EXPERIENCE OF SOURCE APPORTIONMENT STUDY IN INDIA

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PRESENTATION OUTLINE

AIR QUALITY MANAGEMENT

BACKGROUND

- What have been done? – Actions
- What have been achieved? – Status
- Are we on the right track? – Emerging Issues

EXPERIENCE ON SOURCE APPORTIONMENT STUDY

- About Six City Project
  - Approach & Methodology
  - Results
  - Accomplishment
  - Way Forward

ACTIONS

REGULATORY PROVISIONS

- Air (Prevention & Control of Pollution) Act, 1981
- Environment (Protection) Act, 1986
- Revised National Ambient Air Quality Standards – 2009
  - ❖ Health consideration primary focus, Not based on land use, SPM omitted, 12 parameters including some of HAPs

INDUSTRIAL POLLUTION CONTROL

- Mandatory Environmental Clearance – Specified Projects; Central/State clearance based on type and size of projects
- Use of cleaner fuel – Beneficiated coal, NG for Fertilizer Plants

INDUSTRIAL POLLUTION CONTROL

- Emission Norms
  - ❖ Sector specific based on techno-economic considerations – over 75 industrial sectors
  - ❖ States can make it more stringent, if required
- Promotion of Cleaner Technologies – DCDA process for H_2SO_4 plants, Membrane Cell for caustic soda plants
- Environmental audit and statement
- Environmental Surveillance
- Identification of critically polluted areas based on Comprehensive Index (CEPI), and Implementation of action plans
- CREP, ISO certification – voluntary initiative

VEHICULAR POLLUTION CONTROL

- Improved fuel quality – Bharat Stage IV in major cities, Bharat Stage – III in rest of the country
- Alternate cleaner fuel (CNG/LPG)
- Progressive emission norms for vehicles
- Improvement in public transport system (Metro)
- Phasing out of old commercial vehicles
- Better traffic management – Restriction on goods vehicles during day time, Installation of time clocks at important crossings, Construction of more flyovers and subways and closing of T-Junctions, Regular information about traffic flow through radio

STRICTER NORMS FOR EMISSIONS FROM VEHICLES

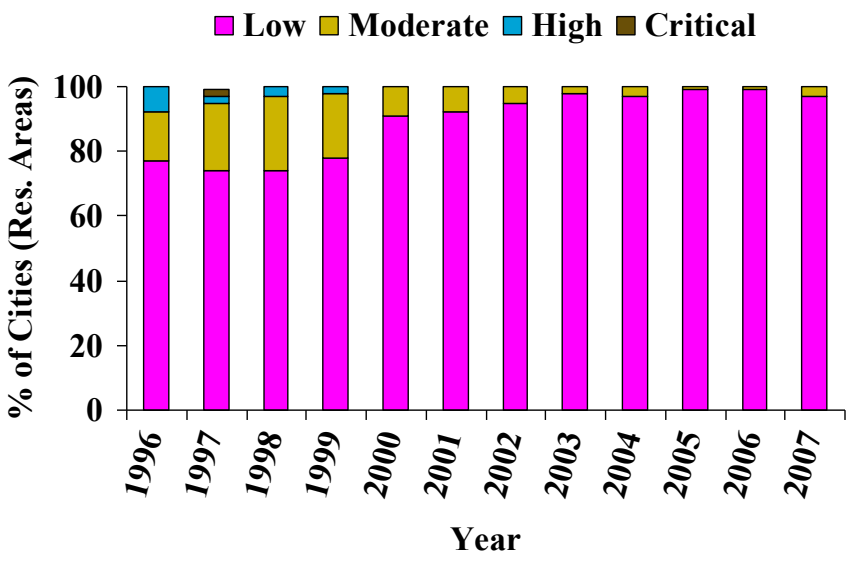
Norms	Year of Implementation
1996	1996
1998 (Cat. Convertor Norms)	1998
Bharat Stage I (Euro I)	1999
Bharat Stage II (Euro II)	2001
Bharat Stage III (Euro III)	2005
BharatStage IV (Euro IV)	2010

