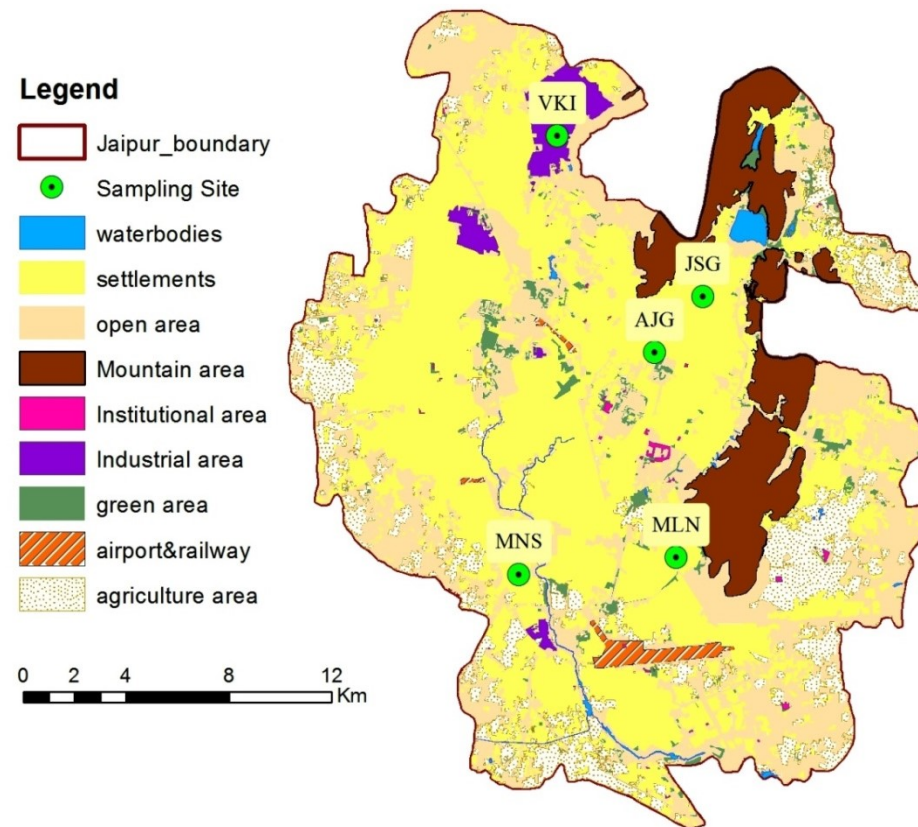


# Air Quality Assessment, Trend Analysis, Emission Inventory and Source Apportionment Study in Jaipur City



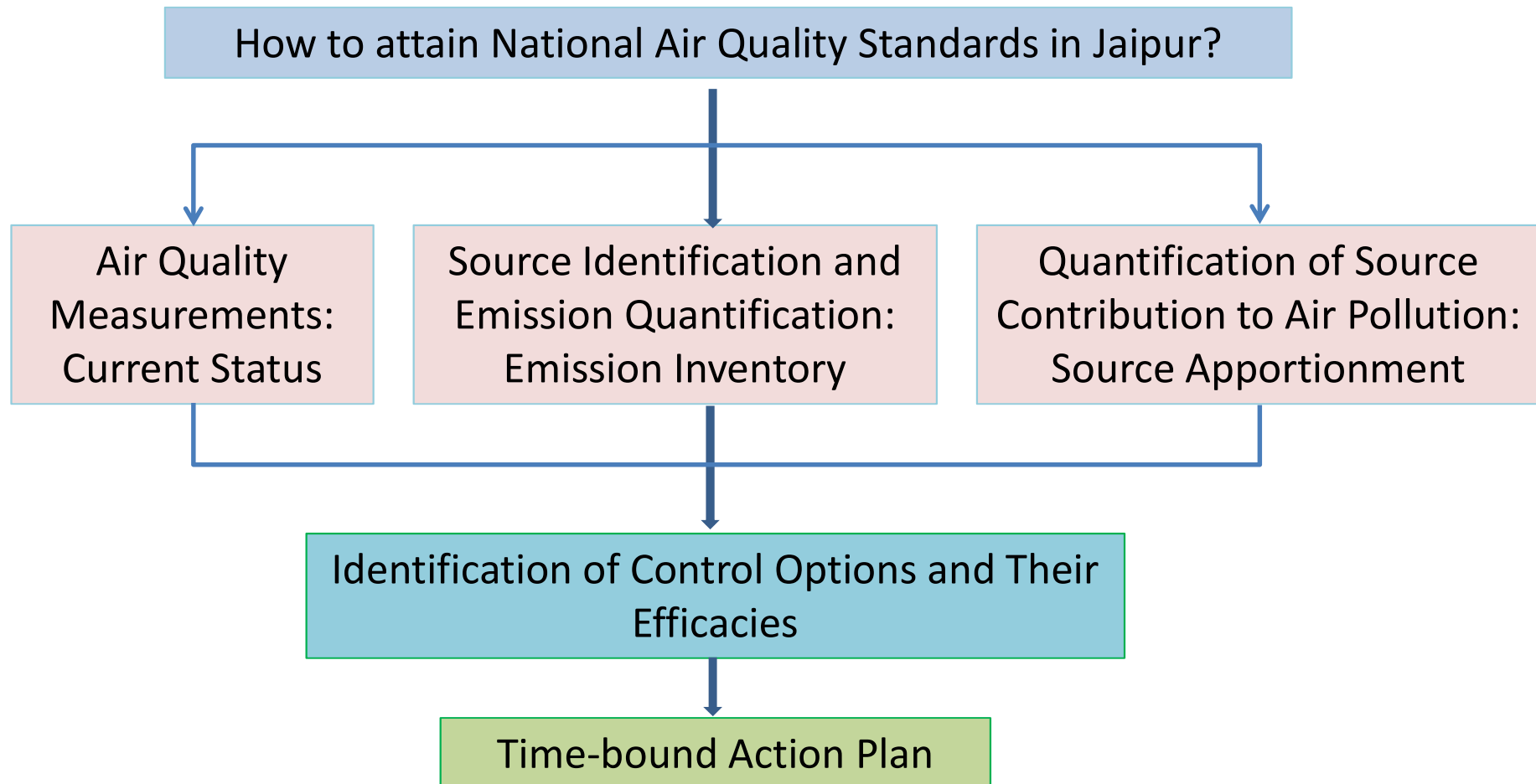
**Mukesh Sharma; PhD, FNAE  
Professor**

**Department of Civil Engineering  
Indian Institute of Technology Kanpur**

## Scope of Work

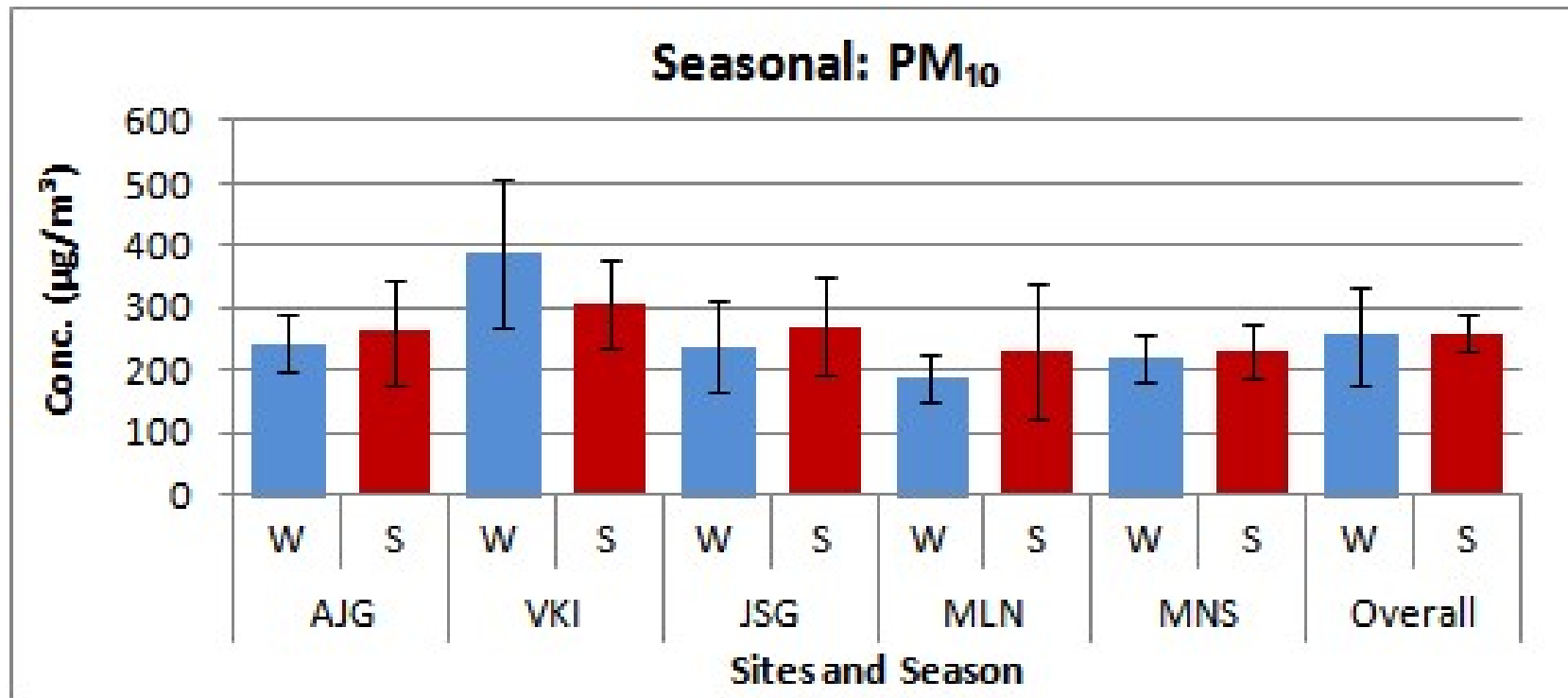
- Development of GIS-based gridded (2 km × 2 km resolution) emission inventory for air pollutants PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, CO, and NO<sub>x</sub> for the base year, 2018.
- Compilation and interpretation of historical ambient air quality data for PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> (trend analysis)
- Monitoring of air pollutants PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, Benzene, Toluene, and Xylene.
- Analyze collected PM<sub>10</sub> and PM<sub>2.5</sub> mass for elemental composition, ions, elemental carbon, organic carbon, PAHs.
- Application of receptor model to establish source receptor linkages of PM<sub>10</sub>, and PM<sub>2.5</sub> using state-of the-art model CMB.
- Development of Control Action Plan

