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OPEN MUNICIPAL SOLID WASTE BURNING IN VADODARA CITY AND ITS MITIGATION MEASURES



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Executive Summary

Introduction

Ineffective management of municipal solid waste (MSW) results in various challenges that negatively impact health and contribute to environmental, economic, and biological losses (Sharholy et al., 2008). One major consequence of inadequate waste management is open waste burning, a significant non-point emission source (Kumari et al., 2019). In urban areas, open waste burning typically involves MSW from households, offices, commercial centers, and restaurants, including garden debris, paper, natural fabrics, food waste, and both recyclable and non-recyclable materials. Burning waste components like plastic, e-waste, thermocol, rubber, and textiles release harmful carcinogens, posing serious health risks (Kumari et al., 2019). As a major contributor to air pollution, waste burning is gradually gaining attention in Indian cities, necessitating focused examination and intervention.

The National Clean Air Programme (NCAP), launched in 2019, aims to improve air quality in 131 non-attainment cities, those that have violated National Ambient Air Quality Standards for five consecutive years (Ganguly et al., 2020). Vadodara, a non-attainment city, has been identified as having waste burning as one of the contributors to air pollution. A review of existing literature revealed a critical data gap regarding MSW burning in Vadodara Municipal Corporation (VMC). No city-level or intra-city-level data on MSW burning quantity or locations was available, making it difficult to develop an effective clean-air action plan.

To fill this gap, WRI India conducted a primary survey using a transect walk method. The survey, carried out in May (summer) and December (winter) 2023, focused on collecting granular data on MSW burning incidents in the VMC area. The city was divided into zones based on socioeconomic status (SES) and land use, with transect routes selected to represent these characteristics. Observations of waste burning were supplemented with personal interviews, and data were collected on the frequency, mass, and composition of MSW burning incidents.

The primary survey was conducted by dividing the VMC area into different zones based on SES and land use. The transect walk method was used to document MSW burning incidents in three sample areas, covering both morning and evening hours over three consecutive days in each season. Data included the number of MSW burning incidents, their mass, and composition, as well as the geographical coordinates of each incident. This data was scaled up to estimate MSW burning mass for the entire VMC area. The primary survey results provided the first estimate of MSW burning incidents and mass in Vadodara, offering valuable insights for developing a clean-air action plan.

Findings

The waste burning survey covered 19 wards across high, medium, low-medium SES, and industrial areas. Waste burning incidents were observed in 15 wards during summer (May 2023) and 17 in winter (December 2023). In Summer, the Industrial area had a maximum number of open MSW burning incidents with 43 incidents/km², followed by medium-SES areas with 24 incidents/km², low-medium-SES areas with 21 incidents/km², and High-SES areas with 11 incidents/km² (Figure 5). In winter, again the industrial area had the maximum number of open MSW burning 43 incidents/km² were observed, followed by medium-SES areas with 26 incidents/km², low-medium-SES with 21 incidents /km² and high-SES areas with 20 incidents/km². The scaled up highest MSW burning mass (kg/km²) was observed (304 kg/km²) in industrial areas and (128 kg/km²) in low-medium SES, followed by (112 kg/km²) in medium SES and (54 kg/km²) in high SES in summers. In winter, 146 kg/km²/day in industrial areas, followed by 101 kg/km² in medium, 73 kg/km² in low medium areas, and 47 kg/km² in high SES areas. The total MSW burning was 7 Tonnes/day in industrial areas, 8 Tonnes/day in medium, 3 Tonnes/day in low-medium, 5 Tonnes/day in high SES areas during the summer season. During the winter, the total MSW burning was 4 Tonnes/day in industrial, 7 Tonnes/day in medium, 2 Tonnes/day in low medium SES, 4 Tonnes/day in high SES areas. The composition of waste burned during summer was mostly plastic and its products, followed by paper and its products, dried leaf, textile, thread, and others. Wood residue and food waste were also found to be burnt during the survey.

In summer, Ward No. 18 had the highest number of waste-burning incidents with 47 open MSW burning cases. This was followed by Ward No. 13 with 14 incidents, Ward No. 10 with 13 incidents, and Ward No. 4 with 13 incidents. During winter, Ward No. 18 again reported the highest number of waste-burning incidents with 35 cases. This was followed by Ward No. 10 with 23 incidents, Ward No. 8 with 22 incidents, Ward No. 4 with 28 incidents, Ward No. 5 with 28 incidents, and Ward No. 11 with 15 incidents.

Recommendations

Improved waste management practices and policy interventions contributed to the positive results in a reduction of Open MSW burning. Vadodara is advancing solid waste management through infrastructure, community engagement, and sustainable practices. However, rapid urbanization has increased waste volumes and mixed waste composition, contributing to waste burning, particularly involving materials like paper, plastic, textiles, and aluminium. Key challenges include unawareness, insufficient infrastructure, low collection efficiency, and infrequent waste collection in industrial areas.

To address these, the report recommends:

- Grassroots awareness programs on the impacts of waste burning.
- Training workshops for municipal workers to enhance skills and infrastructure (e.g., handcarts, trolleys).
- Optimized waste collection and segregation systems.
- Affordable heating alternatives for low-income communities.
- Strict enforcement of anti-burning regulations with penalties for violations.
- Improved waste management in industrial zones.
- Integration of Scrapers, Kabadiwalas, and Ragpickers into the waste management system.

These recommendations are mapped to short-term (2 years), mid-term (5 years), long-term (10+ years), and continuous interventions, with a focus on stakeholder collaboration for effective implementation.

1. Background and Objectives

Ineffective management of municipal solid waste (MSW) gives rise to various challenges that adversely affect health and lead to environmental, economic, and biological losses (Sharholy et al., 2008). One major consequence of this unmanaged waste is open waste burning, which serves as a significant non-point emission source (Kumari et al., 2019). Managing MSW in India is a critical challenge and it is not only driven by environmental and aesthetic concerns but also by the diverse volume of waste generated daily. A significant barrier to effective MSW management is the lack of awareness about the health impacts of open waste burning. In urban areas, open waste burning predominantly involves MSW generated from households, offices, commercial centers, and restaurants. This waste includes garden debris, paper, natural fabrics, food waste, and non-compostable materials such as recyclables and non-recyclables, which collectively form the bulk of the waste burning. Waste components like plastic, e-waste, thermocol, rubber, and textile release carcinogenic substances released into the air, posing severe health risks (Kumari et al., 2019). Waste burning, as a substantial contributor to air pollution, is gradually receiving attention in Indian cities. Recognizing its detrimental effects on air quality and public health, there is an increasing need for focused examination and intervention.

The National Clean Air Programme (NCAP), launched in 2019, is India's flagship initiative aimed at improving air quality in 131 non-attainment cities, those that have consistently

violated the National Ambient Air Quality Standards for five consecutive years (Ganguly et al., 2020). Under the NCAP, cities are mandated to identify air pollution sources like waste burning, prepare emission inventories, conduct source apportionment studies, and develop actionable plans.

Vadodara is classified as one of the non-attainment cities, and waste burning is identified as one of the contributors to air pollution. A comprehensive review of existing literature highlighted a critical data gap regarding municipal solid waste (MSW) burning in the Vadodara Municipal Corporation (VMC) area. Currently, no city-level or intra-city-level primary data exists on the quantity or locations of MSW burning incidents. This lack of data poses a major challenge in formulating an effective clean-air action plan for the city.

To address this issue, a primary survey was designed and conducted at the ward level by the WRI India team. The survey aimed to gather recent and granular data on MSW burning in the VMC area. The study provided the first estimate of waste-burning incidents and quantities in the city. Based on these findings, specific recommendations were developed to mitigate waste-burning issues, paving the way for on-ground implementation and cleaner air in Vadodara.

Vadodara City- Study Area:

Vadodara, also known as Baroda one of the populous and major cities of Gujarat is home to 1.67 million people (Census 2011) and city area of around 220 Sq.km. Vadodara is identified as one of the non-attainment cities under the National Clean Air Programme (NCAP), which means that the air quality of Vadodara exceeded the National Ambient Air Quality Standards (NAAQS) between 2011 to 2015. Vadodara City is governed by the Vadodara Municipal Corporation (VMC) and is divided into 4 zones and 19 wards (Figure 1).

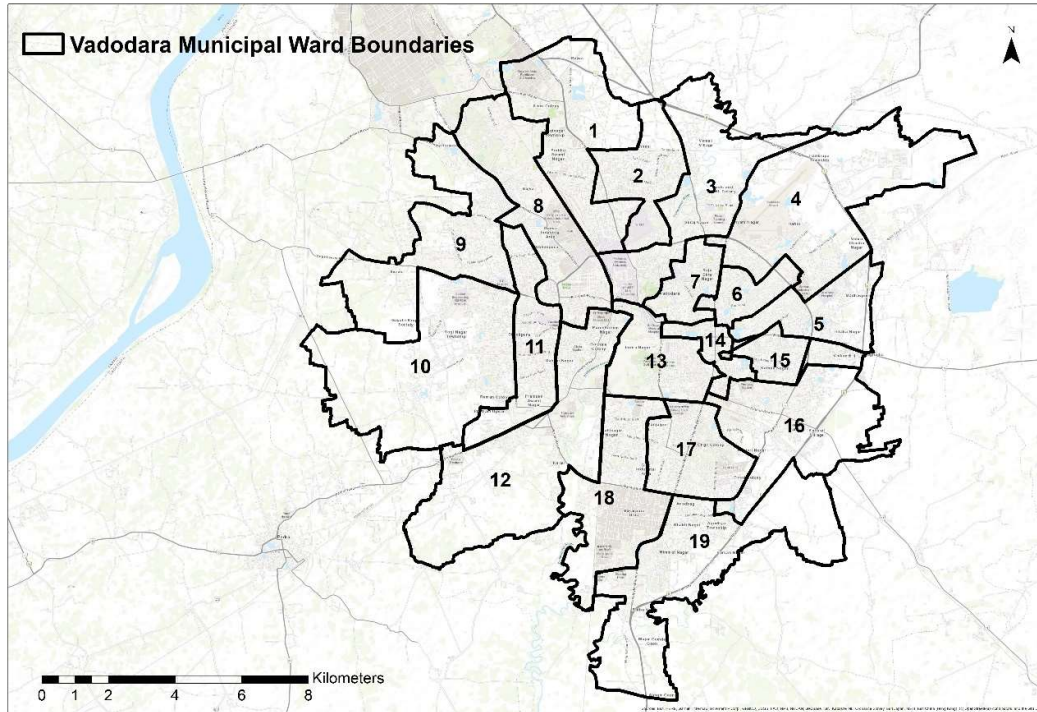


Figure 1 Ward Map of VMC

The VMC area includes industrial zones such as Makarpura in the southern part of the city and a few industries in the northwest (Figure 2). However, many major industries are situated outside the VMC boundary. Within the VMC limits, the predominant industrial sectors include petrochemicals, chemicals, and pharmaceuticals, apart from these, few textile and engineering industries are present.

