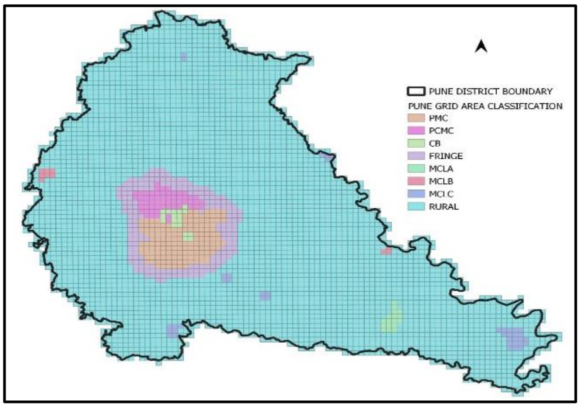
Report

Development of Emission Inventory for Pune District (M.S.)

under

Clean Air Project in India (CAP India)



Submitted to:

Maharashtra Pollution Control Board
महाराष्ट्र प्रदूषण नियंत्रण मंडळ

Maharashtra Pollution Control Board (MPCB)

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September 2022

Supported By

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Acknowledgements

The Automotive Research Association of India (ARAI) is grateful to all experts and specialists for providing insights during the preparation of this report. The acknowledgements are due to Maharashtra Pollution Control Board (MPCB), Pune Municipal Corporation (PMC) for sharing data on various activities in the region. The support from TERI team during the execution of the project is sincerely appreciated. The support by Swiss Agency for Development and Co-operation (SDC), Switzerland is duly acknowledged.

ARAI is also thankful to Prof. Mukesh Sharma of Indian Institute of Technology, Kanpur and Dr. Sachin Ghude of Indian Institute of Tropical Meteorology, Pune for review and constructive inputs on the findings of the report.

Contents

LIST OF FIGURES

LIST OF TABLES

1. Introduction

Air pollution has emerged as a major health risk challenge, particularly in urban agglomerations in India. Rapid economic development, urbanization and population rise are leading to increase in emissions from different sources including but not limited to transport, industries, domestic cooking/heating, fugitive dust, waste burning and biomass burning. The air pollution problem becomes more complex due to the interactions between emissions, prevailing meteorological conditions and atmospheric chemistry.

Clean Air Project in India (CAP India) aims to support India's efforts to improve air quality while contributing to public health, environment, and climate change mitigation. The air quality of the region will be improved by scientifically strengthening the existing air quality management plan and sensitizing general public about the air pollution and health impact related to it. To strengthen or revise existing air quality management plans latest knowledge on emissions and air quality in the region is essential and hence this study is aimed at emission inventorization of air pollutants in Pune district.

1.1. Study Domain – Pune district

Pune is well known as the 'Queen of Deccan' due to its scenic beauty and rich natural resources. Besides, it is famous for its religious and historical places. Pune has made its mark in the Education sector historically and is currently one of the most industrialized districts in Western Maharashtra with established industry sectors including Information Technology, Engineering and Automotive industries. The district has importance as an important military base.

1.1.1. Geography

Geographically, the district lies between 17.50 to 19.20 ^{o}N latitudes, 73.20 to 75.10 ^{o}E longitudes at an average altitude of 560 m. The district occupies a geographical area of 15,643 sq. km.

1.1.2. Administration

Administratively, Pune District is divided into 14 Tehsil, with 2 Municipal Corporations, 3 Cantonment Boards and 13 Municipal Councils. Pune city is the divisional headquarter of Western Maharashtra and headquarter of the district. Figure 1 shows the location map of Pune district with Pune and Pimpri-Chinchwad Municipal Corporations.

1.1.3. Climate

Pune district is part of the tropical monsoon land and therefore shows a significant seasonal difference in temperature and rainfall conditions. The climate of the western region of Pune district is cool, whereas the eastern part is hot and dry. The western part of the district adjacent to the coast, is hilly area having forest cover, due to which receives more rainfall compared to the eastern parts.

April and May are the hottest months in the district. Maximum temperature during these months often reaches above 38°C. The western region of Pune district i.e. talukas Junnar, Ambegaon, Khed, Maval, Mulshi and Velha are cool whereas the eastern part i.e. talukas Shirur, Daund, Baramati and Indapur are hot and dry. December and January are the coldest months, when average temperature falls as low as 11°C.

Most of the rainfall in district is brought by the southwest monsoon winds during the monsoon months. The monsoon onsets in the month of June and continues till September, with the maximum intensity of rainfall during the month of July and August.

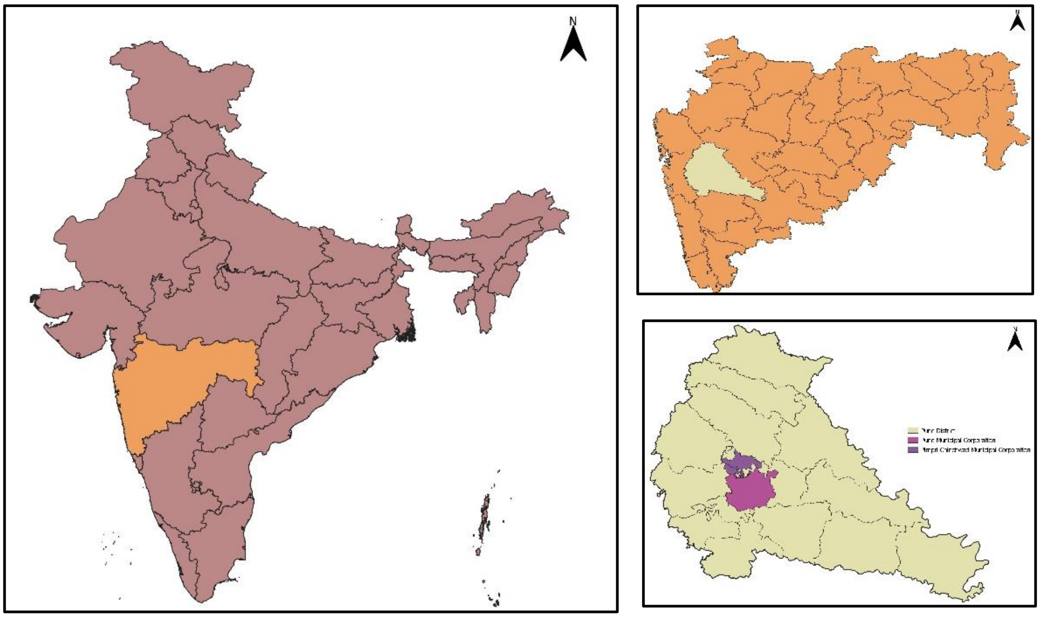

Figure 1: Location map showing Pune district with Pune and Pimpri Chinchwad Municipal Corporations

1.1.4. Demographics

Pune district is the second most populous district in the Indian state of Maharashtra. According to 2011 census the district has a population of 94,29,408 including 49,24,105 males and 45,05,303 females. The population density in the district is 603 persons per sq. km. Figure 2 shows the historic population of Pune district from 1971 to 2011. The population of the Pune district is increasing steadily at an average decadal growth rate of 31.2%. The highest population growth rates are observed in urban areas.

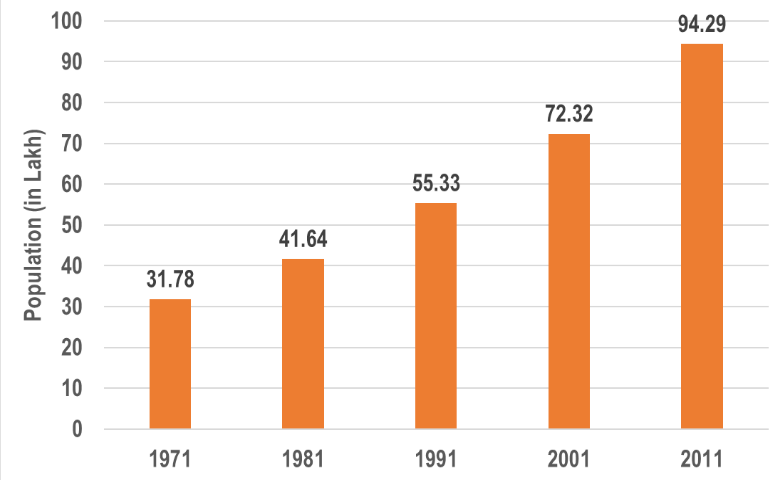

Figure 2: Population growth in Pune district during 1971-2011

(Source: Census of India)

As a part of this study, the population of Pune district is projected for year 2021 following standard methods prescribed by Ministry of Urban Development (MoUD). The total population of the Pune district is estimated to be ~126.18 lakh in year 2021. Figure 3 shows the estimated population distribution in Pune district for year 2021, laid over 2 x 2 km² grids.

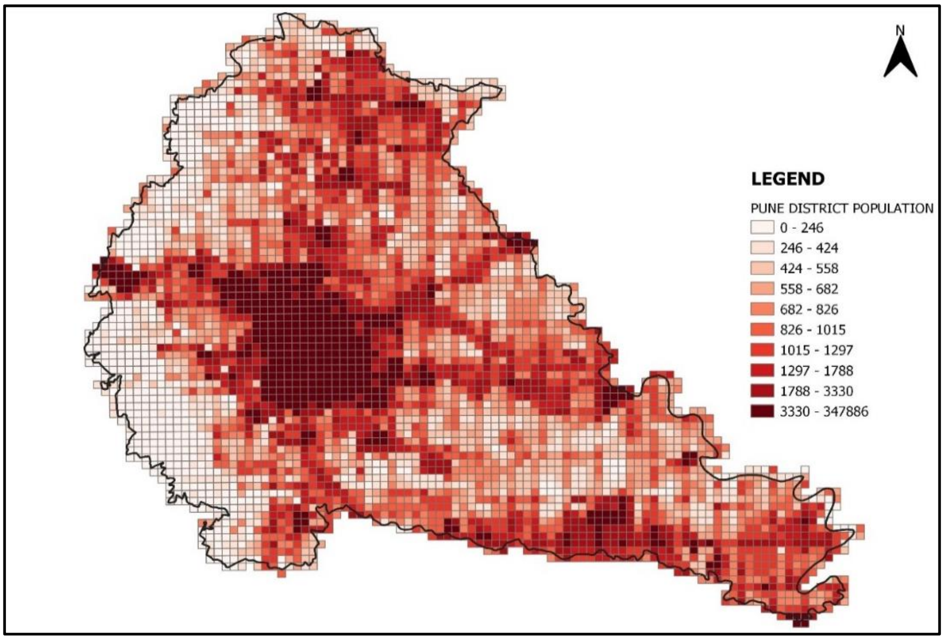

Figure 3: Map showing estimated population distribution in Pune district for year 2021 laid over 2 x 2 km² grids

1.1.5. Industries

As discussed earlier, Pune district hosts a variety of industries. Except IT industry, most of the industries are located outside Pune Municipal Corporation (PMC) limits, in Pune Metropolitan Region (PMR) and/or close to PMR towards North-West, North and North-East. The Pimpri-Chinchwad Municipal Corporation (PCMC) houses a majority of the industrial developments. The MIDC in PCMC is an active industrial hub, hosting close to 3,200 units in production. PCMC MIDC has been instrumental in facilitating the development of the Small and Medium Enterprises in the area that are suppliers to the bigger established players.

1.1.6. Land Cover

Figure 4 shows the land cover map of Pune district derived from MODIS Land Cover Type Product (MCD12Q1) for year 2019. Majority of the area of Pune district is covered by croplands, followed by urban and built-up area. It can be seen that; urban and built-up areas are concentrated at the center around the Pune and Pimpri-Chinchwad municipal limits along with scattered locations around the municipal councils.

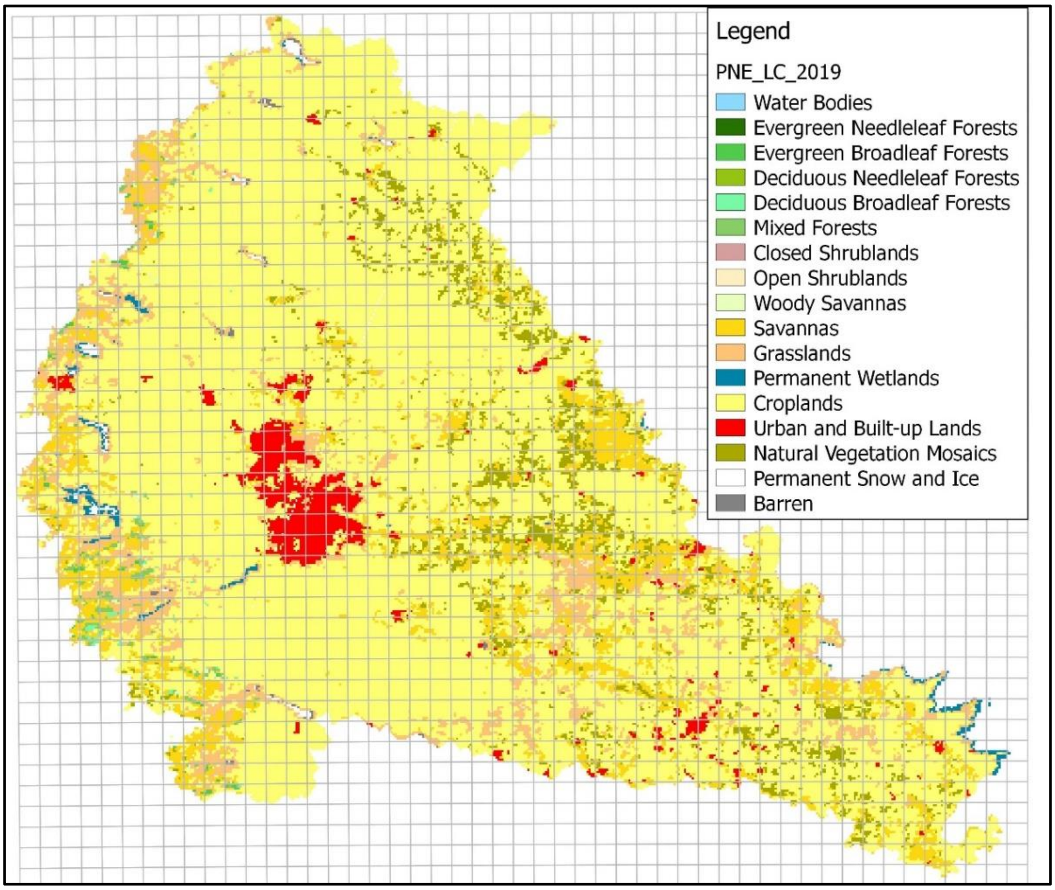

Figure 4: MODIS derived land cover map of Pune district showing different classes for year 2019

2. Methodology

Emissions inventories are the building blocks in understanding contributions of different sources towards prevailing pollutant levels and evaluate the impacts of policies adopted for control. Developing an air emission inventory arose from the need to improve air quality across the region and prevent adverse effects on the health of humans and ecosystems. Emission Inventory is one of the fundamental components of "Air Quality Management" plans which aim to measure progress/ changes in air quality over time. Emission inventorization is done to assess the change in air quality trends of a region. These inventories are generally compiled for various pollutant emissions generated due to energy use in different sectors such as transport, industries, power, residential, etc. In addition, emissions are also contributed by fugitive sources (non-energy use sources), such as road dust, storage and handling of fuels, etc.

The main objectives of this study are to prepare a baseline emission inventory, for year 2021, of air pollutant loads originating from twelve sectors including Transport (TRAN), re-suspended road dust (RDST), Open waste burning (WAST), Residential (RESI), Industries (INDU), Brick kilns (BRIC), Diesel generators (DSGN), Hotels, restaurants, bakeries and open eateries (HRBE), Crematoria (CREM), Aircraft (ARCFT), Construction (CONS), and agricultural residue burning (AGRI) in Pune district. This section explains the quantification of emissions originating from selected sectors in Pune district.

Air pollutants included in this study include particulate matter 10 (PM_{10}), particulate matter 2.5 ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOC). This section explains the quantification of emissions originating from selected sectors in Pune district.

Figure 5 shows the methodology adopted in development of high-resolution emission inventory for Pune district. The first phase of the emission inventory development involves research on previous emission inventories in the region, reconnaissance surveys, collection of secondary datasets. Based on this data analysis, air pollution sources in the study domain were identified. Once the air polluting sources in the study domain are identified, the primary data collection surveys were taken up for different sectors. Details of primary data collection surveys are provided in sectoral manner in subsequent sections. Air pollution sources were categorized into three main types i.e. point, area and line sources and details of sectors included in each type are provided in table 1.

There are several estimation methods to calculate emissions based on data availability. This study uses the most widely used approach based on emission factors and activity rate. A comprehensive literature review was carried out for selection of emission factors for each sector. Emission factors for vehicular sector were adopted from Automotive Research Association of

India (ARAI 2010, 2018), while for other sectors, India specific and local emission factors have been used as far as possible.

