Department of Environment
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Norwegian Institute for
Air Research

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Seminar on
Source Apportionment Methods

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Steinar Larssen

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Seminar on Source Apportionment Methods

1 Introduction

As part on NILU's Mission 2 to Dhaka during 6 – 17 March, 2006 under the Air Quality Management Project contract with the World Bank, seminars were held on Source Apportionment (SA) Methods.

These are methods that enable to estimate the contributions to air pollution concentrations from categories of source sin the area under investigation. There are 2 main types of SA methods:

- Those based upon dispersion models, which use source emission inventories as a basis.
- Those based upon receptor models, which use intensive chemical analysis of samples of pollution measured at monitoring stations (at "receptor points").

Receptor modelling methods have been applied for cities in Bangladesh by the group of Begum and Biswas at the Bangladesh Atom Energy Centre (BAEC).

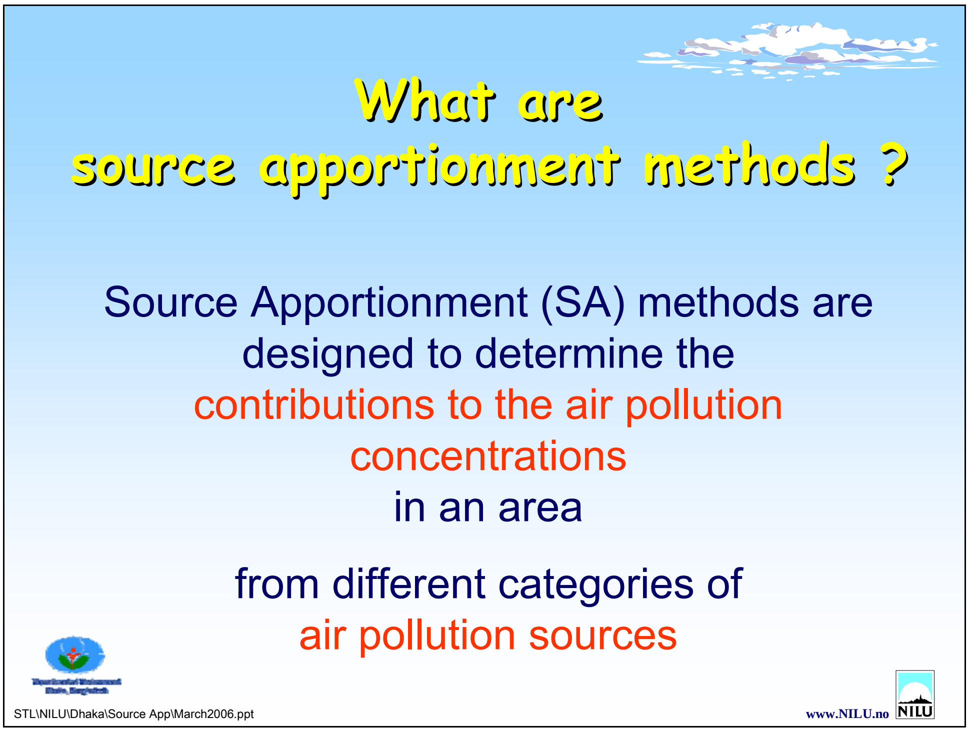
At the seminars, lectures were given by Dr. Steinar Larssen, NILU and Dr. Swagan K. Biswas at BAEC. The slides presented are given in this report.

As part of the NILU contract, two notes were prepared:

1. A Terms of Reference (TOR) for further Source Apportionment studies in Dhaka.
2. Development of Source Apportionment capabilities within the DoE/AQMP project.

These notes are also included in this report.

2 Powerpoint presentation



Two main types of Source apportionment methods

- **Receptor models**

  From receptor back to source

  Statistical methods based upon data from chemical analysis of air pollution samples

- **Source models**

  From source forward to receptor

  Calculate concentration contributions based upon emissions and dispersion models

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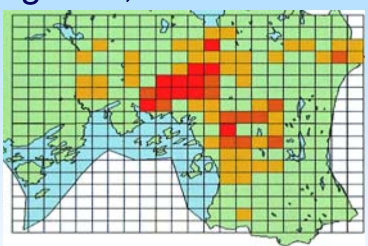
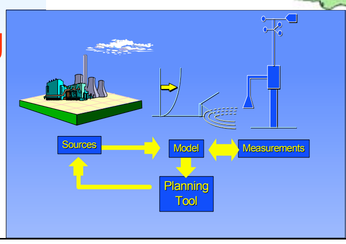
Source models:

calculate the contributions to concentrations in air from different source categories,



based upon:

