

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

**AMRAVATI CITY**

For



Maharashtra Pollution Control Board

by



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&  
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## Executive Summary

This study was initiated by Maharashtra Pollution Control Board (MPCB) as a part of a State-wide effort in ten cities for managing the air quality. Several aspects of the air pollution status in these ten cities have been investigated with an intent to identify the key sources of pollutants, where Particulate Matter (PM) have been used to represent air pollution. An overview of the organization of the work presented in this report is shown in Figure 1.4 (Page 1.8)

Analyses have been carried by using the results from source apportionment, and also the results of inventory of air pollution sources (Table 7.1). The results and suggestions for Amravati are summarized in the following sections.

### Inventory

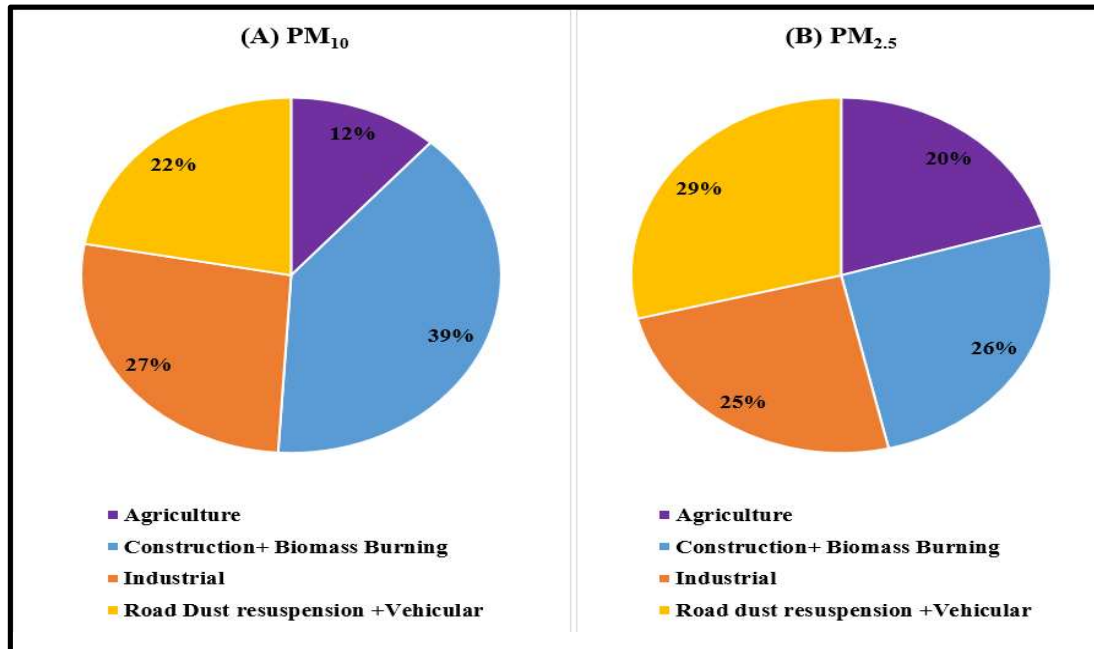
- The inventory for the point, line and area sources were compiled from secondary data made available by the offices of MPCB, AMC and RTO.
- There is a large uncertainty in the quantities, emission factors and the chemical profiles of garbage (wet and dry, often mixed), and biomass (shed leaves from trees etc.) that are burnt in the open. Burning of plastics and anthropogenic dry wastes in an uncontrolled manner is a serious matter of health concern, and requires immediate attention. Measurements and quantification of the emissions from such uncontrolled burning for inventory development is tedious, if not impossible. From a pragmatic perspective, therefore it is best to implement common sense actions required to strictly enforce ban on such uncontrolled burning.

### Source Apportionment

- Sampling for the source apportionment component of the work were carried out at four locations in Amravati to quantify the sources of air pollution that influence the respective locations.
- The chemical analyses were carried out as per CPCB guidelines. The source apportionment analysis was conducted employing the EPA Positive Matrix Factorization (PMF) method and the results for likely sources of PM<sub>10</sub> and PM<sub>2.5</sub> are summarized as Figure ES-1.
- The findings revealed that construction dust, resuspended road dust and combustion emerge as the predominant contributor for PM<sub>10</sub> pollution. This occurrence is attributed to the high dust loadings on the roads, and the possibly the ongoing construction activities near roadways, within, and around the city.
- PM<sub>2.5</sub> pollution was prominently influenced by dust industry, uncontrolled burning, and vehicles.

## Suggested Action Plans

- The analysis indicates that sustained and concerted efforts in all sectors is the key to reaching a point of acceptable air quality. Further, while the focus has largely been on primary sources of PM, the control of gaseous pollutants at source, across all sectors, would lead to a natural outfall of control on the pre-cursors which lead to the formation of secondary aerosols.
- The parameters measured in CAAQMS are a rich data resource, and need to be assessed based on sources of each of the pollutant being measured, Along with temperature, rainfall and other meteorological conditions. Triangulation of data such as CO, NO<sub>x</sub>, PM and ozone could help in quality assurance efforts, as well as an indication of the immediate impact of actions being taken locally.
- The linkage between an identified problem and implementation of it solutions needs to be strengthened. As an example, the design of roads needs to have them be amenable for mechanical sweeping, where dust from the unpaved shoulders is prevented from “drifting” onto the road by design. Biomass from trees can be removed from the roads by vacuum trucks. Another example is the strengthening of the collection efforts for solid wastes (which are often put to fire if left to pile up).
- The effort requires a sector-wise cost analysis for a time-bound implementation by the industry, transport department and the urban local bodies. The cost of public health due to air pollution is well established in previous studies and outweighs the cost of control of air pollution at source itself.
- The timeframe for a sustainable system is typically about 10 years, and requires programme based approach, which would become mainstream with time.
- Management of air quality is a new emerging problem for the cities in india, and therefore requires for a new vertical in the administrative structure. The work is of a nature that would require day-to-day data collection, analysis and ground level control of sources through coordination with multiple agencies.



**Figure ES-1: Percentage Contribution of Sources for (A) PM<sub>10</sub> and (B) PM<sub>2.5</sub> for Amravati**

# CONTENTS

<b>Chapter 1</b>	<b>Introduction</b>	
1.1	Background of the City	1.1
1.2	Demographic Structure of the City	1.1
1.3	Economic Profile	1.3
1.4	Climate and Meteorology	1.5
1.5	Transportation	1.5
1.6	Industrial Profile	1.6
1.7	Objectives	1.6
1.8	Organisation of the report	1.6
<b>Chapter 2</b>	<b>Ambient Air Quality</b>	
2.1	Ambient Air Quality -Secondary Data	2.1
2.2	Ambient Air Quality - Sampling During Summer 2019	2.3
<b>Chapter 3</b>	<b>Emission Inventory</b>	
3.1	Introduction	3.1
3.2	Emission Inventory: Concept & Need	3.1
3.3	Present Objective	3.2
3.4	Generation of Activity Data & Emission Factor	3.2
3.5	Secondary Data Collection	3.3
3.6	Role of GIS	3.3
3.7	Road Network in Amravati City	3.5
3.8	Line Source	3.5
3.9	Point Source	3.9
3.1	Area Source	3.11
3.10.1	Bakeries	3.11
3.10.2	Open Eat-outs	3.12
3.10.3	Hotels and Restaurants	3.13
3.10.4	Crematoria	3.13
3.10.5	Household Fuel Consumption	3.14
3.10.6	Fuel Consumption in Slum Population	3.14
3.10.7	Building & Road Construction	3.15
3.10.8	Road Dust	3.15
3.11	Total Emission Load (for Amravati City)	3.17
3.12	Grid-wise Emission Inventory	3.18
<b>Chapter 4</b>	<b>Receptor Modelling &amp; Source Apportionment</b>	
4.1	Source Apportionment Study using EPA PMF v5.0	4.1
4.2	Methodology	4.2
4.3	Results	4.4
4.3.1	Factors of PM10 and PM2.5	4.4
4.4	Conclusions	4.6

<b>Chapter 5</b>	<b>Air Pollutions Dispersion Modelling</b>	
5.1	Overview	5.1
5.2	Model Input	5.1
5.3	Meteorological Data	5.2
5.4	Modelling Domain & Result	5.2
<b>Chapter 6</b>	<b>Suggestions for Actions for Control of Air Pollution</b>	
6.1	Emission Reduction Action Plan for Amravati City	6.1
<b>Chapter 7</b>	<b>Results and Recommendations</b>	
7.1	Inventory	7.1
7.1.1	Results	7.1
7.2	Source Apportionment (PMF and Dispersion Models)	7.4
7.2.1	Results	7.4
7.3	Suggestions for Success of Sustained Efforts	7.4
7.4	Further Work	7.6

## **References**

## **Acknowledgements**

## LIST OF TABLES

Table 1.1	Summary of Demographic Structure in Study Area	1.1
Table 1.2	Ward wise Population of Amravati City	1.2
Table 2.1	Description of Sampling Sites	2.5
Table 2.2	Target Physical and Chemical Components (groups) for Characterization of Particulate Matter for Source Apportionment	2.9
Table 3.1	Number of Vehicles in the District	3.6
Table 3.2	Emission Factors Considered for Emissions Estimation	3.7
Table 3.3	Contribution of Vehicles to PM Load	3.8
Table 3.4	Point Source Emission Load	3.1
Table 3.5	Emission Load from Bakery	3.12
Table 3.6	Emission Load from Open Eat-outs	3.12
Table 3.7	Emission Load from Hotels & Restaurants	3.13
Table 3.8	Emission Load from Crematories	3.13
Table 3.9	Distribution of Domestic Fuel Consumption Pattern	3.14
Table 3.10	Assumptions of Per Capita Fuel Consumption Pattern	3.14
Table 3.11	Emission Load from Domestic Combustion	3.15
Table 3.12	Emission Load from Construction	3.15
Table 3.13	Road Length in the City	3.16
Table 3.14	Categorised Vehicular Weight	3.16
Table 3.15	Emission Load from Area Sources – Road Dust	3.17
Table 3.16	Total Emission Load from All Sources	3.17
Table 3.17	Grid-wise Emission Rate of PM10	3.18
Table 4.1	Percentage source contribution for PM10 and PM2.5	4.4
Table 5.1	Emission Load for All Pollutants (Tonnes/d)	5.2
Table 5.2	Grid-wise Emission Rate of PM10 [g/m <sup>2</sup> /s]	5.5
Table 6.1	Action Plan for Control of Air Pollution	6.1
Table 7.1 (a)	Summary of Source Apportionment Results for Amravati (Figure 4.1)	7.3
Table 7.1 (b)	Key Sources from Inventory (Table 3.16)	7.3

## LIST OF FIGURES

Figure 1.1	Amravati City Boundary Limit (Source CSIR-NEERI)	1.3
Figure 1.2	Amravati Municipal Ward Map (Source AMC, Amravati)	1.4
Figure 1.3	Windrose Diagram for Amravati City	1.5
Figure 1.4	Flow chart for the organisation of the present study	1.8
Figure 2.1	PM <sub>10</sub> , NO <sub>2</sub> and SO <sub>2</sub> Concentration During Last 5 years	2.1
Figure 2.2 (a)	MPCB AAQ Sites in Amravati City (Source Google Earth)	2.2
Figure 2.2 (b)	PM <sub>10</sub> Concentration at Three Sites in Amravati During 2013-2017	2.2
Figure 2.2 (c)	Monthly Variations in PM <sub>10</sub> Concentration	2.3
Figure 2.3	Manual AAQ Sampling Sites (Source Google Earth)	2.4
Figure 2.4	PM <sub>10</sub> and PM <sub>2.5</sub> Concentration at Sampling Sites	2.6
Figure 2.5	PM <sub>10</sub> and PM <sub>2.5</sub> and PM <sub>2.5</sub> /PM <sub>10</sub> Ratio (Source AAQ sampling, CSIR-NEERI)	2.8
Figure 3.1	A 2 x 2 Kms Grid over the Amravati City (Source ArcGIS, CSIR-NEERI)	3.4
Figure 3.2	Road Network in the City (Source CSIR-NEERI)	3.5
Figure 3.3	Hourly Traffic Count in Amravati City at a Count Location	3.7
Figure 3.4	Percent Emission Load from Line Source (Source CSIR-NEERI)	3.9
Figure 3.5	Fuel Pattern in Industries (TPD) (Source CSIR-NEERI)	3.1
Figure 3.6	Percent Emission Load from Point Source	3.11
Figure 3.7	Total Emission Load from All Sources (Ton/day)	3.18
Figure 3.8	Grid-wise Emission Load for Amravati City	3.19
Figure 4.1	Percentage Contribution of Sources for (A) PM <sub>10</sub> and (B) PM <sub>2.5</sub> for Amravati	4.7
Figure 4.2	Factor Fingerprints of PM <sub>10</sub> for Amravati	4.8
Figure 4.3	Factor Fingerprints of PM <sub>2.5</sub> for Amravati	4.9
Figure 5.1	Monthly Wind rose Diagram of Amravati (Source CSIR-NEERI)	5.3
Figure 5.2	Monthly Wind Speed Frequency in Amravati (Source CSIR-NEERI)	5.4
Figure 5.3	Grid Over Amravati City for Area Source Emission (Source CSIR-NEERI)	5.5
Figure 5.4	Isopleth of GLC of PM <sub>10</sub> Over Amravati City Due to Area Source Emission (Source CSIR-NEERI)	5.6

## Chapter 1

# Introduction

### 1.1 Background of the City

Amravati named after Ambadevi temple was called ‘Audumbaravati or Udumbaravati’ in ancient times due to the presence of a large number of Audumber trees in the region. Earlier, it was also known as Indrapur-the capital of lord Indra. In 17<sup>th</sup> century, the city was mainly owned by Mughal Aurangzeb, whereas in 1722, it was given as a gift to Bhosle by Shahu Maharaj, who maintained it. British government however conquered the city in late 18<sup>th</sup> century. Amravati city (21.30' 21.50'N; 76.35' 78.27'E, 343 MSL) includes the municipal boundaries and has total area of about 121.65 Sq. Km. The city is located on the National Highway NH-6 leading to Mumbai in the west and Kolkata in the east. Amravati has good road and rail connectivity with almost all-important cities in India. Amravati district constitutes 3.96% of the total area of the Maharashtra state and is located in the Vidarbha region on the north eastern side. It located 156 Kms west of Nagpur and is located near the hills with Purna basin to the West and the Wardha basin to the East. There are two lakes in the eastern part of the city, Chhatri Talao and Wadali Talao. Pohara and Chirodi hills are to the east of the city. The Maltekdi hill is inside the city, it is 60 meters high. 75% of the district is covered by Deccan trap while 25% area is covered by Purna alluvium. Amravati City Boundary limit and Municipal Ward Map is depicted in **Figure 1.1**.

### 1.2 Demographic Structure of the City

The population of Amravati city in 2011 was 6,46,801 of which males and females are 330,544 and 316,257 respectively. The sex ratio of Amravati city is 957 per 1000 males. The population in the age range of 0-6 years was 62,497. The effective literacy rate (population over 7 years of age) was 93.03%. The summary of demographic structure of the city is given in **Table 1.1** and the Wardwise population of the city is represented in **Table 1.2**.

**Table 1.1: Summary of Demographic Structure in Study Area**

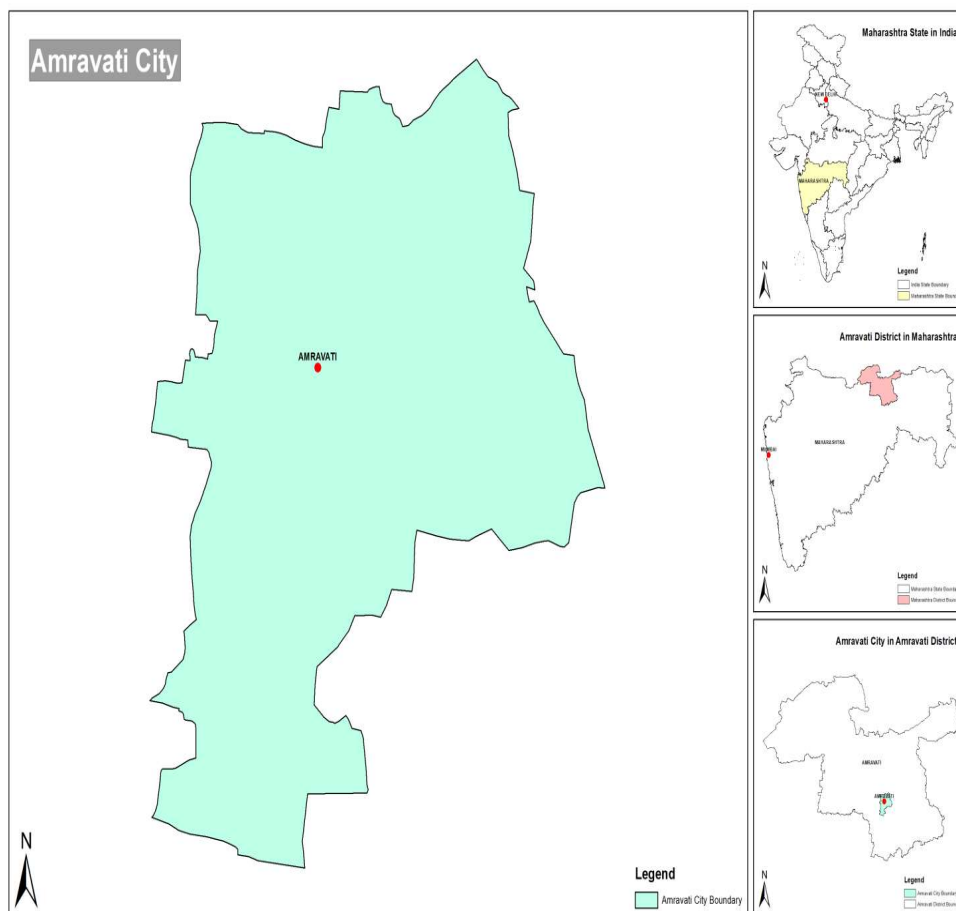
No.	Demographic Parameters	Amravati Municipal Corporation
1	State/District	Maharashtra/Amravati
2	No. of Prabhags	22
3	Total No. of Households	136796
4	Total Population	647057
5	Density of Population (Km <sup>2</sup> )	5319

6	Sex Ratio (Females/100 males)	961
7	Scheduled Castes	111435 (17.22%)
8	Scheduled Tribes	15955 (2.47%)
9	Literate	535594 (82.77%)
10	Main Worker	189628 (29.31%)
11	Marginal Worker	18908 (2.92%)
12	Non Worker	438521 (67.77%)

Source : Primary Census Abstract, 2011 (Amravati District, Maharashtra state)

**Table 1.2: Ward wise Population of Amravati City**

Ward No.	Ward Name	Total Population
1	Shegaon - Rahatgaon	27457
2	Shri Sant Gadgebbaba P.D.M.C	26952
3	Navasari	30705
4	Navasari colony	31005
5	Mahendra Colony-New Cotton market	29268
6	Vilas Nagar -Morbag	29597
7	Jawahar Stadium	27135
8	Jog Stadium -Chaparashi pura	26829
9	S.R.P.F. -Wadali	20452
10	Benoda -Bhimtekadi -Dastur Naga	32235
11	Frejarpura	28585
12	Rukhmini Nagar -Swami Vivekanand	26930
13	Ambapeth -Gaurakshan	27848
14	Jawahar Gate -Budhwara	29870
15	Chhaya Nagar -Gavalipura	32705
16	Alim Ngar -Rahmat Nagar	32004
17	Gadgadeshwar	31860
18	Rajapeth -Shri Sant Kanwarram	32501
19	Sai Nagar	30452
20	Sutgirmi	32518
21	Juni Wasti Badnera	32442
22	Navi Wasti Badnera	27707



**Figure 1.1: Amravati City Boundary Limit (Source:CSIR-NEERI)**

### 1.3 Economic Profile

The per capita income of Amravati is Rs. 63,467, which is quite lower to GDP of the state (Rs. 95,339) making it as one of the poorer in the state (*Survey of Maharashtra 2012-13*). Around 64% of the people live in rural areas and 36% in urban areas. The economy of the region depends on agriculture. Food grains, sorghum, cotton, red gram, wheat, green chickpea, sugarcane, green chillies, oranges, sweet lime and betel leaves are the major crops in the region being cultivated. About 70% of the labor force is engaged in agriculture, of which 17% are farmers and 52% are laborers (*Census of India, 2011*). In addition to the agriculture, Amravati is also known as the major hub/market for textiles. It is also growing as an industrial center with many cotton mills. Many textile industries such as Raymonds, Finlay mills etc. have been established in the outskirts of the city.

