Beyond Source Apportionment

Effects of Air Pollution on Health, Human Capital and Sustainable Development in India

(17th - 18th July, 2019)

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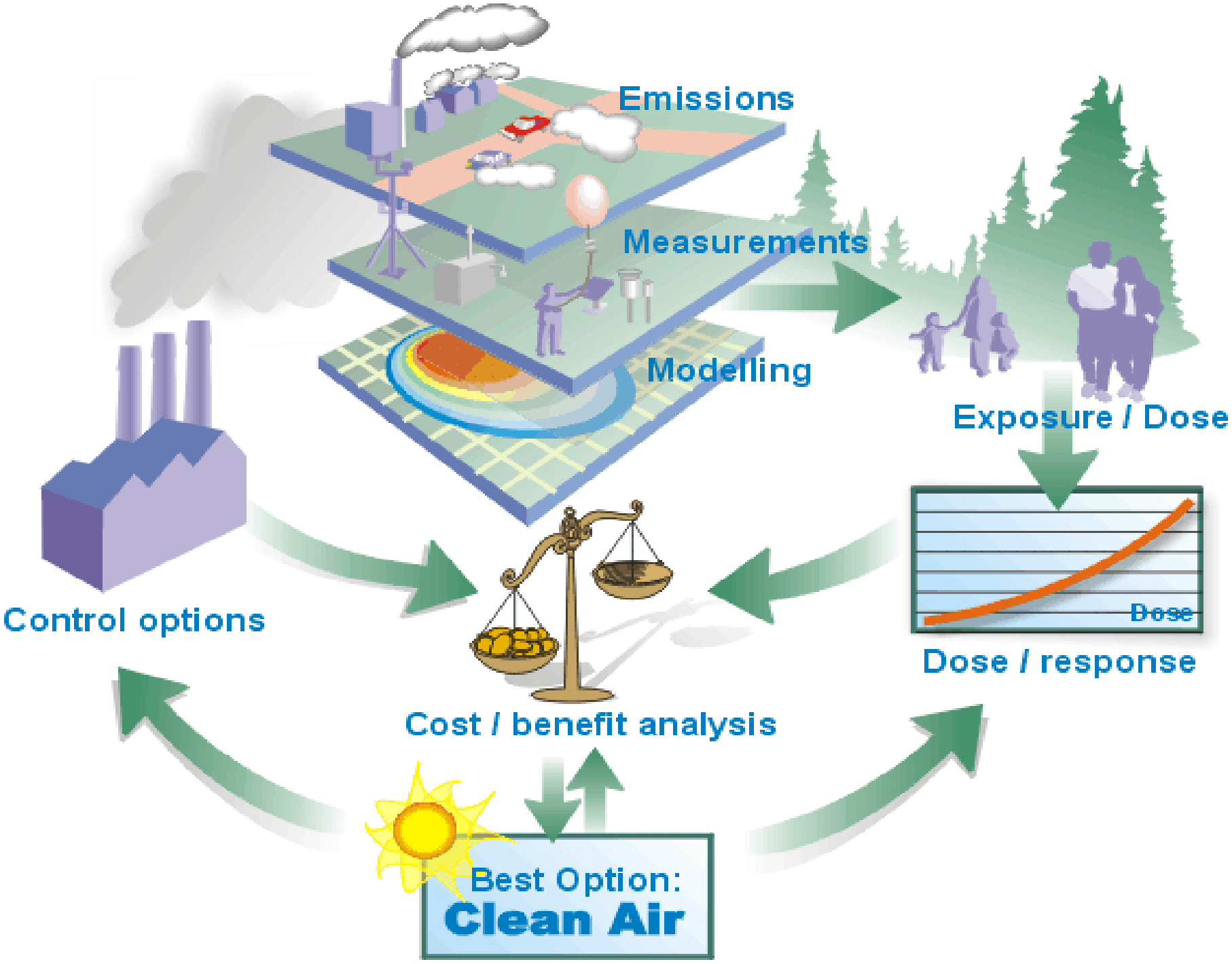
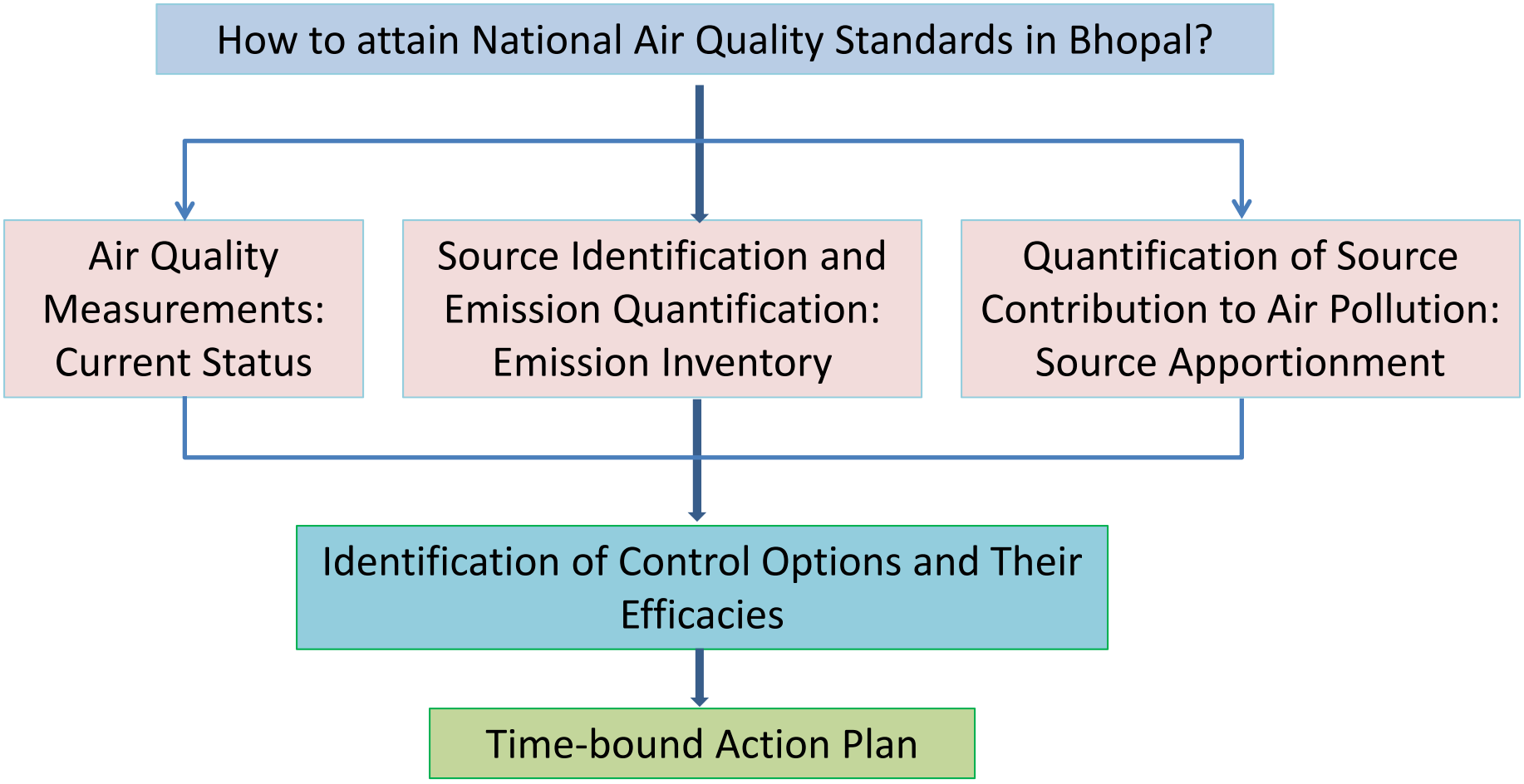
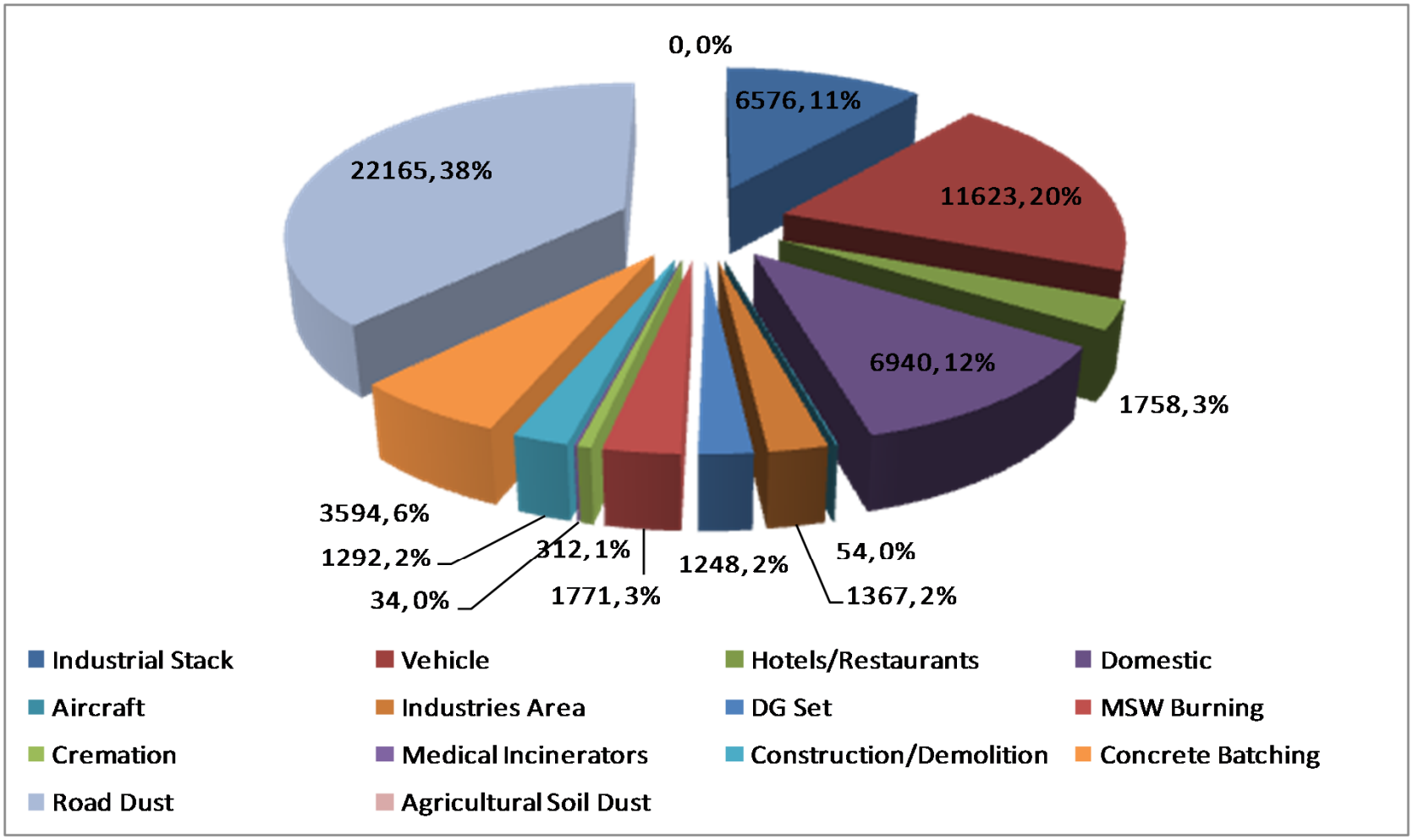