- emission inventories
- and
- dispersion modelling



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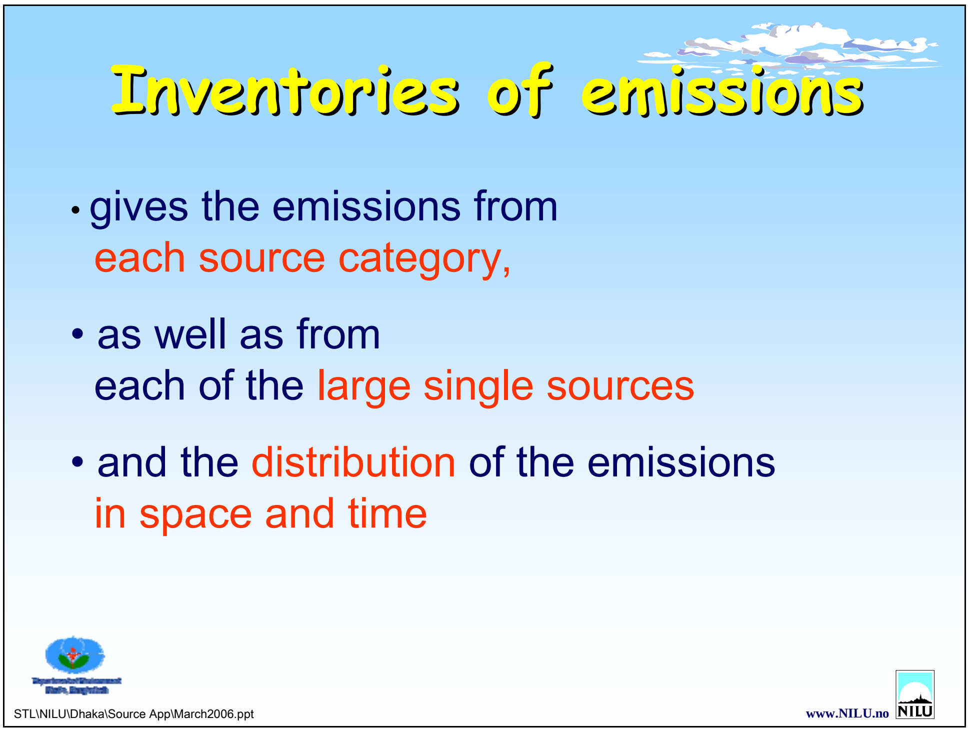
Inventories of emissions
• gives the emissions from each source category,
• as well as from each of the large single sources
• and the distribution of the emissions in space and time
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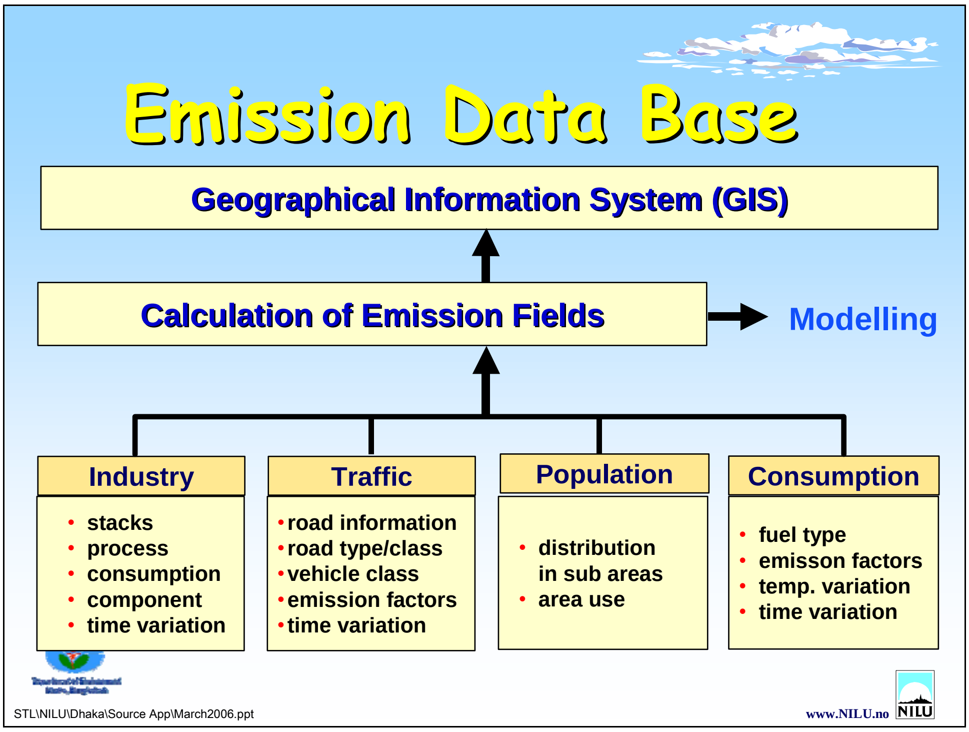
Emission Data Base
Geographical Information System (GIS)
Calculation of Emission Fields
Modelling
Industry
• stacks
• process
• consumption
• component
• time variation
Traffic
• road information
• road type/class
• vehicle class
• emission factors
• time variation
Population
• distribution in sub areas
• area use
Consumption
• fuel type
• emisson factors
• temp. variation
• time variation
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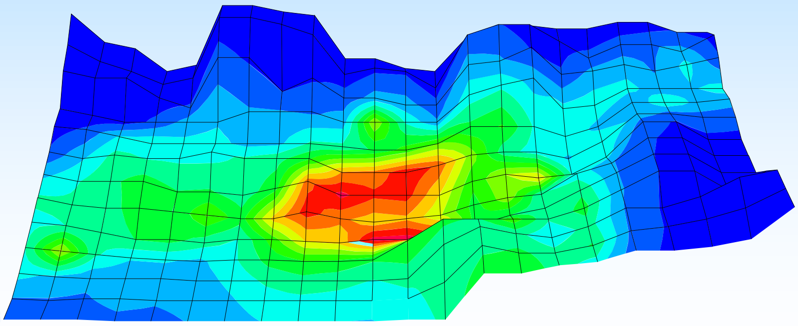
Dispersion models for urban areas

