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Working Group on the State of the Environment
Programme of Dialogue and Co-operation with China

OECD/CHINA SEMINAR ON ENVIRONMENTAL MONITORING

Beijing, 12-14 April 1999

PROCEEDINGS

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BEIJING, 12-14 APRIL 1999

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MR. N. PHIL ROSS, US-EPA

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Introductory Statement

by
Pasi RUTANEN, Ambassador of Finland to China

Introductory Statement

THE OECD/CHINA PROGRAMME

OECD countries attach increasing importance to establishing a dialogue with major actors in the world economy, including China. In 1996, the OECD initiated a Programme of Dialogue and Co-operation with China. The aim of this programme is to establish a forum for dialogue between policy-makers and experts from China and OECD Member countries, with a focus on key policy issues associated with China's integration into the international economy. From the outset environmental issues have been an important element in the OECD/China dialogue, and the OECD and China have already worked together in this field. One aspect which has been given particular attention in this co-operation is the application of economic instruments to environmental policies. Actually, the first workshop of the OECD/China programme was held in October 1996 here in Beijing; it was opened by Minister Xie Zhenhua.

This dialogue has proven extremely beneficial to both OECD countries and China. For OECD countries, it helps to better understand the environmental challenges facing China today and to identify areas where common solutions to common problems can be sought. For China, the dialogue provides insights into the experience gained in OECD countries in implementing cost-effective environmental policies.

SUSTAINABLE DEVELOPMENT AND GLOBALISATION

In recent years, concerns about environmental issues have raised questions about the prevailing paradigm of economic development. As a result, policy makers today are concerned with promoting more sustainable development, i.e. development that seeks to reconcile traditional notions of economic growth with environmental and natural resource management, and with social and inter-generational equity.

The debate about the environmental consequences of economic growth, and about the importance of sustainable development, is high on the international agenda. It has been reinforced by trade liberalisation and increasing globalisation of the world economy.

From the particular perspective of the environment, economic globalisation represents both challenges and opportunities:

- On one side, globalisation changes the context of environmental problems at various levels (local, national, regional, global), and generates concerns about countries' general capacity to develop policies to ensure that economic growth will also advance environmental protection and social welfare.
- On the other side, globalisation is also opening up new opportunities to promote environmental objectives, for example through re-orientation and greater convergence of both economic and environmental policies, or through structural and/or technological change.

However, analysing the environmental consequences of globalisation, economic growth and related policies is not an easy task. Since the economic benefits of policy changes typically appear much sooner than do the environmental benefits, analysing the environmental consequences must be done over a longer time frame than is required for many economic issues. The net environmental effects (including both the positive and negative effects) generated by economic growth, trade liberalisation and globalisation will, in the end, vary depending on the country's specific situation and on the policies it implements.

In this context, three things appear to be essential:

- first, that effective environmental policies are developed and implemented in the fields of pollution control and nature conservation;
- second, that environmental aspects are taken into account when economic and sectoral policies are developed and implemented;
- and finally, that these policies are based on appropriate factual information and that the public is informed about the results of these policies.

ENVIRONMENTAL INFORMATION

The OECD has long advocated better environmental information, including appropriate access to this information. Last year, in April 1998, the OECD Council adopted a Recommendation on Environmental Information which asks OECD countries as well as the OECD itself to strengthen their efforts in this field.

Experience from OECD countries indeed shows that the provision of high-quality information and analysis is crucial to carrying out environmental policy decisions, and environmental strategies. Experience also shows that the availability of environmental data and indicators and well-synthesised information finally lead to better social cohesion and helps improve the accountability of public authorities to public opinion in their own country and beyond.

ENVIRONMENTAL MONITORING AND THIS SEMINAR

Environmental monitoring is at the very beginning of the environmental information chain: it is the basis of environmental data collection, environmental reporting and environmental research, and the basis of our understanding of environmental problems and trends. Environmental monitoring is therefore a powerful tool for supporting decision-making, monitoring the enforcement of policy decisions, and assessing compliance with policy regulations and objectives.

The aim of this seminar was to take stock of current environmental monitoring practices in China and in OECD countries, and to provide a forum for a constructive exchange of experience and views on how to best design and use environmental monitoring to support decision-making and inform the public. The seminar focused on air and water monitoring, areas in which both China and OECD countries have long experience. The roundtable at the end of the seminar presented the opportunity to further broaden and deepen the debate.

All this has provided a very challenging task for the seminar participants, both from China and from OECD countries, and encouraged a stimulating exchange of views.

Executive Summary

by
Dorothy SALATHIEL, United Kingdom

Executive Summary

MAJOR ROLES OF ENVIRONMENTAL MONITORING

Better management of what we measure

Experience from OECD countries and from China shows that monitoring is a crucial tool for providing high-quality data and information to support decision making and public information.

In OECD countries, environmental monitoring and basic environmental data collection have improved considerably since the 1970s, even though a certain variability remains in both the quality and coverage of environmental monitoring and related data across countries.

In China, environmental monitoring enjoys a key status in the supervisory management of the environment. It has assumed an increasingly important role since the mid-1980s in environmental policy-making, enforcement and management.

CHANGING INFORMATION NEEDS

A two-way process

There is a two-way process between decision making and monitoring. Decision-making needs set monitoring requirements and in turn monitoring requirements inform decision-making. Environmental monitoring systems have thus to be viewed not only from the perspective of their design and technical quality but also in terms of how well they meet the needs of decision making and policy evaluation.

Participants from OECD countries stressed the need to clearly define at the beginning of the planning process the objectives, expected products and users of monitoring programmes and to establish the questions to be answered in order to decide what monitoring should be done.

Examples from Chinese experience showed the close links between policy planning, enforcement and monitoring e.g. targets for discharges and air pollution.

Shifting demands

It appears that most countries had gone through a process where the objectives or questions to be addressed had changed.

In OECD countries, the emphasis is shifting increasingly away from environmental monitoring as a tool for reporting towards monitoring to assess the implementation of environmental policies. There is also a general change from curative to preventive to integrated monitoring. In The Netherlands for example water monitoring evolved from quantity to quality to ecology to integrated.

In China, environmental monitoring information is mainly quality monitoring and pollution source monitoring data. Standardised monitoring of air, water systems, oceans and noise began in the 1980s. The 1990s have seen the beginning of routine monitoring of environmental pollution sources and continuous automatic monitoring of air and water, leading to an unprecedented increase in sources of environmental information.

As pollution becomes increasingly severe and widespread, the status of environmental monitoring measures has been strengthened, particularly in the Ninth Five-Year Plan for Environmental Protection. These strategic changes require an adaptation of national environmental monitoring in China to better support national environmental policy. This implies among others a reform of the management, structure, and key functions of the monitoring systems.

An ongoing process

To ensure that environmental monitoring systems keep pace with the demand for information and developments in environmental policies and strategies, it is important to regularly review their organisation and outputs to detect possible gaps, weaknesses or imbalances. Such reviews should cover concerns such as how to make monitoring systems more cost-effective (i.e. how to reduce costs) and how to make them more effective overall (i.e. how to increase benefits).

It is therefore important to recognise that the process of redesigning networks is ongoing.

The seminar discussions identified the following main issues when setting up, running, and reviewing an environmental monitoring system:

- technical implementation issues
- the use of monitoring results in decision-making
- the use of monitoring results in public information
- institutional and financial issues

Other important elements are regulatory instruments and international co-operation.

In the framework of the reform of its environmental monitoring systems China needs in particular to achieve breakthroughs in monitoring management mechanisms, data quality, techniques for controlling total quantities and in the integrated use of reports.

TECHNICAL IMPLEMENTATION ISSUES

Technical issues were at the heart of Chinese concerns. The exchange of experience and lessons from OECD countries appeared to be particularly helpful in this field. The questions raised focused on:

- The coverage and scope of the monitoring systems, with a particular interest in the location of monitoring sites.
- Measurement techniques, methodologies and equipment with a particular interest in technical monitoring standards and in enhancing the scientific quality of environmental monitoring. Some examples of specific questions which China needs to address relate to biological monitoring and to the use of manual versus continuous monitoring.
- The quality of monitoring results with a particular interest in data treatment and interpretation of monitoring results. An example of difficulties encountered in the interpretation of monitoring results in China is how to decide when pollution risk has effectively disappeared?
- Data transmission issues with a particular interest in the management of information flows.

Various factors offer opportunities for improving the quality of monitoring results. Harmonisation in monitoring procedures is essential to assure comparability of results among different monitoring systems. Standard procedures in quality assurance/quality control help to ensure that predefined data quality objectives in the data collection and processing have been met.

Developments in monitoring equipment and computer technologies, also play a role, and can, for example, enhance the speed of information flows and the analytical capability of data production systems.

Experience from OECD countries however suggests that things should be kept as simple as possible, and that pragmatism and common sense be used. One should therefore be cautious about using automatic monitoring methods and expensive laboratory equipment as these can waste money; they often involve increased investment and maintenance costs, and require specific training and skilled personnel.

Only one tool

A related aspect was the message that ‘monitoring cannot by itself answer all the questions’. Monitoring is only one tool. OECD countries stressed the need for data from elsewhere, such as:

- meteorological data to interpret air data
- hydrological data to interpret water data
- information on pressures, e.g. air emissions
- economic data
- modelling and forecasting data

All this requires co-operation with other bodies holding the required data.

USE OF MONITORING RESULTS

Seminar participants agreed that environmental monitoring plays an important role in:

- the development, implementation and assessment of environmental policies and actions
- environmental reporting and public information about environmental problems, measures taken by the Government and results achieved

The assessment, publication and dissemination of monitoring results play important roles in the overall "productivity" of a monitoring programme. It is also important to match output with the needs of decision-makers and the general public.

This was another key area of concern for China, summarised in the expression 'data rich - information poor'. OECD countries gave advice in relation to institutional co-operation and reporting to users and the public, both of which are covered below.

Use in decision making

Environmental monitoring has proven a powerful tool for supporting decision-making. This concerns in particular:

- the development of policies through a better knowledge of the state of the environment,
- the implementation and assessment of policies,
- the enforcement of policy decisions and the assessment of compliance with regulations and objectives.

Monitoring information can further serve as early warning or alert systems, and provide guidance for investment.

In China, environmental monitoring enjoys a key status in the supervisory management of the environment, in 1994 it became a constitutive part of the government's mandate. Three functions of monitoring were spelled out:

- to provide technical support for the implementation of environmental policy and management;
- to enable technical supervision of environmental policy enforcement;
- to provide a technical service to social and economic infrastructure development.

Monitoring information is particularly needed to improve compliance with pollution source discharge targets, to control total pollutant volume, and to intensify the supervision of environmental quality in key regions and cities.

Use in public information

Environmental monitoring plays an important role in providing information to support environmental reporting and to inform the public about environmental problems, measures taken by the Government and results achieved.

A related aspect is the dissemination and communication of monitoring information and public access to it.

In most OECD countries, monitoring data are published regularly as environmental statistics. They are also the basis for environmental indicators or indices and state of the environment reports. A distinction is made between public information in real time, on a periodic basis or on a regular basis. OECD countries give high priority to public information, especially in relation to information on actual and forecasted air concentration levels. They described various approaches including:

- publications geared to users, e.g. simple reports and leaflets
- release of data to the media
- release on TV teletext
- release on the Internet

The Netherlands described a matrix of products against users they had developed to locate gaps in their publication provision. The United States had put their toxic release inventory on the Internet.

China gave examples of the work in progress to inform the public and raise awareness, in particular with weekly reports on air monitoring and with the aim of daily reports by the year 2000.

China also asked how to manage indicators so that the public could understand and relate them to their daily lives. It was agreed this was important, but not easy. The United Kingdom described work it had carried out on air quality indicators.

INSTITUTIONAL AND FINANCIAL ISSUES

Institutional issues

The organisation and co-ordination of the actors involved in monitoring programmes has implications for the co-ordination of monitoring efforts, harmonisation of measurement techniques, efficiency of data management, information flow across and within institutional layers, and data integration.

In most OECD countries, many actors (national environment ministries or agencies, other ministries, local and regional authorities, universities, research departments, private firms, the public) are involved in promoting, managing, operating, financing and using monitoring programmes.

In China, environmental monitoring is managed by the State Environmental Protection Administration (SEPA) and its Environmental Monitoring Centres. Working relationships and co-operation with other relevant ministries or agencies are generally lacking. Main areas of concern to China were:

- co-ordination of local bodies to meet national needs and to better organise related information flows
- co-operation with other national bodies

Experience from OECD countries shows that it is essential to clearly define the actors' respective roles and the stages of the programmes to which they are invited to contribute or for which they are asked to bear responsibility. Specific suggestions focused on the need to bring people together for discussion. They included the following advice:

- understand each other's point of view,
- explore the benefits to both sides of co-operation,
- fully understand differences in methodology in order to work out the scope for harmonisation and avoid dangers of misusing data,
- provide facilities such as software, as well as instruction, to facilitate the process,
- give back information in exchange for data,
- set out national policy plans so all are clear what is required and that changes have to be agreed,
- extend contacts beyond environmental administrations to others.

The effectiveness of institutional arrangements not only depends on the type of relationships among the various actors but may also be influenced by legislative and regulatory frameworks (national, international), national information strategies, and related funding mechanisms.

Financial issues

The level of resources available for monitoring generally depends on the economic situation of the country concerned. Where budget constraints exist, or where new priorities arise, trade-offs need to be made between the desire to widen the scope of monitoring and the need to secure funding. All countries seem to suffer from budgetary constraints, but this is a particularly acute problem for China.

OECD countries expressed the need to prioritise requirements and to maximise use of data. Key advice given by OECD countries was:

- avoid collecting data which are redundant and which are not used
- identifying appropriate data can save money on e.g. treatment plants. Look at showing cost-effectiveness in cost-benefit terms
- look at secondary use of data, e.g. in a geographic information system, to add value to data collected
- ensure a continuous and fairly even funding throughout the existence of the monitoring programme, and a balanced allocation of resources to all stages of the programme including analysis and reporting
- take advantage of the polluter pays principle to provide funding. Where monitoring can be clearly related to a given polluting activity, monitoring should in principle be financed by pollution charges. Such charges, however, may not be practicable in all cases. Practice in OECD countries indicates that most environmental monitoring programmes have to be funded from public sources. All sorts of mixed situations can also be found.

CONCLUSION

The provision of high-quality information is crucial to developing, implementing and assessing environmental policies; in other words, we can better manage what we measure.

The provision of appropriate information is also crucial to informing the public about environmental problems, measures taken by the Government and results achieved.

The seminar discussions have proven extremely beneficial to both OECD countries and China. They demonstrated that both OECD countries and China had to address difficult problems in setting up and running their monitoring systems. OECD countries shared many of China's problems and did not have easy solutions. They provided much advice, which China said would be useful.

It was agreed that OECD countries would offer further help on specific technical issues through bilateral contacts.

The seminar discussions also provided a basis for further developing the dialogue and co-operation between China and OECD countries on other environmental information issues.

PART I.
ENVIRONMENTAL MONITORING ISSUES

Environmental Monitoring Issues
The Experience of OECD Countries

by
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and
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The present document takes stock of current environmental monitoring practices in OECD countries. It identifies major issues affecting the relevance, efficiency and effectiveness of environmental monitoring systems and provides a checklist that could help countries to review their own national monitoring systems. It builds on earlier work carried out by the OECD Working Group on the State of the Environment, and has been updated for the purpose of the OECD/China seminar on environmental monitoring.

Environmental Monitoring Issues
The Experience of OECD Countries

INTRODUCTION

Defining environmental monitoring

Environmental monitoring can be defined in a number of ways. For the purposes of this paper it is defined as gathering, assessing and reporting environmental information obtained through continuous or periodic sampling, observation and analysis of both natural variation or changes and anthropogenic pressures and their effects on humans and the environment. Today the difference between environmental monitoring and the production of other types of environmental information is less distinct than it once was.

Changes in environmental policy priorities

In the 1960s and early 1970s environmental policies were mainly oriented towards controlling the most visible air and water pollution from fixed sources, and often were mainly concerned with protecting human health. In the 1980s the environmental policy agenda expanded to cover new types and sources of pollution (micropollutants, diffuse sources, etc.), natural resource issues (e.g. forest conditions) and management of environmental risks related to industrial activities or natural disasters. In the 1990s large-scale programmes to monitor biodiversity and climate change started. For the next decade, new and more comprehensive ways to measure sustainable development are expected in most OECD countries. Such changes clearly require adaptation of environmental monitoring systems so that adequate information and data continue to be made available.

Increasing demand for information

Public opinion supporting environmental improvement has remained strong over time, according to surveys in several OECD Member countries since the early 1980s. At the same time international environmental issues — such as the Chernobyl incident, climate change and the decline of biodiversity — have illustrated the importance of providing the news media with relevant and timely information on environmental conditions and human health risks associated with economic activities.

In several countries the public is also playing an increasing role in environmental issues: "green parties" have gained institutional recognition at all levels of government. The need for reliable, scientifically sound, co-ordinated environmental data and indicators is more pressing today than ever before; availability of meaningful information should lead to a more democratic debate, and to better accountability of public authorities and various other actors. The principles of right of information and right of appeal for the public have been embodied in many administrative procedures relating to environmental issues (environmental impact assessment, pollution control, management of national parks, etc.) and in international acts such as the Aarhus Convention on access to information, public participation in decision making and access to justice in environmental matters, and the OECD Council Recommendation on Environmental Information.

In the OECD context, environmental information produced by monitoring plays an important role as background for the OECD Environmental Performance Reviews. Monitoring data are also the basis for the biennial Compendium of OECD Environmental Data and the OECD Core Set of Environmental Indicators.

Improvements in science and technology

Efforts in fundamental or applied research concerning the environment and its components (air, water, wildlife, etc.) as well as basic physical, chemical or biological phenomena have led to improvements in the understanding of environmental issues. They have also drawn the attention of decision makers and the public to new or changing environmental issues, concerning, for instance, cross-media developments, new pollutants and multiple exposure to pollutants.

The last two decades have seen rapid technological development not only through improvement of existing technologies (including electronics), but also with new techniques or capacities for monitoring systems, such as automated measuring stations, remote sensing and geographic information systems (GIS).

Economic situation and funding limitations

More than 30 years after the introduction of the first major pollution control laws, which were drafted at a time of high economic growth, the economic context in which environmental monitoring systems are now developed, assessed and reorganised is different. Limited economic growth in a number of OECD countries means increased cost-effectiveness is needed. A general lack of resources both in the private and public sectors and on the part of state and local authorities translates into budget constraints for the development and operation of environmental monitoring systems. The resources available thus need to be optimally allocated.

THE ROLES OF ENVIRONMENTAL MONITORING

This paper focuses on monitoring of the environment; it does not systematically cover all monitoring, such as the monitoring of products (chemicals, motor vehicles, food). The general goals of environmental monitoring are to assess:

- The quantity and quality of anthropogenic pressures on the natural and the built environment.
- The direction, speed and extent of the adverse effects that anthropogenic pressures have on humans, nature and the built environment.
- Trends in the state of the environment and sustainable use of natural resources, and measures to reduce harm to the environment.

Environmental monitoring systems thus play an important role in providing data and information to support:

- The development, implementation and assessment of environmental policies and actions.
- Environmental reporting and public information.
- Research activities.

Major roles of environmental monitoring

Development, implementation and assessment of environmental policies and actions

The provision of relevant data and information is essential for both public and private policies or actions. It should contribute to the different stages of such policies or actions and of early warning or alert systems, including, at a minimum:

- Assessment of the policies and actions, to ensure that there is no return to unsatisfactory situations over the long term.
- Implementation of strategies and actions to reverse degradation, pressure trends, etc.
- Very short-term monitoring of potentially acute problems as part of alert systems to protect human health from acute pollution or natural disasters and to save lives.
- Monitoring of compliance with emission standards, environmental quality standards and other environmental regulations.
- Monitoring as part of environmental impact assessment procedures.
- Recognition of issues and development of strategies and actions needed to bring problems under control (e.g. pesticide monitoring).

Environmental reporting and public information

More generally, the role of monitoring programmes is also to provide data for the factual description of the state of the environment in several areas of interest. In particular, such data concern:

- Most-polluted areas.
- Background levels of pollution and environmental quality in non-polluted areas.
- Areas of special interest for the environment (rich resource areas, sensitive areas, etc.).
- Environmental components or target populations most at risk and sensitive to environmental degradation or pollution (e.g. the young and the elderly).
- Areas of particular public concern.

This role is also important in providing information to the media and the general public.

Monitoring programmes should also be designed and operated to provide data and information over long periods so that long-term trend analysis of the state of the environment is possible.

Data and information for research

In addition, environmental monitoring should be designed to provide useful information and data for all types of research activities that are undertaken for the better understanding of environmental issues, such as:

- Understanding of ecosystem structure and functioning (relationships among environmental components; physical, chemical and biological interrelationships; major natural cycles of elements such as carbon and nitrogen; pathways of substances such as cadmium and lead, etc.).
- Life-cycle tracking of pollutants, from their source to the effects they may have or the damage they may create, by themselves or through their by-products.
- Trend analysis of the state of the environment (trends over time or geographical distribution).
- Environmental modelling.
- Forecasting of environmental issues so that consequences of policies can be simulated over the long term and alternative strategies can be developed.

Adaptation of a monitoring programme to its roles

The components of a monitoring programme have to be carefully designed according to its purpose and role (or combined roles), so that its output is adapted to the needs of the users: policy makers as well as representatives of other major players in agriculture, trade and industry, research and development, non-governmental organisations and the general public. These components are mainly:

- The coverage of the monitoring system: spatial coverage, time scale and the physical, chemical or biological elements that have to be monitored.
- The methodology and techniques to be used.
- The choice of data sets in order to facilitate adapting the results to the various users.
- The organisational structure and institutional arrangements that have to be carried out so that the guidance and co-ordination of monitoring programmes' implementation are well established and the results are made fully available and are used.

MONITORING IMPLEMENTATION ISSUES

Possible gaps, imbalances or weaknesses in monitoring systems' coverage

Designing or restructuring

A number of questions must be considered when a monitoring programme is being designed or restructured. These are mainly of the type "what?", "how?" and "by whom?". It is essential for the objectives of the monitoring programme and the expected products and their users to be clearly defined from the very beginning of the planning process.

In many OECD countries it is air and surface water that have been most comprehensively monitored. A number of countries have established nationwide monitoring networks for air quality and water quality with some hundreds of stations or even more than a thousand. Through these long-established systems, well-known pollutants (e.g. SOx, CO, particulate matter, COD, BOD, SS) have been monitored for at least a decade or two. Particularly in some countries, surface water quality has been monitored not only by environmental authorities but also by water authorities — that is to say, by users of water as such; consequently, much more extensive data have been stocked about water than about other sectors. However, in several countries even these traditional sectors are not yet fully monitored, and considerable variations are found among countries.

Concerning the more traditional monitoring of pollution, most efforts have been devoted to ambient concentrations and emissions. Nowadays emphasis is on monitoring exposure and the effects of pollution, particularly for the protection of human health and preservation of ecosystems. This shift has allowed better evaluation of health risks (which had already been sought through monitoring of ambient quality) and accompanies such approaches as multiple-exposure monitoring, biological monitoring and health effects monitoring.

In many countries increasing progress has been made since monitoring activities started. Monitoring of natural resources is now an important part of national environmental monitoring systems. At the same time, much wider coverage has been required to deal with emerging concerns, in accordance with the widening scope and changing priorities of environmental policy. Soil, noise, biodiversity and global change are just a few of the "new" sectors needing more attention. In some cases early awareness has enabled a country to accumulate experience that could be shared with others. All the while, many of the more traditional monitoring programmes need to be maintained.

As new priorities arise, there is a constant struggle between the pressure to widen the scope of monitoring and the need to secure funding for both traditional and new monitoring. Since additional resources seldom can be expected, the solution to this dilemma is often a difficult restructuring of the monitoring system, with strict priority setting.

Geographic/spatial coverage

Spatial coverage requirements of monitoring activities depend on the geographic scale of the phenomena concerned. In general, the two major orientations for spatial coverage are local monitoring networks for heavily polluted sites such as urban and industrial areas, operated mainly by local authorities and private bodies (often independently); and nationally planned networks, including co-ordinated aggregation of local networks where appropriate, direct monitoring by national governments — particularly for long-term reference and background pollution-level monitoring — and monitoring networks as a part of international monitoring systems. In addition, intensive monitoring is often applied to environmentally significant zones or target areas.

In most OECD countries, "black/hot spots" and "significant targets" are well covered, as is background pollution. More moderately polluted areas, or "grey areas", are less monitored; to cover these, monitoring programmes with average spatial coverage, such as the "grid method", are used.

Monitoring of indoor pollution has become important with a shift of interest towards exposure and human health effects (e.g. occupational health).

Times scales and targets

Depending on their time scales, monitoring activities can be classified into three major types: continuous; periodic; and temporary (which includes emergency monitoring). The differences in sampling interval depend on the purpose of the monitoring as well as on the cycles of the physical/chemical process to be monitored.

Continuous monitoring has been used in some countries for ambient air monitoring systems, which have worked as alert systems to protect human health from serious pollution episodes. Hydrological, meteorological and seismographic monitoring in alert systems for natural disasters are other forms of continuous monitoring. Periodic monitoring with a relatively short cycle has been carried out mainly to evaluate compliance with environmental quality standards. This kind of monitoring can be called "short term", although accumulated data can be used for long-term assessment of achievement of policy goals.

When monitoring relatively stable situations with no or very slow changes, it is reasonable to use longer periods. Extensive natural environment surveys or forest inventories, for instance, can be meaningfully carried out every fifth year. In an even longer-term perspective, several countries have developed environmental specimen banks, which are considered indispensable for tracing "new" pollutants in the future.

Emphasis should be placed on emergency monitoring when accidents occur (e.g. an explosion leading to emission of toxic substances, or leakage of hazardous pollutants into water). When developing monitoring systems it is important to allow for enough flexibility to enable them to deal with such events, particularly for assessing risks to human health.

Some monitoring approaches focus on environmentally sensitive species or areas. In many cases intensive monitoring of such "targets" is effective. For example, certain groups, such as babies and young children, pregnant women and the elderly, are thought to be more sensitive to pollution. Certain species can be used as indicators because of their sensitivity to pollution, land use changes and some other environmental pressures. In human populations certain categories of workers are likely to be exposed to higher pollution.

Use of "integrated" approaches or methodologies

Cross-media and multiple-exposure approaches

The cross-media or integrated and multiple-exposure approaches have been developed to supplement the traditional approach, which monitors phenomena in a single sector of the environment at a fixed site. The cross-media approach means simultaneous monitoring of several media, such as air, water and soil, at a given site, or small catchment area. These overall views can clarify transmedia movements of pollutants. A number of European countries are promoting integrated monitoring at some 43 small catchments, carrying out physico-chemical as well as biological measurements.

Multiple-exposure or "receptor-oriented" approaches measure the overall exposure of a receptor in multiple circumstances (microenvironments) from multiple sources. Using this approach helps in determining the relationship between sources and exposures and in examining the deficiencies of the traditional approach that considered a single ambient pollution level as an index for effects. Total human exposure studies (e.g. exposure to air pollutants or noise) are examples of this approach.

Biological and health effects monitoring

Biological monitoring focuses on the exposure and effects stage. It is used to assess the effects of pollution on human health and ecosystems. Biological testing methods are developed and used mainly for effluent monitoring. Biological monitoring is easier and cheaper than physico-chemical monitoring, as it examines the overall toxicity of samples through direct observation of the biological response. It includes more complex methods such as diversity indices, species indices and morphological damage approaches.

Protecting human health is one of the most important goals of environmental policy. Relationships between pollution and health effects often form a basis for policy decisions, such as the establishment of environmental quality standards and accompanying regulations. Uncertainty or mistakes in information can result in unnecessary costs stemming from excessive regulations, or in excessive damage to human health. Much effort has been made in this connection, and still more effort will be required to obtain increasingly precise and adequate information.

Improving the quality and comparability of monitoring results

Harmonisation in monitoring procedures

Harmonisation in procedures is essential to ensure comparability of results among different monitoring systems. As far as individual countries are concerned, standard methods have often been defined by national governments or research institutes to harmonise activities that in many cases are carried out independently by local authorities and private bodies. Yet measuring methods vary considerably by country, even in "traditional" areas such as air pollution monitoring. The OECD work on environmental data has helped improve data comparability among OECD countries, as did studies carried out by other international organisations such as the World Health Organization and the European Union. Nevertheless, international comparability is still an issue, and countries are often unwilling to change their procedures if it would lead to discontinuities in their trend data. Further efforts are needed in this area.

Technology development

Recent decades have seen dramatic developments in technology. Microelectronics and data and communication technology, especially, have extended the scope of monitoring and improved its efficiency and effectiveness. Databases are effective in storing and using huge amounts of data collected over years. Computer graphics make data more readable and understandable for decision makers and the public.

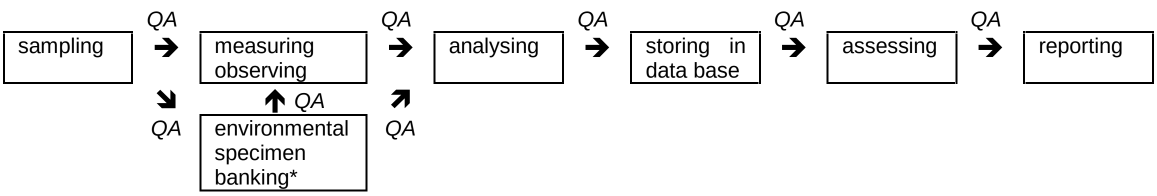
Through a worldwide network of satellites, ground stations, field workers and scientists, remote sensing techniques are used in environmental monitoring. These techniques mainly apply to monitoring of extensive changes in land use and biomass. By identifying events such as forest fires and which areas are most under threat from deforestation, remote sensing is making a vital contribution to improving understanding of tropical forest ecosystems, for example, and the ability to preserve them. Satellites also monitor water quality, primary production, spread of algal blooms, oil spills, etc. Air quality monitoring using laser techniques has proved successful as well.

Improving the use of monitoring results: publication and dissemination

Stages of monitoring

Monitoring activities have various stages (Figure 1). Quality assurance is essential at every stage. Often the data processing/analysis and the data publication/dissemination stages are less developed than the measurement stage, and need to be strengthened if effective use of monitoring data is to be made. This is generally less costly than strengthening the measuring stage, and thus helps increase cost-effectiveness.

Figure 1. **Monitoring stages**



QA: Quality assurance.
* Sampled material may be stored in an environmental specimen bank for future use (e.g. to trace previously unknown pollutants).

Publication and dissemination of monitoring results

In most OECD countries, monitoring data are published regularly as environmental statistics. They are also the basis for environmental indicators or indices and state of the environment reports. Appropriate dissemination processes and transparency of information are also required in the case of accidents. However, many monitoring results are not published and thus are inaccessible to the public, so the degree of transparency is often not enough to meet public “right to know” standards.

Several international attempts have been made to assure public access to environmental information, including monitoring data. The most recent attempt in this respect within the OECD is the Recommendation of the Council on Environmental Information, which the Council adopted at its meeting in April 1998. The Recommendation calls for actions to increase the availability to the public of environmental information and to promote dissemination of environmental information.

Adaptation of dissemination stage to different users

The form in which monitoring results are expressed always requires careful attention; data must be presented understandably and in such a way that they can be correctly interpreted. As different users need different types of information, the dissemination of monitoring data should be adapted to specific users. It should also be part of a broader, clear environmental information strategy for the next generation of environmental policies.

It would be highly desirable to develop widely acceptable output, but this seems quite difficult. Since interpretation of many monitoring data often requires highly technical knowledge, it is advisable to make them available to the public as aggregated or indexed figures and to provide some assistance in interpreting them. Clearer links between monitoring efforts and reporting on the state of the environment are often advisable. Decision makers also prefer indices to be as simple as possible.

INSTITUTIONAL AND FINANCIAL ISSUES

Distribution of roles in monitoring among agencies and other actors

In most countries, many actors (national environment ministries or agencies, other ministries, local and regional authorities, universities and research departments, private firms, the public) are involved in promoting, managing, operating, financing and using the different monitoring programmes in operation. It is therefore essential to clearly define these actors’ respective roles and the stages of the programmes to which they are invited to contribute or for which they are asked to bear responsibility. This will improve the relevance, efficiency and effectiveness of environmental monitoring systems.

Legislative and regulatory backgrounds

The distribution of roles in environmental monitoring is in many instances clearly defined by environmental legislation or regulations (concerning air, water, soils, chemicals, etc.), and generally differs from country to country. Regulatory orientations concerning the role of different agencies provide a strong basis for the establishment of a well-organised environmental monitoring system and for the co-ordination of its components throughout the country. In most cases, the national ministry responsible for the environment, or the national environment agency, plays a leading role in the orientation, guidance and co-ordination of environmental monitoring programmes, and may operate some of these in certain circumstances.

Environmental agencies and others

The roles of national ministries other than the one responsible for the environment, such as the health ministry or industry ministry, depend very much on how responsibilities concerning the environment are distributed among ministries, as well as on the issues involved. Whatever the general institutional arrangement, transministry issues need to be co-ordinated and the institutional arrangements for co-ordinating a given monitoring programme should be clearly defined. The important role played in many countries by organisations external to the actual environment administration shows, however, that parts of monitoring programmes can very well be operated outside this administration, provided the objectives are clear and the activities well co-ordinated, and all parties involved have access to the data produced.

National and local authorities

The distribution of roles in environmental monitoring among national, state and local governments depends on a country's overall institutional structure, on the federal structure in some countries, and on the relative weight of the central, regional and local authorities. It also depends (mainly, in many cases) on the purpose of the monitoring, as well as on the physical characteristics and spatial dimension of the issue monitored.

Public agencies, private firms and the general public

In many countries, private agencies or firms are involved in environmental monitoring, usually in accordance with the polluter pays principle. Since the first step in pollution control is determining knowledge of the type and amount of pollutant emitted, firms and private organisations are essentially involved in straightforward pollution issues, such as monitoring the quantity and quality of their own effluents and discharges to assess compliance with permits, or monitoring local environmental quality near certain equipment or plants (e.g. power plants).