# Background



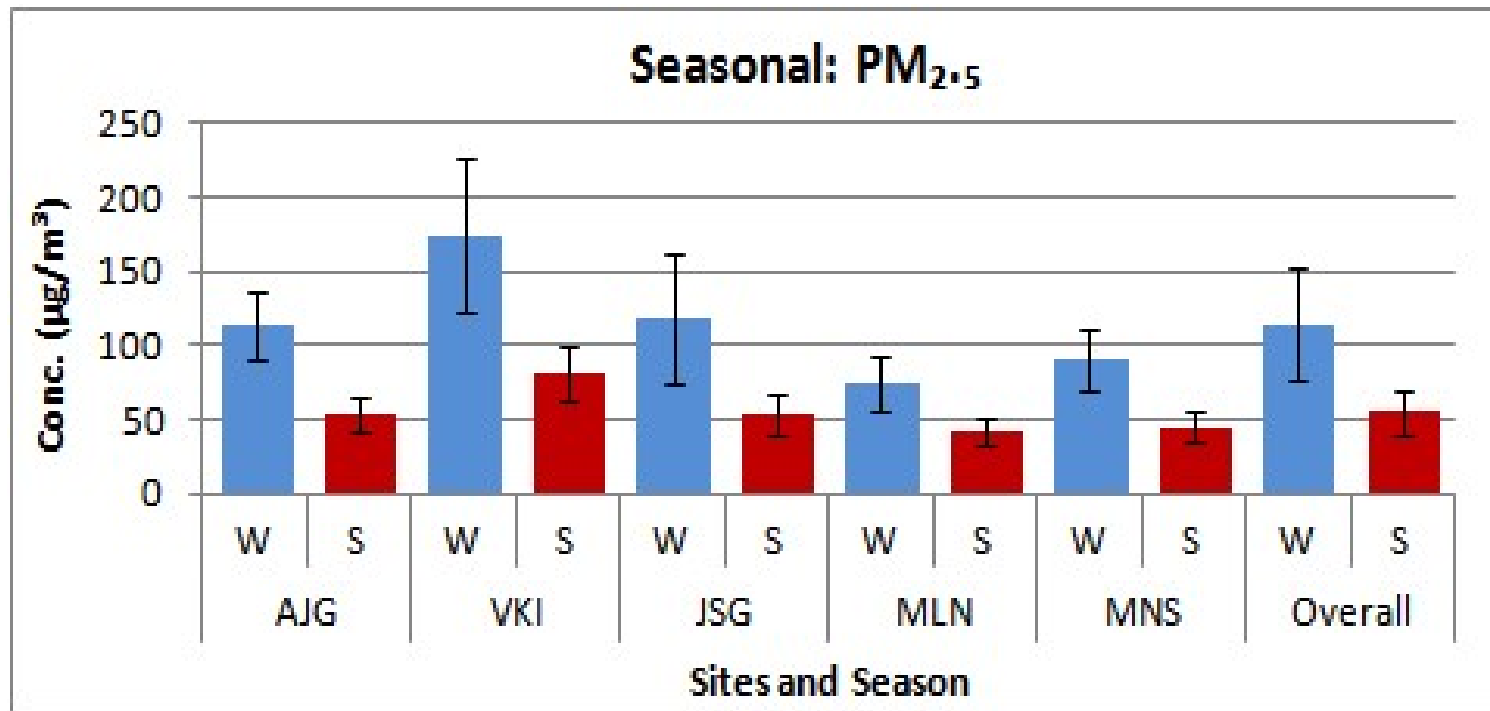
- A Comprehensive **Scientific** Study: **quantified** causal source-receptor impact analysis, control options and their **effectiveness**, action plan - focus: **PM<sub>2.5</sub>**, **PM<sub>10</sub>** and **NO<sub>x</sub>**

## Variation in PM<sub>10</sub>



- PM<sub>10</sub> levels are 2.6 times higher than the national air quality standards in summer and winter season.
- The overall average concentration of PM<sub>10</sub> in summer season is around 261  $\mu\text{g}/\text{m}^3$  against the acceptable level of 100  $\mu\text{g}/\text{m}^3$ .
- The overall average concentration of PM<sub>10</sub> in winter season is around 256  $\mu\text{g}/\text{m}^3$  against the acceptable level of 100  $\mu\text{g}/\text{m}^3$ .

## Variation in PM<sub>2.5</sub>



- PM<sub>2.5</sub> levels are 2 times higher than the national air quality standards in winter months while in summers its generally met the standards
- The overall average concentration of PM<sub>2.5</sub> in summer season is around 55 µg/m³ against the acceptable level of 60 µg/m³.
- The overall average concentration of PM<sub>2.5</sub> in winter is 114 µg/m³ against the acceptable level of 60 µg/m³.

**Ratio PM<sub>2.5</sub>/PM<sub>10</sub>: Winter - 0.44 , Summer - 0.22**

## Statistical Comparison Winter Vs Summer

<div style="text-align: right;">Parameter →</div>	PM <sub>10</sub>	PM <sub>2.5</sub>	OC	EC	NO <sub>2</sub>	SO <sub>2</sub>
AJG	↔	↑	↑	↑	↑	↑
VKI	↑	↑	↑	↑	↑	↑
JSG	↔	↑	↑	↑	↑	↔
MLN	↔	↑	↑	↑	↑	↑
MNS	↔	↑	↑	↑	↑	↑
No significant difference		(Levels higher in winter)		(Levels lower in winter)		
* No pollutant showed lower concentration in winter						

# **Emission Inventory**

# Source Categories

## Source Category

Area Source  
(Stack Height < 20m)

Point Source  
(Stack Height > 20m)

Line Source

Hotels/ Restaurants  
Domestic Cooking  
MSW Burning  
Construction/Demolition  
Road Dust  
Soil Dust  
Industries  
DG Sets  
Aircrafts  
Brick kilns