FUEL QUALITY IMPROVEMENT

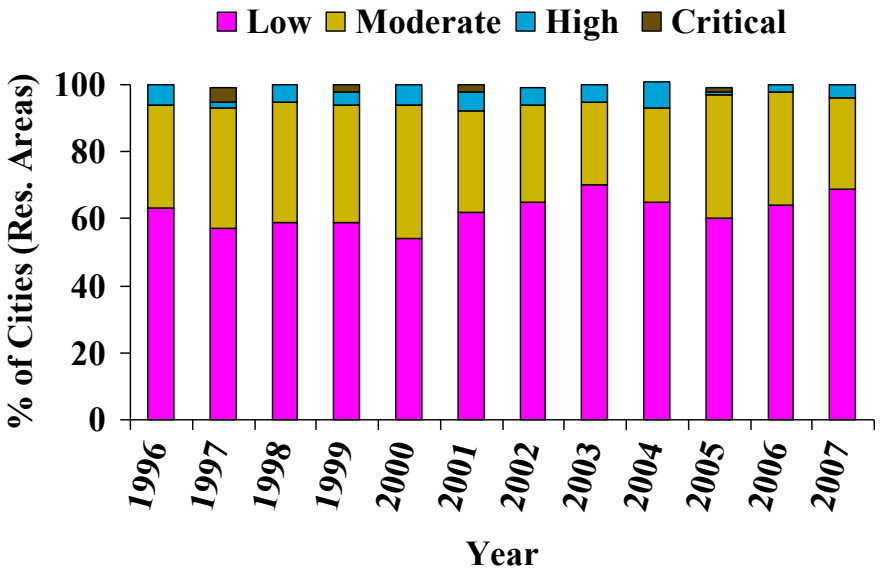
Norms	Year of Implementation
0.5% S – Diesel	1996
0.25% S – Diesel	2000
0.05% S – Diesel	2003
0.035% S – Diesel	2005
0.005% S – Diesel	2010
Unleaded Petrol	2000
Low Smokes 2 T oil	1998