Private monitoring systems may be integrated into local monitoring networks. In France, for instance, air pollution monitoring stations run by private firms are co-ordinated with the local monitoring network of other agencies (e.g. local authorities), and the results of the measurements are centralised by local air pollution monitoring associations in which all interested parties participate.

The general public (individuals, pressure groups, etc.) may also participate in monitoring in areas generally related to wildlife or other natural resources (e.g. participation in national nature surveys and bird censuses).

Research institutes and university departments and laboratories can play an important role as well, with their specialised capacity and knowledge. University departments are especially useful in assessing trends shown by long-term monitoring data and in developing new monitoring techniques.

Institutional issues related to risk

Information requirements related to environmental risk analysis and risk management have specific effects on monitoring systems and institutional arrangements. The organisations involved may include other agencies or participants than those described above, particularly civil security agencies (fire brigades, police forces, etc.) and health services. The period within which situations must be assessed and decisions made can be very specific; the institutional set-up, the communications networks and the strategies prepared in response to acute pollution or environmental risk scenarios all have to be carefully thought out and shared among participants. Pilot studies may help in planning these responses and the exact role of the monitoring more effectively.

Financial aspects

The polluter pays principle

The polluter pays principle must be kept in mind in considering aspects of environmental monitoring. Where monitoring can be clearly related to a given polluting activity, consistency with the polluter pays principle suggests that the monitoring should be financed by charges on the pollution. Such charges may not be practicable in many cases, however. Furthermore, charges for more general monitoring cannot be appropriately allocated to polluting activities (e.g. in the case of long-range pollution or exploratory monitoring for research). In such cases, practice in OECD countries indicates that monitoring systems have to be publicly funded. All sorts of mixed situations can also be found.

The polluter pays principle also applies where private firms or local authorities monitor their own pollutant emissions and, in some cases, local environmental quality. Monitoring is directly financed by private entities only when regulations give responsibilities to organisations such as private firms, and when their responsibility as a source of pollution is clearly established.

Public funds

Most environmental monitoring programmes are funded from public sources. The allocation of expenses between the budgets of central agencies or ministries and those of local authorities is usually determined by the share of responsibilities. Resources may be transferred (for instance through subsidies) from the national budget to local authorities when the latter carry out state responsibilities locally.

How much public money is allocated to which national environment programme (air, fresh water, marine water, wildlife, etc.) should be broadly in line with environmental policy priorities. This should ensure that funding for the environmental monitoring is available within the different programmes.

Monitoring costs and benefits

Very little co-ordinated or comparative information is available for establishing the cost of national monitoring systems as a whole, or of individual programmes[1]. Even as the scope of environmental monitoring is expanding, resources are generally lacking. There is, therefore, an urgent need for better knowledge of the cost of environmental monitoring. Similarly urgent needs exist for arbitration among environmental issues to be monitored, and for decisions as to who should operate the systems and who should bear the costs.

To a certain extent, commercial exploitation of monitoring programmes and their results (publication of data, access to database or data network, etc.) may be seen as a potential source of funds for public monitoring efforts.

The role of the national environment ministry or agency

Experience in OECD countries shows that, whatever the overall institutional arrangement, the national environment agency or ministry has a role to play as regards the areas discussed below.

International issues

A role for the central agency seems essential for all transboundary or global environmental issues, as well as for those related to international environmental policies. Examples of international issues involving national monitoring programmes launched and co-ordinated by the national environment authority are the state of the Rhine waters and the Baltic Sea Monitoring Programme.

New concerns

The role of the national environment authority may also be essential for the recognition, launching and implementation of monitoring programmes related to new or emerging environmental issues. This is also the case where, due to the physical, spatial or complex nature of the issue, it is preferable for monitoring activities to be centrally managed. Examples are long-term pollution trends, cross-media transfer of pollutants, background levels of pollution and evaluation of national environmental policy implementation. Nevertheless, components or elements of such programmes can be operated locally, with close co-ordination.

Co-ordination and guidance of local networks and exploitation of monitoring results

A role for the national environmental agency is also to ensure that:

- Local monitoring networks are launched and operated compatibly so that their objectives and results are well adapted to the environmental issues involved and to related national policies. In this case, the national agency's role is launching, orientation and permanent co-ordination.
- The outputs of local monitoring networks are fully exploited, particularly to help in assessing national environmental policy implementation throughout the country and to ensure that all

[1] In the Swedish state budget, SEK 48 million (about USD 11 million) is allocated to the national environmental monitoring programme for the fiscal year 1998-99. In Finland, it was estimated that in 1998 the total cost for all publicly funded monitoring of the environment and natural resources was roughly FIM 80 million (about USD 15 million).

potential users, from researchers to the general public, make optimal use of data and other results.

In some countries the major responsibility for environmental monitoring is placed on regional authorities, which at this stage are the prime producers and users of the results. The main role or input of the national authority is to make sure the data are correctly stored and made accessible.

Improving the efficiency and effectiveness of monitoring

The level of resources available for monitoring systems generally depends on the economic situation of the country. Where budget constraints exist, environmental monitoring systems need to be reviewed so they keep pace with the demand for information and developments in environmental policies. The review should cover concerns such as how to make monitoring systems more cost-effective (i.e. how to reduce costs) and how to make them more effective overall (how to increase benefits).

The discussion below tries to address these two concerns. Note that cost-effectiveness and general effectiveness are often closely linked.

Reducing monitoring costs

Co-ordinating local environmental networks should help increase their efficiency by reducing the cost of development in two ways: sharing experiences and methodologies for the development, management and running of the monitoring system; and exploiting the results.

Careful planning of the sampling grid and the use of statistical analysis may help reduce the number of monitoring stations while still providing equivalent information. Periodic reviews of monitoring systems may contribute to this reduction, as certain stations may be duplicating each other or may prove unnecessary given changes in the location or extent of pollution sources.

The use of local or decentralised expertise outside the national environment agency (e.g. municipal health laboratories, private companies' monitoring networks, university research laboratories) may help in reducing the costs of national or local monitoring networks by making full use of existing resources, technical capacities and expertise. Extending existing capacities is generally less expensive than a specific development by the central agency.

Developing and regularly updating a national register of environmental monitoring programmes helps provide an overview of: *i)* the programmes that are in operation at the same time, *ii)* the operating agencies, and *iii)* the purposes of the programmes, which may not be purely environmental. Such an overview allows the identification of gaps or overlaps.

The use of modern technology (satellites, computers, laser techniques, data transfer networks) can also reduce operating costs of monitoring systems and at the same time help improve data treatment and analysis capability considerably.

Improving monitoring benefits

To ensure that monitoring programmes produce valuable and relevant information, it is important to clearly identify their purpose(s) and objective(s). The objective(s) or role(s) of a monitoring system have important consequences as to its content, its spatial and time horizons, its implementation, etc. Thus it is important for such objectives to be carefully and regularly reviewed with all interested parties, including data users, to ensure that monitoring activities are continually adapted as needed.

Similarly, environmental monitoring programmes should be flexible so that systems can adapt to changes such as new sources of pollution and new patterns of land use, as well as to the introduction of new environmental concerns.

A relatively inexpensive way to enhance the benefits of environmental monitoring is to improve data analysis and interpretation, and to further develop the dissemination of monitoring information (with increased frequency of distribution and appropriate use of various dissemination media and modes of presentation).

It should also be noted that expenses for environmental monitoring are part of pollution control costs and may be counterbalanced by the reductions in pollution or damage that result from better control of environmental discharges or environmental risks. In other words, monitoring costs are often "reimbursed" through avoidance of environmental damage.

The role of international co-operation

International environmental issues involving monitoring

Environmental monitoring is usually a national or local issue. But several types of problems are international, involving several countries either through physical phenomena or trade of products, or because of requirements from harmonisation in environmental legislation.

In such cases, international co-operation and co-ordination in the field of environmental monitoring are required. Examples are:

- Transboundary pollution problems such as the state of the Great Lakes in North America and the Rhine River in Europe, or regional seas like the Baltic or Mediterranean.
- Regional or global environmental problems requiring common, co-ordinated analysis and action. Global issues include emissions of CO2 and other greenhouse gases, CFCs and other ozone depleting substances.
- Trade-related issues concerning products of environmental significance such as chemicals, cars and food products.
- Cases involving a recognised need for co-ordination and/or harmonisation of environmental policies, as in the European air pollution monitoring network co-ordinated by the UN/ECE.

Types of international co-operation

International co-operation on environmental monitoring is required mainly for the implementation of international agreements and for better understanding of the problems concerned (such understanding may in turn lead to co-operation on their solution). International co-operation on environmental monitoring of non-international issues, aimed at improving comparability of results, can also be found.

Aspects of international co-operation include:

- Exchange of information and expertise on the scientific and theoretical background required for a sound understanding of environmental issues such as long-range transfer of air pollutants and the toxicity of new chemicals.
- Exchange of technology, as well as common research and development concerning monitoring methods and equipment. Biological testing of the effects of pollutants on wildlife and fresh water is one example.
- Intercalibration of the measurement techniques used in different monitoring programmes, to ensure international comparability of measurements and results. Among the many examples are those related to the International Commission for the Protection of the Rhine and the Paris Convention to prevent land-based marine pollution.
- Common development of monitoring programmes, with co-ordination and integration of national networks or components of networks, to ensure common objectives, techniques, spatial distribution, representativeness and comparability of data from the very beginning. For instance, integrated monitoring is carried out jointly by several European countries under the direction of a working group appointed by the UN/ECE.
- Development of international databases and information networks, international environmental data and statistical reports, and international reports on the state of the environment, such as those prepared by the OECD, UNEP and the European Environment Agency. Co-operation among international organisations is also very important.

Environmental Monitoring Issues
The Experience of China

WU Bo
State Environmental Protection Agency (SEPA)
Division of Development and Monitoring

Environmental Monitoring Issues
The Experience of China

Since the first National Environment Conference in 1973, the Chinese Government has recognised environmental protection as a basic national policy goal and developed systems of environmental management, policies and regulations, standards, and planned targets, as appropriate to Chinese national conditions and in line with its strategy for sustainable development. Environmental monitoring, an important component of environmental protection, has achieved impressive results in 26 years of development and now plays a key role in the effort to protect the environment.

ENVIRONMENTAL MONITORING PROGRAMMES AND RESPONSIBILITIES

Environmental supervision and enforcement are the most basic functions of environmental management. Environmental monitoring enjoys a key status in the supervisory management of the environment. Its main functions are: to obtain information on environmental conditions, and monitor changing trends; to evaluate environmental quality; to provide a basis for scientific research and regulation; and to supervise the effective implementation of regulations. In practice, therefore, environmental monitoring applies scientific methods to supervise and monitor the complete cycles of all processes reflecting environmental quality and changing trends, to collect, interpret and use environmental data, and through comprehensive analysis of such data to provide the information necessary to conduct supervisory environmental management according to needs.

With the considerable progress achieved in the enforcement of environmental laws and regulations since the mid-1980s, environmental monitoring has assumed an increasingly important status and role in enforcement, supervision, policy-making and management and in national construction and development. A series of regulations, methods and systems issued by this Agency [NEPA, now SEPA] to govern the practice of environmental monitoring have made possible the further dynamic reinforcement of supervisory management:

- National Environmental Monitoring Management Provisions (1983)
- Provisional Rules on Fees for Specialised Services by Environmental Monitoring Stations (1988)
- Environmental Quality Assurance Management Regulations (1991)
- Environmental Monitoring Personnel Credentials Certification System (1991)
- Environmental Monitoring Optimal Laboratory Appraisal System (1991)
- Management Methods in Monitoring of Industrial Pollution Sources (1991)
- Motor Vehicle Exhaust Emissions Monitoring Management System (1991)
- National Environmental Monitoring Instrumentation and Equipment Management Regulations (1991)
- National Environmental Protection Agency (NEPA) Resolution on Further Reinforcement of Environmental Monitoring (1994)
- Monitoring Methods for the Testing and Acceptance of Completed Environmental Protection Installations in Infrastructure Programmes (1995)
- Reporting System for Environmental Monitoring (1996)

In 1994 the National Environmental Protection Agency [NEPA, now SEPA] declared that ‘environmental monitoring is an act of government’, highlighting the status of environmental monitoring as an constitutive part of the government’s mandate, and elaborated by spelling out the three functions of monitoring: to provide technical support for the implementation of environmental policy and management;

to enable technical supervision of environmental policy enforcement; and as a technical service to social and economic infrastructure development.

Functions and responsibilities of environmental monitoring in day-to-day environmental management

The most basic function of environmental monitoring is to take measurements at certain pre-planned places and times, according to requirements, in order to provide administrative departments responsible for environmental protection with timely data on discharge loads from pollution sources and pollution trends in the various domains of the environment within their respective areas of jurisdiction, thus enabling the adjustment of pollution control measures and technical regulations as and when necessary. This includes:

- monitoring of principal environmental features such as water, air, noise, ecology, biology, radiation.
- supervisory monitoring of pollution sources (concentrations, total quantities and spatio-temporal variations in discharges from fixed and mobile sources).

Environmental monitoring in priority control zones: programmes and responsibilities

Three rivers, three lakes

The official State Council Directive on 'National Environmental Protection Targets for the Ninth Five Year Plan and Long-range Targets to 2010' requires that environmental degradation in certain priority sites, including the Huai, Hai and Liao rivers and Lakes Tai(hu), Chao(hu) and Dianchi, be significantly alleviated by the year 2000, and that further aggravation of environmental pollution in these watercourses be halted, and in some cases reduced, by the year 2010. To this end SEPA, in collaboration with other competent institutions, has successively drawn up water pollution control plans for these six priority basins as well as more explicit and concrete clean-up targets for each basin (system). Environmental monitoring will provide basic data on current water quality in control sections in each basin, and measurements reflecting the quantities of pollutants discharged into, and total pollution received by, river basins or watercourses (e.g. the Huai River and Lake Taihu).

Two types of controlled zones

To effectively control the spread of acid rain, the State Council has designated two types of control zones (SO_2 pollution zones and acid rain control zones) as national pollution control priority zones. The goal for control in these two zones is to bring SO_2 emissions from industrial sources down to target levels by the year 2000, and to control the total volume of SO_2 emissions. In the case of municipalities under direct central government administration, provincial capitals, municipalities in Special Economic Zones (SEZs) or coastal open cities, and busy urban tourist centres, the goal is to reduce the level of SO_2 emissions to within national environmental quality standards, and to slow the trend toward further aggravation of acid rain in those areas designated as priority zones for acid rain control. The target for 2010 requires that the total volume of SO_2 emissions does not exceed year 2000 levels. Atmospheric concentrations of SO_2 in the urban environment shall conform to national environmental quality standards. In acid rain control zones, areas of river water with pH values of below 4.5 must be sharply reduced by 2010 as compared to the year 2000. Environmental monitoring of SO_2 emissions, acid rain and industrial pollution sources shall be carried out in all controlled cities and regions.

'One City'

In 1996, NEPA launched a weekly air quality reporting program. To promote the programme, air quality in Beijing City was identified as one of the priorities in the national environmental protection effort. Environmental monitoring shall provide basic information on current atmospheric conditions and discharges from pollutant sources.

THE ENVIRONMENTAL MONITORING MANAGEMENT SYSTEM

Article 11 of the Environmental Protection Act of the People's Republic of China stipulates that State Council departments responsible for environmental protection shall establish an environmental monitoring system, determine environmental monitoring norms, set up environmental monitoring networks in co-operation with other appropriate administrations, and reinforce environmental monitoring management. Departments of the State Council, Provinces and directly administered cities responsible for environmental protection are required to report on environmental conditions at appropriate intervals.

In its 20-odd years of development, environmental monitoring in China has been continuously adapted to environmental protection needs based on the special characteristics of the Chinese political and administrative systems by integrating the various management mechanisms based on administrative regions, sectors, and environmental zones into a single monitoring management system.

Management by administrative region: according to the basic principles for allocation of environmental quality responsibility to each administrative level, the environmental protection departments at the four levels of the people's government (State, Province, City and County) conduct unified management of environmental monitoring in the area under their jurisdiction.

Management by department or sector: administrative departments in each of the resources, industrial, transport/communications, military, and general public interest sectors, with remits as defined in laws and regulations, form vertical, sectoral management systems extending from State down to local level.

Management by environmental zone: in accordance with the national strategy for trans-jurisdictional environmental management, management mechanisms have begun to be set up for the principal river basins, ocean areas, ecological areas, and air pollution control zones.

The environmental monitoring network

In the early 1970s Beijing, Shenyang and some other major cities successively set up environmental monitoring stations. In the 1980s the Government implemented plans to create a National Central Environmental Monitoring Station and Environmental Monitoring Centres in each Province, Autonomous Region and City under direct central administration. State and local administrations jointly invested to reinforce key elements of infrastructure in Provincial monitoring centres and stations in provincial capitals and major cities. As local environmental protection work gradually developed, a number of heavily polluted cities and counties set up monitoring stations, forming the basis for a 4-tier architecture of environmental monitoring stations under environmental protection agencies at State, Province, City and County levels. At the same time, energy and industrial sector enterprises in each administrative sector began to set up environmental monitoring stations according to needs, and to develop appropriate programmes for monitoring environmental quality and pollution sources.

In 1991, following optimisation studies and screening, NEPA set up a national environmental monitoring network comprising 200 stations with the aim of providing environmental monitoring data to enable evaluation of environmental quality and the publication of general year-end reports. The network includes networks for monitoring air quality (103 stations), surface water (135 stations), acid rain (113 stations), noise (55 stations), the marine environment (29 stations), and ecology (9 stations). The National Central Environmental Monitoring Station is the data centre, technical centre and network centre for the national environmental quality monitoring network. Among nationally administered network stations, 173 had begun monitoring of air quality, 170 of surface water, 169 of noise conditions, 30 of ocean water quality, 127 of biological conditions, 159 of emissions and effluents, and 111 of ground water.

In 1992, NEPA co-ordinated with competent departments to establish a environmental monitoring network comprising 54 stations at State, Provincial and City levels in 27 different administrative sectors.

Since 1993, the environmental protection system has assumed responsibility for the Chinese component of the World Health Organisation (WHO)'s World Environmental Monitoring System. Five cities (Beijing, Shanghai, Shenyang, Xian and Guangzhou) are responsible for air monitoring, while Wuhan, Jinan, Guangzhou Province and Wuxi are responsible for monitoring water quality in the Yangtze River, Yellow River, Taihu and Pearl River systems respectively.

Since 1994, NEPA has established special environmental monitoring networks for the ecology of the Yangtze River and Three Gorges Region, the Huai river basin, the Lake Taihu basin, and China's inner coastal waters.

Today, after 20 years of growth, the national environmental monitoring network comprises 2223 monitoring stations and employs 35,928 staff, of whom 42.4% are environmental protection personnel. Routine monitoring of air, surface water and noise is carried out by 80-85% of city-level stations and 56% of county-level stations. 41% of city-level stations have begun monitoring soil conditions. 39% of stations have begun biomonitoring. 22 stations have begun ecological monitoring. Over 20 cities have established automatic air quality monitoring systems comprising up to 100 automatic substations.

Since 1991, about 81% of city-level stations and 67% of county-level stations have been conducting routine monitoring of pollution sources: this work already accounts for over 60% of the workload of the system as a whole. Every year over 30 million units of validated data are generated by the stations at different levels.

Departments responsible for the management of agricultural, forestry, ocean, hydrological and other resources, and industrial, military and railway administrations, operate a total of more than 2000 stations, employing over 20,000 monitoring staff. Among these, water resource administrations have established networks for monitoring water quality in seven major basins. The National Ocean Agency has established a network of 100 stations to monitor pollution in Chinese waters. The National Meteorological Authority has set up a national acid rain monitoring network based on 81 county-level weather stations. The Geological and Mining Administration operates a network of 216 stations for monitoring ground water. The Agriculture, Forestry, Ocean, Meteorological and Geological administrations, and the Chinese Academy of Sciences, each have their own specialised ecological monitoring and research networks.

The environmental monitoring information system

At present, environmental monitoring information in China is mainly quality monitoring and pollution source monitoring data. In the 1970s, such information consisted mainly of statistical survey data on the three types of discharge: effluents, emissions and waste residue. Standardised monitoring of air, water systems, oceans and noise began in the 1980s. The 1990s have seen the beginning of routine monitoring of environmental pollution sources and continuous automatic monitoring of air and water, leading to an unprecedented increase in sources of information on the environment.

The transmission of environmental information has gone through three stages of development since the 1970s. Before 1989, information was communicated through standard reporting forms. In 1989 the National Central Environmental Monitoring Station produced a single uniform software ('National Environmental Monitoring Data Transmission by Diskette') allowing local environmental monitoring information to be input directly at individual workstations according to the format specified by the standard software and loaded on diskette for transmission. Since 1997, facilities have been gradually installed for direct data communication between individual workstations at the National Central Monitoring Station, Provincial-level stations , and monitoring stations in major cities. Meanwhile, environmental monitoring data processing methods have also developed. The technological capability of some stations already supports graphic processing, geographical and remote sensing information systems, global positioning systems and similar functions.

Quality Assurance in environmental monitoring

In 1983, under the guidance of NEPA, the National Central Environmental Monitoring Station organised and conducted a first training course on quality control in environmental monitoring. Since then, training in quality control and assessment has been integrated as a routine part of the work of monitoring personnel.

In 1986 NEPA promulgated the Technical Standards for Environmental Protection Monitoring, covering surface water and effluents, air and atmospheric emissions, noise and bio-monitoring, as a technical guide to environmental monitoring. In 1991 the Agency published the Technical Requirements for Monitoring of Major Industrial Pollution Sources. These guides were accompanied by the development of standard monitoring methods for each programme. In 1991 and 1993, NEPA organised and implemented a procedure for acceptance and certification at environmental monitoring stations and centres.

In 1991, NEPA published its Environmental Quality Assurance (QA) Management Regulations, which set out practical steps and procedures for meeting requirements in terms of organisational responsibilities, transmission of quantitative values, laboratory testing and personnel, and for the actual content and reporting system for assuring monitoring quality, thus officially creating a national environmental monitoring quality assurance system.

In terms of organisational responsibilities, QA Management Committees and specialised QA units are created at each level in accordance with the principle of management by administrative level. The former are responsible for personnel credentialling, laboratory appraisals, examination and revision of the QA rule system and general work plan, supervision of drafting of technical documents, and presiding over arbitration of any disputes about data quality. The specialised QA units are responsible within their respective administrations for QA functions, organising and implementing technical QA projects, work planning and rules, checking quality control data, and organising technical training, as well as verification and appraisal tasks.

In terms of the transmission of quantitative values, standard materials shall be used as an important material basis when carrying out metrological methods with all types of metrological equipment and making determinations according to the relevant quantitative determination procedures. In terms of laboratory appraisal and personnel, the Regulations propose the establishment of comprehensive systems with all the necessary instrumentation and equipment; a minimum requirement of technical secondary-school (polytechnic) educational level for all personnel, with additional verification of their qualification for specific functions; and examination and approval of samples and reported data at three levels.

On this basis, metrological validation of environmental monitoring stations, and research and development on standard environmental materials and applications, began in 1993.

OUTSTANDING PROBLEMS

Global monitoring capability and technical level still need to be improved

China is a developing nation with limited economic power. However, few nations can compare with the speed of developments in environmental monitoring in China, despite its late beginnings. In scarcely 20 years, NEPA and the various administrations concerned have gradually set in place a range of monitoring networks. Because of limited financing available to networks, there are large local variations in basic infrastructure, instrumentation and equipment, and operating funds, and hence big discrepancies in monitoring capabilities and sophistication. There are now about 4000 or more monitoring stations in operation in China, but the construction and operation of stations and networks in different sectors still depends on the specific needs and economic power of each sector, resulting in certain limitations in the field of monitoring. While these may be normal in an individual monitoring station, they must be urgently remedied in the case of a network. In particular, certain types of monitoring data may not be important to a given region or sector but are indispensable to acquiring a complete picture of ecological and environmental conditions such as biodiversity, greenhouse gases, changes in the ozone layer, ecological degradation, natural disasters, and the environmental impacts of pollution incidents, organic pollutants or toxic effluents. There is still no system capable of monitoring these phenomena.

In national terms, insufficiencies in monitoring are widespread. Water system monitoring is not adequate for total quantity control; atmospheric monitoring does not satisfy requirements for precision of frequency and resolution. Many economically undeveloped regions are still using the ‘five-day method’ of sample collection (five days in each season), and in ecological monitoring do not have the remote sensing capability needed for macro-level periodic monitoring. Pollution source monitoring still lacks continuous sampling and automatic monitoring, which are necessary to obtain an accurate picture of overall volumes and trends of discharges from pollution sources.

Modification of operational mechanisms under the new conditions

Most of the monitoring stations in China were set up under the planned economy, and were designed with capabilities appropriate to serving the needs of a city, a county, a province, or an industrial or administrative sector. Accordingly, personnel, equipment, finances and materials in such stations are managed by a particular local authority, departmental sector or enterprise; they therefore often have a strong local or sectoral character and tend not to reflect the whole community or society. If monitoring station networks which emerged under the planned economy are to operate in a market environment they will necessarily have to face the challenges of profit-driven as opposed to administrative management mechanisms, and of a system driven by individual profit rather than by the collective interest. This naturally creates many new and still unresolved problems for Chinese monitoring networks. As pollution becomes increasingly severe and widespread, and environmental monitoring measures are strengthened, particularly in the Ninth Five-Year Plan for Environmental Protection decreed by central government and its emphasis on ‘three rivers, two zones, one city’, national environmental monitoring will have to adapt to these strategic changes and become better able to support national environmental policy; its management mechanisms will need to be reformed in order to perfect—and indeed to reform—the interconnected structure of monitoring stations and their key functions.

Use of monitoring information

With monitoring networks managed internally by administrative sectors or regions, it has not been possible to generate a single nationally unified environmental data and information transmission system for the large annual volume of administrative data. Since such data is widely dispersed, transmission is slow, which is the main cause of inefficiency in the use of the data.

At the same time, the present challenge is to correlate monitoring information with social, economic and policy effects, in order to enable the overall evaluation of development and thus increase the relevance and effectiveness of monitoring reports as a service to the sustainable development strategy; and to create a unified monitoring information communication system by breaking out of traditional sectoral constraints at each of the successive stages of data collection, storage, processing, evaluation and reporting. These are vital tasks in the field of environmental monitoring.

Main aims of environmental monitoring in the next five years

- To enhance the scientific quality of environmental monitoring.
- To improve compliance with pollution source discharge targets and supervision of total pollutant volume control; and to intensify supervision of environmental quality in key regions and cities.
- To perfect systems of technical monitoring standards, networks, and information management.
- To achieve breakthroughs in environmental monitoring management mechanisms, data quality, techniques for controlling total quantities and the integrated use of reports.

PART II. WATER MONITORING

Nationwide Water Monitoring
The Experience of China

by
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Nationwide Water Monitoring
The Experience of China

GENERAL DESCRIPTION

Objectives and tasks

- To conduct routine monitoring of the water environment, including rivers, lakes, reservoirs, canals, irrigation channels and other bodies of surface water. To survey and evaluate surface water quality, status and trends at appropriate intervals;
- To conduct supervisory monitoring of effluent pollution from residential and production facilities on the basis on the surveying and registration of pollution sources, in order to provide the necessary basis for pollution source management and effluent taxation measures;
- To conduct surveys and emergency monitoring of water-related pollution incidents;
- To provide government departments with accurate and reliable data and documentation on water quality monitoring to support the definition and implementation of water environment regulations and standards and the comprehensive introduction of water management programmes;
- To conduct research into new methods and techniques for water quality evaluation and preventive forecasting and monitoring, and to promote scientific and technological progress in environmental monitoring.

Structure of water monitoring institutions and related bodies

- Level 1: National Environmental Monitoring Headquarters established by the State Environmental Protection Agency.
- Level 2: Provincial-level Environmental Monitoring Centres (Stations) established by each province, autonomous region, or municipality under direct central administration.
- Level 3: Municipal Environmental Monitoring Centres (Stations) established by each municipality under provincial administration.
- Level 4: Environmental Monitoring Stations established by counties, banners, county-level municipalities, and districts of large cities.

STRUCTURE OF WATER MONITORING TECHNICAL SERVICES

Water Monitoring Technical Standards (Vol. 1: Surface and Effluent Water, 1986 pilot)

Monitoring frequency

<u>Surface water</u>

- Sources of drinking water: 12 inspections per annum
- Watercourses in urban and busy tourist areas: ≥ 12 inspections p.a.
- Lakes and reservoirs: ≥ 12 inspections p.a.
- Mainstream rivers in major basins (Yangtze, Yellow, Pearl, Huai, Songhua, Liao, Hailuan): 6 inspections p.a.
- Medium-sized and minor rivers and tidal inland waters: 6 inspections p.a.

- Pollution discharge channels and watercourses: ≥ 3 inspections p.a.
- Background sections: annual inspections.

<u>Effluent discharged from pollution sources</u>

- Industrial effluent: 2-4 inspections p.a.
- Flowing effluent from raw pollution sources: 2 inspections p.a. (spring, summer)
- Hospital effluent: 4 inspections p.a. (seasonal)

Monitoring programmes (mandatory/optional)

<u>Surface water</u>

- Drinking water source sites: 20/10
- Rivers: 19/14
- Tidal inland waters: 22/14
- Lakes and reservoirs: 17/7
- Effluent channels and watercourses: according to pollution load
- Benthic mud: 6/4

<u>Effluent discharged from pollution sources</u>

37 optional programmes according to effluent characteristics.

Technical monitoring methods

- Analytical Methods for Environmental Monitoring
- Unified Methods for Pollution Source Monitoring and Analysis: Effluents Section (Note: in principle, national standard analytical methods must be used where available; otherwise SEPA-recommended procedures may be used)

Technical Standards for Monitoring of Aquatic Bio-organisms (pilot 1986)

Methods for Water and Effluent Monitoring and Analysis (Vol. 3, 1989)

Includes 91 sections and 216 procedures for monitoring and analysis. Used in programmes involving tests of environmental water quality, industrial effluents, residential waste water, benthic mud and biological samples. Many of these standards approximate to requirement levels prescribed in the U.S. Law on Standard Water and Effluent Testing (15th Edition 1980).

Manual of Aquatic Bioorganism Monitoring (1993)

Chinese technical standards for water quality monitoring

As of the end of December 1998 China had published and implemented:

- 21 standards for water environmental quality (6) and pollutant effluent (15), as well as 13 other basic standards and regulations.
- 117 standard methods for water quality monitoring; and 70 descriptions of standard or quality-control water samples (including benthic mud samples).

The 21 water quality and pollutant effluent standards contain 125 provisions relevant to control programmes as follows: general (23); metallic substances (21); non-metallic substances (22); organic pollutants (52); radioactive levels (2); biological levels (5).

The 117 standard water quality monitoring methods cover 135 pollution indicators, including general provisions (12); metallic substances (22); non-metallic substances (16); organic pollutants (70); radioactive levels (11); biological levels (4).

Standardisation of water quality monitoring methods

The standard procedure for defining water quality monitoring methods involves three steps:

- Research and screening to select mature and advanced monitoring methods capable of nationwide implementation.
- Selected method undergoes testing and validation by multiple collaborating laboratories to establish relevant performance parameters, e.g. monitoring limit, precision, accuracy, scope of application etc., and to standardise methodology.
- Completion of procedure for official adoption of the method as a standard: registration of project, selection of responsible unit, designation of official responsible for draft, drafting and preparation of Call for Opinions, which is then circulated to relevant units to elicit responses. The revised draft is prepared for submission to higher authorities: after provisional approval by the Expert Committee on Methodological Standards, a new revised draft is prepared for approval at State level, and is then submitted to the State Environmental Protection Agency. Following approval by SEPA, the new method is filed with the State Technical Supervisory Office, promulgated, and implemented.
- *General (11 provisions)*
- *Metallic substances (32 provisions)*
- *Non-metallic substances (23 provisions)*
- *Organic pollutants (34 provisions)*
- *Radioactive material and nuclear elements (13 provisions)*
- *Biological monitoring (4 provisions)*

Water quality monitoring QA/QC (Quality Assurance and Quality Control)

Handbook on Quality Assurance in Environmental Water Quality Monitoring (Vol 2 1994)

Water quality: standard samples and control samples (70 types in all)

- Simple water quality level (43)
- Mixed water quality levels (8)
- Benthic mud quality levels (19)

Organic pollutants: standard samples and control samples (9 types in all)

FUNCTIONS OF WATER QUALITY MONITORING IN CHINA

To provide a scientific basis for the definition of environmental objectives:

- to assess the situation and trends in water quality; to provide government departments with data and reports on environmental monitoring to support definition of scientific environmental protection objectives and implementation of the environmental responsibility system.

- to assess emissions from pollutant sources; to provide government departments with environmental monitoring data and reports to enable the design of programmes to reduce volumes of the main pollutants discharged from major pollution sources. To monitor implementation of pollution abatement measures; to evaluate success in achieving environmental objectives.

To provide technical support for environmental management, in the form of :

- technical supervision and quality assurance, in environmental impact assessment;
- acceptance testing of construction projects, in implementation of the three-in-one system;
- supervisory monitoring, in implementation of the pollution levy system;
- evaluative monitoring, in the implementation of the quantification and evaluation system for a comprehensive clean-up of the urban environment;
- inspection and monitoring, in the implementation of the pollution permit system;
- inspection and monitoring, in the implementation of measures to clean up pollution sources within specified deadlines;
- surveying and monitoring, in the implementation of pollution concentration control measures.

Survey and monitoring of water pollution incidents

To provide scientific support in dealing with water pollution incidents, and arbitrate in water pollution disputes.

Applications in major scientific research on the water environment

PRESENT WATER QUALITY STATUS OF CHINA'S MAIN WATER SYSTEMS

Water quality in rivers

At present all the main watercourses in China's river systems undergo pollution to some degree. The main pollution indices are permanganate (COD_{Mn}), ammonia-nitrogen (NH_3-N), volatile phenols, etc.

Yangtze River Basin

Water quality in the Yangtze mainstream is basically good. 67.7 % of river sections have a quality of Grade III or better. No section is worse than Grade V. The main pollution indices are permanganate (COD_{Mn}), biological oxygen demand (BOD_5), volatile phenols. The main polluted sections are Nanjingguan at Yichang and Siheshan at Wuhu.