2. Vadodara Waste Management Profile

Vadodara is a major city in Gujarat. With a current population of approximately 1.67 million, the city faces the formidable task of managing over 1200-1250 metric tonnes (MT) of daily waste generation, and per day/person generation of 535 grams (0.53 kg).

The first step towards setting up the Solid Waste Management (SWM) in Vadodara city involved coordinating the establishment of formal systems and facilities to handle waste collection, transportation, and processing. The collected domestic waste is manually sorted into distinct categories, including wet, domestic hazardous, plastic, non-plastic, electronic, and sanitary waste. Subsequently, the waste is transported to a central facility called the garbage transfer station (GTS) and there are presently 3 GTS in Vadodara.

3. Methodology

The primary survey was carried out in May (summer) and December (winter) 2023 for open municipal waste burning (MSW). Transect walk-based survey approach has been used to collect primary data on municipal solid waste burning a 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 hierarchy of each zone. While observing the waste-burning incidents, a few personal interviews with respondents are also taken. Two interns were hired to conduct the survey for this sector along with the WRI team.

Open MSW Burning Primary Survey

In VMC area, the primary data on Open MSW burning was collected using the transect method. In this method, the wards of the VMC area were classified as per their socioeconomic status (SES) and land use pattern (figure 2). Then, the transect routes were laid out into different streets and roads hierarchy, representing the survey area's SES and land-use characteristics.

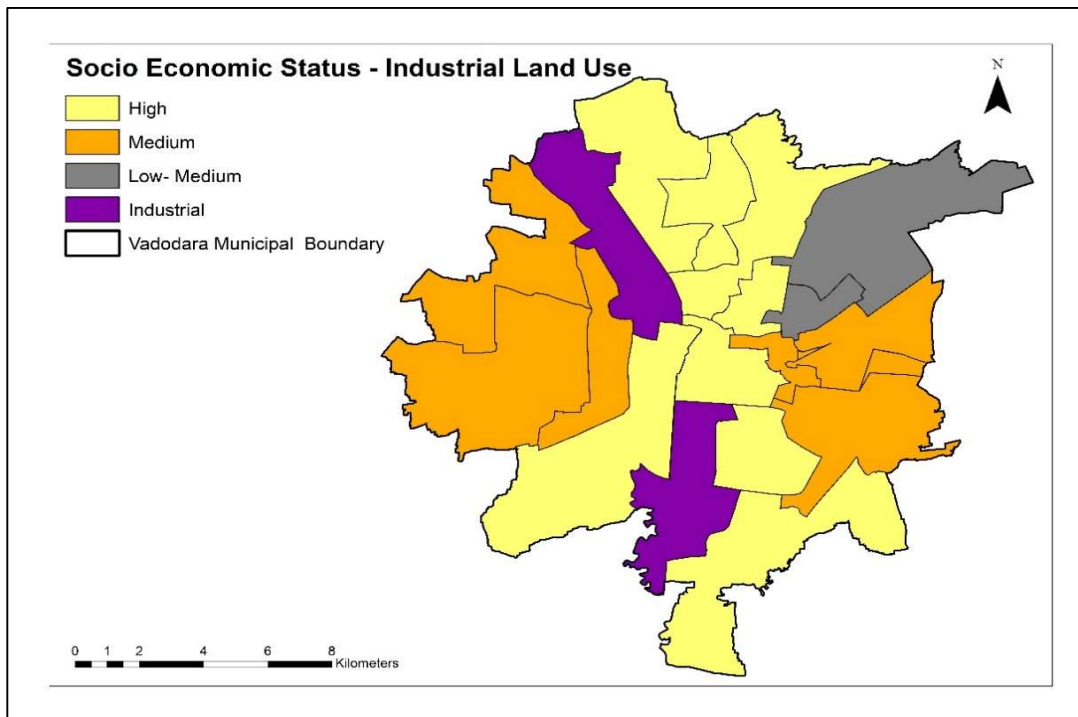


Figure 1 Classification of VMC boundary as per the Socio-Economic Status (SES) and Industrial Land Use Pattern

Three transect routes were covered the VMC boundary (Figure 3 and Table 1). 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 summer (May) and winter (December) seasons in the year 2023. The number of municipal solid waste (MSW) burning incidences (Figure 4) were recorded as a 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 VMC area for summertime 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 VMC area to scale up the results.

Table 1 Showing Open MSW Burning Transect Survey details in the VMC Area

Transect	No. of Wards	Land Covered	Use	Socio-Economic Status Covered	Distance Covered	Incident Found in Summer 2023	Incident Found in Winter 2023
Transect 1	9	Residential, commercial, Industrial, Public and Semi-Public (PSP) Spaces,		High, Medium, Low	29.7 Km	24	40
Transect 2	7	Residential, Commercial, PSP, Industrial		High, Medium, low	27.9 Km	79	62
Transect 3	6	Residential, commercial, PSP,		High, Medium, low	31.7 Km	44	78
Total Open MSW Burning Incident						147	180

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

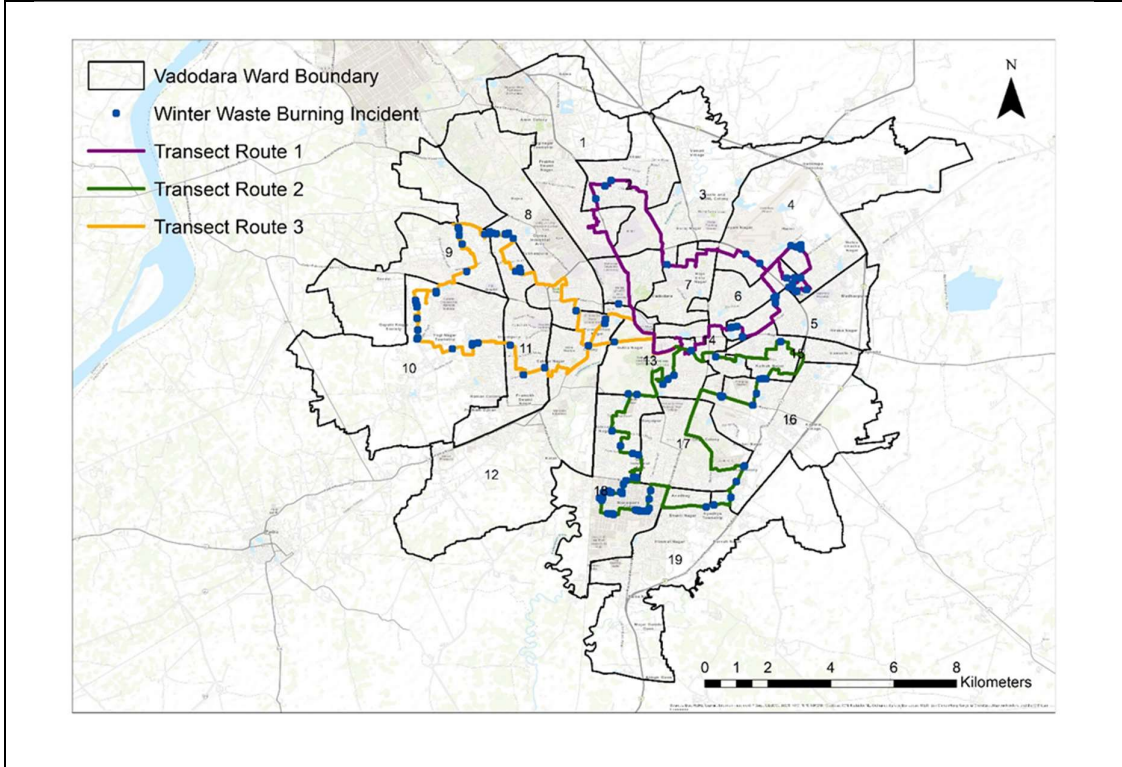
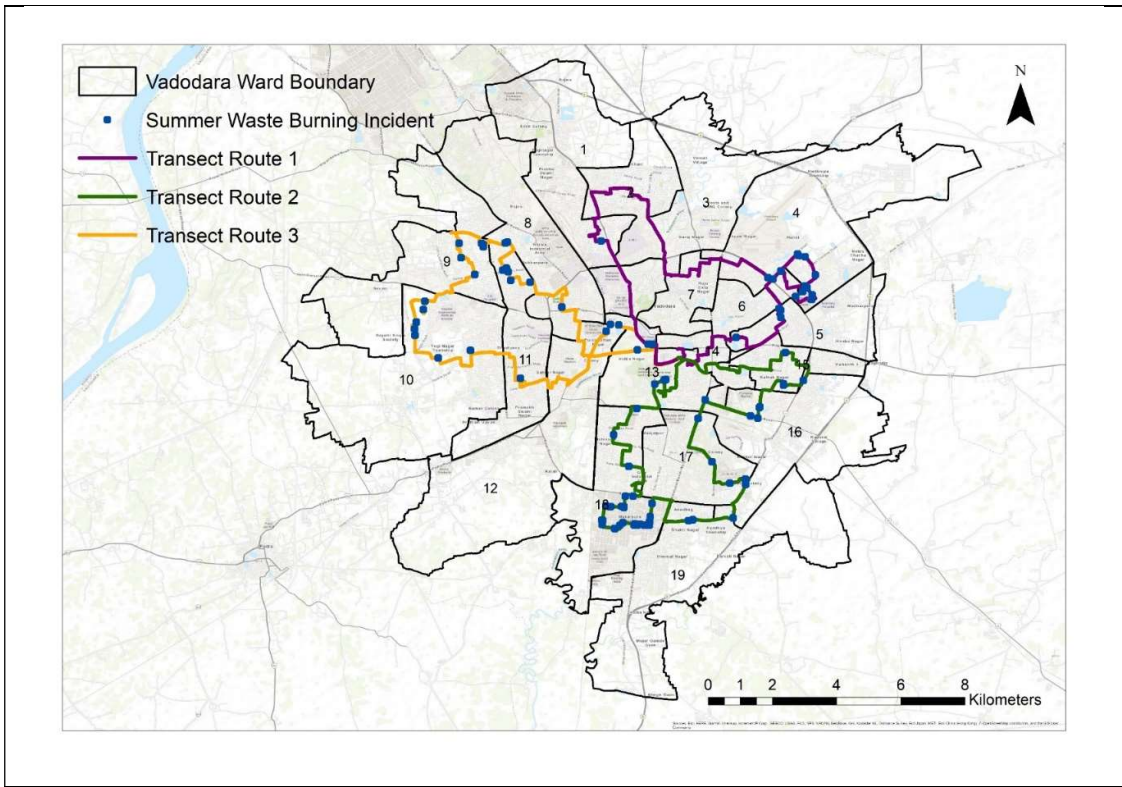


Figure 2 MSW burning survey transect routes during summer and winter (2023) in VMC area



Figure 3 Open MSW Burning incidences in different parts of the VMC area (May 2023)

4. Findings and Results:

The waste burning survey was carried out in the high, medium, and low-medium SES areas along with the industrial areas. All 19 wards were surveyed, and waste burning was observed in a total of 15 and 17 wards in the summer (May 2023) and winter (December 2023) respectively. In Summer, the Industrial area had a maximum number of open MSW burning incidents with 43 incidents/km², followed by medium-SES areas with 24 incidents/km², low-medium-SES areas with 21 incidents/km², and High-SES areas with 11 incidents/km² (Figure 5). In winter, again the industrial area had the maximum number of open MSW burning 43 incidents/km² were observed, followed by medium-SES areas with 26 incidents/km², low-medium-SES with 21 incidents /km² and high-SES areas with 20 incidents/km². Figure 5 illustrates these estimates.