AIR QUALITY STATUS

PERCENTAGE OF CITIES (RES. AREAS) WITH LOW, MODERATE, HIGH AND CRITICAL LEVELS OF SO_2 AND NO_2

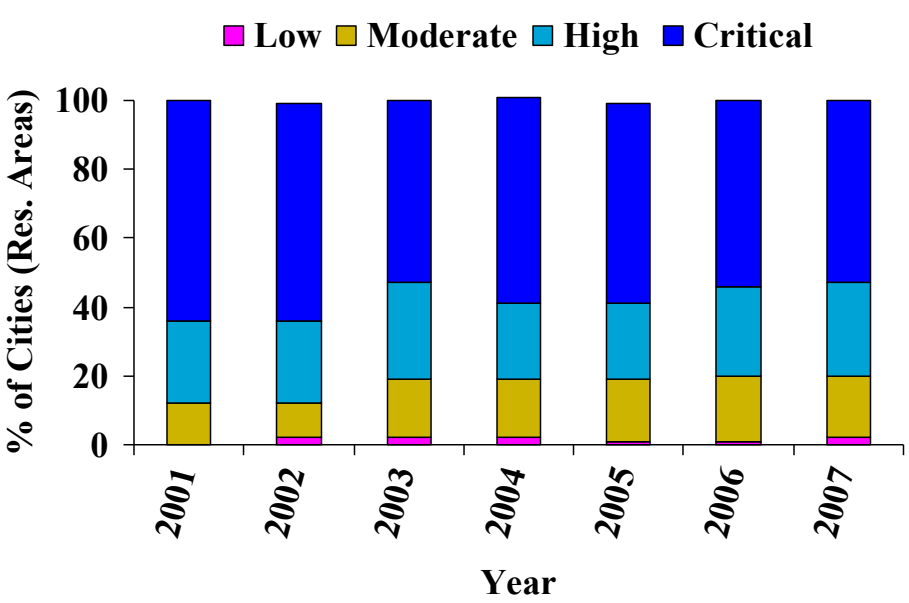


SO_2

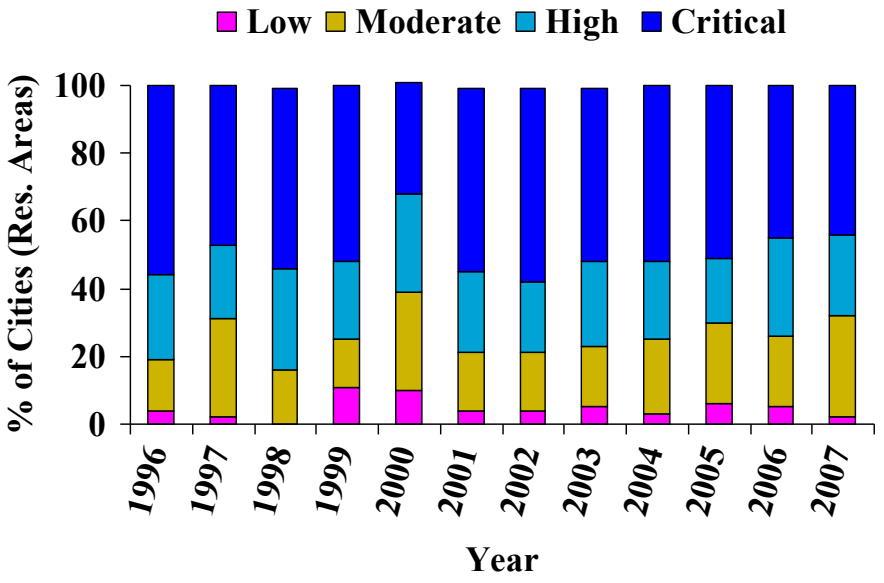


NO_2

PERCENTAGE OF CITIES (RES. AREAS) WITH LOW, MODERATE, HIGH AND CRITICAL LEVELS OF RSPM AND SPM

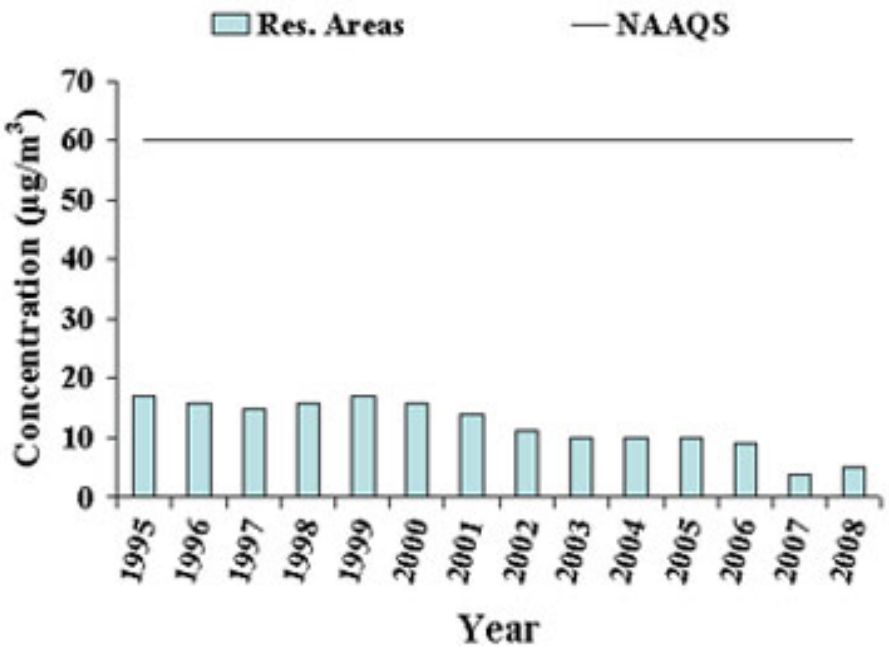


RSPM



SPM

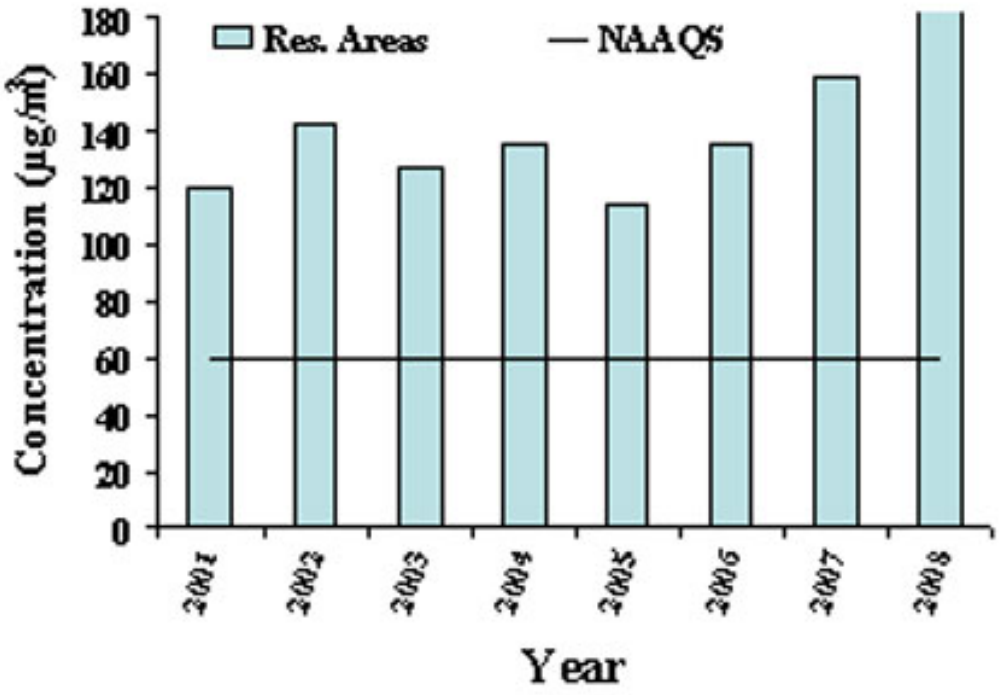
TRENDS OF SO_2 IN DELHI



Trends in Annual Average Concentration of SO_2 in residential areas of Delhi

SO_2 levels much lower than AAQS – Are SO_2 emissions really low? Formation of secondary particulates (SO_4^{--})?? Do we need to control SO_2 for reducing particulates??

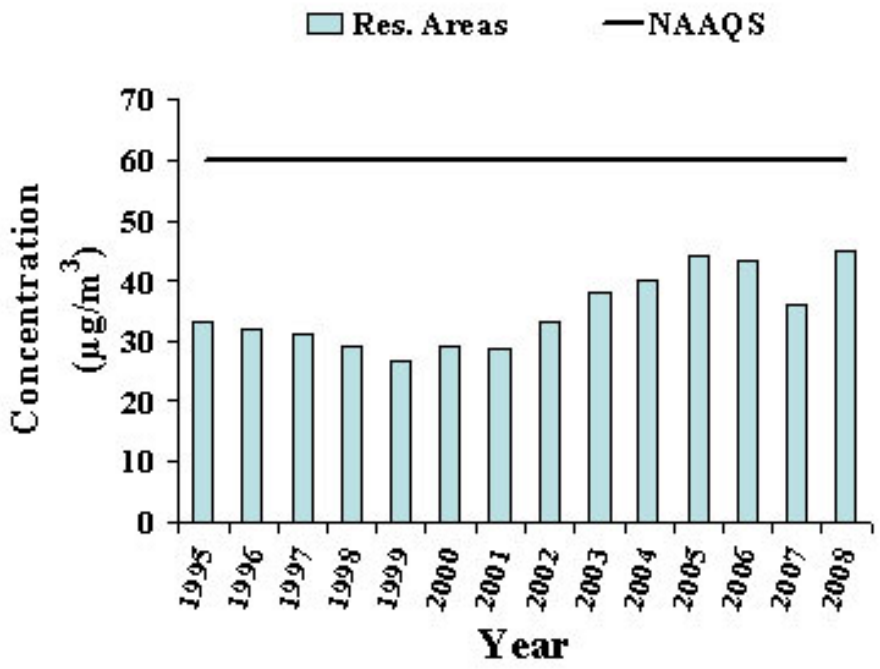
TRENDS OF RSPM IN DELHI



Trends in Annual Average Concentration of RSPM in residential areas of Delhi

Levels of particulates much above AAQS – Does increase in vehicle population offset effects of control measures? Contribution from other sources??

TRENDS OF NO_2 IN DELHI



Trends in Annual Average Concentration of NO_2 in residential areas of Delhi

NO_2 levels generally lower than AAQS but with clear increasing trends – What sources to be tackled on priority? Power plants, Gensets, Vehicles??

URBAN AIR QUALITY MANAGEMENT – EMERGING ISSUES ??

- Many actions – Desired results not achieved
  - WHO Estimates – 527,700 deaths in India every year due to air pollution
  - More than 75 towns are non-attainment areas with respect to PM
- Are actions based on appropriate scientific studies?
