Air Pollution Emission Inventory and Control Plan for Bhiwadi City

Final Report

Submitted to

Rajasthan Pollution Control Board,

4, Jhalana Institutional Area

Jhalana Doongri, Jaipur

(Rajasthan), 302 004

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Acknowledgments

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Executive Summary

Pollution control plans for the attainment of environmental quality standards must provide convincing evidence that (a) the relative importance of polluting sources are comprehended and that (b) the control plans proposed are cost-effective and can be implemented by the community with confidence. To specifically address these issues, the Rajasthan State Pollution Control Board (RSPCB), Jaipur has sponsored this project to the Indian Institute of Technology (IIT) Kanpur for the Bhiwadi City. The project has the following specific components: Development of GIS-based gridded (2 km × 2 km resolution) air pollution emission inventory for air pollutants (Particulate Matter less than or equal to 10 µm (PM_{10}), Particulate Matter less than or equal to 2.5 µm ($PM_{2.5}$), Sulphur dioxide (SO_2), Carbon monoxide (CO), and Oxides of nitrogen (NO_x); Assessment of pollutant emissions from domestic, vehicular, industrial and non-point sources; Extent and severity of impacts of emission on air quality; Identify best practices to improve air pollution control for major sources including industries; and Development of air pollution control action plan.

The overall framework of the study is presented in the figure below.

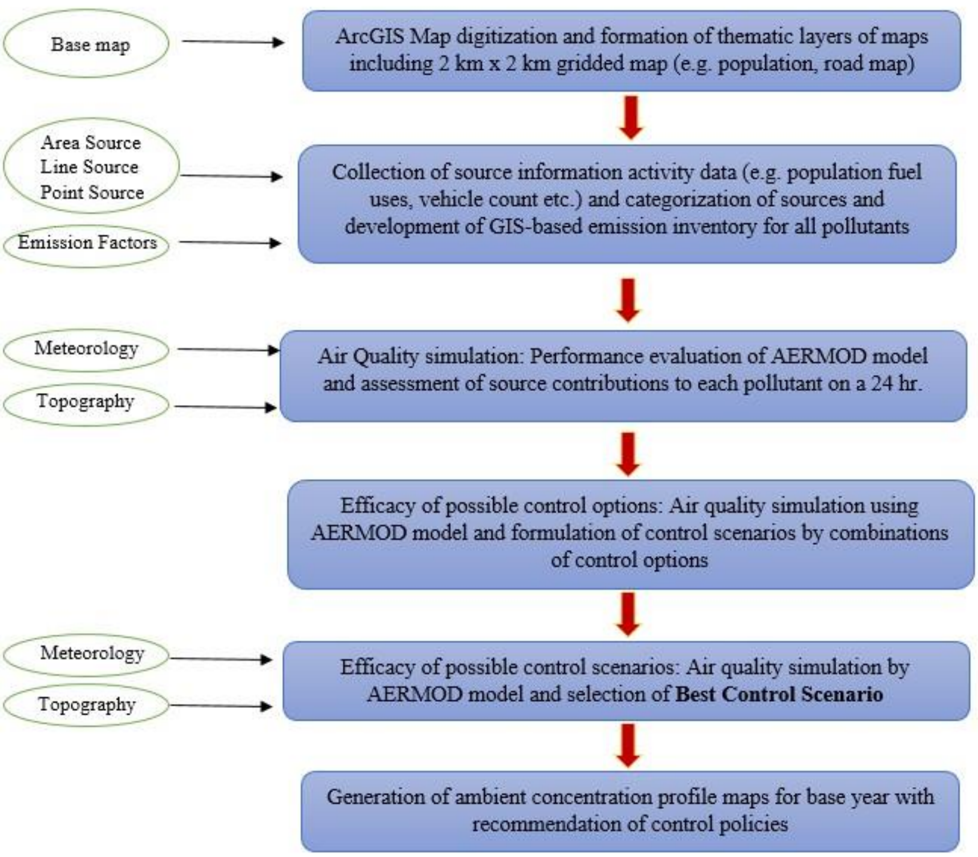

Figure 1: Framework of the study

Emission Inventory

The overall baseline emission inventory for the year 2017 is presented in Table 1.

Table 1: Overall Baseline Emission Inventory (2017) for the Bhiwadi City *(kg/day)*

Category	**PM_{10}**	**$PM_{2.5}$**	**CO**	**SO_2**	**NOx**
Industrial Point	736	663	3070	1901	1712
Vehicle	1485	1336	16439	384	14428
Road Dust	21654	5239	0	0	0
Hotels/Restaurants	42	21	76	29	12
Domestic	172	156	901	14	46
Industries Area	3246	2921	4784	9207	5122
DG Set	317	285	966	295	4474
MSW Burning	296	177	1553	18	111
Construction/Demolition	229	58	-	-	-
Agricultural Soil Dust	44	-	-	-	-
Total	**28221**	**10855**	**27789**	**11848**	**25905**

The total PM_{10} emission load in the city is estimated to be 28 t/d. The two largest contributors to PM_{10} emissions are road dust (77%) and industrial area sources (11%); these are based on annual emissions. The estimated emission suggests that there are many important sources and a composite emission abatement including most of the sources will be required to obtain the desired air quality.

$PM_{2.5}$ emission load in the city is estimated to be ~ 11 t/d. The top four contributors to $PM_{2.5}$ emissions are road dust (48 %), industrial area sources (27%), vehicles (12 %) and industrial point source (6%); these are based on annual emissions.

SO_2 emission load in the city is estimated to be ~12 t/d. Industrial area sources account for 78% of the total emission. It appears there may be a need to control SO_2 from industrial area source as SO_2 is also known to contribute to secondary particles (sulfates).

NOx emissions are about 26 t/d. Nearly 56% of emissions are attributed to vehicular emissions that occur at ground level, making it the most important source followed by industrial area source (20%) and DG sets contributing 17% to NOx emission. NOx apart from being a pollutant itself, it is an important component in the formation of secondary particles (nitrates) and ozone.

The estimated CO emission is about 28 t/d, second highest after PM_{10}. Nearly 59% emission of CO is from vehicles, followed by industrial area sources (17 %), industrial point source (11%), MSW Burning (6%), and DG Sets (4%). Vehicles could be the main target for controlling CO for improving air quality with respect to CO.

Bhiwadi is classified as an industrial city. Due to the government policies and Bhiwadi's proximity to Delhi, the city has attracted many large and MSME industries. Most of these industries use boilers and furnaces. A careful examination of industrial processes brings the following observations to the fore:

- There are about 400 boilers/furnaces that are operational in Bhiwadi and contribute heavily to particulate as well as gaseous emissions. The large contribution is due to the use of coal, wood, and other solid fuels; the industry should shift to clean fuel such as Natural gas and electricity for a significant reduction in emissions.
- Induction Furnace contributes to 44% of PM emission.
- Non-defined process boilers/furnaces are producing major SO_2 (38%) and NOx (24%) emissions and are using fuels like LSHS, LDO, FO, Coal, and Wood. The minimum capacity corresponding to the production of the industry has been worked out and assumed as the capacity of the furnace while estimating emissions.
- The second biggest contributor to SO_2 (16%) and NOx (23%) emission is baby boilers and mostly are running on coal.

Air Quality Modeling

USEPA's AERMOD model was employed to assess the impact of emissions occurring within Bhiwadi on the ambient air at multiple locations for PM_{10} and $PM_{2.5}$. The modeling exercise was performed for different seasons (winter, monsoon, post-monsoon, and summer). Local meteorological data generated through the WRF (Weather Research and Forecasting) model were used for the dispersion modeling and inputs from emission inventory (EI) were taken.

The winter is considered as critical when it comes to dispersion of pollutants and pollution impacts. In air quality dispersion modelling, one of the receptors considered in this study includes the city of Delhi. The city of Bhiwadi is located in the SSW direction of Delhi, whereas the prevalent wind direction at Bhiwadi is from NW direction. This implies that the majority of the time the wind is blowing from NW (Figure 2) and, therefore, emissions from Bhiwadi are unlikely to contribute to Delhi's air pollution.

The air quality model was run to assess the contribution of emissions from Bhiwadi to the City of Delhi. It was seen that, beyond 9.0 km, the average concentration in winter months due to emissions from Bhiwadi was less than 1 $\mu g/m^3$ (Figure 3). The peak 24-hr concentration in winter months due to emission from Bhiwadi was estimated to be 2.0 $\mu g/m^3$. Since winter-season and peak 24-hour concentration due to emissions from Bhiwadi is very low, it is unlikely that closure of industry or very stringent air pollution control measures at sources in Bhiwadi will improve the air quality in Delhi. However, the suggested pollution control measures will significantly improve the air quality within Bhiwadi city (see control action plan) and may be adopted.

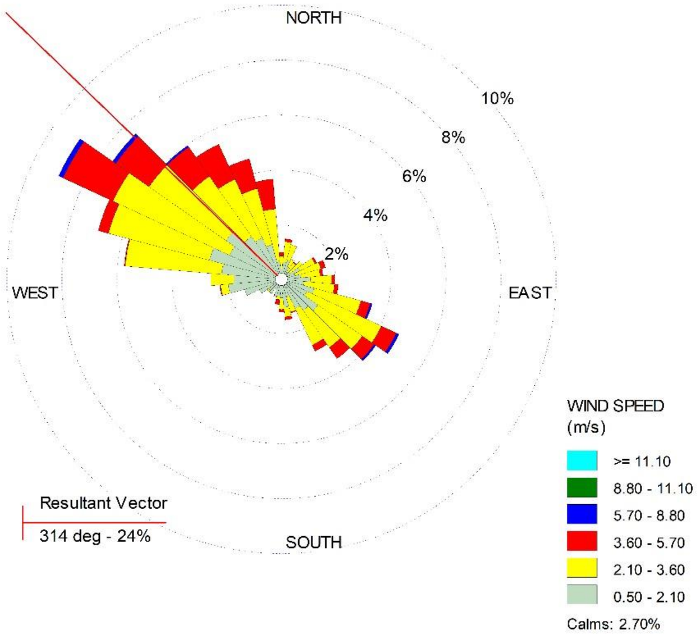

Figure 2: Wind Rose Diagram (Winter: November to February).

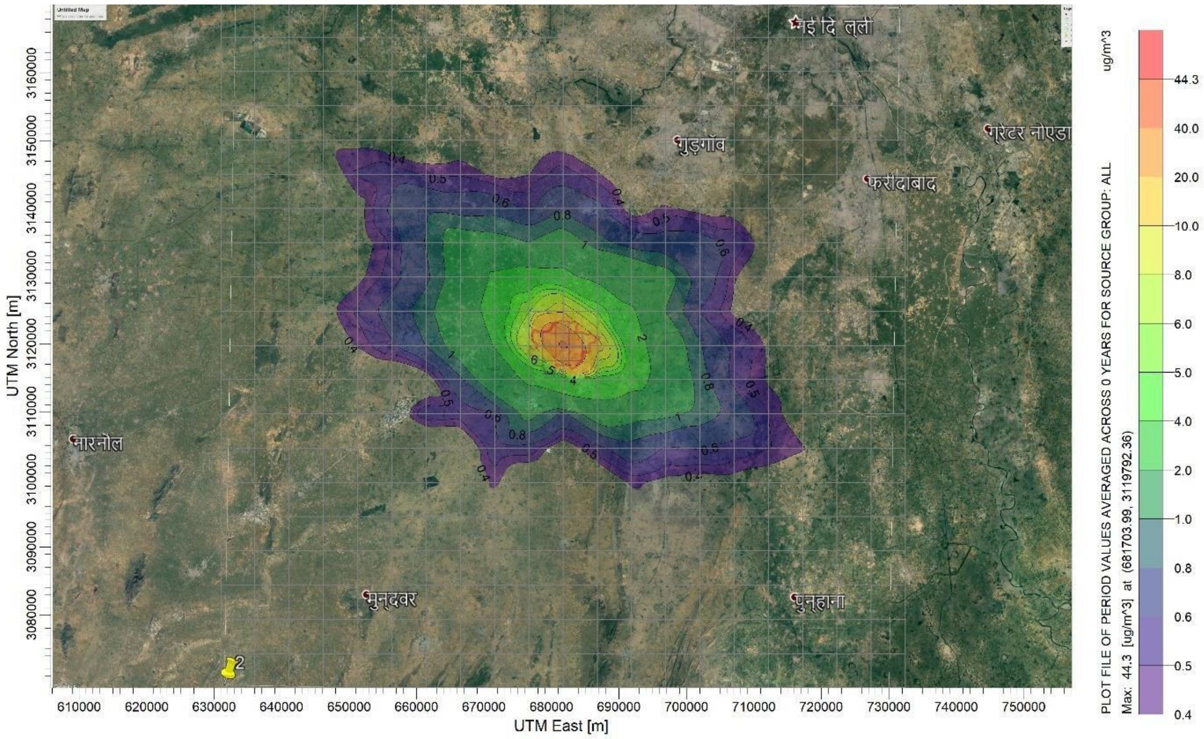

Figure 3: Average Concentration in Winter Season

Control Action Plan

Bhiwadi is considered as one of the major industrial hubs in the region. In addition to industrial and automobile pollution, there is a significant emission from non-point sources. Clusters of small and medium scale industries are also responsible for air pollution. In most of the institutions, hotels, and offices, the diesel generators are used at the time of power failure. Unlike other cities, at several locations, garbage burning is a common practice; it is also seen that not only garbage burning, the industrial waste is also burnt at several places within the city, which can be an important contributor to air pollution. The road condition in the town is quite bad as roads are broken, poorly maintained and partially paved and it is observed that movements of the vehicle may cause non-exhaust road dust emission in a significant amount. The area outside the factories is poorly managed and has become a dumping ground of non-hazardous wastes.

A list of potential control options that include technical and management interventions is presented in Table 2 for PM_{10} and $PM_{2.5}$ respectively.

Table 2: Control Options, Emission Load, and Reductions in PM

Source	Control Action	Responsible authorities	Time Frame
Hotels/ Restaurants	Restaurants of sitting capacity more than 10 should not use coal and shift to electric or gas-based appliances.	Municipal Council, Bhiwadi, Bhiwadi Industrial Development Authority (BIDA)	1 year
	Ash/residue from the tandoor and other activities should not be disposed near the roadside.	Municipal Council, Bhiwadi, Bhiwadi Industrial Development Authority (BIDA)	1 year
Domestic Sector	LPG to all, currently 74.4 % of the households are using LPG for cooking, rest are using solid fuels.	The Department of Food, Civil Supplies and Consumer Affairs and Oil Companies	2 year
Municipal Solid Waste (MSW) Burning	Any type of garbage burning should be strictly stopped.	Municipal Council, Bhiwadi, RIICO(for	Immediate
	Surveillance is required that hazardous waste goes to TSDF.	Municipal Council, Bhiwadi, RSPCB	
	Sensitize people and media through workshops and literature distribution.	Municipal Council, Bhiwadi, Bhiwadi Industrial Development Authority (BIDA),	
Construction and Demolition	Wet suppression	Municipal Council, Bhiwadi, Bhiwadi Industrial, Development Authority (BIDA), Rajasthan Housing Board, PWD, RIICO	Immediate
	Wind speed reduction (for large construction site)		
	Waste should be properly disposed of. It should not be kept lying near the roads as it may contribute to road dust emission.		
	Proper handling and storage of raw material: covered the storage and provide the windbreakers.		
	Vehicle cleaning and specific fixed wheel washing on leaving the site and damping down of haul routes. Vehicle transporting raw materials or waste materials should be covered.		
	Actual construction area should be covered by a fine screen.		
	No storage (no matter how small) of construction material near roadside (up to 10 m from the edge of the road)		
	Sensitize construction workers and contract agency through workshops.		

Road Dust	The silt load in Bhiwadi varies from 7 to 73 g/m^2. The silt load on each road should be reduced under 5 gm/m^2.	Municipal Council, Bhiwadi, Bhiwadi Industrial, Development Authority (BIDA), Rajasthan Housing Board, PWD, RIICO	One Year
	Regular Vaccum sweeping should be done on the road having silt load above 5 gm/m^2.		
	Convert unpaved roads to paved roads.		
	vacuum assisted sweeping carried out four times in a month will reduce road dust emission by 71% (resultant emissions: 6 ton/day)		
	Roads condition should be maintained properly and carpeting of shoulders asap.		6 months
	These roads should be fixed on priority-		
	1. Dhabha Complex to Bhiwadi Mod		
	2. Bhiwadi Mod to Toll Plaza (Alwar road)		
	3. Alwar Road to Mansa Chowk		
	4. Mansa Chowk to Relaxo Chowk		
	5. UIT Residential Area		
	6. Chowpanki Road		
Vehicles	Diesel vehicle entering/registered in the city should be equipped with DPF which will bring a reduction of 40% in emissions (This option must be explored once Bharat stage VI fuel is available)	Transportation Department	3 years
	Industries must be encouraged to use Bharat stage VI vehicles for transportation of raw and finished product	Bhiwadi Manufacturing Association (BMA)	Immediate
	Restriction on plying and phasing out of 10 years old commercial diesel driven vehicles.	Transportation Department	1 years
	Introduction of cleaner fuels (CNG/ LPG) for vehicles.	The Department of Food, Civil Supplies and Consumer Affairs and PNG Regulatory	1 year
	Electric/Hybrid Vehicles should be encouraged; New residential and commercial buildings to have charging facilities.	Transportation Department, BIDA	1 year
Industries and DG Sets	New air polluting industry under Red and Orange categories should be allowed in Bhiwadi only with stringent conditions as per CEPI Mechanism issued by the State Board	RSPCB	Immediate
	Ensuring emission standards in industries	RSPCB	
	Strict action to stop unscientific disposal of hazardous waste in the surrounding area	RIICO, BMA, RSPCB	

Source	Control Action	Responsible authorities	Time Frame
	There should be separate Treatment, Storage, and Disposal Facilities (TSDFs) for hazardous waste.	BMA, RSPCB	2 year
	Industrial waste burning should be stopped immediately	RIICO, BMA, RSPCB	Immediate
	Follow best practices to minimize fugitive emission within the industry premises, all leakages within the industry should be controlled	BMA, RSPCB	Immediate
	Area and road in front of the industry should be the responsibility of the industry	RIICO, BMA	
	Category A Industries (using coal and other dirty fuels)		
	About 400 boilers and furnaces in Bhiwadi are running over coal, wood, and other dirty solid fuels which should be shifted to natural gas and electricity	BMA, PNG Regulatory Board, Haryana City Gas Distributing Co. ltd, RSPCB	2 years
	Almost all rotary furnace having significant emissions are running on coal that needs to be shifted to natural gas and electricity	BMA, PNG Regulatory Board, Haryana City Gas Distributing Co. ltd, RSPCB	2 year
	Multi-cyclones should be replaced by baghouses	BMA, RSPCB	1 year
	Category B Industries (Induction Furnace)		
	Recommended Fume gas capturing hood followed by Baghouse should be used to control air pollution	BMA, RSPCB	1 year
	Diesel Generator Sets		
	Strengthening of grid power supply, uninterrupted power supply to the industries	State Energy Department, JVVNL	2 years
	Renewable energy should be used to cater the need of office requirement in the absence of power failure to stop the use of DG Set	BMA, Rajasthan Renewal Energy Corporation Ltd	1 year
*The above steps should not only be implemented in Bhiwadi municipal limits rather these should be extended to up to at least 25 km beyond the boundary. This will need support from the central government as well as the neighbouring state government			

Induction Furnace Emission Control

There are many industries having induction furnaces, which are very pollution processes, with almost no pollution control devices (Figure 4). The maximum emissions occur when the furnace lids and doors are opened during charging, back charging, alloying, oxygen lancing (if done), poking, slag removal, and tapping operations. These emissions escape from sides and top the building.

Figure 4*:* Inductance Furnace in Bhiwadi *(*Existing*)*

To address the pollution caused by fugitive emissions using induction furnaces, a fume gas capturing device has been developed and commercially available. A side-based suction (Figures 5 and 6) is far more effective than top suction, which interferes with the movement of the crane.

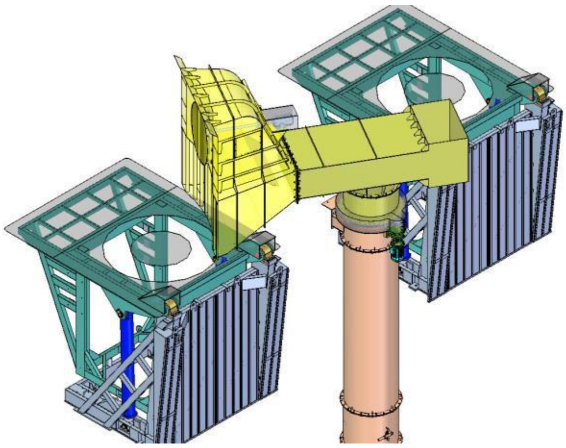

Figure 5*:* Proposed Suction Hood (Pic courtesy: Electrotherm)

Figure 6*:* Working of side-based Suction Hood

It is recommended that a fume gas capturing hood followed by baghouse should be used to control air pollution.

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Chapter 1: Introduction

Background

Industrialization is on the increase and so is the environmental pollution due to emissions and waste discharges from the industries. Industrial pollution has the potential to cause irreversible reactions in the environment and may pose a risk to human health. Since the carrying capacity of the environment is not unlimited and some areas or ecosystems are more susceptible to adverse environmental impacts than others, the unplanned and haphazard location of industries might substantially increase the risk. It is desirable that for existing industrial areas stressed under high ambient pollution levels, a systematic and effective action plan is developed and implemented in a time-bound manner rather than considering the closure of the industries.

Air pollution is an important environmental component and requires an action plan that should be based on cause-effect analysis. However, this is not simple. The problem becomes more complex due to the multiplicity and complexity of the air polluting source mix, automobiles, generators, domestic fuel burning, roadside dust, construction activities, etc., which co-exist with industries.

Since the enactment of the Air Act 1981, air pollution control programs have focused on point and area source emissions, and many communities have benefited from these control programs. Nonetheless, most cities in the country still face continuing particulate non-attainment problems from aerosols of unknown origin (or those not considered for pollution control) despite the high level of control applied to many point sources. It is in the latter case that an improved understanding of source-receptor linkages is especially needed if cost-effective emission reductions are to be achieved. Determining the sources of airborne particulate matter is a difficult problem because of the complexity of the urban source mix. The problem is often compounded by the predominance of non-ducted and widely distributed area (fugitive) sources and the lack of understanding of the sources of secondary aerosol, their formation, and transport.

The city of Bhiwadi (28.21°N, 76.87°E; population:1,04,921) in the state of Rajasthan has witnessed a high level of air pollution (http://cpcb.gov.in/caaqm), believed to have been caused from industrial emissions from large industrial areas (RIICO and Bhiwadi Phase I to

IV Industrial area). The city has attracted many large industries because of government policies, being strategically situated in the Nation Capital Region (NCR), and a direct approach from NH-8. Moreover, Bhiwadi comes under the Delhi-Mumbai Industrial Corridor mega- project which has brought investment from both government and private sectors. It is noteworthy that industries in Bhiwadi city co-exist with multiple activities in surrounding areas (Dharuheda, Tijara, etc) extending beyond the administrative boundary, which results in the overall degradation of air quality of the region.

The Rajasthan State Pollution Control Board (RSPCB), Jaipur has sponsored a study to IIT Kanpur (IITK) for developing air pollution control plan that will cover air pollution sources, dispersion of pollutants in the ambient environment and short and long-term actions for restoration of ambient air quality in the Bhiwadi city.

1.0 Need for the Study

Bhiwadi being one of the industrial hubs in the region is growing rapidly and is playing a major role in the economic development of the region. In addition to industrial sources, the other regular emission from diesel generators, transportation, and movement of man and material, hotels and restaurants, and emissions from outside sources can cause high pollution levels. The city witnesses high pollution levels (Winter Season: October 2017 to January 2018 PM_{10}: 519-614 µg/m^3, $PM_{2.5}$: 269-349 µg/m^3, SO_2: 140-250 µg/m^3, and NO_2: 92-121 µg/m^3; Source: Bhiwadi CAAQMS data). The national air quality index (NAQI) in Bhiwadi during the winter season is in the worst category, *Critical* (https://app.cpcbccr.com/AQI_India/). Therefore, there is a need to identify and quantify the sources and develop an air pollution control action plan to achieve NAAQS (National Ambient Air Quality Standards).

1.1 Scope of Work

The study has been the following scope of work:

- Development of GIS-based gridded (2 km × 2 km resolution) air pollution emission inventory for air pollutants (Particulate Matter less than 10 µm (PM_{10}), Particulate Matter less than 2.5 µm ($PM_{2.5}$), Sulphur dioxide (SO_2), Carbon monoxide (CO), and Oxides of nitrogen (NOx);

- Compilation and interpretation of the past 10 years' ambient air quality data in the city for PM_{10}, $PM_{2.5}$, SO_2, CO, and NOx (24-hr average data) and perform time series analyses of air quality data to provide information in terms of trends such as (i) significant downward, (ii) significant upward, (iii) firstly decreasing and then increasing, (iv) firstly increasing then decreasing and (iv) no trend;

- Assessment of pollutant emissions from domestic and industrial sources as well as non- point sources. This assessment will be used for the preparation of source and pollutant-specific air pollutant source inventories.
- Activity data collection for air pollution sources.
- Emission factor compilation from various scientific literature.
- Identification of suitable emission factor for the study.
- Creation of a database on emission inventory of various air pollution parameters especially with respect to PM_{10}, $PM_{2.5}$, SO2, CO, and NOx.
- Creation of maps to show the concentration in respect of PM_{10}, $PM_{2.5}$, SO_2, CO, and NOx using state-of-the-art USEPA regulatory model AERMOD.
- Interpretation of concentration profile with respect to the emission inventory by employing statistical analysis and GIS-based system.
- Identify best practices to improve air pollution control for industries using induction furnaces.
- Movement and transport of pollutants from outside into Bhiwadi city.
- Identification of primary and secondary sources of air pollutants.
- Identification of various control options and assessment of their efficacies for air quality improvements and development of control scenarios consisting of combinations of several control options;
- Time series and trend analysis and annual pattern of air pollutant concentration.
- Development of Control Action Plan.

1.2 Report Structure

The report is divided into five chapters and annexures at the end. The brief descriptions of the chapters are given below.

Chapter 1

This chapter presents the background of the study, general description of the city including demography, climate and sources of air pollution. The current status of the city in terms of air pollution is described by reviewing the previous studies. The objectives, scope, and approaches for this project are also briefly described in this chapter.

Chapter 2

This chapter enumerates methodology adopted in the study, characterization of sources, data collection and generation. It also gives an overview of the air dispersion modeling and how it will assist in making a control action plan for the city.

Chapter 3

This chapter presents and compares the grid-wise results of emission inventory outputs for various pollutants. The contributions of various sources towards air pollution loads (pollutant-wise) are presented. The QA/QC approaches for emission inventory are also explained in this chapter.

Chapter 4

This chapter briefly describes dispersion modeling, especially the application of AERMOD, USEPA's state-of-the-art model. The chapter also describes the modeling results for the existing emission scenario of the city.

Chapter 5

This chapter describes, explores and analyses emission of control options and analysis for various sources based on the emission inventory and modeling results from Chapters 3 and 4. This chapter also discusses some alternatives for controlling prominent sources with quantified emission reductions.

Chapter 2: Methodology

2.0 Approach to the Study

The approach to the study (Figure 2.1) is based on the attainment of its objectives.

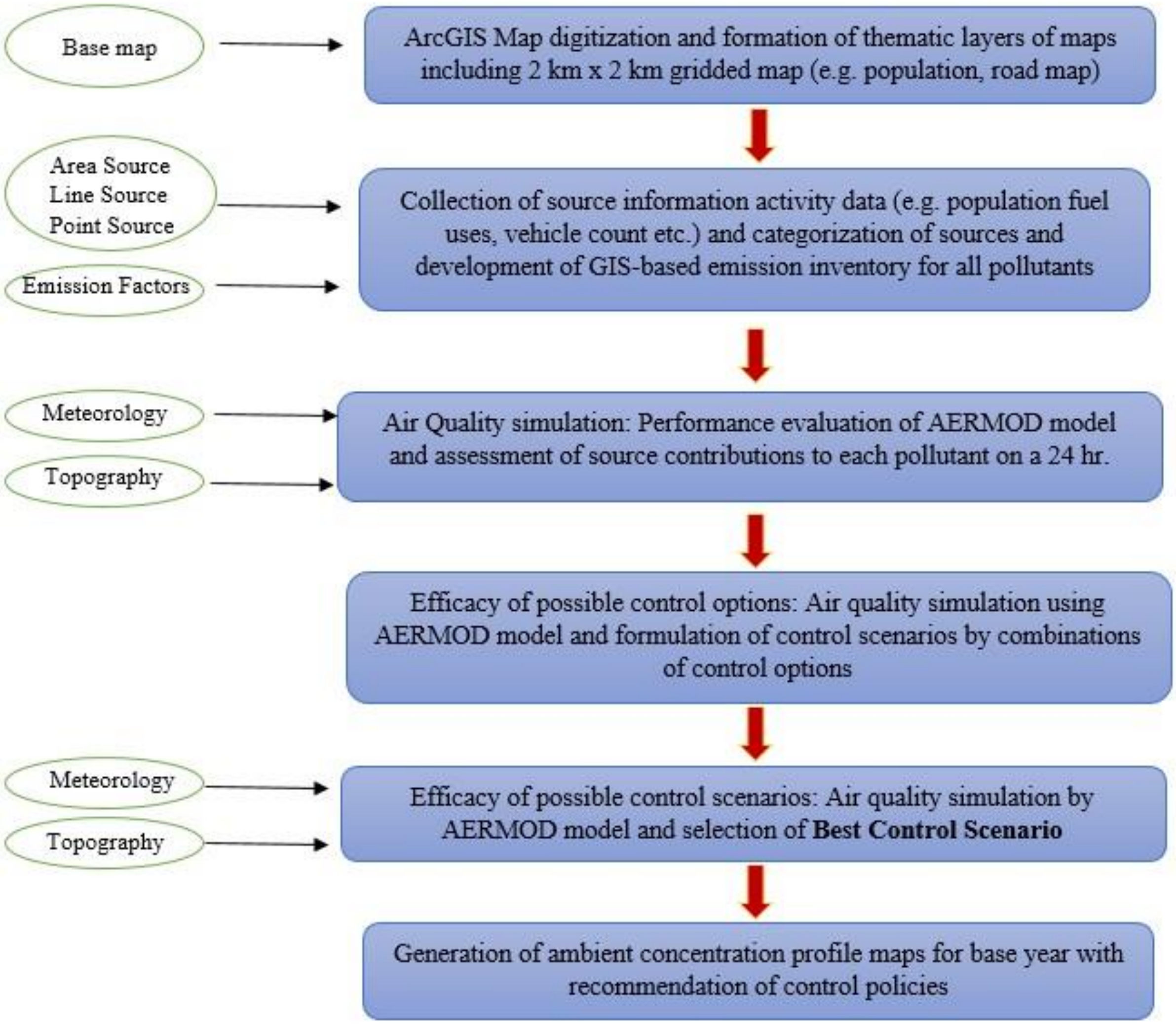

Figure 2. 1 Stepwise Methodology

2.1 Digital Data Generation

The land-use map of the study area is prepared in terms of settlements, forests, agriculture, road network, water bodies, etc. (Figure 2.2). The various generated layers are shown in Figure 2.3 to Figure 2.12. Finally, the digitized map was divided into 22 grids of 2 km x 2 km (Figure 2.13).

