Restoring Air Quality through Source Apportionment Analysis

Orientation Conclave Air Quality Management: Building Strategies for Clean Air, Bhubaneshwar
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Why Control Air Pollution?

- Morbidity – Acute and Chronic
- Mortality – Premature Death and DALY
- Risk and communication – Organics and metals

Smart way

- Know all your sources well spatially and temporally (EI)
- Do not ignore small sources
- Combine meteorology to assess GL impact
- Quantified contribution of each source at breathing level
- Think of best options for controls
- Assess efficacy and cost of control options
- Develop time-sensitive action plan with targets
- Monitor targets and improvements in AQ
- Revise options, if necessary
- Translate better AQ into health benefits
- Responsibilities and fiscal allocations
Hazardous Air Pollutants in Particulate Matter (PM2.5)

- Surface area (Smaller the Size more the HAPS)
- Elemental Carbon (more adsorption of HAPS)
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Pollutant</th>
<th>Time Weighted Average</th>
<th>Concentration in Ambient Air</th>
<th>Methods of Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Industrial, Residential, Rural and Other Area</td>
<td>Ecologically Sensitive Area (notified by Central Government)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>1</td>
<td>Sulphur Dioxide (SO₂) µg/m³</td>
<td>Annual**</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>Nitrogen Dioxide (NO₂) µg/m³</td>
<td>Annual**</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>Particulate Matter (size less than 10µm) or PM₁₀ µg/m³</td>
<td>Annual**</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>Particulate Matter (size less than 2.5µm) or PM₂.₅ µg/m³</td>
<td>Annual**</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>Ozone (O₃) µg/m³</td>
<td>8 hours**</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 hour**</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>6</td>
<td>Lead (Pb) µg/m³</td>
<td>Annual**</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>7</td>
<td>Carbon Monoxide (CO) mg/m³</td>
<td>8 hours**</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 hour**</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>8</td>
<td>Ammonia (NH₃) µg/m³</td>
<td>Annual**</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 hours**</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>9</td>
<td>Benzene (C₆H₆) µg/m³</td>
<td>Annual*</td>
<td>05</td>
<td>05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Benzo[a]Pyrene (BaP) - particulate phase only, ng/m³</td>
<td>Annual*</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>11</td>
<td>Arsenic (As), ng/m³</td>
<td>Annual*</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>12</td>
<td>Nickel (Ni), ng/m³</td>
<td>Annual*</td>
<td>0.20</td>
<td>0.20</td>
</tr>
</tbody>
</table>
National Air Quality Index
(How healthy is the air we breathe?)

AQI = 230; Poor
Responsible Pollutant: \( \text{PM}_{10} \)

Indian Institute of Technology Kanpur, Kanpur

Sponsored by
Central Pollution Control Board, Delhi
Air pollution: NGT orders study of 102 cities
How to attain National Air Quality Standards in Delhi?

- Air Quality Measurements: Current Status
- Source Identification and Emission Quantification: Emission Inventory
- Quantification of Source Contribution to Air Pollution: Source Apportionment

Identification of Control Options and Their Efficacies

Time-bound Action Plan

- 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$_x$
Sampling Location and Land-use Pattern Map of Jaipur

Winter
AJG Nov 19 – Dec 08, 2017
VKI Dec 9 -31, 2017
JSG Dec 14, 2017 – Jan 4, 2018
MLN Jan 26 – Feb 14, 2018
MNS Jan 15 – Feb 04, 2018

Summer
AJG May 6 - 26, 2018
VKI May 6 - 27, 2018
JSG May 29 – June 20, 2018
MLN Apr 15 – May 4, 2018
MNS Apr 15 – May 4, 2018
Different Layers of GIS-based land-use Map

Water bodies  Industrial Area  Green Area  Major Roads

Institutional Area  Mountainous Area  Open Fields  Settlement Area
1. DWK
2. RHN
3. OKH
4. VKJ
5. DSG
6. PUS

**Winter**
1. Nov 03 - 23, 2013
2. Nov 03 - 23, 2013
3. Dec 02 - 22, 2013
5. Jan 24 - Feb 13, 2014
6. Jan 30 - Feb, 2014

**Summer**
1. Apr 04 - 23, 2014
2. Apr 04 - 24, 2014
3. May 01 - 24, 2014
4. Apr 29 – May 19, 2014
5. May 26 - Jun 14, 2014
Emission Inventory
Source Categories

