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Air Quality Management System Applications

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AIR QUALITY MANAGEMENT SYSTEM APPLICATIONS

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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. There is an increasing need for integrated solutions, which include monitoring data and planning tools into one system. A main objective of the modern Air Quality Management System is to enable direct data and information transfer, provide information on how much pollution the population is exposed to, establish a basis for strategies to reduce pollution and estimate air pollution impacts from present and future developments.

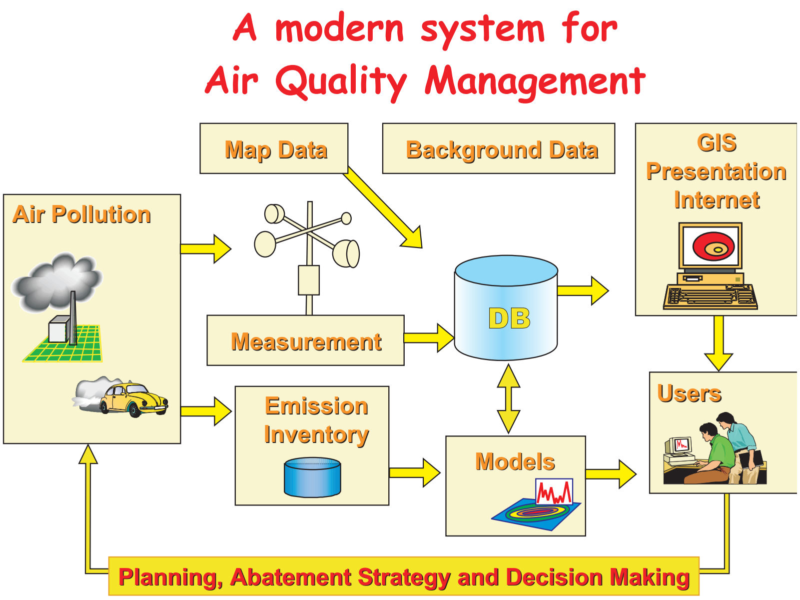
The AirQUIS system developed by the Norwegian Institute for air Research (NILU) includes dispersion and exposure modelling and has been used for forecasting of future air quality and development of cost-effective abatement strategies [1]. The AirQUIS technology has been established in more than 20 locations worldwide and is now being used in air quality management to support integrated pollution prevention and control [2]. Some examples of the AQMS applications are presented in the following.

2 THE AIR QUALITY MANAGEMENT PLATFORM

The integrated Air Quality Management (AQM) platform, AirQUIS, includes all elements needed to undertake assessment and planning of air quality. AirQUIS provides the basis for air quality management through an integrated tool for monitoring and emission inventorying, air quality modelling and assessment, enabling forecasting of future air quality and development of cost-effective abatement strategies.

The GIS based AirQUIS system includes several modules that can be selected and applied according to the user's needs. Important common parts are the measurement database, and the graphical user interface including the GIS (Geographical Information 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



The AirQUIS surveillance and planning system

The GIS (Geographical Information System) functionality of the AirQUIS system is designed to offer several possibilities for understanding the problems of air pollution.

- The GIS makes it easier to place the air pollution sources at the correct location, for example by making it easy to display the total network of road links in a city.
- GIS presentation of area-distributed consumption of fossil fuels and direct emissions gives a good overview of where to expect high impact of air pollution.
- Viewing the measurement stations on a map with the pollution sources will give an idea of what concentrations one may expect to find at the stations for a given wind direction.
- The GIS makes it easier to search for geographically linked data in the database.
- Displaying results of model calculations as a map can be used for public information on pollution levels at different parts of a city.

AirQUIS consists of six components and makes use of an Oracle database. The system has integrated forms and maps, was developed in Visual Basic and Map Object (GIS) and works well on an ordinary NT-server. The different components consist of:

- A manual data entering application,
- An on line monitoring system,
- A module for online data acquisition and quality control,
- A measurement data base for meteorology and air quality,
- A modern 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.