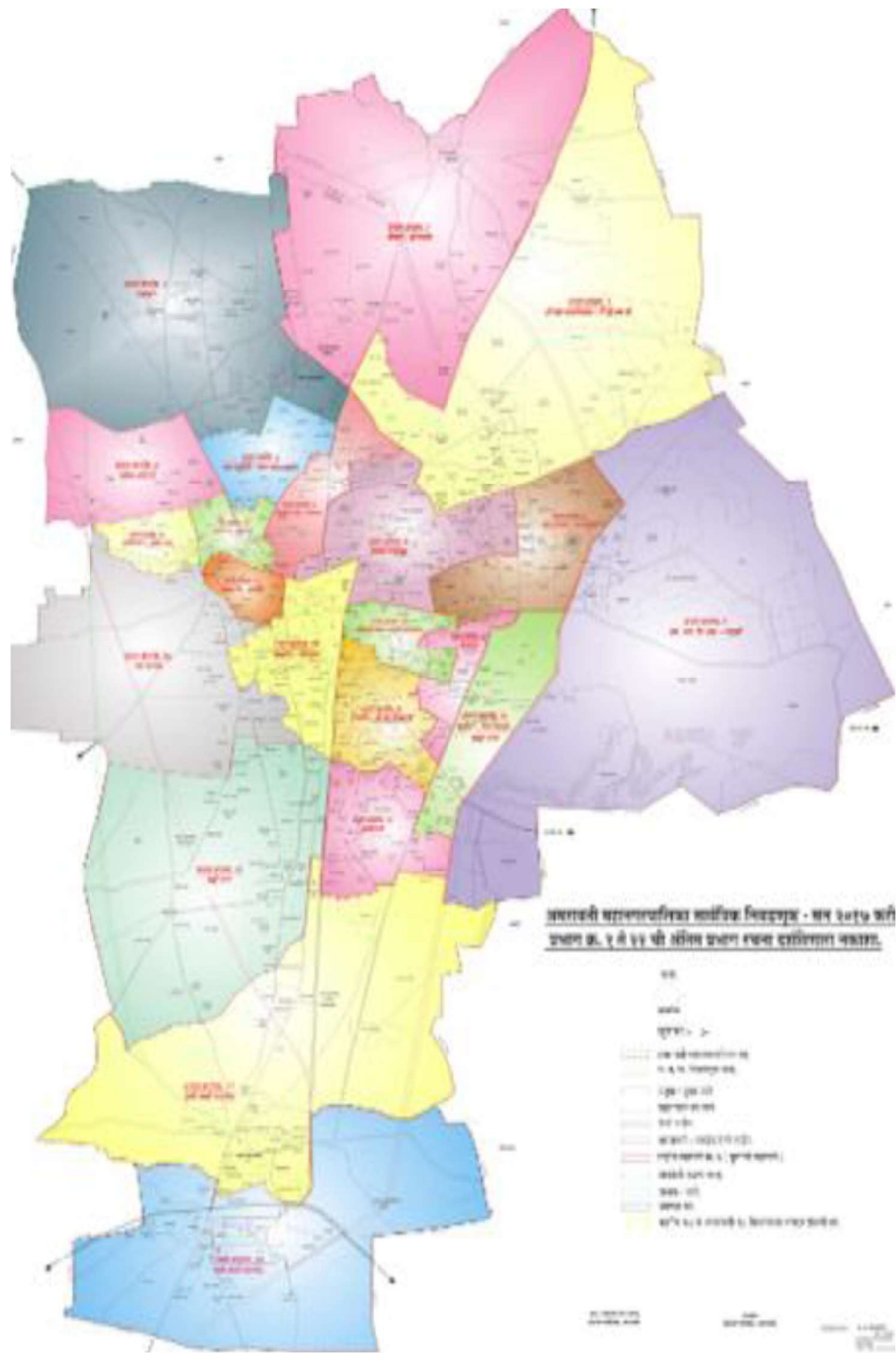
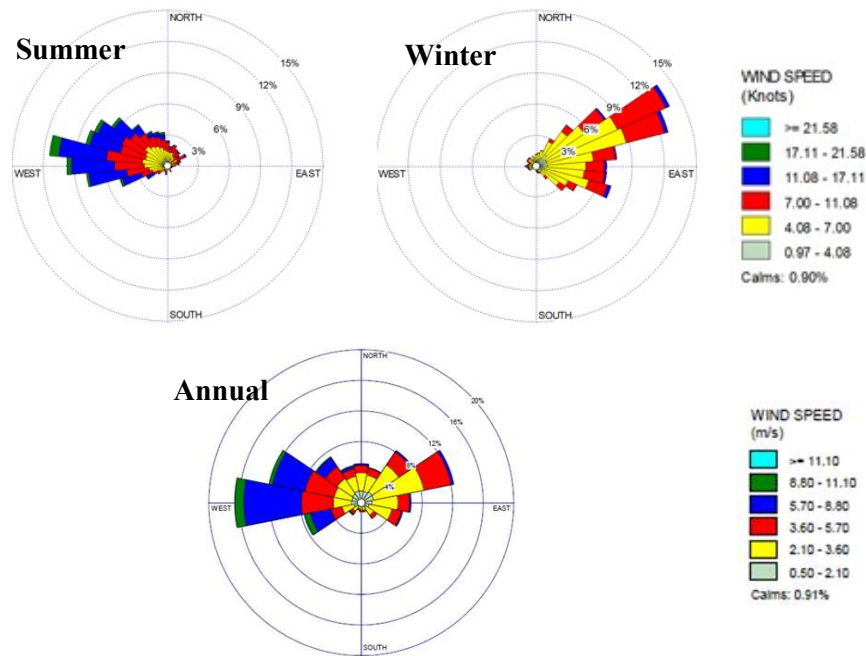


Figure 1.2: Amravati Municipal Ward Map (Source: AMC, Amravati)

## 1.4 Climate and Meteorology

Amravati has a tropical wet and dry climate with hot and dry summers and mild to cool winters. Summer lasts from March to June, monsoon from July to October and winter from November to March. The maximum temperature in summer is recorded as 44°C and minimum as 29°C. In winter, maximum temperature is usually around 28°C and minimum is around 19°C. Wind speed is around 10mph (16.9 km/h) from North West (World weather online, 2018). The wind rose diagram for summer, winter and whole year is shown in **Figure 1.2**. It can be seen that the predominant wind direction is from West, NE and NW direction.



**Figure 1.3: Windrose Diagram for Amravati City  
(Source: CSIR-NEERI Aermod/Calpuff)**

## 1.5 Transportation

Mode of transport in the city is mainly city bus service which is provided by Amravati Municipal Corporation (AMC) and Maharashtra State Road Transport Corporation (MSRTC), private auto rickshaws and cycle rickshaws. 2 wheelers are highest in the city. For intercity and interstate transport MSRTC along with the private operators provide bus services to other major cities like Nagpur, Bhopal, Mumbai, Pune, Aurangabad etc. In

addition to the bus facility the district has mainly three railway stations, Amravati, New Amravati and Bandera junction. Bandera is a junction station on the Howrah–Nagpur–Mumbai, central line.

## **1.6 Industrial Profile**

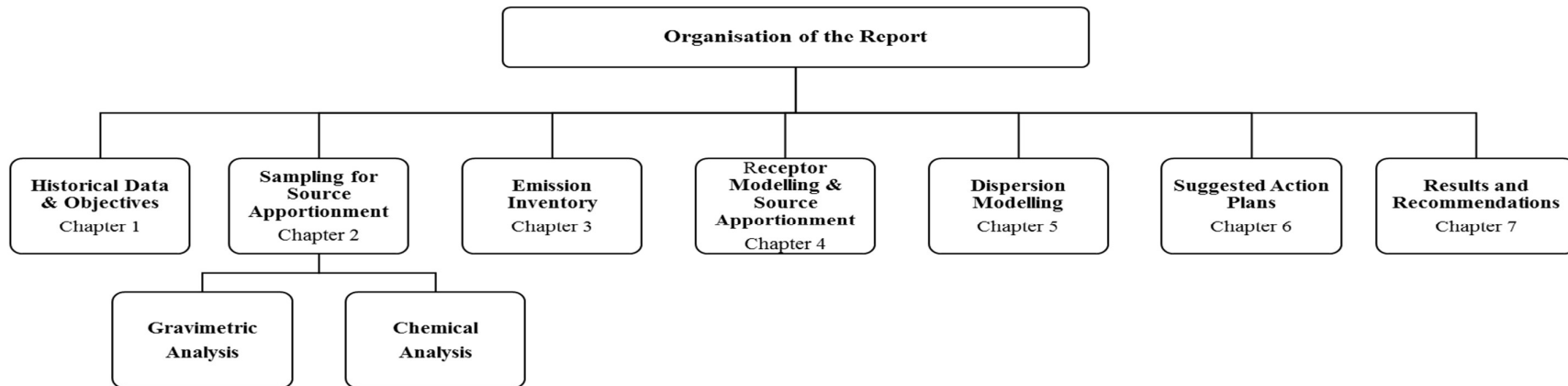
As per the Environment Status Report (2016-17), there are 1138 industries in Amravati region. Out of those, 316 are in orange category and 78 are in red category of industries. Oil mills, dal mills, cottage industries producing handloom cloth, rope making, ginning and pressing industries and spinning mills are the major small-scale industries in the region. The city has significant industrial development potential (Smart Cities Challenge – Amravati Municipal Corporation, October 2015). A 2,700 MW Thermal Power Plant is set up by India Bulls named “Ratan India Thermal Power Plant”, at Nandgaon Peth/Sawardi MIDC. The Thermal power plant is 20 kms away from the city towards north east.

## **1.7 Objectives**

- To measure baseline air pollutants (Particulate Matter) in different parts of the city which includes “hot spots” and kerbside as well.
- To inventorise the various pollutants in the city.
- To conduct source apportionment study of PM.
- Suggest action plan based on various options delineated in the Six City Study of MoEFCC or any relevant workable options.

## **1.8 Organisation of the report**

The report organization is shown Figure 1.4. Chapter 7 highlights the outcomes and the recommendations from this study



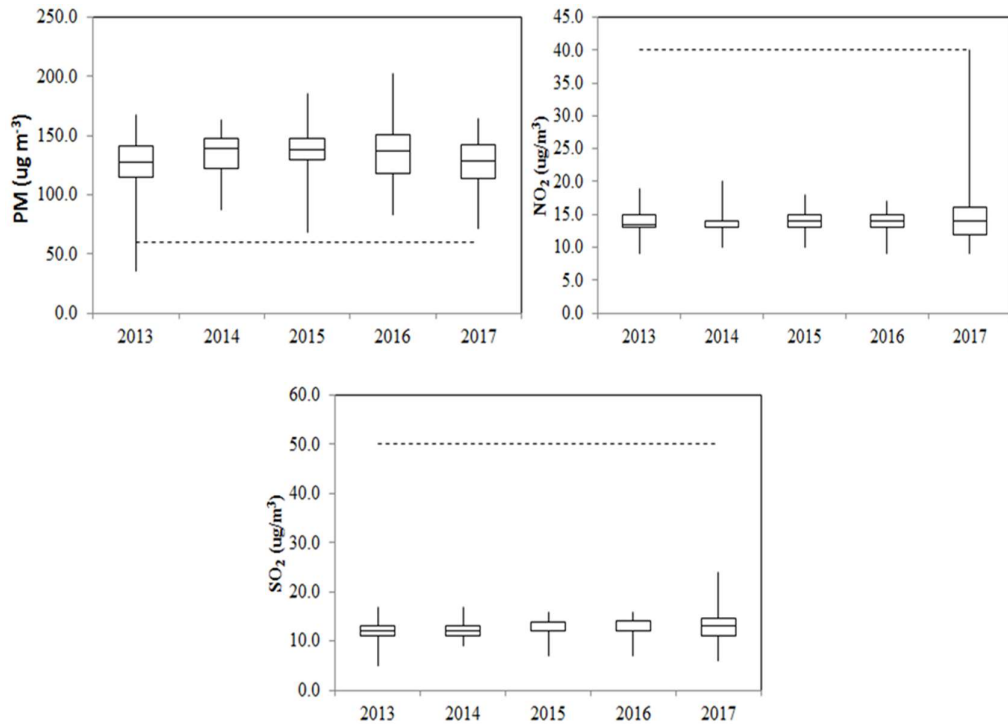
**Figure 1.4: Flow chart for the organisation of the present study**

## Chapter 2

### Ambient Air Quality

#### 2.1 Ambient Air Quality -Secondary Data

Based on last 5 years National Ambient Monitoring Plan (NAMP) data obtained from the MPCB website for PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>x</sub> concentration. Since MPCB provides the AAQ data on SPM, RSPM &/or PM<sub>10</sub> only and PM<sub>2.5</sub> concentration is not provided by them or any other agency, it was not possible to give the historical picture of PM<sub>2.5</sub> concentration. **Figure 2.1** shows the data averaged over the three sites for the entire city. It can be seen that PM<sub>10</sub> is much above the annual CPCB standard (60 µg/m<sup>3</sup>), whereas SO<sub>2</sub> and NO<sub>2</sub> are much below the CPCB standard of 50 and 40 µg/m<sup>3</sup>, respectively. The three monitoring sites, namely Govt. College of Engineering, Amravati, Building of Apurva Oil Industries (Industrial) and Vanita Samaj Building (Commercial) were depicted in **Figure 2.2a** and annual average of PM<sub>10</sub> concentration is plotted in **Figure 2.2b**. Monthly variation plot of PM<sub>10</sub> concentration shows that highest concentration is recorded in April and May, whereas lowest concentration is observed in July and August at the three sites (**Figure 2.2c**).



**Figure 2.1: PM<sub>10</sub>, NO<sub>2</sub> and SO<sub>2</sub> Concentration During Last 5 years**

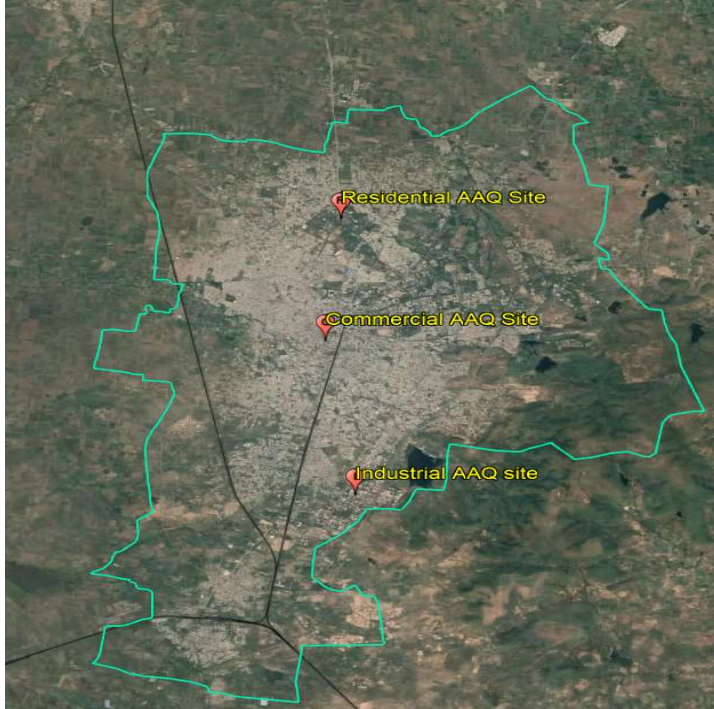


Figure 2.2 (a): MPCB AAQ Sites in Amravati City (Source:Google Earth)

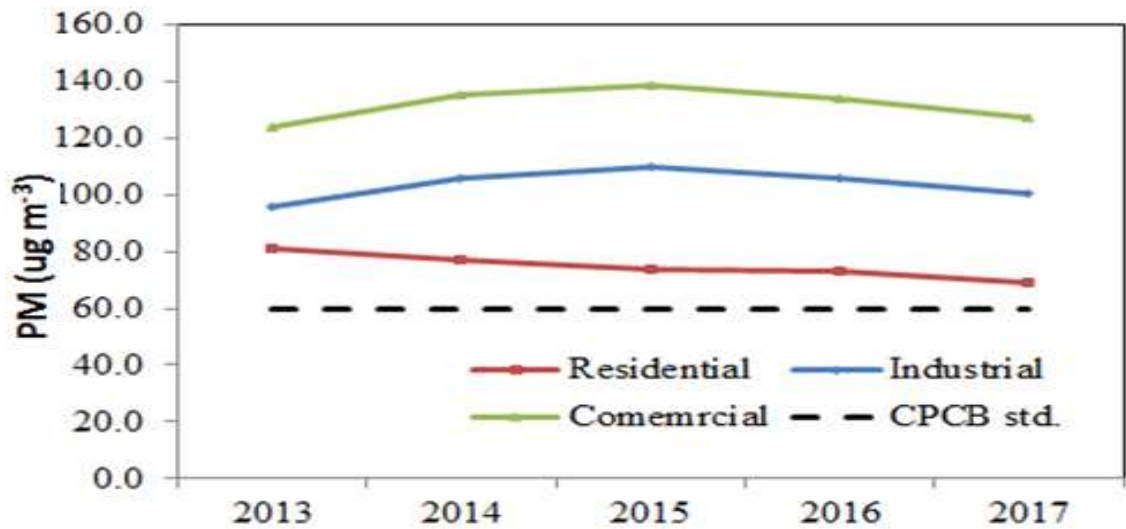
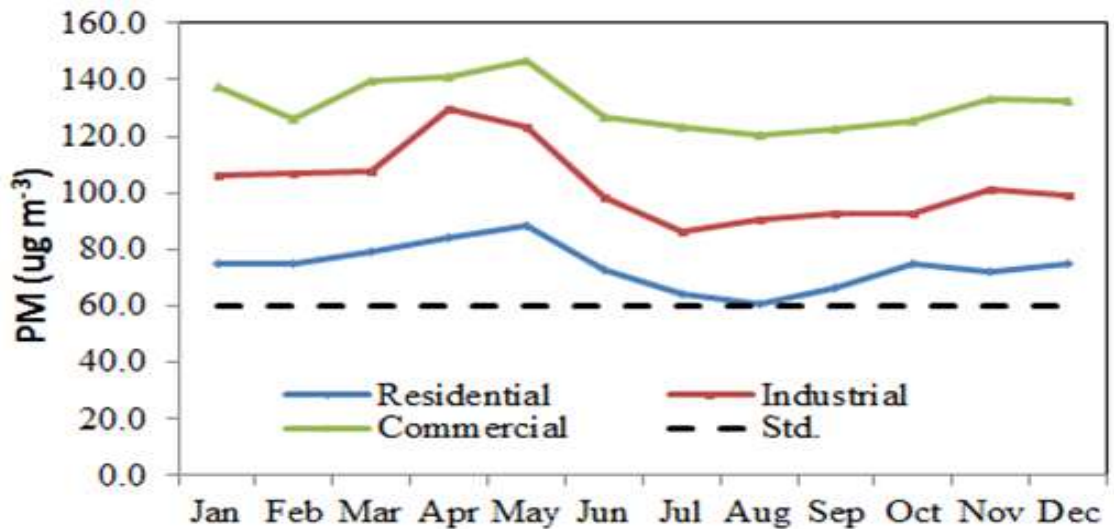


