferred Option I -2020				Annual Point Source (SSI) Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289384.31	2110420.11	0.38	1 <sup>st</sup>	289451.89	2107836.50	1.97
2 <sup>nd</sup>	289384.31	2110420.11	0.29	2 <sup>nd</sup>	289451.89	2109836.50	1.34
3 <sup>rd</sup>	289384.31	2110420.11	0.25	3 <sup>rd</sup>	289451.89	2107836.50	1.15
4 <sup>th</sup>	289384.31	2110420.11	0.24	4 <sup>th</sup>	289451.89	2107836.50	1.15
5 <sup>th</sup>	289384.31	2110420.11	0.24	5 <sup>th</sup>	289451.89	2107836.50	1.11
6 <sup>th</sup>	289384.31	2110420.11	0.21	6 <sup>th</sup>	289451.89	2107836.50	1.05
7 <sup>th</sup>	289384.31	2110420.11	0.20	7 <sup>th</sup>	289451.89	2107836.50	0.81
8 <sup>th</sup>	289384.31	2110420.11	0.17	8 <sup>th</sup>	291451.89	2109836.50	0.75
9 <sup>th</sup>	289384.31	2110420.11	0.15	9 <sup>th</sup>	291451.89	2109836.50	0.67
10 <sup>th</sup>	289384.31	2110420.11	0.14	10 <sup>th</sup>	291451.89	2109836.50	0.57
<b>Avg.</b>	289384.31	2110420.11	0.17	<b>Avg.</b>	291451.89	2109836.50	0.71

**D) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations after Implementation of Control Options (Preferred Option I -2020) at Mumbai City (Annual) (Contd..)**

<b>Annual Line Source Preferred Option I -2020</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	291451.89	2111836.50	27.38
<b>2<sup>nd</sup></b>	291451.89	2111836.50	24.06
<b>3<sup>rd</sup></b>	291451.89	2111836.50	20.70
<b>4<sup>th</sup></b>	291451.89	2111836.50	17.50
<b>5<sup>th</sup></b>	291451.89	2111836.50	17.49
<b>6<sup>th</sup></b>	291451.89	2111836.50	16.06
<b>7<sup>th</sup></b>	291451.89	2111836.50	14.91
<b>8<sup>th</sup></b>	291451.89	2111836.50	12.52
<b>9<sup>th</sup></b>	291451.89	2111836.50	12.44
<b>10<sup>th</sup></b>	291451.89	2111836.50	10.55
<b>Avg.</b>	291451.89	2111836.50	13.31

<b>Annual Resuspended Dust Preferred Option I -2020</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	289384.31	2110420.11	198.37
<b>2<sup>nd</sup></b>	289384.31	2110420.11	176.95
<b>3<sup>rd</sup></b>	289384.31	2110420.11	149.65
<b>4<sup>th</sup></b>	289384.31	2110420.11	127.77
<b>5<sup>th</sup></b>	289384.31	2110420.11	125.26
<b>6<sup>th</sup></b>	289384.31	2110420.11	116.34
<b>7<sup>th</sup></b>	289384.31	2110420.11	106.51
<b>8<sup>th</sup></b>	289384.31	2110420.11	91.35
<b>9<sup>th</sup></b>	289384.31	2110420.11	89.51
<b>10<sup>th</sup></b>	289384.31	2110420.11	77.05
<b>Avg.</b>	289384.31	2110420.11	96.65

**E) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations after Implementation of Control Options (Preferred Option II -2025) at Mumbai City (Annual)**

Annual All Source Preferred Option II -2025				Annual Area Source Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289384.31	2110420.11	153.24	1 <sup>st</sup>	289509.61	2119261.15	4.54
2 <sup>nd</sup>	289384.31	2110420.11	141.06	2 <sup>nd</sup>	289509.61	2119261.15	4.12
3 <sup>rd</sup>	289384.31	2110420.11	111.56	3 <sup>rd</sup>	289509.61	2119261.15	3.48
4 <sup>th</sup>	289384.31	2110420.11	97.24	4 <sup>th</sup>	289509.61	2119261.15	2.91
5 <sup>th</sup>	289384.31	2110420.11	85.15	5 <sup>th</sup>	289509.61	2119261.15	2.77
6 <sup>th</sup>	289384.31	2110420.11	84.80	6 <sup>th</sup>	289509.61	2119261.15	2.73
7 <sup>th</sup>	289384.31	2110420.11	80.27	7 <sup>th</sup>	289509.61	2119261.15	2.42
8 <sup>th</sup>	289384.31	2110420.11	74.74	8 <sup>th</sup>	289509.61	2119261.15	2.16
9 <sup>th</sup>	289384.31	2110420.11	64.88	9 <sup>th</sup>	289509.61	2119261.15	2.02
10 <sup>th</sup>	289384.31	2110420.11	58.66	10 <sup>th</sup>	289509.61	2119261.15	1.82
<b>Avg.</b>	289384.31	2110420.11	70.56	<b>Avg.</b>	289509.61	2119261.15	2.23

Annual Point Source (LSI) Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	133.26
2 <sup>nd</sup>	287451.89	2113836.50	65.89
3 <sup>rd</sup>	291451.89	2111836.50	59.85
4 <sup>th</sup>	291451.89	2111836.50	39.36
5 <sup>th</sup>	293451.89	2111836.50	26.28
6 <sup>th</sup>	291451.89	2111836.50	24.80
7 <sup>th</sup>	293451.89	2111836.50	20.17
8 <sup>th</sup>	293451.89	2111836.50	12.14
9 <sup>th</sup>	293451.89	2111836.50	11.76
10 <sup>th</sup>	293451.89	2111836.50	10.01
<b>All Avg.</b>	291451.89	2111836.50	22.30

Annual Point Source (MSI) Preferred Option II -2025				Annual Point Source (SSI) Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289384.31	2110420.11	0.22	1 <sup>st</sup>	289451.89	2107836.50	1.11
2 <sup>nd</sup>	289384.31	2110420.11	0.17	2 <sup>nd</sup>	289451.89	2109836.50	0.76
3 <sup>rd</sup>	289384.31	2110420.11	0.14	3 <sup>rd</sup>	289451.89	2107836.50	0.65
4 <sup>th</sup>	289384.31	2110420.11	0.14	4 <sup>th</sup>	289451.89	2107836.50	0.65
5 <sup>th</sup>	289384.31	2110420.11	0.13	5 <sup>th</sup>	289451.89	2107836.50	0.63
6 <sup>th</sup>	289384.31	2110420.11	0.12	6 <sup>th</sup>	289451.89	2107836.50	0.59
7 <sup>th</sup>	289384.31	2110420.11	0.11	7 <sup>th</sup>	289451.89	2107836.50	0.46
8 <sup>th</sup>	289384.31	2110420.11	0.09	8 <sup>th</sup>	291451.89	2109836.50	0.42
9 <sup>th</sup>	289384.31	2110420.11	0.08	9 <sup>th</sup>	291451.89	2109836.50	0.38
10 <sup>th</sup>	289384.31	2110420.11	0.08	10 <sup>th</sup>	291451.89	2109836.50	0.32
<b>Avg.</b>	289384.31	2110420.11	0.09	<b>Avg.</b>	291451.89	2109836.50	0.40

**E) Maximum Ten Occurrences of PM<sub>10</sub> Concentrations after Implementation of Control Options (Preferred Option II -2025) at Mumbai City (Annual) (Contd..)**

<b>Annual Line Source Preferred Option II -2025</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	291451.89	2111836.50	16.63
<b>2<sup>nd</sup></b>	291451.89	2111836.50	14.61
<b>3<sup>rd</sup></b>	291451.89	2111836.50	12.57
<b>4<sup>th</sup></b>	291451.89	2111836.50	10.63
<b>5<sup>th</sup></b>	291451.89	2111836.50	10.62
<b>6<sup>th</sup></b>	291451.89	2111836.50	9.75
<b>7<sup>th</sup></b>	291451.89	2111836.50	9.05
<b>8<sup>th</sup></b>	291451.89	2111836.50	7.60
<b>9<sup>th</sup></b>	291451.89	2111836.50	7.55
<b>10<sup>th</sup></b>	291451.89	2111836.50	6.40
<b>Avg.</b>	291451.89	2111836.50	8.08

<b>Annual Resuspended Dust Preferred Option II -2025</b>			
	<b>X length,m</b>	<b>Y length,m</b>	<b>Concentration µg/m<sup>3</sup></b>
<b>1<sup>st</sup></b>	289384.31	2110420.11	120.46
<b>2<sup>nd</sup></b>	289384.31	2110420.11	107.45
<b>3<sup>rd</sup></b>	289384.31	2110420.11	90.87
<b>4<sup>th</sup></b>	289384.31	2110420.11	77.58
<b>5<sup>th</sup></b>	289384.31	2110420.11	76.06
<b>6<sup>th</sup></b>	289384.31	2110420.11	70.64
<b>7<sup>th</sup></b>	289384.31	2110420.11	64.68
<b>8<sup>th</sup></b>	289384.31	2110420.11	55.47
<b>9<sup>th</sup></b>	289384.31	2110420.11	54.35
<b>10<sup>th</sup></b>	289384.31	2110420.11	46.79
<b>Avg.</b>	289384.31	2110420.11	58.69