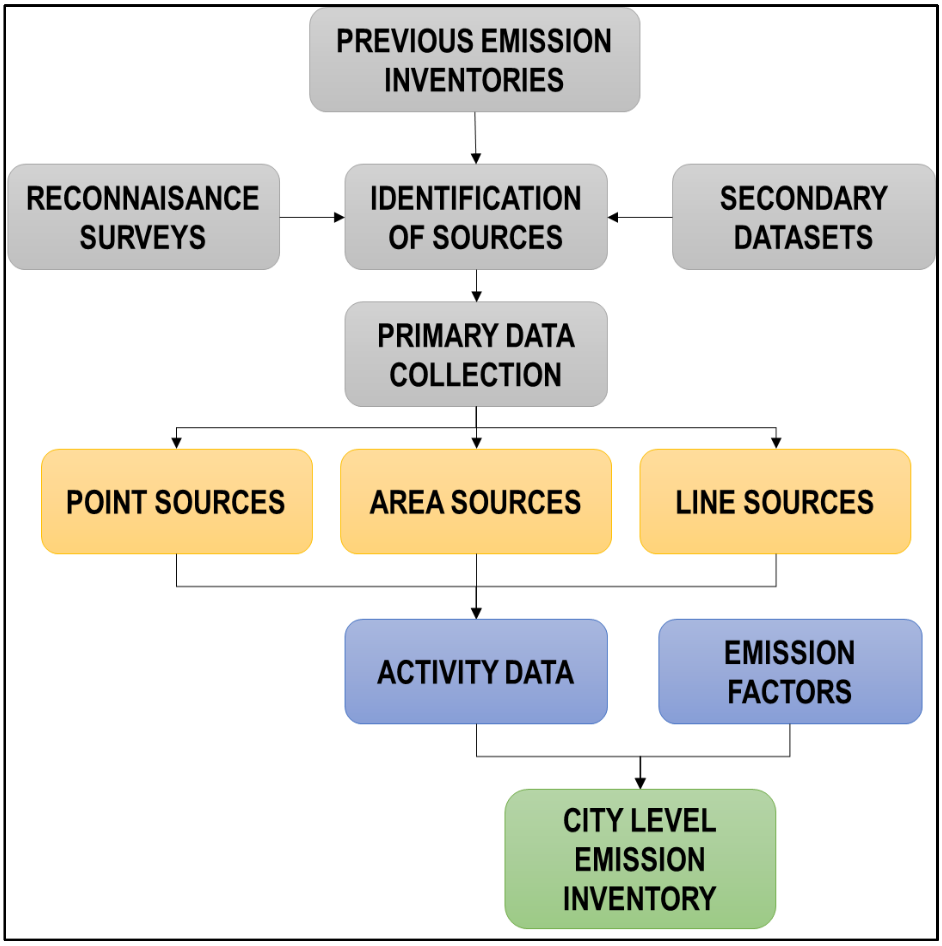

Figure 5: Methodology adopted for emission inventory development at district level

The study area is divided into high resolution grid cells at 2 X 2 km² over the entire study domain using GIS tools. Emission inventory has been prepared for the study area and thereafter allocated to high resolution grid cells. Figure 6 presents the gridded study domain (2 x 2 km²) with areas demarcated as Pune Municipal Corporation (PMC), Pimpri-Chinchwad Municipal Corporation (PCMC), Cantonment boards (CB), areas adjoining city limits (FRINGE), Municipal Councils (MCLA, MCLB and MCLC) and villages (RURAL). The methodologies followed and data collected for estimation of emissions from different sectors are described in subsequent sections.

Table 1: Different air pollution sources inventorised in this study for Pune district

Source Type	Sources included
Point Sources	• Industries • Brick Kilns • Crematoria
Area Sources	• Agriculture waste burning • Residential • Hotels, restaurants, bakeries and eateries • Construction • Diesel generators • Open waste burning • Aircraft
Line Sources	• Transport • Re-suspended road dust

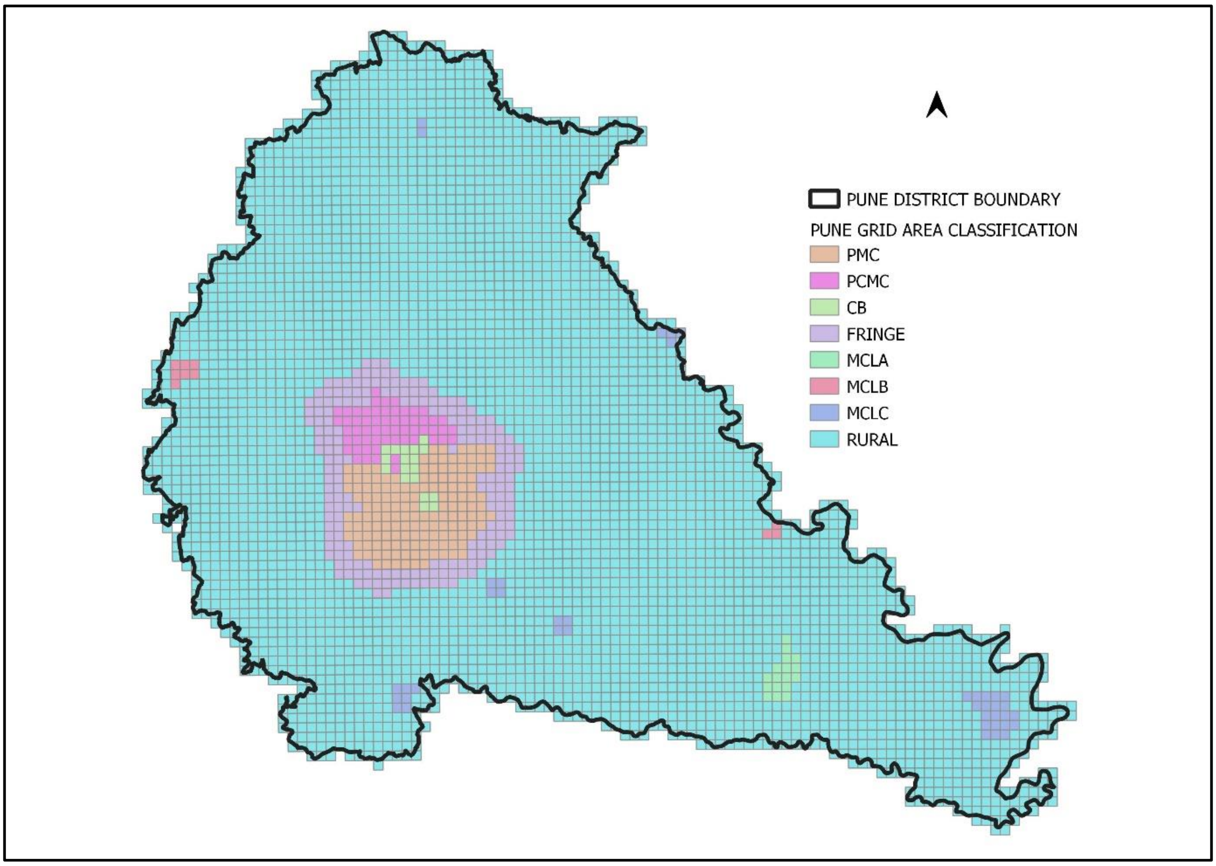

Figure 6: Map showing study area i.e. Pune district and its sub-areas overlaid with emission inventory grids with horizontal resolution of 2 x 2 km^2

2.1. Transport

The transport sector emissions are calculated using data generated from primary surveys for on-road vehicle counts, parking lot surveys, and data available in public domain from different government departments at state and local level. The vehicular exhaust emissions are calculated using equation (1):

$$\textbf{Trasnport Emissions} = \textbf{VKT x EF}_{EX} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, EF_{EX} is the emission factor (g/km) for a particular category of vehicle of particular vintage, fuel and engine technology and VKT is Vehicle Kilometers Travelled, by same category of vehicle, in a day. As illustrated in Eq. 1, the emission factor (EF) is an important input required for quantifying the vehicular emissions at district level. The vehicular emissions factors developed by Automotive Research Association of India (ARAI) for in-use Indian vehicles (ARAI, 2010; 2018) are used in this study.

2.1.1. Road network digitization

Road network in the study area was digitized using Google Earth application (Figure 7). Roads in Pune are classified into five categories viz. i) expressway, ii) highways, iii) major roads, iv) intermediate roads and v) minor roads and residential roads. After complete digitization, road lengths were calculated for each link in the network using GIS software. Category-wise gridded road lengths were also computed using GIS software.

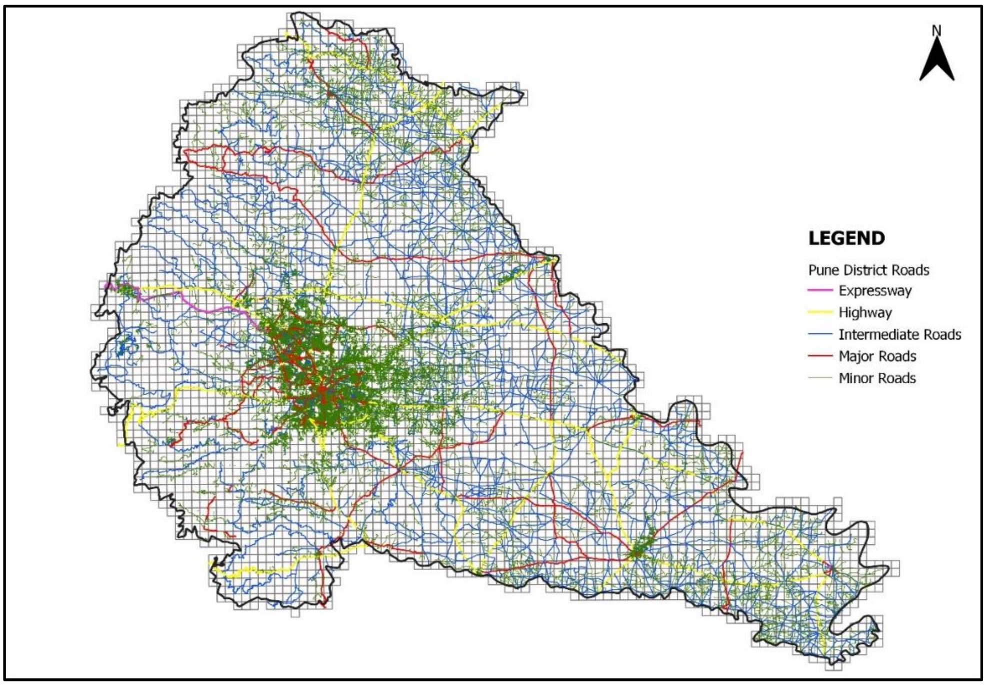

Figure 7: Map showing road network in Pune district digitized using OpenStreetMap and Google Earth Applications

2.1.2. Reconnaissance survey

A Reconnaissance survey was conducted in the Pune region to select the locations for traffic count and parking lot surveys. Reconnaissance surveys helped in understanding the traffic movement in the region, major traffic locations, type of vehicles, etc. Total 15 survey locations were identified in the PMC and PCMC regions to perform the vehicle count surveys and parking lot surveys. Whereas for the outer regions, the traffic movement data was obtained from various sources such as monthly toll collections statistics and previous studies in the region.

2.1.3. Traffic counts and vehicle fleet characteristics

Estimation of reasonably accurate vehicular emissions requires a good characterization of the in-service vehicle fleet. Important characteristics of vehicle fleet include information on vehicle type, size, fuel type, age and emission control technologies. The historic vehicle registration data provides preliminary information vehicle type, size and fuel-type. The vehicle fleet in Pune district was categorized into six categories: 2-wheelers (motorcycles, scooters and mopeds), autos, passenger cars both private and commercial, light commercial vehicles (LCV) such as delivery vans, heavy duty vehicles (HDV) such as trucks and lorries and buses and coaches. Figure 8 depicts the vehicle categories used in this study.

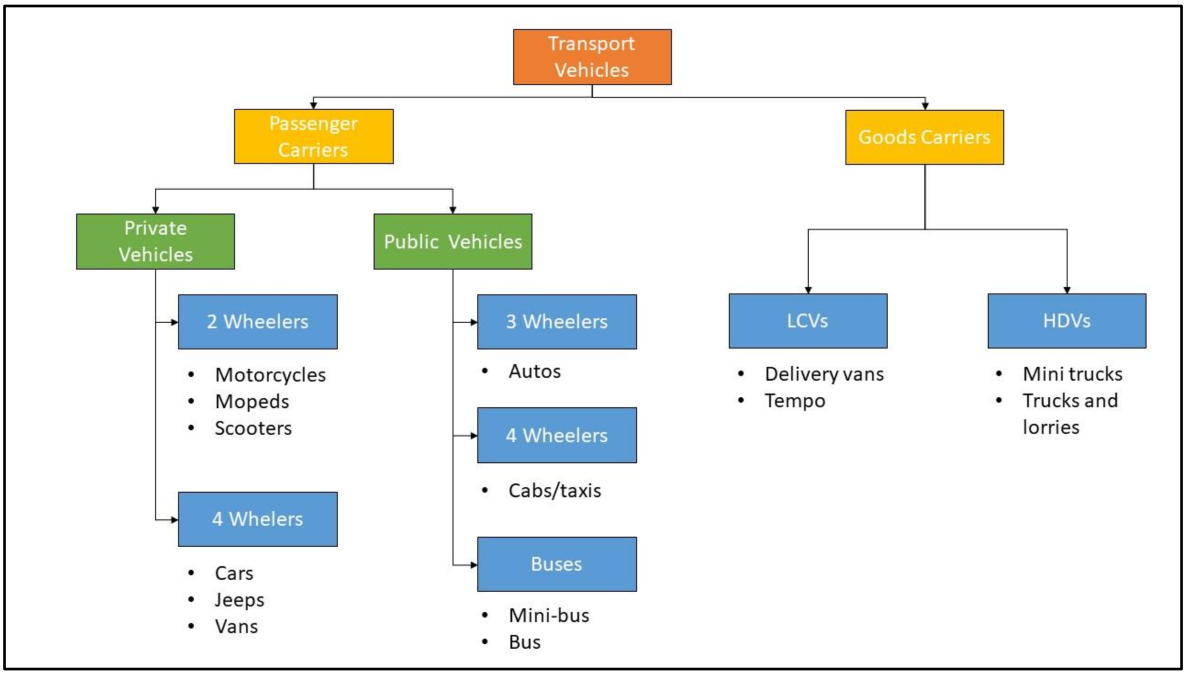

Figure 8: Vehicle categories used in this study

Traffic count surveys are carried out to obtain the information of on-road vehicles plying in the city, such as total number of vehicles, variation of vehicles on different road categories (major, minor and arterial), transit vehicles, temporal variations, etc. Traffic count surveys are conducted manually by teams of surveyors. At each of the selected location, category-wise traffic count data is collected in single direction. The vehicles are counted on 15 locations in PMC and PCMC regions, during 07:00 to 22:00 hours on selected weekdays and weekend during the month of February- March, 2021. Table 2 shows the details of locations of vehicle count surveys. As mentioned earlier, for outer regions, the traffic movement data was obtained from various sources such as monthly toll collection statistics and previous traffic studies in the region.

Parking lot surveys were also carried out to understand the distribution of existing vehicular fleet as per model, vintage, technology, fuel mix, average daily distance travelled, occupancy, and mileage. Parking lot surveys are carried out at 22 locations in PMC and PCMC regions during July-August, 2021. Table 3 shows the details of parking lot survey locations.

Each vehicle category is further differentiated in up to four fuel or engine types respectively: Gasoline, Diesel, Natural Gas, and battery-operated or electric vehicles. In addition, vehicular emission calculations require the vehicle fleet by age, as mass emission factors are significantly different for each vehicle type and control technology. Based on approach adopted by Baidya and Borken-Kleefeld (2009), the in-service vehicles were calculated using Survival function which models the vehicle's finite service life. The survival rate, which is a fraction of vehicles survived in the fleet after a certain age, was calculated for each vehicle category considered in Pune.

Table 2: Locations of vehicle count surveys in PMC and PCMC regions

Station No.	Road Name	Counting Location	Longitude	Latitude
S1	Senapati Bapat Road	Sheti Mahamandal, Laxmi Society, Chattushringi, Gokhalenagar, Pune.	73.830120	18.532753
S2	Prabhat Road	82, Swojas House, Prabhat Road, Deccan Gymkhana, Pune	73.83202	18.51469
S3	Pune-Satara Road	Near Ranka Jwellers, Pune - Bengaluru Hwy, Padmadarshan Society, Sant Nagar, Bibwewadi, Pune	73.85699	18.47794
S4	Karve Road	Warje Malwadi Rd, near ICICI Bank, Karve Nagar, Pune	73.81363	18.49383
S5	Shiv Darshan Road	RG academy of E-learning school & Jr. College, Anurag Society, Parvati Paytha, Pune	73.85410	18.49236
S6	Swami Vivekanand Marg	Jay Vardhaman Society, Vasant Baug Society, Maharshi Nagar, Pune	73.86065	18.48200

S7	Pune-Solapur Road	NH65, Shankar Math, Hadapsar, Pune	73.92498	18.50291
S8	Bhagwan Tatyasaheb Kawade Road	Nigade Nagar, Ghorpadi, Pune	73.90654	18.52135
S9	Hadapsar Industrial Road	St. Patrick's Town, Swami Vivekanand Nagar, Lakshmi Nagar, Wanowrie, Pune	73.909084	18.50707
S10	Aundh - Ravet BRTS Road	Before Rakshak Chowk, Bharat Electronics Colony, Pimple Gurav, Pimpri-Chinchwad, Maharashtra 411027	73.80375	18.57601
S11	New DP Road	Nandanwan Society, Ingawale Nagar, Pimple Nilakh, Pimpri-Chinchwad, Maharashtra 411027	73.78440	18.58119
S12	Roseland Residency Road	Kunal Icon Rd, Pimple Saudagar, Pune, Maharashtra 411027	73.79485	18.59361
S13	Kalewadi Main Road	Kalewadi opp, Dhangar baba mandir, Pune, Maharashtra 411027	73.78248	18.60978
S14	Pimpri-Chinchwad Link Road	Near Elpro City Square, Chinchwad Gaon, Chinchwad, Pimpri-Chinchwad, Maharashtra 411033	73.78494	18.62856
S15	Jawaharlal Nehru Road	370-364, Near Gurudwara Pimpri Shastri Nagar, Pimpri Colony, Pimpri-Chinchwad, Maharashtra 411017	73.80332	18.61860

Table 3: Locations of Parking Lot Surveys in PMC and PCMC Regions

Location No.	Area Name	Location No.	Area Name	Location No.	Area Name
S1	Appa Balwant Chowk	S9	Vadgao	S17	Tata Motors
S2	Dandekar Pool	S10	Aundh	S18	Wagholi
S3	Hingane khurd	S11	Baner Road	S19	Baramati
S4	Katraj	S12	Chinchwad	S20	Sangavi
S5	Laxmi Road	S13	Nigadi	S21	Junnar
S6	Market Yard	S14	Pimple Saudagar	S22	Barav
S7	Savitribai Phule	S15	PMPML Bus Depot	--	--
S8	Swargate	S16	Spine Roads	--	--

The data generated through road network mapping, vehicle count surveys, parking lot surveys, and vehicle registration analysis was used to calculate the vehicle kilometers travelled by different vehicle types on each road type.

