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Monitoring Air Quality Objectives and Design

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1 Introduction

One of the main challenges in today's society is to have timely and appropriate access to relevant and good quality environmental data. The aim is to enable actions whenever environmental requirements and limits are violated. The environmental information system will have to combine the latest sensor and monitor technologies with data acquisition; data base developments, quality assurance, statistical and numerical models and advanced computer platforms for data processing, as well as distribution and dissemination of data and model results.

These technologies are now being used in environmental management to support integrated pollution prevention and control. They can also be part of an emergency management system to support actions and crisis management during emergencies and accidents of various kinds. The content and operability of the system might be quite different in the two cases.

2 Designing air quality monitoring programmes

The design of the air quality monitoring network basically involves determining the number of stations and their location, and monitoring methods, with a view to the objectives, costs and available resources (see Larssen, 1998).

The typical approach to network design, appropriate over city-wide or national scale, involves placing monitoring stations or sampling points at carefully selected representative locations, chosen on the basis of required data and known emission/dispersion patterns of the pollutants under study. This scientific approach will produce a cost effective air quality monitoring programme. Sites must be carefully selected if measured data are to be useful. Moreover, modelling and other objective assessment techniques may need to be utilized to ''fill in the gaps'' in any such monitoring strategy.

Another consideration in the basic approach to network design is the scale of the air pollution problem:

- The air pollution is of predominantly local origin. The network is then concentrated to within the urban area. (e.g. NO_2, SO_2, PM_{10}, CO, benzene)
- There is a significant regional contribution to the problem and more emphasis will be on the regional part. (e.g. ozone, PM).
- Large-scale phenomena, such as winter or summer smog episodes in Europe or the Asian dust cloud (local impacts should be avoided).

Most of the discussions in this chapter will be related to urban air pollution problems. The number of sites will depend upon the size and topography of the urban area, the complexity of the source mix and again upon the monitoring objectives. In Europe the EU Directives specify a minimum number of stations to be established dependent upon the population, and it also indicates what types of areas should be monitored. Some of this background will be referred in the following chapters.

2.1 Integrated pollution prevention and control (e.g. AirQUIS)

The air quality monitoring programme will often has to be designed as an integrated part of an air quality management programme. Generally the users will have individual requirements ranging from simple measurement to full-scale planning and air pollution abatement programmes.

In the modern air quality management system the platform for databases and planning tools are normally based on a geographical information system (GIS) depending upon the users requirements. Typical options may be:

1. A simple monitoring programme with user-friendly solutions for data handling, statistics and presentation of results.
2. A complete “Air Quality Management System” (AQMS) providing environmental management solutions based on combined monitoring and modelling for areas where air quality improvement is required to comply e.g. with air pollution standards and regulations

The integrated approach (also referred to an integrated pathway approach) will include a number of components such as:

- Manual data entering applications,
- On line monitoring systems,
- Online data acquisition and data quality control,
- A measurement data base for meteorology and air quality,
- An emission inventory data base with emission models,
- Numerical models for transport and dispersion of air pollutants,
- A module for exposure estimates and population exposure assessment,
- Statistical treatment and graphical presentation of measurements and modelling results,

Added to these options are also dose/response functions and dose/cost evaluations.

A number of software tools have been developed to handle the integrated air quality management concept. One example is the NILU developed AirQUIS system.

The user interface is to a large extent a map interface from which spatial distribution of pollution sources, monitoring stations, measurements, model results and other geographically linked objects can be presented. The map interface can also be used as an entrance for making queries to the database

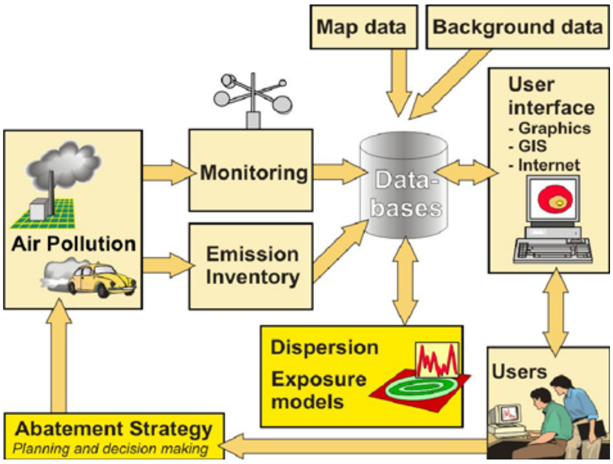


Figure 2.1: The elements of the air quality management system AirQUIS ("About AirQUIS, 2005).

Surveillance and Management. The AirQUIS emission inventory systems and advanced dispersion models may link and compare measurement data to model estimates. Model results may give spatial concentration distributions, which add information to the measurement data. The contribution to the pollution from different source categories, such as industry, traffic and domestic heating can be calculated based on emission or fuel consumption data. In this way the system can be used as a tool for evaluating and comparing different measures to reduce air pollution. The models may also estimate exposures of the population and of materials and ecosystems.

Impact assessment. The AirQUIS exposure estimates may be combined with dose-relationships to evaluate impact and to perform a complete impact and damage assessment. Estimates can be performed for health, material and vegetation impacts.

Optimal Abatement Strategies and Action Plans. Based on defined abatement options and scenarios, cost-benefit analyses can be used to evaluate the best possible options to reduce the air pollution load seen from an economic point of view. The results of such analyses again may lead to the development of Action plans.

2.2 Monitoring programme design

The design of the air quality monitoring programme will depend upon the measuring strategy, which again depends on the objectives of the monitoring, and the pollutants to be assessed. For the relevant air quality parameters or selected indicators the concentration of pollutants and associated averaging time need to be specified. Specifications are also needed on where, how, and how often measurements should be taken.

In the initial design phase we will have to evaluate:

- The variation of pollutant concentrations in space and time;
- The availability of supplementary information;
- The accuracy of the estimate, that is required.

It my be possible to derive, in quantitative terms, a measuring strategy from this information

Before a final programme design is presented it is also important to undertake a preliminary field investigation, often referred to as a screening study. This may consist of some simple inexpensive measurements (e.g. using passive samplers) and simple dispersion models. The data will give some information on the expected air pollution levels, high impacted areas and the general background air pollution in the area.

The number of monitoring stations and the indicators to be measured at each station in the final permanent network may then be decided upon based on the results of the screening study as well as on knowledge of sources and prevailing winds.

Once the objective of air sampling is well-defined and some preliminary results of the screening study is available, a certain operational sequence has to be followed. A best possible definition of the air pollution problem together with an analysis of available personnel, budget and equipment represent the basis for decision on the following questions:

1. What spatial density of sampling stations is required?
2. How many sampling stations are needed?
3. Where should the stations be located?
4. What kind of equipment should be used?
5. How many samples are needed, during what period?
6. What should be the sampling (averaging) time and frequency?
7. What additional background information is needed:
    - Meteorology,
    - Topography,
    - Population density,
    - Emission sources and emission rates,
    - Effects and impacts.
8. What is the best way to obtain the data (configuration of sensors and stations)?
9. How shall the data be accessible, communicated, processed and used?

The answers to these questions will vary according to the particular need in each case. Most of the questions will have to be addressed in the site studies and in the selection of sites as addressed below.

2.3 Monitoring objectives

The air quality monitoring programme design will be dependent upon the monitoring specific objectives specified for the air quality management in the selected area of interest. What are the expected outputs of the monitoring activity? Which problems do we need to address?

Defining the output will influence the design of the network and optimise resources used for monitoring. It will also ensure that the network is specially designed to optimise information on the problems at hand.

There might be different objectives for the development of the environmental monitoring and surveillance system. Normally the system will have to provide on-line data and information transfer with direct /automatically/ online quality control of the collected data. Several monitors, sensors and data collection systems may be applied to make on-line data transfer and control possible.

A general objective for the air quality measurement programme (monitoring, sampling and analysis) is often to adequately characterise air pollution for the area of interest, with a minimum expenditure of time and money. The measurement and sampling techniques to be used in each case will be dependent upon a complete analysis of the problem (emission source, dispersion conditions and the current air pollution situation).

The main objectives stated for the development of an air quality measurement and surveillance programme might be to:

- Facilitate background concentrations measurements,
- Monitor current levels as a baseline for assessment,
- Check the air quality relative to standards or limit values,
- Detect the importance of individual sources,
- Enable comparison of air quality data from different areas and countries,
- To collect data for air quality management, traffic and land-use planning purposes,
- Observe trends (related to emissions),
- Develop abatement strategies,
- Determine exposure and assess effects of air pollution on health, vegetation or building materials,
- Informing the public about air quality and raising awareness,
- Develop warning systems for prevention of undesired air pollution episodes,
- Facilitate source apportionment and identification;
- Supply data for research investigations,
- Develop/validate management tools (such as models),
- Develop and test analytical instruments.
- Support legislation in relation to air quality limit values and guidelines

The relationships between the data collected and the information to be derived from them must be taken into account when a monitoring programme is planned, executed and reported. This emphasizes the need for users and potential users of the data to be involved in planning surveys, not only to ensure that the surveys are appropriate to their needs but also to justify committing the resources.

2.4 Site selection

The urban air quality monitoring programme shall normally provide information to support and to facilitate the assessments of air quality in a selected area and to meet the objectives as stated by the users. Some of the objectives have been presented above.

This normally means that for designing a monitoring programme in an urban area several monitoring stations are needed for characterising the air quality in the total region. The areas are generally divided into urban, suburban and rural areas. Measurements should be undertaken in different microenvironments within these areas, where people are living, staying and moving. In a typical urban air pollution measurement programme the microenvironments selected are often classified as:

- Urban traffic,
- Urban commercial,
- Urban background,
- Suburban (traffic and industrial)
- Rural sites (background areas).

When considering the location of individual samplers, it is essential that the data collected are representative for the location and type of area without undue influence from the immediate surroundings. It is important to bear in mind, when measuring air quality or analysing results from measurements that the data you are looking at is a sum of impacts or contributions originating from different sources on different scales.

In any measurement point in the urban area the total ambient concentration is a sum of:

- A natural background concentration,
- A regional background,
- A city average background concentration (kilometre scale impact),
- Local impact from traffic along streets and roads,
- Local impacts from small area sources like open air burning (waste and cooking),
- Impact from large point sources such as industrial emissions and power plants.

To obtain information about the importance of these different contributions it is therefore necessary to locate monitoring stations so that they are representative for the different impacts. We will, in addition to air pollution data, often need meteorological data to identify and quantify the sources contributing to the measurements. It also will require that more than one monitoring site is needed for characterising the air quality in the urban area, as indicated in Ch4.2.4.2. It is also important to carefully characterise the representativeness of the monitoring sites, and to specify what kind of stations we are reporting data from.

The classification of measurement stations is divided into 3 types of areas; urban, suburban and rural. In each of the areas there may be 3 types of stations; traffic, industrial and background. The background stations are divided into; near-city background, regional and remote background stations.

Descriptions of the areas are given in the Table below:

Table 2.1: Typical area classification of micro-environments for air quality monitoring programmes.

Type of area	Description	Type of station
Urban	Continuously built-up area	Traffic Industrial Background : - Near city - Regional - Remote
Suburban	Largely built-up area: continuous settlement of detached buildings mixed with non-urbanized areas	
Rural	Areas that not fulfil the criteria for urban/suburban areas	

When considering the location of individual samplers, it is essential that the data collected are representative for the location and type of area without undue influence from the immediate surroundings.

Information concerning networks, stations and measurement techniques are presented in the European Commission Decision 97/101/EC of 17 October 2001, Annex II and Guidance on the Annexes to Decision 97/101/EC on Exchange of Information as revised by Decision 2001/752/EC).

2.4.1 Air intake design

In the design of an urban air quality monitoring programme it is necessary also to consider the immediate surroundings around the air intake to the monitoring stations. Small-scale siting considerations are important to ensure meaningful and representative measurement. If baseline concentrations are to be assessed, then monitoring sites should be adequately separated from local pollutant sources (for example, roads or small boilers) or sinks (such as dense vegetation). The following general guidelines should be considered:

- All stations (air intake) should be located at the same height above the surface; a typical elevation in residential/suburban areas is 2 to 6 m above ground level,
- Constraints to the ambient airflow should be avoided by placing the air intake at least 1,5 meters from buildings or other obstructions.
- The intake should be placed away from micro scale or local time varying sources.

A free airflow around the sampling inlet is necessary to ensure representative sampling. For this reason, sampling in a stagnant or highly sheltered microenvironment should also be avoided. For the purpose of health impact assessment, sampling heights need to approximate, as far as is practicable, the breathing zone of relevant population subgroup.

2.4.2 *Number of sites needed*

The number of stations needed to answer the objectives of the air pollution sampling, depends on many factors such as:

- Types of data needed,
- Required mean values and averaging times,
- The need for frequency distributions,
- Geographical distributions,
- Population density and population distribution,
- Meteorology and climatology of the area,
- Topography and size of area,
- Location and distribution of industrial areas.

A rough indication of the minimum number of sampling stations needed have been presented as a function of population density for a typical community air quality network. For a city of 1 million people one need at least 5 to 8 continuous monitors (measuring 1 hr averages), or equivalent to about 20-25 sequential samplers (measuring 24 hr averages). Automatic continuous sampling equipment in general involves fewer stations than an integrating sampling device (24 hr average or more).

The European Air Quality Directives (EU, 2005) presented criteria for the determination of the minimum numbers of sampling points for fixed in situ measurements of NO_2, SO_2 and PM in ambient air. The number of sites given in the table below is for permanent sites designed to assess compliance with limit values for the protection of human health in zones and agglomerations where measurements is the only source of information.

Table 2.2: Minimum numbers of sampling points for fixed in situ measurements of NO_2, SO_2 and PM in ambient air (EU, 2005).