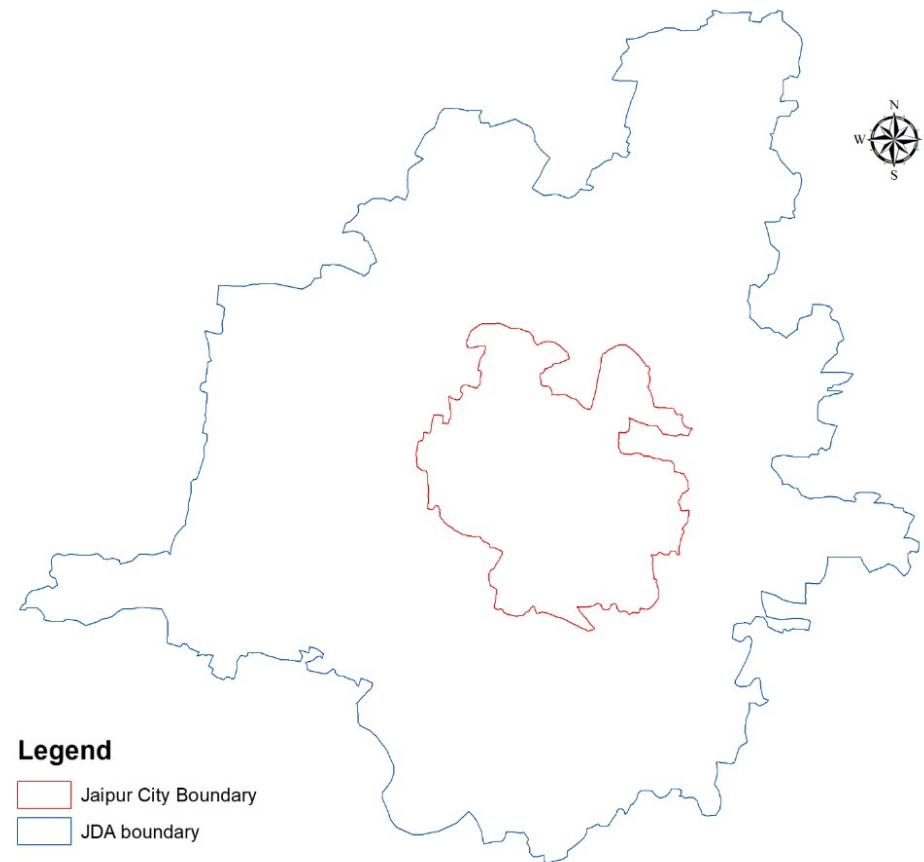
Industries  
DG sets

Vehicles

2W  
3W  
4W  
LCV  
Buses  
Trucks

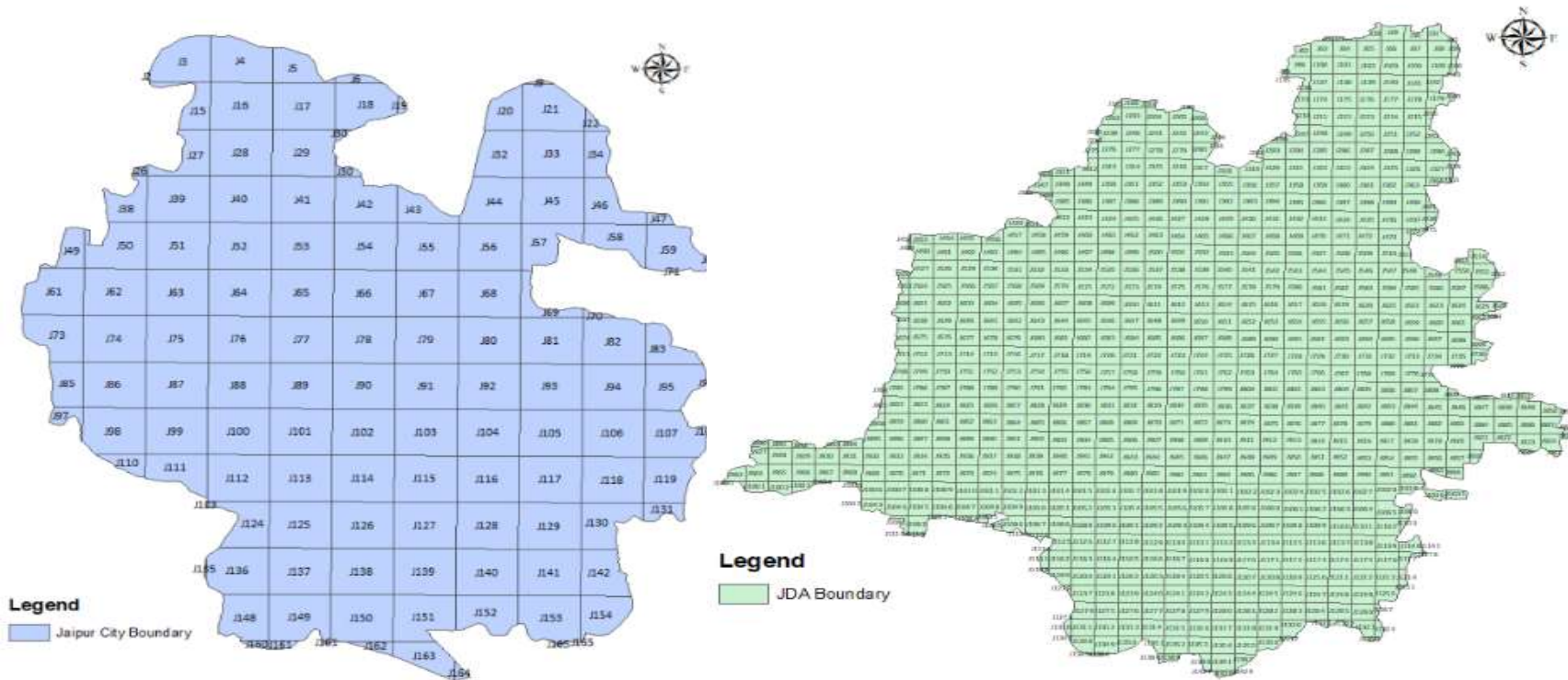


## Boundary Extent of Study Area



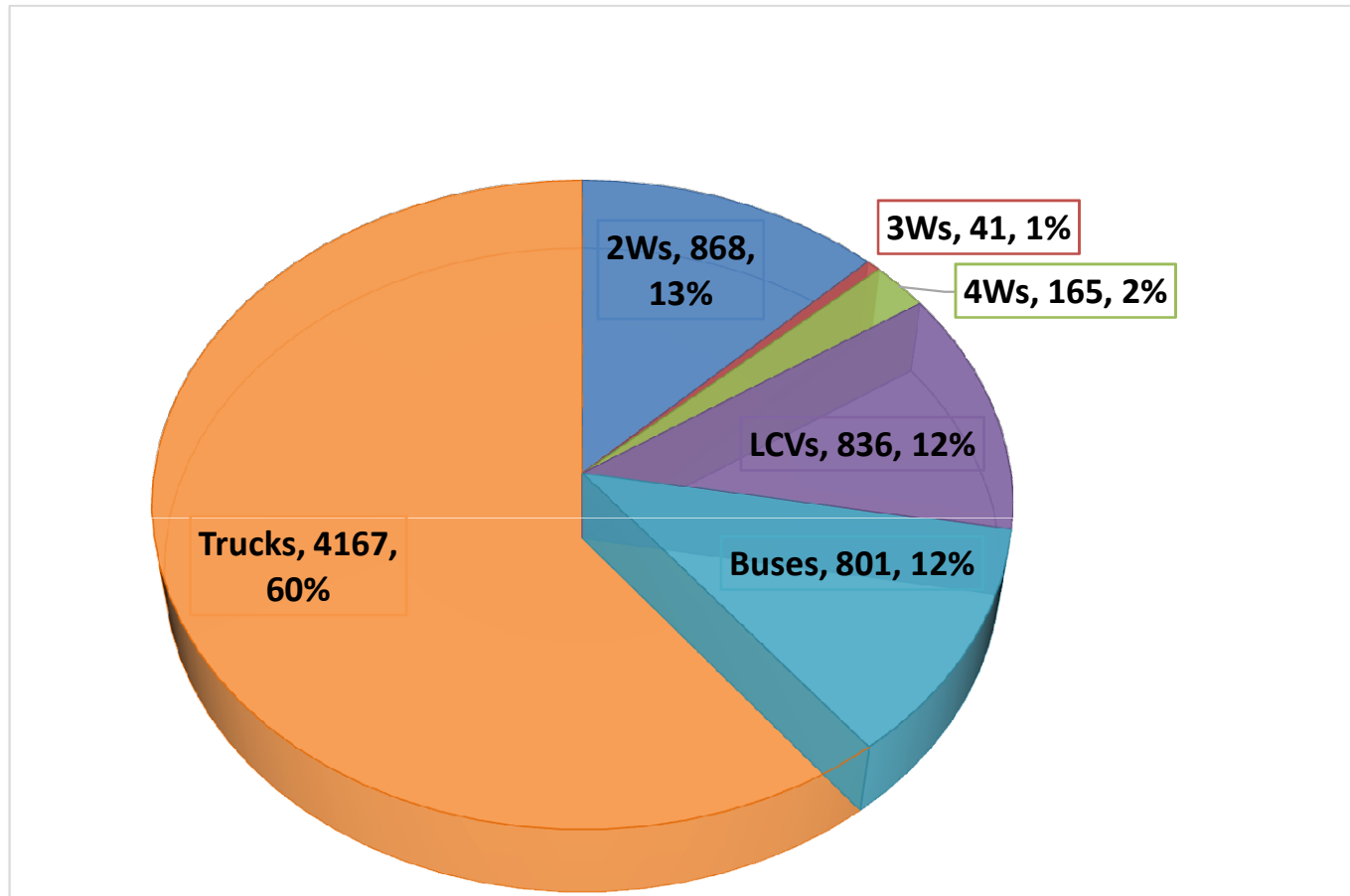
- The emission inventory for the project has been made for current Jaipur City boundary (JCB) as well as Jaipur Development Authority (JDA) boundary.
- The consideration of two boundaries is to counter expansion of boundary limits in future