All objects described above are integrated in a map and menu oriented user-friendly interface with direct link to the databases for measurements, emissions, modelling results and presentation tools. Advanced import/export wizards allow the user to transfer data easily to and from the AirQUIS system.

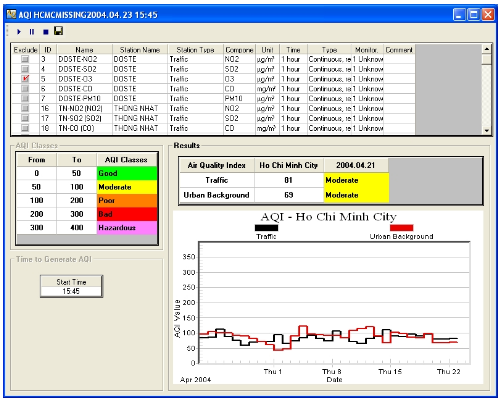
AirQUIS has tools for graphical presentation and control of data, and tables for numerical presentation of data and statistical summaries. The information system provides a report generator and the possibility of exporting data and map images

There are three types of data that can be displayed on the map: shape themes, AirQUIS themes and data set.

3 AIR QUALITY SURVEILLANCE AND MANAGEMENT

The AirQUIS emission inventory system and advanced dispersion models can combine measurement data and model estimates. Model results 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 use 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.

An example of the system used for automatic data retrieval, data presentation and generation of an air quality index, AQI (generated automatically), has been demonstrated in Ho Chi Minh City (HCMC), Vietnam [3].

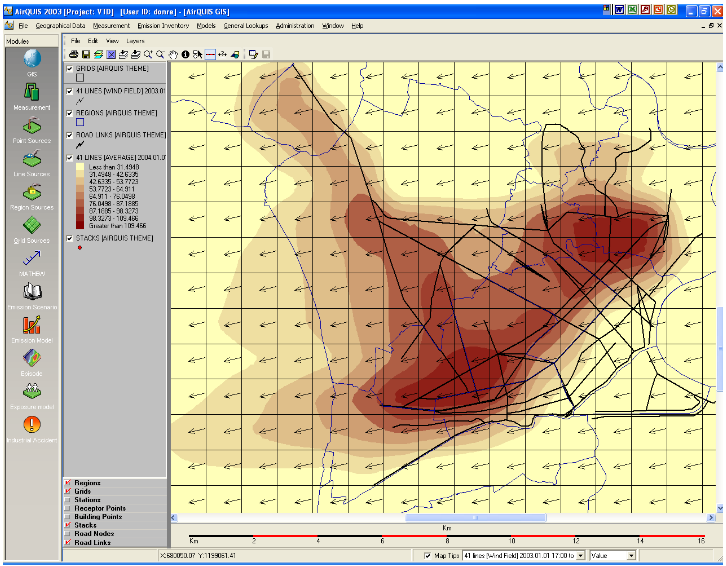


The AQI produced by the automatic system using AirQUIS takes the air quality data, which have been automatically quality assured, and produces a daily AQI for traffic and urban background environments.

The figure to the left shows the raw data selected for generating a daily AQI for HCMC from 25 March to 22 April 2004. This information is now being prepared for dissemination via a Web application.

The monitoring programme in HCMC is supported by atmospheric dispersion modelling. Templates for collection of necessary input data are provided by the AirQUIS system. These templates are being used to collect emission data from point sources area sources and line sources (traffic).

Traffic counting started in 2003 and some modifications of the coordinates had to be performed before final data could be accepted. Road Nodes and Road Links were prepared for importing into AirQUIS. The traffic data that was counted by the students in HCMC was modified to the templates. The emission factors of vehicle were based on the factors provided by NILU based on various projects performed in Asia.



The Figure shows the daily average (1 January 2004) NO_2 concentrations as a result of emissions from 41 roads in HCMC produced by the AirQUIS models. The wind field is also indicated.