## **ANNEXURE - 4**

### **ISOPLETHS OF NO<sub>x</sub> :**

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

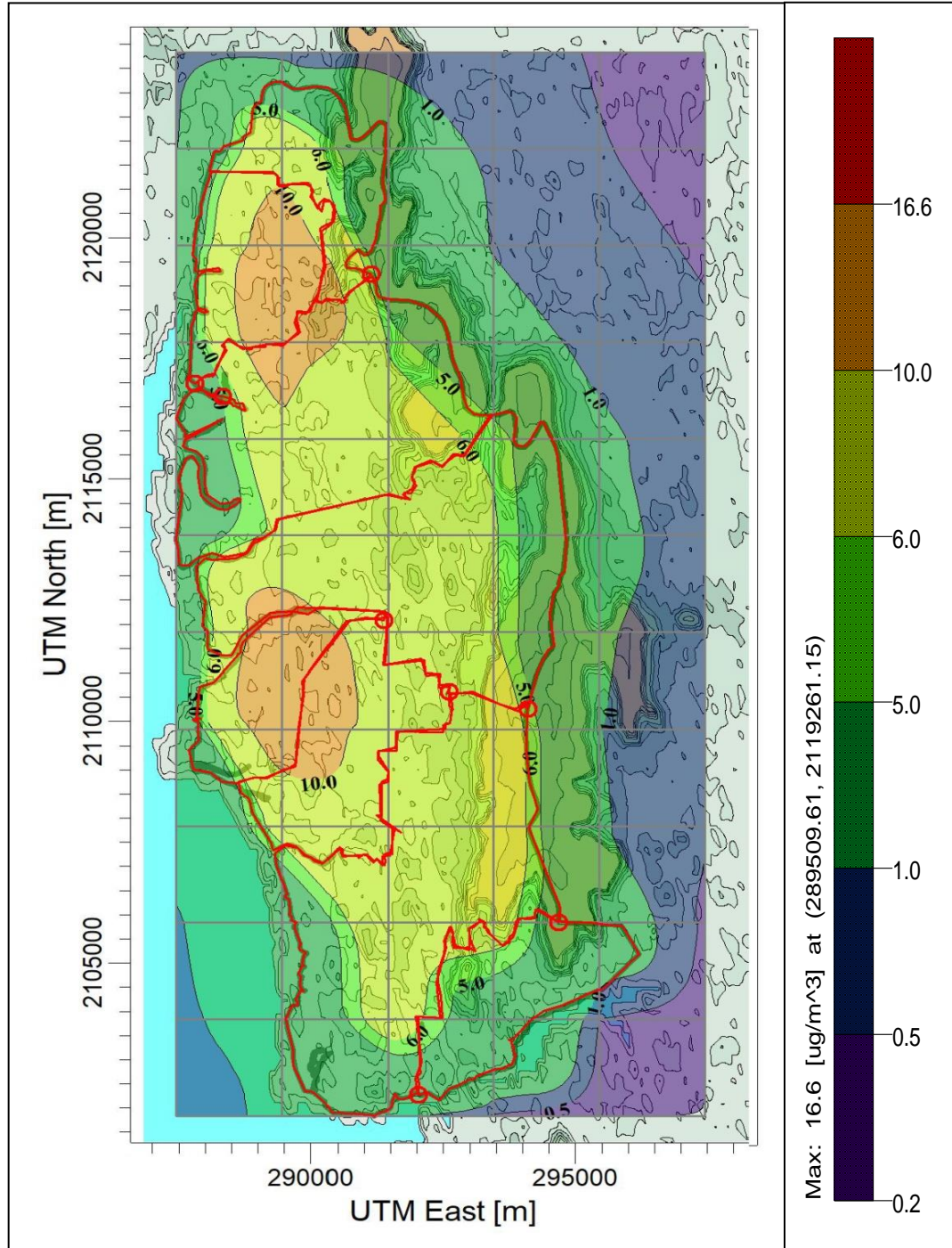
**&**

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

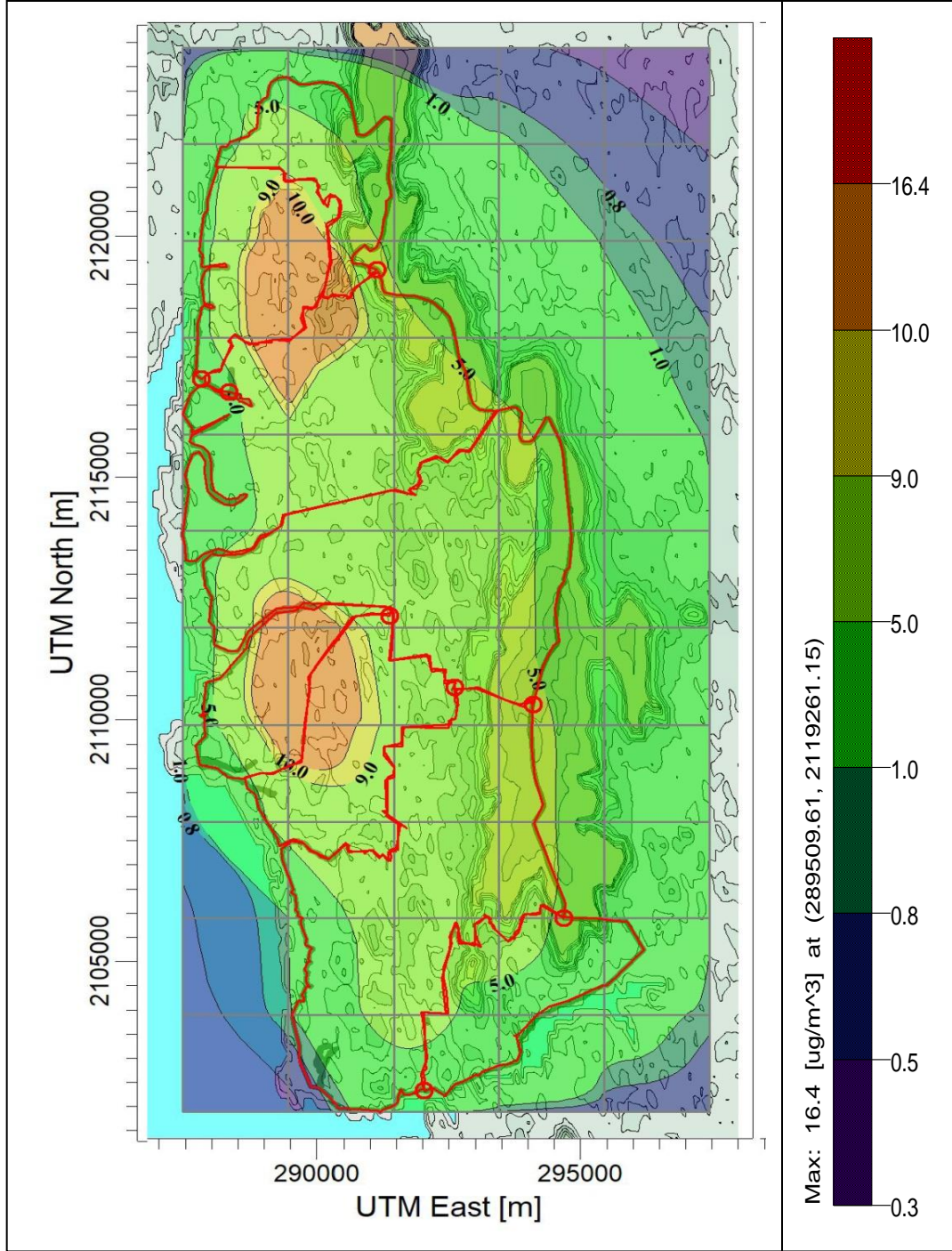
**(Navi Mumbai City)**

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### A) AREA SOURCE – ALL (NO<sub>x</sub>)

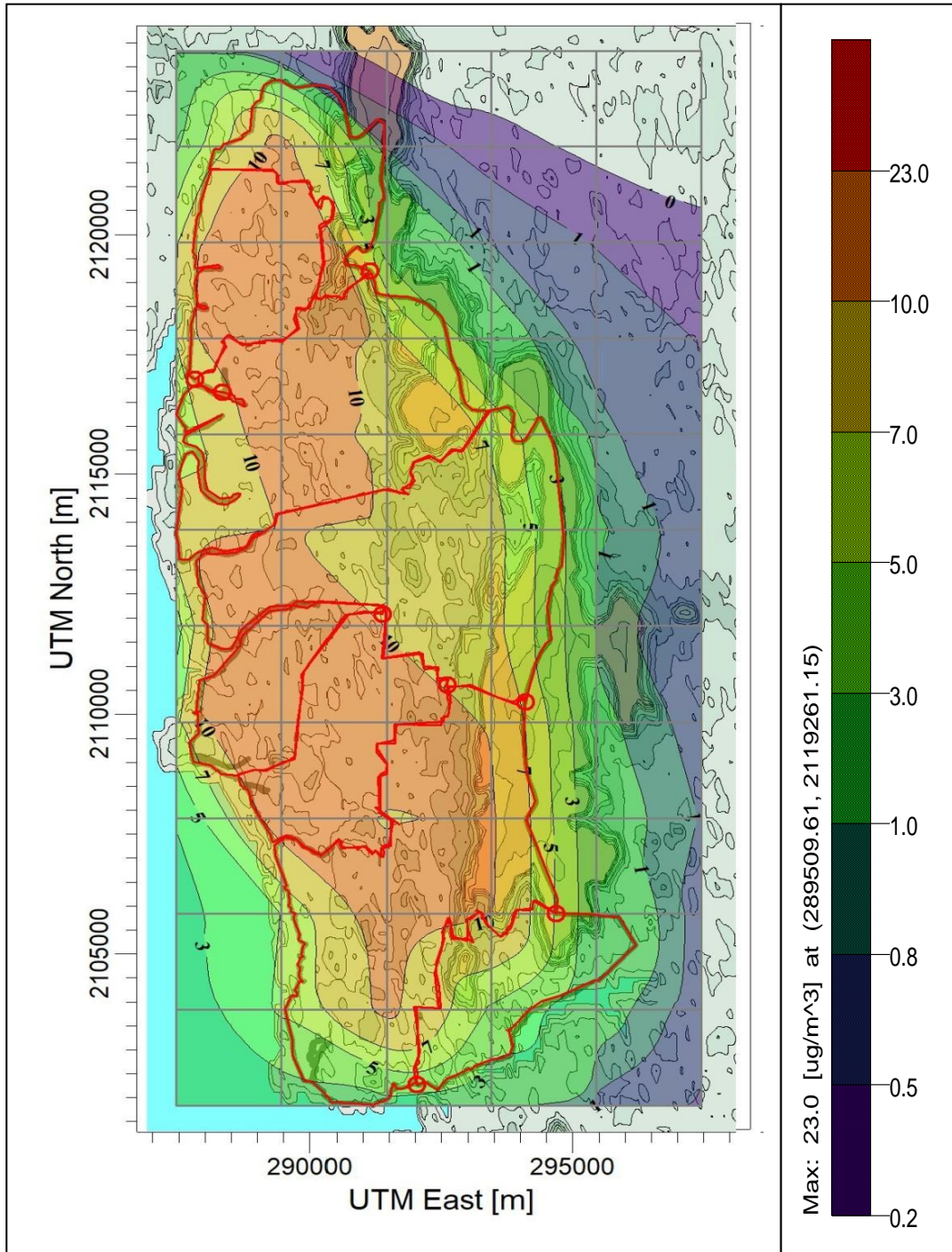


**Figure N1: Isopleths of NO<sub>x</sub> Due to Area Sources – Summer Season (Navi Mumbai City)**

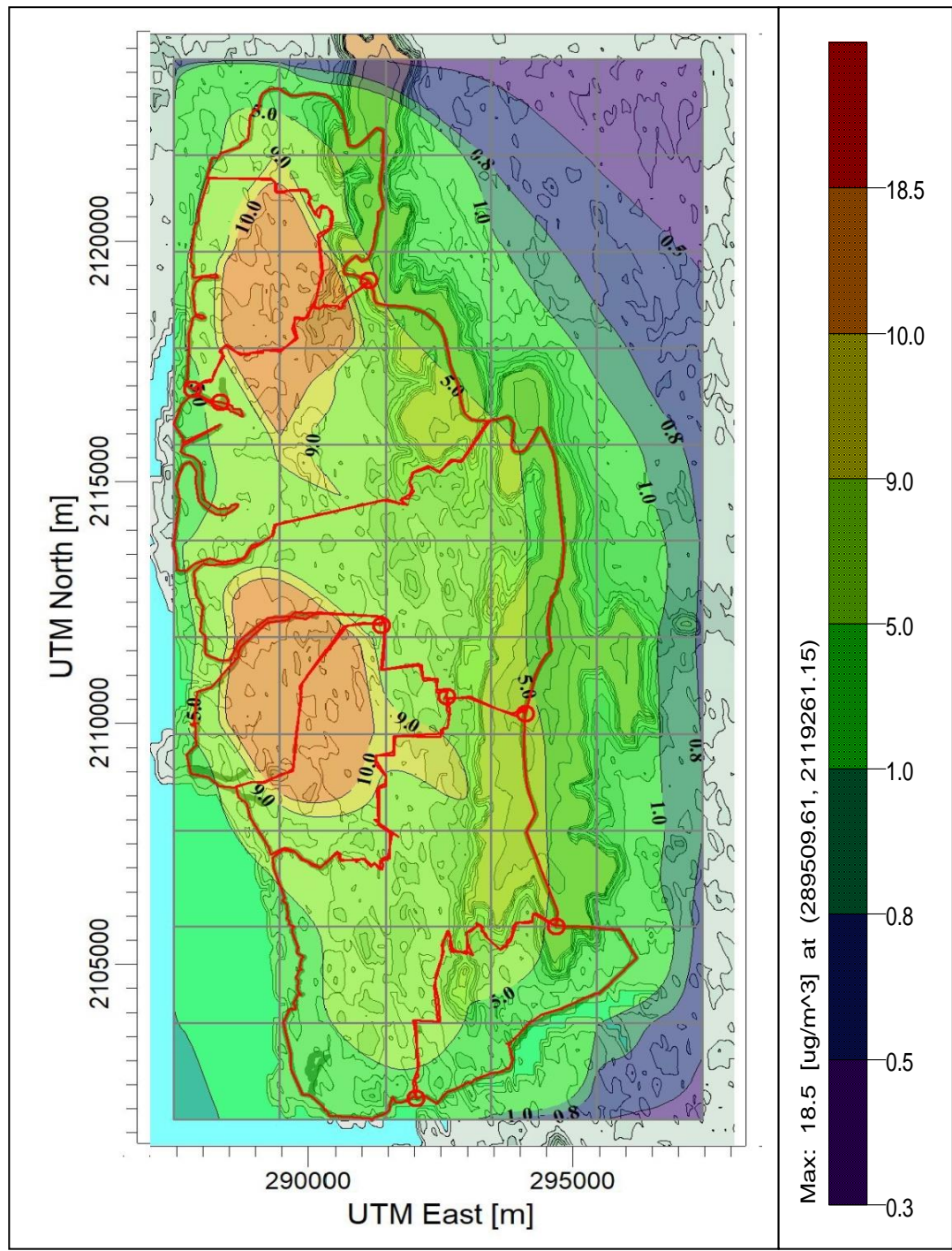


**Figure N2 : Isopleths of NO<sub>x</sub> Due to Area Sources – Post Monsoon Season (Navi Mumbai City)**





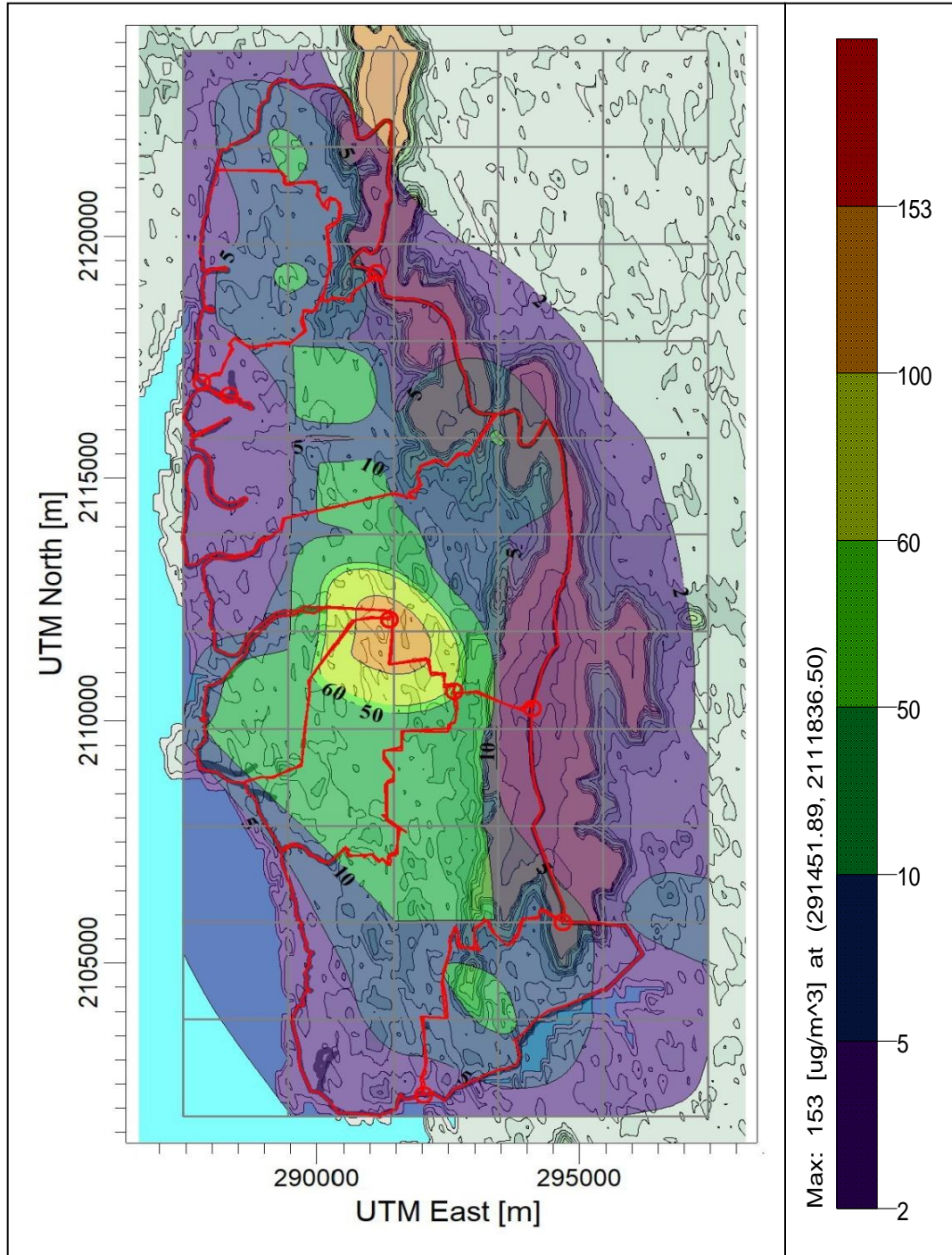
**Figure N3 : Isopleths of NO<sub>x</sub> Due to Area Sources – Winter Season (Navi Mumbai City)**



