

Emission Inventory and Source Apportionment in Indian Cities

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Understanding of Air Quality In India

Major emphasis on emission loads

Visible pollution considered the major issue

Earlier : industries

Now: vehicles

Apparent health impacts : Aggravation of asthma

Indian Background

First emission law for ambient air was promulgated in the year 1905, called Bengal Smoke Nuisance Act.

First major source inventory was prepared for Mumbai (Bombay) in 1968 by NEERI. Later it prepared emission inventory for three cities (Bombay, Calcutta and Delhi) in the year 1990

Industrial stack dispersion studies started sometime in early 80's,

PM10 aerosols at Chembur, Bombay - S.Sadasivan 199

Why Source apportionment

NEED TO UNDERSTAND SOURCES

When regulatory levels are exceeded: investigations required for sources

- Important to know the possible sources
- Identify potential sources and meteorological conditions to assist policy makers and modelers in developing control strategies
- Plan to know how long the present emission inventories and dispersion models represent the ambient conditions which can be used for prediction and control strategies for future
- Action Plan development for all the principal contributors to air pollution
- Cost effectiveness of control plan for each of the sources

IMPORTANT TO KNOW: LOCAL VS. OUTSIDER

- For strategies development, decision maker must know which pollutants set (group) as well as its corresponding quantities belongs to his area.
- Multiple Techniques for assessing the difference:
 - **Spatial and temporal analyses (e.g., Are high concentrations observed on a regional basis or only at a few “hot spots”?).**
 - **Assessing the age of an air mass accompanied with trajectory analysis.**
 - **The use of “tracers-of-opportunity” and species ratios accompanied with trajectory analysis (e.g., using potassium to identify forest fire impact).**
 - **The use of satellite information to corroborate transport (e.g., Saharan dust storm impact on U.S. sites).**
 - **Model the dependence of PM on ozone to determine a component of PM that is photochemically produced.**

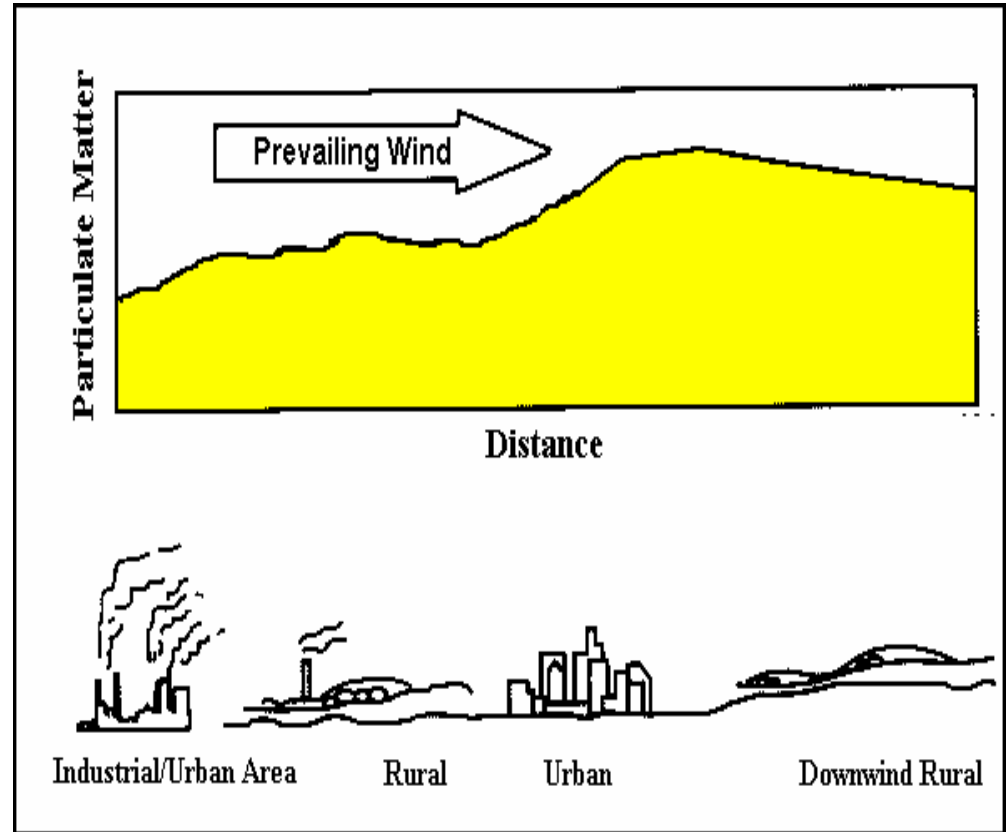
Source: Schichtel B.A.(1999)http://capita.wustl.edu/capita/capitareports/PMFineAn/PM_vs_Trn/finalreport/BltPhx_PMvsWnd_FinalReport.html