The built-in dispersion model system (the EPISODE model [4] [5] is typically run on a 1 km-size grid system. These models have been tested and verified in Norway and through several international inter comparison studies [6].

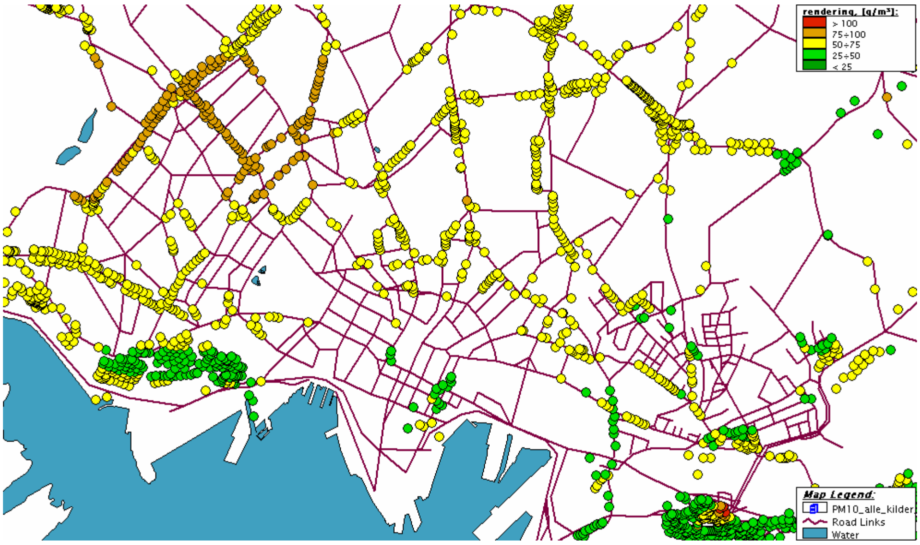
4 POPULATION EXPOSURE CALCULATIONS

The spatial resolution of the models applied in AirQUIS is rather high. The sub grid models, however, incorporated in the system allow for calculation of concentrations in freely specified "receptor points", allowing a resolution of 10 meters or better. Thus, concentrations can be, and typically are, calculated e.g. at individual houses/residences. The accuracy of the calculated concentrations is subject to the accuracy of a number of parameters: emission data, wind fields and various model parameterisations typical for all such model calculations. The time resolution is typically 1 hour.

The AirQUIS model abilities opens the possibility to make estimates of population exposure to air pollutants. An indoor pollution exposure module was not incorporated in AirQUIS, during the Oslo investigations presented below. This is, however, presently being developed.

AirQUIS has been used extensively to calculate potential population exposure distributions in Oslo [7]. Calculations have been carried out for NO_2, PM_{10} and benzene. The model is run on an hourly basis for entire years, and statistics then calculated to give, for example, the number of people potentially exposed to exceedance of AQ limit values at their home address. Examples of results for Oslo are shown in the Figure below.

A shortcoming of this kind of population exposure is that it is not possible to "follow" each person in his daily movements through the different microenvironments. Thus, the population exposure calculated is a "potential" exposure, related to the place in the city where each individual spends most of his time. A possibility to develop this towards better exposure estimates is to define population groups of individuals with similar patterns of daily movements.