Area Source (Stack Height < 20m)
- Hotels/ Restaurants
- Domestic Cooking
- MSW Burning
- Construction/Demolition
- Concrete Batching
- Road Dust
- Industries
- DG Sets
- Aircrafts
- Biomass Burning
- Fly Ash
- Cremation

Point Source (Stack Height > 20m)
- Power Plants
- Industries
- Incinerator
- DG sets

Line Source
- Vehicles
  - 2W
  - 3W
  - 4W
  - LCV
  - Buses
  - Trucks
Vehicles - Line Source

➢ Traffic Data location for vehicle emission
Road dust Sampling
Road Dust Sampling Locations

- PM$_{10}$ emission from road dust: 79626 kg/day
- PM$_{2.5}$ emission from road dust: 22165 kg/day
PM$_{2.5}$ Emission Load from Vehicles (kg/day, %)

- 12000 kg/d
- Major Contributor: Trucks – 46%, 2W – 33%, 4W – 10%
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)

- 28% - Cement plant
- 40% - Power plant
- 15% - Diesel engine
- 17% - Steel plant

Back calculate impacts due to specific sources
Source Composition

Each source may possess unique
- Chemical composition or
- Size distributed species
- Unique tracer compound

Fingerprints
Basic Models

\[ C_{ik} = \sum_{j=1}^{j} a_{ij} S_{jk} \quad \text{for } i = 1, n \]

\begin{align*}
C_{ik} &= \text{Concentration of component “i” in the “k” sample} \\
a_{ij} &= \text{Fractional amount of component “i” in source “j”} \\
S_{jk} &= \text{Total contribution from source “J”} \\
n &= \text{Total number of components measured} \\
\end{align*}

Solve simultaneous equation for \( S_{jk} \)

Assumptions:

• Number of sources “j” is less than or equal to number of components “I”
• The composition of all sources is linearly independent of each other
Molecular Markers: Emission Source Indicator in Kanpur (Sharma 2008)

Sites Wise distribution of molecular markers - Winter season

- **Stigmasterol** – huge quantity, signifies biomass burning, major source of POC and thus SOA
Variation in PM$_{2.5}$

- PM$_{2.5}$ levels are 4-7 times higher than the national air quality standards in summer and winter months.
- The overall average concentration of PM$_{2.5}$ in summer season is around 300 μg/m$^3$ against the acceptable level of 60 μg/m$^3$.
- The overall average concentration of PM$_{2.5}$ in winter is 375 μg/m$^3$ against the acceptable level of 60 μg/m$^3$.

Ratio PM$_{2.5}$/PM$_{10}$: Winter - 0.63, Summer - 0.57
Overall CMB Modeling Results for PM$_{2.5}$

(a) PM$_{2.5}$: Overall Source contribution

(b) PM$_{2.5}$: % Overall Source contribution
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%
Analytical Instruments

(a) 4-Channel Speciation Sampler
(b) Microbalance
(c) OC/EC Analyzer
(d) GC-MS with A TD
(e) Ion Chromatography
(f) ICP-MS
Control Options and Action Plan
### Recommended Control Options

#### A. Immediate Actions

<table>
<thead>
<tr>
<th>Source</th>
<th>Option No.</th>
<th>Description Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotels/ Restaurants</td>
<td>1</td>
<td>Stop use of Coal</td>
</tr>
<tr>
<td>Domestic Cooking</td>
<td>2</td>
<td>LPG to all</td>
</tr>
<tr>
<td>MSW Burning</td>
<td>3</td>
<td>Stop MSW burning: Improve collection and disposal (landfill and waste to energy plants)</td>
</tr>
</tbody>
</table>

**Construction and Demolition**

<table>
<thead>
<tr>
<th>Source</th>
<th>Option No.</th>
<th>Description Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>Vertically cover the construction area with fine screens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Handling and Storage of Raw Material: completely cover the material</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water spray and wind breaker</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Store the waste inside premises with proper cover</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Movement of Vehicles: paved paths/roads</td>
</tr>
</tbody>
</table>