Emissions
Measurements
Modelling
Exposure / Dose
Control options
Dose
Dose / response
Cost / benefit analysis
Best Option:
Clean Air

Framework for Air Quality Management in Bhopal



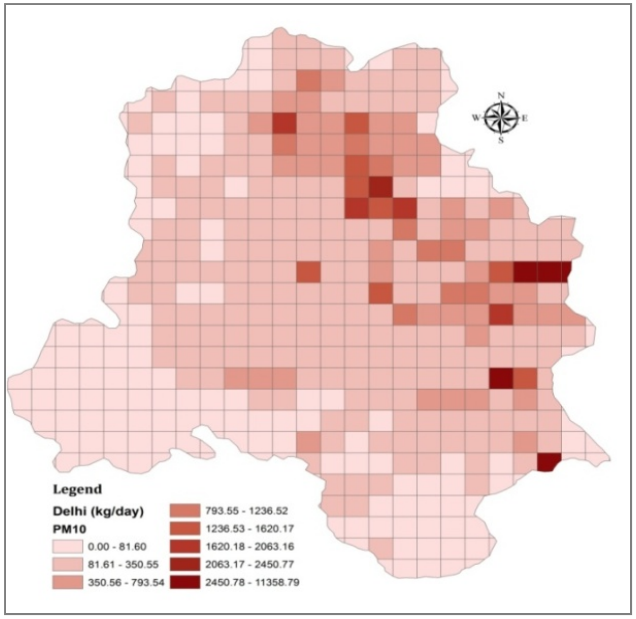
- A Comprehensive Scientific Study: quantified causal source-receptor impact analysis, control options and their effectiveness, action plan - focus: $PM_{2.5}$, PM_{10} and NO_x

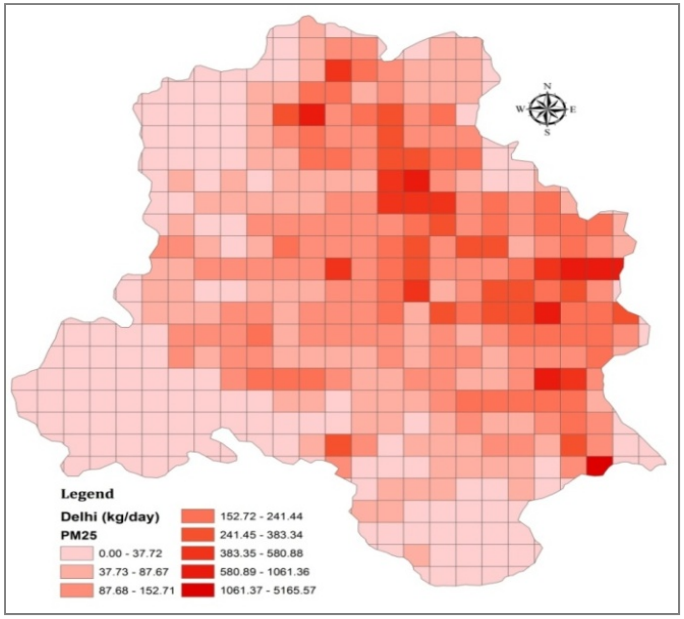
$PM_{2.5}$ Emission Load of Different Sources

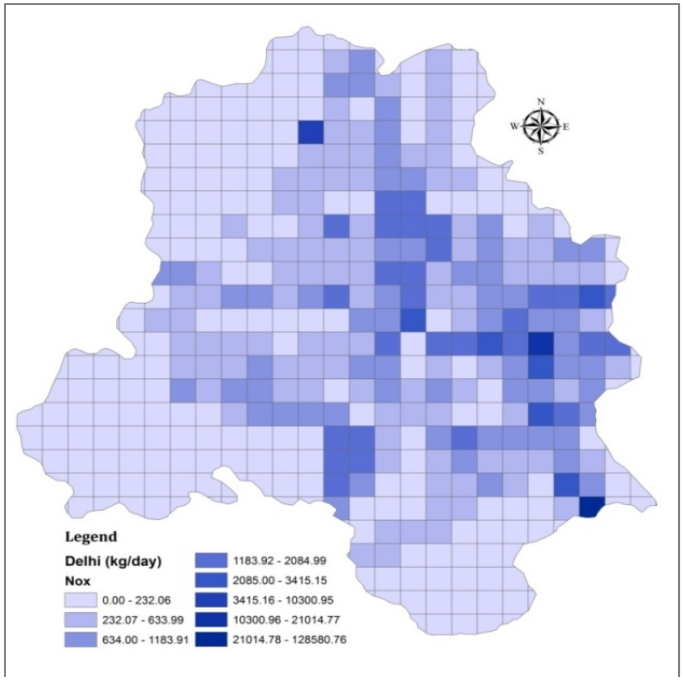


- $PM_{2.5}$ emission load: 59 t/d.
- Road dust (38 %), vehicles (20 %), domestic (12 %) and industrial point sources (11%).
- PM_{10} emission load: 143 t/d.
- Road dust (56%), concrete batching (10%), industrial point sources (10%) and vehicles (9%).

Spatial Distribution of PM_{10} , $PM_{2.5}$ and NO_X

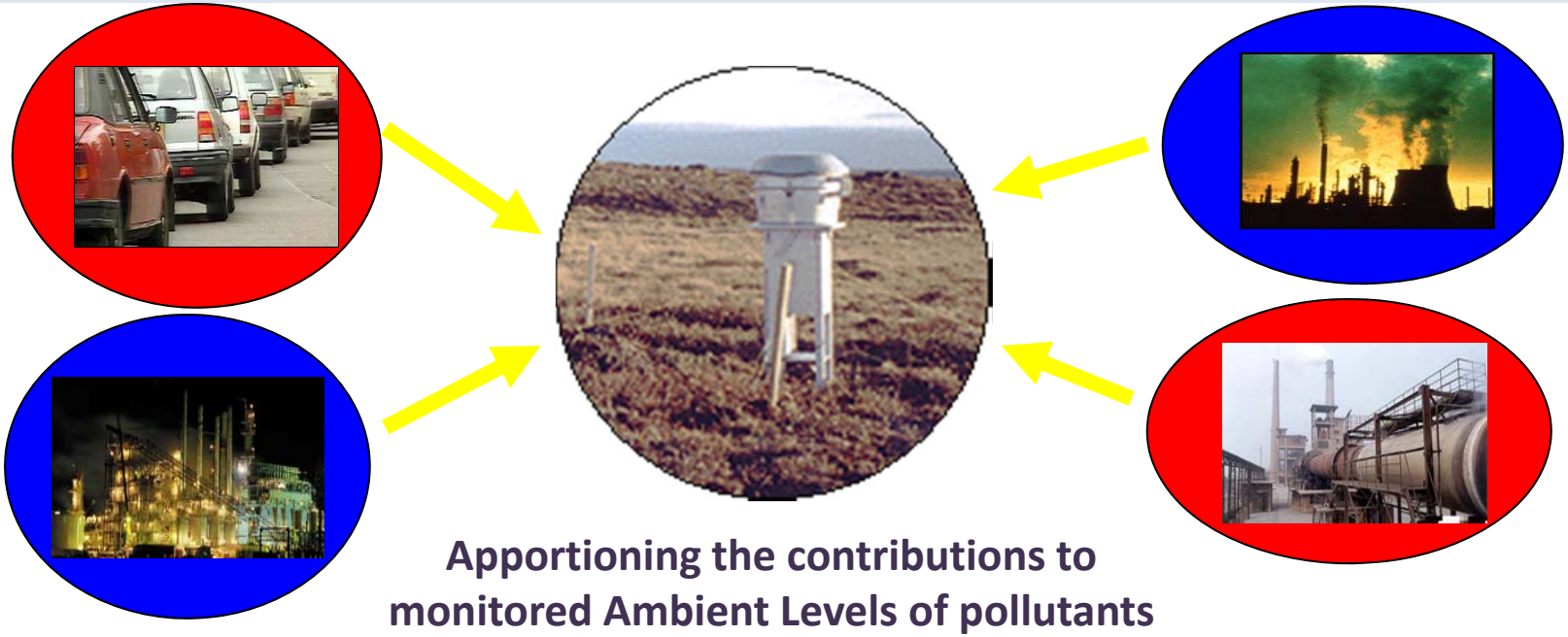






Source Apportionment: PM Composition and Receptor Modeling

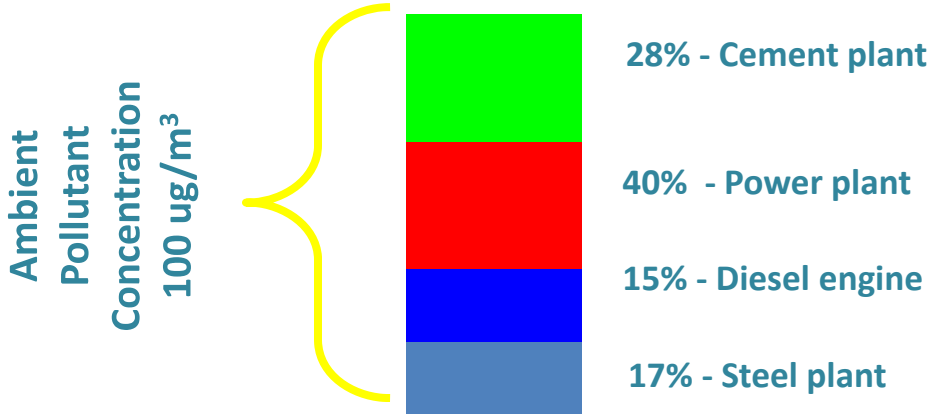
Receptor Modeling: Chemical mass balance (CMB)