Calculates the contribution to the concentrations that results from the emissions from each of the source categories



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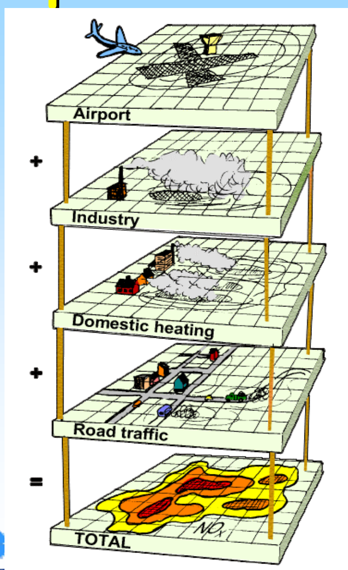
Dispersion modelling



- Spatial distribution of pollutant concentrations
- Source contribution quantification
- Effects of suggested measures
- Exposure Estimates
- Forecasting

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Advantages of source models

- Can be used for all pollution compounds
- Can give the source contributions in all parts of the city
- Can give the contribution not only to the concentrations, but also to the population exposure, and thus to the health effects

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Receptor models

- **'Statistical' methods applied to a data set**
- The data set:
  - a large number of **chemical constituents in PM**,
  - such as elemental concentrations
  - in a **large number of samples**
  - from **one location**
- Can be used only for particles (PM)
- Conservation of mass in PM
- Results are valid only for the location of sampling

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Types of Receptor models

Two main types:

- ***Factor analysis methods***

  - need a large number of samples from one or more stations

- ***Chemical mass balance method (CMB)***

  - is applied to each PM sample separately but needs also a number of samples so that the results can be representative

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The basic CMB equation

All receptor models are based upon this equation

$$c_i = \sum_{j=1}^{m} a_{ij} \bullet s_j \qquad i = 1,2,\ldots.n$$

c_i = concentration of element i at a receptor site (ug/m^3)

a_{ij} = source composition: fraction of element i in the emissions from source j

s_j = total concentration of PM from source j (ug/m^3) at the receptor site

n = number of elements m = number of sources

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The basic CMB equation

What do we actually do with this equation?

$$c_i = \sum_{j=1}^{m} a_{ij} \cdot s_j \qquad i = 1,2,\ldots.n$$

c_i are known, this is what we measure in the samples we take at the stations

a_{ij} are known in CMB, not known in Factor Analysis methods

s_j the source contributions, are determined using this set of equations

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Relevant example equations for Dhaka

$$c_{ec} = a_{ec,3\text{-wheel}} \cdot s_{3\text{-wheel}} + a_{ec,bus} \cdot s_{bus} + a_{ec,brick} \cdot s_{brick} + a_{ec,refuse} \cdot s_{refuse} + a_{ec,road\ dust} \cdot s_{road\ dust} + a_{ec,soil\ dust} \cdot s_{soil\ dust} + + +$$

$c_{oc} = \ldots\ldots$

$c_{Ca} = \ldots\ldots$

$c_{Pb} = \ldots\ldots$ etc

c – concentration of element in the sample (ug/m^3)

a – fraction of the element in the PM from the source

s – contribution of PM from the source (ug/m^3)

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Relevant example equations for Dhaka