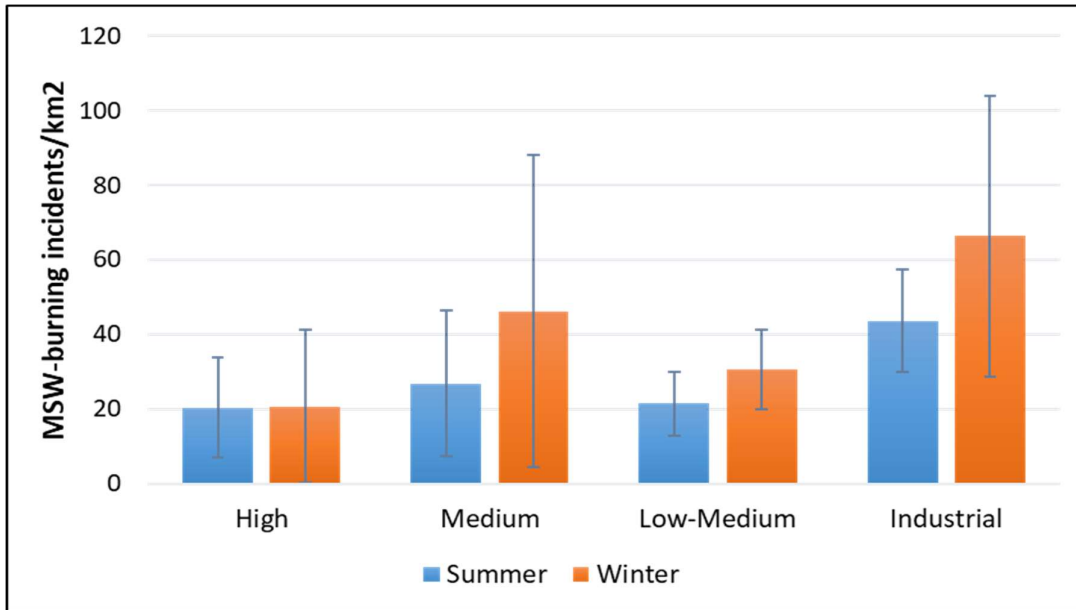


Figure 4 Daily MSW-burning incidents per km² in four areas (high-SES, medium-SES, low-medium-SES- and industrial) of the VMC area during the summer and winter seasons of the year 2023

The scaled up highest MSW burning mass (kg/km²) was observed (304 kg/km²) in industrial areas and (128 kg/km²) in low-medium SES, followed by (112 kg/km²) in medium SES and (54 kg/km²) in high SES in summers. In winter, 146 kg/km²/day in industrial areas, followed by 101 kg/km² in medium, 73 kg/km² in low medium areas, and 47 kg/km² in high SES areas (figure 6)

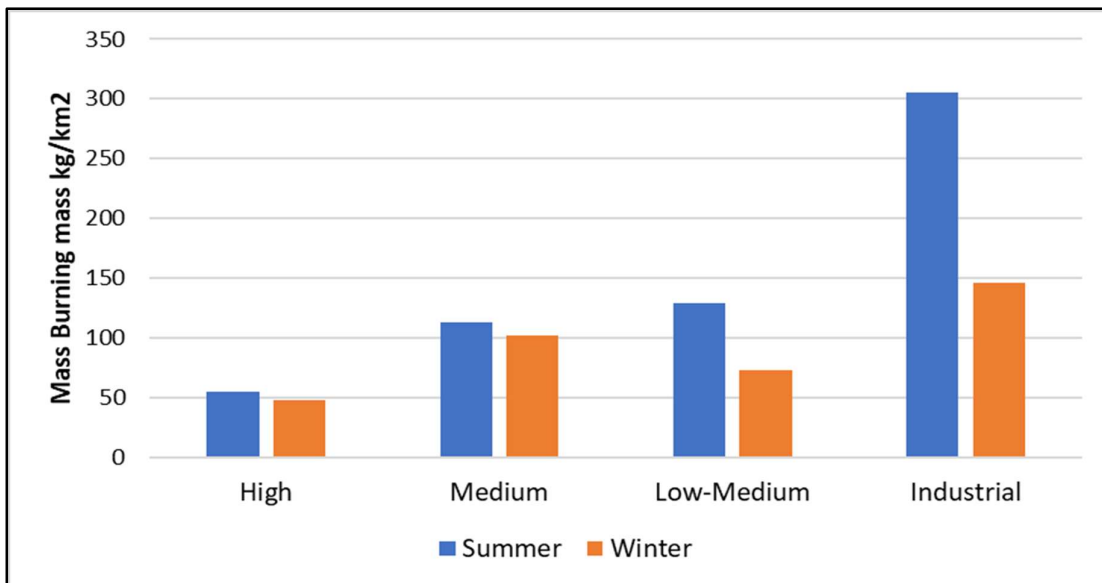


Figure 5 Daily MSW-burning mass/km² in four areas (high-SES, medium-SES, low-medium-SES- and industrial) of VMC area during the summer and winter seasons of the year 2023

The total MSW burning was 7 Tonnes/day in industrial areas, 8 Tonnes/day in medium, 3 Tonnes/day in low-medium, 5 Tonnes/day in high SES areas during the summer season. During the winter, the total MSW burning was 4 Tonnes/day in industrial, 7 Tonnes/day in medium, 2 Tonnes/day in low medium SES, 4 Tonnes/day in high SES areas (Figure 7).

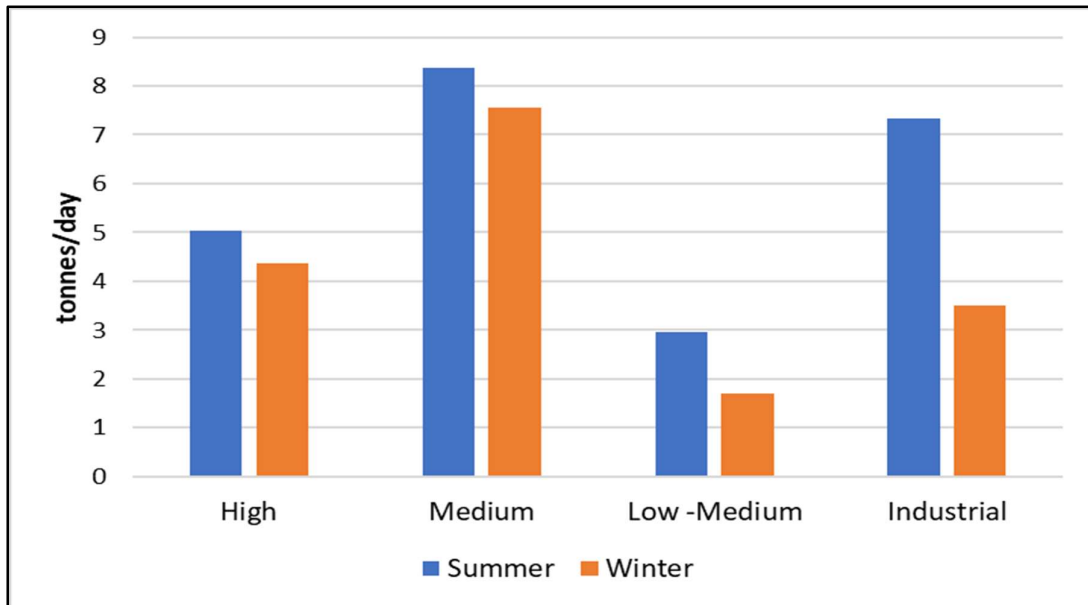


Figure 6 Daily MSW burning in four areas (high-SES, medium-SES, low-medium-SES- and industrial) of the VMC area during the summer and winter seasons of the years 2023

The composition of waste burned during summer were mostly plastic and its products, followed by paper and its products, dried leaf, textile, thread, and others. Wood residue and food waste were also found to be burnt during the survey. In summer, the total degradable waste (paper & paper products, straw, wood residue, food waste, dried leaf, and plant trimming waste) was 36%, recyclable waste (plastic and plastic products, aluminium foil, and textile) was 45%, while 19% belonged to the other category (electric wire, thermocol, jute, rubber, rexine, glass, coconut shell, etc). During winters, the total degradable waste was 48%, recyclable waste was 36%, and 16% belonged to the other category (Figure 8).

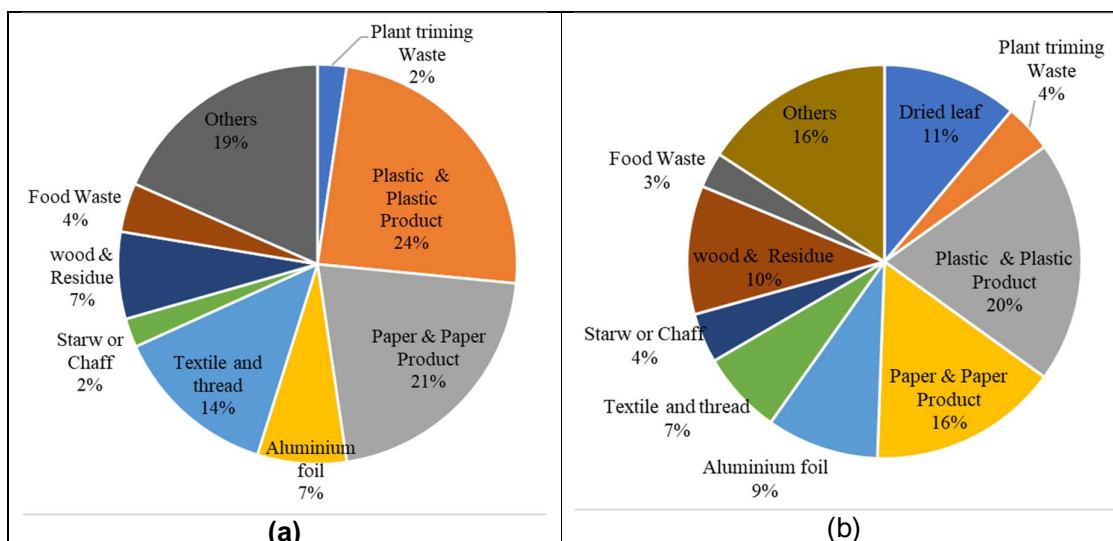


Figure 7 Estimated Waste Composition burnt during the Summer (a) and Winter (b) Survey of VMC area in 2023

In summer, Ward No. 18 had the highest number of waste-burning incidents with 47 open MSW burning cases. This was followed by Ward No. 13 with 14 incidents, Ward No. 10 with 13 incidents, and Ward No. 4 with 13 incidents. During winter, Ward No. 18 again reported the highest number of waste-burning incidents with 35 cases. This was followed by Ward No. 10 with 23 incidents, Ward No. 8 with 22 incidents, Ward No. 4 with 28 incidents, Ward No. 5 with 28 incidents, and Ward No. 11 with 15 incidents. Among these wards, Ward No. 18, located in the Industrial area (Makarpura), consistently reports the highest number of waste-burning incidents in both seasons. Ward No. 10, with a medium SES, and Ward No. 4, with a low medium SES, are also among the wards with high waste-burning incidences. Figure 9 and Table 2 show the high, medium, and low priority wards as per the waste burning incidences.