Population of agglomeration or zone (1000x)	Number of sites if Conc. > UAT
0 – 250	1
250 – 750	2
750-1000	3
1000-1500	4
2000 – 2750	6
3750 – 4750	8
> 6000	10

UAT = Upper Assessment Threshold level (LV=limit value)
NO_2: UAT=0.8LV, SO_2: UAT=0.6LV, PM_{10}: UAT=14 µg/m^3

In addition to the number of sites given in the table at least one background station should be added. The selection of site locations should take into account the spatial distribution and variability of gaseous and particulate pollutants within the urban environment. For example, concentrations of primary traffic pollutants such as CO are highest at roadside locations, whereas ozone levels are more uniformly distributed over the city. Ozone concentrations are normally lowest in near-road locations because of scavenging of ozone due to the formation of NO_2 from NO emissions from cars. From this evaluation it is also evident that it is not necessary to measure all pollutants at all sites.

In a topographical complex area with hills, valleys, lakes, mountains etc., there are considerable local spatial and temporal variations of the meteorological parameters, and thus the dispersion conditions. To answer the same questions more sampling stations are needed in such areas than in flat homogeneous terrain. Typical for a flat area is also that spaced stations (as proposed by the German Federal regulations or by the New York City's aerometric network) average out spatial variations and thus can give net results representative for the area as a whole.

To be able to use the data for comparing air pollution levels between cities or countries or different environments, we may need some specific additional information about station location for some of the stations. Such additional information includes for instance:

For TRAFFIC stations:	♦ Traffic volume (accuracy: ± 2,000 vehicles/ day) ♦ Traffic speed (accuracy: ± 5 km/h, average daytime traffic) ♦ Distance from kerb (accuracy: ± 1 meter
For BACKGROUND/RURAL stations:	♦ Distance to nearest built-up areas and other major sources.

2.4.3 Sampling frequency and sampling time

The selection of sampling time is a function of the air pollutant characteristics (emission rate, life time) and time specifications of the air quality criteria. The ability of combining the air quality data with meteorological data also set requirements for the time resolution in the raw data.

As soon as indicators have been selected the measurement technologies selected must be capable of time resolutions consistent with the pollutant averaging times specified by the limit values, standards or WHO air quality guidelines. Air pollutant concentrations should preferably be expressed in $\mu g/m^3$.

A minimum level of data management could be the production of daily, monthly and annual summaries, involving simple statistical and graphical analysis. For some of the required statistics a time resolution of at least one hour in the raw data will be required for many of the indicators. The use of geographical information systems should be considered, especially for combining pollution data with meteorological data and with those from epidemiological and other geo-coordinated social, economic or demographic sources

The World Health Organization specified in the strategy for monitoring (WHO, 1999) that the expert judgment and the knowledge of local conditions and spatial patterns of pollution have to be used to produce concentrations that most accurately represent the exposure of the population.

The World Health Organization also presented criteria used to establish the validity of a monitoring station. These criteria are:

- To obtain 1-hour average values from data with a smaller averaging time, at least 75% of valid data should be used.
- To obtain 8-hour moving average values from hourly measures, the number of hours where valid measures have been performed must be at least 18 (75%).
- To obtain 24-hour average values from data with a smaller averaging time, over 50% of 1-hour valid data should be used and less than 25% of successive data values should be not accepted.
- To obtain seasonal and annual average values, at least 50% of the valid data for the reported period should be used.

For the stations that comply with the validity criteria, the following indices can be calculated:

- 1-hour average for CO and NO_2;
- Maximum 1-hour average and a maximum 8-hour moving average in a day (24 hours) for ozone;
- Daily (24-hour) average for SO_2, total suspended particulate, black smoke and PM_{10};
- Seasonal and annual average (with valid winter period) for lead and benzo[*a*]pyrene.

Calculation of statistical parameters requires:

- For the mean (arithmetic): over 50% of data accepted; and for the percentile (98) and maximum: over 75% of data accepted.
- To obtain an annual mean, the following criteria of completeness must be met:
- For CO and NO_2: valid winter and summer periods;
- For ozone: a valid summer period; and
- For SO_2, total suspended particulate, black smoke and PM_{10}: a valid winter period.

The time coverage has also be defined. The year is normally the calendar year (1 January to 31 December). The seasons are defined as winter from October to March inclusive and summer from April to September inclusive. In summary the sampling time (sampling resolution) as well as averaging times needed for a selected number of indicators is presented in the following table.

Table 2.3: Sample resolution needed to meet statistics requirements.

Pollutant/ Indicator	Unit	Sample resolution	Average needed
Carbon monoxide	mg/m^3	Hourly average	Hourly, 8-hour running average, annual max
Nitrogen dioxide	$\mu g/m^3$	Hourly average	Daily average Annual average Frequency distribution
Ozone	$\mu g/m^3$	Hourly average	Hourly, 8-hour running average, annual max
Particulate matter	$\mu g/m^3$	Daily average	Daily average Annual average Frequency distribution.
Sulphur dioxide	$\mu g/m^3$	Hourly average	Daily average Annual average Frequency distribution.
Lead	$\mu g/m^3$	Annual average	Annual average
Benzene	$\mu g/m^3$	Annual average	Annual average

2.5 Air quality indicators

It is normally not possible to measure all the air pollutants present in the urban atmosphere. We therefore have to choose some indicators that should represent a set of parameters selected to reflect the status of the environment. They should enable the estimation of trends and development, and should represent the basis for evaluating human and environmental impact. Further, they should be relevant for decision-making and they should be sensitive for environmental warning systems.

The selected parameters for air quality are related to air pollutants for which air quality guideline values are available. The interrelationships between the indicators and other related compounds might vary from region to region due to differences in emission source profiles.

Local and regional authorities are using the selected sets of environmental indicators as a basis for the design of monitoring and surveillance programmes and for reporting the state of the environment.

Air quality indicators should:

- Provide a general picture,
- Be easy to interpret,
- Respond to changes,
- Provide international comparisons,
- Be able to show trends over time.

Measurement techniques should be reasonably accurate and within an acceptable cost. The effect of indicators on health impact, building deterioration, vegetation damage should be adequately documented and linked to public awareness.

Selected indicators should respond to mitigation actions to prevent manmade negative impacts on the environment.

The compounds or indicators selected should also be possible to measure with reasonable accuracy. It should be adequately documented and linked to possible health impact, building deterioration, impacts related to the specific activity in question both during normal release and accidental releases.

Air quality indicators have been selected for different environmental issues and challenges. Not all indicators are specific enough to address only one issue. The nature of air pollution involve that some indicators address several issues. Some of the issues that have to be addressed are

- Climate change,
- Ozone layer depletion,
- Acidification,
- Toxic contamination,
- Urban air quality,
- Traffic air pollution.

As can be seen from the list the indicators have to cover all scales of the air pollution problems (in space and time) to address different type of impacts and effects.

The most commonly selected air quality indicators for urban and industrial air pollution are:

- Nitrogen dioxide (NO_2),
- Sulphur dioxide (SO_2),
- Carbon monoxide (CO),
- Particles with aerodynamic diameter less than 10 μm (or 2,5 μm), PM_{10} ($PM_{2,5}$),
- Ozone (O_3).

The US EPA refers to the compounds listed above as the priority pollutants (US EPA, 1990). They are also given in the Air Quality Daughter Directives of the European Union with specific limit values for the protection of health and the environment (EU, 2005). The first three are also given in the World Bank limit values for ambient air pollution. The World Health Organisation guideline values also include the above indicators (WHO, 2005).

For specific purposes it may be necessary to select other air pollutants as the indicator for impact. This is especially the case where industrial emissions dominate the air quality in a selected area or region. Some of these indicators have also been related to air pollution standards, limit values and air quality guideline values as presented by WHO (WHO, 1999b).

- Polycyclic Aromatic Hydrocarbons (PAH)
- Lead (Pb)

- Benzene or benzene, toluene and xylene (BTEX)
- Volatile organic compounds (VOC)

PAH need specific high volume samplers and can only be sampled intermittently. One of the PAH compound of specific interest may be benzo[*a*]pyrene (BaP).

Instead of sampling of VOC for analyses by gas chromatography in the laboratory, BTEX are often measured with automatic monitors.

The European air quality directives covers many of the pollutants presented above. Some recommended documents from the European Commissions are given in the references. Of special interest may be the following:

- Air quality limit values for sulphur dioxide, oxides of nitrogen, particulate matter and lead (CEC, 1999) and (EU, 2001a)
- Limit values for ozone in ambient air (EU, 2002)
- Limit values for benzene and carbon monoxide in ambient air (EU, 2000)
- A summary of air quality limit values and cleaner air for Europe (EU, 2005)

It is also worth reading the World health Organisation guidelines:

- Air quality guidelines for Europe, WHO (1999) and
- WHO air quality guidelines global update 2005 (WHO, 2005)

2.6 Meteorological measurements

An air pollution monitoring and management programme is not complete unless there are also meteorological data available. In an urban air quality programme at least one meteorological station for local and micro meteorological data collection is needed. These data are needed for air quality assessment and explanation as well as for input to air quality modelling and source impact identification.

Meteorological data are needed from the surface layer of the atmosphere, normally collected along 10 m towers, and to the top of the atmospheric boundary layer. The latter information may be obtained from radiosonde data or from upper air data based on forecast models, supplied by the local Met Office or by World Meteorological Organisation (WMO). It will also be possible to obtain some of this information by using wind profilers, such as sodars.

2.6.1 The automatic weather station

Continuous measurement of meteorology should include sensors for the most important parameters such as:

- Wind speeds,
- Wind directions,
- Temperatures and/or vertical temperature gradients,
- Net radiation,
- Wind fluctuations or turbulence,
- Relative humidity,

- Precipitation and
- Atmospheric pressure

Some of these data are overlapping each other. The final selection of parameters will depend on the instruments available and the type of specific data needed for the user.

The Automatic Weather Station (AWS) will collect high-quality, real-time data that is normally used in a variety of weather observation activities ranging from air quality data assessment and industrial accidental release forecasting to long term modelling for planning purposes.

The weather station designed for air quality studies will have to provide surface data and meteorological information in the surface boundary layer and in the troposphere as a whole. For the purpose of explaining air pollution transport and dispersion most of the sensors may be located along a 10 m high mast.

The basic suite of sensors will measure wind velocity and wind direction, temperature, relative humidity, air pressure, and precipitation. The expanded suite of sensors may offers measurement of solar radiation, net radiation, wind fluctuations (turbulence) vertical temperature gradients and visibility.

To obtain electric power and a data retrieval system with modems and computers the AWS is often co-located with one or several of the air quality monitoring stations.

2.6.2 Wind profilers

To measure wind direction and wind speeds throughout the atmospheric boundary layer it may be possible to use radiosondes and vertical measurements using weather balloons. It is also possible to install a wind profiler or a Doppler Sodar system (DS) at one station in the selected area of interest.

Doppler Sodars are a form of atmospheric echo sounder (or "acoustic radar"). An audible "beep" is beamed up into the atmosphere and very faint echoes from features within the air itself are detected back at the ground. Reflection (echoing) is caused by unevenness ("inhomogeneity") in the structure of the atmosphere, which is mainly small, localised differences in density (due to differences in temperature) and humidity. This unevenness occurs particularly in regions of the atmosphere where turbulence is present, and the earliest sodars were primarily instruments for detecting turbulence. They employed a single; vertically pointing beam, and the time delay between emission of the beep and detection of its echo determined the height of the turbulence, while the strength of the echo determined its intensity.

2.7 Equipment selection

Instruments for measurements of air pollutants may vary strongly in complexity and price from the simplest passive sampler to the most advanced and often expensive automatic remote sampling system based upon light absorption spectroscopy of various kinds. The following table indicate four typical types of instruments, their abilities and prices.

Table 2.4: Different types of instruments, their abilities and price.

Instrument type	Type of data collected	Data availability	Typical averaging time	Typical price (US $)
Passive sampler	Manual, in situ	After lab analyses	7-60 days	10
Sequential sampler	Manual /semi-automatic, in situ	After lab analyses	24 h	2-4 000
Monitors	Automatic Continuous, in situ	Directly, on-line	1h	>15 000
Remote monitoring	Automatic/Continuous, path integrated (space)	Directly, on-line	1 min-1 h	>100 000

Relatively simple equipment is usually adequate to use in preliminary screening studies and in order to get an average picture of the spatial distribution in an area. However, for complete determination of regional air pollution distributions, relative source impacts, hot spot identification and operation of warning systems more complex and advanced monitoring systems are needed. To investigate compliance with long- and short-term air quality limit values and standards automatic monitors, which enable measurements of one-hour average concentrations are needed. Also when data are needed for model verification and performance expensive monitoring systems are usually needed.

Integrating measurement methods such as passive samplers are fundamentally limited in their time resolution. However, as indicated above, they might be useful for the assessment of long-term exposure, as well as being invaluable for a variety of area-screening, mapping and network design functions. Problems can arise, however, when using manual sampling methods in an intermittent, mobile or random deployment strategy. The data collected may have limited applications in assessing diurnal, seasonal or annual pollutant patterns or when assessing the population exposure and possible impacts.

Well-recognised semi-automatic methods such as acidimetric SO_2 samplers are perfectly adequate for measurement against daily standards or criteria. For automatic analysers or samplers to reliably measure ambient pollutant concentrations, it is essential that these pollutants be transferred unchanged to the instrument reaction cell. The air intake system is a crucial component of any monitoring system, which strongly influences the overall accuracy and credibility of all the measurements made.

Even if intermittent sampling is still widely used worldwide the solution for a permanent air quality monitoring system will mainly contain automatic monitoring equipment located at permanent measurement sites. A total air quality monitoring programme may combine the use of different type of equipment covering near zone or local measurement as well as regional scale measurements. In general the instrumentation may be combinations of:

- Permanent monitoring sites,
- Mobile or movable stations,
- Active samplers,
- Passive samplers and
- Special designed field studies using e.g. open path measurements.

The main ambient monitoring programme will be using in-situ measurement instrument located at permanent measurement stations. Instruments are needed for determination of ambient concentrations of the indicators selected for the monitoring programme such as:

- Particulate matter (PM),
- Nitrogen dioxide (NO_2),
- Ozone (O_3),
- Carbon monoxide (CO),
- Sulphur dioxide (SO_2)
- Hydrocarbons (VOC or BTEX)
- Lead (Pb).

