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CLEAN AIR CATALYST

Detailed Analysis of Air Pollution Sources and Activities in Indore City

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Clean Air Catalyst

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ABOUT THE REPORT

The “Detailed Analysis of Air Pollution Sources and Activities In Indore City” has been prepared by WRI India, as part of the Clean Air Catalyst (CAC) Program. The CAC is a five-year flag ship program, supported by the USAID (United States -Agency for International Development) and led by the World Resources Institute, the Environmental Defense Fund, and a consortium of partners.

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EXECUTIVE SUMMARY

According to the 2022 World Air Quality Report, India is the eighth most polluted country in the world[1]. The entire population in India lives in areas with annual average particulate matter (PM2.5) concentration exceeding air quality guidelines recommended by the World Health Organization (WHO), and ninety- four percent of people reside in areas with PM2.5 concentration exceeding the Indian National Ambient Air Quality Standards[2]. Air pollution accounted for 1·67 million deaths in India in 2019, which was 17·8% of the total deaths nationwide[3]. Better understanding of the sources affecting air quality through monitoring and emission inventories is crucial to inform actions to reduce emissions and improve health.

To understand the local sources of air pollution and identify sustainable solutions for clean, healthy air for better health, climate, and development outcomes, United States Agency for International Development (USAID) launched a five-year-long Clean Air Catalyst (CAC) air pollution program in Indore Municipal Corporation (IMC). The purpose of the CAC program is to ensure solutions for air pollution problems that are effective and inclusive in the IMC area. The CAC is being implemented by the World Resources Institute, the Environmental Defense Fund, and a consortium of partners.

Under the CAC, a bottom-up high-resolution emission inventory is being developed based on activity data. An emission inventory is a database that lists the air pollution sources and the amount (mass of pollutants emitted) of air pollutants discharged into the atmosphere during a year or other time period by a specific activity[4]. The various sectors covered under the emission inventory are transport, road dust, industries, household cooking, solid waste burning, construction and demolition, brick kiln, diesel generator (DG) sets, crematoria, agriculture burning, and eateries and restaurants. The secondary data for various sectors were collected from the Census of India (2011), Economic Census of India,

[1] World air quality report 2022. Region and city PM2.5 ranking. IQAir World Air Quality Report 2022
[2] India - AQLI (uchicago.edu)
[3] India State-Level Disease Burden Initiative Air Pollution Collaborators. Health and economic impact of air pollution in the states of India: the Global Burden of Disease Study 2019. Lancet Planet Health. 2021 Jan;5(1):e25-e38. doi: 10.1016/S2542-5196(20)30298-9. Epub 2020 Dec 27. PMID: 33357500; PMCID: PMC7805008.
[4] Managing Air Quality- Emissions Inventories, https://www.epa.gov/air-quality-management-process/managing-air-quality-emissions-inventories#:~:text=An%20emissions%20inventory%20is%20a,year%20or%20other%20time%20period.

Annual Survey of Industries, and National Sample Survey Organization (NSSO). A primary survey was designed to fill the data gaps from the secondary data analysis to get a more realistic understanding of the IMC area. A detailed survey was conducted in IMC administrative boundary to collect primary data from solid waste burning, eateries, traffic and transport, brick kilns, and industries. This survey was designed to collect more reliable activity data, which will help in understanding the activities of various air pollution sources in the city and in developing a microscale comprehensive emission inventory at the ward and village level.

The main objectives of the survey are:

1. To collect primary activity data to develop a robust local Emission Inventory: Most of the emission inventories are based on secondary data, which involves a lot of uncertainties. Collecting primary data helps to reduce uncertainty and validate our results.

2. To identify root causes of air pollution and fill the data gap from available secondary data and literature: The available secondary data are not always of the exact study year, hence the gaps in the data can be filled with the help of a primary survey.

3. To dig out recent sector-specific data for a better understanding of the present condition and acquire recent information for emission inventory: Secondary data is not always available for every sector, for instance, the eateries and open MSW burning, in such cases, the primary data provides a baseline information for estimating the emissions.

4. Primary survey data will be used in the Source Apportionment study for air quality modeling purposes: The primary survey data will be used to generate emissions, which will further be used to carry out the dispersion modeling, a part of the Source Apportionment study.

5. To understand the ground conditions and verify the available secondary data: As discussed in the above points, the secondary data is sometimes not available for current years, due to which the data is extrapolated and leads to uncertainty. For instance, the Census data is for the year 2011, and if we want to estimate emissions

for 2020, then extrapolating this data will not be correct. A lot of policies have been introduced in between these years in various sectors like the Pradhan Mantri Ujjwala Yojana (PMUY) yojana for the household cooking sector, BS-VI, and scrapping policy which removes vehicles more than 15 years old in the transport sector. The primary survey provides updated ground information and thereby reduces uncertainty.

6. Identification and mapping of various sources at the ward level of the different activities in the IMC area: Identify hotspots and other local air pollution sources and activities at the ward level. For instance, found waste burning incidences in some areas, which were prioritized as hotspots.

7. To prioritize and formulate Sector-specific solutions: The on-ground survey helps in understanding the local issues and the reasons behind them, which helps in identifying proper solutions and strategies to combat those issues at the local level.

Before starting the survey, wards in the IMC boundary were identified based on population size, land use pattern, socio-economic status, literacy, female population, working female number, connectivity, and access. Based on the above parameters, a primary survey was conducted in 54 wards. The number of representative samples taken from these wards for each sector was then calculated. The survey consisted of a questionnaire survey, a commercial establishment survey, a transect route-based survey, a classified traffic volume count (TVC), and an origin-destination (OD) survey.

A total of approximately 4262 samples were collected for all the sectors. The number of samples collected from rural and urban areas was 3456 from the transport origin-destination survey, 207 waste-burning incidences in both winter and summer seasons, 469 samples from eateries, 86 from brick kilns, and 44 samples from industries. These samples are considered to represent the specific sectors covered under the primary Survey and are used to estimate emissions.

1. Background and objective

An emission inventory is used to identify the sources of air pollution and to quantify the pollution load in a defined area. Preparation of an emission inventory involves a detailed

literature review, identification of pollution sources/sectors, activity data collection, emission estimation and spatial mapping of pollutants at 1 X 1 Km grid (figure 1).

The present report is a compilation of activity surveys carried out as part of the CAC program. The main sectors covered under the emission inventory are transport, industries, household cooking, solid waste burning, construction and demolition, brick kiln, diesel generator (DG) sets, agriculture burning, eateries and restaurants, and crematoria. A detailed literature review and secondary activity data analysis were done for all these sectors of the IMC area. To fill these data gaps and get recent sector-specific data with granular information, a primary survey was designed and conducted at the ward and village levels. The survey under the CAC program was conducted by WRI India team to collect primary data from the sources contributing to air pollution in the IMC area. These include municipal solid waste burning, eateries, traffic and transport, industries, and brick kilns. The survey consisted of a questionnaire survey, a commercial establishment survey, and a transect route-based survey. The data collected from the secondary and primary surveys are used to calculate the emission loads from different sectors.

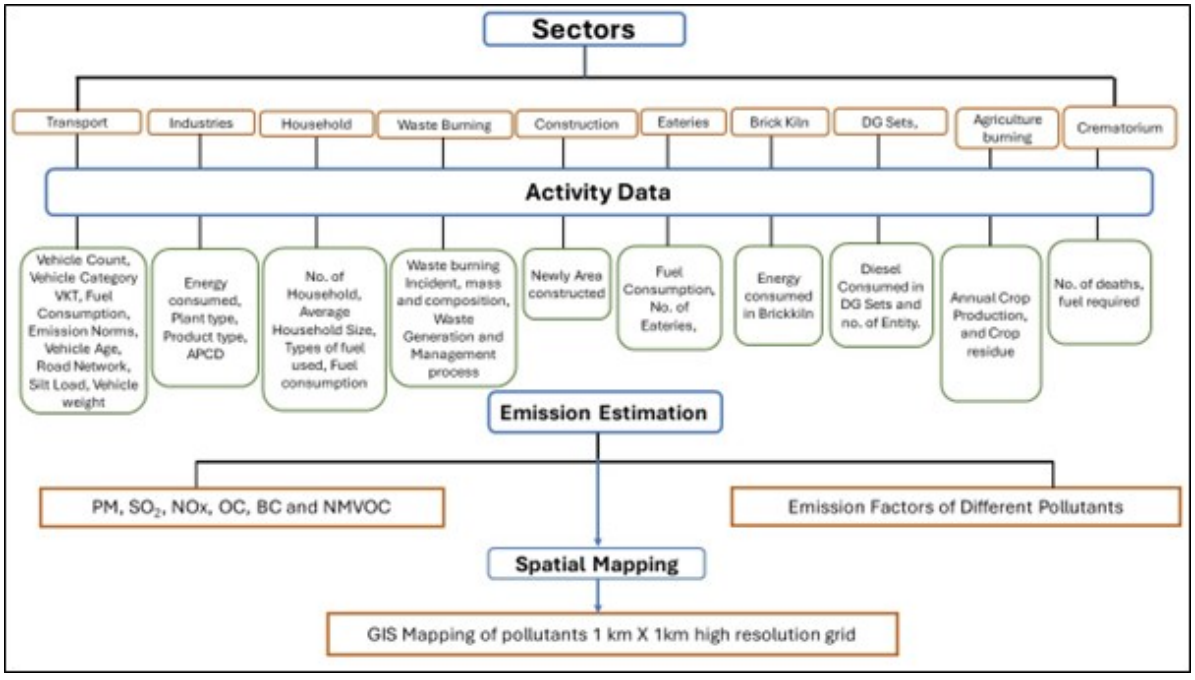

Figure 1: Steps carried to prepare an emission inventory

Survey Area:

Indore, the most populous city of Madhya Pradesh is home to 2.1 million people (Census

2011). It has been ranked as India's cleanest city in terms of solid waste management for six consecutive years, from 2017 to 2022, as per the Swachh Survekshan. Indore has been declared India's first "water plus" city under Swacch Survekshan 2021. Identical to many Indian cities, Indore is no stranger to air pollution and is identified as one of the non-attainment cities under the National Clean Air Programme (NCAP), which means that the air quality of Indore is exceeding the National Ambient Air Quality Standards (NAAQS) between 2011 to 2015. The slums in Indore have grown by 8% from 2010 to 2015 and hold around 38% of the total city population (Smart City Indore | SWOT Analysis). IMC is divided into 12 zones and 85 wards. Indore has 1 continuous and 3 manual ambient air quality monitoring stations. Indore being the cleanest city in India is also working to achieve clean air. Under the CAC program, WRI and EDF are working to ensure solutions related to air pollution problems that are effective and inclusive for IMC area.

The objectives of the survey are as follows:

1. To collect primary activity data to do the Emission Inventory estimation.
2. To identify root causes of air pollution and fill the data gap from available secondary data and literature.
3. To dig out recent sector-specific data for a better understanding of the present condition and acquire recent information for emission inventory.
4. Primary survey data will be used in the Source Apportionment study for air quality modeling purposes.
5. To understand the ground conditions and verify the available secondary data.
6. Identification and mapping of various sources at the ward level of the different activities in the IMC area.
7. To prioritize and formulate sector-specific solutions.

2. Methodology

The primary survey was carried out between December 2021 to May 2022 for open municipal waste burning (MSW), eateries, brick kilns, and transport. The survey for industries was carried out during the month of September 2022. Primary survey data collection was carried out through the following methods (Table 1)

(a) Questionnaire-based survey, where information is collected for specific activity through interviews with respective audiences. The questionnaire-based survey carried out for the industries included inquiries like the type of fuel used, Air Pollution Control Device (APCD) used, number of employees, female staff, stack height, working hours, etc.