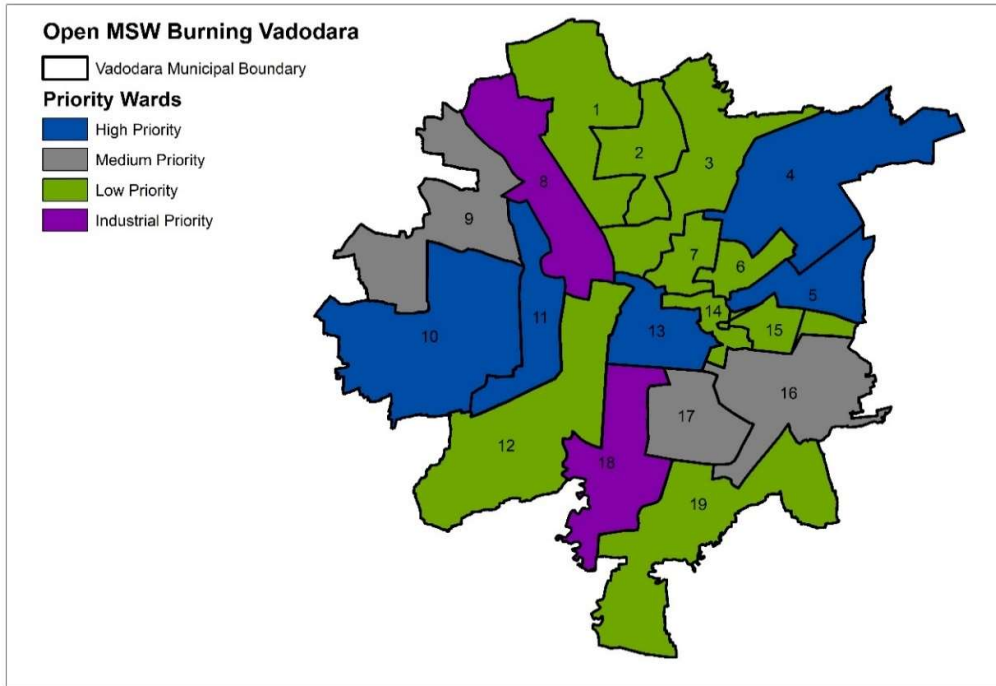


Figure 8 Prioritization of wards as per the MSW burning incidences

Table 2 Waste Burning incidents found during the Summer and Winter Surveys with Priority Criteria Ward wise in the VMC area

Waste Burning incidents found during Summer and Winter Surveys with Priority Criteria				
Sl.No.	Ward No	No of Waste Burning Incidents Found in Summer	No of Waste Burning Incidents Found in Winter	Priority Criteria
1	1	2	0	Low Priority
2	2	0	4	Low Priority
3	3	0	2	Low Priority
4	4	13	18	High Priority
5	5	6	17	High Priority
6	6	2	3	Low Priority
7	7	0	0	Low Priority
8	8	8	22	Industrial Priority
9	9	9	9	Medium Priority
10	10	13	23	High Priority
11	11	8	15	High Priority
12	12	1	8	Low Priority
13	13	14	10	High Priority
14	14	0	1	Low Priority
15	15	3	1	Low Priority
16	16	8	8	Medium Priority

17	17	10	3	Medium Priority
18	18	47	35	Industrial Priority
19	19	3	1	Low Priority
Total Incidents		147	180	

5. Reasons for Open MSW Burning

During the primary survey, open-ended interviews were conducted with randomly selected households, shopkeepers, and workers from various areas within the Vadodara Municipal Corporation (VMC) to understand their perceptions of municipal solid waste (MSW) burning. These interviews were conducted alongside a primary transect survey to gather insights on the reasons behind waste-burning practices. Respondents cited several reasons for burning waste. For many households, burning MSW was considered an easy and convenient way to dispose of waste, especially to avoid accumulation in the vicinity. Some respondents mentioned that burning had become a daily routine to manage waste. Others admitted that they resorted to burning because they missed the waste collection truck in the morning or due to infrequent waste collection services, particularly in wards located in the west and north zones.

Additionally, it was reported that waste collectors themselves sometimes burned waste, particularly large volumes, or refused to collect it altogether. Industrial areas were also identified as hotspots for waste burning, often for material extraction purposes. These varied reasons highlight behavioral, logistical, and systemic gaps in the waste management process, contributing to the prevalence of MSW burning across the city (Table 3).

Table 3 Common reasons cited by the citizens for waste burning in the VMC area

Sl.No	Common Reasons Cited
1	Easy way to rid of Waste (Waste Reduction)
2	Behavioral issues among citizens
3	Waste collectors burn waste to reduce their travel trips
4	No trolley for collecting waste-Sweepers
5	Waste Collectors decline to collect waste sometimes such as dried leaves/plant trimming waste
6	Less or infrequent Collection of Waste in some wards
7	No collection of waste (In some of the areas)
8	Extraction/recovery of Material (Commercial Burning)

After the analysis of waste-burning incidents, including their frequency, mass, and underlying reasons, key stakeholders were identified, and focus areas for intervention were determined. This comprehensive assessment provided a foundation for understanding the complexities of waste-burning practices and their impact. The analysis helped pinpoint the primary actors involved, such as municipal authorities, waste collectors, industrial representatives, residents and households. These stakeholders play crucial roles in addressing the issue and implementing solutions. Additionally, the study highlighted specific areas requiring targeted interventions, such as improving waste collection efficiency, enhancing public awareness, and enforcing regulations against waste burning.

To address these challenges effectively, cities must adopt tailored strategies. Potential interventions include strengthening waste collection systems, particularly in areas with infrequent services, promoting decentralized waste management practices like composting, and providing training for waste collectors to reduce incidents of burning and separate collection systems for industrial areas. Furthermore, raising mass public awareness about the environmental and health impacts of waste burning and ensuring stricter enforcement of anti-burning regulations are critical steps to mitigate this issue (Table 4).

Table 4 Reasons for waste burning behaviors and drivers by different stakeholders

Focus Area	Key Stakeholders	Where?	How?	Why?	Possible Interventions
Behavioral Issue	Households, waste collectors	Streets, Kerbside, outside and inside housing premises and society	Open Burning	Waste reduction, Heating	Mass awareness against harmful consequences of waste burning. All awareness and capacity building interventions should be designed to address underlying socio-economic and cultural factors contributing to waste burning practices. These efforts should be tailored to the diverse needs of different communities within Vadodara.

					Provide alternative to heating solution
Increase Collection efficiency in some wards	Municipal Corporation, Waste collectors and inspectors	Roadside, street	Open burning	To reduce the number of waste collection trips	Actions toward improving collection efficiency in informal settlements, educational institutions, government offices, parks, and other public places and deployment of vehicles suited to narrow lanes
Collection of dried leaves and plant-trimming waste	Municipal Corporation, Waste collectors and inspectors	Household, Park, School, Hospital	Open Burning	No collection of dried leaves especially in case of large amounts	Separate collection system for dried leaves and plant trimming waste in households, offices, schools, parks hospital, and other public spaces
Commercial burning	Small shops and Kabadiwalas, rag pickers	Outside of Shop, Narrow alleyways and confined places	Open Burning	Source of material such as metal.	<p>Awareness raising and personalized training. Using scientific techniques to recover metal. Ensure large Involvement of this Stakeholder in mainstream waste management.</p> <p>It is also essential to acknowledge the complex and interconnected barriers contributing to this problem. Merely implementing awareness raising and personalized training may not suffice due to the presence of various overlapping challenges such as corruption, gender</p>

					norms, and socio-economic marginalization
Industrial Area burning	Factories, and workshops	Inside and outside of industry premises.	Open Burning	Waste reduction	Separate solid waste collection system in industrial area

6. Proposed Solutions and Actions

Vadodara has distinguished itself in efficiently managing the solid waste generated by its residents, commercial entities, industries, and educational and medical institutions. However, the practice of open burning of solid waste remains a pressing issue within the sector. During the transect walk primary survey, it was found that paper, plastics, textile and threads, and dry leaves were the main forms of waste being burned. Pollutants released during open waste burning emit particle-bound metals which have a higher carcinogenic potential than wood combustion, hence people living around places with regular waste burning episodes have higher risk of cancer (Ramadan et al. 2022). Along with the transect walk survey, a random, open-ended interview was conducted with different stakeholders to identify the appropriate mitigation measure to curb waste burning

Some questions/reason about these ongoing burning activities were asked, in which response came out in different unexpected ways. Some senior citizens replied that it was simple, they were just habitual of doing that. The second reason was to reduce the waste load and to maintain cleanliness on the streets. Shopkeepers justified their burning activities by reducing the littering on the streets. Last but not least contributing reason was not having enough capacity of vehicles to carry the waste to the treatment facility. Vehicles having less or limited capacity to carry waste result in unpicked waste. This waste now is the major problem to both Municipal Corporation and locals. When municipal workers (sweepers) are off duty and encounter waste littered on the streets, they often resort to burning it being the easiest solution. In VMC, this survey also made its way to industrial areas, in which burning was most prominent and it has severe to extremely harmful impact due to constituents of the waste. The main reason behind it was the unwanted byproduct/product generated from the raw materials, such as textile thread, cotton, rexin, nylon, etc. As per the Solid Waste Management (SWM) Rules 2016, industries should have their waste treatment facilities, if not, then they must treat their waste by paying additional charges to various non-government/government waste management authorities unlike the burning activity that take place in residential areas.