Emission factors (EF) are essential input required to calculate the emissions originating from transport sector. Emissions measured on vehicle using chassis dynamometers are expressed in grams of pollutant per unit of distance travelled (g/km). Vehicular emissions are dependent on the large range of variables such as vehicle technology, age, condition, road profiles, driving habits, emission control regulatory levels, fuel and payload (Bawase et al., 2021). For this study, EFs developed by ARAI during 2010 and 2018 are used to calculate the total on-road vehicular emissions. It is important to note that, as BS-VI vehicles were recently introduced in i.e. year 2020, the mass emission factors for in-service vehicles in India are not available. Hence, the emission factors for such vehicles were derived using BS-VI emission limits.

2.2. Road Dust

Emissions from road dust re-suspension due to movement of vehicles were calculated using US EPA (AP-42) method. These dust emissions due to movement of vehicles varies with the silt loading on the road surface and also the average weight of the vehicles plying on the road. The term silt loading (sL) refers to the mass of the silt-size material (equal to or less than 75 μm in physical diameter) per unit area of the travel surface. Silt loading values from a recent TERI study are used here to calculate emissions originating from road dust resuspension in Pune.

Particulate matter emissions from re-suspension of road dust due to movement of vehicles on roads were calculated using Eq. 2:

$$\textbf{Emissions load} = \textbf{VKT x EF}_{RD} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

where, VKT is Vehicle Kilometer Travelled (km/day) and EF_{RD} is paved road dust emission factor and calculated using Eq. 3:

$$\textbf{EF}_{RD} = \textbf{k x w}^{1.02} \textbf{ x (sL)}^{0.91}\textbf{x} \left(1 - \frac{P}{4N}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

Where, EF_{RD} = particulate emission factor (having units matching the units of k)

k = constant (function of particle size) in g/VKT, value of k for PM_{10} and $PM_{2.5}$ is 0.62 and 0.15, respectively.

sL = road surface silt loading in g/m^2

w = average weight of the vehicles (in tons) travelling on the road

P = number of "wet" days with at least 0.254 mm (0.01 in) of precipitation during the averaging period,

N = number of days in the averaging period (e.g., 365 for annual).

As discussed earlier, the silt loading for Pune are adopted from recent TERI study. The gross vehicle weights for different classes are obtained from vehicle specifications sheets through online surveys. Number of rainy days in a year were obtained from climatology data for 1991-2012 (IMD, 2015). The paved road emission factors for $PM_{2.5}$ and PM_{10} are listed in Table 4. These emission factors are then multiplied by gridded VKT values obtained earlier for calculation of vehicular emissions to obtain total road dust emissions.

Table 4: Road dust resuspension emission factors (in g/km) used in this study

FRACTION	AREA TYPE	E-WAY	HIGHWAY	MAJOR	INTERMEDIATE	MINOR	RESIDENTIAL
$PM_{2.5}$	PMC	0.25	0.04	0.04	0.03	0.06	0.04
$PM_{2.5}$	PCMC	0.25	0.04	0.04	0.03	0.06	0.04
$PM_{2.5}$	CB	0.25	0.04	0.04	0.03	0.06	0.04
$PM_{2.5}$	FRINGE	0.25	0.25	0.05	0.03	0.10	0.05
$PM_{2.5}$	MCL	0.25	0.25	0.05	0.03	0.10	0.05
$PM_{2.5}$	RURAL	0.25	0.25	0.07	0.04	0.10	0.05
PM_{10}	PMC	1.02	0.18	0.18	0.11	0.26	0.15
PM_{10}	PCMC	1.02	0.18	0.18	0.11	0.26	0.15
PM_{10}	CB	1.02	0.18	0.18	0.11	0.26	0.15
PM_{10}	FRINGE	1.02	1.02	0.23	0.14	0.39	0.22
PM_{10}	MCL	1.02	1.02	0.23	0.14	0.39	0.22
PM_{10}	RURAL	1.02	1.02	0.27	0.16	0.39	0.22

2.3. Open Waste Burning

The basic equation followed to estimate the emissions of different pollutants from the open burning of solid waste is:

$$\mathbf{E_p = W_b \text{ x } EF_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)}$$

Where, E_p the emission of a particular pollutant from the burning of the refuse material, W_b is the quantity of waste materials burnt in an area, and EF_p is the emission factor of the particular pollutant (p) from the burning of the waste material.

In this study, the MSW burnt for the sake of disposal at the household level or on the street (W_b) is quantified using methodology adopted by Sharma et al. (2019). MSW burnt refers to the non-inert fraction of the uncollected MSW left behind after collection (MSW_C), recycling (MSW_R), and secondary use as fodder, fertilizer, and fuel (MSW_F). f_i in Eq. 5 stands for the inert fraction of the waste (ash and dust), which is estimated to be about 15% for Pune city (PMC, 2021). Additionally, it is assumed that out of the uncollected waste 60% of the total waste available to be burned that is actually burned (IPCC, 2006; Wiedinmyer, 2014).

$$\mathbf{W_b = (MSW_P - MSW_C - MSW_R - MSW_F) \times (1 - f_i) \times 0.6} \dots\dots\dots\dots\dots\dots\dots (5)$$

The waste burnt daily in each administrative area is dependent upon the population, per capita waste generation, waste collection efficiency in the ward and fraction of uncollected waste burnt. The details on waste generation and waste collection are obtained from different solid waste management reports of PMC, PCMC, and MPCB. The emission factors of various pollutants considered in present study are illustrated in Table 5.

Table 5: Emission factors (g/kg) for open waste burning

Pollutants	EF (g/kg)	References
PM_{10}	14	Sharma et al., 2019
$PM_{2.5}$	13	
SO_2	0.892	
NO_x	2	
CO	67	
NMVOC	14.5	TERI, 2016

2.4. Residential

The basic equation employed for emission estimation from the residential sector is:

$$\mathbf{E_p = \sum_{f=1}^{6} Pop_f \times C_f \times EF_{f,p}} \dots\dots\dots\dots\dots\dots\dots (6)$$

where, E_p is the emissions of a particular pollutant (p) from the residential sector, Pop_f is the population of the study region using a particular fuel (f), C_f is the per capita consumption of a particular fuel (f), and $EF_{f,p}$ is the Emission factor in (g/kg) of the particular pollutant (p) of the particular fuel type (f). Six major fuels are used in the residential households for cooking and lighting purposes– a) Fuel wood, b) dung cake, c) crop residue, d) coal, e) kerosene and f) LPG and were included in the estimation of emissions.

The latest census data for Pune is available for year 2011 but Pune has undergone huge transformation in the last decade and old data cannot be used. Hence, the population for baseline year (2021) is projected considering the growth factors in demarcated areas.

Population residing in slum areas cities is an important input required for calculation of residential sector emissions. Spatial slum information dataset for Pune and Pimri-Chinchwad areas, created by Shelter Associates is re-created using google earth imagery and used for estimating the slum population for year 2021. The percentage of population using different fuels and daily average fuel consumption is obtained from the primary surveys in PMC, PCMC, MCL and rural areas. Additionally, the secondary data from NSSO (2014), Census of India (2011), Paryas (2020) and SAFAR (2021) are also merged to estimate the area-wise fuel consumption in residential sector. The emission factors for residential sector used in this study are summarized in Table 6.

Table 6: Emission factors (g/kg) of different pollutants from different fuel types used in the residential sector

Fuel type	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	NMVOC
Fuel wood	6.8	4.6	0.8	1.7	66.5	15.9
Coal	8.3	4	15.3	2.16	59.5	10.5
Kerosene	3.6	3.0	0.4	1.3	43.0	17.0
LPG	0.4	0.4	0.4	2.9	2.0	19.0

2.5. Industries

Pune district mainly hosts industries such as heavy engineering, automobile manufacturing, sugar, distilleries, pharmaceutical, engineering, electrical and electronics, information and technology, and food processing industries. Beside the manufacturing processes, an important source or activity which contributes to industrial emissions is usage of diesel-based generator sets, which are mainly used in the event of power failure.

The latest industrial data such as type of industry, production capacity, fuel consumption, air polluting processes, control equipment and stack details were obtained from the Pune regional office of Maharashtra Pollution Control Board (MPCB). A fuel consumption-based approach is used in this study to estimate the industrial emissions. Table 7 lists the emission factors for different fuels used in industrial processes.

Table 7: Emission factors for the industrial sector

Fuel Type	EF Unit	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	NMVOC
Wood	kg/tonnes	1.73E+01	1.57E+01	2.00E-01	1.30E+00	1.26E+02	--
Diesel	kg/KL	2.40E-01	2.16E-01	1.73E-01	1.20E+00	6.00E-01	--
FO	kg/KL	2.59E+00	1.74E+00	3.77E+01	6.60E+00	6.00E-01	9.10E-02
Natural Gas	kg/m3	1.22E-04	1.22E-04	9.60E-06	1.60E-03	1.34E-03	5.36E-04
LPG	kg/tonnes	1.17E-03	1.17E-03	2.22E-04	1.00E-03	1.40E-04	4.89E-02
Bagasse	kg/tonnes	7.80E+00	5.07E+00	1.80E-01	6.00E-01	1.24E+01	--
Coal	kg/tonnes	3.75E+01	1.31E+01	9.75E-01	4.50E+00	3.00E-01	--
Lignite	kg/tonnes	1.88E+02	6.57E+01	9.75E+00	4.50E+00	3.00E-01	--
LDO	kg/KL	2.40E-01	2.16E-01	3.39E-01	1.20E+00	6.00E-01	--
Rice Husk	kg/tonnes	5.30E+00	4.82E+00	1.10E-01	1.90E-01	1.41E+01	--
Briquettes	kg/tonnes	7.70E+00	3.30E+00	1.20E-01	4.90E-01	5.80E+01	--

(Source: CPCB, 2011)

2.6. Non-industrial diesel generators

For urban areas, due to the lack of primary data on installation of DG sets, the emissions are derived based on previous work by Urban Emissions Info (2021). The emissions from diesel generators are allocated based on the installed capacity of DG sets, location of commercial establishments such as theatres, shopping malls, restaurants, banks and offices, etc., and residential localities using DG sets for power backup.

In rural areas, residential and commercial usage of diesel is very limited but diesel engines are used for irrigation of agricultural land. The recent diesel engines statistics available from agriculture department reports is used to estimate the emissions originating from DG sets.

2.7. Hotels, Restaurants and Bakeries

Emissions from this sector are generated due to coal and wood use in tandoors/barbeques. The common fuels used by restaurants/hotels in Pune district are and LPG, coal and wood. The formula used for calculating emissions by this sector includes:

$$\mathbf{E_p = C_f \ x \ EF_{f,p}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\mathbf{7})$$

Where, E_p is the emission of a particular pollutant (p), C_f is the Fuel consumption by the hotel/ restaurant and E_f is Emission factor for the pollutant (p) generated by the use of fuel (f).

Primary surveys are conducted in different localities of PMC, PCMC, municipal councils, and rural areas of Pune to understand the fuel usage pattern in hotels, restaurants, bakeries and open eateries. The data on hotels, restaurants, bakeries are obtained from various online sources including online food delivery portals. The data collected fuel consumption in restaurants and open eateries is used to quantify the emissions for year 2021. The emissions factors are used from the CPCB (2011, refer Table 8). It is also assumed that no control devices are installed in the restaurants to control the emissions.

Table 8: Emission factors (g/kg) for the Hotels/Restaurants

Fuel	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	NMVOCs
Coal	14	8.4	13.3	3.99	24.92	9
LPG	2.1	2.1	0.4	1.8	0.252	10.5
Wood	17.3	12.1	0.2	1.3	126.3	0.01

(Source: CPCB, 2011)

2.8. Crematoria

Cremating the bodies of dead people is an ancient ritual and practice in India. The total emissions from cremation calculated using Eq. 8:

$$\mathbf{E_p = F_{\mathit{b}}\ x\ EF_{f,p}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\mathbf{8})$$

Where, E_p is the emission of a particular pollutant p, F_b is the amount of fuel used per body in the crematoria, $EF_{f,p}$ is Emission factor for pollutant p.

The data on crematoria and average number of dead bodies cremated each month is obtained from Electrical Department of PMC. In addition to number of dead bodies cremated, the data also include type of fuel used viz. wood, electricity, gas, and cow dung cakes. Earlier i.e. before expansion of city limits, there were 24 crematoria in Pune city (PMC, 2020) and with recent inclusion of new villages this number has increased to 45.

For other areas of Pune district, the number of deaths are calculated based urban and rural crude death rates for Maharashtra. The fraction of population of Hindus, Sikhs and Jain communities, which use wood for cremating the dead body are used to calculate wood burnt. According to a study by NEERI (2010), on an average 350 kg of wood is burnt in each cremation. The estimate for total amount of wood burnt for cremation at district level is calculated from the Eq. 9:

$$\mathbf{TW\ (kg) = P\ x\ F\ x\ CDR\ x\ 350} \ldots\ldots\ldots\ldots\ldots..(\mathbf{9})$$

Where TW is Total amount of wood burned in kg, P – Total population, F – Religious Fraction or Fraction of Hindus, Jains and Sikhs in the total population and CDR – Crude Death rate. The emission factors for wood burning at crematoria are taken from Akagi et al. (2011) and Sharma et al. (2016). The emission factors for different types of fuels used for cremation are listed below in Table 9. The emissions are quantified using equation 9.

Table 9: Emission Factors (g/kg) for different types of fuels used in crematoria

Fuel	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	NMVOCs
Wood	18.50	9.10	0.40	2.50	93.00	51.90
Dung cake	10.50	4.40	0.60	1.00	78.60	24.10
Gas	0.40	0.25	0.40	2.90	2.00	19.00
Electricity	3.60	2.25	3.60	26.10	18.00	171.00

2.9. Brick Kilns

Pune district hosts more than 600 clamp type brick kilns spread across different clusters. The locations of brick kilns are mapped using latest available satellite imagery in GIS software. In addition, a survey was carried out in different brick kiln clusters to understand their production capacity, fuel usage and operation pattern. Based on previous literature and findings of primary surveys, annual brick production is estimated for brick kilns in Pune district.

The production-based approach is used to estimate the brick kilns emissions. In this method, emissions are estimated based on tonnes of bricks produced annually. Weight of one brick is assumed as 3 kilograms which helps in the estimation of total weight of produced bricks from all the kilns. Total number of produced bricks multiplied with the weight of a brick (3 kg) to get activity data i.e. total production in kilograms. This weight is taken as activity data (technology wise percentage distribution) which is further multiplied with the emission factor for specific pollutant's emission calculation. The emission factors are provided in Table 10.

$$\mathbf{E_p = W_b \times EF_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)}$$

Where, E_p Stands for emissions of particular pollutant, W_b is weight of annual production of bricks and EF_p is the emission factor for a particular pollutant.

Table 10: Emission Factors (g/kg) for different technology brick kilns

Technology	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	NMVOC
Clamp	1.3	1	0.3	0.00015	10	0.15

2.10. Agricultural residue burning

Emission inventory of different pollutants from the burning of different crop residues in the agriculture fields has been developed by following the IPCC (2006) inventory preparation guidelines. The primary crops that will be considered for inventory preparation will be based on the primary survey of the district as well as literature survey of the studies conducted in the study area. Emission from the in-situ burning of crop residue will be calculated using the equation below:

$$E_p = \sum_{a=1}^{x} P_a \; x \; R_a \; xfD_a \; x \; fB_a \; x \; Bf \; x \; EF_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(11)$$

Where, E_p = Emission of a particular pollutant (p) (g); P_a is the total production of a particular crop (a) in kilogram and (x) will be number of crops selected for estimation of emission; R_a is the fraction of residue generated for the production (P_a) of the particular crop (a); fD_a is the fraction of dry matter in the residue of the particular crop (a); fB_a is the combustion efficiency of crop residue that is burnt, Bf is the burning fraction of the crop estimated on the basis of MODIS FRP data (has been explained below) and EF_p is the emission factor of the particular pollutant (g/Kg).

