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An integrated Air Quality Management System for sustainable development

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An integrated Air Quality Management System for sustainable development

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Abstract: In recent years, different international legislations and directives related to air quality have been set into force. A main aim of the directives is to protect human health and the environment by defining air quality objectives, limit values, alert thresholds, guidance on monitoring, siting and measurement methods. 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 air quality management system 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 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. This paper will present the integrated functionality needed in such an Air Quality Management system and examples of different applications related to air quality management and assessment.

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. An 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.

AirQUIS represents a main tool for establishing and integrating the different components of the AQMS. The system has been established and operated in more than 20 cities and urban areas world-wide. It received the European IT prize in 1998, and is being further developed and improved for a variety of applications.

The development of GIS based monitoring and planning systems may vary depending upon 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.

2. AirQUIS, an integrated monitoring and management system

AirQUIS consists of several components, is modular and makes use of integrated menus and GIS to obtain a user-friendly system. The AirQUIS system consists 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 in air of 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 are an important part to allow the user to transfer data easily to and from the AirQUIS system.

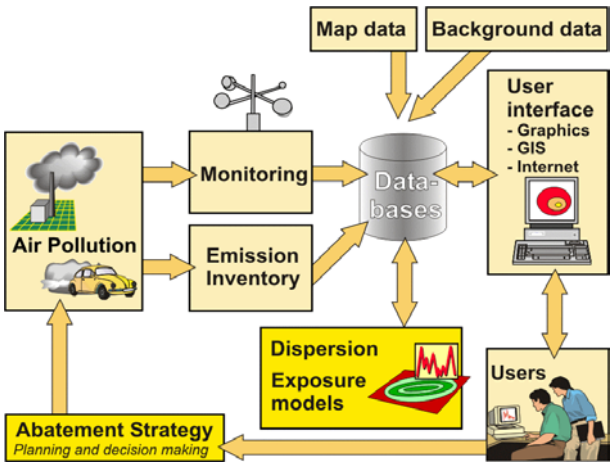

Figure 1: The modules of an integrated air quality management system.

2.1 On-line measurement system

The AirQUIS measurement module consists of modern on line sensors for selected air pollution indicators according to local standards and indicators. The air quality monitoring stations are equipped with a modern digital data logger unit to collect and store data at each site. Hourly average data is transferred as raw data via modem and telephone lines to the central computer unit with frequency specified by the user.

2.2 Handling system for manual data

In addition to the online monitoring system, with automatic input of measured data to the database, data can be entered manually, if desired. A user-friendly system for entering chemical analysed data into the database is established with routines for quality control of the entering of data.

2.3 Automatic data acquisition system

To collect air quality and meteorological data from various measurement stations to the central database, NILU has developed a robust and stable data acquisition system, ADACS, to obtain high frequency of operation. In addition to automatic data transfer, this module contains aggregation and scaling functionality as first level of quality control.

2.4 The databases

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

- On-line collected ambient air quality data,
- Calculated fields of emissions, concentrations and exposure,
- Historical data with trends, background information (land use, population)
- National and international regulations, air quality limits or guideline values
- Information on the support and decision-making processes.

The databases 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.

2.5 The Air Emission Inventory Database

The sources of air pollution are divided in three categories.

- **Point sources;** single activities like industries, energy production etc., that are linked to single stacks, are treated as point sources.
- **Line sources;** moveable sources like road traffic, air flights and shipping are treated as line sources in the emission database.
- **Area sources;** home heating/cooling, public and private services, open burning, windblown dust etc., are treated as area sources.

The emission module calculates all combinations of emissions in an area, such as total emissions of a component in selected areas or divided into source categories in a selected time period.

The emission data are easily accessed through search for area or region, line or point data sets. The specific industry can also be accessed through advanced search functionality on type of industry. The user can also have the functionality to find/edit information on emission sources by searching by polygon/rectangle on geographical areas via the map.

2.6 Atmospheric dispersion models

A major part of the AirQUIS system is the dispersion models which covers air pollution on all scales; traffic in street canyons and along roads, industrial emissions and gridded pollution from household etc. within the urban areas and on a regional scale.

The NILU developed source oriented numerical dispersion model EPISODE calculates spatial distribution of hourly concentration of selected indicators, such as SO_2, NO_2 and suspended particles. The NILU models ROADAIR and CONTILENK are used to estimate sub grid concentrations close to roads within the square grid. A puff-trajectory part of the model is used to calculate the influence of point sources.

To obtain a good description of the wind field in a complex terrain, NILU has included a terrain influenced wind field model. This model is fast and can on hourly basis perform inhomogeneous wind fields as input to the dispersion models for emissions to the atmosphere.

