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Critical success factors for professional management of air quality

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Critical success factors for professional management of air quality

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ABSTRACT

Air quality goals set forth through national and international legislations and directives require comprehensive air quality monitoring and assessment systems and technical knowledge in the field of air pollution. New tools for performing advanced air quality assessment, planning and information dissemination have been developed during the last few years. A main objective of the modern Air Quality Management System, AQMS, is to provide direct data and information transfer to end-users, to give population exposure information, to establish a basis for pollution reduction strategies and to estimate impacts from present and future activities.

A main challenge for a modern AQMS system is the complex know-how and competence required in establishing complete well working solutions. The first challenge is of a technical character. The system has to make monitors and instruments of different fabrication work together with data transfer solutions, databases, models, GIS based software and Internet presentations. In addition comprehensive Quality Assurance and Quality Control (QA/QC) procedures are required throughout the system. In practice this often involves people with very different needs, and the experiences and skills in understanding air quality data varies.

The solution to theses challenges, in addition to using state-of-the-art technical solutions in all parts of the systems, is to ensure a common core of know-how, technical specifications and quality assurance. The integrated system AirQUIS developed by the Norwegian Institute for Air Research (NILU) can be used as a platform, and it is presently being installed and applied worldwide. AirQUIS has been developed to provide the basis for air quality management through an integrated tool for emission inventories, air quality modelling and assessment, forecasting of future air quality and development of cost-effective abatement strategies.

This paper elaborates on 4 critical success factors for professional management of air quality:

- Transparent data communication solutions and standards,
- QA/QC as the core focus,
- monitoring networks designed to be used in combination with advanced models and
- use of model based GIS managements software.

1 Introduction

NILU has been working on Air Quality issues for several decades. From global issues like climate change, ozone depletion and acid rain to air quality in urban areas. This paper covers the issues of ambient air pollution based on NILU's experience worldwide together with industries and city authorities.

What are the future challenges for managing air quality? New policies focus less on emissions and more on population exposure. What are the common factors of those who succeed in accessing air quality correctly and achieve cost efficient improvements?

Tables from Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air

Limit values for sulphur dioxide

	Averaging period	Limit value	Margin of tolerance	Date by which limit value is to be met
1. Hourly limit value for the protection of human health	1 hour	350 μg/m³, not to be exceeded more than 24 times a calendar year	150 μg/m³ (43%) on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005	1 January 2005
2. Daily limit value for the protection of human health	24 hours	125 μg/m³, not to be exceeded more than 3 times a calendar year	None	1 January 2005
3. Limit value for the protection of ecosystems	Calendar year and winter (1 October to 31 March)	20 μg/m³	None	19 July 2001

Limit values for nitrogen dioxide and oxides of nitrogen

	Averaging period	Limit value	Margin of tolerance	Date by which limit value is to be met
1. Hourly limit value for the protection of human health	1 hour	200 μg/m³ NO_2, not to be exceeded more than 18 times a calendar year	50 % on the entry into force of this Directive, reducing on1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2010	1 January 2010
2. Annual limit value for the protection of human health	Calendar year	40 μg/m³ NO_2	50 % on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentagesto reach 0% by 1 January 2010	1 January 2010
3. Annual limit value for the protection of vegetation	Calendar year	30 μg/m³ NO_x	None	19 July 2001

Limit values for particulate matter (PM_{10})

	Averaging period	Limit value	Margin of tolerance	Date by which limit value is to be met
STAGE 1				
1. 24-hour limit value for the protection of human health	24 hours	50 μg/m³ PM_{10}, not to be exceeded more than 35 times a calendar year	50 % on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005	1 January 2005
2. Annual limit value for the protection of human health	Calendar year	40 μg/m³ PM_{10}	20% on the entry into force of this Directive, reducing on 1 January 2001 and every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2005	1 January 2005
STAGE 2(¹)				
1. 24-hour limit value for the protection of human health	24 hours	50 μg/m³ PM_{10}, not to be exceeded more than 7 times a calendar year	To be derived from data and to be equivalent to the Stage 1 limit value	1 January 2010
2. Annual limit value for the protection of human health	Calendar year	20 μg/m³ PM_{10}	50 % on 1 January 2005 reducing every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2010	1 January 2010

(¹) Indicative limit values to be reviewed in the light of further information on health and environmental effects, technical feasibility and experience in the application of Stage 1 limit values in the Member States.

2 New type of regulations

In many countries Air Quality regulations have been quite easy to relate to. Legal binding limits have been set for emission concentrations, and measurement techniques have been developed to measure air quality more or less correctly. This is now undergoing a change. For example, the new regulations on ambient air quality in Europe, which started with the Council Directive 1999/30/EC of 22 April 1999, set legal binding maximum limit values in ambient air for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air. The focus is more and more put on exposure concentrations, and even partly how many individuals that are exposed. Table 1 shows the regulations set in the

April 1999 Directive. Similar directives on carbon monoxside, ground level ozone etc will later follow. In addition to setting the maximum concentrations allowed and number of allowed exceedences, the Directives also set other limits such as where measurements in an area have to be performed, how to locate the monitoring stations etc. The consequence is that local and national governments in each European country has a legal commitment to ensure that its people are not exposed to levels above the limit values.