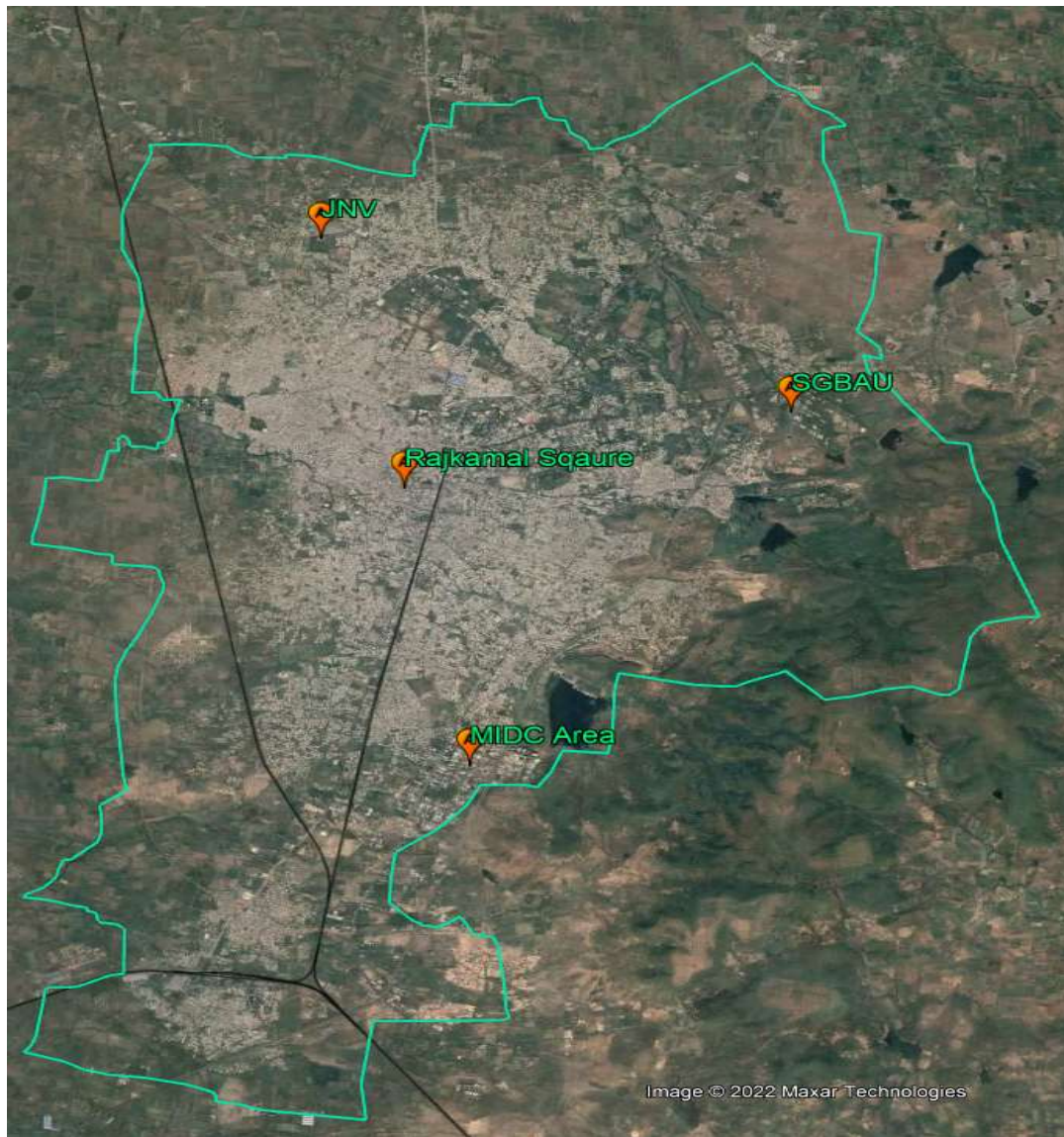
Figure 2.2 (b) : PM<sub>10</sub> Concentration at Three Sites in Amravati During 2013-2017



**Fig. 2.2 (c): Monthly Variations in PM<sub>10</sub> Concentration**

## 2.2 Ambient Air Quality - Sampling During Summer 2019

Ambient air quality monitoring exercise was carried out keeping in view the protocol for source apportionment (SA) study. CPCB guidelines document for source apportionment through receptor modeling was followed. Monitoring for particulate Matter of diameter 10 micron and 2.5 micron (PM<sub>10</sub> and PM<sub>2.5</sub>, respectively) was carried out as per standard operating procedures prescribed in CPCB guidelines document on SA studies. The sampling was carried out at 4 sites selected based on the land-use activity and dispersion modeling results. The location of the sites is given in **Figure 2.3**. The description of the sampling sites is given in **Table 2.1**.



**Figure 2.3: Manual AAQ Sampling Sites (Source: Google Earth)**

**Table 2.1: Description of Sampling Sites**

<b>Sampling Location</b>	<b>Type</b>	<b>Geographic Location Lat./ Long.</b>	<b>Characteristics</b>
Navoday Vidyalay	Residential	20.96447, 77.74209	1 Km away from highway, sporadic open burning observed, a crematorium at 600 m distance but not much in use
Rajkamal Square	Commercial/ Traffic	20.92867, 77.75265	Clothing shops, electrical, hardware, eateries, heavy flow of vehicles, congested with parked vehicles, roads and flyover construction undergoing
MIDC	Industrial	20.88098, 77.75844	Mumbai-Kolkata highway nearby
St. Gadge Baba University	Residential	20.94059, 77.79967	Road-1.5 km away, bus stand nearby, canteen and flow of staff vehicles

Air quality status at four sites in terms of PM<sub>10</sub> and PM<sub>2.5</sub> is given in **Figure 2.4**. It can be seen that PM<sub>10</sub> concentration violated the CPCB threshold (100 µg/m<sup>3</sup>) during the entire study period at commercial/ traffic site (Rajkamal square). At residential site (St. Gadge Baba University), PM<sub>10</sub> exceeded the standard at 40% of times. At another residential site named Jawahar Navodaya Vidyalaya (JNV), PM<sub>10</sub> is observed to be at boundary line of CPCB standard. At industrial site (Sumit Agro), PM<sub>10</sub> is observed to be 1.5 times the standard concentration. PM<sub>2.5</sub> on the other hand is observed to be below the CPCB threshold of 60 µg/m<sup>3</sup> at commercial/ traffic, industrial and residential site except at Jawahar Navodaya Vidyalaya, it exceeded the standard once (on 26<sup>th</sup> May 2019). Open burning activity was witnessed on this day leading to the exceedance of PM<sub>2.5</sub>.

PM<sub>2.5</sub>/PM<sub>10</sub> ratio is also plotted in **Figure 2.5** to assess the dominance of combustion activities at the sampling sites. High ratio generally suggests the presence of combustion activity at or near the site. PM<sub>10</sub> concentration is observed to be high at MIDC sites followed by Rajkamal Square; whereas PM<sub>2.5</sub> concentration is observed to be high at Jawahar Navodaya Vidyalaya followed by MIDC. PM<sub>2.5</sub>/PM<sub>10</sub> ratio is observed to be highest at Jawahar Navodaya Vidyalaya followed by St. Gadge Baba University, MIDC and Rajkamal Square. It can be seen that PM<sub>2.5</sub>/PM<sub>10</sub> ratio is less than 0.5 at all the sites during the sampling period except on two days at Jawahar Vidyalay when open burning cases were observed.

This suggests that at the residential sites, combustion activity is prevalent. The chances of traffic and other combustion activities related emissions from nearby areas contributing to high PM<sub>2.5</sub>/PM<sub>10</sub> ratio at these sites cannot be ruled out. Further the medium of the ratio is less than 0.5 suggesting the anthropogenic emissions are quite less in the city.

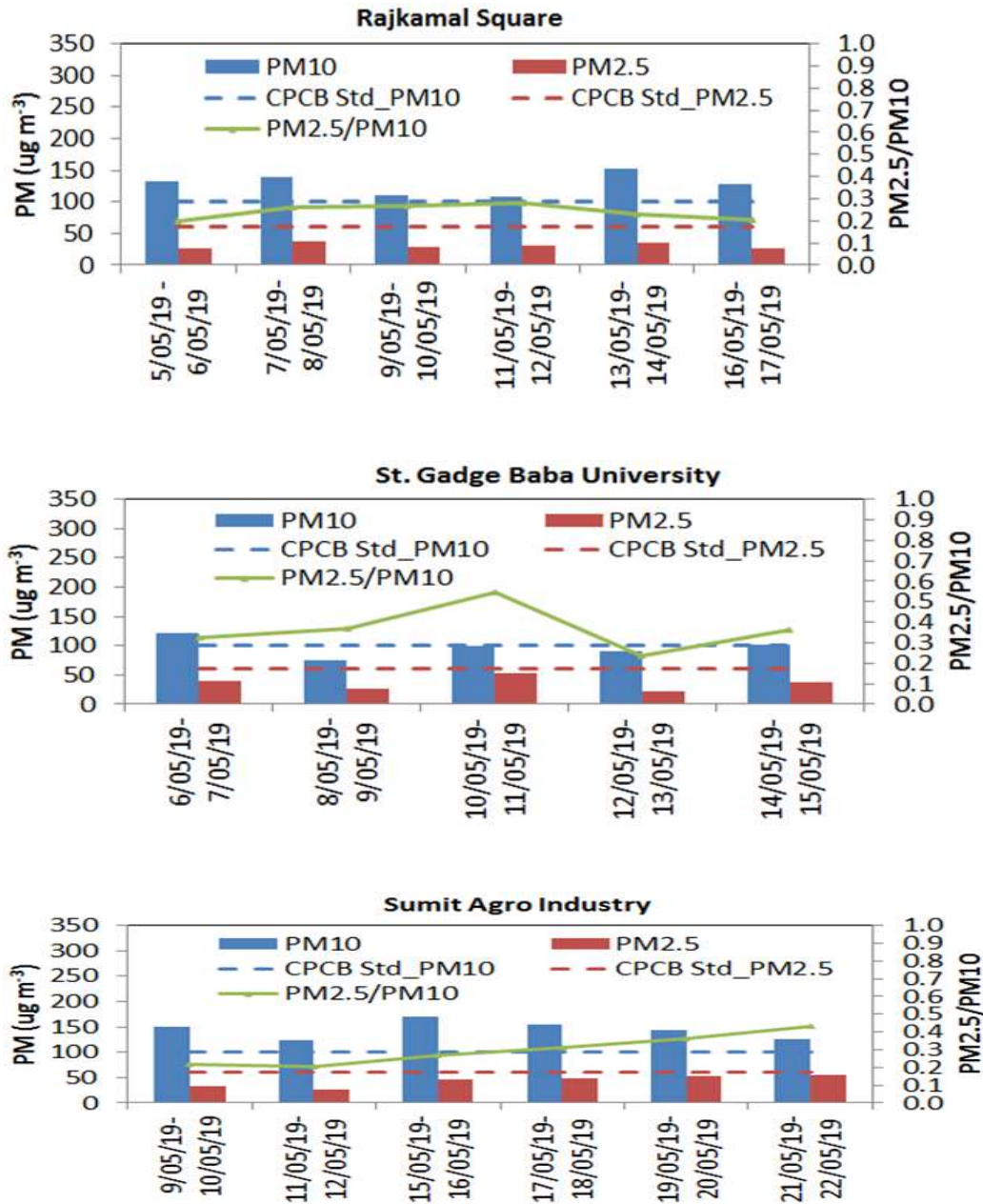


Figure 2.4: PM<sub>10</sub> and PM<sub>2.5</sub> Concentration at Sampling Sites

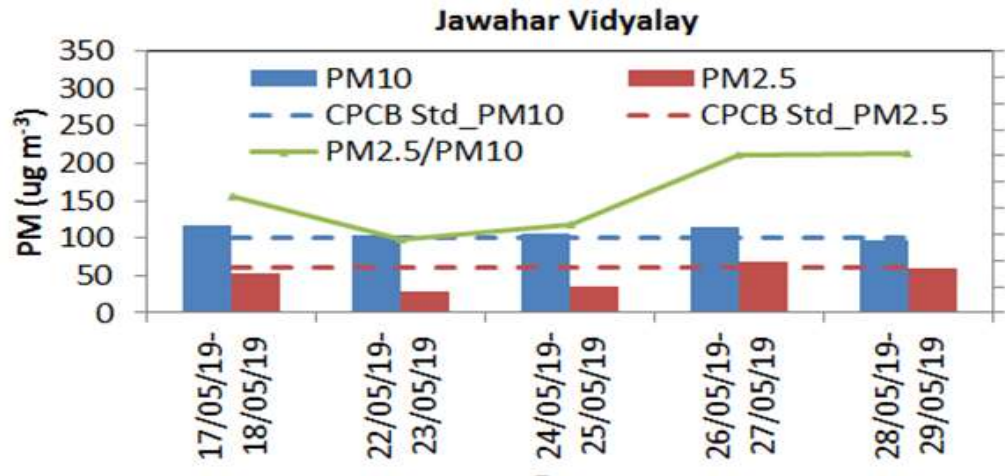


Figure 2.4 (Contd..) : PM<sub>10</sub> and PM<sub>2.5</sub> Concentration at Sampling Sites

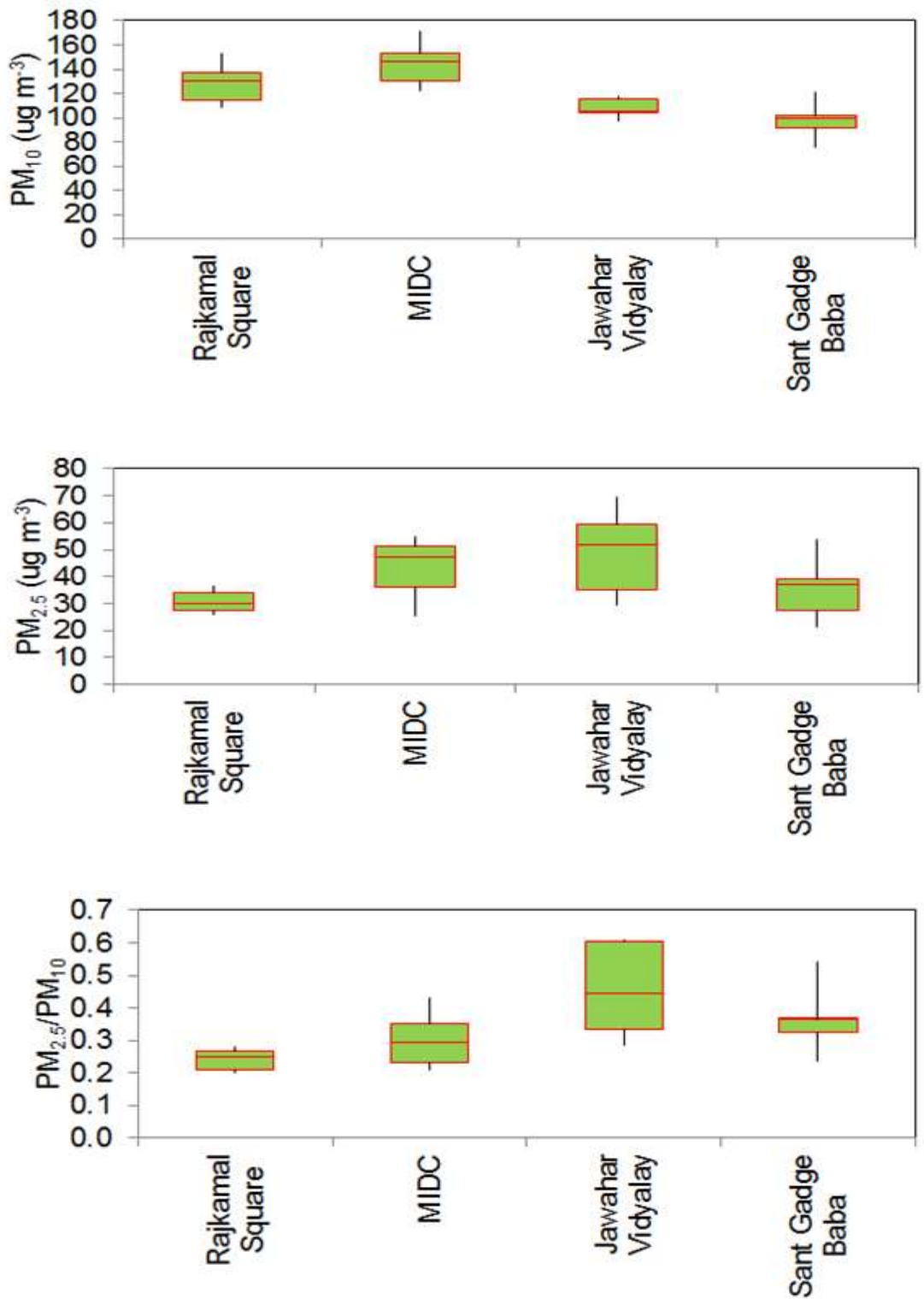


Figure 2.5: PM<sub>10</sub> and PM<sub>2.5</sub> and PM<sub>2.5</sub>/PM<sub>10</sub> Ratio (Source: AAQ sampling, CSIR-NEERI)

**Table 2.2: 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	Filtration of aerodynamic sizes with a size cut by impaction			
Flow Rate	5 LPM	5 LPM	5 LPM	5 LPM
Sampling Period	24 Hourly (Summer 2019)			
Sample Type	Quartz and PTFE filter simultaneously for both PM <sub>10</sub> and PM <sub>2.5</sub>	Quartz and PTFE filter simultaneously for both PM <sub>10</sub> and PM <sub>2.5</sub>	Quartz filter simultaneously for both PM <sub>10</sub> and PM <sub>2.5</sub>	PTFE Filter simultaneously for both PM <sub>10</sub> and PM <sub>2.5</sub>
Analytical Instrument	Electronic Balance	Electronic Balance	OC/EC Analyzer	Ion Chromatography
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	Element specific LDL

Components	Required Filter Matrix	Analytical Methods
PM <sub>10</sub> and PM <sub>2.5</sub>	Teflon or Nylon filter paper. Pre and post exposure conditioning of filter paper is mandatory	Gravimetric
Elements (Na, Mg, Al, Si, P, S, Cl, Ca, Br, V, Mn, Fe, Co, Ni, Cu, Zn, As, Ti, Ga, Rb, Y, Zr, Pd, Ag, In, Sn, La Se, Sr, Mo, Cr, Cd, Sb, Ba, Hg, and Pb)	Teflon filter paper	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 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 Total Carbon)	Quartz filter. Prebaking of quartz filter paper at 600 °C is essential	TOR/TOT method

## Chapter 3

### Emission Inventory

#### 3.1 Introduction

An air emission inventory is a compilation of air pollutant emissions from sources of anthropogenic (human-made) and biogenic (naturally occurring) sources. The sources are categorized into three sectors, each making up one component of the inventory. The emission inventories consist of actual and projected air emissions.