Yellow River Basin

Most of the mainstream is Grade IV. Baolanqiao at Lanzhou, and the Jinan and Wufosi sections of the Yellow River, are Grade V. The main pollution indices are ammonia-nitrogen, volatile phenols and permanganate.

Huai River Basin

Water quality in the Huai mainstream is mostly Grade III or IV. Dafukou in Xixian County (Henan Province) and the Dajiangou section in Huainan (Anhui Province) are worse than Grade V quality. As regards primary tributaries, 52% of sections in the Yinghe, Guohe and others are worse than Grade V. The main pollution index is ammonia-nitrogen. In secondary and tertiary tributaries, 71% of sections are worse than Grade V. Of these, nearly 50% of sections of the Shangwuzhu River within the boundaries of Shandong province are below Grade V. The main pollution indices in the Huai River Basin are ammonia-nitrogen and permanganate.

Hai River Basin

Nearly 50% of sections in the Hai River Basin are Grade V or below. The main polluted sections are Sangyuanqiao at Cangzhou, and the Yulingzhuang section of the Northern Grand Canal, at Beijing. The main pollution indices in the Hai River Basin are permanganate, ammonia-nitrogen and biological oxygen demand.

Liao River Basin

Nearly 50% of sections in the Liao River Basin are below Grade V. The main polluted sections are Qitaiziqiao, Yujiafangqiao and Shendatieluqiao at Hunheliaozhong, Shenyang. The main pollution indices are ammonia-nitrogen, total mercury and volatile phenols.

Pearl River Basin

62.6% of sections in the Pearl River Basin are Grade III or above. 29.2% of sections are Grade IV. In the mainstream, Donglang and Liede sections are Grade V or below. Ammonia-nitrogen and permanganate are the main pollution indices in the Pearl River Basin .

Songhua River Basin

Most watercourses in the Songhua River Basin are of Grade IV quality. 23.2% of sections are Grade V. Shaokou, Jiuzhan and Hongqi sections at Jilin, and Ashihekou section at Harbin, are rather heavily polluted. The main pollution indices are permanganate, volatile phenols and biological oxygen demand.

Lakes and reservoirs

The most polluted major freshwater lake is (Lake) Chaohu (western half); the least polluted is Lake Erhai. The highest eutrophication levels are found in (Lake) Dianchi(hu), followed by (Lake) Chao(hu); the lowest levels are in (Lake) Tai(hu). The main pollution indices are total nitrogen, total phosphorus, permanganate and biological oxygen demand.

Lakes in urban areas rank as follows in descending order of the degree of pollution: Daminghu (Jinan), Xuanwuhu (Nanjing), Donghu (Wuhan), Dianshanhu (Shanghai), Xihu (West Lake, at Hangzhou) and Kunminghu (Beijing). The main pollution indices are: total nitrogen, total phosphorus, permanganate and biological oxygen demand.

Major reservoirs rank as follows in descending order of pollution: Fenhe, Menlou, Laoshan, Dongpu, Shimen, Dahuofang, Songhuahu, Yuqiao, Xinanjiang and Miyun. The main pollution indices are total phosphorus, total nitrogen and volatile phenols.

Inner coastal waters

Water quality in China’s inner coastal waters is generally below Grade III. The main pollution indices are:

- Inorganic nitrogen: ND ~ 13.4 mg/l, average value 0.535 mg/l; 76.2% of waters are above standard levels, mostly in the Donghai [East China Sea] and Bohai;
- Inorganic phosphorus: ND ~ 1.38 mg/l, average value 0.029 mg/l; 61.1% of waters are above standard levels (mostly in the Donghai);
- Oils: ND ~ 1.44 mg/l, average value 0.065 mg/l (mostly in Bohai);

A shortage of dissolved oxygen (DO) is observed in some coastal waters. Some copper pollution is found in a minority of coastal waters.

Quality of underground water

Underground water is widely tapped in Northern China. Watertable subsidence funnels have formed in some cities. The main pollution indices are mineral degree, total hardness, nitrate content, nitrite content, ammonia-nitrogen, and ferric and manganese content. Underground water pollution is distributed in pockets (points); the more heavily polluted cities include Jinzhou, Fuxin, Liaoyuan, Langfang, Cangzhou, Yantai, Xuchang, Baotou, Xian, Kuerle, Zhangzhou.

CURRENT PROBLEMS AND REMEDIES FOR WATER QUALITY MONITORING IN CHINA

- Monitoring methods not compatible with water quality standards.
- Lack of monitoring techniques for comprehensive pollution control.
- Insufficient programmes and methods to control organic pollution.
- Lack of methods and techniques for emergency response to pollution incidents and for on-site monitoring.
- Quality Assurance/Control in water quality monitoring not yet fully programmed and systematised.
- Data transmission for water quality monitoring not yet modernised.

Nationwide Water Monitoring
The Experience of The Netherlands

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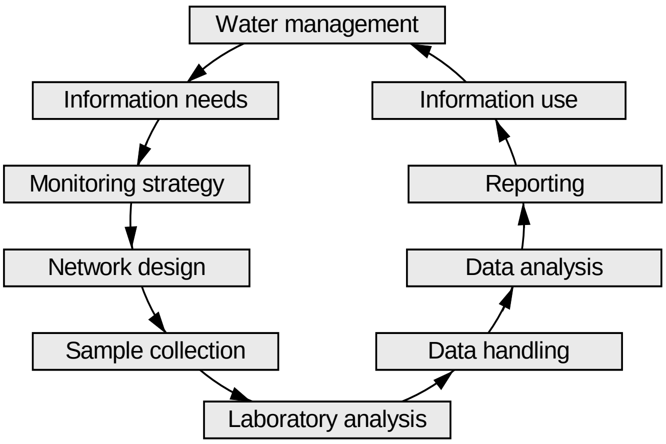
Nationwide Water Monitoring
The Experience of The Netherlands

INTRODUCTION

The need of policy makers and managers for good information on which to base decisions and measures is particularly important in environmental management, where the relationship between measures and effects is so strong and direct. Environmental measures can be very expensive and their effects can be major, sometimes irreversible. For insight into these effects and measures' cost-effectiveness, sound information is essential.

This paper presents the approach for the design of monitoring systems that has evolved in The Netherlands. In this approach, careful and detailed specification of information needs is a key to the effectiveness of information products. Figure 1 shows the "monitoring cycle" as an illustration of the approach, describing the essential steps in continuous monitoring. The cyclic character provides a quantitative means of connecting information expectations and/or products required with monitoring system design and operations (Timmerman et al., subm.).

Figure 1. **The Monitoring Cycle**



Source: UN/ECE, 1996.

INFORMATION NEEDS

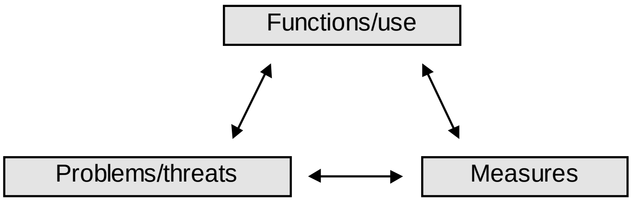
Three core elements

Over the last two decades, the focus of European water management has changed from distinct sectors to integrated management, interrelating chemical aspects, physical planning, ecology, emissions, etc. In addition, increasing knowledge of the complexity of processes in water systems has led to a growing demand for information.

Integrating disciplines also means integrating large sets of data and information. Moreover, computers enlarge information availability by providing numerous possibilities to store, retrieve and analyse data. Policy makers and water managers are thus overwhelmed with data that may or may not be of use to them. There is a call today for less, but more targeted, tailor-made information.

The most critical step in developing a tailor-made, cost-effective monitoring programme is defining information needs clearly. One way to approach this task involves a triangle of core elements: *i)* the function or use of the water, *ii)* problems with and threats to this function and *iii)* measures that may be taken (Figure 2). For example, much of the Dutch shoreline consists of dunes, which protect the land from flooding (function). During storms, parts of these dunes are washed away (problem). The damage is repaired by supplying sand (measure). By elaborating the problems and measures related to all functions, a comprehensive analysis of a given situation can be made.

Figure 2. **Core elements of water management**



Source: UN/ECE, 1996.

Dutch developments in specifying information needs

In the past few years, The Netherlands has been involved in developing a structural approach towards water monitoring. Among the influences on this approach are Dutch experiences with designing and optimising monitoring networks (Adriaanse, 1993; Breukel et al., 1995), two international conferences on monitoring ("Monitoring Tailor-made" I and II in 1994 and 1996), and an inventory of the experiences of many European countries, accumulated in drafting the United Nations guidelines for water quality monitoring and assessment of transboundary rivers (UN/ECE, 1996). The guidelines strongly focus on the importance of clearly specifying what kind of information users need so that tailor-made information can be produced.

The development of water management policy in The Netherlands reflects changing information needs. In the first National Policy Document on Water Management (1968), water quantity was the central issue. The second document (1984) added economic aspects and resulted in attention to water quality. The third document (1989) portrayed water as existing in systems, with ecology valued alongside economy. The current trend is towards integrated water management, incorporating economics, ecology and sociology. These aspects are reflected in the main aim of the fourth national policy document: "to have and maintain a safe and habitable country and to develop and maintain healthy and resilient water systems which will continue to guarantee sustained use" [Timmerman et al., subm.].

Asking the right question

"All too often, monitoring projects are initiated with a minimum of forethought, and result in a collection of poorly-documented data which are never analysed, provide little [if] any feedback to resource managers, and contribute little or nothing to our understanding of the systems being monitored" (MacDonald, 1994).

Managers should identify the information objectives of monitoring networks, in consultation with technical staff; but management issues often tend to be vague and loosely specified. Policy makers, politicians, the public and other information users tend to ask questions such as: '"Is this country safe against flooding?" or "How will dry years affect agriculture?" Such questions are neither easily nor simply answered; furthermore, they raise new questions. What is "safe"? A statistical chance of one in 10 000 years? And at what cost? On the other hand, experts, scientists and other information producers tend to provide answers like: "The maximum water level is 34.6 m above mean sea level." Many users find it difficult to relate such answers to their questions (Timmerman et al., subm.).

The different worlds of thinking reflected in such questions and answers need to be linked through dialogue between information users and producers to develop "connecting" questions that can be clearly articulated and understood by both sides.

Quantification of information needs

The right questions should also involve some quantitative aspects that are necessary for the next steps in the monitoring cycle, such as the “monitoring strategy” and “network design” steps. Examples are such characteristics as significance, accuracy and period of availability. These more quantitative aspects make it possible for information providers to formulate accurate monitoring objectives. Some examples:

- The monitoring goal of the Dutch water plants monitoring network is to enable the determination of any trend of 25% or more in the floristic quality of the Rhine alluvial forests within a period of 15 years, with a chance for detection of 80% and a significance of 95%.
- For the Dutch early-warning network, the monitoring goal is the continuous monitoring of water quality with a choice of instruments and communication infrastructure, so as to be able to warn interested parties within 24 hours after exceeding of determined water quality standards.

It is not always easy to fulfil such strictly formulated information needs and monitoring goals, but there are many advantages in so doing. Not only will strictly formulated goals help water authorities design their monitoring efforts, but they also force everyone concerned to think very carefully about their information needs and the effects these have on the extent of monitoring efforts.

An extra advantage is that quantitative formulation of goals facilitates an objective evaluation of the monitoring effort.

The use of indicators in specifying information needs

In communication between information users and producers, indicators are useful in further defining the information needs because they can present information in a condensed/aggregated form and are often linked to specific problems or issues, which are in turn based on specific management needs.

Indicators are observable or measurable quantities, variables or parameters representing a process in the environment and having significance beyond their face value (Bakkes, 1994; OECD, 1993). They provide a way to reduce data volume while retaining significance for particular questions. Suitable indicators take into account the three core elements in Figure 2. When indicators are further aggregated, the term “index” is used. An index is generally a set of aggregated or weighted variables or indicators describing a situation (OECD, 1993).

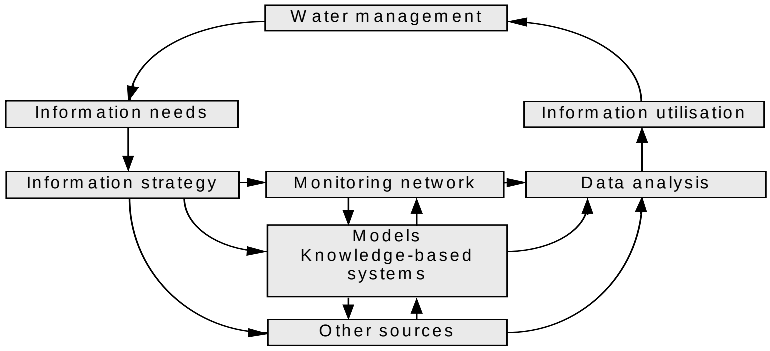
MONITORING STRATEGY

When the information needs have been specified in enough detail, the next step is the monitoring strategy: determining how and where to get the information. Monitoring, however, is not the only way to gather information.

Information strategy: sources of information

While monitoring is still the method most used to collect data for water management, integrated management requires integrated information, for which the sources are varied. They include: computer models, to make forecasts on the basis of monitoring data; surveys, to provide insight into specific issues; and studies and data from other disciplines, such as agriculture, recreation, sociology, ecology and economics. Figure 3 shows different sources of information as well as different ways of collecting and analysing data. This paper, however, concerns monitoring only.

Figure 3. **Sources of information**



Source: UN/ECE, 1996.

Strategies for monitoring Dutch national surface waters

Once it is decided that information is to be collected by monitoring, a strategy must be chosen. In The Netherlands different approaches are taken, depending on the purpose and goals of the network (Table 1).

The monitoring effort for national surface waters (i.e. state waters, as opposed to those administered at subnational level) is divided into three different strategies or modules, each of which can be divided into submodules on the basis of specified objectives. The modules are designed to meet specific information needs and can be developed independently, in an effort to ensure that the monitoring produces exactly the information needed.

Table 1. **Dutch monitoring strategies**

Modules	**Sub-modules**		
Ambient monitoring Involves observing water systems with standarised methods for several years to establish status and trends so that policy makers can reach tactical and strategic decisions, and for the testing of standards and calculation of loads.	Ambient monitoring Meeting 80-100% of all national and international information needs as well as 30-100% of the needs of regional water authorities.	Additional ambient monitoring Meeting specific (national/ international), routine information needs not covered by nationwide routine monitoring; specific demands concern variables, locations, frequencies, methods of sampling or analysis.	
Operational monitoring Continuous monitoring to support safety and operational decisions.	Early warning In exceptional circumstances, protection of functions and uses (drinking water, flood forecasting).	Operational water management High frequency monitoring for operational water management (agriculture, industry) and (inter-)national obligations.	
Specific monitoring Time-limited monitoring aimed at answering specific questions for use in research and development.	Specific monitoring, ambient To support research and development in ambient monitoring.	Specific monitoring, operational To support research and development in operational monitoring.	Specific monitoring, others To meet other needs, mainly related to scientific research and surveys and/or the development and calibration of models.

Note: Effluent monitoring is not included, as the table (like this chapter) concerns surface waters only.

Different monitoring networks

Using the above strategies, different networks are designed to gather the information needed. The networks are divided according to discipline. Nationwide monitoring includes the following disciplines: hydrological (physical) monitoring; chemical monitoring; biological monitoring; and operational water quality monitoring.

For each of these, one or more monitoring programme(s) is/are published every year, taking into account demands from the different modules and submodules. These programmes specify the results to be achieved, the network design, the necessary means, and an evaluation in order to fine-tune the programme for the following year.

If the evaluation shows information needs changing, several options to adjust the monitoring programmes are specified, including their financial consequences. They are discussed with the parties concerned, and the chosen option is integrated in the following year's programme.

Optimisation of the Dutch national water monitoring network

Dutch monitoring networks are optimised regularly. In the last optimisation of the chemical network, the starting point was to determine the main objectives of the network: assessment of status and trends (surveillance monitoring), assessment of loads/fluxes, and compliance testing (statutory monitoring to meet legal obligations). These were more limited than the former objectives. Secondary objectives such as information collection for operational water management, research and development, and development and calibration of models, were not taken into account in this step (Ottens et al., 1998; Breukel et al., 1995).

For these objectives the information need was specified per variable, per water system (lakes/rivers), and per medium (water/dissolves, suspended solids), and was determined to the detail of "relevant margin" — the range in information values that is still of interest to the user (Breukel et al., 1991). From this detailed specification, the sampling frequencies and the density of sampling locations could be determined. A statistical study was performed to check the frequency needed to detect trends or calculate loads. A complicating factor in these studies was the availability of long term consistent historical series (Klavers, 1992).

Other factors taken into account were: cost-effectiveness, expert judgement, new legal obligations and the forthcoming water policy document. The resulting national monitoring network ended up with:

1) Lower density of sampling locations (from 135 to 27).

2) Higher measurement frequency.

3) The same costs as the previous network.

4) Better linkage of monitoring data and objectives.

NETWORK DESIGN

The following Dutch monitoring networks, based on the ambient, operational and specific monitoring strategies and on four disciplines (hydrological, chemical, biological and operational), are used for inland waters. The information in this section is mainly derived from a new report by RIZA, the Institute for Inland Water Management and Waste Water Treatment (RIZA, forthcoming).

Hydrological monitoring networks

General objectives

- Information to benefit (inter-)national water policy. Establishes status and trends in hydrological characteristics of national water systems.
- Information to benefit national operational water management.
- Collection of hydrological data necessary for the interpretation of the ecological standards and target values specified in the new national policy plan for water management. (This and the following are recently developed objectives for which adjustments of the monitoring programmes are necessary.)
- Meeting increased demand for physical and hydrological data due to growth in research on measures and policy plans in connection with floods and safety problems as a result of high water levels in the large transboundary rivers in the last few years.

Objectives per (sub)module

Ambient monitoring

Ambient monitoring: Monitoring of river regimes supplies the data necessary to establish status and trends in hydrological characteristics. The data are also necessary for load calculations on transport of sediments and pollutants and to interpret the data from chemical and biological monitoring.

Operational monitoring

Early warning (flood forecasting): Early warning monitoring gives water levels and other relevant data at times of floods. The data are essential for computer modelling.

Operational water management and (inter-)national agreements: On-line data are used in operating important bridges, sluices and other waterworks, establishing water depth and other criteria for shipping, and supporting decision makers in operational water management.

Hydrological network design

National water level network

This network consists of 69 locations on inland waters. Siting is based on the risks in case of a breach in a dike and obstacles for shipping. Most locations are near cities, weak spots in dikes, bridges, and rims in the water bed.

If the equipment at one location should break down, the system requires that it must be possible to calculate the water level at that location from the data of the remaining locations.

The accuracy of the monitoring is ± 2.5 cm. The difference between computer-calculated and monitored data must not be more than ± 3.5 cm. The data are monitored every ten seconds but transformed to average-values of ten minutes. The data are recorded and transmitted on-line.

National flow monitoring network

This network consists of 16 locations, with siting determined by the distribution of water flows and the information needed by policy makers.

Discharge is determined by acoustic flow meter (ADM), by discharge water level graph, by calculation from other discharge data and by spillage data from sluices, locks and weirs.

The aim is to determine flow with 90% accuracy. The data gathering with ADMs is carried out on-line. The other data sources do not deliver on-line.

Chemical monitoring networks

General objectives

- Evaluation of national water quality policy and testing of standards.
- Establishment of status and trends in pollutant concentrations and loads.
- Compliance with (inter-)national obligations and agreements related to water quality monitoring.
- Detection of new water quality developments or problems.

Objectives per (sub-)module

Ambient monitoring

Ambient monitoring. Policy preparation and evaluation is the first key objective. Establishing status and trends (trends of 20% or more over five years) is the next. Also serves as a reference for other monitoring programmes.

International agreements. This programme generates information to reconcile (if need be) national programmes and agreements made in an international context, which are becoming increasingly important for integrated water management. For transboundary waters, increased international co-operation is sought, under the basin approach.

Specific monitoring

Specific monitoring, ambient. Projects in this sub-module involve developing and optimising ambient monitoring.

Specific monitoring, operational. Inventories, surveys and screenings are conducted to generate new monitoring or assessment methods.

Specific monitoring, others. Inventories, surveys and screenings are conducted to generate information on "new" substances and on new monitoring or assessment methods (such as p.e. load calculations).

Chemical network design

Ambient monitoring programme

Ambient monitoring is carried out in one network whose 27 locations are chosen as representative of the different water systems. The locations are weighted by their importance to national and international water policy. This weight is reflected in the number of variables and frequencies monitored.

The variables (at every location) consist primarily of problem and status indicators and parameters, plus a limited number of effect indicators. The variables include field parameters, general parameters, non-organic pollutants (such as heavy metals), organic pollutants, ecotoxicology (e.g. the Ames test), radioactivity and microbiology.

The media covered are: surface water (filtered and unfiltered), suspended solids (sampling by centrifuge), sediments and biota (pollutants in fish and mussels).

The analyses are carried out by RIZA's laboratories or delegated to other laboratories under the responsibility of RIZA.

Specific project networks

A large number of project-related monitoring networks exist, each with specific duration and selection of locations, variables and media. The relevant project manager decides the network design in close co-operation with the monitoring department that controls the larger national networks. These programmes aim to produce information that the national regular networks do not provide.

Biological monitoring networks

Ambient monitoring of biological variables, at first limited to specific projects, started on a routine basis in 1992. The network aims to monitor the effects of national policy with respect to ecological consequences of pollution, eutrophication and (re-)construction of water systems. There is also growing demand related to international river commissions and agreements.

The network design is based on existing chemical and operational networks within RIZA, but is also in line with other national institutes' biological networks in order to improve information quality and reduce costs. Some biological monitoring is performed by or in co-operation with other institutes and organisations.

General objectives

- Detection of effects in ecosystems resulting from changes in water quality, water management and/or (re-)construction of water systems.

- Collection of ecological data for policy evaluation and preparation to ensure ecologically sustainable use.
- Preparation of and compliance with international agreements to further international co-operation in river basin committees such as the International Rhine Commission, as well as European Union and United Nations efforts.

Biological network design

Biological monitoring covers a wide range of variables, each calling for specific monitoring and assessment techniques. It is then necessary to integrate the information into one general assessment of ecological status, which has always been an important criterion when designing biological networks.

Biological monitoring necessitates a completely different strategy from chemical or hydrological monitoring; frequency, for example, is not determined at all the same way. Basic biological monitoring is carried out yearly, but each water system also gets a more thorough inventory every four years. These years of more intensive monitoring (inventory years) are planned in four-year rotation.

Frequency of monitoring for ecological variables differs considerably. Plankton, for example, is monitored once a month, water plants once a year and border vegetation every four years, in line with the expected time scale of possible changes in the variables. Another important aspect in designing these networks is the seasonal dynamics that occur with almost any biological variable.

The biological ambient monitoring network covers nine groups of variables, each requiring a different schedule:

<u>Phyto- and zooplankton</u>

The network for plankton involves every national water system and is strongly connected with the chemical ambient network. Chlorophyll-a, phytoplankton and zooplankton, including lengths of *Daphnia* (water fleas), are measured every two to four weeks in spring and summer.

In the inventory years, both phyto- and zooplankton are analysed more thoroughly, down to individual species and biovolume.

<u>Macro-invertebrates</u>

The schedule for macro-invertebrates has three parts:

- Yearly sampling of rocks and stones in the IJssel River (adding to a long series already existing) and of standardised artificial substrate (a metal box filled with marbles) in surface waters.
- In the inventory years, a sampling in the autumn of macro-invertebrates in the most important ecotopes, such as shallow and deep water, sediments, stones, water plants, border plants and dead wood.
- Once every eight years, an inventory of *Dreissena* (zebra mussels) in a selection of water systems.

<u>Water plants</u>

Water plants are inventoried in the field every year in stagnant waters, always at the same locations. In addition aerial photography is used every inventory year (see Ecotope charts, below).

<u>Fish</u>

The fish monitoring network comprises active and passive monitoring. The latter is intended to gather information about diversity of species and the occurance of rare species. The information comes from professional fishermen who report their catches with one to three times a week from May to October.

Active monitoring, with fishing boat and electric net is concentrated in a few areas, where the same ecotopes are sampled every year, distinction being made between deep summer beds, shallow summer beds and river arms.

Water birds

Spotting and counting of water birds is carried out at least once a month in all national water systems, mainly by volunteers and organisations that own or manage the areas in question. The programme, which is co-ordinated not by RIZA but by a volunteer organisation, is designed in accordance with January counting in the West Pelearctic area for the benefit of Wetlands International.

River bank vegetation

River bank flora is monitored every four years in inventories covering about 25% of the area. The data are used in detection of trends in the vegetation quality for several types of ecosystems. The monitoring is co-ordinated by a special foundation working in this field.

River bank fauna

The network monitoring fauna reflects increased interest in (re-)creating and restoring habitats through rehabilitation projects, with a major impact on ecotopes, in an effort to achieve sustainable development of natural values.

Only this year has regular collection of data to monitor the effects of such measures begun, in co-operation with national programmes of other ministries and organisations. So far, programmes for breeding birds and amphibia have been set up.

Ecotoxicological variables

Ecotoxicological monitoring checks for: *i)* accumulation of micropollutants in eels and zebra mussels; *ii)* toxicity of sediments and pore water (using bioassays); and *iii)* toxicity of surface waters. The locations coincide with those of the chemical monitoring network, and the usual four year rotation is applied.

Ecotope charts

Ecotope charts of individual water systems are produced every eight years, in a cycle synchronised with the inventory years. These maps, covering the full water system, are based on true-color aerial photos (scale 1:10,000), with extra information from depth charts and groundwater charts. A standardised system is used to make the charts compatible, and they are presented in a GIS format to enable further interpretation and research.

Operational water quality monitoring network

This network is designed to survey water quality and rapidly inform actors such as drinking water suppliers in cases of accidental pollution. In the 1970s, after several serious incidents, seven monitoring stations were built on the main Dutch rivers, at first checking just a few relatively simple variables (oxygen, temperature, etc.). They now monitor many organic variables and include several biological warning systems (based on fish, water fleas and mussels). The system and its functions are being optimised this year.

General objectives

- Continuous surveillance of water quality, enabling early warning.
- Data gathering to support operational water management and (inter-)national agreements.
- Gathering, storage and presentation of on-line data on water quality.
- Supply of information for trend research and models.

Objectives per (sub-)module

Operational monitoring

Early warning in exceptional circumstances (water quality)

Operational monitoring facilitates surveillance of water quality. Acute changes in water quality due to discharges of 10-100 kg of polluting substance can be traced. If an acute water quality problem is monitored and signalled on-line, a procedure is started automatically; first, a member of a group of specialists, on call 24 hours a day, is notified and co-ordinates reaction to the incident. This involves consulting specialists, computer models and databases to generate information for users such as drinking water suppliers and the regional water authorities (whose role is discussed later in this paper).

Operational water management and (inter-)national agreements

This involves very frequent monitoring of water quality for operational water management and (inter-)national agreements. The data are stored in a system called AQUALARM and are available on-line, including via the Internet.

Specific monitoring

Specific monitoring, operational and others

In support of the planned optimisation of the operational monitoring network, a programme has been started to supply information for research and development on operational monitoring. Furthermore, many data from operational monitoring are used as input for model development and calibration. For this purpose, several additional programmes have been started.

Operational water quality network design

The current system has four stations. Two are highly sophisticated, with equipment for sampling, analysis and communication, a crew of four and an extensive package of variables. These stations are inland on the Rhine and Meuse, the most important transboundary rivers of The Netherlands. The two other stations, with fewer facilities, are situated where the rivers enter the North Sea. A fifth location is used for research purposes.

For the particular purposes of this network, aspects such as availability of data, speed and response time are more important than accuracy (within certain limits, of course). The prescribed response time is two hours. Quantification of unknown substances takes place within 24 hours.

The analytical equipment for organic pollutants at the stations must function properly at least 98% of the time, and for other pollutants 80-90% of the time. The maximum period non-operational is one to three days, depending on the relevance of the variable.

DATA HANDLING

Data storage and management

Data from the national hydrological and chemical monitoring programmes are stored in a database called Donar. Data from the biological networks, gathered in co-operation with institutes other than RIZA, are stored partly at those institutes, but plans are in progress to ensure that all these data are also stored in Donar. An exception will be the geographical data from the ecotope charts and water plant monitoring, which are GIS files in a form that cannot be stored in Donar.

The operational monitoring network has a great deal of continuous on-line monitoring, generating large amounts of data. These data are stored temporarily and can be displayed on-line at any location in The Netherlands with access to the network. They are also available on the Internet at *www.waterland.net/riza/aqualarm*. Data on some variables, such as oxygen, temperature and chloride, which are measured with sufficient accuracy to allow trend detection and the testing of standards, are transformed to values for longer periods (6 to 24 hour averages) and stored in Donar.

Proper data management is often underestimated in the process of monitoring and assessment. It is not sufficient to record the location, date, time and result of the measurement. Much extra information is necessary to support good data management. This is often referred to as "meta-information". Table 2 shows the minimum characteristics recorded for all data from all the different monitoring programmes.

Table 2. **Meta-information recorded for Dutch monitoring programmes**

WHO	Ordering organisation	**WHERE**	Location
	Data managing organisation		Area
	Analysing organisation		
	Sampling organisation		
WHAT	Variable	**HOW**	Analytic method
	Compartment (media)		Sampling method
	Unit		Sample treatment method
	Domain		Sampling equipment
	Entity		
	Organ		
	Species		
	Biotic taxon		

To ensure a certain degree of quality in data management, as well as unity and comparability of data, only particular employees can make any changes to the meta-information.

Data quality management

Every year, as soon as all data from the previous monitoring year are available, a co-ordinated plausibility check takes place. The first step is to note any data that are outside the range of three times the standard deviation of the time series. Next, all the data are printed on paper, and RIZA employees manually assess the data and note any anomalies. They form an expert judgement on whether the values should be considered anomalies or regular values. The experts' judgement is expressed in a quality code attached to every value. When using the data, one can choose to include or exclude data with a particular quality code.

Data availability

Data from RIZA are not available to the public until after this assessment has been made. Once this yearly check has been carried out, the data are freely accessible to anyone. Some (e.g. data from the operational network) can be accessed by Internet at the above-mentioned Web site.

The data can be derived straight from the Donar database (for employees of the Rijkswaterstaat, the national organisation responsible for water management and policy concerning major national waters) or with the assistance of a help desk. Several products make the data available to scientists, research employees and other users (management, politicians, the public).

INFORMATION USE

The data from the monitoring networks serve many purposes. A wide range of products is generated, their nature depending on the objectives of the network, the data users and the possibilities of the technical infrastructure. Sometimes these products are raw data and sometimes highly aggregated information formed via a thorough assessment of the data.

Providing exactly the "tailor-made" information that is of interest to users, rather than an overabundance of data or answers to questions that were never asked, requires continuous dialogue between information providers and users so as to fine-tune the information products to reflect changing information needs. The different types of monitoring data, networks and users necessitate many different products, each designed for a specific use.

Data use for operational water management

For operational water management, raw data from operational networks, such as water levels, flows or temperature, are available on-line to the regional water authorities. Other information is assessed and transformed into useful products. For example, the water levels in rivers and the heights of bridges are transformed into information for shipping (e.g. the maximum height of ships that can pass under a given bridge). The outlook for the following few days (derived from computer models) is also included. This and other information for shipping is available via a daily updated service channel on regular televison, and can be faxed or e-mailed to shipping firms or to ships.

Operational monitoring also provides the data for dealing with exceptional situations, whether water quantity problems such as floods or shortages, or water quality incidents such as accidental discharges from industry or shipping.

Data assessment

To support the evaluation and preparation of water policy and management, a thorough assessment of raw data is generally necessary. The techniques used and the assumptions and decisions made must be agreed and documented so that different assessments are comparable. In The Netherlands, a set of standards has been agreed for:

- Values at the detection limit.
- Anomalies in the time series.
- Calculation methods for loads.
- Calculation methods for trends.
- Calculation methods for the testing of standards.

These are also applied to the design and construction of the computer tools used to do the assessments.

The standards are applied for all standard products based on the monitoring data, except for information products destined for international river or sea commissions. Most international commissions have their own policies on these issues, and they are not always identical to the national ones or to each other. It is important to recognise and understand these differences. This is another reason the standards must be carefully documented and regularly updated.

Data use for water management policy and the public

Some information products for water policy evaluation and preparation are produced yearly, others upon request. The information in these products ranges from almost raw data to highly processed information. All products are freely accessible to the public. Some of the main reports are discussed below.

Yearbook Monitoring National Waters

Probably the oldest product of environmental monitoring in The Netherlands is the Yearbook Monitoring National Waters, which has been produced annually for 145 years. The first, hand-written issue, dating from 1853, gives recorded water levels and ice conditions at various locations in the main rivers.

Today the yearbook consists of three parts: a small report (Cronicle) describing developments in the national waters that have been recorded by the national monitoring programmes; and two other parts (Numbers and Presentor) containing the main features of the time series of the last 10-15 years for most monitoring locations and variables. This includes information from all the main national monitoring networks (hydrological, chemical, biological and operational). “Numbers” presents this information on paper while “Presentor” has it in digital form (CD-ROM, including selection and presentation facilities). The feasibility of distributing these data on the Internet is being studied. The yearbook meets a large part of the everyday information needs of scientists, experts, advisers and water managers.

Several other annual reports based on the monitoring data are also produced. They contain more thoroughly processed information, meeting more complicated information needs.

Monitoring newspaper

As soon as the time series of the last monitoring year are available, a group of experts produces a general impression of the developments. On the basis of this assessment, a newspaper is published, giving a short, timely explanation of developments in the water quality and ecosystems of the national waters. This newspaper is intended for the broader public, rather than experts.

Annual reports on assessed information

Since 1992, annual water system reports have been published. All national water systems are described, on a rotating schedule of four years, giving an accurate status and trends assessment. These reports describe long-term developments in water quality and ecology, and link these developments to the problems and measures relevant for the water system in question. This product helps the water authorities in developing and evaluating water management and policy.

Additional thematic reports

As information needs vary with developments in water management, standard reports can meet only a part of these needs. Often, water managers have specific questions requiring tailor-made answers. To this end, many thematic reports are produced, focusing on specific subjects such as high water levels and floods, quality of suspended solids, drinking water production from surface waters, pesticides and quality standards for fish.