The European countries are now implementing the directives, and many countries will report their first year of data this summer to the European Union. They have to report number of exceedences and actions plans undertaken. Guidelines and recommendations for ambient air quality have been drawn up and existed for many years both by national authorities and by WHO, but legally binding concentration maximums clearly marks a change in policy.

It is well accepted by most governments that this new regulations focusing on the actual exposure to people, is scientifically and politically correct if the goal is to reduce the unwanted exposure of human beings. However, many industries and governments now have a management challenge:

- ✓ Many compounds emitted from various sources react with each other, and fast
- ✓ Air concentrations changes extremely rapidly and metrological condition influences all aspects

So, when an unwanted episode happens. Who is to blame? What are the correct measurements? How to predict it again? The law binding regulations force the governments to take action to avoid exceedences to happen.

3 The technical challenges

Many good technical solutions exist for both monitoring of emissions and ambient air. Numerous vendors with different types of monitors/instruments are in the market. Also, the accumulated experience and expertise in various parts of the world start to get substantial and great efforts have been put into fin-tuning equipment and technical solutions for specific purposes. Intercalibration and comparison tests under various harsh climates and different operating conditions have also put further pressure on the developers of the equipment to produce reliable, stable and easy to use solutions. However, it is clear that the different technical solutions have more or less strong and weak sides. Understanding this is crucial when choosing the right instrumentation.

However, in practice it is much more crucial for success that the various parts of the system communicate smoothly. In most cases modern air quality surveillance and monitoring networks consist of equipment from many different suppliers. Data logging, transfer and storage from the various monitors/instruments create in many cases a lot of problems. Different types of instruments use different data recording systems, as for example different numbering systems for instrument status. One instrument can have one number for “everything okay” while the same number from an other supplier means “Problem with filter-disregard measurement”. Some instruments organise the collected data in a specific way that only a very special logger can understand and therefore have to be used. Some loggers have output formats which is rather difficult to convert to standard data files, and can therefore not be transferred and stored together with datasets from other instruments/loggers. It is our clear hope that over the next 5-10 years we will find more standardized data exchange formats when monitoring air quality data.

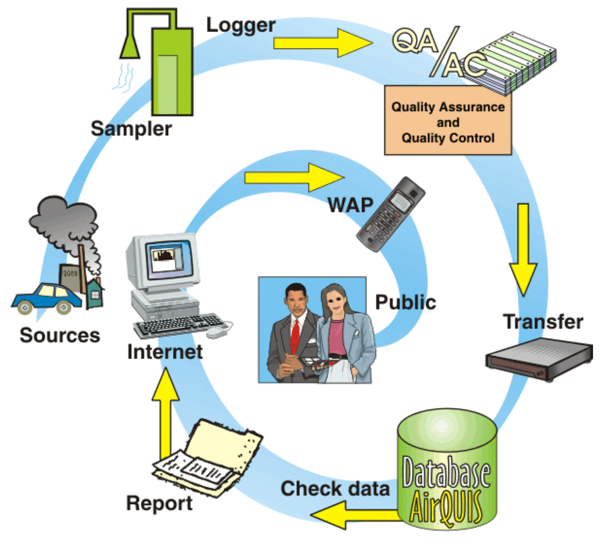

Figure 1. The technological challenge in practice is really to get various systems to talk correctly and efficiently with each other.

A lot of work has been done over the last decades to improve reporting to national and international governments, for example the European Union through the work on the new data directives on ambient air quality and through the Topic Centre on Air Quality. However, the data collection and storing from monitors and instruments remain rather unregulated. As part of national coordinated monitoring programs on ambient air quality more and more countries have established reference laboratories that sets standard operation procedures for instruments and data collection. This can have some influence, but in practice the responsibilities lie with the instruments, monitors and data logger producers, and not least on the clients who buy various solutions. Our clear recommendations are for all to have a stronger focus on data collection and transfer systems when new systems are built to force the suppliers to follow easier standards and more transparent solutions.

In Europe a network of excellence, Metropolis, started last year. The METROPOLIS project is an innovative approach towards a better European-wide environmental monitoring research networking. Thirty-two institutes, universities, or enterprises from 17 countries, with the co-operation of four pan-European organizations, including CEN (the European Standards Organization), and of two Institutes of the Joint Research Centre of the EC are going to pave the way towards the creation of the European Research Area in the field of environmental and precautionary sciences.

The METROPOLIS initiative grew out of the conclusions of the EU conference on "Environment, Health, Safety: A challenge for measurements" held in Paris in June 2001. This conference recognised the need to create a thematic network in order to pursue three main objectives, in the broad field of environmental meteorology:

- to improve the performance of environmental measurement systems and their harmonisation at EU level
- to foster the dialogue between those who provide measurement methods and associated services, and the users of measurement results
- to prepare the ground - by establishing communication and liaison arrangements between European research bodies and other interested parties - for further integration of research expertise and resources in environmental monitoring across Europe.

It is widely recognised that reliable, comparable and useable measurement results are a key component of effective environmental monitoring and successful sustainable development policies. With initiatives like the Metropolis, and a consistent focus from the various buyers of technical solutions, it is good hope that future systems will be easier to operate, expand and maintain.

