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The Environmental Monitoring and Information System

NILU

The Norwegian Institute for Air Research

The environmental monitoring and information system

An automatic surveillance system for the environment

Development of technical monitors and telemetric systems have made environmental data more readily available to planners, authorities and to the public. In line with awareness and the strong focus on our environment the modern environmental monitoring and surveillance systems have also become information systems that can provide relevant information at different levels about the state of the environment, quickly and precisely.

The integrated approach towards environmental management is based on the view that the environment should be monitored and followed as an entity. This is also in line with the concept "sustainable development" introduced by the Brundtland Commission, and which has been widely adopted by both national governments and international organizations.

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.

These technologies can be 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. In the following we will describe the content of a surveillance system for local and regional environmental management, for urban areas or regions dealing with industrial problems, traffic, energy sources and solid and liquid waste.

Most of the examples below are related to the development of a system for air pollution monitoring and information. The examples given mostly apply to air quality studies in urban areas. However, the descriptions can also very well be applied to other types of environmental issues. Biological monitors or direct impact monitoring (on man and the environment) is not covered by the described system.

The technical features of the system

The key features of the modern environmental information system is the integrated approach that enables the user in a user friendly way to not only access data quickly, but also use the data directly in the assessment and in the planning of actions. The demand of the integrated system to enable monitoring, forecasting and warning of pollution situations has been and will be increasing in the future.

The data may also be used for generating new indicators that relate directly to health impacts. This will require that numerical dispersion models for air pollutants are available with on-line data input as a part of the system in urban areas.

Several systems are currently being developed and have been demonstrated in selected areas in Europe. One such system, "ENSIS '94", an ENvironmental Surveillance and Information System, was developed as part of the Eureka project for the Winter Olympic Games in Lillehammer. (*Sivertsen and Haagenrud, 1994*). The following description is based on this prototype.

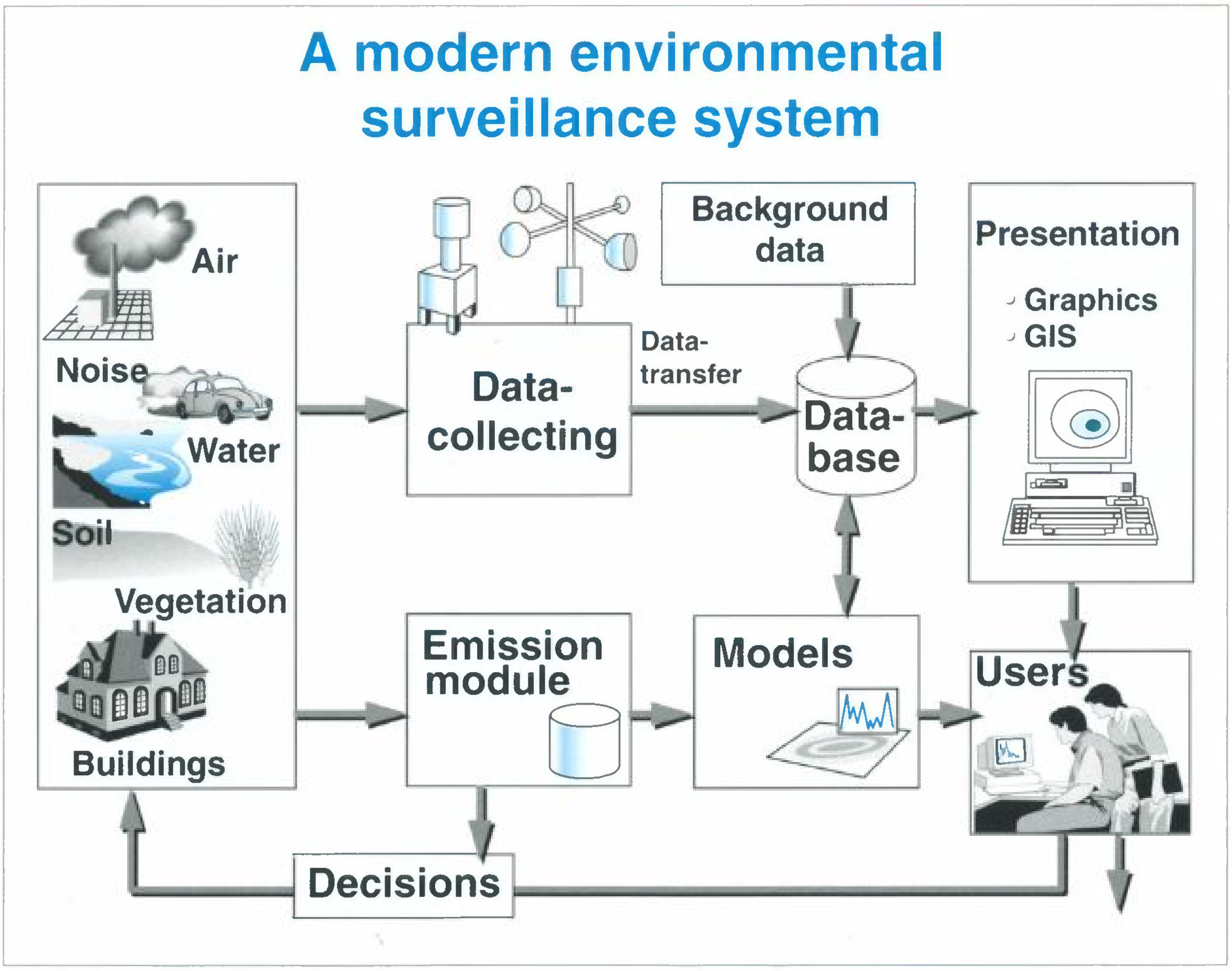
The ENSIS concept has later been developed further into an AirQUIS module for air pollution surveillance, a WaterQUIS module for water pollution, and similar modules for noise, deterioration of materials and buildings etc. The different modules are all operated under the same main framework and can be combined in a flexible total system.