**Concrete Batching**

<table>
<thead>
<tr>
<th>Source</th>
<th>Option No.</th>
<th>Description Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>Water Spray</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wind Breaker</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bag Filter at Silos</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enclosures, Hoods, Curtains, Telescopic Chutes, Cover Transfer Points and Conveyer Belts</td>
</tr>
</tbody>
</table>

**Road Dust and Soil dust**

<table>
<thead>
<tr>
<th>Source</th>
<th>Option No.</th>
<th>Description Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.1</td>
<td>Vacuum Sweeping of major roads (Four Times a Month)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carpeting of shoulders, maintenance of road, dividers and kerbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical sweeping with water wash</td>
</tr>
<tr>
<td></td>
<td>6.2</td>
<td>plant small shrubs, perennial forages, grass covers in open areas</td>
</tr>
</tbody>
</table>
# Recommended Control Options

## B. Time-bound Actions

<table>
<thead>
<tr>
<th>Source</th>
<th>Option No.</th>
<th>Description Option</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicles</strong></td>
<td>7.1</td>
<td>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</td>
</tr>
<tr>
<td></td>
<td>7.2</td>
<td>Retrofitment of Diesel Particulate Filter: wef July 2018</td>
</tr>
<tr>
<td></td>
<td>7.3</td>
<td>Implementation of BS – VI for all diesel vehicles including heavy duty vehicles (non-CNG buses and trucks) and LCVs (non-CNG): wef January 2019</td>
</tr>
<tr>
<td></td>
<td>7.4</td>
<td>Inspection/ Maintenance of Vehicles</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>Ultra Low Sulphur Fuel (&lt;10 PPM); BS-VI compliant: wef January 2018</td>
</tr>
<tr>
<td></td>
<td>7.6</td>
<td>2-Ws with Multi Point Fuel Injection (MPFI) system or equivalent: wef January 2019</td>
</tr>
<tr>
<td><strong>Industry and DG Sets</strong></td>
<td>8.1</td>
<td>Reduce sulphur content in Industrial Fuel (LDO, HSD) to less than 500 PPM</td>
</tr>
<tr>
<td></td>
<td>8.2</td>
<td>Minimize uses, uninterrupted power supply, Banning 2-KVA or smaller DG sets</td>
</tr>
<tr>
<td><strong>Secondary Particles</strong></td>
<td>9.1</td>
<td>De-SOx-ing at Power Plants within 300 km of Delhi</td>
</tr>
<tr>
<td></td>
<td>9.2</td>
<td>De-NOx-ing at Power Plants within 300 km of Delhi</td>
</tr>
<tr>
<td><strong>Secondary Organic Aerosols</strong></td>
<td>10</td>
<td>Controlling Evaporative emissions: Vapour Recovery System at petrol pumps (Fuel unloading and dispensing)</td>
</tr>
<tr>
<td><strong>Biomass Burning</strong></td>
<td>11</td>
<td>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</td>
</tr>
</tbody>
</table>

Similar action plan should be implemented in NCR
1. Hotels and Restaurants

- Stop use of Coal

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing (kg/day)</th>
<th>Controlled (kg/day)</th>
<th>Mean Modeled Concentration (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Existing</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>3493</td>
<td>1350</td>
<td>4</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>1758</td>
<td>675</td>
<td>3.6</td>
</tr>
</tbody>
</table>

- 9000 Hotels/Restaurants uses coal (mostly in tandoors)
- Restaurants of sitting capacity more than 10 should not use coal and shift to electric or gas-based appliances
2. Domestic Sector

- LPG should be made available to remaining 10% households to make the city 100% LPG-fueled.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing (kg/day)</th>
<th>Controlled (kg/day)</th>
<th>Mean Modeled Concentration (µg/m³)</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Existing</td>
<td>Controlled</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>7381</td>
<td>4111</td>
<td>8.0</td>
<td>3.6</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>6940</td>
<td>4111</td>
<td>7.2</td>
<td>3.6</td>
</tr>
</tbody>
</table>
3. Municipal Solid Waste (MSW) Burning