Due to violation of permissible limit of particulate matter standards, CPCB has listed Amravati city as one of the non-attainment cities. The number of non-attainment cities listed in India is 132. Out of which 19 cities are from Maharashtra. Emissions inventory is the first exercise, under that identification and quantification of various sources are necessary to link them with the existing air quality levels measured at certain locations as well as predict air quality for whole region. It helps in assessing the impact of additional nearby sources in and around the region and also to evaluate the control strategies for certain emission sources.

Extensive fossil fuel use and speedy growth of energy intensive sectors like power, steel, cement, chemicals and fertilizers, transport etc. have contributed to high growth rate of emissions at above 5% per annum during 2000s in India. National level emission inventories have been prepared by several researchers for metro cities in India. Amravati city has no emission inventory estimate report earlier published. Keeping in view the lack of exclusive emission inventory estimates for Amravati, the emission inventory has been prepared for PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub> and NO<sub>x</sub> emitted from various sources.

#### 3.2 Emission Inventory: Concept & Need

To improve the air quality in the area/city, detailed information of air pollution sources along with the local meteorological condition and topographical factors are needed. For the purpose the effective science-based air quality management is a need of the hour. Emission inventories helps to identify the emission sources in the region and contribution of each source to the total emission which will eventually guide us to set priorities for the action plan for different sources, evaluating the various options available to reduce the emissions from identified potential sources and formulate and implement the appropriate action plan. Thus, an inventory

provides basic information of sources and sink of different gases along with information like what gases to mitigate, how to mitigate, when to mitigate and where the mitigation action should be allocated. In addition to the above, it has been used as one of the important fundamental components in air quality modelling application.

For scientific purposes, emission inventories can be used as an input for dispersion modelling and taking immediate actions on the source to reduce air pollution. As mentioned earlier the emission inventory is an essential input required to forecast the air quality, moreover, the quality of forecast depends on the accuracy and reliability of emission inventories.

### **3.3 Present Objective**

In the present study, an attempt has been made to develop a very high-resolution Emission Inventory. The grids have been plotted over Amravati city of 2 Km x 2 Km (**Figure 3.1**). The inventory has been developed for PM<sub>10</sub>, PM<sub>2.5</sub>, NO<sub>x</sub> and SO<sub>2</sub>. The high-resolution emission inventory developed for Amravati city will help in appropriate and timely implementation of the action plans. Effective solutions to reduce air pollution require a process of continual improvement in understanding where pollution is coming from and how much each source is contributing. A robust Amravati emission inventory will provide information to policy makers to significantly aid in the design and implementation of emission reduction plans and regulations. There is a need for sharing existing sources and studies to frame solutions.

### **3.4 Generation of Activity Data & Emission Factor**

Emission of particulate matter is related with different source emissions. Its intensity determines the control action required on the emission source to reduce emissions. So, it is the need of the day to identify the emission source to reduce air emission load of Particulate matter. For this purpose, the potential sources of emission are considered in the present work and source specific activity emission load estimates are done.

The activity data consist of two types, (1) Primary Data and (2) Secondary data. Primary data consists of the data collected by actual visualization the site details. This data is not available in any documents/ books. Secondary data is readily available with the offices and can be collected. The data sets available have very less information. For example, corporations have the data of hotels, restaurants and bakeries, but they do not have data on type of fuel used. This fuel data must be available with offices. It will be very much easy to target reduction in the

use of fuel emitting more pollution load into atmosphere. Primary data for brick kilns, vehicular count, bakeries and hotels survey, slum areas survey, MSW burning and dump yard survey, road resuspension, paved-unpaved roads and city activities survey has been carried out. CSIR-NEERI has conducted a detailed survey for Amravati city for source data collection. The same data is used for the estimation of emission inventory. To make the emission inventory more accurate a large number of site-specific primary data has been collected. The secondary data sets have been collected from all possible authentic sources for the selected departments in the city.

The purpose of generating primary data is to generate the information not available and to improve the data accuracy and authenticity of the secondary data available. To collect such data an extensive field survey work was carried out during several years. The primary data is collected by carrying out surveys at the brick kilns, MSW dumping yards, door to door survey for residential, commercial sectors, local transport offices, vehicular count at traffic intersections and fuel used data are collected. Data sheets were prepared to collect the required information for emission inventory.

Residential and commercial sectors contribute significant amount of emission to air. To estimate the emission load from this sector data for fuel used, quantity required per day, time required for cooking etc. has been collected.

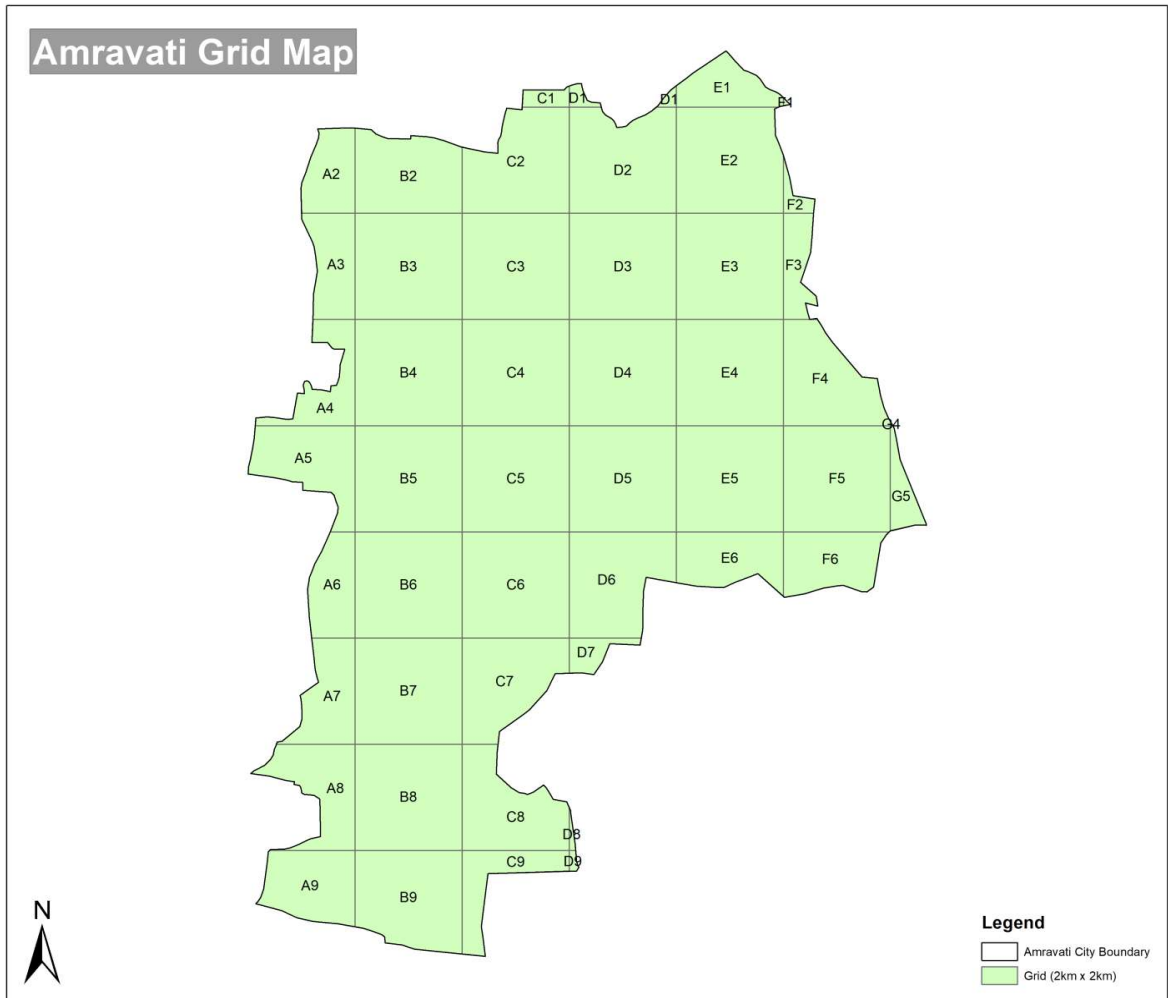
### **3.5 Secondary Data Collection**

Information or data available for number of slums, hotels, industries, thermal power plants, number of registered vehicles etc, are collected. Also, the data related to the fuel consumption in industries and thermal power plants has been obtained from the published official governmental resources. In addition to this, CSIR-NEERI has in house data repository for the information required. The information was collected for different projects ongoing.

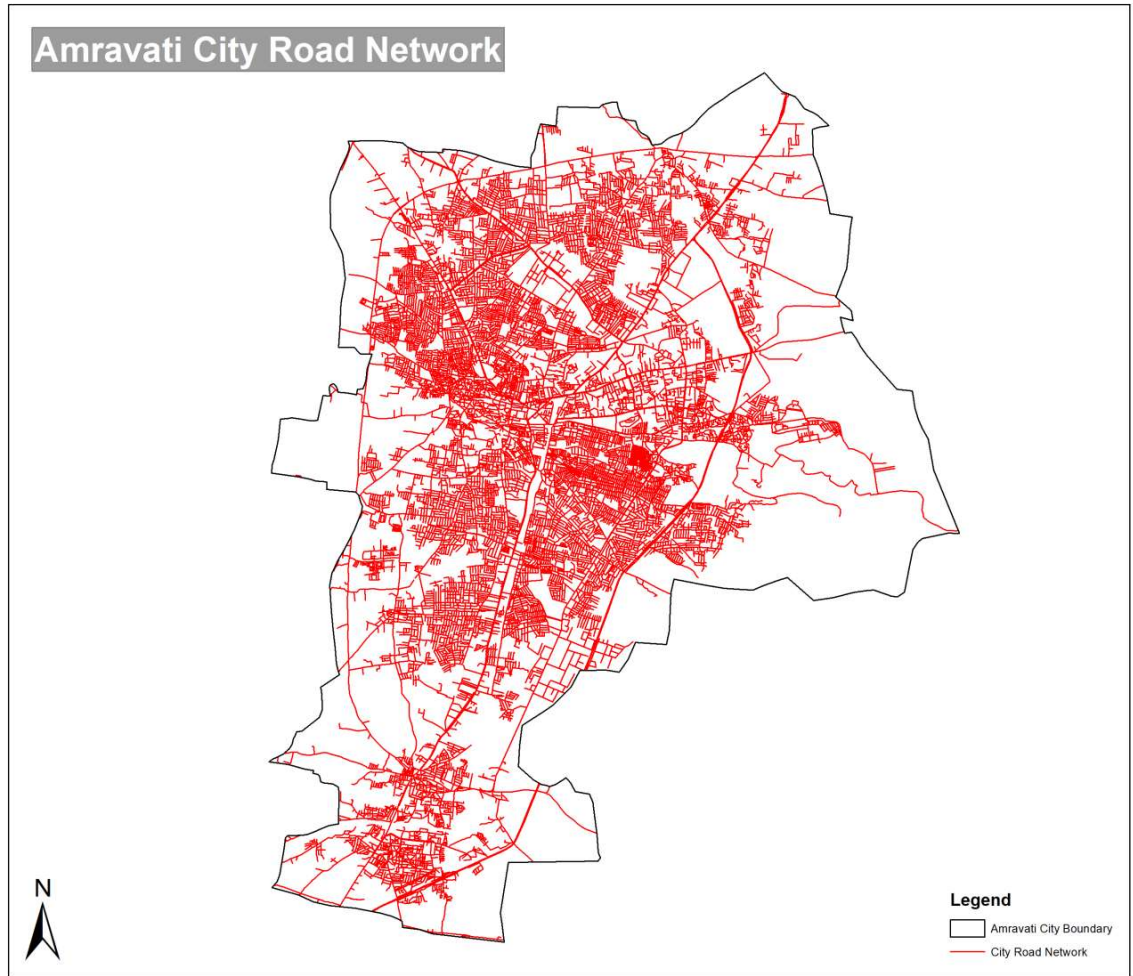
### **3.6 Role of GIS**

GIS has made it possible to directly view the source emission. The grids plotted over Amravati city, makes it easier to identify the maximum emission load and the source responsible. The required information is feeded and the required maps are prepared. Maps for water bodies, railway network, and road network in Amravati city are prepared by the use of GIS. Also, geo-mapping of emission load is done using GIS technology for developing accurate emission

inventories. GIS will substantially improve ability to develop effective plans to meet air quality standards and help understand the effects of air pollution at the local community level. The GIS based emission inventory is used to meet the goal about when and where the emissions occur, and how they can be reduced to benefit the most people. With the help of GIS we can improve air quality in those areas that are disproportionately affected by air pollution.



**Figure 3.1: A 2 x 2 Kms Grid over the Amravati City (Source: ArcGIS, CSIR-NEERI)**



**Figure 3.2: Road Network in the City (Source: CSIR-NEERI)**

### 3.7 Road Network in Amravati City

The data on road condition is provided by Amravati Municipal Council. The total road network in the city is represented in **Figure 3.2**.

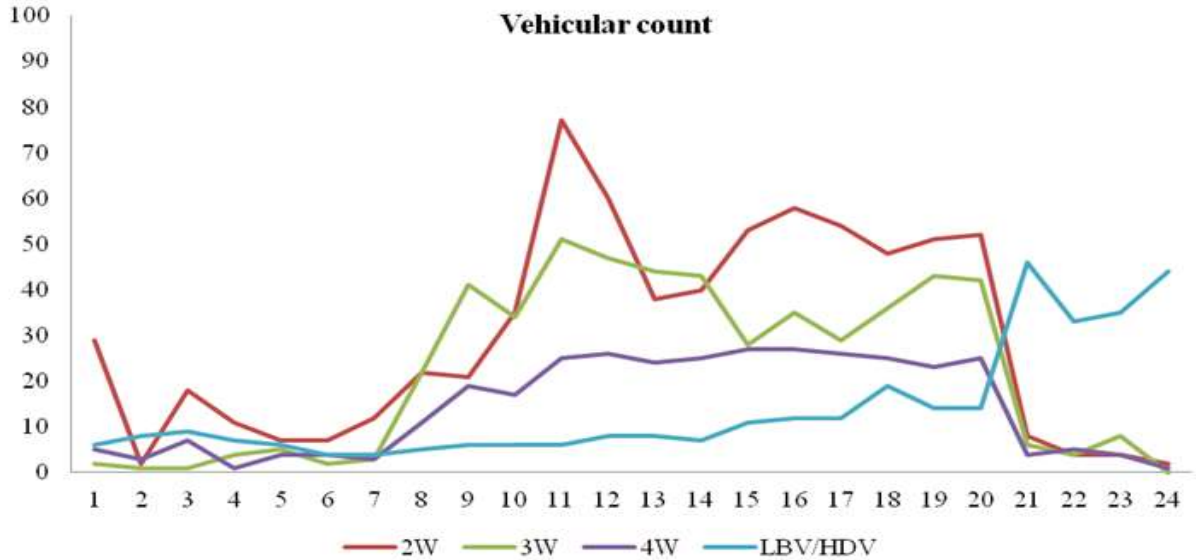
### 3.8 Line Source

There are about 2,58,925 Lakhs registered vehicles in Amravati District. The data collected from regional transport office of Amravati is represented in **Table 3.1**.

**Table 3.1: Number of Vehicles in the District**

<b>No.</b>	<b>Type of Vehicles</b>	<b>No of Vehicles</b>
1	2 wheelers	213538
2	4 wheelers	19702
3	Auto Rickshaws	6402
4	Mini Bus	163
5	School Bus	200
6	Trucks/Tankers	3496
7	Tractors	5974
8	Trailers	3490
9	Others	243
10	<b>Total</b>	<b>253208</b>

As per line sources, vehicle counting was carried out in 20 different locations across the city boundary. Traffic Counting was carried out as per the methodology. The collected data is used for vehicular emission estimation per hour and then identified for its grid position. The percentage of different type of vehicle viz. 2w, 3w, 4w, etc. operating with different fuel is estimated as per “A Report on Total Fuel Consumption by Transport Sector in India”, Press Information Bureau, Government of India, Ministry of Petroleum & Natural Gas, dated January 28, 2014. A **Figure 3.3** below shows the hourly vehicular count at a traffic count location in the city.



**Figure 3.3: Hourly Traffic Count in Amravati City at a Count Location**

Following emission factors **Table 3.2** are used to calculate emission load from line sources. The emission factors derived by ARAI, Pune are used for calculations. During survey, it was informed that the city has 5 parking sites located at Bandera cycle stand, central railway (pay and park), city hospital, railway station parking and Main MSRTC Bus depot. Public transport in Amravati city is a road-based bus, operated by AMC.