The district's agricultural production data (P_a) of different crops is collected from reports of the Agriculture Department of State Government. In case data gaps the data is projected to baseline year with suitable assumptions. The residue to crop fractions (R_a) of different crops has been replicated as in Sharma and Kumar (2016). The dry matter fraction in different crop residues (fD_a) replicates as reported by Jain et al. (2014). The combustion efficiency (fB_a) of different crop residues was used as reported in Turn et al. (1997). Table 11 presents summary of coefficients used in the emission estimates.

Table 11: Co-efficients of different crop residues to estimate the emissions of different pollutants

Ratios	Cereals	Coarse Cereals	Oil Seeds	Cotton	Sugarcane
Residue to Crop ratio (R_a)	1.645	1.78	3	2.755	0.53
Dry fraction of residue (fD_a)	0.87	0.9	0.9	0.85	0.8
Combustion efficiency (fB_a)	0.875	0.92	0.91	0.905	0.68

The burning fraction (Bf) is calculated from the MODIS Fire Radiative Power (FRP) data. The FRP dataset of the NASA's MODIS (aqua and tera) satellites will also be used to identify the crop residue burning locations at 2 Km × 2 Km grid over the study region. This will be further employed to spatially allocate the emissions.

The FRP products retrieved from MODIS C6 datasets are plotted on GIS along with LULC (land use and land cover) for baseline year. The FRP's detected over agricultural land use area are extracted for further analysis, as it is assumed that rest of the FRP's being detected may represent some other form of biomass burning being detected. The emission factors (g/kg) are presented in Table 12.

Table 12: Emission Factor (g/kg) of different pollutants for different types of crop residues

Pollutant	Cereals	Coarse Cereals	Oil Seeds	Cotton	Sugarcane
PM_{10}	7.55	6.6	10	10	6.9
$PM_{2.5}$	5.425	6	5.5	5.5	5.4
BC	0.8	0.2	0.2	0.2	1
OC	1.4	0.3	0.3	0.3	2.7
CO	62.2	46.4	28.1	28.1	28.1
SO_x	1.925	1.8	0.5	0.5	0.5
NO_x	0.475	0.2	1.7	1.7	1.5
NMVOC	3.4	4.5	19.1	19.1	0.5

2.11. Aircraft

Emission from aircrafts have been estimated for the domestic and international flights movement at Pune International Airport located at Lohegaon. Emissions from aircrafts are calculated from the aircraft movements in an LTO cycle. 2 aircraft movements constitute 1 LTO cycle and emissions are calculated using equation 12.

$$\mathbf{E_p = N_{LTO} \times EF_p} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (\mathbf{12})$$

Where, E_p is the emission of a particular pollutant p, N_{LTO} is the average number of landing and take-off (LTO) cycles per day, and EF_p is Emission factor for pollutant p.

The data on monthly domestic and international flight movements at Pune International Airport in year 2021 was obtained from Airport Authority of India (https://www.aai.aero/en/business-opportunities/aai-traffic-news). This data was converted to number of LTO cycle per day and emission factors listed in Table 13 were used to calculate the aircraft emissions. The emissions from aircraft are allocated only to grids covering the airport area.

Table 13: Emission Factors based on LTO

	PM	SO_2	CO	NO_x	NMVOCs
Emission Factor (kg/LTO)	0.27	1.54	39.5	19.11	20.38

(Source: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories Aircraft Emissions)

2.12. Construction

The PM emissions from construction sector are estimated on the basis of total construction activities in the region. The data and statistics on construction activities in study area is compiled from databases available from PMC, PCMC building permissions department and Maharashtra Real Estate Regulatory Authority (MahaRERA). The emissions are obtained by using Equation 13.

$$\mathbf{E = A_s \ x \ EF \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. Eq. (13)}$$

Where, E is Total PM Emissions; A_s is total construction area and EF is Emission Factors (USEPA). The emissions from construction activities will be estimated using PM emission factor of 1.2 tons/acre/month of activity provided by EPA. Based on the area of construction and emission factors, the total emissions from the construction sector are estimated.

In addition to emissions from actual construction sites, emissions from allied activities such as ready-mix concrete plants (RMC), hot mix plants and stone crushers in Pune district are also calculated based on their production capacity as per US EPA Ap-42 methodology.

3. Sector-wise emission inventory of Pune district

3.1. Transport

3.1.1. Vehicle registrations and traffic counts

Figure 9 shows the yearly vehicle registration in regional transport offices of Pune i.e. Pune (MH-12), Pimpri-chinchwad (MH-14) and Baramati (MH-42) starting year 1998 till 2021. The yearly registration showed a sharp decline in vehicle numbers during year 2020 and 2021, mainly due to the COVID-19 pandemic. Figure 10 shows the vehicle counts observed at selected locations in Pune and PCMC areas.

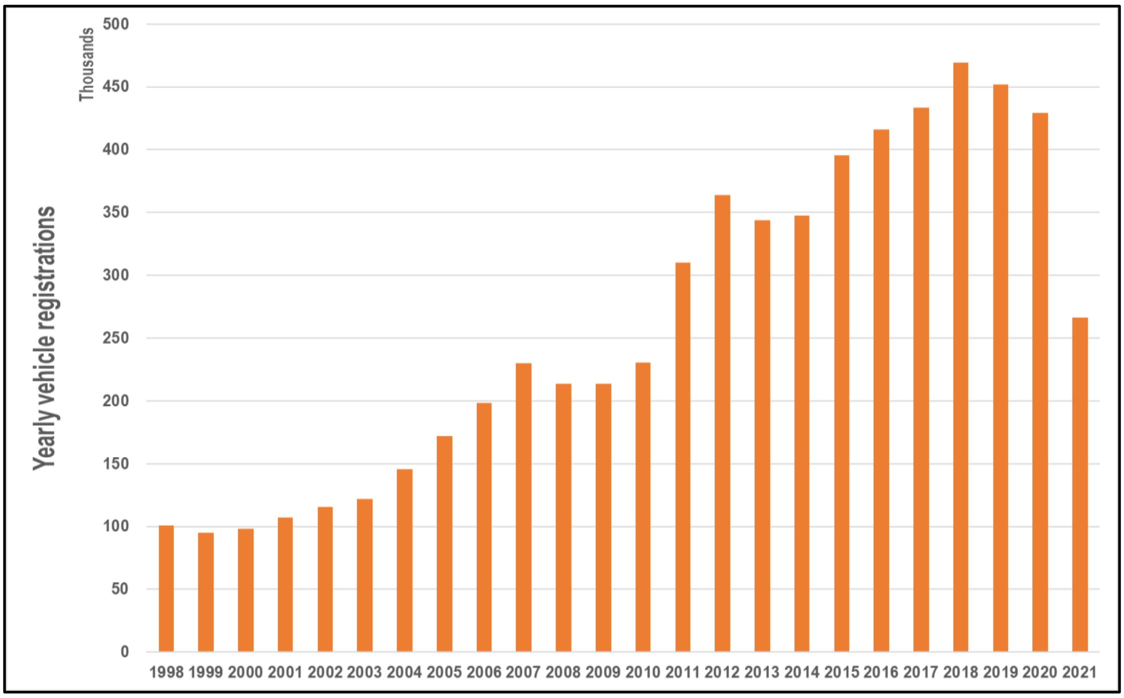

Figure 9: Yearly vehicle registrations in Pune district

(Source: Regional transport offices of Pune, Pimpri-chinchwad and Baramati)

Figure 11 shows the emissions of pollutants originating from transport sector in Pune district. Geographically, the twin cities of Pune and Pimpri-Chinchwad together contribute to more emissions than the remaining district. The city areas account for more emissions compared to rest of district, owing to dense road network, population and higher on-road vehicular activities. It can be seen that CO is the maximum contributing pollutant with emissions of 2,18,926 tonnes per year, followed by NMVOCs (1,11,892 tonnes per year), NO_x (1,04,689 tonnes per year). Transport sector contribution to district level PM_{10} and $PM_{2.5}$ was found to be 7,351 and 6,616 tonnes per year, respectively. It is important to note that, the vehicular exhaust PM emissions predominantly consist of fine particles i.e. particles having aerodynamic diameter less than or equal to 2.5 µm.

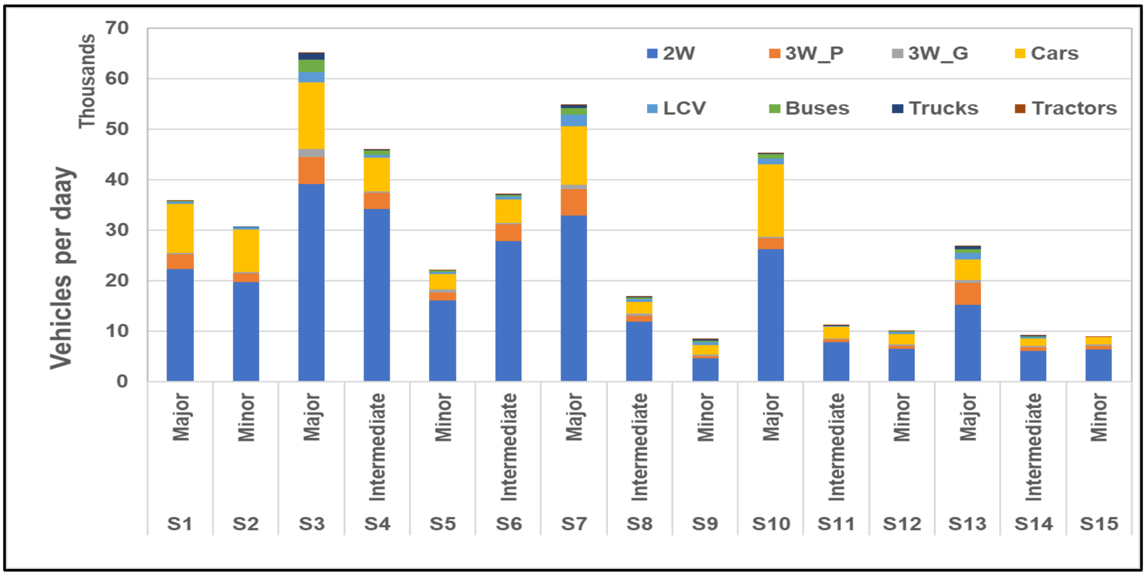

Figure 10: Vehicle counts at different locations in PMC and PCMC areas

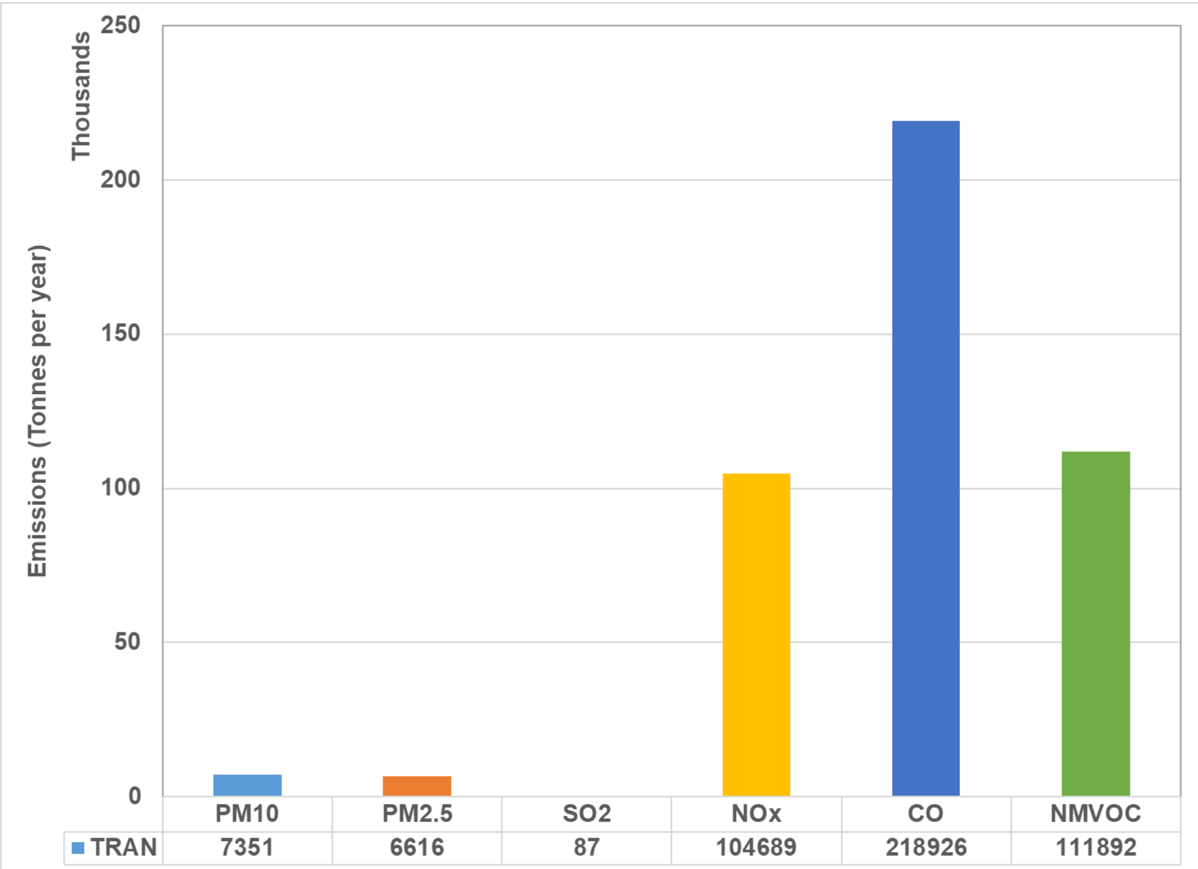

Figure 11: Emission loads (tonnes per year) of pollutants originating from the transport in Pune district

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3.2. Road dust re-suspension

The emissions generated due to road dust re-suspension in Pune district are depicted in Fig. 12. The road dust contributes only to particulate matter and not the gaseous pollutants. The road dust primarily contributes to the coarse fraction of PM i.e. PM_{10} and emissions are estimated to be 25275 tonnes per year in the district. Although, vehicular activity is lower in the rural parts of the district, the PM_{10} contributions are significantly higher. This can be mainly attributed, to the rough road conditions and higher silt loading on the roads. $PM_{2.5}$ emissions from road dust re-suspension are about four times lower than PM_{10} emissions i.e. 6115 tonnes per year in Pune district.

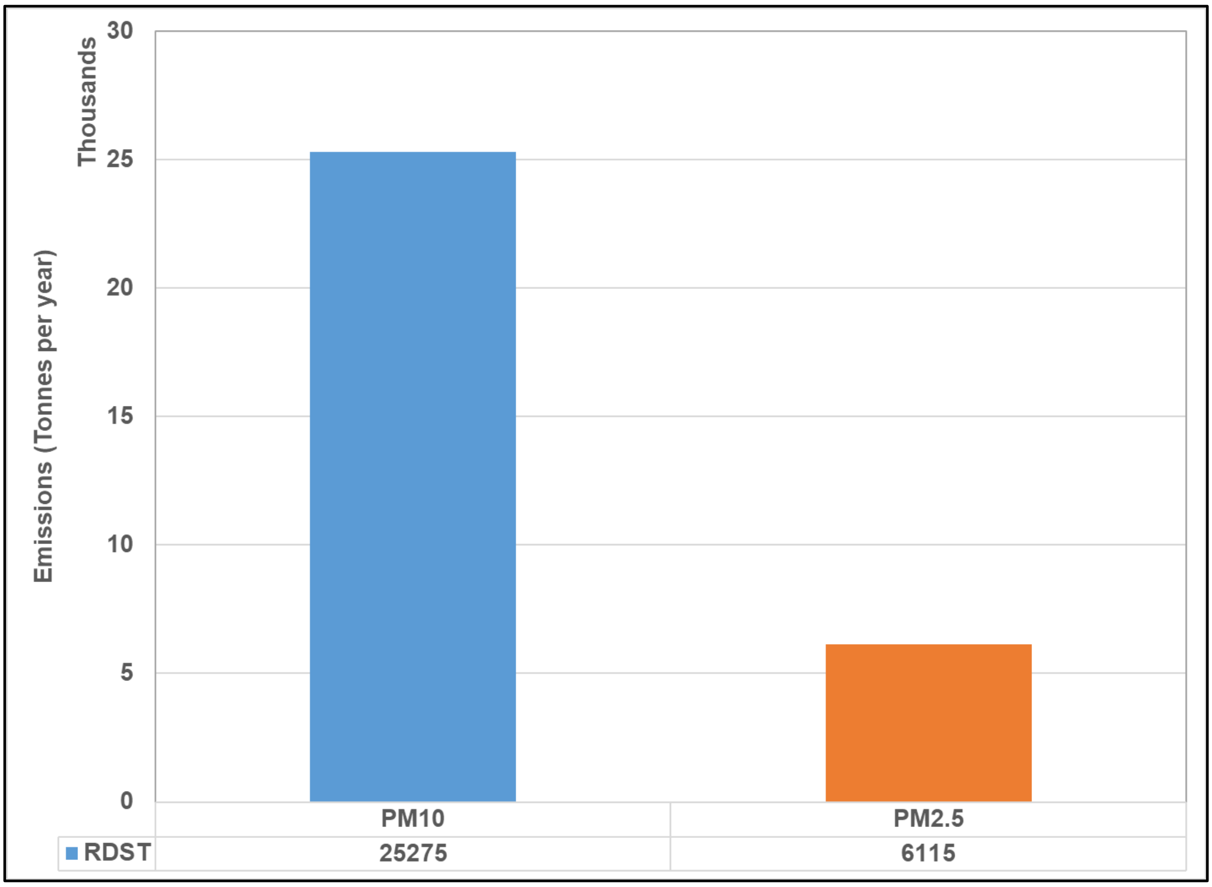


Figure 12: Emission loads (tonnes per year) of pollutants originating from the road dust in Pune district

3.3. Open waste burning

Figure 13 presents the emissions of air pollutants originating from open waste burning in Pune district. Geographically, rural parts are contributing more compared to PMC and PCMC together. This could be attributed to poor waste management and lower solid waste collection efficiencies in other parts compared to cities. It is observed that, due to incomplete combustion of the waste a large amount of CO would be introduced into the atmosphere (10756 tonnes per year) followed by NMVOCs (2328 tonnes per year), PM_{10} (2248 tonnes per year) and $PM_{2.5}$ (2087 tonnes per year).