Vadodara is making strides in solid waste management through joint operations of infrastructure development, community engagement, and sustainable evolving techniques to form a cleaner and healthier environment for its residents. However, like many cities, Vadodara is also increasing its waste volumes and mixed solid waste composition due to rapid urbanization caused by commercialization, industrialization, and increasing opportunities, which will eventually lead to more waste generation. Most of the composition of waste includes paper, plastic, textile thread, and aluminium as a primary ingredient in burning activities.

Further, suggested recommendations are based on various factors such as unawareness among the residents about not burning their waste, heating in winter for warming, increased collection efficiency, sufficient infrastructure, and infrequent collection of waste in industrial areas. With key focus areas mentioned in Table 4, derived from the primary survey aimed at reducing waste-burning incidents, and consultation with municipal waste worker and staff and other stakeholders, we have finalized below listed recommendations. Upon implementation, penalizing continuous violations, strict enforcement, and monitoring of the following recommendations can help achieve minimal or zero waste-burning:

- Conduct awareness programs at the grassroots level to educate residents about the impacts of open MSW burning.
- Organize workshops for municipal waste workers and street sweepers to improve their skills in efficient and safe solid waste management, and to address the infrastructure needs for effective waste collection such as handcarts and trollies.
- Optimize waste collection and segregation.
- Actions to provide alternative, affordable heating for low-income communities relying on polluting fuels.
- Strictly enforce regulations that prohibit open burning of waste. Impose substantial fines and penalties on individuals and businesses found in violation of these regulations.
- Enhanced Solid Waste Management in Industrial Zones.
- Integrate scrapers, kabadiwalas, and rag pickers into the waste management process. Involving these individuals can help prevent commercial waste burning.

The recommendations presented in this report are tailored to include an action plan, levels of intervention in terms of spatial considerations, and implementation periods categorized as Short-term (2 years), Mid-term (5 Years), Long-term (10 years and more), and continuous period. Furthermore, emphasis is given to the scope of various implementing agencies involved in executing these recommendations for the city of Vadodara.

Conduct awareness programs at the grassroots level to educate residents about the impacts of open MSW burning.

Based on a primary survey conducted across all zones of the Vadodara Municipal Corporation (VMC), it has been observed that despite the availability of waste collection and transportation facilities, some residents continue to burn municipal solid waste (MSW). During interactions with these residents, several reasons were identified for this behaviour. Many residents find it convenient to burn waste as a quick way to reduce the amount of waste at home. Others mentioned that they occasionally miss the waste collection trucks, which further prompts them to burn waste. This behaviour is largely driven by a lack of awareness about the harmful consequences of air pollution caused by burning MSW and its impact on human health.

Instead of taking alternative actions, such as waiting for the next collection truck or reporting the missed collection to the relevant authorities, residents opt to burn their waste. As long as they remain unaware of the environmental and health impacts of burning waste, this practice will likely continue as a preferred and cost-free method of dealing with excess and unwanted waste.

An examination of the social, educational, and land-use factors within Vadodara City underscores the urgent need for a comprehensive awareness campaign to address the issue of open MSW burning. To effectively tackle this problem, a well-designed awareness program must target and engage various segments of the population, fostering an understanding of their responsibilities and the broader impacts of waste burning. Below is a detailed plan for an effective awareness campaign (Table 5):

Table 5 Proposed Action, strategies, Intervention Level, implementation period and agency for an awareness program in Vadodara City on the impact of open burning of MSW

Mitigation Strategies	Level of Intervention	Proposed Actions	Implementation Period	Implementing Agency
<p>Leveraging Multiple Channels for Maximum Impact</p>	<p>Develop neighborhood-centric awareness programs tailored to different SES and land use characteristics</p>	<p>Residential Areas: Conduct interactive workshops and seminars across various localities in Vadodara City. These sessions will be delivered in the local language and include visual demonstrations to effectively communicate the ill effects of open burning. The focus will be on educating residents about the health risks associated with air pollution from burning waste, highlighting its harmful effects on both human health and the environment.</p> <p>Commercial Zones: Educate all businesses and entities regarding the health impacts of waste burning, particularly those that generate significant amounts of waste.</p> <p>Inform business owners about existing laws against open waste burning and emphasize the importance of civic responsibility.</p>	<p>Short - mid-term (but repeat after every 2-3 years)</p>	<p>VMC (with help of multiple stakeholders such as NGOs, RWAs, Women's Association, local leaders, educational institutions, business associations, and SHGs)</p>

		<p>Schools and Educational Institutions: Conduct specialized educational workshops in schools and educational institutions to educate students about the harmful consequences of open burning, and their role in reducing waste generation and its burning.</p> <p>For this, small projects can also be done as part of their extracurricular activities.</p>		
	<p>Engage citizens at the city level through mass media communication</p>	<p>Leverage multiple communication channels such as social media, local newspapers, radio, television, and wall murals & paintings to spread awareness about the impacts of open burning. Utilize infographics, videos, and real-life case studies to illustrate the serious consequences of this harmful practice effectively.</p> <p>The communication strategy should be carefully designed to address the needs of vulnerable populations and deliver information in the local language. Women, particularly from low-income communities, often rely on face-to-face communication for information and have greater access to newspapers and radio compared to men. Therefore, in addition to digital and traditional media campaigns, it is crucial to place equal emphasis on face-to-face communication in the local</p>	<p>Short -Mid-term</p>	

		language to effectively reach and engage these groups.	
	Community-level program for Segregation at Sources in all Zones	<p>Collaborate with Resident Welfare Associations (RWAs), local community centers, women's groups, voluntary organizations, NGOs, and religious institutions to lead community engagement initiatives. Encourage residents to take charge of waste segregation and reduce open burning, fostering a sense of ownership in creating a cleaner, healthier environment.</p> <p>In waste management, women often handle household waste disposal but lack decision-making power. To address this, implement gender equality awareness campaigns to challenge stereotypes and emphasize women's crucial role in waste management. Additionally, actively involve women in creating community forums or committees to ensure diverse voices are represented.</p>	Mid-term

Organize workshops for municipal waste workers and street sweepers to enhance skills and address infrastructure needs like handcarts and trolleys for effective waste collection.

During interactions with waste workers through the primary survey and waste worker capacity-building workshops, it was found that some municipal waste workers are involved in burning waste, whether street and road sweeping workers or door-to-door waste collection workers. They cited the unavailability of waste-carrying hand trolleys and the need to reduce trips due to high waste volumes as reasons for this practice. Like residents, these workers need more awareness of the harmful effects of air pollution from burning MSW and its impact on health.

To address this, workshops aimed at enhancing waste management skills, should focus on providing practical knowledge and raising awareness. It is also crucial to supply enough large-sized hand trolleys to enable workers to transport more waste efficiently. Here are some details (Table 6)

Table 6 Proposed Action, strategies, Intervention Level, implementation period and agency for organizing workshop and providing infrastructure to the municipal waste worker in Vadodara City on the impact of open burning of MSW

Mitigation Strategies	Level of Intervention	Proposed Actions	Implementation Period	Implementing Agency
Enhance waste management skills by providing practical knowledge, raising awareness, and supplying adequate infrastructure for waste collection	Waste Worker (formal and informal)	Conduct comprehensive training sessions for waste workers to educate them about the hazards of open burning. Equip them with the skills and knowledge needed to safely manage various types of waste, including dried leaves and plant trimmings	Short to Mid Term (but repetitive)	VMC (with help of waste collection agency, NGOs, and SHGs)
	Municipal corporation	Provide essential infrastructure to support waste workers in their duties. This includes sufficient collection bins and handcart trolleys to facilitate efficient waste collection and transportation. Coordinate waste collection truck trips with street sweeping operations to ensure timely disposal of swept waste. This will minimize the need for waste workers to walk long distances, improving overall efficiency.		
	Local Authorities and Policymakers	Foster open communication and sessions with local authorities and policymakers to address		

		<p>waste management challenges.</p> <p>Advocate for policy reforms and the implementation of stringent regulations, including monetary penalties or service restrictions, to deter open burning and encourage sustainable waste disposal practices.</p>		
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Optimize Waste Collection and Segregation.

The city's expansion and inclusion of new areas have given rise to urban and peri-urban characteristics, low-income neighborhoods, and informal settlements. These areas often experience inadequate waste collection services due to the insufficient number of municipal trucks and the need for more frequent collections. While conducting the waste-burning survey, the WRI team received complaints about infrequent collection services in some neighborhoods and the refusal to collect garden and dried leaf waste. Additionally, during waste worker and staff capacity-building workshops, participants highlighted poor coordination among contractors, sweepers, ward officers, and sanitary officers, emphasizing the need for decentralized supervision of trucks. The West and North Zones expressed a lack of waste staff, trolley carts, and inadequate collection coverage.

To address these challenges, it is imperative to expand the waste collection vehicle fleet, increase collection frequencies to twice daily, conduct public awareness campaigns, implement separate collection for green waste and dry leaves, establish separate collection for bulk generators, provide more staff and handcart trollies, and ensure efficient tracking and coordination among contractors, sweepers, ward officers, and sanitary officers. The primary goal should be to eliminate waste burning and promote viable alternatives. Engaging informal workers as last-mile collection agents in areas with narrow lanes and confined spaces can enhance collection efficiency while creating job opportunities. Vehicles suitable for narrow lanes, such as electric two-wheelers, three-wheelers, and handcarts, can help ensure that residents in low-income and informal settlements are not excluded from the municipality's waste collection services (Table 7).

Table 7 Proposed Action, strategies, intervention level, implementation period and agency for improvement of waste collection frequency and segregation in Vadodara City to reduce open burning of MSW

Mitigation Strategies	Level of Intervention	Proposed Actions	Implementation Period	Implementing Agency
Increase Collection frequencies	West and North Zone	Implement more frequent waste collection rounds to ensure timely pickup and	Short-Mid Term	VMC (Waste collecting agencies,

and Expansion of Waste Collection Fleet		<p>schedule once in the morning and again in the evening</p> <p>Increase the number of waste collection vehicles and more frequent waste collection trips to minimize the accumulation of waste</p>		other NGO's, waste pickers, and SHG)
Provision of Additional Resources	West and North Zone	Allocate more staff and handcart trolleys to improve waste collection coverage, particularly in underserved areas.	Short-Mid Term	
Separate Collection for Specific Waste Types	City Level	Implement separate collection services for green waste, such as plant trimmings and dried leaves, as well as for bulk waste generators.	Short Term	
Efficient Tracking of waste Collection vehicles and Coordination among waste workers	City Level	<p>Enhance the tracking of waste collection vehicles so every section waste staff can track and coordinate with them through a GPS tracking system, Mobile apps, optimized route plans, and an automatic update system.</p> <p>Improve coordination among contractors, sweepers, ward officers, and sanitary officers through clear communication channels, regular coordination meetings, and defined roles and responsibilities.</p>	Short Term	
Use of Specialized Vehicles	City Level	Deploy vehicles suited for narrow lanes, such as electric two-wheelers, three-wheelers, and hand carts, to ensure that low-income and informal settlements are included in	Short Term	

		the municipality's waste collection services		
Streamlining informal worker/ rag pickers in waste collection	City Level	Involving informal workers as last mile collection agents (area with narrow lanes and confined places) will help in improving collection efficiency and also generate livelihood.	Mid Term	

Actions to provide alternative, affordable heating for low-income communities relying on polluting fuels.