Other integrated systems are being established in Europe. One of the important topics of the European Commission DG XIII Telecommunications, Information Market and Exploitation of Research, Telematics Application Programme (1994-1998) is deals with this subject. Several major urban areas in Europe will thus be involved in the establishment and demonstration of such systems.

An important objective for the modern environmental surveillance platform is to enable on-line data and information transfer with direct quality control of the collected data. This may require new sensor technology or modification of present monitoring methods. Several monitors and sensors that makes on-line data transfer and control possible are already available on the market. For several other compounds and indicators this is not the case.

The system should include:

- Data collectors; sensors and monitors,
- data transfer systems and data quality assurance/control procedures,
- data bases included emission and discharge modules,
- statistical and numerical models (included air pollution dispersion models and meteorological forecast procedures),
- user friendly graphical presentation systems including Geographical Information Systems (GIS),
- a decision support system
- data distribution systems and communication networks for dissemination of results to "outside" users.

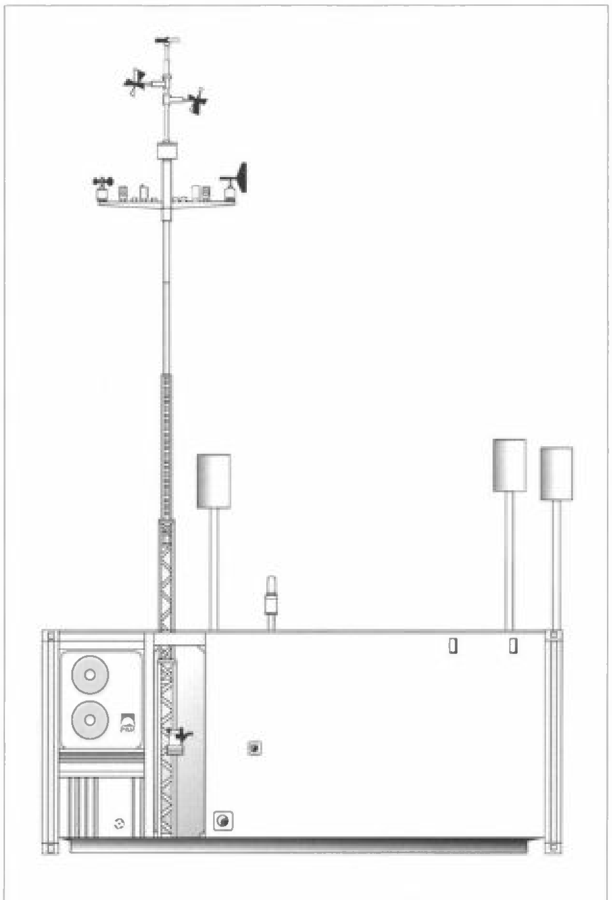


The principal structure of a modern environmental monitoring and information system.

Sensors and monitors

New instruments needed

Modifications and development of new sensors and monitors are necessary to establish a complete environmental information system that meets the requirements of today's users. Several sensors and monitors for meteorology, noise, air- and water quality are already available on the market. However, not all of these can be linked on-line to a data transmission and data quality control system.



NILU mobile field laboratory and measurement platform.

A description of measurement techniques for all environmental parameters will take too much space here. For air pollutants it is important to decide whether one wants to measure in situ to obtain a point measurement or take an integrated sample over a distance or a volume. In the latter case different optical methods using light absorption have been developed and used during the last few years. Specific methods including single line spectroscopy with advanced optical filters or tuneable diode lasers emitting light at one particular wavelength have also been, or are being developed for selected individual air pollutants. However, it is difficult to obtain in situ measurements i.e. in streets with these instruments. The cost of these instruments is also high, depending on the number of parameters needed to get a good indication of the status of the air quality. (See indicators.)

A new generation of water quality sensors for process control and water management was demonstrated during the ENSIS programme in Lillehammer 1994. It included the monitoring of drinking water, waste water treatment and river water acidity.

Meteorological data

Meteorological data are important input data to a system that is to be used for information, forecasting and planning purposes. Meteorological data are also important for explanatory reasons together with climatological data. Meteorological data are needed from the ground, normally collected along 10 m towers, and up to the top of the atmospheric boundary layer. Automatic weather stations are currently being used in most large field studies, in remote areas and in complex terrain. Meteorological "surface data" such as winds, temperatures, stability, radiation, turbulence and precipitation are being transferred to a central computer via radio communication, telephone or satellite.

One of the more difficult parameter to obtain on a routine basis is the height of the boundary layer as a function of time. This height is often related to and referred to as the mixing height. When air quality models are being applied for exposure modelling, information and forecasting and decision making purposes, meteorological input data from the boundary layer are crucial.

To improve the meteorological input data for numerical air quality models in urban areas, more advanced three dimensional wind and turbulence measurement equipment should be included. These instruments can measure the atmospheric turbulence directly. These turbulence data can be used directly to estimate the dispersion more accurately. Many areas have already installed Doppler sodar systems that can measure the vertical structure of wind and turbulence. These data are also subject to certain ambiguities, but represent a valuable additional input to the models for on-line information and warning.

A combination of measurement data (at several locations) and model estimated wind fields will represent the necessary input to numerical air pollution dispersion models in a complex urban area. These models are usually set to estimate concentration distributions on an hourly basis, and the most important parameters are therefore the flow pattern and a correct picture of the transport of pollutants. In some cases, especially when applying mesoscale and regional scale models, remote sensing of weather systems from satellites may prove a useful tool for estimating input data.