Derived uses of monitoring data

Among the many other purposes for which monitoring data are used, one of the most important is the construction and calibration of computer models for flood forecasting, water quality developments, etc., to support long term policy planning. The ambient monitoring networks are not designed for this purpose, so additional specific-project monitoring is often necessary.

The data reported in the products discussed here also are frequently used for the water chapters of integrated environment reports, such as the yearly state of the environment reports made by Dutch ministries and the European Commission.

QUALITY ASSURANCE

To achieve and maintain a high quality standard in monitoring, several quality assurance measures have been taken. Some are described below.

Determining and updating information needs

To determine information needs, a five-step plan has been developed, translating policy goals and targets into monitoring objectives and network criteria. This method enables a rapid, thorough determination of information needs, relying on close co-operation between information users and suppliers.

As was noted earlier, the monitoring programmes are evaluated every year. If the evaluation shows a change of information needs, several ways to adjust the programmes are specified, including their financial consequences, and discussed with the parties concerned. The agreed option is integrated in the following year’s programme.

Sampling, field measures and analyses

Sampling and field measures are strictly regulated, and the employees concerned are highly trained. The procedures and regulations are checked by audits.

Only laboratories with quality assurance systems can perform laboratory analyses, whether they are RIZA laboratories or external sites. The system for quality assurance complies with certification standards and is supervised by an independent national institute.

Every year a report is published on the validation of all analytical methods and their characteristics: recovery, detection limits, etc.

INSTITUTIONAL AND FINANCIAL ISSUES

Institutional aspects

The Netherlands has a very long history of water management. The first dikes and dams were built more than 2 000 years ago. Land reclamation and impoldering resulted in large parts of the country being below sea level, by as much as 6.7 metres. With these developments and growth in population, towns and economic interests, water management became increasingly important. Over the past 500 years, water management has become institutionalised. At first, numerous authorities were in charge of relatively small areas. At one point The Netherlands had more than 600 relatively independent water authorities on a territory of no more than 41 000 km^2.

Although the number of organisations involved has decreased steadily, The Netherlands still has a very complex water management structure:

- There are 66 different water authorities for smaller, regional waters; 39 deal with water quantity only and 27 handle quality management (some of these also deal with quantity).
- The 12 provinces are responsible for developing and evaluating strategic surface water management policy, and for groundwater management.
- A national organisation, the Rijkswaterstaat, deals with water management and policy concerning the larger or national waters. It has nine directorates and is supported by scientific research and advisory institutes, such as RIZA.

The number of organisations involved in water management is an aspect that is under study, and adjustments in both organisational and financial structures may be expected.

Furthermore, the almost 100 organisations involved in water management are not the only players in Dutch environmental monitoring. Water management increasingly involves integrated assessment of water systems, including river banks, flood plains, nature restoration, economics and other aspects that often fall within the jurisdiction of ministries, organisations and institutes dealing with agriculture, industry, recreation, nature and environment, shipping and transport, etc. This makes communication, co-operation and information supply and availability even more important.

Monitoring by regional water authorities

The monitoring activities described in this paper are carried out by the Rijkswaterstaat for inland national water systems to facilitate national water management. Regional water authorities usually do their own monitoring, which more or less follows the same strategies used for national monitoring. In general, monitoring of regional waters includes at least ambient water quality monitoring for status and trend detection and the testing of standards. Other types of monitoring depend on the functions and uses of the water system concerned. The water authorities that handle water quantity management perform hydrological monitoring — partly ambient, partly operational.

RIZA gathers some of the results of regional water monitoring in a yearly survey, and the water authorities send RIZA the monitoring data from their main locations. These data are used in national policy evaluation and the testing of standards.

Financial aspects

Regional water management and waste water treatment, under the jurisdiction of the 66 water authorities, is funded through specific taxes paid by property owners and users such as industry, farmers and households. As has been mentioned, this system is being reorganised. It is expected that in future the costs of managing regional waters (including water quality management, infrastructure management and safety) will be met by users and property owners in proportion to the management's economic value.

Costs of waste water treatment will be paid by households based either on a fixed price per inhabitant or on drinking water consumption. The water authorities will be able to make special deals with large dischargers in accordance with the free market principle.

In 1998, the cost of water management by the 66 water authorities was about USD 1.725 billion, of which some 65% was related to waste water treatment and the rest to water quantity tasks, dikes, etc. The costs of national water management totalled an additional USD 1.05 billion. Water management costs and the rates of the taxes that meet them are published yearly in freely accessible policy plans.

The total cost of all monitoring for national water management is about USD 45 million. The monitoring networks described in this paper, for inland waters only, cost some USD 14 million, including personnel costs.

In general, the cost of monitoring is estimated at 4-5% of the total cost of water management.

STRENGTHS AND WEAKNESSES

The long tradition of water monitoring in The Netherlands is an advantage in certain respects, as knowledge on water monitoring and water management in general is highly developed. Sometimes, however, having an edge in knowledge or methods may become a disadvantage if it means newer developments are disregarded. For instance, several hundred years ago the water authorities were cutting edge, but now they are a disadvantage.

Some of the strong and weak points in Dutch water monitoring are listed below.

Strengths

- Integrated monitoring of toxicity, suspended solids, sediments, biota, plants, fish, etc.
- High level of expertise, high quality standards.
- Well co-ordinated organisation with little overlap between programmes.
- Good relationship between monitoring effort and information needs.
- High cost-effectiveness.
- High availability of results, good reporting and publication of products.

Weaknesses

- Extensive communication necessary among national, provincial and water authority levels.
- Organisations designed according to administrative boundaries instead of watersheds or water systems.
- Methods and techniques vary among the parties involved.
- Useful indicators, e.g. in relation to habitat aspects in biological/hydrological monitoring, sometimes lacking.
- Programmes cover too many variables, not all of them used for relevant products.

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River Basin Monitoring
The Experience of France

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River Basin Monitoring
The Experience of France

THE ENVIRONMENTAL MONITORING SYSTEM

Administrative and basin organisation

Metropolitan France extends over 550 000 km^2. The organisation of water issues reflects the political organisation, based on four levels (in ascending order of size): approximately 36 000 municipalities; 95 departments, which are collections of municipalities; 22 regions, which are collections of departments; and the state. Administrative bodies at each level have their own duties. For example, mayors of municipalities are in charge of delivering tap water that meets standards for human consumption, which are enforced by the state under EU directives (the European Union as a supranational body is of increasing importance in environmental monitoring).

It was recognised in the 1960s, however, that the hierarchical organisation described above was not suitable for responding efficiently to water issues. Hence a new legal concept was developed: the river basin area, a cluster of physical drainage basins in which human activities are interdependent with respect to water issues. For practical purposes, the outer limits of the river basin areas roughly correspond to those of municipalities (Figure 1).

The 1964 Water Act divided metropolitan France into six river basin areas, each named for a region and the main river draining it. For every river basin area, a Water Agency conducts water policy at basin level, in close co-operation with representatives of each of the four political levels. The Water Agency is entitled to collect water fees and apportion the revenue as soft loans or subsidies for the construction of sewage treatment plants, water supply facilities, etc.

The Water Agencies are also the main operators of the river basin monitoring networks, under state regulations. Other monitoring systems also exist, and are treated in this review as well.

Features common to all networks

The objective of monitoring is to provide data — both ”raw data” (elementary pieces of information such as concentrations of nitrates in river water sampled at a certain date on a certain location) and “elaborated data” (information derived in a more or less complex process that results in a statistic, a map, an indicator, etc.).

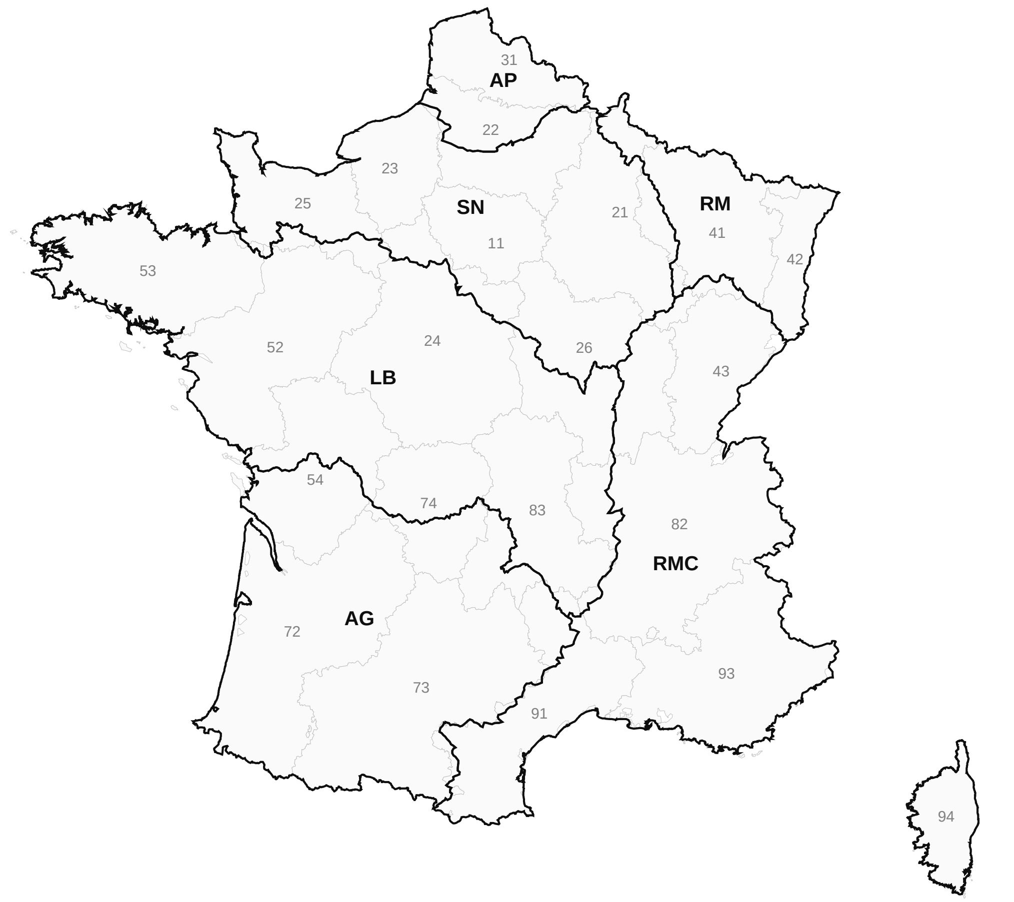
The monitoring of water systems includes: *i)* stream water discharge and flood assessment and warning; *ii)* stream water quality (chemical and biological) for general purposes and policy assessment; *iii)* groundwater levels and quality; *iv)* assessment of polluting discharges (municipal, industrial, etc.); *v)* metering of water abstraction (municipal, industrial, agricultural, for energy production, etc.); and *vi)* tap water sanitary monitoring.

Until 1986, each network was managed independently of the others, in accordance with past practice. Then, in 1986, the National Water Data Network (RNDE) was set up through a general agreement between data producers and field monitoring managers. This agreement concerns:

- Development of a common language for data description and handling. The construction of this language, called SANDRE, is the responsibility of a national secretariat and as many expert task forces as are needed, depending on the topics under consideration (e.g. water quality, sewage purification).
- Data sharing among the partners in the RNDE, including publication of raw and elaborated results.

This paper details both tasks, along with two of the main networks, which represent two different types of design, financing and management.

Figure 1. **Map of French administrative and River basin boundaries**



Water agency limits are printed in dark lines. The main river of each water agency has been drawn in pale lines.

Water agency code	Water agency name and address	Main characteristics.
AG	Adour-Garonne (Location : Toulouse)	c.a., 118.8 10^3 km^2
AP	Artois-Picardie (Location : Douai)	c.a., 19.9 10^3 km^2
LB	Loire-Bretagne (Location : Orléans)	c.a., 156.9 10^3 km^2, 11 million inhabitants
RM	Rhin-Meuse (Location : Metz)	c.a., 31.4 10^3 km^2
RMC	Rhône-Méditérranée-Corse (Location : Lyon)	c.a., 130.5 10^3 km^2
SN	Seine-Normandie (Location : Nanterre)	c.a., 94.9 10^3 km^2, 17 million inhabitants

More details available through the water agencies web site : http://www.eaufrance.tm.fr/

The list of regions is reported in the table below. The region code (first column) is reported on the map. Rounded area and population values (1990 census) are given for information. The limits of the Regions (administrative unit just below the State) are reported as grey (clear) lines with their numeric code indicated in the map.

Region code	Full name of region	Area (km2)	Population (millions inhab.)	Region code	Full name of region	Area (km2)	Population (millions inhab.)
11	ILE-DE-FRANCE	12000	10,66	52	PAYS DE LA LOIRE	32100	3,06
21	CHAMPAGNE-ARDENNE	25600	1,35	53	BRETAGNE	27200	2,80
22	PICARDIE	19400	1,81	54	POITOU-CHARENTES	25800	1,60
23	HAUTE-NORMANDIE	12300	1,74	72	AQUITAINE	41300	2,80
24	CENTRE	39200	2,37	73	MIDI-PYRENEES	45300	2,43
25	BASSE-NORMANDIE	17600	1,39	74	LIMOUSIN	16900	0,72
26	BOURGOGNE	31600	1,61	82	RHONE-ALPES	43700	5,35
31	NORD-PAS-DE-CALAIS	12400	3,97	83	AUVERGNE	26000	1,32
41	LORRAINE	23500	2,31	91	LANGUEDOC-ROUSSILLON	27400	2,12
42	ALSACE	8300	1,62	93	PROVENCE-ALPES-COTE D'AZUR	31400	4,26
43	FRANCHE-COMTE	16200	1,10	94	CORSE	8700	0,25

Water discharge monitoring network

Structure of water resource monitoring networks

Meteorological and hydrological services are fully separated in France. Rainfall and climatic networks, on the one hand, and hydrological networks, on the other, were developed to meet different objectives. Only the latter are discussed here.

In continental France, 3 400 limnimetric stations[1] exist, of which 2 000 are fully operational, including flood early warning networks, which are managed by *ad hoc* organisations. The networks for flood warning and management must meet special standards, such as being operational during extreme events, providing data in real time and having enough units to avoid false warnings. Therefore they are tailored to the catchments where flood hazards justify the extra expense entailed.

The general purpose hydrological network is organised to provide timely and accurate discharge values for long term water management and for studies where water discharge data are needed. Paradoxically, water elevation data production is not the network's main purpose, even though that is the primary data type collected.

The locations of the limnimetric stations are to some extent a result of the addition of stations belonging to successive networks. A few units were set up in the mid-19th century. The first large set of limnimetric stations was installed between 1930 and 1960 by hydropower producers, and by the Ministry of Industry to monitor hydropower production. A second large set of stations was added between 1950 and 1980 by the Ministry of Agriculture, on rivers in crop areas, to assess water availability for irrigation.

The 1992 Water Act merged both services into the new Regional Environment Offices (DIRENs). As a result, the hydrometric networks are being reorganised.

Basically, the measurements are the continuous recording of water elevation, allowing at least the production of daily discharge data, provided a calibration curve exists. Since government offices do most of the measuring, the cost is not accurately known. The best estimate is FRF 70 million per year (USD 14.286 million or 12.196 million euros[2]).

Management of the network: the HYDRO database

As early as 1971, all organisations involved in water discharge monitoring decided to design a database, the National Hydrometric and Hydrological Database (HYDRO), to achieve four objectives:

1. Ensure the conservation of national reference data in hydrometry (level/time) and calculate the flow from the levels and the updated stage discharge curves; the oldest data stored go as far back as 1860.
2. Centralise the management of hydrometric and hydrological data to ensure uniform data collection and acquisition.
3. Disseminate raw data for all regional or national hydrological studies.
4. Provide users with reference data (statistics and estimates) from the hydrological calculation procedures offered by direct access to HYDRO.

The HYDRO database is now a cornerstone of the RNDE. It is also a powerful tool for enhancing the reorganisation of the physical network. Around 210 individual users (both data producers and others) are connected to the central server, representing 120 organisations. These include 40 main producing organisations, of which 24 are Regional Environment Offices; ten flood warning services; and EDF the national electricity producer.

At the end of 1998, HYDRO contained 38.5 million level/time data sets, 62 500 flow years, 17 500 stage discharge curves and 10 500 gauged measurements. Most of the data have usage codes giving information on the data quality.

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[1] *The term "limnimetric station" is used instead of "gauging station" to indicate that water elevation is measured or permanently recorded ("gauging" indicates that calibration curves are maintained as well, and allow discharge calculation).*

[2] *For convenience, all monetary values are rounded to the nearest USD 1 000 or 1 000 euros, converted at USD 1 = FRF 5.5 and 1 euro = FRF 6.55957.*

In practice, the French hydrometric system is a partnership of field networks. Each partner network has its own management and financing. Data collected through these networks are pooled and shared in HYDRO, which is overseen by nine co-administrators at the Ministry of the Environment.

The annual budget of HYDRO is FRF 1.9 million (387,000USD or 331,000 EUROS), financed as follows: 34% by the Ministry of the Environment, 9% by the Ministry of Agriculture, 12% by EDF and 45% by the six Water Agencies.

The database can be accessed through several multimodal communication platforms, the simplest being the Internet. Organisations providing data have free access to the database and its services, in exchange for updating data. Any other user (individual or organisation) can obtain access to the HYDRO data for a fee set by the HYDRO steering committee.

River water quality monitoring: The national basin network

Structure and objectives

Water quality cannot be monitored; only the determinants of water quality (chemicals, organic matter, etc.) can be measured. Water quality is assessed by applying interpretation methods to monitoring results. The conceptual difficulties of water quality assessment are reflected in the differences in design of “water quality monitoring” networks.

Network design should ideally be based on the interpretation methods to be employed. However, in practice, interpretation methods are developed using data collected on natural waters, and thus there is permanent feedback between field monitoring and improvements in network design.

The legal provisions of the 1964 Water Act determined the initial organisation of water quality monitoring. The basic principle was to carry out national inventories every five years.

Three such inventories were conducted, in 1971, 1976 and 1981. In 1972, a limited set of monitoring points, called “permanent sampling points”, financed jointly by the state and the Water Agencies, was set up to provide data in between inventories. However, this method was expensive and hard to organise, and did not prove very informative, so to supplement the information the Water Agencies developed their own, complementary network [the National Basin Network, or RBN].

The five-year interval was based on an assumption that this would be enough time for the effects of municipal and industrial sewage treatment plants that were under construction to become discernible.

As local authorities were responsible for the choice of sampling locations, no national harmonisation was possible, although the sampling frequency was fixed by decree (normally four times per year, though many points were sampled eight or 12 times a year).

When it came time to prepare for the fourth inventory, scheduled for 1986, criticism of the method, along with budget problems, proved so strong that it was decided to review the very principle of the inventory. Hence, in 1987, the system was radically transformed. The result was the RNDE. Most of the previous parameters (constituents analysed and environmental data) and sampling points were kept. The main changes involved:

- A substantial increase in the number of sampling points and in the frequency of sampling (now annual).
- Rationalisation and homogenisation of the sampling point locations nationwide, the network being operated at river basin level.
- Adoption of new water quality assessment methods taking into account eutrophication, microbiological contamination and micropollutants. Use of the recently approved EC standards related to specific water uses was also considered.

The RBN was made part of the RNDE, and while it still operates at basin level, it is co-ordinated at state level. State co-ordination involves:

- Checking on how the national rules are implemented in each basin (though each Water Agency is free to assess specific problems).

- Ensuring laboratory intercalibration and laboratory approval.
- Co-operating with AFNOR, the national standardisation body, on periodic improvement of analytical methods and normalisation of new methods.
- Providing data in response to public requests at national level.

The Ministry of the Environment and the Water Agencies have a contract specifying five objectives:

1. Assess reference values, the impact of human activities and the state and trends of river water quality. Three types of sampling points are defined: reference stations, impact stations and tendency/flux stations.
2. Warn about possible new types of contamination; each basin is entitled to adjust its monitoring programme accordingly (the same holds for point 4).
3. Provide the basic information required for enforcement of national and EU regulations.
4. Allow overall assessment of the impact of industrial, municipal and non-point sources on river water quality.
5. Allow long term assessment of the effect of prevention and protection policies on rivers.

Measurements

The determinants to be measured, which depend on the type of station, comprise compulsory parameters, complementary parameters and optional (useful) parameters. The comprehensive list of the core group of determinants, units and recommended methods is provided in Appendix 1. Compulsory parameters, i.e., those that must be measured on every sample, are:

- Water discharge (use of hydrometric data, gauging or interpolation).
- COD (bichromate), COD (permanganate), DO (concentration and saturation percentage), dissolved organic carbon, BOD_5, Kjeldahl nitrogen, NH_4^+, pH, soluble reactive phosphorus, total phosphorus, suspended solids, transparency, turbidity, faecal coli, faecal streptococci, temperature and a biological indicator (IBG, method AFNOR 90350/1992), and suspended active chlorophyll during spring and summer in eutrophicated areas.

Complementary parameters are measured wherever the calculation of SEQ (“quality assessment system”) indicators is demanded. The basic components of mineralisation are measured in almost all samples.

Optional parameters group all toxics, i.e. pesticides, solvents, heavy metals (and assimilated), halogenated aliphatics and halogenated aromatics; their presence in river water is always the consequence of pollution by agriculture or industry, so they are monitored only where they are likely to occur. Basin authorities choose the sites.

The optional parameters are divided into a main list (seven all-purpose pesticides, 12 aromatics, eight mineral toxics [As, Cd, Cr, Cu, Hg, Ni, Pb, Zn], eight chlorinated aromatics, three solvents and the aggregated halogenated aliphatics) and a secondary list (76 micropollutants originating in urban or industrial waste, 259 pesticides and 53 miscellaneous micropollutants). The lists are based on well assessed analytical methods and specify which media must be analysed. Depending on the water solubility and the log Kow[3] of each substance, measurements are required on the water phase, the suspended solids or mosses collected in the river, as close as possible to the water sampling point. There are several hundred possible determinants in all, not dealt with in this paper.

[3] The decimal logarithm of the partition coefficient octanol to water of the substance considered, measured in the laboratory. As a rule, substances whose log Kow is less than 3 are measured only in the water phase.

Frequency of sampling

Many points are sampled quarterly to weekly; the most common frequency is monthly. The exceptions are a handful of sites (mainly early warning stations for large domestic water supply systems, or research sites) where continuous devices provide data as often as every ten minutes or daily.

The question of measurement of fluxes has not yet been fully solved. For drainage areas of 10 000 km2 or greater, 24 samples a year (or 18, i.e. fortnightly in the high water period and monthly in summer) yield a 30% uncertainty on a three year interannual flux mean of nutrients and organic matter. The greatest uncertainty comes from rivers with extreme discharge patterns, or from events during which no sampling is practicable (e.g. severe floods).

Institutions and management

The overall legal authority for the RNB lies with the state, which delegates its responsibility to the Water Agencies. To achieve the network objectives, each Water Agency (working at river basin level) must manage the operation of its part of the national network in co-operation with the Regional Environment Offices. Since the boundaries of the river basins and the regions do not coincide, some overlaps or discrepancies occur. In practice this has little effect on data value.

A five year general agreement between the Ministry of the Environment and the Water Agencies determines the organisation of the network. The present agreement, for 1997-2001, covers 1 105 sampling points (4) (Table 1).

Table 1. **Number of sampling points of the National Basin Network**

Type of measurement	Water Agency (See Figure 1 for location)						Total
	AG	AP	LB	RM	RMC	SN	
Compulsory determinants	171	66	240	248	130	250	1 105
Organic micropollutants	40	66	42	19	118	50	335
Mineral micropollutants	118	66	60	59	130	142	575

Source: 1997-2001 general agreement between Ministry of the Environment and Water Agencies.

The Water Agencies contract out water sampling and analysis to private and public organisations, after a call for tenders. An organisation wishing to bid must qualify in advance, especially as regards its capacity for producing accurate, repeatable analytical results. This implies cross-checking and intercalibration procedures, laboratory inspection and use of “best laboratory practices”. ISO 9000 certification is not yet compulsory.

The analyst systematically enters data into magnetic files, and a first set of data validation is performed. All data regarding the river basin area are calculated by the Water Agency, which carries out secondary data validation checks — comparison with previous values monitored on the same point, statistical tests, etc.

In 1998, the budget for monitoring (sampling and analysis) was FRF 45 million (USD 8.036 million/6.86 million euros). This excludes the cost of data validation and processing carried out by the Regional Environment Offices and the Water Agencies.

USE OF THE MONITORING SYSTEM IN PUBLIC INFORMATION AND DECISION MAKING

Types of uses

A large number of potential users determine the type of uses of the different monitoring networks. Policy makers typically demand a few relevant and timely indicators. In contrast, experts need raw data for day to day work. Numerous other users — consultants, students, researchers, etc. — ask for a whole range of elementary data and more or less aggregated indicators.

[4] *This is the number of stations reported in the agreement. Some Water Agencies have complementary networks, monitored as if they were in the RNB, but not including the stations in the agreement. This explains why the numbers in this report may differ.*

The tasks of meeting these needs can be summarised by division into the following groups:

- Group 1. Provides elementary data to everyone who asks for them. This is the function of national or basin databases.
- Group 2. Produces elaborated results for any user or the general public. The method definition is the task of the RNDE, the actual calculation may be at either national or basin level.
- Group 3. Calculates aggregated indicators, using data from both monitoring networks and statistical sources. This is the role of the French Environment Institute (IFEN).
- Group 4. Responds to European or international obligations. IFEN does this when technical results are considered. If the response is to meet legal requirements (such as EU directives), the Ministry of the Environment responds.

Examples regarding the three first groups are given below.

Information techniques, mechanisms and software used for data transmission

Prerequisites

An important aspect of information techniques is the quality and consistency of information, which is an ongoing issue. The actual computer facilities change as new types of communication networks and computer products are developed These possibilities evolve independently of the information they convey.

Data provision to every user who asks means that data description and quality assurance procedures have had to be developed. As these procedures have become the core issue in all data transmission techniques, they deserve to be discussed in some detail.

They resulted essentially from *i)* the widening of the number of users entitled to receive data, and *ii)* the now systematic use of computer systems to process data.

From the 1970s, soon after the systematic monitoring of inland waters started, most data were processed by the experts who had done the monitoring, so the need for comprehensive, precise descriptions of data was limited. But the technical progress and cost reductions in computer systems since the early 1990s have allowed data processing by many organisations, which are encouraged to do so to facilitate open access to information.

All data that are shared must therefore be accurately defined and situated in context, to avoid errors in calculation and mistakes in interpretation. A simplified example illustrates the need for precise definition. Oceanographers present their chemical results in µmole l^{-1} for common ions and in mg l^{-1} for complex substances (e.g. pesticides). Inland water chemists use mg l^{-1} of substance (e.g. NO_3). Soil experts may use reference to other chemical types; for example, total phosphorus may be expressed as mg l^{-1} P_2O_5 in drainage water.

The serious mismatches in data that might result when such sources of information are combined has led the RNDE to develop a National Water Data Reference System, which provides the common language known as SANDRE.

The SANDRE system

SANDRE fulfils the requirements of efficient data exchange and accurate production of outputs from data resulting from monitoring systems. It includes:

- A data dictionary with the definitions particular to each water-related item. Each term that SANDRE compiles is described according to its meaning, the rules for codification, if relevant, the list of possible values and the various stages of the life cycle of the data related to the subject.
- A word list, which is a universal codification for data, ensuring that an unambiguous code is assigned to each of the various pieces of information, whether analytical methods, water quality determinants, river codification, description of water abstraction facilities, etc.
- A general exchange format comprising all context and descriptive information needed to ensure accuracy of the data exchanged.

- Expert assistance and free dissemination of reference and updates.

More detailed information and codification files are available on the Web site *www.rnde.tm.fr*.

The basin and national databases

The raw data the monitoring networks provide are stored and processed in basin and national databases. For example, in each basin, the Water Agency and the DIRENs first validate and process water quality data. These data, raw and elaborated, are publicly available through the basin database. In a second step, they are transferred to the national water database (BNDE).

Users who need raw data concerning any sub-basin or region are invited to apply to the basin database. Most (if not all) of the raw data stored in the basin database are supposed to be transferred to the BNDE; in fact, a network of databases is gradually being constructed, interweaving the basin databases, thematic databases and the BNDE, and so the pathways of information may be very different from one topic to another. They depend both on the monitoring system and on the data management approach.

The transfer of data may be physical (data files are copied from one computer to another), or virtual if only the links to the data are reported on a system. Conversely, data collected at the national level are transferred to basin databases if they are relevant for basin purposes.

Table 2 describes the data pathways of the five main monitoring programmes. For example, hydrometric data monitored at local (organisations) or regional level are transferred to the HYDRO database, which disseminates data at the basin level through basin databases. Water quality data, monitored at the regional and basin level, are processed at these levels before being transferred to the national database. Data proper are stored on data files, managed by applications developed under common software programmes, such as ORACLE, INFORMIX and ACCESS, supported by Windows NT or UNIX platforms[5].

Table 2**. Data monitoring and pathways of France's 5 major monitoring programmes**

Level of monitoring and data handling	Monitoring systems				
	Surface water hydrometry	Drinking water quality	Surface water quality	Pollution discharges	Coastal and marine water
Local/organisation	❍				
Department		❍			
Region	❍		❍	❍	
Basin			❍	❍	
National	HYDRO	SISE-Eau	BNDE	BNDE	❍QUADRIGE

Key: ❍ level of the initial data monitoring. The arrows indicate the data pathways. Names are database names. See Appendix 2 for details.

Dissemination of raw data

Raw data can be provided to any user, under the following conditions:

- Data from publicly funded monitoring (or collection) are free, but a fee may be charged for their transfer (on paper, diskette or downloading). This fee, which is intended to cover the costs of data conservation and availability, can be quite high.
- Whether private data are disseminated depends on the goodwill of their owners, except for data from monitoring to meet legal requirements, where the public authorities are entitled to provide these to external users.
- In all cases, data dissemination may be subject to conditions. Access to data may require a previously signed agreement defining the scope of data use and possible restrictions on use (e.g. no further dissemination, respect of statistical secrets).

[5] *The trademarks are mentioned only for information; this does not imply any endorsement by IFEN.*

In practice, the general public does not normally use raw data. Such data necessitate particular software to process the transfer formats, and users must be specially informed and trained to exploit the data accurately. Therefore, organisations are the main users: consulting firms, government administrations, universities, etc.

Production and dissemination of elaborated data

To ensure reliability and comparability of elaborated data aimed at the general public, the RNDE has defined a set of procedures that are flexible to permit maximum efficiency. The principles of these procedures are:

- The RNDE's permanent group of experts evaluates a new "product". This evaluation encompasses the interest, targets and tasks required to achieve the product. A "product" can be a complex issue, which may be disseminated through several media. Data related to a product issued in printed form are always available as magnetic files as well.
- The RNDE steering committee prioritises proposed products and allocates funding for the ones that are accepted.
- Depending on the product, either a previously existing task group or a new *ad hoc* one is entrusted with designing the product. The production may be carried out by the experts participating to the group and by subcontractors. External experts belonging to organisations not members of the RNDE can be part of the task group, with previous permission by the steering committee.

The following sections describe two key products of the RNDE system.

<u>Hydrometric characteristics at selected river gauging stations.</u>

Until recent years, information related to the limnimetric stations was available only from the producers. Now RNDE publishes a directory of all stations and, separately, relevant hydrometric data. Both publications appear on standardised forms on which information is harmonised according to SANDRE principles (Appendix 2).

The directory contains large- and small-scale maps and describes the purpose of the station, its equipment and the years for which data are available.

The relevant data are reported on a standardised template that situates the discharges recorded during the previous year (in fact, 15 months, to cover both calendar and hydrological years) against the statistical characteristics of the point. Main discharge indicators (yearly flood, average and low water) are also reported for the previous ten years. Another graph reports the daily flows of the previous 15 months and provides the weekly reference values.

This product is issued as a booklet dealing with 190 stations representing the various hydrological regimes observed in France. The BNDE Web server allows calculation of updated templates (other years, other stations).

<u>Main characteristics of water quality; water quality maps</u>

Water quality is assessed by processing monitoring data against reference values, according to some interpretation rules. The method currently used in France is the SEQ (Appendix 3).

Since raw data are of little use to the general public, the BNDE carries out a systematic classification of yearly data to help interested people and organisations. Results calculated for 190 sampling points (chosen among the 1 700 sampling points in the RNB; see footnote 4) have been published, indicating the quality classes of each sample with respect to the main uses (Appendix 3, table), the quality classes assessed for past monitoring campaigns, etc.

Again, this product is complemented by another publication, giving sampling site characteristics (very similar to those published for limnimetric stations), and by the possibility of getting updated values by using the BNDE's computer service.

Many users need more aggregated data, especially government decision makers. Hence, the RNDE surface water expert group produces water quality linear maps, directly derived from the calculations reported above. These maps are still produced partly by hand. They show water quality classes over some 39 000 km of river reaches, covering the major river systems of metropolitan France. These maps are available as GIS layer upon request.

Other products are available from the BNDE. Detailed information can be obtained at www.rnde.tm.fr

Providing these raw data and products takes a significant budget: USD 4.76 million or 4.05 million euros (Appendix 4).

Use of monitoring information for advanced data processing

IFEN, with the help of the Water Agencies and on behalf of European bodies, is developing aggregated statistics and water accounts.

Aggregated indicators

The main objective of the European Environment Agency is to provide the European Commission with reliable indicators. For water, relevant indicators need to deal with such issues as whether nitrate concentrations are greater in France than in Norway, or whether phosphate concentrations are higher in the Rhine basin than in the Danube basin. The EUROWATERNET system is intended to design representative networks on a European scale to produce responses to such questions using data from monitoring by Member States' networks.

The design of these European networks is carried out by selecting the sampling points that meet stratification criteria. In France, a pilot and a prototype project have been carried out and a representative network consisting of 552 sampling points resulted. The selection procedure involves calculating the cumulated population density and agricultural land use upstream of each sampling point. These calculations yield four driving force classes: *i)* urban, *ii)* agricultural, *iii)* urban and agricultural, and *iv)* neither urban nor agricultural. The aggregated yearly averages of nitrate, phosphate and ammonium show clear-cut values directly related to the stratum from which sampling points were selected (Appendix 5).