The models have been presented for evaluation, discussions and model comparisons within the European Environmental Agency (EEA). The models are already part of the models approved by Norwegian Authorities. They have also been used in several countries in Europe.

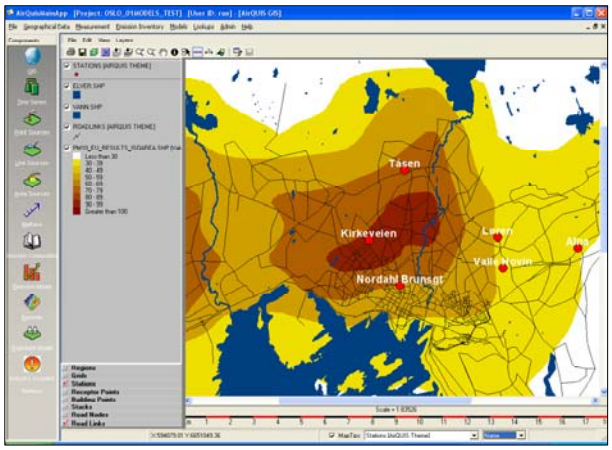

Figure 2: AirQUIS integrated GIS Module for presentation of modelling results.

2.7 Population exposure

The AirQUIS contains a module for exposure estimates. Based on concentration calculations and population distribution, exposure estimates for human health can be performed. The exposure estimates can be related to air quality guidelines or other air quality indicators used for the component considered. Exposure estimates may also be linked to other inventories and spatial distributions such as different materials, cultural heritage and plants.

2.8 Exposure

AirQUIS has an Exposure or Abatement Module, which in an efficient way can perform analysis of different scenarios to improve air quality. This module has global functionality to select source by category or in areas direct from the map. Different recommended measures to reduce air pollution can easily be evaluated due to population exposure and cost-benefit or cost-efficiency analyses. A priority list of the selected measures can be developed, taking into account air pollution exposure, health aspects and related costs.

2.9 The geographical information system

The integrated geographical information system is important as a platform for integrating the presentation of measurements, emission inventory and results from model estimates. The geographical information system must be directly linked to the databases, from which statistical evaluations, graphical presentations and spatial distributions of emissions and model results can be presented.

3. Applications

The AirQUIS system is installed in several places and is used in different ways, from a national monitoring system to a local air quality management system for monitoring, modelling and exposures calculations.

3.1 Surveillance and Management

The AirQUIS emission inventory system and advanced dispersion models can compare measurement data to 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. The models may also estimate exposures of the population, materials and ecosystems.

3.2 Impact assessment

Regulatory risk assessment in air pollution management includes a consideration of hazard identification, exposure-response relationships, exposure assessment and quantitative risk characterization. Numerical models, which are part of the AirQUIS system, may estimate the exposure of harmful pollution to human health, materials and the ecosystem.

3.3 Cost-benefit analyses

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.

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. 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. 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.

3.4 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.

4. Information to the public

Information of air quality in urban areas has been issued to the public on a daily basis described in terms of "very good", "good", "poor" etc. Many European cities already provide this type of information.

Information to the public is given to the public as text, graphs, maps, SMS-messages, e-mail etc, and updated on hourly basis.

NILU participates in several European research projects. One important part of these projects is to establish user-friendly information services for the citizens and communities to improve the quality of life in Europe. Modern information systems as AirQUIS will be the basis for enabling citizens to easier access and exchange of information about air pollution in urban regions. Information will be distributed by mobile telecommunication system such as SMS, WAP and Voice.

5. Conclusions and recommendations

An integrated air quality management 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 Air Quality Management System AirQUIS 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.

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AirQUIS

Modern Air Quality Management for a sustainable development

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TB/AQMS.ppt slide 1

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Models

AirQUIS

Meteorology
- Meteorological pre-processor
- Wind field models

Emission Model
- Traffic and stationary sources

Dispersion Models
- Urban scale grid model
- sub-grid point source model
- street and road models

Effect Models
- Population exposure
- Impact on materials and buildings

TB/AQMS.ppt slide 5

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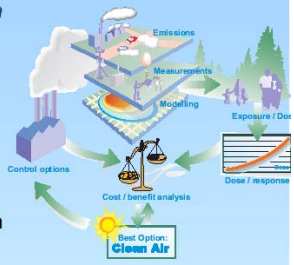
AirQUIS - GIS-based Air Quality Management System

Main objectives of the system

- To enable **on-line air quality data presentation** → Internet
- To provide complete **air pollution exposure information**
- To enable development of **cost-effective air pollution abatement strategies**



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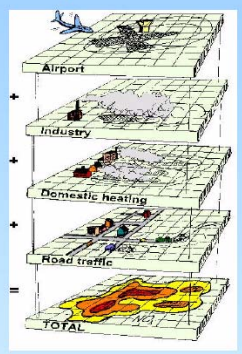
Dispersion modelling