Environmental indicators

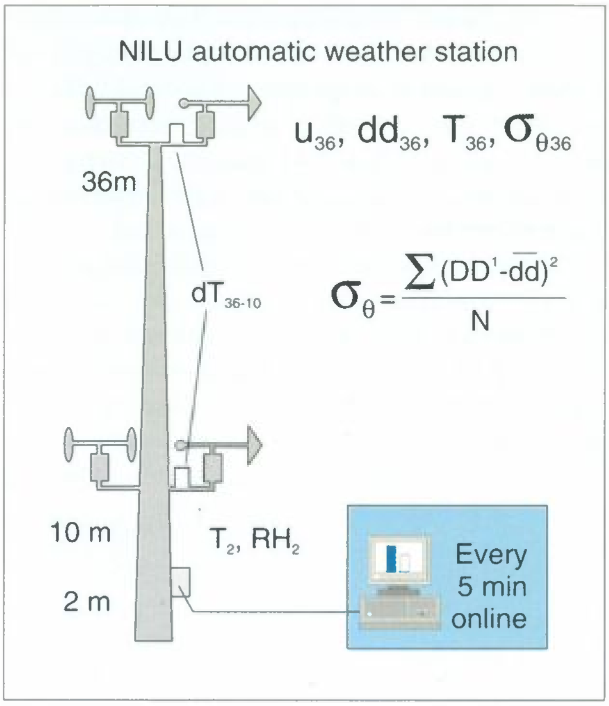
The selection of parameters included in the monitoring and model estimate programme should enable an automatic access to data relevant for assessing the environment included air pollution and atmospheric conditions, pollution of rivers and seas, ground water, waste, noise and radiation. For all these environmental compartments there should be a set of environmental indicators.

These indicators should represent a set of parameters selected to reflect the status of the environment. An indicator may be a single variable of sufficient sensitivity to reflect changes in the status of the environment. In some cases, however, indicators may be derived from a set of independent variables in the system. The selection of indicators should also allow evaluation of trends and developments. The aim is that the indicators can form a basis for evaluating the impact on humans and the environment as a whole and thereby be relevant for information, warning and decision making purposes.

Many national and international authorities are presently working with processes to select environmental indicators. The result of this work will not be available in another few years. In the meantime, for air quality, the selected parameters are mostly related to air pollutants for which air quality guideline values are available.

The development of environmental indicators in Europe will contribute to the harmonization of several initiatives. This activity will be important input to the design and content of monitoring programmes. Harmonization is an important concept both in monitoring and in modelling. It allows different methods to be used to measure the same variable to predetermined levels of accuracy and precision. Even if different methods are applied the data from each location can be comparable and compatible

The selected set of environmental indicators will be used by local and regional authorities as a basis for the design of measurement programmes and for reporting the state of the environment.



Typical automatic weather station with sensors on 36 m tower.

The establishment of environmental indicators will help to:

- identify the quality of the environment,
- quantify the impact,
- harmonize data collection,
- assess the status and the rate of improvement/deterioration,
- identify needs for and support the design of control strategies,
- support input to management and policy changes.

The indicator should represent the "pressure" on the environment and include both background indicators and stress indicators. So-called response indicators are selected to reflect the societies awareness or response to its surroundings.

The indicator should:

- be relevant in connection with environmental quality,
- be easy to interpret,
- respond to changes,
- provide international comparisons,
- have a target or threshold value that provides a basis for assessment,
- be able to show trends over time.

It should also be possible to measure with reasonable accuracy. It should be adequately documented and linked to public awareness; health impact, building deterioration, vegetation damage etc. Selected indicators should respond to mitigation actions to prevent human made negative impacts on the environment.

Indicators might also be aggregated data and not necessarily observed single parameters. The modern environmental surveillance and information systems (ENSIS) include good quality on-line meteorological data, numerical dispersion models with emission inventories. These models are capable of estimating concentration distributions on an hourly basis. These distributions can be linked to population distribution maps, building material inventories, vegetation maps etc. to give exposure estimates.

These aggregated, estimated data will express directly the impact and stress to the environment (health, materials, vegetation) and will in the future represent a better indicator for international comparisons and trend analyses. It will also represent an improved measure for the actual air pollution problem in a given (well defined) area or region.