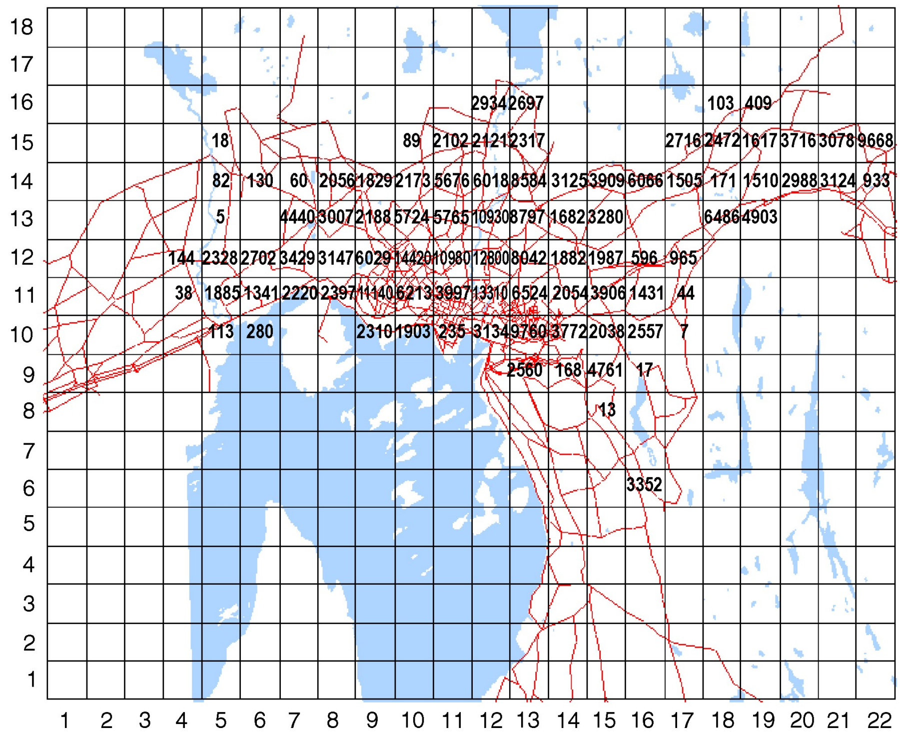
An ongoing EU research project, “Urban Exposure”, will provide a better understanding of the exposure. The AQMS tool such as AirQUIS will include indoor and ambient exposure estimates and the tool will be operationally implemented. The assessment of human exposure from indoor and outdoor air pollution will thus in the future facilitate a more correct exposure estimate. Also other pathways are being studied in this project.

5 AIR QUALITY IMPROVEMENTS?

National targets for air quality in Norway have been drawn up for several pollutants. These are based on socio-economic considerations as well as considerations of public health, and are to be achieved by 2005 or 2010.

For the city of Oslo the AQMS tools have been used to study the trend of air pollution and exposure to the population during the last ten years. NILU estimated the total exposure of PM_{10} and NO_2 from the winter season 1995 till the winter season 2001. Number of persons exposed to exceedances of national air quality target values and EU directive limit values have been reported. The results have been presented both as square kilometre averages and in specific building points.

Examples of results for Oslo are shown for PM_{10} in the Figure below. Other statistics could also be calculated, e.g. the total exposure distribution for the city population.



Number of people exposed above national air quality limit values for PM_{10}. The results show the numbers for each square kilometre grid cell for 1998.

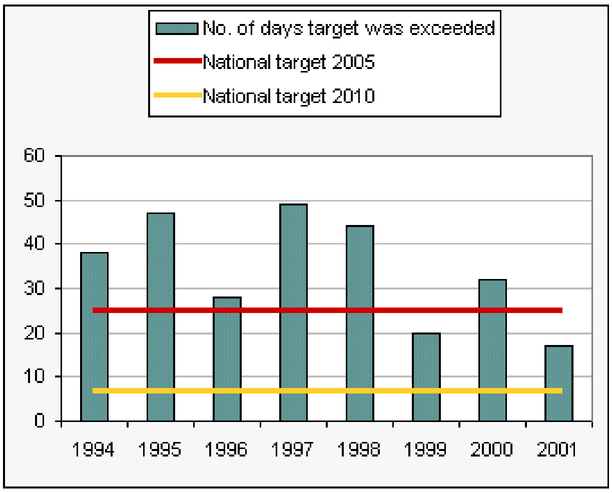
To illustrate the long term trend and development the total number of exposed people have been estimated based on input data from 1995 to 2001. The total number of people exposed to PM_{10} and NO_2 exceeding the national target values are presented below [8].