  - No detailed emission inventories in urban areas
  - Limited exposure assessment – focus on numbers, cost-effectiveness not considered
  - Reliance on measurements – integrated approach not followed earlier, limited use of models
  - Strategies often short-term

EMERGING ISSUES…..

- RSPM – critical pollutants in most the urban areas
- Complex problem – multiplicity and complexity of sources
- Information on air quality and source contribution crucial input for taking policy & investment decisions – application of modeling tools

SOURCE APPORTIONMENT

ABOUT SIX CITY SOURCE APPORTIONMENT STUDY

- **Challenging Task:** Comprehensive study, First study of this nature and extent, Multiple agencies
- **Project Cities:** Delhi, Mumbai, Chennai, Bangalore, Pune and Kanpur
- **Integrated Approach**
  - **Air quality measurements**
    - 07 locations covering different activity profiles
    - Seasonal variations
    - Parameters: PM_{10}, SO_2, NO_2, C_6H_6, O_3, $PM_{2.5}$, etc.
    - 1,00,000 samples analyzed
  - **Chemical speciation of PM_{10} and $PM_{2.5}$ (limited)**
    - 3000 samples analyzed for 36 elements, 11 ions, OC, EC and mol. markers representing typical urban sources

❖ Emission factors for vehicles

- Mass emission tests on in-use vehicles covering different technologies, types of vehicles, vintage, etc.
- 450 nos. of emission tests; 89 of vehicles; additional data of 96 vehicles under source profiling study.
- Expert Group critically examined the data and finalized EF.