During the winter season, the primary survey revealed that across various locations in Vadodara city, a significant number of residents of low-income groups and industrial areas are using waste materials as a source of heating. This practice is prevalent in several areas, where people burn waste to stay warm during the winter months. The survey highlights a critical issue, as the use of waste for heating not only reflects the scarcity of proper heating resources but also raises environmental and health concerns.

The burning of waste, which often includes plastics, rubber, and other harmful materials, releases toxic fumes and pollutants into the air, contributing to air pollution and posing serious health risks to the individual and community. However, most of them are not aware of the harmful consequences of burning waste, so many residents continue to rely on this method due to a lack of affordable and accessible alternatives. This practice underscores the urgent need for interventions that provide safer, more sustainable heating options for the city's residents, particularly during the winter months.

Raise source awareness about waste burning for heating and alternatives: Raising awareness about the harmful effects of waste burning for heating and promoting alternative solutions is vital for safeguarding public health and the environment. Effective strategies include community outreach through demonstrations and public awareness campaigns. The assumption is that once residents understand the health and environmental impacts of waste burning and are offered alternative heating solutions, their dependency on waste burning will decrease. This would reduce emissions and minimize exposure to harmful pollutants from waste burning (Table 8).

Provide alternatives to waste burning for heating and Subsidized Heating Equipment: This could be achieved by providing insulation through the deployment of portable heating devices suitable for small areas and the distribution of appropriate winter clothing, potentially sourced through government-led distribution programs, including provisions for reusing secondhand products where appropriate. Government and non-governmental organizations can introduce subsidized heating equipment, such as energy-efficient space heaters or portable stoves, specifically designed for low-income households. These devices could be powered by electricity power, reducing the need for burning harmful materials. (Table 8).

Community Heating Solutions: Establishing community-based heating solutions, such as shared heating centers or communal stoves, can provide warmth for multiple households. These centers could be equipped with clean and efficient heating systems that are more economical and less polluting (Table 8).

Table 8 Proposed action, strategies, intervention level, implementation period and agency to raise awareness about waste burning for heating and alternatives, and provide alternatives for waste burning

Mitigation Strategies	Level of Intervention	Proposed Actions	Implementation Period	Implementing Agency
<p>1. Raise source awareness about waste burning for heating.</p> <p>2. Provide insulation in the form of winter clothing and heating devices or alternative fuels, for staff employed in waste-burning hotspots identified by the WRI India.</p> <p>3. Community heating solution</p>	<p>Low-income societies, mohallas and neighborhood ward-level, nearby Industrial and Commercial setups,</p>	<p>Community outreach program through demonstration of how using polluting fuel/waste causes harmful effects</p> <p>Public awareness campaign through social media and other mass media</p> <p>Choose alternatives for winter heating such as portable stoves and heaters to reduce dependence on waste-burning</p> <p>Establishment of community-based heating solutions, such as shared heating centers or communal stoves.</p>	<p>Short – Mid Term</p>	<p>VMC, Housing Societies and mohallas leader, RWAs, Industrial and commercial association</p>

Strictly enforce regulations that prohibit open burning of waste. Impose substantial fines and penalties on individuals and businesses found in violation of these regulations.

Strict enforcement of laws and regulations is necessary to address this long-standing practice of open waste burning. Imposing fines and penalties for violations is crucial. The primary survey identified open waste burning as a behavioural issue that needs strict penalties. To minimize waste burning, a tiered penalty system should be implemented and modified for different areas and types of waste in Vadodara city. Those who burn waste in sensitive areas like hospitals, schools, and parks should face higher penalties. Burning hazardous waste should also have more severe penalties. This approach can be gradually extended to cover various parts of the city, ensuring comprehensive enforcement (Table 9).

The survey also revealed that commercial and industrial entities, in addition to households, are contributing to the problem of waste burning. Some of this waste is toxic or hazardous, and these entities often generate large quantities of waste, contributing significantly to pollution. To address this issue, stricter enforcement and higher penalties should be imposed on these entities to deter such harmful practices (Table 9).

Table 9 Proposed action, strategies, intervention level, implementation period and agency to enforce regulations and imposed fines & penalties to stop waste burning

Mitigation Strategies	Level of Intervention	Proposed Actions	Implementation Period	Implementing Agency
Guidelines for Penalizing based on Tiered Penalty System	City Level	<p>To curb MSW burning, specific guidelines should be developed for taking action against individuals found burning MSW. These guidelines should outline fine slabs and types of penalties.</p> <p>For example, a single household could face a fine ranging from INR 500 to 2000, with the amount varying based on socio-economic conditions. A low-income household might be fined INR 500, while a medium-income household could face a fine of INR 1000. High-income households could be subject to a fine of INR 2000.</p>	Short-Mid Term	VMC (especially waste management cell)
Higher Penalty for Sensitive areas	City Level	Higher penalties should be imposed for burning waste in sensitive areas, such as near healthcare facilities, educational institutions, and public parks.	Short-Mid Term	
Strict but Tiered Penalty for Commercial and	City Level	Strict penalties should be imposed on commercial and industrial entities that engage in open waste burning. These penalties	Short-Mid Term	

Industrial Entity		<p>could include fines and the cancellation of licenses.</p> <p>A tiered penalty system should be implemented, with larger entities facing higher fines, such as INR 20,000, while smaller entities may be subject to lower fines, such as INR 5,000.</p>		
Phase wise Implementation	Hotspot area	Gradually extend the enforcement of these regulations across different parts of the city, starting with areas most affected by waste burning. This will help ensure that resources are allocated effectively, and enforcement is thorough.	Short Term	
Monitoring and Reporting Mechanisms	City Level	<p>Establish a Monitoring System: Set up a robust system to monitor compliance with waste management regulations. Use technology like drones or CCTV to monitor areas prone to illegal waste burning.</p> <p>Enable Public Reporting: Create a platform for citizens to report instances of illegal waste burning. Quick response teams can be deployed to address reported incidents.</p>	Short Term	

Enhanced Solid Waste Management in Industrial Zones.

The primary survey revealed that industrial waste burning is prevalent in Vadodara, second only to medium SES areas. Some industries are improperly disposing of their solid waste by burning it, sometimes in combination with industrial waste. It is necessary to separate solid and industrial waste and eliminate burning practices. Implementing an effective waste management system is crucial to address this issue.

Although industries are primarily responsible for managing their Industrial Solid Waste (ISW), collaborative efforts between the Gujarat Pollution Control Board (GPCB), the Vadodara Municipal Corporation (VMC), and industries can significantly improve the situation. Non-toxic and non-hazardous ISW can potentially be managed similarly to household waste. However, proper waste management practices are essential to prevent environmental harm and health risks. Here are some specific steps that can be taken to effectively manage this type of waste (Table 10):

Table 10 Proposed action, strategies, intervention Level, implementation period and agency for Solid Waste Management in Industrial Zones

Mitigation Strategies	Level of Intervention	Proposed Actions	Implementation Period	Implementing Agency
Ensure efficient waste collection systems and develop robust infrastructure	Industrial Area/Cluster (Makarpura)	Implement a rigorous door-to-door collection system for industrial solid waste to prevent burning. Establish a robust infrastructure for waste collection, segregation, and disposal to facilitate effective management of industrial solid waste.	Short Term	Industries Association (With the help of GPCB and VMC)
Promote stronger collaborative initiatives between VMC, GPCB, industries, and waste management Organisation		Collaborating with the GPCB and VMC to develop specific guidelines and initiatives for managing non-hazardous industrial solid waste (cardboard, wood, packaging materials) can lead to effective waste management strategies. This involves sharing best practices, technologies, and resources for improved waste handling.	Short to Mid Term	Industries Association (With the help of waste management organizations, GPCB and VMC)
Implement strict enforcement and conduct comprehensive educational programs		Strictly enforce existing waste disposal regulations in industrial areas. Conduct comprehensive awareness campaigns to educate industries about the importance of eliminating MSW burning and separating industrial and solid waste.	Continuous	Industries Association and Industry owner
Offer incentives and		Offering incentives such as tax benefits or subsidies for the use of eco-friendly	Short - mid term	GPCB and state government

promotions to encourage industries to adopt sustainable waste management practices		packaging materials and implementing advanced waste management technologies can motivate industries to invest in sustainable waste management practices and minimize the generation of non-hazardous industrial solid waste.		
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Integrate Scrapers, Kabadiwalas, and Rag Pickers into the waste management process. Involving these individuals can help prevent commercial waste burning.

Primary survey findings indicate that some informal waste workers, including rag pickers and scrapers, resort to burning of waste for extracting valuable materials. These individuals play a crucial role in recycling, reusing, and recovering discarded waste, serving as last-mile collection agents. However, their practice of burning waste contributes to air pollution, especially when conducted in open or confined spaces without proper emissions control.

Integrating these informal waste workers into the conventional waste management system is essential to encourage more sustainable practices and eliminate waste burning. The VMC's collaboration with 217 rag pickers demonstrates the positive impact of such integration. Expanding this collaboration to include a larger number of informal waste workers is crucial. To address the issue of open burning of waste by informal waste sector workers and to integrate them into sustainable waste management practices, consider the following recommendations (Table 11):

Table 11: Proposed Action, strategies, Intervention Level, implementation period, and agency for Mainstreaming scrapers/ Kabadiwala's and ragpickers into waste management to stop commercial burning

Mitigation Strategies	Level of Intervention	Proposed Actions	Implementation Period	Implementing Agency
Formalization and Integration of Informal Workers	City Ragpickers	Formalize informal waste workers, including rag pickers and scrapers, under the VMC or other relevant organizations. Provide comprehensive training on sustainable waste management practices, including proper waste sorting, handling, and disposal methods	Short to Mid Term	VMC (with the help of NGOs and waste management Companies)

Strengthen collaboration with local scraper and Kabadiwala communities	local scraper and Kabadiwala communities	Formulate structured partnerships with local scraper and kabadiwala communities. This could involve collaborations with the VMC or private waste management companies to provide these individuals with a reliable and sustainable source of income.	Short to Mid Term	VMC (with the help of NGOs and waste management Companies)
Incentivizing Scraper and Kabadiwala Communities to Manage Recyclable Waste from Commercial Entities		Develop a framework that incentivizes local scraper and kabadiwala communities to collect and manage recyclable waste from commercial entities. This could include financial support for the installation of eco-friendly equipment (small material recovery facilities) and offering higher prices for properly segregated and recycled waste		
Technology Integration		Provide advanced equipment for metal recovery, such as high-efficiency incinerators and shredders, to enable scrapers and kabadiwalas to extract metals without resorting to harmful burning practices	Mid to Long Term	VMC (Technology solution Provider company)
Policy Advocacy and Support:	City Ragpickers, local Scrapers and Kabadiwala communities	Advocate for policies that support the integration of informal sectors into the formal waste management system. Work with local authorities to create a conducive regulatory environment that recognizes the important role of ragpickers and scrapers/kabadiwalas in the waste management Chain.	Long term	VMC and State and Central Govt.