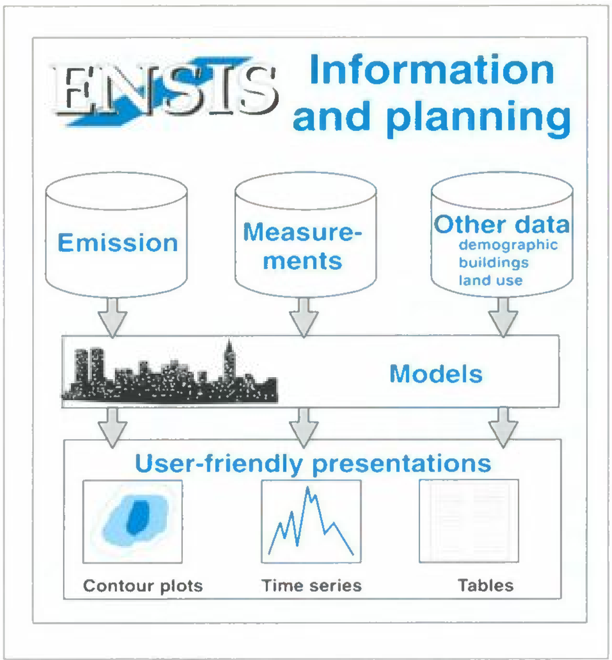
Data transfer and quality assurance

Specially designed data loggers for environmental data are available. Data loggers designed and built by NILU were included in the ENSIS '94 application. The logger should be robust and serve as a local backup storage unit in case of link brake down (lightening, storms etc.). The logger is directly linked to a modem.

Data transfer can be via local radio communication for limited distances. This has been the case for a distributed local net of several meteorological stations where data are transmitted via radio link to the main station in the area. Data will further be transmitted on public telephone lines or via satellite to the main computer facility. The central unit might be a major field station or a central laboratory. For an emergency system developed for the Eureka project MEMbrain, a field laboratory has been established with a work station computer including all modelling tools. (*Sivertsen, 1994.*)

Data quality assurance programmes including direct quality control is performed at different levels in the data collection process;

- in field during automatic and manual calibrations and controls,



The associated data bases are linked to a modelling system which provides user friendly presentations of all kinds of information from the system.

- at the central data collection base following quality assurance routines as described i.e. in ISO 45001 from the International Standardization Organization,
- in approvals to the final data base,
- through simple statistical and graphical evaluations to check validity and representativeness of data.

The quality control procedures give the data credability. The data become reliable, which is essential when using the data for reporting, controls and planning. To be used with confidence for scientific and environmental management purposes the data must also be comparable and compatible.

Integrated data from local sites and from various environmental compartments require comparable data quality. The various local networks have to operate to high standard including proper implementation of good practice by network managers and site responsible personnel.

The data bases

The development of an associated data base or metadata is important to all modern environmental monitoring and information systems. The data base system may consist of several data bases which serve as main storage platforms for:

- on-line collected environmental data,
- emission and discharge data included emission modelling procedures,
- historical data and background information like area use, population distributions and trends,
- regulations, guideline values and information on the support and decision making process.

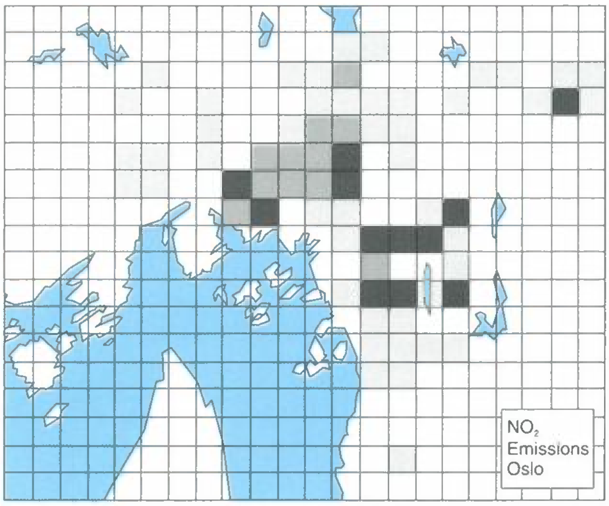
The data bases contain information that enables an evaluation of the actual state of the environment and it includes data for establishing trend analyses, warnings and the undertaking of countermeasures in case of episodic high pollution.