(b) Commercial establishment survey, this survey was carried out for the eateries and brick kilns where information regarding fuel consumption, number of employees, female staff, and brick production, was collected.

(c) Transect walk-based survey, primary data on municipal solid waste burning is collected using the transect method developed by Nagpure et al. (2015), where the city is classified into different zones as per their socio-economic status (SES) and land use pattern. Representing the survey area's SES and land-use characteristics, the transect routes were laid out into different streets and roads of each zone. While observing the waste-burning incidents, a few personal interviews with respondents are also taken.

(d) Classified Traffic Volume Count (TVC) and Origin-Destination (OD) survey, TVC is an observation-based survey in which different vehicle types are counted at an interval of 15 minutes from 8 am to 8 pm to understand the peak traffic volume time and average passenger car unit (PSU) on the road. Origin destination survey is a questionnaire-based survey that includes the vintage and technology used, vehicle kilometer traveled (VKT) vehicle and fuel type, origin and destination of the traveler, and emission norms.

Table 1: Sector and area covered under the primary survey

S. NO.	SECTORS COVERED	AREA COVERED	SAMPLES COLLECTED	SURVEY TYPE
1	Transport	IMC and Surroundings	3456	TVC and OD & Questionnaire-based
2	Waste burning	IMC area	207	Transect walk
3	Eateries	IMC area	469	Commercial establishment
4	Brick Kilns	IMC and Surroundings	86	Questionnaire-based
5	Industries	IMC area	44	Questionnaire-based

Five interns and eighteen volunteers (only for transport survey) from local institutes of Indore- SGSITS, Indore School of Social work, and Acropolis, were hired to conduct the survey for the various sectors along with the WRI team.

a) Selection of area

Presently, Indore has 85 municipal wards (figure 2), although for the CAC project, we used the ward and village level secondary data and boundary as per the Census of India (2011). All the analyses for the present study were based on the Census of India (2011), Economic Census, (2013), NSSO, and Annual Survey of Industries data. Hence, as per the data availability and to represent it spatially on a map, the older Indore ward boundary- Pre 2015 (69 wards- figure 3) and additional added area/villages in 2015 (13 wards- figure 4) were merged to generate 82 wards (figure 5) only for CAC study. Table 2 presents the number of wards and areas used for the CAC study along with the pre and present ward boundaries.

Table 2: Present, Pre 2015 and CAC study ward boundary for IMC area

	INDORE WARD BOUNDARY – POST-2015 (PRESENT)	INDORE WARD BOUNDARY- PRE 2015)	INDORE WARD BOUNDARY (FOR CAC STUDY -INDORE WARD BOUNDARY- PRE 2015 + ADDITIONAL ADDED AREA/VILLAGES- IN 2015)
No. of Wards	85	69	82
Area	276 Sq. Km	131 Sq. Km	275 Sq. Km

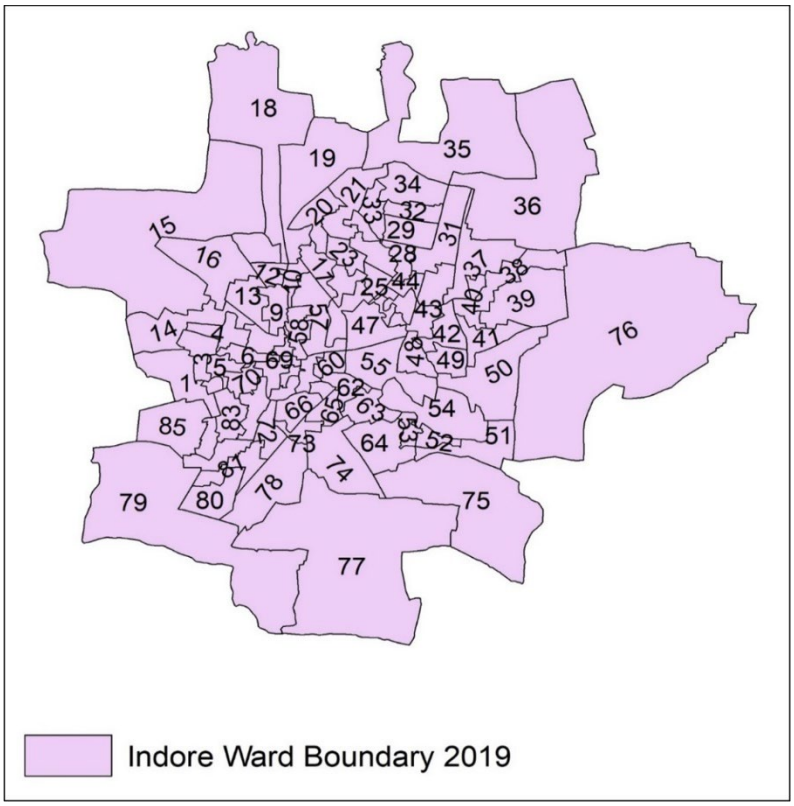

Figure 2: Indore ward boundary post 2015- Present

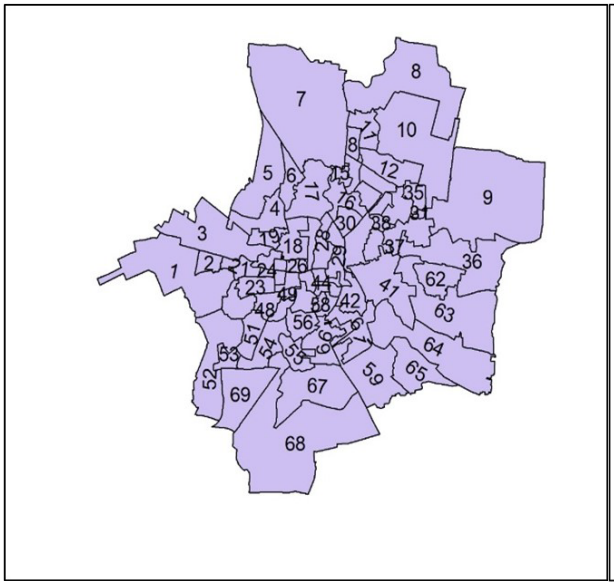

Figure 3: Indore ward boundary- pre 2015

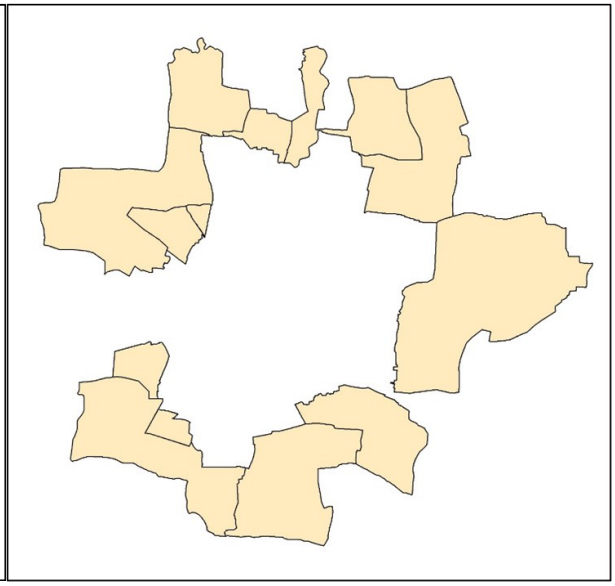

Figure 4: Additional added area/villages in 2015

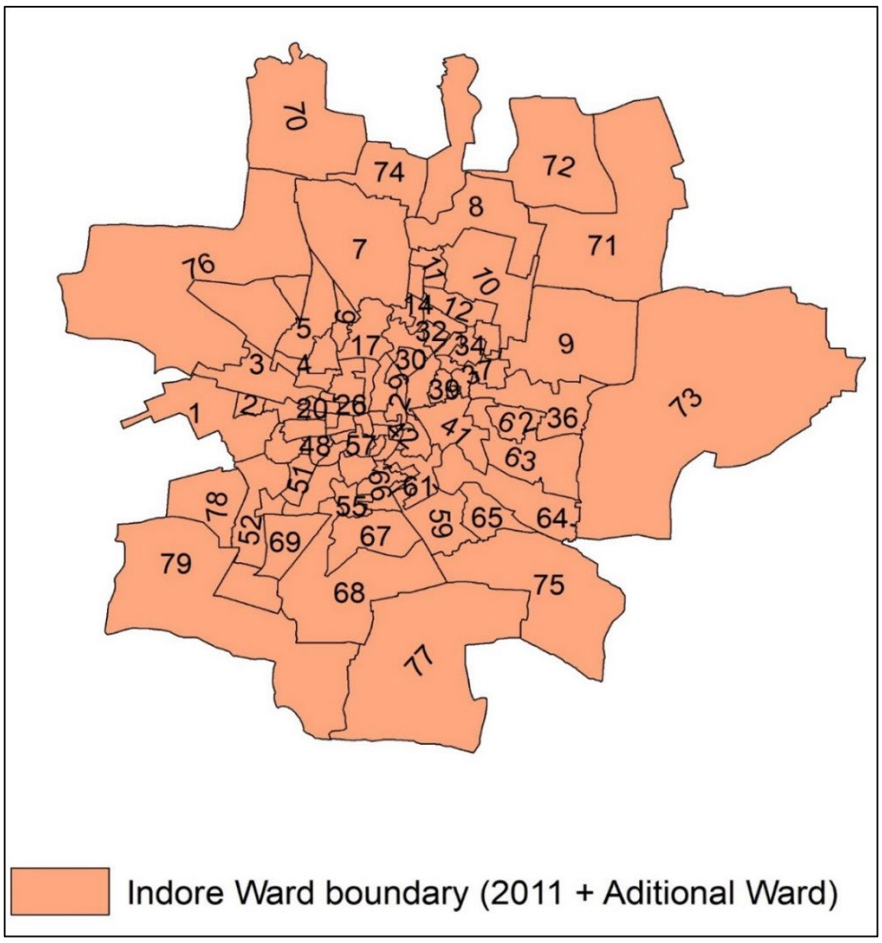

Figure 5: Indore Ward Boundary (For CAC Study -Indore Ward Boundary- Pre 2015 + Additional added Area/Villages- In 2015) (Source: IMC; Created by: WRI team)

Out of these 82 wards, 54 wards were selected for carrying out the primary survey. The parameters used to select these wards were population size, land use pattern, socio-economic status, literacy, female population, working female number, connectivity, and access. These wards were used as a representation of the entire city (Figure 6).