**Table 3.2: Emission Factors Considered for Emissions Estimation**

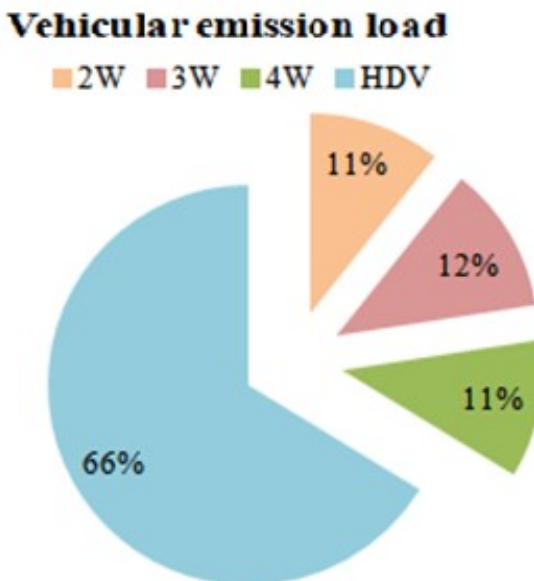
Emission Factor for BS-III Stage Engine						
No.	Vehicular Type	PM	NOx	HC	CO	Unit
1	2-Wheeler	0.035	0.27	0.61	1.65	g/km
2	3W_Petrol	0.05	1.2	0.7	1.2	g/km
3	3W_Diesel	0.05	0.5	0.5	0.5	g/km
4	4W_Petrol	0.05	0.12	0.19	3.01	g/km
5	4W_Diesel	0.12	0.67	0.2	0.51	g/km
6	HDV	1.24	9.3	0.37	6	g/km
Emission Factor for BS-IV Stage Engine						
No.	Vehicular Type	PM	NOx	HC	CO	Unit
1	2-Wheeler	0.1	0.1	0.13	1.81	g/km
2	3W_Petrol	0.035	0.5	0.3	0.75	g/km
3	3W_Diesel	0.035	0.5	0.3	0.75	g/km
4	4W_Petrol	0.08	0.1	0.1	1	g/km

5	4W_Diesel	0.08	0.1	0.1	1	g/km
6	HDV	0.06	0.39	0.42	0.74	g/km
<b>Emission Factor for BS-VI Stage Engine</b>						
<b>No.</b>	<b>Vehicular Type</b>	<b>PM</b>	<b>NOx</b>	<b>HC</b>	<b>CO</b>	<b>Unit</b>
1	2-Wheeler	0.0045	0.09	0.068	0.5	g/km
2	3W_Petrol	0.025	0.1	0.1	0.22	g/km
3	3W_Diesel	0.0045	0.08	0.1	0.5	g/km
4	4W_Petrol	0.0045	0.06	0.1	1	g/km
5	4W_Diesel	0.0045	0.08	0.1	0.5	g/km
6	HDV	0.01	0.08	0.1	0.5	g/km

Currently the city buses operated by AMC are privatized with the operation & maintenance done by the contractors. A total of 27 buses run throughout the city covering a daily run of 3963 Kms. Since the vehicles of same category uses different fuels, it is considered that 55% of vehicle category use diesel as fuel and 45% of vehicular category use petrol as fuel. The total emission load from line source is found to be 0.43 tons per day in Amravati city. The emission load from different category of vehicle is shown in **Table 3.3** and **Figure 3.4**.

**Table 3.3: Contribution of Vehicles to PM Load**

<b>Vehicles</b>	<b>PM (Ton/Day)</b>
2W	0.046
3W	0.051
4W	0.048
HDV	0.285



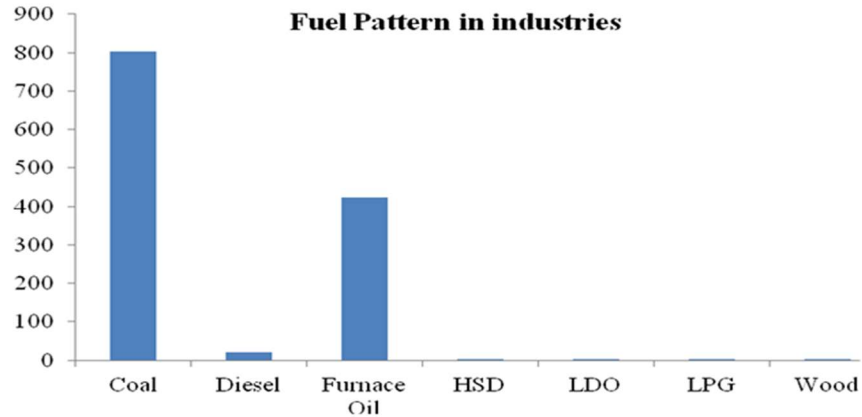
**Figure 3.4: Percent Emission Load from Line Source (Source: CSIR-NEERI)**

### 3.9 Point Source

Amravati region is developing at a rapid pace today paving way for the establishment of various other industries in the area. Industries like auto repairing and engineering, textile industries, ginning and pressing, metal ware industries, etc. are established on large scale. The expansion in the roadways, construction of flyovers, nearness to highway and a boom in the motor vehicles have given an upper hand to this small-scale industry. The people in this industry are mainly engaged in engineering works like welding, manufacturing of agricultural equipment, vehicle repairing and production of spare parts for the machines.

As Cotton is being the major crop of this region, Amravati is home to a number of cotton mills. The first textile mill to be opened in this region was in the year 1885 and it was known as the Berar Manufacturing Company Ltd. This is another industry that relies heavily on the production of cotton in this region. Just like the textile industry, it is yet another old industry to be established here. A part of the cottage industry, metalworking is an old industry in Amravati. The city was well known for its production of pharmaceutical, musical bells tied around cattle and gongs. As on year 2016-17, the total numbers of registered units in Amravati district are 4077 approximately. All the consents from pollution control board are verified and it is seen that out of the registered 4077 units, 48 industries in Amravati MIDC and nearby are

using solid fuel for manufacturing processes. Hence the fuel used in these industries is considered for emission load estimation (**Figure 3.5**).



**Figure 3.5: Fuel Pattern in Industries (TPD) (Source: CSIR--NEERI)**

From the above figure it is clear that coal and furnace oil are used in large quantity in the industries located in Amravati MIDC. The emission factors used from estimation of emission load is referred from AP42 and CPCB documents. The emission load from industries is calculated in the **Table 3.4** and **Figure 3.6**.

**Table 3.4: Point Source Emission Load**

Fuel	PM <sub>10</sub> Load (TPD)	PM <sub>2.5</sub> Load (TPD)
Coal	0.0439	0.03
Furnace oil	0.016	0.011
Wood	0.452	0.302
Diesel	0.213	0.142
HSD	0.054	0.036
Briquettes	0.021	0.014
Bagasse	0.009	0.006
LDO	0.005	0.003
<b>Total</b>	<b>0.8139</b>	<b>0.544</b>

### Emission load from point source

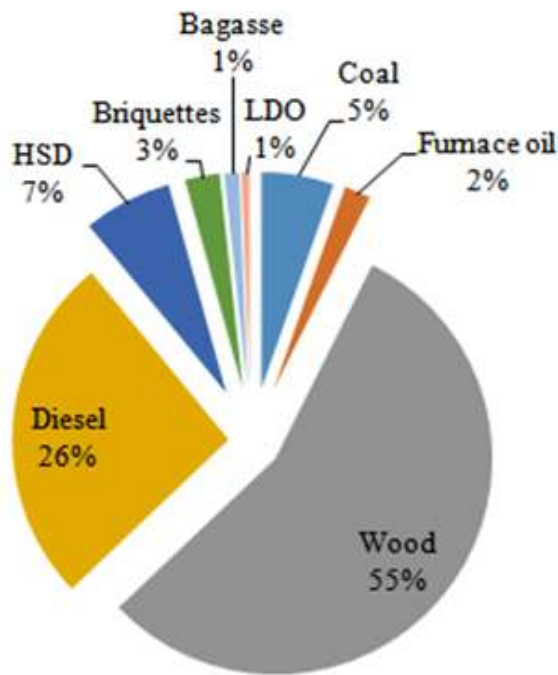


Figure 3.6: Percent Emission Load from Point Source

### 3.10 Area Source

The individual sources that cannot be considered as point and mobile / line sources are categorized as area sources, which includes; bakeries, open eat outs, hotels/restaurants, crematories, construction, domestic cooking, paved/unpaved road dust, solid waste burning. The details of the major area sources in short are given below. The details on the solid waste generation and construction activities are given in the respective sections.

#### 3.10.1 Bakery

Based on the survey, it was observed that there are 12 major bakeries in the representative area. Wood and coal burning are the two major fuels used in these bakeries. The fuel consumption in each bakery ranges from 20-300 kg/d. It was found that most of the bakeries are operating as coal based (63.64%) with average coal usage of 590 kg/d. The wood-based bakeries are 36.36% with average daily consumption of 845 kg/d.

**Emission Estimates:**

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

The PM emission load from bakeries is given in **Table 3.5**.

**Table 3.5: Emission Load from Bakery**

Source	Fuel/Type	PM <sub>10</sub> (TPD)	PM <sub>2.5</sub> (TPD)
Bakery	Wood	0.014	0.0061
	Coal	0.0092	0.0095

**3.10.2 Open Eat-outs**

Based on the survey, it was observed that 234 open eat out units are operating in the city. Most of the open eat-outs are operating as LPG based (82.4%) with kerosene (12.8%), coal (12%), diesel (1.2%) and wood (2.4%) based units. The average consumption of kerosene per day is approximately 1-3 litters, ½ cylinder (21kg capacity) /day of LPG, 4 kg/day of diesel, 10-30 kg/day of wood, and 1 kg/day of coal for cooking. Average operating hours of street vendors is 12 hours. The actual number of tea stalls/snack bars/fast food centres could be more than the observed number, however the observed data through survey is considered for the emission estimates. The PM emission load from open eat-outs is given in **Table 3.6**.

**Emission Estimates:**

Emission from fuel burning (PM) per day

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

**Table 3.6: Emission Load from Open Eat-outs**

Source	Fuel/Type	PM <sub>10</sub> (TPD)	PM <sub>2.5</sub> (TPD)
Open Eat-outs	Kerosene	0.000156	0.000104
	Coal	0.000448	0.000299
	Wood	0.0022	0.001496
	Diesel	0.0	0.0
	LPG	-	0.0018

### 3.10.3 Hotels and Restaurants

There are 236 hotels in the city. Hotels and restaurants are mostly LPG based (91.1%) with presence of kerosene (3.81%), coal (1.6%) and wood (3.38%) units. The PM emission load from hotels is given in **Table 3.7**.

#### Emission Estimates:

Emission Load from LPG

Only PM<sub>2.5</sub> emissions are present in the LPG

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

= Number of Hotels x LPG consumption (TPD) x Emission Factor (Kg/MT)

Emission Load from Coal

= No. of Hotels x Coal consumption (TPD) x Emission Factor (Kg/MT)

**Table 3.7: Emission Load from Hotels & Restaurants**

Source	Fuel/Type	PM <sub>10</sub> (TPD)	PM <sub>2.5</sub> (TPD)
	Wood	0.00229	0.0014
	Coal	0.00282	0.00188
	LPG	--	0.0038

### 3.10.4 Crematoria

There are 12 crematories in the city. About 3338 number of bodies/years are burnt. Crematoria are operating as wood and kerosene-based units. Based on the survey, it was observed that the wood consumed per body is 300 Kgs, Kerosene consumed per body is 5 litres and dung cakes consumed is 5 Kgs per body. The PM emission load from crematories is given in **Table 3.8**.

#### Emission Estimations:

Emission (TSP) = No. of Hindu Death /yr \* wood required per body (Kg) \* emission factor  
+ Number of Hindu Death /yr \* kerosene required (litres) \* emission factor

**Table 3.8: Emission Load from Crematories**

Source	Fuel/Type	PM <sub>10</sub> (TPD)	PM <sub>2.5</sub> (TPD)
Crematoria	Wood	0.0398	0.0265
	Dung Cakes	0.00011	0.0

### 3.10.5 Household Fuel Consumption

There are 22 wards in the city and 10 LPG distributors in the area. The fuel consumption pattern is executed based on the Census 2011 report. The number of LPG holders is projected based on the assumption of population growth rate of 1.77% as per the **Table 3.9**. As per the Prime Minister Ujjawala Yojana (PMUY) 2017, the numbers of consumers shifted from other fuel to LPG are 63%. The distribution of the fuel consumption pattern of the households is given below **Table 3.10**.

**Table 3.9: Distribution of Domestic Fuel Consumption Pattern**

No. of households	Firewood	Crop residue	Cow dung	Coal	Kerosene	LPG	Electricity	Other
165617	49558	6369	535	244	7950	98836	41	2194

**Table 3.10: Assumptions of Per Capita Fuel Consumption Pattern**

Fuel	Per Capita Consumption	Unit
LPG	12	Cylinder/year
Kerosene	0.833	Ltr/d
Wood	4	kg/d
Coal	5	Kg/d
Cow dung	3	Kg/d
Crop residue	3	Kg/d

For emission calculations, the assumption on the usage of each fuel unit based on the survey and literature (NEERI Report-Mumbai, 2011).

### 3.10.6 Fuel Consumption in Slum Population

A survey of 36 households was conducted, spread over 7 areas within the city which were known to have significant slum population. It was seen that majority of the slum houses used a combination of fuels such as LPG (6.06%), wood (77.79%) and kerosene (16.13%). The kerosene consumption based on ration shops survey was found to be 7179 litres/month. The PM emission load from domestic combustion is given in **Table 3.11**.

**Table 3.11: Emission Load from Domestic Combustion**

Source	Fuel/Type	PM <sub>10</sub> (TPD)	PM <sub>2.5</sub> (TPD)
Domestic	Kerosene	0.0034	0.0023
	Wood	0.398	0.265
	Coal	0.012	0.0084
	Crop residue	0.18	0.120
	Cow-dung	0.0069	0.0046
	LPG	-	0.031

### 3.10.7 Building & Road Construction

There were 109 numbers of building constructions going on in the city. The data is issued from construction department of AMC and 7 road constructions were ongoing during the survey of the city. The data upto year 2018 is considered for the study. The PM emission load from construction activity is given in **Table 3.12**.

#### Emission Estimation:

PM<sub>10</sub> Tons /years = 1.2 x total number of acres – months (AP42, Section 13.2.3.3)

Acre-months: construction area (acres) x months of activity (18 for new and 6 for old/on-going construction)

**Table 3.12: Emission Load from Construction**

Source	Type	PM <sub>10</sub> (TPD)	PM <sub>2.5</sub> (TPD)
Construction	Building	0.047	0.0315
	Road	0.94	0.063

### 3.10.8 Road Dust

Due to the plying vehicles, resuspension of road dust, which may either be paved or unpaved, is a major cause of concern with respect to particulate matter. Road length data is given in **Table 3.13**, which shows that unpaved road length is higher than paved road length. Silt loading of the paved surface, mean weight of the vehicles traveling over the surface and vehicle kilometre travelled (VKT) are the three important parameters required for computing the emission load from road dust. The average weight of vehicle is considered as given in **Table 3.14**. The PM<sub>10</sub> emission load for road dust is given in **Table 3.15**.

**Table 3.13: Road Length in the City**

Road Type	Length (Km)
Bitumen	366.78
Concrete Road/Paver block	226.49
WBM	522.4
Un surface Road	420.14
<b>Total</b>	<b>1535.81</b>

**Table 3.14: Categorised Vehicular Weight**

Vehicle	2w	3w	4w	Bus/Truck
Weight (Kg)	175	450	1425	7500

Source: NEERI Report-Mumbai, 2010 (*cross-referred: 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 Estimates:**

**Paved Road dust**

Emission factor,  $E_{Pvd} = \{k \times (sL/2)^{0.65} (W/3)^{1.5} - C\} (1-P/4N)$

E = particulate emission factor (having units matching the units of k)

k = particle size multiplier for particle size range and units of interest (k (g/vkt) = PM<sub>2.5</sub>-1.1, PM<sub>10</sub>-4.6)

sL = Road surface silt loading (grams per square meter) (g/m<sup>2</sup>) – 0.531

(Source: NEERI Report-Mumbai, 2010)

W = average weight (tons) of the vehicles traveling on the road (as per above table)

P = No. of wet days with at least 0.254 mm of precipitation during avg. period (assumed 120 days)

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);

Emission from Paved Road (g/d)=  $E_{Pvd} (g/VKT) \times VKT (km/d)$

**Emission Estimation for Unpaved Dust**

Emission factor,  $E_{unpvd} = \{([k (s/12)^a (S/30)^d] / (m/0.5)^c - C)\} \times (365-P) / 365$

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) (PM<sub>2.5</sub>= 0.21, PM<sub>10</sub>=1.386)

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

**Table 3.15: Emission Load from Area Sources – Road Dust**

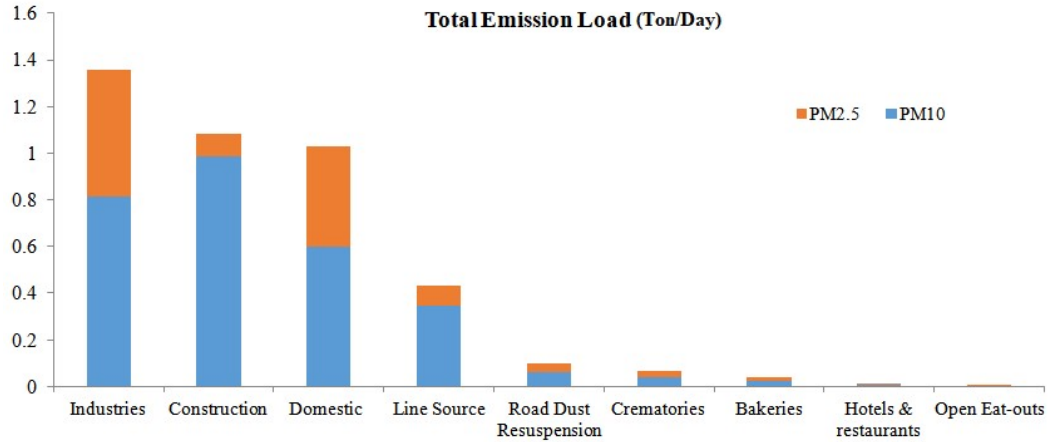
Source	Type	PM <sub>10</sub> (TPD)	PM <sub>2.5</sub> (TPD)
Road dust	Paved	0.032	0.021
	Unpaved	0.027	0.018

### 3.11 Total Emission Load (for Amravati City)

Cumululating all the emission loads from significant sources viz., Area, Point and Line sources for Amravati city wide emission inventory is developed as shown in **Table 3.16 and Figure 3.7**.