- Stop MSW burning

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing (kg/day)</th>
<th>Controlled (kg/day)</th>
<th>Mean Modeled Concentration (µg/m$^3$)</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Existing</td>
<td>Controlled</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>1968</td>
<td>0</td>
<td>3.2</td>
<td>0.0</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>1771</td>
<td>0</td>
<td>1.8</td>
<td>0.0</td>
</tr>
</tbody>
</table>

MSW burning of 190-246 tons/day (~2–3% of MSW generated; 8390 tons/day) (Nagpure et al., 2015)
4. 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing (kg/day)</th>
<th>Controlled (kg/day)</th>
<th>Mean Modeled Concentration (µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Existing</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>5167</td>
<td>2584</td>
<td>3.4</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>1292</td>
<td>646</td>
<td>0.8</td>
</tr>
</tbody>
</table>

![Suppression System](image1.png)  
Windscreen for dust control
5. Ready Mix Concrete Batching

- Wet suppression
- Wind speed reduction
- The transfer of cement and pozzalan material to silos is one of the major emission sources in the plant, and installation of fabric filter should be compulsory
- Proper handling and storage of raw material
- No storage (no matter how small) of construction material near road side (up to 10m from the edge of road)
- Regulations must be brought in for concrete batching

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing (kg/day)</th>
<th>Controlled (kg/day)</th>
<th>Mean Modeled Concentration (µg/m³)</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Existing</td>
<td>Controlled</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>14370</td>
<td>516</td>
<td>8.0</td>
<td>2.0</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>1292</td>
<td>646</td>
<td>0.8</td>
<td>0.4</td>
</tr>
</tbody>
</table>
6. Road Dust

- Vacuum Sweeping of major roads (Four Times a Month)
- Roads are maintained properly
- Watering of roads
- paved wall to wall
- open fields should be kept slightly wet and small shrubs are planted to prevent drift of dust in summer
- No storage and disposal of material (construction, ash, etc) near road side (up to 10 m from the edge of road).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing (kg/day)</th>
<th>Controlled (kg/day)</th>
<th>Mean Modeled Concentration (µg/m³)</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM&lt;sub&gt;10&lt;/sub&gt;</td>
<td>79626</td>
<td>23887</td>
<td>Existing: 131.0</td>
<td>Controlled: 38.0</td>
</tr>
<tr>
<td>PM&lt;sub&gt;2.5&lt;/sub&gt;</td>
<td>22165</td>
<td>6649</td>
<td>Existing: 36.0</td>
<td>Controlled: 10.8</td>
</tr>
</tbody>
</table>
# 7. Vehicles

- Electric/Hybrid Vehicles: 2% of 2-Ws, 10% of 3-Ws And 2% 4Ws wef January 2017
- Retro Fitment of Diesel Particulate Filter: wef July 2016
- Implementation of BS – VI: wef January 2019*
- Inspection/ Maintenance of Vehicles
- Ultra Low Sulphur Fuel (<10 PPM): wef January 2018

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing (kg/day)</th>
<th>Controlled (kg/day)</th>
<th>Mean Modeled Concentration (µg/m³)</th>
<th>Existing</th>
<th>Controlled</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM_{10}</td>
<td>12914</td>
<td>6453</td>
<td>38.0</td>
<td></td>
<td>18.5</td>
<td>51.3</td>
</tr>
<tr>
<td>PM_{2.5}</td>
<td>11623</td>
<td>5807</td>
<td>33.2</td>
<td></td>
<td>16.6</td>
<td>50.0</td>
</tr>
</tbody>
</table>
- **Introduction of Electric/Hybrid Vehicles:**
  - Introduction of electrical and hybrid vehicles by January 2017, 2% of 2-Ws, 10% of 3-Ws and 2% 4Ws will be electric/hybrid vehicles. There will be reduction of 2.3% in PM10 and PM2.5 emissions.
  - If we assume additional multiplier of 1.5 to electrical and hybrid vehicles by January 2017, there will be reduction of 4-5% of PM10 and PM2.5 emissions. Net improvement in air quality concentration by about 1-2 µg/m3.

