NILU: F 05/2004

NILU: F 05/2004
REFERENCE: Q-303
DATE: FEBRUARY 2004

Critical success factors for professional management of air quality

Presented at Fourth Speciality Conference on Environmental Progress in the Petroleum & Petrochemical Industries, 23-25 February 2004, Kingdom of Bahrain

Geir Endregard

Critical success factors for professional management of air quality

by
Geir Endregard
Norwegian Institute for Air Research (NILU)
P.O. Box 100, NO-2027 Kjeller, Norway
URL: http://www.nilu.no

ABSTRACT

Air quality goals set forth through national and international legislations and directives require comprehensive air quality monitoring and assessment systems as well as 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. The main objectives of the modern air quality management system (AQMS) are 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.

The main challenges for a modern AQMS system is the complex know-how and competence required in establishing complete well working solutions. 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.

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 measurements, emission inventories, air quality modelling and assessment, forecasting of future air quality and development of cost-effective abatement strategies.

1 Introduction

NILU has been working on air quality issues for several decades. The problems addressed range from global and regional 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 world-wide in collaboration with industries and city authorities. Important issues to be raised are:

- 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?

2 New type of regulations

In many countries air quality regulations have been quite easy to relate to. Legally binding limits have been set for emission concentrations. 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,

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 percentages to 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.

Table 1: Regulation set in the Council Directive 1999/30/EC of 22 April 1999

particulate matter and lead. The focus is increasingly put on exposure concentrations, and to some degree on how many individuals that are exposed to various levels of concentrations. Table 1 shows the regulations set in the April 1999 Directive. Similar directives on carbon monoxide, ground level ozone etc. followed later. The consequence is that local and national governments in each European country has a legal commitment to ensure that its citizens 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 by national authorities and the WHO and have existed for many years. However, legally binding concentration maximums clearly mark a change in policy.

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

- ✓ Many compounds emitted from various sources react with each other, and fast
- ✓ Air concentrations change extremely rapidly and meteorological condition influences all aspects
- ✓ Source contribution to pollution levels must be given

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

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 fine-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 another 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 are 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 and methods when monitoring air quality data.

A lot of work has been done over the last decades to improve on the reporting to national governments and 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, an increasing number of countries have established reference laboratories that set standard operation procedures for instruments and data collection. This can have some positive influence, but in practice the responsibilities lie with the producers of instruments, monitors and data logger, and last but not least on the clients who buy various solutions. Our clear recommendations are to have a stronger focus on data collection and transfer systems when new systems are established in order to force the suppliers to follow easier standards and more transparent solutions.

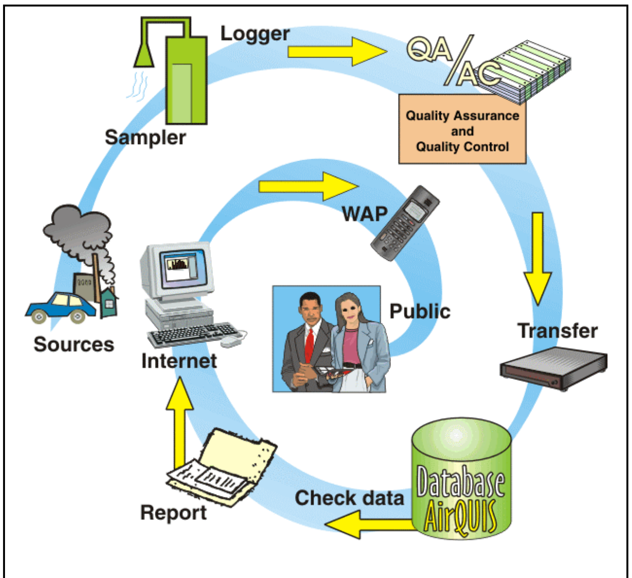

Figure 1. The technological challenge in practice is really to get various systems to talk correctly and efficiently with each other.