UNDERSTANDING LOCAL AND OUTSIDE SOURCE Particulate Matter

- Assess the differences between the concentrations of average urban and nearby rural monitoring data.
- Conduct preliminary modelling exercise to assess the PM dependence on wind speed and wind direction to understand the site characteristics (local/outside)
- Some developed countries are preparing “regional background” profiles to assist in apportioning PM. These profiles could be used in an attempt to quantify the regional contribution to PM concentrations. (Schichtel B.A.;1999)
- **It has been noticed that sites are strongly influenced by sources less than 10 km distance**
- **On the other hand even minor sources close to the sampler could overwhelm any outside component in a 24-hr integrated sample (VanCuren, 1998).**
- **However, individual small emitters can have a zone of influence less than 1 km (e.g., Chow et al., 1999).**

Discerning Local vs. Outside Factors

- Each site has its own changing background : understand the logic
- Influence of wind speed on local concentrations
- PM 2.5 levels at rural sites of Rajasthan : effect of surface wind ??
- PM 2.5 levels at upwind sites outside Delhi and inside Delhi : Effect of surface wind
- Seasonal Urban-urban and Rural-rural Difference



Schichtel (1999b)

Source Apportionment

- Source apportionment in India poses many daunting questions.
- Particularly in urban centres, many of these places are actually mixture of industrial, commercial, village, slum and high transport activities.
- All of these activities have diverse sources and therefore, complex emission characteristics.

The First Step ?

Towards SA is Emission Inventory:

- sources of the criteria pollutants,
- amount of each pollutant emitted,
- any processes or control devices utilized

Needs of Emission Inventory:

- quantifying the sources with a view to know the locations and assess the impact on human health

Source apportionment require addressing following issues :

- Major problem is to identify all the possible sources such as:
 - cow dung burning,
 - waste (of various types) burning,
 - resuspended dust (of various types),
 - unorganized small scale industries,
 - varying degree of many of such activities,
 - addition of new sources etc.
- Emission profiles of all these sources
- Picking up of some of these sources and their emission factor from USEPA (AP-42, AIR Chief)
- Methodologies of data generation
- Analysis of parameters such as BC and EC/OC as per international norms

The Second Step: Emission Factor

What do we have?

- Emission factor of all the sources (at least the major sources) [some improvement in place]
- Uncertainty in emission factor of major source in urban centres: vehicular, resuspension, biomass/refuse burning, gen-sets etc.
- India still has large numbers of vintage technology vehicles, two and three wheelers, other types of utility vehicles.

Emission Factor (Contd...)

