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MONITORING AIR QUALITY, OBJECTIVES AND DESIGN

Today's environmental information systems combine the latest sensor and monitor technologies with data transfer; data base developments, quality assurance, statistical and numerical models and advanced computer platforms for processing, distribution and presenting data and model results. Geographical Information Systems (GIS) are an important tool, particular for the presentation of data. An important part of the integrated air quality management system is the establishment of a monitoring programme for air quality. Once the objective of the air monitoring programme is well defined, a certain operational sequence has to be followed. The best possible definition of the air pollution problem, together with the analysis of the personnel, budget and equipment available, represent the basis for the final design. The specification of monitoring objecttives, data quality objectives together with proper site selection, data quality assurance and well-defined data presentation and assessment are important elements in this process.

Key words: air quality monitoring; GIS system; AQ management.

AIR QUALITY MONITORING NETWORK DESIGN

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.

The typical approach to the network design, appropriate over the 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 the network design is the scale of the air pollution problem:

– The air pollution is of predominantly local origin. The network is then concentrated on 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).

This presentation is mainly 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 [1]. 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 sections [2].

MONITORING OBJECTIVES

The air quality monitoring programme design will be dependent upon the monitoring specific objecttives 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 to?

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

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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 a direct /automatically/ on-line 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 [3].

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

− facilitate the background concentration(s) 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 the air quality data from different areas and countries,

− collect data for the air quality management, traffic and land-use planning purposes,

− observe trends (related to emissions),

− develop abatement strategies,

− determine the exposure and assess the effects of air pollution on health, vegetation or building materials,

− inform the public about the air quality and raise the awareness,

− develop warning systems for the prevention of undesired air pollution episodes,

− facilitate the source apportionment and identification,

− supply data for research investigations,

− develop/validate management tools (such as models),

− develop and test analytical instruments and

− to support legislation in relation to the 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.

SCREENING STUDIES AND OPERATIONAL SEQUENCE

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 as based on the results of the screening study as well as on the knowledge of the sources and prevailing winds.

Once the objective of air sampling is well-defined and some preliminary results of the screening study are available, a certain operational sequence has to be followed. The best possible definition of the air pollution problem, together with the analysis of the personnel, budget and equipment available, represent the basis for the 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 and during what period?

6. What should the sampling (averaging) time and frequency be?

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 will 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.

Site selection

The urban air quality monitoring programme will normally provide the information to support and facilitate the assessments of the 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 live, stay and move. 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 the undue influence from the immediate surroundings. When measuring air quality or analysing the results from measurements it is important to bear in mind that the data you are looking at are 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:

– natural background concentration,

– regional background,

– city average background concentration (kilometer 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 the information about the importance of these different contributions it is therefore necessary to locate monitoring stations so that they are representative for different impacts. In addition to the air pollution data, we will often need meteorological data to identify and quantify the sources contributing to the measurements. 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. More than one monitoring site is often needed in order to characterise the air quality in the urban area [4].

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 [1,5,6]. Descriptions of the areas are given in the Table 1.

Table 1. Typical area classification of micro-environments for the air quality monitoring programs

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
Rural	Areas that do not fulfill the criteria for urban/suburban areas	Background: – Near city – Regional – Remote

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.

Air quality indicators

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 the air pollution involves some indicators addressing several issues. Some of the issues that have to be addressed are:

– climate change,

– ozone layer depletion,

– acidification,

– toxic contamination,

– urban air quality and

– traffic air pollution.

As it 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 [7].

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 (and 2,5 μm), PM10 (and PM2,5) and

– ozone (O_3).

The US EPA refers to the compounds listed above as the priority pollutants [5]. 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 [2]. 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 [8,9].

Other elements in the design

In the design of the air quality monitoring programme we will also have to include the measurements of meteorology. Weather stations should be located in order to assess the general wind flow over the study area.

Weather stations do not need to be placed at all air quality sites, but some co-locations will decrease the total cost of these measurements.

Before the air quality data can be used to assess the situation in the area, it is important to 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 the input to the air quality assessment and evaluation, the following main questions may be asked:

− Have the 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 the 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 the process credibility and validity of the data. Good data quality is essential for adequate reporting of the air quality [10].

Data retrieval and storage

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 min 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 the modem, transmission lines or the central computer. A typical dataflow from instruments to a user is shown in Figure 1.

The data retrieval from monitoring stations, which are equipped with modems and telephone lines, may be performed by the Computer centre using a variety of different ways. These may be:

− The Computer centre data base system asks for data automatically once a day (normally during night hours, at 02:00 hrs).

− The Computer centre operator initiates downloading (manually) which requires that the modem is functioning.

− Data are automatically retrieved from the station every hour or every five minutes into the central database.

Data may also be transferred to the central database through a wireless data service such as GPRS (General Pocket Radio Service).

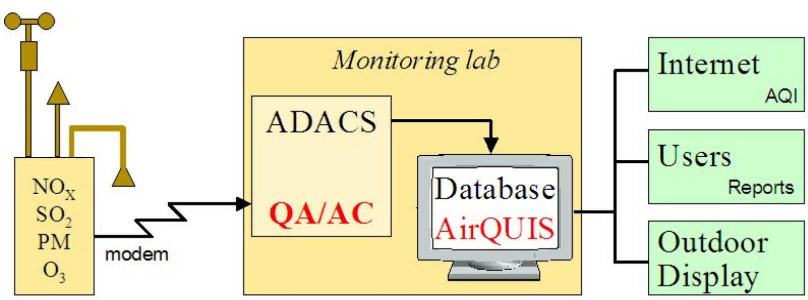

Figure 1. Dataflow from instruments and through the data retrieval system (ADACS) and database to different applications and users. The AirQUIS system was developed by NILU dealing with air pollution, information technology and geographical information systems (GIS). The combination of on-line data collection, statistical evaluations and numerical modeling enable the user to obtain the information, carry out forecasting and future planning of the air quality.

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