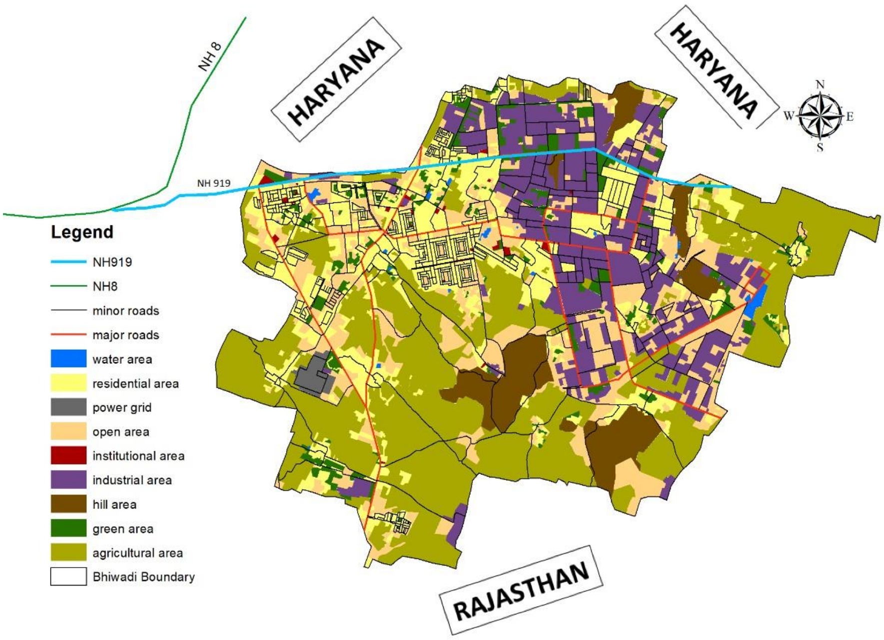

Figure 2. 2: Land-use Map of the Study Area

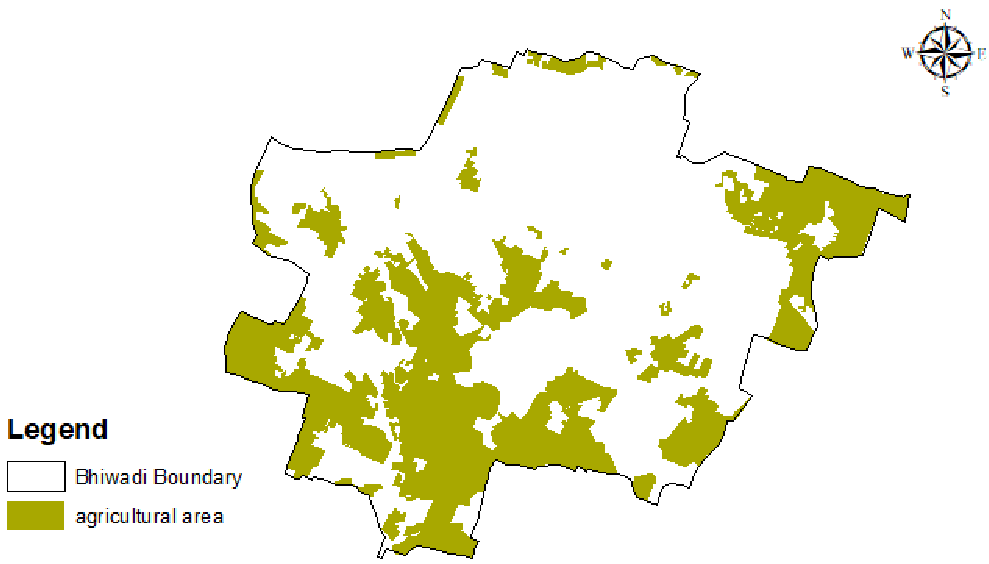

Figure 2. 3: Agricultural area

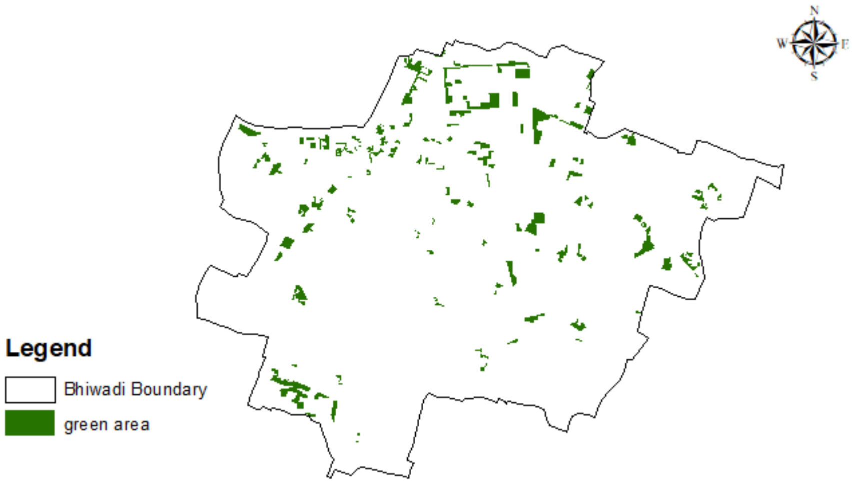

Figure 2. 4: Green area

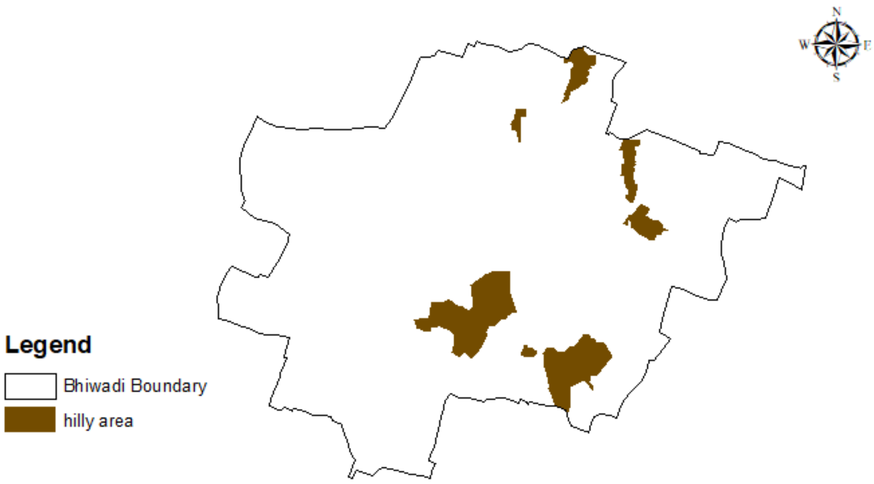

Figure 2. 5 Hills

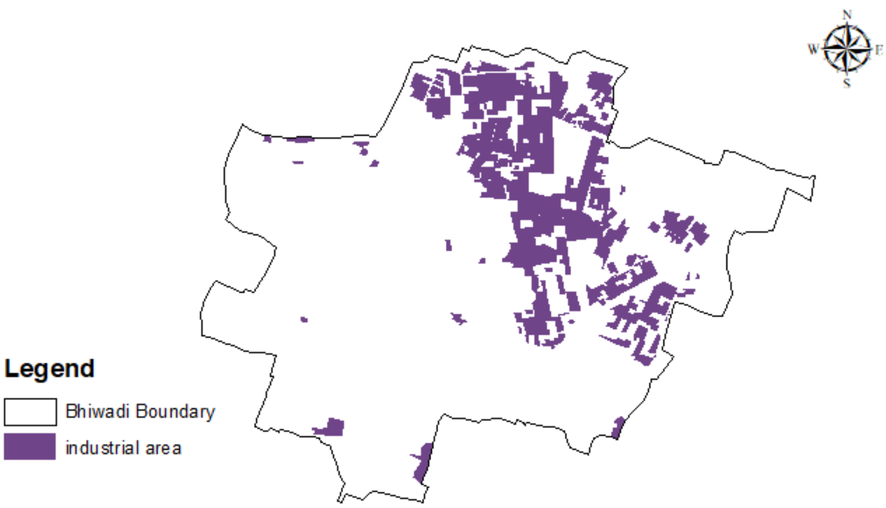

Figure 2. 6: Industrial area

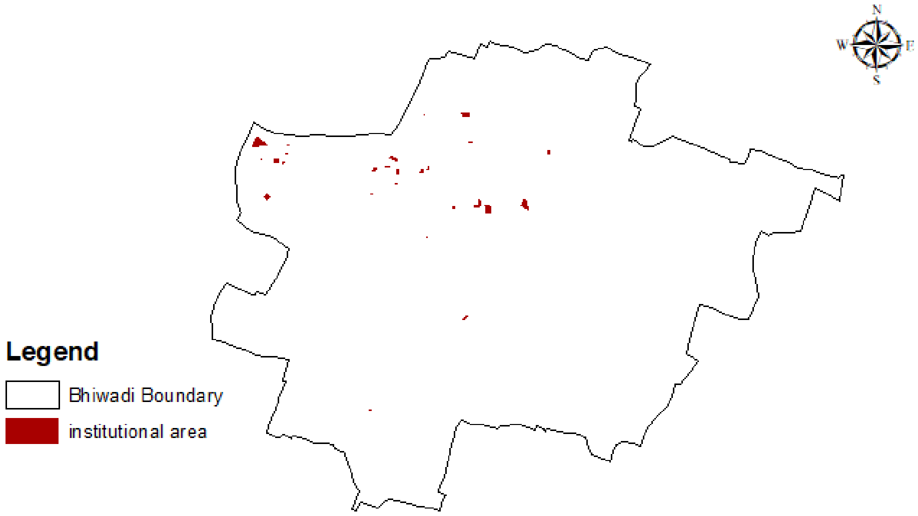

Figure 2. 7: Institutional area

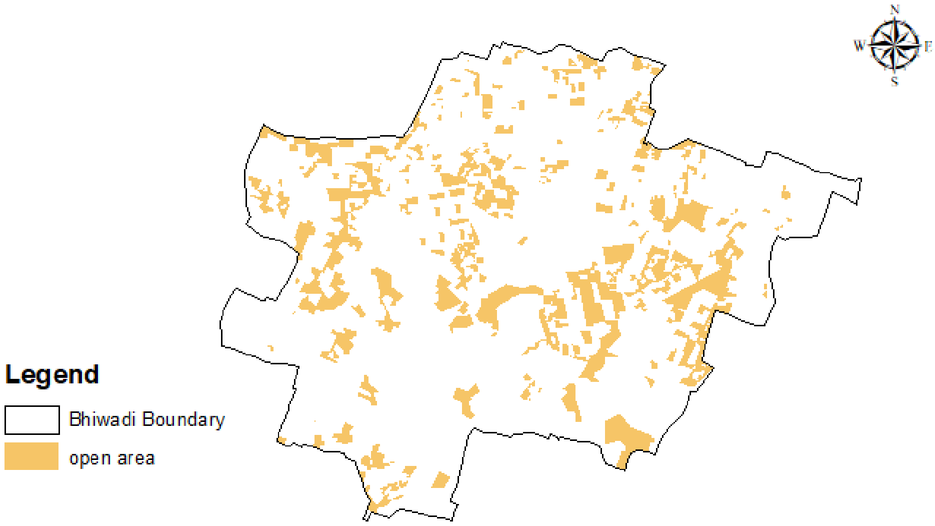

Figure 2. 8: Open area

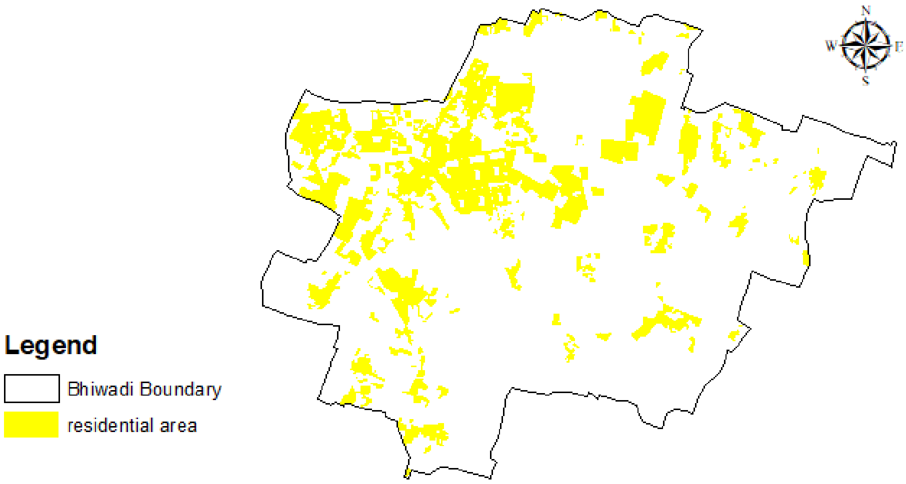

Figure 2. 9: Residential area

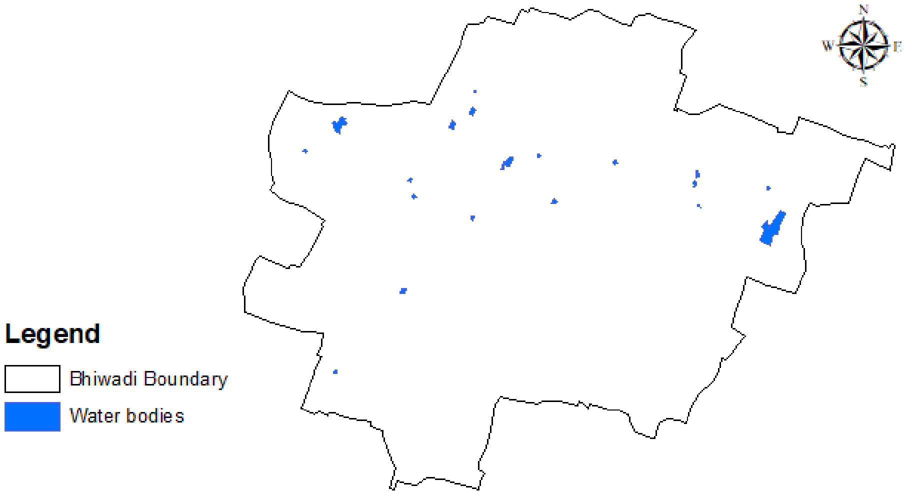

Figure 2. 10*:* Water bodies

Figure 2. 11*:* Major roads

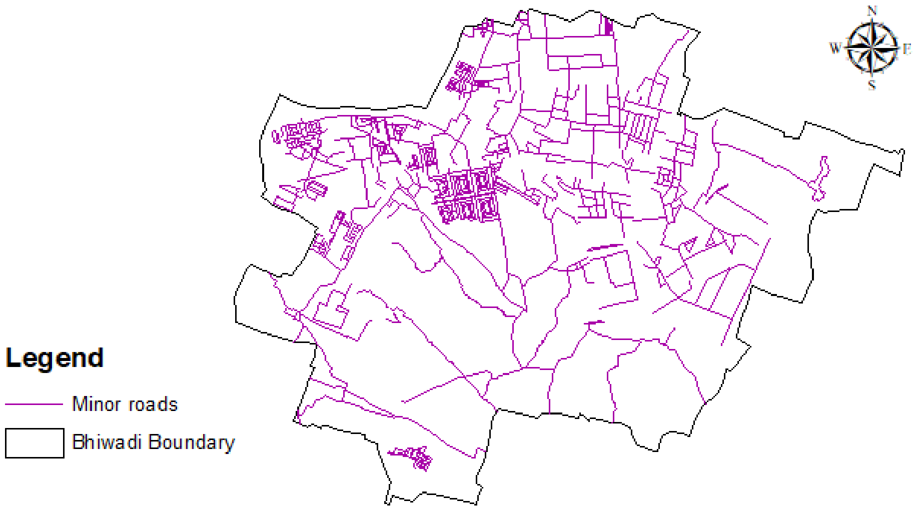

Figure 2. 12*:* Minor roads

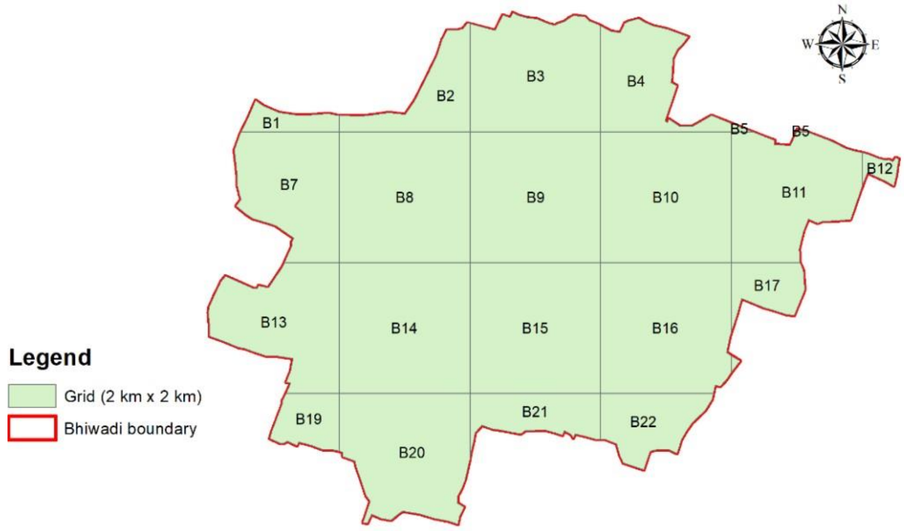

Figure 2. 13: Grid Identification Numbers

At the time of development of the emission inventory for the city, a suitable coding system has been adopted to avoid the confusion and misrepresentation of results and interpretation. The map with grid identity numbers is shown in Figure 2.13.

2.2 Emission Inventory

2.2.1 Identification and Grouping of Sources

An on-the-field exercise was taken up to physically identify all small and large sources in the study area. This exercise included emission sources like MSW (Municipal Solid Waste) burning, road dust, and coal/coke burnt by street vendors/small restaurants to large units like industries and various vehicle types. It was necessary to group some of the similar sources to keep the inventory and modeling exercise manageable. Finally, the collected data were used to develop emission inventory for the following pollutants: SO_2, NOx, CO, PM_{10} and $PM_{2.5}$ and software for emission database and information/data retrieval systems were designed and implemented.

All the sources were broadly classified into three categories; (1) point sources (stack height >20m), (2) area sources (stack≤20m) and (3) line sources (vehicles) (Figure 2.14).

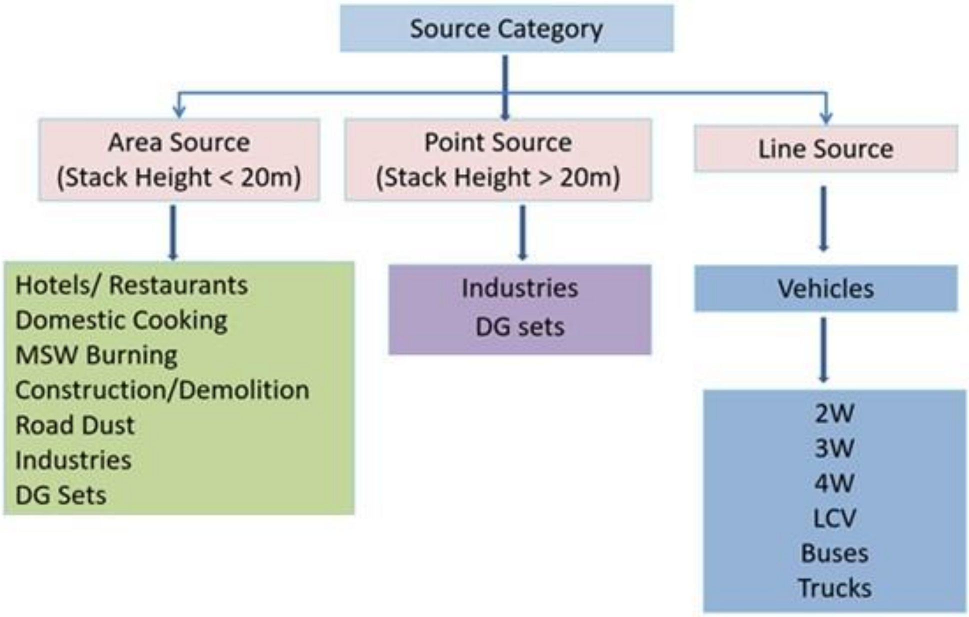

Figure 2. 14: Classification of air pollution sources

2.2.2 Data Collection

A physical survey of the entire study area was done by the IITK team to understand source-wise activities. Various air pollution sources were identified and locations for on-field data collection were finalized. For developing traffic counts including vehicle types, movement of the vehicle was recorded at six major traffic intersections within Bhiwadi municipal limit; the traffic recordings were provided by RSPCB, Bhiwadi office.

As emissions from vehicles vary on engine size, year of manufacturing and daily distance traveled, parking lane surveys were conducted at six locations to assess types of vehicles (engine size, fuel type, and their vintage) plying on the roads. Road dust sampling was done at eight locations to obtain the silt load on the roads. Ongoing construction activity information was collected from the public works department and ground proofing was done through field surveys. The construction areas were validated through satellite imageries. The main sources of secondary data collection were RSPCB Bhiwadi office, Census of India (Census 2011), CPCB's (www.cpcb.nic.in) scientific reports, and papers. The information has also been collected through the Internet by visiting various websites. Although all possible efforts have been made to collect the data, some information/data could be missing.

Hotels/Restaurants

The details of the hotels and restaurants were collected through field surveys and websites. During the field survey, it was observed that hotels, restaurants, etc. use coal as fuel in tandoors. The average consumption of coal in tandoor based on the survey was 30 kg/day. We assume that 25% of these enterprises use tandoor for food preparation. The common fuel other than coal in the tandoor was LPG. The fuel consumption for each fuel type was estimated for each grid. In most of the cases, it was found that there were no air pollution control devices installed at hotels and restaurants. The emissions of SO_2, NOx, PM_{10}, $PM_{2.5}$, and CO were estimated from the activity data from each fuel type and then were summed up in each grid cell. The emission factors given by CPCB (2011) were used. For spatial distribution of different pollutants, the hotel's locations were geotagged, and a separate shapefile was created. The hotels and restaurants emissions were then distributed into the 2 km x 2 km grid of the city.

Domestic Sector

The ward map of the Bhiwadi area was obtained from Nagar Nigam and it was digitized. The Bhiwadi consists of 35 municipal wards. The data on a number of households, fuel usage (coal, LPG, crop residue, cow dung, and wood) and population were collected from the Census of India (2011). LPG cylinders allotted to the citizens through Ujjawala yojna (11%; source: https://data.gov.in) were also considered while estimating the emissions. The emission factors are given by CPCB (2011) and AP-42 (USEPA, 2000) were used for each fuel type. Emissions of various pollutants were calculated from the activity data assuming no control device was installed.

MSW Burning

Open burning activities are broadly classified into refuse and biomass burning. The refuse or municipal solid waste (MSW) burning depends on solid waste generation and extent of disposal and infrastructure for collection. The emission factors are given by CPCB (2011) and AP-42 (USEPA, 2000) were used for estimating the emission from MSW burning.

Construction and Demolition

A detailed survey was undertaken to assess construction and demolition activities in the study area. The construction and demolition locations were then verified with satellite imagery.

Information on several buildings, roads, and flyovers under construction were collected from the Public Works Department (PWD) and the sites were physically surveyed. The areas under construction activities were calculated based on survey data and using GIS. The emissions were estimated using Eq (2.1) given by AP-42 (USEPA, 2000). The unit of the activity data is m^2, i.e. area of these activities.

$$E = 1.2 \text{ tons/acre/month of activity (tons/m}^2\text{/month)} \quad (2.1)$$

Agriculture Soil

The total agricultural area has been obtained through GIS by making a separate shapefile for the agricultural area. The emission factor for crop type is obtained from EMEP/EEA air pollutant emission inventory guidebook (EEA, 2013).

Industries as Ares Source

All industries having stack height below 20 m have been considered as an industrial area source. The majority of the industries is having small boilers, furnaces, etc. Most of the information on the industrial areas concerning fuel consumption, stack height, production capacity has been collected from RSPCB, for missing data standard default values were assumed to estimate the emissions. Ash content in the coal was assumed to be 35% and 'S' content as 1.8% for LDO;

1% for HSD (https://www.iocl.com/). CPCB (2011) and AP-42 (USEPA, 2000) emission factors were used to calculate the emissions. Finally, all the emission for each pollutant is summed up for each grid.

Industries as Point Source

The industries having a stack height of more than 20 m have been taken as a point source. The information on stacks, fuel, and its consumption was obtained from RSPCB. The AP-42 (USEPA, 2000) emission factors were used to calculate the emission.

Vehicle

The average daily flow of vehicles in each hour for 2Ws, 3Ws, 4Ws, LCVs, Buses, and Trucks at six locations were video recorded for a 24-hour duration. Road lengths in each cell for major and minor roads were calculated from the digitized maps using the ArcGIS tool, ArcMap and extracted into the grids. The information on traffic flow from traffic counts was translated into the vehicles on the roads in each grid. Wherever it was feasible, either traffic flow was taken directly from the traffic data, and for interior grids, traffic from medium roads going the highways was taken to flow in the interior part of the city. The emissions from each vehicle category for each grid is estimated and summed up.

To obtain the prevalence of vehicle technology types operating in the city and fuel used, parking lot questionnaire surveys (engine technology and capacity, vehicle age, fuel use, etc.) were done at seven locations (Relaxo chowk, Bhiwadi Mod, RIICO Chowk, Dhabha Mod, KG Plaza, Capital Mall, and Mansa Chowk) in the city of Bhiwadi.

The traffic flow from outside Bhiwadi from Daruhera, Alwar, and Gurgaon. ARAI (2011) was considered to calculate the emissions using CPCB (2011) emission factors. The emission factors vary considerably for engine size, fuel uses, and age of the vehicles.

Road Dust

Dust emissions from paved and unpaved roads depend on the ‘silt loading’ present on the road surface and average weight of vehicles traveling on the road. The term silt loading (sL) refers to the mass of the silt-sized material (equal to or less than 75 μm in physical diameter) per unit area of the travel surface. The quantity of dust emissions from the movement of vehicles on a paved or unpaved road can be estimated using the following empirical expression 2.2:

$$E_{ext} = [\ k\ (sL)^{0.91} \times (W)^{1.02}\ ]\ (1 - P/4N) \quad ...(2.2)$$

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

sL = road surface silt loading (grams per square meter) (g/m2), and

W = average weight (tons) of the vehicles traveling the road.

E_{ext} = annual or other long-term average emission factors in the same units as k,

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

N = number of days in the averaging period.

K : constant (a function of particle size) in g VKT^{-1}(Vehicle Kilometer Travel).

DG Sets

DG sets are used as the source of power in shopping complexes and industries during the power-cuts. From the results of the survey, it can be concluded that there is a minimum of 4 hours/day power cut in the city, especially in summer. The DG set details were obtained from the RSPCB Bhiwadi office; the DG sets were geotagged on the map using GIS.

The unit of the activity data is KWh power generation. The emissions from DG sets installed in industries were estimated and then were summed up for each grid. The calculation is based on Eq (2.3), where ER, overall efficiency reduction was taken as zero. The CPCB (2011) emission factors were used for emission estimation.

The general equation for emissions estimation is:

$$E = A \times EF \times (1 - ER/100) \qquad (2.3)$$

Where:
E = Emissions;
A = Activity rate;
EF = Emission factor, and
ER = Overall emission reduction efficiency, %

2.2.3 Emission Estimation

For estimating the emissions activity data is calculated using the collected and generated data (Eq.2.3). The activity data is then multiplied with emission factors of a process type for that activity.

Emission Factor

An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the mass of pollutant per unit mass of raw material, volume, distance traveled, or duration of the activity (e.g., grams of particulate emitted per kilogram of coal burnt). Such factors facilitate the estimation of emissions from various sources of air pollution. In most cases, these factors are simply averaging of all available data of acceptable quality and are generally assumed to be representative of long-term averages for all facilities in the source category.

2.3 Dispersion Modelling

The dispersion modeling can assist in examining the (i) impact of emission on air quality, (ii) spatial extent of impact of pollution sources, (iii) possible impact of outside sources and (iv) planning emission control and improvement in air quality. The state-of-the-science, comprehensive meteorological and regulatory air dispersion modeling systems were used to conduct air emission modeling in this study are briefly described below.

The modeling approach is shown in Figure 2.15 and is based on the AERMET diagnostic meteorological model and the American Meteorological Society/ Environmental Protection Agency Regulatory Model (AERMOD) dispersion model (USEPA, 2018).

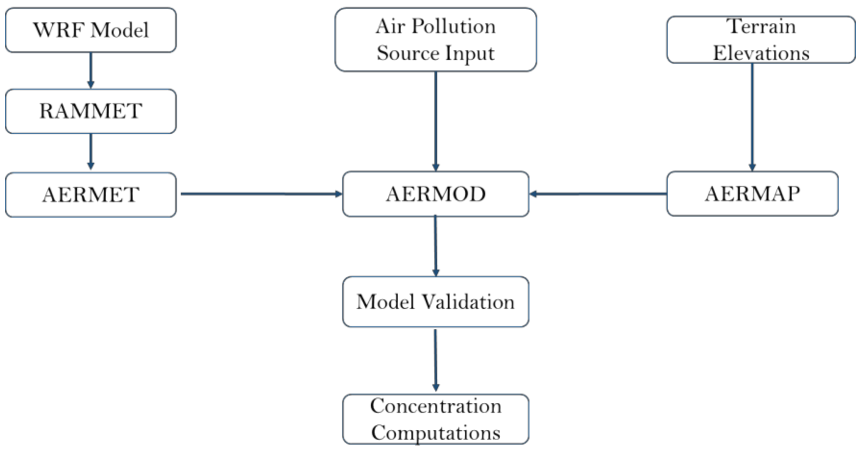

Figure 2. 15: Methodology adopted for Air Quality Modeling

AERMOD is a dispersion model having the ability to characterize the planetary boundary layer (PBL) through both surface and mixed layer scaling. This model is called the AMS/USEPA regulatory model, or AERMOD and a complete and powerful air dispersion modeling package which seamlessly incorporates the following popular USEPA air dispersion models into one integrated interface:

- AERMOD
- ISCST3
- ISC-PRIME

The AERMOD modeling system consists of one main program ***(***AERMOD***)*** and two preprocessors (AERMET and AERMAP)**.** AERMOD uses terrain, boundary layer, and source data to model pollutant transport and dispersion for calculating temporally averaged air pollution concentrations**.**

Onsite hourly meteorological data were generated and validated by WRF (weather research and forecast) model**.** This validated meteorological data were used as the inputs to AERMOD in pre-processor RAMMET and AERMET of the model**.** These meteorological parameters from the WRF model ***(***wind speed, wind direction, rainfall, temperature, humidity, pressure, ceiling height, global horizontal radiation and cloud cover***)*** were prepared for the dispersion model**.** The terrain elevations were also being considered, this will provide a relationship between terrain features and the behavior of air pollution plumes**.**

2.4 Emission Control Options: Analysis and Prioritization of Options

The emission control plan depends on current air quality levels and options and extent of control required at various sources including line, area, and point source and analyzes the results in terms of air quality improvements. An impact and action matrix were developed for the existing scenario. The developed matrix is used for prioritizing the list of management options for sources in a temporal framework leading to the city-specific action plan. The study evolves a city-specific control action plan consisting of several control options of various sources. In the process of finding the best control scenario, possible control options are identified to reduce the ambient PM via emission reduction at source. After the finalization of selected control options, the control scenario was formulated by combinations of the various control options.

Chapter 3: Emission Inventory

3.0 Introduction

Emission inventory (EI) is a basic necessity for planning air pollution control activities. EI provides a reliable estimate of total emissions of different pollutants, their spatial and temporal distribution, and identification and characterization of main sources. This information on EI is an essential input to air quality models for developing strategies and policies. The ultimate goal of the planning process is to identify and achieve emission patterns that do not result in violations of ambient air quality standards. In this chapter, the emission inventory of the area is presented.

The broad emission source categories of air pollution in an urban area include; (i) transport (motor vehicles and railways), (ii) commercial establishments, (iii) industrial, (iv) domestic cooking/heating, (v) fugitive dust and (vi) biomass burning. There could also be some unique or specific sources in a particular area. Procedures and reliability of emission inventory for regular point, area and line sources are well-established. However, identification and quantification of fugitive/non-point emission sources (emissions not released through stacks, vents, ducts or pipes) are quite challenging but best available practices have been used in this study. Digital data generated in Chapter 2 (reproduced as Figure 3.1) having multiple layers of spatially sensitive information are extensively used in EI estimation.

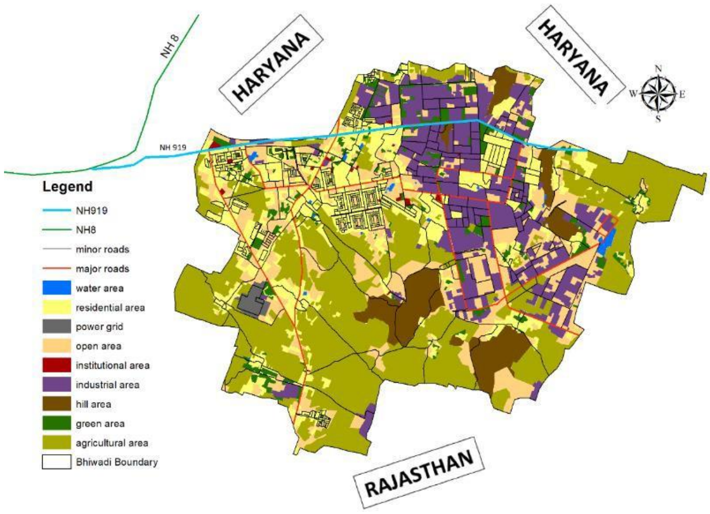

Figure 3. 1*:* Landuse Map of the Study Area

At the time of development of the emission inventory for the city, a suitable coding system has been adopted to avoid the confusion and misrepresentation of results and interpretation. The map with grid identity numbers is shown in Figure 3.2.

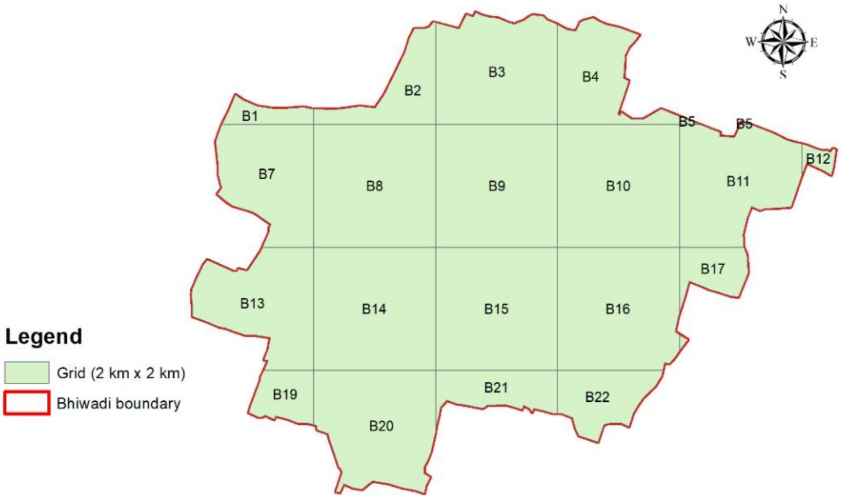

Figure 3. 2*:* Grid Map of the City Showing Grid Identity Numbers

3.1 Area Sources

3.1.1 Hotels/Restaurants

The overall emission from this area source (Hotels/Restaurants) is presented in Figure 3.3.

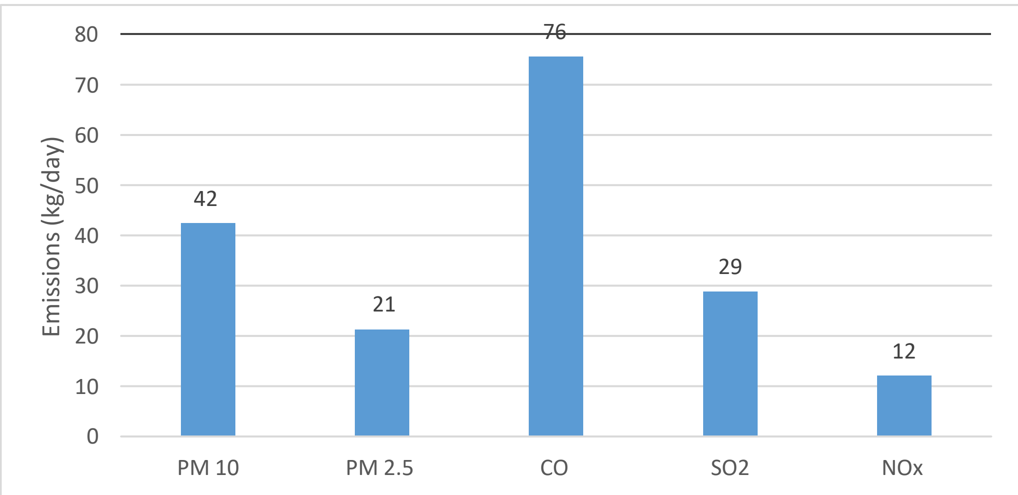

Figure 3. 3*:* Emission Load from Hotels/Restaurant

The spatial distribution of emissions of PM_{10}, $PM_{2.5}$, NOx, SO_2 and CO from Hotel/Restaurants is presented in Figure 3.4 to 3.8.

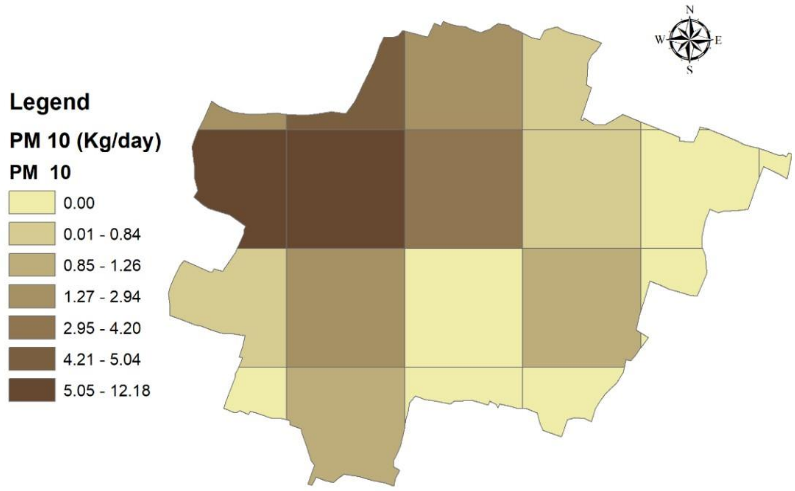

Figure 3. 4*:* Spatial Distribution of PM_{10} Emissions from Hotel/Restaurants

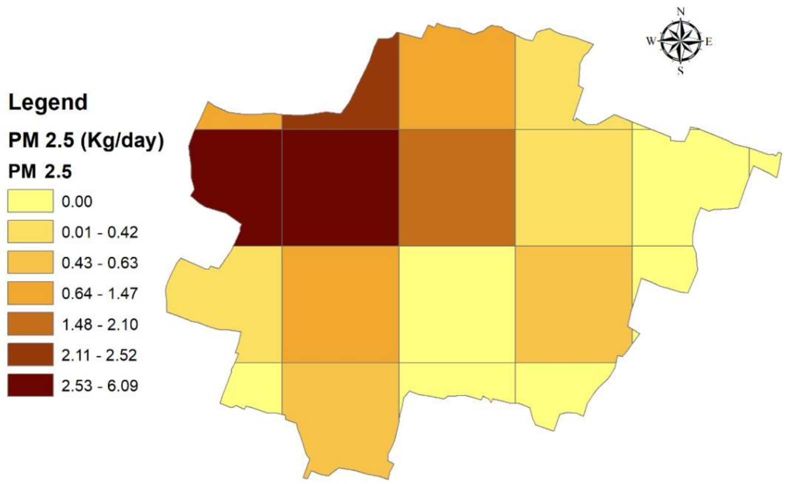

Figure 3. 5*:* Spatial Distribution of $PM_{2.5}$ Emissions from Hotel/Restaurants

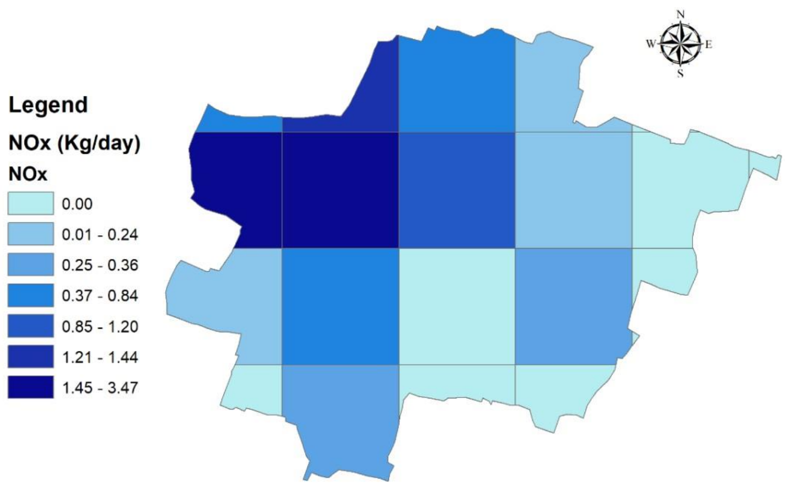

Figure 3. 6*:* Spatial Distribution of NOx Emissions from Hotel/Restaurants

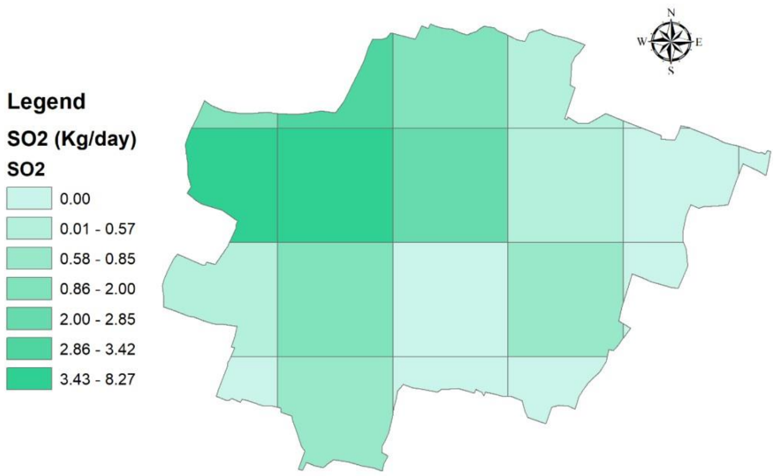

Figure 3. 7*:* Spatial Distribution of SO_2 Emissions from Hotel/Restaurants

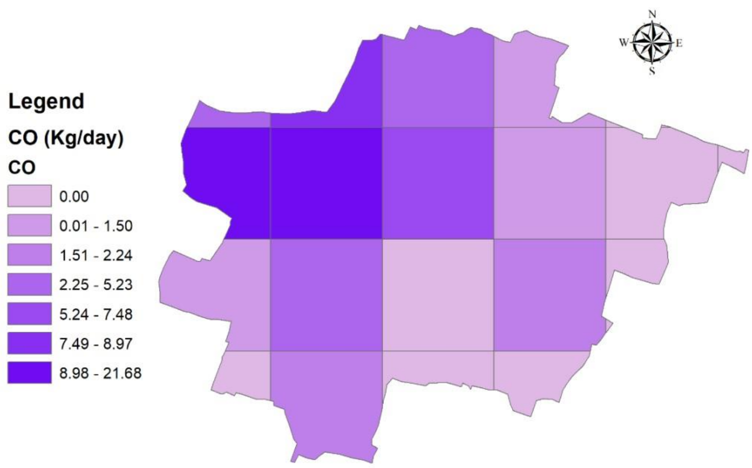

Figure 3. 8*:* Spatial Distribution of CO Emissions from Hotel/Restaurants

3.1.2 Domestic Sector

The interior boundaries in the map (Figure 3.9) show the administrative boundaries of wards and villages. After obtaining the area of wards and villages, the emission density for each ward is calculated for different pollutants (PM_{10}, $PM_{2.5}$, SO_2, NOx, and CO).