Apportioning the contributions to monitored Ambient Levels of pollutants among various sources

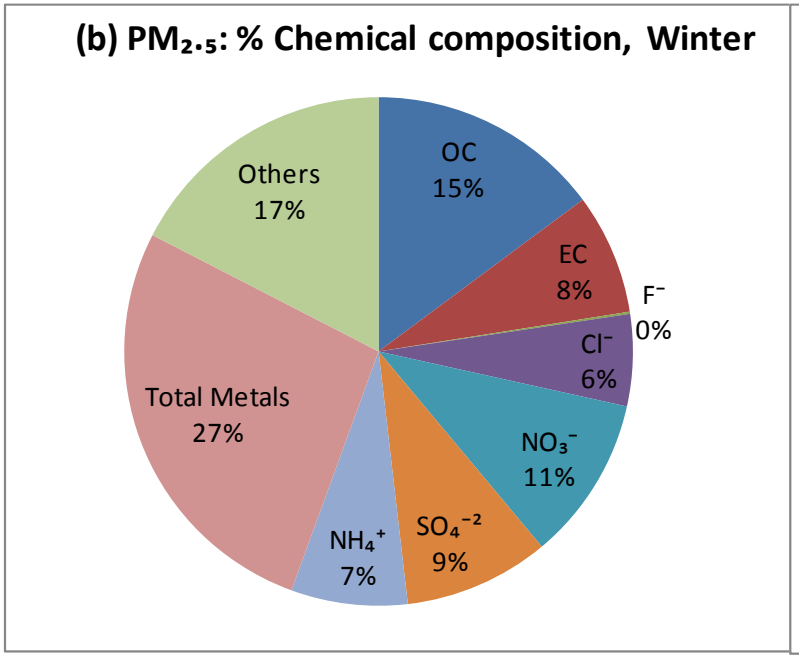
Capabilities

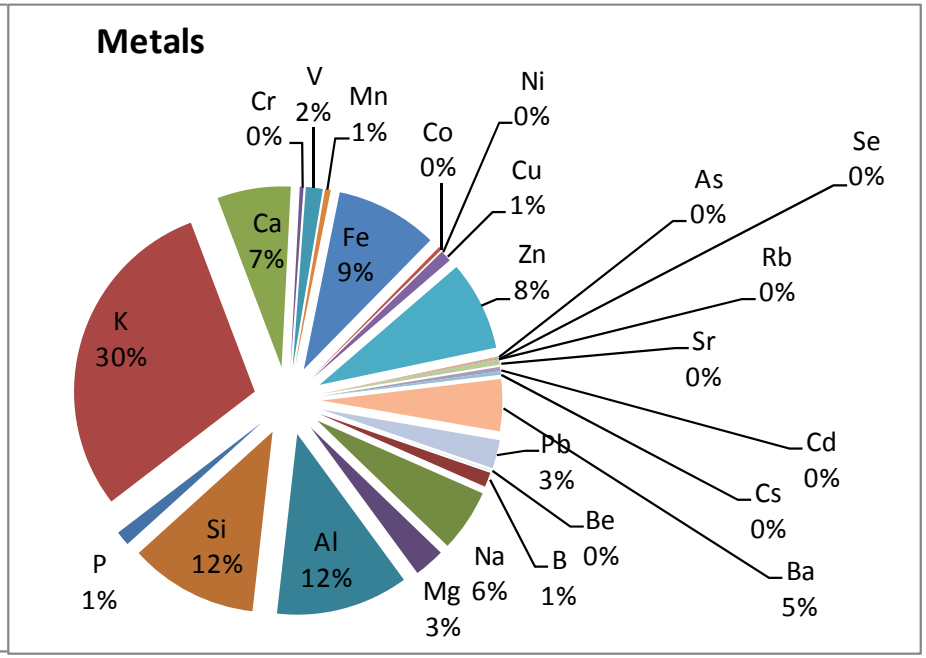
Identification of pollutant contribution due to several sources (for example)

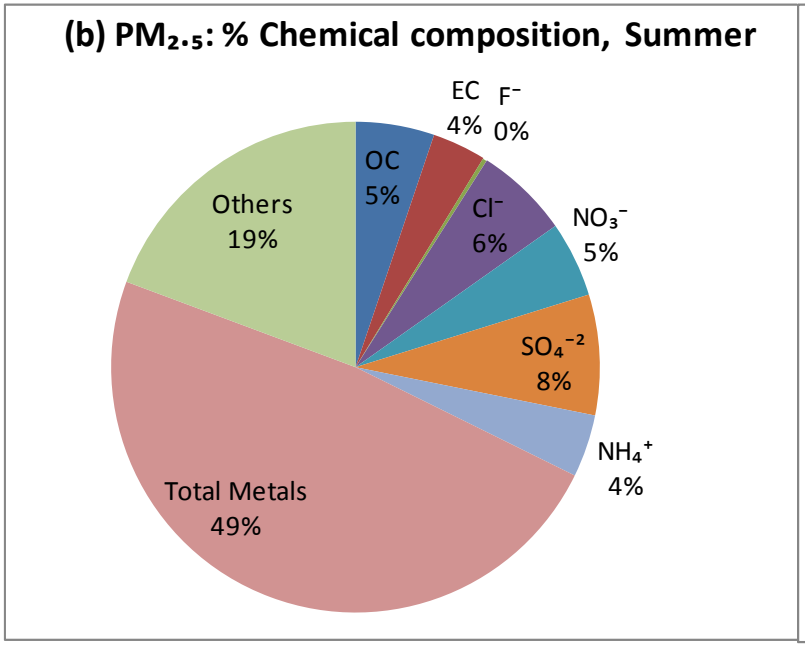


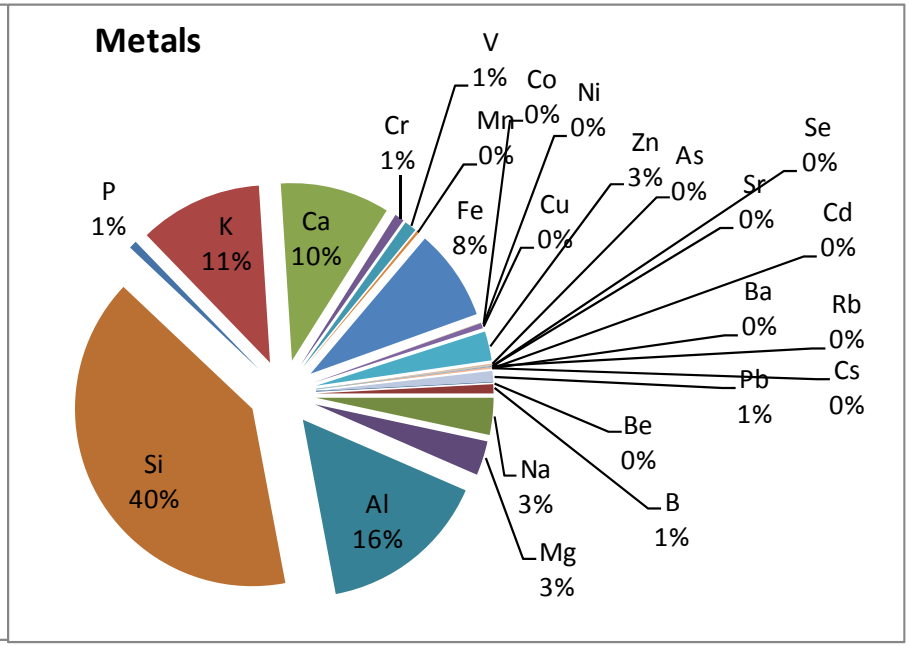
Back calculate impacts due to specific sources