❖ Emission factors for non-vehicular sources

- Identification of sources through primary surveys
- Review of information on reported emission factors and data on emissions.
- Uniform EF finalized by an Expert Group.

Emission inventory

- Detailed primary surveys within zone of influence (2x2-km grids)
  - Identification of significant sources
  - Collection of primary data on activity levels
  - city-level projections based on land use and EI for monitoring grids
- Traffic count surveys
  - Different categories of roads
  - Parking lot/petrol pump surveys for obtaining data on vintage, fuel use, VKT per day
  - Video recording
- Future projections considering developmental plans, changes in the land-use and activities and/or activity levels
- BAU – 2007, 2012 and 2017

❖ Source emission profiles

- 54 stationary and 13 vehicle sources
- Sources identified based on primary surveys in the cities
- Categorized based on their nature (combustion or non-combustion) and occurrence (city specific or common to all cities) – CC, CCS, NCC, NCS
- Sampling was done depending on source type – all the cities/one city/lab simulation
- Sampling methodologies – Dilution sampling for combustion sources, re-suspension sampling for dust sources, and source dominated sampling for area sources.
- Total 192 mass emission tests on 96 vehicles (2 tests on each vehicle)
- Detailed chemical analysis similar to ambient air samples

- **Source Apportionment**
  - **PM_{10} and $PM_{2.5}$ (limited)**
  - **Mass Closure – concentration of signature elements**
  - **Chemical speciation data and profiles were used**
  - **CMB model was run for each location for each day of sampling (at the location) for three seasons**
  - **Source contribution estimates for individual daily samples for a site in a season were averaged to calculate source contribution to that site for that season**
- **Evaluation of control strategies – dispersion modeling**

❖ Formulation of action plan

- Identification of prominent sources based on CMB-8, EI
- Each potential control option evaluated for assessing efficacy, feasibility and broad economic analysis
- BAU and Controlled scenarios generated for 2012 and 2017
- Combination of options (3 – 4 scenarios) were evaluated using dispersion model
- Most appropriate scenario – formulation of Action Plan

QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

- Participating institutes, being reputed scientific institutions, were responsible for ensuring QA/QC
- SOPs were developed – complete description of the measurement process
- Study design was presented in the Asian Aerosol Conference, held in Mumbai in 2005; reviewed by International expert from Germany.
- Uniformity in monitoring and analysis methodology.
- Surveys for siting of appropriate monitoring location.
- Training of field and analytical staff by International experts.

AIR POLLUTION LEVELS (µg/m^3) AND PERCENT EXCEEDANCE

		SPM						PM_{10}						$PM_{2.5}$					
		W*		P**		S***		W		P		S		W		P		S	
		Mean	%E	Mean	%E	Mean	%E	Mean	%E	Mean	%E	Mean	%E	Mean	%E	Mean	%E	Mean	%E
Background	Bangalore	110	0	82	0	83	0	47	0	105	32	66	10	27	0	23	0	27	0
	Chennai	117	17	76	0	178	22	55	0	88	50	71	31	35	14	39	0	34	14
	Delhi	549	100	546	100	517	100	355	100	300	100	232	100	--	--	--	--	131	100
	Kanpur	361	100	329	93	342	97	204	97	169	97	187	90	172	100	132	100	136	100
	Mumbai	246	63	204	57	159	17	184	97	139	86	91	39	92	67	60	33	29	0
	Pune	257	95	204	65	139	5	123	60	63	5	76	10	45	0	32	0	22	0
Residential	Bangalore	294	100	301	100	177	25	133	88	93	35	69	14	36	0	41	33	29	0
	Chennai	164	19	173	14	175	24	82	25	200	46	86	23	78	86	34	0	34	0
	Delhi	828	100	967	100	284	90	505	100	671	100	81	40	301	100	--	--	30	0
	Kanpur	429	100	373	97	422	100	226	100	195	100	217	100	208	100	161	100	190	100
	Mumbai	523	100	445	100	277	54	267	100	236	100	119	48	97	100	87	100	54	33
	Pune	499	100	362	95	206	50	165	95	128	72	103	58	58	0	35	0	28	0
Industrial	Bangalore	262	0	245	0	171	0	171	81	171	50	69	5	30	0	21	0	22	0
	Chennai	311	8	348	11	319	5	138	31	147	44	141	38	67	57	41	0	79	30
	Delhi	965	100	1239	100	611	70	546	100	781	100	229	8	197	100	314	100	52	100
	Kanpur	603	62	577	58	591	61	396	76	371	74	388	74	305	100	273	100	232	100
	Mumbai	395	3	388	0	238	3	271	100	218	96	99	7	127	100	87	100	17	0
	Pune	400	25	164	0	270	0	216	85	71	10	121	22	63	33	26	0	37	0
Kerbside	Bangalore	306	100	287	93	411	100	199	100	184	85	109	43	64	50	43	33	38	0
	Chennai	350	78	243	59	211	36	111	48	128	77	271	67	73	57	56	29	51	14
	Delhi	1082	100	2592	100	#####	100	451	100	941	100	337	100	306	100	361	100	107	100
	Kanpur	564	100	532	100	561	100	292	100	260	100	273	100	216	100	226	100	218	100
	Mumbai	383	100	383	100	314	8	256	100	234	100	124	65	119	100	126	100	41	18
	Pune	655	100	583	100	507	100	254	100	193	95	138	95	124	100	62	67	46	0