Water accounts

In the water accounts approach, water issues are considered from a national accounts point of view. The expected results are input-output tables, organised in classic budgetary balances. This is rather simple to imagine when considering water resources. The water balance, expressed as rainfall minus evaporation, etc., is a classic hydrological approach. But water quality accounting is a newer concept, requiring results from both the water quality and hydrometric networks.

In water quality accounting, every river is broken down into as many reaches as possible. Each reach has a length, a reference discharge and a water quality indicator. The value of length of reach × reference discharge has interesting properties. The sum of the values of all reaches tends rapidly to a constant when the length of the reaches tends to zero. The calculated value, expressed in km.m3.s-1 ("standardised kilometre"), is a powerful weighting factor.

The calculation involves sorting the standardised kilometres according to the water quality indexes of each reach. This has been done in France, using the water quality maps issued by the RNDE as the source of the water quality indexes. Since the value expressed in standardised kilometres can be aggregated, the river reaches are sorted according to river size, the data are processed separately and data can eventually be aggregated at state level. This weighted water quality index has been calculated for two distinct periods (for more details, see website http://www.ifen.fr).

STRENGTHS AND WEAKNESSES

At the beginning of the monitoring surveys, fully centralised procedures were used, resulting in inadequate economic efficiency and low data accuracy. This was due principally to insufficient awareness of field issues by the people involved in the design of the monitoring. The hierarchical organisation in place was a strong barrier to improvement.

To tackle this problem, monitoring responsibility was transferred to basin level, but co-ordination and harmonisation procedures were not firmly established, and the hierarchy that had proved so insufficient at state level was simply transferred to basin level, more or less ignoring the importance of involving all partners in monitoring procedures.

Nevertheless, the main strengths of the French basin monitoring systems come from the degree of freedom given to each basin authority to design a network system that is suited to the particularities of the basin. This is especially efficient in France, where climatic conditions, altitude and pressures on water resources vary widely by region. Since the Water Agencies have had to tackle very different problems, this has resulted in tailored approaches.

The main weaknesses, however, derive directly from these tailored approaches. There is a severe lack of homogeneity, and issues important at state or European level were long neglected if they were not considered important at basin level. Examples are sewerage and sewage purification data, which, paradoxically, are the core data for the Water Agencies but have been collected and processed on very different bases to respond solely to basin needs.

In contrast, data that must be monitored are better harmonised, since the measurement procedures are defined scientifically rather than to fit administrative procedures.

The orientations enforced since 1992 within the RNDE agreement aim at optimising the efficiency of the basin approach by implementing common procedures, languages and interfaced databases. The co-ordination that is being done seems the best possible compromise. A corollary to this approach is that the various partners invest enough time in comparing their respective approaches, and share their results. To this end, not only must data be treated in computer networks, but experts also have to learn networking.

Appendix 1. Water quality determinants measured in the French National Basin Network

SANDRE code	**Determinants**	Compulsory	Complementary	useful	Unit of the result	Nb of decimals	# significative digits	Analytical method reference	Detection limit (*)	Observations
?	Algal cells		X1		u/ml					
1439 1436	chlorophyll + phéopigments	X	X1		µg/l	integer	2	NF T90-117	1	Filtration at sampling site
1318	Dissolved organic carbon		X2		mg/l C	1	2	NF T90-102	0,5	
?	Conductivity 25°C	X			µS/cm	integer	3	NF EN 27888		On the spot
1309	Color	X			mg/l Pt	integer rounded to the next 5 (values <40), to the next 10 otherwise	2	NF EN ISO 7887		
1311	Dissolved oxygen		X3		mg/l O2	1	3	NF EN 25814 NF EN 25813		On the spot
1312	Saturation percentage	X	X3		%	integer	3	NF T90-032		
1315	COD KMnO4		X2		mg/l O2	1	2	NF T90-050	0,5	hot, acidic
1313	BOD5	X			mg/l O2	integer	2	NF T90-103	1	
1314	COD (bichromate)		X2		mg/l O2	integer	2	NF T90-101	20	
1319	Kjeldahl N (NKJ)		X4		mg/l N	1	2	NF EN 25663	0,5	
1335	NH4+	X	X4		mg/l N	2	2	NF T90-015	0,01mg/l NH4	
1351	NH3		X5		mg/l N	2	2			
1339	NO2-		X5		mg/l N	2	2	NF EN 26777 NF EN ISO10304-1	0,01	
1340	NO3-	X			mg/l N	1	2	NF EN ISO10304-1 NF T90-012 NF T90-045	1 mg/l NO3 0,1mg/l NO3 0,5mg/l NO3	
1302	pH	X				1	2	NF T90-008		On the spot
1433	Soluble reactive phosphorus		X6		mg/l PO4	2	3	NF EN ISO10304-1 NF T90-023	0,02	
1350	total phosphorus (P)		X6		mg/l P	2	3	NF T90-023	0,02	
1301	water temperature	X			°C	1	3	NF T90-100		On the spot
1305	Total SS	X	X7		mg/l	integer	3	NF T90-105	2	
1332	transparency		X7		cm	integer		NF T90-033		
1295	turbidité		X7		NTU	1		NF T90-033		
1370	aluminium			X	mg/l			NF T90-119	0,005	
1396	baryum			X	mg/l			NF T90-118 NF T90-119	0,2 0,005	
1362	Boron			X	mg/l			NF T90-041		
1325	TOC			X	mg/l C	1	2	NF T90-102	0,5	
1374	calcium			X	mg/l	integer	3	NF T90-005 NF T90-016	0,5 2	
1337	Chlorine Cl-			X	mg/l	integer	3	NF EN ISO10304-1 NF T90-014	1 2	
1390	Total cyanide			X	mg/l	2	2	NF T90-107	0,01	
	Hardness			X	°F			NF T90-003		1°F=10mg/lCa CO3
1393	iron			X	mg/l			NF T90-112	0,02	
1391	Fluorine			X	mg/l			NF EN ISO10304-1 NF T90-004	1 0,02	
1372	magnesium			X	mg/l			NF T90-005	0,5	
1394	Mangan			X	mg/l			NF T90-112 NF T90-119	0,01 0,002	
1334	potassium			X	mg/l	1	2	NF T90-019 NF T90-020	0,5 0,1	
1385	selenium			X	µg/l			NF T90-025 NF T90-119	2	
1348	silica			X	mg/l SiO2			NF T90-007		
1375	sodium			X	mg/l Na	integer	3	NF T90-019 NF T90-020	0,5 0,03	
1338	sulfates			X	mg/l SO4	integer	3	NF EN ISO10304-1 NF T90-009 NF T90-040	5	
1346	TA			X	mg/l			NF T90-036	10 mg/l HCO3	
1347	TAC			X	mg/l			NF T90-036	10 mg/l HCO3	
1409	Air temperature			X	°C	integer	2			
1447	Faecal coli		X8					NF T90-413 NF T90-414		
1450	Faecal streptococci		X8					NF T90-411 NF T90-416		

Source : RNB agreement between the Ministry for the Environment and the water agencies.

Appendix 2. The main networks related to water issues currently operated in France and the associated data banks.

IIn all cases, updated information can be obtained through the National Water databank web server: **http://www.rnde.tm.fr .** Several entries provide links to services and other data banks. It is emphasised that the basin data banks are not considered separately. Those organisations that wish obtaining more details regarding the basin data banks are invited to link to the relevant web sites. Access is possible through the above mentioned web site or through the inter-basin web site **http://www.eaufrance.tm.fr**, on which all basin data banks are mentioned.

Monitoring network considered			Associated Data bank.
Field and scope	**Level**	**General description**	
Water level in rivers. Water discharge data.	National	See details in main text. Data monitoring carried out by 40 organisations. All data and data base meet SANDRE data description and organisation.	HYDRO data bank. Exists since 1971. New version released in 1998. Oldest data dated 1860. Is one of the topic banks of the BNDE. No web site. Access in client / server mode, via software installed in user's computer. The data bank service is open to individual users, who have to sign agreement and are charged according to the volume of data transferred or processed.
Information: hydro@environnement.gouv.fr		Network operational costs (per year) : 14,286,000 USD or 12,196,000 EUROS	Data bank operational costs (per year) : 387,000USD or 331,000 EUROS.
Daily rainfall	National	Rainfall data comprises physical and administrative characteristics of stations and data on rainfall levels. Around 1200 monitoring points. Different producers, mainly the national meteorological office, carry out monitoring. Two different networks : rainfall only, operated mainly by voluntary observers, Climatic network operated by civil services.	The PLUVIO databank stores the information, co-ordinates the different producers, and offers users immediate consultation of data (raw and statistics) by network transmission. Is one of the topic banks of the BNDE. No web site. Access in client / server mode, via software installed in user's computer. Access is charged for non-producers.
Information: michele.blanchard@meteo.fr		Network operational costs (per year) : a/ rainfall : 536,000USD or 457,000 EUROS, (expenses cover sensors maintenance) Climatic : 3,571,000USD or 3,049,000 EUROS .	Data bank operational costs (per year) : 269,000 USD or 230,000 EUROS
Fish population in French rivers Manage fish populations.	Region,	The network comprises 600 stations where development of fish populations and ecological value of the reach is monitored. Main outputs are the assessment of the impact of climatic events and man-made actions on aquatic environments through the use of biological indicators.	BHP data bank (under development). Is one of the topic banks of the BNDE. At the present moment, access is limited to research.
Information: erick.bagliniere@csp-rennes.environnement.gouv.fr		Network operational costs (per year) : The estimation for annual monitoring costs are 2,700,000 USD or 2,300,000 EUROS.	Data bank operational costs (per year) : 179,000 USD or 152,000 EUROS
Coastal and marine surveys. *Network and Data bank operated by IFREMER (French Institute for Research on Marine Resource Use), on behalf of the Ministry of the Environment and Ministry of Industry and Research*	National	Three national surveys are currently operated on coastal waters. Chemical monitoring is carried out in the frame of the RNO network. The first data dates from 1974. Phytoplankton monitoring, merely red tides and toxic phytoplankton early warning is carried out in the frame of the REPHY network, operated since 1987. Microbiological monitoring of see-food, mainly shellfish compliance with health standards is carried out in the frame of the REMI network, operated since 1987 as well.	Coastal marine data are all hosted in the QUADRIGE data bank, which contains most of the results of the physical, chemical and biological description parameters of the environment. Results are permanently updated. The QUADRIGE database is accessible via the QUADRIGE application which is based on client / server architecture. Client posts equipped with this application can access the server by local Ethernet network, by Internet, or by telephone line.
Information: Web site: http://www.ifremer.fr/delao/surveillance/quadrige/quadrige.htm.		Network operational costs (per year) : Not communicated	Data bank operational costs (per year) : 339,000USD or 290,000 EUROS.

Monitoring network considered			Associated Data bank.
Field and scope	**Level**	**General description**	
Ground water (elevation of the water table and chemical composition of water) Information: Web site: *http://www.rnde.tm.fr*	Basin	Under complete design changing. Former networks being replaced by a National groundwater monitoring network, operated by the Water agencies. Network operational costs (per year) : *Not yet operating*	Former data bank is ONQUES, operated by the BRGM (Geological and Mining Research Bureau). Data will be accessible near the 6 basin data banks and through the BNDE data bank. ONQUES operation was 89,000 USD or 76,000 EUROS.
Drinking water compliance with standards Information: No web site. Documentation on SISE-Eaux may be obtained by application by e-mail daniel.marchand@sante.gouv.fr:	Departmental and national	Distributed water and raw water are monitored according to the currently enforced regulations. The determinations help assessing the compliance with the standards concerning water for human use. Survey primarily concern the c.a., 2000 main "distribution units" that serve 43 million people. The frequency of sampling is less for the smallest distribution units. Up to 300 determinants may be used to assess compliance. Network operational costs (per year) are 53,571,000 USD or 45,735,000Not EUROS of which respectively 10,714,000 USD or 9,147,000 EUROS cover raw water analytical determinations. This represents about 3 US cents per cubic metre.	SISE-Eaux, operated by the Ministry for Employment and Solidarity, Secretary of State for Health/General Directorate for Health (DGS. The data bank comprises three groups of items: 1. Factual data, including the type and techniques applied to prepare water, 2. Compliance with distribution standards, 3. Raw analytical data. Data of group 3 are publicly available, with restrictions on use to avoid misuse of data. The assessment on compliance requires expertise by health services, analytical data being only one of the utilised criteria. Data bank annual operation cost not communicated.
River water quality monitoring Information: Web site: *http://www.rnde.tm.fr*	Basin	See main text dealing with the RNB (chapter 1.4, page 3) Network operational costs (per year) : 8,036,000 USD , 6,860,000 EUROS	Data hosted in each of the 6 basin banks. Data also accessible through the BNDE. BNDE operational costs are 576,000 USD or 492,000 EUROS.

No total has been calculated since many data are not available.

Appendix 3. Basic principles of the SEQ (Water Quality Assessment System)

Principles

Water quality is always an assessment that is based on a judgement. Since water quality cannot be described by a set of dimension equations, such a judgement is, without exception, a compromise between criteria, standards and subjective evaluation.

It is very important to consider the indications above that explain why so many methods of water quality assessment currently exist.

However, the meaning of the terms “water quality” can be defined as “those properties of water that fulfil intrinsic properties of water or that permit some uses of water”. Starting with this very general definition, groups of experts, working on behalf of RNDE and Water agencies, defined a new concept in water quality assessment, the SEQ. In fact, the SEQ concept is a method that leads to rationalise the use of criteria and standards that were applied without sound technical background.

Definitions

In the next sections, “criteria” means values related to any determinant that are established according to scientific evidences. For example, threshold concentrations of 0.01, 0.05, 0.1 mg P l-1, constitute a set of criteria defining 4 classes of potential eutrophication of fresh water bodies. These values represent actual limits that define phytoplanktonic growth, although they are not reported in any regulation.

On the contrary, drinking water standards stipulates that compliance requires that water must contain low pesticide levels (under 0.1µg/l for individual substances - except 0.03µg/l for some substances -, with a maximum of 0.5µg/l for the total of the detected concentrations of individual substances). These values are purely standards, since they derive entirely from the application of precautionary principle. However, close relationships may exist between criteria and standards. Most of standards are, in practice, a simplification of criteria values.

Water quality issues can be considered as depending on the respect of criteria and compliance with standards. For example, the possibility to prepare tap water from a particular resource depends on the matching between composition of raw water and plant capabilities. This is evaluated through criteria. Nevertheless, water may be prepared and distributed only if it complies with the raw water standards currently enforced.

Concepts

The SEQ approach defines indicators and water uses and functions. The SEQ indicators describe the water quality. The water quality determines the possible water uses and functions. Indicators, on the one hand, uses and functions and uses on the other hand have been precisely described and evaluated in order to limit their respective numbers. Eight indicators and 5 uses and 1 function are fully described at the present moment.

Water quality determinants are grouped together into indicators, which correspond to particular water quality themes of concern. For example, the indicator “mineral content” groups the determinants conductivity, concentration in chlorine, etc. The indicator “organic matter” groups for example BOD5, dissolved oxygen, NH4+ (considered as oxygen demander), etc.

The suitability of the water for each function and use is determined considering if the indicator is or is not relevant to this function or use and is mentioned in the double entry table on the next page.

For each indicator, the water quality is measured by a quality index, varying from 0 (the worst quality) to 100 (the best quality). This water quality index is frequently represented as a 5 classes colour chart, which correspond to the 0-20, 21-40, etc., values of the water quality index. The calculation of the index itself the SEQ system takes into account:

1. The relative importance of individual determinants
2. The frequency and seasonal differences in sampling

3. The considered function or use. Specific assessment grids have been constructed, taking into accounts the relevant criteria and standards that determine the suitability of water for these functions and uses.

The final result for each indicator corresponds to the worst quality observed in at least 10% of the samples.

Table, Appendix 3: Relevancy of indicators to functions and uses.

Indicator		**Water functions and uses**					
		Biological potential of the water	Public water supply	Recreation	Irrigation	Drinking water for animals	Fish farming
Mineral content	X7		X		X	X	X
Organic matter	X2,X3,X4	X	X				X
Nitrogen compounds	X5	X	X			X	X
Phosphorus compounds	X6	X					X
Phytoplankton	X1	X	X				X
Micro-organisms	X8		X	X	X	X	
Inorganic micropollutants		X	X		X	X	X
Organic pollutants		X	X		X	X	X

NOTE : X1 to X8, in correspondence with the name of the indicator refer to the determinants reported in the column "Complementary" of the table in Appendix 1, in which the main determinants are listed. Those determinants are not systematically measured, but their determination is strongly recommended if the SEQ is to be used.

The assessment grids that have been constructed take into account both criteria and standards. The work has been carried out by expert task groups and thoroughly checked against the monitored data. It is beyond the scope of this paper to report the sets of thresholds limits, which represent dozen of pages.

Full details are presently available only on paper reports, which can be obtained by application to the IOWater documentation office (information on the web site : http://www.oieau.fr.

The SEQ system summarised above is the water-SEQ. In fact SEQ is a comprehensive approach of global inland water quality assessment.

Considering only rivers, it distinguishes the following aspects :

1. The quality of the water (system described in this appendix),
2. The quality of the physical environment (river hydro-morphology and hydrology), that influences animal and plant habitat as well as river interactions with other environments. It may include aspects such as river banks, flow obstacles, depth of water, etc.
3. The biological quality, which can be assessed using surveys of benthic invertebrates, fish or plants. The biological quality is influenced by the quality of river water and the physical environment.

A SEQ devoted to groundwater is currently being checked and validated.

Appendix 4. National basin Network costs and financing (monitoring excluded)

These tables report the operating costs and financial resources of the RNDE for year 1998.

Expenses	**Proportion of expenses for investment**	**Proportion of expenses for operating costs**	**Total expense**	
National overview and secretariat			**USD**	**EUROS**
RNB, BNDE and RNDE secretariat				
· Project and task leaders 536 person-days j		100%	240,000	205,000
· Technicians 630 person-daysj		100%	169,000	144,000
RNDE operation		100%	391,000	334,000
SANDRE secretariat and development		100%	340,000	290,000
National publications		100%	40,000	34,000
Sub total			*1,180,000*	*1,007,000*
National databanks				
· BHP (Fish populations)	20%	80%	179,000	152,000
· BNDE (water quality and all topics)	41%	59%	576,000	492,000
· HYDRO (hydrometry)	19%	81%	387,000	331,000
· PLUVIO (rainfall)	17%	83%	269,000	230,000
· QUADRIGE (coastal data)		100%	339,000	290,000
· ONQES (old system for groundwater)		100%	89,000	76,000
Sub total			*1,839,000*	*1,571,000*
Basin data banks and overview of basin networks (dos not include monitoring)				
· Adour-Garonne basin network and data bank	70%	30%	343,000	293,000
· Artois-Picardie basin network and data bank	32%	68%	250,000	213,000
· Loire-Bretagne basin network and data bank	71%	29%	319,000	272,000
· Rhin-Meuse basin network and data bank	78%	22%	252,000	215,000
· Rhône-Méditerranée-Corse basin network and data bank	58%	42%	425,000	363,000
· Seine-Normandie basin network and data bank	40%	60%	141,000	120,000
Sub total			*1,730,000*	*1,476,000*
GRAND TOTAL	**30%**	**70%**	**4,749,000**	**4,055,000**

Sources of financing	**Proportion of contribution as cash**	**Proportion of contribution as expert time**	**USD**	**EUROS**
Adour-Garonne Water agency	77%	23%	521,000	445,000
Artois-Picardie Water agency	59%	41%	379,000	324,000
Loire-Bretagne Water agency	79%	21%	527,000	450,000
Rhin-Meuse Water agency	77%	23%	428,000	366,000
Rhône-Méditerranée-Corse Water agency	80%	20%	724,000	618,000
Seine-Normandie Water agency	95%	5%	729,000	622,000
BRGM (Geological and Mining Research Bureau)		100%	9,000	8,000
Conseil Supérieur de la Pêche (national Council for Fishing)		100%	241,000	205,000
DIREN(Some DIREN only)		100%	134,000	115,000
EDF(national electricity producer, pending)	100%	0%	32,000	27,000
IFREMER (French Institute for Research on Marine Resource)		100%	279,000	238,000
IFEN (French Institute for the Environment)		100%	13,000	11,000
Météo-France		100%	58,000	50,000
Ministry for Environment	62%	38%	529,000	452,000
Ministry for Health	Pending			
External inputs (sellings, etc.)	100%	0%	145,000	124,000
PROVISIONAL GRAND TOTAL	**66%**	**34%**	**4,749,000**	**4,055,000**

Source of data : International Office for Water (IOWater / OIEau). Provisional data.

Appendix 5. EUROWATERNET French prototype project

The objective of the EUROWATERNET European project is to implement representative networks in each Member State of the EC, or in any European State (6) volunteer to participate to the project. These networks are based on the existing networks.

The expected outputs are representative indicators of the state of river waters, lakes, etc. to calculate these indicators, it is necessary select representative sites from the existing networks and define precisely the way these indicators (yearly average, quantiles, etc.) should be computed and their precision assessed.

The EUROWATERNET French prototype project comprises several steps, the most important being the definition and calculation of the Selection criteria to characterise rivers in order to ensure the best representativity with respect to: river types, basin size, human pressures, etc.

To characterise rivers and choose points, the indicators that quantify the criteria must be derived from:

- Simple data, independent of the network,
- Data that measure permanent values or slowly changing phenomena), i.e., that represent DRIVING FORCES rather that PRESSURES.
- Data that are relevant with respect to the monitoring objectives. ,

The CORINE Land Cove GIS layer has been used to calculate the cumulated indicators of agricultural driving Forces along the river systems delimited by the c.a., 6200 elementary catchments of metropolitan France (the “hydrographic zones”). To achieve that, a first database named HYDROSOL has been calculated, by intersecting CORINE Land Cover layer with the NUTS5 layer and the Rivers catchment boundaries layer. This method, combined with population density data yielded 4 well clear-cut groups of sampling points, according to the cumulated main driving force indicator upstream each sampling point.

1. Points that are determined by elevated population density only, (‘Urban” points)
2. Points that are determined by high proportion of agricultural land only (agricultural land leading to important inputs of fertilisers),(“agricultural points”),
3. Points that are determined by both driving forces (“mixed points”),
4. Points that are determined by none of the driving forces.

The proposed network, representative of the presence of nutrients in rivers comprises 552 sampling stations selected among the 1738 monitored points of the RNB network. This selection has been carried out to by applying selection criteria calculated thanks to indicators derived from CORINE Land Cover and other sources. In particular, the repartition of chosen points all over the main basins has been considered when applying the selection criteria.

The resulting network has been used to calculate water quality statistics that demonstrate the value of the approach.

The yearly averages of nitrate, ammonium and phosphate are undoubtedly depending on the urban and agricultural driving forces. The selected stations allow calculation of statistics representing, in the given example, the annual mean of nitrate (NO3), ammonium (NH4) and soluble reactive phosphorus (“PO4”). These statistics are presented below. Points have been clustered according to the 4 Driving Forces mentioned above that represent the major potential threat on the catchment upstream a sampling points. The results are reported in the next graphs.

It can be seen that:

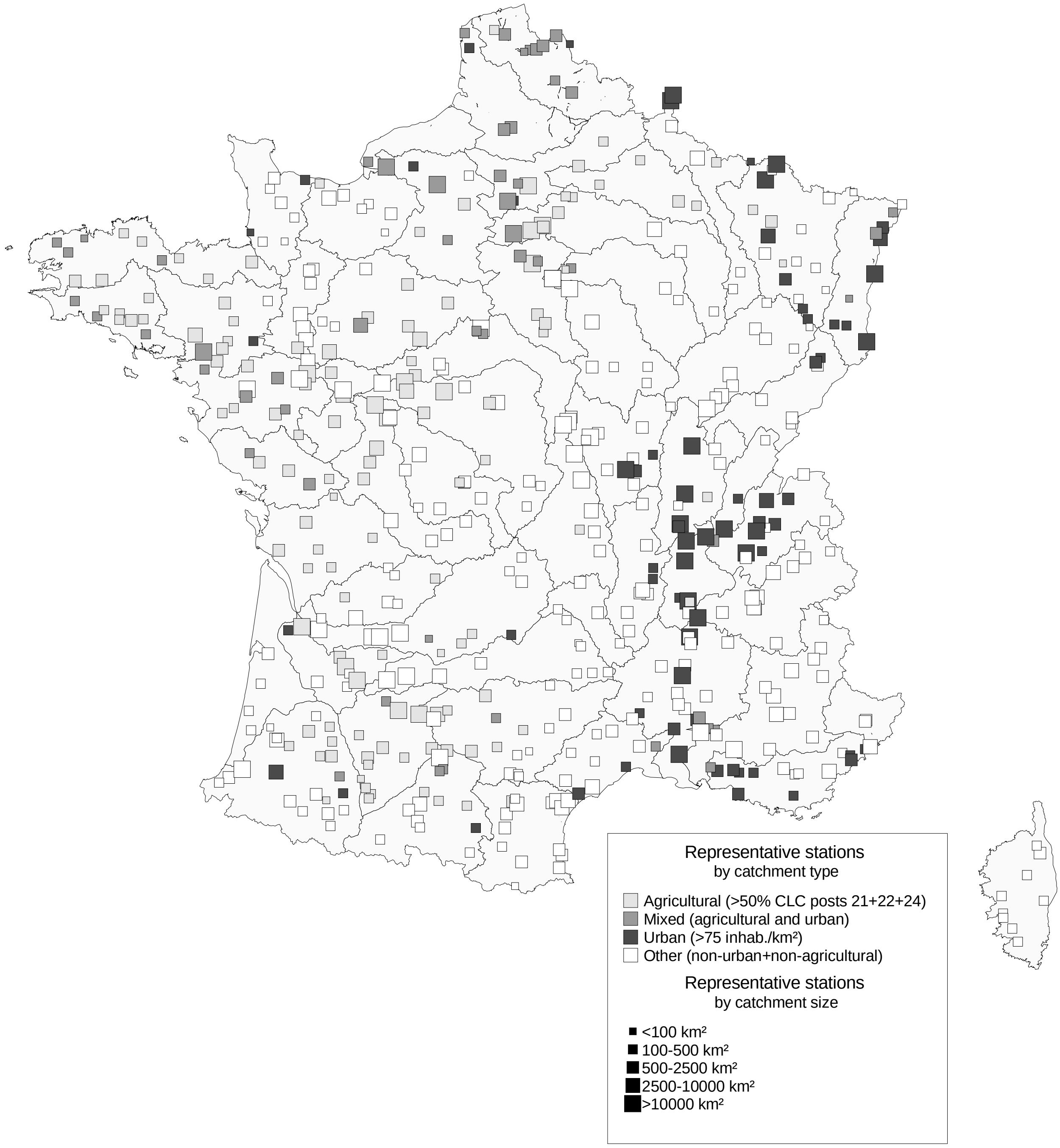
- Nitrate averages are the greatest where both driving forces are observed, still great where only agricultural DF are exerted, and lesser where only domestic DF exist.

[6] *The European Environment Agency (Web server **: http:// www.eea.dk**) operates at the European Community level and with non EC states , such as the former Eastern countries, Russian federation, etc.*

- Ammonium and phosphate averages are the greatest where both driving forces are observed, still great where only domestic DF are exerted, and lesser where only agricultural DF exist.
- In all cases, the points that are submitted to limited driving forces show low concentrations.

These rankings are in the expected order. Complementary work is on way forward to assess the statistical comparability of results among sub basins.

Map, Appendix 5. The French representative network for EUROWATERNET (provisional)



River Basin Monitoring
The Experience of China

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This paper describes the experience of China, taking the Huai River Basin as an example.

River Basin Monitoring - The Experience of China
Water Monitoring in the Huai River Basin

Abstract: With the gradual progress and intensification of water pollution prevention programmes in the Huai river basin, a combined three-part monitoring system has been implemented based on monitoring of water quality control sections (points), intakes of pollutants to rivers, and pollution sources. Water quality conditions in control sections provide a basic indicator for assessing and testing the effectiveness of water pollution prevention; pollution sources are a basic factor affecting the quality of the water environment; and river pollution intakes form a bridge between pollution sources and the water environment. The volume of pollutants discharged at river pollution intakes is the factor most directly influencing the impact of pollution on the water environment: effective monitoring of river pollution intakes enables both supervision of discharges from pollution sources and collection of comparatively reliable data on total pollutant volumes discharged and received by the river in a given region.

Keywords: Huai river basin, water quality, river pollution intakes, pollution sources, total volume control.

Over a thousand kilometres in length, the Huai rises below Taibaiding (Peak) in the Tongbai mountain range on the border between Henan and Hubei Provinces. From west to east, the river and its numerous tributaries run through the provinces of Henan and Anhui, then into Lake Hongze (Hongzehu) in Jiangsu Province, before dividing into two streams. The main channel passes through the Sanhe (Three River) Lock south of the Hongze Dam before finally flowing into the Yangtze south-east of Yangzhou; the minor channel flows through Gaoliang Lock at the Hongze Dam then passes through the Northern Jiangsu Province (Subei) Main Irrigation Canal before discharging into the Huanghai (Yellow Sea). The Huai river basin straddles the four provinces of Henan, Anhui, Jiangsu and Shandong, passing through 33 urban areas and 182 counties; the system drains an area of 270,000 sq. km. with a total population of about 150 million. The Huai basin, a fertile area rich in agricultural produce, was historically one of China's earliest centres of economic development, as echoed in the time-worn proverb 'when the harvest is ripe in Jiang-Huai (the Yangtze and Huai basins) there is plenty for all'. But with the rapid economic development and accelerating urbanisation of the last few decades, the basin has suffered ever-worsening pollution. Rapidly deteriorating water quality has become a significant factor constraining sustainable economic development of the region and is having a major impact on public health and social harmony in the population. Combating water pollution in the Huai basin has become a central focus of public concern.

THE PRESENT HUAI BASIN MONITORING SYSTEM

To strengthen water resource conservation in the Huai basin and obtain a full, timely and accurate understanding of the parameters of change in the water environment, the Huai River Water Environmental Monitoring Network was officially established at the end of 1994 under the leadership of the Supervision and Management Department of the Chinese State Environmental Protection Administration (SEPA) (formerly National Environmental Protection Agency, NEPA). The member organisations of the network include 36 provincial, municipal (-regional) and county environmental monitoring stations from Henan, Anhui, Jiangsu, Shandong and other provinces. The lead institution is the Central Environmental Monitoring Station of Henan Province, which as headquarters of the Huai basin monitoring network is also responsible for the day-to-day running and technical direction of the project. The Central Environmental Monitoring Stations of Anhui, Jiangsu and Shandong Provinces have the status of deputy lead units assisting the lead institution in the implementation of the programme. Running costs for the programme are borne by the Environmental Protection Bureaux (EPBs) of the provinces, municipalities (or municipal regions) and counties in which the network's stations are located. Pilot versions of three documents have been prepared: the 'Huai River Basin Water Environment Monitoring Network Statutes', the 'Huai River Basin Water Environment Monitoring Network Project Outline', and the 'Huai River Basin Water Environment Monitoring Network Technical Regulations for Compilation of Reports'.

With the continuing intensification of water pollution prevention programmes, the demand for water quality monitoring is also growing steadily. The past four years of exploratory and practical work have led to the creation of a ‘three-in-one’ water quality monitoring system in the basin, based on water quality control sections (or points), intakes of pollutants to rivers, and pollution sources.

Water quality monitoring as the basic indicator for testing impact of pollution control measures

The Huai river system comprises numerous tributaries; its northern and southern watersheds, which are highly asymmetrical, contain 38 major tributaries feeding the mainstream. To conserve areas which are sources of drinking water, control water quality in sections across provincial boundaries and effluents discharged by cities and townships, and enable targeted water quality monitoring and control, 82 water quality control sections (28 of which cross provincial boundaries) have been designated basin-wide. Based on current requirements for water characteristics and total volumes to be controlled, the following parameters have been selected for mandatory determination: total flow volume, water temperature, pH, dissolved oxygen, permanganate index, COD_{Cr}, nitrate-nitrogen, nitrite-nitrogen, non-ionised ammonia and volatile phenols (10 values in all). The following values may also optionally be determined: cyanide, arsenic, total mercury, valency-6 chromium, cadmium, and BOD_5. Testing is carried out between the 1st and 5th of each month, i.e. 12 times per annum. At present, monitoring and sample analysis still rely on the traditional methods of manual sample collection by personnel and chemical testing with laboratory instrumentation.

Supervision and monitoring of industrial pollution sources

Industrial pollution is one source of water pollution, and was the main cause of pollution in the Huai river basin up to 1997. Accordingly, the objective of the first phase of the Huai basin clean-up programme has been to reduce discharges by enterprises releasing more than 100 tons of pollutants down to this maximum permitted level by the end of 1997. Following this first phase (dubbed ‘Target 97’) the two main objectives with regard to industrial pollution sources have been: firstly, to intensify supervision and monitoring, and verify that clean-up measures for these sources were proceeding correctly; and at the same time, to control and continue to reduce total discharge volumes in sections which have not achieved the target. This requires monitoring of pollutant concentrations and total effluent volumes discharged from industrial enterprise sources, from which a total discharged volume of pollutants W_i can be computed.

Formula for calculating total discharged volume of a given pollutant from an industrial pollution source:

(1) $W_i = C_i \times Q_i$

where W_i : total amount of a given pollutant discharged from a given outlet

C_i : average concentration of a given pollutant in discharge

Q_i : average volume of effluent discharged from the outlet concerned

At present, since the main factor to be controlled in the Huai basin is chemical oxygen demand, supervisory monitoring of industrial pollution sources is aimed mainly at flow volumes and COD. Currently, apart from the proportional sampling and laboratory analysis methodology used by a few enterprises (like the Zhoukou monosodium glutamate production plant) the vast majority of enterprises are still using the conventional method of sample collection by personnel followed by laboratory testing.

Monitoring of river pollution intakes

‘River pollution intakes’ were mentioned for the first time in the General Programme and Implementation Schedules [see below]. Monitoring began in November 1997. The concept of river pollution intakes is new to environmental monitoring personnel, and many problems have arisen in connection with the interpretation of the concept and for monitoring in practice. In what follows, the authors offer a detailed presentation of various aspects of river pollution intake monitoring, based on their own understanding and practical experience.