# Grid Map of JDA and JCB



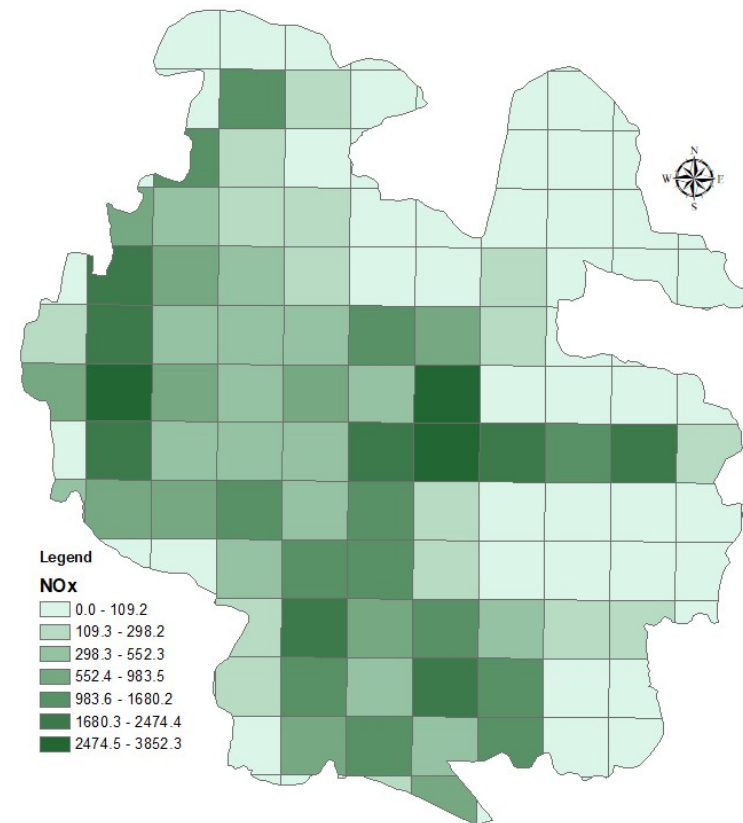
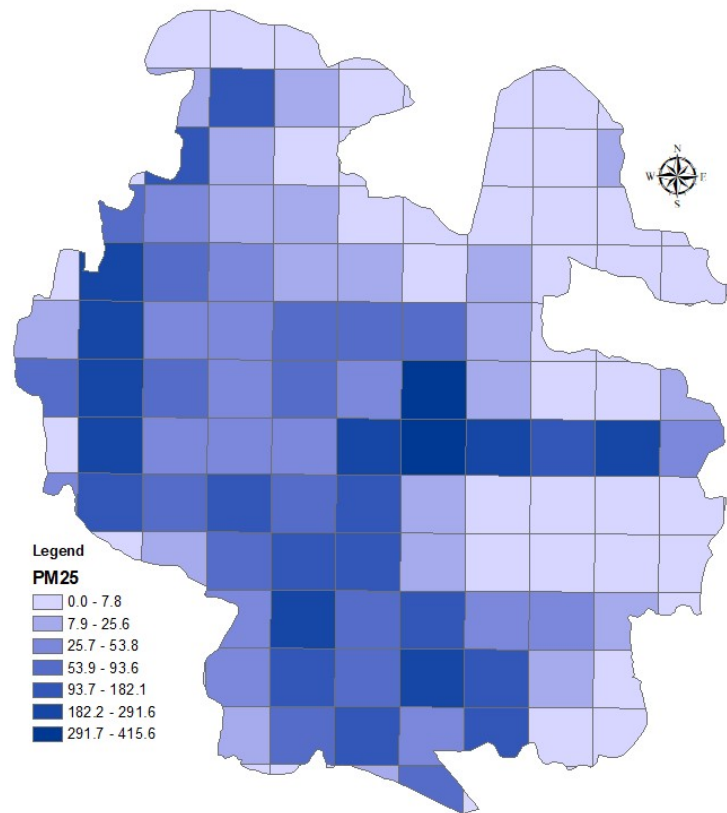
Grid cell of 2 km x 2 km

## PM<sub>2.5</sub> Emission Load from Vehicles (kg/day, %)

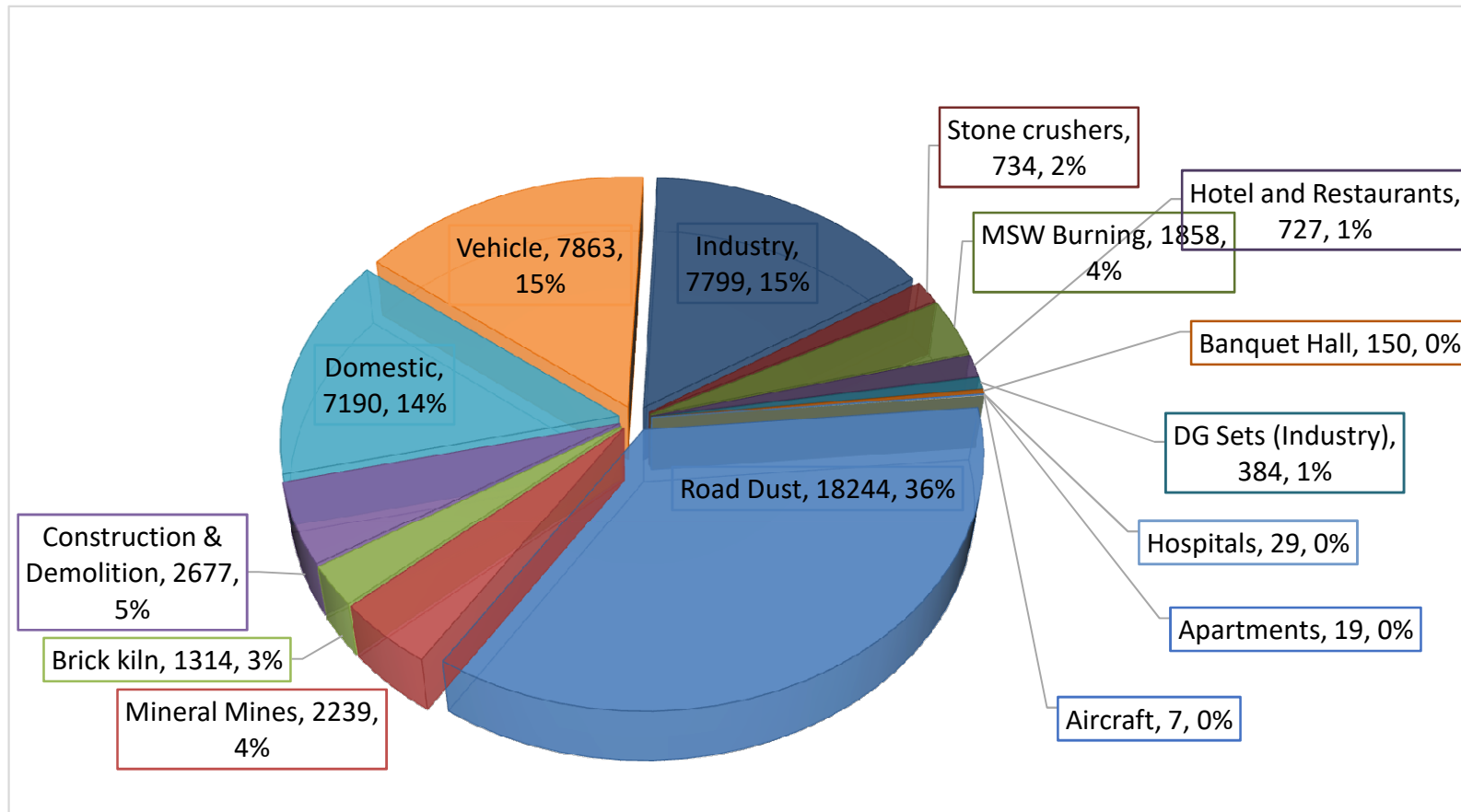


- Total = 6879 kg/d
- Major Contributor : Trucks – 60% , 2W – 13%, LCVs- 12%, Buses-12%