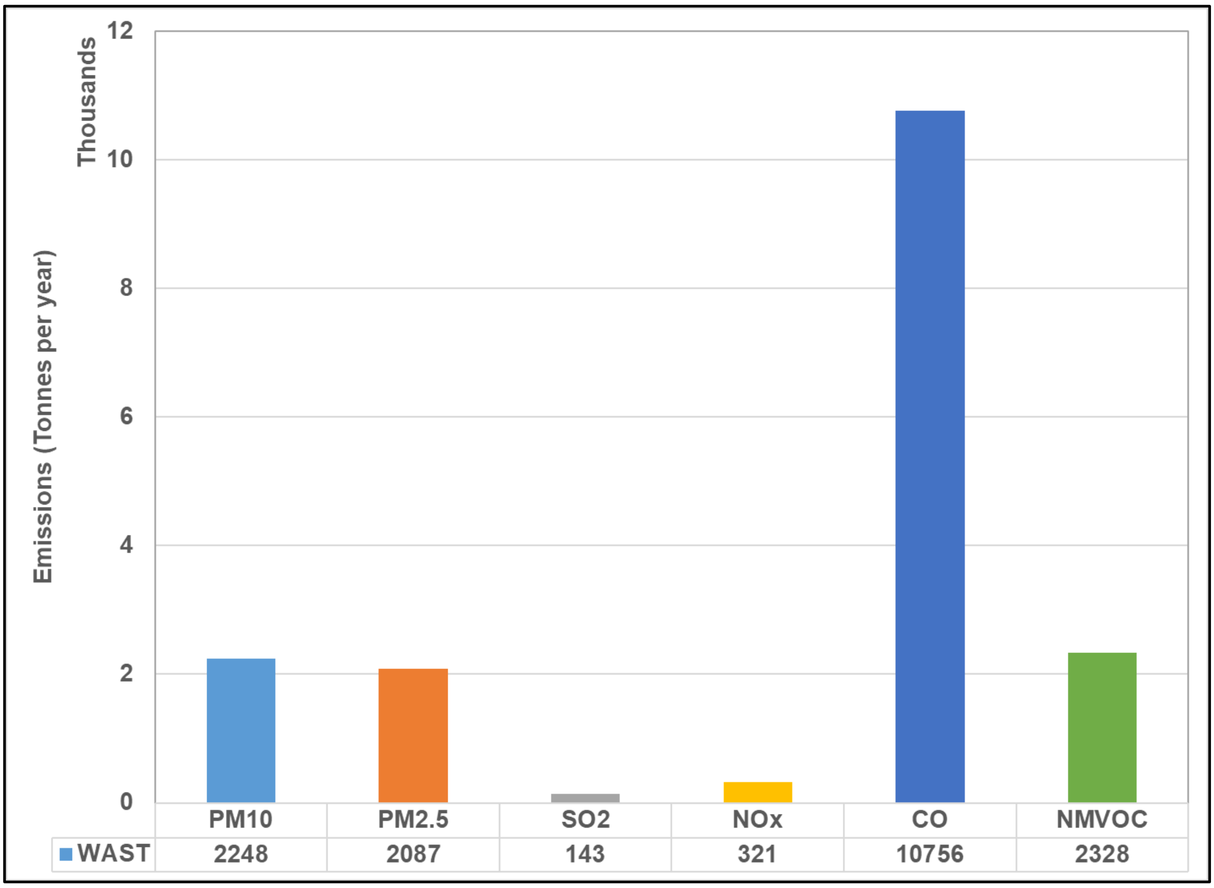


Figure 13: Emission loads (tonnes per year) of pollutants originating from the open waste burning in Pune district

3.4. Residential

Figure 14 depicts the emission loads originating from residential sector in Pune district. CO is found to be the major pollutant from residential sector with annual emissions of 27971 tonnes, followed by NMVOC (18147 tonnes per year) and NO_x (2482 tonnes per year). About 2997 and 2095 tonnes per year of PM_{10} and $PM_{2.5}$, respectively are estimated to be to be originating from residential sector in Pune district. It is important to note that, pollutant contribution from rural parts is high, mainly due to use of solid fuels such as firewood, coal, and dung cakes. The city households on the other hand, prefer LPG as fuel along with occasional use of coal and wood for cooking activity.

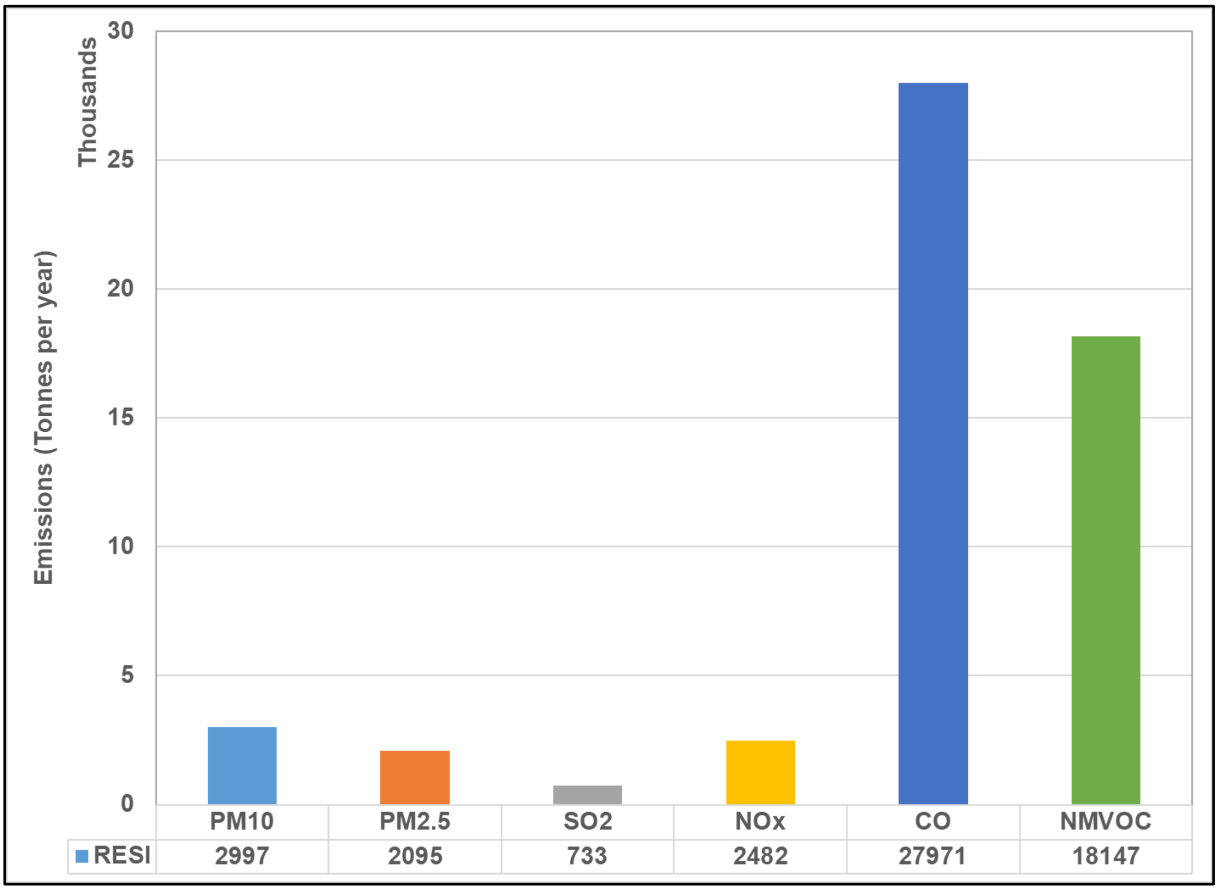


Figure 14: Emission loads (tonnes per year) of pollutants originating from the residential sector in Pune district

3.5. Industries

The emissions originating from industries are shown in Figure 15. CO (65,588 tonnes per year) and SO_2 (19,695) are the two dominant pollutants from industries in Pune district. High NO_x (16,601 tonnes per year) can be attributed to combustion processes and diesel generators. The industrial activities also contribute to significant amount of PM_{10} (10434 tonnes per year) and $PM_{2.5}$ (6124 tonnes per year).

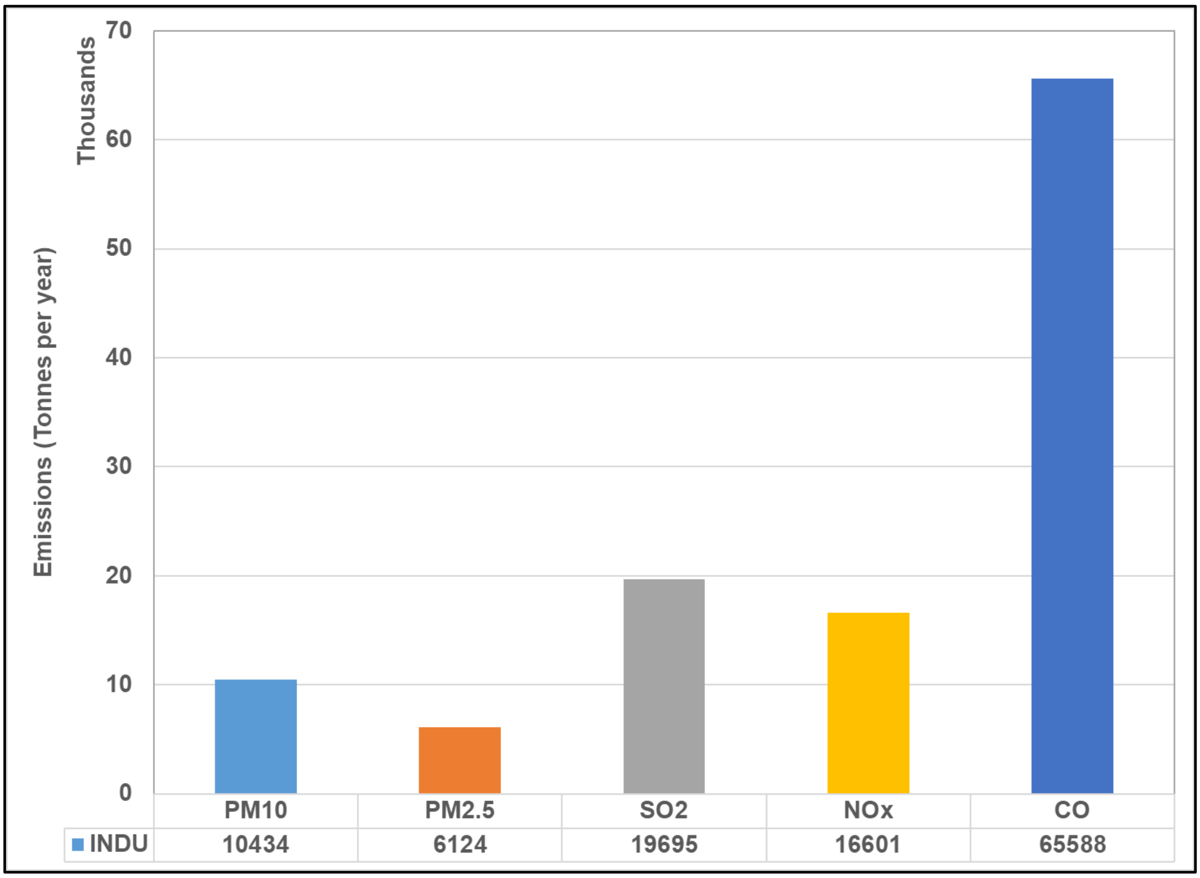


Figure 15: Emission loads (tonnes per year) of pollutants originating from the industrial sector in Pune district

3.6. Non-Industrial diesel generators

As discussed earlier, due to the lack of primary data on installation of DG sets, the emissions are derived based on previous work by Urban Emissions Info (2021) for city areas whereas diesel engine usage for irrigation and other activities is estimated based on latest available agricultural statistics. Figure 16 shows emissions of pollutants originating from diesel generators usage.

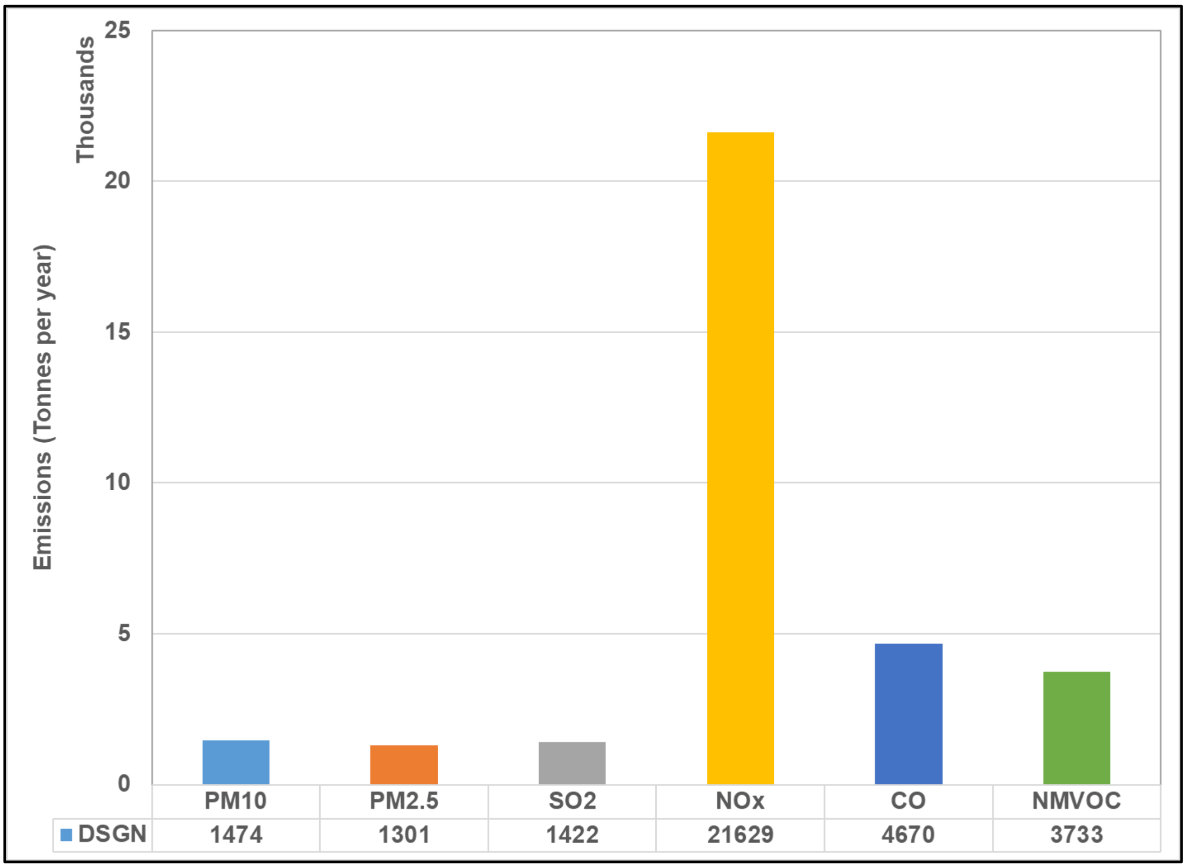


Figure 16: Emission loads (tonnes per year) of pollutants originating from the diesel generators in Pune district

3.7. Hotels, restaurants, bakeries and open eateries

Figure 17 presents the emissions load contributed by Hotels, Restaurants, Bakeries and open eateries in Pune district. CO has been found to be the major contributor with 3095 tonnes per year, followed by PM_{10} (747 tonnes per year), NMVOCs (691 tonnes per year), $PM_{2.5}$ (523 tonnes per year) and SO_2 (306 tonnes per year). NO_x was found to be the lowest contributing pollutant in this sector with emissions of 197 tonnes per year. This is primarily because of the type of fuel used in hotels and restaurants. Restaurants generally prefer use of LPG for general purposes and coal/wood for tandoor like applications, which in turn leads to lower NO_x but higher CO emissions. In addition, restaurants and open eateries located outside city limits, still prefer use of wood and coal over LPG due to abundance and lower fuel prices.