The overall emission from domestic sources is presented in Figure 3.10. The emission contribution from different fuel types to different pollutants is shown in Figures 3.11 to 3.15. The spatial distribution of emissions from the domestic sector is shown in Figure 3.16 to 3.20.

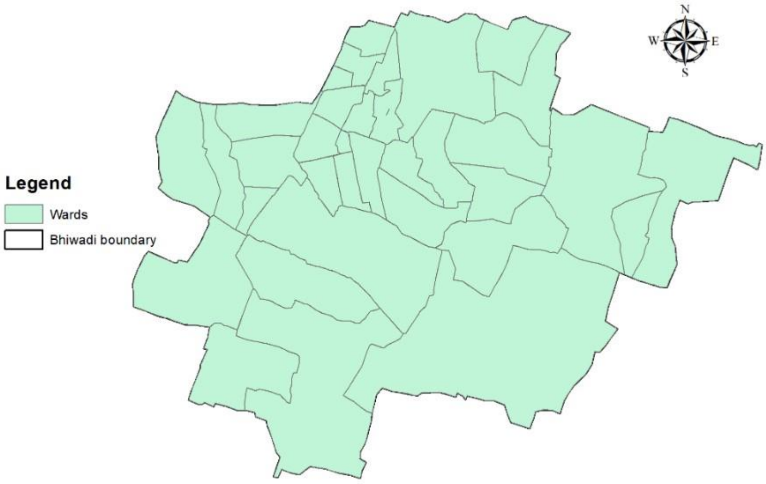

Figure 3. 9*:* Administrative Boundaries of Wards and Village

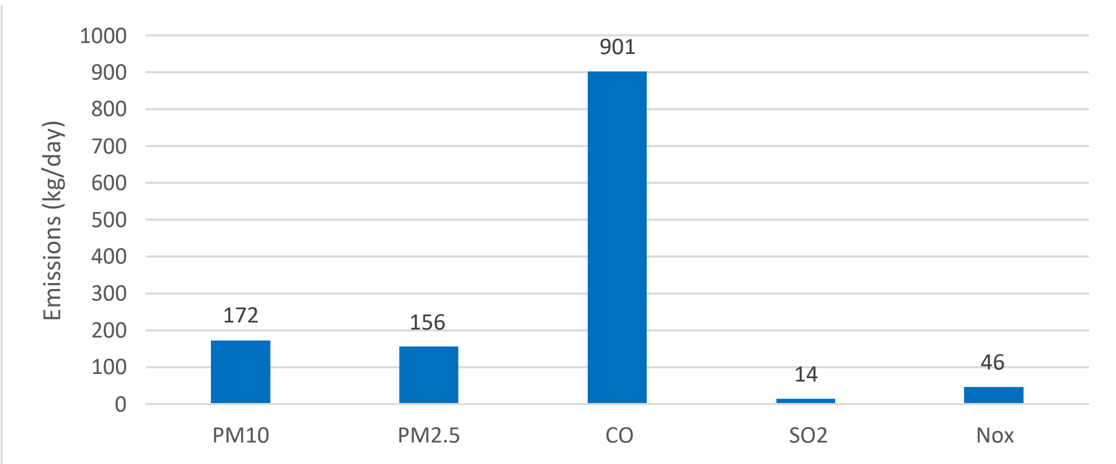

Figure 3. 10*:* Emission Load from domestic sources *(*kg/day*)*

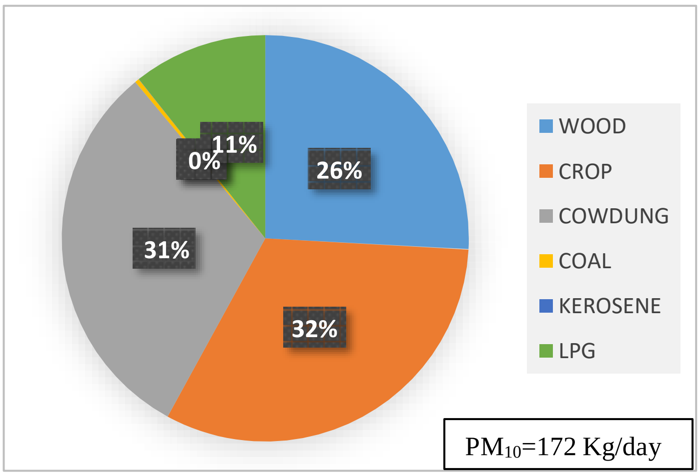

Figure 3. 11:PM_{10} Emission Load from domestic sources *(*kg/day, *%)*

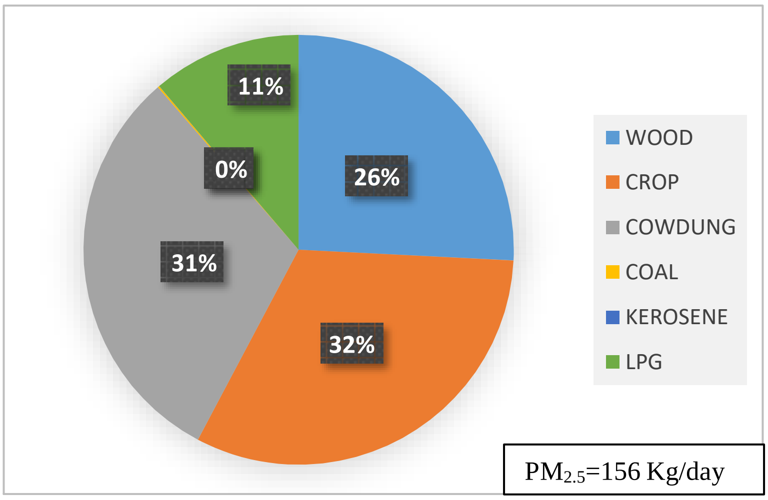

Figure 3. 12*:* $PM_{2.5}$ Emission Load from domestic sources *(*kg/day, *%)*

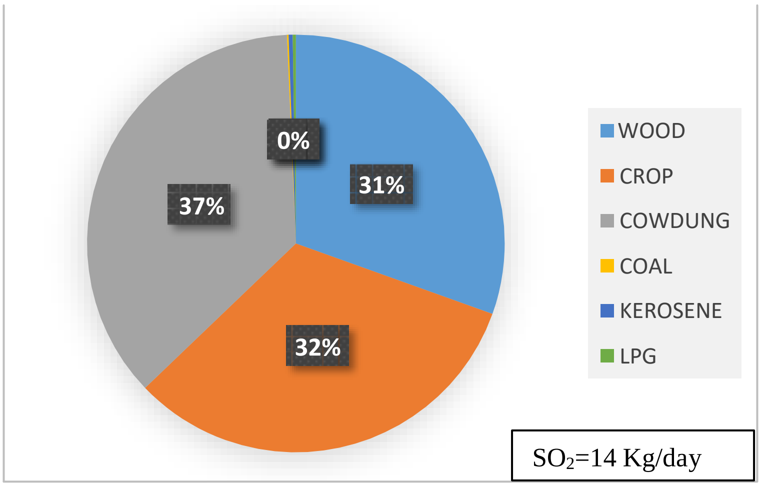

Figure 3. 13*:* SO_2 Emission Load from domestic sources *(*kg/day, *%)*

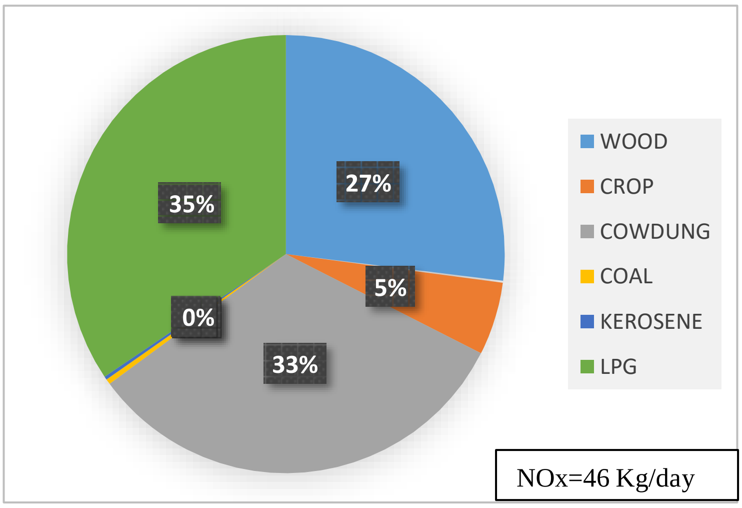

Figure 3. 14*:* NOx Emission Load from domestic sources *(*kg/day, *%)*

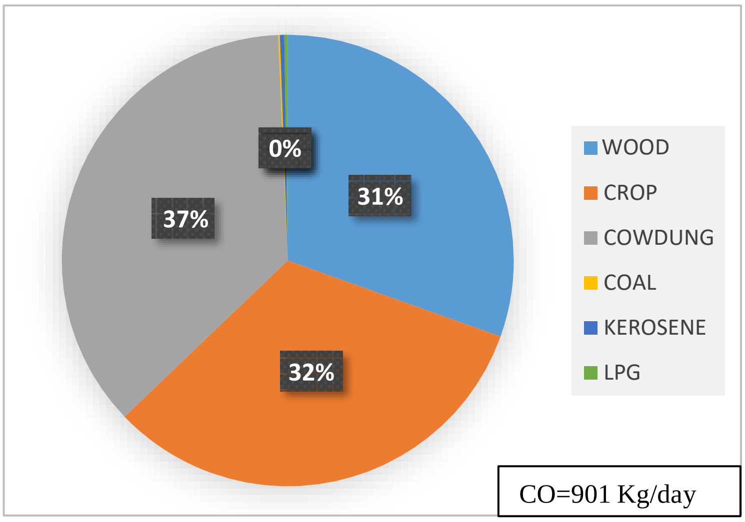

Figure 3. 15*: CO Emission Load from domestic sources (kg/day, %)*

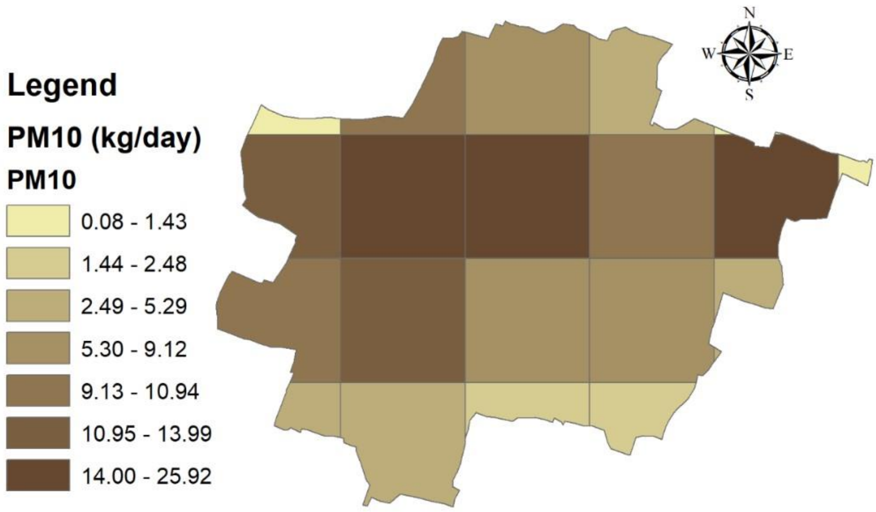

Figure 3. 16*: Spatial Distribution of PM_{10} Emissions from Domestic Sector*

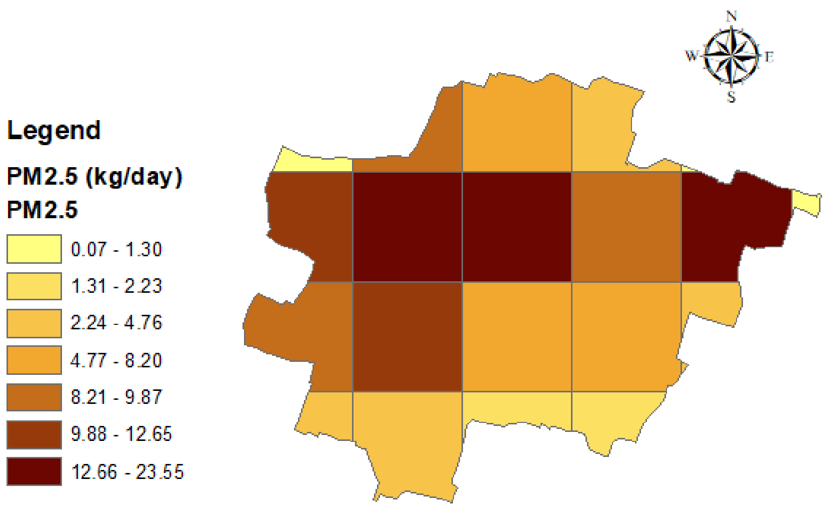

Figure 3. 17*: Spatial Distribution of $PM_{2.5}$ Emissions from Domestic Sector*

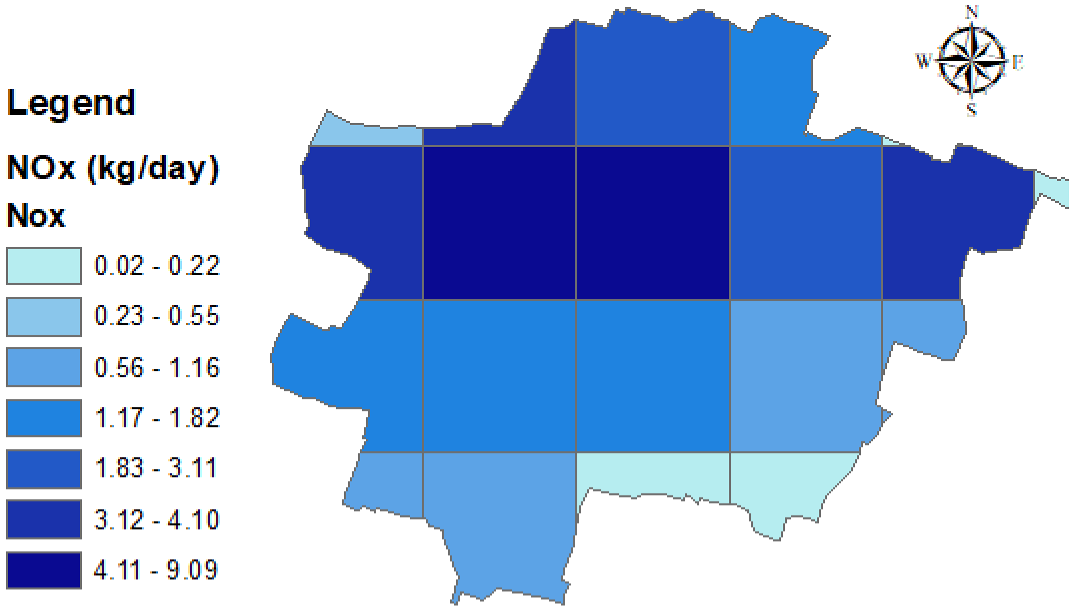

Figure 3. 18*:* Spatial Distribution of NOx Emissions from Domestic Sector

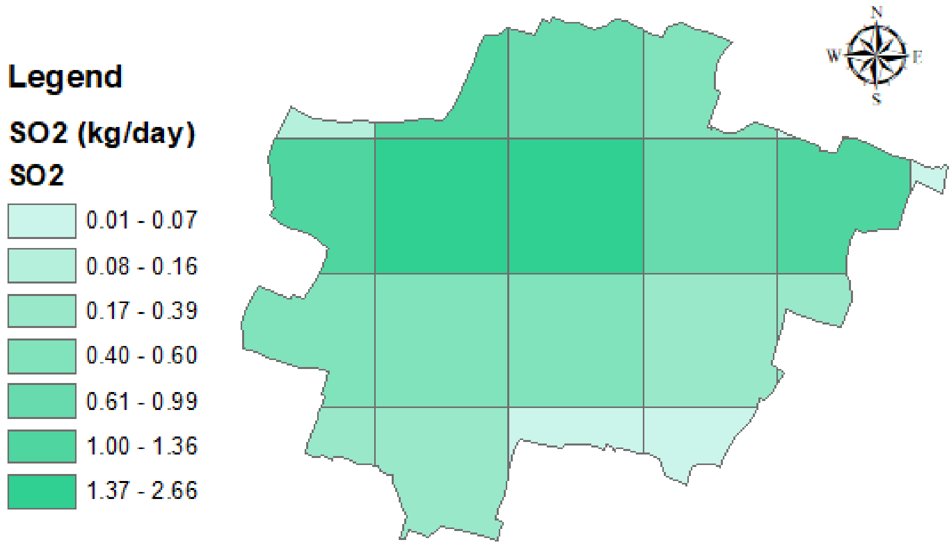

Figure 3. 19*:* Spatial Distribution of SO_2 Emissions from Domestic Sector

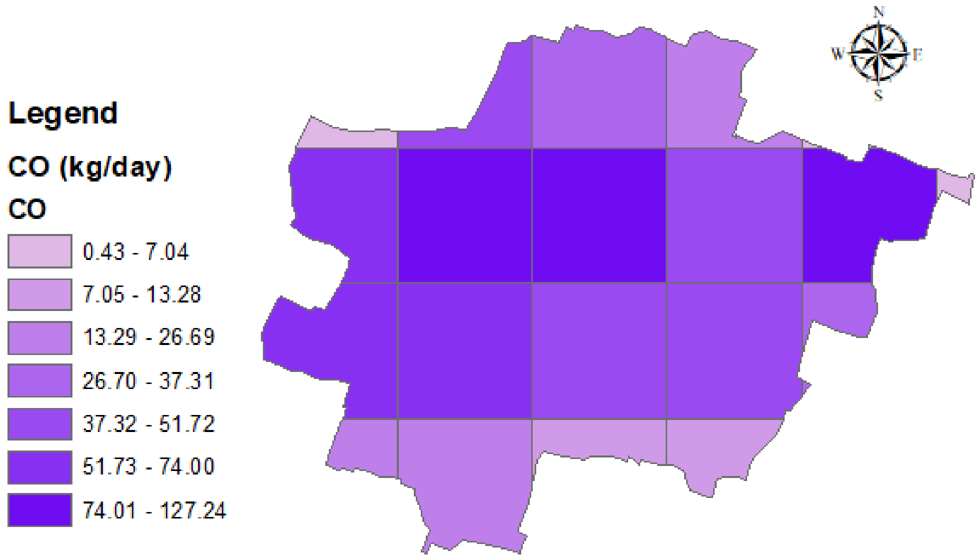

Figure 3. 20*:* Spatial Distribution of CO Emissions from Domestic Sector

3.1.3 Municipal Solid Waste Burning

The ward-wise MSW generation is presented in Figure 3.21. Bhiwadi city is generating about 42 tonnes per day of MSW. The MSW burning is widespread in Bhiwadi, which is more frequent in winter.

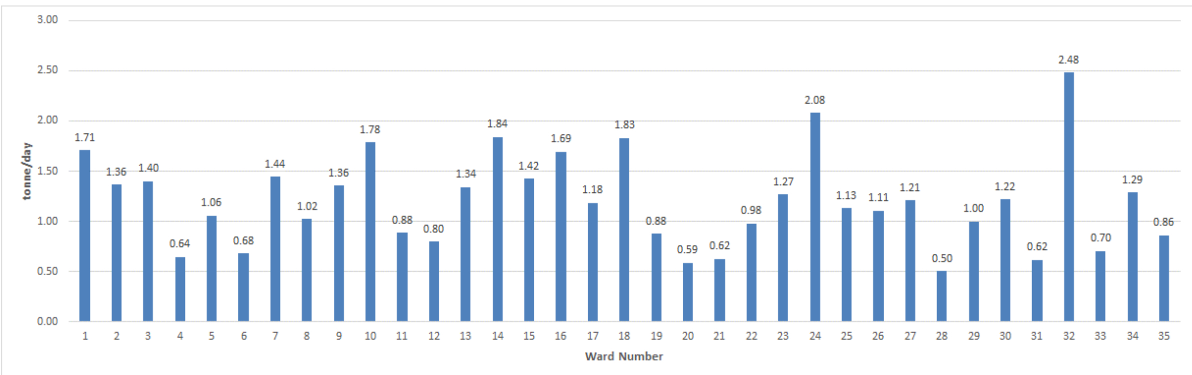

Figure 3. 21*:* Estimated Ward-wise MSW Generation

Out of 42 tonnes/day of MSW, only about five tonnes/day is collected and disposed of perhaps unscientifically (CPCB 2011). In the absence of any designated dumping ground/ landfill site, agencies entrusted with the task of waste management are dumping waste indiscriminately in open areas. The MSW burning in Bhiwadi is also widespread (Figure 3.22). It is clearly seen that MSW burning is a major source that can contribute to both PM_{10} and $PM_{2.5}$. This emission is expected to be large in the regions of economically lower strata of the society which do not have proper infrastructure for the collection and disposal of MSW.

It is assumed that uncollected MSW is disposed of by burning it in open areas. This MSW could also have hazardous industrial waste disposed of in a clandestine manner that also may get burnt with MSW (Figure 3.23).

The estimated emissions from MSW burning are: 296 kg/d of PM_{10} and about 177 kg/d of $PM_{2.5}$ (Figure 3.24) and spatially variation is shown in figure 3.25 to 3.29.

(a) (b) (c)

Figure 3. 22: MSW Burning in Bhiwadi

Figure 3. 23:: Industrial Waste Burning in Bhiwadi

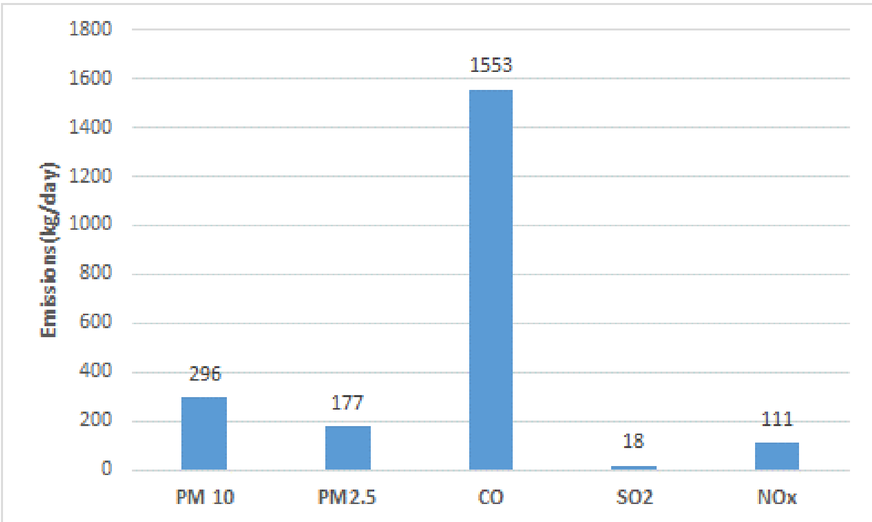

Figure 3. 24*: Emission Load from MSW Burning (*kg/day*)*

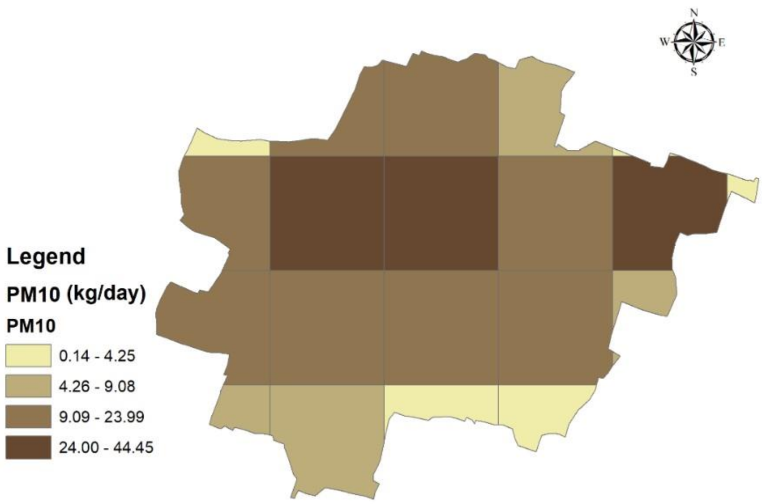

Figure 3. 25*: Spatial Distribution of PM_{10} Emissions from MSW Burning*

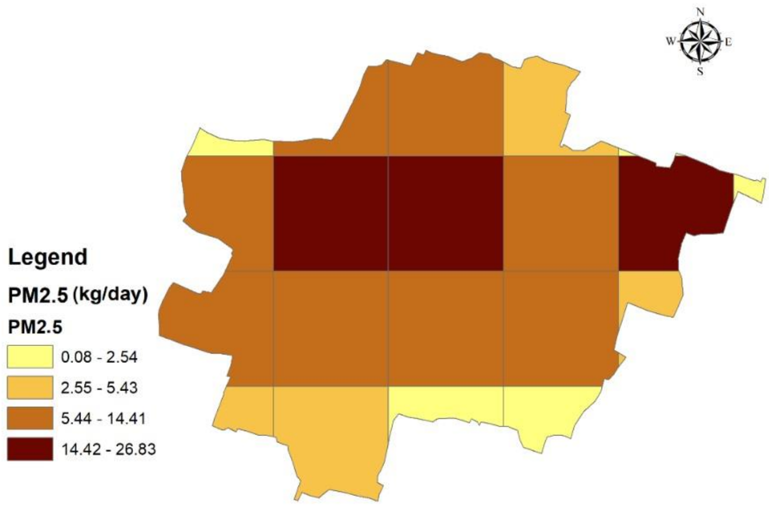

Figure 3. 26*:* Spatial Distribution of $PM_{2.5}$ Emissions from MSW Burning

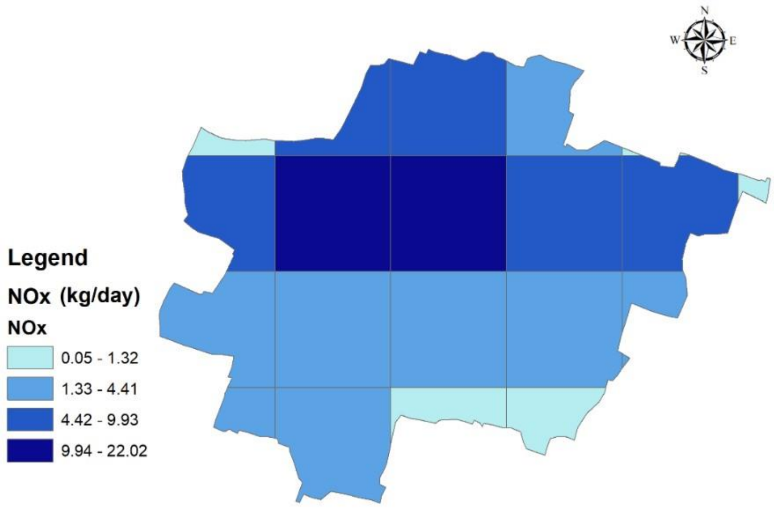

Figure 3. 27*:* Spatial Distribution of NOx Emissions from MSW Burning

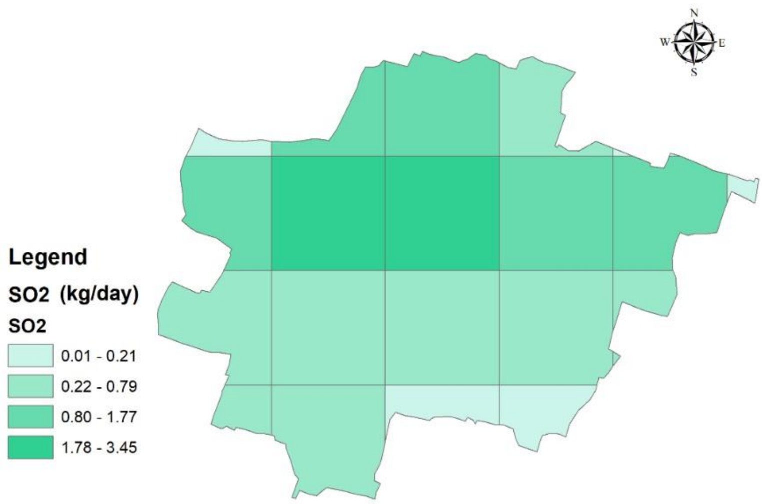

Figure 3. 28*:* Spatial Distribution of SO_2 Emissions from MSW Burning

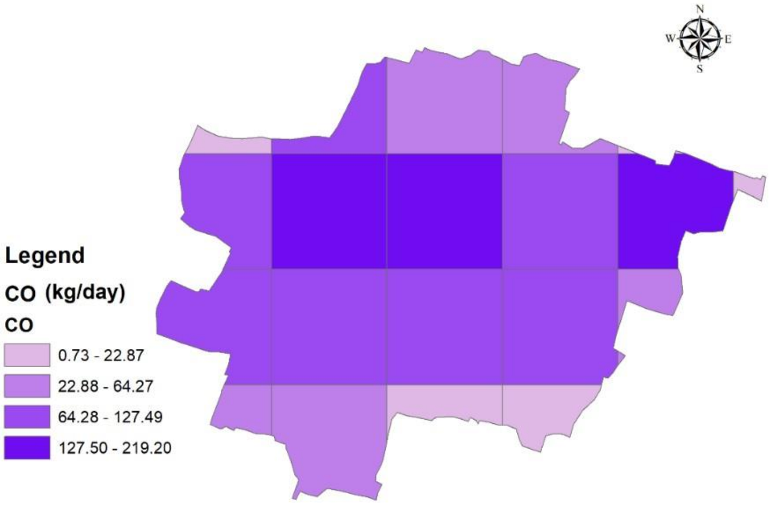

Figure 3. 29*:* Spatial Distribution of CO Emissions from MSW Burning

3.1.4 Construction and Demolition

A detailed survey was undertaken to assess construction and demolition activities. The construction and demolition sites are shown in Figure 3.30 with a total area of 68980 m^2 under building construction. The major construction activities include residential housing as well as commercial construction. Construction in the industrial area is relatively small.

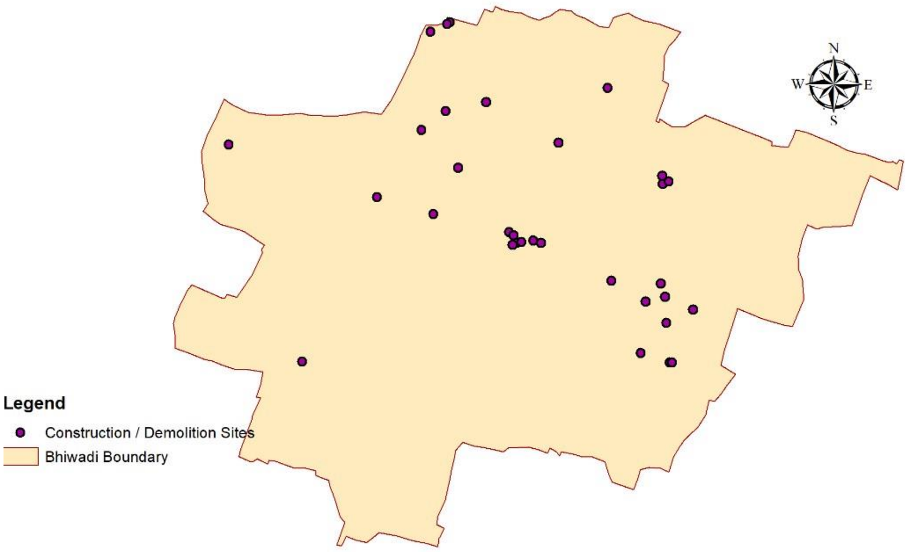

Figure 3. 30*:* Construction/Demolition Sites

Total emission from construction and demolition activities is presented in Table 3.1. The spatially resolved map of construction and demolition activities is shown in Figures 3.31 to 3.32.

Table 3. 1*: Emission Load from Construction and Demolition activities (*kg/day*)*

Category	**TSP**	**PM_{10}**	**$PM_{2.5}$**
Buildings	682	170	43
Roads	235	59	15
Totals	**917**	**229**	**58**

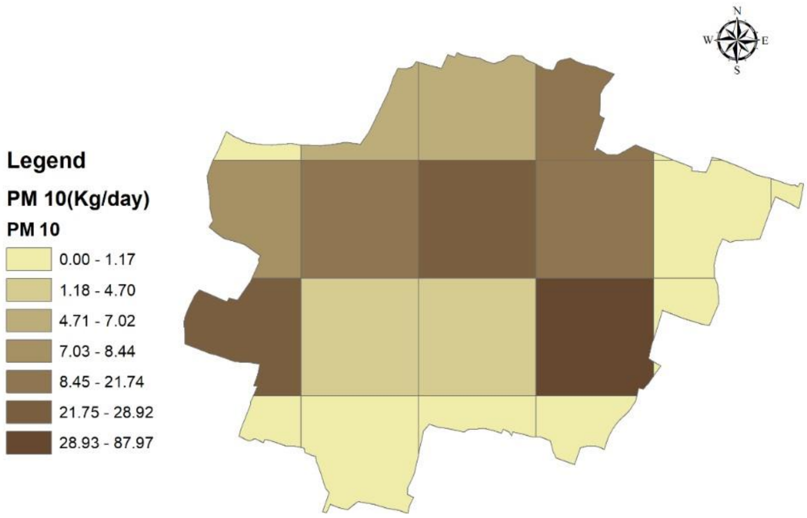

Figure 3. 31*: Spatial Distribution of PM_{10} Emissions from Construction/Demolition*

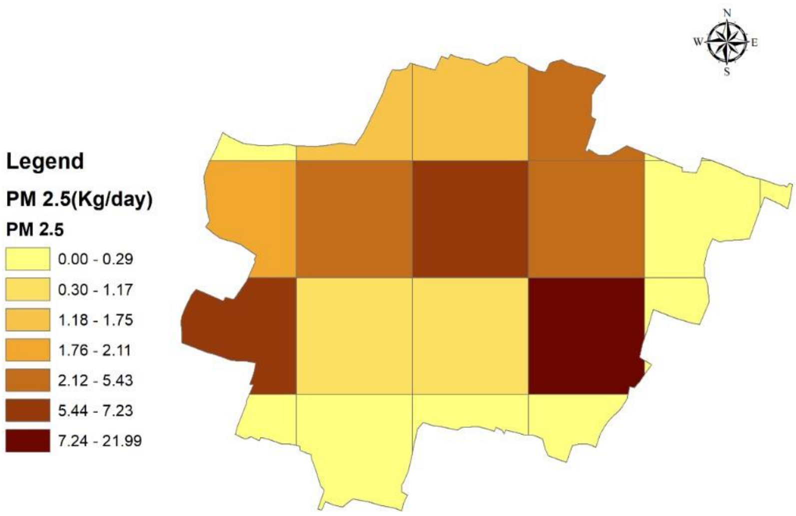

Figure 3. 32*: Spatial Distribution of $PM_{2.5}$ Emissions from Construction/Demolition*

3.1.5 Diesel Generator Sets (DG sets)

There are about 630 DG sets (422 with > 100 KVA and 208 <100KVA capacity). The total emissions from DG sets are presented in Figure 3.33. It is assumed that DG sets operate for two hours per day. Spatial distribution of emissions from DG Sets is shown in Figures 3.34 to 3.38.