7. Decentralized Waste Management for Vadodara: A Pilot Intervention Proposal

Decentralized waste management, which involves treating municipal solid waste (MSW) closer to its source, is an effective approach to waste processing. For wet waste, technologies like composting or biomethanization can be employed, while dry waste can be managed by incentivizing collectors to deliver it to local franchises or Material Recovery Facilities (MRFs).

Decentralizing waste treatment facilities by distributing processes across multiple smaller sites rather than relying on a single centralized facility offers several advantages, including reduced transportation costs, improved system resilience, and better environmental outcomes. The following measures can facilitate a smooth transition to decentralized waste management:

To address the problem of waste burning, the establishment of local recycling centers for managing plastic, paper, and textile waste is essential. Additionally, small composting pits should be set up in parks, residential societies, neighbourhoods, colonies, and educational institutions to handle organic waste effectively. A pilot intervention is proposed to implement decentralized waste management in one ward of Vadodara city. If successful, this model can be replicated in other wards across the city. A detailed cost analysis and implementation plan are provided below (Table 12).

Table 12 Proposed Action, mitigation strategies, Intervention Level, implementation period, and agency for a pilot level decentralized waste management model in one ward of Vadodara City

Mitigation Strategies	Level of Intervention	Proposed Actions	Implementation Period	Implementing Agency
To maximize waste segregation at the household and commercial levels and pilot a decentralized waste management model in one ward of Vadodara City	Pilot Ward Level	Ward Selection: Identify a ward in Vadodara with a diverse population and representative waste composition.	Short to Mid Term	VMC (with help of waste management agency, RWA's NGOs, and SHGs)
		Construct composting pits in designated locations within the ward.		
		Conduct community workshops and training sessions to educate residents and waste workers on proper waste segregation and disposal practices		
		Encourage waste collectors and residents to participate in the decentralized waste management model by offering incentives for delivering dry waste to local franchises or Material Recovery Facilities (MRFs). This approach fosters public engagement and ensures greater community involvement in the proper		

		sorting and processing of waste.		
		Track the performance of the pilot project, measure waste reduction and diversion rates, and assess community satisfaction.		

Cost Analysis

- **Composting Pits:** Setting up a small composting pit costs approximately INR 5,000. For a ward with 34,600 households, around 260 composting pits would be required, assuming 15 pits are needed per 2,000 households.
- **Total Cost:** The total cost for constructing 260 pits for 34,600 households is approximately INR 13 Lakhs.

Upon implementation of this pilot project, Vadodara can take significant steps toward decentralized waste management, segregation at source, reducing the incidence of waste burning, enhancing community engagement, and improving the city's overall environmental health.

Note: During the waste worker capacity building workshop, the west zone emphasized the significant generation of garden/green waste and the lack of facilities to manage it. Additionally, the west zone recently expanded its area, now including peri-urban regions with large open spaces. Therefore, any ward within the west zone would be suitable for a pilot project focused on garden/green waste management.

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Annexure

Annexure 1- List of waste-burning Incidents in Summer and Winter and their Locations

Table 13: Waste Burning Incidents location at VMC area in Summer 2023 as per Survey

Date	Shift	Transect	Incident No. over all	Incident No. Date and Shift wise	Ward Name	Area/ Locality	GPS Way Point No.
15-05-2023	Morning	Transect 1	1	1	5	Kishanvadi	271
			2	2	5	Kishanvadi	271
			3	3	5	Kishanvadi	272
			4	4	5	Vidhyama ndir Vidhyalaya	273
			5	5	5	Vidhyama ndir Vidhyalaya	273
			6	6	4	Nizampura	274
			7	7	1	Nizampura	277
			8	8	1	Nizampura	277
24-05-2023	Morning		9	1	4	Sardar Estate	312
			10	2	4	Sardar Estate	313
			11	3	4	Khodiyar Nagar	314
			12	4	4	Khodiyar Nagar	315
	Evening		13	1	5	Aalam gadi talav	316
			14	2	4	Near Sardar Estate	317
25-05-2023	Morning		15	1	4	Sardar Estate	318
			16	2	4	Near Sardar Estate	319
			17	3	4	Near Temple	320
			18	4	4	Khodiyar Nagar	321
			19	5	6	Khodiyar Nagar	322
			20	6	6	Khodiyar Nagar	323
			21	7	13	Police Bhavan	324

	Evening		22	1	4	Near Sardar Estate	325
			23	2	4	Near Sardar Estate	326
			24	3	4	Near Sardar Estate	326
26-05-2023	Morning	Transect 2	25	1	13	Near Maharaja Fatehsingh Museum	327
			26	2	18	Manjalpur	328
			27	3	18	Manjalpur	328
			28	4	18	Manjalpur	328
			29	5	18	Manjalpur	328
			30	6	18	Makkarpur a GIDC	329
			31	7	18	Makkarpur a GIDC	330
			32	8	18	Makkarpur a GIDC	330
			33	9	18	Makkarpur a GIDC	331
			34	10	18	Makkarpur a GIDC	331
			35	11	18	Makkarpur a GIDC	332
			36	12	18	Makkarpur a GIDC	333
			37	13	18	Makkarpur a GIDC	334
			38	14	18	Makkarpur a GIDC	335
			39	15	18	Makkarpur a GIDC	336
			40	16	17	Tarsali	337
			41	17	17	Tarsali	338
			42	18	16	Waghodia	339
			43	19	15	Waghodia	340
	Evening		44	1	13	Baroda High School	341
			45	2	18	Manjalpur	342
			46	3	18	Makkarpur a GIDC	343
			47	4	18	Makkarpur a GIDC	344
			48	5	18	Makkarpur a GIDC	345

27-05-2023	Morning	49	6	18	Makkarpur a GIDC	346
		50	7	18	Makkarpur a GIDC	347
		51	8	17	Tarsali	348
		52	9	16	Waghodia	349
		53	1	13	Near Baroda High school	350
		54	2	18	Manjalpur	351
		55	3	18	Makkarpur a GIDC	352
		56	4	18	Makkarpur a GIDC	353
		57	5	18	Makkarpur a GIDC	354
		58	6	18	Makkarpur a GIDC	355
		59	7	18	Makkarpur a GIDC	356
		60	8	18	Makkarpur a GIDC	356
		61	9	18	Makkarpur a GIDC	357
		62	10	18	Makkarpur a GIDC	358
		63	11	18	Makkarpur a GIDC	359
	64	12	18	Makkarpur a GIDC	360	
	65	13	18	Makkarpur a GIDC	361	
	66	14	19	Tarsali	362	
	67	15	17	Tarsali	363	
	68	16	17	Tarsali	363	
	69	17	17	Tarsali	364	
	70	18	16	Waghodia	365	
	71	19	16	Waghodia	366	
	72	1	15	Makarpura GIDC	367	
	73	2	18	Makarpura GIDC	368	
	74	3	18	Makarpura GIDC	369	
	75	4	19	Tarsali	370	
76	5	17	Tarsali	371		
77	6	15	Revapark	372		
28-05-2023	Morning	78	1	18	Manjalpur	373
		79	2	18	Manjalpur	374
		80	3	18	Makarpura GIDC	375

			81	4	18	Makarpura GIDC	376
			82	5	18	Makarpura GIDC	377
			83	6	18	Makarpura GIDC	377
			84	7	18	Makarpura GIDC	378
			85	8	18	Makarpura GIDC	379
			86	9	18	Makarpura GIDC	380
			87	10	18	Makarpura GIDC	380
			88	11	18	Makarpura GIDC	380
			89	12	19	Anand baug society	381
			90	13	17	Tarsali	382
			91	14	17	Near ONGC	383
			92	15	17	Lalbaug	384
			93	16	16	Waghodia	385
			94	17	16	Waghodia	385
			95	18	13	Waghodia	386
			96	19	13	Waghodia	386
			97	20	13	Waghodia	386
			98	21	13	Waghodia	386
			99	22	13	Waghodia	386
15-05- 2023	Evening		100	1	18	Makkarpur a GIDC	278
			101	2	18	Makkarpur a	279
			102	3	16	Makkarpur a	280
			103	4	16	Makkarpur a	280
16-05- 2023	Morning	Transect 3	104	1	11		281
			105	2	8		282
			106	3	8		282
			107	4	8		282
			108	5	9		283
			109	6	9		284
			110	7	10		285
			111	8	13	Sayaji Hotel	286
			112	9	13	Police Bhavan	287
	Evening		113	1	11		288
			114	2	11		288

17-05-2023	Morning	115	1	13	Akota Bridge	289	
		116	2	8	Alkapuri	290	
		117	3	11	Subhanpura	291	
		118	4	11	Subhanpura	292	
		119	5	11	Subhanpura	293	
		120	6	8	Laxmipura road	294	
		121	7	8	Laxmipura road	294	
		122	8	8	Laxmipura road	294	
		123	9	9	Laxmipura	295	
		124	10	9	Laxmipura	295	
		125	11	9	Laxmipura	296	
		126	12	9	Laxmipura	296	
		127	13	9	Gotri	297	
		128	14	10	Gotri	298	
		129	15	10	Gotri	299	
	130	16	10		300		
	Evening	131	1	10	Gotri	301	
		132	2	10	Gotri	301	
		133	3	10	Gotri	302	
		134	4	13	Near Vishwamitri River	303	
	18-05-2023	Morning	135	1	11	Subhanpura	304
			136	2	11	Subhanpura	304
			137	3	8	Laxmipura Road	305
			138	4	9		306
			139	5	9		306
			140	6	10	Gotri	307
			141	7	10	Gotri	307
			142	8	10	Akota	308
			143	9	12	Near Vishwamitri river	309
		144	10	13	Police Bhavan	310	
Evening		145	1	10	Gotri	311	
		146	2	10	Gotri	311	
		147	3	10	Gotri	311	