4 Setting QA/QC as the core for Air Quality

Our experience over several decades with setting up Air Quality monitoring networks, or complete management systems, is that the QA/QC work is often not completely understood or partly ignored. To install a monitor and get data produced into a database and presentation tool of some kind is normally not a problem. But what is the value of the numbers listed in the nice looking reports?

4.1 The QA/QC needs for air quality

In ambient and emission air quality measurement systems, the Quality System is concerned with all activities that contribute to the quality of the measurements. The aim of the Quality System is to assure that the results meet the predefined standards of quality. To produce results of known and sufficient quality, a whole range of tasks have to be performed such as periodic status checking, maintenance, calibrations, data evaluation and so on. Failure to perform all or some of these tasks will decrease the data quality.

The Quality System shall assure that:

- Data is reliable for its intended use (fulfils the Data Quality Objectives).
- Data has known quality (fulfils the performance standards).
- Data from different sites can be compared.

- The receiver of the measurement results (management, public, etc.) has confidence in the results.

The quality terms relevant for QA/QC procedures and criteria can be defined as follows (ISO 8402, 1994):

- Quality is the totality of characteristics of an entity that bare on its ability to satisfy stated or implied needs.
- Quality Assurance involves the management of the entire process, which includes all the planned and systematic activities that are needed to assure and demonstrate the predefined quality of data, to provide adequate confidence that an entity will fulfil requirements for quality.
- Quality Control comprises the operational techniques and activities that are undertaken to fulfil the requirements for quality.

The Quality Assurance activities cover all the pre-measurement phases, ranging from definition of data quality objectives to equipment and site selection and personnel training.

The Quality Control activities cover all operational work such as routine maintenance, calibration, data collection, data validation and data reporting. For emission inventories and modelling it may cover activities such as entering or editing emission data in the emission inventory, running models and reporting results.

Figure 2: No results are of value if the QA/QC is not done properly.

In addition to QA/QC, a third activity called Quality Assessment is usually implemented in the Quality System. The Quality Assessment provides for a periodic external audit of the Quality System and the operational activities.

Quality Assurance, Quality Control and Quality Assessment will all be parts of the Quality Plan. They have to be operational and co-ordinated and must be considered as necessary parts of any Air Quality Management System.

4.2 Turning numbers to representative concentration

People will be surprised on how many times, and where we have experienced complete lack of QA/QC understanding for Air Quality. The location of a station can be completely wrong to be representative for an area, and consequently a dataset for a year is useless for comparison or reporting. Lack of calibration of the field instruments etc. can also give such a result.

The key is to really understand the difference between numbers coming out of an instrument, and the meaning of this concentration value (number). It requires knowledge and procedures for all QA/QC aspects as well as good understanding of the pollutants behaviour in the air. Organisations that are able to establish QA/QC as the core for their monitoring network, will produce data that can be used for decision-making.

5 Understanding modelling compared to measurements

It is a trend to move away from extended monitoring networks to model based systems. The costs are lower and there is a wider range of application of the results. Due to the advanced models developed for air pollution dispersion combined with modern GIS techniques, the results coming from such systems are found to be better since they give concentrations at “every location” covered by the model, while monitors only give the concentration at their exact location.

An important factor to go for such systems is also the change in legislation from monitored levels set for chimneys to levels set for exposure to people, as for instance reflected in the new EU directives on Air Quality.

Table 2. Some key differences between a monitoring system and a management system

NO.	Monitoring system	Management system
1	Results direct from monitors	Results from model calculations, in addition to monitored air quality data.
2	Many monitors placed at selected locations and at emission points	Few ambient monitoring stations combined with meteorological stations and emission inventory databases.
3	Strong emphasis on technical installations of different monitors	Strong emphasis on emission source inventory, general background facts and model validation
4	Gives exact data at each monitored place	Gives air quality concentrations 3D all over the model area
5	No exposure calculation of population	Prediction of exposure of population.
6	Forecasts at single points based on statistical data	Forecasts of AQ for all areas covered, based upon physical modelling.

NO.	Monitoring system	Management system
7	No quantitative abatement strategies based on cost-benefit.	Full planning tool for abatement strategies.
8	Simple software needed	Advanced GIS based software needed, and provided

It is obvious beneficial to use model based systems, because the models now are getting better and better and the experience in using them during various conditions accumulates. However, there is a clear reluctance in using models by many industries and governments, and especially more technological oriented engineers show some reluctance. We feel that most of the time this is due to lack of knowledge of how models work, and that old habits are difficult to change.

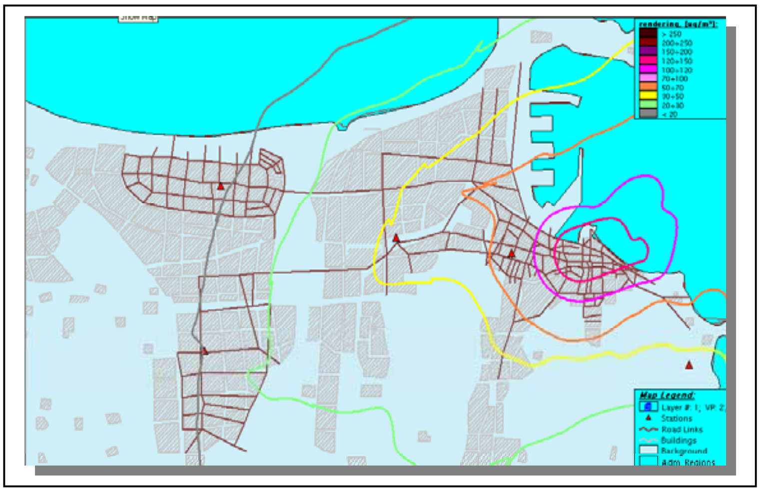

Figure 4. A model result of SO_2 distribution in Yantai China, after installing central heating.