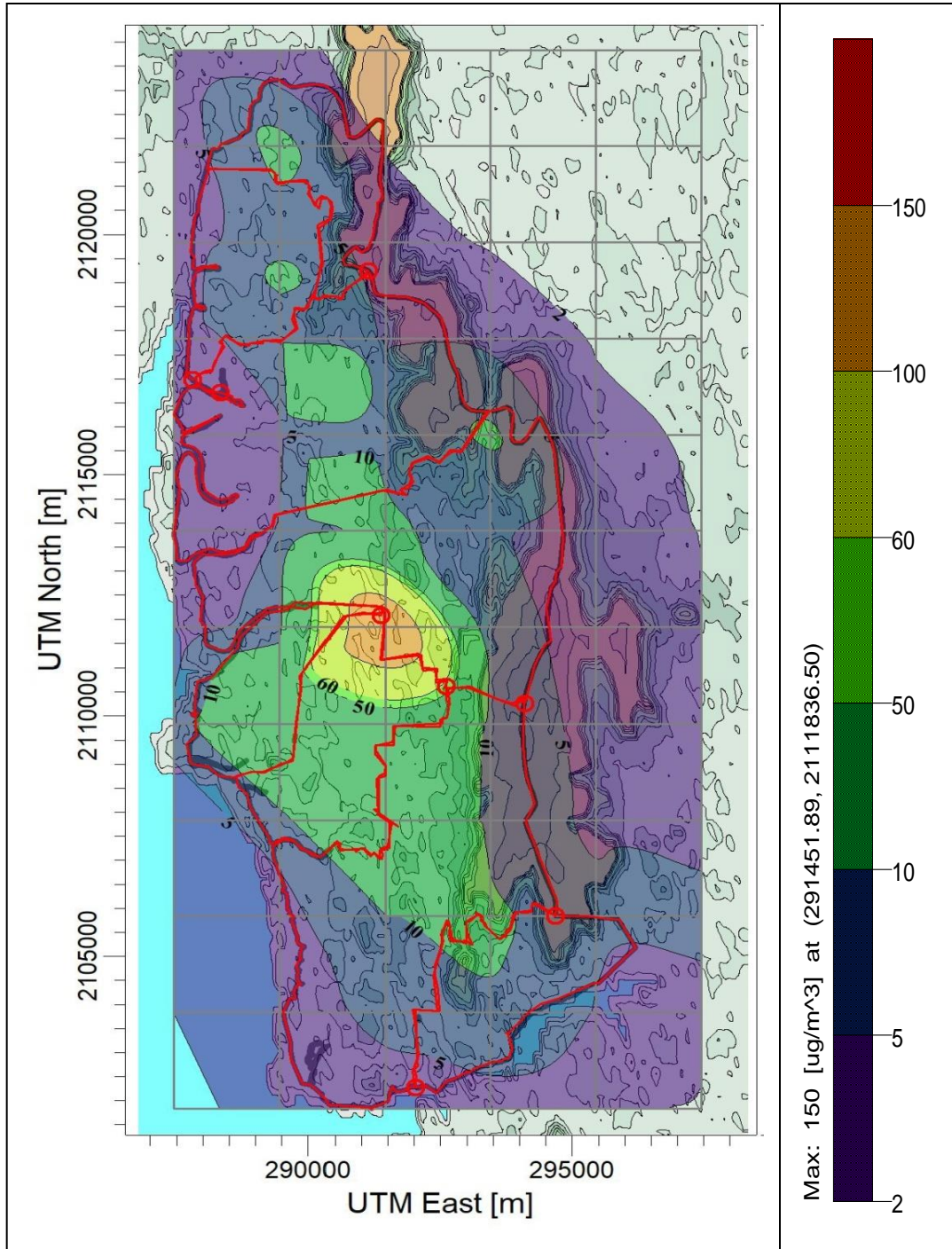
**Figure N4 : Isopleths of NO<sub>x</sub> Due to Area Sources – Annual  
(Navi Mumbai City)**