Overall Distribution of Species in $PM_{2.5}$

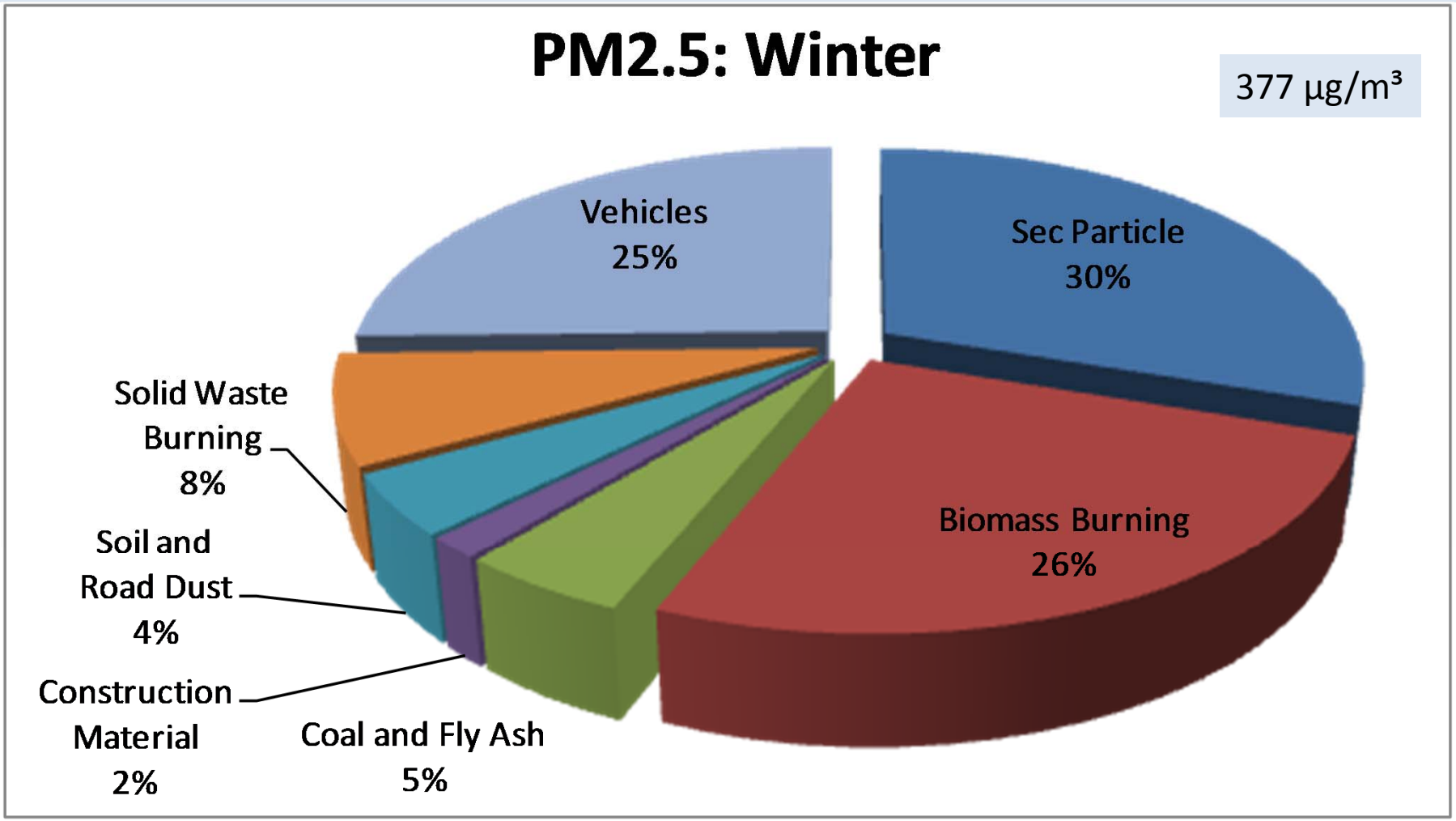








CMB: Overall Summary of Source contribution in Delhi

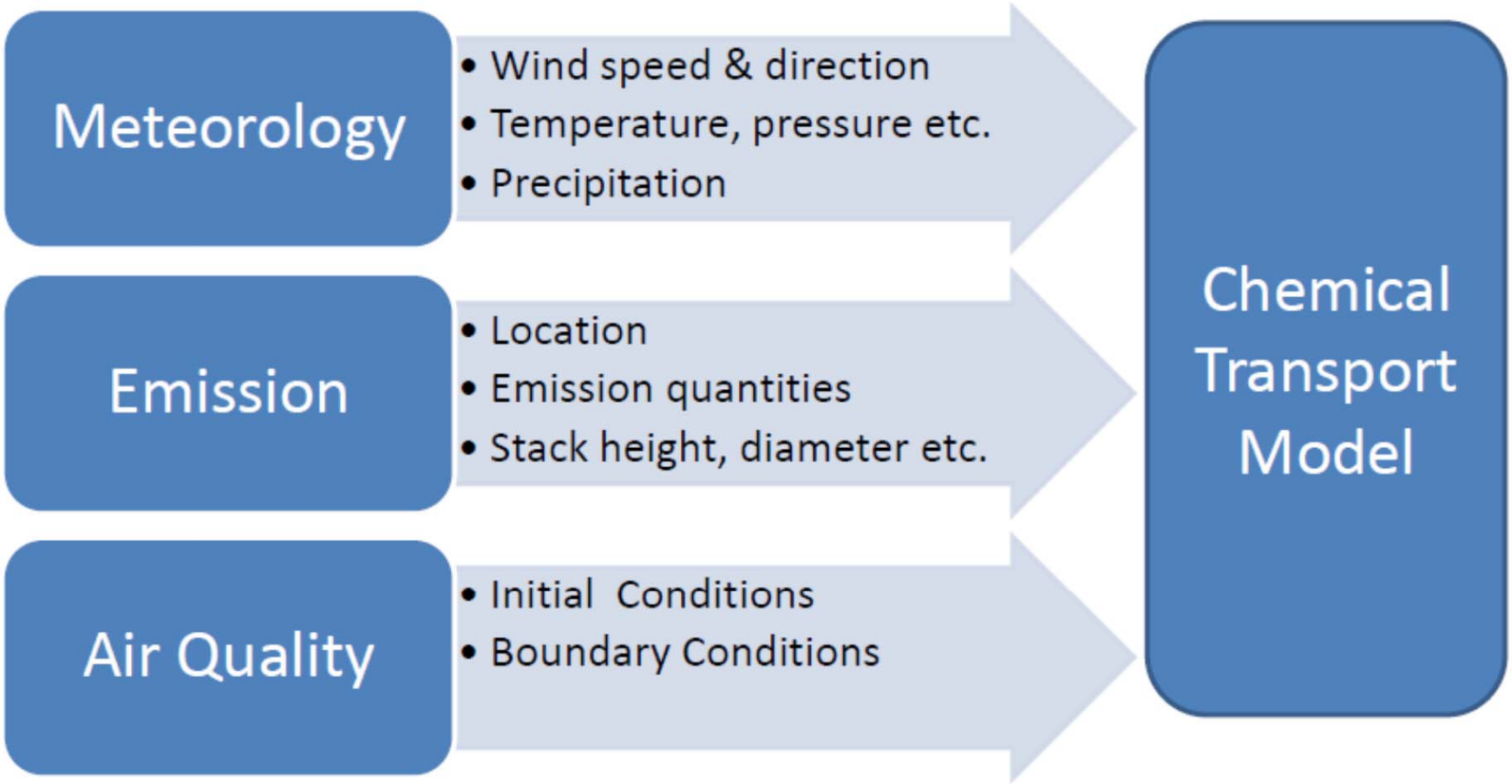


- **Winter sources % contribution**: **Secondary particles** (30%), **vehicles** (25%), **biomass burning** (26%), **MSW burning** (8%)
- **Secondary nitrate particles of vehicles origin contribute to 3% of total $PM_{2.5}$**
- **Total Average vehicle contribution to $PM_{2.5}$ at about 28%**

Beyond Source Apportionment

Synergy of Receptor- Source and Source-Receptor Models

CTM input parameters



The Chemical Transport Model used is WRF - Chem

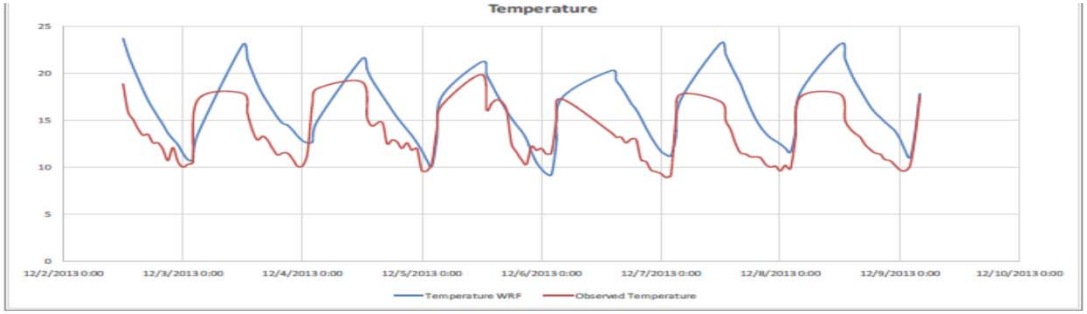


Figure 5.1: Temperature Validation of WRF generated values with IMD values

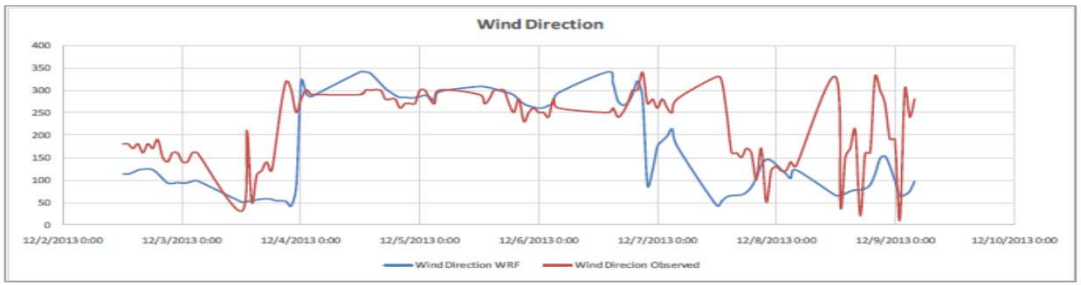


Figure 5.2: Wind Direction Validation of WRF generated values with IMD values.