A fixed, permanent network of stations are normally required if the main objective of the air quality monitoring programme is to assess possible health impacts and evaluate trends and compliance with standards. Measurement instrumentation for each of the pollutants is discussed in the following.

2.7.1 Samplers

Simple passive samplers have been developed for surveillance of time integrated gas concentrations. These types of samplers are usually inexpensive in use, simple to handle and have an adequate overall precision and accuracy dependent upon the air pollution concentration level in question.

A number of manual and semi automatic samplers have been developed for measurements of gaseous and particulate compounds. The methods of collecting gases and particulate matter by these type of samplers include:

- Adsorption
- Absorption
- Freeze-out
- Impingement
- Thermal and electrostatic precipitation
- Direct measurement
- Mechanical filtration.

The most commonly used device for gaseous sampling has been the bubbler with an absorption solution, often together with a filtration system. A chemical solution is used to stabilize the pollutant for subsequent analysis with minimum interference by other pollutants. Samplers have also been used with impregnated filters based on the iodide absorption method. The flow is set with a restrictor and measured with a mass flow meter. In the sequential version of these samplers the desired start time can be set to start sampling at the same start time every day for 24 hours interval.

The collection device is based on discrete sampling periods, semi continuous or continuous sampling coupled to a recorder or a computer network. Automatic sequential samplers have been developed and used for collection of time-integrated samples with averaging times from a few hours and usually up to 24 hours. A few semi-automatic sequential samplers have been used for measurements of daily average concentrations of SO_2 and NO_2. The samplers have also a pre-filter that may be analysed for PM and Black Smoke (BS).

For measurements of ambient suspended particles the most accurate way to determine aerosol mass concentration is to pass a known volume of air through a filter. Each filter has to be weighed unexposed, before installed in the sampler. The weighing should be performed in a conditioned room for 24 hours at a pre-controlled temperature and relative humidity (se Ch. 4.3). After weighing, the filter is placed in the plastic bag with zip tightening and marked with station identification and/or number.

For traceable and robust measurements, samplers must be fitted with a tested PM_{10} or $PM_{2.5}$ inlet head and an accurate flow control system. The PM_{10} sampling inlet should be tested to ISO Standard 7708 (ISO, 1995) to ensure accurate size fractionation at the point of sampling

To determine the pollutant concentration, it is necessary to measure the air volume sampled. The gas flow rate or the total gas volume integrated over the sampling period may be determined using gas flow meters, rotameters, anemometers or liquid burettes. Temperature and pressure corrections are taken to convert the air volume to standard condition

2.7.2 Automatic monitors

The most commonly used methods for automatic monitoring of some of the major air quality indicators are discussed in the following. Methods and instruments for measuring air pollutants continuously must be carefully selected, evaluated and standardised. Several factors must be considered:

- *Specific, i.e. respond to the pollutant of interest in the presence of other substances,*
- *Sensitive and range from the lowest to the highest concentration expected,*
- *Stable, i.e. remain unaltered during the sampling interval between sampling and analysis,*
- *Precise, accurate and representative for the true pollutant concentration in the atmosphere where the sample is obtained, adequate for the sampling time required,*
- *Reliable and feasible relative to man power resources, maintenance cost and needs, zero drift and calibration (at least for a few days to ensure reliable data),*
- *Response time short enough to record accurately rapid changes in pollution concentration,*

- *Ambient temperature and humidity shall not influence the concentration measurements,*
- *Maintenance time and cost should allow instruments to operate continuously over long periods with minimum downtime,*
- *Data output should be considered in relation to computer capacity or reading and processing.*

If one consider the typical air concentrations of some pollutants of interest in air pollution studies, it is seen that as we go from background to urban atmosphere and from urban into the down wind area of an industrial complex the concentration for the most common pollutants may increase roughly by a factor 1000. In the next step from ambient air pollution to emission measurements we see another factor of about 1000. The selection of instruments therefore has to be set to measure over the “correct” range of pollution levels.

Analytical principles or measurement methods used in automatic air pollution monitors are:

- UV fluorescence for SO_2
- Chemiluminescence for NO_2
- Non-dispersive infra-red spectrometry for CO
- Gas chromatograph for benzene and VOC
- UV photometry for ozone
- Atomic absorption spectroscopy for lead

In more details the commonly used methods for automatic monitoring of some of the major air quality indicators are discussed in the following:

Sulphur dioxide (SO_2)
SO_2 should be measured from the fluorescent signal generated by exciting SO_2 with UV light.

Nitrogen oxides (NO and NO_2)
The principle of chemiluminescent reactions between NO and O_3 will be used for measuring NO_X. NO and total NO_X is being measured.

Ozone (O_3)
An ultraviolet absorption analyser is being used for measuring the ambient concentrations of ozone. The concentration of ozone is determined by the attenuation of 254 nm UV light along a single fixed path cell.

Suspended particles; TSP, PM_{10} and $PM_{2.5}$
Gravimetric methods including a true micro weighing technology have been used to measure ambient concentrations of suspended particulate matter. For automatic monitoring an instrument named "Tapered Element Oscillating Microbalance (TEOM)" has been most frequently used. Using a choice of sampling inlets, the hardware can be configured to measure TSP, PM_{10} or $PM_{2.5}$.

Measurement on filter tape using the principles of beta attenuation for estimating 30 minutes or one hour average concentrations of PM_{10} or $PM_{2.5}$ have been operated with an air flow of about 18 l/min.

Carbon monoxide (CO)
The CO analyser often used in urban air pollution studies is a non-dispersive infrared photometer that uses gas filter correlation technology to measure low concentrations of CO accurately and reliable by use of state-of-the-art optical and electronic technology.

Hydrocarbons and VOC
Hydrocarbons (NMHC, Methane and THC) should be measured using a flame ionisation detector (FID). Experience has proven that there may often be problems in the continuous power supplies. Short power breaks may interrupt these continuous measurements, and they will thus have to be started manually.

To avoid these problems VOC have been sampled manually and analysed by gas chromatography in the laboratory. An alternative is presently to measure BTEX by automatic monitors.

BTEX monitor
A multipurpose gas chromatograph has been designed to continuously monitor single or multiple gas components in a wide range of applications. The BTEX analyser provides direct measurement of Benzene, Toluene, Ethyl benzene and Xylene's in ambient air. It employs a photo ionisation detector (PID) as the sensing element. This detector is specific to volatile organic compounds. The Benzene, Toluene, Ethyl benzene and Xylene's in the gas sample are physically separated using proprietary GC columns.

2.8 Data transfer systems

All data from the instruments mentioned above may be collected by a data logger and transferred directly to a database for processing, control and presentations. There are many different options existing on the market for efficient data communication from monitors to a database. The various conditions at the locations decide the best solutions. Several factors may have to be considered such as: availability of telephone networks, quality and speed of the network, the amount of data to be transferred, the frequency of transfer, available mobile telephone options and satellite communication systems.

For every site there is a need for a data acquisition system (DAS) to receive the measurement values collected by one or several gas or dust analysers, meteorological sensors or other parameters. These parameters must be stored, every minute, every 5 minute or every hour locally and then transmitted to a central computer via modem and telephone lines. The local storage time must be several days or up to some months in case of problems with modem, transmission lines or the central computer. Automatic Data Acquisition Systems are available from a number of companies and instrument providers. Further details concerning data networks and data communications will be presented in the following.

2.8.1 Data retrieval via telephone lines

Air quality data collected by automatic monitors are normally transferred directly from a data logger unit to a central data unit at a monitoring centre. This transfer may take place on an hourly or on a daily basis. Data are often transferred via public telephone lines during night time hours.

The data retrieval from monitoring stations, which are equipped with modems and telephone lines, may be performed by the monitoring or computer centre using the following procedures:

- The central data base system asks for data automatically once a day (normally during night time hours, e.g. at 02:00 hrs).
- The Computer centre operator initiates download (manually) which requires that the modem is functioning.

The automatic data acquisition system (ADACS) is often a sophisticated modern solution using standardized and object-oriented technology to handle data flow, data retrieval, quality assurance and data storage. All these processes can be scheduled to run automatically. The system will thus save time in terms of replacing the manual routines and avoiding unnecessary human error.

The ADACS system typically consists of the following features:

- Configuration for defining necessary information for accessing the monitoring stations and collecting data through the data logger,
- Quality Assurance with automatic flagging of the measurement data,
- Calibration of measurement data,
- Logging all the steps during acquiring the measurement data.

The total associated database system will also serve as a link to a Meta information system, which includes information on external environmental data. The supporting database contains information on regulations, requirements, and air quality guideline values for various applications. These functions might also include:

- Navigation facilities to access the needed information,
- Support for standardization activities,
- Worldwide web/internet functions and bridges.

The data base model is designed to support local and regional levels and meets most of the requirements specified by the users. Modifications and additions must be easily made in the database. Routines for safety copying and reconstruction must be available. Different data deliveries might be operating in different systems. This requires the establishment of different communication systems with open communication solutions.

2.8.2 Monitoring stations without telephone lines

A number of communication options for data retrieval can be used in cases that telephone lines are not available. Data have been transferred via blue-tooth to radio frequency transmission as well as via satellite and mobile phones. On-site options also include storage modules and laptop computers, which enable storage of air quality and meteorological data for several months.

In the absence of any telecommunication system data have to be collected manually via diskettes, CD or memory stick. Calibration values should always follow the data collection units for transmission into the database. This will then enable the necessary data quality controls and calibrations to be taken into account before data are approved. This manual collection of data should follow the instrument calibration routines. Normally the stations are visited every week for check and calibrations. The same frequency should be applied for collecting the data.

Manually collected data should be imported to the Central data base system immediately and checked. Reports should be printed at least once a week and controlled manually and by some statistical procedures before approval.

3 Screening study

Screening studies are often performed as part of the design of air quality monitoring programmes. The main objective of these studies is to collect background information for designing a permanent air quality monitoring programme for the area in the future.

Different passive samplers have been used by NILU for these studies consisting of simple inexpensive equipment for NO_2, SO_2, VOC and O_3. These samplers are normally located in at least 20 to 50 positions in the area covering different microenvironments. The passive samplers for NO_2, SO_2, and O_3 are normally exposed for 2 to 4 weeks. The passive samplers of VOC are exposed over 3 to 7 days, depending on the location and the source strength impacting on this.

3.1 Design of screening study

The background for the design of the screening study is the identification of main emission sources and areas of highest impact of pollution, as well as existing air quality data and meteorological data.

The sites should be selected from three main criteria:

- Measure in different microenvironments (e.g. street canyon, road side, urban background, industrial area, regional background etc);
- Selection of component to measure at the different microenvironments depending on emission sources;
- Prevailing wind directions for the campaign period.

Most of the samplers will, if possible, be located downwind from the main emission sources. A major part of the samplers should be located along traverses perpendicular to the prevailing wind.

3.1.1 Emission sources

The most important industrial areas and areas with heavy traffic should be identified. From the identified emission sources, the most important sources are normally the ground level sources.

On a general basis it seems that traffic jams on some of the main roads produce high emissions of CO. High traffic density on the main roads also lead to large emissions of NO_X and particles. The general activities in the city often produce high background levels of suspended particles. Location of industrial areas combined with the knowledge of prevailing winds will indicate areas of industrial impacts.

3.1.2 Compounds and indicators

The selections of components to measure in the different microenvironments should be decided by the presence of the local emission sources. A list of typical indicators is presented in Table below.

Table 3.1: Air pollution indicators measured in various microenvironments.

Station type/Microenvironment	Components
Regional background	NO_2, SO_2, PM_{10}, O_3
Industry	NO_2, SO_2, VOC, O_3, PM_{10}
City centre	NO_2, SO_2, O_3, PM_{10}, $PM_{2.5}$, CO, VOC
Traffic/street canyon	NO_2, SO_2, O_3, CO, VOC, PM_{10}
Urban background	NO_2, SO_2, O_3
Suburban	NO_2, SO_2, O_3

Ozone is a secondary pollutant formed by chemical reactions in the atmosphere. Measurements of ozone, especially in the background air, are essential for understanding the formation of NO_2 in the city.

3.1.3 Meteorological conditions

Climatologically data from the weather service or from previous studies in the area will indicate the prevailing wind directions. Wind roses and wind statistics may be obtained from official records or from the larger industries in the area.

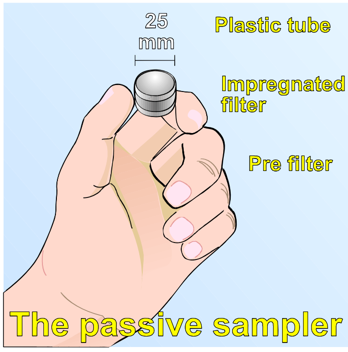
Annual average and seasonal variations of wind directions will give a good background for evaluating air pollution transport and impact areas in the area.

Also the frequency of wind speeds less than 2 m/s should be observes to evaluate the possibility for air pollution episodes.

3.2 Some instruments used in screening studies

3.2.1 The passive samplers

A sensitive diffusion sampler for sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) in ambient air has been used in several investigations to undertake a screening of the spatial concentration distribution. The sampler was developed by the Swedish Environmental Research Institute (IVL) and has been used in several cases by NILU. The sampler includes an impregnated filter inside a small plastic tube. To avoid turbulent diffusion inside the sampler, a thin porous membrane filter covers the inlet. Gases are transported and collected by molecular diffusion.



The samplers are very easy to manufacture. For example, the samplers used by NILU are produced from commercially available 50 mm long polypropylene tubes. All components, except the impregnated filter can be reused. They have many other advantages as well for use in the field. For example they are small, light (~2 g), and require no electricity.

It should be emphasised that they provide time-integrated concentrations with continuous time coverage, with the averaging time determined by the period they are exposed to ambient air (which can be daily, weekly, monthly, etc.). They are obviously not well suited for monitoring temporal variations over short time intervals, or for detection of individual peak values, or when real time measurements are needed.