ROLE OF RIVER POLLUTION INTAKES IN THE MONITORING OF TOTAL FLOW VOLUMES

Definition of 'river pollution intakes'

The term 'river pollution intakes' does not appear in the [Chinese] Dictionary of Environmental Science. On the basis of practical experience, it can be defined as a composite of two terms: 'river intake', equivalent to the term 'river mouth' in the sense given in the Dictionary, 'a point at which a stream discharges into the sea, a lake or a major watercourse.' The second component, 'pollution intake', can be defined as an outlet from which polluted effluent is discharged to a river or body of water from a pollution source. The composite term can thus be defined as 'an outlet from which pollutant effluent is discharged directly from a pollution source to a river (body of water)'. At present, with the exception of a few minor tributaries near the headwaters, the vast majority of streams and courses in the basin are recipients of pollution. We therefore treat a stream receiving polluted effluent from different sources as a single source, and the point at which it discharges into the mainstream as a 'river pollution intake'. By the same criterion, municipal discharges also fall within this category.

River pollution intakes can be classified into three types on the basis of this definition:

- discharges of combined tributary streams;
- direct discharges from the pollution source;
- municipal waste discharge points.

River pollution intakes are further defined according to three criteria:

- river discharge: they discharge directly into the target watercourse;
- pollutant discharge: they discharge a minimum volume of pollutants;
- relative to needs: target watercourses and river pollution intakes are mutually defined relative to management requirements, i.e. a given watercourse may be managed as a river pollution intake over a given period, or at a given management level, but as a target watercourse at another time, or at a different management level.

River pollution intakes and the water environment

Pollution is a basic factor affecting the quality of the environment. At present, the priority in the control of total volumes is to determine the effect of basin pollution sources both individually and collectively, and how and through what channels pollutants enter the watercourses, in order to form a basis for accurate assessment of the current total volumes of pollutants and of the total amounts discharged into the river. Classification of pollution sources by spatial distribution of the pollutants discharged yields three broad types: point sources, surface (flat) sources and linear sources. Figure 1 shows the regional pattern of pollution sources.

Figure 1. **Analytic table of pollution sources in the Huai river basin**

Pollution sources basin-wide:

'point' sources	industrial residential and domestic other (e.g. livestock, animal husbandry)
'surface' sources	mostly from chemical pesticides and fertilisers
'linear' sources	mostly from traffic and transportation

Experience teaches that during the rainy season, nearly half of all water environment problems stem from non-point sources, and that China still faces considerable difficulty in effectively controlling surface (flat) and linear pollution sources. Industrial pollution sources include township and village enterprises (TVEs), which have certain specific characteristics: they are numerous, small-scale and unstable, and frequently discharge effluent intermittently and irregularly. At present, TVE discharges generally escape effective monitoring and management. Domestic effluent discharge volumes are proportional to the number of urban outlets, and to the average daily per capita discharge; provisional estimates can be computed using statistical methods. Among other pollutant effluents, discharges from the livestock industry and animal husbandry deserve special attention: research shows that the COD due to effluent from these activities in a few major cities already exceeds that of a population of 30-40 million people, and is already the largest pollution source in cities outstripping the pollution generated by domestic-residential and industrial effluents (Fu 1997). We still have very little data on this component of pollutant volumes and its proportional contribution to urban effluents.

Due to the present inadequacy of China's environmental monitoring capabilities and management methods, it is very difficult to obtain an accurate picture of the total volumes discharged from different pollution sources. However, on the basis of past experience we can say that pollution from the great majority of sources enters a given stretch of river through some river pollution intake which thus acts as a bridge between the pollution source and the water environment. The volumes entering the river system through such intakes are therefore the main contributing factor to the impact of pollution on the water environment. For this reason, we use river pollution intake monitoring as a method of determining the total pollution load on a given target watercourse, while at the same time using the data on volumes discharged from such intakes together with any clear data on waste from industrial municipal sources, and statistical estimates of domestic effluent levels, as a basis to infer the residual volume from sources for which no data is available.

River pollution intakes and pollution sources: quantitative and qualitative relationships

Calculation of pollutant volumes discharged to river

The pollution load discharged to the river from a given intake (L_i) can be calculated from actually measured values as follows:

(2) $$L_i = C_i \times Q_i$$

where L_i : total volume of a given pollutant discharged from a given intake in a given time period
C_i : average concentration of a given discharged pollutant over a given period
Q_i : average flow volume from a given intake over a given period.

Relationship between pollution sources and volume of pollutants discharged to river

In addition to calculation from actual measured values, the quantity of pollutant discharged from a river pollution intake can also be derived statistically from the volumes discharged by pollution sources. Outside irrigation and high-water (flood) seasons, the following formula can be applied:

(3) $$L_i = \sum_{i=1}^{n} W_i K_i$$

where W_i : volume of a given pollutant discharged by a given industrial pollution source
K_i : coefficient of impact, for a given pollutant from a given industrial pollution source, from the point of discharge at the pollution source to the point of discharge of the pollutant to the river;
n: number assigned to industrial pollution source

During irrigation and high-water seasons, surface (flat) sources play a role, so that

(4) $$L_i \geq \sum_{i=1}^{n} W_i K_i$$

(where symbols represent the same values as in equation (3))

Quantitative and qualitative relationship between river pollution intakes and the water environment

The volume of pollutant transiting a given control section in a watercourse can be calculated on the basis of river pollution intakes. This ‘throughput volume’ (V) refers to the quantity of pollutants transiting a given target water quality control section within a given period. There are two methods for computing V; one through actual on-site measurement, whereby

$$(5) \quad V_i = C_i \times Q_i$$

where V_i : volume of a given pollutant transiting a given water quality target section
C_i : concentration of pollutant
Q_i : water flow through the target section

The other method of calculation is as follows:

$$(6) \quad V_i = V_{i-1} \times K_{i-1} + \sum_{i=1}^{n} L_i \times K_i$$

where V_{i-1} : volume of the pollutant transiting the upstream section
K_{i-1} : pollutant impact coefficient from the upstream section to this monitored section
L_i : volume of the pollutant discharged from river pollution intakes between the upstream section and this target section
K_i : pollutant impact coefficient from this river pollution intake to the target section

From formulae (5) and (6) we obtain:

$$C_i \times Q_i = V_{i-1} \times K_{i-1} + \sum_{i=1}^{n} L_i \times K_i$$

hence

$$(7) \quad C_i = \frac{V_{i-1} \times K_{i-1} + \sum_{\underline{i=1}}^{n} L_i \times K_{i} \ \ (i = 1)}{Q_i}$$

By formula (9) [*sic*] we know that the concentration of water quality [*sic*] in a given section and the pollutant concentration in the upstream section are directly proportional to the volume discharged into the river from intakes between the two sections.

River pollution intake management and supervisory monitoring

Most Chinese rivers are long, rising in remote regions, have numerous tributaries, and cross several administrative jurisdictions, posing a challenge for identifying and managing river pollution intakes. In the authors’ view, management should be organised at different levels. Responsibility for particular target watercourses should first be assigned to either State, provincial (city in the case of directly administered cities), municipal-regional, or county authorities on the basis of the quantities of pollutants discharged to the river in each jurisdiction, as far as such can be clearly distinguished, then the river pollution intakes for a given target watercourse should be assigned to each administrative level. Stratified management should reduce the workload at each management level, while fully utilising the resources and maximising the impact of efforts at each level.

Once river pollution intakes are defined, monitoring should be conducted at set intervals to provide a basis for management policy decisions:

- *Definition of monitoring frequency*: in the initial stage this should be co-ordinated with water quality monitoring, in order to identify the river pollution intakes with the most impact on water quality, and intensify supervisory monitoring on these intakes. Monitoring frequency on other intakes can then be reduced.
- *Definition of monitoring programmes*: flow volume and major control factors for the current phase (e.g. in the Huai river basin, chemical oxygen demand (COD)).
- *Definition of monitored sections*: the circumstances of discharge into the river from different pollutant intakes are complex; sections should be located where there is no backflow in the target watercourse, nor any other combined inflows from pollution sources.

CORROBORATION OF ON-SITE MEASUREMENTS

The 'Huai River Basin Pollution Prevention Plan General Programme and 9th Five-Year Plan Implementation Schedules' define 169 river pollution intakes in the Huai basin as being within the jurisdiction of Henan Province, but the target watercourses into which they discharge are not clearly defined. These should be unambiguously defined as 'pollution outlets', since present statistical estimates of pollutant amounts discharged into the river and the system and basin as a whole based on these 169 points contain duplications, and hence do not reflect reality. Henan Province has therefore conducted a fresh survey and definition of river pollution intakes within its jurisdiction according to the description and definition criteria presented above. In line with State policy, a total of 85 river pollution intakes within the Henan provincial area, located in State-level target watercourses containing 19 water quality target sections, are assigned to State-level control. Reconciling central government requirements and criteria for distinguishing municipal and regional spheres of responsibility, 95 river pollution intakes have been assigned to provincial-level control. Municipal regions within the Henan provincial jurisdiction have assigned other river pollution intakes to municipal-regional level control as required.

CURRENT ISSUES AND RECOMMENDATIONS

- At present the definition of 'river pollution intakes' is still fuzzy. In current practice the notions of 'pollution outlet' and 'river pollution intake' are often confused. The concept of 'pollution outlet' relates to the control of the volume of pollutants discharged from a given source, which is not necessarily discharged directly into the river; whereas the 'river pollution intake' relates to the control of the volume of pollutants discharged into a given target section of river from a direct outlet into the river.
- Extrapolation of the volume of pollutants discharged over a period from the volume of instantaneous discharges does not accurately reflect the reality of discharges. The present conversion method, by which total discharges from pollution sources or river pollution intakes over a given period are calculated by multiplying the volume of instantaneous discharges by a time period, cannot reflect the true situation regarding discharges. As monitoring is steadily intensified in the Huai river basin, proportional sampling and linear monitoring instruments will need to be gradually introduced for monitoring enterprise discharge points and river pollution intakes. Standardisation of industrial pollution sources (outlets) is currently in progress, but there has not yet been any pressure for standardisation of river pollution intakes. However, both for the purpose of present measurement of flow volumes, and in anticipation of the future use of proportional sampling and linear monitoring apparatus, it is recommended that standardisation of river pollution intakes be addressed in the next phase of work.
- Improved methods for identification of river pollution intakes.

River pollution intakes form a bridge between pollution sources and the water environment. Effective monitoring of river pollution intakes contributes both to effective supervision of pollution sources and to obtaining relatively reliable values for pollutant flow volumes and amounts discharged to the river in a particular region. River pollution intakes therefore currently provide the basis for control of total pollution volumes.

River pollution intakes should be managed at different administrative levels. The lower the administrative level, the greater will be the number of direct pollution outlets, and the fewer the number of river intakes combining several pollution sources. Among river intakes under the control of Level 4 stations, the majority may be direct outlets from pollution sources. Level 4 stations therefore play the most direct role in the supervisory management of pollution sources: their quantitative measurements must therefore be authenticated in order to enable supervisory monitoring of the specific pollution characteristics of areas under their jurisdiction.

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PART III. AIR MONITORING

Nationwide Air Monitoring
The Experience of China

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This paper describes the experience of China in the field of acid deposition and ambient air quality monitoring.

Nationwide Air Monitoring
The Experience of China

INTRODUCTION

In order to contain pollution by acid rain and sulphur dioxide, the Standing Committee of the National People's Congress particularly specified the delineation throughout the country of an Acid Rain Control Zone and Sulphur Dioxide Pollution Control Zone (hereinafter abbreviated to "Two Control Zones") in August 1995 in the "Atmospheric Pollution Prevention and Treatment Law". In January 1998 the Two Control Zones Delineation Plan drawn up by the National Environmental Protection Bureau was approved for implementation by the State Council in State/Letter No. 5 [1998]. In that plan the National Environmental Protection Bureau clearly pointed out: "In order to gain a timely understanding and mastery of the dynamics of SO_2 pollution and acid rain control, and in order to provide a scientific basis for government policy, we should establish SO_2 and Acid Rain Monitoring Networks". The National Environmental Protection Headquarters Bureau requested in the "National Environmental Monitoring Requirements for the Second Half of 1998" that "In the Two Control Zones authorised by the State Council, we must construct a Two Control Zones environmental monitoring network and expand the work as rapidly as possible".

The National Environmental Air Quality Monitoring Network and Acid Rain Monitoring Network established and implemented in 1992 are currently playing a major role in reflecting environmental air quality and acid rain pollution in our country, but with a gradual deepening of environmental management, it is already difficult for the existing monitoring networks to form national and environmental regional systems and so provide complete monitoring information. They cannot scientifically and accurately reflect national and regional environmental quality and changing trends therein. In the new situation it is therefore necessary to make clarification of national and regional environmental quality and changing trends therein the objective. We must unify planning, comprehensively adjust the existing monitoring networks and systematically plan and establish the monitoring tasks and monitoring technology used by each National Environmental Monitoring Network station, based on developments in monitoring technology and the requirements of environmental management.

Based on the dual requirements described above while also taking into consideration the fact that there is no contradiction between the monitoring objectives of the Environmental Air Quality Monitoring Network and Acid Rain Monitoring Network of the Two Control Zones on the one hand and the objectives of the National Environmental Monitoring Network on the other, we propose combining the construction of an environmental monitoring network for the Two Control Zones with the adjustment of the National Environmental Monitoring Network to form a new National Environmental Monitoring Network. The Environmental Air Quality Monitoring Network and Acid Rain Monitoring Network of the Two Control Zones will become parts of the National Environmental Air Quality Monitoring Network and the National Acid Rain Monitoring Network respectively.

ACID RAIN MONITORING NETWORKS

Historical review of acid rain monitoring networks in this country

The work of monitoring acid rain in this country began in the late 1970s and early 1980s with the monitoring of the acidity of precipitation in some cities, and in 1984 an acid rain survey was developed in some regions throughout the country, but this did not constitute a nationwide acid rain monitoring network, and problems existed. For example, the distribution of network nodes covered a small area, sampling and analytical methods were not unified, and data processing methods were not consistent. The following main National Acid Rain Monitoring Networks have been established through research and synchronised monitoring across the whole country since 1985:

- In 1985 our country's first research national precipitation monitoring network was completed, based on the research theme of "The Source and Effects of Acid Rain in Our Country and Measures for Controlling It" agreed between the National Science Committee and the National Environmental Protection Bureau. This included 189 measuring stations and 533 sampling points in 27 provinces, cities and autonomous regions. Through a year's unified monitoring, the distribution of acidity of precipitation in this country and the state of acid rain pollution were basically clarified.
- The "85" National Science and Technology Key Project "Research into the Pattern of Temporal and Spatial Distribution of Acid Precipitation in Our Country" established a national acid precipitation research monitoring network of 261 measuring stations in 1992 (including 86 measuring stations of the Environmental Monitoring Department, 94 measuring stations of the Water Conservancy Department and 81 measuring stations of the Meteorology Department). Its objective through monitoring for one year (3 years for some of the measuring stations) was to clarify the current situation and trends of acid precipitation in our country and provide the necessary data for analysing the sources and causes of acid precipitation, establishing an acidic pollutant transportation model and acid precipitation pollution prevention and treatment measures.
- In 1992, measuring stations in the National Environmental Quality Monitoring Network specified in Environmental Monitoring Document 142 of the National Environmental Protection Bureau "Notification on Adjustments to the National Environmental Quality Monitoring Network" undertaking the task of acid rain monitoring (hereinafter abbreviated to "National Acid Rain Control Network") included 113 measuring stations in 30 provinces, cities and autonomous regions (see Figure 1 for the distribution of their locations). Currently, apart from a few measuring stations, acid rain monitoring and the reporting of monitoring data has basically been developed in accordance with national requirements.

Regional characteristics of acid rain pollution

There are significant differences in the annual mean pH value of precipitation and the frequency of acid rain between the Acid Rain Control Zone and other areas. The statistical results of the monitoring data for 1995 show that the mean annual pH < 5.6 for 13% of measuring stations outside the Acid Rain Control Zone, while the mean annual pH < 5.6 in 62% of the measuring stations in the Acid Rain Control Zone; 66.1% of measuring stations outside the Acid Rain Control Zone had an acid rain frequency of 0, while 92.2% of measuring stations in the Acid Rain Control Zone monitored acid rain.

Judged from the point of view of the distribution characteristics of mean annual pH of precipitation in the Acid Rain Zone, acid rain pollution is most severe in the two strips of Hunan, Guangdong and Jiangxi, and Sichuan, Chongqing and Guizhou, and there were significant differences between them and other regions within the Acid Rain Zone. Only 18.7% of measuring stations in the areas of Hunan, Guangdong and Jiangxi showed a mean annual pH > 5.6; only 7.7% of measuring stations in the area of Sichuan, Chongqing and Guizhou showed a mean annual pH > 5.6; while 51.8% of measuring stations in other regions of the Acid Rain Zone apart from the above-mentioned two strips had a mean annual pH > 5.6. Judged from the acid rain frequency distribution characteristics, the same pattern applies, and the two strips of Hunan, Guangdong and Jiangxi and Sichuan, Chongqing and Guizhou had more serious acid rain pollution than other regions.

There are also significant differences in the degree of acid rain pollution in areas not in the Acid Rain Zone, and judging from the characteristics of mean annual pH of precipitation and acid rain frequency distribution, pollution is more serious in areas around the Acid Rain Zone.

Design plan for national Acid Rain Monitoring Network

General principles

- Objective in establishing this country's Acid Rain Monitoring Network: to provide technical support for the accurate and timely mastering of the acid rain pollution situation and developmental trends inside and outside the Acid Rain Control Zone in this country and for the control and management of acid rain pollution in this country, in accordance with the national control objectives for the Two Control Zones.

- Tasks of this country's Acid Rain Monitoring Network: on the basis of unified monitoring methods and technical requirements, to develop routine monitoring of the acidity and chemical composition of precipitation, to report monitoring results, write annual reports; and to develop research into acid precipitation and analysis of its effects.

Principles for siting of national Acid Rain Monitoring Network stations

- The distribution of Acid Rain Monitoring Network stations should as far as possible cover all provinces and regions throughout the country, including all areas throughout the country having typical geological, climate, social and environmental characteristics. They should have a uniform spatial distribution and be regionally representative. They should to a certain extent be capable of reflecting the characteristics of national distribution and regional distribution of acidity of precipitation in this country;
- Emphasis is placed on consideration of the coverage of distribution of measuring stations within the Acid Rain Control Zone, that is to say consideration of the uniformity of spatial distribution. Consideration also has to be given to the selection of sufficient representative measuring stations between areas having different precipitation pH and acid rain frequency data;
- They should be more closely spaced in areas of severe acid rain pollution within the Acid Rain Control Zone, and importance is placed on the location of measuring stations in the regions bordering and close to the Acid Rain Control Zone;
- In order to reflect to a fairly large degree the characteristics of changes in the acidity of precipitation, background stations should be placed in regions which do not suffer localised environmental effects;
- In accordance with Environmental Monitoring Document 142 of the National Environmental Protection Bureau, the existing "National Acid Rain Control Network" stations will all be incorporated in the National Acid Rain Monitoring Network;
- Consideration should be given to the conditions at a station location, including regional characteristics, communications, the foundation for acid rain monitoring work and the feasibility of implementing monitoring;
- The different functions and tasks of each monitoring station are to be determined according to the distribution and monitoring capability of the various measuring stations in the National Acid Rain Monitoring Network.

Determination of number and locations of measuring stations in the national Acid Rain Monitoring Network

Acid Rain Control Zone

<u>Basic situation regarding the Acid Rain Control Zone:</u>

The planned Acid Rain Control Zone approved by the State Council covers the 14 provinces, directly governed cities and autonomous regions of Jiangsu, Anhui, Zhejiang, Jiangxi, Fujian, Hubei, Hunan, Guangdong, Guangxi, Guizhou, Yunnan, Sichuan, Chongqing and Shanghai, and its surface area is approximately 800,000 km^2. It accounts for approximately 8% of the total area of the country and, according to statistics on administrative boundaries, includes 572 large, medium and small towns at county level and above, two directly governed cities, 105 regional level cities (or county level cities and towns within regions) and 465 other county level cities and towns.

As stipulated in Environmental Monitoring Document 142 [1992] of the National Environmental Protection Bureau, there are currently 113 "National Acid Rain Control Network" measuring stations, of which 48 are located in the Acid Rain Control Zone. They include two directly governed cities, 45 regional level cities (or county level cities and towns in regions), one subordinate district of a directly governed city (Fuling District of Chongqing). Within the Acid Rain Control Zone there are 60 measuring stations in regional level cities (or county level cities and towns within regions) which have not yet been listed under the "National Acid Rain Control Network".

Acid rain monitoring network of the Acid Rain Control Zone:

According to the principle whereby Acid Rain Monitoring Network measuring stations should have a uniform spatial distribution and be regionally representative, and that they should be appropriately closer in the Acid Rain Control Zone, they are so placed that one monitoring station covers approximately 5000 km^2, with a total of 158 measuring stations (see Table 1).

When placing the stations, consideration should first be given to bringing all of the "National Acid Rain Control Network" measuring stations in the Acid Rain Control Zone and all measuring stations at regional level and above within the National Acid Rain Monitoring Network, totalling 108 (apart from Fuling District of Chongqing, the other "National Acid Rain Control Network" measuring stations are all at regional level or above); secondly, according to the uniformity of spatial distribution and regions where acid rain pollution is relatively severe, 50 county level measuring stations in the Acid Rain Control Zone are to be selected for inclusion in the National Acid Rain Monitoring Network.

Outside the Acid Rain Control Zone

Basic situation regarding areas outside the Acid Rain Control Zone:

Areas outside the Acid Rain Control Zone include the whole of the17 provinces, directly governed cities and autonomous regions of Heilongjiang, Jilin, Liaoning, Hebei, Shandong, Shanxi, Henan, Hainan, Inner Mongolia, Shaanxi, Ningxia, Gansu, Qinghai, Xinjiang, Tibet, Beijing and Tianjin , together with some areas in provinces/regions within the Acid Rain Control Zone, accounting for approximately 92% of the total area of the country.

As specified in Environmental Monitoring Document 142 [1992] of the National Environmental Protection Bureau, there are 65 "National Acid Rain Control Network" measuring stations outside the Acid Rain Control Zone.

Acid Rain Monitoring Network outside the Acid Rain Control Zone:

According to the principle whereby Acid Rain Monitoring Network measuring stations should have a uniform spatial distribution and be regionally representative, there are to be 76 measuring stations outside the Acid Rain Control Zone (see Table 1).

When placing the stations, consideration should firstly be given to bringing all the 65 "National Acid Rain Control Network" measuring stations not in the Acid Rain Control Zone into the National Acid Rain Monitoring Network (including 3 background stations). Secondly, 11 measuring stations (including one background station) are to be located in the areas bordering and close to the Acid Rain Control Zone, according to the degree of severity of acid rain pollution as historically monitored (mainly based on the 1995 data) and to reflect the changing situation in acid rain polluted regions surrounding the Acid Rain Control Zone.

Siting of background stations

Acid Rain Control Zone:

Three background stations are to be located at Emei Shan in Sichuan Province, Hengshan in Hunan Province and Huangshan in Anhui Province respectively.

Outside the Acid Rain Control Zone:

The ecological stations in the original "National Acid Rain Control Network" at Lijiang in Yunnan Province, Wuyi Shan in Fujian Province and Fusong in Jilin will be retained as 3 background stations, to which will be added the background station at Fanjing Shan in Guizhou Province in the Mufang Plan, making a total of 4 background stations.

Table 1. **Number and Distribution of Measuring Stations in the National Acid Rain Monitoring Network**

Province/ Region	Acid Rain Zone	Non-Acid Rain Zone	Total	Province/ Region	Acid Rain Zone	Non-Acid Rain Zone	Total
Jiangsu	10	2	12	Heilongjiang	/	6	6
Anhui	8	4	11	Jilin	/	5	4
Zhejiang	12	2	14	Liaoning	/	4	4
Jiangxi	10	2	12	Hebei	/	3	3
Fujian	11	1	12	Henan	/	4	4
Hubei	12	2	14	Shandong	/	6	6
Hunan	19	2	21	Shanxi	/	3	3
Guangdong	22	1	23	Inner Mongolia	/	2	2
Guangxi	11	2	13	Shaanxi	/	4	4
Guizhou	8	3	11	Ningxia	/	2	2
Yunnan	9	4	13	Gansu	/	2	2
Sichuan	20	1	20	Qinghai	/	2	2
Chongqing	5	1	6	Hainan	/	2	2
Shanghai	1	/	1	Xinjiang	/	1	1
Beijing	/	1	1	Tibet	/	1	1
Tianjin	/	1	1	Total	158	76	234

Determination of number of measuring points and point locations in National Acid Rain Monitoring Network measuring stations

Number of measuring points

- Generally speaking one sampling point should be established in the suburbs of large and medium cities with a population of over 500,000, and 2 sampling points should be installed in the urban area; for small cities with a population of under 500,000, one sampling point should be installed in both the suburbs and the urban area; and just one sampling point can be installed in the outlying districts of ordinary county level cities.
- It is estimated that the National Acid Rain Monitoring Network will consist of 234 measuring stations with a total of 458 measuring points.

Location of measuring points

- Sampling points should as far as possible be located away from localised sources of pollution such as those releasing acid, alkali and dust, and they should avoid the effects of pollution from traffic on main roads. The surroundings of sampling point should be open, avoiding trees and buildings capable of adsorption. The horizontal angle between the sampling intake direction and surrounding buildings should not be less than 30°.
- The ground around sampling points should as far as possible be lawn to avoid the effect of localised dust raising. The sampling intake should be over 1.2 m above the foundation surface.
- Measuring points for regional background stations should be sited over 100 km from major pollution sources, and the ground surrounding measuring points must have a high proportion of plant cover.
- In order to preserve the continuity and comparability of sample collection, once the location of sampling points has been determined, it should not lightly be changed.

Subjects for monitoring and monitoring frequency

pH value and amount of precipitation:

All National Acid Rain Monitoring Network measuring stations (points) should carry out measurement as and when there is rain, and when there is continuous rain for over 24 hours, one rain sample is to be collected each 24 hours for monitoring analysis;

Electrical conductivity, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Ca_2^+, Mg_2^+, K^+, Na^+ indices:

All measuring stations at directly governed city and regional (city) level and the 7 background measuring stations (totalling 180 measuring stations) within the National Acid Rain Monitoring Network are to select a rain sample from when the amount of rainfall was fairly high for each month in which there is precipitation, and they must carry out a single measurement for all the 9 subjects mentioned above;

Depending on their working capability, some or all of the subjects may be selected for measurement at measuring points controlled by county level measuring stations, and the monitoring frequency can be determined as a matter of discretion.

Complete monitoring technology

Sampling

The collection and storage of rainwater samples is to be carried out as required by the National Standard "Collection and Storage of Atmospheric Precipitation Samples GB 13580.2-92".

Sample collector

The collection of rainwater samples can be by means of an automatic precipitation sample collector or a polythene cylinder (upper mouth diameter 40 cm, height 20 cm). Collection of dew samples may be by a polythene container with an upper mouth diameter of over 60 cm. (It is recommended that an automatic precipitation sample collector is used wherever possible at all measuring points within the National Acid Rain Monitoring Network).

Sampling method

Each precipitation sample should be collected from the beginning of precipitation to the conclusion of the precipitation process. If there are several precipitation processes in the course of a day, the samples collected from several precipitation processes may be combined in one sample for measurement. If there is continuous precipitation for several days, the sample collected each day between 8:00 am to 8:00 am the following day can serve as a single sample for measurement.

The properly collected sample should be transferred to a clean and dry polythene bottle, which is sealed and stored at 4°C. The sample bottle is also to be labelled and given a serial number, and the sampling location, date, starting and finishing time, and amount of precipitation are also to be recorded.

Monitoring analysis methods

See Table 2 - Precipitation Monitoring Analysis Methods - for the monitoring analysis methods to be used when monitoring of precipitation is carried out by National Acid Rain Monitoring Network measuring stations.

Table 2. **Precipitation Monitoring Analysis Methods**

Monitoring Subject	Analysis Method	Method Source
Electrical conductivity	Atmospheric precipitation conductivity measurement method	GB 13580.3-92
pH	Atmospheric precipitation pH measurement -electrode method	GB 13580.4-92
SO_4^{2-}	Ion chromatography, atmospheric precipitation sulphate measurement	GB 13580.5-92, GB 13580.6-92
NO_3^-	Ion chromatography, atmospheric precipitation nitrate measurement	GB 13580.5-92, GB 13580.8-92
Cl^-	Ion chromatography, atmospheric precipitation chloride measurement	GB 13580.5-92, GB 13580.9-92
NH_4^+	Atmospheric precipitation ammonium salt measurement	GB 13580.11-92
Ca_2^+, Mg_2^+	Atomic absorption spectroscopy	GB 13580.13-92
K^+, Na^+	Atomic absorption spectroscopy	GB 13580.12-92

National Acid Rain Monitoring Network measurement station instrumentation

Sampling equipment

The equipment listed below is essential equipment for all National Acid Rain Monitoring Network measuring stations and measuring points:

- Automatic precipitation sample collector or polythene container. (It is recommended that an automatic precipitation sample collector is used wherever possible at all measuring points within the National Acid Rain Monitoring Network);
- Rainfall measuring cylinder.

Equipment for laboratory analysis

The equipment listed below is essential equipment for all National Acid Rain Monitoring Network measuring stations:

- pH meter;
- Rainfall gauge.

The equipment listed below is essential equipment for all regional and city level measuring stations in the National Acid Rain Monitoring Network:

- Conductometer;
- Spectrophotometer;
- Ion chromatograph;
- Atomic absorption spectrophotometer.

Data processing and data transmission equipment

Feasibility study on the implementation of the National Acid Rain Monitoring Network plan

National Acid Rain Monitoring Network plan and comparison with other networks

Comparison with the nationally existing 1992 "National Acid Rain Control Network"

The "National Acid Rain Control Network" had a total of 113 acid rain monitoring stations, all of which are brought into the National Acid Rain Monitoring Network.

Comparison with this country's first research national precipitation monitoring network of 1985

That network had a total of 189 acid rain monitoring stations, of which 77 were within the Acid Rain Control Zone, and 112 were not located in the Acid Rain Control Zone. Of the 77 measuring stations in the Acid Rain Control Zone, 70 overlapped with measuring stations in the National Acid Rain Monitoring Network. Of the 112 measuring stations not in the Acid Rain Control Zone, there were 42 which overlapped with the National Acid Rain Monitoring Network.

Comparison with the National Acid Precipitation Research Monitoring Network of 1992

In that network there were 81 acid rain monitoring stations of the Meteorology Department, of which 26 were located within the Acid Rain Control Zone, and 55 were not located in the Acid Rain Control Zone. Of the 26 measuring stations in the Acid Rain Control Zone, apart from the two measuring stations at Lushan and Jianan, the remaining 24 measuring stations overlapped with measuring stations of the National Acid Rain Monitoring Network; of the 55 measuring stations not in the Acid Rain Control Zone, there were 28 which overlapped with the National Acid Rain Monitoring Network.

In that network there were in total 180 acid rain monitoring stations of the Environmental Protection and Water Conservancy Departments. 93 of the measuring stations were located within the Acid Rain Control Zone, of which 39 measuring stations overlapped with measuring stations of the National Acid Rain Monitoring Network, while of the 87 measuring stations not located in the Acid Rain Control Zone, 15 overlapped with the National Acid Rain Monitoring Network.

Technical feasibility of implementation of Acid Rain Monitoring by each measuring station in the National Acid Rain Monitoring Network

Monitoring technology

There are already national standard sampling and analysis methods for acid rain monitoring, including the collection and storage of precipitation samples and measurement of the conductivity and pH of precipitation as well as the measurement of all the various anions in the precipitation. The numbers of the standards are GB 13580.1-13-92.

Monitoring equipment

According to incomplete statistics (survey results from 152 measuring stations in the Acid Rain Control Zone), there are currently only 17 measuring stations in the provinces of Jiangsu, Zhejiang, Guangdong, Guangxi and Hubei using automatic precipitation sample collectors for the collection of rainwater samples. The majority of the measuring stations use polythene or other plastic buckets for collection. In order to guarantee the accuracy and comparability of data from the National Acid Rain Monitoring Network, it is recommended that an automatic precipitation sample collector is used wherever possible at all measuring points within the National Acid Rain Monitoring Network.

Analytical instruments for acid rain monitoring. Generally speaking all measuring stations at above regional/city level have pH meters, conductometers, spectrophotometers, ion chromatographs and atomic absorption spectrophotometers (the detailed situation is currently being surveyed and awaits supplementation), which can basically meet conventional acid rain monitoring requirements.

AIR QUALITY MONITORING NETWORKS

State of our country's environmental air quality monitoring networks

National Atmospheric Control Network (1992)

Network organisation

With the requirements for the normalising, standardising and networking of environmental monitoring in the middle 1980s, the National Environmental Protection Bureau organised the China Environmental Monitoring Headquarters and developed research into an optimised layout for atmospheric environmental monitoring throughout the country. On this foundation, the National Environmental

Protection Bureau assembled the National Atmospheric Environmental Monitoring Network in 1988, which included 72 measuring stations in 30 provinces, cities and autonomous regions throughout the country. In 1992, the National Environmental Protection Bureau , based on the requirements for rationalising and completing the National Environmental Quality Monitoring Network in the National Environmental Monitoring "95" Plan and 10 Year Plan, carried out a rationalising of the National Control Network assembled in 1988 in Environmental Monitoring Document 142 [1992] " Notification on Adjustments to the National Environmental Quality Monitoring Network Stations". The reorganised National Atmospheric Environmental Monitoring Network (hereinafter abbreviated to Atmospheric National Control Network), included 103 measurement stations in 31 provinces, cities and autonomous regions throughout the country.