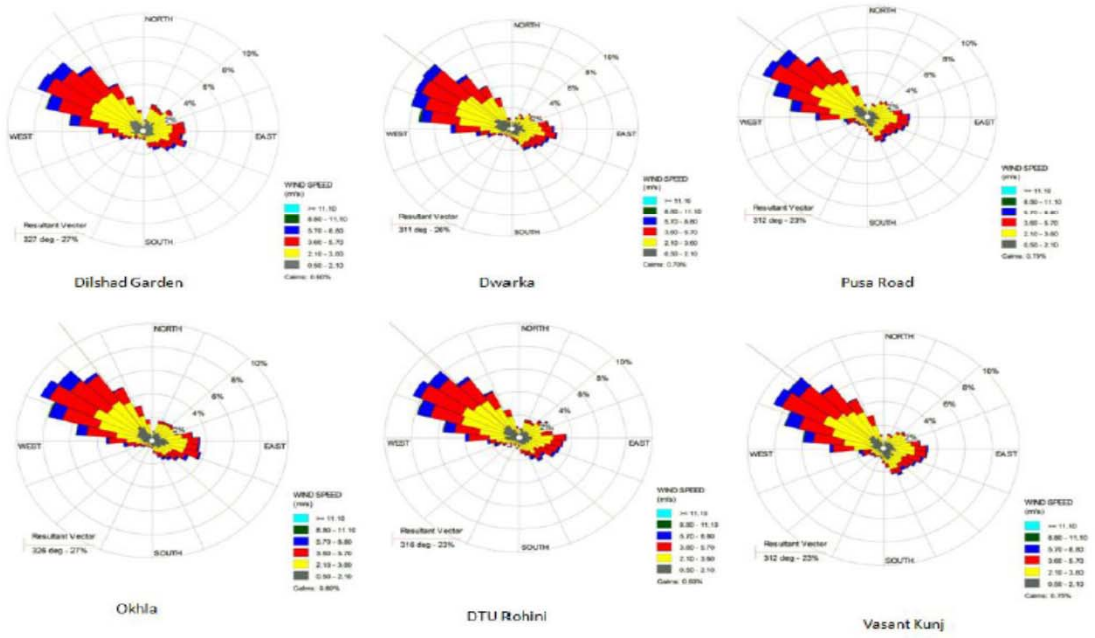


Figure 5.3: Wind Rose Diagram at Six Air Quality Sampling Locations.

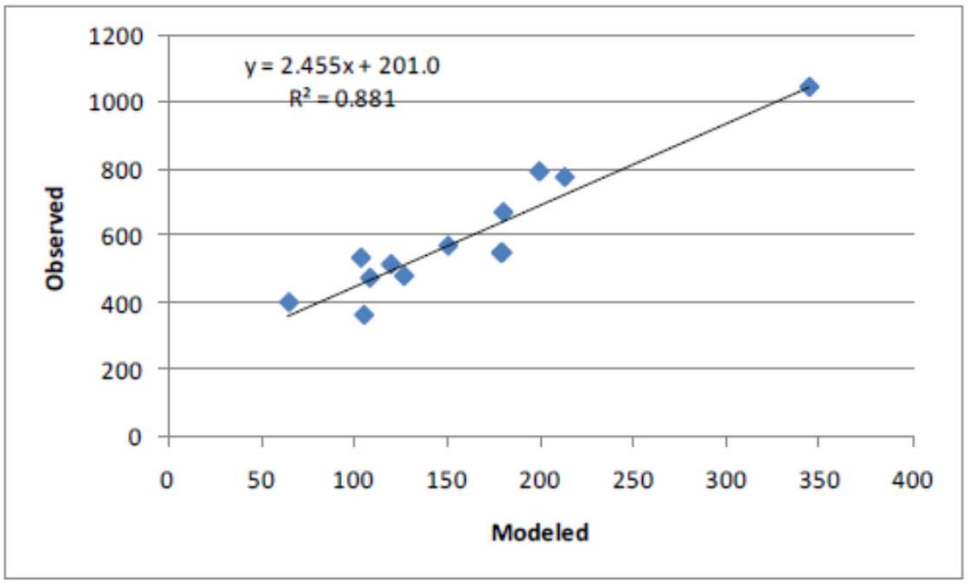


Figure 5.4: Observed vs computed PM_{10} ($\mu g/m^3$), Winter, RHN

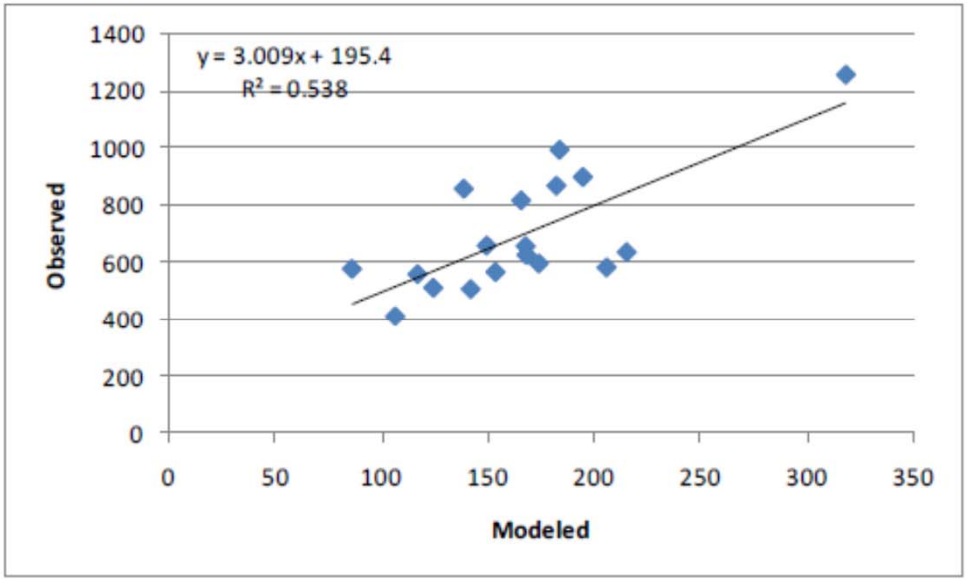
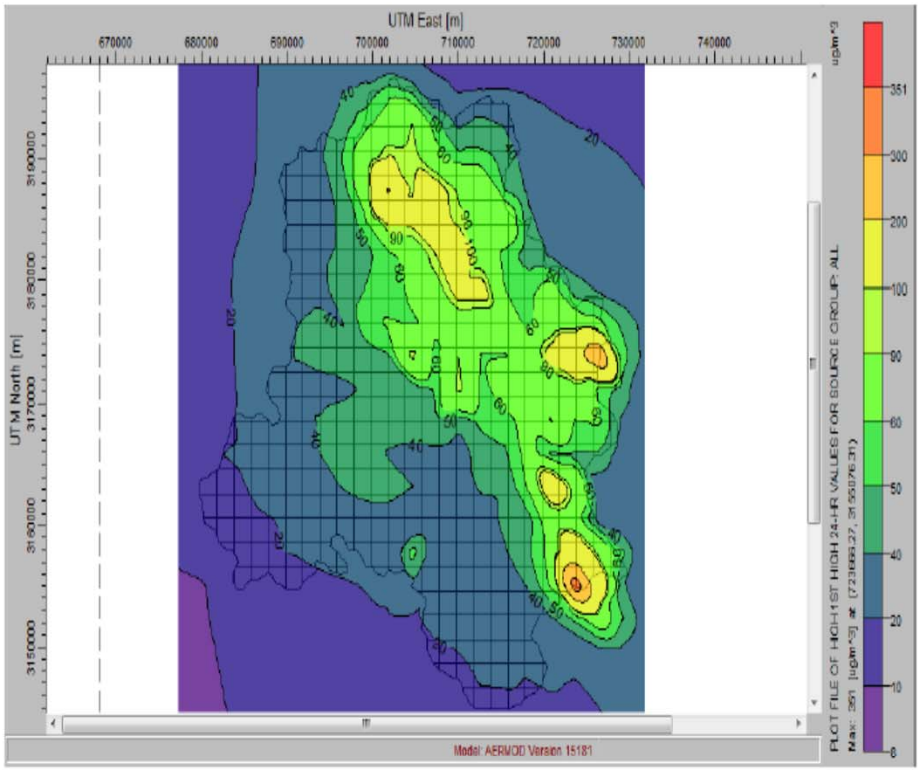


Figure 5.5: Observed vs Predicted of PM_{10} for Winter, OKH

Model Performance



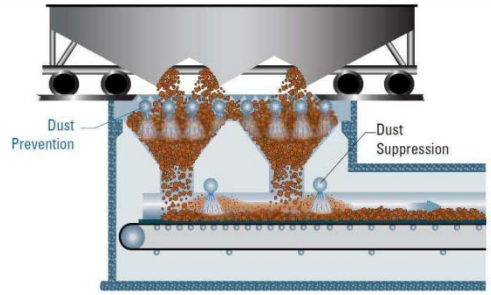
Source-specific Hotspots

Control Options and Action Plan

An Example: Construction and Demolition

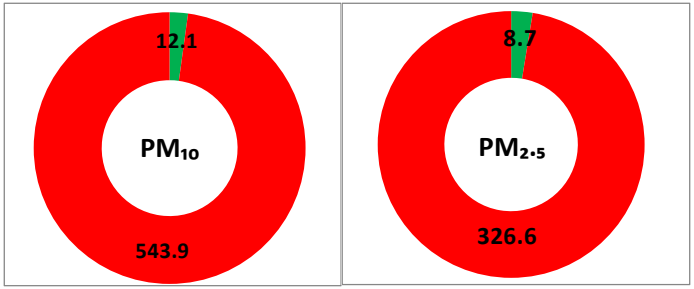
- Wet suppression
- wind speed reduction
- Actual construction area is covered by fine screen
- Proper handling and storage of raw material
- No storage (no matter how small) of construction material near road side (up to 10 m from the edge of road)
- Regulations must be brought in for construction/demolition

Parameter	Existing (kg/day)	Controlled (kg/day)	Mean Modeled Concentration (µg/m^3)		
			Existing	Controlled	% Reduction in AP Level
PM_{10}	5167	2584	3.4	1.6	52.0
$PM_{2.5}$	1292	646	0.8	0.4	50.0