# Spatial Distribution from Vehicles (kg/day, %)

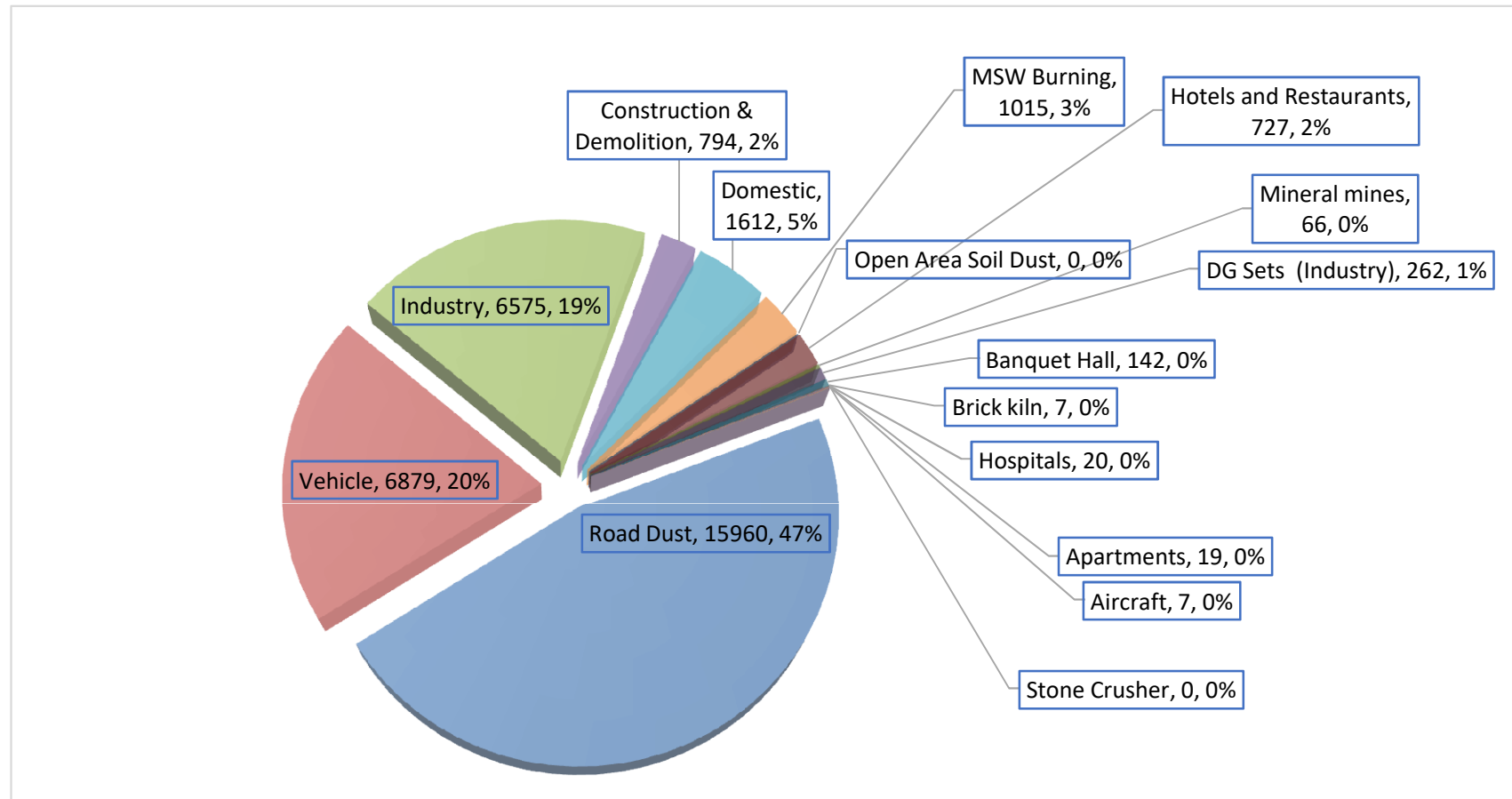


# PM<sub>2.5</sub> Emission Load of Different Sources (JDA)



- PM<sub>2.5</sub> emission load: 51 t/d.
- Road dust (36 %), vehicles (15 %), industry (15%) and domestic (14 %)
- PM<sub>10</sub> emission load: 160 t/d.
- Road dust (47%), Mineral Mines (14%) and Brick Kilns (8%)

# PM<sub>2.5</sub> Emission Load of Different Sources (JCB)



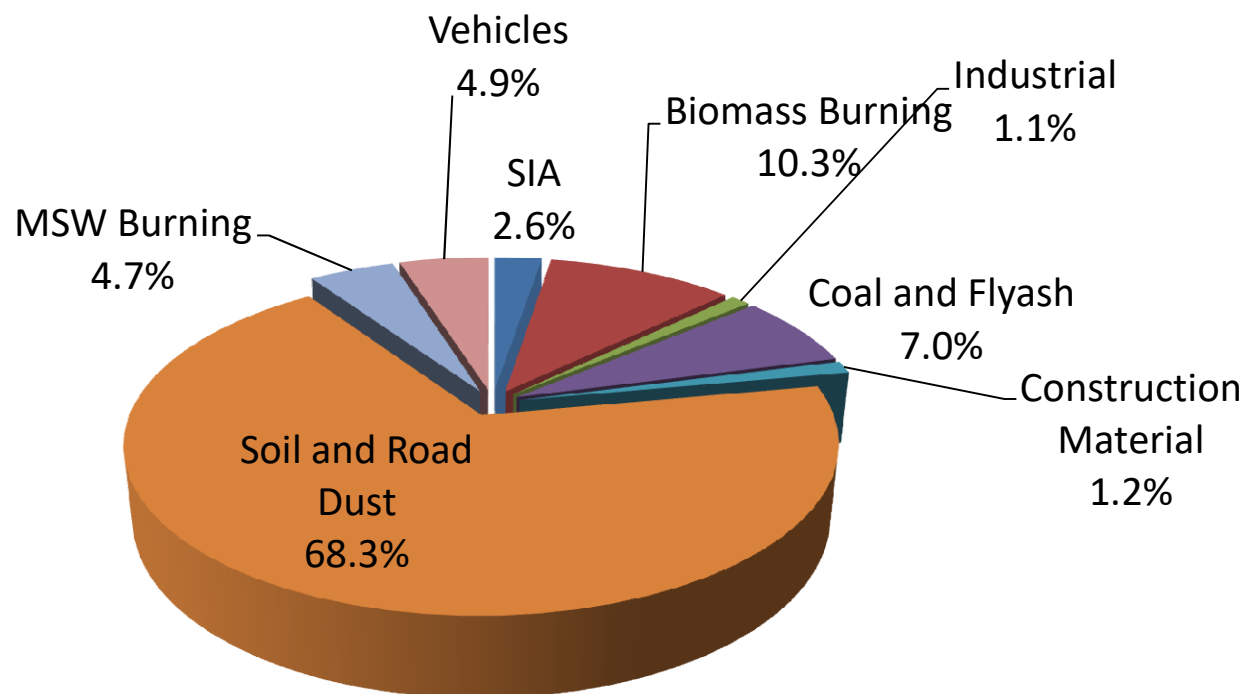
- PM<sub>2.5</sub> emission load: 34 t/d.
- Road dust (47 %), vehicles (20 %), industry (19 %) and domestic (5%).
- PM<sub>10</sub> emission load: 91 t/d.
- Road dust (72%), vehicles (9%), industry (10%)