## B) LINE SOURCE – ALL (NO<sub>x</sub>)

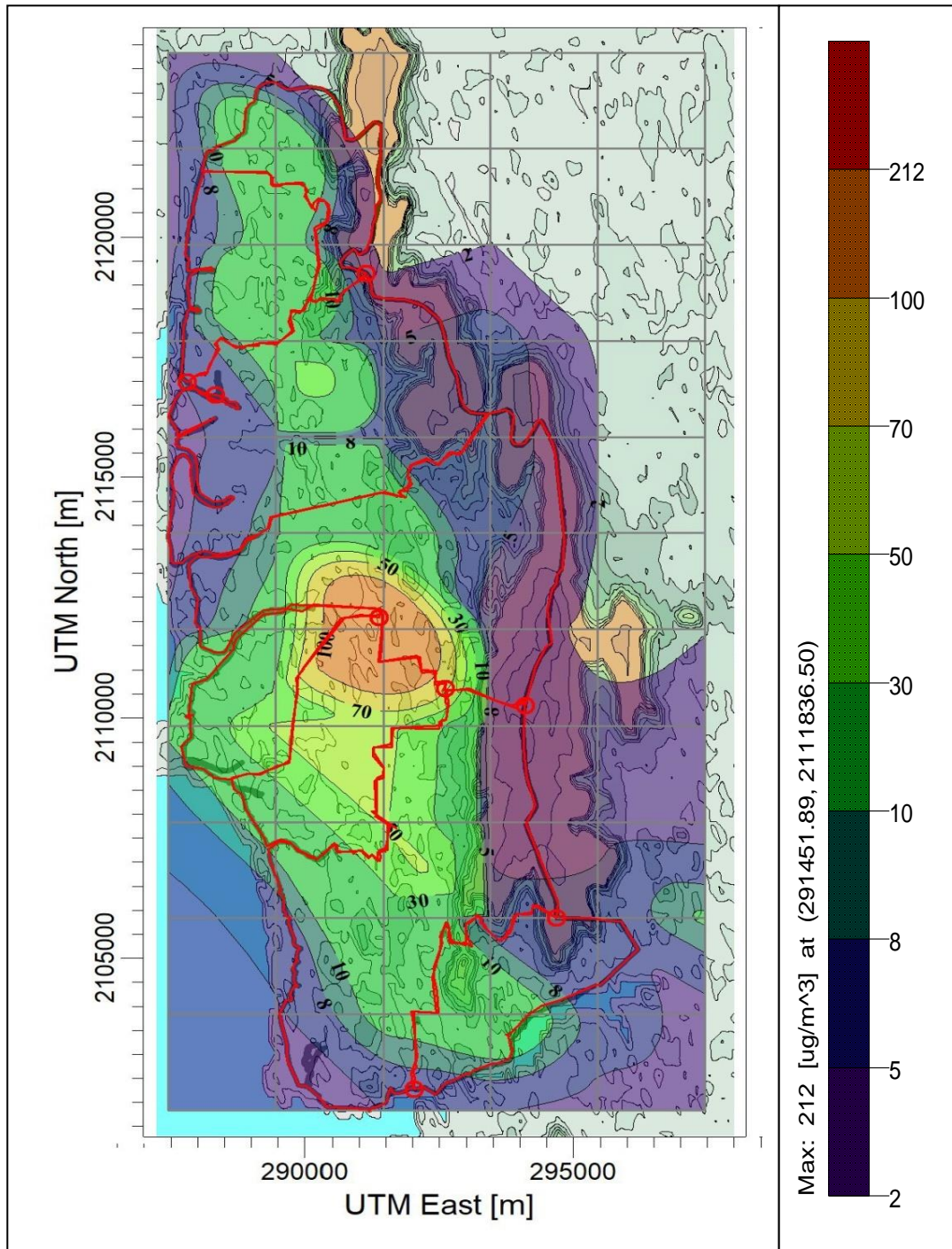


**Figure N5 : Isopleths of NO<sub>x</sub> Due to Line Sources – Summer Season (Navi Mumbai City)**

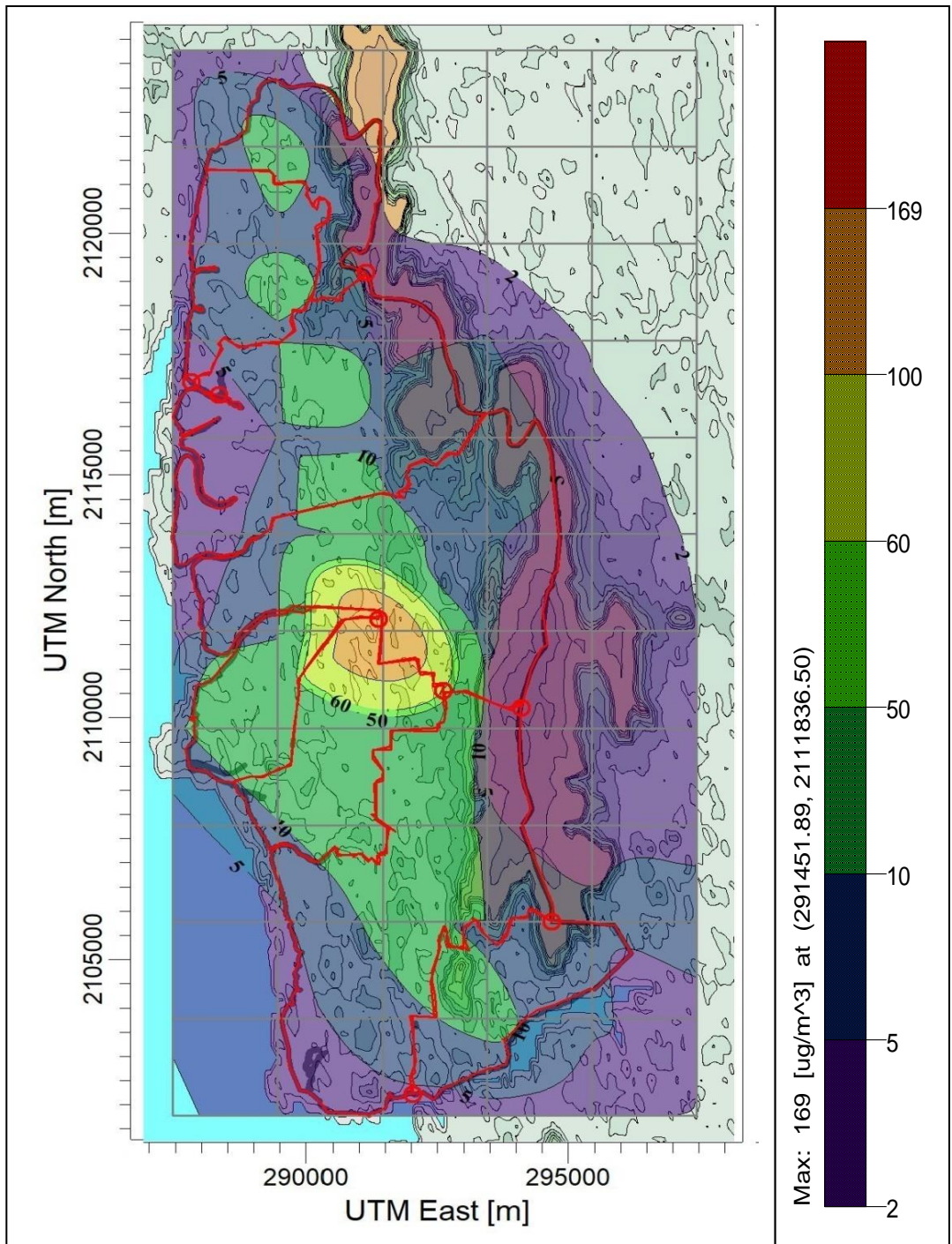


**Figure N6 : Isopleths of NOx Due to Line Sources – Post Monsoon Season (Navi Mumbai City)**





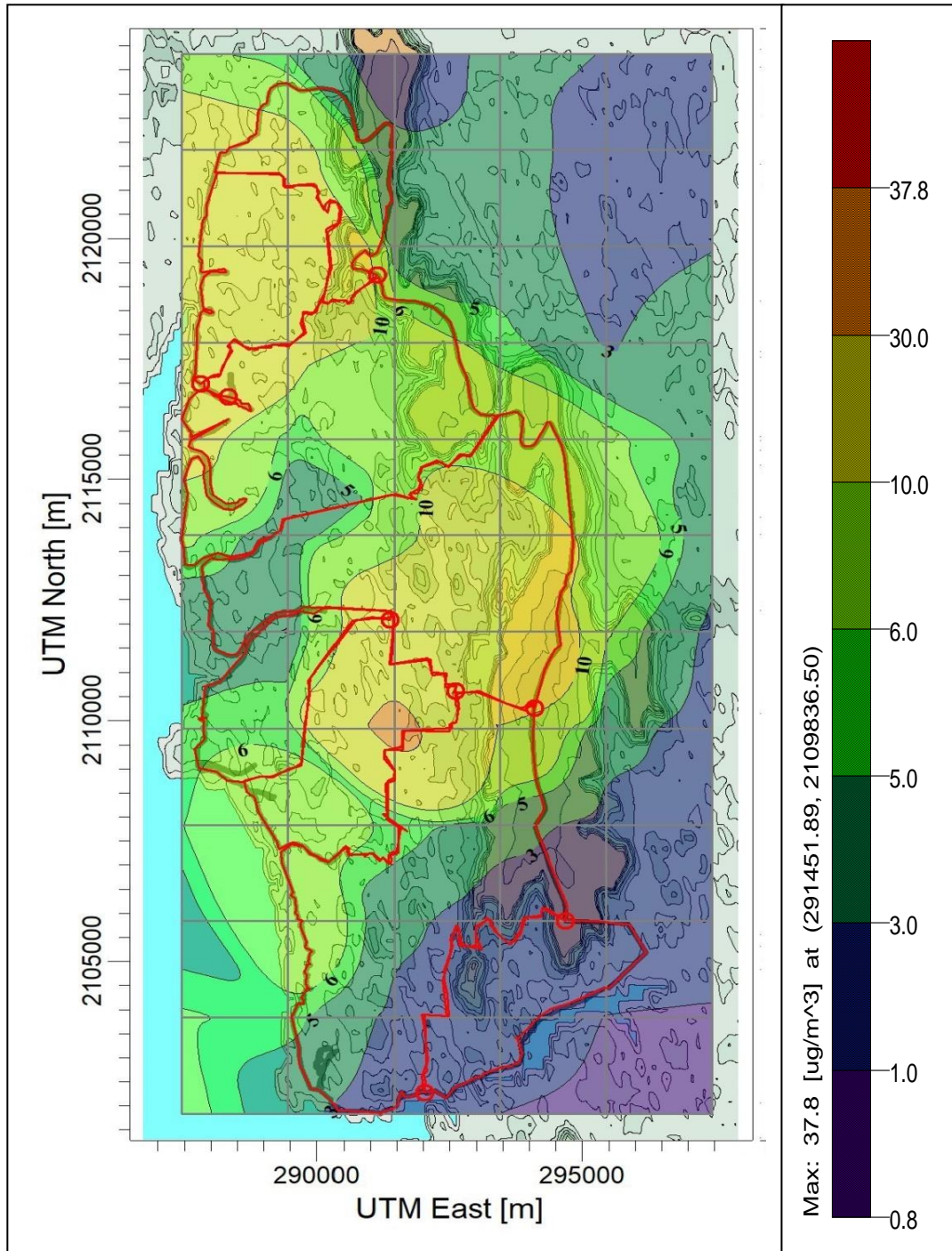
**Figure N7 : Isopleths of NOx Due to Line Sources – Winter Season  
(Navi Mumbai City)**