$c_{ec} = a_{ec,3\text{-wheel}} \bullet s_{3\text{-wheel}} + a_{ec,bus} \bullet s_{bus} +$

$a_{ec,brick} \bullet s_{brick} + a_{ec,refuse} \bullet s_{refuse} +$

$a_{ec,road\ dust} \bullet s_{road\ dust} + a_{ec,soil\ dust} \bullet s_{soil\ dust} + + +$

c_{oc} = ……

c_{Ca} = ……

c_{Pb} = …… etc

CMB: a is known; find s
- One sample is enough
- Number of compounds must be larger than number of sources

FA: a is not known; find s
- Large number of samples needed

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Types of Receptor models

- CMB Chemical Mass Balance
- PCA Principal Component Analysis
- FA Factor analysis
- UNMIX ‘Edge detection’
- PMF Positive Matrix Factorization
- ME-2 ‘Multilinear engine’
- and others…..

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Representativeness of results from Receptor models

- Related to area:
  - Results are valid only for the location of sampling
- Related to time:
  - The samples taken from each location (station) represent a time series.
  - CMB and PMF give then the source contributions as a function of time (how it varies from day to day).
  - The average contribution from each source can then be found.
  - Combining the day-by-day contributions with meteorological data (wind direction etc) gives more knowledge about source contributions.

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Needed input data for Receptor modelling

- PM concentrations and chemical composition in air the c_i

CMB:
- In principle only one sample is enough, but many samples to get representative results.
- Composition analysis must include tracer/marker elements/compounds for each source.

PMF:
- Large number of samples per location (> 100).
- Composition analysis: selection of elements/compounds must represent the sources in the area.

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Needed input data for Receptor modelling

- **Source elemental composition data**

Source profile: elemental composition of the emitted PM from each source)

CMB: Source elemental profiles needed

PMF: Source profiles are not needed, but some source profile data are very useful to verify and interpret the results

- **Useful data to interpret the results:**

  - Meteorological data (wind direction, speed, etc)
  - Emissions inventory data

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Elements in source profiles

Element/ compound	Mobile	Gasoline	Vehicles w/catalyst	Vehicles no catalyst	Diesel	Vegetative burning	Secondary aerosol	Crustal /soil	Marine	Oil-fired power plant	Municipal incinerator
OC1	-	X			X	X		X	X		X
OC2		X			X	X	X	X	X		
OC3	X	X			X	X	X	X	X		
OC4		X			X	X	X		X		X
OC	X	X	X	X	X	X	X	X	X	X	
EC1	-	X			X	X		X		X	X
EC2	-					X		X			
EC3	-										
EC	X		X	X	X	X	X	X		X	
Na								X	X		
Al		X	X		X			X		X	
Si					X			X		X	X
Cl	X		X						X		X
K	X	X				X	X	X			X
Ca	X	X	X		X			X	X	X	X
Ti								X			
V										X	
Cr					X						
Mn	X										
Fe	X		X		X			X		X	
Ni										X	
Cu											
Zn			X							X	X
As											
Br	X										
Mo					X						
Sb			X								
Pb	X	X								X	X
SO4	X	X			X	X	X	X	X		X
NO3		X			X	X	X				X
Levoglucosan						X					
Coniferyl aldehyde						X					
Sinapyl aldehyde						*					
Hopanes	X				X						
Cholestanes	X				X						
n-nonadecane	X				X						
n-eicosane	X			X	X						
n-heptacosane	X				X						

* hardwood only

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Typical tracer / marker compounds in major sources

• Motor vehicles	Gasoline:	previously Pb now: EC,OC, organics
	Diesel:	EC, OC, organics
• Fuel oil		V
• Coal		As, Se
• Vegetative burning		Levoglucosan
• Refuse burning		Zn
• Soil		Al, Fe
• Sea salt		Na, Cl

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Source profile literature

- Main source of information on source profiles:

US EPA data base 'SPECIATE'

http://www.epa.gov/ttn/chief/software/speciate

- To find more up-dated profiles, and profiles more relevant for your area and main sources, you have to go to the scientific literature, especially to review articles on Receptor modelling.

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Available analytical methods

Table 2. Inorganic and organic species and measurement methods commonly used for receptor modeling.