% Exceedance

0-25	25-50	50-75	75-100

* W: Winter
** P: Post Monsoon, Summer in case of Bangalore
*** S: Summer, Pre Monsoon in case of Bangalore

AIR POLLUTION LEVELS (µg/m^3) AND PERCENT EXCEEDANCE

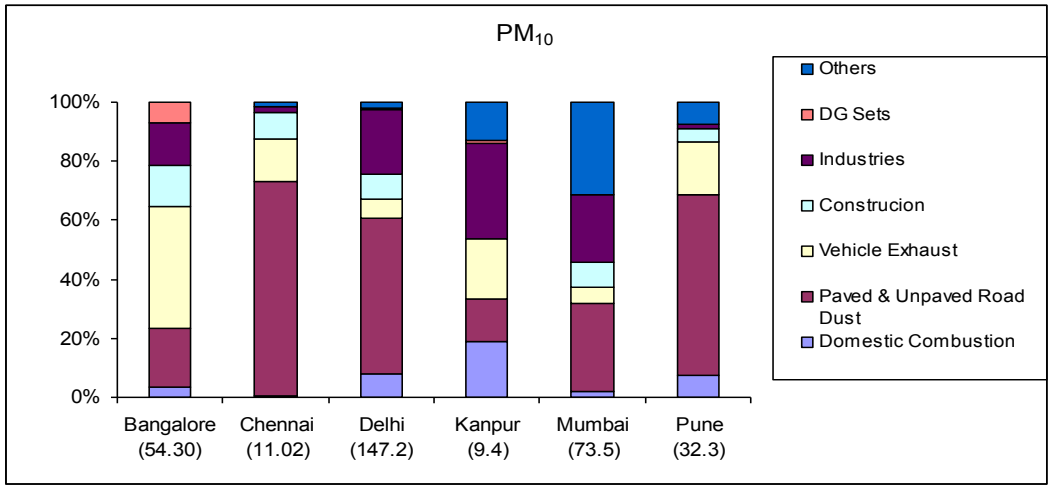
		NO_x						SO_2					
		W		P		S		W		P		S	
		Mean	%E	Mean	%E	Mean	%E	Mean	%E	Mean	%E	Mean	%E
Background	Bangalore	18	0	45	18	91	56	6	0	14	0	9	0
	Chennai	27	0	8	0	14	0	3	0	1	0	5	0
	Delhi	31	0	33	0	25	0	8	0	15	0	8	0
	Kanpur	23	0	20	0	20	0	8	0	8	0	4	0
	Mumbai	53	10	38	0	18	3	15	0	13	0	5	0
	Pune	36	0	34	0	10	0	23	0	10	0	5	0
Residential	Bangalore	46	0	29	0	90	46	9	0	15	0	15	0
	Chennai	32	0	17	0	28	0	4	0	3	0	3	0
→	Delhi	73	35	88	65	29	0	14	0	18	0	78	0
	Kanpur	49	0	32	3	19	0	14	0	8	0	4	0
	Mumbai	72	25	60	7	25	0	12	0	13	0	6	0
	Pune	41	6	43	0	14	0	18	0	11	0	6	0
Industrial	Bangalore	53	6	30	0	89	44	9	0	10	0	10	0
→	Chennai	45	0	20	0	42	0	6	0	4	0	6	0
	Delhi	159	85	142	80	60	0	85	20	77	20	11	0
	Kanpur	35	0	24	0	23	0	26	0	19	0	15	0
	Mumbai	72	0	53	0	20	0	18	0	15	0	7	0
	Pune	55	0	17	0	22	0	40	0	16	0	22	0
Kerbside →	Bangalore	94	62	105	65	66	26	10	0	19	0	13	0
	Chennai	45	0	33	0	43	0	6	0	1	0	4	0
→	Delhi	109	85	121	95	47	0	20	0	20	0	12	0
	Kanpur	46	0	42	7	37	0	15	0	9	0	8	0
→	Mumbai	82	43	64	20	33	2	14	0	15	0	6	0
→	Pune	71	50	43	0	59	20	36	7	12	0	7	0