**Figure N8 : Isopleths of NO<sub>x</sub> Due to Line Sources – Annual  
(Navi Mumbai City)**

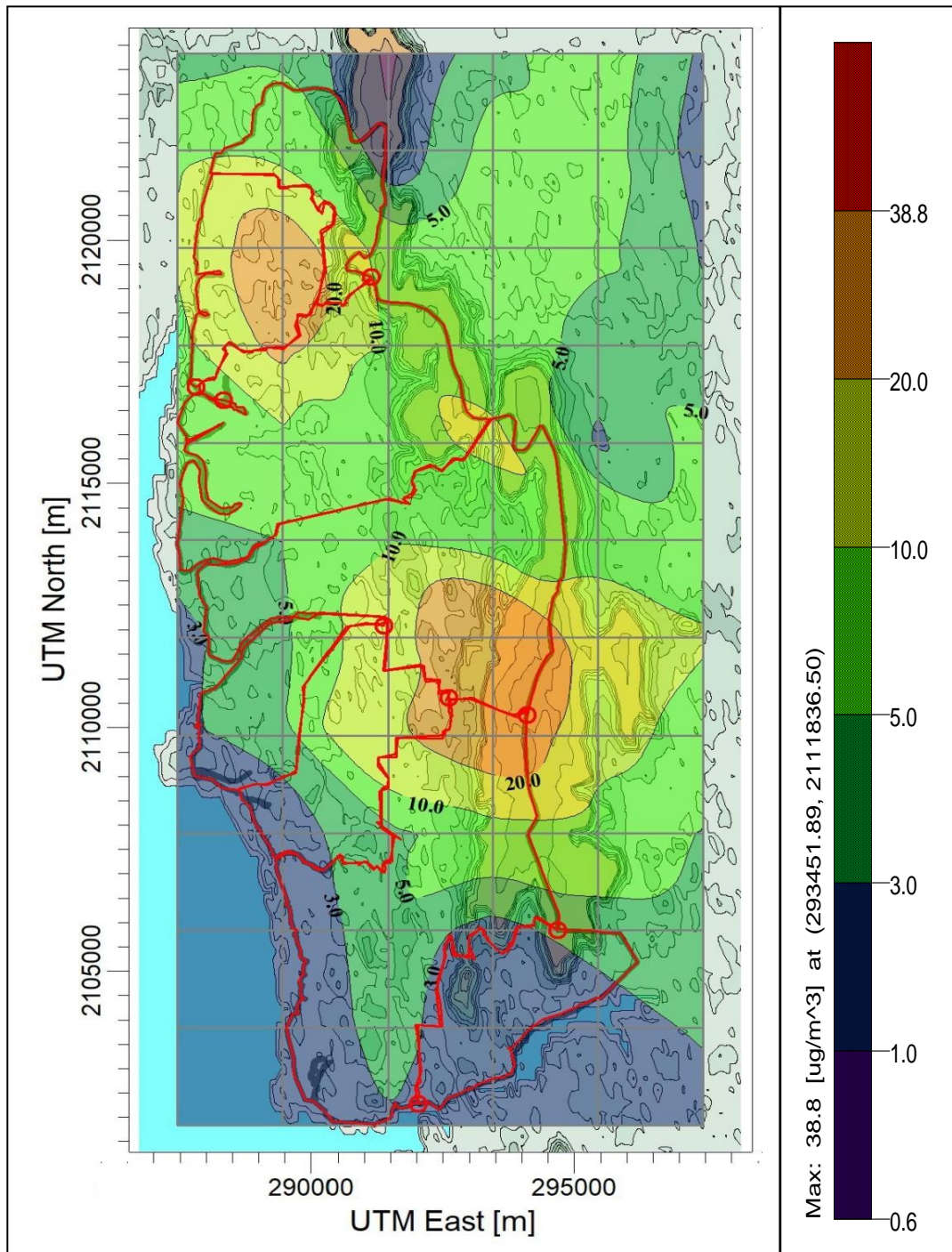


### C) POINT SOURCE – LSI (NO<sub>x</sub>)

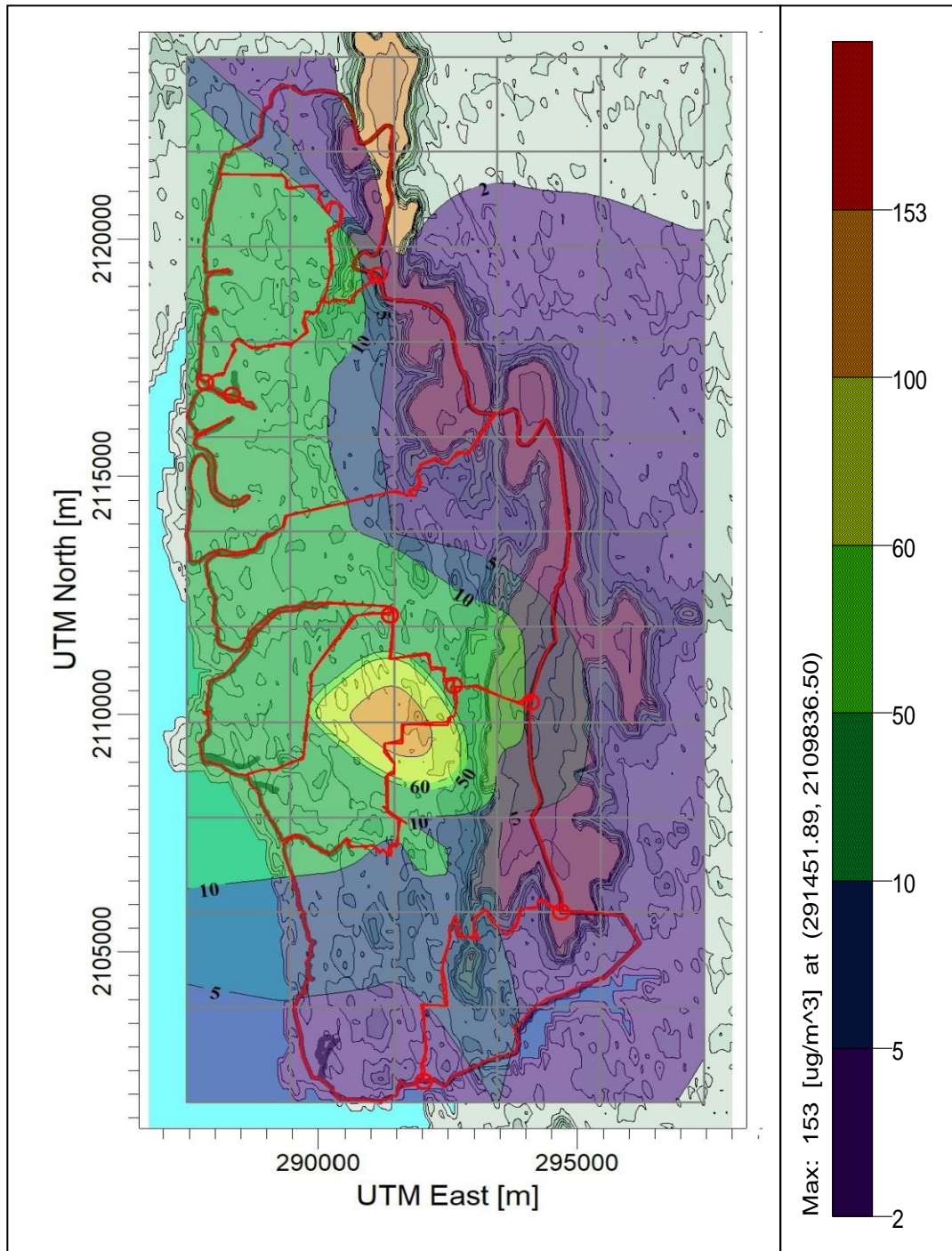


**Figure N9 : Isopleths of NO<sub>x</sub> Due to Point Sources (LSI) – Summer Season (Navi Mumbai City)**



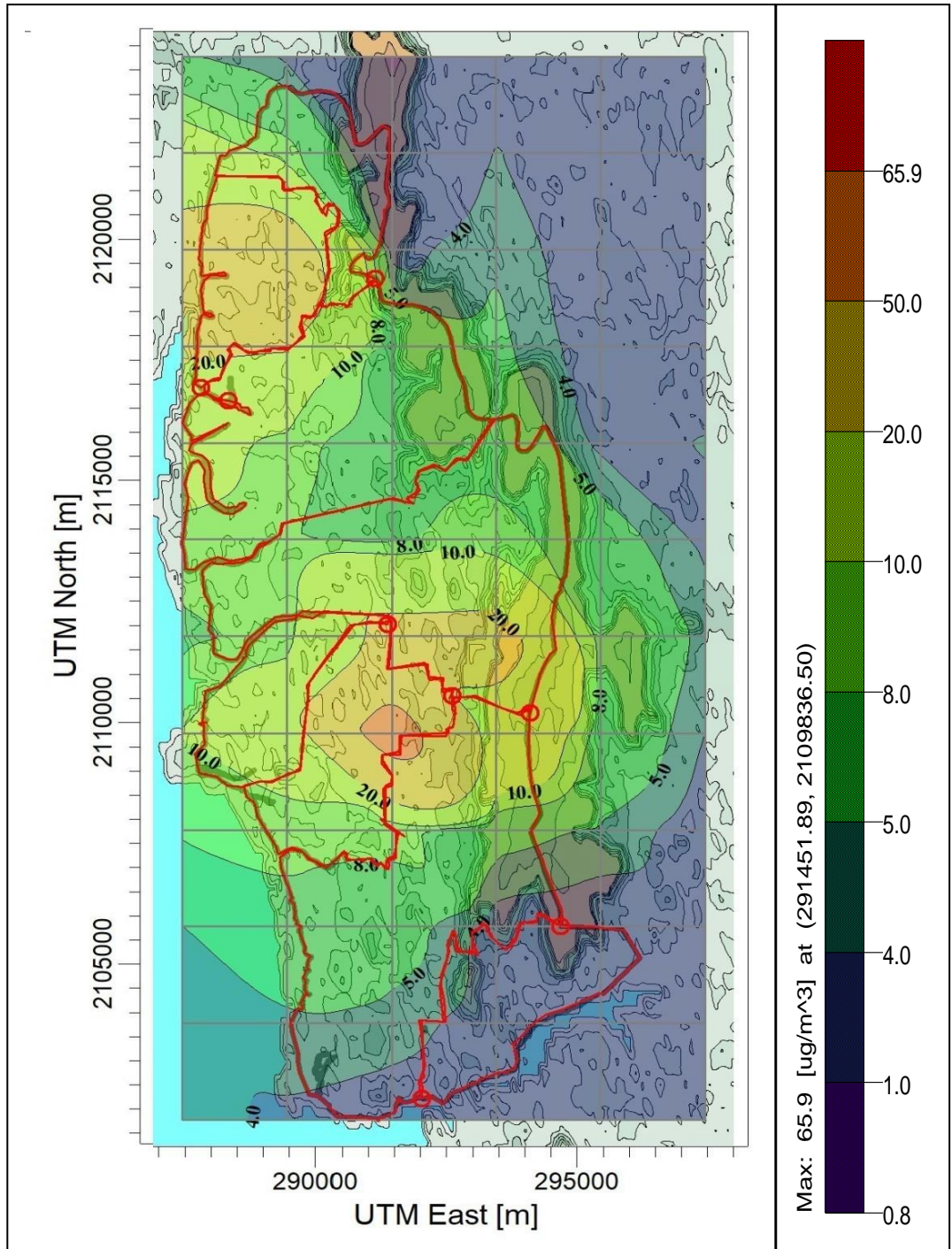


**Figure N10 : Isopleths of NO<sub>x</sub> Due to Point Sources (LSI) – Post Monsoon Season (Navi Mumbai City)**



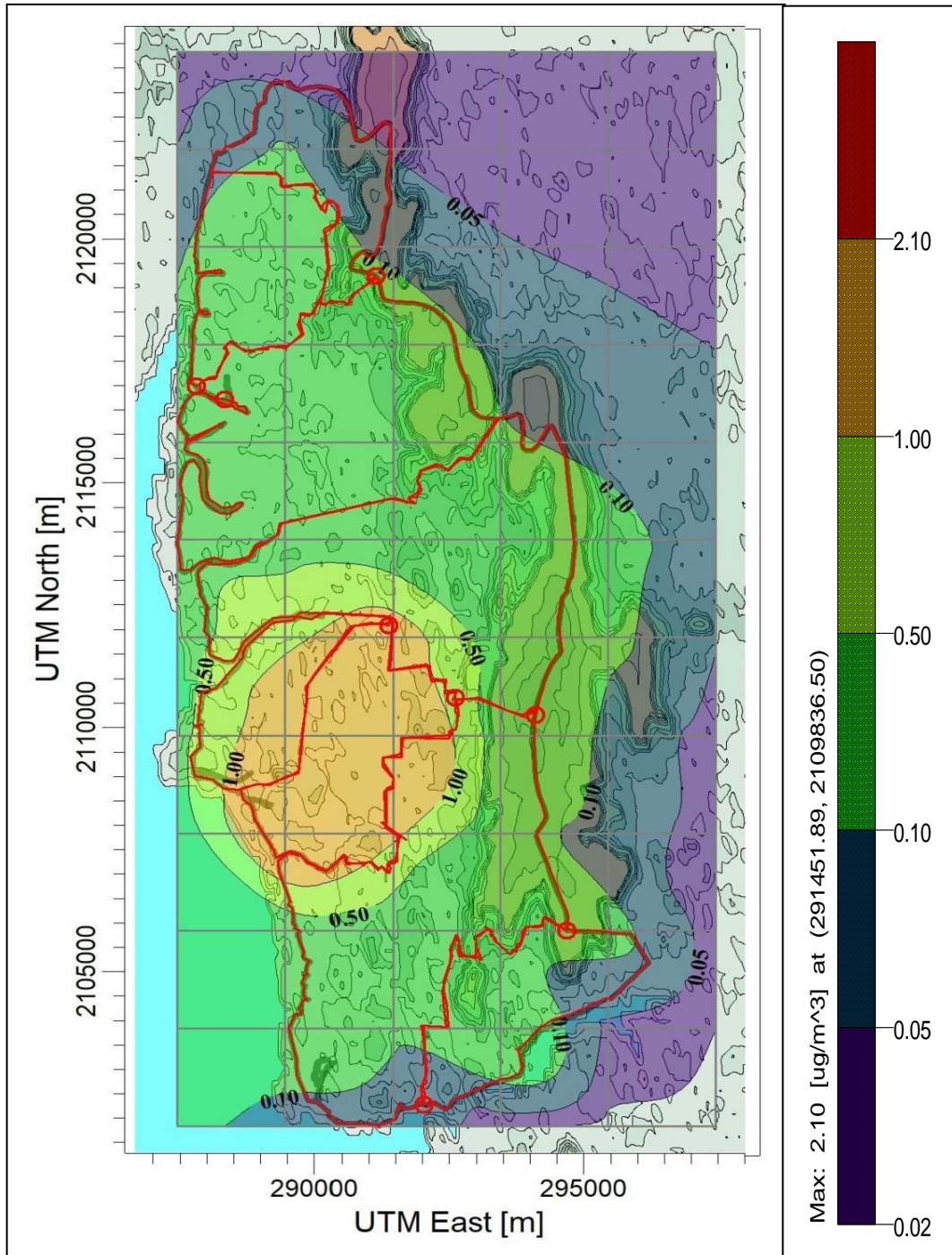
**Figure N11 : Isopleths of NO<sub>x</sub> Due to Point Sources (LSI) – Winter Season (Navi Mumbai City)**





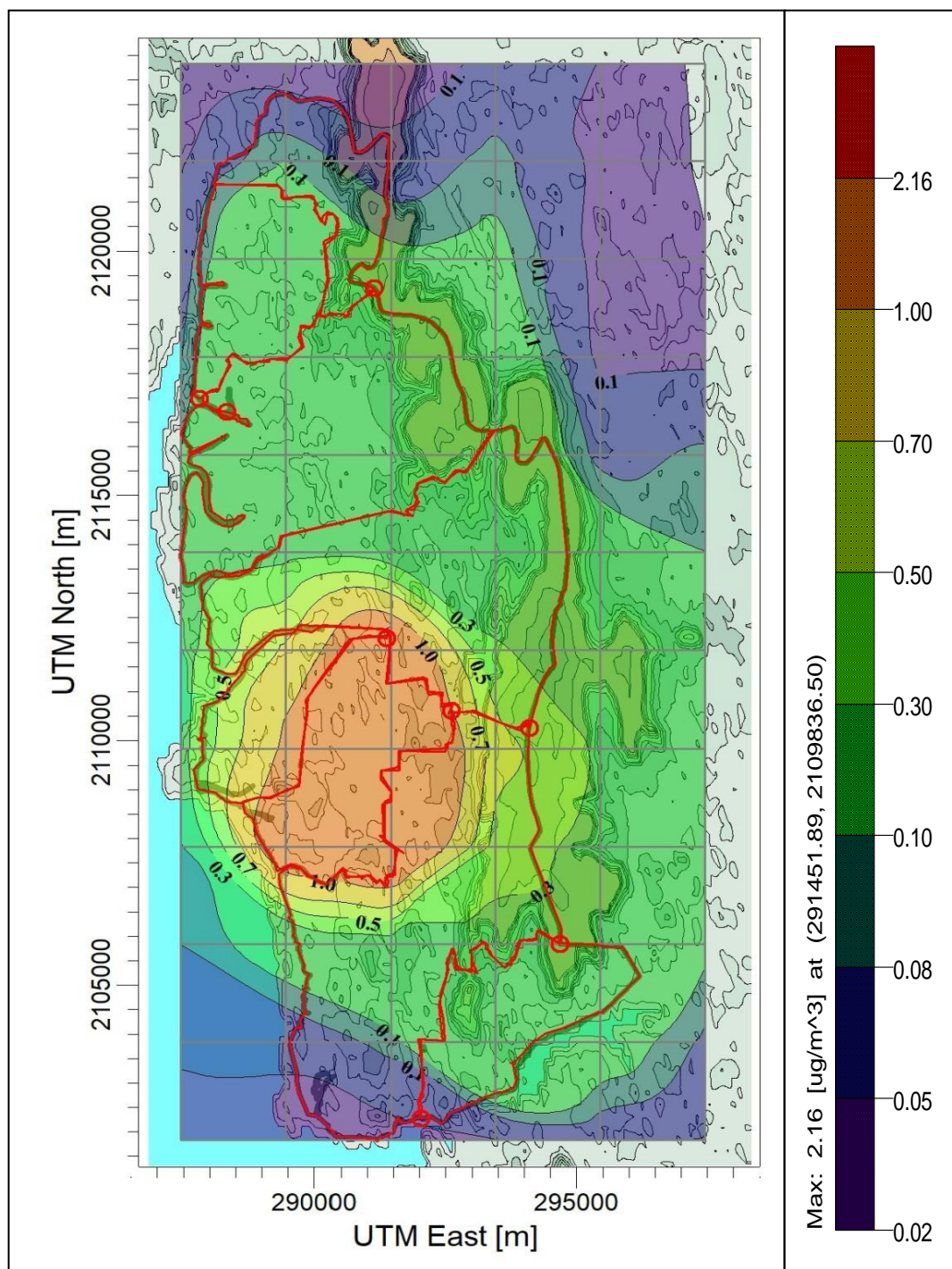
**Figure N12 : Isopleths of NO<sub>x</sub> Due to Point Sources (LSI) – Annual (Navi Mumbai City)**