**Table 3.16: Total Emission Load from All Sources**

No.	Type of Sources	PM <sub>10</sub>	PM <sub>2.5</sub>
<b>A. Area Sources</b>			
1	Bakeries	0.0232	0.0156
2	Open Eat-outs	0.0028	0.0037
3	Crematories	0.04	0.027
4	Construction	0.987	0.095
5	Road Dust Re-suspension	0.059	0.039
6	Domestic	0.6	0.43
7	Hotels & restaurants	0.009	0.003
<b>B</b>	<b>Line Source</b>	0.344	0.086
<b>C</b>	<b>Point Source</b>	0.814	0.544
<b>Total Emission Load</b>		<b>2.879</b>	<b>1.2433</b>
*All values are in Tonnes/day			



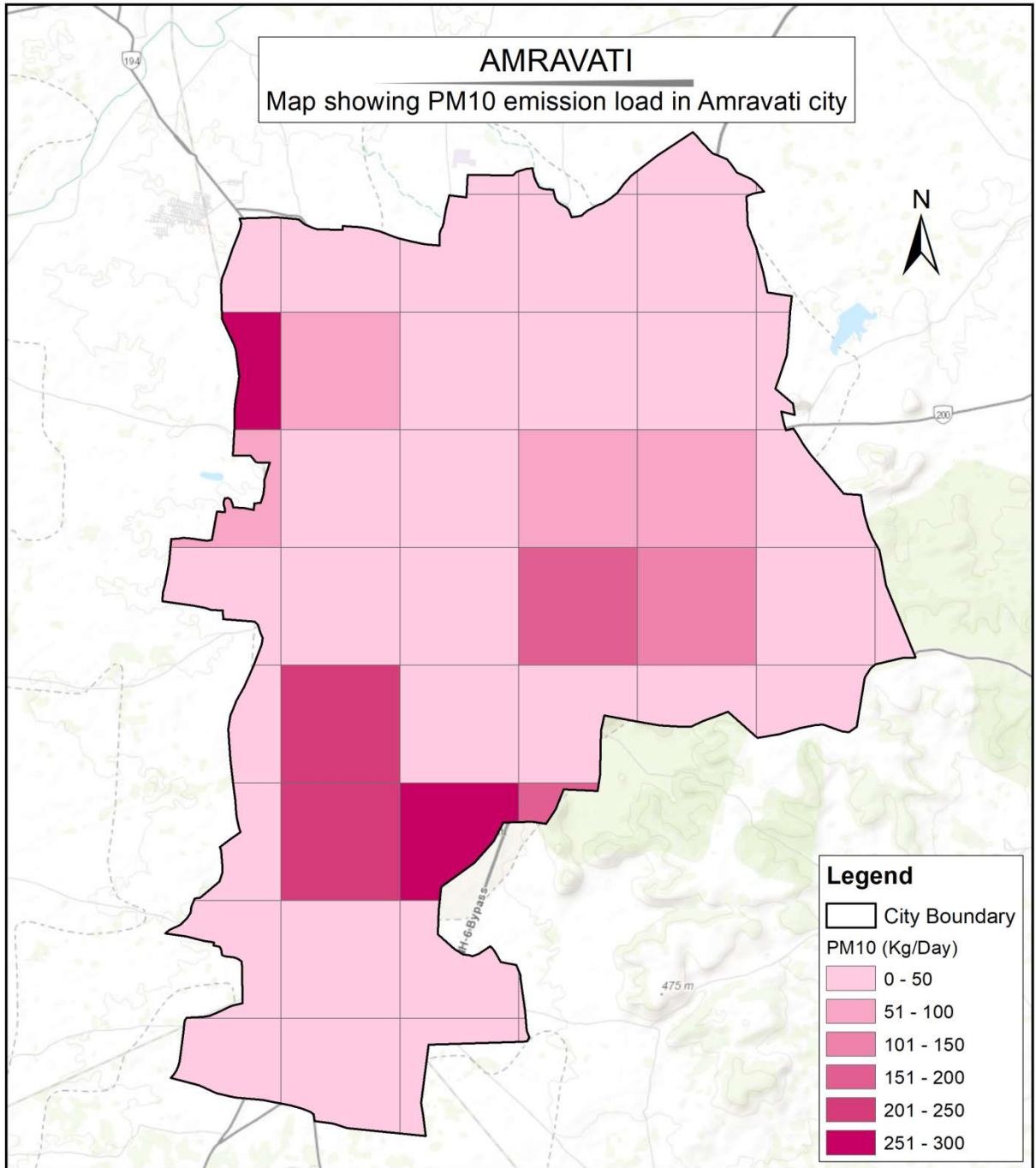
**Figure 3.7: Total Emission Load from All Sources (Ton/day)**

### 3.12 Grid-wise Emission Inventory

The sources considered for estimation of emission load were point, area and line sources. These grid wise emission loads will be effective in consideration of policy making decisions for reducing air pollution to a great extent. The grid-wise emission load from respective source is given in **Table 3.17**. The pictorial view of grid-wise emission load is shown in **Figure 3.8**.

**Table 3.17: Grid-wise Emission Rate of PM<sub>10</sub>**

No.	ID	Emission rate [kg/d]	No.	ID	Emission rate [kg/d]
1	A3	266.68	12	C5	4.13
2	B3	64.02	13	D5	170.10
3	C3	15.73	14	E5	124.30
4	D3	0.03	15	B6	226.93
5	E3	7.42	16	C6	2.81
6	A4	75.33	17	D6	1.70
7	B4	40.60	18	B7	234.89
8	C4	0.58	19	C7	288.28
9	D4	73.46	20	D7	192.30
10	E4	84.53	21	B8	35.95
11	B5	28.36	22	C8	4.79



**Figure 3.8: Grid-wise Emission Load for Amravati City**

## Chapter 4

### Receptor Modelling & Source Apportionment

#### 4.1 Source Apportionment Study using EPA PMF v5.0

Positive Matrix Factorization (PMF) was used in the present study as the receptor model to identify and quantify sources of pollution and their contribution (USEPA, 2014). This multivariate statistical approach for source identification relies on observed data, operating independently of any prior knowledge regarding emission profiles. PMF takes into consideration uncertainties within the measured data and deduces source contributions based on observations at the receptor site. The method involves the utilization of two user input files: one containing species concentration and the associated uncertainties. The chemical mass balance, involving species concentrations and source profiles, is subsequently resolved using Equation 4.1. The air particulate matter samples, featuring chemical speciation, are portrayed as a data matrix 'X' with dimensions  $i \times j$ , where 'i' represents the number of samples and 'j' denotes the number of chemical species analysed during the assessment.

$$x_{ij} = \sum_{k=1}^p g_{ik} f_{jk} + e_{ij} \quad \text{Eq. 4.1}$$

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 presents a weighted least squares problem wherein the determination of a specific number of factors is imperative for the minimization of an 'objective function,' as illustrated in Equation 4.2. The calculations of factor contributions and profiles are

executed through the minimization of the said 'objective function' denoted as 'Q' within the PMF model.

$$Q = \sum_{i=1}^n \sum_{j=1}^m \left( \frac{x_{ij} - \sum_{k=1}^p g_{ik} f_{kj}}{u_{ij}} \right)^2 \quad \text{Eq. 4.2}$$

Where,  $u_{ij}$  is an estimate of uncertainty in the  $j^{\text{th}}$  variable in  $i^{\text{th}}$  sample. The uncertainties ( $u_{ij}$ ) are computed using Equation 4.3, as specified by (Norris et al., 2014). This calculation encompasses both field and analytical uncertainties. In instances where the uncertainty value is absent, it is admissible to substitute it with 5/6 times the Method Detection Limit (MDL) (Norris et al., 2014)

$$\text{Unc} = \sqrt{(\text{conc of ion} \times 0.05)^2 + (\text{Mdl} \times 0.5)^2} \quad \text{Eq. 4.3}$$

Where, Conc of ion = Concentration of ion,  $\mu\text{g}/\text{m}^3$ ; MDL = Minimum Detection Limit,  $\mu\text{g}/\text{m}^3$

## 4.2 Methodology

The present study was carried out for representative samples of  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$  collected during the sampling campaign at 4 locations: RKS (S1); SGU (S2); SAI (S3); JNV (S4).  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  were collected on 47 mm Whatman quartz and PTFE filters using samplers with 5 LPM flow rate (Air Metrics - Minivol Sampler) for 24-hour sampling period at all locations concurrently. The gravimetric analyses were carried out for all the collected samples to obtain total  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  concentration levels.

To carry out source apportionment, Elemental carbon and Organic carbon analysis (DRI); Elemental analysis (ED-XRF) and Ionic Analysis (IC) were conducted for all samples. The preparation of the input file involved compiling concentration datasets of the samples and their associated uncertainties. The model processes input files, computing the 'Signal to Noise' (S/N) ratio for each species to categorize them as strong, weak, or bad. This classification, guided by the principle of minimizing errors in strong variables and maximizing errors in weak variables (Paatero & Hopke, 2003), informs subsequent analysis. Species with an S/N ratio above 3 are labelled strong, those between 1 and 3 as weak, and those below 1 as bad for model execution. Additionally, species with 80% of values below the Minimum Detection Limit (MDL) are considered bad and excluded from the model analysis.

The modelling process necessitates multiple trial-and-error iterations to attain optimal solutions. Accordingly, a broad spectrum of factors ranging from 3 to 8 was explored, conducting 100 trial runs with a random start on each occasion. The evaluation of modelled results employed the  $Q_{\text{true}}/Q_{\text{robust}}$  ratio.  $Q_{\text{true}}$  is computed by considering the entire dataset, while  $Q_{\text{robust}}$  is derived by excluding outliers. A ratio close to 1.0 signifies a favourable solution with negligible outlier influence, whereas a ratio exceeding 1.5 indicates a noteworthy impact of outliers (Paatero & Hopke, 2003). Additionally, the correlation coefficients ( $R^2$ ) between measured and modelled metal concentrations were scrutinized, aiming for values exceeding 0.80. Such correlations indicate a robust fit of the model to the measured data.

In addressing the challenge of non-unique solutions in Positive Matrix Factorization (PMF), known as rotation ambiguity, various rotations were systematically explored using the F-peak parameter (Paatero et al., 2002). This parameter, ranging from -3 to 3, aimed to minimize changes in the objective function (Q) to identify a unique solution. Monitoring Q-values during this exploration revealed the solution with the lowest Q-value, indicative of minimal rotational ambiguity, as the optimal solution at that specific

F-peak. Implementation of bootstrapping, altering the dataset for uncertainty estimation, demonstrated less than 5% variability in species percentages. Criteria, including a minimum correlation value of 0.8 and default block size, ensured robustness in results. Following these considerations, comparing factor fingerprints and contributions to standard profiles. The results were subsequently utilized for determining the percentage contribution of sources at receptor locations with their source profiles.

### 4.3 Results

The results of both cases for PM<sub>10</sub> and PM<sub>2.5</sub> are presented in this section. The source contributions are shown in **Table 4.1** and **Figure 4.1**. The base profiles are given in Annexure II.

**Table 4.1: Percentage source contribution for PM<sub>10</sub> and PM<sub>2.5</sub>**

Most likely source(s)	% Contribution	
	PM <sub>10</sub>	PM <sub>2.5</sub>
Agriculture	12	20
Construction+ Biomass Burning	39	26
Industrial	27	29
Road Dust resuspension +Vehicular	22	25

#### 4.3.1 Factors of PM<sub>10</sub> and PM<sub>2.5</sub>

EPA PMF run analysis identified 4 factors in the study location for PM<sub>10</sub> and PM<sub>2.5</sub> samples with factor finger prints as shown in Figure 4.2 and Figure 4.3

##### **Factor 1: Agriculture**

Factor 1, representing approximately 12% and 20% of total PM<sub>10</sub> and PM<sub>2.5</sub> emissions respectively. This factor is characterized by a combination of elements associated with

agriculture such as  $\text{Ca}^{2+}$ ,  $\text{NH}_4^{-3}$ ,  $\text{Mg}^{2+}$ ,  $\text{Cl}^-$ , Si, Sr, Ti, Cd, Zn.  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  are indicative of soil dust, while  $\text{NH}_4^{-3}$  suggests contributions from fertilizer use (Panda et al., 2022).  $\text{Cl}^-$  may originate from agricultural pesticides, and Si from soil erosion (Srivastava & Ramanathan, 2018). Additionally, the inclusion of trace elements like Sr, Ti, Cd and Zn highlights potential sources such as fertilizers and agrochemicals.

### **Factor 3: Construction Dust + Biomass Burning**

Factor 3 is identified as construction dust with 39% and 26% of total  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  emissions respectively indicated by key markers EC, OC,  $\text{Cl}^-$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{NH}_4^{-3}$ , Al, As, Co, Mg, Ni, Zn.  $\text{Mg}^{2+}$  and  $\text{Ca}^+$  are major indicators of construction dust from cement and aggregate mixing (Bhuyan et al., 2018; Garaga et al., 2020; Jain et al., 2019; Keerthi et al., 2018; Patil et al., 2013) Construction dust is mainly contributed from all infrastructure development going in and around the city. There have been many studies in the past suggesting that  $\text{K}^+$  and OC are clear indicator of biomass burning Garaga et al., 2020; Police et al., 2016) whereas  $\text{NH}_4^{3-}$  is a major indicator of wood combustion (Jain et al., 2019; Mukherjee et al., 2018; Police et al., 2016)

### **Factor 3: Industrial source**

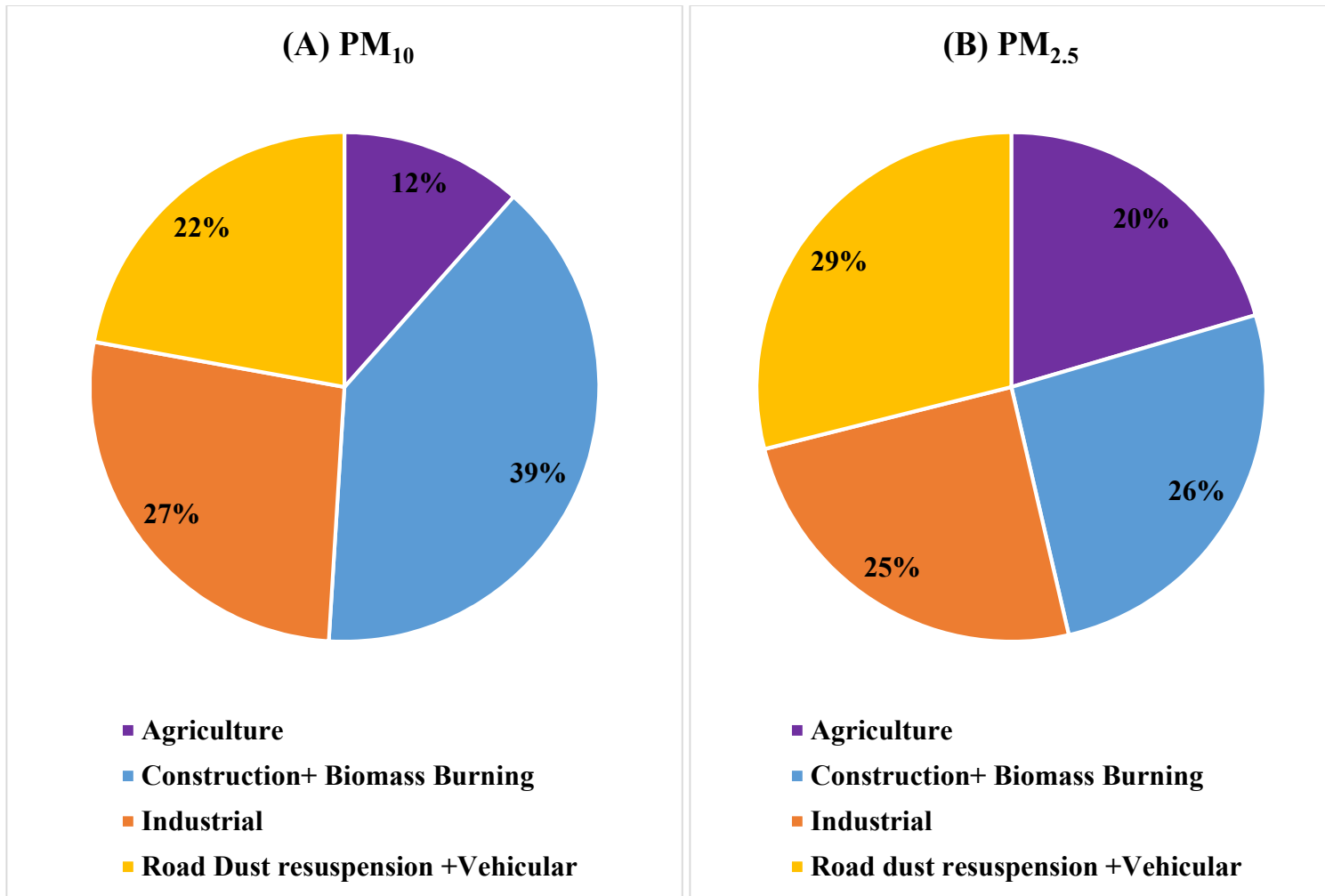
Factor 3 is identified as an industrial source, contributes significantly to both  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  emissions, accounted for 27% and 29%, respectively. The key indicators for this source encompassed Cd, Cr, Cu, Pb, Se, Sr, Ti and Zn. Cu, Cr, Fe, Zn indicates metal plating industries (Mehta et al., 2022) Cd and Sr are associated with industrial activities such as metal smelting and manufacturing while Pb is particularly associated with activities like lead-acid battery manufacturing and metal smelting (Gupta et al., 2012; Sharma et al., 2016; Taghvaei et al., 2018; Zong et al., 2016). Locations of industries surrounding the study region justify the influence of industrial activities on this observed factor.

#### **Factor 4: Road dust resuspension + Vehicular Emissions**

Factor 4 is represented by the significant levels of EC, OC,  $\text{NO}_3^{2-}$ ,  $\text{NH}_4^{2-}$ ,  $\text{SO}_4^{2-}$ , K, Ni, Si, Ti, Zn and Mg, Al contributing to 22% and 25% of total  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  pollution respectively. 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 (Jain et al., 2019; Mukherjee et al., 2018; Panwar et al., 2020; Shukla & Sharma, 2008). Also, EC,  $\text{SO}_4^{2-}$ , S & OC were present in this factor indicating emissions from burning of fossil fuel from vehicles (Keerthi et al., 2018). Substantial amount of paved road dust is being resuspended by vehicular movements which is indicated by minor markers such as Fe, EC, OC and Zn are indicators of road dust re-suspension (Jain et al., 2017; Panwar et al., 2020). Road dust gets re-suspended due to natural gust of winds or moving objects like vehicles (Ashrafi et al., 2018; Banerjee et al., 2015; Kothai et al., 2008) Since the study was done in dry summer conditions wind-blown dust has large influence on this source.

#### **4.4 Conclusions**

In conclusion, the Positive Matrix Factorization (PMF) analysis has provided an estimate of the contributing factors to both  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  concentrations in Amravati. The study identified 4 distinct factors, shedding light on the sources influencing particulate matter in the city. Notably, Construction and Biomass burning was dominant in both  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  pollution. To address these findings, stricter regulations and monitoring for construction activities, as well as initiatives to control biomass burning should be implemented. Additionally, public awareness campaigns and alternative, cleaner technologies should be promoted to mitigate the impact of these significant contributors.