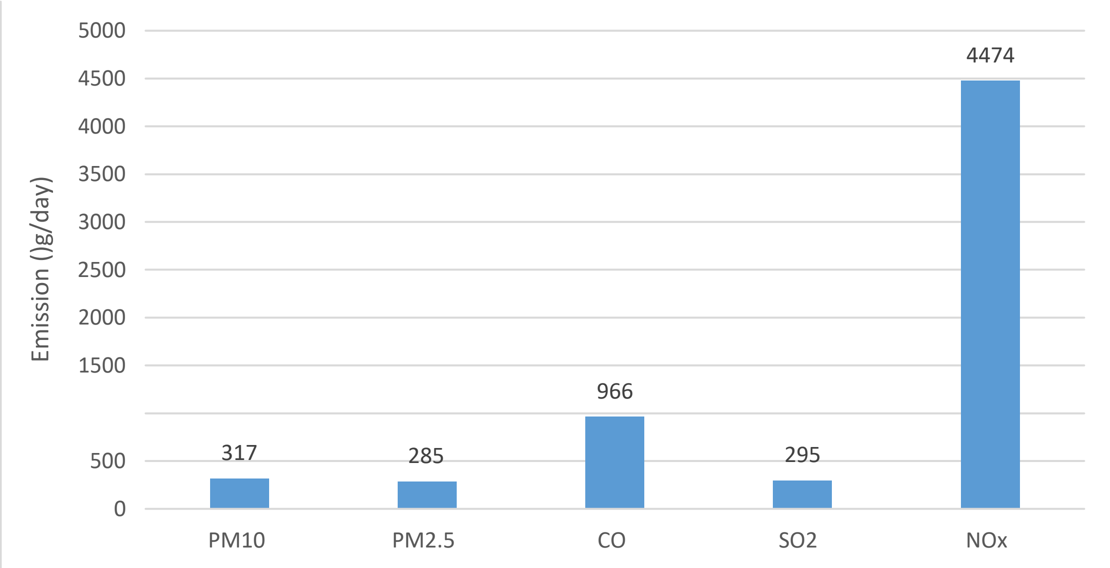

Figure 3. 33*: Emission Load (kg/day)* from DG sets

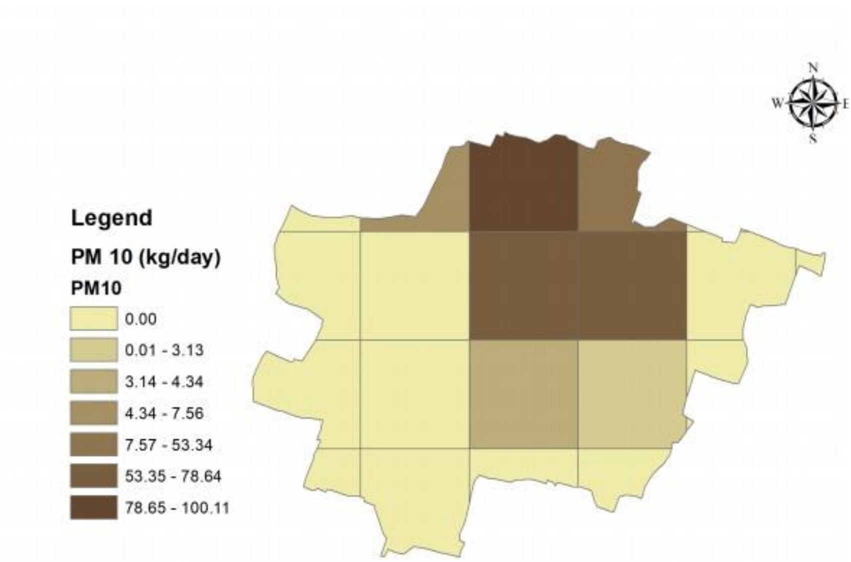

Figure 3. 34*:* Spatial Distribution of PM_{10} Emissions from DG Sets

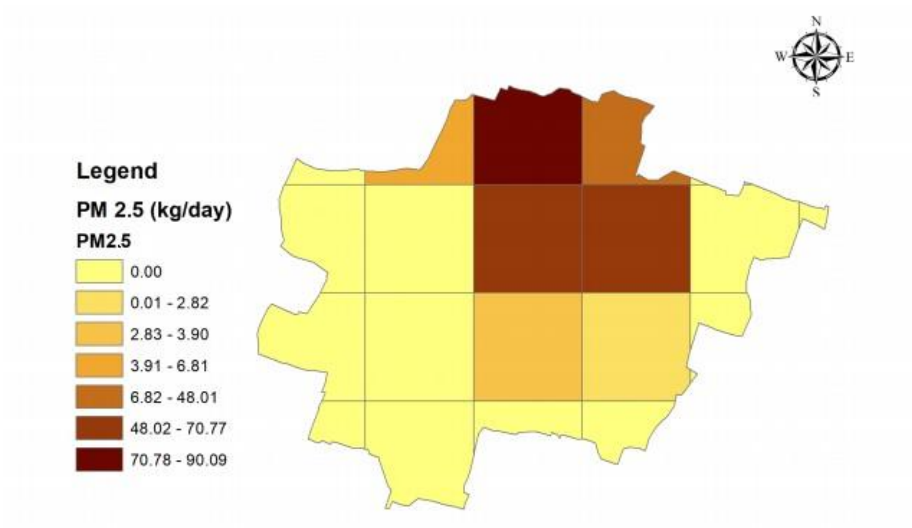

Figure 3. 35*:* Spatial Distribution of $PM_{2.5}$ Emissions from DG Sets

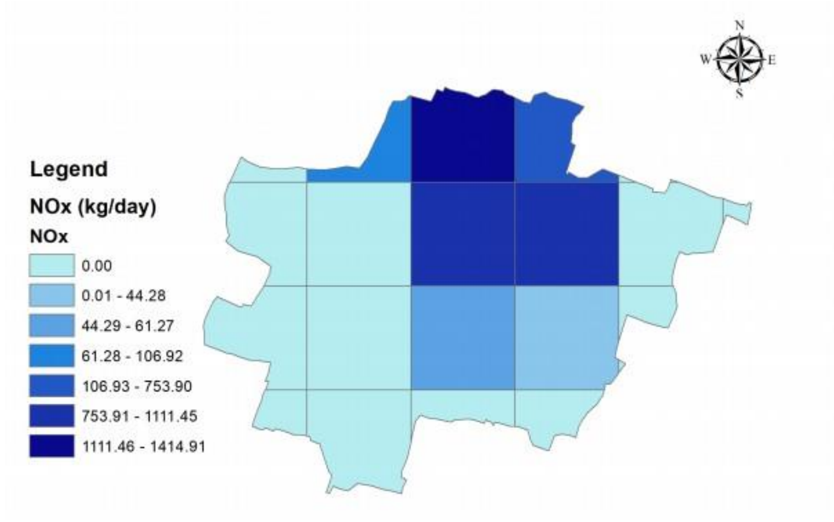

Figure 3. 36*:* Spatial Distribution of NOx Emissions from DG Sets

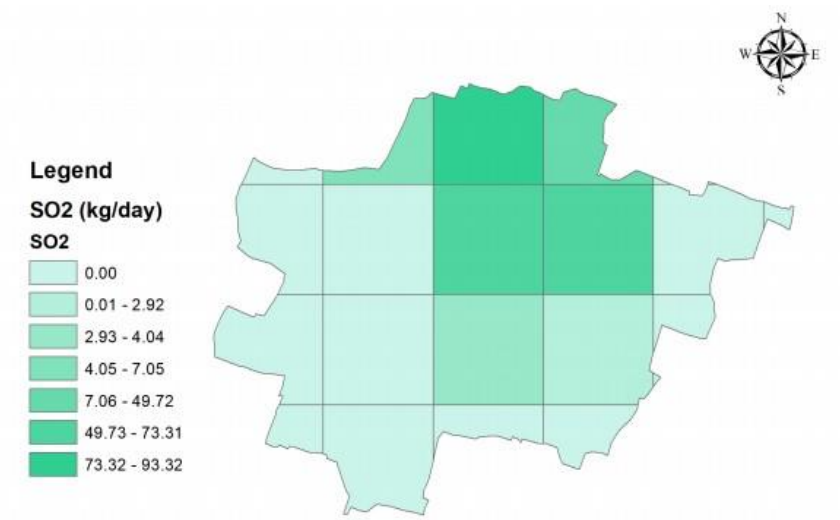

Figure 3. 37*:* Spatial Distribution of SO_2 Emissions from DG Sets

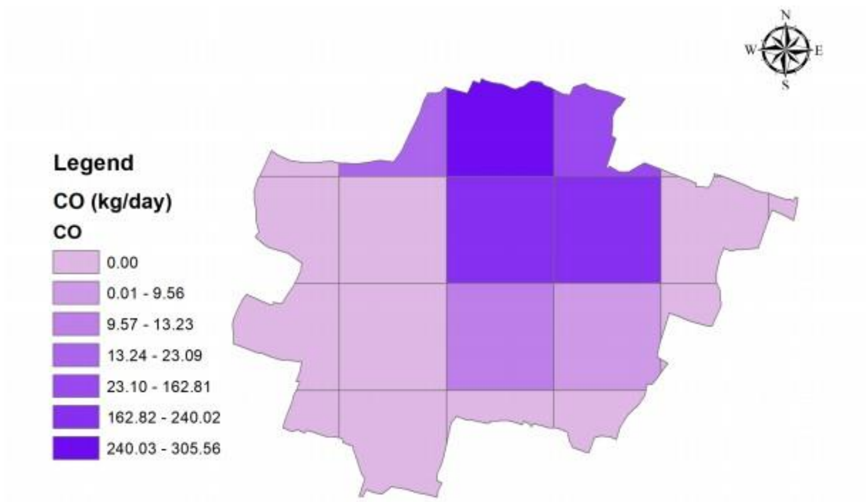

Figure 3. 38*:* Spatial Distribution of CO Emissions from DG Sets

3.1.6 Agricultural Operations

The total agricultural land in the Bhiwadi estimated from the land-use pattern is 1650 hectares. The total PM_{10} emission from agricultural soil dust is estimated to be 44 kg/day. The $PM_{2.5}$ emissions are negligible from this source.

3.1.7 Industry (Area Source)

The south and southwest region of Bhiwadi consists of an agricultural and hill area, whereas most industries are located in the central and north regions of the city (Figure 3.39). Figure 3.40 presents the overall emissions from industries (stack height < 20 m) as an area source. Spatial distribution of emissions from industries as an area source is presented in Figures 3.41 from
3.45.

There are about 250 air polluting industries in Bhiwadi operating in Bhiwadi city, out of which, about 120 are metal processing industries, which include automobile parts manufacturers, forging, alloy and steel parts (sheets, ingots, etc). Another category of industries includes chemical manufacturing, etc.

These industries are extensively using coal, especially in baby boilers, which is causing heavy air pollution. The less efficient air pollution control devices in most induction furnace operations (pouring and casting, casting cleaning, charge handling and casting cooling) contribute significantly to the emissions (for details see Section 3.3).

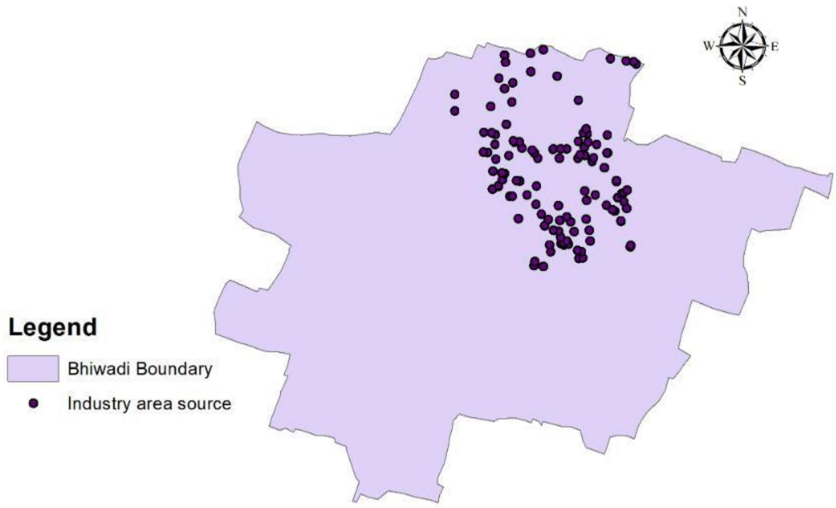

Figure 3. 39*:* Location of Industries in Bhiwadi

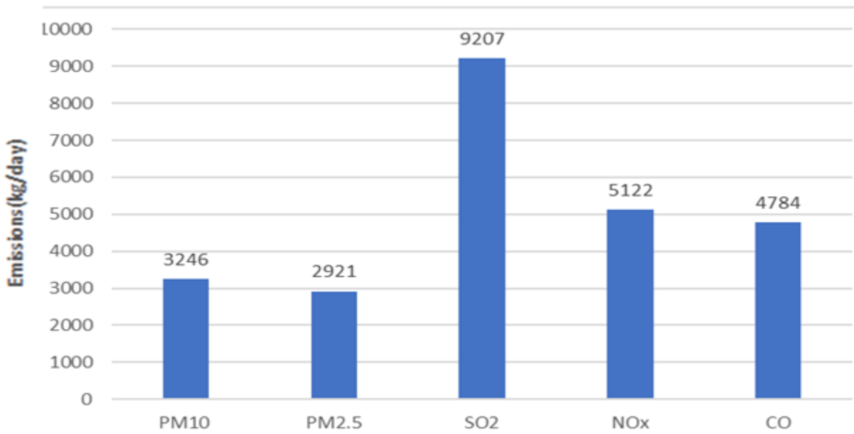

Figure 3. 40*:* Emission Load from Industries as Area Source (kg/d)

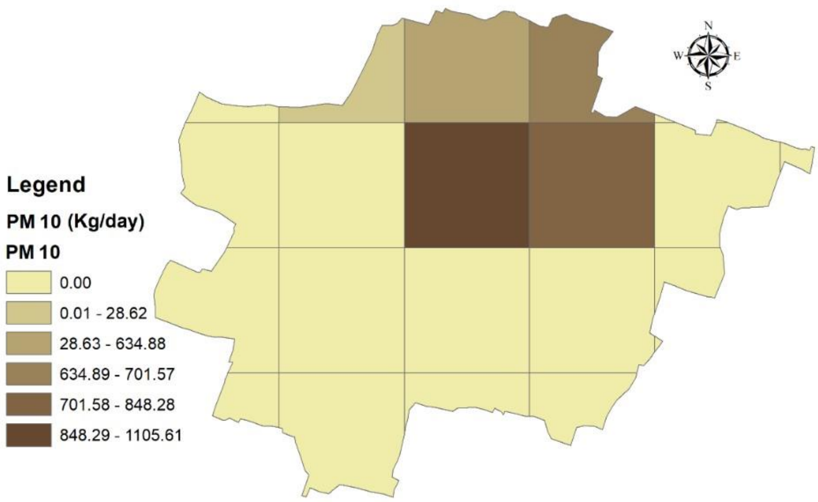

Figure 3. 41*:* Spatial Distribution of PM_{10} Emissions from Industries as Area Source

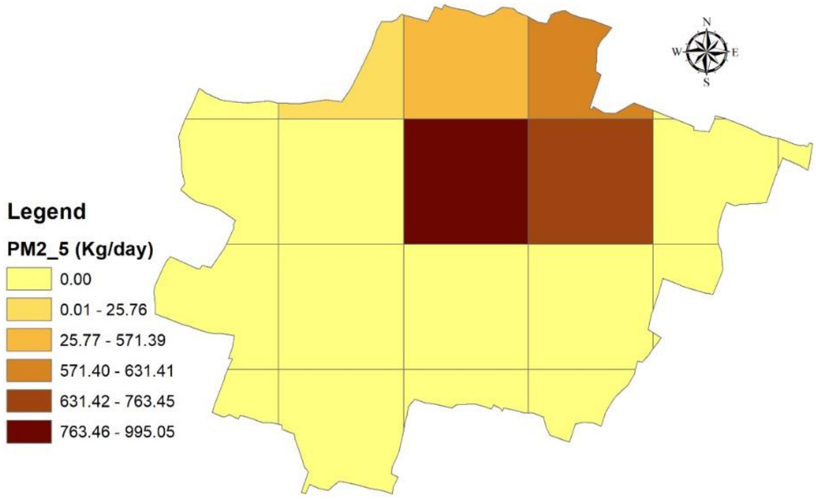

Figure 3. 42*:* Spatial Distribution of $PM_{2.5}$ Emissions from Industries as Area Source

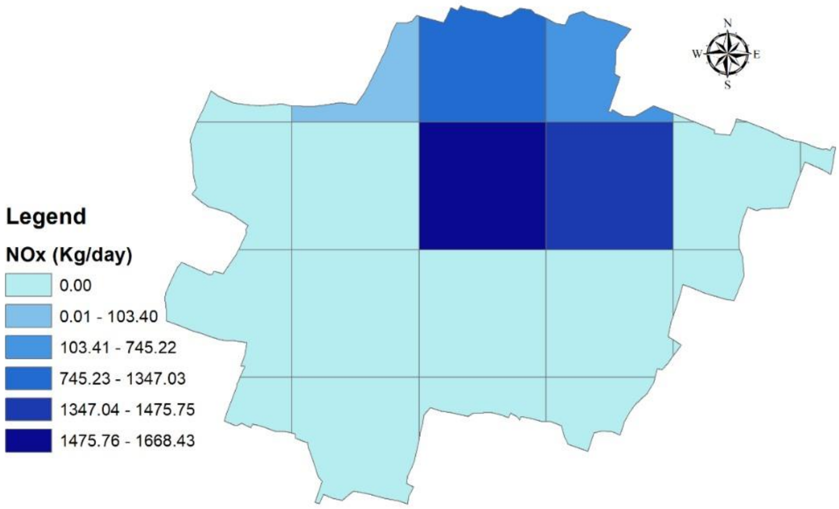

Figure 3. 43*:* Spatial Distribution of NOx Emissions from Industries as Area Source

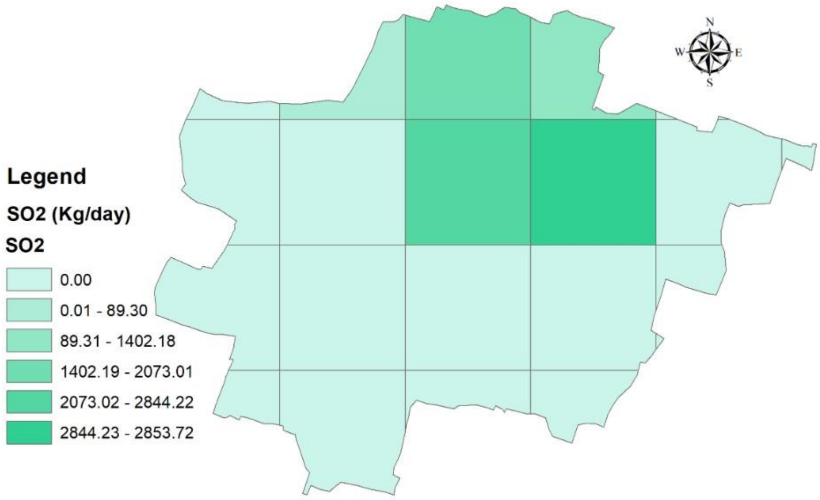

Figure 3. 44*:* Spatial Distribution of SO_2 Emissions from Industries as Area Source

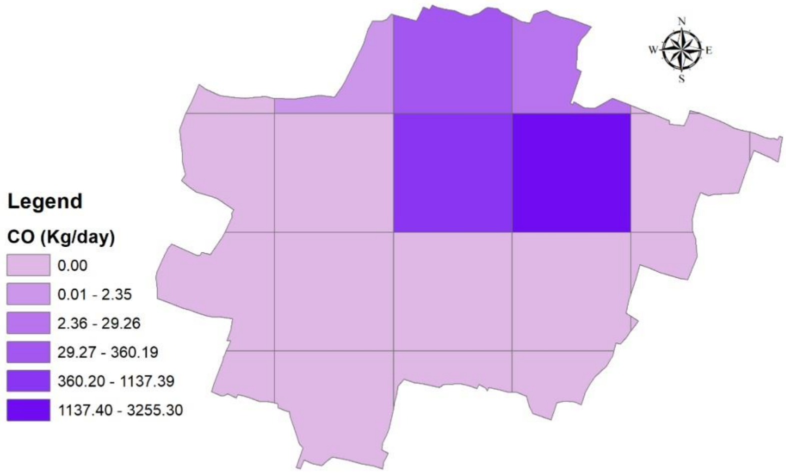

Figure 3. 45*: Spatial Distribution of CO Emissions from Industries as Area Source*

Summary of emissions from various area source categories discussed above are presented in Table 3.2.

Table 3. 2*: Summary of Emission Load from Area Sources (*kg/day*)*

Category	PM_{10}	(%)	$PM_{2.5}$	(%)	CO	(%)	SO_2	(%)	NOx	(%)
Hotel	42	1	21	1	76	1	29	0	12	0
Domestic	172	4	156	4	901	11	14	0	46	0
Industrial Area	3246	75	2921	81	4784	58	9207	96	5122	52
DG Set	317	7	285	8	966	12	295	3	4474	46
MSW Burning	296	7	177	5	1553	19	18	0	111	1
Contruction/Demolition	229	5	58	2	0	0	0	0	0	0
Agricultural Soil Dust	44	1	0	0	0	0	0	0	0	0
Total	**4346**	**100**	**3618**	**100**	**8280**	**100**	**9564**	**100**	**9765**	**100**

The major contribution for PM_{10} is from industries (stack height < 20 m), followed by DG sets and MSW burning. For NOx, the largest source is Industry (Area source) followed by DG sets.

3.2 Point Sources

The large industries having stack height >20 m industries have been located on the map (Figure 3.46); there are more than 60 such industries. The emission of pollutants from large industries is given in Table 3.3 and Figure 3.47. The spatial distribution of emissions from point sources is presented in Figures 3.48 to 3.52.

Table 3. 3: Emission Load from Point Sources

Category	PM_{10}	$PM_{2.5}$	CO	SO_2	NOx
Industries	736	663	3070	1901	1712

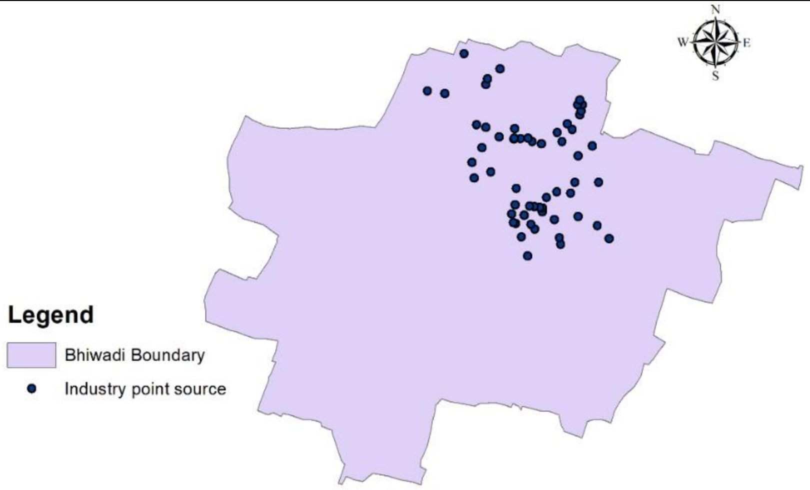

Figure 3. 46: Locations of Points Sources in the City

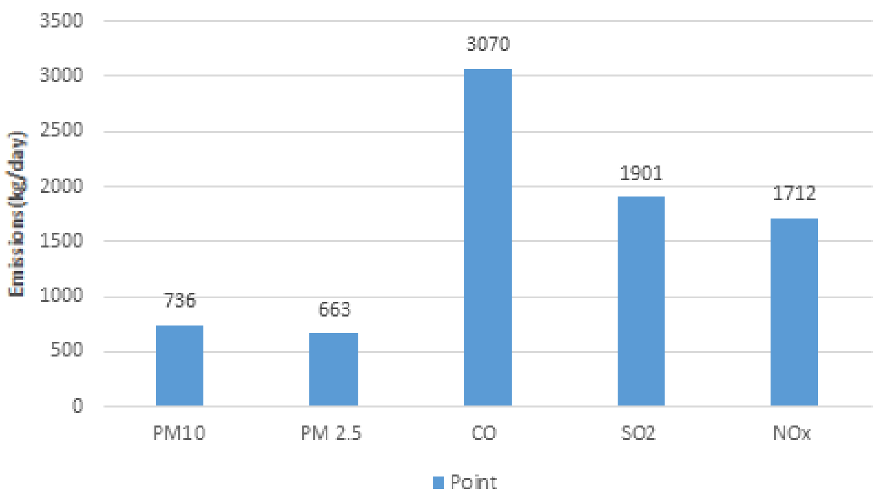

Figure 3. 47: Emission Load from Point Sources

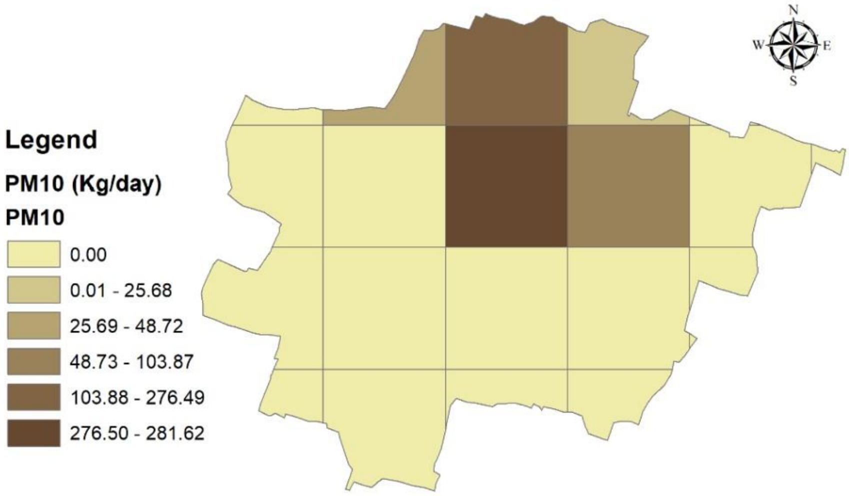

Figure 3. 48*:* Spatial Distribution of PM_{10} Emissions from Point Sources

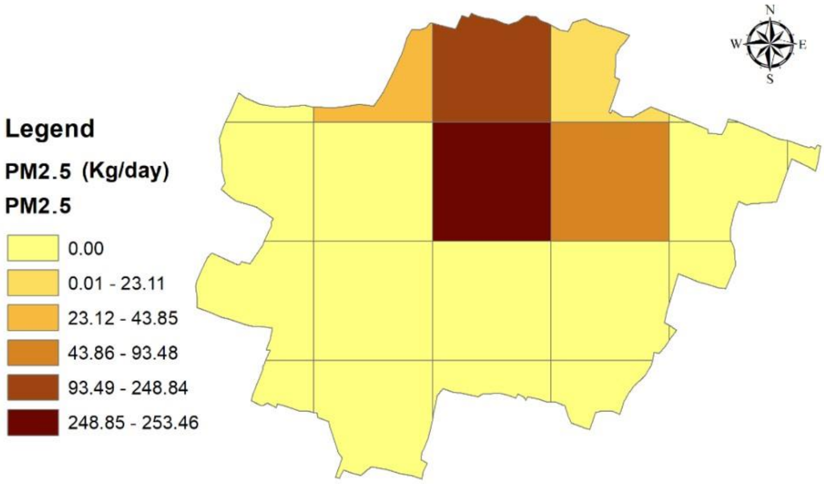

Figure 3. 49*:* Spatial Distribution of $PM_{2.5}$ Emissions from Point Sources

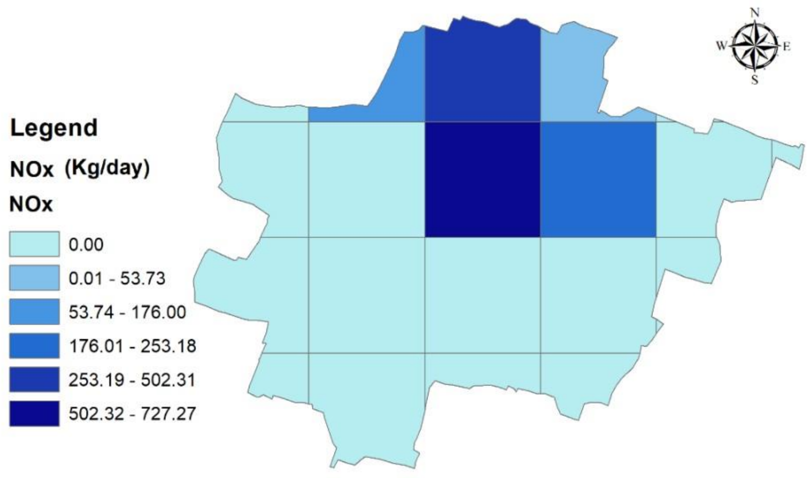

Figure 3. 50*:* Spatial Distribution of NOx Emissions from Point Sources

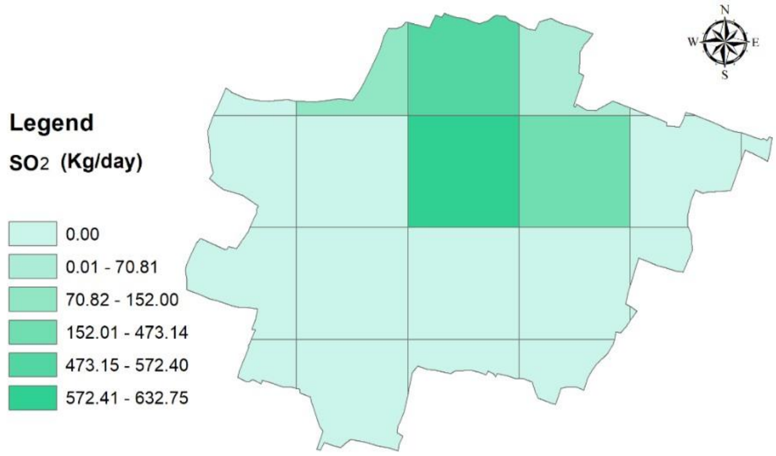

Figure 3. 51*:* Spatial Distribution of SO_2 Emissions from Point Sources

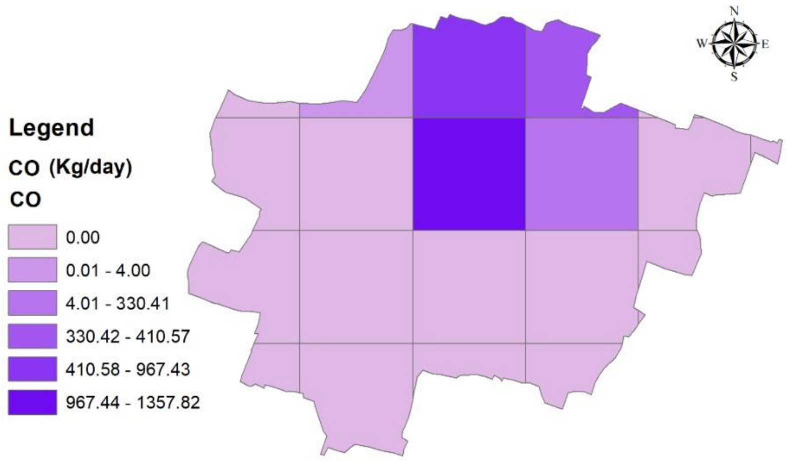

Figure 3. 52*:* Spatial Distribution of CO Emissions from Point Sources

3.3 Industry: Emission, Types and fuel usage

Bhiwadi is an industrial city and it is worthwhile to quantify the emission in terms of technology and fuel-wise distribution**.** The overall emissions estimated from the different types of boilers, furnaces, etc are presented in Table 3**.**4**.**

There are about 400 boilers/furnaces that are operational in Bhiwadi and contribute heavily to particulate as well as in gaseous emissions. The large contribution is due to the use of coal, wood, and other dirty fuels, the industry should shift to clean fuel such as Natural gas and electricity will significantly reduce the emissions. Induction furnace emits a large amount of particulate matter as control measures are not adequate and rudimentary except some units (for details see Chapter 5).

From table 3.4 we can infer that:

- Induction Furnace contributes to 44% of PM emission.
- Non-defined boilers/furnaces (maybe mandir, rotary furnaces) are producing major SO_2 (38%) and NOx (24%) emissions and are using fuels like LSHS, CBFS, LDO, FO, Coal, and Wood. The minimum capacity corresponding to the production of the industry has been worked out and assumed as the capacity of the furnace while estimating emissions.
- The second biggest contributor to SO_2 (16%) and NOx (23%) emission are baby boilers and the majority are running on coal.
- CO emissions from the thermic fluid heater are highest (about 20%).

Table 3. 4*:* Furnace/Boiler Details in Bhiwadi

Boiler/Furnace Type	Fuel used in Boiler/Furnace	No of Furnaces/ Boilers	PM10 kg/day	PM2.5 kg/day	SO2 kg/day	NOx kg/day	CO kg/day
Baby Boiler	Coal, Wood, HSD, Gas, Briquettes	42	447	402	1831	1589	1597
Coal pulveriser	Coal	14	152	137	474	549	12
Hot Air/Water Generator	LPG, Wood, Coal, HSD,	9	59	53	20	28	1365
Induction Furnace	Electricity	46	1762	1586	0	0	0
Ball mill	Electricity	42	96	87	0	0	0
Down Draft Shuttle Kiln	LPG, PNG, LDO	13	4	3	176	43	8
Sintering Furnace	Electrical and LPG	6	0	0	0	1	1
Annealing Furnace	LSHS, CBFS, LDO	21	26	23	1240	241	22
Cupola Furnace	Coal	4	33	29	102	118	3
Heating & Re- Heating Furnace	LSHS, LDO, FO, Coal, HSD	20	312	281	1362	1179	32
Mandir Furnace	Coal, Wood	10	37	33	107	124	74
Pit furnace	Electricity, LSHS, Coal	12	197	177	139	161	4
Non-defined Furnace	LSHS, CBFS, LDO, FO, Coal, Wood	73	454	409	4194	1651	1477
Rotary Furnace	Coal, HSD, LDO	14	246	221	1084	968	29
Thermic Fluid Heater	Wood, LDO, Coal, HSD	52	151	136	332	160	3140
Thermo Pack	LSHS, Wood, Coal, HSD	6	6	5	47	22	77
Total		384	**3982**	**3584**	**11108**	**6834**	**7842**

3.4 Vehicular - Line Sources

The six locations that were selected for video recording for the 24-hour duration as shown in Figure 3.53.