Observables	Chemical Analysis Method
Particulate mass on filters	Gravimetrry
Particulate elements (Na to U) on filters	X-ray fluorescence (XRF) Proton-induced X-ray emission (PIXE) Instrumental neutron activation analysis (INAA) Inductively coupled plasma/atomic emission spectroscopy (ICP/AES) Inductively coupled plasma/mass spectrometry (ICP/MS)
Particulate water-soluble anions on filters (F^-, Br^-, Cl^-, NO_3^-, $PO_4^=$, $SO_4^=$)	Ion chromatography (IC) Automated colorimetry (AC)
Particulate water-soluble cations on filters (NH_4^+, Na^+, Mg^{++}, K^+, Ca^{++})	Ion chromatography (IC) Atomic absorption spectrophotometry (AAS) (flame or graphite) Automated colorimetry (AC)
Particulate carbon (OC, EC, carbonate, other fractions defined by thermal or optical properties)	Thermal/optical reflectance (TOR) Thermal/optical transmission (TOT) Thermal manganese oxidation (TMO)
C_2-C_{10} organics, volatile organic compounds (VOCs)	Canister and gas chromatography measurement with various detectors
C_{11}-C_{20} organics, VOCs, and semi-volatile organic compounds (SVOCs)	Tenax cartridge with thermal desorption and gas chromatography with various detectors
SVOC polycyclic aromatic hydrocarbons (PAH)	Filter/PUF/XAD with extraction in solvents of different polarities and gas chromatography with various detectors
Carbonyl VOCs	Dinitrophenylhydrazone (DNPH)-coated C_{18} cartridge and gas or liquid chromatography
Oxygenated VOC compounds (e.g., alcohol, ethers, esters)	Carbotrap canister, solvent extraction, derivitization, and gas chromatography with various detectors
Particulate single-particle morphology on filters	Computer-controlled scanning electron microscopy (CCSEM) Electron Microprobe Transmission Electron Microscopy (TEM)

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Results from source apportionment in Bangladesh, using PMF and ME-2, by Begum and Biswas et.al.

Factors → sources to PM2.5 at HSD (traffic hot spot) Dhaka

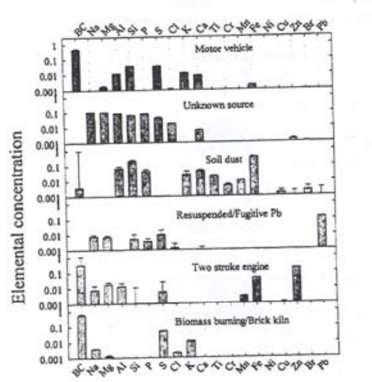

Figure 5. Source compositions for FPM analyzed by PMF at the HSD in Dhaka.

Factors → sources to PM2.5 at AECD (semi-residential), Dhaka

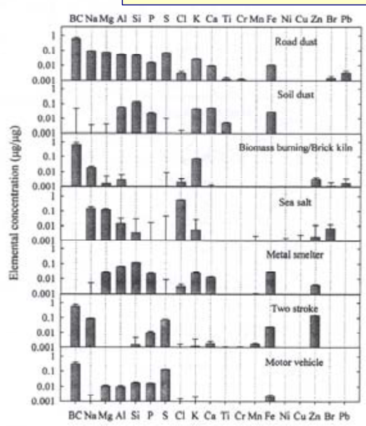

Fig. 2. Source compositions for FPM at semi-residential area in Dhaka.

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Results from Begum and Biswas et.al.

Source contributions to

PM2.5

at 3 different sites in Bangladesh

Table 3. A comparison of average percentage contributions of the sources for three sites from PMF modeling.

Source Profile	HSD (Dhaka)	SR (Dhaka)	Rajshahi
Coarse particle			
Sea salt	9.41	4.45	12.7
Soil dust	48.7	43.0	44.1
Road dust	—	7.30	14.2
Two-stroke engine	12.9	3.78	—
Metal smelter	—	1.21	—
Motor vehicle	23.4	40.2	23.2
Resuspended/fugitive Pb	2.29	—	—
Construction	3.20	—	5.87
Fine Particle			
Road dust	—	19.4	5.29
Soil dust	1.00	10.2	1.88
Biomass burning/brick kiln	37.5	11.9	50.4
Sea salt	—	1.00	13.9
Metal smelter	—	9.96	—
Two-stroke engine	2.41	9.36	—
Motor vehicle	43.0	38.2	28.5
Resuspended/fugitive Pb	3.32	—	—
Unknown source	12.7	—	—

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Examples of studies worldwide