3.2.2 The Volatile Organic Components (VoC) samplers

The VOC samples are taken on adsorption tubes filled with Chromosorb or Tenax TA. Samples can be taken either by passive sampling (diffusive sampling) or active sampling (pumped sampling). The analysis is done by NILU using thermo desorption followed by GC-MS analysis. Standardised Perkin Elmer adsorption tubes are used. The method is carried out according to CEN/DIN norms (CEN/TC 264) and widely used as a standard measurement technique for monitoring BTEX and VOC levels in European cities. The accuracy of the method is better than ± 10 %.

3.2.3 PM samplers

SEQ47/50

A sequential gravimetric sampler, SEQ47/50, for daily monitoring PM_{10} and $PM_{2.5}$ has been used in screening studies. The sequential sampler is designed for outdoors use at all temperatures and environmental conditions. This measurement technique is a European Commission reference method. The instrument holds 15 filters, which are automatically changed after 24 hours exposure. The filters are weighed before exposure and re-weighed after exposure by NILU. Corresponding concentrations of PM_{10} and $PM_{2.5}$ are calculated based on the airflow and weight.

Dust trak

For the short-term measurement of PM_{10} in different microenvironments in the urban area, TSI's DustTrak Aerosol Monitor (8520) was used. The DustTrak is a portable, battery-operated laser photometer. The light emitted from the laser diode is scattered by particles drawn through the unit in a constant stream; the amount of light scatter determines the particle mass concentration based on a calibration factor. The instrument has a mass resolution of ±0.1% or 1 μg m^{-3} (whichever is greater) and a detection range of 0.1–10 µm ($PM_{0.1-10}$). The DustTrak detects potential problems with airborne contaminants such as dust, smoke, fumes, and mists.

Comparison of measured PM_{10} concentrations with various instruments indicates that accuracy of the dust track is dependent on the calibration of aerosol for different optical depth.

3.2.4 The CO sampling and monitoring

A TSI Q-track has been used to measure hourly CO concentrations and short-term measurement of 1minutes averages. The instrument is calibrated by TSI according to NIST- standard.

4 Evaluation and use of air quality data

4.1 Data validity and traceability

Before air quality data can be used to assess the situation in the area it is important assure that the data collected are real concentration values, which may be compared to similar information from other areas and countries. For each pollutant, which is measured as input to the air quality assessment and evaluation, the following main questions may be asked:

- Have suitable quality assurance procedures been set up for all stages and activities?
- Is technical advice available?
- Is monitoring being carried out at suitable locations?
- Have suitable arrangements for data handling and storage been made and implemented?

The documentation to support the credibility of data collection and initial data quality assurance are the responsibility of the data provider. This includes the process of data collection, application of calibration factors, initial Quality Assurance procedures (QA/QC), data analysis, data “flagging”, rollups (averaging) and reporting. A combination of data record notes, data quality flags and process documentation are all part of this first phase of processing. During the data collection phase, one role of the data provider is to assist in maintaining process credibility and validity of the data.

The basis for the assessment can only be performed if the three characteristics have been tested:

- Validity
- Traceability
- Reproducibility

"Validity" is supported by documentation that provides:

1. Proof that all applicable standard scientific procedures were adhered to.
2. Precise descriptions of all collected and processed numeric data. (This is *metadata* and is defined as data that describes other data. Among many other data elements, metadata includes: collection method; instrument type; instrument accuracy; instrument precision; data format; unit conventions; variable naming conventions; QA/QC flags.
3. Justify technically all calculations and processes including, parameter interpolations and quality assurance criteria. In addition, technical justification should be provided for all scientific conclusions based upon new data processing routines. For example, this could include special data processing and analysis procedures built into the data management system. This enables inter-comparisons of new state-of-science monitoring technologies with existing technologies.
4. Reference should be given to external information upon which calculations, processes and conclusions are based.

"Traceability" is a documented history of all processes performed on each raw data set transmitted to the database.

Traceability is assured by maintaining tabulated, chronological listings, which summarize each step that is performed along with the method by which it is performed. It indicates how this occurred (e.g., programme name, etc.) along with the verification and quality assurance procedures implemented and the corresponding results.

"Reproducibility" allows the duplication of results from any data validity level. Reproducibility requires traceability, since all processing steps performed in producing specific results must be duplicated. Reproducibility requires that all data management tools used be stored together with a chronological set of data validation records for all data sets (e.g., source code for processing programmes must be stored and available if needed).

It is of primary importance that data providers and the data manager make the necessary efforts to ensure that all aspects of the data collection, handling, and analysis and evaluation are well documented. This is essential with respect to considerations of data validity, traceability, and reproducibility. Documentation accompanying data are a requisite for providing a data *history,* which gives value to the data. To accomplish this requires that good reporting procedures be maintained and implemented at each step of data handling and processing.

The above elements implemented to assure good quality data need adequate procedures for Quality Assurance and Quality Control (QA/QC). The final verification of the QA/QC programme is verified through a Quality Assessment, which verifies that all procedures have been successfully followed. These procedures will also at least satisfy the data quality objectives (DQOs) defined by the responsible authorities. Complete QA/QC procedures are rather complex, and they should be documented. A very important element in the quality control procedures is the calibration procedures and the traceability of the calibration standards used in the network/station back to absolute standards of known quality. Institutions responsible for the QA/QC procedures and their follow-up may be national, regional or local. For further details on QA/QC see Chapter 4.4.

4.2 Air Quality Assessment and reporting

Standardized statistical analysis should be performed to assess air quality trends, changes in emissions or impact from specific types or groups of sources. The severity of the air pollution problem or the air quality should be specified relative to air quality guideline (AQG) values, standards or pre defined levels of classification (e.g. good, moderate, unhealthy or hazardous).

The number of hours and days, or percentage of time when the air pollution concentrations have exceeded AQG values should be presented. This will also need minimum requirements of data base completeness. Long-term averages (annual or seasonal) should be presented relative to AQG.

Before undertaking statistical evaluations the data should be presented and validated based upon a form of time series. These data must be evaluated logically to correct for drift in instruments, and eliminate data that are identified to be including errors. It is also important that the data are checked with other relevant information.

Different use of the data collected and different presentations are needed for the different users. Data presentations have been produced to meet the requirements from:

- Specialists on air pollution,
- Policy makers and
- The public.

The ***specialist*** often needs a tool that gives easy access to the data with the ability to treat these data in different ways. The specialist also wants to apply the data and prepare his own way of presenting results graphically.

The ***policy makers*** need presentations that illustrate the conclusions that the specialist has drawn from the information available. This is usually best done through a graphical presentation.

The ***public*** needs information on the general state of the environment. The type of information that is needed is more general than that of the policy maker. It often needs to cover environmental issues that are of special concern to the public. This could be the air quality that is expected to occur in the urban area on this specific day. This information could be given as a short term forecast or based upon actual on-line data.

The information may be multimedia: texts, tables, graphs, images, sound or video dependent on the end user. The presentations have to be designed to meet the user needs.

The information to the policy makers should be presented in summaries and in annual reports. These reports may include simplified tables and graphs for the data period in question. Tables will give the reader the necessary numerical values, while the graphs will present a picture of the situation, which for many are easier to understand. The public needs information that is easily available. This could be done through leaflets, Radio forecasts of the air pollution situation in several locations. It could also be done through screens located at public places in the city. These may give a simplified air quality index for the city on the given day, or it can give continuous up-to-date or on-line information on air quality measured in the area. In many countries air quality information are now also available on Web and on your personal mobile telephone.

On-line air quality monitoring systems enable access to the data and the treatment of data quickly so that presentation in a number of different media has been made possible.

For the evaluation and assessment of air quality data collected by the monitoring system statistical tools are available. The measurement databases may include some of the basic statistics needed to assess the air quality in the area monitored.

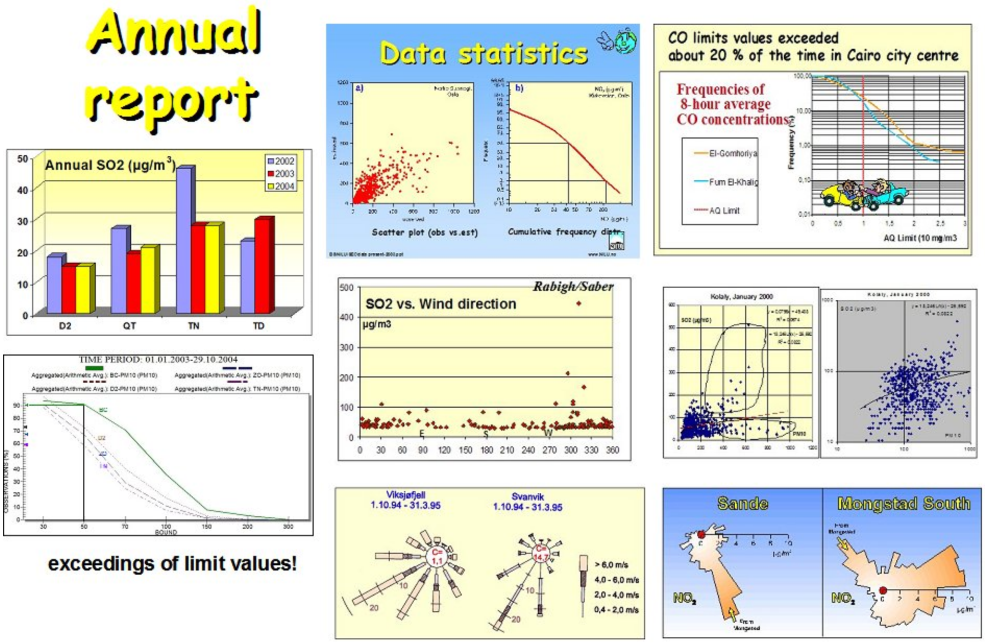


Figure 4.1: Some examples of graphs and figures prepared for a typical annual report on air quality data collected in an urban area.

The most frequently used graphics are:

- Time series of measurements or their short-term means from one monitoring location (for one or more pollutants) or comparing various locations,

- Bar charts or line graphs presenting long-term (annual) mean values presented over a longer period,
- The cumulative frequency distribution of short-term mean values (hourly) presented over a longer period (year),
- Spatial distribution of concentrations of selected indicators,
- Percentage of exceeding of limit values (in tables or on maps as spatial distributions),
- Wind frequency distributions (wind roses) and stability frequencies,
- Average concentration as a function of wind directions (Breuer diagram),
- More complicated spatial comparisons of pollution patterns are greatly facilitated by the use of maps. The (mean) pollution concentrations in various locations can be simplified by presenting bars or dots with varying colour or size on a map of the area.

In Europe guidance have been given to Member States and authorities responsible for the establishment of an air quality assessment system in accordance with the directives. It gives guidance by interpretation and explanation of the main content of the directives, describing how existing assessment methods can be used and illustrates this by practical examples. The target group for this document have typically been managers of the air quality monitoring systems in Members States, experts in the field of air quality assessment of governmental or local authorities and consultants.

Guidance has been presented on basic assessment techniques such as measuring methods, models, and databases. These techniques can be learned from books, courses and practical experience; the Guidance on Preliminary Assessment (Van Aalst et al., 1998) gave an outline of these methods. This guidance will focus on how such techniques can be applied, improved and combined to assess air quality in the framework of the new directives.

4.3 Concentration data for compliance testing

Prior to the use of air quality data for compliance testing a comprehensive Quality Assurance Site Survey should be undertaken to evaluate the performance of ambient air monitoring stations in the area of interest. Each station should be addressed to verify that the accuracy and representativeness of data being generated meets the requirements. In the USA the requirements and the siting criteria are set forth in U.S. EPA, 40 CFR 58 (US-EPA, 2006). Each year, a thorough evaluation is made at each station for such criteria as sampler model, purpose, objective, residence time, scale, station temperature, obstacles, traffic, local sources, and dominant influence. While most ambient air monitoring stations carefully adhere to regulations during the initial site set-up, as reflected by their site reports, changes occur over time that are overlooked by the station operators. Some changes that occur include scaling problems, source problems, obstacles, and temperature requirements.

When the monitoring programmes including the data have been quality assured and found valid, local and national authorities often give reporting procedures for compliance testing. Some forms of reporting are regulated by national (or international) legislation as standards, directives or conventions. They specify the subject, format and frequency of reporting. The amount by which a certain standard or threshold concentration established by the regulation is exceeded should be reported.

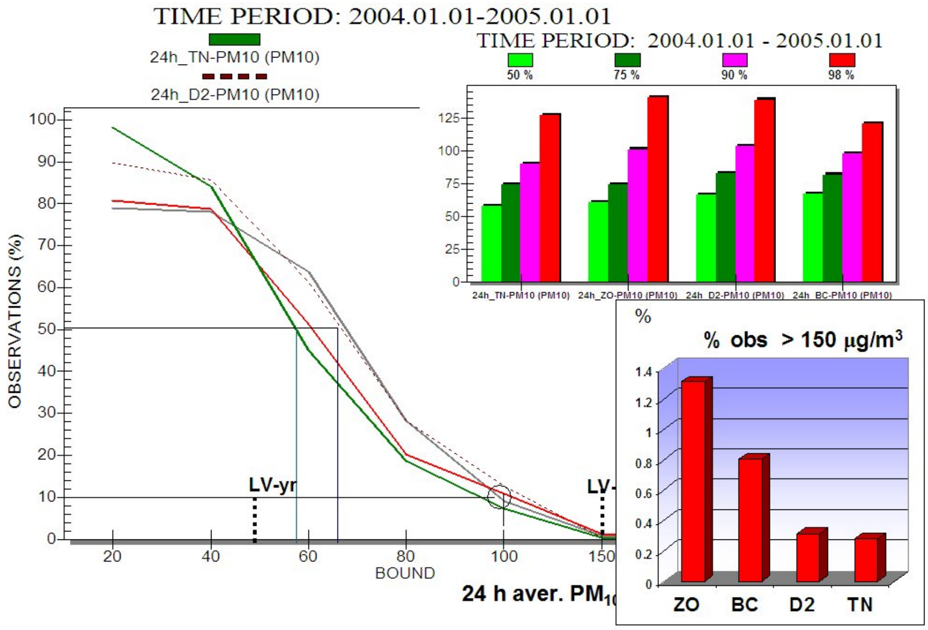


Figure 4.2: Daily PM_{10} concentrations measured in HCMC, Vietnam; Cumulative frequency distribution, percentile values and percentage of exceeding Vietnamese air quality standards at four measuring sites.