Suppression System

Windscreen for dust control



An Example: Action Plan for NCT of Delhi

A. Immediate Actions

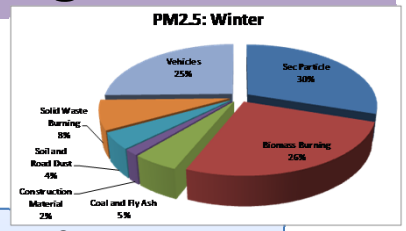
Source	Option No.	Description Option	2016	2017	2018	2019	2020-2023	Percent improvement in AQ
Hotels/ Restaurants	1	Stop use of Coal						80.56
Domestic Cooking	2	LPG to all						50.00
MSW Burning	3	Stop MSW burning: Improve collection and disposal (landfill and waste to energy plants)						100.00
Construction and Demolition	4	Vertically cover the construction area with fine screens						50.00
		Handling and Storage of Raw Material: completely cover the material						
		Water spray and wind breaker						
		Store the waste inside premises with proper cover						
Concrete Batching	5	Water Spray						40.00
		Wind Breaker						
		Bag Filter at Silos						
		Enclosures, Hoods, Curtains, Telescopic Chutes, Cover Transfer Points and Conveyer Belts						
Road Dust and Soil dust	6.1	Vacuum Sweeping of major roads (Four Times a Month)						70.00
		Carpeting of shoulders						
		Mechanical sweeping with water wash						
	6.2	plant small shrubs, perennial forages, grass covers in open areas						--
Note: for implementation year 2016 may begin from July 2016								

An Example: Action Plan for NCT of Delhi

B. Time-bound Actions

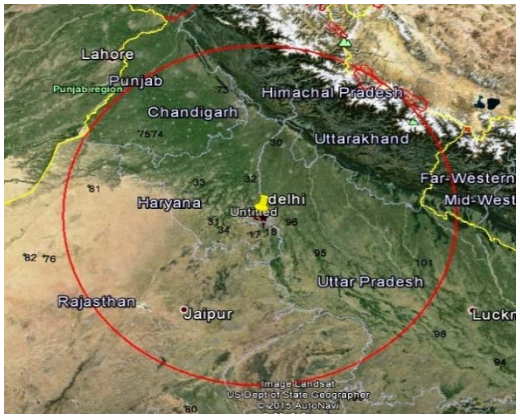
Source	Option No.	Description Option	2016	2017	2018	2019	2020-2023	Percent improvement in AQ
Vehicles	7.1	Electric/Hybrid Vehicles: 2% of 2-Ws, 10% of 3-Ws and 2% 4Ws wef July 2017: New residential and commercial buildings to have charging facilities						50.0
	7.2	Retrofitment of Diesel Particulate Filter: wef July 2018						
	7.3	Implementation of BS – VI for all diesel vehicles including heavy duty vehicles (non-CNG buses and trucks) and LCVs (non-CNG): wef January 2019						
	7.4	Inspection/ Maintenance of Vehicles						
	7.5	Ultra Low Sulphur Fuel (<10 PPM); BS-VI compliant: wef January 2018						
	7.6	2-Ws with Multi Point Fuel Injection (MPFI) system or equivalent: wef January 2019						
Industry and DG Sets	8.1	Reduce sulphur content in Industrial Fuel (LDO, HSD) to less than 500 PPM						30.00
	8.2	Minimize uses, uninterrupted power supply, Banning 2-KVA or smaller DG sets						--
Secondary Particles	9.1	De-SOx-ing at Power Plants within 300 km of Delhi						90.0
	9.2	De-NOx-ing at Power Plants within 300 km of Delhi						90.1
Secondary Organic Aerosols	10	Controlling Evaporative emissions: Vapour Recovery System at petrol pumps (Fuel unloading and dispensing)						80.0
Biomass Burning	11	Managing crop residue burning in Haryana, Punjab and other local biomass burning, Potential alternatives: energy production, biogas generation, commercial feedstock for cattle, composting, conversion in biochar, Raw material for industry: wef July 2016						90.0
Fly Ash	12	Wind Breaker, Water Spraying, plantation, reclamation						--
Note: for implementation year 2016 may begin from July 2016								

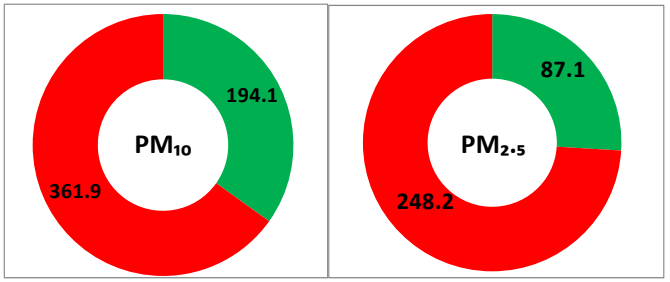
9. Secondary Particles: Control of SO_2 and NO_x from Large sources



- De-SOx-ing at Power Plants Within 300 Km of Delhi
- De-NOx-ing at Power Plants Within 300 Km of Delhi

Parameter	Controlled (kg/day)	Mean Modeled Concentration ($\mu g/m^3$)		
		Existing	Controlled	% Reduction in AP Level
PM_{10}	132437 (SO2 emissions)	69.0	6.9	90
$PM_{2.5}$		38.5	3.9	90
PM_{10}	153349 (NOx emissions)	41.0	4.1	90
$PM_{2.5}$		25.2	2.5	90





Traffic congestion (may not be captured by model)

DATE	Airport Circle	Ambabari Circle	Acharya tulshi circle	Bhaskar flyover	Badi Chopad	BSNL	Chomu Pulia Circle	Club Factory	D Circle	Gail Temple	Gandhi Circle Garden	Global Circle	Jawaher nagar Circle	Kanwatiya Hospital	Khasha Khoti Flyover	Madho Singh Circle	Mandir Mod Circle	Maulana Ziaudin Circle	Panchwati Circle	Bhagwan Pasuram Circle	Peacock Garden	Police Thana Manka Chouk	Richo Kanta Chauraha	Sanganer stadium	Sant Dabu Circle	Smirti Park	Vidyanager Circle	Sidhi Vinayak Temple	Collectrate 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
	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
	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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	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
	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm
9/27/2018	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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9/28/2018	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
	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
	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
	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	**2pm-4pm**	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm
	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
	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm
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
	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
	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
	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	**2pm-4pm**	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm	2pm-4pm
	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
	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm	6pm-8pm

Total Location examined: 29

Highly congested locations

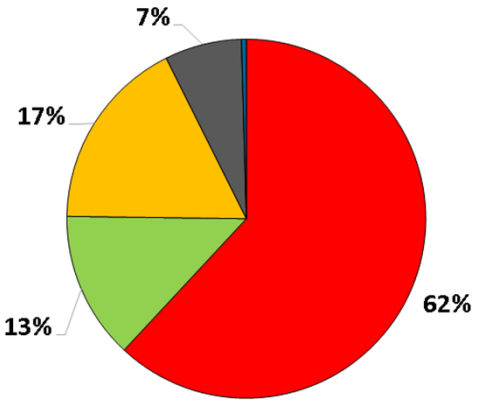
- **Badi Chopad and Manak Chowk**
- **BSNL Circle**
- **Chomu Pulia**
- **D Circle/sindhi camp/ stn road**
- **Jawahar Nagar Circle**

congested locations

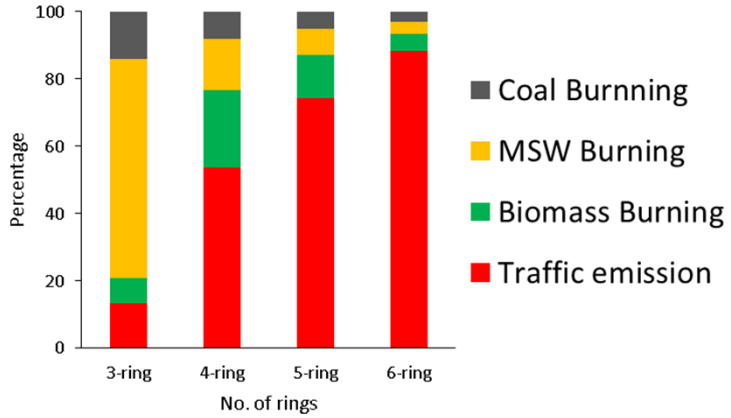
- **Collectorate Circle**
- **Sant Dabu circle**
- **Sanganer stadium circle**
- **RICCO Kanta chauraha, Mansarover**
- **Gandhi Circle**

Spatio-temporal variations of $PM_{2.5}$-bound PAHs in Delhi, India: Source apportionment and assessment of associated human health risks

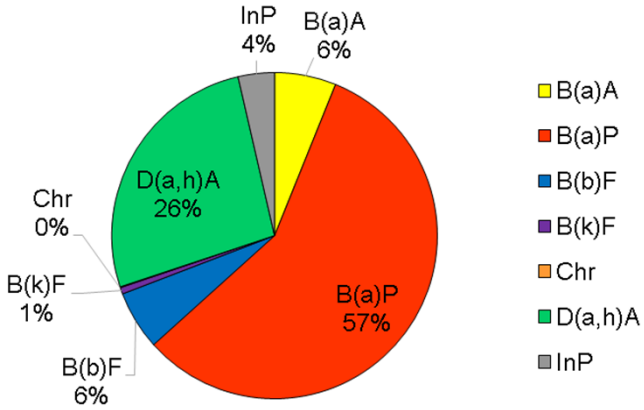
(Yadav, Sharma, et al., Science of the Total Environment, under review, 2018)



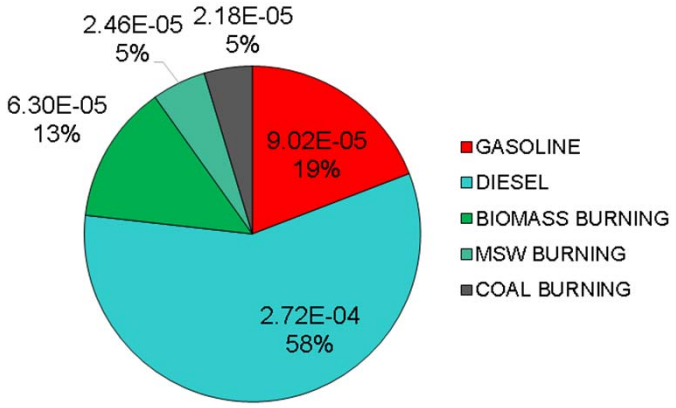
Overall Source contribution



Source contribution to 3, 4, 5 & 6-ring PAHs



PAHs contribution to lifetime risk



Source contribution to lifetime risk

4 to 6-ring PAHs have large carcinogenic risk: disproportionately high from traffic emissions (mostly from diesel)

Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi

(Final Report: Air Pollution component)

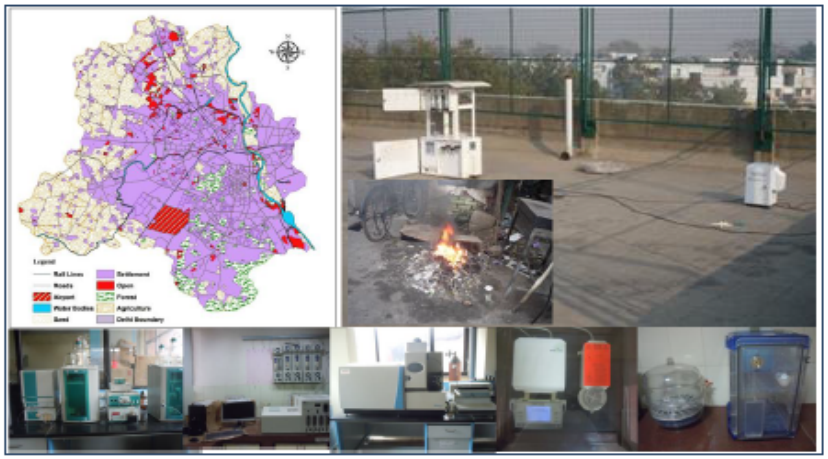
Submitted to

Department of Environment

Government of National Capital Territory of Delhi

and

Delhi Pollution Control Committee, Delhi



Mukesh Sharma; PhD and Onkar Dikshit; PhD

Professors, Department of Civil Engineering

Indian Institute of Technology Kanpur, Kanpur- 208016

January 2016

Apportionment of Air Pollution Sources at Taj Mahal, Agra

(Summer Analysis)

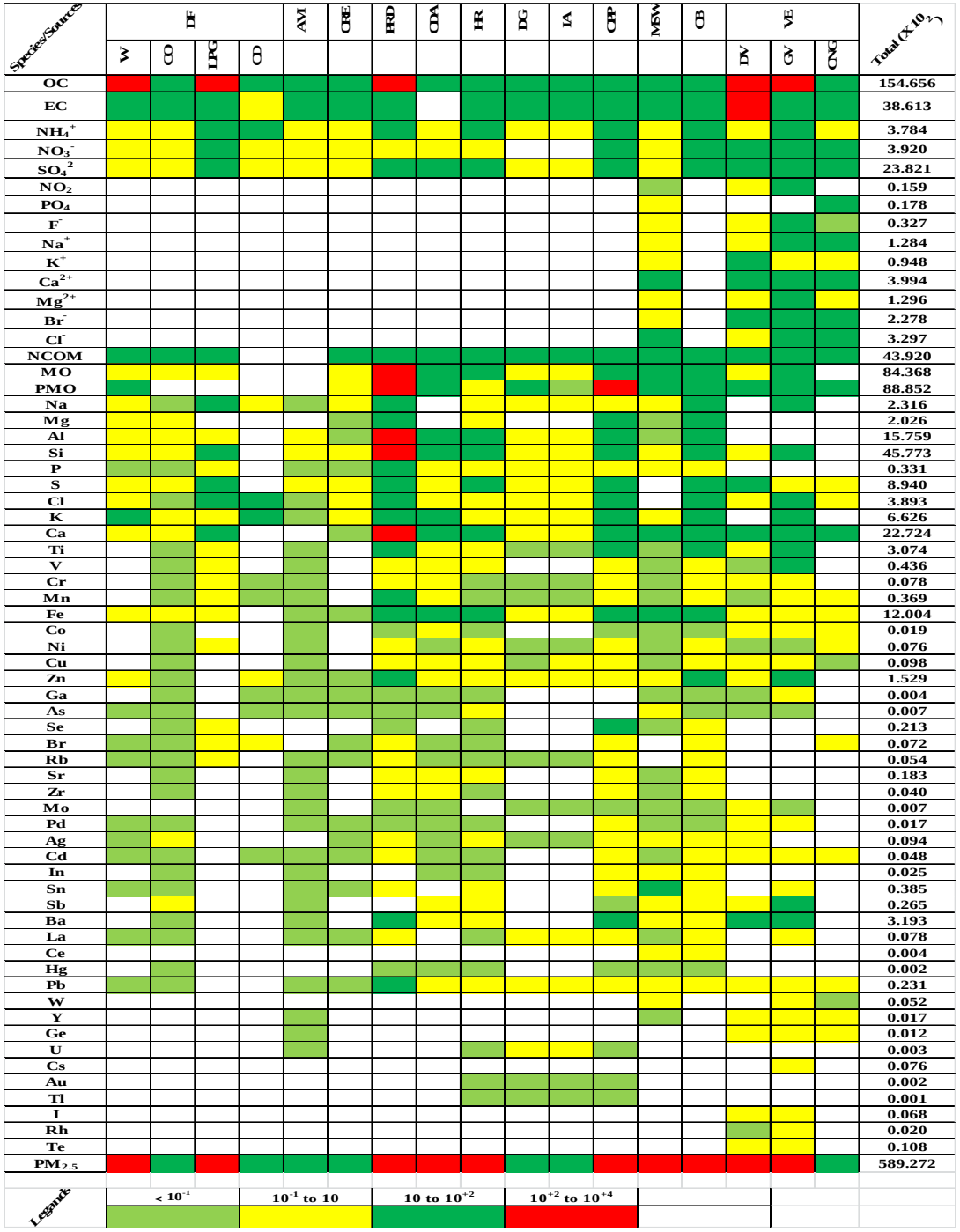
The Future of SA and Planning

Not all $PM_{2.5}$ particles are equally toxic.

Sala et. al (2014) Environ. Sci. Technol.
C.Y. Wu (2001). Air Waste Manag. Assoc.
Park et al. (2018) Science
Krzyzanowski et al. (2005). WHO
HEI, (2016). www.healtheffects.org.
Pozzer, et al. (2015) Nature

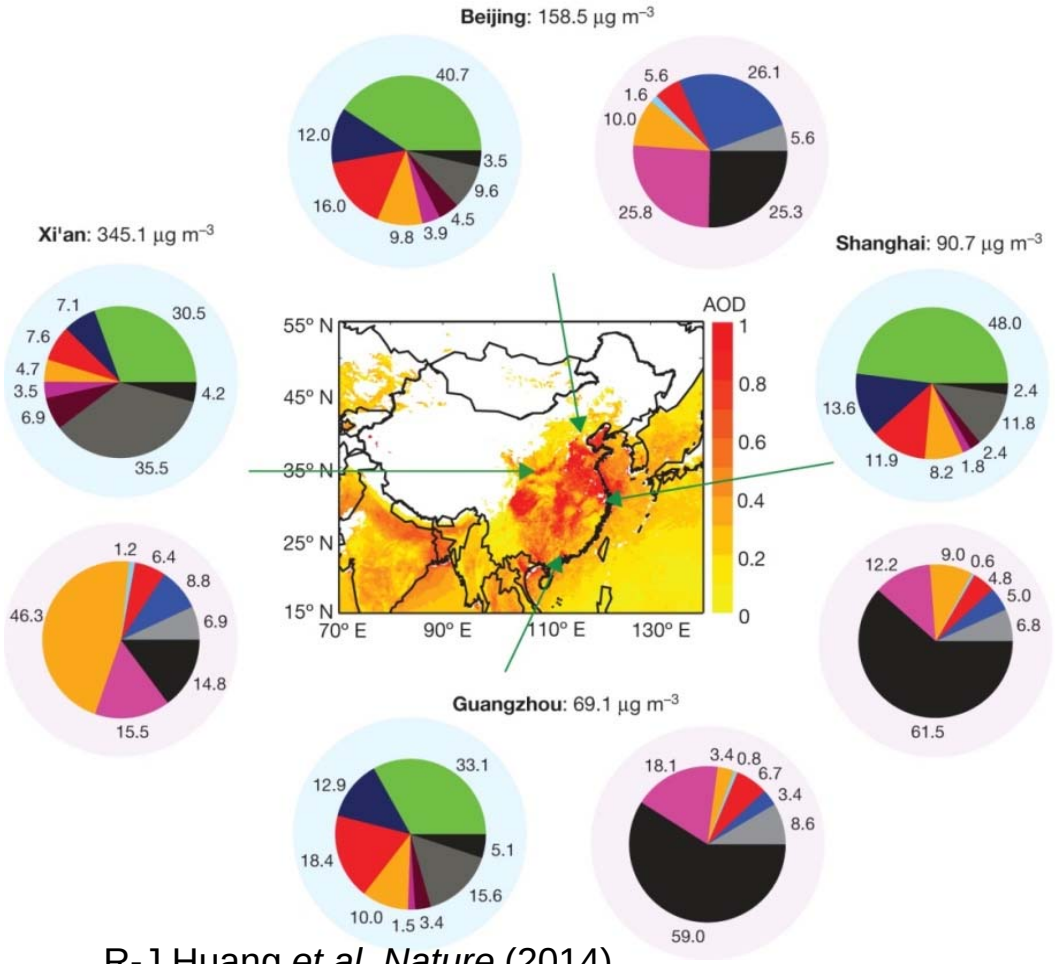
The HEI non-specific $PM_{2.5}$ mass alone may underestimate the total mortality risk of $PM_{2.5}$ exposure.