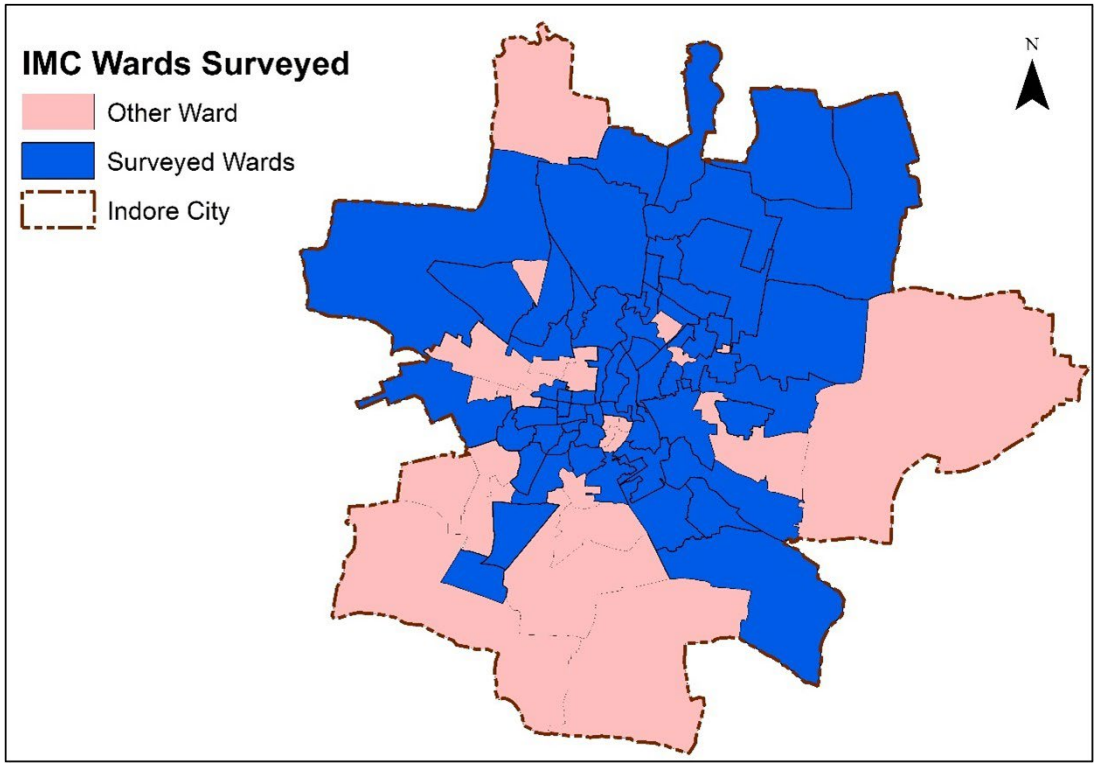

Figure 6: IMC wards where the primary survey was conducted

b) Sample size and collection

After identifying the wards and villages for carrying out the primary survey, a number of samples per sector were selected through the Cochran formula as shown in eq. 1 (Cochran, 1977),

$$n_0 = \frac{Z^2 pq}{e^2} \quad \text{..... Eq (1)}$$

Where,

n_0 is the sample size
Z^2 is Z value found in the Z table at a given Confidence level
p is the estimated proportion of an attribute that is present in the population

q is (1-p)
e^2 is Desired Level of precision

A total of 4262 samples were collected for all the sectors. The number of samples collected from both rural and urban areas were 3456 from transport origin-destination survey, 207 waste burning incidences in both winter and summer season, 469 samples from eateries, 86 from brick kilns, and 44 samples from industries. The sector- wise details are presented in the below section.

3. Sectors Covered During the Primary Survey

a) Transport and Traffic Survey

In the IMC area, a traffic count survey was conducted to determine the number of different types of vehicles on the road. This was completed by counting the number of vehicles and their variations on the major, minor, and arterial roads of IMC area. For conducting traffic vehicle count and Origin-Destination (OD) survey, six outer cordon points (OC) situated on highways outside the municipal limits were selected to understand the vehicle movement from the city to the outside and vice versa. Selected 11 inner cordon points (IC) inside the city covered all types of land use patterns, which represented roads from the residential settlement, commercial areas, industrial hubs, and mixed land use. These roads consisted of all types of road hierarchy comprising arterial (major roads), sub-arterial (connecting roads), local (minor roads), and highways which interconnect Indore into surrounding districts.

A survey team (18 volunteers, 5 interns, and 2 experts from WRI India) were deployed to count, classify, and interview the different vehicle categories for both directions of the road (Figure 7 and 8). Around 3456 samples were collected from an interview-based OD survey over the period of seven days along with counting and classification of different types of vehicles (Table 3). The transport and traffic survey were conducted for 12 hours from 8 AM to 8 PM at the selected location presented in Table 3 and Figure 9. In the OD survey, we also collected data related to fuel use, vintage, Bharat Stage (BS) norms, vehicle age, major servicing, gender-based vehicle drivers, etc.

Figure 7: Volunteers Conducted a Traffic and Transport Survey near C2Mallll (left) and Sirpur Lake (Right) (Survey date: 18 and 21 April 2022)

Figure 8: Volunteers Conducted a Traffic and Transport Survey near Aurobindo Hospital (Left) and Luv Kush Square (Right) (Date 16 April 2022)

Table 3: Location of Traffic and Transport Surveys in Indore

CORDON POINTS	LOCATION OF SURVEY	ROAD HIERARCHY	DATE OF SURVEY
OC-1	IDTL toll plaza	National Highway	16-Apr-22
OC-2	Luv kush square	Arterial Road	
OC-3	Near Sirpur Lake Garden	Sub Arterial Road	18-Apr-22
OC-4	Papaya tree Hotel Rau	National Highway	

OC-5	Tejaji Nagar Square	State Highway	19-Apr-22
IC-1	Bada Ganpati Mandir Square	Collector Road	20-Apr-22
IC-2	Near Gangwal bus Stand	Local Road	
IC-3	Mhow Naka	Collector Road	
IC-4	Near Satya Sai Chauraha, Vijay nagar	Local Road	21-Apr-22
IC-5	Bholeram Bhakt HanumanMandir Bhamori Square, Astha Talkies road	Sub Arterial Road	
IC-6	C21 Mall	Arterial Road	
IC-7	Musakhedi square (Eastern ring road)	Sub Arterial Road	22-Apr-22
IC-8	Teen imli chauraha Palda	Collector Road	
IC-9	State Bank of India Nipa	Local Road	23-Apr-22
IC-10	Nipania Square(pipliya kumar near Mercedes Benz)	Local Road	
IC-11	BP Petrol Pump, Talawli Chanda AB Road	Sub Arterial Road	

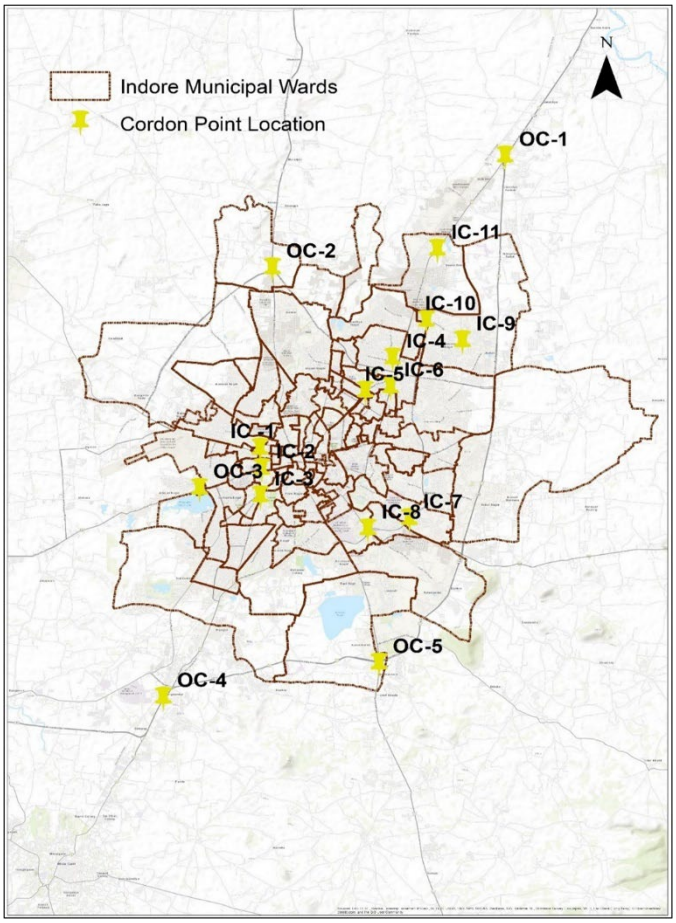

Figure 9: Survey Locations for Traffic and Transport Survey

b) Waste Burning

Indore has been ranked as the cleanest city in India in the past six years from 2017 to 2022 under Swach Survekshan, Govt. of India. The challenge faced today in solid waste management is the burning of waste due to behavioral issues. In IMC area, the primary data on solid waste burning was collected using the transect method developed by Nagpure et al. (2015). In this method, the wards of IMC area were classified as per their socioeconomic status (SES) and land use pattern (Figures 10 and 11). Then, the transect routes were laid out into different streets and roads, representing the survey area's SES and land-use characteristics.

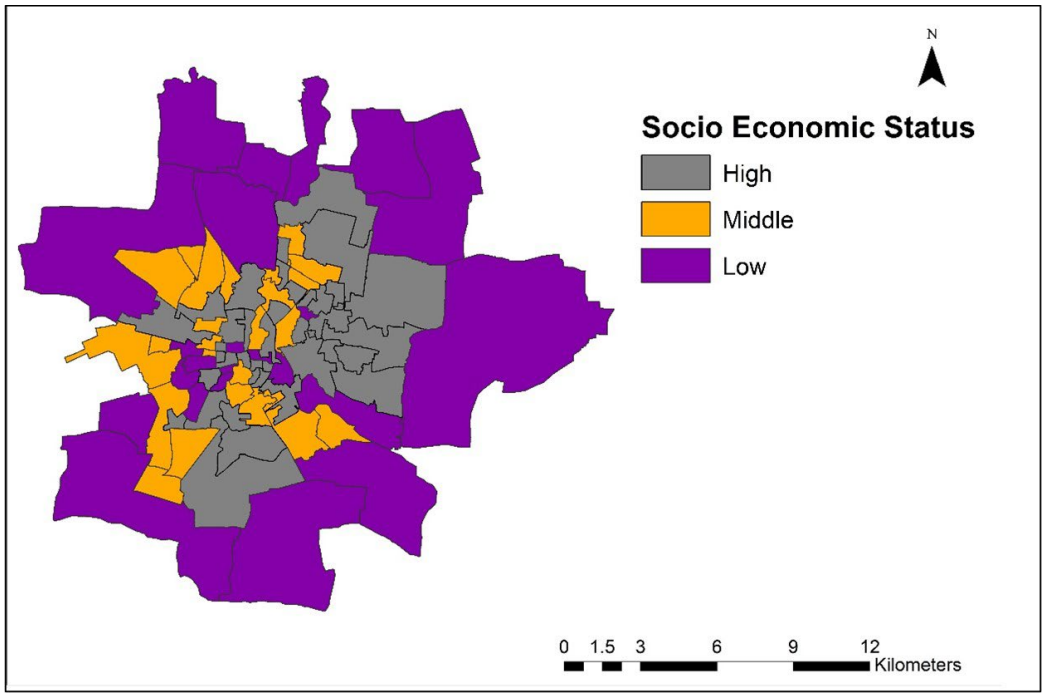

Figure 10: Classification of IMC boundary as per the Socio-Economic Status (SES)