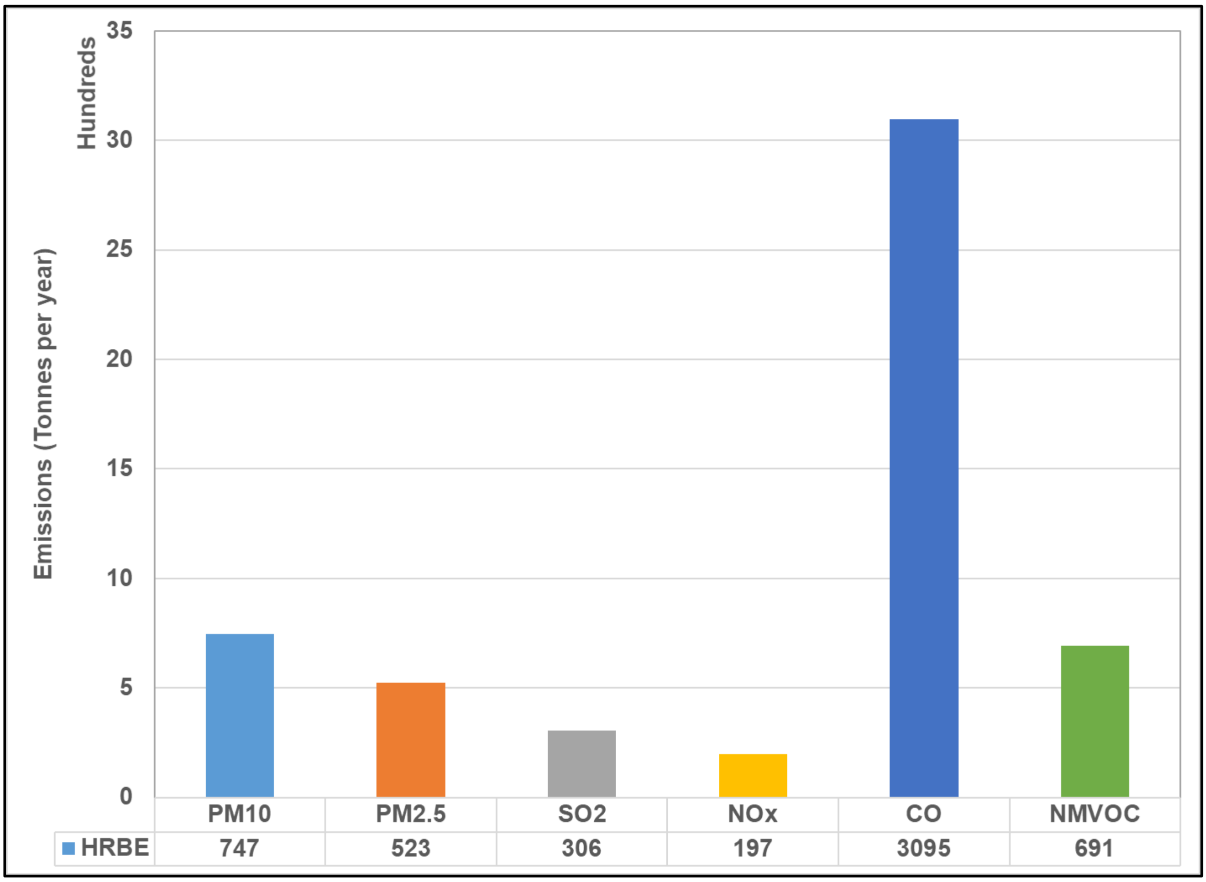


Figure 17: Emission loads (tonnes per year) of pollutants originating from the hotels, restaurants, bakeries and open eateries in Pune district

3.8. Crematoria

Figure 18 shows the emissions of pollutants originating from crematoria in Pune district. CO is the maximum contributor with emissions of 1282 tonnes per year followed by NMVOCs (716 tonnes per year), PM_{10} (254 tonnes per year) and $PM_{2.5}$ (125 tonnes per year). NO_x was found to contribute 35 tonnes per year of emissions while SO_2 was found to be the lowest among the pollutants with 6 tonnes per year of emissions. As many crematoria in the cities are equipped with electrical cremation facilities, the emissions are lower compared to wood-based crematoria in other parts of the district.

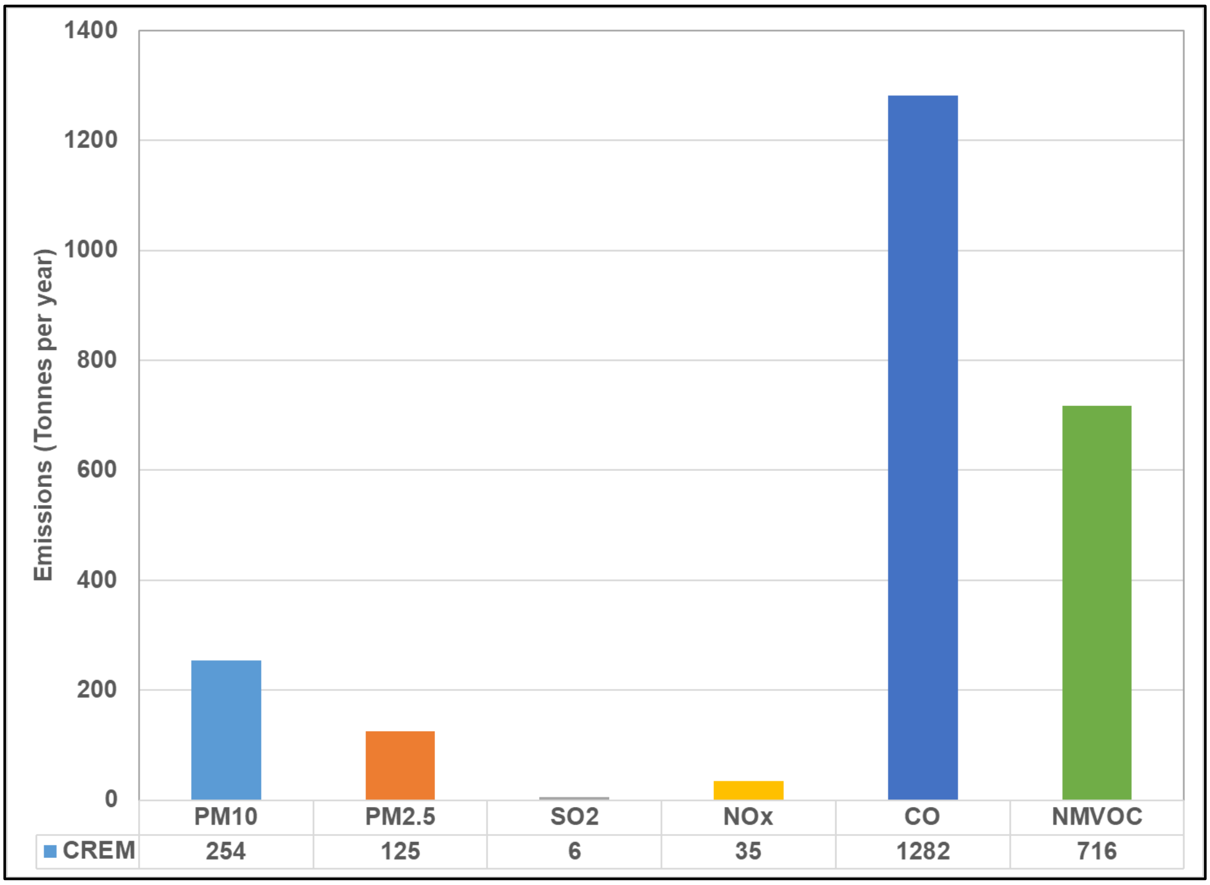
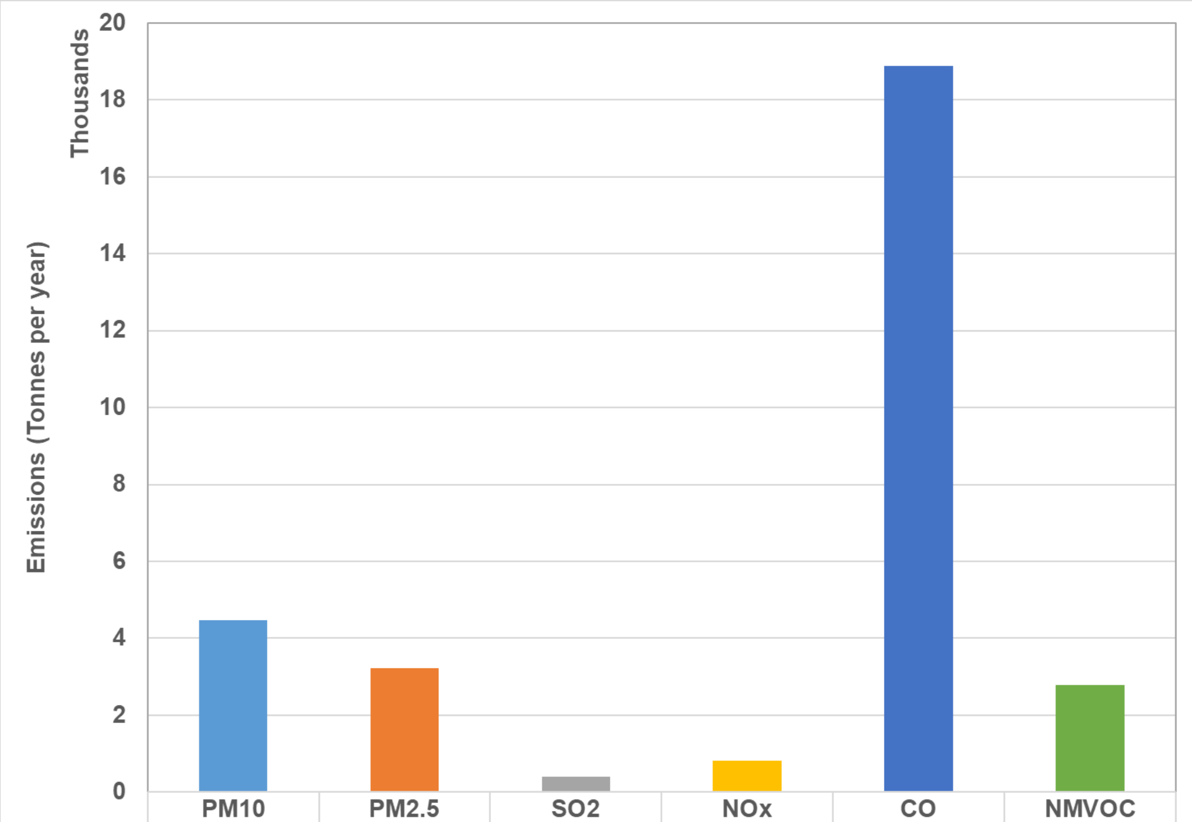


Figure 18: Emission loads (tonnes per year) of pollutants originating from the crematoria in Pune district

3.9. Agricultural residue burning

Figure 19 shows the emissions of pollutants originating from open agricultural residue burning. CO is the maximum contributor with emissions of 18,883 tonnes per year followed by PM_{10} (4,478 tonnes per year), $PM_{2.5}$ (3,218 tonnes per year), NMVOCs (2,794 tonnes per year), NO_x (823 tonnes per year). SO_2 was found to be the lowest among the pollutants with 404 tonnes per year of emissions.



	PM10	PM2.5	SO2	NOx	CO	NMVOC
AGRI	4478	3218	404	823	18883	2794

Figure 19: Emission loads (tonnes per year) of pollutants originating from the agricultural residue burning in Pune district

3.10. Brick Kilns

Pune district houses more than 600 brick kilns spread across different clusters and all of them are clamp type. Figure 20 shows the emissions of pollutants originating from brick kilns in Pune district. CO is the maximum contributor with emissions of 7404 tonnes per year due to inefficient combustion in clamp type kilns. The other pollutants follow the order, PM_{10} (963 tonnes per year), $PM_{2.5}$ (740 tonnes per year), SO_2 (222 tonnes per year) and NMVOCs (111 tonnes per year). NO_x was found to be the lowest among the pollutants with 0.1 tonnes per year of emissions.

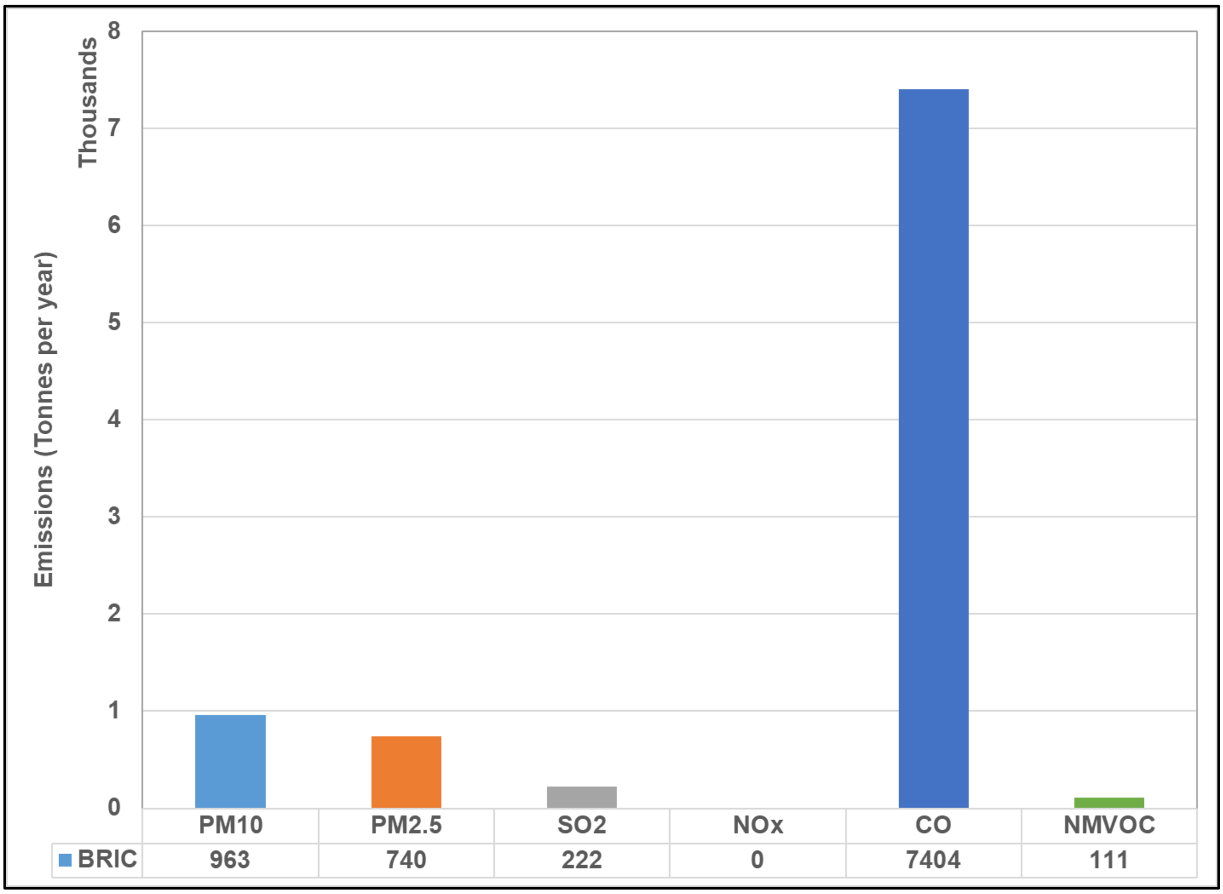


Figure 20: Emission loads (tonnes per year) of pollutants originating from the brick kilns in Pune district

3.11. Aircraft

Figure 21 shows the emissions load originating from aircraft due to flight operations at Pune International Airport. CO was estimated to be the highest contributor with 0.557 tonnes per followed by NMVOC (0.287 tonnes per year), and NO_x (0.269 tonnes per year).