Figure 4.2 shows a typical statistical presentation produced to evaluate the exceeding of limit values for PM_{10} in Ho Chi Minh City (Sivertsen, 2005). The statistical analyses of the measured air quality data will give, in addition to average and maximum concentrations, the frequency of occurrence of given concentration levels. This analyses may be used to identify exceedances of limit values, where a given frequency or number of exceedances are permitted.

In Europe a questionnaire has been prepared for annual reporting on ambient air quality assessment under Council Directives 96/62 (EU, 2001d). The questionnaire includes a number of forms, which distinguish between items that are legally required to report and items that are voluntary to report for the Member State. All cases of violation of limit values for NO_2, PM_{10}, SO_2 and other indicators given in the list of limit values are to be reported. If the margin of tolerance at a station has been exceeded this also will have to be reported. The total number of hours and days when limit values were exceeded is part of the reporting procedures.

Reports from such compliance monitoring networks are of limited use for assessing population exposure and health effects. Certain health effects may be expected at concentrations below the standard level, and these are not reported. In addition, the location of monitors in the compliance monitoring may be not optimal for assessing population exposure, and the reporting may give an incorrect picture of the exposure. More about exposure estimates is presented in the following.

4.4 Air quality and exposure data

Assessment of human exposure to air pollutants is a part of total risk assessment, and a necessary part of air quality management where it contributes to information on prioritising abatement measures. Exposure assessment as a step of risk assessment, or external dose assessed through predicted environmental concentration, has been implicitly taken into account in regulatory processes by assuming that population exposures are well represented by outdoor ambient concentrations. Exposure assessment however has been a research topic in its own merit, inside and outside of epidemiological studies. The general idea is to look at air concentrations

- Outdoors in ambient air where people move,
- Indoors where people normally spend most of their time,
- Through measurements of personal exposure.

Each of these refinements is often adding a layer of complexity onto the exposure assessment. Some major questions are:

- Which of the complicating factors are most important?
- How do we quantify them and arrive at a suitable population exposure model?

The challenge is especially present if only monitoring data are to be used in the exposure assessment. Normally these tasks are undertaken in a combination of measurement data for air quality and air pollution modelling. Also the World Health Organisation (WHO, 1995) discussed exposure assessment in general terms, and concluded that it is probably best carried out with a combination of measurements and models.

In general two different methods exist for estimating human exposure to air pollutants. The two main models have been to estimate:

a) Integrated number of people living within areas of given concentration levels,
b) Individual exposure based upon diaries and micro-environment concentration estimates.

Integrated models may use measurement data and statistical interpolation procedures to produce concentrations in each square kilometre. These concentrations can then be used together with the population distribution to estimate a rough exposure curve for each km^2. When added for all grids the method became a fairly robust method for obtaining a complete picture of the population exposure to air pollutants. The method has been applied in Oslo where the number of people living within areas of concentrations exceeding given levels was presented on maps.

Personal exposure of NO_2 and PM_{10} was estimated by a combination of exposure calculations in building points along major roads and for each model grid square. The number of persons exposed to exceedances of limit values for PM_{10} is shown as an example in Figure 4.3. The total number of persons exposed to PM_{10} was 320 000 persons in 1995, and reduced to 220 000 persons in 2001 (Bøhler et al., 2003).

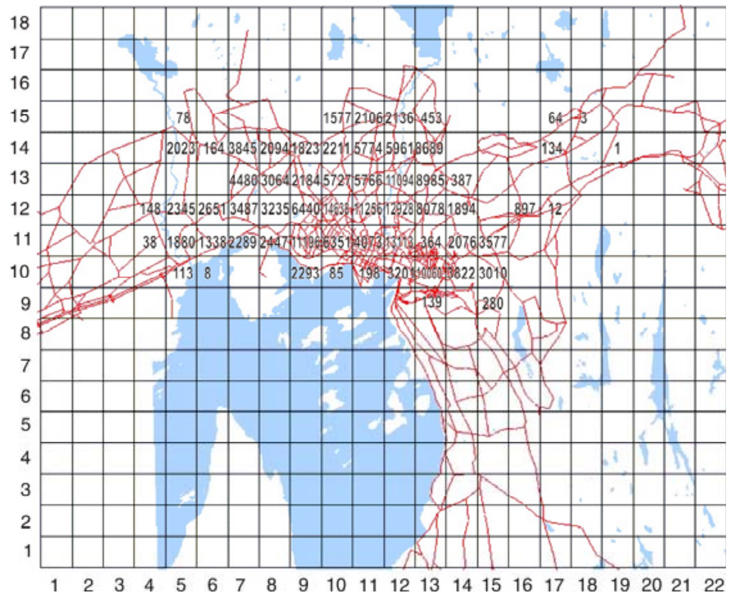


Figure 4.3: Number of people exposed above national AQ limit value for PM_{10} (daily) in 2001, calculated per km^2 grid cell.

The individual exposure approach assumes that each person is exposed to a contaminant represented by the measured or estimated concentration in the microenvironment that he/she is in at the moment. For example, the exposure is dependent on whether that geographical area is in proximity of heavy traffic or whether the individual is indoors or outdoors, travelling or shopping.

Therefore, a microenvironment can be a city sidewalk, out in the woods, indoors at home, indoors at work, at a lunchroom, at work, in a restaurant or at the movies, etc. Without doubt the best method of measuring exposure is by the use of personal monitors, especially when people move from place to place. However, this is impractical when several compounds are being studied simultaneously. In addition, it is uncertain how much people change their routines when they have to carry some of the larger portable units. It can therefore be more practical to use computer models based upon data from diaries to estimate each individual's exposure to each pollutant for each prescribed time span. This model has used as little as one hour the unit of time. With this time resolution, it is possible to reflect major changes in microenvironments without requiring a diary that is impossible for people to fill out.

The major elements of an air concentration exposure model are:

- Geographical location,
- Proximity to traffic,
- Being indoors or outdoors,
- Shopping
- Travelling.

In this approach the number of microenvironments of importance and interest is normally large. The study therefore will have to be made manageable by judiciously reducing the number of measurements within each microenvironment type. Institutional and public microenvironments lend themselves easily, by definition, to a reduced number of measurements. Decisions on how much reduction in measurements can be achieved can largely be made only during the pilot phase of the project through site visits, walk-through surveys, analysis of secondary information and discussions. However, to the extent possible in the proposal we will describe this process in detail.

Air quality standards and guidelines have been established based upon air pollution impact also to the human health and well-being. The best available background material for evaluation of health impacts is the US- EPA criteria documents and the air quality guidelines for Europe (WHO, 1987 and 1999). The air quality guidelines is formulated to ensure that populations exposed to concentrations lower than the guideline values should not inflict harmful effects. In cases where the guideline for a pollutant is exceeded, the probability of harmful effects will increase.

A number of different approaches to exposure assessment have typically been used in environmental epidemiology investigations. In terms of increasing order of sophistication, these include:

- Classification of individual exposure (high versus low);
- Measured or modelled outdoor concentrations;
- Measurement of indoor and outdoor concentrations;
- Estimation of personal exposure using indoor, outdoor and other micro environmental concentrations along with time–activity diaries;
- Direct measurement of personal exposure; and
- Measurement of breath and other biomarkers of exposure.

Clearly, the least sophisticated approach in classifying exposure groups using a categorical variable (such as homes with gas versus electric cooking stoves for NO_2 impact assessment) could lead to significant exposure misclassification bias. However, many existing environmental health studies are based on ambient or community surveillance monitoring data. Aside from the usual spatial variation in outdoor pollutant concentrations, human exposure to many pollutants also involves pollutant exposure sources and locations other than outdoor pollutants and monitored ambient environments (such as for PM, NO_2, and VOC). For reactive pollutants, such as ozone, indoor pollution levels are significantly lower than the outdoor concentrations. Since people spend more time indoors, personal ozone exposure is more closely related to indoor than outdoor ozone concentrations. In general, therefore, exposure models based on ambient data only are much less accurate than the micro environmental models that combine indoor and outdoor concentration measurements (or predictions) with time–activity.

Human exposure modelling for environmental contaminants has received considerable attention over the past decade. A number of human exposure assessment field studies, such as the Total Exposure Assessment Methodology (TEAM) studies of the US Environmental Protection Agency, have provided an important foundation for models of human exposure to CO, volatile organic compounds (VOC), pesticides and PM_{10} .The results from these field studies have produced greater understanding of the variation in the indoor, outdoor and personal pollutant concentrations. However, the measurements can usually be generalized and technically interpreted in terms of human exposure using exposure models.

The exposure models provide an analytic structure for combing data of different types collected from disparate studies in a manner that may make more complete use of the existing information on a particular contaminant than is possible from direct study methods. The uncertainty about various components of environmental health assessment can be formally incorporated into such models to estimate uncertainty about the prediction endpoint (such as exposure, dose or health outcome), to identify the components that influence prediction accuracy and precision by comparing predicted values to those measured in the field. Validated models can then be used to investigate the efficacy of various strategies for managing the public health risks associated with exposure to doses of environmental contaminants.

4.5 Use of AQI in different countries of Asia

The Air Quality Index, AQI, is an index for reporting daily air quality. It tells you how clean or polluted your air is, and what associated health concerns you should be aware of. The AQI focuses on health effects that can happen within a few hours or days after breathing polluted air. The definition of an Air Quality Index (AQI) was first introduced and applied in USA. Today most of the air quality monitoring systems in Asia is presenting daily values of AQI.

US-EPA generates AQI based on five major air pollutants regulated by the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide, sulphur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect against harmful health effects. The AQI can be considered a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution is and the greater the health danger. For example, an AQI value of 50 represents good air quality and little potential to affect public health, while an AQI value over 300 represents hazardous air quality.

Many countries and urban areas in Asia have adapted AQI values especially for the information provided to the public. An AQI value of 100 generally corresponds to the national air quality standard for the pollutant. AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy.

The purpose of the AQI is to help the user to understand what local air quality means to the health. In order to make the AQI as easy to understand as possible, the AQI values have been divided into six categories, often presented to the public as a colour code as shown below:

Air Quality Index (AQI) Values	Levels of Health Concern	Colours
When the AQI is in this range:	*...air quality conditions are:*	*...as symbolized by this color:*
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Each category corresponds to a different level of health concern. For example, when the AQI for a pollutant is between 51 and 100, the health concern is "Moderate."

From examples of AQI values generated in Asia we have seen that the procedures may vary slightly from one country to another. In Bangladesh the Air Quality Monitoring Programme generates a daily AQI value linked to the National Ambient Air Quality Objectives. The air quality is classified in five classes. In other countries the selected values used for generating the AQI values have been compared with the World Health Organisation's proposed guideline values for air quality.

In Ho Chi Minh City, Vietnam AQI values are generated automatically every day. The measured results for the potential harmful species PM_{10}, NO_2, CO, SO_2, and O_3 are included for determination of the AQI. All parameters may not be measured at a given station. In this case only the measured parameters are included. Further both hourly and daily averages are included to take into account that the health deterioration may be initiated both of short time exposure to high concentrations and long time exposure to lower levels. This fact is also reflected in the Air Quality Standards. The Air Quality Index (AQI) has been established in the air quality database and management system (AirQUIS) based on the present and proposed air quality standards for Vietnam (TCVN 5937 – 1995 and TCVN 5937 – 2005).

The simplest way to estimate the AQI for HCMC is dividing the procedures into hourly AQI(h) based on hourly concentrations and 1-hr average standards given for Vietnam, and daily AQI(d) based on daily average concentrations and 24-hr average standards. The final AQI for each day will be the highest value of the hourly maximum AQI value and the daily AQI.

In the analyses below we have used the following nomenclatures:

h = hour j = site i = compound d = daily (24 hour) C = concentration S = standard (hourly, daily, annual)	Sites: 1 = DOSTE 2 = Hong Bang 3 = Tan Son Hoa 4 = Thu Duc 7 = Zoo, District 1 9 = Quang Trung 8 = District 2 PC 5 = Thong Nhat Hospital 6 = Binh Chanh Educ Centre

The highest ratio of concentration to standard for any site and compound during this hour is being estimated from:

$$AQI(h,j) = Max_h\ (C(h,i,j)/S(h,i))*100$$

A daily index is also established for the compounds available at each station, such a SO_2, NO_2, CO, O3 and PM_{10}. The procedure is similar to the hourly giving:

$$AQI(d,j) = Max\ (C(d,i,j)/S(d,i,))*100$$

The daily air quality index will be selected as the higher of the two indexes:

$$Max((\ AQI(h,j),AQI(d,j))$$

Based on a total of 9 stations in operation in HCMC, the index has also been divided in two categories, one for traffic stations one for urban background stations:

- Traffic:
  AQI(traffic) = (AQI(1)+AQI(2)+AQI(5)+AQI(6))/4
- Urban/residential:
  AQI(urban/residential) = (AQI(4)+AQI(7)+AQI(9))/3

To assure that adequate data quality has been taken into account in the generation of an AQI, the following quality assurance has been considered:

- Data with *warning and exclude flags* will not be part of the AQI estimate.
- Negative concentrations are not included.
- At least 6 one-hour average concentrations are needed to produce a daily AQI.

Exclude flags include missing data and too many equal values after each other (presently set at 3 values). Warning flags relates to expected minimum and maximum values. The air quality is categorized in five classes, similar to the US-EPA guidelines *(US Federal Register Part III, Environmental Protection Agency, 40 CFR Part 58*), The classes are presented according to the following table:

Classification of index	
0 to 50	Good
51 to 100	Moderate
101 to 200	Poor
201 to 300	Unhealthy
301 and above	Hazardous

The generated AQI values are being transferred every day to the information board near Binh Thanh marked in the city centre of HCMC. The AQI estimated for the preceding day is also presented on an Internet page for HEPA. The final evaluation of the automatic AQI generator has been tested and evaluated and is now being presented on the HEPA web page: www.hepa.gov.vn.