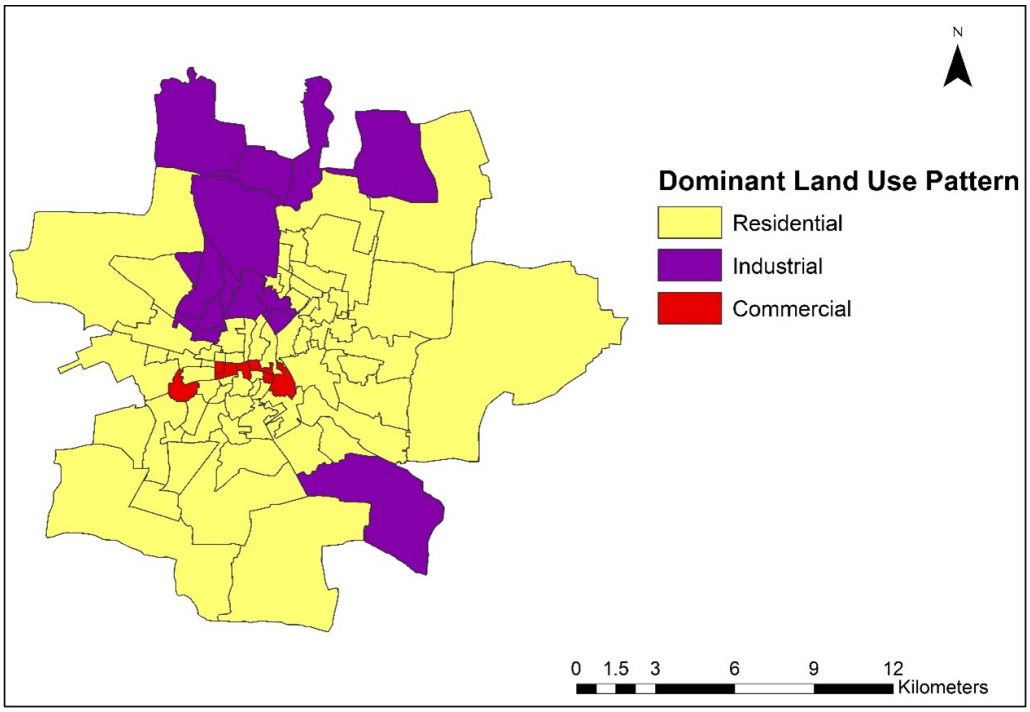

Figure 11: Classification of IMC boundary as per the land use pattern

Five transect routes were covered in IMC boundary (Figure 12). All transect routes in the sample wards were covered either on foot or by a vehicle in the morning and evening hours for three consecutive days during the winter (January -February 2022) and summer (May - June 2022) seasons. The number of municipal solid waste (MSW) burning incidences were recorded as part of each day's transect sampling, including latitude and longitude waypoints of each MSW burning incident, rough mass, and composition. By considering the number of MSW burning incidences, transect length, and width (including street width and building length of each side of the street), MSW burning frequencies/km2 for each zone of the IMC area for both winter and summer time were estimated. MSW burning incidences and mass (per capita) were calculated for each zone and then applied to the population of the rest of the similar zones in the IMC area to scale up the results.

As it is not possible to weigh burning MSW, the samples of MSW were weighed before and during burning by extinguishing it by sprinkling water on it and then subtracting the added water weight. The composition was measured by spreading out the burning (extinguished) MSW and observing the incompletely burned components.

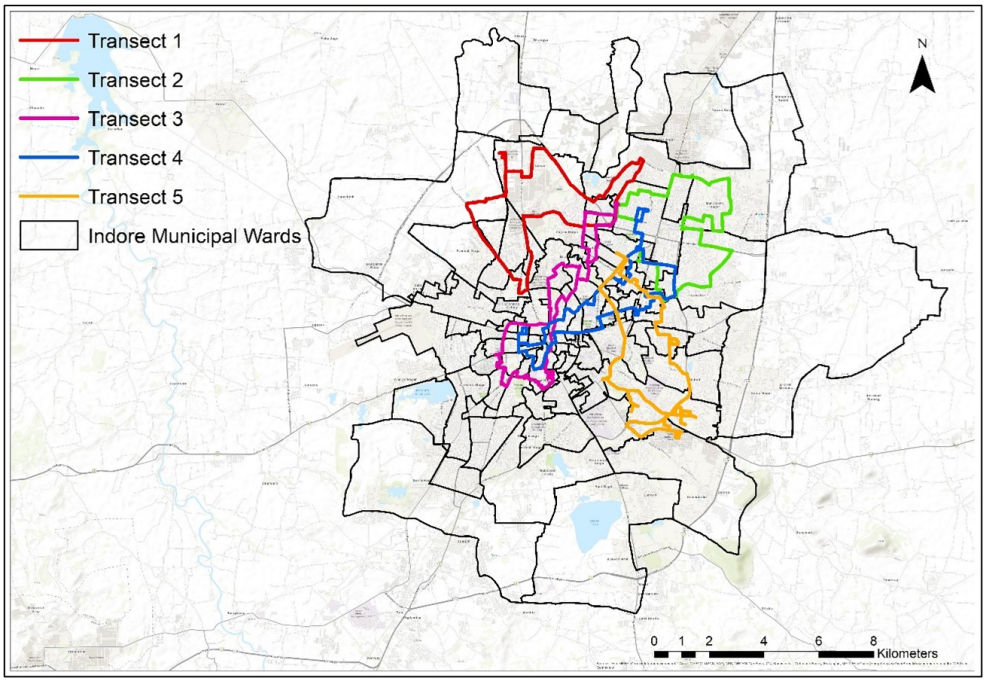

Figure 12: MSW burning survey transect routes during winters and summer (2022) in IMC area

c) Eateries and Restaurants

The number of available small and large eateries in different wards of IMC area were collected from Economic Survey of India (2013-14). There are around 2000 small and large eateries in IMC boundary. The minimum sample size required to collect information on fuel consumption in the city, calculated from the Cochran formula was about 350 eateries. A preliminary reconnaissance survey has been conducted in IMC area to identify the areas where all types of eateries were present. Other parameters considered for the final selection of the questionnaire-based survey were land use pattern, accessibility, food service market, and socio-economic characteristics.

Finally, the samples collected from the restaurants/eateries were 469 in IMC area, which represented a mix of small, and large ones, based on the number of people employed and people that could be served at a time. The surveyed eateries represented the whole range of fuels used in the commercial cooking sector (Figures 13 and 14).

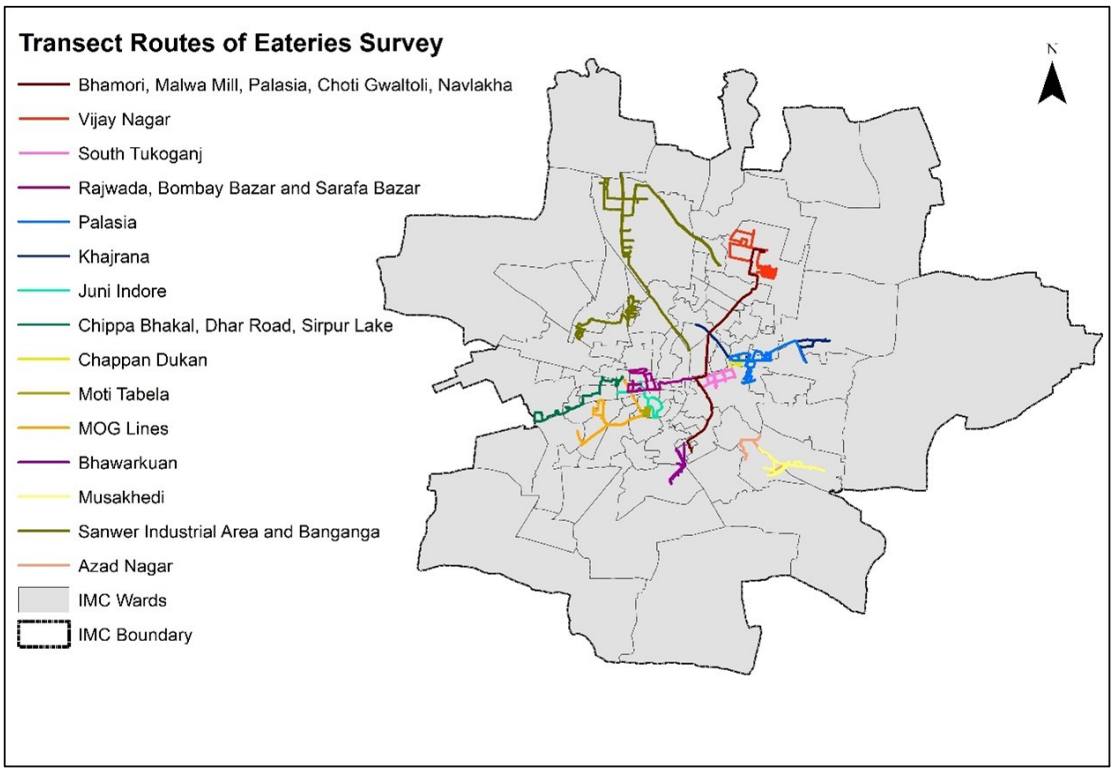

Figure 13: Transect routes of Surveyed Eateries in IMC boundary

Figure 14: Surveyed Eateries in different parts of the IMC area (January and February 2022)

d) Brick Kiln

The brick industry in the Indore district is thriving among small-scale industries as demand for bricks rises due to increased urbanization and city expansion. As per the study conducted by Guttikunda et al. (2019) in Indore, approximately one hundred twenty brick kilns with clamp technology were present in 2015. For the survey, Google Earth was used to mark brick kilns around the IMC and Indore district.

The primary survey questionnaires for brick kilns included the types of brick kilns, technology, different types of fuel, and the quantity used. A total of 86 brick kilns were surveyed in the Indore district, including the IMC area and villages (Figure 15). To understand the female participation and their personal exposure in the brick kilns, the number of females working in brick kilns was also collected in the surveyed brick kilns.

Figure 15: Brick Kiln Survey in IMC area and Indore district (April 2022)

e) Industries

According to MPPCB, total of 168 industries are located in the IMC area. Out of these industries, 146 are small, 21 are medium and 1 industry is large (Table 4). The maximum number of industries are on Sanwer road (126), followed by Mangaliya road (9), and Palda (7). A total of 44 industries were surveyed in the primary survey. The maximum number of industries surveyed are located in Sanwer road and Laxmibai nagar. A questionnaire-based survey was carried out for the industries, where the type of APCD used, type of industry-manufacturing product, type and quantity of fuel used, number of employees, working hours, and fuel to energy conversion units were inquired. Figure 16 represents the location of industries in the IMC region.

Table 4: Location of industries in the IMC area

INDUSTRIAL AREA	SMALL	MEDIUM	LARGE	TOTAL
Sanwer Road	113	13	0	126
Mangaliya Road	4	5	0	9
Palda	6	0	1	7
Pardeshipura	5	0	0	5
Pologround	4	1	0	5
Laxmibai Nagar	4	0	0	4

Bhagrirath Pura	1	1	0	2
Kumhedi	2	0	0	2
Lasudia Mori	2	0	0	2
Others	5	1	0	6
Total	**146**	**21**	**1**	**168**