- **Retro-fitment of Diesel Particulate Filter (DPF):**
  - Diesel Vehicles (entering and running on Delhi roads) should be equipped with DPF.
  - Reduction of 40% emission in PM may be achieved. This reduction in emission will reduce the ambient air concentration by 10 µg/m3.
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<tbody>
<tr>
<td>9/26/2018</td>
<td>8am-10am</td>
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<td>9/27/2018</td>
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<td>9/28/2018</td>
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<tr>
<td>9/29/2018</td>
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</tr>
</tbody>
</table>

**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
Implementation of BS – VI: wef January 2019

- Both PM and NOx emissions are expected to reduce
- Expected reduction in ambient air concentration is 2.4 μg/m³ for the introduction year (2019)
- The reduction in NOx emission will help in reducing secondary nitrates and will also prevent formation of ozone

Inspection/Maintenance of Vehicles

- Ensure that vehicles are properly maintained as per the recommendation of the manufacturer
- The automobiles manufacturing company owned service centers (AMCOSC) should be fully equipped for complete inspection and maintenance of vehicles ensuring vehicles conforming to emission norms and fuel economy after servicing

Ultra Low Sulphur Fuel (<10 PPM): wef January 2018

- Sulphur content in diesel should be brought down to 10 ppm or less by end of 2017
- Reduce PM emissions from vehicles by about 6 percent
8. Industries and Diesel Generator Sets

- Reduce sulphur content in Industrial Fuel (LDO, HSD) to less than 500 PPM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing (kg/day)</th>
<th>Controlled (kg/day)</th>
<th>Mean Modeled Concentration (µg/m³)</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM₁₀</td>
<td>1937</td>
<td>1355</td>
<td>4.7</td>
<td>30</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>1743</td>
<td>1220</td>
<td>3.9</td>
<td>30</td>
</tr>
</tbody>
</table>

- Sulphur Content (Present Day)
  - LDO = 18000 ppm; HSD = 10000 ppm
  - Expected PM control would be about 15 to 30 %.
  - DG sets of size 2 KVA or less should not be allowed to operate
9. Secondary Particles: Control of $\text{SO}_2$ and $\text{NO}_x$ 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Controlled (kg/day)</th>
<th>Mean Modeled Concentration ($\mu g/m^3$)</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Existing</td>
<td>Controlled</td>
</tr>
<tr>
<td>$\text{PM}_{10}$</td>
<td>132437 (SO2 emissions)</td>
<td>69.0</td>
<td>6.9</td>
</tr>
<tr>
<td>$\text{PM}_{2.5}$</td>
<td>38.5</td>
<td>3.9</td>
<td>90</td>
</tr>
<tr>
<td>$\text{PM}_{10}$</td>
<td>153349 (NOx emissions)</td>
<td>41.0</td>
<td>4.1</td>
</tr>
<tr>
<td>$\text{PM}_{2.5}$</td>
<td>25.2</td>
<td>2.5</td>
<td>90</td>
</tr>
</tbody>
</table>
10. Secondary Organic Aerosols

- Controlling Evaporative Loss during fuel unloading and Re-Fueling through Vapour Recovery System at petrol pumps

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean Modeled Concentration (µg/m³)</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Existing</td>
<td>Controlled</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>48.9</td>
<td>9.7</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>40.1</td>
<td>8.0</td>
</tr>
</tbody>
</table>

- The evaporative losses from solvent industries should also be minimized.
11. Biomass Burning

- Managing crop residue burning in Haryana, Punjab and other local biomass burning.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean Modeled Concentration (µg/m³)</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Existing</td>
<td>Controlled</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>97.0</td>
<td>9.7</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>84.0</td>
<td>8.4</td>
</tr>
</tbody>
</table>

- Biomass contribution in PM₁₀ in the month of November could be as high as 140 µg/m³ and about 120 µg/m³ for PM₂.₅ (mean of contribution in entire winter season: 97 µg/m³ and 86 µg/m³) respectively.