Indian vehicle emission factors are not available for certain vehicle types: particulate matter are not available as shown below :

Vehicle Category	Indian Institute of Petroleum (IIP)	W. B. Literature
Two-Wheelers	-	0.21
Three-Wheelers	-	2.1
Cars/Taxis	-	0.27
Four Wheelers	-	-
Urban Buses	0.275	-
Trucks	0.450	3
Light Commercial Vehicles	0.100	3

All values are g/km. The petrol four wheelers no PM emission factor is available. The World Bank literature refers to some estimates used in a study carried out in Dhaka, Bangladesh

Currently obtained EF, under Six City Study (source CPCB website)

- We now have numbers from all types of vehicles
- These are for different fuel specs
- EF also for different vintage
- Some issues of numbers of data points and validity of driving cycle still remains

Dispersion Modelling

- Limited work carried out: mainly for point sources
- Large scale models not yet applied (MM 5, UAM etc.)
- Low scale models: kerb-side data recently started
- Problems of data and meteorology for each of the sites
- Low cost portable met station

Development Planning

- Urban planning based on air quality goals
- Damage control planning based on air quality standards
- Health based linkages for urban air quality improvement and study to establish the correlation

YET TO TAKE OFF!!!

Source Apportionment: How We Move ahead?

- Limited Data Availability
- Limited Need ??
- Larger view to take abatement decision

Indian Situation

- SPM values for developed countries are normally less than $100 \mu\text{g}/\text{m}^3$
(Rojas et al 1990,
Camuffe & Bernardi, 1996)
- India has annual averages : $200 - 500 \mu\text{g}/\text{m}^3$
(Sadasivan & Negi, 1990
Sharma & Patil, 1992,
NEERI NAAQM Data)
- No source composition available
(Sharma & Patil, 1994)

International Studies

- Thurston and Spengler, 1985
 - Quantitative information for apportionment of PM could be found based on characteristics of particulate matter with minimum information about the sources
 - Assessed the air quality on a regional scale for fine ($<2.5 \mu\text{m}$) and coarse ($2.5\text{-}15 \mu\text{m}$) fractions
 - Identified a fugitive source (coal combustion aerosols transported in the area) which accounted for 40% of the mass

International Studies

- Chan *et al.*, (2000)
 - PM mass (42%) related to elements from natural sources found in $>2.7 \mu\text{m}$ size range
 - PM mass (41%) related to human activities found in $<0.5 \mu\text{m}$ size range
 - The soil and sea salt factors contribute more than 80% of the mass of the $>2.7 \mu\text{m}$ aerosol samples, while the organics and vehicular exhaust factors explained 95% of the mass of the $<0.61 \mu\text{m}$ aerosol samples

India Specific Studies

- Sadasivan *et al.* (1984); Negi *et al.* (1987 and 1988), Sadasivan and Negi (1990)
 - Crustal source as the major source of PM has been reported
 - Sampling was done using a vacuum pump with a filter mounted on it

India Specific Studies

- Sharma and Patil (1992 and 1994)
 - PM < 30 μ m using a high volume sampler
 - Factor analysis of the elemental and ionic concentration data resulted in the identification of seven source types
 - Crustal and marine sources were identified as the highest contributor

India Specific Studies

- Kumar *et al.* (2001)
 - Sampled SPM at two traffic junctions in Mumbai, representing a mixed industrial, vehicular and residential site
 - Road dust and vehicular emissions were found to contribute 40% and 15% to the SPM

Source Apportionment at Traffic Junction

- Quantitative factor analysis – multiple regression Model indicated

	<u>Sakinaka</u>	<u>Gandhi Nagar</u>
- Road dust :	41%	33%
- Vehicle emission :	15%	18%
- Marine aerosol :	15%	15%
- Metal industries :	06%	08%
- Coal combustion :	06%	11%

Source Apportionment at Traffic Junction (Contd...)

Due to limitations in source marker elements analysed, about 16% of SPM could not be apportioned.