### E) POINT SOURCE – MSI (NO<sub>x</sub>)

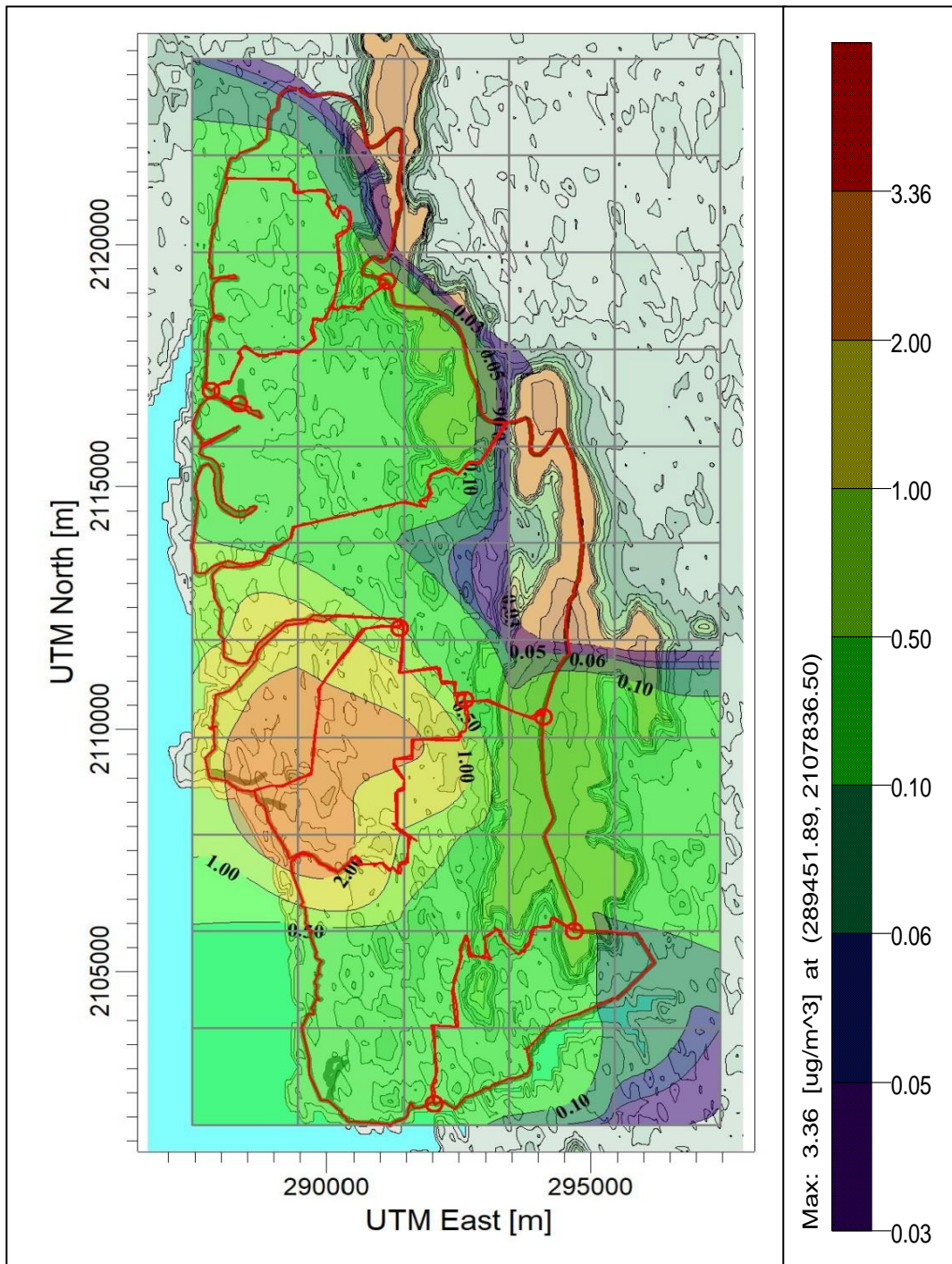


**Figure N13 : Isopleths of NO<sub>x</sub> Due to Point Sources (MSI)– Summer Season (Navi Mumbai City)**



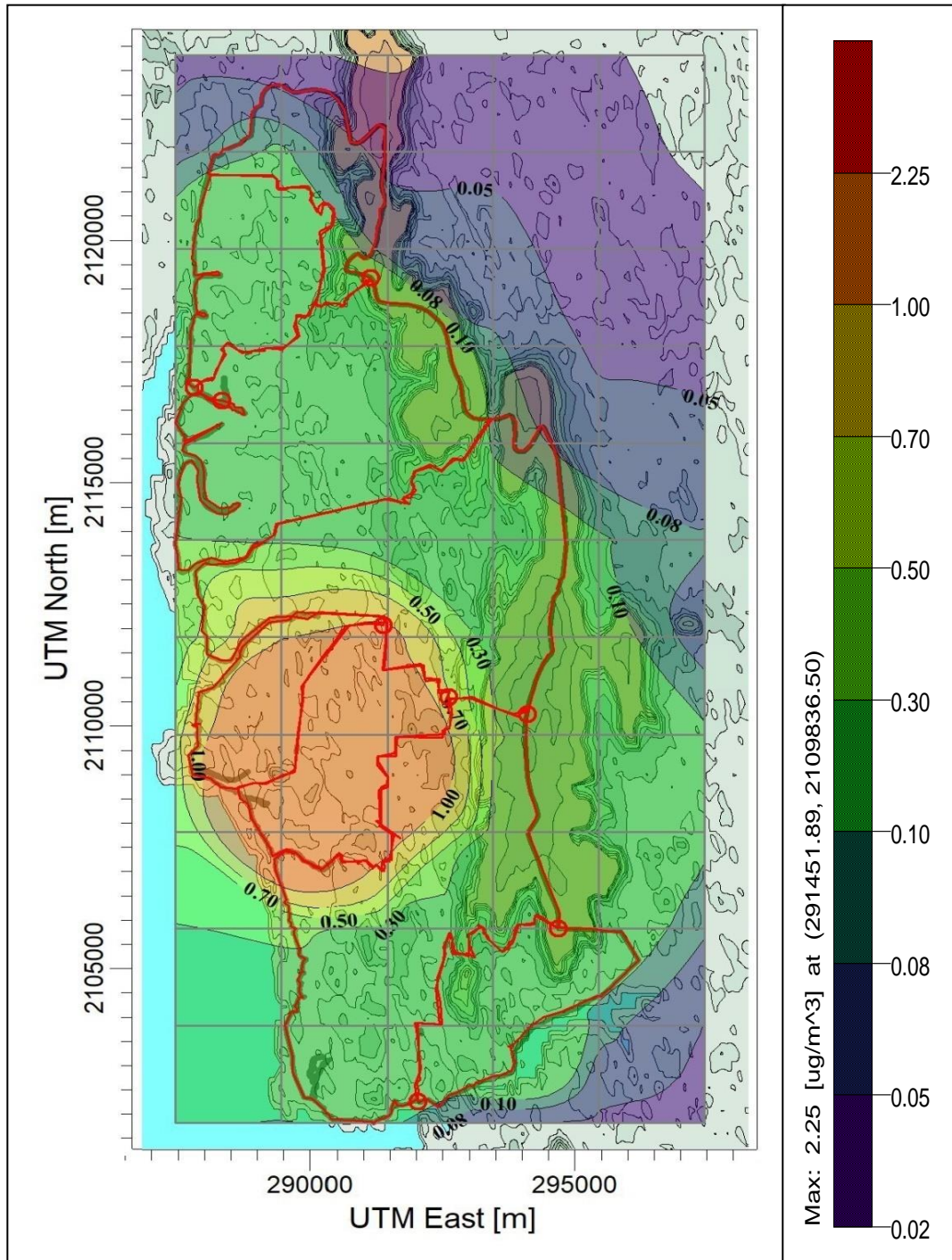


**Figure N14 : Isopleths of NO<sub>x</sub> Due to Point Sources (MSI)– Post Monsoon Season (Navi Mumbai City)**



**Figure N15 : Isopleths of NO<sub>x</sub> Due to Point Sources (MSI) – Winter Season (Navi Mumbai City)**

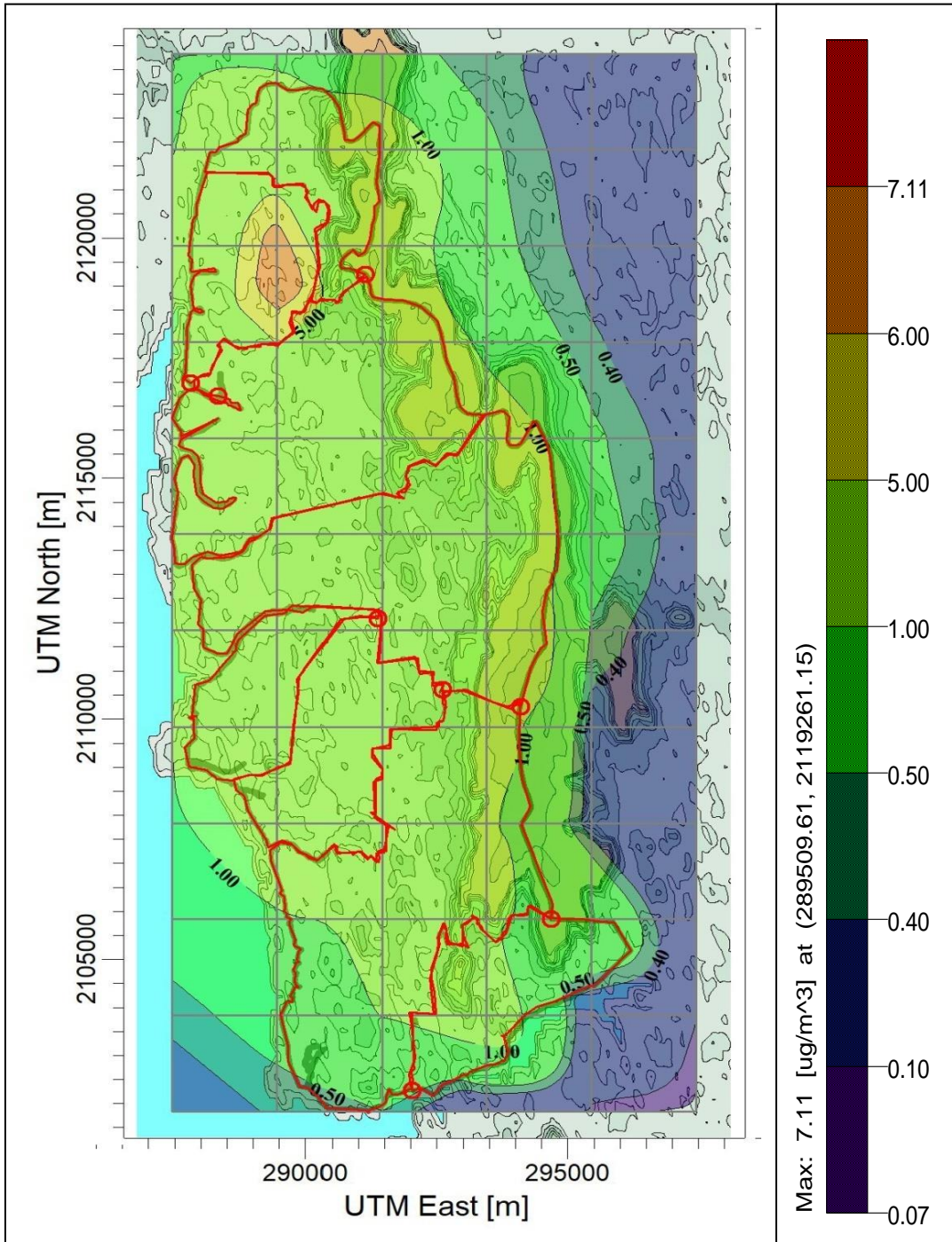




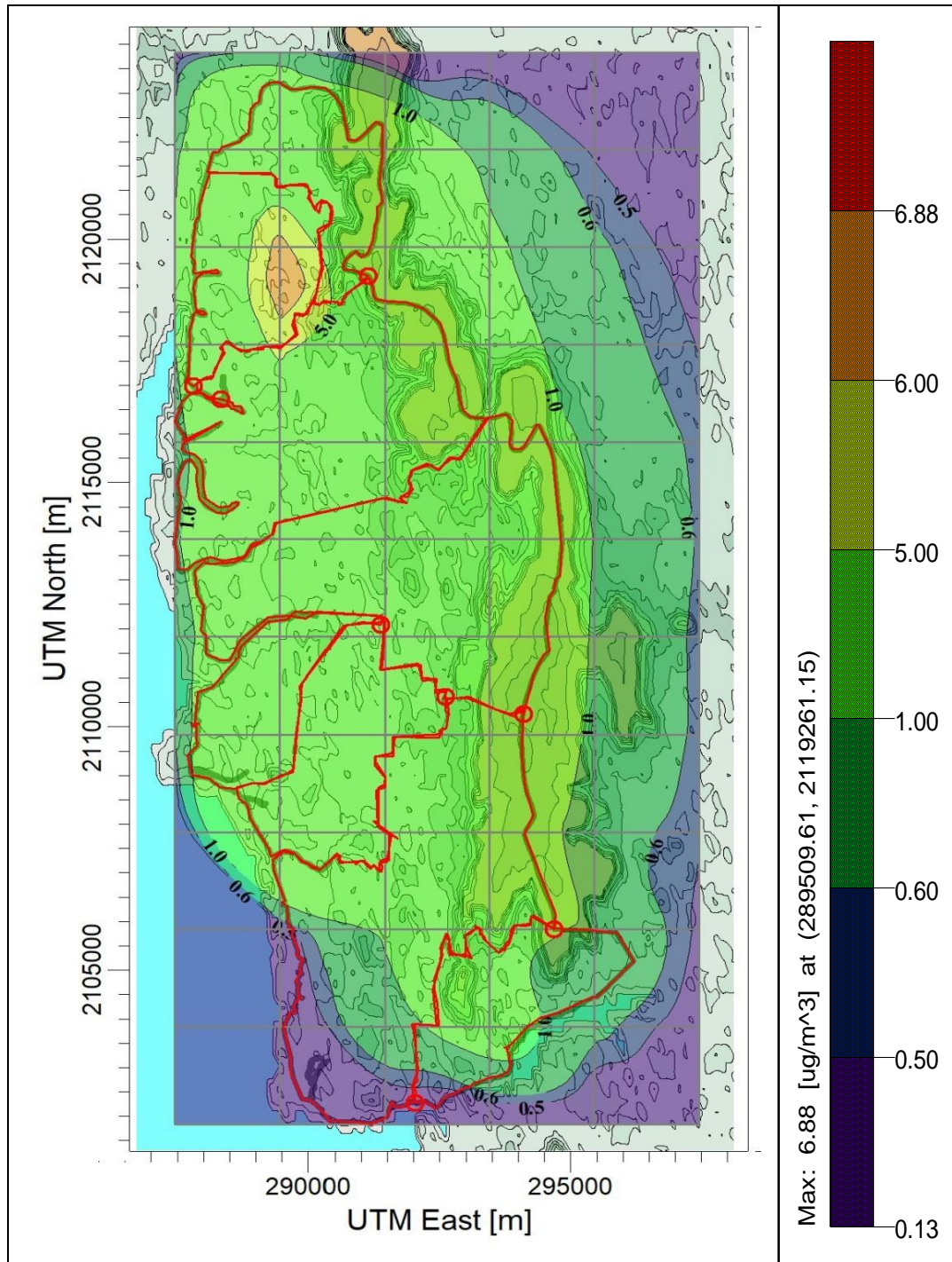
**Figure N16 : Isopleths of NOx Due to Point Sources (MSI) – Annual (Navi Mumbai City)**