AirQUIS



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

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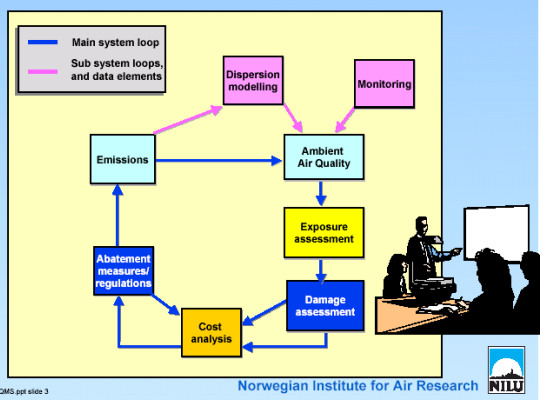
AQ Management Model Concept



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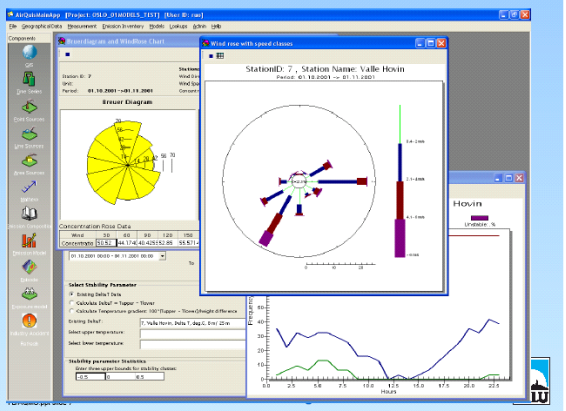
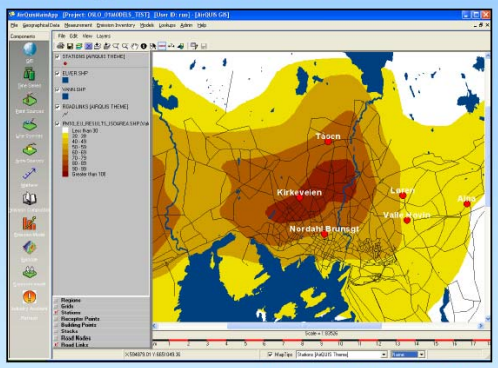
Management software

AirQUIS



Management software - GIS



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Air Pollution Indicators

First priority pollutants:
- SO_2 (Sulphur dioxide)
- NO_2 (Nitrogen dioxide)
- PM_{10} (Particles, diameter < 10 micrometer)
- Pb (lead)

Limit values for other indicators:
- Ozone
- Benzene
- CO
- PM 2,5

TB/AQMS.ppt slide 11

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Applications

- Environment impact assessment
- Air Quality management
- A.Q. forecasting and early warning
- Optimal abatement strategies
- A.Q. information systems

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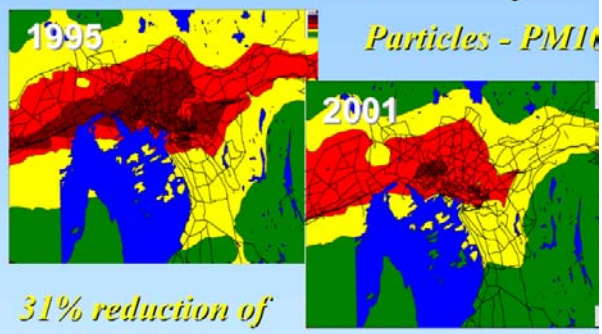
AirQUIS Trend analysis



Particles - PM1

31% reduction of exceedences

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EU-directive

Ambient Air Quality Assessment and Management Directive
(Council Directive 96/62/EC + Daughter Directives)

- Local authorities responsible
- Periodic reviews and assessment of air quality
- Local authorities must make action plans

TB/AQMS.ppt slide 10

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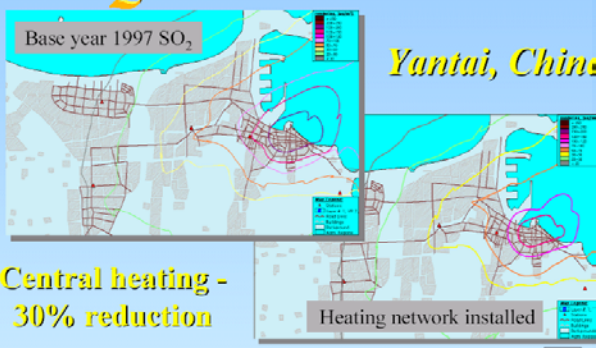
AirQUIS Assessment