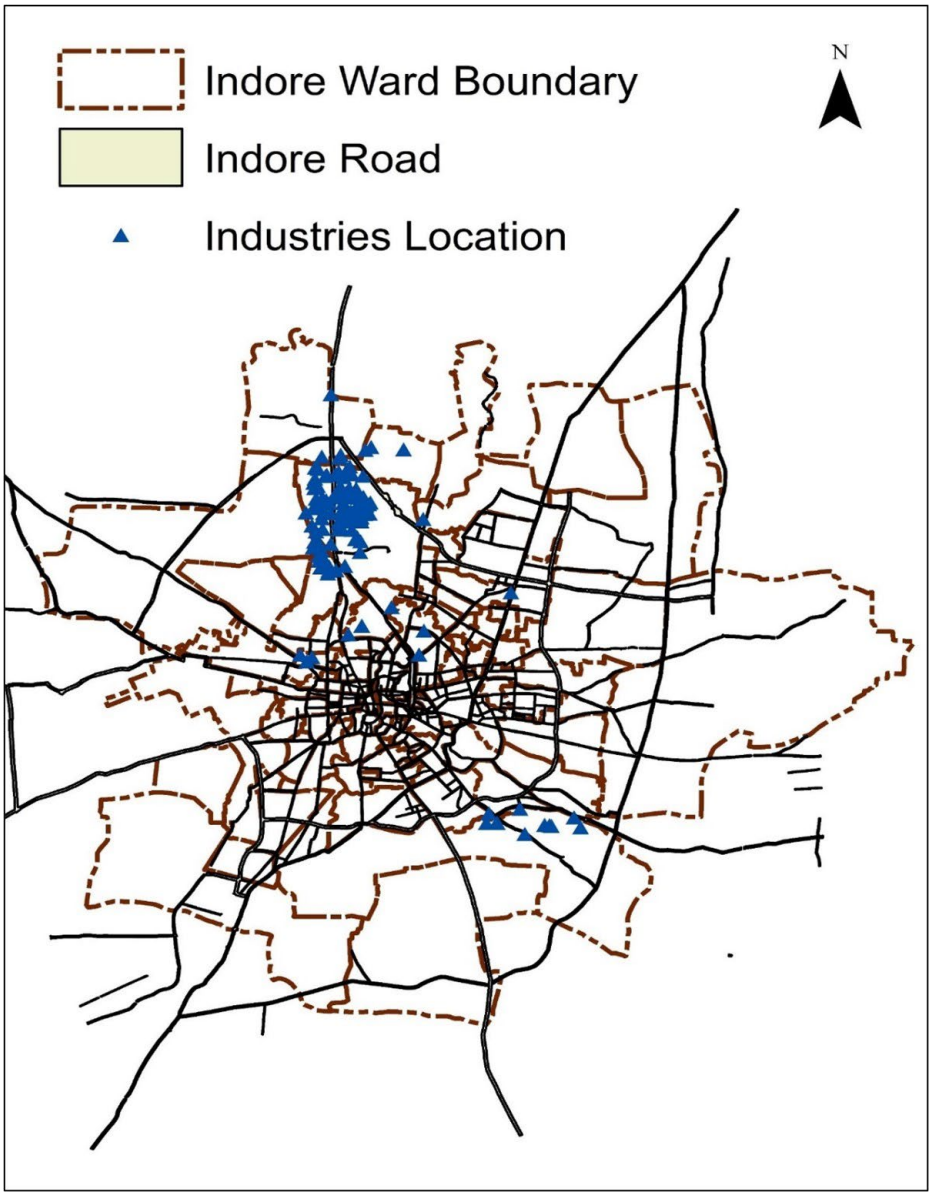

Figure 16: Location of air polluting industries

4. Findings and Results

The primary survey data was analyzed to understand the status of various activities in the IMC area. Wards with high incidences of waste burning and its composition in different zones of the IMC area, and eateries using wood and coal were identified, along with LPG with the help of survey results. The survey of industries helped in understanding the type of fuel, APCD present, fuel use, vehicle composition, and age. The activity data were used in estimating emissions and understanding the ward-wise conditions.

a) Transport

The activity data from the transport sector at the inner and outer cordon points was analyzed. For the survey, we selected all types of road hierarchy in Indore city, which was extrapolated throughout the city based on the same road types. Among the surveyed inner cordon points, the highest passenger vehicle count was found at Bholeram bhakt Hanuman mandir, Bhamori Square (IC 5), followed by C21 Mall (IC-6), Musakhedi Square-Eastern ring road (IC-7) and teen imli chauraha, Palda (IC- 8). In the outer cordon points, the highest vehicle count was near Sirpur Lake Garden, (OC-3), followed by Luv Kush Square and Papaya Tree Hotel Rau. The number of 2-wheelers was the highest at all the survey points, while four-wheelers were the second highest, except the Musakhedi square where other passenger vehicles (like state roadway buses, city buses, and private buses, BRT buses, auto rickshaws) were more compared to the four wheelers (figure 17). The passenger and goods vehicle count were also found to be highest at the same locations (figure 18).

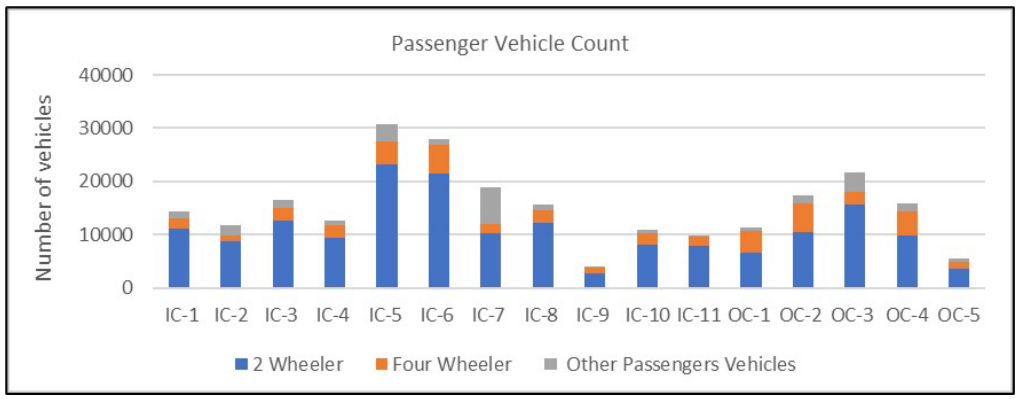

Figure 17: Total Passenger vehicle count in the surveyed locations

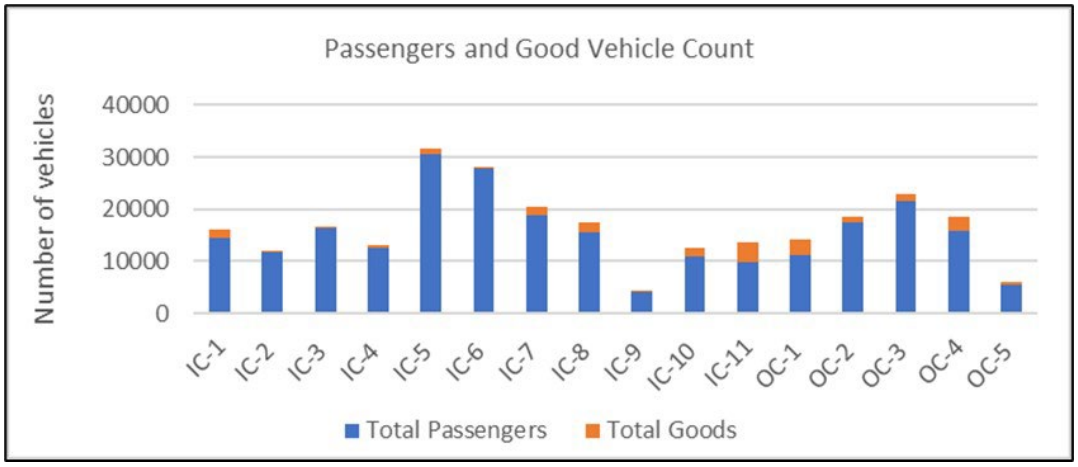

Figure 18: Total Passengers and Goods vehicle count in the surveyed locations

Figures 19 and 20 present the fuel-wise distribution of passenger and good vehicles. Among all the 2155 passenger vehicles, 170 were older than 12 years (2011). In the case of goods vehicles, 7.8% were before 2011, while the rest were after 2011. During the traffic survey, around 1358 of the 2- wheelers used petrol as fuel, while 8 of them operated on electricity. The fuel used by 190 of the 4- wheelers was petrol, 175 used diesel, and 62 operated on CNG. In the case of other vehicles, 233 used CNG as fuel, while 54, 32, and 23 of the vehicles used diesel, petrol and electricity. Most of the vehicles transporting goods (737) are diesel based, while the maximum (1580) passenger vehicles are petrol based, with 295- CNG based and 229 diesel-based, and 33 operated on electricity.

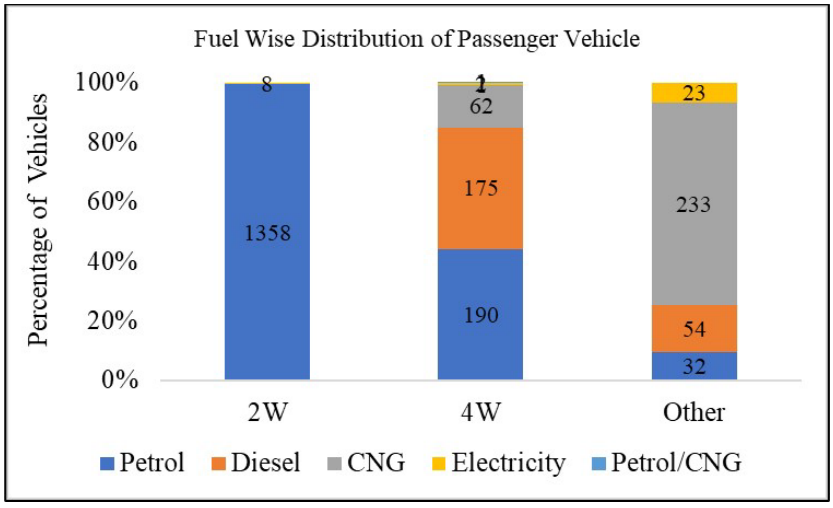

Figure 19: Fuel- wise distribution of Passenger vehicles

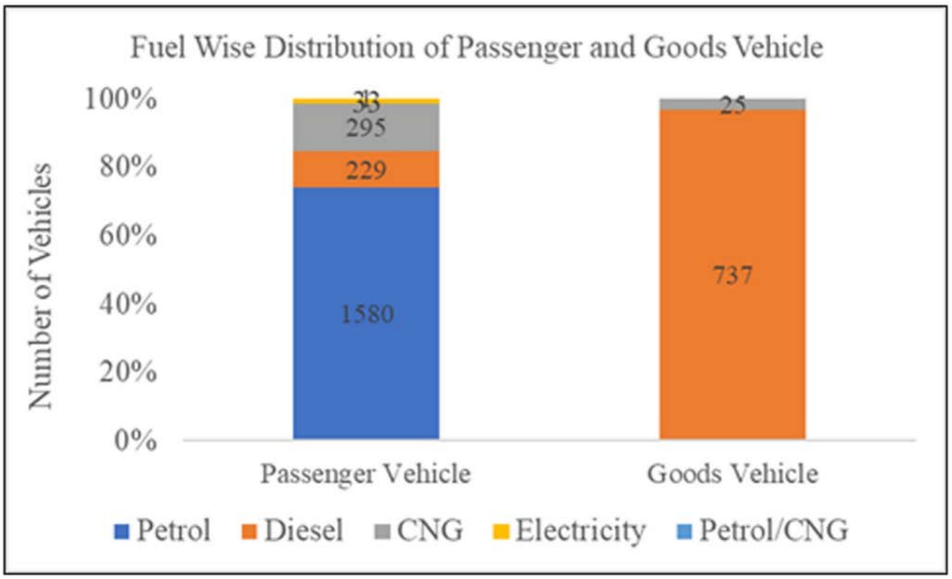

Figure 20: Fuel- wise distribution of Passenger and Goods vehicle

b) Eateries

A total of 464 eateries were surveyed with 392 small and 72 large eateries during the month of January – February 2022. The eateries surveyed in different land areas are presented in Figure 21. In total, 89% of the eateries were found to be using LPG, 7% electricity, 1% diesel and the rest were using LPG with other fuels. Electricity was used with LPG in all the eateries, for baking and heating food. The number of eateries surveyed in different land uses was highest in the commercial areas with 295 small and 59 large eateries. A total of 15 eateries in the residential, 29 in the industrial, and 65 in the residential cum commercial area were surveyed. The different types of fuel used in the eateries are LPG, biodiesel, wood, petrol, and diesel. Out of these fuels, LPG is the most commonly used fuel (Figure 22). As a fuel, LPG was used with wood and biodiesel in 3 large and 11 small eateries.