4.6 Data for policy development

Air quality data from measurements and from a combination of measurements and modelling are being used for policy development in different ways:

- Setting and verifying standards and limit values
- Identifying areas where actions and measures need to be implemented
- Input to licensing e.g. through impact assessment studies
- Identifying and verifying the impact of abatement scenarios
- Increasing public awareness.

In **setting ambient air quality standards**, any areas that require special environmental protection should be identified, to avoid new or continued damage to sensitive ecosystems. Such protection may be needed to maintain biodiversity. An ambient air quality standard is a goal. It establishes the maximum concentration of each pollutant that should be allowed in the air of a geographical area. Many sources within the geographical area may emit a pollutant. The total sum of emissions of that pollutant from all sources is what the ambient standard addresses. It does not address the amount of emissions that may come from each source.

The authorities of a region, state or a union of states decides the air quality standards or limit values. The setting and application of ambient air quality standards is an example of the authorities right to define the standards and to implement them. The state has the right to exclude people and industries from using the air as a waste disposal site. It has the right to determine who may release pollutants into the air and at what level this may be accepted. The authorities may also enforce its right to exclude users. In most countries the ambient standards are set so as to reduce ecological and human health risks as much as possible.

Examining the benefits and costs of abatement can give information whether these limits are higher or lower than the efficient level. The efficient ambient level is where the marginal social benefit of abatement is equal to the marginal social cost. A regional limit makes sense when the benefits and costs of abatement significantly differ by region. For example, a higher air quality standard may be desirable in rural areas compared to cities where abatement costs are high. Similarly the setting of standards for PM in a given area has proven difficult as the “natural background” concentrations due to wind blown dust from dessert areas or wild fires in Asia have contributed considerably to the general regional air pollution level. To evaluate the situation as input to the decision making process will require air quality measurement data.

The type of monitoring required must be appropriate to the nature and size of the source and the pollutant under consideration. In certain cases, non-continuous (intermittent or “spot check”) monitoring at intervals of some months may be satisfactory. This would be appropriate especially where the process operating parameters are reasonably constant over time and the pollutant (e.g. a heavy metal) is of concern to human health in terms of its long term average, not peak, concentration.

Where a process varies significantly over time due to changes in emissions to air or where the pollutant can affect human health or the environment in the short term (e.g. sulphur dioxide), then continuous monitoring may be necessary. The competent authority will need to ensure, as part of the inspection procedure, that monitoring is being carried out to an acceptable standard and that also the emission rates specified in the licence are within the limits.

All data used for assessment purposes must be quality assured, because of the high potential expenditure, which may hinge on such results. From the results of these initial monitoring activities, other areas where limit values may be exceeded or where it is unlikely that they are exceeded can be identified, and monitoring or other forms of assessment can be undertaken where necessary.

Planning should be carried out as a first priority in any areas where air quality needs to be improved i.e. where prescribed limit values are exceeded. If there are many such areas, prioritisation could be carried out on the basis of the number of people exposed in each area and the magnitude of the difference between the limit value and the actual ambient level in that area. In many cases, modelling can be used to predict the effect of different emission reduction scenarios and to assist in the selection of the most acceptable solution. Models will need to be based on up-to-date and accurate inventories of emissions.

Optimal abatement strategies were developed by the World Bank for four large urban areas in Asia as early as in 1996-97. Air quality measurements combined with models, dose response functions and effect/cost estimates produced a list of the most cost effective actions that could be implemented in Kathmandu, Mumbai, Jakarta and Manila.

The Urban Air Quality Management Strategy (URBAIR) project was undertaken to assist in the design and implementation of policies, monitoring, and management to restore air quality in Asian metropolitan areas. Its goal was to identify the components of a general action plan to manage and control air pollution. Abatement measures in the plan were categorized according to cost-effectiveness, as well as the time required implementing them and when they would become effective.

The air quality management strategy planning tool (AQMS) contains the following main components:

- Air quality assessment
- Environmental damage assessment
- Abatement options assessment
- Cost-benefit or cost-effectiveness analyses
- Abatement measures
- Optimum control strategy

Assessment: Air quality assessment, environmental damage assessment and abatement options assessment provide input to the cost analysis, which is also based on established air quality objectives (e.g. air quality standards) and economic objectives (e.g. reduction of damage costs). The analysis leads to an Action Plan containing abatement and control measures for implementation in the short, medium, and long term. The goal of this analysis is an optimum control strategy.

The AQMS depends on the following set of technical and analytical tasks, which can be undertaken by the relevant air quality authorities:

- Creating an inventory of polluting activities and emissions;
- Monitoring air pollution and dispersion parameters;
- Calculating air pollution concentrations with dispersion models;
- Assessing exposure and damage;
- Estimating the effect of abatement and control measures;
- Establishing and improving air pollution regulations and policy measures.

These activities, and the institutions necessary to carry them out, constitute the prerequisites for establishing the AQMS as illustrated in Figure 4.4.

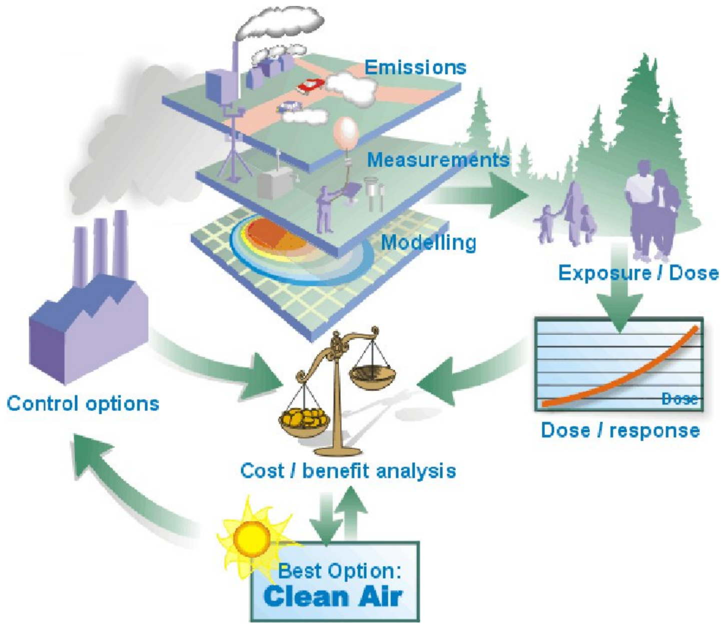


Figure 4.4: The elements of an optimal abatement strategy planning system.

Action plans and implementation: Categories of "actions" include the following:

- Technical abatement measures;
- Improvements of the factual database (e.g. emission inventory, monitoring, etc.);
- Institutional strengthening;
- Implementing an investment plan;
- Awareness raising and environmental education.

Monitoring: A third essential component of AQMS is continued monitoring, or surveillance. Monitoring is essential to assessing the effectiveness of air pollution control actions. The goal of an Air Quality Information System (AQIS) is, through thorough monitoring, to keep authorities, major polluters and the public informed on the short- and long-term changes in air quality, thereby helping to raise awareness; and to assess the results of abatement measures, thereby providing feedback to the abatement strategy. This part of the AQMS will also include institutional building and training in order to assure sustainability in the system established in the area or region in question.

A system for air quality management requires activities in the following fields:

- Inventorying of air pollution activities and emissions
- Monitoring of air pollution, meteorology and dispersion
- Calculation of air pollution concentrations, by dispersion models
- Inventorying of population, materials and urban development
- Calculation of the effect of abatement/control measures
- Establishing/improving air pollution regulations

The implementation of plans and strategies for air quality improvements, in Asian cities as elsewhere, is done through the use of policy instruments by ministries, regulatory agencies, law enforcers and other institutions. Indeed, some of these institutions may well be the same institutions as those, which must be in place to carry out the AQMS analysis described above, which ideally is the basis for the plans and strategies. Thus, the existence of relevant institutions, and an organisational institution structure, is part of the basis for AQMS work.

Different levels of government - national, regional and local - have different roles and responsibilities in the environmental sphere. Air quality standards or guidelines are usually set at the national level, although local government may have the legal right to impose stricter regulations. National governments usually assume the responsibility for scientific research and environmental education, while local governments develop and enforce regulations and policy measures to control local pollution levels.

Institutional arrangements, laws and regulations are important parts of an AQMS. Some roadblocks to successful air quality management in Asia are weak institutions that lack technical skills and political authority; enforcement agencies that often lack both the necessary information and the means to implement policy, and unclear legal and administrative procedures. Countries have their own political and administrative hierarchies and technical expertise that affect institutions, laws and regulations related to air pollution control. AQMS procedures similar to the URBAIR project have been undertaken in other urban areas and regions in China, such as Guangzhou, Yantay and the Shanxi province. One of the experiences from these studies is pointing at the importance of clarity in the organisational structures and the division and description of responsibilities and "lines-of-command".

Data dissemination and information to the public is an important tool in raising public awareness. Data can be prepared and distributed from databases in many different ways to meet the needs of the users. Data presentation systems are often based on the air quality management system. Several applications have also been designed for use directly in Internet presentations, WAP (Wireless Application Protocol) solutions, SMS (Short Message Service) and MMS (Multimedia Messaging Solution) services. Several projects have been designed for utilizing such services and also in international research programmes like EU-Information Society of Tomorrow e.g. through the APNEE (www.apnee.org) project where links to several Web pages in Europe may be found.

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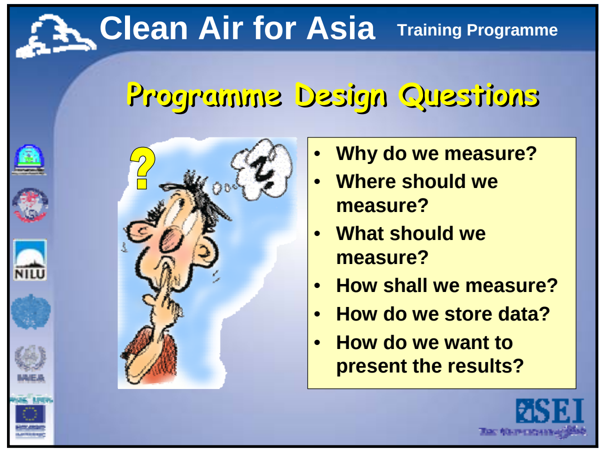
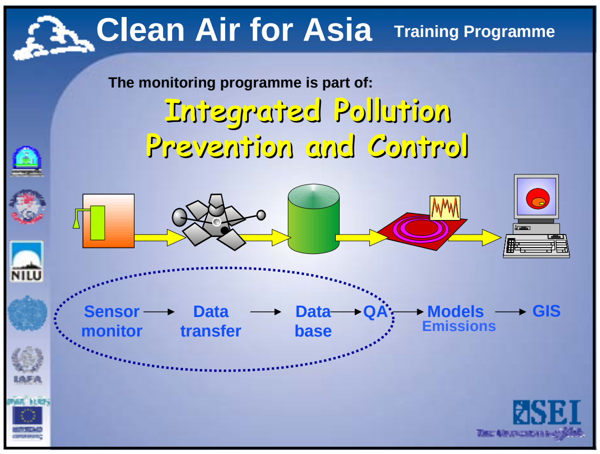
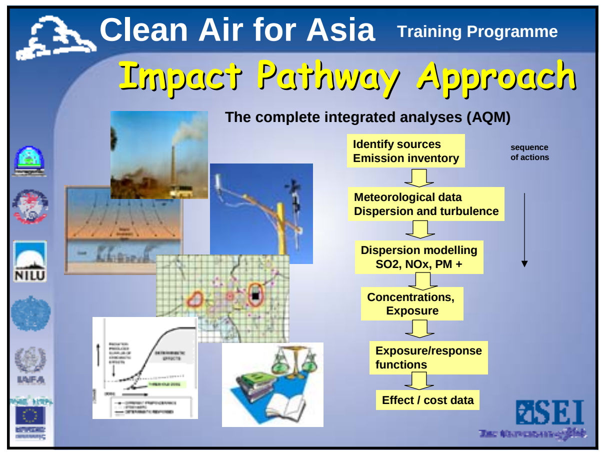
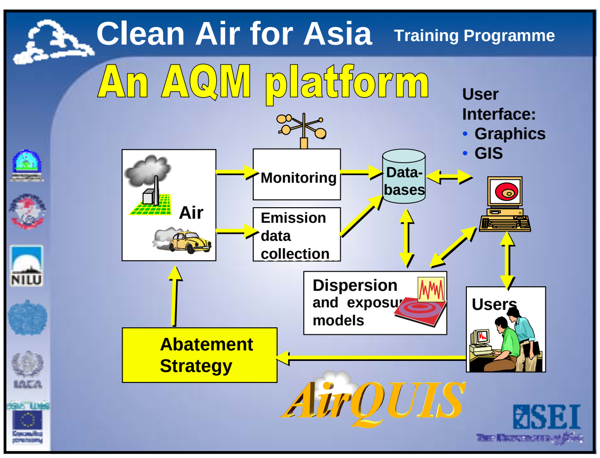
Clean Air for Asia Training Programme
Air Quality Monitoring
System Design
Bjarne Sivertsen
Norwegian Institute For Air Research
HoChiMinh City
NILU
SEI


Clean Air for Asia Training Programme
Programme Design Questions
Why do we measure?
Where should we measure?
What should we measure?
How shall we measure?
How do we store data?
How do we want to present the results?
NILU
SEI


Clean Air for Asia Training Programme
The monitoring programme is part of:
Integrated Pollution Prevention and Control
Sensor monitor
Data transfer
Data base
QA
Models Emissions
GIS
NILU
SEI


Clean Air for Asia Training Programme
Impact Pathway Approach
The complete integrated analyses (AQM)
Identify sources Emission inventory
sequence of actions
Meteorological data Dispersion and turbulence
Dispersion modelling SO2, NOx, PM +
Concentrations, Exposure
Exposure/response functions
Effect / cost data
NILU
SEI


Clean Air for Asia Training Programme
An AQM platform
User Interface:
Graphics
GIS
Air
Monitoring
Emission data collection
Data-bases
Dispersion and exposure models
Users
Abatement Strategy
AirQUIS
NILU
SEI


Clean Air for Asia Training Programme
Monitoring programme design
Characteristics of ambient air pollution :
source mixture (local, area or regional sources)
air pollution vary spatially on different scales.
annual and diurnal variations
depend upon winds
avoid random local impacts
NILU
SEI

Clean Air for Asia Training Programme

Air Quality Monitoring

Input to be considered

- ✓ Monitoring Objectives
- ✓ Data quality objectives
- ✓ Select sites and stations
- ✓ Select indicators
- ✓ Limit values and standards
- ✓ Frequency and period
- ✓ Instruments
- ✓ Statistics
- ✓ Design meteorology
- ✓ Which impacts?