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Oslo Calculated PM_{10}-concentrations

8. highest daily building point value (µg/m³)

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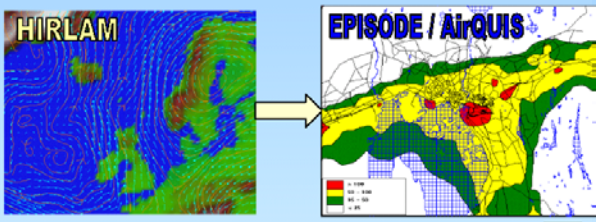
"Episode" forecasts

Numerical weather predictions
+
Numerical dispersion models



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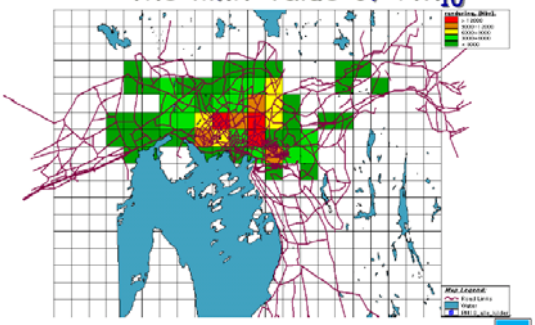
Oslo Number of people exposed above the limit value of PM_{10}



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On-line information for your mobile telephone

With AirQUIS as a GIS-based database on-line data can be accessed directly:

- Cities in Norway
- Industrial impact, Svanvik
- Haifa, Israel
- Romania
- Durban (RSA)
- Several EU-projects

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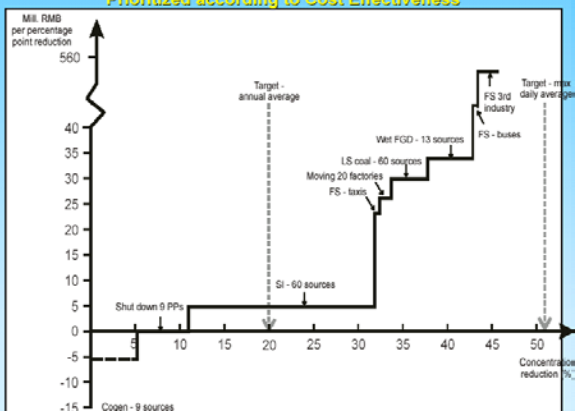
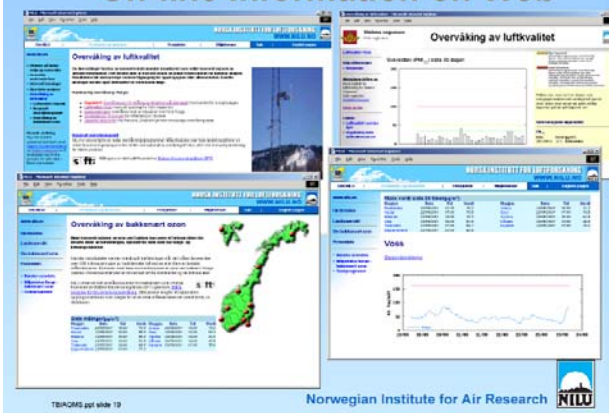
ACTION PLAN 2001, GUANGZHOU
CONTROL OPTIONS FOR SO2
Prioritized according to Cost Effectiveness



On-line information on Web



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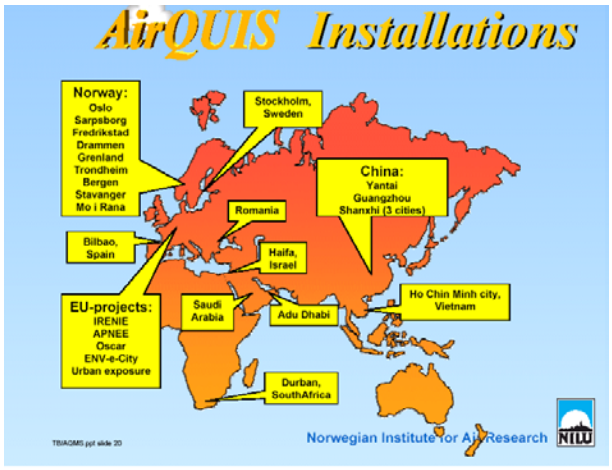
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Norway:
Oslo
Sarpsborg
Fredrikstad
Drammen
Grenland
Trondheim
Bergen
Stavanger
Mo i Rana
Stockholm, Sweden
China:
Yantai
Guangzhou
Shanxhi (3 cities)
Romania
Bilbao, Spain
Haifa, Israel
EU-projects:
IRENIE
APNEE
Oscar
ENV-e-City
Urban exposure
Saudi Arabia
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