Table 14: Waste Burning Incidents location at VMC area in Winter 2023 as per Survey

Date	Shift	Transect	Incident No.overall	Incident No. Date and Shift wise	Ward Name	Area/Locality	GPS Way Point No.
26th Dec'23 Temp=25 C	Morning	Transect 1	1	1	3	Sayajiganj	559
			2	2	2	Nizampura	560
			3	3	3	Karelibaug	561
			4	4	4	Khodiyar nagar	562
			5	5	4	Khodiyar nagar	563
			6	6	4	Raghukul vidhyalaya	564
			7	7	4	Sardar Esatate, Ajawa Road	565
			8	8	4	Sardar Esatate, Ajawa Road	566
			9	9	4	Sardar Esatate, Ajawa Road	567
			10	10	4	Kamla nagar	568
			11	11	4	Shree shyam mandir	569
			12	12	4	Shree shyam mandir	570
			13	13	5	Kishanwadi	571
			14	14	5	Kishanwadi	571 WP2
			15	15	5	Shreeji Hospital	572
			16	16	5	Shreeji Hospital	572 WP2
	Evening	17	1	5	Alamvadi talav (slums)	573	
		18	2	4	Khodiyar nagar	574	
		19	3	4	Khodiyar nagar	575	
		20	4	4	Khodiyar nagar	575 WP2	
27th Dec'23 Temp 27 C	Morning		21	1	5	Alamvadi talav (slums)	576
			22	2	5	Kishanwadi	577
			23	3	6	Raghukul vidhyalaya	578
			24	4	6	Sayajipura	579

	Evening		25	5	4	ramdev nagar	580			
			26	6	5	Khodiyar nagar	581			
			27	7	2	Dominoz	582			
			28	1	4	Sardar Esatate, Ajawa Road	583			
			29	2	4	Sayajipura	584			
28th Dec'23 Temp 27C	Morning		30	1	5	Alamvadi talav (slums)	585			
			31	2	5	Alamvadi talav (slums)	585 WP 2			
			32	3	5	Alamvadi talav (slums)	586			
			33	4	5	Ayurvedic College, Panigate	587			
			34	5	5	Kishanwadi	588			
			35	6	6	Sayajipura (school)	589			
			36	7	4	ramdev nagar	590			
	Evening		37	8	2	Chhani jakatnaka	591			
			38	1	2	Alamvadi talav (slums)	592			
			39	2	4	Sayajipura	593			
			40	3	4	Sayajipura	593 WP 2			
			29th Dec'23 Temp 25 C	Morning	Transect 2	41	1	15	Waghodia	594
						42	2	16	Waghodia	595
						43	3	16	Surya nagar	596
44	4	16				Tarsali	597			
45	5	18				Makkarpura GIDC	598			
46	6	18				Makkarpura GIDC	599			
47	7	18				Makkarpura GIDC	599 WP 2			
48	8	18				Makkarpura GIDC	600			
49	9	18				Makkarpura GIDC	601			
50	10	18				Makkarpura GIDC	602			
51	11	18				Manjalpur	603			
52	12	18				Manjalpur	604			
53	13	18				Manjalpur	605			
54	14	13		Chhani jakatnaka		606				
Evening	55	1	18	Makkarpura GIDC	854					

			56	2	18	Makkarpura GIDC	855	
30th Dec'23 Temp 24 C	Morning		57	1	13	Navapura	856	
			58	2	18	RTO Manjalpur	857	
			59	3	18	Makkarpura GIDC	858	
			60	4	18	Makkarpura GIDC	859	
			61	5	18	Makkarpura GIDC	860	
			62	6	18	Makkarpura GIDC	861	
			63	7	18	Makkarpura GIDC	862	
			64	8	18	Makkarpura GIDC	863	
			65	9	18	Makkarpura GIDC	864	
			66	10	18	Makkarpura GIDC	865	
			67	11	18	Makkarpura GIDC	866	
			68	12	16	Zenith School (Pratap nagar)	867	
			69	13	16	Zenith School (Pratap nagar)	868	
			70	14	16	Zenith School (Pratap nagar)	868 WP2	
		Evening		71	1	13	Navapura	869
			72	2	13	Navapura	870	
			73	3	13	Navapura	870 WP2	
			74	4	18	Manjalpur	871	
			75	5	18	Makkarpura GIDC	872	
			76	6	18	Makkarpura GIDC	873	
	77		7	18	Makkarpura GIDC	874		
	78		8	19	Makkarpura GIDC	875		
	79		9	17	Tarsali	876		
31st Dec'23 Temp 24C	Morning		80	1	13	Central Jail Area	877	
			81	2	13	Central Jail Area	877 WP2	
			82	3	13	Central Jail Area	877 WP3	

			83	4	18	Manjalpur	878
			84	5	18	MGVCL (Manjalpur)	879
			85	6	18	Makkarpura GIDC	880
			86	7	18	Makkarpura GIDC	881
			87	8	18	Makkarpura GIDC	882
			88	9	18	Makkarpura GIDC	883
			89	10	18	Makkarpura GIDC	884
			90	11	18	Makkarpura GIDC	885
			91	12	16	Tarsali	886
			92	13	17	Tarsali	887
			93	14	17	Tarsali	888
			94	15	14	Pratapnagar	889
			95	16	5	Waghodia	890
			96	17	5	Waghodia	891
			97	18	5	Waghodia	891 WP2
	Evening		98	1	18	Makkarpura GIDC	892
			99	2	18	Makkarpura GIDC	893
			100	3	16	Pratapnagar	894
			101	4	5	Gajerawadi	895
			102	5	13	Sultanpura	896
1st Jan'24 Temp=24 c	Morning	Transect 3	103	1	12	Akota	897
			104	2	8	Subhanpura (GST Bhavan)	898
			105	3	8	Subhanpura (GST Bhavan)	899
			106	4	8	Akota	899 WP2
			107	5	11	Subhanpura	900
			108	6	8	Gorwa	901
			109	7	8	Gorwa	901 WP2
			110	8	8	Gorwa	901 WP3
			111	9	8	Gorwa	902
			112	10	8	Gorwa	902 WP2
			113	11	11	Laxmipura Road	903
			114	12	11	Subhanpura	904
			115	13	11	Subhanpura	904 WP2

			116	14	10	Gotri	905
			117	15	10	Gotri	905 WP2
			118	16	10	Gotri	906
			119	17	10	Gotri	906 WP2
			120	18	10	Gotri	907
			121	19	10	Gotri	908
			122	20	10	Gotri	908 WP2
			123	21	10	Vasna	909
			124	22	12	Sayajipura	910
			125	23	12	Sayajipura	910 WP2
	Evening		126	1	9	Laxmipura Road	911
			127	2	10	Gotri	912
			128	3	10	Gotri	913
			129	4	10	Gotri	914
			130	5	12	Sayajigunj	915
			131	1	8	Haripura	916
			132	2	11	GST Bhavan	917
			133	3	8	Gorwa	918
			134	4	11	Gorwa	919
			135	5	11	Gorwa	919 WP2
			136	6	11	Gorwa	919 WP3
			137	7	11	Subhanpura	920
			138	8	11	Subhanpura	920 WP2
			139	9	9	Gorwa	921
			140	10	9	Gorwa	922
			141	11	10	Gorwa	923
			142	12	10	Bhayli	924
			143	13	10	Bhayli	924 WP2
			144	14	10	Bhayli	924 WP3
			145	15	10	Bhayli	925
			146	16	10	Bhayli	925 WP2
			147	17	10	Bhayli	926
			148	18	10	Vasna	927
			149	19	10	Vasna	927 WP2
			150	20	11	Diwalipura	928
			151	21	12	Sayajigunj	929
	Evening		152	1	11	Subhanpura	930
2nd Jan'23 Temp=24 C	Morning						

3rd Jan' 24 Temp=22 C	Morning	153	2	8	Gorwa	931
		154	3	9	Gorwa	932
		155	4	9	Gorwa	932 WP2
		156	1	13	Anandpura	933
		157	2	8	Gorwa	934
		158	3	8	Gorwa	934 WP2
		159	4	8	Gorwa	934 WP3
		160	5	8	Gorwa	935
		161	6	8	Gorwa	935 WP2
		162	7	8	Gorwa	935 WP3
		163	8	8	Gorwa	935 WP4
		164	9	8	Gorwa	936
		165	10	8	Gorwa	936 WP2
		166	11	8	Gorwa	936 WP3
		167	12	8	Gorwa	936 WP4
		168	13	11	Subhanpura	937
		169	14	9		938
		170	15	9	Gotri	939
		171	16	9	Gotri	939 WP2
		172	17	9	Gotri	939 WP3
		173	18	10	Gotri	940
		174	19	10	Vasna	941
		175	20	10	Vasna	941 WP2
		176	21	11	Tandalja	942
		177	22	12	Sayajigunj	943
		178	23	12	Sayajigunj	943 WP2
		179	24	12	Sayajigunj	943 WP3
		Evening	180	1	11	

Annexure 2- Socio-Economic Considerations for Scaling-Up Study Findings

The SES of wards in the VMC area was derived from the Census of India 2011 data on population density, women's literacy and working population, marginalized workers and household amenities and assets. Data on access to basic amenities, such as electricity, drinking water, toilet facility, and drainage facility, has been extracted for constructing the Relative Wealth Index. The index helped in the application of the ranking system, providing scores (1-27) in all categories of SES as per amenities [High (24-27) availability, Medium (18-23) availability, Low (1-17) availability], and ranking these to define the SES¹. Using these criteria, VMC wards were categorized into wards with high, medium, and low-medium socio-economic sources/amenities². After defining the SES of wards, wards were again classified based on dominant land use activity, especially for industrial activity (Table 15).

Table 15: Wards in the VMC area as socio-economic status and land use activity

SES and Land Use Activity	Ward Number
High SES Neighbourhood	1, 2, 3, 7, 12, 13, 17 and 19
Medium SES Neighbourhood	5, 9, 10, 11, 14, 15 and 16
Low - Medium SES Neighbourhood	4 and 6
Industrial Area	8 and 18

¹ Kishore, J., Kohli, C., Kumar, N., & Gupta, N. (2017). Scales used in India to Evaluate Socio-economic Status in Medical Research: Limitations of Existing Scales and the need of a more Comprehensive One. *JIMSA*, 30(2), 66.

² Fry, K., Firestone R., & Chakraborty, N. M. (2014). *Measuring Equity with Nationally Representative Wealth Quintiles*. Washington, DC: PSI.

Results

The findings reveal that industrial areas had the highest prevalence of open waste burning, with significant amounts of MSW burned during both summer and winter. Waste composition played a crucial role in emissions, prompting surveys across all SES wards. Medium SES areas ranked second after industrial zones in waste-burning incidents, highlighting their contribution to the issue.