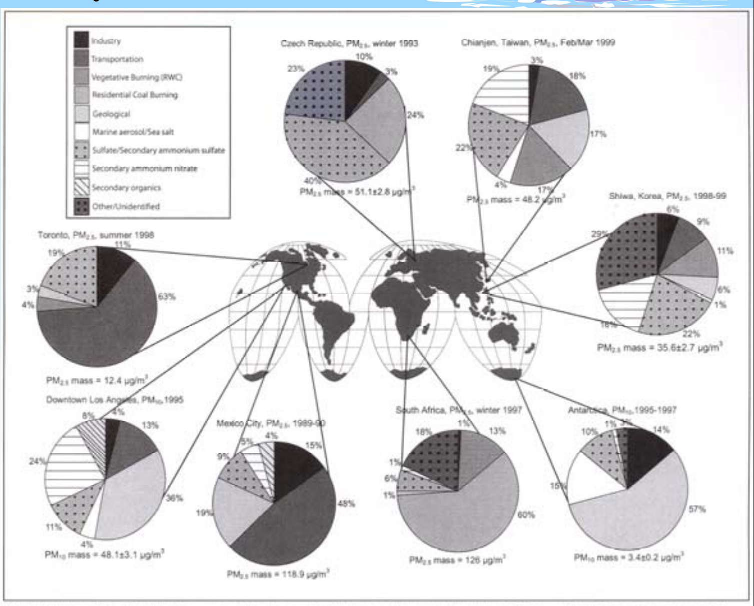

Figure 1. Examples of worldwide source contributions estimated by receptor models for better defining worldwide air quality management options.

Reference:

Watson and Chow, 2004

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How to establish a capability for Source Apportionment (SA) studies in AQMP ?

Elements of a TOR addressing this issue

- Two parts: Dispersion modelling
  Receptor modelling

- Dispersion modelling
  - Establish an emissions inventory
  - Acquire urban scale dispersion models
  - Acquire an AQMS software system
  - Training
  - Design and carry out dispersion modelling SA in Dhaka

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TOR for Receptor modelling

- Theoretical basis
- Technical and analytical basis
  - Knowledge of sources in Dhaka and BD
  - Sampling equipment
  - Chemical analysis equipment and cooperation opportunities
  - Receptor model soft-wares
- Training
- Design of RM studies for Dhaka
- Carry out pilot study
- Carry out full-scale RM study in Dhaka

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3 Terms of Reference for a Source Apportionment study in Dhaka: Development of methodology and approach on source apportionment using samples from PM sampler at the CAMS

3.1 Background

Source apportionment methods provide the basis for estimating or calculating the contributions to the air pollution in an area, from the different air polluting sources in the area. The contribution from sources outside the area of study (in-transported air pollution) also needs to be taken into account. There are two main groups of source apportionment (SA) methods:

- Source models: Starts with the sources, and looks at how their emissions spread and disperse in the area. These methods calculate the concentration contributions from sources based upon emissions inventories and dispersion models.

  Source models can be used for all pollution compounds (Particles, gases, primary and secondary compounds), and can give the contribution from sources in principle in all parts/points of the area.

- Receptor models: Starts with measurements at monitoring stations (‘receptor points’). These methods are statistical methods that calculates source contributions based upon chemical composition of the air pollution samples. Some data or information about the sources, such as chemical composition of the emissions, is needed for some of these (CMB) methods.

  Receptor models are mostly applied to particles in air (PM), and the results are restricted to the location(s) where the PM samples are taken. They can also be applied to analysis of sources of VOC.

Assessment of source contributions to the air pollution in an area, which is a necessary background for effective pollution abatement efforts, should use a combination of source and receptor models, for best results.

Source models have not yet been applied to study of air pollution in Dhaka or Bangladesh. Receptor model studies have been carried out rather extensively, through the work of Dr. Bilkis A. Begum and Dr. Swapan K. Biswas of Bangladesh Atomic Energy Centre (BAEC) and their foreign research colleagues. They have used state-of-the-art receptor modelling methods using PM samples from several locations in Bangladesh (a semi-residential area and a traffic hot-spot area in Dhaka as well as a residential site in Rajshahi. They have been able to estimate the size of contributions from sources such as motor vehicles, 2-stroke vehicles, road dust, soil dust, biomass burning/brick kilns, sea salt, metal smelter, construction, dependent upon the sampler location. Their main analytical technique has been the PIXE method, which enables the analysis of a selection of some 30 metals and elements, as well as an optical method which is relevant for elemental carbon (EC).

3.2 Objectives

There is a need for continuing source apportionment work in Dhaka and Bangladesh, associated with the AQMP project. The Dhaka CAMP station of the AQMP project includes suitable samplers for taking PM samples for receptor model studies (the Thermo RAAS 400 sampler). A sampling program for CAMS needs to be developed that supports receptor modelling work. This TOR deals only with the receptor model part of SA methods, not the source oriented methods.

For work on source apportionment to be sustainable in Bangladesh, there is a need for developing the capabilities for SA work in the AQMP project, in association with other institutions, such as BAEC for receptor modelling, and other when it comes to dispersion modelling. The requirements that needs to be filled for this work to be sustainable are described in this chapter.