6 The involvement of the public

If we combine the new regulations focusing on the exposure of humans with the increasing approved right to access environmental information, we will see a dramatic change in relative few years towards Internet- and SMS-solutions in this field. What for most countries were business between industries and national EPA's with some media debate and NGO involvement, is suddenly turned into a completely open public debate. In Norway since last year, all measured concentrations in the major cities are presented on-line on the Internet with hourly update and monthly report of exceedences of the regulations.

In Norway in a few weeks time, the public as well as the media, will be offered a solution where the users will be able to order the status and forecast for air-quality to their mobile phones or e-mails. In addition the user can request the status of air quality by sending a request from the mobile phone on any given location in the city and immediately receive the last stored information from the on-line monitoring network.

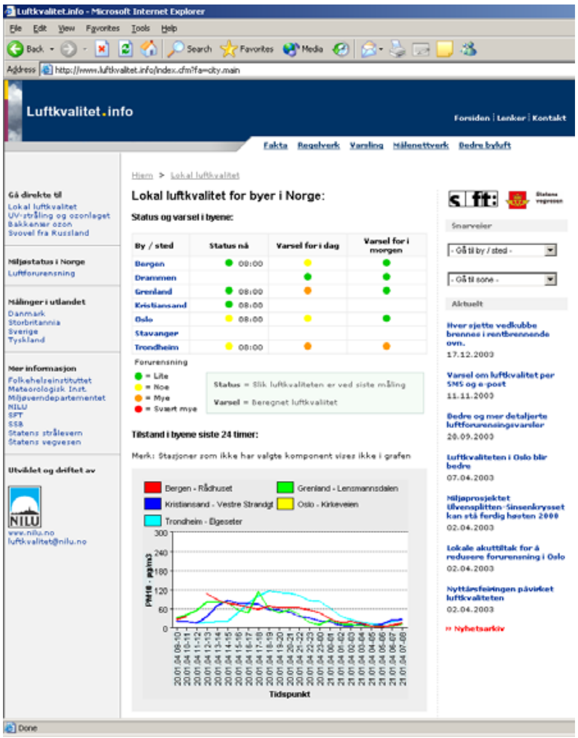

Figure 5 The new public solution for showing ambient air quality on-line from all major cities in Norway.

This solution is a result of a four year European research programme studying new ways of dissemination air quality information. The programme is called APNEE, www.apnee.org, and is a consortium of scientific telecommunication and governmental institutes who has studied the potential use of new information dissemination techniques for air quality.

7 Using integrated management solutions

NILU has, based on our scientific and consultancy experience, developed professional management software that stimulates to professional air quality management in all steps, AirQUIS (www.nilu.no/airquis). The key factor has been to develop a system that are flexible enough, are scientifically correct, and stimulates to the correct operation, management and decision-making.

7.1 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.

7.2 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.

7.3 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.

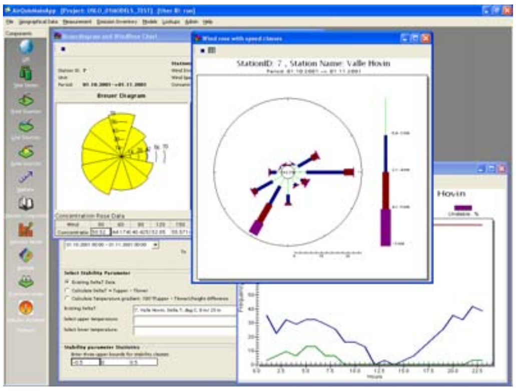

Figure 6 An air Quality management software must integrate air quality measurements, air emission, basic statistics with metrology data in user friendly interfaces

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.

7.4 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 may again lead to the development of Action plans.

8 Conclusions

Based on our experience in establishing air quality monitoring and management systems for industries and authorities in many different countries, there are 4 important critical practical success factors:

- Transparent data communication solutions and standards
- Establishing QA/QC as the core with adequate resources allocated
- The network to be designed should be able to be used in combination with advanced models
- Use of an integrated model based GIS based managements software

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1st February 2005

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Content of this presentation

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The elements of air quality management systems

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AQMS main physical elements

Emission monitoring of major sources

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Ambient monitoring network, AQ and meteorology

↓

Data acquisition and transfer solutions

↘

Data storage and access/ display solution

→

QA/QC roles and procedures. Reference laboratory, training

↗

Background statistical facts, maps, etc.