In Europe, a scientific network, METROPOLIS, was 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 involved. The project is 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, 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 metrology:

- 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, there 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 import data into a database and presentation tool of some kind is normally not a problem. But what is the quality 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 would be surprised at 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 misplaced in order 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 result in a similar outcome.

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 a specific location.

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 obviously 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 have doubts. 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.

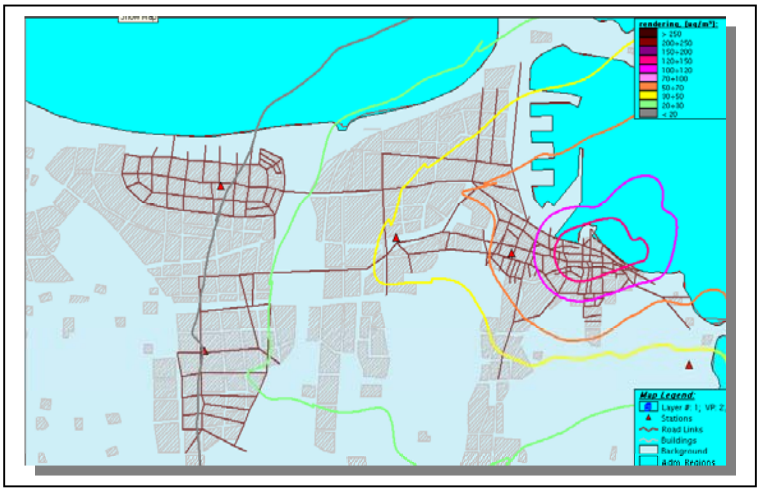

Figure 4. A model result of SO_2 distribution in Yantai China, after installing central heating.

6 The involvement of the public

If we combine the new regulations that focus on the exposure of humans with the increasingly approved right to access environmental information, we will see a dramatic change in relative few years towards dissemination solutions in this field. What for most countries was viewed as the business between industries and national EPAs with some media debate and NGO involvement, is suddenly turning into a completely open public debate. In Norway for instance, all measured concen-

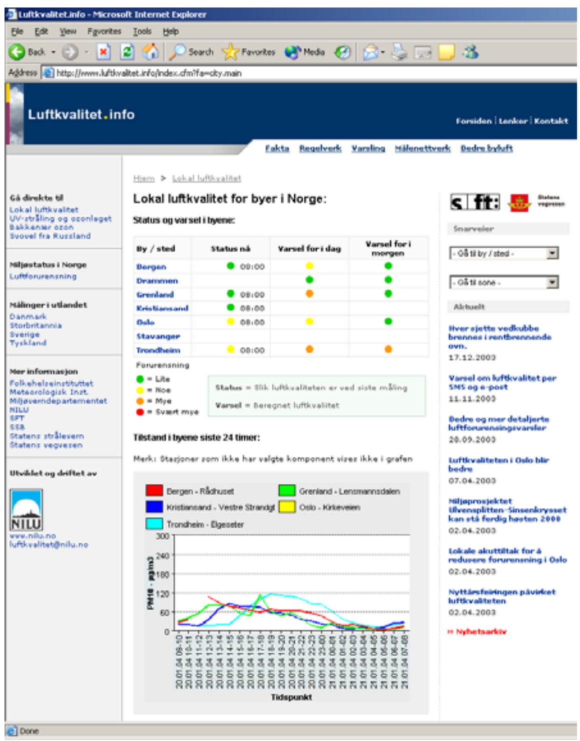

Figure 5 The new public solution for showing ambient air quality on-line in Norway.

trations in the major cities are presented on-line on the Internet with hourly update and monthly report of exceedences of the regulations, since last year. 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 air quality status by sending a request from their mobile phone on any given location in the city and immediately receive the latest available information from the on-line monitoring network.

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 have 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 professional air quality management in all steps, through the air quality management system, AirQUIS (www.nilu.no/airquis). The main aim has been to develop a system that is flexible enough, scientifically correct, and stimulates the correct operation, management and decision-making.