3.3 Scope of work

A receptor modelling study for Dhaka should include the following main tasks:

1. Basic design of receptor modelling study appropriate for the present situation in Dhaka.

Consider the results from receptor modelling work already carried out in Dhaka and Bangladesh, and based upon that, specify the needs for further studies.

Consider the available receptor modelling methods (incl. CMB, FA, PCA, UNMIX, PMF and its variations), in terms of their suitability for establishing source contributions in Dhaka. Select method(s) to be used, and specify the criteria for the selection.

2. Design and establish a PM sampling and analysis program at the CAMS station for receptor modelling.

Use of the available samplers at the CAMS station, including the Thermo RAAS 400, to take appropriate samples of PM10 and PM2.5 (fine and course fraction of PM). Consider the needed number of samples to be taken, time schedule of sampling (spread of sampling over time and seasons), the needed selection of elements and chemical compounds to be analysed in the samples to enable the specification of sources as a result of the receptor modelling analysis. Consider the needed analytical methods for the elements and compounds, and the possibilities of carrying out these analysis within or, if necessary, outside of Bangladesh. Specify data uncertainty objectives, and QA/QC procedures to support that these objectives are fulfilled.

3. Design program for collection of additional input data

This includes data such as:

- source profiles of main PM emission sources in Dhaka (in case CMB is to be used)
- emission inventory for PM for Dhaka. Any available emissions data from sources and source groups should be collected to support the interpretation of the results from the receptor modelling
- meteorological data from Dhaka (wind speed and direction, precipitation and humidity, on a daily basis), also to support interpretation of results.

4. Establish the Receptor modelling capability for the study

Select the institution where the receptor modelling and the interpretation of results shall take place. Criteria are experience, quality of work, and costs.
AQMP staff and other relevant Bangladeshi institutions, if not involved in the actual receptor modelling, shall be included in a project reference group and be involved in results interpretation.

5. Plan the study in detail, involving all the parts described above.

The plan shall contain involvement of actors (administrative and task structure), details of tasks/responsible actors, indicative contents of report(s) from the study, time frame, costs.

6. Implementation of receptor modelling study for Dhaka

Provided funding for the study in obtained, implement the study, and report the findings.

3.4 Sustainability

The consultant will provide the tools, extended technical input and provide training to the DoE and AQMP staff. Further requirements to development of capabilities at DoE to continue receptor modelling work are described in the Annex to this TOR (see chapter 4).

4 Development of Source Apportionment capabilities within the AQMP project

4.1 Objective

The objective of this chapter is to define and describe the prerequisites for establishing a Source apportionment (SA) capability within the AQMP project under DoE, and to specify the contents and quality demands of the tasks involved in carrying out SA studies in Bangladesh.

The need for source apportionment capabilities derive from the AQMP project design:

- In order to reduce the harmful exposure of the population to air pollutants in a cost-effective way, it is necessary to determine the contributions to the air pollution from the various source categories in cities in Bangladesh.

4.2 Scope

Source apportionment methods comprise source-oriented methods (dispersion models) and receptor oriented models (receptor models). This chapter deals with both these classes of SA methods.

This chapter sets the prerequisites for establishing the capabilities and their actual application in Dhaka.

4.3 Elements (tasks) to establish an SA capability

4.3.1 Source oriented methods (dispersion modelling)

Task 1: Establish an inventory of emissions for Dhaka

For emissions inventories to support dispersion modelling methods, there is a need to establish an inventory of air pollution emissions that includes data on the location and time variation of the emissions. It is not sufficient to provide estimates of total emissions, based upon e.g. number of vehicles, the total fuel consumption or their annual driving distance, and emission factors. The spatial and temporal distribution/variation over the city must be provided. The spatial and temporal variations can be estimated based upon top-down methods, or more detailed by bottom-up methods (involving for instance data on traffic on each of the main streets, their location, distribution of vehicle types, etc).

It is referred to the TOR for emissions inventorying, developed for the AQMP project under the same consultancy, for details on the various methods to establish an emissions inventory suitable for dispersion modelling studies.

Task 2: Acquire urban-scale dispersion model(s) suitable for the Dhaka situation

a) Theoretical basis
The AQMP staff should acquire a basic theoretical basis regarding the science of dispersion of air pollutants. This can be acquired through studies and training at knowledgeable institutions in Bangladesh or abroad.

b) Select and acquire model(s)
There are a large number of types of dispersion models, and there are many software codes and packages available, free of charge or at a cost. Free of charge models usually require more proficiency in using such models, while licensed models usually come with a more user friendly user interface, possible to use also for non-experts.

c) Integrated AQM software package
Dispersion modelling studies are, when used by city authorities or institutions commissioned by them, usually performed as part of air quality management (AQM) efforts to improve the air pollution situation. Integrated AQM software packages usually contains different modules, such as for emissions inventorying, input data provisions, dispersion models, abatement options modules. This enables more efficient work on air quality management. DoE/AQMP staff should be acquainted with such software packages, and possibly acquire a package suitable for Dhaka and Bangladesh.