**F) POINT SOURCE – SSI (NO<sub>x</sub>)**

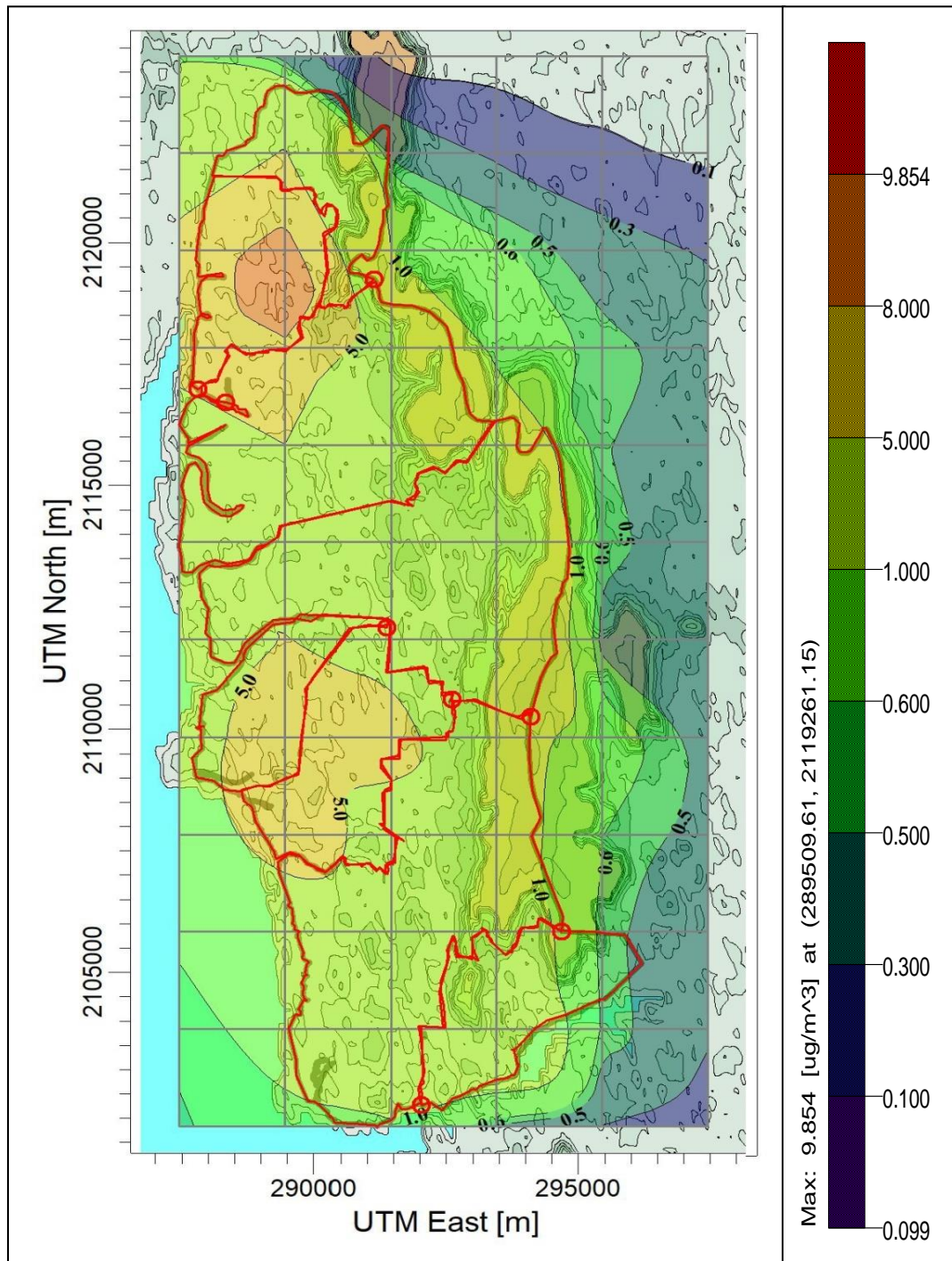


**Figure N17 : Isopleths of NO<sub>x</sub> Due to Point Sources (SSI) – Summer Season (Navi Mumbai City)**

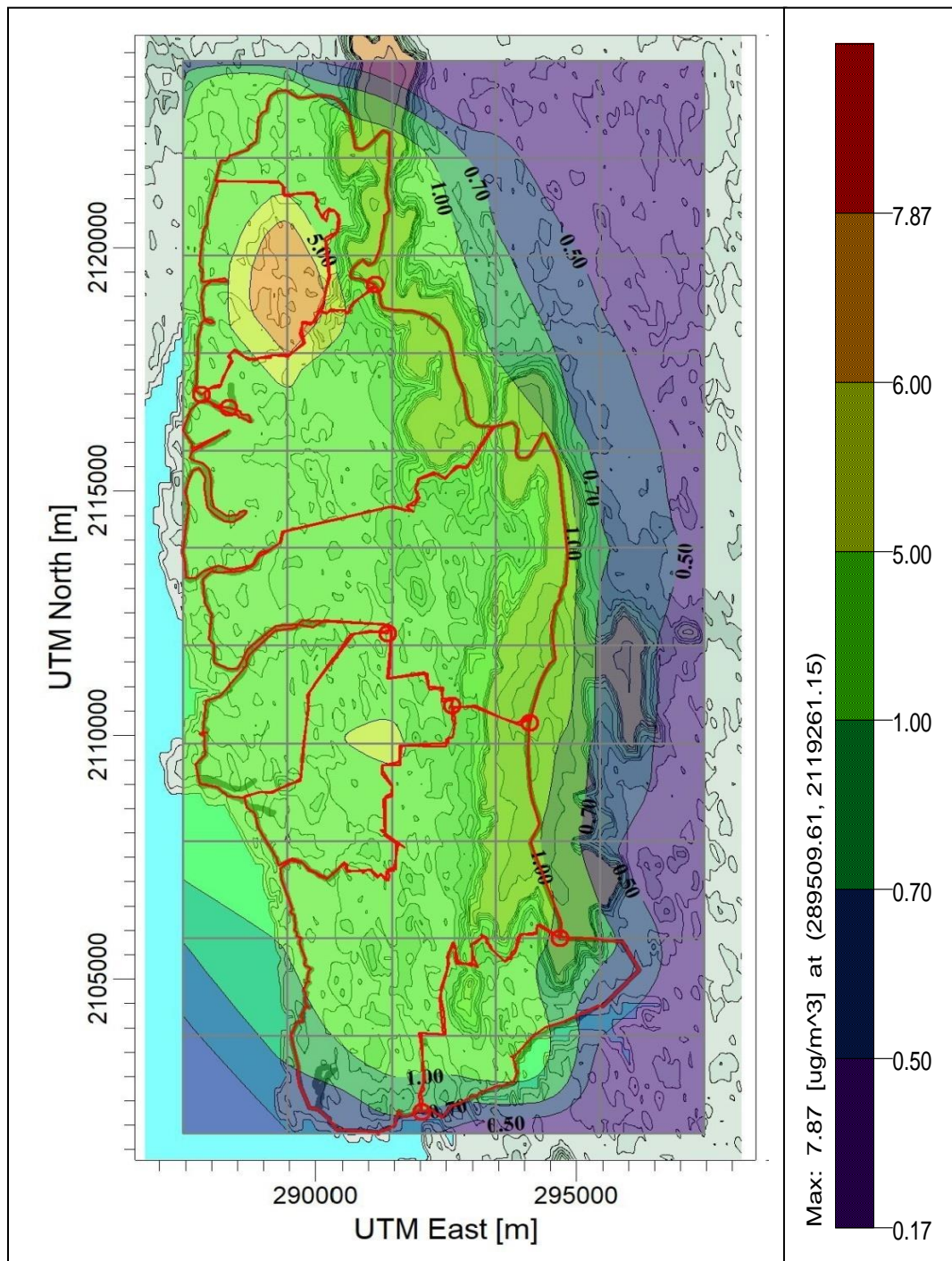


**Figure N18 : Isopleths of NO<sub>x</sub> Due to Point Sources (SSI) – Post Monsoon Season (Navi Mumbai City)**





**Figure N19 : Isopleths of NO<sub>x</sub> Due to Point Sources (SSI) – Winter Season (Navi Mumbai City)**



**Figure N20 : Isopleths of NO<sub>x</sub> Due to Point Sources (SSI) – Annual (Navi Mumbai City)**

## **ANNEXURE – 5**

**Maximum Ten Concentrations of NO<sub>x</sub> (Annual) BaU 2018, 2020,  
2025 and Preferred Option I -2020, Preferred Option II – 2025**

**Navi Mumbai City**

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## Annexure 5

### A) Maximum Ten Occurrences of NO<sub>x</sub> Concentrations in BaU 2018 at Navi Mumbai City (Annual)

Annual - All Source – BaU 2018				Annual - Area Source – BaU 2018			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	445.34	1 <sup>st</sup>	289509.61	2119261.15	42.84
2 <sup>nd</sup>	291451.89	2111836.50	382.18	2 <sup>nd</sup>	289509.61	2119261.15	36.88
3 <sup>rd</sup>	291451.89	2111836.50	339.60	3 <sup>rd</sup>	289509.61	2119261.15	33.00
4 <sup>th</sup>	291451.89	2111836.50	300.60	4 <sup>th</sup>	289509.61	2119261.15	26.53
5 <sup>th</sup>	291451.89	2111836.50	289.41	5 <sup>th</sup>	289509.61	2119261.15	25.17
6 <sup>th</sup>	291451.89	2111836.50	275.71	6 <sup>th</sup>	289509.61	2119261.15	25.07
7 <sup>th</sup>	291451.89	2111836.50	262.86	7 <sup>th</sup>	289509.61	2119261.15	23.59
8 <sup>th</sup>	291451.89	2111836.50	262.63	8 <sup>th</sup>	289509.61	2119261.15	23.04
9 <sup>th</sup>	291451.89	2111836.50	247.88	9 <sup>th</sup>	289509.61	2119261.15	22.57
10 <sup>th</sup>	291451.89	2111836.50	234.51	10 <sup>th</sup>	289509.61	2119261.15	22.43
Avg.	291451.89	2111836.50	205.75	Avg.	289509.61	2119261.15	18.45

Annual – Line Source – BaU 2018				Annual - Point Source (LSI)– BaU 2018			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	384.83	1 <sup>st</sup>	287451.89	2119836.50	354.35
2 <sup>nd</sup>	291451.89	2111836.50	337.85	2 <sup>nd</sup>	287451.89	2119836.50	282.48
3 <sup>rd</sup>	291451.89	2111836.50	291.13	3 <sup>rd</sup>	287451.89	2119836.50	251.58
4 <sup>th</sup>	291451.89	2111836.50	246.02	4 <sup>th</sup>	287451.89	2119836.50	232.89
5 <sup>th</sup>	291451.89	2111836.50	245.80	5 <sup>th</sup>	287451.89	2119836.50	129.48
6 <sup>th</sup>	291451.89	2111836.50	225.91	6 <sup>th</sup>	287451.89	2119836.50	126.84
7 <sup>th</sup>	291451.89	2111836.50	212.38	7 <sup>th</sup>	287451.89	2117836.50	110.97
8 <sup>th</sup>	291451.89	2111836.50	210.56	8 <sup>th</sup>	287451.89	2117836.50	86.00
9 <sup>th</sup>	291451.89	2111836.50	209.57	9 <sup>th</sup>	287451.89	2117836.50	75.71
10 <sup>th</sup>	291451.89	2111836.50	202.65	10 <sup>th</sup>	287451.89	2117836.50	35.33
Avg.	291451.89	2111836.50	168.98	Avg.	289509.61	2119261.15	65.91

Annual – Point Source (MSI) – BaU 2018				Annual – Point Source (SSI) – BaU 2018			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289451.89	2107836.50	7.08	1 <sup>st</sup>	289509.61	2119261.15	20.28
2 <sup>nd</sup>	289451.89	2109836.50	5.62	2 <sup>nd</sup>	289509.61	2119261.15	15.54
3 <sup>rd</sup>	289451.89	2107836.50	4.58	3 <sup>rd</sup>	289509.61	2119261.15	16.25
4 <sup>th</sup>	289451.89	2107836.50	4.39	4 <sup>th</sup>	289509.61	2119261.15	12.78
5 <sup>th</sup>	289451.89	2107836.50	4.37	5 <sup>th</sup>	289509.61	2119261.15	12.48
6 <sup>th</sup>	289451.89	2107836.50	4.17	6 <sup>th</sup>	289509.61	2119261.15	9.81
7 <sup>th</sup>	289451.89	2107836.50	4.05	7 <sup>th</sup>	289509.61	2119261.15	10.70
8 <sup>th</sup>	289451.89	2107836.50	3.92	8 <sup>th</sup>	289509.61	2119261.15	10.28
9 <sup>th</sup>	289451.89	2107836.50	3.81	9 <sup>th</sup>	289509.61	2119261.15	10.14
10 <sup>th</sup>	289451.89	2107836.50	3.04	10 <sup>th</sup>	289509.61	2119261.15	10.12
Avg.	291451.89	2109836.50	2.25	Avg.	289509.61	2119261.15	7.86



**B) Maximum Ten Occurrences of NO<sub>x</sub> Concentrations in BaU 2020 at Navi Mumbai City (Annual)**

Annual - All Source – BaU 2020				Annual - Area Source – BaU 2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	475.24	1 <sup>st</sup>	289509.61	2119261.15	45.19
2 <sup>nd</sup>	291451.89	2111836.50	408.47	2 <sup>nd</sup>	289509.61	2119261.15	38.91
3 <sup>rd</sup>	291451.89	2111836.50	362.19	3 <sup>rd</sup>	289509.61	2119261.15	34.81
4 <sup>th</sup>	291451.89	2111836.50	319.62	4 <sup>th</sup>	289509.61	2119261.15	27.99
5 <sup>th</sup>	291451.89	2111836.50	308.42	5 <sup>th</sup>	289509.61	2119261.15	26.55
6 <sup>th</sup>	291451.89	2111836.50	292.05	6 <sup>th</sup>	289509.61	2119261.15	26.45
7 <sup>th</sup>	291451.89	2111836.50	280.38	7 <sup>th</sup>	289509.61	2119261.15	24.88
8 <sup>th</sup>	291451.89	2111836.50	278.83	8 <sup>th</sup>	289509.61	2119261.15	24.31
9 <sup>th</sup>	291451.89	2111836.50	264.32	9 <sup>th</sup>	289509.61	2119261.15	23.82
10 <sup>th</sup>	291451.89	2111836.50	250.30	10 <sup>th</sup>	289509.61	2119261.15	23.67
Avg.	291451.89	2111836.50	218.87	Avg.	289509.61	2119261.15	19.47

Annual – Line Source – BaU 2020				Annual - Point Source (LSI)– BaU 2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	413.70	1 <sup>st</sup>	291451.89	2109836.50	356.35
2 <sup>nd</sup>	291451.89	2111836.50	363.19	2 <sup>nd</sup>	291451.89	2109836.50	284.48
3 <sup>rd</sup>	291451.89	2111836.50	312.97	3 <sup>rd</sup>	291451.89	2109836.50	252.58
4 <sup>th</sup>	291451.89	2111836.50	264.48	4 <sup>th</sup>	291451.89	2109836.50	233.89
5 <sup>th</sup>	291451.89	2111836.50	264.24	5 <sup>th</sup>	291451.89	2109836.50	130.48
6 <sup>th</sup>	291451.89	2111836.50	242.85	6 <sup>th</sup>	291451.89	2109836.50	127.84
7 <sup>th</sup>	291451.89	2111836.50	228.31	7 <sup>th</sup>	291451.89	2109836.50	111.97
8 <sup>th</sup>	291451.89	2111836.50	226.35	8 <sup>th</sup>	291451.89	2109836.50	87.00
9 <sup>th</sup>	291451.89	2111836.50	225.29	9 <sup>th</sup>	291451.89	2109836.50	76.71
10 <sup>th</sup>	291451.89	2111836.50	217.85	10 <sup>th</sup>	291451.89	2109836.50	36.33
Avg.	291451.89	2111836.50	181.66	Avg.	291451.89	2109836.50	65.91

Annual – Point Source (MSI) – BaU 2020				Annual – Point Source (SSI) – BaU 2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289451.89	2107836.50	7.08	1 <sup>st</sup>	289509.61	2119261.15	20.25
2 <sup>nd</sup>	289451.89	2109836.50	5.62	2 <sup>nd</sup>	289509.61	2119261.15	15.53
3 <sup>rd</sup>	289451.89	2107836.50	4.58	3 <sup>rd</sup>	289509.61	2119261.15	15.25
4 <sup>th</sup>	289451.89	2107836.50	4.39	4 <sup>th</sup>	289509.61	2119261.15	11.78
5 <sup>th</sup>	289451.89	2107836.50	4.37	5 <sup>th</sup>	289509.61	2119261.15	11.48
6 <sup>th</sup>	289451.89	2107836.50	4.17	6 <sup>th</sup>	289509.61	2119261.15	10.81
7 <sup>th</sup>	289451.89	2107836.50	4.05	7 <sup>th</sup>	289509.61	2119261.15	10.70
8 <sup>th</sup>	289451.89	2107836.50	3.92	8 <sup>th</sup>	289509.61	2119261.15	10.48
9 <sup>th</sup>	289451.89	2107836.50	3.81	9 <sup>th</sup>	289509.61	2119261.15	10.44
10 <sup>th</sup>	289451.89	2107836.50	3.04	10 <sup>th</sup>	289509.61	2119261.15	10.42
Avg.	291451.89	2109836.50	2.25	Avg.	289509.61	2119261.15	7.87