The on-line data base

All data collected on-line will after quality assurance and controls be part of the information data base. From this base it will be possible to obtain quick graphical presentations, or to substract data for public information purposes etc.

The emission data base

The emission data base is an interactive platform for collecting input data for emission estimates. It contains information about the sources, emission factors, consumption data, information on locations (gridded co-ordinates), stack heights, stack parameters, fuels etc. The emission data base can be operated directly by the user, who can use the emission models directly to present emission data directly. Any changes and additions to the emission data base will result in updated emission estimates with links to the dispersion models and resulting database for graphical presentation.



Gridded NO_X emission estimates for Oslo based upon fuel consumption data, industrial sources, traffic and emission factors.

Historical and background data base

The historical and background data base module includes relevant objects and information such as monitoring stations and sensors, sensor developers, responsible institutions, locations and measurement schedules, methods, data owners, maintenance routines etc. It also contains information about earlier and additional environmental data collected in the area. Background information such as area use, population distributions and inventories of vegetation and materials/buildings in the area may be an important part of this data base. Such information can be used for impact assessment estimates and for some of the emission estimates.

Supporting data base

The supporting data base, which may be part of the background data base contains information on regulations, requirements, air quality guideline values or water quality standards for various applications.

Information about regulations and plans given by local authorities or by governmental bodies should be included in this database, as well as support actions and emergency procedures.

The total associated database system will also serve as a link to a meta information system which includes information on external environmental data. These functions might also include:

- navigation facilities to access the needed information,
- support for standardization activities,
- world wide web/internet functions and bridges.

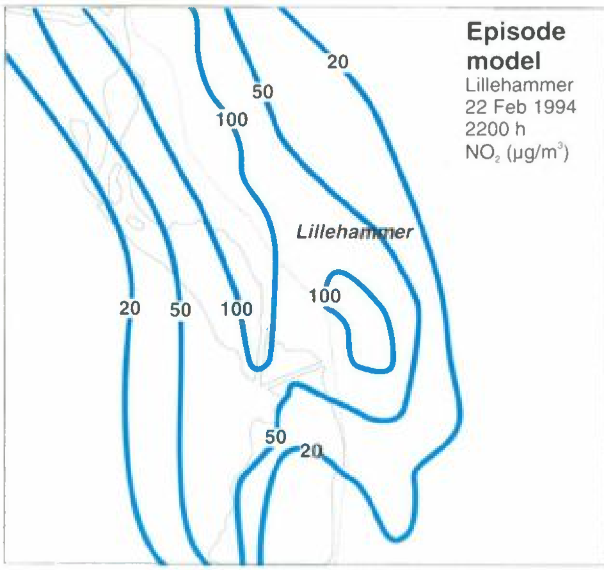
The data base model is designed to support local and regional levels and meets most of the requirements specified by the users.

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.

The models

In the modern multi compartment environmental information system (like ENSIS) steps have been taken to establish models for air pollution dispersion, for water quality and noise and for other environmental impact assessment estimates. Models for these media will be essential when the programmes are to be used for planning purposes.

The air pollution dispersion models are a well-established and fully implemented part of the system. These models have been tested and demonstrated as part of the integrated surveillance systems and is presently being operated in several cities on a routine basis. Also water quality modelling is available and is being tested and verified as part of the ENSIS system.



An example of one hour average NO_2 concentration distributions taken from the Lillehammer Olympics presentation using ArcInfo and a numerical dispersion model together with monitoring data from Lillehammer.

The description of models below is, however, strictly limited to air pollution dispersion estimates and examples are given for various air quality models available in the ENSIS system. Different types of dispersion models have been developed and applied to estimate the ambient impact of air pollution emissions from point- line and area sources.