↑

GIS based modelling and management software

↑

Data distribution and dissemination solution

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Management compared to monitoring

Emission monitoring of major sources

↓

Ambient monitoring network, AQ and meteorology

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Data distribution and dissemination solution

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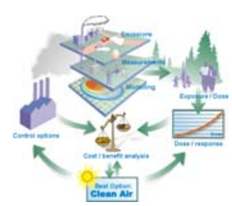
New type of regulations



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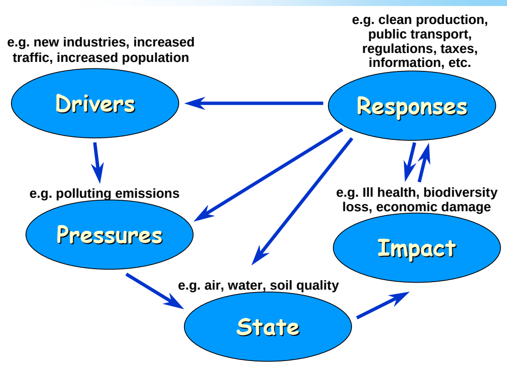
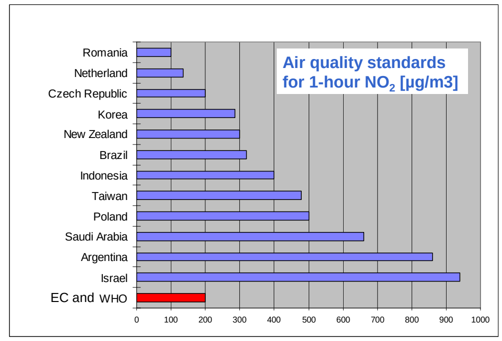
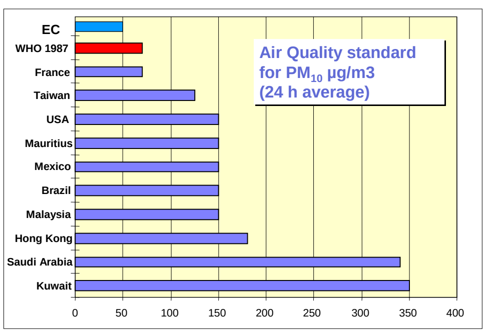
Must support all aspects



Country variations NO_2



Country variations PM_{10}



EC Air Quality Directive

Number of exceedences are not to be exceeded
Legally binding

Averaging time	1 h	24 h	annual
SO_2	350 (24)	125 (3)	20*
NO_2	200 (18)	-	40
PM10		50 (35)	40
Benzene			5

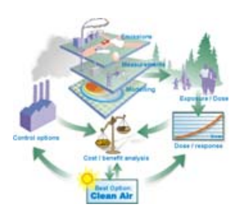
* related to ecosystems (µg/m³)

Focus is on human exposure

When unwanted episodes happen:

- Who to blame? Industry, traffic?
- What to do to prevent it from happen again?

Technical challenges



Physical monitoring

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Ensure easy dataflow

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Setting QA/QC as the core

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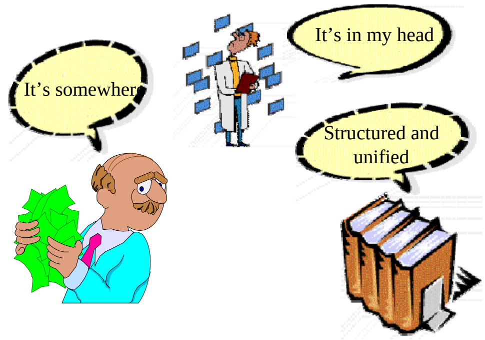
No AQ monitoring without QA/QC



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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 (surrogate DQOs)

4) Site selection

Must be representative for the Monitoring Objectives

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Role of a reference laboratory

- A unified quality system
  - Maintaining the Quality Handbooks
  - Advices and training in QA/QC matters
- National reference standards
  - Providing traceability in calibrations
- Audits
  - Checking on QA/QC work in local networks
- Keeping Central Database for Air Quality
  - Monthly data collection from local networks/stations
  - Final data validation

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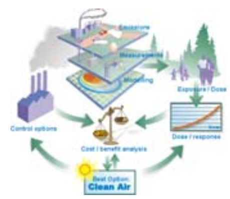
The use of models



Models

- Why use models:
  - Provides emission data
  - Gives air quality independent of monitor locations
  - Needed for:
    - Forecasting
    - Population exposure

- AQMS models:
  - Air emission model
  - Meteorological model
  - Air dispersion model
  - Population exposure model

Models compared to monitoring

Monitoring system	Model based management system
Results direct from monitors	Results from model calculations, in addition to monitored air quality data.
Many monitors placed at selected locations and at emission points	Few ambient monitoring stations combined with meteorological stations and emission inventory databases.
Strong emphasis on technical installations of different monitors	Strong emphasis on emission source inventory, general background facts and model validation
Gives exact data at each monitored place	Gives air quality concentrations 3D all over the model area
No exposure calculation of population	Prediction of exposure of population.
Forecasts at single points based on statistical data	Forecasts of AQ for all areas covered, based upon physical modelling.
No quantitative abatement strategies based on cost-benefit.	Full planning tool for abatement strategies.
Simple software needed	Advanced GIS based software needed, and provided

Air emission model

Input from the Industry module

Input from the Traffic module

Input from area sources

Temperature correction

Model calculations

Emission distributed as grid

Emission distributed as line

Emission distributed as point

Meteorological model:

Met monitoring

temperature

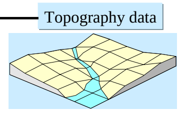
stabilize (ΔT)

Wind speed

Wind direction

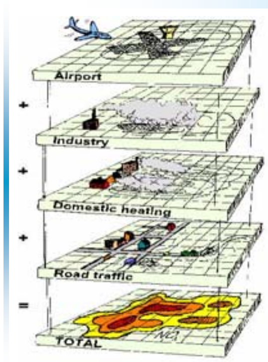
Geography data

Topography data



Calculation 3D wind field model

Dispersion Models



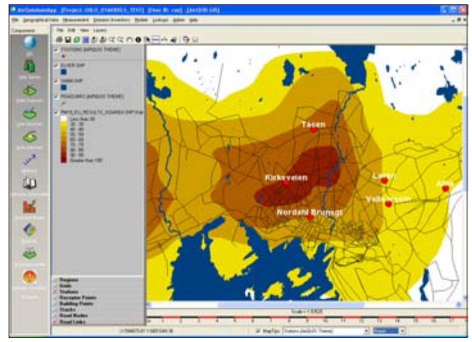
- Spatial distribution of pollutant concentrations
- Source contribution quantification
- Effects of suggested measures
- Exposure estimates
- Forecasting

Population exposure model

Links population data to concentration fields

- **Exposure hours**
  - Number of hours a number of people is exposed to pollution
- **Person dose**
  - Accumulated exposure of pollution per person
- **Population Load**
  - Accumulated exposure of pollution for all persons within an area

Forecasting – and preventing episodes



Public involvement

Basic dissemination options

Internet WAP — Pull services

Information Dissemination System

SMS E-mail — Push services

Early warning, alarms

Such solutions can give

- Information to public
  - Direct AQ-status with health warnings
  - Forecasts/episodes
  - Relevant facts
- Information to non-expert managers
  - Comparisons between cities/areas
  - Overviews towards regulations
  - Trends
- Support tools for AQMS managers
  - Status for network
  - Easy overviews of all latest measurements
  - Advanced messaging systems (SMS, MMS etc.)

Information as a policy backbone

- Good public understanding of AQ is necessary:
  - For new environmental policies
  - For implementing difficult actions in urban areas
  - For back though decisions towards industries
- The only way is to give the public interesting AQ information – the value of the advanced management systems
  - What they need, not what we like to tell

Using integrated management solutions

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Country set-ups

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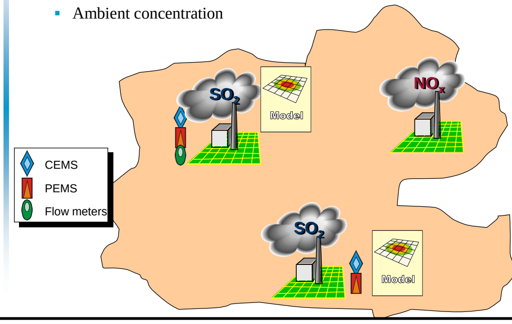
- Industries are monitoring:
  - Emissions
  - Ambient concentration



Country set-ups

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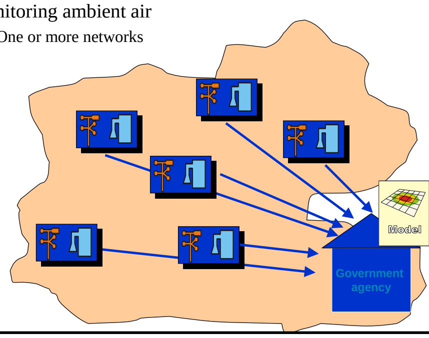
- Governmental agencies are monitoring ambient air
  - One or more networks



All should have Integrated solutions

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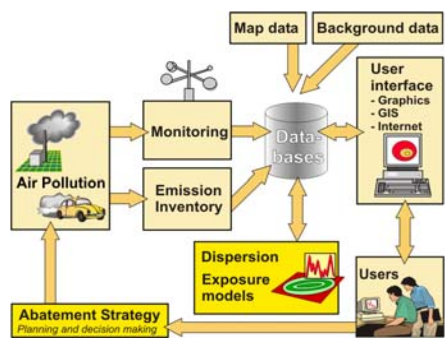

AirQUIS management software

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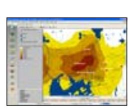
For use at national level, in urban areas or industrial areas/facilities.

- Ambient network operation
- Air quality assessment
- Abatement measure assessment
- Cost/benefit analysis
- Optimum abatement strategy identification

AirQUIS



AirQUIS management software

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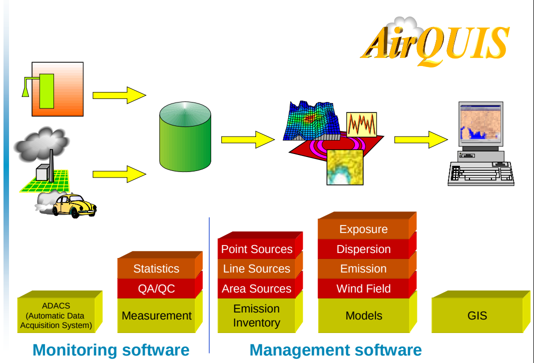