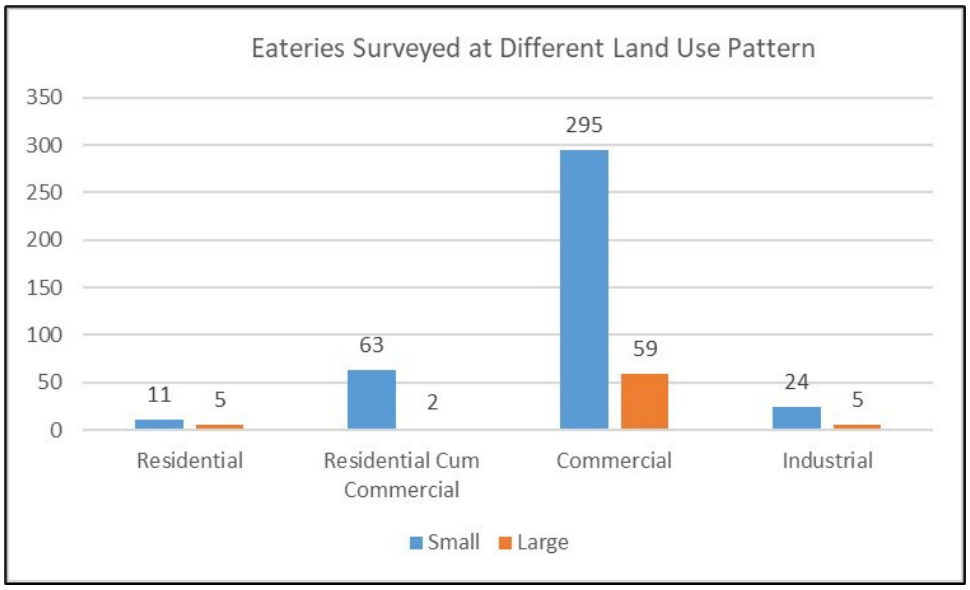

Figure 21: Eateries Surveyed at Different Land Use

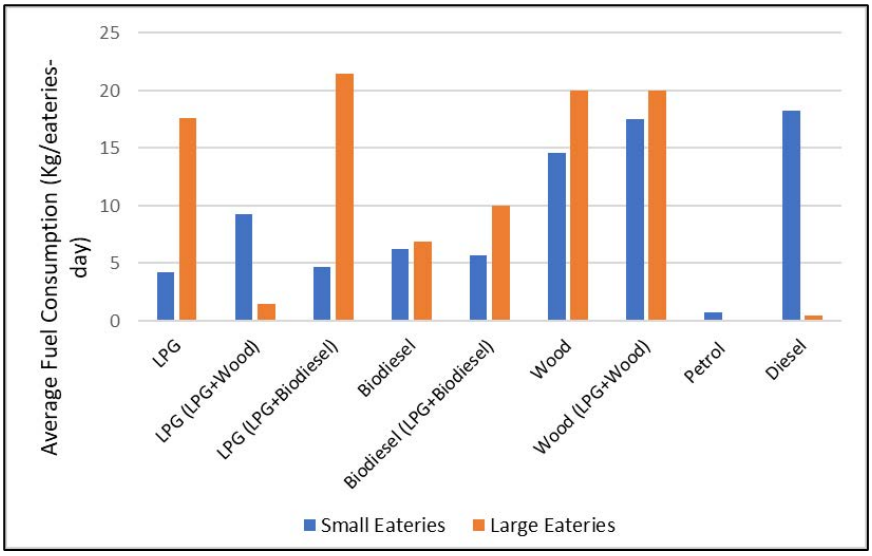

Figure 22: Total Fuel Consumption in the Surveyed Eateries

The average LPG consumption in a large eatery is found to be 17.6 kg per day, while it is 4.2 kg for small eateries. On average, around 14 and 20 kg of wood is consumed in small and large eateries respectively. The consumption of diesel is more in small eateries compared to large eateries. Only one large eatery at Moti Tabela was found using wood, while the rest of the wood was used in the

small eateries only. Wood was used in the small eateries located at Bombay Bazar-Rajwada, Sanwer Industrial area; near Bada Ganpati, Azaad Nagar, and Bhawarkua.

The average number of employees in a large eatery is 10, while it is 2 to 3 for the small ones. The dry waste generated per day in small eateries is around 1.75 kg/day, and wet waste is 3 kg/day. For large eateries, the waste generated is 5.36 kg/day dry and 8 kg/day is wet waste.

c) Waste Burning

The waste burning survey was carried out in the high, medium, and low SES areas along with the industrial areas. Out of the 54 wards surveyed, waste burning was observed in 19 wards in summer (May 2022), and 23 in winter (December 2021 to January 2022). The waste-burning incidents observed during the primary survey were mostly high during the winter season. In winter, the low-SES area had a maximum number of MSW incidents with 61 incidents/km$_2$, followed by industrial areas with 56 incidents/km$_2$, high-SES areas with 24 incidents/km$_2$, and medium-SES areas with 16 incidents/km$_2$. In Summers, industrial areas had the highest number of MSW burning incidents with 46 incidents/km$_2$, followed by low SES areas (43 incidents/ km$_2$), medium-SES areas (33 incidents/km$_2$), and high SES areas (21 incidents/km$_2$). Figure 23 illustrates these estimates.

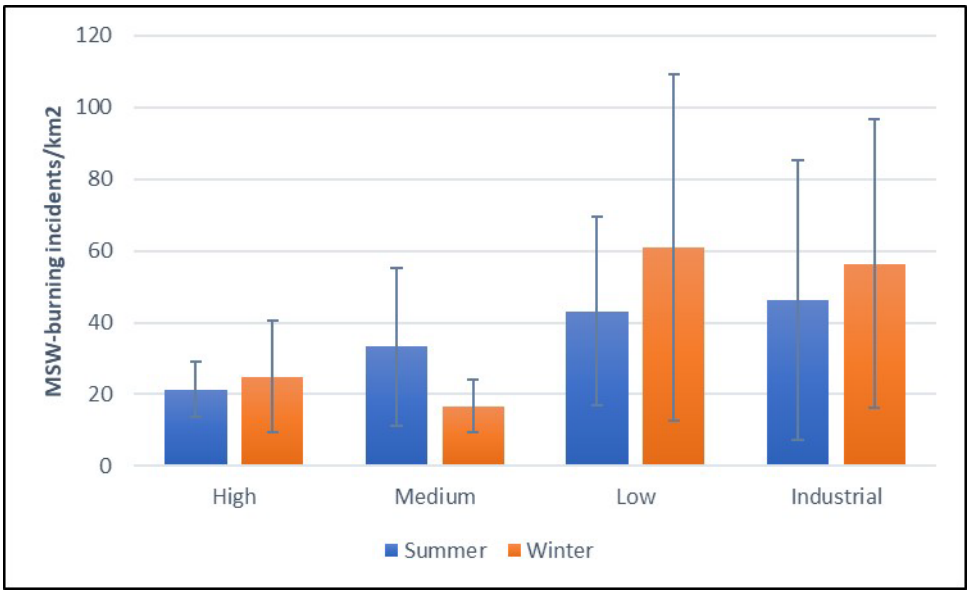

Figure 23: MSW burning incidences per Km² observed

The highest MSW burning mass (kg/km2) was observed almost the same (115 kg/km2) in low SES and industrial areas during summers, while in winters it was high in the industrial (196 kg/km2), followed by low SES area (figure 24).

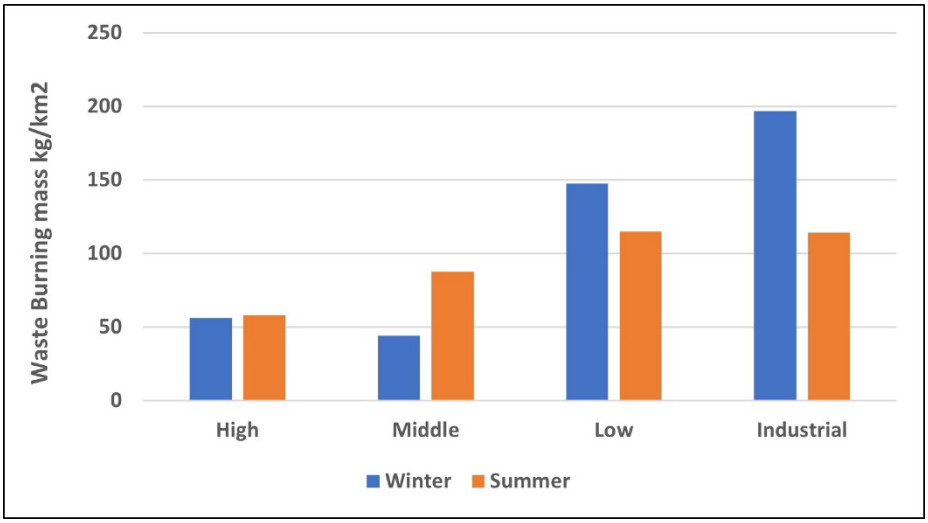

Figure 24: Municipal Solid Waste burning mass (Kg/Km²)

The amount of waste burned was 18 tonnes/day in the low SES areas during winters and 14 tonnes/day during summers. In the industrial areas, daily waste burned was 11 and 6 tonnes during winter and summer, respectively (figure 25). The reason for more waste burned in high SES areas was the plastic and paper waste which was more in comparison to the medium SES.

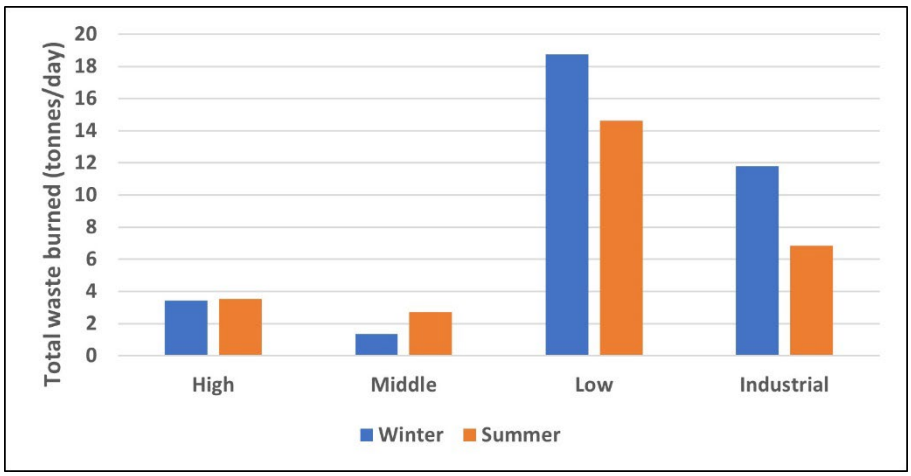

Figure 25: Total MSW burned (tonnes/day)

The composition of waste during winters was mostly plastic products, followed by paper and its products, wood and residue, textile, and thread. In summer, apart from plastic and paper waste, plant trimming waste is also a part of the waste burned (Figure 26).