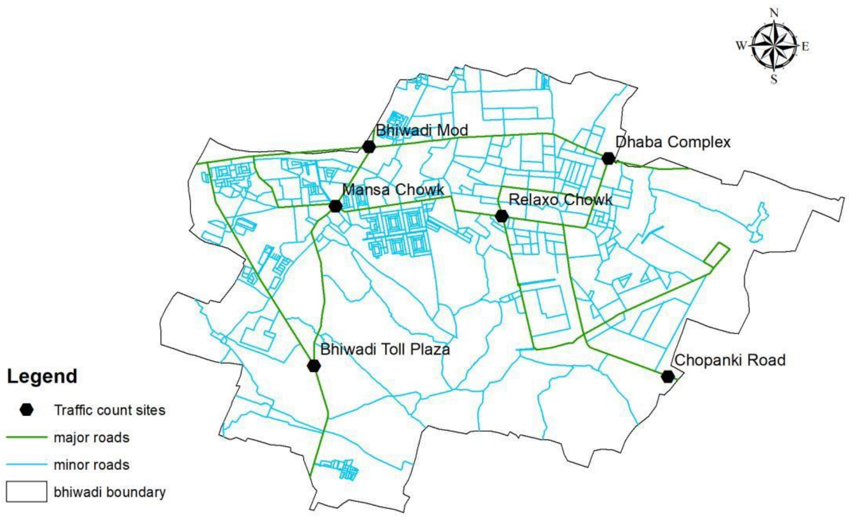

Figure 3. 53*: Traffic location considered for vehicle emission in the city of Bhiwadi.*

3.4.1 Parking Lot Survey

Out of a total of 2609 vehicles surveyed; the breakdown was: 639 2-Ws; 107 3-Ws; 1749 4-Ws; 27 Buses and 87 Trucks. During the parking lot survey, 217 LCVs were surveyed, and it was found out that all LCVs run on diesel fuel and 99% LCVs are post-2005. All the Autos, buses and trucks were running on diesel fuel and are of post-2000. Figures 3.54 and 3.55 present parking lane survey results (for 2Ws and 4Ws) in terms of engine size and year of manufacturing.

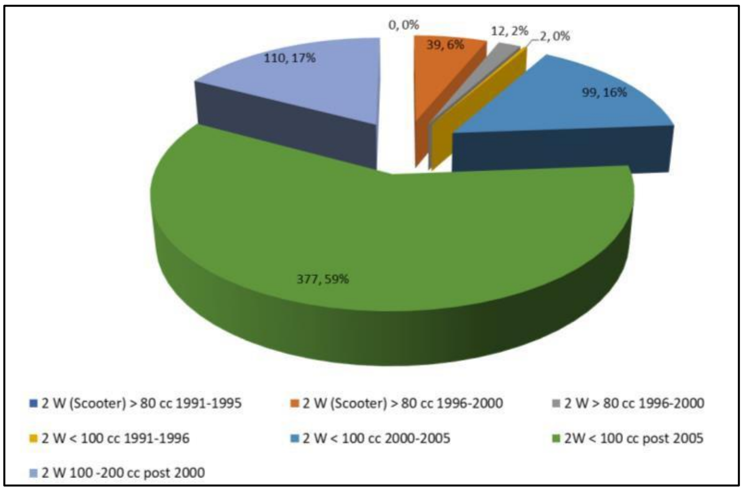

Figure 3. 54*: Distribution of 2-Ws in the study area (parking lot survey)*

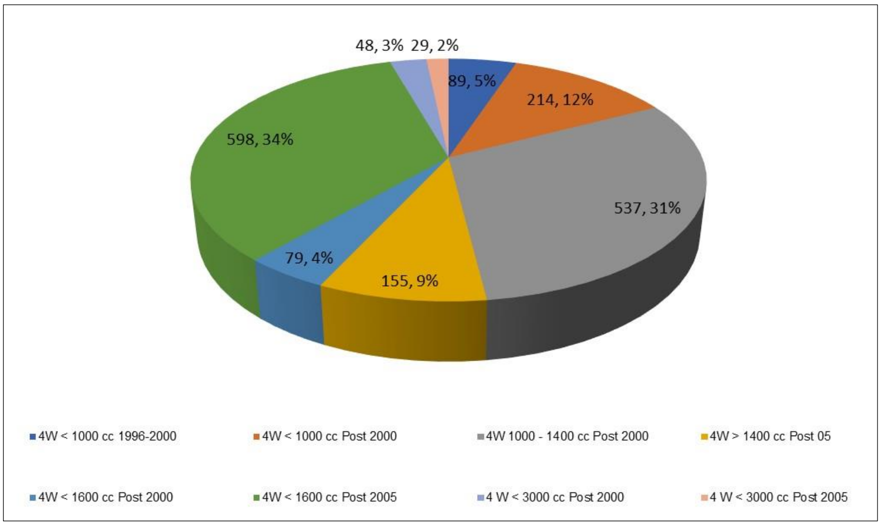

Figure 3. 55*: Distribution of 4-Ws in the study area (*parking lot survey*)*

The emission from vehicles is shown in Figure 3.56. The emission contribution of each vehicle type in the city of Bhiwadi is presented in Figures 3.57 to 3.61. The spatial distribution of emissions from vehicles are presented in Figures 3.62 to 3.63.

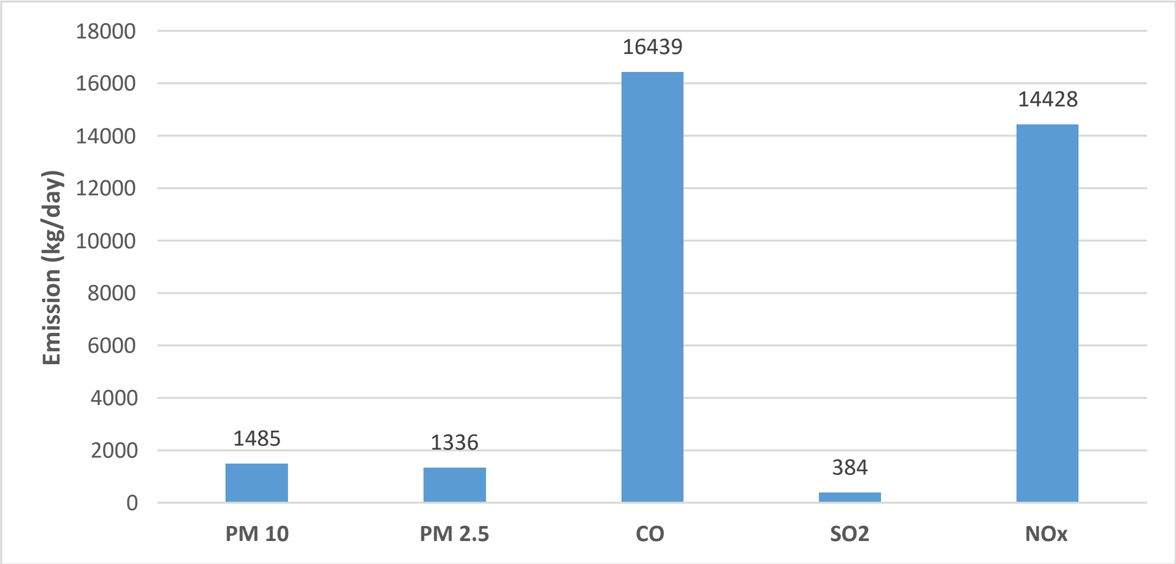

Figure 3. 56*: Emission Load from Vehicles (*kg/day*)*

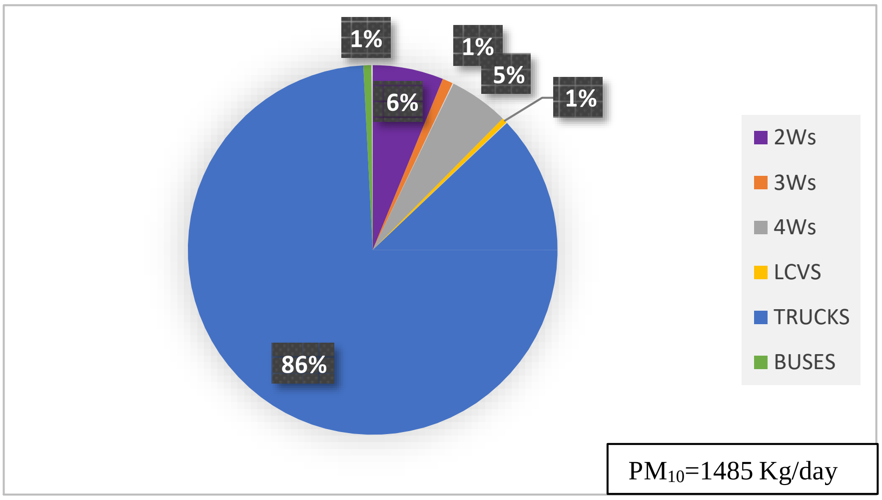

Figure 3. 57*:* PM_{10} Emission Load contribution of each vehicle type in the city

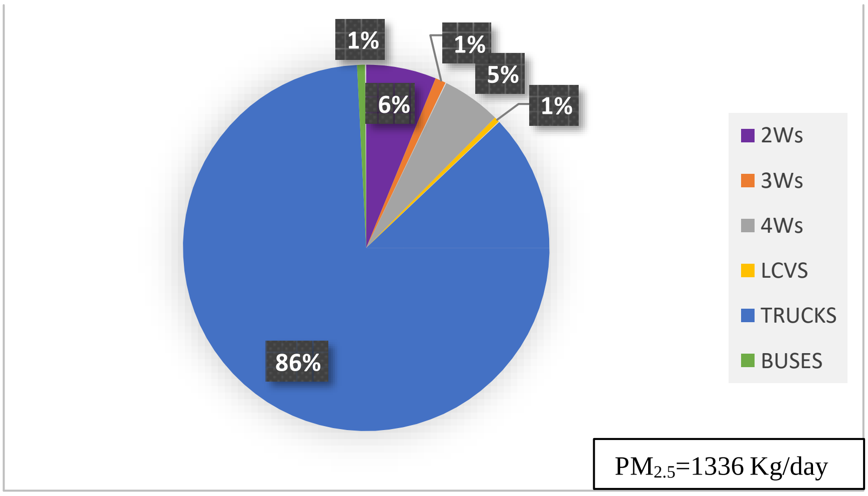

Figure 3. 58*:* $PM_{2.5}$ Emission Load contribution of each vehicle type in the city

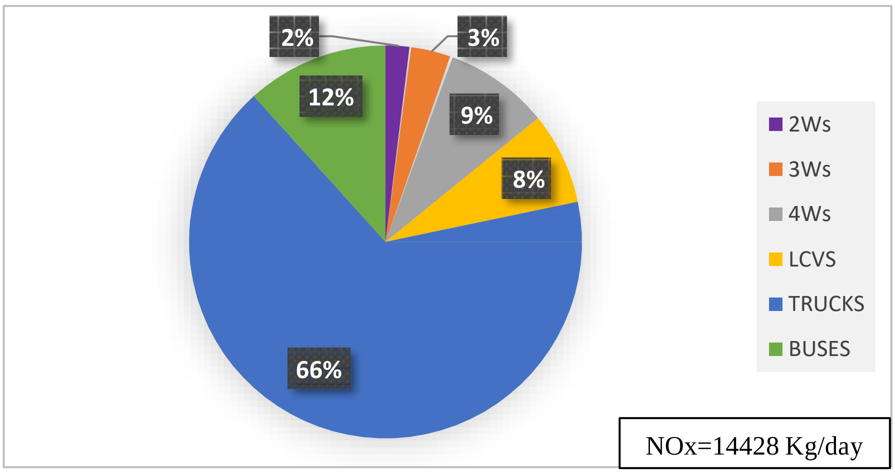

Figure 3. 59*:* NOx Emission Load contribution of each vehicle type in the city

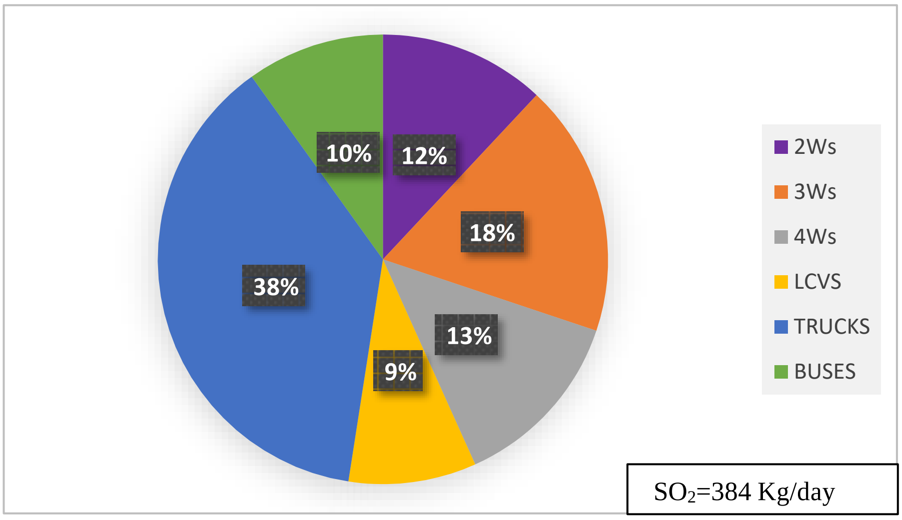

Figure 3. 60*:* SO_2 Emission Load contribution of each vehicle type in the city

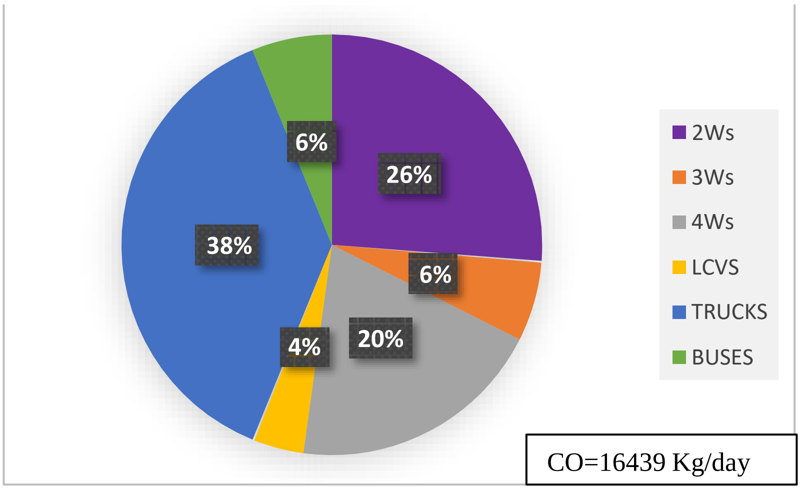

Figure 3. 61*:* CO Emission Load contribution of each vehicle type in the city

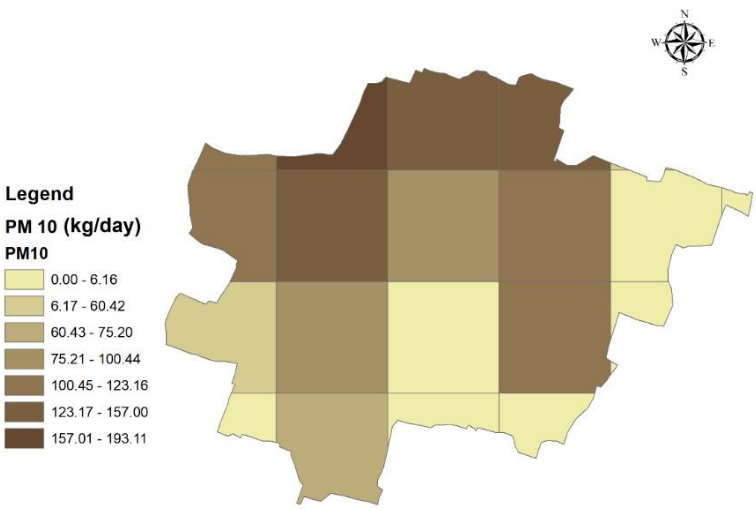

Figure 3. 62*:* Spatial Distribution of PM_{10} Emissions from Vehicles

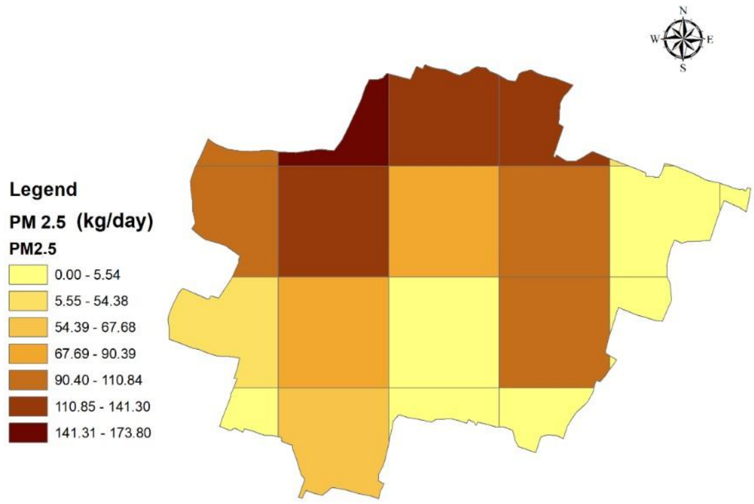

Figure 3. 63*:* Spatial Distribution of $PM_{2.5}$ Emissions from Vehicles

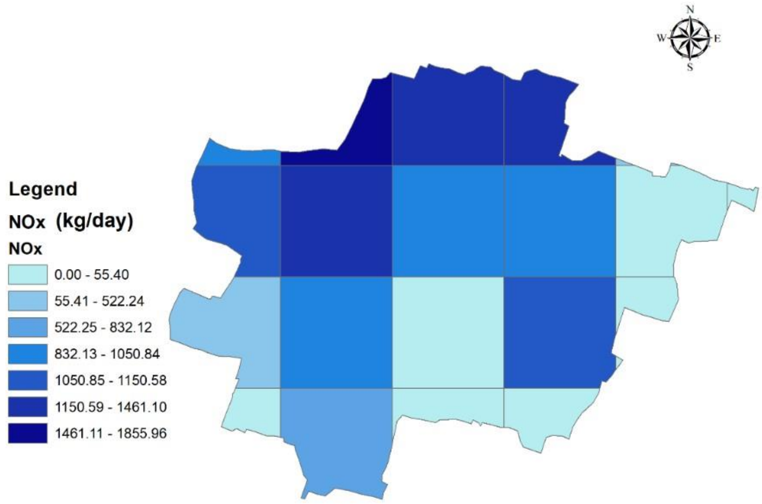

Figure 3. 64*:* Spatial Distribution of NOx Emissions from Vehicles

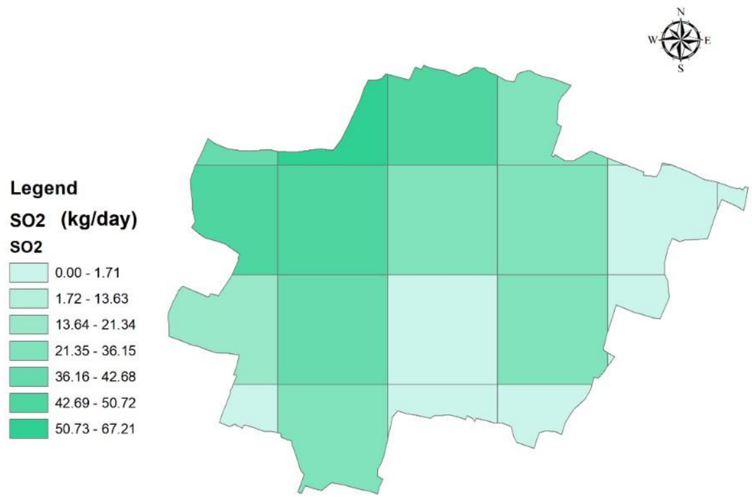

Figure 3. 65*:* Spatial Distribution of SO_2 Emissions from Vehicles

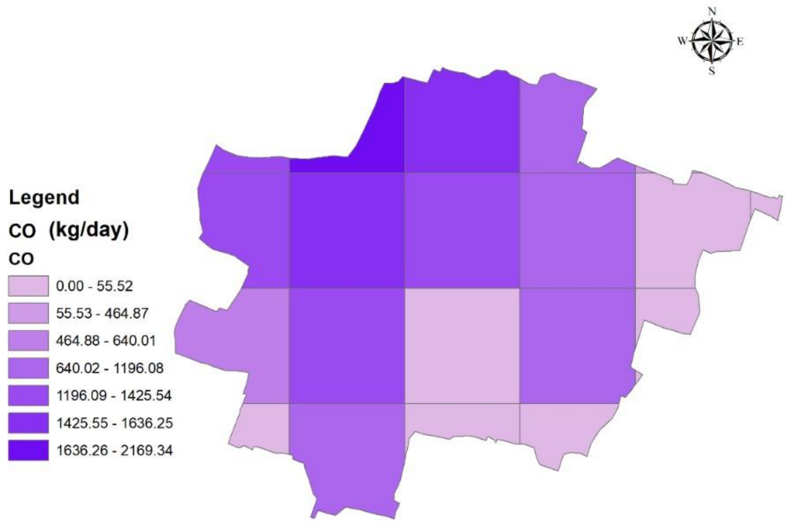

Figure 3. 66*:* Spatial Distribution of CO Emissions from Vehicles

3.4.2 Paved and Unpaved Road Dust

The silt loads (sL) samples from thirteen locations were collected (Figure 3.67). Then the mean weight of the vehicle fleet (W) was estimated by giving the weight to the percentage of vehicles of all types with their weight. The emission rate (g VKT-1) was calculated based on Eq (3.1). VKT for each grid was calculated by considering the tonnage of each road. Then finally the emission loads from paved and unpaved roads were found out by using Eq (3.1).

$$E_{ext} = [\ k\ (sL)^{0.91} \times (W)^{1.02}\ ]\ (1 - P/4N) \qquad ...(3.1)$$

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

sL = road surface silt loading (grams per square meter) (g/m2), and

W = average weight (tons) of the vehicles traveling the road.

E_{ext} = annual or other long-term average emission factor in the same units as k,

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

N = number of days in the averaging period.

k : constant (a function of particle size) in g VKT^{-1}(Vehicle Kilometer Travel).

It was assumed that the observed silt load on road was the result of one month of accumulation. The road dust resuspension from various cities is shown in Figure 3.68.

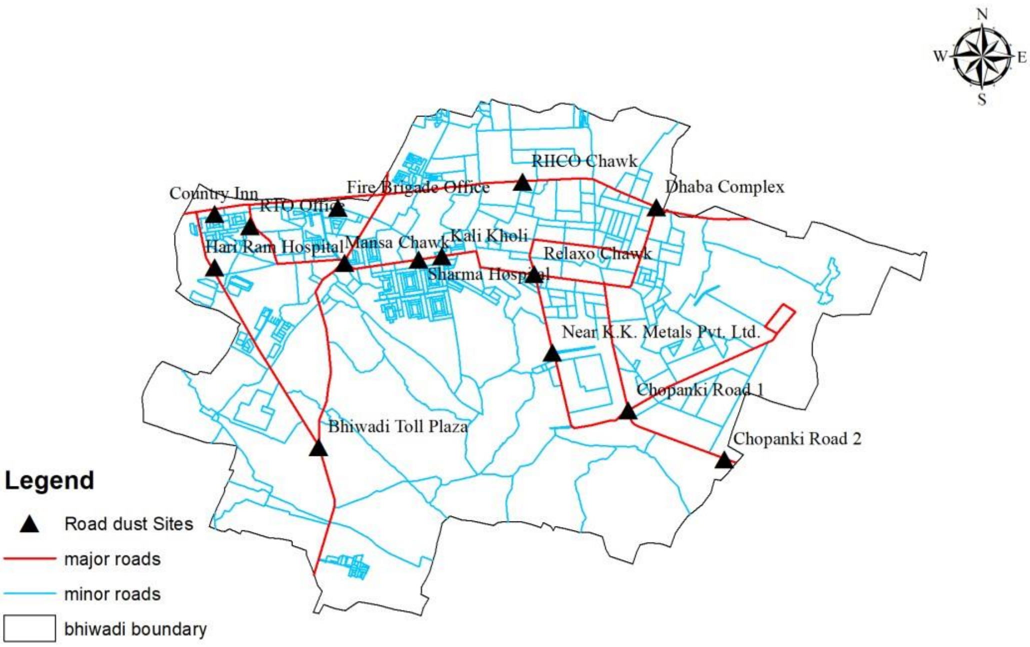

Figure 3. 67*:* Road Dust Sampling Location

Figure 3. 68: Road Dust Emission in Bhiwadi

The PM_{10} and $PM_{2.5}$ emissions from road dust are 21653 kg/day and 5238 kg/day respectively. Silt load varies a lot, in winter and monsoon season it is less due to moisture, dew, and atmospheric condition. The spatial distribution of emissions from road dust Re-suspension is presented in Figure 3.69 to 3.70.

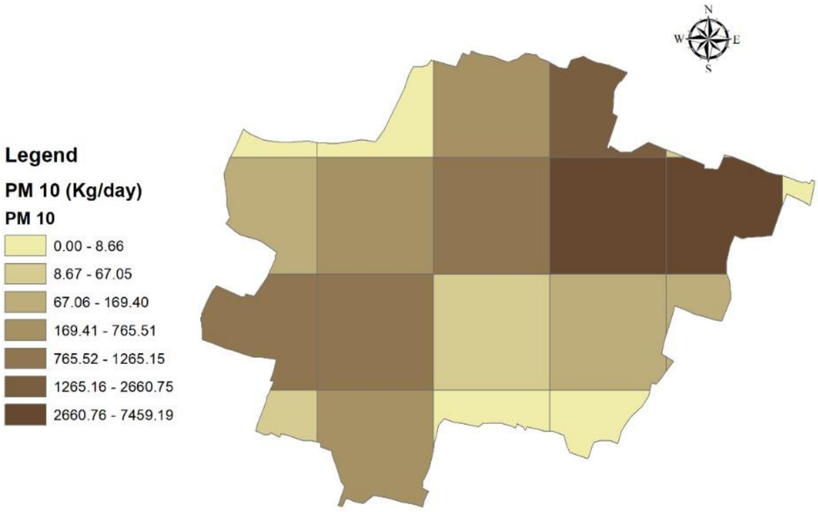

Figure 3. 69*:* Spatial Distribution of PM_{10} Emissions from Road Dust Re-suspension

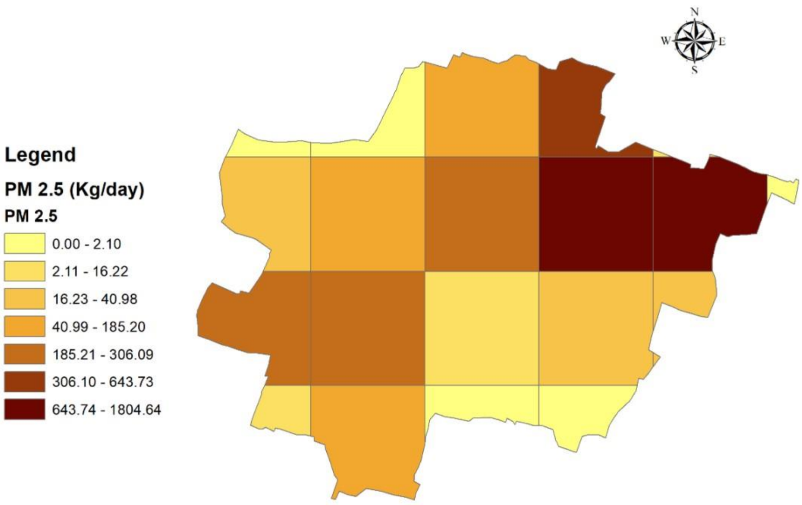

Figure 3. 70*:* Spatial Distribution of $PM_{2.5}$ Emissions from Road Dust Re-suspension

3.5 City Level Emission Inventory

The overall baseline emission inventory for the entire city is presented in Table 3.5. The pollutant wise contribution is shown in Figures 3.71 to 3.75. The spatial distribution of pollutant emissions from all sources is presented in figures from 3.76 to 3.80.

It has been found that PM10 emissions are highest followed by CO and NOx. It is to be noted that road dust is the biggest emitter of PM_{10} and $PM_{2.5}$, the vehicle is the biggest emitter of CO and NOx while Industrial area source is the biggest emitter of SO_2

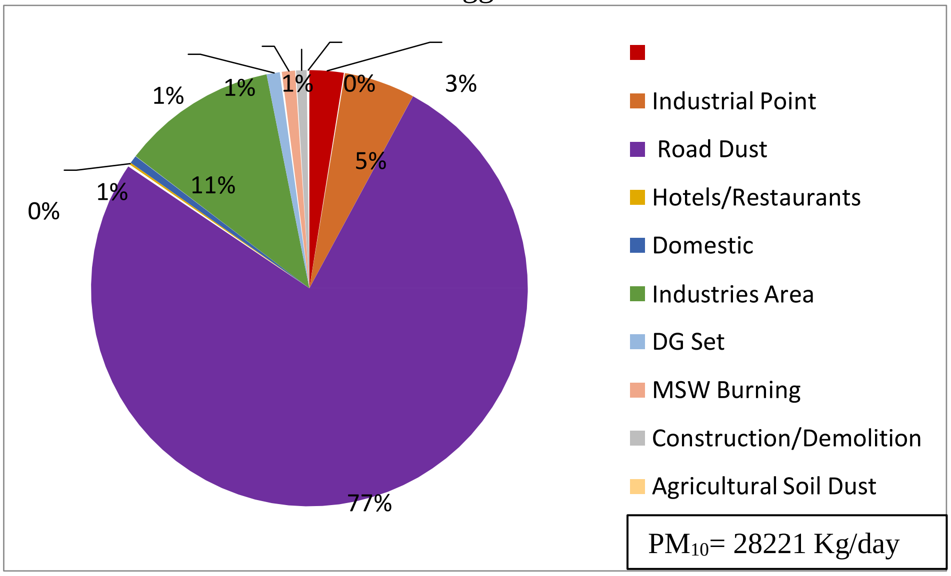

Figure 3. 71: PM_{10} Emission Load of Different Sources in the city of Bhiwadi

The total PM_{10} emission load in the city is estimated to be 28 t/d. The two biggest contributors to PM_{10} emissions are road dust (77%) and industrial area sources (11%); these are based on annual emissions. The estimated emission suggests that there are many important sources and a composite emission abatement including most of the sources will be required to obtain the desired air quality.

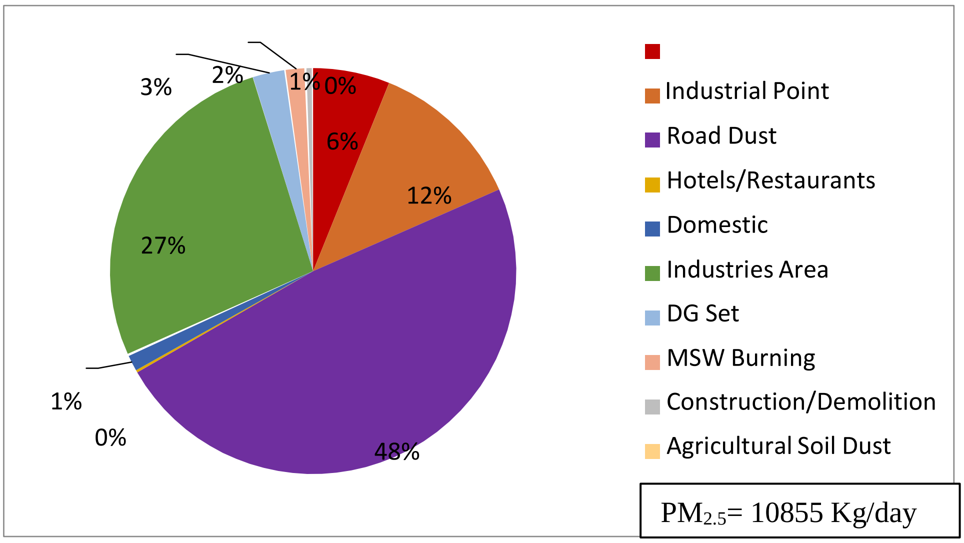

Figure 3. 72: $PM_{2.5}$ Emission Load of Different Sources in the city of Bhiwadi

$PM_{2.5}$ emission load in the city is estimated to be ~ 11 t/d. The top four contributors to $PM_{2.5}$ emissions are road dust (48 %), industrial area sources (27%), vehicles (12 %) and industrial point source (6%); these are based on annual emissions.

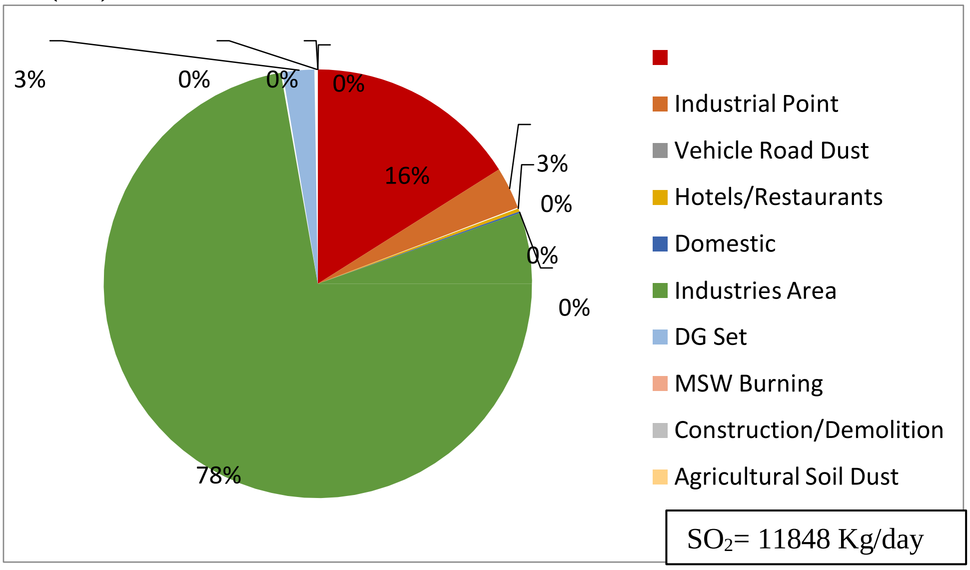

Figure 3. 73: SO_2 Emission Load of Different Sources in the city of Bhiwadi

SO_2 emission load in the city is estimated to be ~12 t/d. Industrial area sources account for 78% of the total emission. It appears there may be a need to control SO_2 from industrial area source as SO_2 is also known to contribute to secondary particles (sulfates).

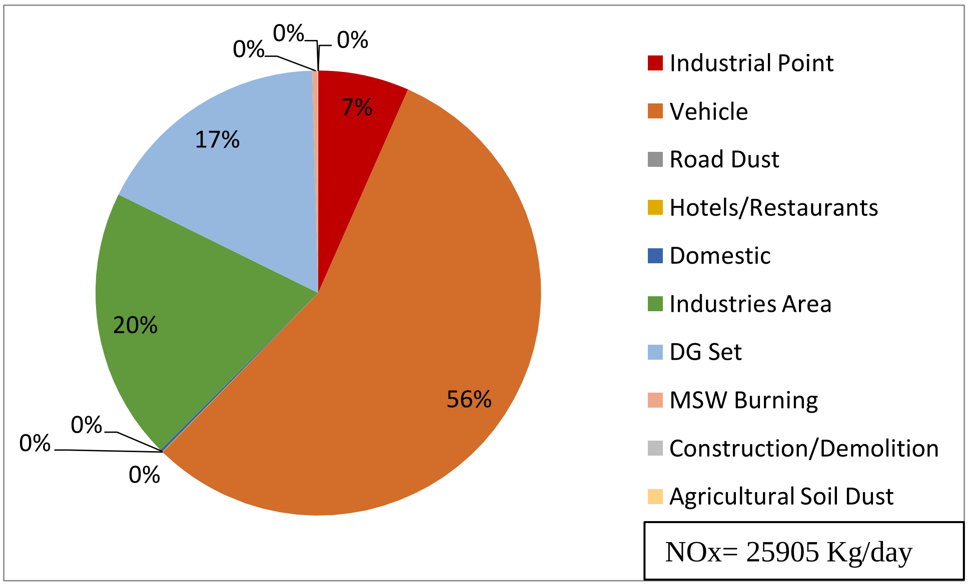

Figure 3. 74: NOx Emission Load of Different Sources in the city

NOx emissions third-highest emission ~ 26 t/d. Nearly 56% of emissions are attributed to vehicular emissions that occur at ground level, probably making it the most important followed by Industrial area source (20%) and then DG sets contributing 17% to NOx emission. NOx apart from being a pollutant itself, it is an important component in the formation of secondary particles (nitrates) and ozone.