Observed Pb, about 62%	-	Automobiles
17%	-	Road Dust
11%	-	Metal Industries
07%	-	Coal Combustion
03%	-	Marine Aerosol

India Specific Studies

- NEERI, PMRAP studies 2004
 - SPM and PM₁₀ were measured at various locations in Mumbai
 - Diesel and gasoline vehicle exhaust emissions accounted for 6% to 54% of PM₁₀ at different locations
 - Industrial sources accounted for 6% to 42% of PM₁₀ at these sites
 - Other sources were identified as resuspended dust (10% - 20%) and marine aerosols (12% - 14%)

Kanpur Source Apportionment Study

- Study carried out for a limited period
- Major Outputs:
 - Automobile contribute in the range of 16-39%
 - Resuspended dust ranged 20-31%
 - Other identifiable sources (earth crust, secondary aerosols) : 6-12%
 - Industries : 8-16 %

Major outputs : Kanpur

- The method of using factor analysis did not lead to identification of about 24-29% of the sources
- Industrial sites were necessarily not impacted by the industries
- Impact of automobile and diesel gensets were felt more in residential areas than even kerbside

Limited information collected only for PM 10 necessarily is not providing the details as fine particles (PM2.5) if monitored can be easily correlated with some sources easily (Vehicle and Diesel gen-sets)

Principal Component Analysis

- PCA can be used without the source profile composition
- **It can be used to identify the missing sources**
- **It can use tracers which are somewhat reactive**
- However, it needs large number of receptor samples and also know how many factors to retain
- Use your own judgment to identify the factors responsible for the respective sources
- It can give negative values that cannot be accounted for any source

Positive Matrix Factorization

- Modelling using PMF for source apportionment is comparatively new
- PMF is a multivariate modelling, where the source profiles are not needed
- It identifies factors and their sources at a place
- It does not lead to negative values of chemical components unlike PCA
- It can also handle missing or very low values in the input data as also the uncertainties in input measurements

Example of PMF : Yakovleva et al. 1999, Env.Sc.&Tech. 33, pp.3645

Use of CMB in India

- Sharma et al (1992-93) used CMB 7 for a limited area in Mumbai
- Source profile from the Source Composition Libraries of USEPA Profile
- Based on known profile of Bombay, sources selected were: vehicles, combustion processes (industrial and others), resuspended dust, sea salt, ferrous and non-ferrous industrial sources

Major outcome of CMB

- It could identify the major sources at all the sites
- When used in combination with molecular marker, it can provide some additional information about sources.
- Accounting of secondary aerosol possible
- Knowing nearby sources alone is not good enough

Advantages and Disadvantages of CMB

- Suitable for single receptors
- Specific identification of well known sources
- Trace metals and ionic species can be used
- Even stable organic tracer can be used

- Need to have complete composition of sources
- Can not have missing sources
- Non-reactive sources/tracers
- Problems of collinear Sources