SA and Planning: Sum ($Source_{lj} \times Toxicity_j$)


Species/Sources
DF
W
CO
LPG
CD
AM
CRE
HDD
CDA
HR
DG
IA
CPP
MSW
CB
VE
DV
GV
CNG
Total (X 10^2)
OC 154.656
EC 38.613
NH4+ 3.784
NO3- 3.920
SO4 2 23.821
NO2 0.159
PO4 0.178
F- 0.327
Na+ 1.284
K+ 0.948
Ca2+ 3.994
Mg2+ 1.296
Br- 2.278
Cl- 3.297
NCOM 43.920
MO 84.368
PMO 88.852
Na 2.316
Mg 2.026
Al 15.759
Si 45.773
P 0.331
S 8.940
Cl 3.893
K 6.626
Ca 22.724
Ti 3.074
V 0.436
Cr 0.078
Mn 0.369
Fe 12.004
Co 0.019
Ni 0.076
Cu 0.098
Zn 1.529
Ga 0.004
As 0.007
Se 0.213
Br 0.072
Rb 0.054
Sr 0.183
Zr 0.040
Mo 0.007
Pd 0.017
Ag 0.094
Cd 0.048
In 0.025
Sn 0.385
Sb 0.265
Ba 3.193
La 0.078
Ce 0.004
Hg 0.002
Pb 0.231
W 0.052
Y 0.017
Ge 0.012
U 0.003
Cs 0.076
Au 0.002
Tl 0.001
I 0.068
Rh 0.020
Te 0.108
PM2.5 589.272
Legends
< 10^-1
10^-1 to 10
10 to 10^+2
10^+2 to 10^+4

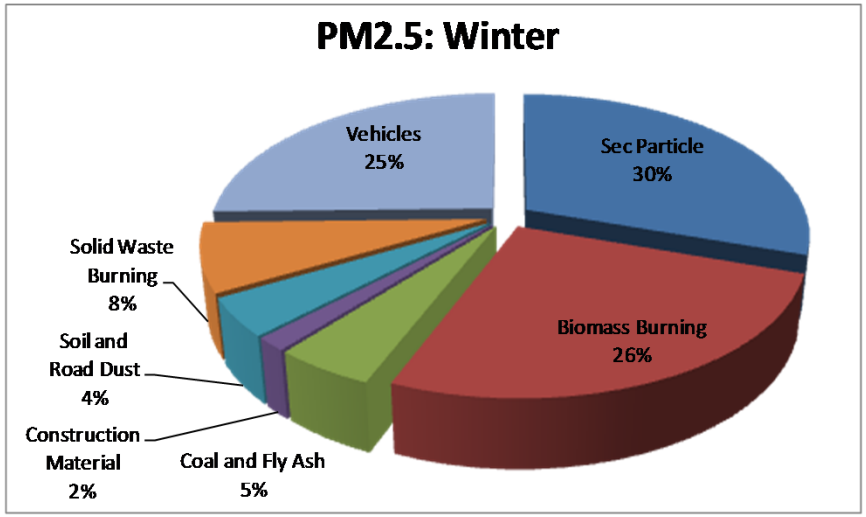
- Its worth it only if….
  - Quality control and quality assurance
  - Data collection, quality instruments, trained manpower, experience, committed team
  - Right TOR and Scoping
  - Right model selection
  - Deal with sources from outside

Comparison: Delhi Vs Beijing, Shanghai, Xi'am, Guangzhou



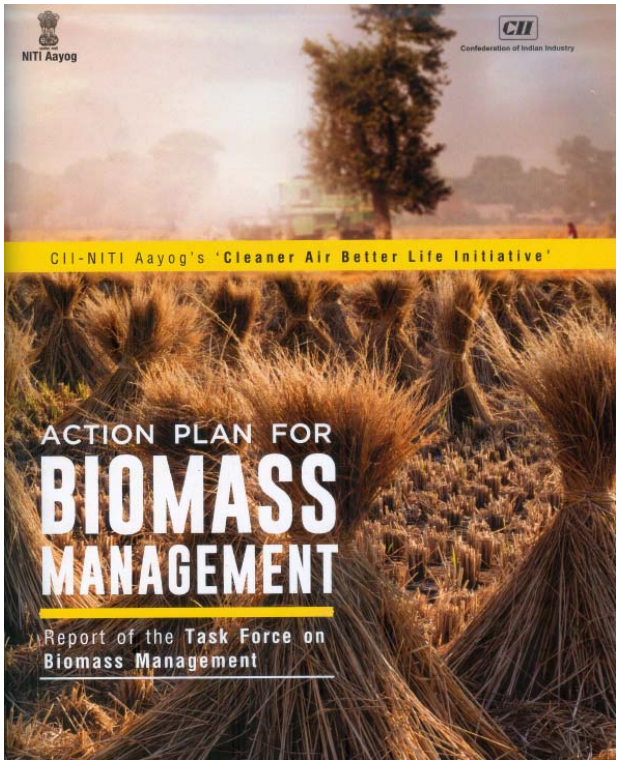
R-J Huang *et al. Nature* (2014)

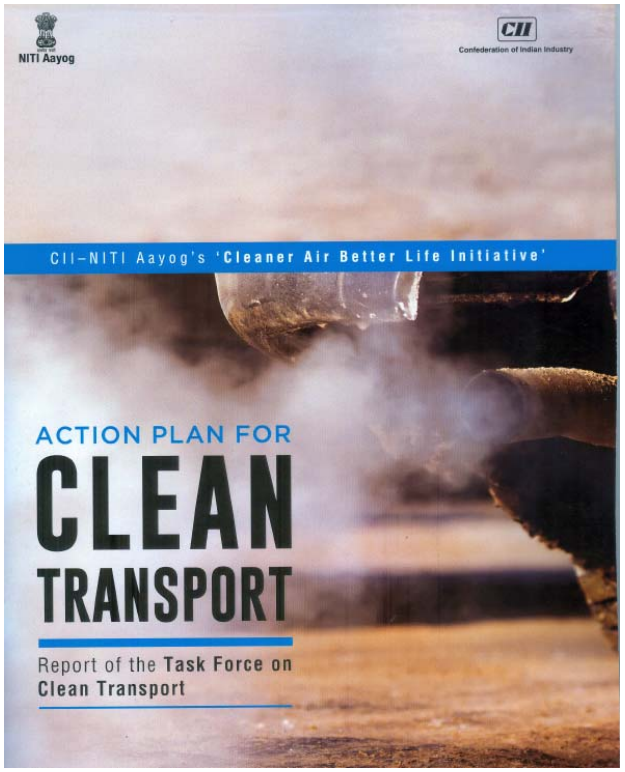
"In response to the severe haze events of 2013, the Chinese State Council quickly released the 'Atmospheric Pollution Prevention and Control Action Plan' on 10 September 2013 which aims to reduce PM2.5 by up to 25% by 2017 relative to 2012 levels, and is backed by US $277 billion in investments from the central Government."

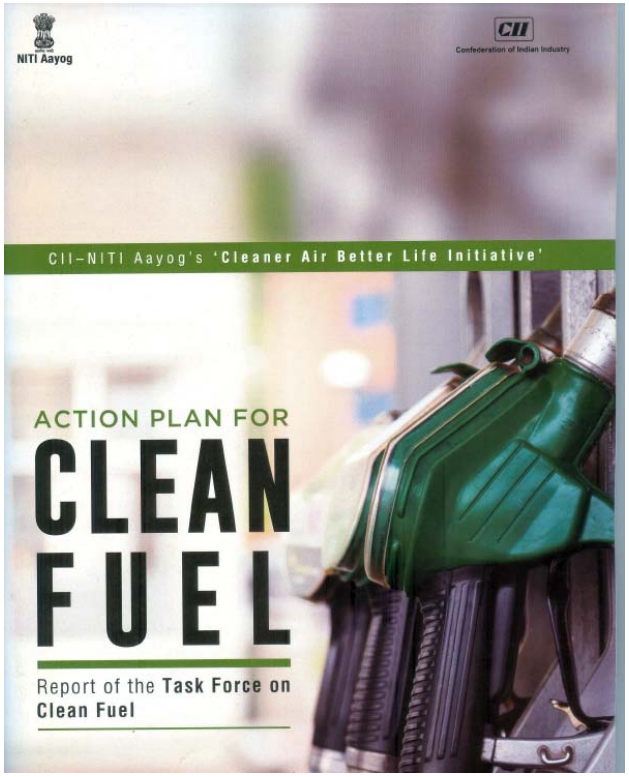


Impact of Report?

S.No.	Status before report	Recommendation and Status After report
1.	BS IV to BS V	BS IV leap frog to BS VI - Agreed
2.	BS VI in 2023/2024	BS VI 2019 now 2021/2020
3.	No road sweeping	Yes started, shoulder carpeting ?
4.	Soil dust control - none	Plant small shrubs, perennial forages, grass cover (initiated)
5.	No attention to MSW burning	Stop fully. Problem recognized
6.	SO4/NO3 control (65 – 75%)	90% control (change in regulation)
7.	2-W single point fuel injection	Multi point fuel injection – talked about
8.	Biomass burning	energy production, biogas generation, commercial feedstock for cattle, composting, conversion in biochar
9.	10 ppm Sulfur in Diesel (2022)	Now 2019
10.	Concrete batching – no plan	Recognized – action being initiated
11	Construction activity	Being enforced
12	NCR – no plan	Implement everything of Delhi in NCR – no takers







There are several studies conducted by various institutions regarding the deteriorating air quality of Delhi. A recent and most comprehensive source apportionment study has been done by IIT-Kanpur (IIT-K) on behalf of the Government of Delhi. For this initiative, the findings of IIT-K study are being considered as basis of designing the action plans. One of the major sources of air quality deterioration in Delhi in the months of October and November is burning of agricultural biomass residue, or Crop Residue Burning (CRB) in the neighboring states of NCR.

Mr. Pavan Kumar Nagar, P.hD Scholar and Mr. Dhirendra Singh, Senior Project Engineer, IIT Kanpur worked tirelessly from field sampling to analysis and preparation of report; thanks to Pavan and Dhirendra for their inestimable support. Sincere thanks are also due to the entire IITK team engaged in the project including Preeti Singh, Sandhya Anand, Akshay Singh, Nitish Kumar Verma, Harvendra Singh, Pravin Kumar, Toofan Singh, Gaurav, Gulab Singh, Saurabh, Deepak Panwar, Durga Prasad Yadav and Virendra. Special thanks to Mr. Anu N, Assistant Professor, UKF College of Engineering and Technology for his support.

Thank you.