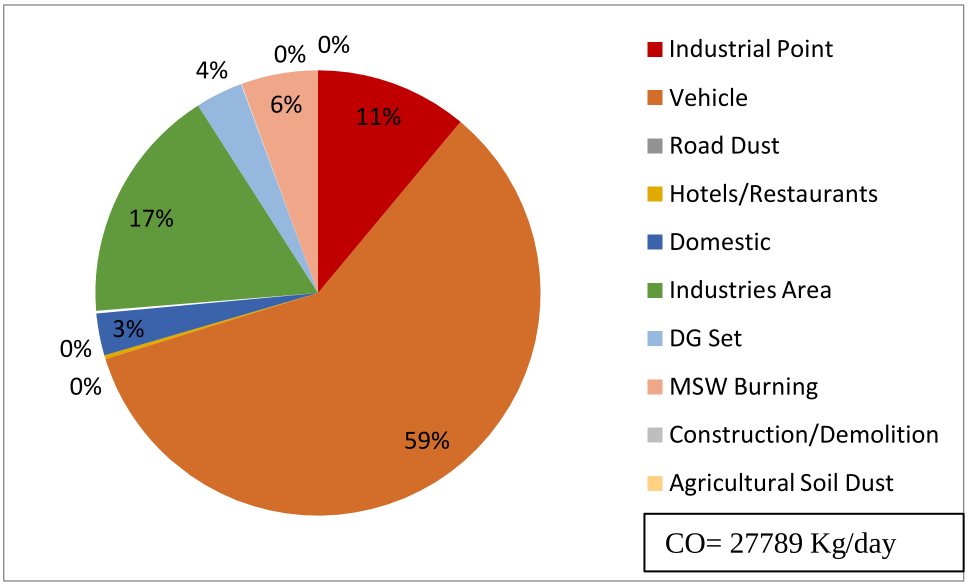

Figure 3. 75: CO Emission Load Contribution of Different Sources in the City

The estimated CO emission is about ~28 t/d, second highest after PM_{10}. Nearly 59% emission of CO is from vehicles, followed by industrial area sources (17 %), industrial point source (11%), MSW Burning (6%), and DG Sets (4%). Vehicles could be the main target for controlling CO for improving air quality with respect to CO.

Spatial variation of emission quantity suggests that the central and northern part of the city shows higher emissions than other parts of the city.

Table 3. 5: Overall Baseline Emission Inventory for the Bhiwadi City (kg/day)

Category	PM_{10}	$PM_{2.5}$	CO	SO_2	NOx
Industrial Point	736	663	3070	1901	1712
Vehicle	1485	1336	16439	384	14428
Road Dust	21654	5239	0	0	0
Hotels/Restaurants	42	21	76	29	12
Domestic	172	156	901	14	46
Industries Area	3246	2921	4784	9207	5122
DG Set	317	285	966	295	4474
MSW Burning	296	177	1553	18	111

Category	PM_{10}	$PM_{2.5}$	CO	SO_2	NOx
Construction/Demolition	229	58	-	-	-
Agricultural Soil Dust	44	-	-	-	-
Total	**28221**	**10855**	**27789**	**11848**	**25905**

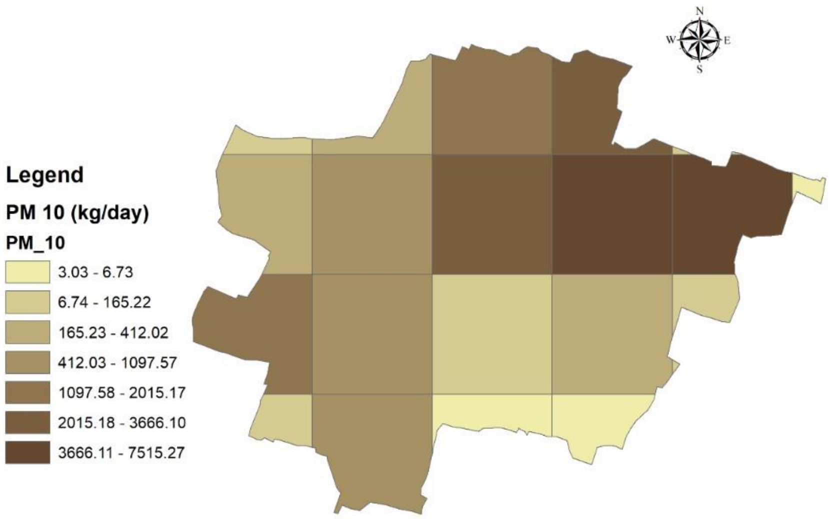

Figure 3. 76*: Spatial Distribution of PM_{10} Emissions in the city of Bhiwadi*

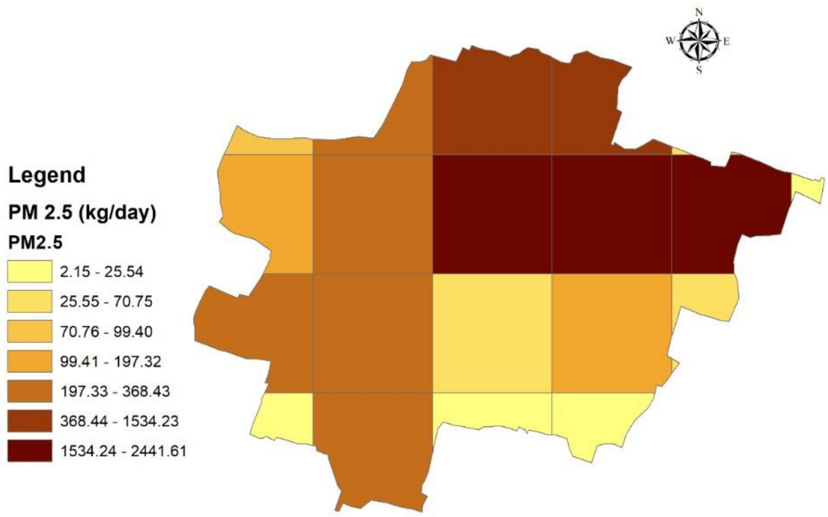

Figure 3. 77*: Spatial Distribution of $PM_{2.5}$ Emissions in the city of Bhiwadi*

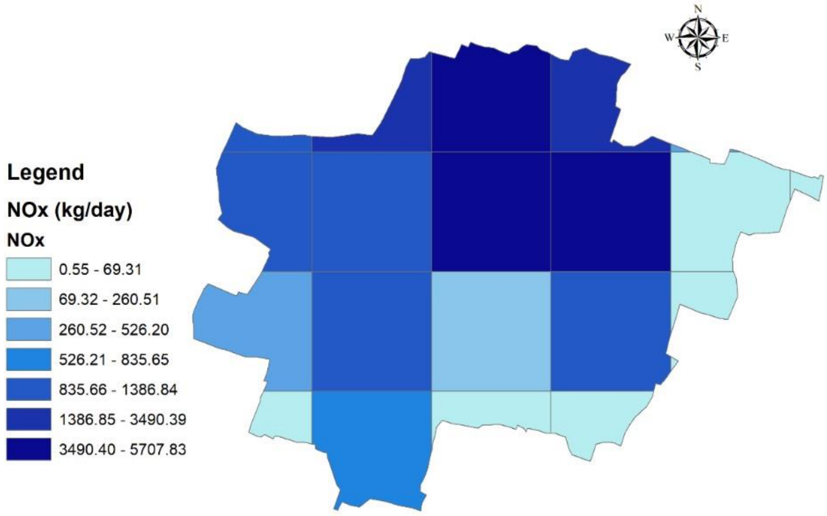

Figure 3. 78*:* Spatial Distribution of NOx Emissions in the city of Bhiwadi

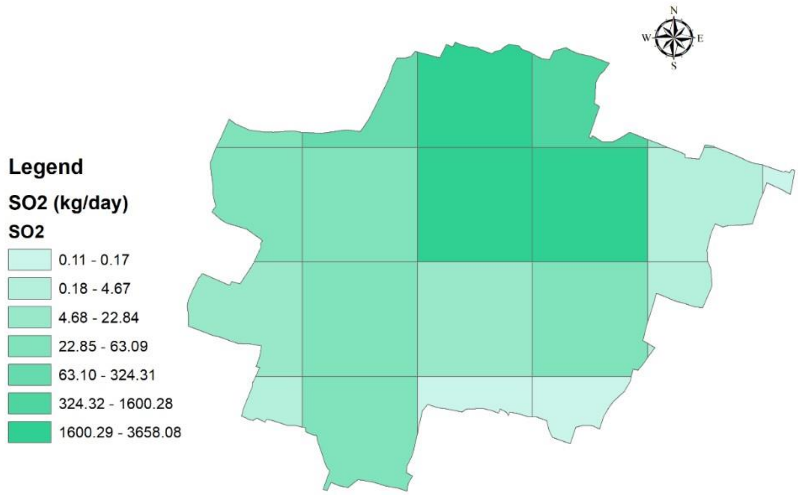

Figure 3. 79*:* Spatial Distribution of SO_2 Emissions in the city of Bhiwadi

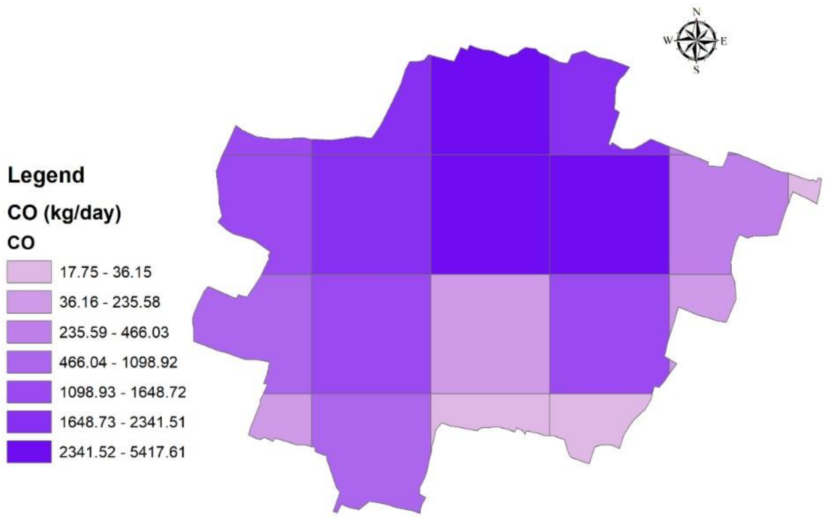

Figure 3. 80*:* Spatial Distribution of CO Emissions in the City of Bhiwadi

Chapter 4: Air Quality Dispersion Modeling

4.0 Introduction

USEPA's AERMOD model was employed to assess the impact of emissions occurring within Bhiwadi on the ambient air at multiple locations for PM_{10}, and $PM_{2.5}$. The modeling exercise was performed for different seasons (winter, monsoon, post-monsoon, and summer). Local meteorological data generated through the WRF (Weather Research and Forecasting) model were used for the dispersion modeling and inputs from emission inventory (EI) were taken from Chapter 3.

4.1 Meteorological Data

In evaluating the emission dispersion from the city of Bhiwadi, the meteorological data-set was generated using the weather research and forecasting model for the period of January 01, 2018 – December 30, 2018. The frequency distribution and frequency count data are obtained by processing the hourly surface file. The wind class frequency distribution is shown in Figure 4.1.

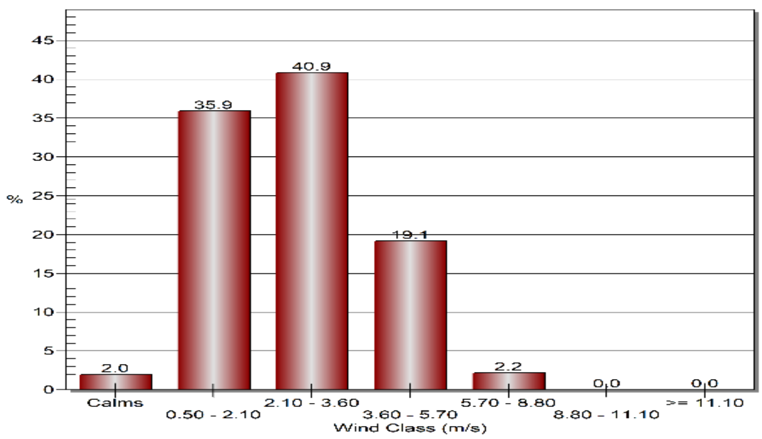

Figure 4. 1: Wind Class Frequency Distribution for Bhiwadi (winter)

The wind rose diagrams for Bhiwadi city were developed using the software WRPlot for an entire year and seasons (summer, winter, monsoon, and post-monsoon) are shown in Figures 4.2 to 4.6.

Most of the time the wind blows from NNW and SE. The wind direction suggests that most of the pollutants will come from the NW sector and some also from the SE sector. The average wind speed was 3.0 m/s.

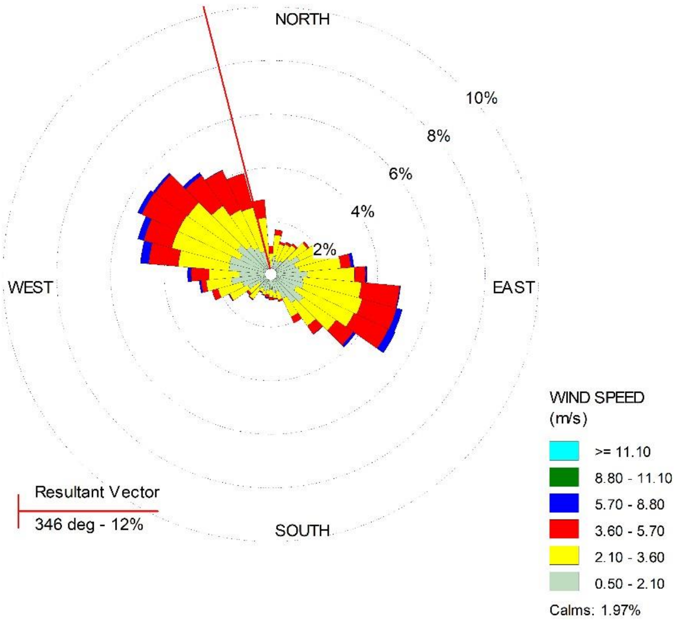

Figure 4. 2: Wind Rose Diagram (annual).

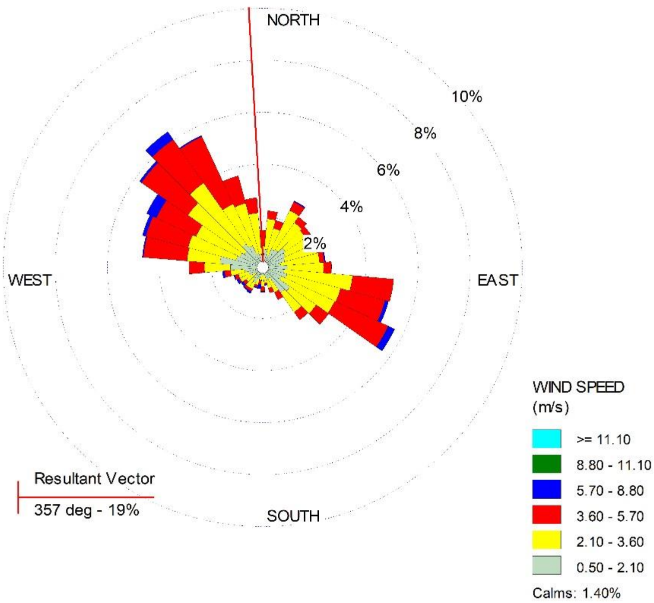

Figure 4. 3: Wind Rose Diagram (Summer: March to May).

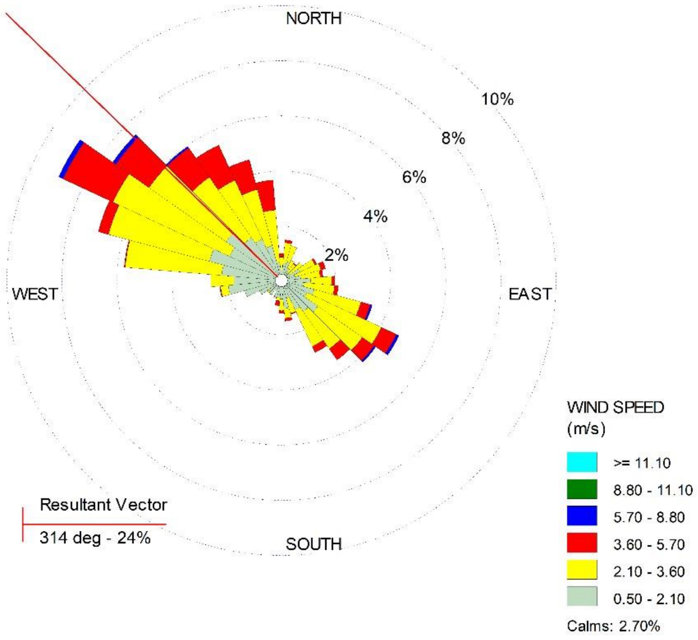

Figure 4. 4: Wind Rose Diagram (Winter: November to February).

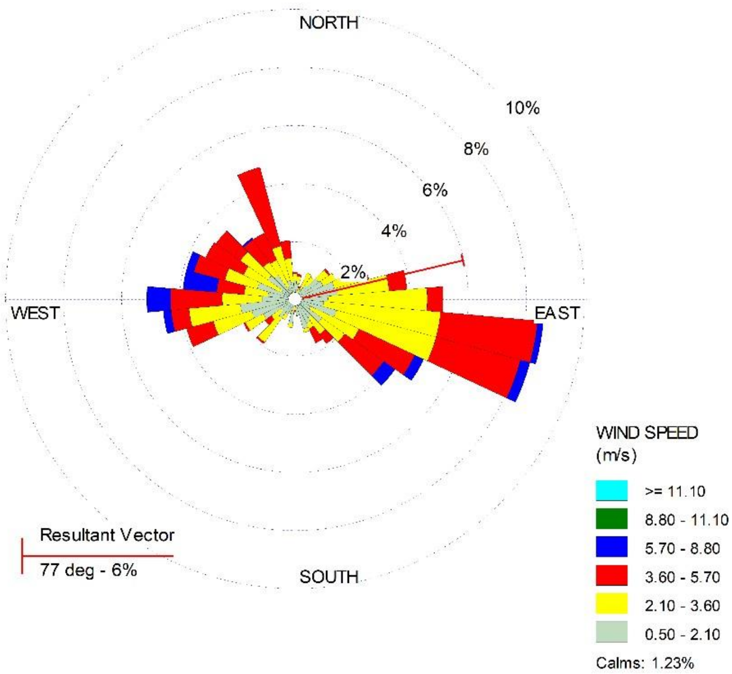

Figure 4. 5: Wind Rose Diagram (Monsoon: June-July).

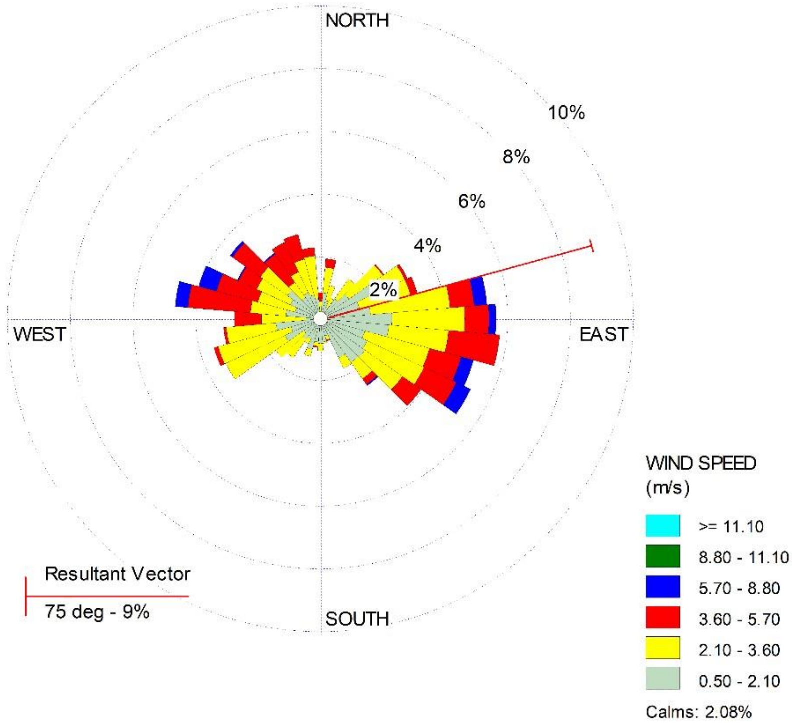

Figure 4. 6: Wind Rose Diagram (Post-monsoon: August to October)

4.2 Land Use and Geophysical Parameters

The AERMOD modeling systems require a physical description of the ground surface to determine meteorological parameters in the boundary layer. The geophysical parameters are land use type, terrain elevation, surface roughness, albedo, Bowen ratio was taken as default values in the model.

4.3 Digital Terrain Elevation Model (DEM)

The DEM is the most critical information required for complex terrain. AERMOD processes DEM data and creates an elevation and height scale for each receptor in the domain.

The DEM results are important for the following inputs:

- DEM is required to predict wind flow patterns and dispersion.
- Receptor elevations will be required for air quality analysis. The DEM is necessary for determining receptor elevations.
- In complex terrain, AERMOD simulates a plume according to the concepts of the

critical dividing streamlines that define which plumes flow over the hill and which flow around it. USEPA recommends the use of AERMOD while modeling in complex terrain.

- Special attention to DEM is given to obtain the results with better accuracy and precision.

The terrain is the vertical dimension of the land surface. Gridded terrain elevations for the proposed modeling domain were derived from 3 arc-second digital elevation models produced by the United States Geological Survey (USGS). Data are provided in files covering 1 degree by 1-degree blocks of latitude and longitude. The processed terrain elevation data is shown in Figure 4.7.

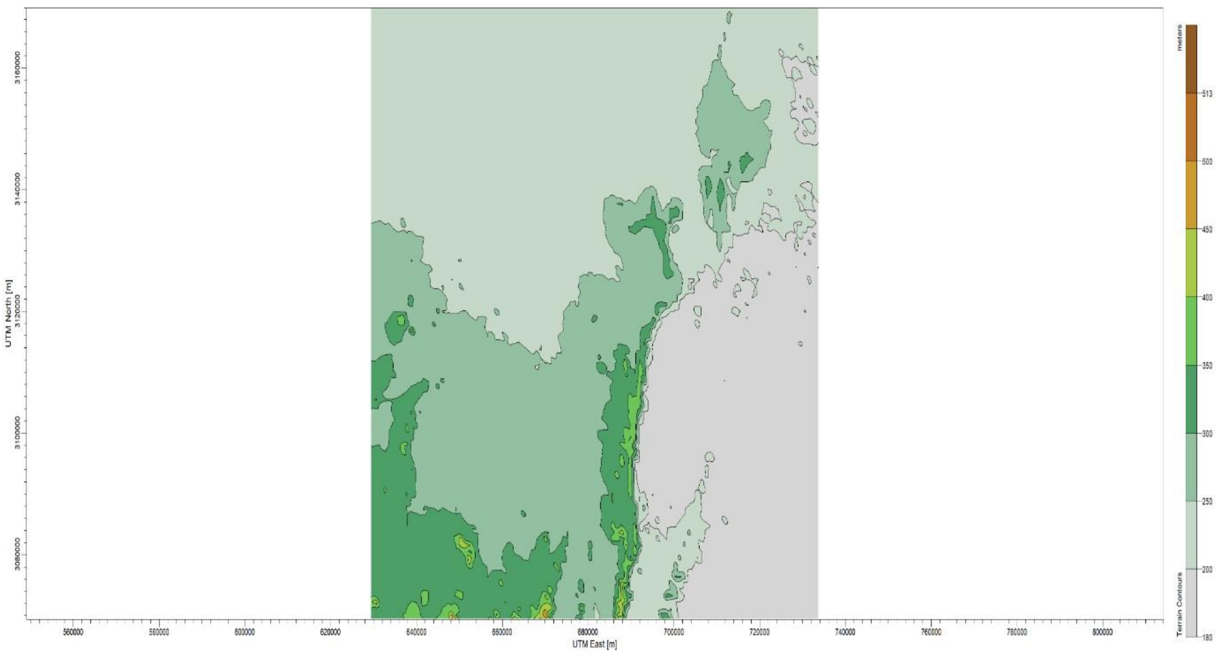

Figure 4. 7: DEM of the Study Area

4.4 Receptor Elevation

Receptor elevations were obtained from the National elevation dataset (NED, USGS). The NED data was processed with AERMAP, a pre-processor program that was developed to process terrain data (base elevation and hill height scale data) in conjunction with a layout of receptors and sources to be used in AERMOD.

4.5 Evaluation of Dispersion Modelling Results

The air dispersion modeling was done with complex terrain. By this approach, all the elevations of terrain are accounted, and the air dispersion will reflect more accurate results as compared to flat terrain.

4.6 Air Quality Modeling Results

The air quality modeling results considering the identified sources (Chapter 3) are presented in Table 4.1. The winter is considered as critical when it comes to dispersion of pollutants and pollution impacts. In air quality dispersion modelling, one of the receptors considered in this study includes the city of Delhi. The city of Bhiwadi is located in SSW direction of Delhi, whereas the prevalent wind direction at Bhiwadi is from NW direction. This implies that majority of the time the wind is blowing from NW (Figure 4.2) and, therefore, emissions from Bhiwadi are unlikely to contribute to Delhi's air pollution.

The air quality model was run to assess the contribution of emissions from Bhiwadi to the City of Delhi. It was seen that, beyond 9.0 km, the average concentration in winter months due to emissions from Bhiwadi was less than 1 $\mu g/m^3$ (Figures 4.8 and 4.9). The peak 24-hr concentration in winter months due to emission from Bhiwadi was estimated to be 2.0 $\mu g/m^3$. Since winter-season and peak 24-hour concentration due to emissions from Bhiwadi is very low, it is unlikely that closure of industry or very stringent air pollution control measures at sources in Bhiwadi will improve the air quality in Delhi. However, the suggested pollution control measures will significantly improve the air quality within Bhiwadi city (see control action plan) and may be adopted.

Table 4. 1: Air Quality Dispersion Modeling Results

	Season	**PM_{10}**	**$PM_{2.5}$**
Peak Concentration (24-hr)	Summer	125	102
	Winter	164	128
	Monsoon	151	125
	Post-Monsoon	186	154
Average Concentration for the seasons	Summer	31	25
	Winter	45	34
	Monsoon	28	22
	Post-Monsoon	39	31

The 24-hr peak concentration and average concentration isopleths for various seasons are shown in Figure 4.8 to 4.23.