- In all likelihood, the PM from biomass burning is contributed from CRB prevalent in Punjab and Haryana in winter.
12. Fly Ash

- Control at other sources (hotels/restaurants and rapid mix plants, fly ash ponds etc)
- Install Wind Breaker at construction and fly ash pond sites.
- Keep fly ash pond moist and possibly maintained about 1mm of water layer over the entire fly ash pond

13. Control outside Delhi in NCR

- Control option should be implemented in NCR in similar manner as in Delhi
## Control Options, Emission Load and Reductions in NOx

<table>
<thead>
<tr>
<th>Source</th>
<th>Option No.</th>
<th>Description Option</th>
<th>Existing NO₂ (kg/day)</th>
<th>Controlled NO₂ (kg/day)</th>
<th>% Reduction in AP Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotels/Restaurants</td>
<td>1</td>
<td>Prohibit use of Coal</td>
<td>1103.0</td>
<td>502.5</td>
<td>54.4</td>
</tr>
<tr>
<td>Domestic Cooking</td>
<td>2</td>
<td>LPG to all</td>
<td>7682.0</td>
<td>7047.5</td>
<td>8.3</td>
</tr>
<tr>
<td>MSW Burning</td>
<td>3</td>
<td>Prohibit MSW burning</td>
<td>738.0</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Vehicles</strong></td>
<td>4.1</td>
<td>Electric/Hybrid Vehicles: 2% of 2-Ws, 10% of 3-Ws And 2% 4Ws Wef January 2017</td>
<td>113443.0</td>
<td>111264.0</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>4.2</td>
<td>Implementation of BS – VI : Wef January 2019</td>
<td>119607.0</td>
<td>116558.3</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>4.3</td>
<td>Inspection/ Maintenance of Vehicles</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>4.4</td>
<td>Ultra Low Sulphur Fuel (&lt;10 PPM): January 2018</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Power Plants</td>
<td>5.1</td>
<td>De-NOx-ing at Power Plants Within Delhi</td>
<td>161612.0</td>
<td>32322.4</td>
<td>80.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
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<td><strong>34</strong></td>
</tr>
</tbody>
</table>
## Action Plan for NCT of Delhi

### A. Immediate Actions

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

Note: for implementation year 2016 may begin from July 2016
Action Plan for NCT of Delhi

### B. Time-bound Actions

<table>
<thead>
<tr>
<th>Source</th>
<th>Option No.</th>
<th>Description Option</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020-2023</th>
<th>Percent improvement in AQ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicles</strong></td>
<td>7.1</td>
<td>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</td>
<td></td>
<td></td>
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<td></td>
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<td>50.0</td>
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<tr>
<td></td>
<td>7.2</td>
<td>Retrofitment of Diesel Particulate Filter: wef July 2018</td>
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<td></td>
<td>7.3</td>
<td>Implementation of BS – VI for all diesel vehicles including heavy duty vehicles (non-CNG buses and trucks) and LCVs (non-CNG): wef January 2019</td>
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<td></td>
<td>7.4</td>
<td>Inspection/ Maintenance of Vehicles</td>
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<tr>
<td></td>
<td>7.5</td>
<td>Ultra Low Sulphur Fuel (&lt;10 PPM); BS-VI compliant: wef January 2018</td>
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<td></td>
<td>7.6</td>
<td>2-Ws with Multi Point Fuel Injection (MPFI) system or equivalent: wef January 2019</td>
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<tr>
<td><strong>Industry and DG Sets</strong></td>
<td>8.1</td>
<td>Reduce sulphur content in Industrial Fuel (LDO, HSD) to less than 500 PPM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30.00</td>
<td></td>
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<td></td>
<td>8.2</td>
<td>Minimize uses, uninterrupted power supply, Banning 2-KVA or smaller DG sets</td>
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<td></td>
</tr>
<tr>
<td><strong>Secondary Particles</strong></td>
<td>9.1</td>
<td>De-SOx-ing at Power Plants within 300 km of Delhi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.2</td>
<td>De-NOx-ing at Power Plants within 300 km of Delhi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90.1</td>
<td></td>
</tr>
<tr>
<td><strong>Secondary Organic Aerosols</strong></td>
<td>10</td>
<td>Controlling Evaporative emissions: Vapour Recovery System at petrol pumps (Fuel unloading and dispensing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80.0</td>
<td></td>
</tr>
<tr>
<td><strong>Biomass Burning</strong></td>
<td>11</td>
<td>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</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90.0</td>
<td></td>
</tr>
<tr>
<td><strong>Fly Ash</strong></td>
<td>12</td>
<td>Wind Breaker, Water Spraying, plantation, reclamation</td>
<td></td>
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</tr>
</tbody>
</table>

Note: for implementation year 2016 may begin from July 2016
“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.”
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
• 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
   – Ground truthing