Network operation

In 1986 the National Environmental Protection Bureau published the "Environmental Monitoring Technical Norms" and in 1998 officially implemented them. Measuring stations in the Atmospheric National Control Network according to the requirements of the "norms" carried out optimisation of monitoring point locations for measuring points in the measuring stations over the period from 1988 to 1993. According to statistics, 96 of the 103 measuring stations in the Atmospheric National Control Network basically have the monitoring capability and have submitted data to the State, accounting for 93% of the entire network. There were 439 measuring points participating in the data statistics. Measuring stations which have not yet submitted data to the State include Hulun Buir Meng in the Inner Mongolia Autonomous Region, Jagdaqi City in Heilongjiang, Wuyi Shan and Quanzhou City in Fujian, Changdao County in Shandong, Lijiang Region in Yunnan and Golmud City in Qinghai.

State of this country's keypoint city air quality monitoring network

It was clearly pointed out in 1996 in the "Decision on some Problems of Environmental Protection" of the State Council that by the year 2000 the environmental air quality in directly governed cities, provincial level cities, cities in special economic zones, coastal open cities and keypoint tourist cities would meet environmental air quality standards according to functional delineation of areas. In the spirit of the above pronouncement, the National Environmental Protection Bureau studied and implemented the development of air quality weekly reporting in 47 cities throughout the country in early 1997, and it organised and drew up the "National Keypoint City Air Quality Weekly Reporting Technical Specifications" and notified all relevant units in Environmental Monitoring Document 371 [1997]. Currently 46 of the 47 keypoint cities (all except Lhasa in Tibet) have developed air quality weekly reporting and have formed a National Keypoint City Air Quality Monitoring Network.

Design of the national environmental air quality monitoring network

Siting of urban measuring stations in the Sulphur Dioxide Control Zone and Acid Rain Control Zone *(Table 3)*

Basic situation with regard to the Sulphur Dioxide Control Zone and Acid Rain Control Zone

The Sulphur Dioxide Control Zone drawn up with the approval of the State Council is located across the 14 provinces, directly governed cities and autonomous regions of Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Jiangsu, Shandong, Henan, Shaanxi, Gansu, Ningxia, Xinjiang, Beijing and Tianjin. Its surface area is approximately 290,000 km^2, accounting for approximately 3% of the total area of the country. According to statistics on administrative boundaries, the Sulphur Dioxide Control Zone includes two directly governed cities, 16 regional level cities (including county level cities in regions) and 66 county level cities and towns.

The Acid Rain Control Zone drawn up with the approval of the State Council is located in the 14 provinces, directly governed cities and autonomous regions of Jiangsu, Anhui, Zhejiang, Jiangxi, Fujian, Hubei, Hunan, Guangdong, Guangxi, Guizhou, Yunnan, Sichuan, Chongqing and Shanghai. Its area is approximately 800,000 km^2, accounting for approximately 8% of the total area of the country. According to statistics on administrative boundaries, it includes 572 large, medium and small cities above county level, 2 directly governed cities, 106 regional level cities (including county level cities in regions) and 464 other county level cities and towns.

As specified in Environmental Monitoring Document 142 [1992] of the National Environmental Protection Bureau, there are currently 103 "Atmospheric National Control Network" measuring stations, of which 30 are located in the Sulphur Dioxide Control Zone, including 2 directly governed cities, 27 regional level cities and one county level city (Ji'an City in Jilin Province); there are 38 "Atmospheric National Control Network" measuring stations located in the Acid Rain Control Zone, including 2 directly governed cities, 36 regional level cities; there are thus 68 "Atmospheric National Control Network" measuring stations located in the Two Control Zones, accounting for 66%.

Of the 47 keypoint cities across the country in which weekly reporting of air quality has been developed, apart from the 9 cities of Changchun, Harbin, Hefei, Haikou, Xining, Qinhuangdao, Lianyungang, Beihai and Lhasa, the remaining 38 cities are all located within the Two Control Zones.

Environmental air quality monitoring network in the two control zones

All 62 cities at regional level (including county level cities in regions) and above in the Sulphur Dioxide Control Zone (including 15 keypoint cities and 29 "Atmospheric National Control Network" measuring stations) as well as one 1998 Model City (Laizhou City in Shandong), totalling 63, are all brought within the National Environmental Air Quality Monitoring Network.

All 106 cities at regional level (including county level cities in regions) and above in the Acid Rain Control Zone (including 23 keypoint cities, one Model City (Zhongshan City in Guangdong Province) and 38 "Atmospheric National Control Network" measuring stations), as well as two 1998 Model Cities (Zhangjia Gang City and Kunshan City in Jiangsu) totalling 108, are all brought into the National Environmental Air Quality Monitoring Network.

There are 170 urban measuring stations in the Two Control Zones.

Urban environmental air quality monitoring network not in the two control zones

Of the original "Atmospheric National Control Network" measuring stations not in the Two Control Zones, apart from the 6 measuring stations at Hulun Buir Meng in Inner Mongolia, Changhai County in Liaoning, Jagdaqi in Heilongjiang, Wuyi Shan in Fujian, Changdao County in Shandong and Lijiang Region in Yunnan, the remaining 29 measuring stations are all brought within the National Environmental Air Quality Monitoring Network.

Of the 9 keypoint cities outside the Two Control Zones, Beihai City is brought within the National Environmental Air Quality Monitoring Network (the other 8 cities overlap with the "Atmospheric National Control Network").

The two 1998 Model Cities outside the Two Control Zones (Weihai City and Rongcheng City in Shandong) are brought within the National Environmental Air Quality Monitoring Network.

There are in total 32 measuring stations outside the Two Control Zones.

Table 3. **Number and Distribution of Urban Measuring Stations in the National Environmental Air Quality Monitoring Network**

Province/ Region	Acid Rain Control Zone	Non-Two Control Zone	Total	Province/ Region	SO_2 Control Zone	Non- Two Control Zone	Total
Jiangsu	10	1	12 *	Jilin	4	2	6
Anhui	6	2	8	Liaoning	9	0	9
Zhejiang	9	0	9	Hebei	8	1	9
Jiangxi	7	1	8	Henan	5	2	7
Fujian	6	0	6	Shandong	11	2	13
Hebei	6	1	7	Shanxi	8	0	8
Hunan	12	0	12	Inner Mongolia	4	0	4
Guangdong	17	0	17	Shaanxi	4	3	7
Guangxi	8	2	10	Ningxia	2	0	2
Guizhou	5	1	6	Gansu	4	1	5
Yunnan	6	0	6	Xinjiang	1	1	2
Sichuan	13	0	13	Beijing	1	0	1
Chongqing	1	1	2	Tianjin	1	0	1
Shanghai	1	0	1	Hainan	/	1	1
Qinghai	/	2	2	Heilongjiang	/	5	5
Tibet	/	3	3	Total	170	32	202

** Xuzhou City in Jiangsu Province is in the SO_2 Control Zone but featured in the statistics for the number of measuring stations in Jiangsu Province.*

Siting of rural stations

It is proposed to site 8-10 measuring stations such that their monitoring data is capable of reflecting to a great degree the regional air quality situation. It is proposed to select from keypoint cities those rural areas within their areas of jurisdiction which are representative, and then site the rural measuring stations there.

Siting of background stations

It is proposed to site 3-5 measuring stations such that their monitoring data is capable of reflecting to a great degree the regional background air quality situation. Three locations for stations have been confirmed at Jagdaqi in Heilongjiang, Wuyi Shan in Fujian and Lijiang in Yunnan.

Siting of other measuring stations

Provided they have the capability of monitoring environmental air, all regional and county level measuring stations throughout the country can be brought within the National Environmental Air Quality Monitoring Network. According to a preliminary survey, we currently have approximately 627 measuring stations in addition to the 202 measuring stations mentioned above. Of these 46 are regional level stations (all outside the Two Control Zones), and 581 are county level stations. Of these measuring stations, 215 are located in the Acid Rain Control Zone, 44 are in the SO_2 Control Zone, and 368 are not in a control zone.

Subjects for Monitoring and Monitoring Frequency

Table 4. **Subjects for Monitoring (After 2000)**

Monitoring Subject	Keypoint City Station	Ordinary City Station	County Level Station	Rural Station	Background Station
SO_2	■	■	■	■	■
TSP	❿	❿	❿	❿	❿
NO_x	❿	❿	❿	❿	❿
CO	■	❿	❿	❿	❿
O_3	■	❿	❿	■	■
PM_{10}	■	■	■	■	■
NO_2	■	■	■	■	■
Pb	■	■	❿	■	■
BaP	❿	❿	❿	❿	❿
F	❿	❿	❿	❿	❿

* ■ Stipulated monitoring subject ❿ Optional monitoring subject depending on regional characteristics

Table 5. **Monitoring Frequency (After 2000)**

Measuring Station	SO_2, NO_2 (No_x), CO, O_3	PM_{10} (TSP), BaP, Pb	F
Keypoint City Station	Stipulated subjects to meet requirements for daily or weekly reporting of air quality, optional subjects to meet requirements for air quality standards	Stipulated subjects to meet requirements for daily or weekly reporting of air quality, optional subjects to meet requirements for air quality standards	To meet requirements for air quality standards
Ordinary City Station	To meet requirements for air quality standards	To meet requirements for air quality standards	To meet requirements for air quality standards
County Level Station	According to actual monitoring capability	According to actual monitoring capability	According to actual monitoring capability
Rural Station	To meet requirements for air quality standards	To meet requirements for air quality standards	To meet requirements for air quality standards
Background Station	To meet requirements for air quality standards	To meet requirements for air quality standards	To meet requirements for air quality standards

Nationwide Air Monitoring
The Experience of Japan

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Nationwide Air Monitoring
The Experience of Japan

OUTLINE OF THE NATIONWIDE AIR MONITORING SYSTEM IN JAPAN

Historical overview

Regular air monitoring started in the mid-1960s, when Japan suffered from severe air pollution along with rapid industrialisation. The first priority substance was SOx, which was thought to be the main cause of pollution-related respiratory diseases. Since 1970, monitoring of other substances, including NOx, CO, Ox, fallout dust and particulate matter (PM) has been carried out under the Air Pollution Control Law (APCL). Monitoring of non-methane hydrocarbons was added later, and PM was replaced by SPM (suspended particulate matter), with a revised measurement method. The number of monitoring stations rapidly increased in the 1970s. The monitoring network — which is dense, consisting of more than 1 000 stations — was not completed until the early 1980s. Monitoring of conventional pollutants is still undertaken. Figure 1 shows long-term trends of SOx and NOx.

Since the 1980s, the scope of air monitoring has been expanded in two directions. First, surveying for acid deposition has begun, showing that the observed acidification level in precipitation was almost the same as in Europe and North America. The Acid Deposition Monitoring Network in East Asia is in a preparatory phase. Second, preliminary monitoring of hazardous air pollutants (HAPs) was instituted so that precautionary measures could be taken to reduce health risks from long term exposure. Periodic monitoring of HAPs began in 1997 after amendment of the APCL in 1996.

A brief chronology:

- Early 1960s — Air monitoring by local governments is begun, to respond to severe pollution.
- 1965 — Continuous monitoring begins at state-established stations.
- 1971 — The Environment Agency of Japan (JEA) is established.
- 1970s-1980s — The nationwide continuous monitoring network is expanded.
- 1985 — JEA starts preliminary monitoring of HAPs.
- Late 1980s — The acid deposition monitoring network comes into operation.
- 1997 — Nationwide periodic monitoring of HAPs by local governments begins.

Type, structure and spatial coverage of monitoring network

Japan's nationwide air monitoring system consists of two networks (Table 1): the NASN, which is a network of state-established stations; and a nationwide air pollution surveillance network operated by local governments under the APCL (hereafter referred to as the APCL network).

The role of the NASN includes *a)* monitoring of the most polluted areas, average (typical) areas and background areas; *b)* provision of reference sites for the APCL network; and *c)* advance monitoring of substances not yet covered by regulation. The NASN is being restructured, including clearer role sharing with the APCL network, to strengthen its role as part of the East Asian monitoring network and providing reference sites for the global air monitoring network.

The role of the APCL network, which is based on article 22 of the APCL, is periodic monitoring for air pollution in areas within the jurisdiction of local governments.

Spatial coverage of the two networks is as follows.

NASN: National monitoring network for the surveillance of air pollution (state-established)

- Air pollution monitoring stations (15 sites[1]).
- Background air monitoring stations (8 sites[2]).
- Automotive exhaust gas monitoring stations (5 sites).
- Acid deposition monitoring stations (48 sites: 15 urban, 8 rural, 14 remote and 11 ecological area sites).

APCL network: Nationwide air pollution surveillance network conducted by local governments under the APCL

- Ambient (general) monitoring stations: 1 722 sites in FY 1997.
- Roadside (automotive exhaust gas) monitoring stations: 410 sites in FY 1997.
- HAPs monitoring stations: about 400 sites in FY 1997.
- Locations: ambient (about 240 sites), near point sources (about 80 sites), roadside (about 80 sites).

Types and scope of measurements

The types of pollutants monitored, the time scale of sampling and the measurement methods are as follows:

Types of pollutants and time scale

- Conventional pollutants (NOx, SPM, SOx, CO, Ox, NMHC): continuous, hourly.
- Fallout dust: monthly, chemical composition of particulate: monthly.
- HAPs (19 priority substances): more than once per month.
- Acid deposition (pH, nitrate, sulfate, etc.): continuous, daily.
- Meteorological parameters (wind direction and speed, atmospheric stability, etc.).

Measurement methods

"Wet" methods have been mainly used for conventional pollutants. "Dry" methods were added for SOx, NOx and Ox as authorised methods in 1996 to meet international standards.

Institutional and financial arrangements

Legislative background

The APCL network, operated by local governments, was established under the APCL, article 22 (general) and article 20 (automotive exhaust): see Annex.

Financial arrangement

JEA provides subsidies to prefectural/municipal governments to buy monitoring equipment.

Role of private enterprises

Monitoring by voluntary groups exists, but the results are not included in nationwide reporting. Continuous monitoring of emissions is used by large point sources and the result is reported by telemetry to local governments.

[1] *Of which 6 were turned into acid deposition monitoring stations starting in the 1997 fiscal year.*
[2] *Of which 7 were turned into acid deposition monitoring stations starting in FY 1997.*

USE OF THE MONITORING SYSTEM IN PUBLIC INFORMATION AND DECISION MAKING

Types of use of the monitoring system

- Reviewing and reporting compliance with environmental quality standards.
- Alert system for emergent pollution (see Annex, articles 21 & 23 of the APCL).
- Baseline data for reviewing policy performance and formulating new regulations.
- Baseline data for preventing health effects (input to health effect surveillance system).
- Input for scientific analysis and modelling (e.g. dispersion modelling, epidemiological studies).

Information techniques and data transmission mechanisms

Data collection and transmission

- Telemeter system: real-time data collection from monitoring stations and meteorological authorities, enabling local governments to take emergency measures.
- Nationwide data collection for annual reporting; local governments report monthly and annual data to JEA by magnetic tape/diskette. JEA edits annual report.

Dissemination of monitoring results to the public

- Press release (annual report for every year, around December of the following fiscal year).
- Summary results reported in *Quality of Environment in Japan* (“white paper” or state of the environment report).
- Data set of monthly/annual data in printed reports: more than 2 000 pages annually.
- Data set of monthly/annual data in computer data files: MT/MOD/FD, spreadsheets for PC.
- Data set of hourly data in computer data files: restricted use for scientific analysis, etc.

Use of monitoring information for modelling and/or forecasting

- JEA and several local governments undertake photochemical pollution forecasting.
- Monitoring data used for validation of area-wide dispersion modelling.

STRENGTHS AND WEAKNESSES

Strengths

- Indispensable role in providing information on the state of and trends in pollution.
- Stock of continuous monitoring data, from dense spatial coverage, for more than two decades.
- Periodic reporting of monitoring results, e.g. in the *Quality of the Environment* report.
- Well-organised alert system using telemetry for prevention of emergent pollution.
- Expansion/restructuring of monitoring system to catch up with newly emerging issues.
- Integration with effect monitoring in the environmental health surveillance system.

Weaknesses

- International incomparability because of differences in measurement method.
- Difficulties in measurement method (e.g. HAPs, physical/chemical properties of SPM).
- Imbalances between conventional pollutants and new ones (HAPs, etc.).
- Insufficient integration with cross-media monitoring and multiple exposure monitoring.
- More possibilities for real-time data disclosure (e.g. via Internet).

Figure 1. **State of acid deposition in Japan**
(Results from 2nd monitoring phase: 1989-1992)

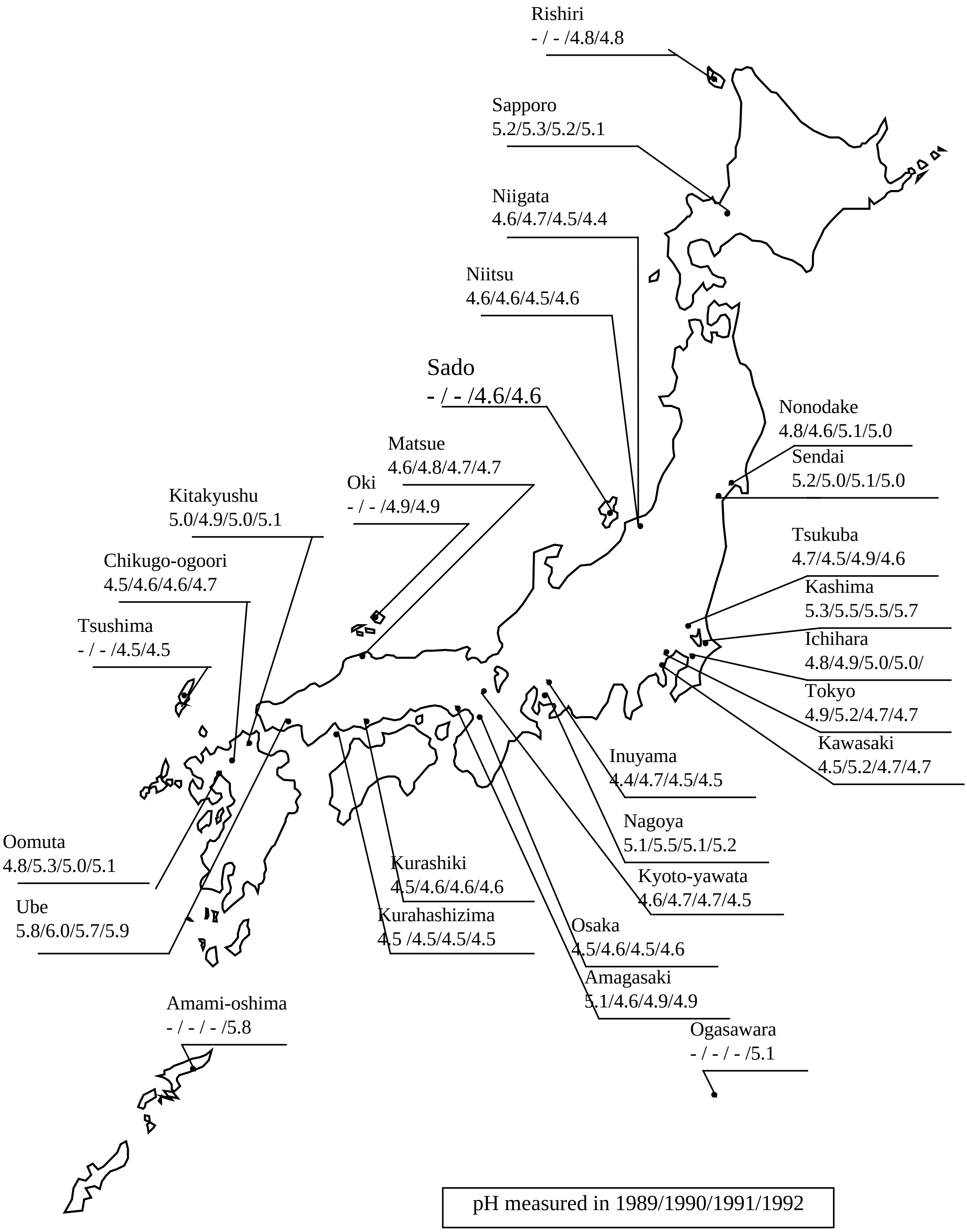

Table 1. **Overview of the Japanese nationwide air monitoring network**

Type of Network	NASN		Nationwide APCL Network	
Sub-type of Network	Air pollution	Acid deposition	Conventional	HAPs
Number of stations	28	48	2 132	About 400
Location	Urban sites (15) Background sites (8) Roadside sites (5)	Urban sites (15) Rural sites (8) Remote sites (14) Ecological areas (11)	Ambient (1 722) Roadside (410)	Ambient (240j) Roadside (80) near point sources (80)
Substances monitored	SO_x NO_x SPM (PM10) Ox HC (CH4, NVHC) CO Fallout dust Composition of PM[a]	pH Sulfate Nitrate Ammoniate Chloride Cations (Na, K, Ca, Mg)	SO_x NO_x SPM (PM10) Ox HC (CH4, NMHC) CO Fallout dust	22 substances[a] of which, 19 substances are monitored up to now.
Sampling Frequency	Hourly [a] only once a month	Daily	Hourly	More than once per month
Manager	JEA	JEA	Local government	Local government
Budget	National	National	National subsidies Local government	National subsidies Local government

a) Acrylonitrile, Acetaldehyde, Vinyl chloride, Chloroform, (Chloromethyl methyl ether), (Ethylene oxiode), 1-2 Dichloroethane, Dichloromethane, Mercury compounds, (Talc), Dioxines, Tetrachloroethylene, Trichloroethylene, Nickel compounds, Arsenic compounds, 1,3-Butadiene, Beryllium compounds, Benzene, Benzo(a)pyrene, Formaldehyde, Manganese compounds, Chromium compounds (iv).

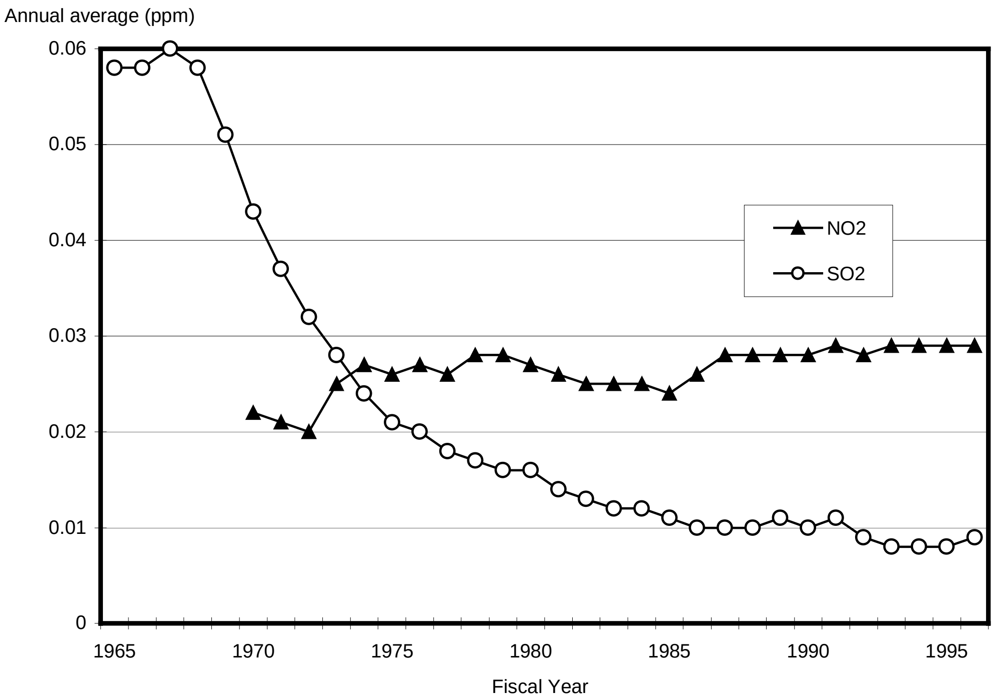

Figure 1 **Long-term trends in annual average concentration at continuously monitoring stations (SO2: average of 14 stations, NO2:average of 15 stations)**

ANNEX. **EXTRACTS FROM AIR POLLUTION CONTROL LAW (APCL)**

APCL CHAPTER III. MAXIMUM PERMISSIBLE LIMITS, ETC. OF MOTOR VEHICLE EXHAUSTS

Maximum Permissible Limits (*Article 19): omitted from the extracts*.

Measuring of Density of Motor Vehicle Exhausts (*Article 20)*

The governor of the prefecture shall measure the density of motor vehicle exhausts in the air, on the road or in places surrounding the road where serious air pollution by motor vehicle exhausts occurs or is likely to occur on account of auto traffic congestion occurring at traffic intersections, etc.

Request for Actions on the Basis of Measurement (*Article 21)*

1. In cases where the governor of the prefecture recognizes that according to measurements under the preceding article the level of air pollution caused by motor vehicle exhausts on the road or in places surrounding the road exceeds the limit prescribed by Order of the Prime Minister's Office, the governor shall request the Prefectural Public Safety Commission to take measures in accordance with the provisions of the Road Traffic Law (Law No. 105 of 1960).

2. In cases where the governor of the prefecture finds it especially necessary according to the measurements under the preceding article, except in cases where a request is made under the provision of the preceding paragraph, the governor may offer to the manager of the road or the head of the related governmental agency concerned, his opinion on matters which will contribute to the reduction of the density of motor vehicle exhausts, such as improvement of the structure of the road.

Responsibility of citizens (*Article 21-2): omitted from the extracts*

APCL CHAPTER IV. MONITORING OF THE LEVEL OF AIR POLLUTION, ETC.

Monitoring and Surveillance (*Article 22)*

The governor of the prefecture shall monitor and survey from time to time the level of air pollution.

Emergency Measures, etc. (*Article 23)*

1. In cases where the air pollution reaches the extent, designated by Cabinet Order, which may cause damage to human health or the living environment, the governor of the prefecture shall call attention to such a situation and at the same time ask soot and smoke emitting persons, or users or drivers of motor vehicles who are likely to further aggravate the air pollution to cooperate in reducing the level of soot and smoke emissions or in voluntarily curtailing the operation of their motor vehicles.

2. In cases where a situation arises where on account of the meteorological conditions the air pollution suddenly reaches the extent designated by Cabinet Order, which may cause serious damage to human health or the living environment, the governor of the prefecture shall order, in accordance with the provisions by Order of the Prime Minister's Office, soot and smoke emitting persons to take necessary measures, such as reduction of the volume and density of soot and smoke emission, decrease of the operation of facilities when such a situation is attributable to soot and smoke, or he shall demand the Prefectural Public Safety commission to take measures under the provisions of the Road Traffic Law when such a situation is attributable to motor vehicle exhausts.

Public Announcement
Article 24

The governor of the prefecture shall publish the conditions of air pollution in the areas under his jurisdiction.

Airshed Monitoring
The Experience of Germany

by
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This paper describes the experience in Germany, taking the Land (state) of North Rhine-Westphalia (NRW), one of the 16 Länder in Germany, as an example. NRW has about 18 million inhabitants.

(⮱) = More detailed information may be found in the tables and figures at the end of this chapter.

Airshed Monitoring
The Experience of Germany

THE AIR POLLUTION MONITORING SYSTEM IN NORTH RHINE-WESTPHALIA

Background

The legal basis for air pollution monitoring in Germany was established in 1974 in the Federal Immission Control Act ("immission", as used in the German context, refers to the concentration of a substance in an environmental medium; hereafter we shall refer to the Federal Air Pollution Control Act) and the Technical Instructions for Air Pollution Control (TI Air). The Act lays out the basic requirements and framework for the licensing of industrial facilities and for air pollution monitoring and enforcement. It requires the appropriate Länder or federal authorities to implement specific regulations on air quality monitoring and reporting. The TI Air sets specific technology-based emission limits for numerous pollutants, requires stringent control technologies for new and existing industrial facilities, and sets ambient air quality standards.

Since the early 1980s, the national framework has been complemented with several directives of the European Union (EU), requiring Member States to assess ambient air quality throughout their territories. These directives relate to sulphur dioxide and suspended particles, lead, nitrogen dioxide and ozone **(↳)**. Furthermore, there is a new EU Directive on Ambient Air Quality Assessment and Management, which, with related directives, will govern monitoring in the future.

Although the legal framework is given by the European Union and Germany's Federal Government, the Länder execute and implement the regulations.

Purpose and planning of air monitoring

Controlling air quality in an area as large as North Rhine-Westphalia (NRW) (34 000 km²) implies *i)* precise definition of the questions to be addressed and *ii)* appropriate planning of ambient air measurements.

Examples of important pollution measurement tasks are:

Measurements for specified areas

- General air pollution monitoring, measurements of trends.
- Representative measurement of expected pollution in the area affected by a planned factory (licensing procedures according to specific regulations).
- Real-time measurements of acute episodes of high atmospheric pollution (winter smog, high ozone concentrations).
- Investigation of traffic-related air pollution in street canyons and residential areas.
- Monitoring at fixed sites in various microenvironments (e.g. urban background, industrial sites, rural sites) to check compliance with EU limit values.
- Screening measurements.
- Scientific investigations, e.g. of the transport of atmospheric pollutants, chemical reactions, calibration of diffusion modelling.

Measurements in and around industrial plants

- Measurements following complaints.
- Investigation of emitters, cause analysis.

- Measurements in cases of fire and accidents.
- Monitoring of the effectiveness of pollution abatement measures.
- Monitoring of installations producing diffuse emissions.

The NRW air pollution monitoring system covers most of these tasks. Each task requires its own dedicated measurement plan. All measurements should be planned in such a way that, at minimum cost, the results answer all the questions for which they are designed, meeting given requirements for the uncertainty (accuracy) and representativeness of the data. The measurement plan therefore includes an assessment of technical, financial and personnel aspects.

Type and structure of the NRW network

Generally, the basic problems in air pollution monitoring are spatial and temporal variations in air pollution. Spatial variations are due to inhomogeneities of sources and complex transport mechanisms; temporal variations stem from the time dependence of meteorological conditions and emissions (from traffic, etc.).

Furthermore, there is a need to get a quick overview of air quality, if possible, in real time, for example as the basis for a smog alert system and public information during episodes of high ozone concentrations (under an EU directive).

The requirements of high time resolution, and especially of real time monitoring, can only be fulfilled by continuous measurement. Therefore, the pollution components which can be checked by automated instruments are measured via a network of monitoring stations.

Another question is: which air pollutants are of interest? Annex I of the EU framework directive lists the most important substances.

The monitoring of all these different groups of substances requires a sophisticated system. The monitoring network of the NRW State Environment Agency (LUA) is one of the largest and most extensive in Europe **(✎)**.

In line with the aim of describing the pollution burden in a given area as representatively as possible, most measurement sites in NRW are arranged in a regular grid of 8 x 8 km² (except for deposition, described later). While this structure does not take into account features of the investigation area such as street location and the difference between residential and industrial areas, the grid arrangement ensures a representative sample of all theoretically possible measurement sites. This strategy makes allowance for the fact that air pollution monitoring necessarily takes the form of spot checks, at least with respect to the spatial distribution of air pollutants.

Beginning in the late 1970s, 76 fixed measurement stations were set up in NRW. Under the Federal Air Pollution Control Act, 66 stations were placed in the cities of NRW's industrial area, the Rhine-Ruhr region (including Cologne, Düsseldorf, Duisburg, Essen and Dortmund). There are ten rural stations, fairly distant from the polluted districts **(✎)**. All the sites were chosen in accordance with guidelines for measuring stations in Germany and met the requirements of the old European Community directives.

Now a new general concept for air pollution monitoring in NRW is being developed. It follows an alternative approach to designing monitoring networks, looking at different microenvironments of measurement locations, e.g. urban background areas, traffic-exposed sites, rural areas, industrial sites. One or more measurement stations are then placed at the locations that are representative of the pollution burden of the microenvironments **(✎)**.

The new network, called LUQS (the German abbreviation for "air quality monitoring system"), follows an approach chosen by the European Union. In Annex VII of the directive on limit values for SO_2, NO_x, particles and lead in ambient air, minimum numbers of measurement sites are prescribed for typical microenvironments, depending on the number of inhabitants. In addition, Annex VI gives some guidance on the placement of measurement sites. An EU guidance report on preliminary assessment contains further examples on screening measurements.

The network will thus be reduced to about 60 fixed stations and reorganised on a grid of about 11 km in the Rhine-Ruhr area, with new stations in four major agglomerations.

Type and scope of measurements

Continuous measurement

Because of the requirement of real time information on air quality — for example, during smog episodes or periods of high concentrations of photo-oxidants — the basis of the air pollution monitoring network in NRW is the telemetric air pollution monitoring system, TEMES.

The TEMES network, with its fixed stations, is complemented by continuous measurement using automated mobile units known as MILIS. These are set up, usually for periods of between one month and one year, at the request of communities, citizen organisations, etc., in different regions (in the industrial urban area between the TEMES stations, and particularly outside the main agglomerations).

The main tasks of TEMES are:

- General monitoring of air quality according to EU and national regulations.
- Presentation of a realistic, quick overview of pollution loading in real time, with information on trends in and causes of air pollution.
- Supply of a smog alert system (the rural stations, fairly distant from the emission sources of the Rhine-Ruhr region, provide very important information on long range transport and serve as "early warning stations").
- Provision of an information system during high ozone episodes.

Other tasks are:

- A check on the effectiveness of pollution control measures.
- Comparison of the air quality of different regions in Germany and in the European Union.

The housing of the stations **(**↳**)** consists of air conditioned containers of about 30 m^3. On the roof of every station are two sampling systems, one for gases and one for suspended particulate matter (SPM). Measuring equipment is installed for **(**↳**)**:

- Sulphur dioxide (SO_2).
- Nitric oxide (NO).
- Nitrogen dioxide (NO_2).
- Carbon monoxide (CO).
- SPM.
- Ozone (O_3).
- Hydrocarbons (BTX), at some mobile stations.

At selected stations, additional measurements are taken for several meteorological parameters:

- Wind speed and direction.
- Ambient temperature.
- Humidity.
- Atmospheric pressure.
- Precipitation.
- Solar radiation (radiation budget).

Each instrument produces not only a current signal or serial data for the measuring value, but also digital "status signals" indicating operating status (measurement, calibration, maintenance) and possible errors. In this way critical parameters (flow rates, lamp intensities, temperature of measuring cells, high-voltage power supplies, etc.) are permanently checked.

Furthermore, each gas analyser is connected to a calibration unit, which produces blank gases and span gases in two known concentrations **(☞)**. The concentrations of the span gases are regularly analysed by reference methods (see Quality assurance). Calibration procedures can be made manually or automatically (computer control).