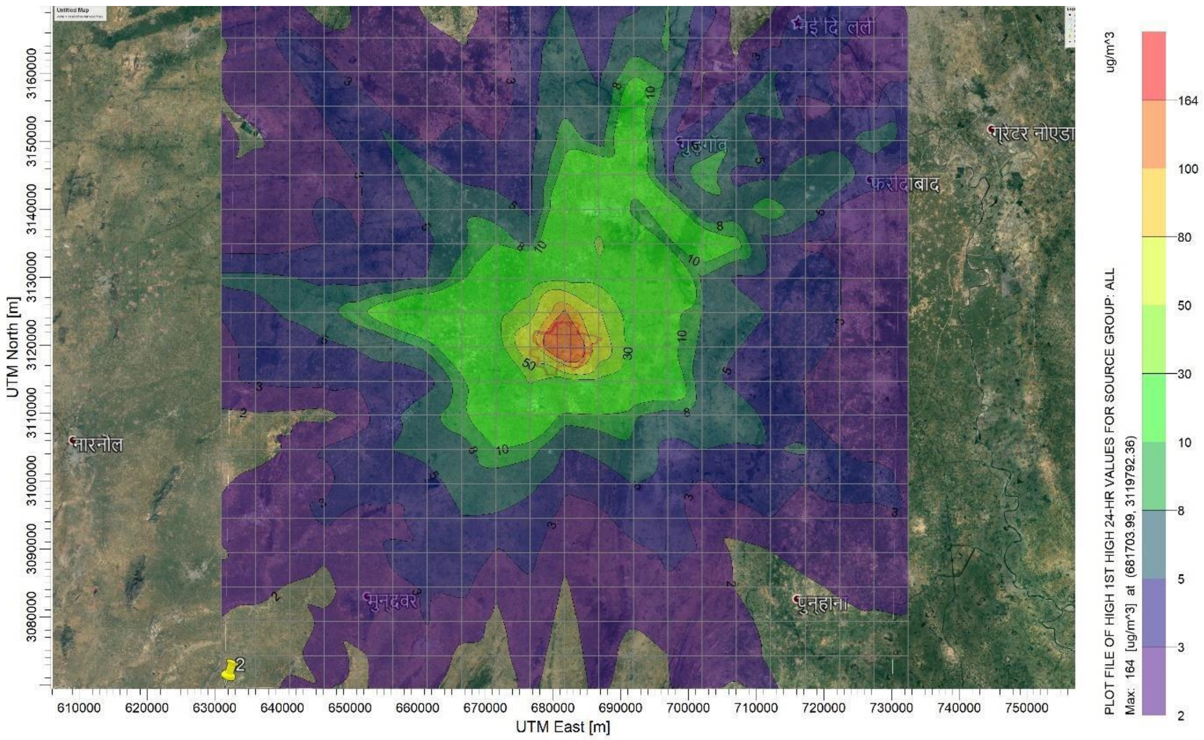

Figure 4. 8: 24-hr Peak Concentration in Winter Season

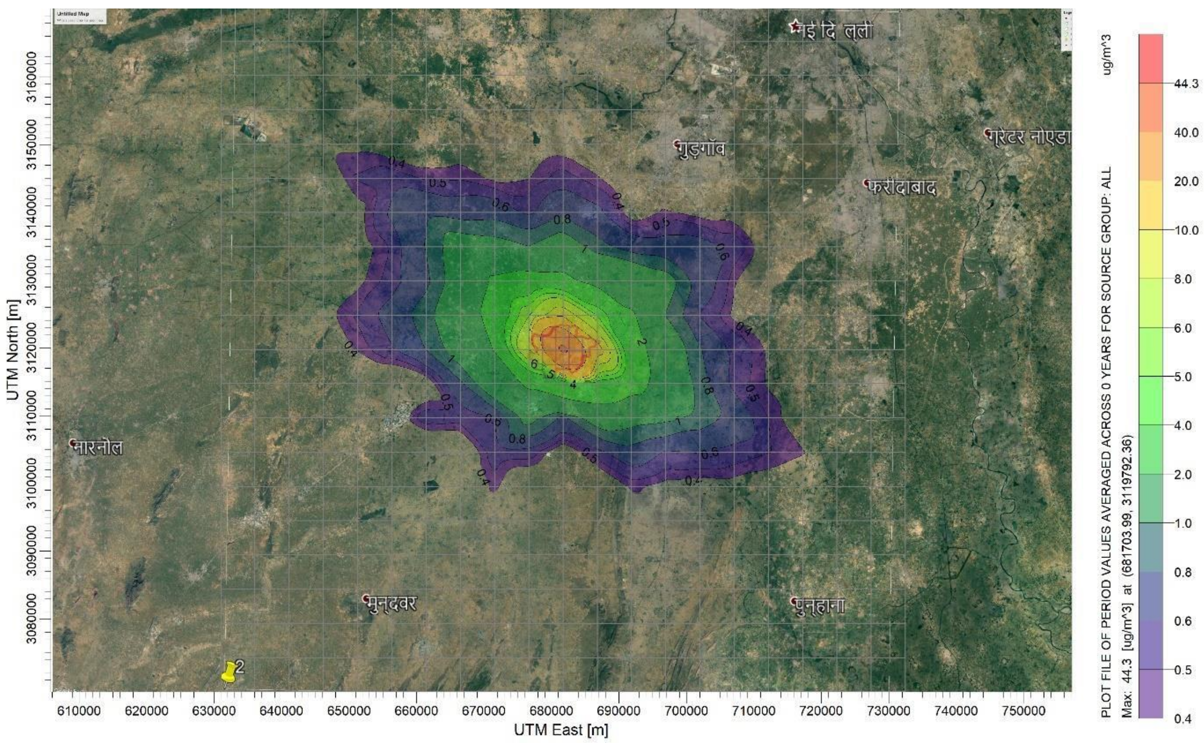

Figure 4. 9: Average Concentration in Winter Season

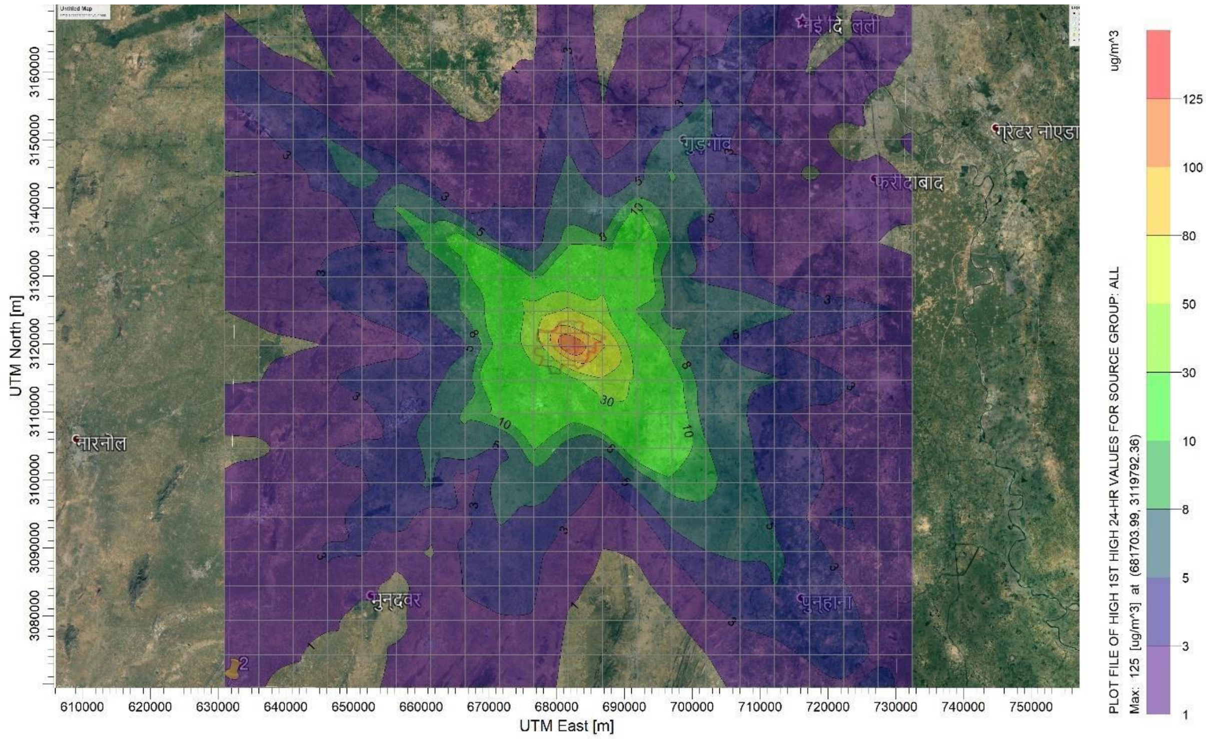

Figure 4. 10: 24-hr Peak Concentration in Summer Season

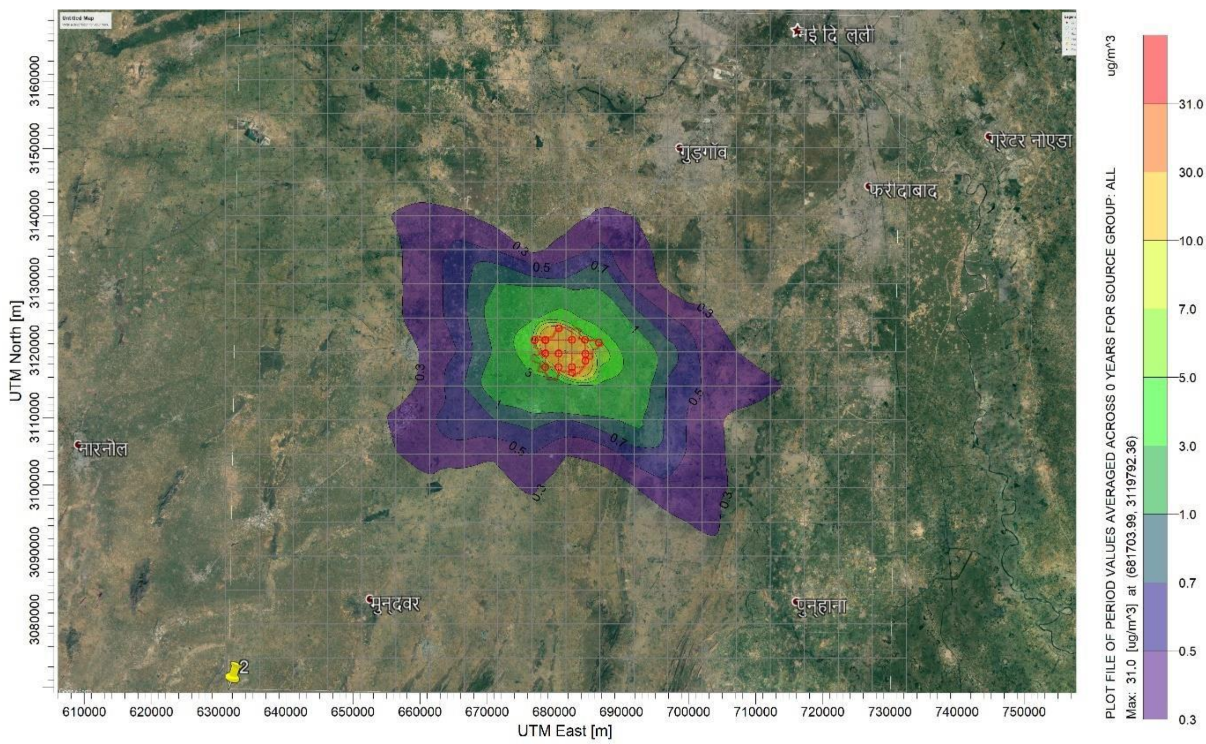

Figure 4. 11: Average Concentration in Summer Season

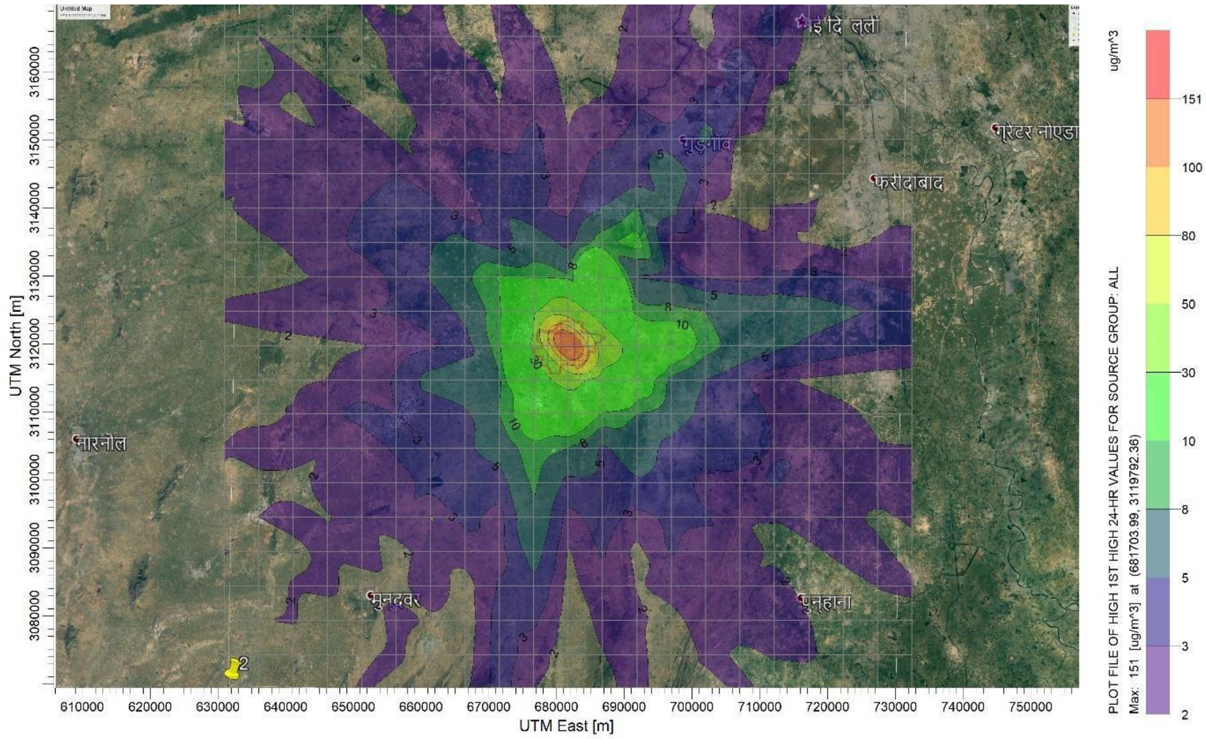

Figure 4. 12: 24-hr Peak Concentration in Monsoon Season

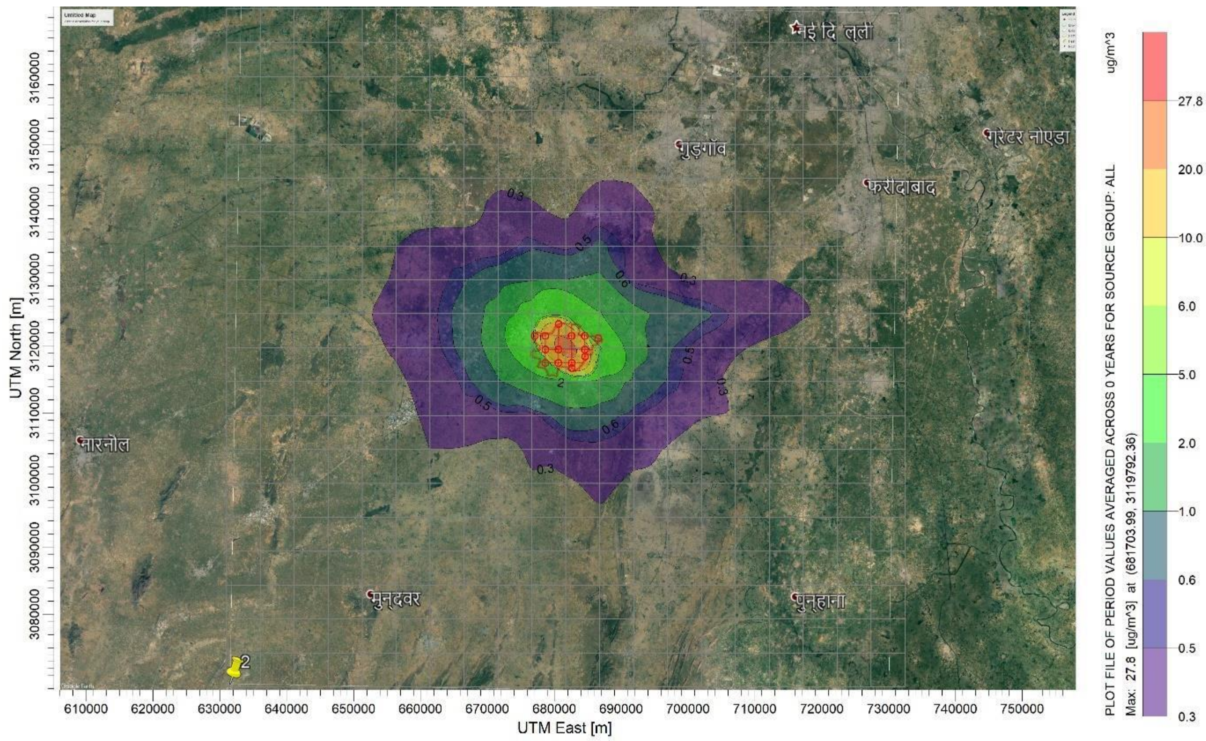

Figure 4. 13: Average Concentration in Monsoon Season

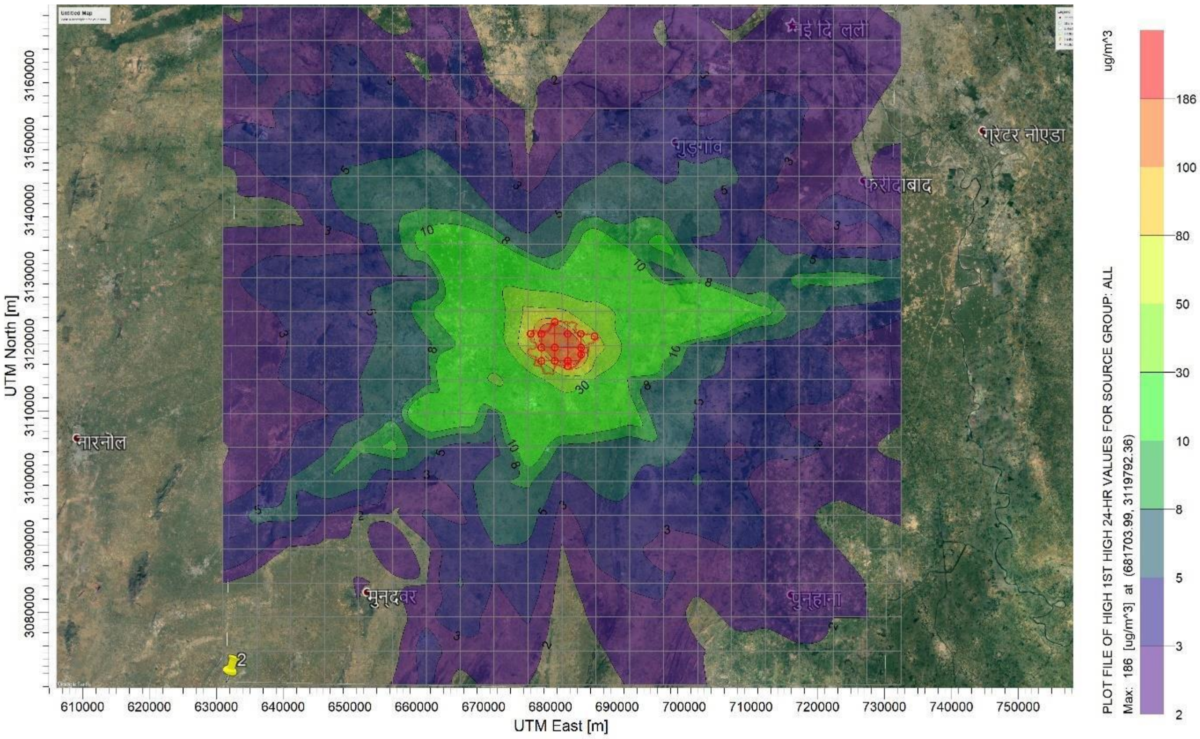

Figure 4. 14: 24-hr Peak Concentration in Post-Monsoon Season

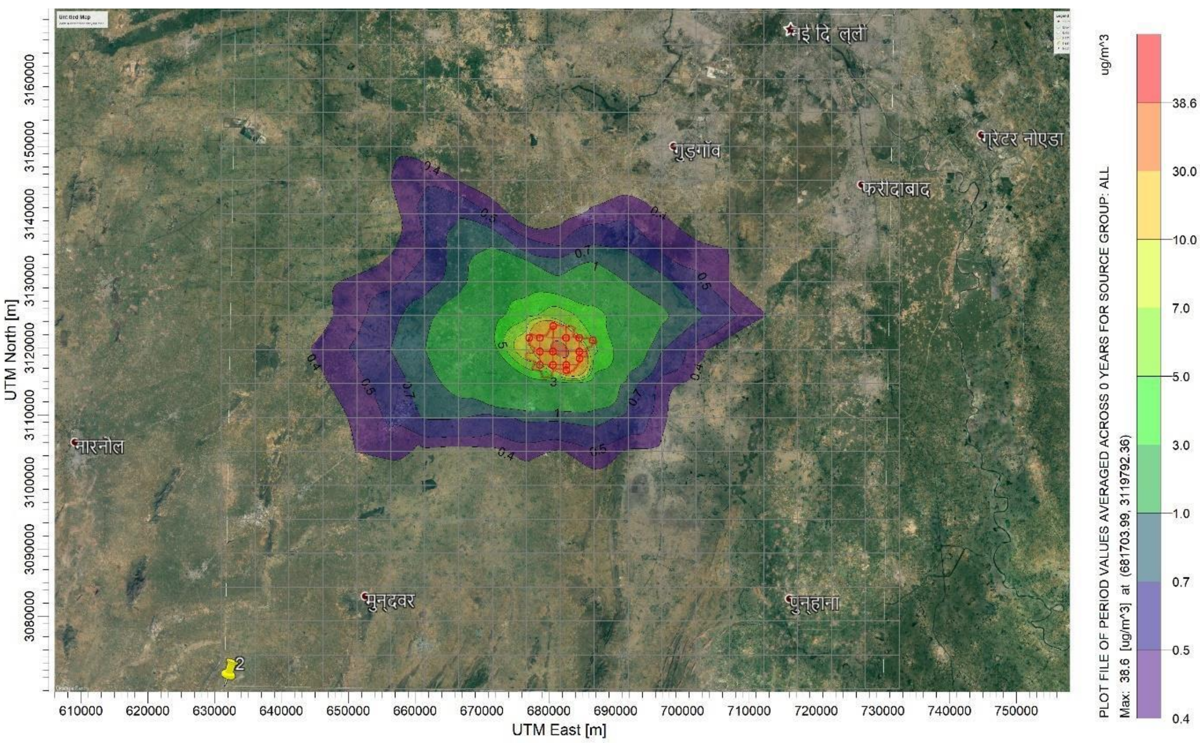

Figure 4. 15: Average Concentration in Post-Monsoon Season

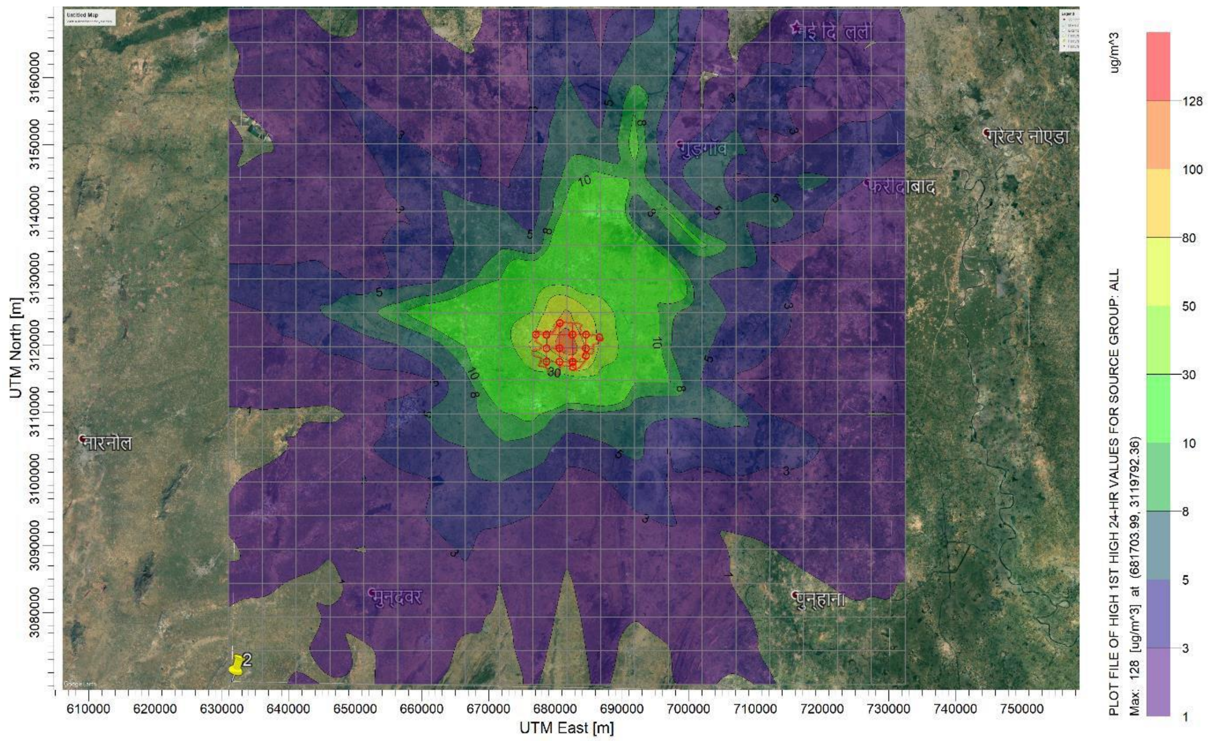

Figure 4. 16: PM2.5 24-hr Peak Concentration in Winter Season

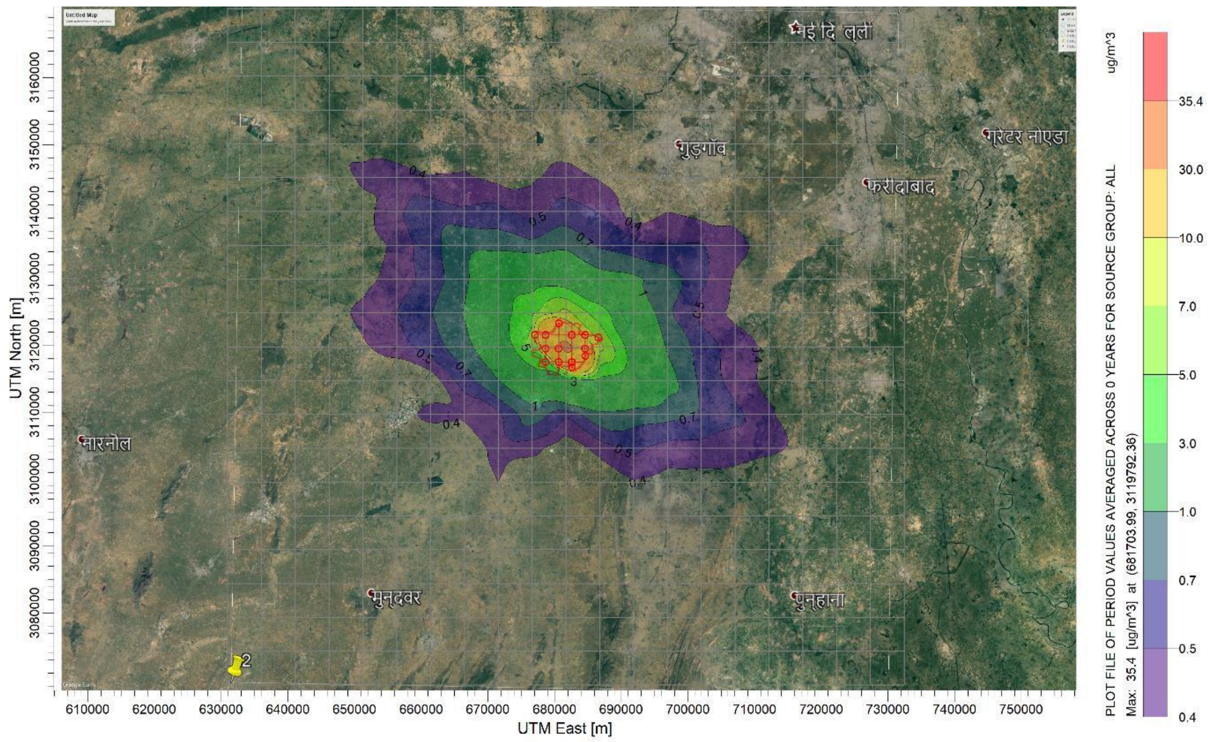

Figure 4. 17: PM2.5 Average Concentration in Winter Season

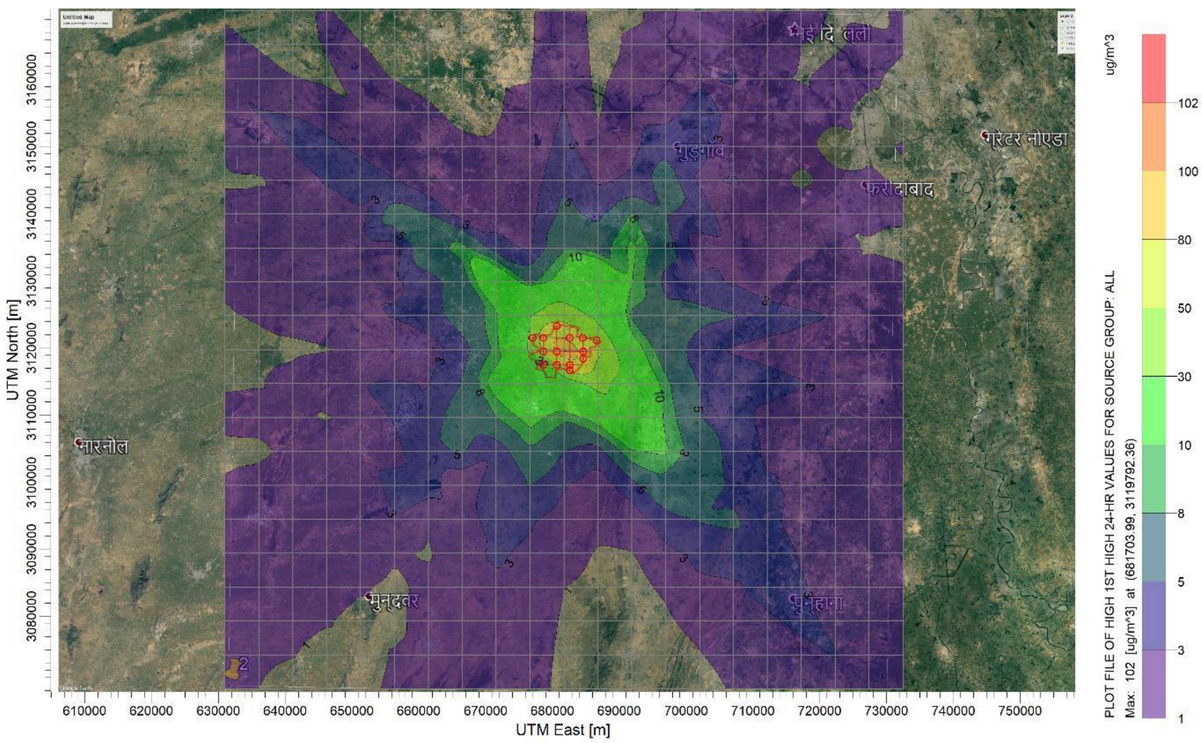

Figure 4. 18: PM2.5 24-hr Peak Concentration in Summer Season

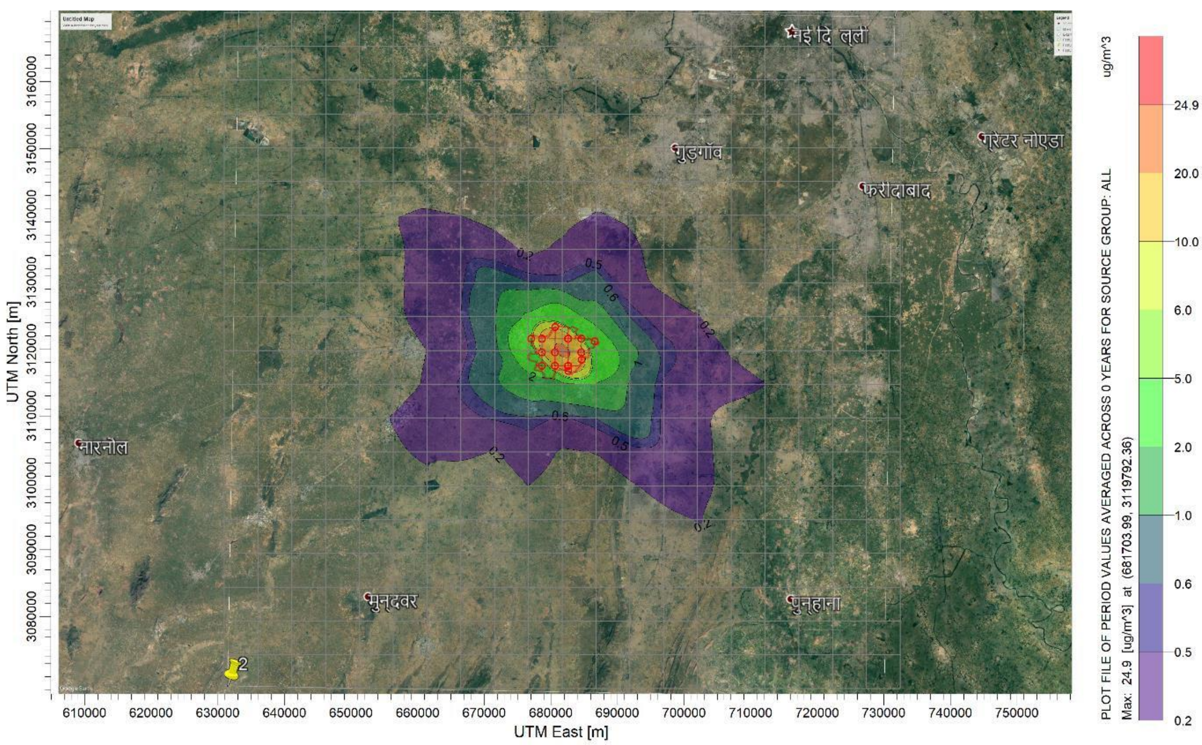

Figure 4. 19: PM2.5 Average Concentration in Summer Season

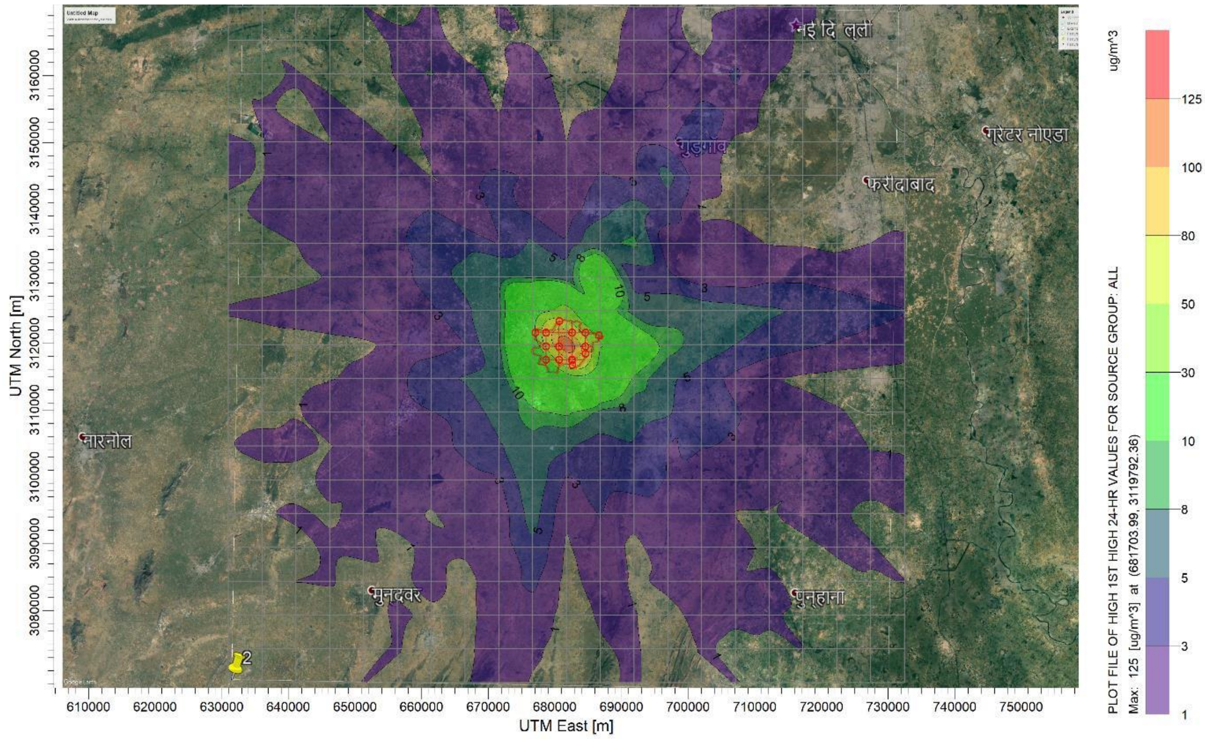

Figure 4. 20: PM2.5 24-hr Peak Concentration in Monsoon Season

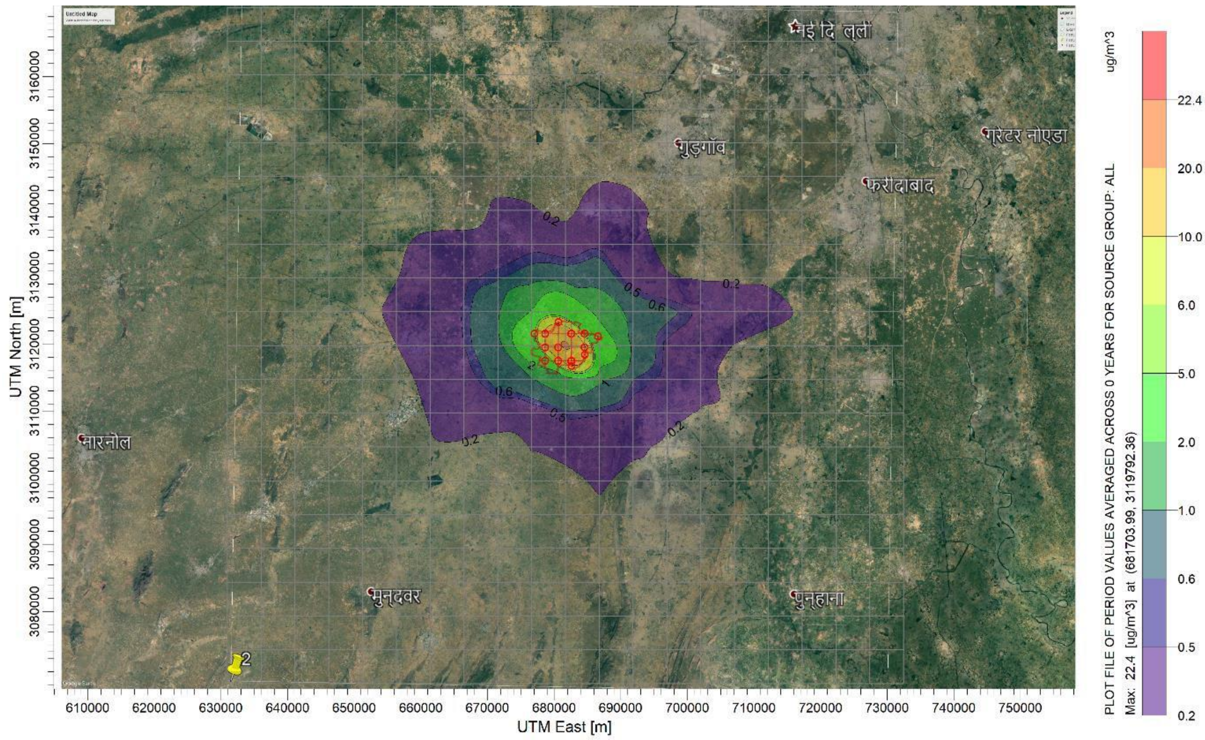

Figure 4. 21: PM2.5 Average Concentration in Monsoon Season

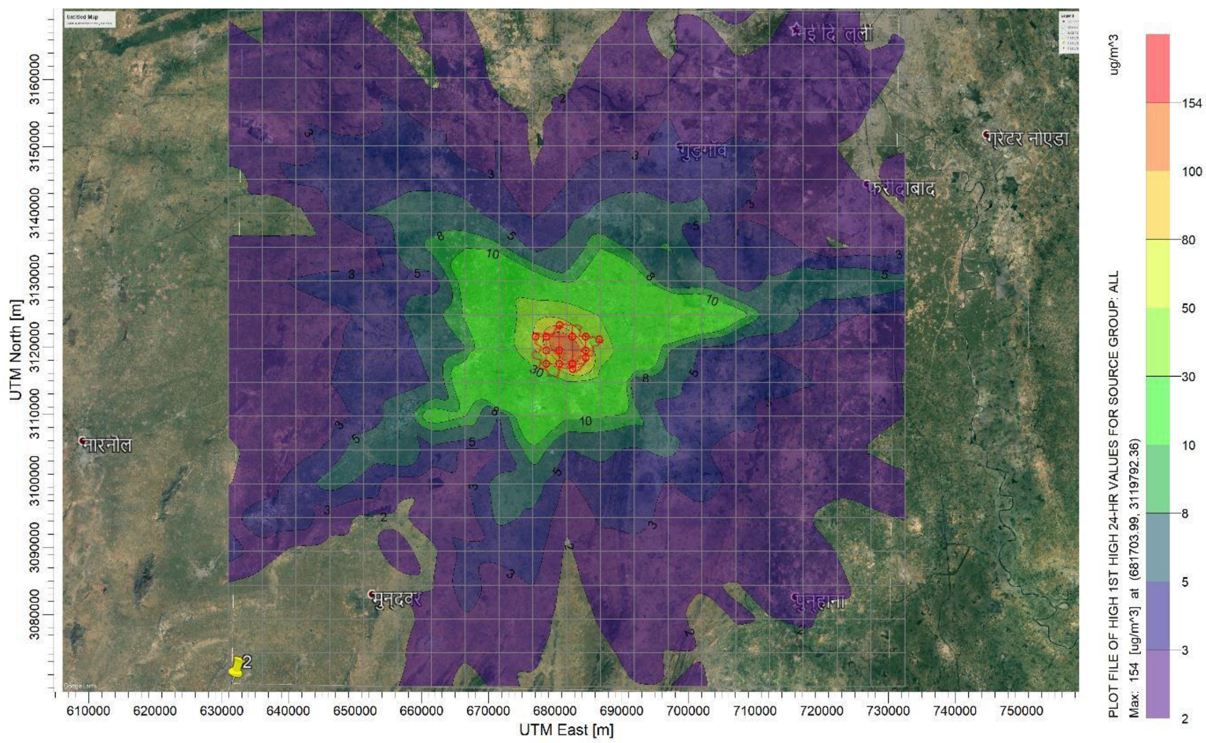

Figure 4. 22: PM2.5 24-hr Peak Concentration in Post-Monsoon Season

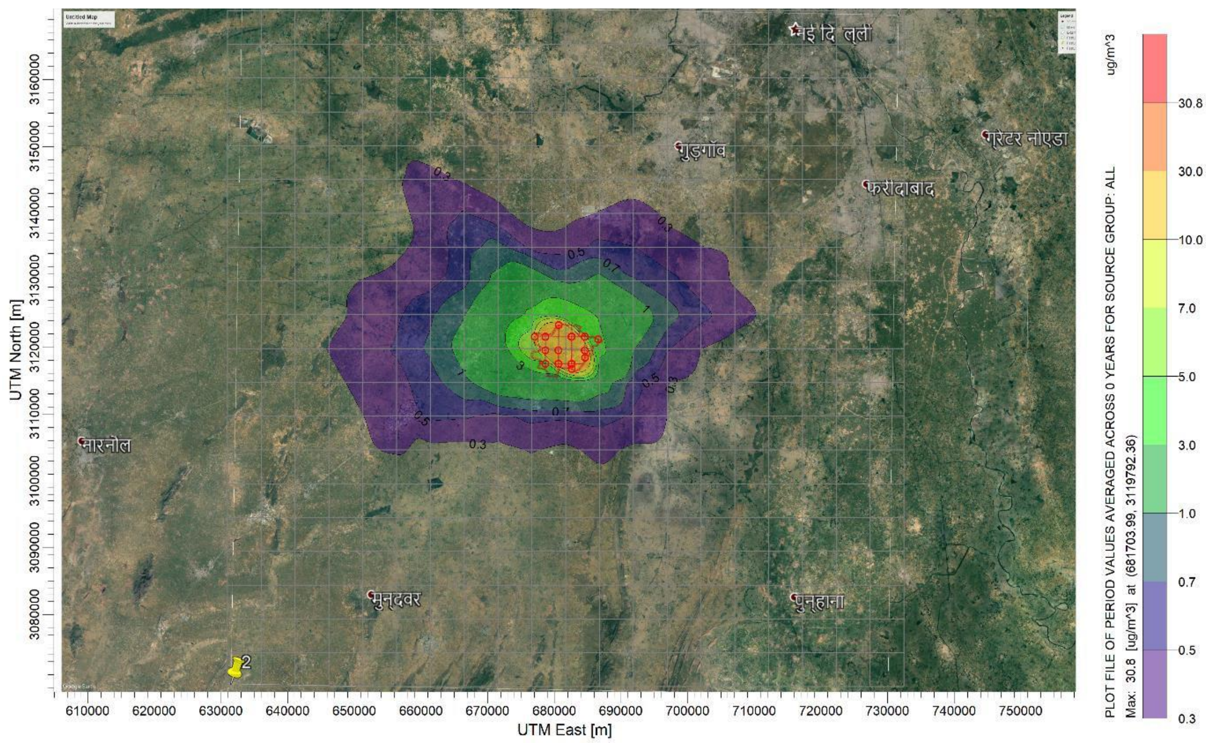

Figure 4. 23: PM2.5 Average Concentration in Post-Monsoon Season

Chapter 5: Control options, Analyses and Action Plan

5.0 Air Pollution Scenario in the City of Bhiwadi

The city of Bhiwadi has a complex industrial environment with respect to air pollution and faces severe air pollution of PM_{10}, $PM_{2.5}$, SO_2, and NO_2. There are several prominent sources within and outside Bhiwadi contributing to pollution levels in ambient air; these pollutants can be taken as a surrogate of other pollutants also, as most of the pollutants coexist and have common sources.