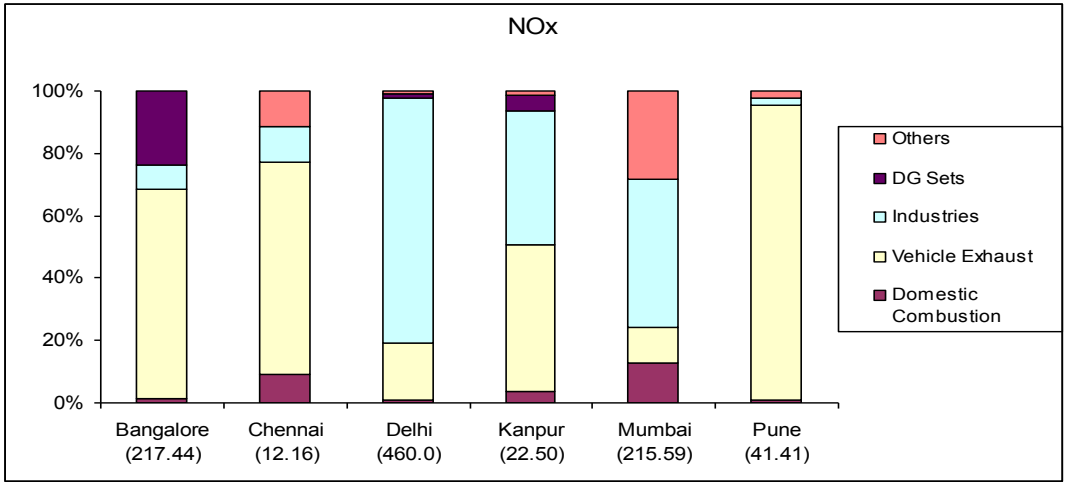
% Exceedance

0-25	25-50	50-75	75-100

* W: Winter
** P: Post Monsoon, Summer in case of Bangalore
*** S: Summer, Pre Monsoon in case of Bangalore

EMISSION INVENTORY





PM_{10}:

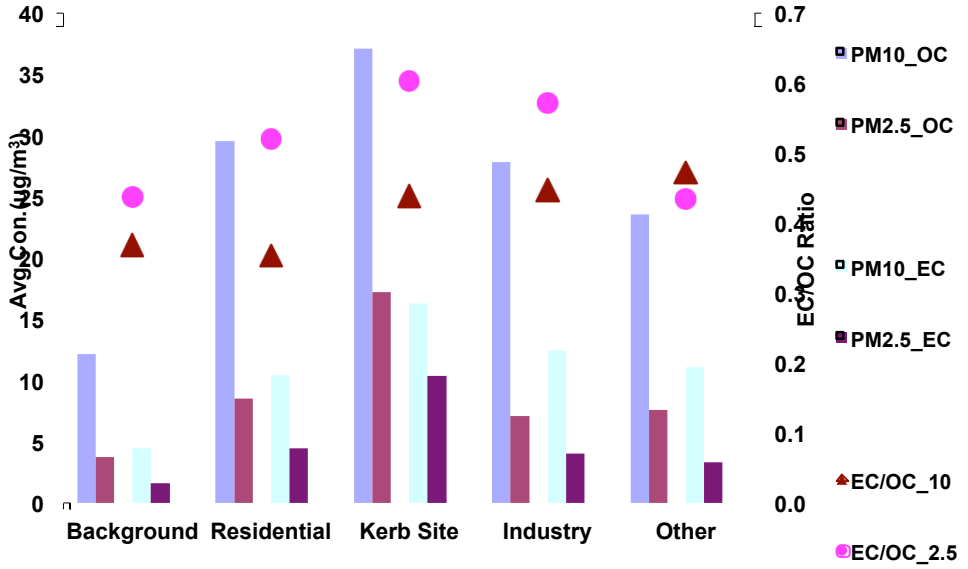
- **Major Source – Road dust re-suspension**
- **Significant contribution of industries in Kanpur, Mumbai and Delhi**