**C) Maximum Ten Occurrences of NO<sub>x</sub> Concentrations in BaU 2025 at Navi Mumbai City (Annual)**

Annual - All Source – BaU 2025				Annual - Area Source – BaU 2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	507.66	1 <sup>st</sup>	289509.61	2119261.15	48.36
2 <sup>nd</sup>	291451.89	2111836.50	436.99	2 <sup>nd</sup>	289509.61	2119261.15	41.64
3 <sup>rd</sup>	291451.89	2111836.50	386.67	3 <sup>rd</sup>	289509.61	2119261.15	37.25
4 <sup>th</sup>	291451.89	2111836.50	340.21	4 <sup>th</sup>	289509.61	2119261.15	29.95
5 <sup>th</sup>	291451.89	2111836.50	329.00	5 <sup>th</sup>	289509.61	2119261.15	28.41
6 <sup>th</sup>	291451.89	2111836.50	309.76	6 <sup>th</sup>	289509.61	2119261.15	28.30
7 <sup>th</sup>	291451.89	2111836.50	299.37	7 <sup>th</sup>	289509.61	2119261.15	26.63
8 <sup>th</sup>	291451.89	2111836.50	296.38	8 <sup>th</sup>	289509.61	2119261.15	26.01
9 <sup>th</sup>	291451.89	2111836.50	282.14	9 <sup>th</sup>	289509.61	2119261.15	25.48
10 <sup>th</sup>	291451.89	2111836.50	267.42	10 <sup>th</sup>	289509.61	2119261.15	25.33
Avg.	291451.89	2111836.50	233.09	Avg.	289509.61	2119261.15	20.83

Annual – Line Source – BaU 2025				Annual - Point Source (LSI)– BaU 2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	444.72	1 <sup>st</sup>	291451.89	2109836.50	356.35
2 <sup>nd</sup>	291451.89	2111836.50	390.43	2 <sup>nd</sup>	291451.89	2109836.50	284.48
3 <sup>rd</sup>	291451.89	2111836.50	336.44	3 <sup>rd</sup>	291451.89	2109836.50	252.58
4 <sup>th</sup>	291451.89	2111836.50	284.31	4 <sup>th</sup>	291451.89	2109836.50	233.89
5 <sup>th</sup>	291451.89	2111836.50	284.06	5 <sup>th</sup>	291451.89	2109836.50	130.48
6 <sup>th</sup>	291451.89	2111836.50	261.07	6 <sup>th</sup>	291451.89	2109836.50	127.84
7 <sup>th</sup>	291451.89	2111836.50	245.43	7 <sup>th</sup>	291451.89	2109836.50	111.97
8 <sup>th</sup>	291451.89	2111836.50	243.33	8 <sup>th</sup>	291451.89	2109836.50	87.00
9 <sup>th</sup>	291451.89	2111836.50	242.19	9 <sup>th</sup>	291451.89	2109836.50	76.71
10 <sup>th</sup>	291451.89	2111836.50	234.19	10 <sup>th</sup>	291451.89	2109836.50	36.33
Avg.	291451.89	2111836.50	195.28	Avg.	291451.89	2109836.50	65.91

Annual – Point Source (MSI) – BaU 2025				Annual – Point Source (SSI) – BaU 2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289451.89	2107836.50	7.00	1 <sup>st</sup>	289509.61	2119261.15	20.25
2 <sup>nd</sup>	289451.89	2109836.50	4.95	2 <sup>nd</sup>	289509.61	2119261.15	15.53
3 <sup>rd</sup>	289451.89	2107836.50	4.49	3 <sup>rd</sup>	289509.61	2119261.15	15.25
4 <sup>th</sup>	289451.89	2107836.50	4.33	4 <sup>th</sup>	289509.61	2119261.15	11.78
5 <sup>th</sup>	289451.89	2107836.50	4.20	5 <sup>th</sup>	289509.61	2119261.15	11.48
6 <sup>th</sup>	289451.89	2107836.50	4.14	6 <sup>th</sup>	289509.61	2119261.15	10.81
7 <sup>th</sup>	289451.89	2107836.50	4.05	7 <sup>th</sup>	289509.61	2119261.15	10.70
8 <sup>th</sup>	289451.89	2107836.50	3.92	8 <sup>th</sup>	289509.61	2119261.15	10.48
9 <sup>th</sup>	289451.89	2107836.50	3.71	9 <sup>th</sup>	289509.61	2119261.15	10.44
10 <sup>th</sup>	289451.89	2107836.50	2.97	10 <sup>th</sup>	289509.61	2119261.15	10.42
Avg.	291451.89	2109836.50	2.19	Avg.	289509.61	2119261.15	7.87

**D) Maximum Ten Occurrences of NO<sub>x</sub> Concentrations after Implementation of Control Options (Preferred Option I -2020) at Mumbai City (Annual)**

Annual - All Source Preferred Option I -2020				Annual - Area Source Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	285.73	1 <sup>st</sup>	289509.61	2119261.15	27.17
2 <sup>nd</sup>	291451.89	2111836.50	245.59	2 <sup>nd</sup>	289509.61	2119261.15	23.39
3 <sup>rd</sup>	291451.89	2111836.50	217.76	3 <sup>rd</sup>	289509.61	2119261.15	20.93
4 <sup>th</sup>	291451.89	2111836.50	192.16	4 <sup>th</sup>	289509.61	2119261.15	16.83
5 <sup>th</sup>	291451.89	2111836.50	185.43	5 <sup>th</sup>	289509.61	2119261.15	15.96
6 <sup>th</sup>	291451.89	2111836.50	175.59	6 <sup>th</sup>	289509.61	2119261.15	15.90
7 <sup>th</sup>	291451.89	2111836.50	168.57	7 <sup>th</sup>	289509.61	2119261.15	14.96
8 <sup>th</sup>	291451.89	2111836.50	167.64	8 <sup>th</sup>	289509.61	2119261.15	14.62
9 <sup>th</sup>	291451.89	2111836.50	158.92	9 <sup>th</sup>	289509.61	2119261.15	14.32
10 <sup>th</sup>	291451.89	2111836.50	150.49	10 <sup>th</sup>	289509.61	2119261.15	14.23
Avg.	291451.89	2111836.50	131.59	Avg.	289509.61	2119261.15	11.71

Annual – Line Source Preferred Option I -2020				Annual Point Source (LSI) Preferred Option I -2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	248.73	1 <sup>st</sup>	291451.89	2109836.50	214.25
2 <sup>nd</sup>	291451.89	2111836.50	218.36	2 <sup>nd</sup>	291451.89	2109836.50	171.04
3 <sup>rd</sup>	291451.89	2111836.50	188.17	3 <sup>rd</sup>	291451.89	2109836.50	151.86
4 <sup>th</sup>	291451.89	2111836.50	159.01	4 <sup>th</sup>	291451.89	2109836.50	140.62
5 <sup>th</sup>	291451.89	2111836.50	158.87	5 <sup>th</sup>	291451.89	2109836.50	78.45
6 <sup>th</sup>	291451.89	2111836.50	146.01	6 <sup>th</sup>	291451.89	2109836.50	76.86
7 <sup>th</sup>	291451.89	2111836.50	137.27	7 <sup>th</sup>	291451.89	2109836.50	67.32
8 <sup>th</sup>	291451.89	2111836.50	136.09	8 <sup>th</sup>	291451.89	2109836.50	52.30
9 <sup>th</sup>	291451.89	2111836.50	135.45	9 <sup>th</sup>	291451.89	2109836.50	46.12
10 <sup>th</sup>	291451.89	2111836.50	130.98	10 <sup>th</sup>	291451.89	2109836.50	21.84
Avg.	291451.89	2111836.50	109.22	Avg.	291451.89	2109836.50	39.62

Annual Point Source (MSI) Preferred Option I-2020				Annual Point Source (SSI) Preferred Option I-2020			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289451.89	2107836.50	4.25	1 <sup>st</sup>	289509.61	2119261.15	12.17
2 <sup>nd</sup>	289451.89	2109836.50	3.38	2 <sup>nd</sup>	289509.61	2119261.15	9.34
3 <sup>rd</sup>	289451.89	2107836.50	2.76	3 <sup>rd</sup>	289509.61	2119261.15	9.17
4 <sup>th</sup>	289451.89	2107836.50	2.64	4 <sup>th</sup>	289509.61	2119261.15	7.08
5 <sup>th</sup>	289451.89	2107836.50	2.63	5 <sup>th</sup>	289509.61	2119261.15	6.90
6 <sup>th</sup>	289451.89	2107836.50	2.51	6 <sup>th</sup>	289509.61	2119261.15	6.50
7 <sup>th</sup>	289451.89	2107836.50	2.43	7 <sup>th</sup>	289509.61	2119261.15	6.43
8 <sup>th</sup>	289451.89	2107836.50	2.36	8 <sup>th</sup>	289509.61	2119261.15	6.30
9 <sup>th</sup>	289451.89	2107836.50	2.29	9 <sup>th</sup>	289509.61	2119261.15	6.28
10 <sup>th</sup>	289451.89	2107836.50	1.83	10 <sup>th</sup>	289509.61	2119261.15	6.27
Avg.	291451.89	2109836.50	1.35	Avg.	289509.61	2119261.15	4.73

**E) Maximum Ten Occurrences of NO<sub>x</sub> Concentrations after Implementation of Control Options (Preferred Option II -2025) at Mumbai City (Annual)**

Annual - All Source Preferred Option II -2025				Annual - Area Source Preferred Option II -2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	307.73	1 <sup>st</sup>	289509.61	2119261.15	29.31
2 <sup>nd</sup>	291451.89	2111836.50	264.89	2 <sup>nd</sup>	289509.61	2119261.15	25.24
3 <sup>rd</sup>	291451.89	2111836.50	234.39	3 <sup>rd</sup>	289509.61	2119261.15	22.58
4 <sup>th</sup>	291451.89	2111836.50	206.23	4 <sup>th</sup>	289509.61	2119261.15	18.16
5 <sup>th</sup>	291451.89	2111836.50	199.43	5 <sup>th</sup>	289509.61	2119261.15	17.22
6 <sup>th</sup>	291451.89	2111836.50	187.77	6 <sup>th</sup>	289509.61	2119261.15	17.15
7 <sup>th</sup>	291451.89	2111836.50	181.47	7 <sup>th</sup>	289509.61	2119261.15	16.14
8 <sup>th</sup>	291451.89	2111836.50	179.65	8 <sup>th</sup>	289509.61	2119261.15	15.77
9 <sup>th</sup>	291451.89	2111836.50	171.02	9 <sup>th</sup>	289509.61	2119261.15	15.45
10 <sup>th</sup>	291451.89	2111836.50	162.10	10 <sup>th</sup>	289509.61	2119261.15	15.35
Avg.	291451.89	2111836.50	141.29	Avg.	289509.61	2119261.15	12.63

Annual – Line Source Preferred Option II -2025				Annual Point Source (LSI) Preferred Option II-2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	291451.89	2111836.50	269.58	1 <sup>st</sup>	291451.89	2109836.50	216.01
2 <sup>nd</sup>	291451.89	2111836.50	236.67	2 <sup>nd</sup>	291451.89	2109836.50	172.44
3 <sup>rd</sup>	291451.89	2111836.50	203.94	3 <sup>rd</sup>	291451.89	2109836.50	153.11
4 <sup>th</sup>	291451.89	2111836.50	172.34	4 <sup>th</sup>	291451.89	2109836.50	141.78
5 <sup>th</sup>	291451.89	2111836.50	172.19	5 <sup>th</sup>	291451.89	2109836.50	79.10
6 <sup>th</sup>	291451.89	2111836.50	158.25	6 <sup>th</sup>	291451.89	2109836.50	77.49
7 <sup>th</sup>	291451.89	2111836.50	148.77	7 <sup>th</sup>	291451.89	2109836.50	67.88
8 <sup>th</sup>	291451.89	2111836.50	147.50	8 <sup>th</sup>	291451.89	2109836.50	52.73
9 <sup>th</sup>	291451.89	2111836.50	146.81	9 <sup>th</sup>	291451.89	2109836.50	46.50
10 <sup>th</sup>	291451.89	2111836.50	141.96	10 <sup>th</sup>	291451.89	2109836.50	22.02
Avg.	291451.89	2111836.50	118.37	Avg.	291451.89	2109836.50	39.95

Annual Point Source (MSI) Preferred Option II-2025				Annual Point Source (SSI) Preferred Option II-2025			
	X length,m	Y length,m	Concentration µg/m <sup>3</sup>		X length,m	Y length,m	Concentration µg/m <sup>3</sup>
1 <sup>st</sup>	289451.89	2107836.50	4.29	1 <sup>st</sup>	289509.61	2119261.15	12.27
2 <sup>nd</sup>	289451.89	2109836.50	3.41	2 <sup>nd</sup>	289509.61	2119261.15	9.42
3 <sup>rd</sup>	289451.89	2107836.50	2.78	3 <sup>rd</sup>	289509.61	2119261.15	9.24
4 <sup>th</sup>	289451.89	2107836.50	2.66	4 <sup>th</sup>	289509.61	2119261.15	7.14
5 <sup>th</sup>	289451.89	2107836.50	2.65	5 <sup>th</sup>	289509.61	2119261.15	6.96
6 <sup>th</sup>	289451.89	2107836.50	2.53	6 <sup>th</sup>	289509.61	2119261.15	6.55
7 <sup>th</sup>	289451.89	2107836.50	2.45	7 <sup>th</sup>	289509.61	2119261.15	6.49
8 <sup>th</sup>	289451.89	2107836.50	2.38	8 <sup>th</sup>	289509.61	2119261.15	6.35
9 <sup>th</sup>	289451.89	2107836.50	2.31	9 <sup>th</sup>	289509.61	2119261.15	6.33
10 <sup>th</sup>	289451.89	2107836.50	1.84	10 <sup>th</sup>	289509.61	2119261.15	6.32
Avg.	291451.89	2109836.50	1.37	Avg.	289509.61	2119261.15	4.77