The selection of models to be used in a specific case is dependent upon the spatial and temporal scales, complexity of source configurations and chemistry, topographical features, climate and instationarity/inhomogeneity in the meteorological conditions of the area. It is advisable to consult experts in this process.

A variety of different models are available on the market today. However, one should note that it may be a significant step from obtaining a model to actually having an operable modelling tool for a specific area and application.

The following examples of different types of models available are taken from the air pollution surveillance programmes. They range from single quasi stationary Gaussian type single source models based upon analytical solutions of the mass balance equations, to advanced numerical models which require large computers.

The simplest models can be used on personal computers for impact assessment. These models can estimate 1 h average concentration distributions downwind from ground level, diffusive and elevated single sources. (*Sivertsen 1980, Bøhler 1987*)

One step up represents the short term model for estimating 1 h average concentration distributions for emissions from multiple source industrial complexes (*Bøhler 1987*). This includes the multiple source Gaussian type models for estimating short term or long term integrated concentrations in a gridded co-ordinate system. Two different type of such models have been developed at NILU; CONDEP for monthly, seasonal and annual average concentration distribution estimates (*Bøhler 1987*) and KILDER which is a flexible emission inventory linked to multiple source Gaussian type dispersion models for line, area and point sources. (*Gram and Bøhler 1992*).

The grid system used by the models is specified by the user to match the specific problem and the area considered. The resolution, grid spacing and total area can easily be modified and changed depending upon the specific needs.

These models need as input data some background information on;

- source characteristics and emission data,
- area characteristics (surface roughness, topography etc.),
- measurement data (measurement type, heights etc.),
- meteorological data (wind, stability, mixing height, temperatures etc.),
- dispersion coefficients (type to be used and parameters),
- dry and wet removal coefficients,
- location of receptor points (distances or grid specifications).

All the NILU models have been well documented and are being used for planning purposes and for impact assessments both nationally and internationally.

Small scale models are also available for estimating the air pollution load from traffic in street canyons and along roads. A commercially available model, ROADAIR (*Larssen and Torp, 1993*), estimates emissions, concentrations and exposure along the road system based upon traffic data. These input data may originate from traffic models or from traffic density data and on-line traffic countings.

On a spatial scale from about 1 to 100 km there are several types of numerical models available; both Lagrangian type and Eulerian type models. The Lagrangian type models follow puffs of air pollutants estimating in each puff the turbulent diffusion, chemical reactions and deposition processes. The turbulence description and the diffusion processes may be treated in different ways.

One example is the INPUFF model (*Knudsen and Hellevik, 1992*) which is based upon Gaussian concentration distributions in the puff. This model also includes chemical and physical reactions and processes. Another model of this type is the Danish operational puff diffusion model RIMPUFF (*Mikkelsen et al., 1987*). This model was developed by Risø National Laboratory to provide risk and safety assessment in connection with e.g. nuclear installations.

One example of an Eulerian type numerical dispersion model is the EPISODE model developed by Grønskei et al. (1993). This is a time-dependent finite difference model normally operating in three vertical levels, combined with a puff trajectory model to account for subgrid effects close to individual sources. When the size of the puffs reaches the horizontal and vertical grid size the transport and dispersion is treated as a numerical box model. The mass of pollutants are then added to the average value for that grid element. The model can thus treat point sources, area/volume sources and line sources. The wind field used as input to the model may be homogeneous or inhomogeneous for each time step dependent upon the meteorological input data available.

For the selection of models to be used in a specific case there have been different methods indicated. Sivertsen (*1979*) indicated a flow chart for selecting models dependent upon type and complexity of the sources, spatial and temporal scales, chemical composition (secondary or primary pollutants), topographical features, climate and meteorological features of the selected area.