NO_x:

- **Vehicles are major source**
- **Contribution of industries (power plants) high in Delhi, Mumbai and Kanpur**

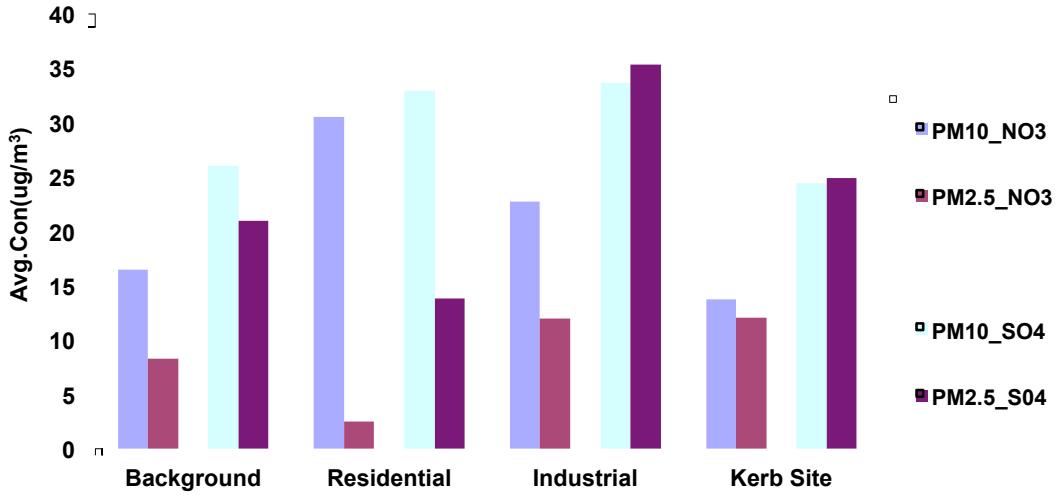
Important observation: A few prominent sources in a city can mask the contribution of the other sources.

CHEMICAL CHARACTERIZATION OF PM: EC, OC, EC/OC



- EC and OC: 20 – 45% of PM_{10}, indicating effect of combustion/fuel related emissions.
- High EC/OC represents freshly contributed diesel/combustion particles
- EC/OC: less in PM_{10} than $PM_{2.5}$ indicating EC dominance in finer fractions
- Higher EC/OC at Kerbside indicate contribution of vehicular sources.

CHEMICAL CHARACTERIZATION OF PM: SO_4^{-2}/NO_3^-



- Significant quantities of SO_4^{-2} and NO_3^- : contribution of secondary particles
- Control strategy for reduction of secondary particulate will have to consider control of SO_2, NO_x and NH_3

PM_{10} SOURCE CONTRIBUTIONS: ALL LOCATIONS

City	Bangalore	Chennai	Delhi	Kanpur	Mumbai	Pune
Sources						
Roadside Dust	45 – 55	6 – 27	14 – 29	7 – 9	29 – 47	49 – 64
Vehicles	10 – 22	35 – 48	9 – 20	15 – 17	8 – 26	2 – 10
Industries	27	-	6 – 9	2 – 19	1 – 7	-
Construction	-	-	23	-	28 – 46	6 – 28
Secondary Particulates	2 – 11	-	-	16 – 19	10 – 21	-
LPG/Domestic	-	4 – 20	3 – 9	15 – 26	3 – 18	-
DG Sets	7 – 18	14 – 16	7 – 12	5 – 8	-	3 – 4

Roadside dust and vehicles are prominent sources in all the six cities

OUTCOME

- City-specific Action Plans
- Sector Specific Strategies at National Level
- Standard methodology for UAQM established
- Provided most needed scientific basis, evidence and insight to urban air quality issues.
- Useful database on various air quality parameters.
- Technical competence, experience and capacity building in terms of infrastructure as well as trained manpower.
- Refined EF for vehicular exhaust emissions
- More reliable EI
- Source emission profiles
- Cohesive Group of Expert Institutions

WAY FORWARD

- Implementation of Study Findings
- Simpler and quicker methodology
- Use of better available models such as AERMOD
- Strengthening Molecular markers analysis
- More studies on secondary particulates
- Include Exposure Assessment in the process
- Capacity Building

Thank You