The waste burning was observed mostly in the wards of Niranjanpur (8), Bhamori (12), Nipaniya (71), Residency (64), Bhagat Singh Nagar (7), Sheel Nath Camp (16), and Lasudiya Mori (72). Among these wards, Niranjanpur lies in the high SES, while Bhamori is in the medium SES; Nipaniya and Residency in the low SES and Bhagat Singh Nagar, and Sheel Nath Camp in the Industrial area. The common reasons cited by the citizens during the primary survey were:

- Behavioral issues among citizens
- Waste Collector decline to collect waste such as dried leaves/plant trimming waste
- Waste collectors burn waste to reduce their travel trips
- Less or infrequent Collection of Waste
- Extraction/recovery of Material (Commercial Burning)
- No collection of waste by IMC (In some industrial areas)
- Industries burn their own waste
- Heating Purpose in winter
- Prevent mosquito breeding

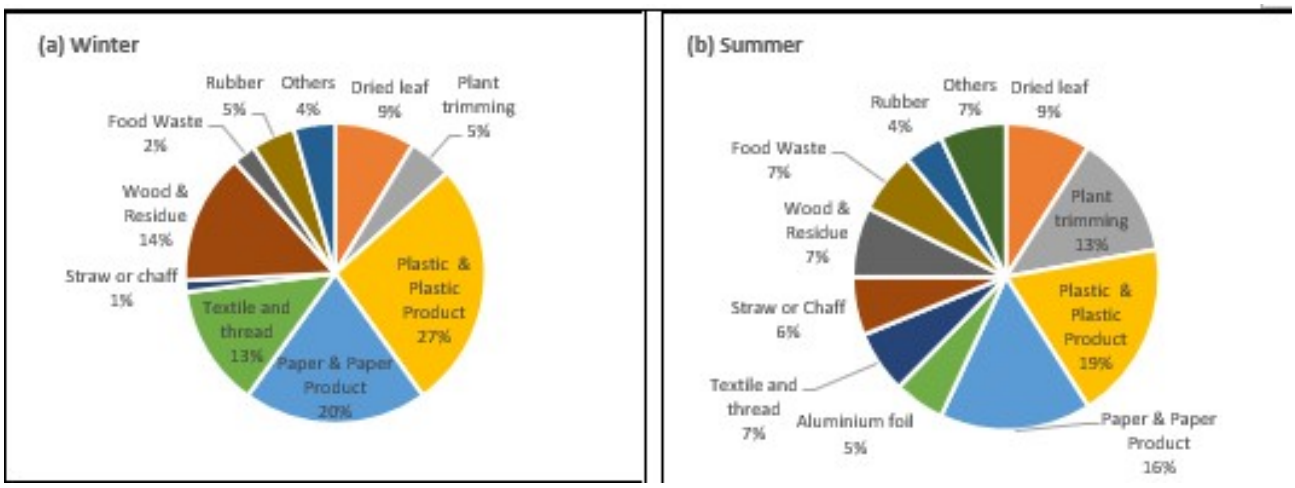

Figure 26: Waste composition during (a) winters and (b) Summers

d) Brick Kiln

A total of 79 brick kilns were surveyed in April 2022, which were classified as small, medium, and large brick kilns. The bricks were made by the clamp kiln technique, where brick and fuel are placed at alternate layers. Around 47% of the surveyed brick kilns were medium, with 32% small and 21% large. A total of 2301 employees were working in the surveyed brick kilns, out of which 947 were female employees. Among all the brick kilns surveyed 39 were permanent and 40 were temporary.

The average brick production in the small, medium, and large brick kilns was estimated to be 2.6, 5.7, and 21.9 lakhs per season (figure 27).

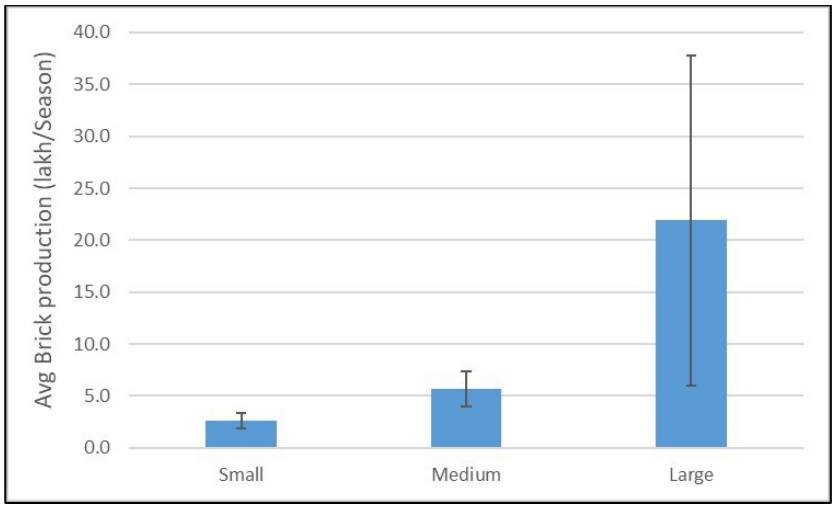

Figure 27: Average brick production in the brick kilns

The fuels used in making bricks was largely coal, some used wood, and cow dung alongside coal. In producing approximately 1 lakhs of bricks the average coal consumption is 3.3 tonnes for small industries, while it is 3.7 and 7.7 tons for medium and large brick kilns (figure 28). No Air Pollution Control Device (APCD) was used by any of the brick kilns. Of all the brick kilns surveyed, only 2 had chimneys.

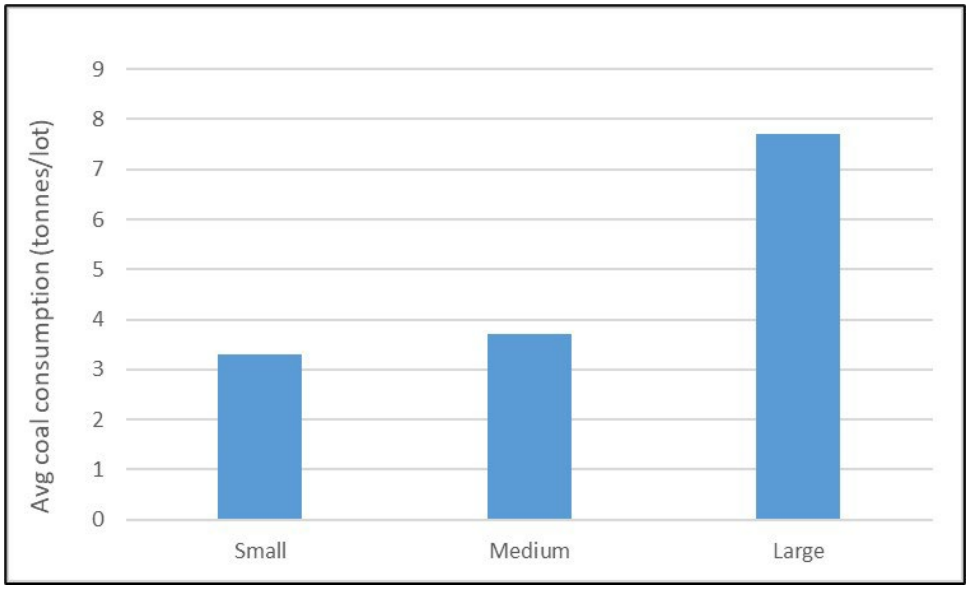

Figure 28: Average coal consumption (tonnes/day)

e) Industries

A total of 44 industries were surveyed in the IMC area. Out of these industries, 31 were small-scale, 8 were medium, and 5 were closed. The industries surveyed were pharmaceuticals (27%), followed by basic precious and ferrous metals (25%), food products (14%), rubber and textile products (7% each) (figure 29).

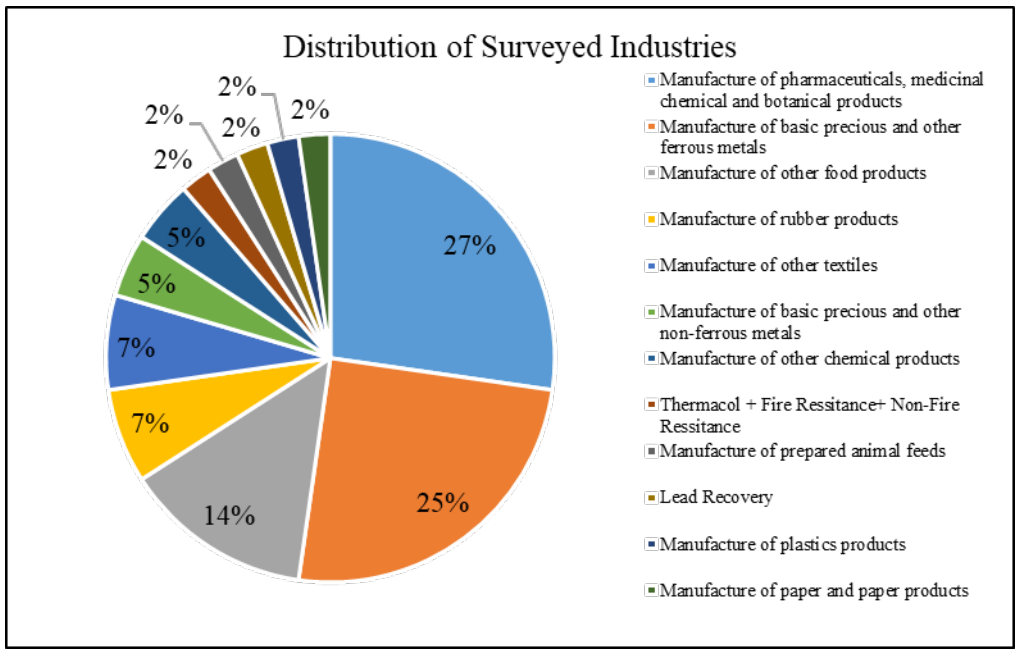

Figure 29: Distribution of Surveyed Industries

The working shifts in the small and medium industries are presented in Figure 30. The working shifts were 8 to 12 hours for 21 small-scale and 3 medium industries. A working shift of 24 hours was also seen in 8 small and 4 medium-scale industries. The primary survey revealed that the fuel-to-energy conversion units (figure 31) used in the industries were mostly boiler (49%), followed by the furnace (31%), boiler and thermal heaters, thermic fuel heaters (7%), and baby boilers (5%).