**Figure 4.1: Percentage Contribution of Sources for (A) PM<sub>10</sub> and (B) PM<sub>2.5</sub> for Amravati**

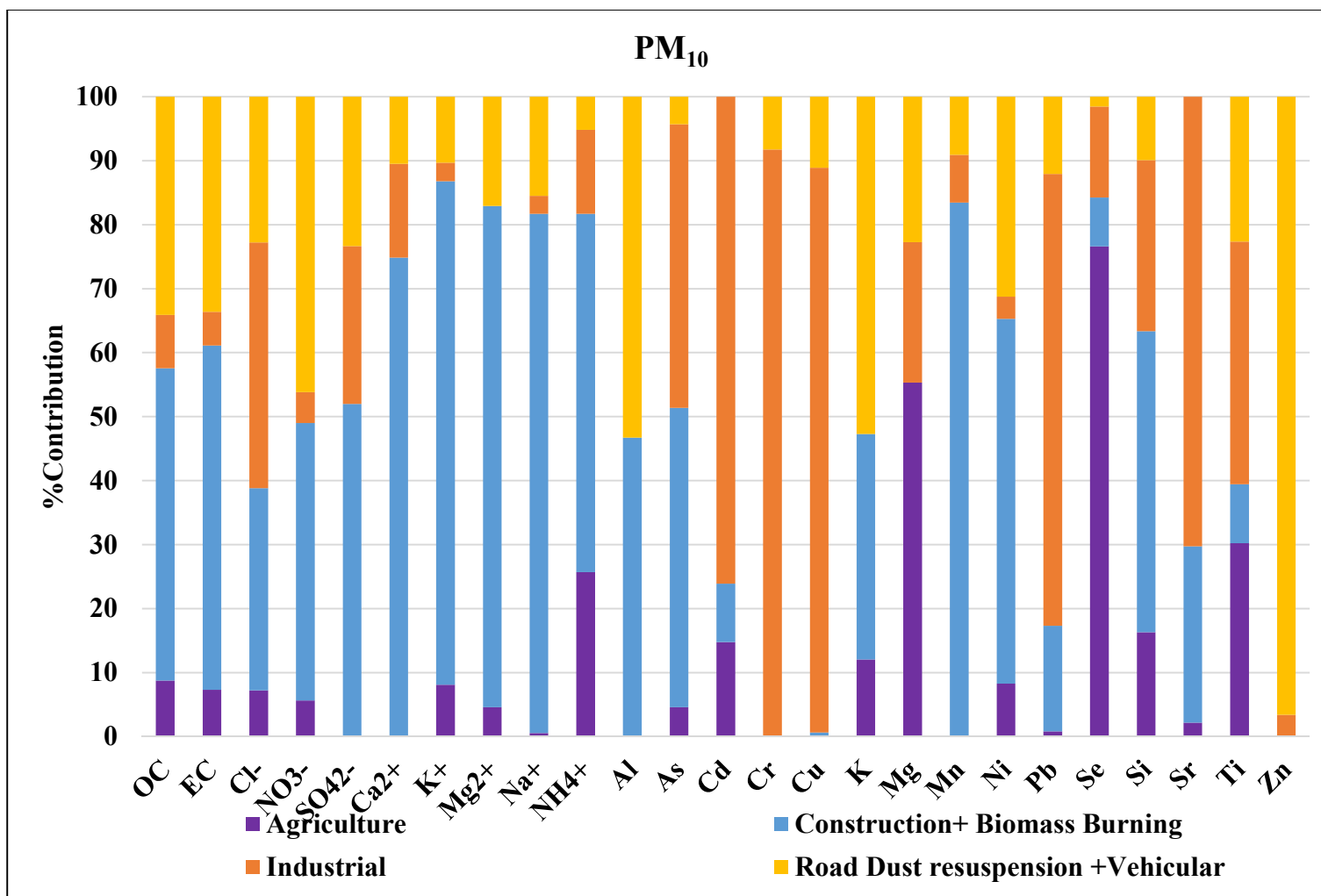


Figure 4.2: Factor Fingerprints of PM<sub>10</sub> for Amravati

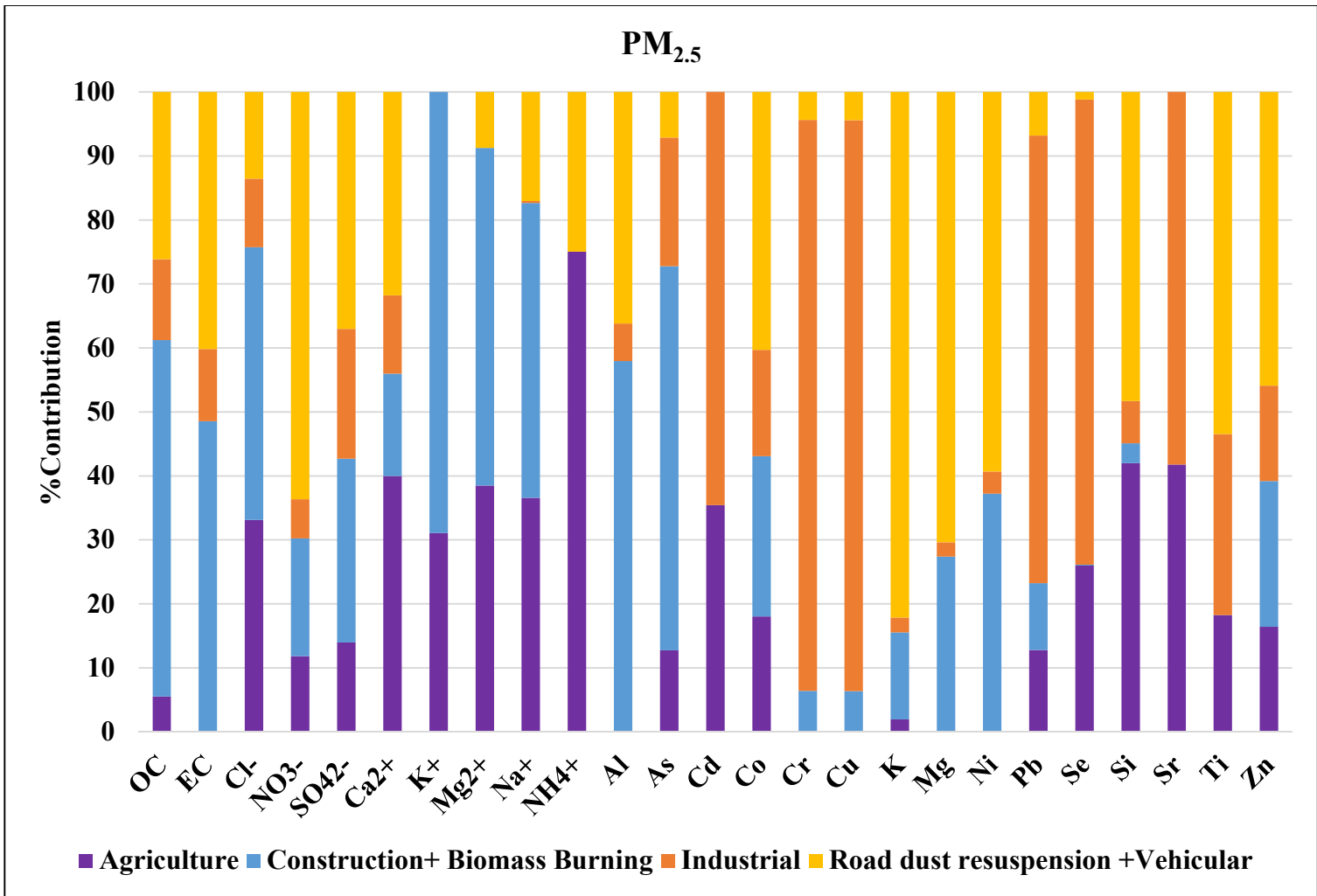


Figure 4.3: Factor Fingerprints of PM<sub>2.5</sub> for Amravati

## Chapter 5

### Air Pollutions Dispersion Modelling

#### 5.1 Overview

Dispersion modeling uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by single or multiple sources. Air quality dispersion modeling has been undertaken with a view to identify the impact and the important sources on ambient air quality in Amravati region. Emission inventory for different pollutant is generated and its dispersion simulated to determine the ground level concentration (GLC) of pollutants. AERMOD Source dispersion modeling tool has been also used for the whole city air quality scenario generation for emission loads from all grids in the city. The existing scenario model runs are 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 output of modeling exercise is shown through isopleths and tables.

#### 5.2 Model Input

Air quality modeling is carried out for complete one year. The Gaussian Dispersion Model (GDM) is used to predict spatial distribution of different pollutant's concentration in ambient air. The model has various options including the capability to handle Polar or Cartesian coordinates, simulating point, area, and volume sources, consideration of wet and dry deposition, accounting for terrain adjustment, building downwash algorithm, etc. The data pertaining to source characteristics, meteorological parameters and receptor network required as input to the model include

- (i) Source data: physical dimensions (stack location, stack height, stack top inner diameter), exit velocity, temperature of gas and pollutant emission rate and location. For Amravati city, the emission from different sources like vehicular emission, crematoria, bakery, road side eatery, etc. are combined in their respective grid and area source emission in terms of  $\text{g/s/m}^2$  is determined as input to the model.
- (ii) Hourly meteorological data for the simulation period: wind speed, wind direction, ambient temperature, mixing height and upper air data generated from weather research forecast (WRF) model at hourly interval.

- (iii) Co-ordinates of receptors, where the model would estimate the ground level concentration of pollutants.

### 5.3 Meteorological Data

Meteorological conditions play a vital role in transport and dispersion of pollutants in the atmosphere. WRF processed hourly meteorological data is generated and used AERMET, which estimates the surface and vertical profile of meteorology. The meteorological data is used in estimating the horizontal and vertical dispersion coefficient ( $\sigma_x, \sigma_y$ ) from the estimated atmospheric turbulence. For this study, a meteorological domain of 25 Kms radius is considered which covers the entire Amravati city. Monthly windrose diagram is plotted and the same is shown in **Figure 5.1**. It can be seen that January to March is a period of very low wind with predominant wind from North. Strong winds starts in April from North-West. Gradually the summer sets with predominant wind of more than 6 m/s from the West. July brings monsoon wind, which is very strong and is from the west. In order to understand the monthly variation of wind speed, its frequency distribution is plotted and is shown in **Figure 5.2**. It can be seen that April to August shows very high wind speed where as for other months, the wind speed is relatively lower.

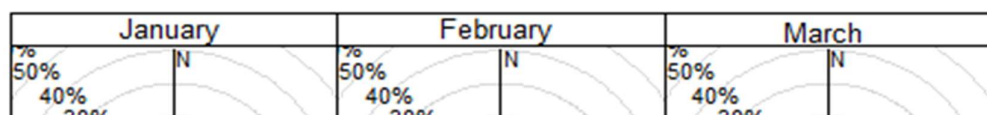
### 5.4 Modelling Domain & Result

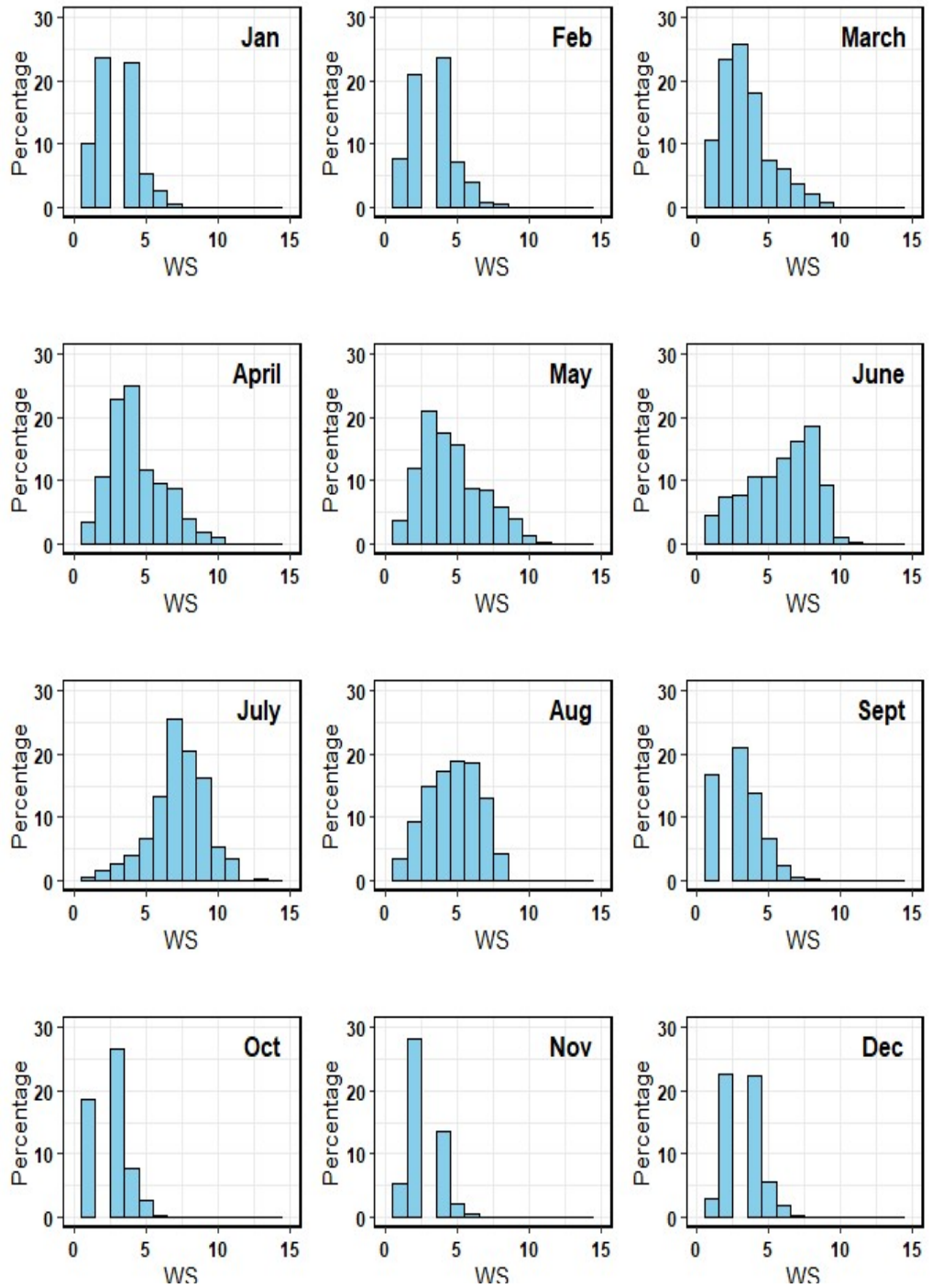
A domain of 25 Kms radius around the centre of the study area is considered for dispersion modelling. A receptor location in the study area were configured in a square grid pattern to facilitate coverage of all the important sites located in and around major urban growth centres with a spacing of 500 m. The area sources were distributed in a square grid pattern and an available emission rate within each grid was used. Hourly frequency distributions of wind speed, wind direction, ambient temperature, stability class and mixing height processed from AERMET is used in the model. Since the standard weighted emission load of PM<sub>10</sub> is the highest, the source dispersion modelling is carried out only for PM<sub>10</sub> (**Table 5.1**). The GLC of all other pollutant (SO<sub>x</sub> and NO<sub>x</sub>) will be below the values obtained for PM<sub>10</sub> as the model option is conservative pollutant. With this consideration dispersion simulation is carried out for PM<sub>10</sub> only.

**Table 5.1: Emission Load for All Pollutants (Tonnes/d)**

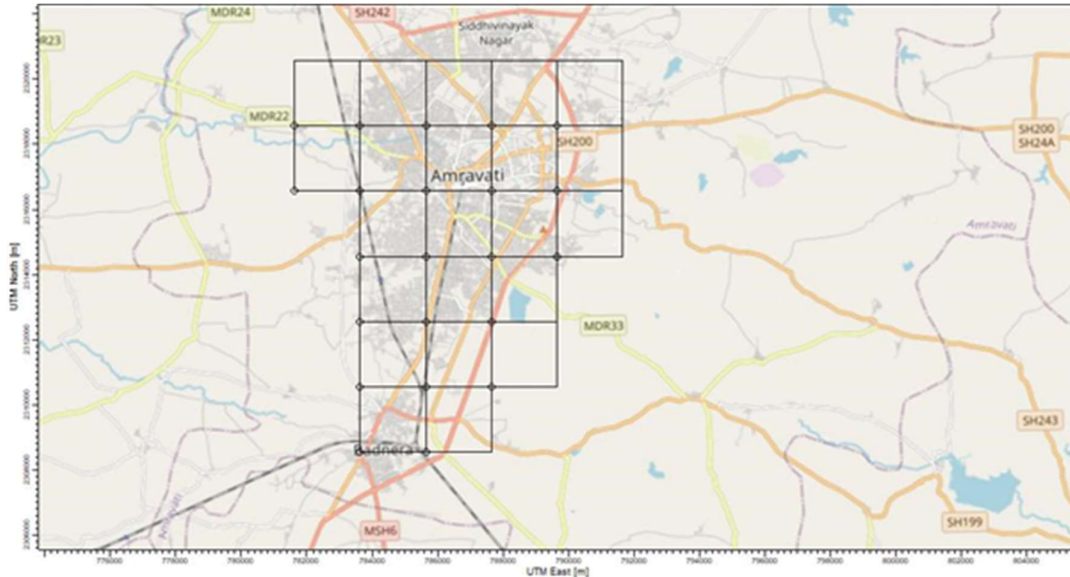
Parameter	Regulatory Stand. [ $\mu\text{g}/\text{m}^3$ ]	Area Emission	Industry Emission	Vehicle Emission	City Emission
PM <sub>10</sub>	100	1.7	0.8	0.3	2.9
PM <sub>2.5</sub>	60	0.6	0.5	0.1	1.2

### Amravati-2017 Windrose





**Figure 5.2: Monthly Wind Speed Frequency in Amravati (Source: CSIR-NEERI)**

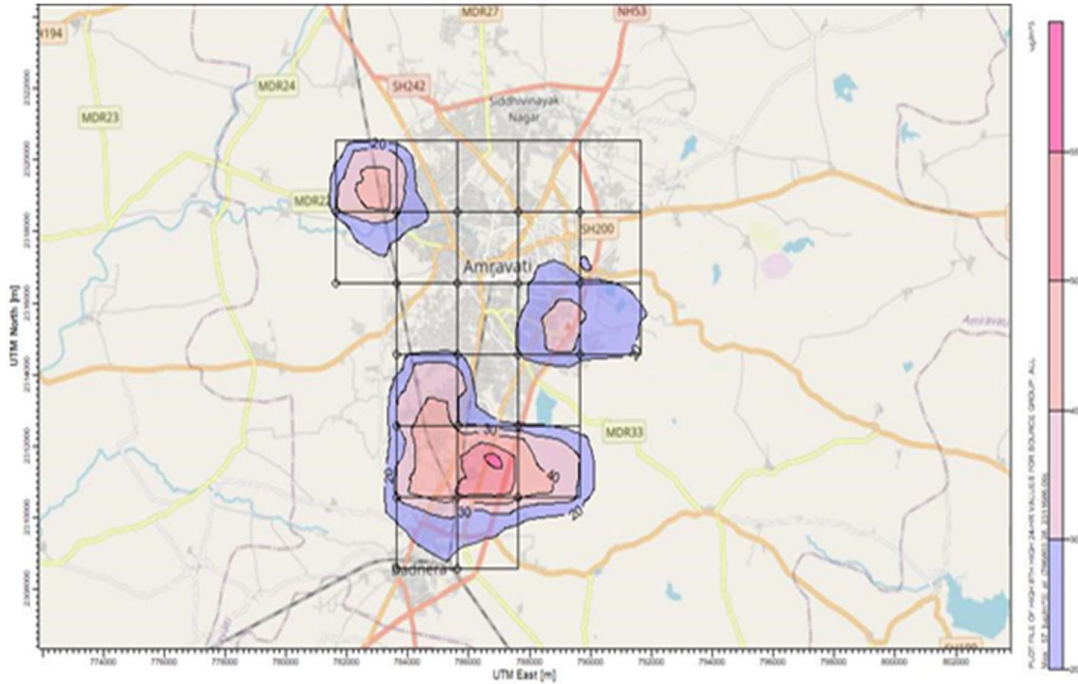


**Figure 5.3: Grid Over Amravati City for Area Source Emission(Source: CSIR-NEERI)**

**Figure 5.3** shows the grid setup on the Amravati city for the purpose of finding the emission load for each grid area. **Table 5.2** shows the emission load from each grid that is used for dispersion modelling. With this emission load, the source dispersion modelling is executed and the ground level concentration (GLC) of pollutant is determined. **Figure 5.4** shows the GLC of PM<sub>10</sub> in Amravati city.