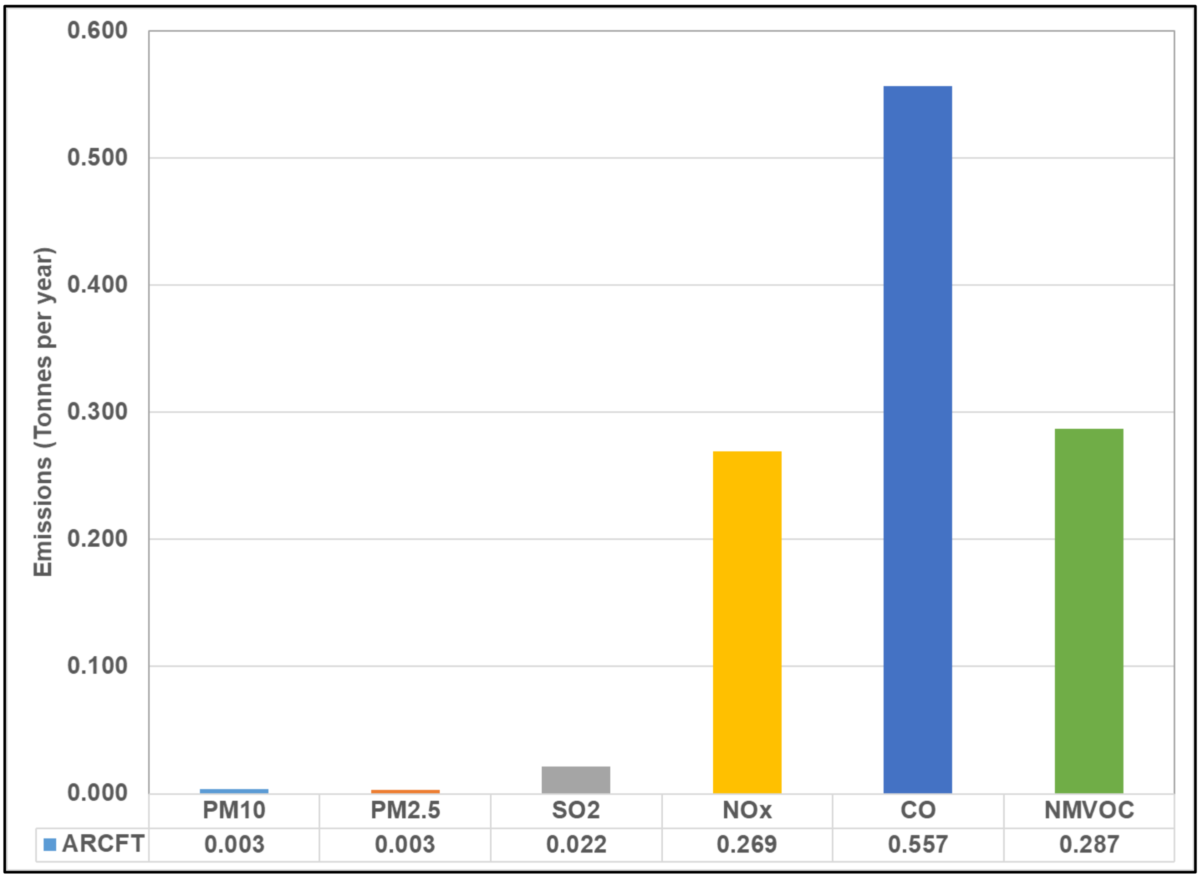


Figure 21: Emission loads (tonnes per year) of pollutants originating from the aircraft operations in Pune district

3.12. Construction

Figure 22 shows the PM_{10} and $PM_{2.5}$ emissions originating from construction and allied activities in Pune district. Construction sector is estimated to contribute about 17,006 tonnes per year of PM_{10} and 3,910 tonnes per year of $PM_{2.5}$. This is mainly because of activities such as ready-mix concrete plants, stone crushers which emit a large amount of dust during processing and most of the process are unabated. Additionally, active construction sites on the periphery of the city limits with availability of land at lower costs compared to core city areas, also add significantly to PM emissions.

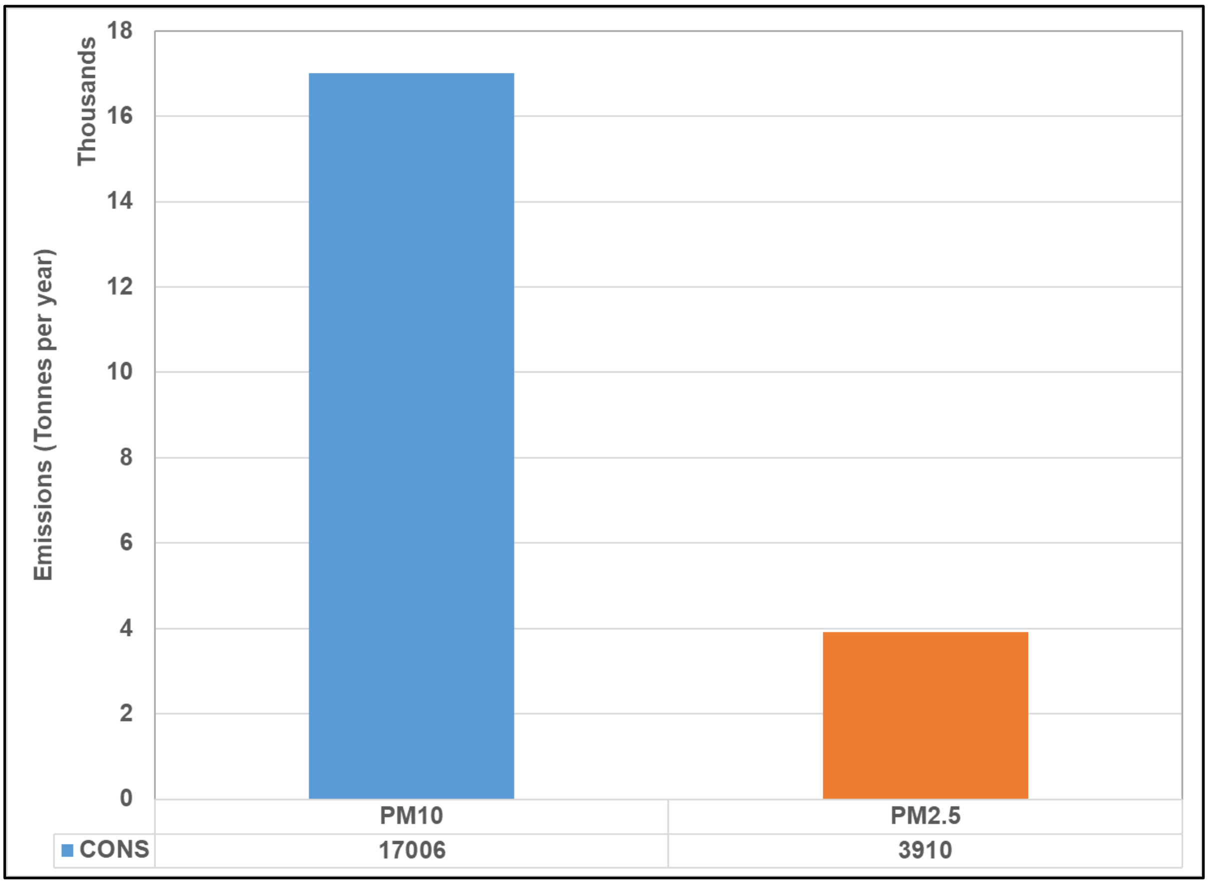


Figure 22: Emission loads (tonnes per year) of pollutants originating from the construction activities in Pune district

4. District level emission inventory

The overall baseline emission inventory (Year 2021) for the Pune district is presented in table 14. The sectoral contribution to each pollutant is shown in Fig. 23-27 and the district level spatial distribution of pollutants is provided in Figures 28 to 32.

The total PM10 emission load in the Pune district is estimated to be 73,226 tonnes per year. The top four contributors to PM10 emissions are road dust (35%), construction and allied activities (23%), industries (14%), and transport (10%). Daily and seasonal emissions could be highly variable. Daily and seasonal emissions could be highly variable.

PM2.5 emission load in the Pune district is estimated to be 32,854 tonnes per year. The top four contributors to PM2.5 emissions are transport (20%), road dust and industry (19% each) and construction and allied activities (12%). These emission loads are based on annual emissions whereas daily and seasonal emissions could be highly variable.

The annual NOx emission load in the district is estimated to be 1,47,560 tonnes per year. Transport sector is the largest contributor to NOx emissions (71%), followed by diesel generators (15%), Industry (11%), while other sectors contributions are low (<3%). The total annual CO emissions in the Pune district are estimated to be 3,59,214 tonnes per year. Transport sector is the major contributor to CO emissions i.e. 61%, followed by industry (18%), residential (8%), agricultural waste burning (5%).

Table 14: Baseline (Year 2021) Emission Inventory for the Pune district (tonnes per year)

SECTOR	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	NMVOC
TRAN	7351	6616	87	104689	218926	111892
RDST	25275	6115	NA	NA	NA	NA
WAST	2248	2087	143	321	10756	2328
CONS	17006	3910	574	783	638	4572
DSGN	1474	1301	1422	21629	4670	3733
RESI	2997	2095	733	2482	27971	18147
HRBE	747	523	306	197	3095	691
INDU	10434	6124	19695	16601	65588	1337
AGRI	4478	3218	404	823	18883	2794
BRIC	963	740	222	0.11	7404	111
CREM	254	125	6	35	1282	716
ARCFT	0.003	0.003	0.022	0.269	0.557	0.287
TOTAL	**73226**	**32854**	**23591**	**147560**	**359214**	**146321**

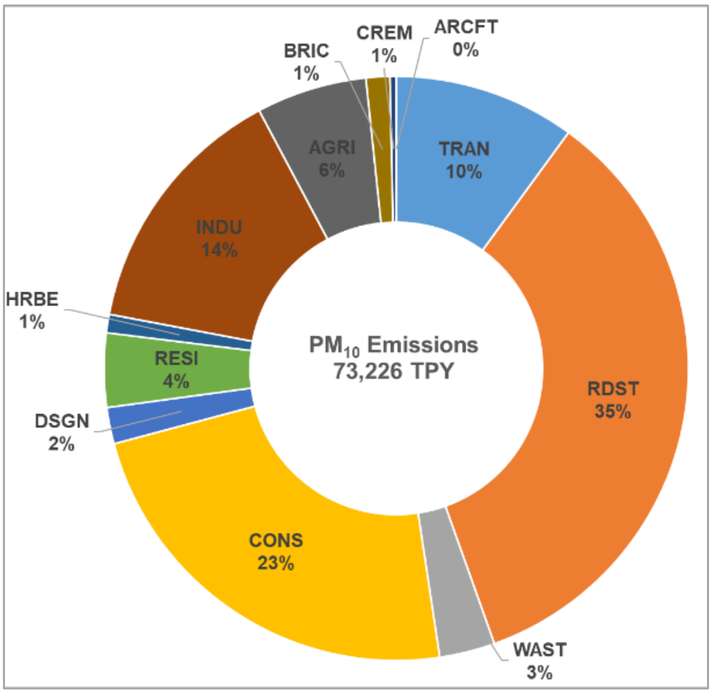


Figure 23: Relative contribution of selected source sectors in PM_{10} emission inventory of Pune district for year 2021

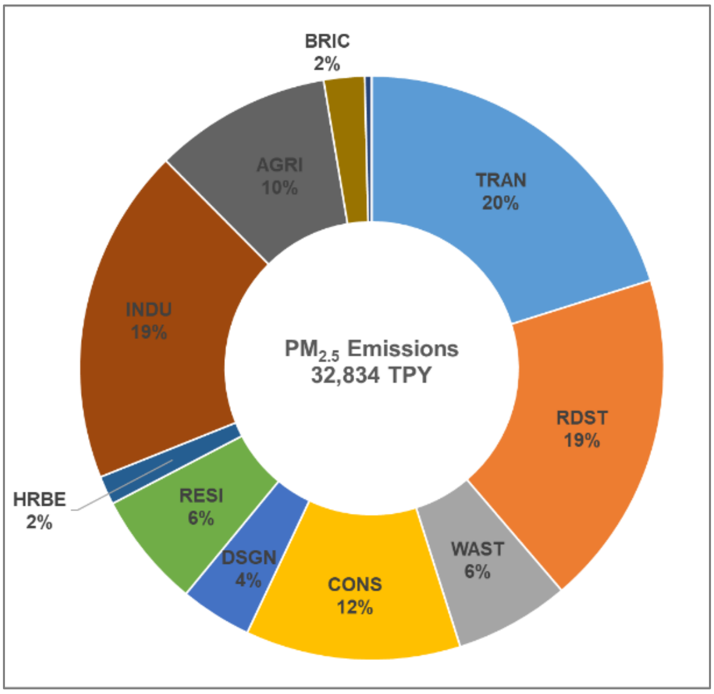


Figure 24: Relative contribution of selected source sectors in $PM_{2.5}$ emission inventory of Pune district for year 2021

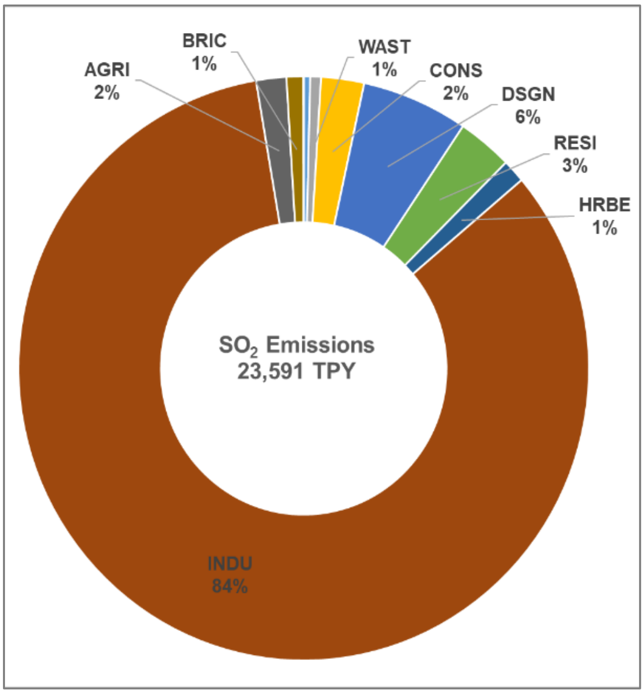


Figure 25: Relative contribution of selected source sectors in SO_2 emission inventory of Pune district for year 2021

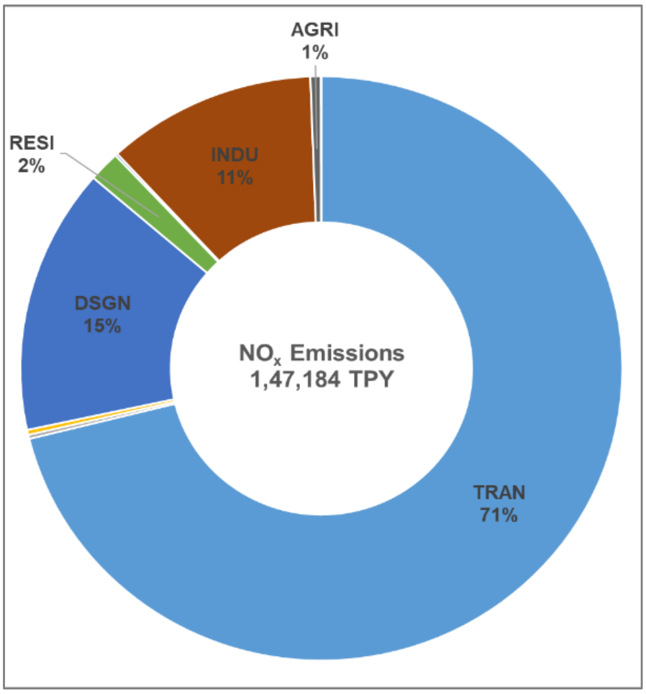


Figure 26: Relative contribution of selected source sectors in NO_x emission inventory of Pune district for year 2021

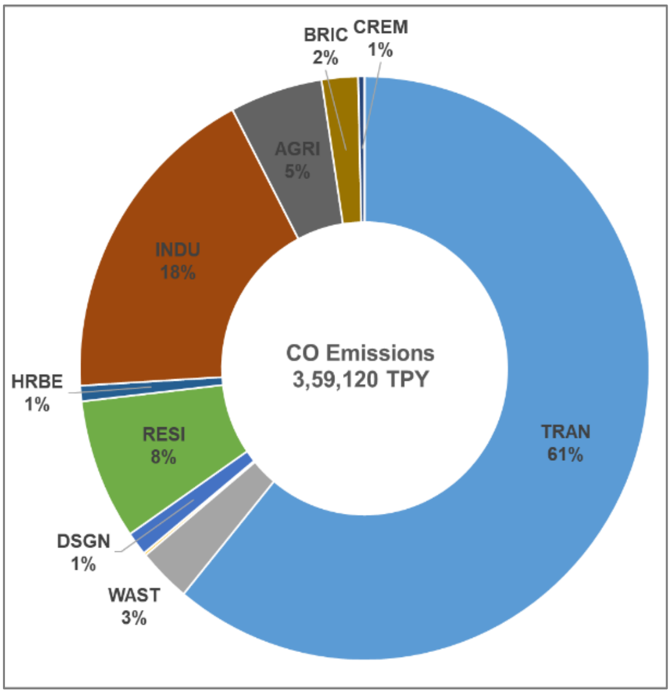


Figure 27: Relative contribution of selected source sectors in CO emission inventory of Pune district for year 2021