	1995/96	1998	2001
PM_{10}	319 041	306 140	220 783
NO_2	58 481	59 807	13 556

When dispersion and exposure models of this kind have been established, tested and evaluated, it will also be possible to estimate the relative importance of the different sources in the modelling area. The following table presents the relative contribution in percent to the population exposure of NO_2 in Oslo.

NO_2	Wood	Traffic	Background	Other sources
Building points converted to fields	0.11	93.80	0.13	5.96
Field averages	0.16	86.93	0.07	12.85

Percentage contribution of NO_2 concentrations from 4 source categories.

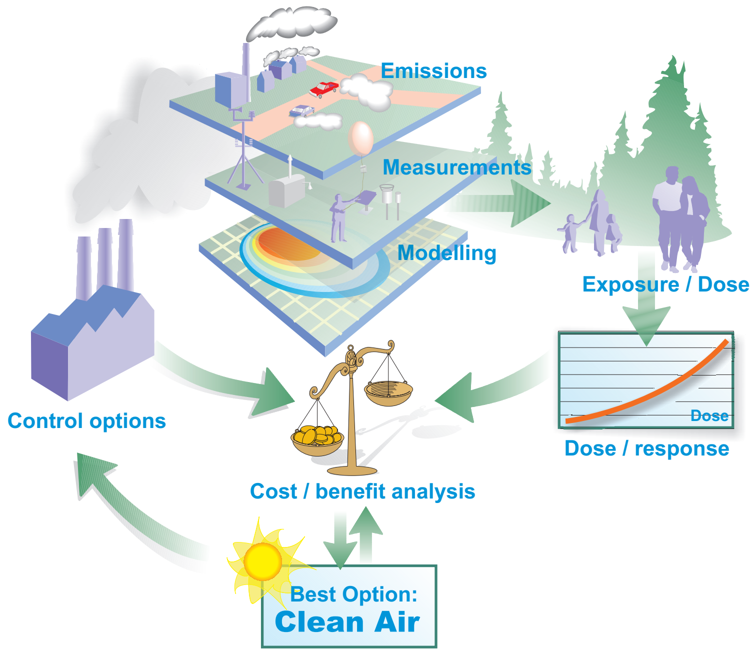


The exposure estimates presented above have been based on a combination of air quality measurement data and model results. The models have been verified against measured concentrations.

The figure presented to the left shows the number of days when levels of PM_{10} have exceeded 50 $\mu g/m^3$ (24-hour mean) at one selected monitoring station in Oslo. Concentrations of sulphur dioxide and benzene in air in urban areas of Norway have been predicted to drop to acceptable levels by 2005 and 2010 respectively. Levels of nitrogen oxides and particulate matter will still be too high unless further steps are taken to reduce them.

6 COST BENEFIT ANALYSES

Monetary valuation of control actions, and of the effects on health and the environment, may be different in concept and vary substantially from country to country. The cost-benefit analyses (CBA) are a highly interdisciplinary task. The CBA should provide a benefit-cost ratio based on monetarised costs and benefits, and be accompanied by a description of the non-monetarised items that also should be considered.



NILU has conducted such CBA of possible measures for reducing the extent of pollution damage in several major urban areas in Asia. The World Bank project “URBAIR” was a forerunner for these analyses [9]. All the various possible measures are cost estimated and put together in relation to calculated reductions in air pollution and the consequences for damage impact.