# **Source Apportionment: PM Composition and Receptor Modeling**

# PM10: Overall Summary of Source contribution in Jaipur

PM<sub>10</sub>: Summer

PM<sub>10</sub>: 261 µg/m<sup>3</sup>

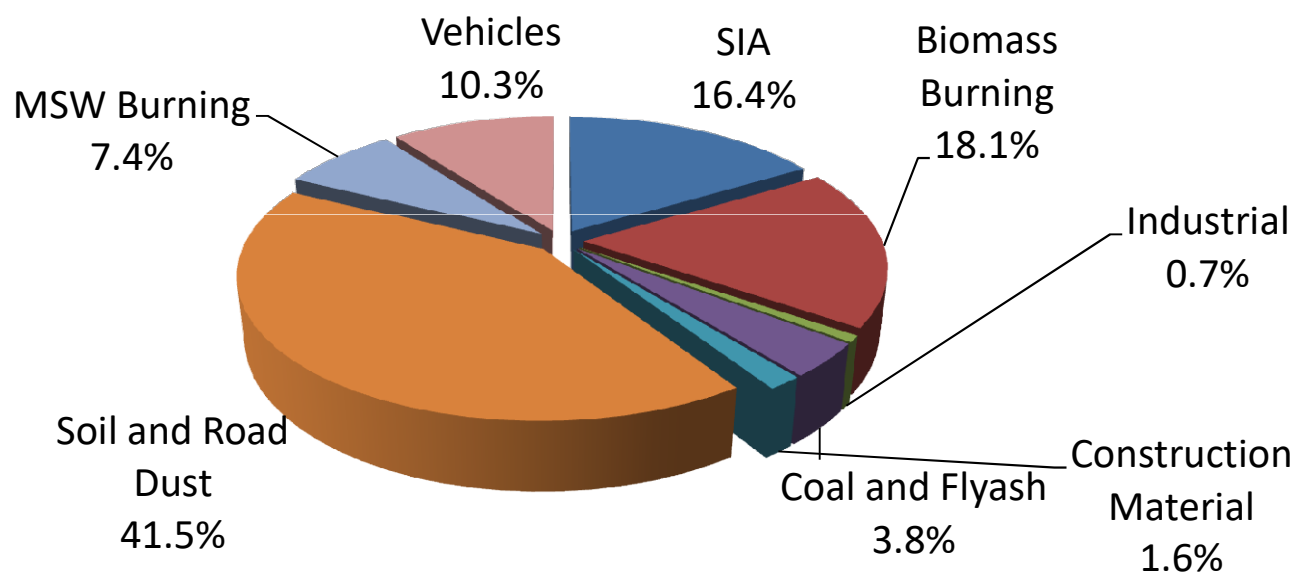




# PM<sub>10</sub>: Overall Summary of Source contribution

PM<sub>10</sub>: Winter

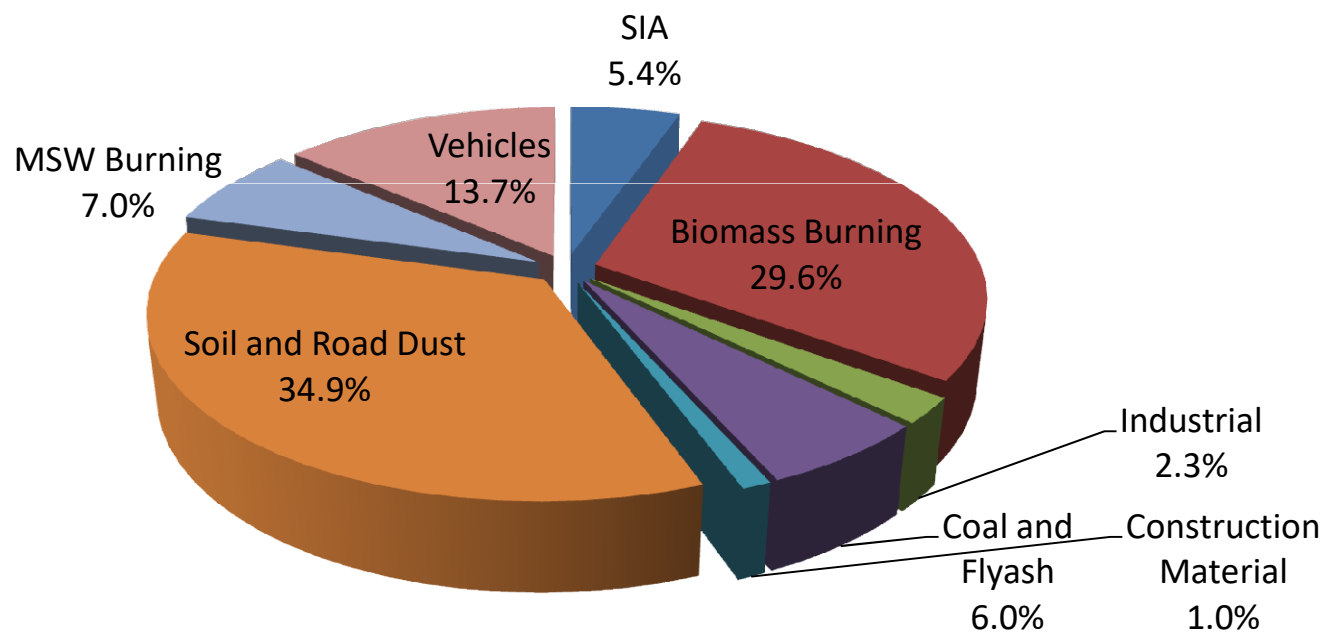
PM<sub>10</sub>: 256 µg/m<sup>3</sup>



## PM<sub>2.5</sub>: Overall Summary of Source contribution

PM<sub>2.5</sub>: Summer

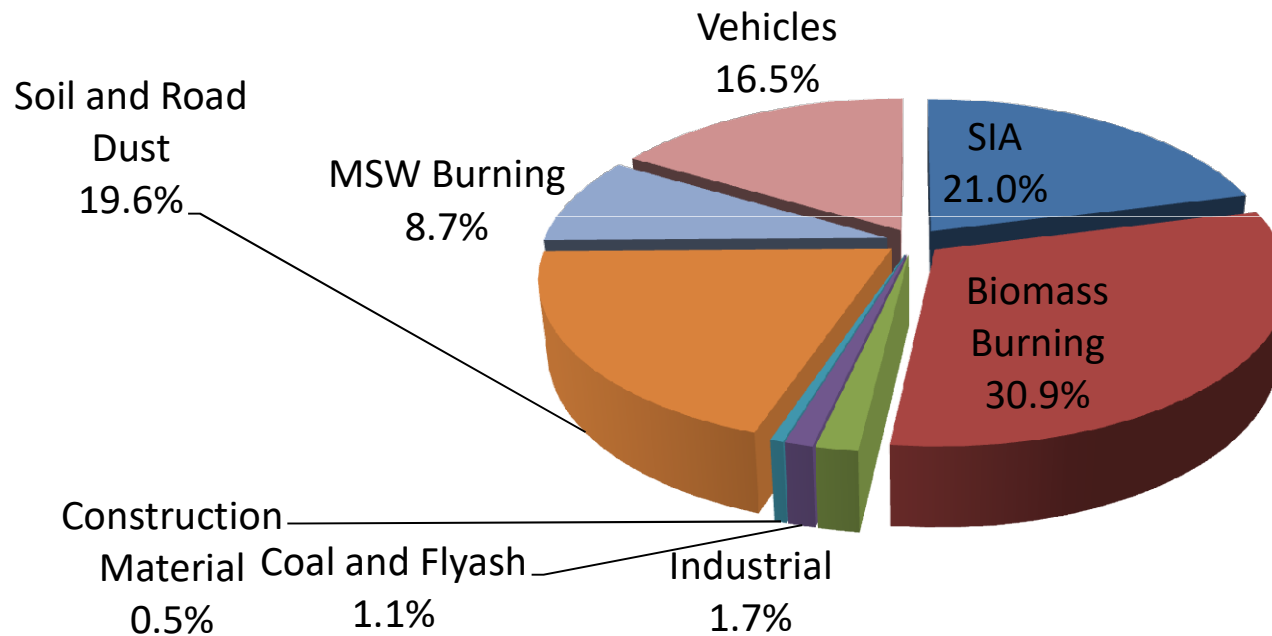
PM<sub>2.5</sub>: 55 µg/m<sup>3</sup>



## PM<sub>2.5</sub>: Overall Summary of Source contribution

PM<sub>2.5</sub>: Winter

PM<sub>2.5</sub>: 114 µg/m<sup>3</sup>



## **Control Options and Action Plan**

# Industries

- No more air polluting industry be allowed in Jaipur City Boundary
- Use of Wood, Coal, Agricultural Waste should be stopped as Industrial Fuel
- Shift to low sulphur fuel LSHS/LDO ( $S \leq 0.5$ ). **Reduction in 40% emission in PM2.5.**
- MSW Burning should be stopped in industries (boiler) and industrial areas
- New regulations for SO<sub>2</sub> and NO<sub>2</sub> for all industries should be enforced.
- Road conditions are poor in industrial areas and are subjected to heavy vehicles. The shoulders are not paved and interlocked. The roads should be properly maintained.
- Non-hazardous and non-combustible waste is disposed of indiscriminately outside industry area.
- Good Housekeeping : Leakages, Transport point, Loading and Unloading

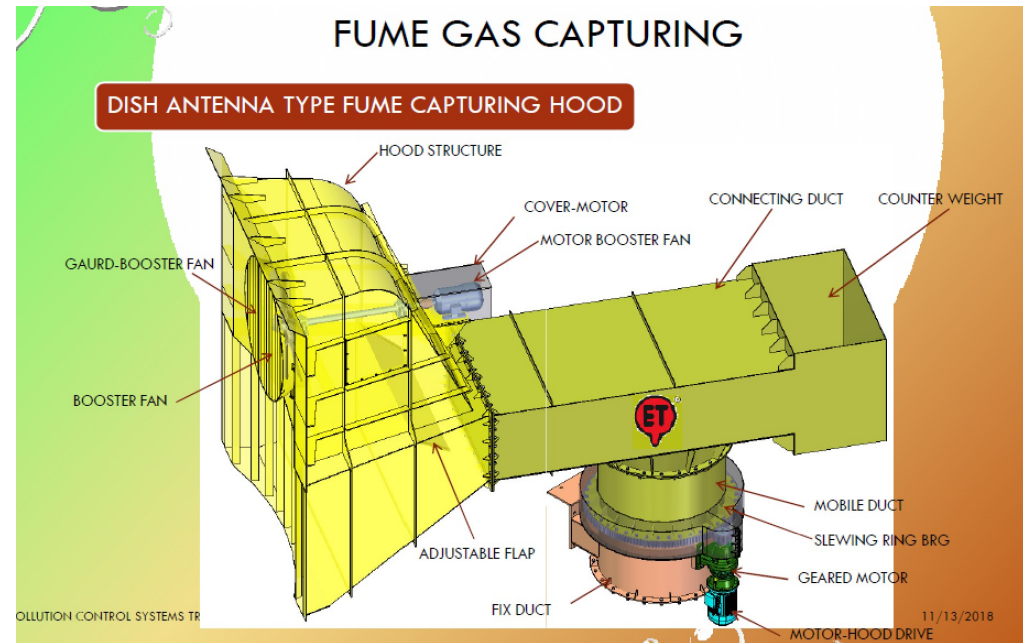
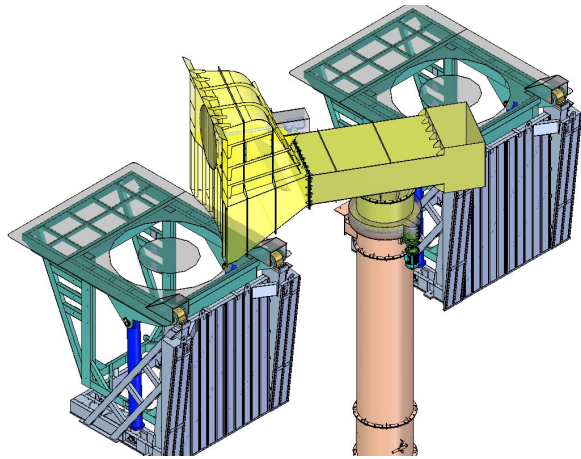
Timeline: 0 – 1 years