Task 3: Training

Basic training is needed for DoE/AQMP staff in tasks such as emissions inventorying and dispersion modelling, as well as operation of software packages to analyse effects of various control options and abatement strategies to select the most effective strategies to control air pollution in the city. They should consider the various institutions which are capable of providing such training, and specify training programs, including Bangladeshi and foreign institutions. A combination of Bangladeshi and foreign institutions could be considered to provide the needed training at reasonable costs and use of time. The training programs should be a combination of short-term and long-term training.

Task 4: Design and implementation of dispersion modelling study for Dhaka

After studies and training, DoE and AQMP staff will be able to design and carry out dispersion modelling for cities in Bangladesh, as needed for their AQM work.

4.3.2 Receptor models

Task 1: Theoretical basis

The DoE/AQMP staff should acquire a basic theoretical basis regarding the science of receptor modelling. This basis can be provided by BAEC staff, which have a full proficiency of this science. Basic training in statistical concepts may be needed as a prerequisite.

Task 2: Technical and analytical basis

a) Knowledge of sources and source categories in Dhaka and Bangladesh
It in necessary to know the basic structure of air pollution sources in the area, and the characteristics of the particles they emit. DoE/AQMP staff already know much about which sources are of importance. The emissions inventory work under Part A above will provide more. Receptor modeling requires more specific data on elemental/chemical composition of the emitted particles from each main source type. It may be needed to have emission samples takes from various sources, for elemental/chemical analysis.

b) Sampling equipment
The DoE/AQMP has proper PM sampling equipment at the CAMP station in Dhaka. This equipment must be operated according to the instructions of the instrument provider and according to state-of-the-art data quality (QA/QC) procedures.

c) Chemical analysis equipment and cooperation opportunities
Receptor modeling methods require a suit of state-of-the-art chemical analysis methods for analysis of the composition of the PM samples. They include (Watson and Chow, 2004):

- PM mass on filters: Gravimetry
- Elements on filters:
  - -X-ray fluorescence (XRF)
  - -Proton-induced X-ray emission (PIXE)
  - -Instrumental neutron activation analysis (INAA)
  - -Inductively coupled plasma/atomic emission spectrometry (ICP/MS)
- Water soluble anions and cations on filter:
  - - Ion chromatography (IC)
  - - Automated colorimetry (AC)
  - - Atomic absorption spectrophotometry (AAS)
- Carbon on filters (EC, OC, carbonate,..)
  - - Thermal/optical reflectance or transmission(TOR/TOT)
  - - Thermal Mn oxidation (TMO)
- C2-C10 organics, VOCs
  - - Canister and GC measurement with various detectors

- C11-C20 organics,
  VOCs,
  semivolatile SVOCs - Tenax cartridge with thermal desorption and GC

- SVOC – PAH - Filter/PUF/XAD with extraction in solvents of different polarities, and GC
- Carbonyl VOCs - DNPH-coated C18 cartridge and gas or liquid chromatography
- Oxygenated VOC compounds
  - Carbotrap canister, solvent extraction, derivitization, GC
- Particulate single-particle
  morphology on filters - Electron-microscopy (CCSEM, TEM).

DoE/AQMP do not have any of these methods in-house at present. DoE/AQMP should investigate the possibilities for collaboration with BD or external institutions regarding chemical analysis of filters. BAEC has PIXE capabilities, although their PIXE facilities are presently not operational.

d) Receptor model soft-wares
Soft-wares are available from the US EPA.

Task 3: Training

The AQMP staff needs substantial basic training in source apportionment theory and methods as a basic requirement for developing these capabilities. Regarding receptor modelling, this training can to a large extent be provided by the experts at BAEC in Dhaka. For training in dispersion modeling, training outside Bangladesh is probably needed.

Task 4: Design of RM studies for Dhaka

a) List of source types in Dhaka

b) Source profiles and essential elements and compounds to be included

c) Selection of representative sampling locations

d) Number of samples needed

e) Additional data

f) Chemical analysis plan

g) Data quality considerations, and QAQC plan

h) Alternative study designs

i) Workshop to discuss and determine the study design(s)

Task 5: Carry out pilot study

Objective is to test the technical and analytical capabilities and quality.

Workshop to discuss in depth the results of the pilot study.

Task 6: Carry out full-scale RM study in Dhaka

Task 7: Present and discuss results: Stakeholder workshop