7 OPTIMAL ABATEMENT STRATEGIES AND ACTION PLANS

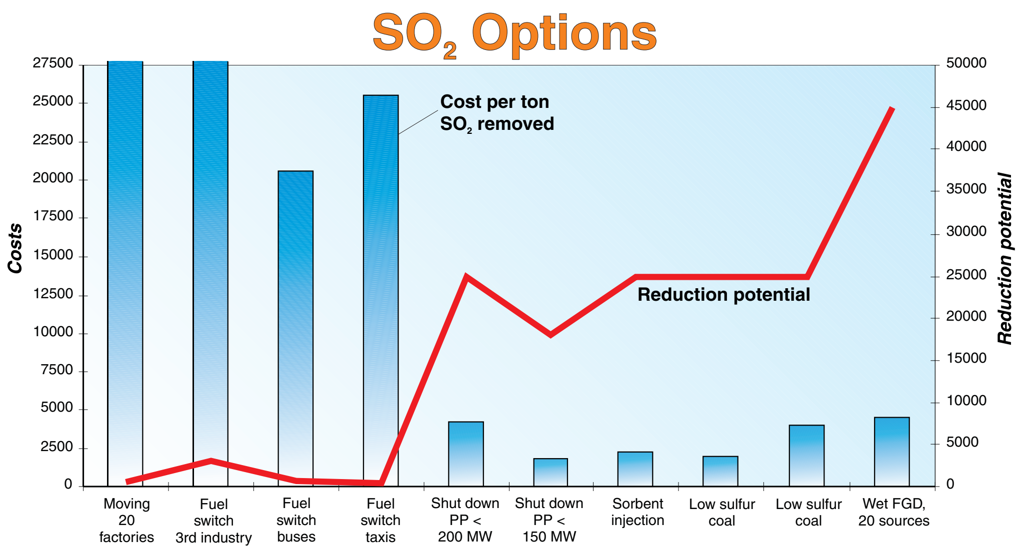
Based on defined abatement options and scenarios, cost-benefit analyses can be used to evaluate the best possible options to reduce the air pollution load seen from an economic point of view. The results of such analyses may again lead to the development of action plans.

An Air Quality Management and Planning System (AQMS) was established in the city of Guangzhou (6 mill. inhabitants) in South China [11]. The core of the system was the GIS based AirQUIS system. The system is applied to develop action plans for air quality improvement in a cost-efficient manner.

The project was a co-operation effort between involving several Norwegian institutes (with NILU as the leading institute) and research and municipal government institutions in Guangzhou. The nature of the project was "knowledge and tools transfer.

The essence of the Action Plan dealt with air pollution exposure of the population rather than just emissions. In the action plan, the costs of each control option were calculated in terms of costs per percentage point of exposure reduction, and this is compared with the potential to reduce the pollution exposure that is associated with the option.

Based upon this, the control options are ranked according to their cost-effectiveness. Least cost packages of control options to arrive at a given target for air quality can then be developed. This method is superior to the most used method of looking only at costs of emissions reduction and prioritising according to that, without taking into consideration the large effects that the emission conditions (location compared to the population centres, the stack height, etc.) have on the resulting pollution concentrations and exposure of the population.



Evaluating ten different SO_2 control options indicated that plant shut down and low sulphur coal use are the most cost effective options in Guangzhou.

8 SUMMARY AND CONCLUSIONS

An integrated surveillance and planning tool is needed to select the right decisions in order to protect human health as well as materials and the ecosystem from an increasing impact of pollution. Heavily populated and industrialised areas experience a change in impact that is difficult to handle. Not only is the amount of pollution increasing in many areas, but also the composition and complexity is becoming more difficult to monitor, understand and solve.

The GIS based surveillance and planning tool presented in this paper is one step towards obtaining the adequate and relevant information in order to select the right actions in the process of preventing too large damages. The GIS based on-line monitoring and warning system can predict the impact of selected scenarios for the future, and thus make it possible to implement the best available solutions. It is recommended that the monitoring, modelling and planning tools included cost/benefit analyses are used in order to get as much benefit out of the investments as possible.

The AirQUIS system represents one of these GIS based platforms that enable direct quality assurance of the input data, which are essential for understanding the problems and in the next phase select the most cost effective solutions to avoid damages from environmental impacts.

9 AKNOWLEDGEMENT

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About AirQUIS: http://www.nilu.no/airquis/