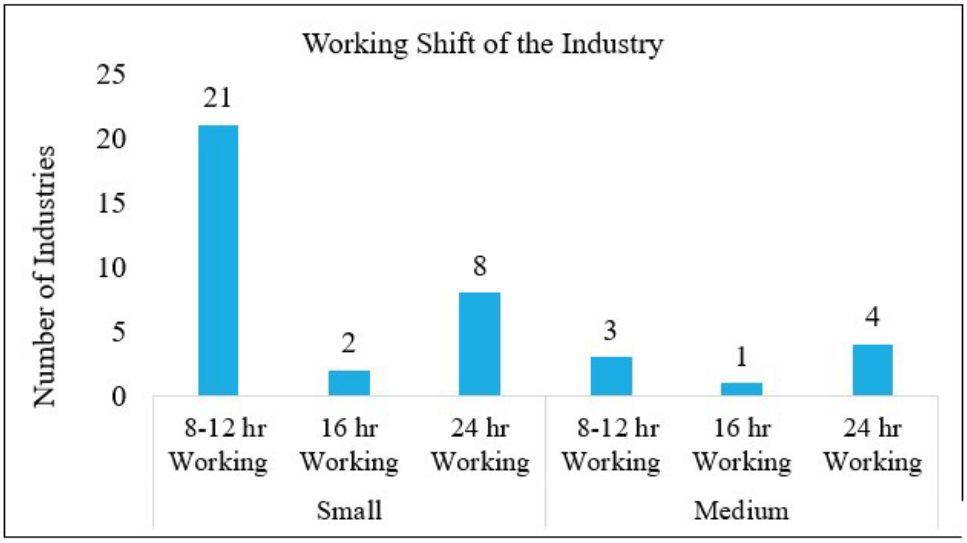

Figure 30: Working shift of the industries

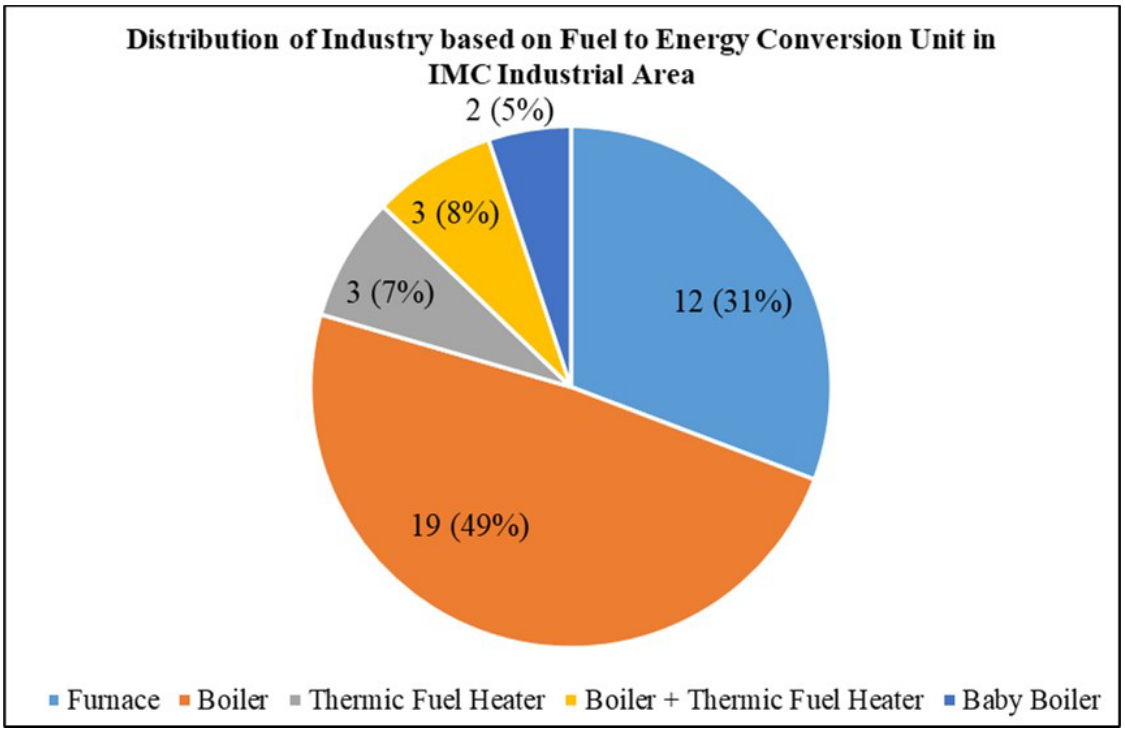

Figure 31: Distribution of Industry based on Fuel to Energy Conversion Unit in IMC Industrial Area

As per the survey (figure 32), the different fuels used in the IMC industrial area are coal (33%), followed by a mixed use of coal and wood (18%), wood (15%), agricultural residue (11%), and other fuels like light diesel oil (LDO), furnace oil, Piped Natural Gas (PNG).

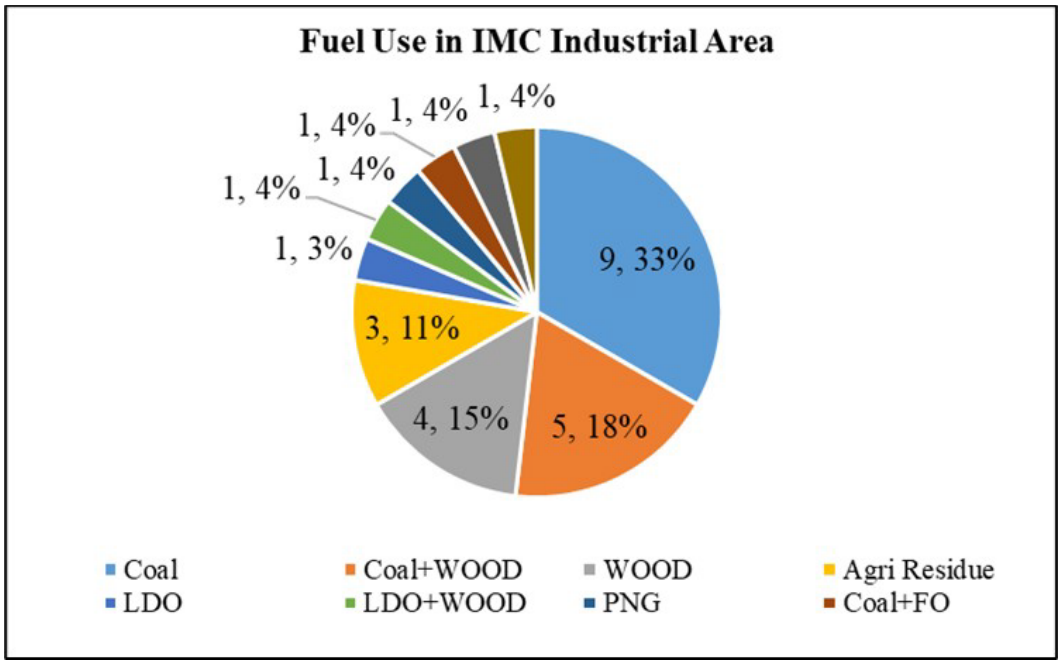

Figure 32: Fuel used in the IMC Industrial Area

The Air Pollution Control Devices (APCD) used in the surveyed industries (figure 33) are bag filters (77%), wet scrubbers and chimneys (10% each), and cyclones (3%). All the furnace-based industries were found operating in one shift (8-12 hrs.) only. Coal is a major source of fuel in 75% of the furnaces. Almost 26% of the boilers were found to be using coal, coal + wood, 21% using wood, and 16% using agriculture residue as fuel. The DG set is only used for 4-5 hours a month, due to efficient power supply in IMC industrial area.

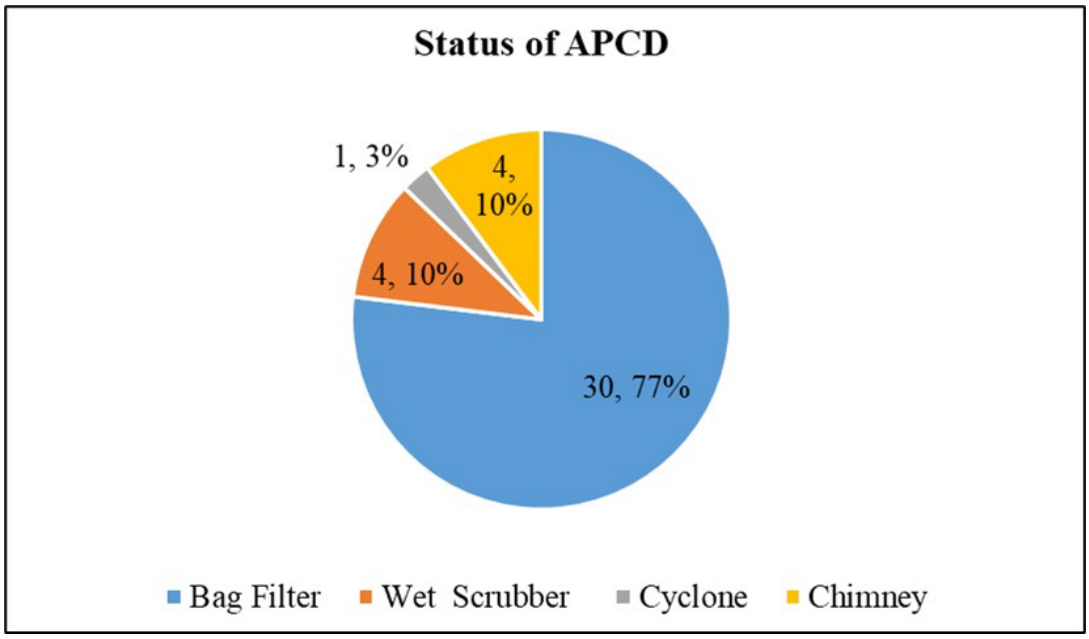

Figure 33: Status of APCD in the Industries

In the surveyed industries, the type of APCD used in the various fuel-to-energy conversion units was also inquired. It was found that almost all of the boilers used bag filters, while in the furnaces, 50% of industries used bag filters, followed by bag filters and chimneys. In the industries with baby boilers, 50% used bag filters and 50% used cyclones (Figure 34).

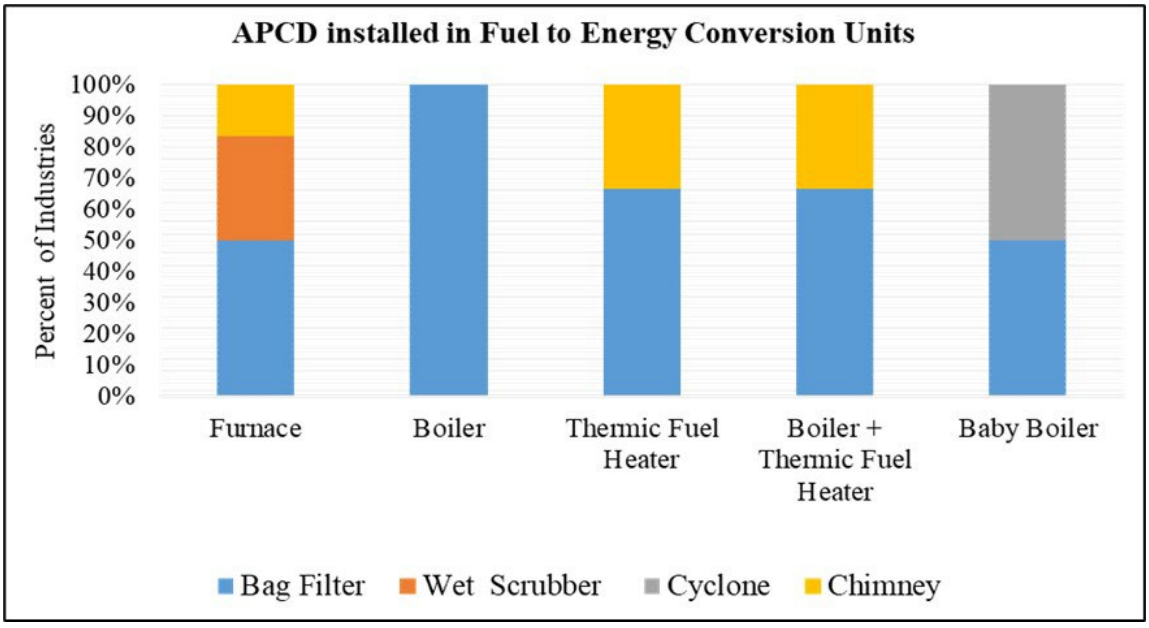

Figure 34: APCD installed in Fuel to Energy Conversion Units

5. Integration of Survey results in the Emission Inventory

The outcomes from the primary survey will be used for developing an accurate emission inventory. This data will then be fed into a suitable air quality model to generate the spatial distribution of PM_{10} and $PM_{2.5}$ concentrations at the IMC boundary level. The survey will also help in identifying the underlying issues behind air pollution problems like waste burning, transport, using polluted fuels like fuelwood and coal for cooking in eateries. Priority sources and air quality issues associated with these sectors will be identified with the help of primary survey data. Sector-wise control measures can then be suggested for the MC area.