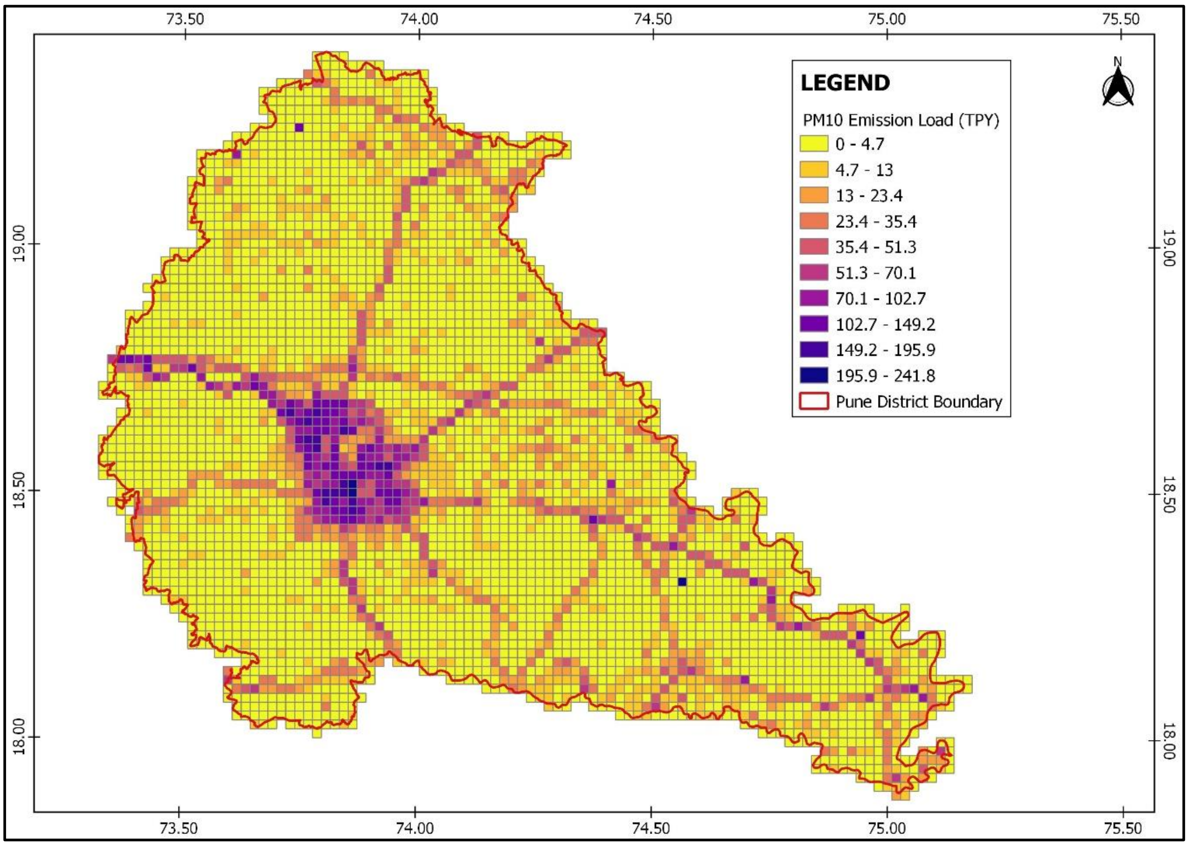


Figure 288: Spatial distribution of PM_{10} emissions (TPY) over Pune district for year 2021

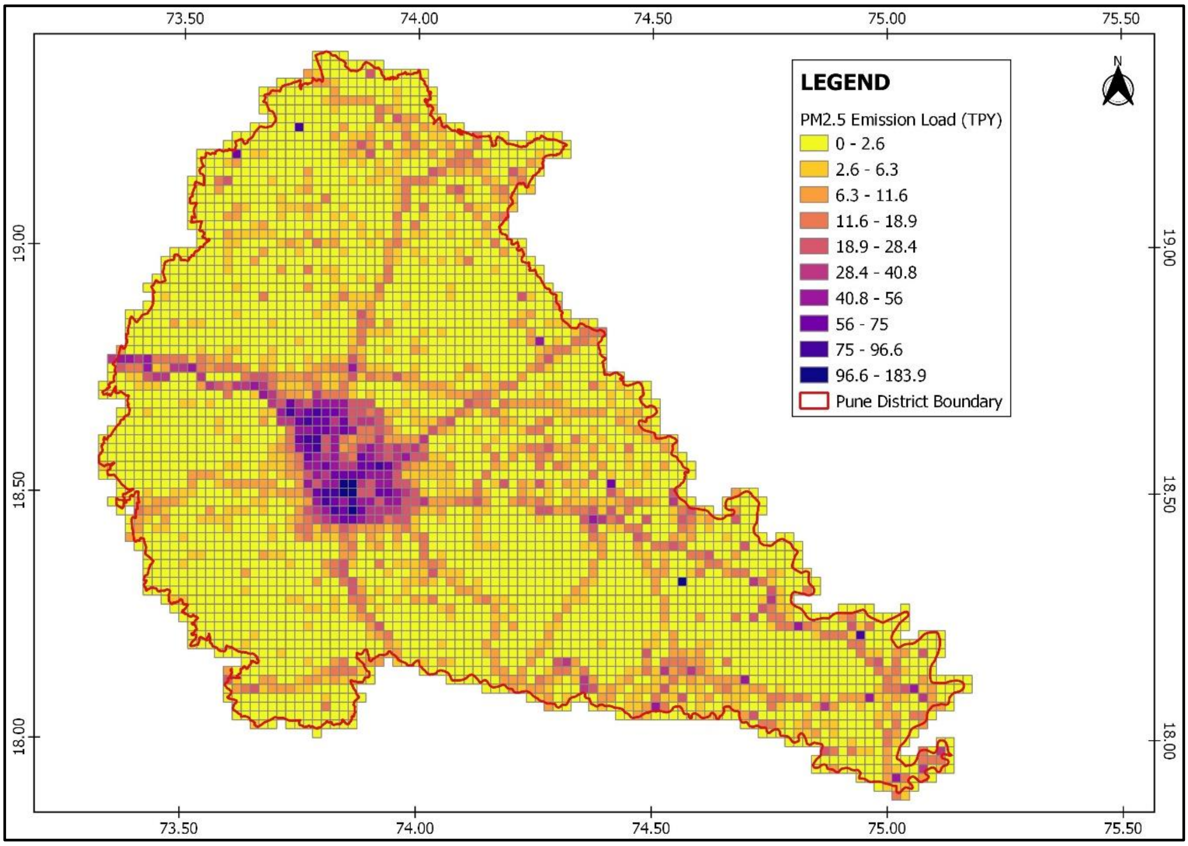


Figure 29: Spatial distribution of $PM_{2.5}$ emissions (TPY) over Pune district for year 2021

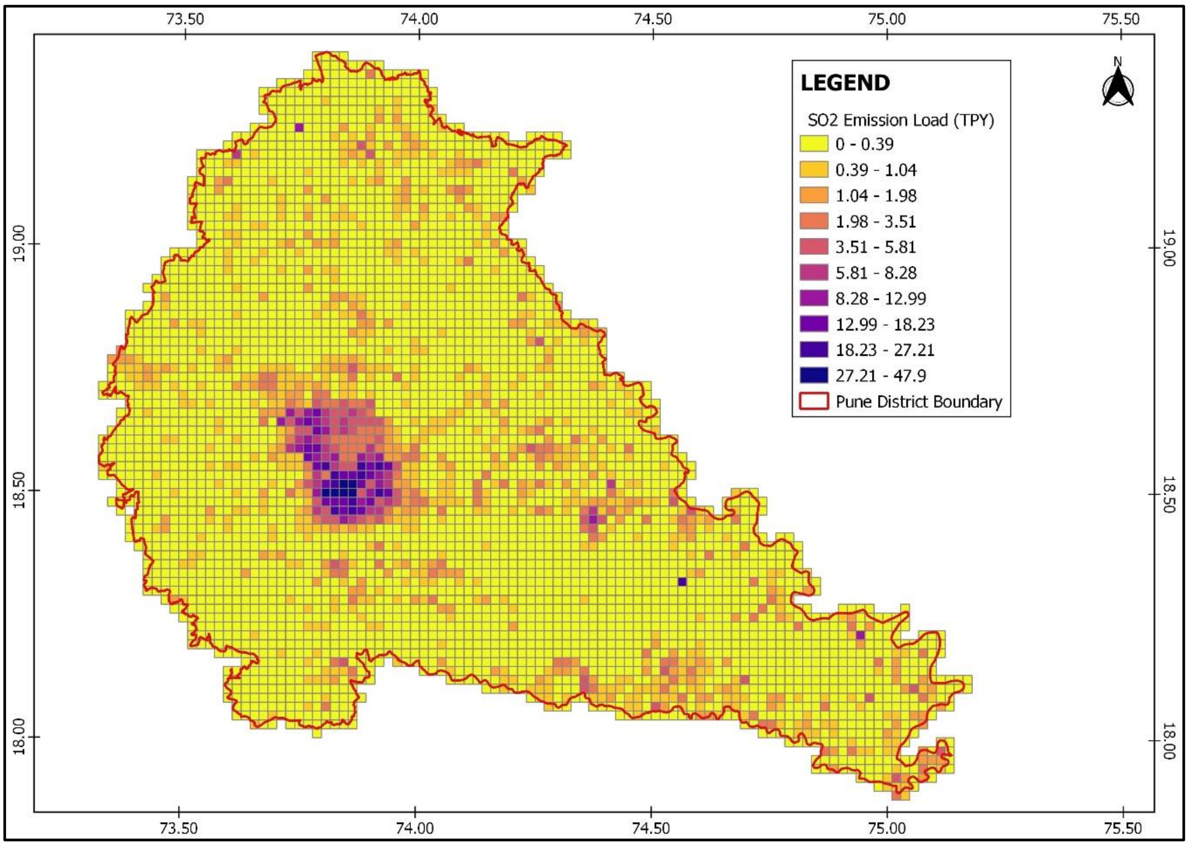


Figure 290: Spatial distribution of SO_2 emissions (TPY) over Pune district for year 2021

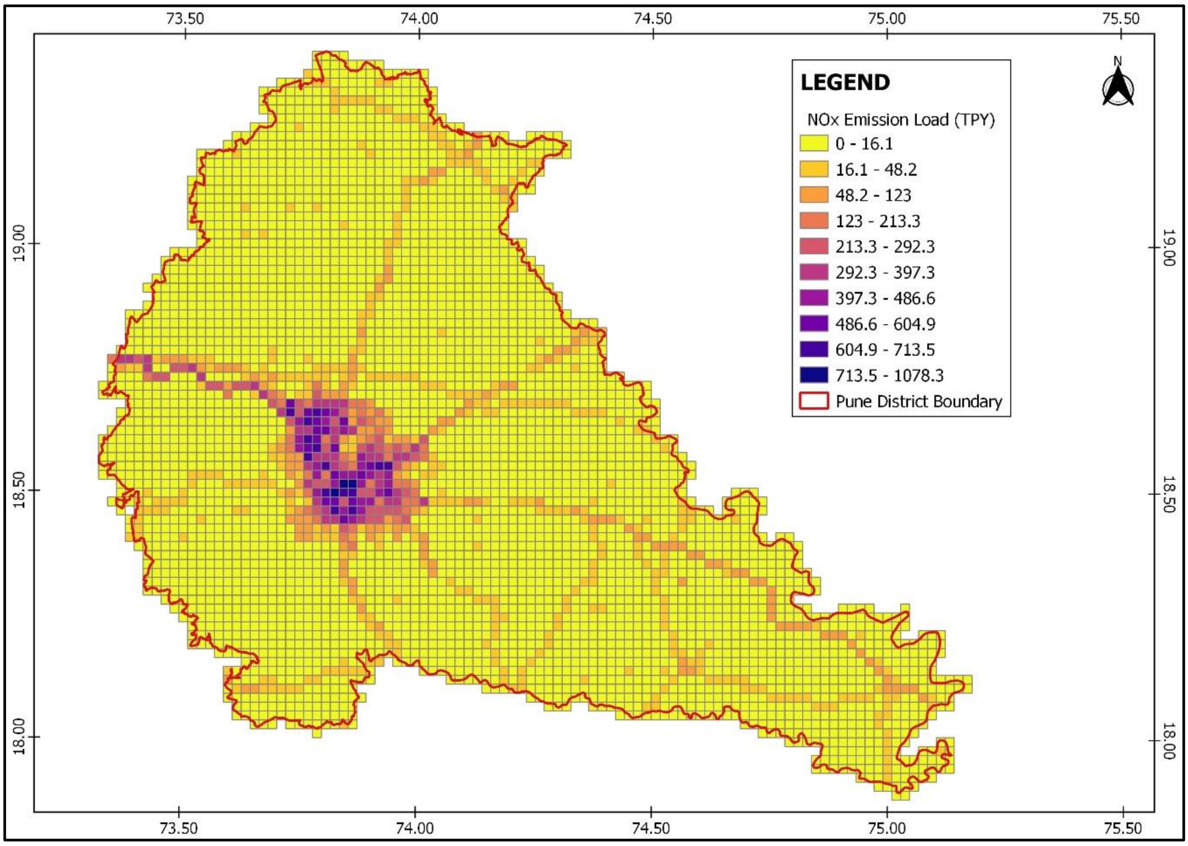


Figure 301: Spatial distribution of NO_x emissions (TPY) over Pune district for year 2021

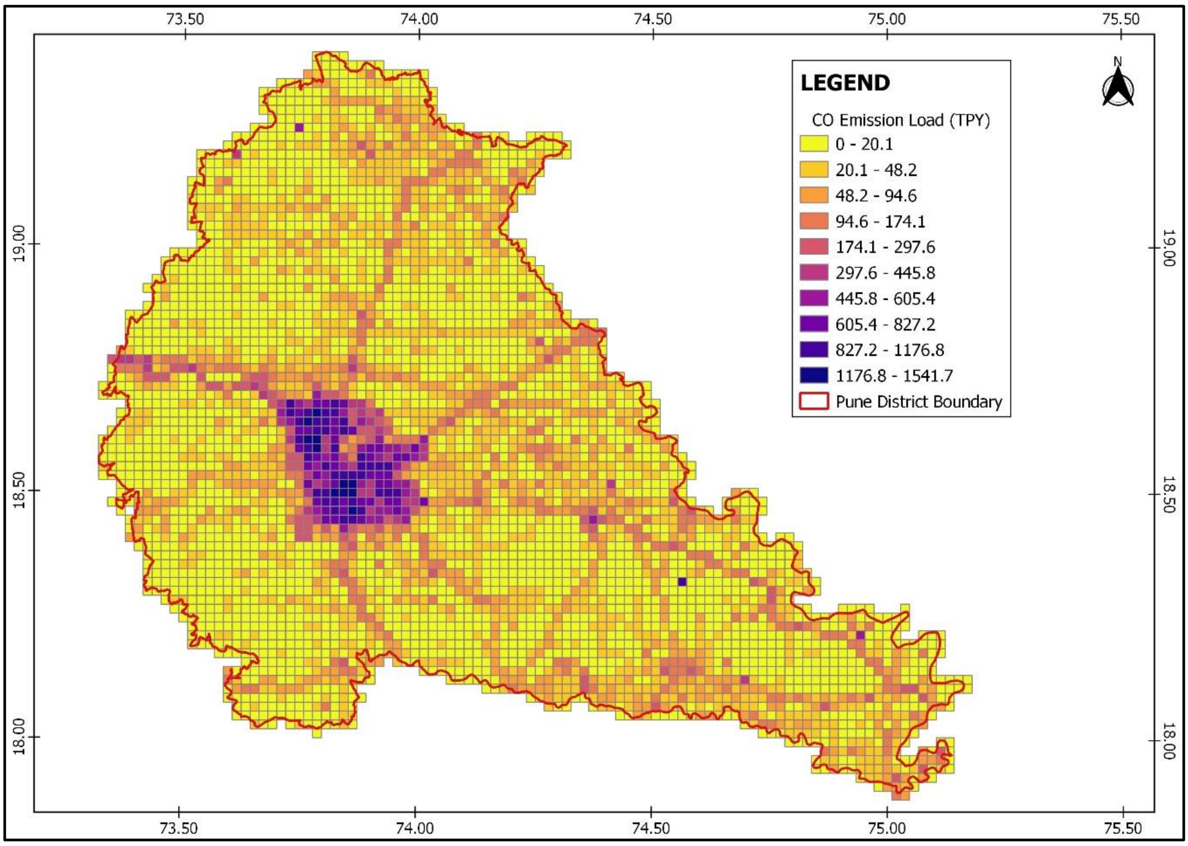


Figure 312: Spatial distribution of CO emissions (TPY) over Pune district for year 2021

5. Summary

The major findings are summarized below:

- The baseline emissions of air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO, and NMVOC) loads originating from twelve different sectors in Pune district viz. Transport, Dust, Open Waste Burning, Residential, Industries, Diesel generators, Hotels, Restaurants and Bakeries (HRB), Crematoria, Agricultural residue burning, Aircraft and Construction are quantified.
- Major PM_{10} sources in Pune district include road dust (34%), construction and allied activities (23%), industries (10%), and transport (10%) whereas $PM_{2.5}$ emissions are primarily dominated by transport (19%), road dust and industry (18% each) and agricultural waste burning (13%).
- Gaseous pollutants viz. SO2, NO_x, and CO are emitted mainly from the combustion processes and industries and transport sector is the major contributor to their emissions.
- The emission inventory of city areas is found to be dominated by transport related emissions such as vehicular exhaust and road dust re-suspension followed by open waste burning and hotels restaurants. This can be attributed to densely populated areas with higher vehicular movement.
- Whereas the emissions from rural areas are mainly dominated by agricultural residue burning and residential cooking and heating emissions.

Acknowledgement

The Automotive Research Association of India (ARAI) is grateful to all experts and specialists for providing insights during the preparation of this report. The acknowledgements are due to Maharashtra Pollution Control Board (MPCB), Pune Municipal Corporation (PMC) for sharing data on various activities in the region. The support from The Energy and Resources Institute (TERI) team during the execution of the project is sincerely appreciated. The support by Swiss Agency for Development and Co-operation (SDC), Switzerland is duly acknowledged.

ARAI is also thankful to Prof. Mukesh Sharma of Indian Institute of Technology, Kanpur and Dr. Sachin Ghude of Indian Institute of Tropical Meteorology, Pune for review and constructive inputs on the findings of the report.

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