Clean Air for Asia Training Programme

Monitoring objectives

- ▪Individual sources
- ▪Impact from outside
- ▪Inform the public
- ▪Warning
- ▪Forecasts

- ✓ Mapping the air quality, current levels, baseline;
- ✓ To judge compliance with ambient air quality standards;
- ✓ To observe pollution trends throughout the region;
- ✓ To evaluate progress made towards meeting standards;
- ✓ To provide a data base for research evaluation of effects;
- ✓ A database for urban, land-use, and transportation planning;
- ✓ Basis for development and evaluation of abatement strategies;
- ✓ Data as input to and development and validation of models;
- ✓ To activate emergency control procedures that prevent or alleviate air pollution episodes.

Influence on design !

Clean Air for Asia Training Programme

Data quality objectives (DQO)

In Europe the objectives that guide the quantification of DQOs, are defined such as to:

- ✓ Enable comparison of air quality across Europe,
- ✓ Enable detection of the trend over a reasonable time period in air quality in Europe, as well as in each area where stations are located,
- ✓ Enable the assessments of exposure.

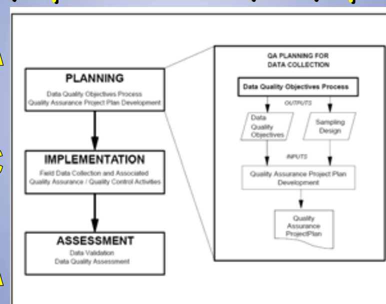
Clean Air for Asia Training Programme

DQO part of the QA/QC process

QA

QC

QA



Clean Air for Asia Training Programme

Quality Assurance

All planned and systematic activities which are needed to assure and demonstrate the predefined quality of data

1) Monitoring Objectives
Determine use of data, e.g. monitoring of trends

2) Data Quality Objectives
Determine necessary data quality to fulfil the Monitoring Objectives

3) Equipment selection
Results must fulfil the DQO. Select best measuring practice

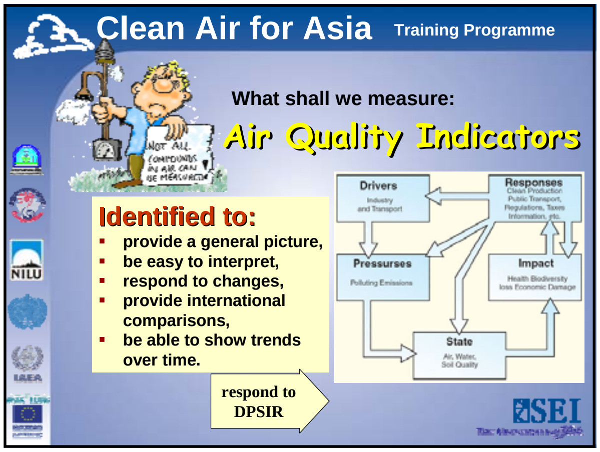
4) Site selection
Must be representative for the Monitoring Objectives

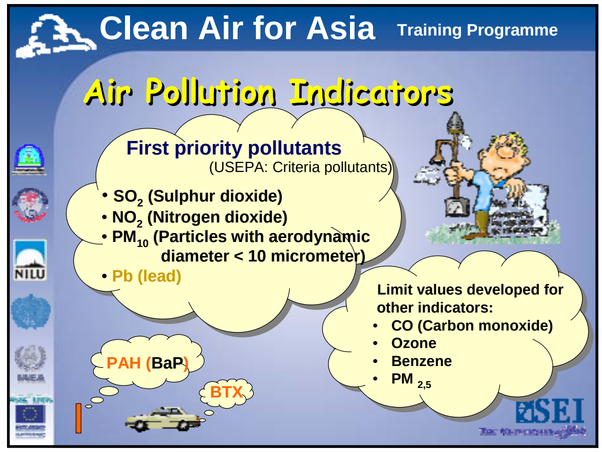
Clean Air for Asia Training Programme

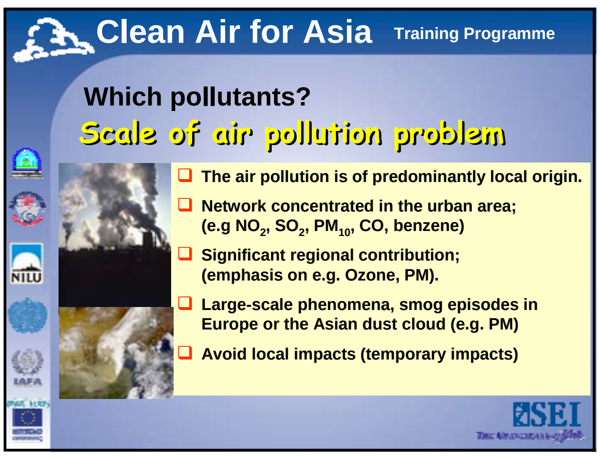
A summary of DQOs

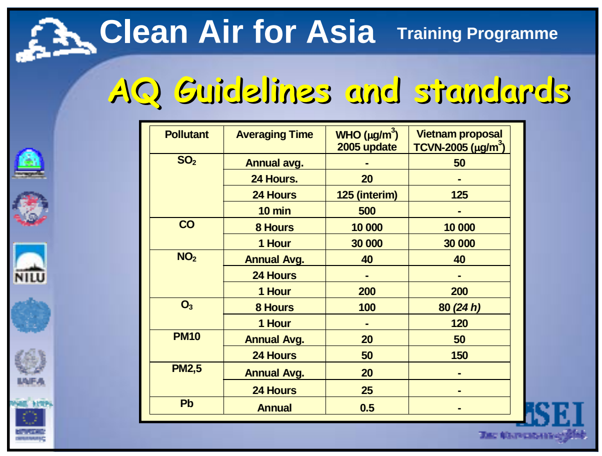
Monitoring programme/ *Monitoring objective*	Compounds	Accuracy	Precision	Data time coverage
EU Regulatory Monitoring 1) *Detect non-compliance with directives*	SO_2, NO_2 PM, Pb	15% 2) 25% 2)		90% annual "
EMEP *Provide basis for control of models*		15-25% 3)		90% annual
WMO-GAW *Detect trends over short term (5 years)*	Examples: O_3 NO_2 $PM_{2.5}$	15% or 3 ppb 20% or 50 ppt 0,05+5% M	10% or 1 ppb 10% or 25 ppt 10%	80% monthly " 90% monthly

1) Minimum DQOs. Final approval of the directive (EC 97/0266(SYN)) is pending (as of July 1998).
2) Combined accuracy and precision.
3) Total "uncertainty (combined accuracy and precision) for sampling and analysis combined). Dependent upon compound.

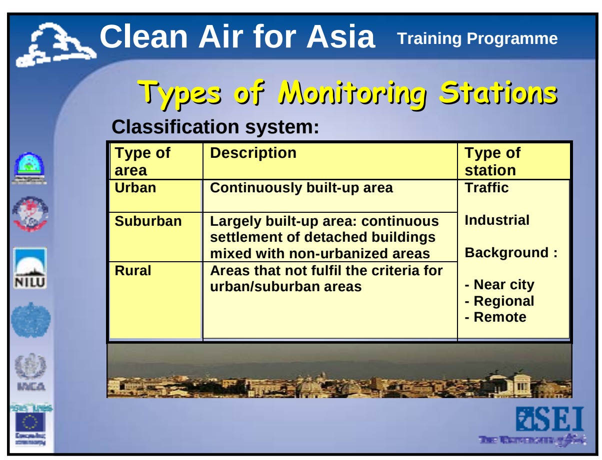




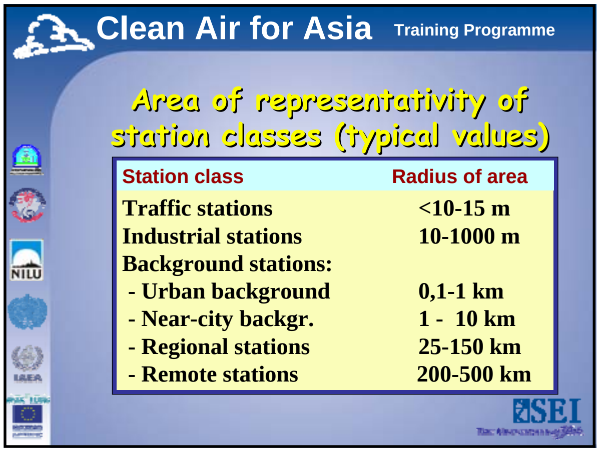




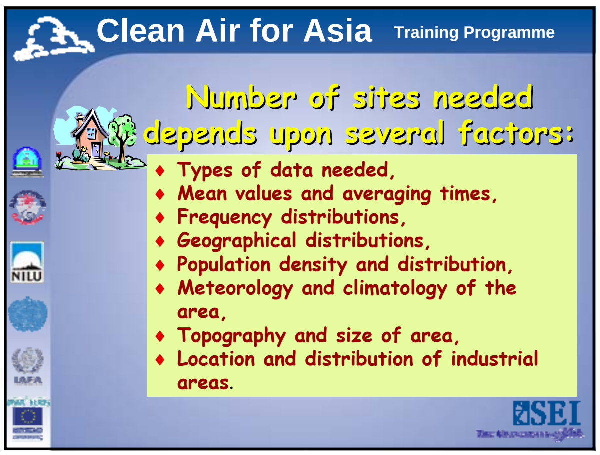
Pollutant	Averaging Time	WHO (µg/m³) 2005 update	Vietnam proposal TCVN-2005 (µg/m³)
SO_2	Annual avg.	-	50
	24 Hours.	20	-
	24 Hours	125 (interim)	125
	10 min	500	-
CO	8 Hours	10 000	10 000
	1 Hour	30 000	30 000
NO_2	Annual Avg.	40	40
	24 Hours	-	-
	1 Hour	200	200
O_3	8 Hours	100	80 *(24 h)*
	1 Hour	-	120
PM10	Annual Avg.	20	50
	24 Hours	50	150
PM2,5	Annual Avg.	20	-
	24 Hours	25	-
Pb	Annual	0.5	-

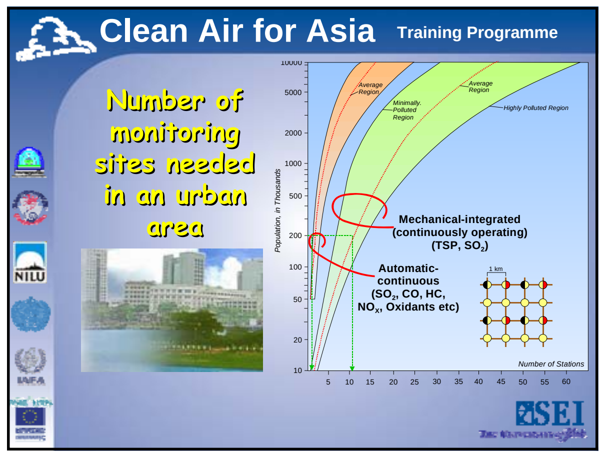


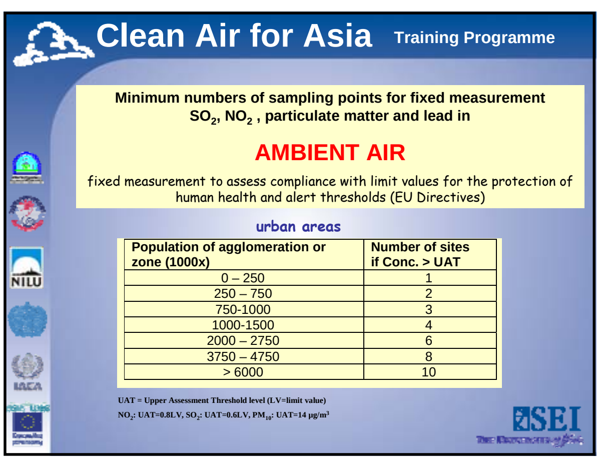
Type of area	Description	Type of station
Urban	Continuously built-up area	Traffic
Suburban	Largely built-up area: continuous settlement of detached buildings mixed with non-urbanized areas	Industrial Background :
Rural	Areas that not fulfil the criteria for urban/suburban areas	- Near city - Regional - Remote



Station class	Radius of area
Traffic stations	<10-15 m
Industrial stations	10-1000 m
Background stations:	
- Urban background	0,1-1 km
- Near-city backgr.	1 - 10 km
- Regional stations	25-150 km
- Remote stations	200-500 km