What are the problems

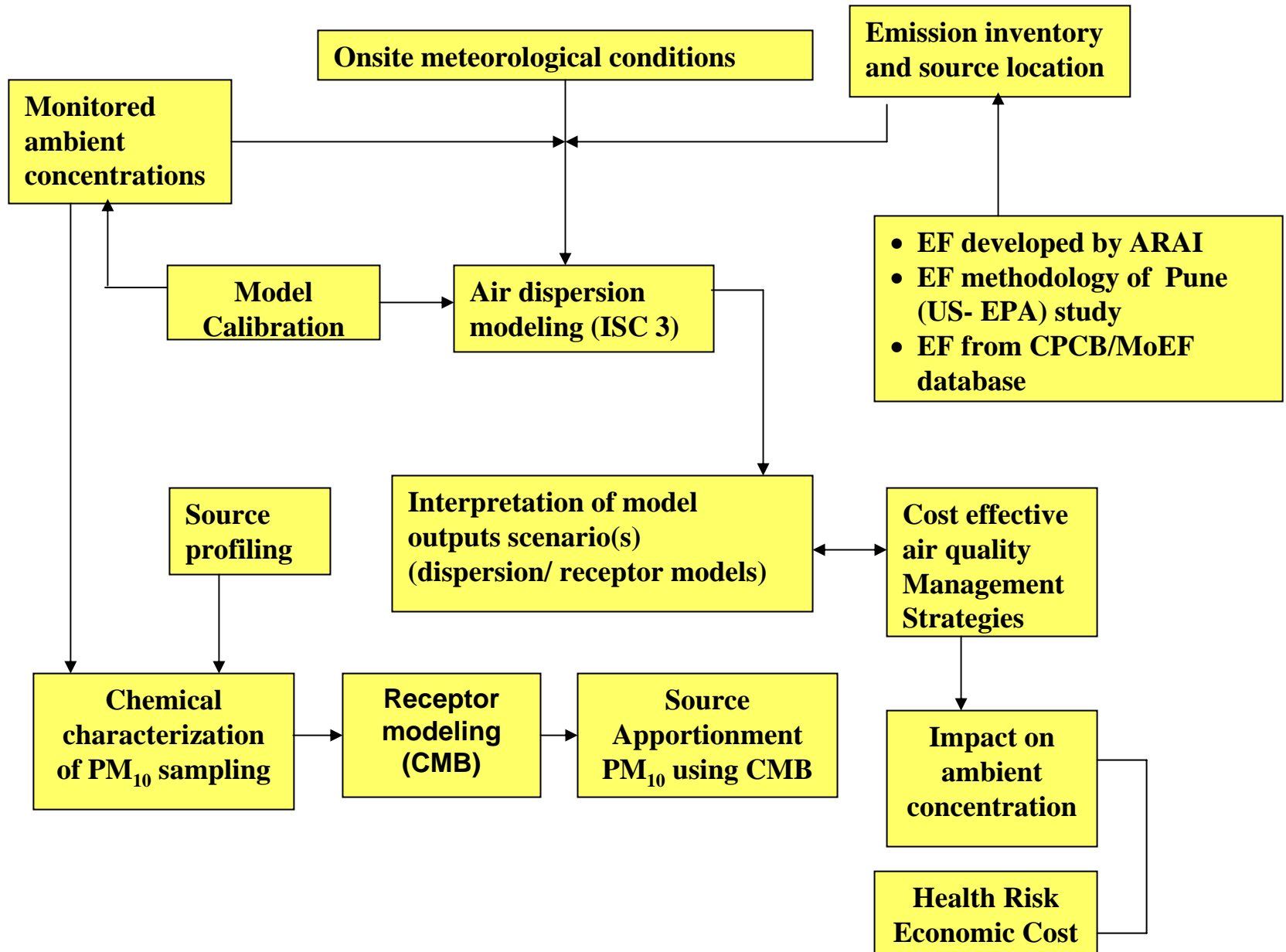
Though receptor modelling appears a better option some of the major issues are:

- Limited locations and their results are not/ may not be representative for the whole city
- Highly data intensive exercise (large sets of data, large numbers of variables: better results)
- Large issues of QA/QC of such data generation

Emission Inventory and Source Apportionment Initiative : MOEF/CPCB- for Six Cities

- Emission Inventory
- Air quality Monitoring of all major and important parameters
- Receptor Modelling using FA/PMF and CMB 8
- Dispersion Modelling for Scenario generation
- Action Plan and Prioritization

STUDY FRAMEWORK



What new knowledge has been added recently!!

- Emission factors for vehicles of different vintage and fuel [issue of number, driving cycle remains]
- Source profiles of many local sources including vehicles [markers data improvement]
- Relatively better inventory for sources [first time estimates of re-suspended dust, ports and airport, refuse and biomass burning, DG sets etc.]
- CMB application in many cities