For further information on the use of models Hanna et al. (*1982*) give a good overview of the topic. One important issue when using dispersion models is to obtain adequate meteorological input data. Meteorological pre-processors have been developed during the last few years to handle this problem. (*Paumier et al., 1985 and Bøhler et al., 1995*). These pre-processors can estimate meteorological dispersion and the basic meteorological variables of interest for diffusion modelling based upon the current concepts regarding the structure of an idealized boundary layer. (*Gryning et al., 1987*). Methods are also provided for estimating the vertical profiles of wind velocity, temperature and the variances of the vertical and lateral wind velocity fluctuations.

Data presentation; graphics and GIS

Environmental data collected through the automatic monitoring and telematic network will be quality controlled and transferred for storage in the integrated relational databases. Statistical programmes for control of quality and representativeness will be used, and the first results can within one hour after field collection be presented using user-friendly graphical tools.

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. These users may be:

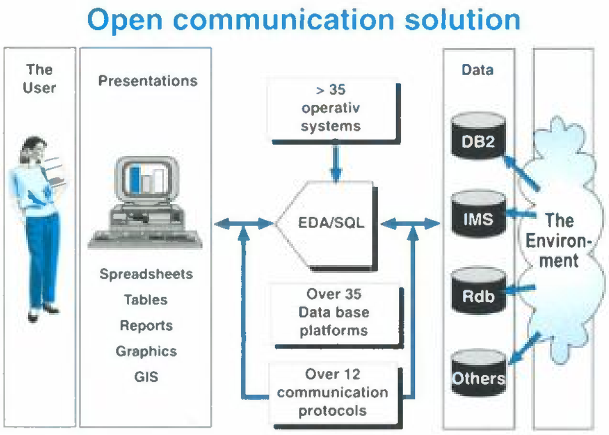
- authorities at different levels (municipal, regional, national, international),
- industrial users,
- schools, universities and the scientific community,
- various organisations,
- the public and media.

The environmental data are usually linked to geographical sites. In particular when monitoring data are supported and supplied by model estimates of spatial concentration distributions and impacts, it is suggested that the presentation of the results would involve the use of maps or digitalized Geographical Information Systems (GIS).

Geographical information systems based on advanced raster/vector technology has been developed to handle maps, networks, symbols and various objects. They can handle both geographical information and technical documentation and present this in graphical form. The basic raw map information has normally been work-station based, but user friendly PC based applications for displaying e.g. environmental data have been developed during the last few years.

The GIS user can easily organise selected data from various data bases. Tematic maps can be produced combined with time series graphical presentations and results from model calculations. The system will display the results of planned actions based upon simulation models and thus act as a more user friendly decision support system.

For the application of ENSIS during the Winter Olympics in 1994 ArcInfo and ArcView were selected as the map reference systems. The GIS tool was directly linked to the data bases, from which statistical evaluations, graphical presentations and spatial distributions from numerical models were presented.



The user oriented open communication solution established during the Eureka ENSIS development project. Any type of data could be accessed and presented through a flexible graphical user interface based on Microsoft Windows.

Environmental information to the public

A wider distribution of environmental data to the public has become a part of the development of modern environmental surveillance and information systems. New approaches have been developed for dissemination of environmental information which can be adapted to different information distribution systems. These systems could be teletext, public telephone network, special designed health advice information lines, telefax distributions, Internet networks etc..

Information of air quality in urban areas have been issued to the public on a daily basis described in terms of "very good", "good", "poor" etc. Some European cities already provide this type of information. The modern information system will focus more on variable messages and more updated access to the data through teletext or Internet applications.

As part of the ENSIS development a windows-based PC presentation solution was developed giving multiple access to different databases meeting common graphical user interfaces. It is important that the platform is graphical and preferably MS-Windows or X-Windows operating systems in a client-server network configuration, that can provide access via wide area networks (WAN) to external databases.

Several local authorities in Norway can presently obtain air quality information in graphical form from several urban areas participating in the national surveillance programme co-ordinated by the Norwegian Pollution Control Authorities. In Oslo and Bergen this system is being used to develop information and forecasts on air quality to the public. Lines have been set up to an information screen available for the public and information is also being issued in the media daily.

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