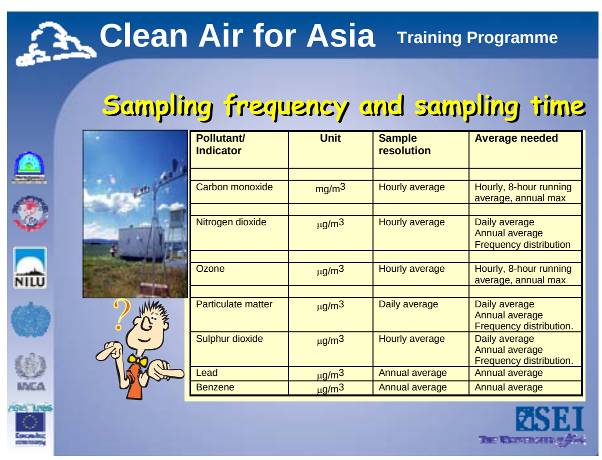




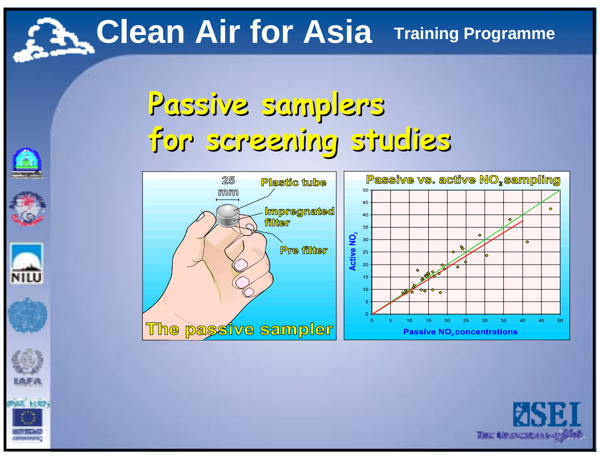
Population of agglomeration or zone (1000x)	Number of sites if Conc. > UAT
0 – 250	1
250 – 750	2
750-1000	3
1000-1500	4
2000 – 2750	6
3750 – 4750	8
> 6000	10

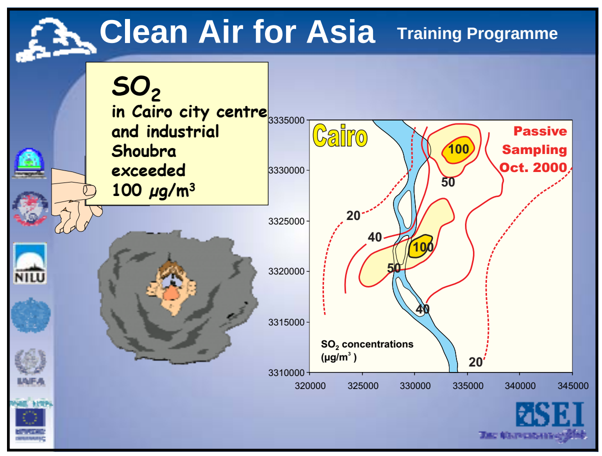
UAT = Upper Assessment Threshold level (LV=limit value)

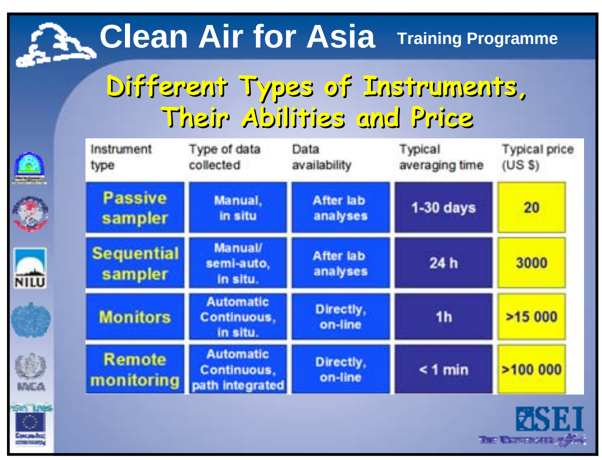
NO_2: UAT=0.8LV, SO_2: UAT=0.6LV, PM_{10}: UAT=14 µg/m³



Pollutant/ Indicator	Unit	Sample resolution	Average needed
Carbon monoxide	mg/m3	Hourly average	Hourly, 8-hour running average, annual max
Nitrogen dioxide	µg/m3	Hourly average	Daily average Annual average Frequency distribution
Ozone	µg/m3	Hourly average	Hourly, 8-hour running average, annual max
Particulate matter	µg/m3	Daily average	Daily average Annual average Frequency distribution.
Sulphur dioxide	µg/m3	Hourly average	Daily average Annual average Frequency distribution.
Lead	µg/m3	Annual average	Annual average
Benzene	µg/m3	Annual average	Annual average



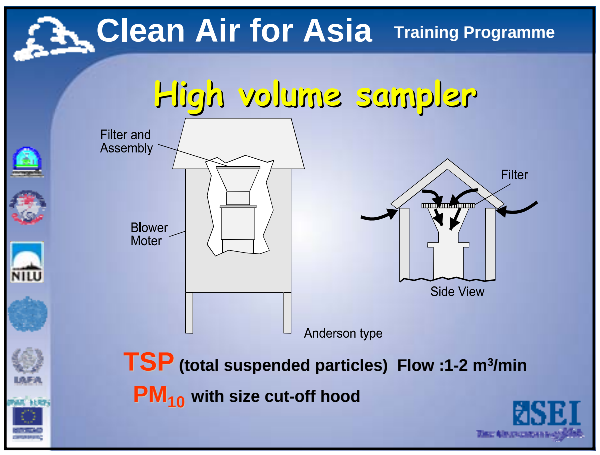




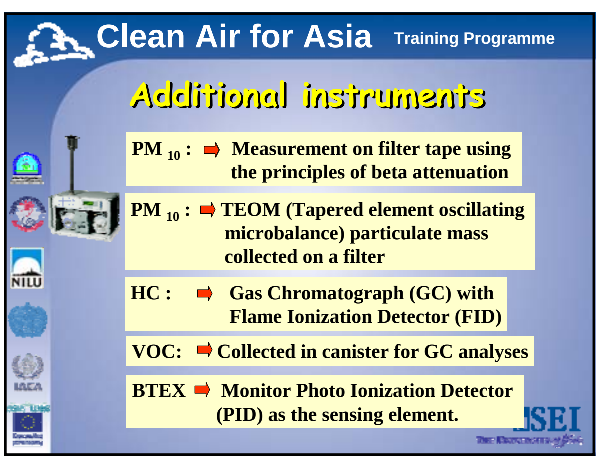
Instrument type	Type of data collected	Data availability	Typical averaging time	Typical price (US $)
Passive sampler	Manual, in situ	After lab analyses	1-30 days	20
Sequential sampler	Manual/ semi-auto, in situ.	After lab analyses	24 h	3000
Monitors	Automatic Continuous, in situ.	Directly, on-line	1h	>15 000
Remote monitoring	Automatic Continuous, path integrated	Directly, on-line	< 1 min	>100 000

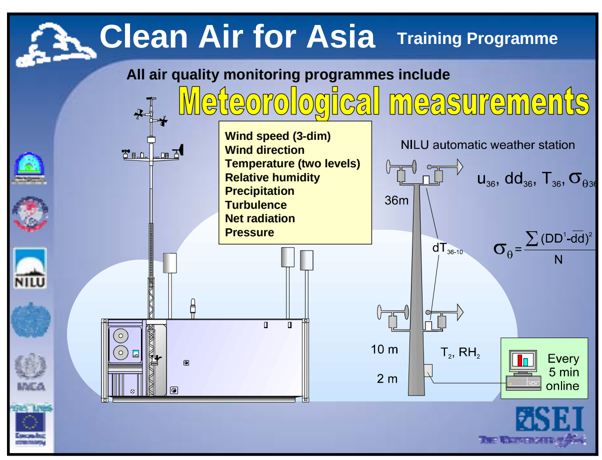

Clean Air for Asia Training Programme
Sequential sampler for SO2 and NO2
SEI


Clean Air for Asia Training Programme
Simple instruments for PM10 and PM 2,5
Minivol sampler
Kleinfilter
SEQ sampler
Dust track
SEI


Clean Air for Asia Training Programme
High volume sampler
Filter and Assembly
Blower Moter
Filter
Side View
Anderson type
TSP (total suspended particles) Flow :1-2 m3/min
PM10 with size cut-off hood
SEI


Clean Air for Asia Training Programme
Air quality Gas Monitors
SO2 ⇨ fluorescent signal exiting SO 2 with UV
NO, NO2 ⇨ chemiluminiscent reaction NO/O
O3 ⇨ UV absorption analyser
CO ⇨ non-dispersiveinfrared photometer
Reference instruments !
SEI

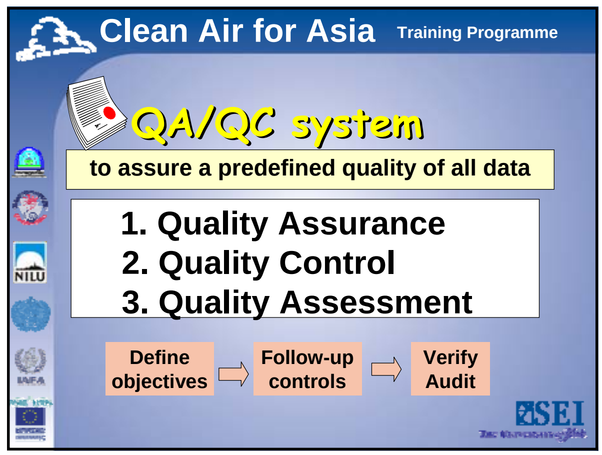

Clean Air for Asia Training Programme
Additional instruments
PM 10 : ⇨ Measurement on filter tape using the principles of beta attenuation
PM 10 : ⇨ TEOM (Tapered element oscillating microbalance) particulate mass collected on a filter
HC : ⇨ Gas Chromatograph (GC) with Flame Ionization Detector (FID)
VOC: ⇨ Collected in canister for GC analyses
BTEX ⇨ Monitor Photo Ionization Detector (PID) as the sensing element.
SEI


Clean Air for Asia Training Programme
All air quality monitoring programmes include
Meteorological measurements
Wind speed (3-dim)
Wind direction
Temperature (two levels)
Relative humidity
Precipitation
Turbulence
Net radiation
Pressure
NILU automatic weather station
36m
10 m
2 m
Every 5 min online
SEI

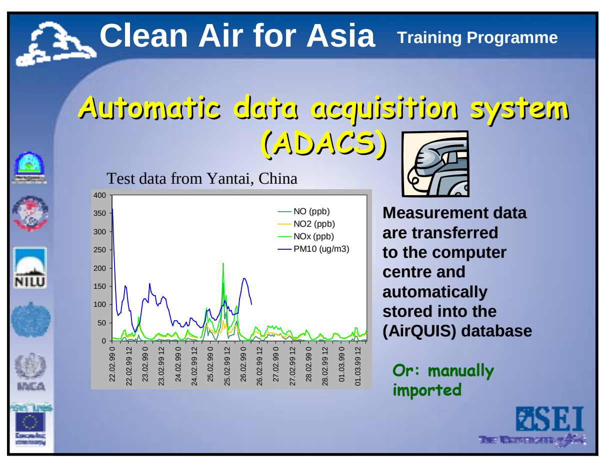

Clean Air for Asia
Training Programme
Meteorological station HCMC
wireless communication
NILU
IAEA

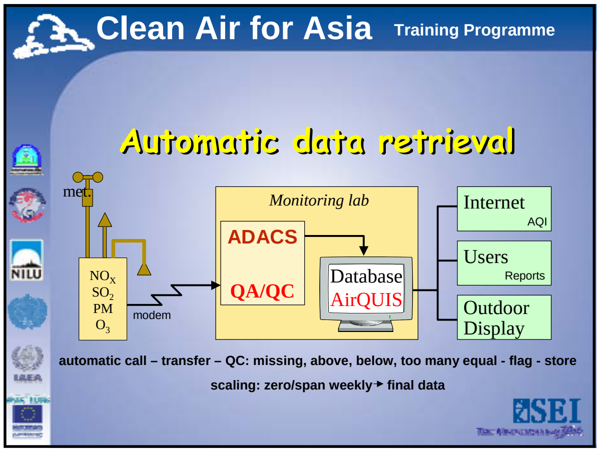

Clean Air for Asia
Training Programme
Objectives
Requirements
Permanent network !
Should map:
1. Highest concentrations and hotspots;
2. Representative concentrations in areas of high population density;
3. Impact from significant sources or source categories;
4. General background concentration levels.
NILU
IAEA
SEI


Clean Air for Asia
Training Programme
A typical monitoring station
QA/QC !
Urban background site in HCMC
NILU
IAEA
SEI


Clean Air for Asia
Training Programme
QA/QC system
to assure a predefined quality of all data
1. Quality Assurance
2. Quality Control
3. Quality Assessment
Define objectives
Follow-up controls
Verify Audit
NILU
IAEA
SEI


Clean Air for Asia
Training Programme
Air Quality
Data quality
Data transfer
Data availability
NILU
IAEA
SEI


Clean Air for Asia
Training Programme
Automatic data acquisition system (ADACS)
Test data from Yantai, China
NO (ppb)
NO2 (ppb)
NOx (ppb)
PM10 (ug/m3)
Measurement data are transferred to the computer centre and automatically stored into the (AirQUIS) database
Or: manually imported
NILU
IAEA
SEI


Clean Air for Asia Training Programme
Automatic data retrieval
met.
NOx SO2 PM O3
modem
Monitoring lab
ADACS
QA/QC
Database AirQUIS
Internet AQI
Users Reports
Outdoor Display
automatic call – transfer – QC: missing, above, below, too many equal - flag - store
scaling: zero/span weekly → final data
SEI


Clean Air for Asia Training Programme
ADACS Module
contains the following main features
Configuration of data logger
Configuration of automatic QC-flags (Quality Control) for incoming data
Automatic job queue with history logs for tracking and handling of data transfer in case of communication break down or system maintenance of the instruments/sensors
Automatic Schedule for data retrieval
SEI


Clean Air for Asia Training Programme
Air Quality Index (AQI)
Generated automatically every day
Displayed on board at Benh Thanh
Presented daily on Internet
SAMSUNG
SEI


Clean Air for Asia Training Programme
Available in Norway
E-mail
SMS
WAP
MMS
Forecasts
Status
SEI


Clean Air for Asia Training Programme
Input to the AQ Management Systems
The modern air quality monitoring system is an important part of the complete AQM system
Logger
QA/AC
Quality Assurance and Quality Control
Sampler
WAP
Sources
Internet
Public
Transfer
Report
Check data
SEI


Clean Air for Asia Training Programme
Thank you !
Questions ???
www.nilu.no
SEI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