Measurement database

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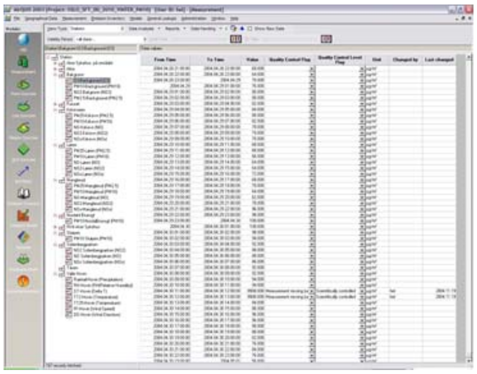

Measurement get station code

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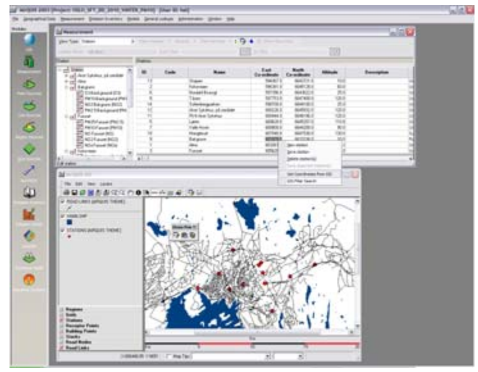

Measurement graph

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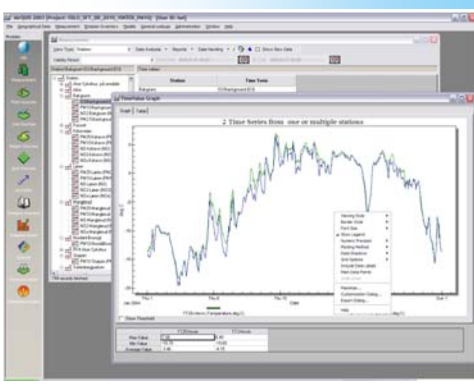

Measurement aggregation

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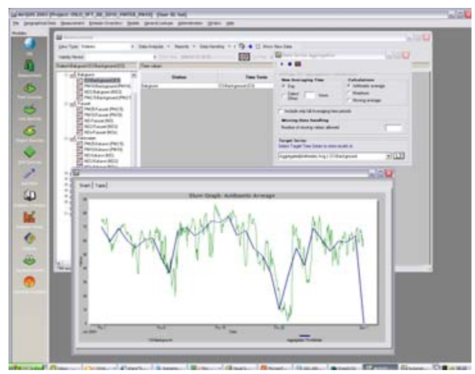

Measurement regression

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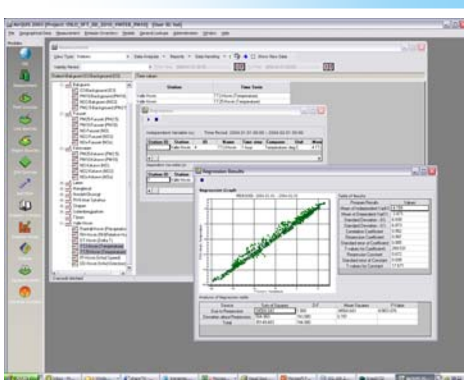

Measurement WindRose

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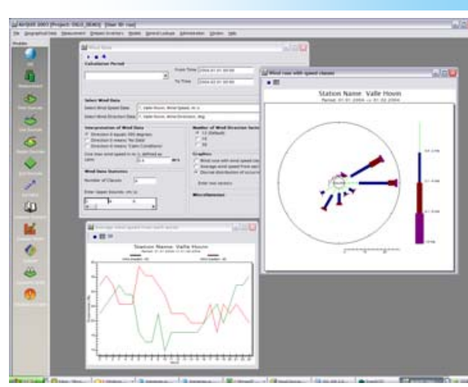

Measurement import

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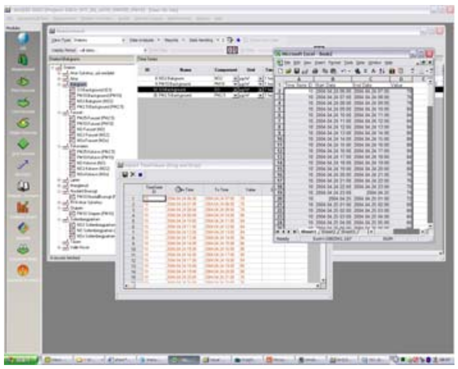

Measurement statistics

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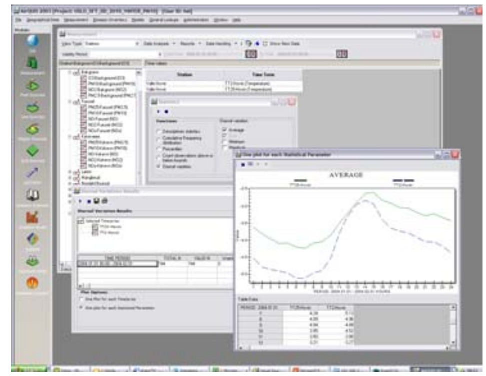