**Table 5.2: Grid-wise Emission Rate of PM<sub>10</sub> [g/m<sup>2</sup>/s]**

No.	ID	Emission Rate [kg/d]	No.	ID	Emission Rate [kg/d]
1	A3	266.68	12	C5	4.13
2	B3	64.02	13	D5	170.10
3	C3	15.73	14	E5	124.30
4	D3	0.03	15	B6	226.93
5	E3	7.42	16	C6	2.81
6	A4	75.33	17	D6	1.70
7	B4	40.60	18	B7	234.89
8	C4	0.58	19	C7	288.28
9	D4	73.46	20	D7	192.30
10	E4	84.53	21	B8	35.95
11	B5	28.36	22	C8	4.79



**Figure 5.4: Isopleth of GLC of PM10 Over Amravati City Due to Area Source Emission (Source: CSIR-NEERI)**

Simulation using AERMOD yields maximum GLC of PM10 is very low and is around 55  $\mu\text{g}/\text{m}^3$  (Figure 5.4). Since this value is lower than the regulatory limit, all other pollutants GLC will be below the regulatory limit value.

## Chapter 6

### Suggestions for Actions for Control of Air Pollution

#### 6.1 Emission Reduction Action Plan for Amravati City

The action plan based on the emission load and its reduction is presented in **Table 6.1**

**Table 6.1: Action Plan for Control of Air Pollution**

Sources	Short Term- 2019	Long Term- 2022	Action Required
<b>Line Source</b>			
Vehicles	10% reduction in emissions	25% reduction in emissions	<ul style="list-style-type: none"> <li>• Heavy duty vehicles are the significant contributors to PM load. Although the number is less, high emissions are observed due to high emission factor and VKT. High number of heavy duty, 4Ws are observed at Shegaon Sq., Dastur Nagar Sq., Old bypass, Welcome gate. Bypass exists for non-destined vehicles.</li> <li>• Retro fitment of Diesel Oxidation Catalyst (DOC) in 4-wheeler public transport.</li> <li>• Retro-fitment of Diesel Particulate Filter in 4-wheeler public transport.</li> <li>• Inspection/maintenance of all commercial vehicles. Restrict commercial vehicle entering city by having ring roads.</li> <li>• 2W are significant contributor to PM load. With proper maintenance, the emissions are assumed to be same in spite of increase in number of vehicles.</li> <li>• High number of 2Ws are observed at Railway stn bridge, Pachwati Sq. Shegaon naka, Kathora naka sq. and Tapovan sq.</li> <li>• For reducing the traffic congestion, no parking zones at the traffic areas need to be delineated. Roads hindering the smooth traffic movement need to be identified and either may be closed and traffic may be diverted or some other suitable option may be exercised. Roads need to be identified for widening.</li> <li>• Maintain potholes free roads for free flow of traffic. Introduce bi-cycle tracks/paths and encourage the use of bi-cycles.</li> <li>• Immediate launch of extensive fuel adulteration drive and random monitoring of fuel quality data.</li> </ul>

Sources	Short Term-2019	Long Term-2022	Action Required
Vehicles (Contd..)	10% reduction in emissions	25% reduction in emissions	<ul style="list-style-type: none"> <li>Launch public awareness campaigns for air pollution control, vehicle maintenance, minimizing use of personal vehicles, lane discipline etc. NGOs need to be involved for this purpose.</li> </ul>
The above mitigation measures reduce the line source emissions by 10% in short term and 25% in long term			
<b>Point Source</b>			
Industry	To get the 10% reduction in emissions till 2019	To get the 25% reduction in emissions till 2022	<ul style="list-style-type: none"> <li>The coal-based power plant is up to date with the control technologies required for particulate emission control.</li> <li>The existing capacity of TPP is 1350 MW which is proposed for expansion up to 2700 MW in next few years. Considering the increase in capacity, PM<sub>10</sub> emission load from TPP will increase twice. Considering this fact in mind, the following suggestions are made: <ul style="list-style-type: none"> <li>Change in coal quality with less ash content. The need is to focus on the less ash content and high calorific value of the coal to increase the plant efficiency.</li> <li>Technological improvement option as given in <i>Ma et al. (2017)</i> can be studied.</li> <li>Efficacy of use of solar power needs to be studied.</li> </ul> </li> <li>For the other coal-based industries, the aged boilers need to be replaced. The latest control technologies are needed for these industries as the PM emission load is quite high.</li> <li>Efficacy of use of solar power in industries and other control measures needs to be studied.</li> <li>Visit observations: water sprinkling after the arrival of the officials, needs to be a regular practice in fugitive dust areas. Regular audit of stack emissions for QA/QC. Strict emission control norms.</li> <li>Brick kilns: Brick kiln contribution is higher. Shifting of natural draft brick kilns to induced draft, banning of operation of Brick</li> </ul>

			kilns in city area is envisaged for the emission reduction.
The above mitigation measures reduce the point source emissions by 10% in short term and 25% in long term			
<b>Area Source</b>			
Fuel burnt Res and Commercial Cooking	5% reduction in emissions	20% reduction in emissions	As given below for individual sources
Domestic combustion			<ul style="list-style-type: none"> <li>▪ Household wood and cow-dung burning is to be reduced. Increase in LPG usage through Ujjwala scheme.</li> <li>▪ Alternate fuel options e.g. solar needs to be assessed and exercised.</li> <li>▪ Crop residue burning needs to be banned gradually but at least 60% reduction in the practice is required.</li> </ul>
Hotels, dhaba and open eat-outs			Use of LPG in hotels and eateries.
Bakery			In bakeries, reduction in wood usage is to be emphasized through replacement with other options such as electric-ovens.
Crematoria			Total 10 crematories. Renewable fuel/biomass briquette etc. to be encouraged.
<p><b>Assumptions or required actions to reduce the emissions:</b></p> <p>To get the 5% reduction in emissions, LPG consumers (domestic) need to be increased to 10% in 2019 in order to reduce the emissions from wood. The PM<sub>10</sub> load will be reduced from wood combustion but from LPG, PM<sub>2.5</sub> emissions will increase. To get the 20% reduction in emissions till 2022, crop residue burning needs to be banned or at least practice needs to be reduced to 60%.</p> <p>The emissions from hotels, open eat outs and crematories are not much. Few general regulations in all these source activities will help maintain the reduced levels. However, the increase in population and people's consumption pattern need to be taken care off.</p>			
Solid waste/open burning	5% reduction in emissions	15% reduction in emissions	<ul style="list-style-type: none"> <li>• Increase in segregation, collection and proper disposal with increased Green Belt.</li> <li>• Launch extensive drives against open burning. Decrease in waste burning. Public awareness drives.</li> <li>• Proper collection of Horticulture waste and its disposal following composting-cum-gardening approach.</li> <li>• Bio-methanation and biogas plant need to be installed</li> </ul>

<p><b>Assumptions or required actions to reduce the emissions:</b>          To get the 5% reduction in emissions, solid waste burning needs to be reduced to 5% in 2019.          Bio-methanation and biogas plant installation till 2022 will surely reduce the emissions to 15%.          Increase in green belt resulted in the air quality improvement in terms of PM<sub>10</sub> to 0.13%  <i>(Nowak et al., 2014).</i></p>			
<p><b>Area Source (Contd..)</b></p>			
Road Dust and C&D	20% reduction in emissions	40% reduction in emissions	<ul style="list-style-type: none"> <li>• Enforcement of construction &amp; demolition rules.</li> <li>• Reduction in unpaved roads by paving.</li> <li>• AMC has proposed plan for creation of green buffers along the traffic corridors (AMC has passed the order Vide letter no AMC/ENV/MC/817/2017 dated 07/02/2016 forwarded to GM BSNL, PWD, for proper action). Plantation drive along the road side, Greening of open areas, garden, community places, schools and housing societies.</li> <li>• Wall to Wall paving (brick).</li> <li>• Ensure carriage of construction material in closed/covered Vessels. Control measures for fugitive emissions from material handling, conveying and screening operations through water sprinkling, curtains, barriers and suppression units.</li> </ul>
<p><b>Assumptions or required actions to reduce the emissions:</b> The above action plan shall reduce the PM<sub>10</sub> emissions from construction activity and road dust.</p>			

**Some of the technologies developed by NEERI to curb air pollution load from area and line sources can be implemented phase wise. (Annexure I to V)**

## Chapter 7

# Results and Recommendations

This study has addressed several aspects of the air pollution status in Amravati with an intent to identify the key sources of pollutants, where criteria pollutants have been used to represent the quality of air. An overview of the organisation of the work presented in this report is shown in Figure 1.4 (Page 1.8).

An attempt for the analysis has been made by using the results from source apportionment analysis, and also the results based on the source inventory (Table 7.1). The same are discussed in the following sections.

### 7.1 Inventory

#### 7.1.1 Results

The inventory for the point, line and area sources were compiled from secondary data made available by the offices of MPCB, AMC and RTO. The inventory has been built ground up and is to be regarded as a best estimate, and is considered to be adequate for the present work to infer an order of magnitude estimate to identify the key sources (Chapter 3).

It is to be emphasised that the size of a particular source in the inventory is not a direct reflection of its contributions to ambient air pollution. The emissions are dispersed and diluted based on the wind conditions and the height of release of the emissions. The dispersion model helps in estimation of the ground level concentrations resulting from emissions from sources after the mixing, dilution and dispersion of the pollutants.

#### 7.1.2 Recommendations

7.1.2.1 It is recommended that the inventory developed in this study may be digitised and maintained as a dynamic dataset for impact assessment of new sources which result from activities related with population growth, industrial installations and/or mobility-transport related projects for Amravati city and the region. Further, it is important that each stakeholder may validate the inventory at a ward level, especially for all non-industrial municipal domain activities.

- 7.1.2.2 Area and line sources are more likely to impact the ground level ambient air pollution than point sources, especially if the latter have been designed for emission through tall chimneys. Thus, the inclusion of all possible “near- ground level” emissions is crucial. In Table 7.1 source apportionment results indicate that the contribution from industries is of the order of 27-29 %, while that from the inventory indicates 28-42%.
- 7.1.2.3 This decrease points to the dispersion of the sources in the inventory with non-point sources and requires further work in inventory development. Source apportionment indicates a ~61% contribution from construction and combustion sources.
- 7.1.2.4 There is a large uncertainty in the quantities and types of garbage and biomass (shed leaves from trees etc.) that are burnt in the open. Further, since they are burnt in an uncontrolled manner, the emission factors and the associated source chemical profiles also add to the uncertainty. Strict enforcement to ensure that open burning is prevented would be the most pragmatic approach to control emissions from this activity, and the associated perception and nuisance value. Timely collection of garbage would minimise the need for such enforcement efforts.
- 7.1.2.5 Services of the Fire Brigade department may be sought through ward-specific telephone/web based hotlines for quenching any uncontrolled garbage and/or biomass burning.
- 7.1.2.6 Burning of plastics and anthropogenic dry wastes in an uncontrolled manner is a matter of health concern, and requires immediate attention. Measurements of the toxic emissions from these is rather tedious and, in a pragmatic sense does not require quantification for validating the need for prevention.

**Table 7.1 (a): Summary of Source Apportionment Results for Amravati (Figure 4.1)**

Sr. No.	Most likely source(s)	% PM <sub>10</sub>	% PM <sub>2.5</sub>
1	Agriculture	12	20
2	Construction+ Biomass Burning	39	26
3	Industrial	27	29
4	Road Dust resuspension +Vehicular	22	25
	<b>Total</b>	<b>100</b>	<b>100</b>

**Table 7.1 (b): Key Sources from Inventory (Table 3.16)**

Sr. No.	Type of Sources	% PM <sub>10</sub>	%PM <sub>2.5</sub>
A	Area Sources		
1	Bakeries	0.81	1.20
2	Open Eat-outs	0.10	0.28
3	Crematories	1.39	2.07
4	Construction	34.28	7.29
5	Road Dust Re-suspension	2.05	2.99
6	Domestic	20.84	37.60
7	Hotels & restaurants	0.31	0.23
B	Line Sources	11.95	6.60
C	Point Sources	28.27	41.74
	<b>Total</b>	<b>100</b>	<b>100</b>

## **7.2 Source Apportionment (PMF and Dispersion Models)**

### **7.2.1 Results**

- 7.2.1.1 Sampling for the source apportionment component of the work were carried out at four locations to cover representative air pollution (Chapter 2). Airmetrics (Federal Reference Method) samplers were special ordered for the study for a customised flowrate of 5 lpm to prevent filter overloading in 24-hour averaged samples. The sampling period was during Summer 2019.
- 7.2.1.2 The chemical analyses were carried out as per CPCB guidelines (Table 2.2). The source apportionment analysis was conducted employing the EPA Positive Matrix Factorization (PMF) method and the results are summarised as Figures 4.1, 4.2 and 4.3 and Tables 4.1.
- 7.2.1.3 The findings revealed that dust and combustion sources emerge as predominant contributors for PM<sub>10</sub> pollution. This occurrence is attributed to the high dust loadings on the roads, and the ongoing construction activities around the city, vehicles and uncontrolled biomass and garbage burning.
- 7.2.1.4 Additionally, PM<sub>2.5</sub> pollution was prominently influenced by Industry (29%) Agriculture (20%), Biomass burning/Construction (26%), and 25% from road dust and vehicles.
- 7.2.1.5 Dispersion modelling was carried out using AERMOD dispersion model (Chapter 5). The inputs for sources were taken from the inventory developed in Chapter 3, and the datasets made available by MPCB. MM5 data were used for the meteorological inputs.

### **7.3 Suggestions for Success of Sustained Efforts**

The following recommendations have emerged from several discussions at meetings, conferences, stakeholder workshops throughout India with experts from multiple organisations (Numerous to list and gratefully acknowledged).

Each city carries its own pulse and character, and therefore a “one size fits all” approach is not likely to be feasible or effective. However, some basic infrastructural and systemic additions in the concerned agencies may help streamline the efforts and start producing results in time, to be then sustained. While the experience of the present study and these recommendations are based on the work carried out in 10

cities in Maharashtra (supported through MPCB), the same would be applicable to all cities in India (including the smaller cities that are presently not listed as non-compliant due to the use of size of the population criterion used).

**7.3.1** Realizing the impact of air quality on health, there is an ardent need of air quality surveillance system in place in the city. This should be led by urban local body, equipped with qualified and trained manpower. This calls for establishing an air quality monitoring cell (AQM Cell) in each ULB with dedicated responsibility. AQM Cell should co-ordinate between regulatory authority (MPCB) and other department of ULB and traffic department for regular data gathering. A dash board of gridded emission inventory should be ready with the ULB for regular updating. Each department related with emission activity should have access to the dash board and direct data entry will give online updated emission inventory. For example, crematoria data should be entered in the dash board, which will update the emissions from crematoria.

**7.3.2** Each AQM Cell should have air quality monitoring system for the city. This should include manual monitoring and CAAQMS. The manual AQM need not necessarily be National Network, instead based on the city needs, up-wind background monitoring, city down-wind monitoring, rotation of monitoring station depending on predominant wind direction, source dispersion modelling based monitoring station needs to be set up. Monitoring of only PM, SO<sub>2</sub> and NO<sub>x</sub>, which are criteria pollutants, needs to be carried out. Capacity building of AQM Cell for manual monitoring should be a part along with setting the laboratory infrastructure. The cell should have appropriate laboratory, computational facility, etc. or should have tie up with local Government academic Institution for the same. The CAAQMS data should be directly accessible to the AQM Cell. Dash board of CAAQMS data should provide daily updated status of air quality, so that any corrective action, calibration if needed can be taken. Meteorological station along with ozone monitoring must be a part of CAAQMS.

**7.3.3** The monitoring network may also be designated for different kind /quality of data, possibly as:

- Residential areas (ward-specific)
- Kerb side
- Hot spot (say industrial region or high density populated areas)
- Urban background and
- Research grade data

This may be integrated with National Network also.

**7.3.4** Meteorological data of ULB for previous years should be analysed to present the boundary layer height and ventilation. The data for each year should be updated based on the meteorological data gathered through CAAQMS station.

**7.3.5** A significant part of the air pollution in urban centres is from vehicular emissions. The correct estimate of vehicular emissions is possible only if the

vehicle type identification and its counting on each road can be carried out. Artificial Intelligence / Machine Learning (AI/ML) tool can be used for online identification and counting of vehicles. Such tools are already developed and ready. CCTV operators are required to give access to the IP address so that online counting of vehicles can be carried out and used in the emission inventory and source dispersion modelling.

**7.3.6** Dispersion modelling of the gridded emission should be carried out and be ready online with the AQM Cell. All additional emission load should be included regularly so as to improve the prediction of ground level concentration of pollutant.

**7.3.7** Health data from primary health centre should be digitised and online for drawing any correlation with air pollution and health condition. The hospitals, should be taken on-board the AQM cell.

## **7.4 Further Work**

**7.4.1** The strength of using the results of this study depends on the validation of the source inventory at the ground level. Control measures would need to be strategized accordingly.

**7.4.2** The effort would require a sector-wise cost analysis for a time-bound implementation by the industry, transport department and the urban local bodies. The cost of public health due to air pollution is well established in previous studies and outweighs the cost of control of air pollution at source itself.

**7.4.3** Long term sustained success will require public participation and a reward based approach (rather than enforcement based) maybe attempted – even as a test case in a few wards where the pro-active citizen participation could set an example for success.

**7.4.4** Management of air quality is a new emerging problem for cities in india, and therefore asks for a new team and a new administrative structure. The work is of a nature that would require day-to-day data collection, analysis and ground level control of sources through multiple agencies. This team could also monitor the progress laid out for the immediate as well as for the next 5 to 10 years, and pool in the resources for the entire state as through multiple agencies (MPCB, RTO, Fire Brigade, IoR's, Research Institutes and Industries and other stakeholders).

**7.4.5** Use of satellite data is highly recommended as a mainstream analytical tool for the entire state of Maharashtra. Collaborations with ISRO, IMD and National Remote Sensing Agency are essential for this effort.

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