# Induction Furnace

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



# Induction Furnace

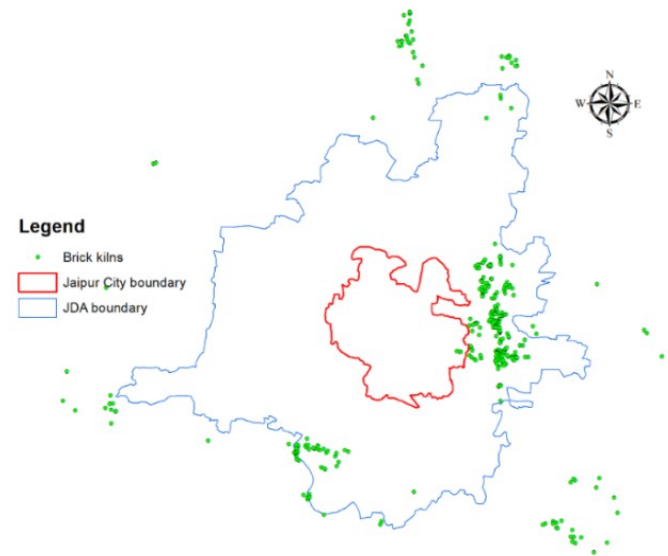


## Side-based Suction Hood



# Brick Kilns

- Brick Kilns nearby and around the city shall be converted to Zig Zag/cleaner technology within stipulated period.
- Brick Kiln should be 15 km away from the city boundary.
- Timeline: 0 – 1 years





# Road Dust

- Municipal Council should carry out vacuum assisted Sweeping.
  - If the sweeping is done twice a month, the road dust emission will be reduced by 42%
  - If the frequency of sweeping is increased to four times in a month, then the road dust emission will be reduced by 71% (19 t/day).
  - If the silt road is greater than 5 gm/m<sup>2</sup>, the vacuum-assisted sweeping should be carried out by the municipal council and the RSPCB should surveillance.



# Road Dust

- Convert unpaved roads to paved roads. PWD (Public Works Department) and city administration should act immediately to reduce the pollution load from road dust.
- It is more important that the condition of the roads is maintained properly, and shoulder paved by interlocking concrete blocks.
- The truck carrying construction material or any airborne material should be covered.

# Vehicle

- Sindhi camp bus stand handles over 500 public buses every day and this causes extreme congestion and increased emissions. To decongest the area, it is recommended that the city should have three more large inter-district/inter-state bust stations in north (towards Sikar and Bikaner), east (towards Bharatpur – Agra) and south (towards Tonk).
- There is no place for parking in Sindhi camp bus stand except for government bus (that is also limited). However, many private buses of long distance from the same area cause early morning and night time congestion. This affects the traffic and leads to congestion up to Chandpole, Collectorate and other nearby areas. It is recommended to shift the private bus stands to other locations similar to one suggested in the above point.

# Vehicle

- Parking Causes Congestion. Approximately 60% of the city's roads are used for parking in Jaipur – the highest in any city in India (source: urban emissions)
- Removal of free parking zone (MI road, Badi chaupad, choti chaupad, other commercial areas)
- Parking policy in congestion area (high parking cost, at city centers, only parking is limited for physically challenged people, etc).
- Synchronize traffic movements or introduce intelligent traffic systems for lane-driving.
- E-rickshaw : Training and awareness
- Minimize the cuts, develop smooth U-turns
- Other railway stations should be developed with modern infrastructure  
For e.g Patna: 3 stations, Varanasi: 2 stations, Lucknow: 4 stations

# Traffic congestion

DATE	Airport Circle	Ambabari Circle	Accharaya tulshi circle	Bhaskar flyover	Badi Chopad	BSNL	Chomu Pulia Circle	Club Factory	D Circle	Gail Temple	Gandhi Circle Garden	Global Circle	Jawahar nager Circle	Kanwatya Hospital	Khasha Khoti Flyover	Madho Singh Circle	Mandir Mod Circle	Maulana Mauldin Circle	Panchwati Circle	Bhagwan Pasuram Circle	Peacock Garden	Police Thana Manka Chouk	Richo Kanta Chauraha	Sanganer stadium	Sant Dabu Circle	Smirti Park	Vidyanagar Circle	Sidhi Vinayak Temple	Collectra te Circle
9/26/2018	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am
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9/27/2018	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm
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9/28/2018	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm	12pm-2pm
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9/29/2018	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am	8am-10am
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9/29/2018	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm	4pm-6pm
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	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p	10am-12p

Total Location examined: 29

## Highly congested locations

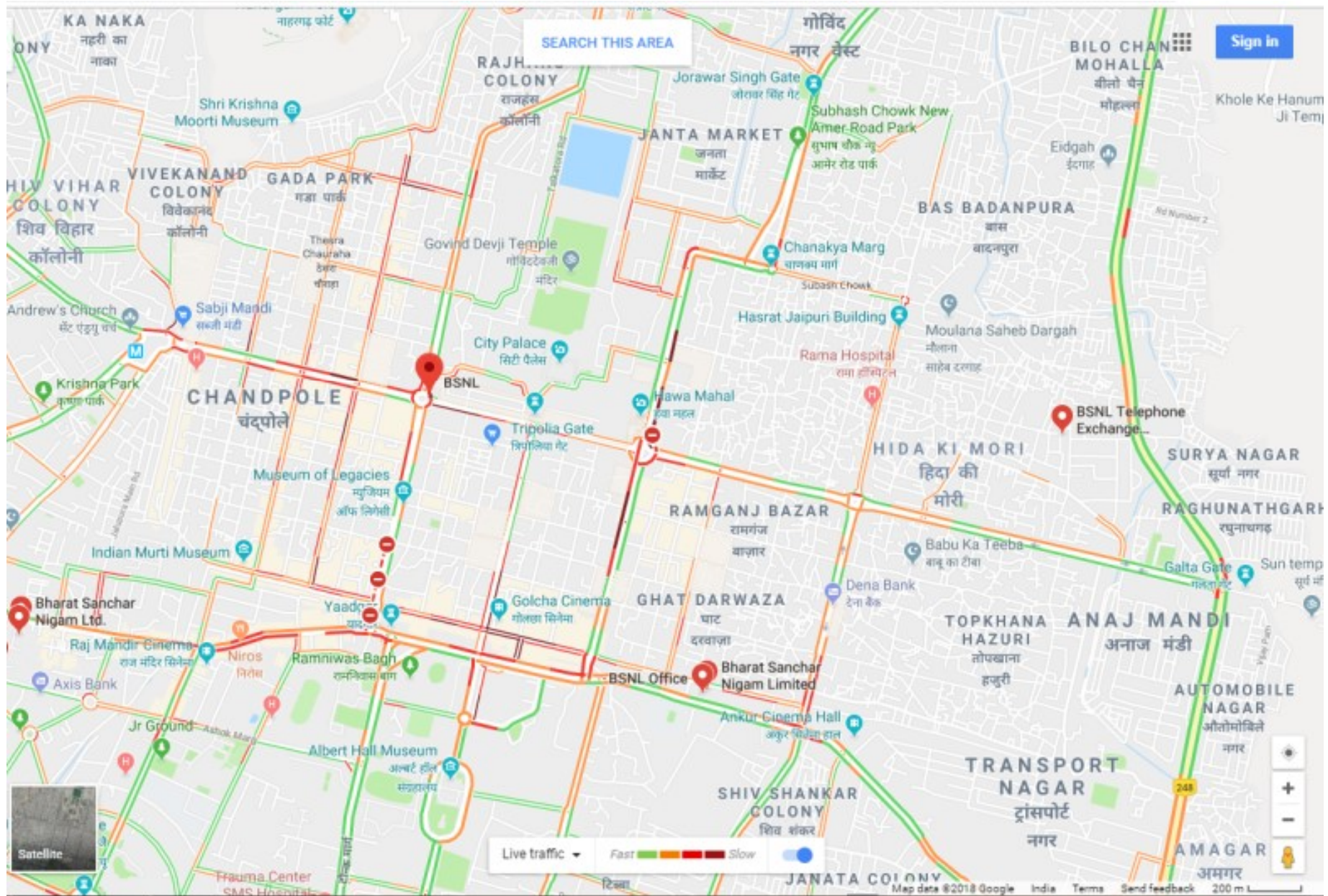
- Badi Chopad and Manak Chowk
- BSNL Circle
- Chomu Pulia
- D Circle/sindhi camp/ stn road
- Jawahar Nagar Circle

## congested locations

- Collectorate Circle
- Sant Dabu circle
- Sanganer stadium circle
- RICCO Kanta chauraha, Mansarover
- Gandhi Circle