Emission inventory

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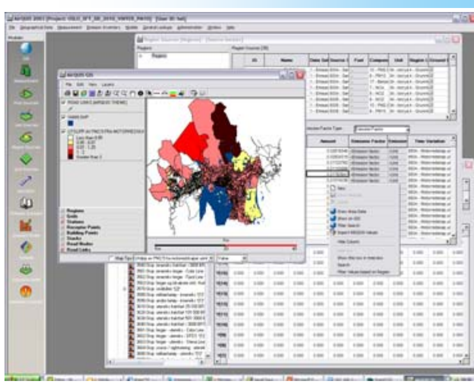

Emission model

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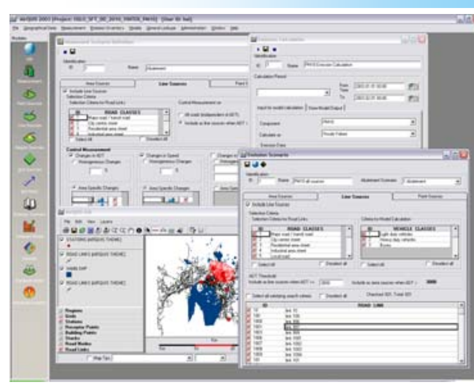

Wind Field model

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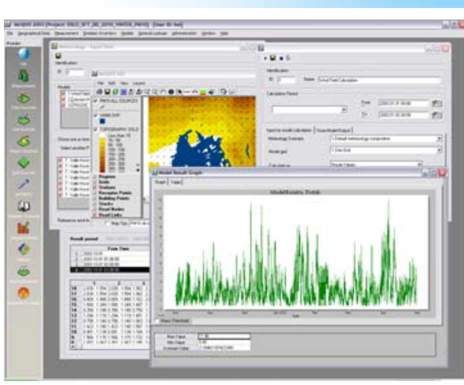

Dispersion model

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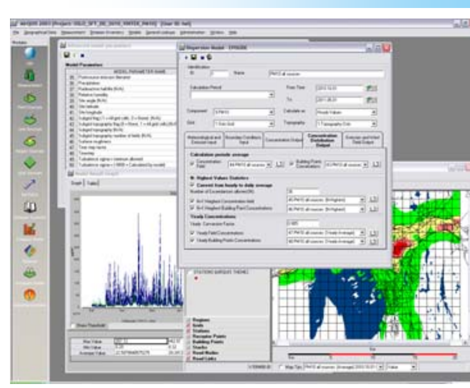
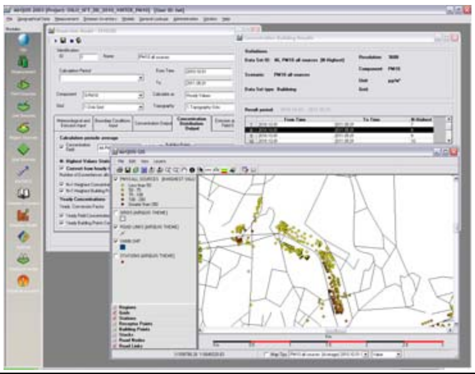


Dispersion model 2



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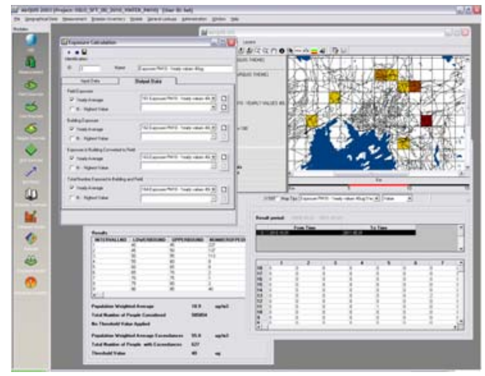
Population exposure model



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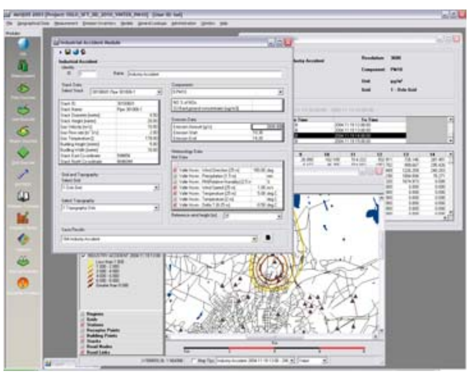
Industry accident



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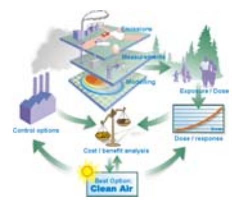
Conclusions



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Conclusions

Industries and government involved in management of air quality succeeds when they:

- Ensure transparent data communication solutions and standards
- Establish QA/QC as the core with adequate resources allocated
- Design the network to be used in combination with advanced models
- Use integrated model based GIS management software
- Disseminate information on-line to the public and/or decision makers

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Positive development in Abu Dhabi

Our main clients

- ERWDA
- ADNOC
- ADWEA

- All has a a knowledge and attitude that gives us a strong believe they will succeed. Still hard work, but they are clearly on their way.

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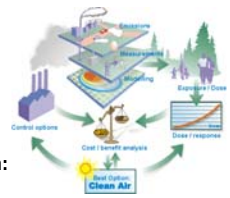

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