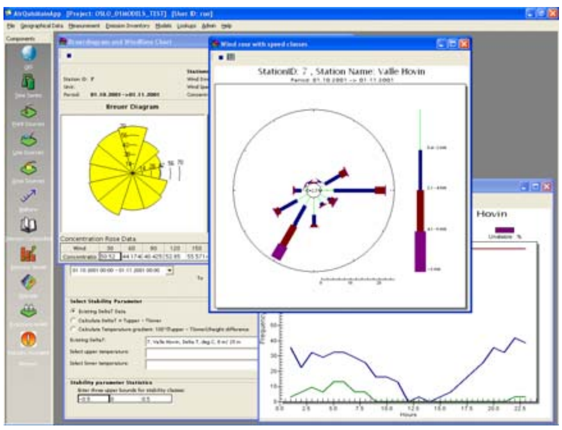

Figure 6 An air quality management software must integrate air quality measurements, air emission, basic statistics with metrology data

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.

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 five important critical and 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
- Disseminate information on-line to the public and authorities

9 References

Berge, E., Walker, S.E., Sorteberg, A., Lenkopane, M.L., Eastwood, S., Jablonska, H.J. and Ødegaard,M. (2001) A real-time operational forecast model for meteorology and air quality during peak air pollution episodes in Oslo, Norway. *In: Third International conference on urban air quality. Measurement, modelling and management.* Loutraki, 19-23 March 2001. London, Institute of Physics.

Endregard, G. (2002). AirQUIS, A Modern Air Quality Management Tool*. In workshop proceedings from Saturn-Eurasap, Urban Air quality management systems, Eurotrac-2.*

Karatzas, K., Dioudi, E. and Moussiopoulos, N. (2003) Identification of major components for integrated urban air quality management and information systems via user requirements prioritisation. *Environmental Modelling and Software, 18, 2*, 173-178.

Karatzas, K. and Moussiopoulos, N. (2000) Development and use of integrated air quality management tools in urban areas with the aid of environmental telematics. *Environmental Monitoring and Assessment, 65*, 1-2, 451-458.

Larssen, S, Barrett, K.J., Fiala, J., Goodwin, J, Hagen, L.O., Henriksen, J.F. de Leeuw, F. and Tarrason, L. (2002) Air quality in Europe: State and trends 1990-99. Copenhagen (EEA Topic report 4/2002).

Larssen, S. et al. (1995) URBAIR - Urban air quality Management Strategy in Asia, Metro Manila City Specific Report. Kjeller (NILU OR 57/95).

de Leeuw, F., Moussiopoulos, N., Sahm, P., Bartonova, A. (2001) Urban air quality in larger conurbations in the European Union. *Environmental Modelling and Software, 16*, 4, 399-414.

Moussiopoulos, N., Sahm, P., Munchow, S., Tønnesen, D., de Leeuw, F., Tarrason, L (2001) Uncertainty analysis of modelling studies included in air quality assessments. *International Journal of Environment and Pollution, 16,* 1-6, 175-190.

N. Moussiopoulos, N., Karatzas, K., Endregard, G., Fedra, K., Friedrich, R., Johansen, P.H., Kalognomou, L., Karppinen, A., Kraggerud, P.H., Kukkonen, J., Larssen, S., de Leeuw, F., Lohmeyer, A., Naneris, C., Nicklass, D., Papaioannou, G., Peinel, G., Pulles, T., Reis, S., Rose, T., Sedlmayr, M. and van den Hout D. (2003). Environmental Services and Data Brokerage Portal: ENV-e-CITY in action, in *Proceedings of "The Information Society and Enlargement of the European Union"-17th International Cenference Informatics for Environmental Protection*, A. Gnauck and R. Heinrich eds., Part 2: Applications, Workshops, Posters, pp. 652-659, ISBN 3-89518-440-3.

Sivertsen, B. and Bøhler, T. (2000) On-line air quality Management System for Urban Areas in Norway. *Presented at "The air of our cities – it's everybody's business",* Paris 16-18 February 2000. Kjeller (NILU F 4/2000).