# BSNL Circle

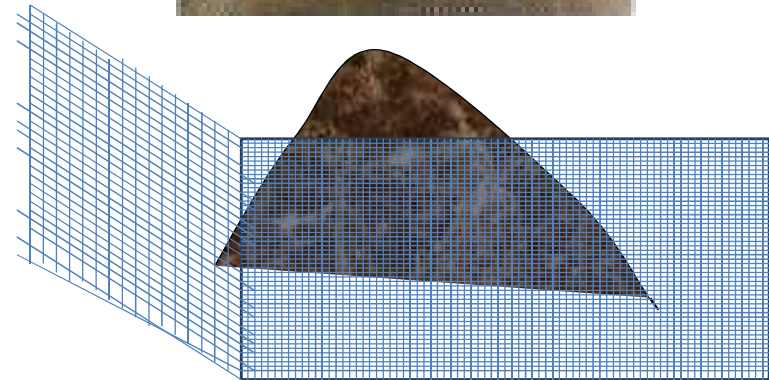
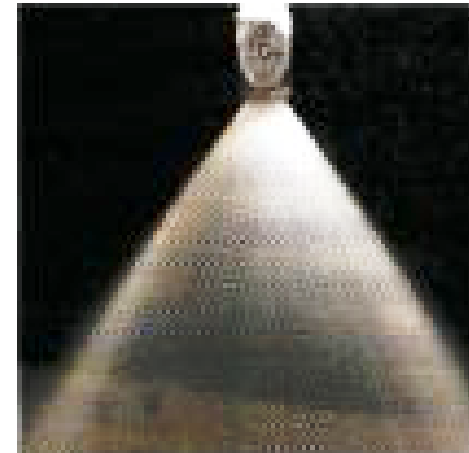


# Construction and Demolition

- C&D Plant should be built and operation as early as possible.
- Every C&D activity should fully comply with C&D Waste Management Rules, 2016.



Wet Suppression



Wind Breaker

**Reduction in 55% emissions**

# Construction and Demolition

- Wet suppression
- wind speed reduction (for large construction site)
- Waste should be properly disposed of. It should not be kept lying near the roads as it may contribute to road dust emission.
- Proper handling and storage of raw material: covered the storage and provide the windbreakers
- vehicle cleaning and specific fixed wheel washing on leaving the site and damping down of haul routes
- The actual construction area is covered by a fine screen
- No storage (no matter how small) of construction material near roadside (up to 10 m from the edge of the road)



# Hotels and Restaurants

- It is proposed that all restaurants of sitting capacity more than 10 should not use coal and shift to electric or gas-based appliances. A 70 % reduction of PM10 (351 kg/d) and PM2.5 (218 kg/d) emission from this source can be achieved by stopping uses of coal.
- It is also seen that the ash/residue from the tandoor and other activities are disposed near the roadside. This will contribute to road dust emissions.
- The Hotel Association, City Municipal Council and RSPCB need to limit this source and have proper disposal of ash and residues. It is recommended to link the commercial license to clean fuel.

# Domestic Cooking

- Although in Jaipur, 81% of the households use LPG for cooking, the remaining 19 % uses wood, crop residue, cow dung, kerosene and coal for cooking (Census-India, 2012). The LPG should be made available to the remaining 21% of households to make the city 100% LPG-fuelled. This action is expected to reduce 85% of PM10 (317kg/day) and 84% of PM2.5 (257 kg/d) emissions from domestic sector.
- The city should plan to move to electrical appliances/cooking by 2030?

# Municipal Solid Waste (MSW) Burning

- The banning of MSW waste reduce emission by 100% of PM10 (1492kg/day) and PM2.5 (1015 kg/d) emissions from this sector.
- The city municipal council should prioritize the MSW collection mechanism starting in a systematic manner in each ward. Special attention is required for fruits, vegetable markets and commercial areas and high-rise residential buildings, where MSW burning is common.
- It is seen that waste is sometimes burnt in industrial areas; this must stop. It is recommended that there should be a separate industrial non-hazardous dump site for industrial waste and they should not be allowed to dispose of the waste on roads or front of the industry.

Source	Control Action	Responsible authorities	Time Frame
Hotels/ Restaurants	Restaurants of sitting capacity more than 10 should not use coal and shift to electric or gas-based appliances.	Jaipur Municipal Corporation	1 year
	Link Commercial license to clean fuel	Jaipur Municipal Corporation, Department of Food, Civil Supplies and Consumer Affairs and Oil Companies (Indian Oil/HP, etc.)	1 years
	Ash/residue from the tandoor and other activities should not be disposed near the roadside.	Jaipur Municipal Corporations	1 year
Domestic Sector	LPG to all. Slums are using wood as cooking fuel.	Department of Food, Civil Supplies and Consumer Affairs and Oil Companies (Indian Oil/HP, etc.)	2 year
	By 2030, city may plan to shift to electric cooking or PNG.	Department of Food, Civil Supplies and Consumer Affairs and Oil Companies (Indian Oil/HP, etc.)	2 year
Municipal Solid Waste (MSW) Burning	Any type of garbage burning should be strictly stopped.	Jaipur Municipal Corporation	Immediate
	Surveillance is required that hazardous waste goes to TSDF.	Jaipur Municipal Corporation, RSPCB	
	Desilting and cleaning of municipal drains	Jaipur Municipal Corporation	
	Waste burning in Industrial area should be stopped.	RIICO, RSPCB	
	Daily, Monthly mass balance of MSW generation and disposal	Jaipur Municipal Corporation	
	Sensitize people and media through workshops and literature distribution	Jaipur Municipal Corporation, RSPCB and NGO	

Source	Control Action	Responsible authorities	Time Frame
Construction and Demolition	Wet suppression	Jaipur Development Authority, Rajasthan Housing Board, Jaipur Municipal Corporation, Urban Development Department, PWD	Immediate
	Vehicle cleaning and specific fixed wheel washing on leaving the site and damping down of haul routes.	Jaipur Development Authority, Rajasthan Housing Board, Jaipur Municipal Corporation, Urban Development Department, PWD	Immediate
	Diesel vehicle entering the city should be equipped with DPF which will bring a reduction of 40% in emissions (This option must be explored once Bharat stage VI fuel is available.)	State Transportation Department	3 years
Vehicles	Check overloading: Expedited installation of weigh-in-motion bridges and machines at all entry points to Jaipur.	Transport Department, Traffic Police, Jaipur, NHAI, Toll agencies	Immediate
	IT systems in buses, bus stops and control centre and passenger information systems for reliability of bus services and monitoring.	Jaipur Development Authority, Jaipur City Transport Services Pvt. Ltd, Traffic Police, Jaipur	1 year
	Movement of materials (raw and product) should be allowed between 10 PM to 5 AM.	Transport Department, Jaipur Development Authority, Jaipur City Transport Services Pvt. Ltd, Traffic Police, Jaipur	1 year

Source	Control Action	Responsible authorities	Time Frame
Industries and DG Sets	Ensuring emission standards in industries. Shifting of polluting industries.	RSPCB, Industries Department	1 year
Decongestion of Roads at high traffic areas	The Jaipur railway station is the hub of urban activities for transport of man and material, hotels, shops, etc., which cause severe traffic congestion in the area. It is recommended that other railway stations in the city are developed and modernized to cater more railway traffic so to decongest the main railway station.	Indian Railways, Jaipur Development Authority, Jaipur City Transport Services Pvt. Ltd, Jaipur Municipal Corporations, Jaipur	6 months
	It is recommended to add more metro railway lines for rapid public transport system to discourage the use of personalized vehicles and preventing traffic congestions.	Jaipur Metro Rail Corporation Ltd, Jaipur Development Authority, Jaipur City Transport Services Pvt. Ltd, Jaipur Municipal Corporations, Jaipur	
*The above steps should not only be implemented in Jaipur municipal limits rather these should be extended to up to at least 25 km beyond the boundary. This will need support from the central government.			

# Recommendations (Bhiwadi)

## B. Time-bound Actions

Source	Description Option
Vehicles	Electric/Hybrid Vehicles: New residential and commercial buildings to have charging facilities
	Retrofitment of Diesel Particulate Filter
	Implementation of BS – VI for all diesel vehicles including heavy duty vehicles (non-CNG buses and trucks) and LCVs (non-CNG)
	Inspection/ Maintenance of Vehicles
	Ultra Low Sulphur Fuel (<10 PPM); BS-VI
	2-Ws with Multi Point Fuel Injection (MPFI) system or equivalent
Industry and DG Sets	Reduce sulphur content in Industrial Fuel (LDO, HSD) to less than 500 PPM
	Minimize uses, uninterrupted power supply, Banning 2-KVA or smaller DG sets
Secondary Particles	De-SO <sub>x</sub> -ing at Power Plants within 300 km
	De-NO <sub>x</sub> -ing at Power Plants within 300 km
Secondary Organic Aerosols	Controlling Evaporative emissions: Vapour Recovery System at petrol pumps (Fuel unloading and dispensing)
Biomass Burning	Managing crop residue burning: local biomass burning, Potential alternatives: energy production, biogas generation, commercial feedstock for cattle, composting, conversion in biochar, Raw material for industry

# Construction Debris Near Road





# Dumping of MSW



## Burning of Waste





# Burning of Waste (Bhiwadi)



(a)



(b)



(c)



# Open Drains