Bhiwadi is considered as one of the major industrial hubs in the region. In addition to industrial and automobile pollution, there is a significant emission from fugitive sources. Clusters of small and medium scale industries are also responsible for air pollution. In most of the institutions, hotels, and offices, the diesel generators are used at the time of power failure. Unlike other cities, at several locations, garbage burning is a common practice; it is also seen that not only garbage burning, the industrial waste is also burnt at several places within the city, which can be an important contributor to air pollution. The road condition in the town is quite bad as roads are broken, poorly maintained and partially paved surfaces and it is observed that movements of the vehicle may cause non-exhaust road dust emission in a significant amount. The area outside the factories is poorly managed and has become a dumping ground of non-hazardous wastes.

This chapter presents various air pollution control options and their effectiveness in improving air quality. At the end of the chapter, a time-sensitive action plan is presented.

5.1 Control Options

It may be noted that air polluting sources are plenty and efforts are required for every sector/source. In addition, there is a need to explore various options for controlling air pollutants for increased emission in the future. A list of potential control options that include technical and management interventions is presented in Tables 5.1 for PM_{10} and $PM_{2.5}$ respectively. The assessment of efficacies of control options and development of these tables is the outcome of thorough modeling exercise and further analyses and interpretation to arrive at improvements in ground-level air quality throughout the city. The description of control options is given below.

Table 5. 1: Control Options, Emission Load, and Reductions in PM

Source	Control Action	Responsible authorities	Time Frame
Hotels/ Restaurants	Restaurants of sitting capacity more than 10 should not use coal and shift to electric or gas-based appliances.	Municipal Council, Bhiwadi, Bhiwadi Industrial Development Authority (BIDA)	1 year
	Ash/residue from the tandoor and other activities should not be disposed near the roadside.	Municipal Council, Bhiwadi, Bhiwadi Industrial Development Authority (BIDA)	1 year
Domestic Sector	LPG to all, currently 74.4 % of the households are using LPG for cooking, rest are using solid fuels.	The Department of Food, Civil Supplies and Consumer Affairs and Oil Companies	2 year
Municipal Solid Waste (MSW) Burning	Any type of garbage burning should be strictly stopped.	Municipal Council, Bhiwadi, RIICO(for	Immediate
	Surveillance is required that hazardous waste goes to TSDF.	Municipal Council, Bhiwadi, RSPCB	
	Sensitize people and media through workshops and literature distribution.	Municipal Council, Bhiwadi, Bhiwadi Industrial Development Authority (BIDA),	
Construction and Demolition	Wet suppression	Municipal Council, Bhiwadi, Bhiwadi Industrial, Development Authority (BIDA), Rajasthan Housing Board, PWD, RIICO	Immediate
	Wind speed reduction (for large construction site)		
	Waste should be properly disposed of. It should not be kept lying near the roads as it may contribute to road dust emission.		
	Proper handling and storage of raw material: covered the storage and provide the windbreakers.		
	Vehicle cleaning and specific fixed wheel washing on leaving the site and damping down of haul routes. Vehicle transporting raw materials or waste materials should be covered.		
	Actual construction area should be covered by a fine screen.		
	No storage (no matter how small) of construction material near roadside (up to 10 m from the edge of the road)		
	Sensitize construction workers and contract agency through workshops.		

Road Dust	The silt load in Bhiwadi varies from 7 to 73 g/m^2. The silt load on each road should be reduced under 5 gm/m^2.	Municipal Council, Bhiwadi, Bhiwadi Industrial, Development Authority (BIDA), Rajasthan Housing Board, PWD, RIICO	One Year
	Regular Vaccum sweeping should be done on the road having silt load above 5 gm/m^2.		
	Convert unpaved roads to paved roads.		
	vacuum assisted sweeping carried out four times in a month will reduce road dust emission by 71% (resultant emissions: 6 ton/day)		
	Roads condition should be maintained properly and carpeting of shoulders		6 months
	These roads should be fixed on priority-		
	1. Dhabha Complex to Bhiwadi Mod		
	2. Bhiwadi Mod to Toll Plaza (Alwar road)		
	3. Alwar Road to Mansa Chowk		
	4. Mansa Chowk to Relaxo Chowk		
	5. UIT Residential Area		
	6. Chowpanki Road		
Vehicles	Diesel vehicle entering/registered in the city should be equipped with DPF which will bring a reduction of 40% in emissions (This option must be explored once Bharat stage VI fuel is available)	Transportation Department	3 years
	Industries must be encouraged to use Bharat stage VI vehicles for transportation of raw and finished product	Bhiwadi Manufacturing Association (BMA)	Immediate
	Restriction on plying and phasing out of 10 years old commercial diesel driven vehicles.	Transportation Department	1 years
	Introduction of cleaner fuels (CNG/ LPG) for vehicles.	The Department of Food, Civil Supplies and Consumer Affairs and PNG Regulatory	1 year
	Electric/Hybrid Vehicles should be encouraged; New residential and commercial buildings to have charging facilities.	Transportation Department, BIDA	1 year
Industries and DG Sets	New air polluting industry under Red and Orange categories should be allowed in Bhiwadi only with stringent conditions as per CEPI Mechanism issued by the State Board	RSPCB	Immediate
	Ensuring emission standards in industries	RSPCB	
	Strict action to stop unscientific disposal of hazardous waste in the surrounding area	RIICO, BMA, RSPCB	

Source	Control Action	Responsible authorities	Time Frame
	There should be separate Treatment, Storage, and Disposal Facilities (TSDFs) for hazardous waste.	BMA, RSPCB	2 year
	Industrial waste burning should be stopped immediately	RIICO, BMA, RSPCB	Immediate
	Follow best practices to minimize fugitive emission within the industry premises, all leakages within the industry should be controlled	BMA, RSPCB	Immediate
	Area and road in front of the industry should be the responsibility of the industry	RIICO, BMA	
	Category A Industries (using coal and other dirty fuels)		
	About 400 boilers and furnaces in Bhiwadi are running over coal, wood, and other dirty solid fuels which should be shifted to natural gas and electricity	BMA, PNG Regulatory Board, Haryana City Gas Distributing Co. ltd, RSPCB	2 years
	Almost all rotary furnace having significant emissions are running on coal that needs to be shifted to natural gas and electricity	BMA, PNG Regulatory Board, Haryana City Gas Distributing Co. ltd, RSPCB	2 year
	Multi-cyclones should be replaced by baghouses	BMA, RSPCB	1 year
	Category B Industries (Induction Furnace)		
	Recommended Fume gas capturing hood followed by Baghouse should be used to control air pollution	BMA, RSPCB	1 year
	Diesel Generator Sets		
	Strengthening of grid power supply, uninterrupted power supply to the industries	State Energy Department, JVVNL	2 years
	Renewable energy should be used to cater the need of office requirement in the absence of power failure to stop the use of DG Set	BMA, Rajasthan Renewal Energy Corporation Ltd	1 year
*The above steps should not only be implemented in Bhiwadi municipal limits rather these should be extended to up to at least 25 km beyond the boundary. This will need support from the central government as well as the neighbouring state government			

5.1.1 Hotels/Restaurant

There are approximately 53 Hotels/Restaurants (more than sitting capacity of 10 persons) in the city of Bhiwadi, which use LPG and coal (mostly in tandoors). The PM emission in the form of flyash contributes to air pollution. It is proposed that all restaurants of sitting capacity more than 10 should not use coal and shift to electric or gas-based appliances. A 70 % reduction of PM_{10} (29 kg/d) and $PM_{2.5}$ (15 kg/d) emission from this source can be achieved by stopping uses of coal.

It is also seen that the ash/residue from the tandoor and other activities are disposed near the roadside. This will contribute to road dust emissions. The Hotel Association, City Municipal Council and RSPCB need to limit this source (see above) and have proper disposal of ash and residues.

5.1.2 Domestic Sector

Although in Bhiwadi, 74.4 % of the households use LPG for cooking, the remaining 25.6 % uses wood, crop residue, cow dung, kerosene and coal for cooking (Census-India, 2011). The LPG should be made available to the remaining 25.6% of households to make the city 100% LPG-fuelled. This action is expected to reduce 85% of PM_{10} (147kg/day) and 84% of $PM_{2.5}$ (132 kg/d) emissions from domestic sector. The Department of Food, Civil Supplies and Consumer Affairs and Oil Companies (Indian Oil/HP, etc.) should formulate a time-bound LPG supply to plan to all in Bhiwadi.

5.1.3 Municipal Solid Waste (MSW) Burning

Any form of garbage burning should be strictly stopped and monitored for its compliance. It will require the development of infrastructure (including access to remote and congested areas) for effective collection of MSW and disposal at the scientific landfill site.

The city municipal council should prioritize the MSW collection mechanism starting in a systematic manner in each ward (Figure 5.1 Shows estimated MSW generation). Special attention is required for fruits, vegetable markets and commercial areas and high-rise residential buildings, where MSW burning is common.

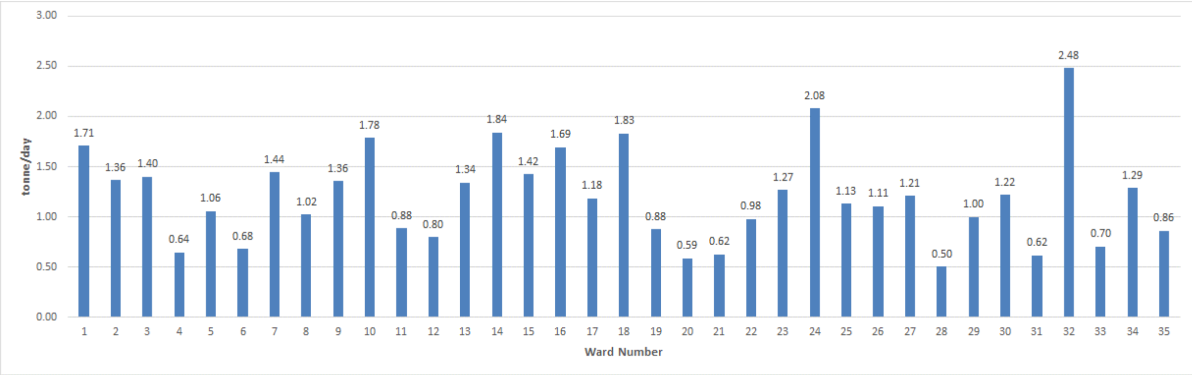

Figure 5. 1*:* **Ward-wise MSW Generation**

It is seen that industrial waste (hazardous in nature) is mixed with MSW and sometimes burnt; this must stop. It is recommended that there should be a separate industrial non-hazardous dumpsite for industrial waste and they should not be allowed to dispose of the waste on roads or front of the industry. Strict compliance and surveillance are required that hazardous waste goes to TSDF.

5.1.4 Construction and Demolition

The construction and demolition emission can be classified as temporary or short term. In the industrial area, these activities are frequent. It can be seen from Chapter 3 that this source is one of the significant ground-level emission sources and the fourth most contributor to area source emission in PM_{10}. The control measures for emission may include:

- Wet suppression (Figure 5.2)
- wind speed reduction (for large construction site) (Figure 5.3)
- Waste should be properly disposed of. It should not be kept lying near the roads as it may contribute to road dust emission.
- Proper handling and storage of raw material: covered the storage and provide the windbreakers
- vehicle cleaning and specific fixed wheel washing on leaving the site and damping down of haul routes
- The actual construction area is covered by a fine screen

- No storage (no matter how small) of construction material near roadside (up to 10 m from the edge of the road)

The suggested control measures will reduce the emission by 50% in PM_{10} (229kg/day) and 72% in $PM_{2.5}$ (58 kg/day). This will also reduce the road dust and fly ash contribution to ambient air concentration.

Figure 5. 2: Dust Suppression System; Sprays are used to capture airborne dust

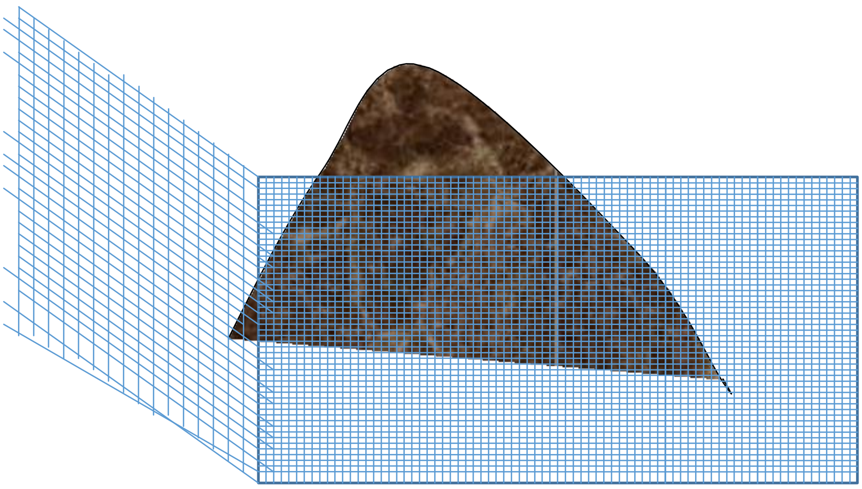

Figure 5. 3: Windscreen for dust control from the storage area

5.1.5 Road Dust

It can be seen from chapters 3, that the road dust emission and its contribution to ambient air concentration is consistent and it is one of the largest sources of PM_{10} and $PM_{2.5}$ emissions. The silt load from various sampling sites are shown in Figure 5.4

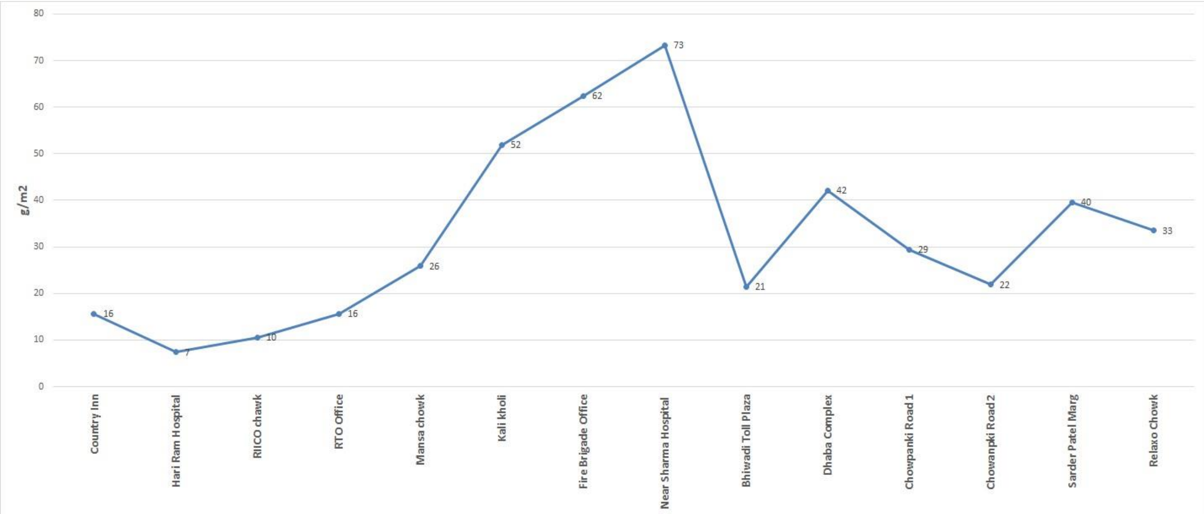

Figure 5. 4*:* Silt Load at Various Sampling Sites in Bhiwadi

It can be seen from figure 5.4 that the silt load varies from 7 to 73 g/m2. One can say that the city has a high silt load, which is caused by poor, broken roads, unpaved shoulders, movement of heavy trucks and poor maintenance.

The second highest silt road is at the Fire Brigade office, which is a minor road (having less traffic). The emission in this grid is less than other grids. Not only silt loads, but the traffic also plays a major role in road dust emission. The Dhabha Complex, Relaxo chowk, Mansa chowk, Bhiwadi mod is having road dust emission, due to the bad road condition and high traffic movement.

The industrial area, where the heavy vehicle movement is seen, also shows the high road dust emission. It is suggested that high traffic density roads should be properly maintained, paved carpet, shrubs should be planted on-road divider and the unpaved area near the roadside. These roads should be fixed on priority (listed below)

1. Dhabha Complex to Bhiwadi Mod
2. Bhiwadi Mod to Toll Plaza (Alwar road)
3. Alwar Road to Mansa Chowk

4. Mansa Chowk to Relaxo Chowk
5. UIT Residential Area
6. Chowpanki Road

In many places it is seen that the people are using unpaved roads for commutation, one such place is near Hari Ram Hospital (Figure 5.5). These areas can be classified as residential and the number of trips from these areas are frequent. It is important to maintain the roads in residential areas and in modern city, unpaved roads are not acceptable.

Figure 5. 5*: Unpaved Road used for Commutation*

The following control measures are evaluated and suggested to reduce the dust emissions on major roads:

1. Convert unpaved roads to paved roads. PWD (Public Works Department) and city administration should act immediately to reduce the pollution load from road dust.

2. Municipal Council should carry out vacuum-assisted Sweeping. The efficiency of vacuum-assisted sweeping is taken as 90% (Amato et al., 2010). If the sweeping is done twice a month, the road dust emission will be reduced by 42% i.e road dust emission at the end of the month will be 13 ton/day. If the frequency of sweeping is increased to four times in a month, then the road dust emission will be reduced by 71% (6 t/day).

3. If the silt road is greater than 5 gm/m^2, the vacuum-assisted sweeping should be carried out by the municipal council and the RSPCB should surveillance.

4. It is important that the condition of the roads is maintained properly, and shoulder paved by interlocking concrete blocks.

5.1.6 Vehicles

It can be seen from Chapters 3 that the vehicle emission contribution is highest for CO and NOx emissions as well as they have a significant contribution to PM_{10} and $PM_{2.5}$ There is a relatively large contribution of diesel vehicles (trucks, buses, LCVs, cars, etc) to PM_{10}, $PM_{2.5}$ CO, $SO_{2,}$ and NOx. Therefore, control measures have focused on advanced technological intervention for diesel vehicles.

1. Retro-fitment of Diesel Particulate Filter (DPF): These filters have PM emission reduction efficiency of 60-90%. If the diesel vehicle entering the city has been equipped with DPF, there is a reduction of 40% emission. This option must be explored once Bharat stage VI fuel is available.

2. Industries must be encouraged by the transportation department to use Bharat stage IV vehicles for transportation of the raw and finished product.

3. PUC checks are the means to check emissions from on-road vehicles; this should be strengthened. Emissions from in-use vehicles also depend on the maintenance and upkeep of vehicles. In this regard, it is suggested that each vehicle manufacturing company should have its own service centers in sufficient numbers to cater to the need of their vehicles in the city. The automobiles manufacturing company-owned service centers (AMCOSC) should be fully equipped for complete inspection and maintenance of vehicles ensuring vehicles conforming to emission norms and fuel economy after servicing.

4. Restriction on plying and phasing out of 10 years old commercial diesel-driven vehicles.

5. Introduction of cleaner fuels (CNG/ LPG) for vehicles.

6. Electric/Hybrid Vehicles should be encouraged; New residential and commercial buildings to have charging facilities.

5.2.7 Industries and Diesel Generator Sets

Industries

- New air polluting industry under Red and Orange categories should be allowed in Bhiwadi only with stringent conditions as per CEPI Mechanism issued by the State Board.

- The types of industrial fuel, boilers, furnaces, etc are presented in Table 5.2 Approximately 400 boilers/furnaces are operational in Bhiwadi and contribute heavily to particulate as well as in gaseous emissions. The heavy contribution is due to the use of coal, wood, and other solid fuels, the industry should shift to clean fuel such as natural gas and electricity. Majority of solid fuel-based industries used multi-cyclone as an air pollution control device. It is recommended that these cyclones should be replaced by baghouses for effective control of particulate emission.

- Ensuring emission standards in industries

- Strict action to stop unscientific disposal of hazardous waste in the surrounding area

- Industrial waste burning should be stopped immediately

- Area and road in front of the industry should be the responsibility of the industry

Table 5. 2: Furnace/Boiler Details in Bhiwadi

Boiler/Furnace Type	Fuel used in Boiler/Furnace	No of Furnaces/Boilers	PM10 kg/day	PM2.5 kg/day	SO2 kg/day	NOx kg/day	CO kg/day
Baby Boiler	Coal, Wood, HSD, Gas, Briquettes	42	447	402	1831	1589	1597
Coal pulveriser	Coal	14	152	137	474	549	12
Hot Air/Water Generator	LPG, Wood, Coal, HSD,	9	59	53	20	28	1365
Induction Furnace	Electricity	46	1762	1586	0	0	0
Ball mill	Electricity	42	96	87	0	0	0
Down Draft Shuttle Kiln	LPG, PNG, LDO	13	4	3	176	43	8
Sintering Furnace	Electrical and LPG	6	0	0	0	1	1
Annealing Furnace	LSHS, CBFS, LDO	21	26	23	1240	241	22
Cupola Furnace	Coal	4	33	29	102	118	3
Heating & Re- Heating Furnace	LSHS, LDO, FO, Coal, HSD	20	312	281	1362	1179	32
Mandir Furnace	Coal, Wood	10	37	33	107	124	74
Pit furnace	Electricity, LSHS, Coal	12	197	177	139	161	4
Uncategorised Furnace	LSHS, CBFS, LDO, FO, Coal, Wood	73	454	409	4194	1651	1477
Rotary Furnace	Coal, HSD, LDO	14	246	221	1084	968	29
Thermic Fluid Heater	Wood, LDO, Coal, HSD	52	151	136	332	160	3140
Thermo Pack	LSHS, Wood, Coal, HSD	6	6	5	47	22	77
Total		384	**3982**	**3584**	**11108**	**6834**	**7842**

- There are many industries with induction furnaces, which is a very polluting process, with almost no pollution control devices (Figure 5.6). The maximum emissions occur when the furnace lids and doors are opened during charging, back charging, alloying, oxygen lancing (if done), poking, slag removal, and tapping operations. These emissions escape from sides and top the building.

Figure 5. 6*: Inductance Furnace in Bhiwadi (*Existing*)*

- To address the pollution caused by fugitive emissions using induction furnaces a fume gas capturing device has been developed and commercially available. A side-based suction (Figure 5.7 to 5.9) is far more effective than top suction, which interferes with the movement of the crane.

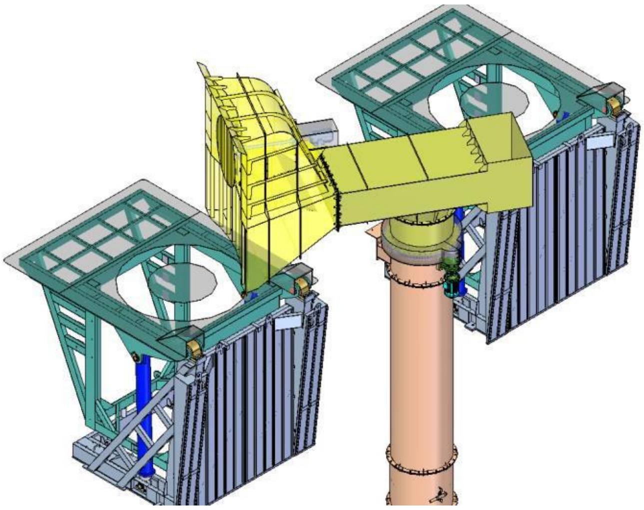

Figure 5. 7*: Proposed Suction Hood (Pic courtesy: Electrotherm)*

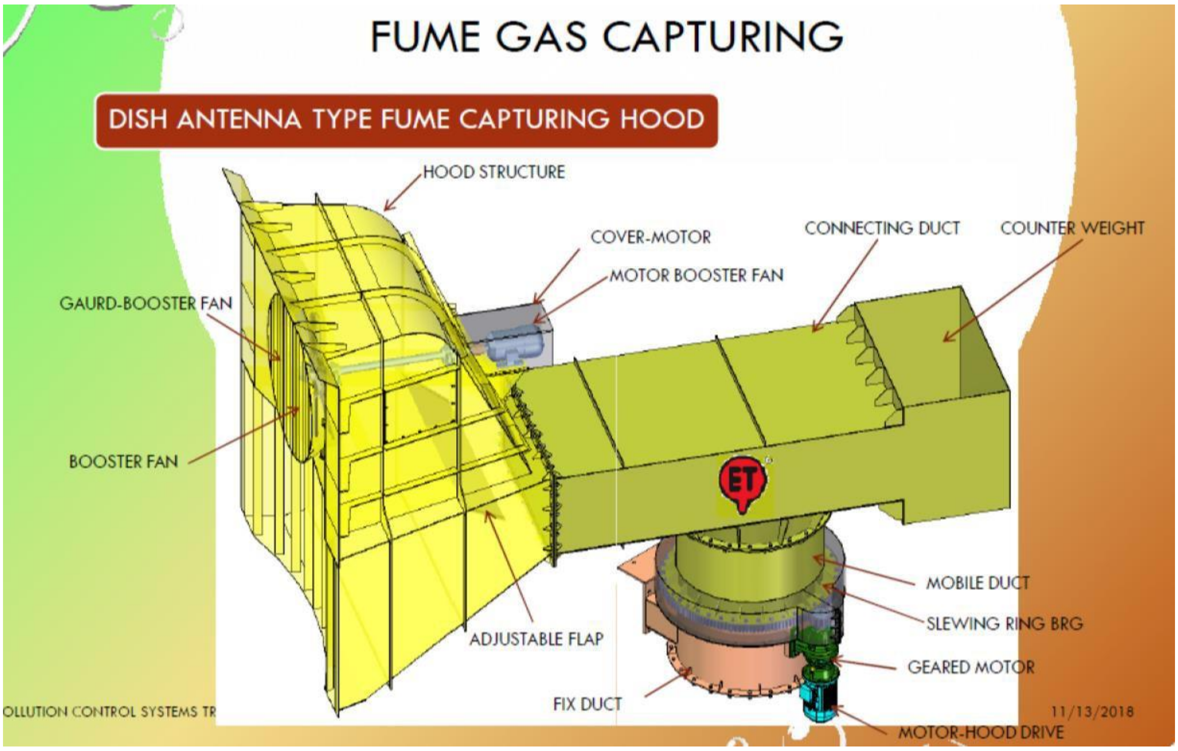

Figure 5. 8: Side-based Suction Hood (Pic courtesy: Electrotherm)

Figure 5. 9: Working of side-based Suction Hood

- It is recommended that a fume gas capturing hood followed by baghouse should be used to control air pollution.

The economics of the side-based suction hood for an induction furnace:

Assume capacity 8 ton per batch

Running time = 8 hrs.

Capital Cost of Suction Hood= Rs. 40 lakhs

Electricity cost for Running for year = Rs. 26.5 lakhs

Running + Capital Cost for ten years = Rs. 3.0 cr

Per year operational cost (including maintenance) = Rs. 30 lakhs

Turnover of the company per year = Rs. 3 crore

Pollution control cost is 10% of turnover. Which is somewhat high and may raise the question of the economic viability of the industry, especially when other such industries in the country do not do such a level of investment. The industry will need some support in terms of soft loans or even some subsidy.

- The baby boiler is the second type of boiler which is being used by many industries with coal and HSD. This results in high emission load in PM, SO_2, NO_2, and CO from these industries.

- Rotary Furnace (14 nos) is being by a lesser number of industries but contributes significantly to high emission load in PM, SO_2, NO_2, and CO. Nearly all the rotary furnaces use coal as fuel.

- The top 20 contributors to estimated industrial emissions are presented in Table 5.3.

Table 5. 3: Top Industrial Contributor

S.No	Name	PM_{10} (kg/day)
1	Ashiana Ispat Ltd.	210.785
2	Tarun Alloys Ltd.	184.437
3	Sun Sands Pvt Ltd	154.836
4	Sewa Steels(P) Ltd.	152.400
5	Shree Balaji Forgings Private Limited	121.920*
6	Shree Balaji Furnaces (P) Ltd.	121.920*
7	Mani Mahesh Ispat Pvt Ltd (Old NameMMMR Estate Pvt. Ltd.)	121.920*
8	Naman Casting Pvt. Ltd.	121.920*
9	Shri Shyam Kripa Steel Pvt. Ltd	121.920*
10	Shree Jagdamba Metals	106.680*
11	Kiwi Alloys Limited	106.680*

S.No	Name	PM_{10} (kg/day)
12	Young Steels (P) Ltd.	106.680*
13	Titan Biotech Ltd.	103.821
14	Mars Forgings	81.888
15	Satra Industries	77.724
16	Rohan Metals Pvt. Ltd	77.343
17	Elegance TMT Pvt. Ltd.,	76.490
18	Reby Casting (P) Ltd.	60.960
19	Metallic Rolls	55.541
20	S.M. Herbals Pvt. Ltd	51.44

**Estimated values on the basis of the assumption*

- The industry should use renewable energy to cater to the need for office requirement in absence of power failure i.e. zero loads of office on DG Set.
- The Rajasthan government should supply sufficient grid power to industries for an effective industrial run.
- All leakages within the industry should be controlled
- Follow best practices to minimize fugitive emission within the industry premises (Figure 5.10)
- It is seen that industrial waste (hazardous in nature) is mixed with MSW and burnt in several parts of Bhiwadi. It is recommended that no industrial waste should be mixed with MSW. There should be separate Treatment, Storage, and Disposal Facilities (TSDFs) for hazardous waste that should be developed under the guidance of RSPCB.
- The area inside and outside the industry premises should be properly maintained. The respective industry should be held responsible for not maintaining the area properly.

Figure 5.10: Industrial waste within the premises

5.2 Environmental Surveillance

1. A system should be developed for monitoring environmental quality in order to detect areas of pollution concentration in time for remedial measures.

2. GRAP System (Graded Response Action Plan) should be developed: It is an emergency plan through which pollution control strategize to act according to air quality status suitable and rapid action that can be implemented quickly.

3. Pollution Control Board should take regularly do visits to check the status of road dust as it is seen that road dust is a major emission source for particulate matter.

4. Visual emissions must be informed and properly documented so that data of industries or sectors is causing pollution can be identified.

5. For doing the above steps manpower must be increased in the respective departments so that the surveillance can be conducted uninterrupted.

6. Industries illegally running night shifts must be checked through surveillance. At night dispersion is more difficult that will cause more impact of pollution.

5.3 Strengthen Bhiwadi Regional Office

- New manpower recruitment for sampling, analysis, assessment, and surveillance

- Automated Stack Testing Kit

- Surveillance team should work in two shifts (day and night)
- Strict action against visible emission
- Proper documentation of violation of emission norms
- Capacity-building should be done through regular training of personals
- Laboratory Upgradation

5.4 Other Control Options

1. Management of non-hazardous industrial solid waste has not been given due importance. The industrial clusters have an unkempt appearance due to indiscriminate dumping of solid waste. Solid waste is often burned, causing severe air pollution. The officially designated solid waste dumping grounds in industrial these clusters are not managed in a scientific manner.

2. Currently, only 2.037 km^2 area is a green area as per the land-use made during the study (shown in chapter 2). Not many efforts have been made towards the planting of trees and the overall beautification of the industrial areas.

3. Capacity-building should be done through regular training of personals to improve work efficiency and avoid delay in action.

4. Integrated waste to energy plants should be installed for waste management that is one of the major sources of pollution in Bhiwadi. Agricultural waste and municipal waste could be used to produce energy that could be used by small industries. This should have the following facilities:
   T.S.D.F.: Treatment Storage and Disposal Facilities
   C.W.T.F.: Common Waste Treatment Facilities

5. Bhiwadi has a suitable location for installing a solar plant as a number of sunny days is more in Bhiwadi. Solar power should be installed in Bhiwadi to reduce the running hours of Diesel Generators as well as to power infrastructural facilities in the commercial area.

APPENDIX 1

Table 1: Emission Factor Considered for this Study

Source		Units	PM_{10}	$PM_{2.5}$	NOx	SO_2	CO
Cremation		g/kg	6.53	5.88	1.81	0.62	40.18
Domestic	Wood	g/kg	5.04	4.54	1.40	0.48	31.00
	Crop residue	kg/ton	11.00	9.90	0.49	0.12	58.00
	Cow dung	g/kg	5.04	4.54	1.40	0.48	31.00
	Coal	g/kg	13.20	4.60	3.99	13.30	24.92
	Kerosene	g/lit	0.61	0.55	2.50	4.00	62.00
	LPG	g/lit	2.10	2.10	3.60	0.40	2.00
DG Set		g/kwh	1.33	1.20	18.80	1.24	4.06
Industrial Area	LDO	g/lit	2.37	2.13	6.60	33.91	0.60
	HSD	g/lit	1.49	1.34	6.60	18.84	0.60
	LPG	g/lit	0.10	0.10	1.80	0.00	1.01
	Natural gas	g/lit	0.00	0.00	0.00	0.00	0.00

Source		Units	PM_{10}	$PM_{2.5}$	NOx	SO_2	CO
	Coal(cyclone)	g/kg	10.15	1.05	11.00	9.50	0.25
	Coal(scrubber)	g/kg	7.35	5.25	11.00	9.50	0.25
	Dal mill	kg/hr	85.00	-	-	-	-
Industrial Stack	LDO	g/lit	2.37	2.13	6.60	33.91	0.60
	HSD	g/lit	1.49	1.34	6.60	18.84	0.60
	LPG	g/lit	0.10	0.10	1.80	0.00	1.01
	Natural gas	g/lit	0.00	0.00	0.00	0.00	0.00
	Coal(cyclone)	g/kg	10.15	1.05	11.00	9.50	0.25
	Coal(scrubber)	g/kg	7.35	5.25	11.00	9.50	0.25
Vehicle	2 wheelers(BS-iii)	g/vkt	0.04	0.03	0.15	0.00	2.30
	2 wheelers (BS-iv)	g/vkt	0.04	0.03	0.08	0.00	1.00
	3 wheelers (CNG)	g/vkt	0.02	0.01	0.50	0.00	1.00
	4 wheelers (BS-iii)(p)	g/vkt	0.01	0.00	0.15	0.00	2.30
	4 wheelers (BS-iv)(p)	g/vkt	0.01	0.00	0.08	0.00	1.00
	4 wheelers (BS-iii)(d)	g/vkt	0.05	0.05	0.50	0.00	0.64

Source		Units	PM_{10}	$PM_{2.5}$	NOx	SO_2	CO
	4 wheelers (BS-iv)(d)	g/vkt	0.03	0.02	0.25	0.00	0.50
	4 wheelers (CNG)	g/vkt	0.01	0.01	0.74	0.00	0.06
	LCV(CNG)	g/vkt	0.02	0.02	3.10	0.00	1.86
	LCV(Diesel)	g/vkt	0.48	0.43	2.12	0.00	3.66
	Bus (CNG)	g/vkt	0.04	0.04	6.21	0.00	3.72
	Bus (Diesel)	g/vkt	0.30	0.27	6.53	0.00	3.92
	Truck	g/vkt	1.24	1.12	9.30	0.00	6.00
Tandoor		kg/day	14.00	7.00	3.99	9.50	24.92
Construction		kg/day/m^2	0.0025	0.0006	-	-	-

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