Action Plan

❖ Vehicular Source

- ❖ **Reducing Emissions per Unit of Fuel**
 - ❖ **Fuel Quality Improvement**
 - ❖ **Installation of after treatment devices**
 - ❖ **Tackle fuel adulteration**
 - ❖ **Use of alternative fuels**
 - ❖ **Renewal of vehicle fleet**
 - ❖ **Improve traffic flow**
 - ❖ **Reduce dust re-suspension**
- ❖ **Reducing Fuel Consumption per unit Distance**
 - ❖ **Change to better technology engines**
 - ❖ **Improve vehicle I&M**
 - ❖ **Better road maintenance**
- ❖ **Reduce Vehicle Distance Traveled**
 - ❖ **Increase private vehicle occupancy**
 - ❖ **Promote better and more public transport**
 - ❖ **Demand management (parking)**
 - ❖ **Encourage non motorized transport**

Action Plan (Contd..)

❖ Point Source

- ❖ **Emission Reduction per unit Fuel Used**
 - ❖ **S reduction / Ash content in fuel**
 - ❖ **Combustion Processes**
 - ❖ **Alternate Fuel**

- ❖ **Emission Reduction by Industrial Policy and Standards**
 - ❖ **Promoting Cleaner Industries**
 - ❖ **Location Specific emission Reduction**
 - ❖ **Fugitive Emission control**

Action Plan (Contd..)

❖ Area Source

- ❖ **Mixed sources and varied strategies**
 - ❖ **Improve fuel used for domestic purposes (LPG/PNG)**
 - ❖ **Bakeries /crematoria (Wood base to Electric /LPG)**
 - ❖ **Biomass/trash burning (Better control, collection, disposal)**
 - ❖ **Resuspension (better paved roads, regular sweeping and spray of water)**
 - ❖ **Illegal SSI (Control on operation and their contribution)**
 - ❖ **Construction (Better practices of digging, demolition and vehicle movement)**

Problems Specific to India in the use of Source Apportionment Techniques

- Large scale data collection and its updating a mammoth task
- Source profiling is most difficult in India:
 - Shifting industrial practices
 - Changing land use pattern
 - Changes in diffused source combustion etc.
- Lack of resources
- Single/multiple agency for data generation

Possible pathways for Source Apportionment Study plan

- **Crustal PM contributes to the mass by virtue of its size, and masks the contribution of anthropogenic (toxic) PM in the near 1.0 μm size range**
- **Perception as well as some SA studies in India suggests that background (many times outside) PM need careful assessment before complex and expensive action plans are adopted**
- **We must not forget NO_x as a major source impacting the air quality all across the country in quest of elusive PM !!!!!!!!!!!**

Possible Solutions

- Need based data collection (e.g. meat cooking data may not be relevant)
- Emission factor to be developed (dependence on US-EPA should be reduced)
- Source profiles for some major activities need development (resuspended dust, refuse burning, etc) to be developed
- Link the data collection with census activities (may be every 5 years)

Realistic Expectations Researcher

- Complete understanding of all the sources within the city, region, country and elsewhere
- Carry out programmes which also support the expectations of the local/national policy maker (CNG/Diesel ??)
- Effective validated models for forecasting and continuous upgraded system
- **More stronger linkages with MET researcher for effective outputs**

Realistic Expectations Public

- Realistic goals:
 - what level of pollution reduction is achievable?
 - what level of pollution reduction is acceptable?
 - The answers to all these have to come from a combined team of :
 - Air pollution specialist
 - Health experts
 - Environmental economist ,
 - Policy makers
- and

PUBLIC

Realistic Expectations Policy Makers

- What areas of air pollution will make the biggest Impact ?
 - PM, Visual aspects, SO₂, NO_x, Ozone, etc.
- Which method or combinations will show immediate improvement ?
- How much will it cost?
- Will it have mass appeal?

Finally

- Air quality improvement have been seen in Indian Cities.
- Poor quantification and credible reporting
- One sided success stories
- Limited research and policy intervention success stories
- Air quality studies highly biased for Transport sector
- Many simpler policies may reduce PM emissions to greater extent.
- We must not forget NO_x issue along with VOCs which are showing increase.