In some cases, nitrogen and synthetic air in cylinders are used as blank gases. Such gases are relatively easy to handle, but can have the disadvantage that their properties (e.g. moisture) often differ from those of the matrix air being analysed. There is also the need to change the gas cylinders. Therefore, blank gases are best prepared immediately before use, from the air to be analysed (e.g. by filtration through sorbents).

For some substances, standard gases can be obtained commercially in pressure cylinders. If the cylinders contain the gas in the concentration required, dilution is unnecessary. However, such gases can present problems of high gas consumption and sometimes poor storage stability (generally, as concentration decreases, so does stability). Alternatively, if gas cylinders are used in which concentrations are 50 to 100 times as high as that required, controlled dilution with the base gas must be carried out. A standard gas generator operating on this principle is more expensive, and the dilution stage is a potential source of error. Advantages include the generally better storage stability and lower rate of consumption of the bottled gas.

The standard gas mixture can also be prepared by permeation, or, in the case of nitrogen oxides, by gas phase titration.

Normally, every five seconds the measuring values and status information of all instruments in a station are transmitted to a local (PC) computer system, which collects the data, makes plausibility tests, calculates averages for 30 minutes and for 1, 3 or 24 hours, and stores the information (data processing and data management). At regular intervals (e.g. hourly), or by request, all data are transmitted via ISDN to the central computer system at the LUA in Essen.

There, in a central room for air quality control, all measurement results can be prepared on terminals, printers and plotters in the form of tables and graphics, making it possible to observe all air quality parameters for any given interval.

Furthermore, the computer and staff continually check for exceedance of various air quality standards, thus ensuring that any critical situation will be quickly recognised.

Discontinuous measurement

With the automated systems described above, only the so-called common substances can be measured. But air pollution has many other important components, such as heavy metals, soot, polycyclic aromatic hydrocarbons (PAH) and other organics, including the carcinogenic benzene. Most of these currently cannot be measured automatically in the field with sufficient accuracy.

Therefore, the monitoring network is supplemented by additional measuring programmes using semi-automated and manually operated sampling equipment **(☞)**.

For random measurements, not only must the size of the statistical sample be adequate, but also measurement times must be randomly selected to ensure accurate representation of the time dependence. As atmospheric pollution often shows marked variation over the course of a day or the seasons, measurements only at certain times of the day or year would not give representative results.

Random sample measurements are particularly well suited for determining annual averages or percentiles not higher than 98%. For these characteristic values, the additional uncertainty introduced by cost-effective random sampling can be kept reasonably small. However, peak values or very high percentiles have to be determined by continuous measurement.

One outstanding example of the basic concept of grid measurements combined with random sampling is the pollution measurement prescribed for the German licensing procedure in the TI Air, which gives a general measurement plan for this task in clauses 2.6.2 and 2.6.3.

Measurement of suspended particles

The suspended particles measured in Germany have mostly been SPM, also known as total suspended particles (TSP); but for the past two years or so, PM10 and PM2.5 have also been measured.

At most automatic stations suspended particles are collected over 24 hours with the so-called LIB procedure. The samples are analysed for metals such as cadmium (Cd), lead (Pb), nickel (Ni), arsenic (As) and beryllium (Be), using atomic absorption spectrometry (AAS). The organic fraction is analysed for six different types of PAH, using HPLC.

Additional measurements of PM10 and PM2.5 are performed with automated filter changers (DIGITEL DHA-80) and small filter devices (LVS 3).

In recent years, soot — especially diesel soot — has become increasingly important because of its high carcinogenic potential. Measurements for the fine particle fraction are done especially at traffic-related sites.

Owing to the variable and complex composition of diesel soot, and because some of its constituents are also emitted from other sources, there is no specific method for measuring it; rather, existing methods for workplace monitoring have been adapted for outdoor air measurements. The fraction of fine dust (e.g. of particles < 7 µm in diameter, in accordance with the Johannesburg Convention, or of PM10) is collected on a glass fibre filter. After solvent extraction and thermal desorption of organic constituents, the carbon content is determined by combustion in a stream of oxygen and coulometric titration of the carbon dioxide formed. The coulometric method is the reference method for measurement of soot in Germany.

The advantages and disadvantages of fractionating measurement of SPM have been the subject of national and international dispute. In Germany, all national limit values and criteria have so far been based on measurement of total SPM, while in the United States, limit values are based on the PM10 and PM2.5 fraction. Recent studies, however, indicate that measurements of PM10 and PM2.5 correlate better with health related effects than do TSP measurements. This is one reason the European Union will base its upcoming ambient air quality standards on PM10, and will stipulate PM2.5 measurements in addition.

Hydrocarbons/halogenated hydrocarbons

In other programmes, about 35 single hydrocarbons and chlorinated hydrocarbons are analysed at about 60 sites in NRW using various gas chromatographic techniques.

Despite the high sensitivity of gas chromatographic detectors, direct measurement of VOCs in the air is not possible (except for methane) without prior concentration on sorbents during sampling or in traps before analysis, as detection limits in the range ng/m³ to µg/m³ must be achieved. Sampling and preconcentration are performed either by actively pumping an air stream through tubes or traps filled with sorbents, or by passive sampling. The collected VOCs are then desorbed either thermally or by solvents and the resulting gas streams or solutions are injected into a gas chromatograph. The preconcentration step with subsequent thermal desorption can be part of the chromatographic system, so that air samples (e.g. from cylinders) can be introduced directly.

In pilot measurement projects at sites of different land use and emission structures in NRW, air samples are taken and analysed for polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) using GC-MS.

Dust deposition

Till the end of 1992, measurements for dust deposition were taken in a 1- or 2-km grid at more than 1 800 sites in NRW using the BERGERHOFF method. The samples were analysed for lead, cadmium, nickel, arsenic, beryllium and, in some cases, thallium and zinc. In view of the decrease in dust and metal deposition in most of the Rhine-Ruhr area, this programme was reduced in 1993 to about 600 sampling points.

Source-related measurements and emergency task force

Measurements also are performed around special sources (traffic, industries), and — last but not least — in emergencies. For the latter case, a special task group can be put in action at any time, around the clock. It has at its disposal special vehicles equipped with measurement devices **(✎)**.

Diffusive samplers (screening measurements)

Diffusive samplers can be used for a wide range of substances. In NRW, diffusive samplers are used to measure BTEX (benzene, toluene, ethylbenzene and xylene).

Solid adsorbents such as Chromosorb 106 or charcoal in specially designed tubes can be used for passive (diffusive) sampling of VOCs. The great advantage of passive samplers is their easy and cheap handling in the field, with no need for electricity — they are simply exposed for one to several weeks. Then, in the laboratory, they are either thermally desorbed or, with charcoal as adsorbent, desorbed with CS_2. The samples are then analysed by gas chromatography, as for active sampling. Passive samplers are commercially available (e.g. Perkin Elmer with thermal desorption, Dräger or Radiello with solvent desorption) and widely applied in ambient air to measure aromatic hydrocarbons such as BTX (benzene, toluene and xylene). Comparative measurements between active and passive sampling in the field have shown overall uncertainties of 10-25% for diffusive samplers. In combination with their easy handling, this makes them ideally suited for indicative measurements.

For example, in NRW benzene and other hydrocarbons are measured by diffusive sampling in a spatial resolution of 200 metres in residential quarters adjacent to an old cokery where the pollution has a very inhomogeneous spatial structure **(✎)**.

Quality assurance

Because of the environmental and economic consequences of air pollution measurements, a great effort has to be made to assure the quality of the measurements.

A large number of monitors taking continuous measurements is available for SO_2, NOx, CO and O_3 (✎). Instruments and devices are checked by institutes and federal or state agencies, which are independent of the equipment's producers. Automatically operated measuring stations and instruments have to pass a qualification test to meet standards set by the Federal Government. Approved instruments are listed by the Federal Ministry for Environment.

All automatic measuring methods based on physicochemical principles must be calibrated. For this purpose, the standard gases supplied at the stations by gas generators are analysed at regular intervals using manual reference methods, e.g. the TCM method for SO2.

The following table lists some of the calibration methods used for inorganic gases measured continuously in the network.

Substance	Calibration techniques
• SO_2	Static dilution; permeation; TCM method
• NO/NO_2	Static dilution; permeation (NO_2); Saltzman method
• CO	Static dilution; IR absorption
• O_3	UV absorption (Potassium Iodide Method)
• VOCs	Static dilution; dynamic dilution; diffusion; solutions

All measurement methods are thoroughly examined by expert groups and published as ISO/CEN standards, or (at national level) as VDI guidelines. More than 100 guidelines exist. Furthermore, a great effort is made to assure the quality of the technical equipment and organisational procedures in the whole network.

In addition, round robin tests of several laboratories with reference standards are performed regularly. Such tests are mostly run at the LUA in Essen, which operates a device for preparing and providing test gases and test aerosols. The participating laboratories measure simultaneously from a sample line containing the same test gas or test aerosol. Both automatic and manual methods are used.

Since 1981, all laboratories of the Länder control agencies and the federal agencies have met regularly in Essen, normally two times a year. Comparisons are made for SO2, NO, NO2, CO, O3, benzene and several other organics, and suspended particles.

Within the framework of co-operation in the European Union and the World Health Organization, several international round robin tests have also been performed at the LUA. The next European interlaboratory exercise, involving EU national reference laboratories and those of eastern European countries, will take place at the LUA in October.

All private laboratories that have been approved to carry out air monitoring also are required to join interlaboratory exercises at the LUA (see Role of private enterprises and laboratories, below).

Institutional and financing aspects

Institutional aspects

While monitoring of ambient air in Germany is the responsibility of the Länder (e.g. NRW, Bavaria, Hesse, Saxony, Rhineland Palatinate), it is co-ordinated by the State Committee for Environmental Protection (whose members represent the state environment ministries and the Federal Ministry for Environment) and the Federal Environmental Agency (UBA). The federal agency also collects all data from routine monitoring in the Länder.

As regards the new EU directives on air pollution monitoring, national reference laboratories co-ordinate implementation. In Germany, the UBA and the LUA in Essen are the national reference laboratories.

Generally, monitoring activities within the Länder are planned and carried out by state environment agencies, such as the LUA, though approved private enterprises can do some monitoring and/or analysis on behalf of these agencies (see below). Such enterprises usually perform measurements for licensing procedures and surveillance of industries, for instance.

Universities and other research institutions conduct research on air pollution monitoring. Funding may come from the federal or state environment ministries or from ministries for research and technology, health, etc.

Role of private enterprises and laboratories

Under the Federal Air Pollution Control Act, the Länder can approve private laboratories to perform air pollution measurements. Before approval, expert groups of state authorities (in NRW, experts at the LUA) evaluate the laboratories. In addition, all approved laboratories in Germany have to join interlaboratory comparisons at a special facility at the LUA in Essen every three years.

Private enterprises measure dust deposition in NRW and carry out some analyses (metals and PAH in suspended particles). All other air pollution monitoring in NRW is done by LUA staff.

Financial aspects

Measurements related to licensing procedures and surveillance of industries have to be paid for by the firms involved. Routine airshed monitoring in NRW is financed entirely by the state budget.

The following section examines some aspects of the costs of monitoring (see also the section on Strengths and weaknesses).

The air pollution monitoring network (LUQS) is being equipped with a new data processing system, at a cost of about 1.25 million euros for hardware (data centre and stations) and about 1.25 million euros for software.

Continuous measurement

The cost of an automated monitoring station is about 250 000 euros. For network operations, the following amounts can be taken as indicative (in euros per year for about 70 stations):

♦ Replacement of old monitoring or data processing equipment	1 500 000
♦ Small investments, repair and maintenance (without personnel), gases, filters, etc.	375 000
♦ Data lines, telephone (now changing)	300 000
♦ Electricity	150 000
♦ Software maintenance	60 000

Discontinuous measurement

♦ Replacement of old monitoring equipment, new equipment	250 000
♦ Small investments, repair and maintenance (without personnel), gases, filters, chemicals, etc.	150 000
♦ Measurements of dust deposition and metals at approx. 800 sites in NRW (external enterprises)	170 000
♦ Chemical analyses of external enterprises	40 000
♦ Research (universities, etc.)	75 000

Not included are investments for the analytical laboratories (AAS, HPLC, GC, etc.).

Personnel

About 85 people (chemists, physicists, engineers, technicians, lab assistants, etc.) work in pollution monitoring, including planning, operation of the networks, laboratories, (statistical) data analysis and reporting.

USE OF THE AIR POLLUTION MONITORING SYSTEM IN NORTH RHINE-WESTPHALIA

Types of use

All data generated by the LUQS network are used for the various purposes mentioned in previous chapters. This chapter describes some special aspects.

Ozone information service

During the summer, informing the public in accordance with the EU directive on ozone (information at 180 µg/m³; warning at 360 µg/m³) is an extremely important task, relying on both electronic and print media.

Smog alert systems

Germany's smog alert systems are primarily designed for classic London type winter smog, whose important components are SO_2, NO_2, CO and SPM. In NRW, the Rhine-Ruhr region is divided into five smog districts **(↳)**. The alert stages are: prealert, alert stage 1 and alert stage 2. Smog alerts can be triggered by:

- A meteorological inversion situation where the weather forecast does not exclude the possibility of the situation lasting 24 hours or more.
- Exceedance of specific concentration criteria for at least one component and at least one-third of the stations in a given smog district **(↳)**.

Alert stages 1 and 2 can also involve a time factor:

- Stage 1 is announced if the values for prealert are exceeded for more than three days.
- Stage 2 is announced if the values for stage 1 are exceeded for more than three days.

The measures taken, in brief, are **(☞)**:

Prealert: informing the public, hospitals, industries, etc., via newspaper, radio and TV; calling on everybody to reduce emissions as much as possible.

Stage 1: prohibiting traffic from 6-10 a.m. and 3-8 p.m., except for emergency vehicles; allowing only low sulphur fuels.

Stage 2: generally prohibiting traffic, allowing only low sulphur fuels and reducing production or even closing power plants and factories.

Smog alerts were called in NRW in 1979, 1985 (prealert, alert stage 1 and alert stage 2) and 1987.

Publication and dissemination

Generally, all air pollution data in NRW are published as soon as possible, in various ways:

- Real time data on the Internet and TV (videotext/teletext).
- Daily reports for authorities and newspapers.
- Monthly and yearly reports
- Special publication in scientific journals, at conferences, etc.

The most important task in air pollution monitoring in NRW and Germany for some time to come will be implementing the new EU directives. In this connection, all air pollution data are also being transmitted to the European Environment Agency in Copenhagen.

STRENGTHS AND WEAKNESSES

The North Rhine-Westphalia State Environment Agency (LUA) runs one of Europe's largest, most extensive air quality monitoring networks. It covers all relevant air pollution monitoring tasks at regional level, especially measurements in different microenvironments, such as urban background areas, traffic exposed sites, rural areas and industrial sites.

Expenses related to these measurements (in terms of number of sites and samples, degree of accuracy, etc.) is linked to concentration levels and the type of figures needed (e.g. annual averages, percentiles). Discontinuous measurement with random sampling and screening methods (e.g. diffusive samplers) thus plays a very important role. Nevertheless, the system's financial needs are considerable, involving:

- About 70 containers (fixed and mobile stations) equipped with computer systems and automatic monitors and calibration systems for SO_2, NO_x, CO, O_3, TSP/PM10 and VOCs, as well as meteorological parameters.
- Samplers for TSP, PM10 and PM2.5.
- Equipment for random measurements (sampling facilities).
- Special vehicles and equipment for the emergency task force.
- A central data unit with computer systems, databases and tailor-made software.
- Technical/physical and analytical laboratories for inorganic gases, organic gases like BTEX, suspended particles, metal compounds, PAH, dioxins/furanes/PCBs, etc.
- Staff for the emergency task force.
- Staff for maintenance and repair of stations and measurement equipment (engineers, technicians).
- Academic analytical and laboratory staff (chemists, engineers, lab assistants).
- Academic staff/engineers for data evaluation and analysis, reporting, etc.

TABLES

Table 1. **Limit Values of Old European Directives**
Concentrations in µg/m³

Compound	Value	Period	Remarks
	120 (80)	01.04. - 31.03.	Median of daily means (SPM > 150)
• Sulphur Dioxide	180 (130)	01.10. - 31.03.	Median of daily means (SPM > 200)
	350 (250)	01.04. - 31.03.	98 %-value of daily means (SPM > 350)
• Suspended Particles (SPM)	150	01.04. - 31.03	Arithmetic Mean
	300	01.04. - 31.03	95 %-value of daily means
• Nitrogen Dioxide	200	01.01. - 31.12.	98 %-value of hourly means
• Lead	2	01.01. - 31.12.	Arithmetic Mean
• Ozone	180/360	01.01. - 31.12.	hourly mean; Information/Warning

Table 2. **List of atmospheric pollutants to be taken into consideration in the assessment and management of ambient air quality**

Council Directive 96/62/EC of 27 September 1996 on Ambient Air Quality Assessment and Management (Annex I)

I. Pollutants to be studied at an initial stage, including pollutants governed by existing ambient air quality directives	II Other air pollutants
1. Sulphur dioxide	7. Benzene
2. Nitrogen dioxide	8. Carbon monoxide
3. Fine particulate matter such as soot (including PM10)	9. Polyaromatic hydrocarbons
4. Suspended particulate matter	10. Cadmium
5. Lead	11. Nickel
6. Ozone	12. Mercury

Table 3. **Smog Alert Regulations in North Rhine-Westphalia**

Threshold Levels (Concentrations in mg/m³)

Substance	Time Basis	Prealert	Stage 1	Stage 2
Sulphur Dioxide	3 h	0,60	1,20	1,80
Nitrogen Dioxide	3 h	0,60	1,00	1,40
Carbon Monoxide	3 h	30	45	60
"Smog Index"	3 h/24 h	1,10	1,40	1,70

"Smog Index" = $c[SO_2] + 2 * c\ [SPM]$

Measures

Prealert	Stage 1	Stage 2
• information of public, hospitals, industries, etc. via newspapers, radio, TV • call to everybody to reduce emissions as far as possible	• prohibition of traffic from 6-10 a.m. and 3-8 p.m. in special areas (exceptions for emergency vehicles) • only low sulphur fuels allowed	• general prohibition of traffic in special areas (exceptions for emergency vehicles) • only low sulphur fuels allowed • reduction of production or even total shut-down of power plants, factories, etc.

Table 4. **LUQS - Monitoring System for Air Pollution in NRW**

Automated Monitoring Systems	Semi-Automated Monitoring Systems	Discontinuous Monitoring Systems	Emergency Task Force
Continuous Measurements	Filter Methods	Multi-Component Measurements	Special Analytic Chemistry
• Sulphur Dioxide • Nitric Oxide • Nitrogen Dioxide • Carbon Monoxide • Suspended Particles • Ozone • Hydrocarbons • Wind Direction • Wind Velocity • Air Temperature • Atmospheric Pressure • Air Humidity • Solar Radiation • Precipitation	PM10 / PM2.5 SPM and its Components • Lead • Cadmium • Nickel • Arsenic • Beryllium • Benzo[a]pyrene • Benzo[e]pyrene • Benz[a]anthracene • Dibenz[a,h]anthracene • Benzo[ghi]perylene • Coronene	• Dust Deposition and its Components • Soot • Benzene, Other Hydrocarbons • Highly volatile Hydrocarbons • Halogenated Hydrocarbons • Polyhalogenated Dibenzodioxines and Dibenzofuranes • PCB´s	A great number of inorganic and organic substances by means of special equipment: • *Test Tubes* • *Sensors* • *Continuous Monitors* • *Gas chromatographs* • *Mobile GC/MS-Coupling* • *Mobile REM* • *Meteorological Instruments*

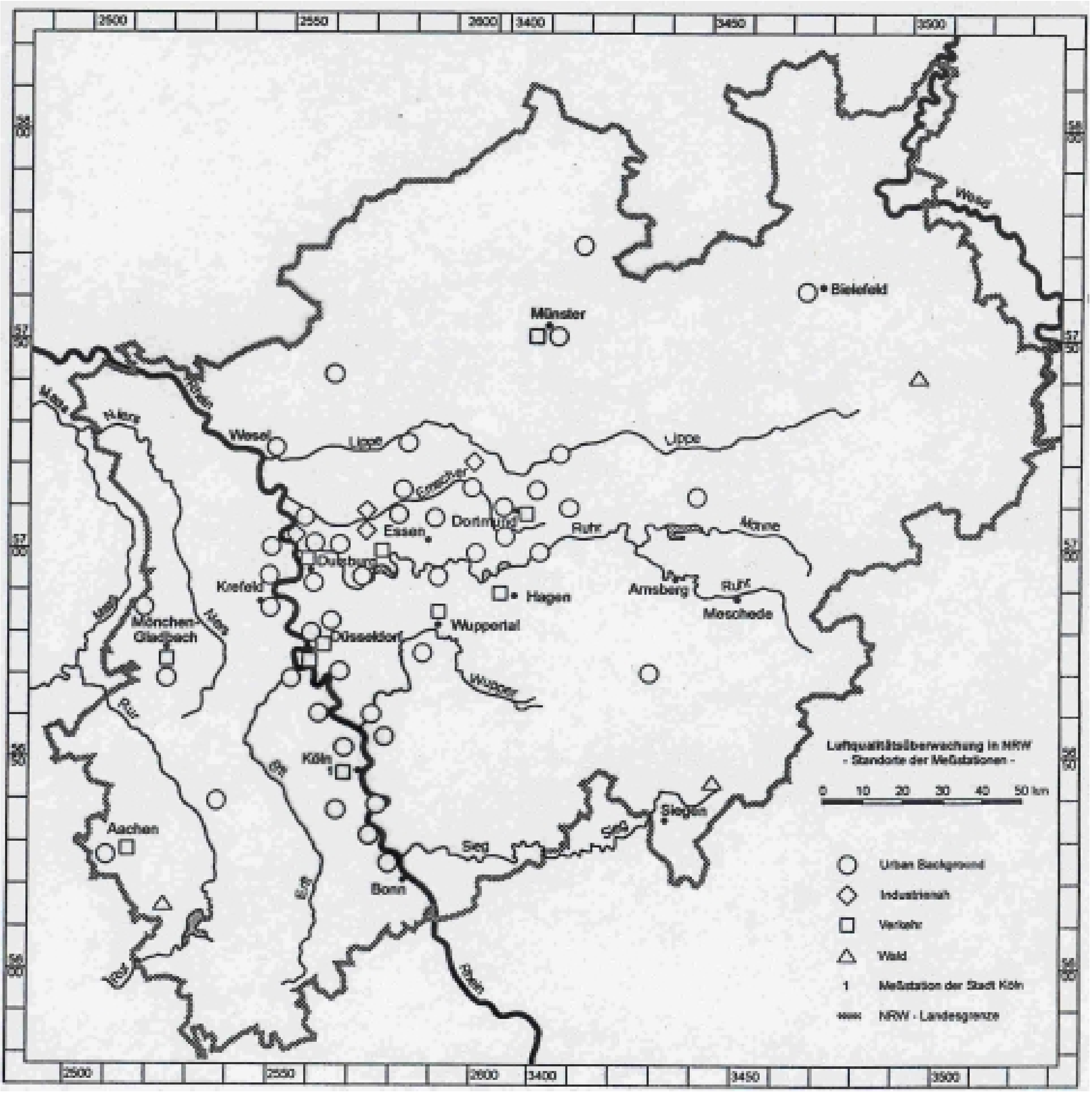
Table 5. **Continuous Measurement**

Component	Monitor	Manufacturer	Measurement Priciple
• Sulphur	U3RK SO_2	Wösthoff	Conductometry
• Dioxide	API 100	API	UV-Fluorescence
	AF 21 M	Environnement	UV-Fluorescence
• Nitrogen Oxides	AC 30/31 M	Environnement	Chemiluminescence
• Carbon	UNOR 5 N	Maihak	IR-Absorption
• Monoxide	APMA 300/350 E	Horiba	IR-Absorption
	CO 11 M	Environnement	IR-Absorption
• SPM	FH 62 I/N	Thermo Instruments	β-Radiation
• Ozone	APOA 350 E	Horiba	UV-Absorption
	O_3 41 M	Environnement	UV-Absorption
• Organic Gases	HC 1010	Airmotec	GC

Table 6. **Calibration Systems for Continuous Measurement**

Component	Gas	Ambient Air	Cylinder direct	Cylinder with dilution	Permeation	Gas-phase Titration
SO_2	blank gas	X				
	span gas			X	X	
NO	blank gas	X	X			
	span gas		X	X		X
NO_2	blank gas	X				
	span gas					X
CO	blank gas	X	X			
	span gas		X			
O_3	blank gas	X				
	span gas	X				
Organic	blank gas	X				
Gases	span gas			X		

Figure1. **Air Pollution Monitoring Network in NRW (LUQS)**



○ ***Urban Background*** □ ***Traffic***

◇ **Industrial** △ **Rural**

Figure 2. **TEMES-Stations in NRW 1996**

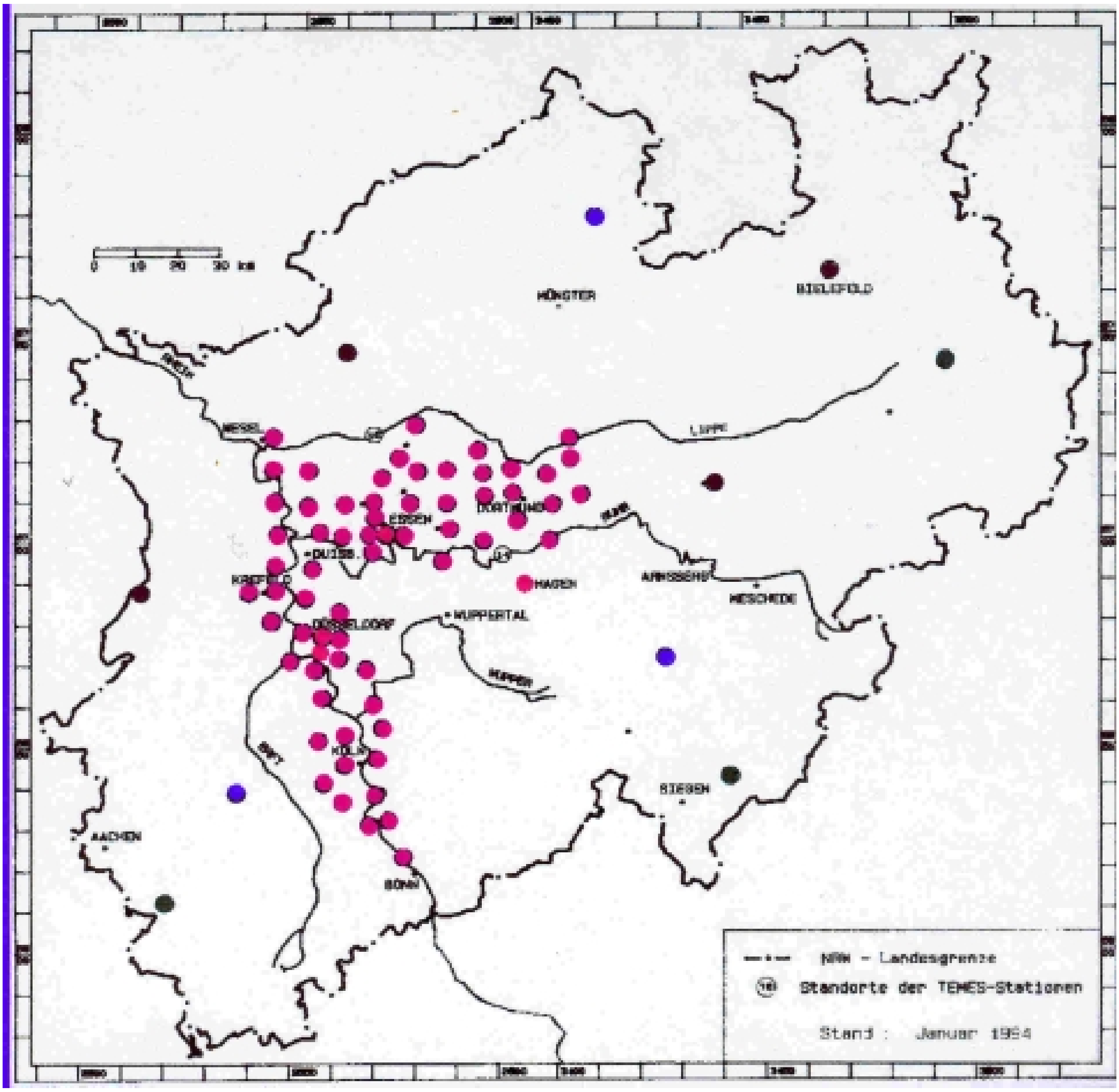
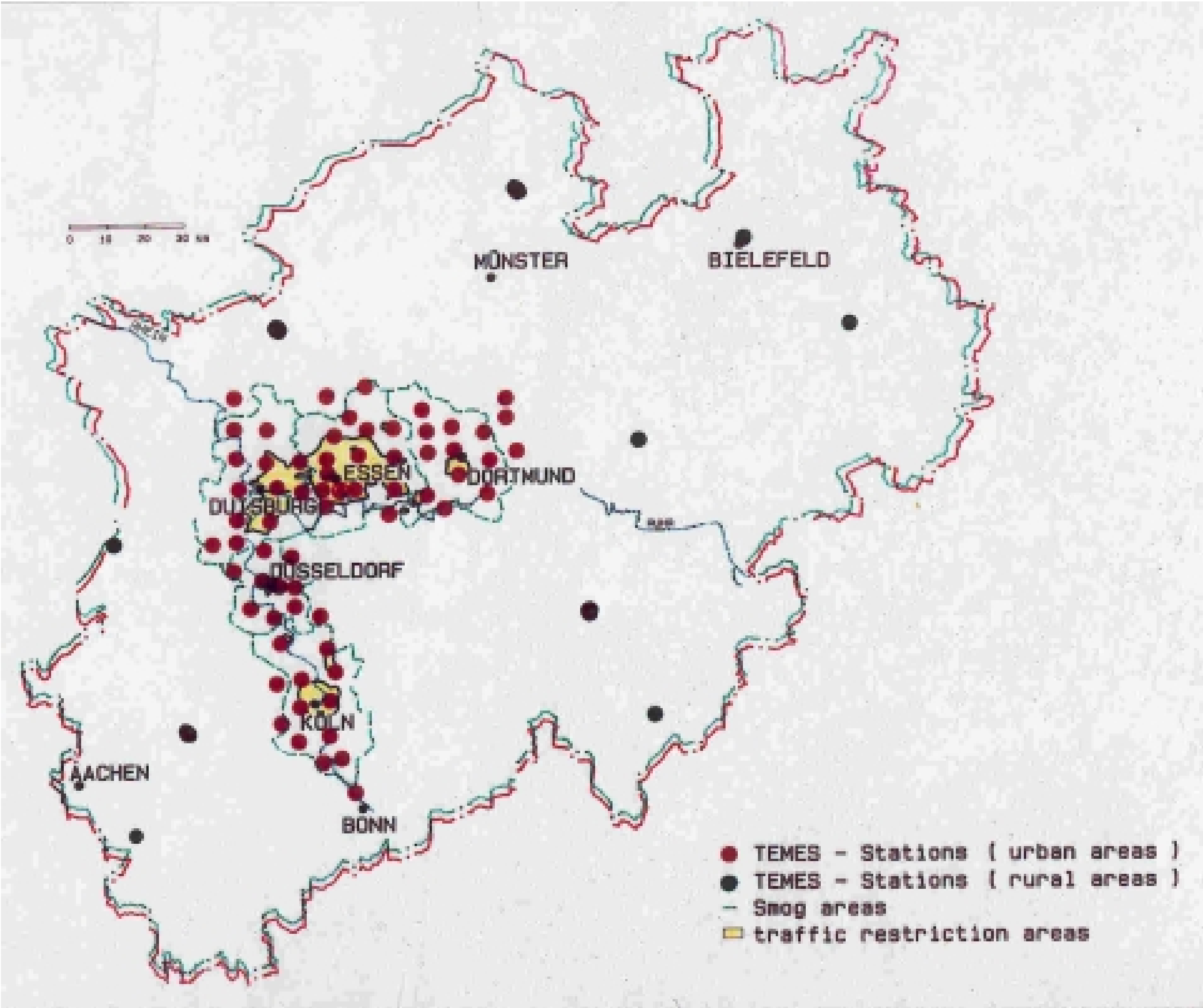


Figure 3. **Smog Areas and Monitoring Stations in NRW 1996**



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Airshed Monitoring
The Experience of China

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Airshed Monitoring - The Experience of China

Urban Air Quality Monitoring in China

Abstract :

This paper discusses the current state of urban air quality monitoring in China. It covers such aspects as environmental quality standards, monitoring networks, analytical methods of routine monitoring, technical standards, operational modes and quality assurance. Under China's system of ambient air quality standards, concentration values for pollutants produced by burning coal are somewhat higher than international standards, while concentration values for pollutants produced by motor vehicles are far lower than international standards. At present, 350 of China's 666 cities have begun monitoring air quality; of these, 103 selected monitoring stations comprise the National Air Quality Monitoring Network, with others known as the Provincial Air Quality Monitoring Network. Routine monitoring of urban air quality has established 81 categories for 149 analytical methods and established relevant technical monitoring norms. The Monitoring Network currently employs three operational modes: continuous automatic monitoring, continuous automatic (24-hour) sampling with laboratory analysis and manual (intermittent) sampling with laboratory analysis. Making a comprehensive assessment to determine the ambient air quality situation and trends poses the problem of data comparability. Since 1997 some 46 key cities have been using the API in issuing public urban air quality reports. Reporting is currently limited to retrospective weekly reports, but it is planned that by the year 2000 a number of large cities will issue next-day air quality forecasts and set up air- quality warning systems. The final section uses Beijing as an example in discussing urban air quality monitoring.

URBAN AIR QUALITY

China is one of the world's major coal-burning countries, with coal accounting for 76 per cent of all energy consumption. Pollution of ambient urban air is prominent, with the major pollutants being sulphur dioxide (SO_2) and total suspended particles (TSP). The range of pollution is extensive and the level is critical, having stabilised over the years at a relatively high level.

Polluted areas are distributed more heavily over northern cities than southern cities, with winter and spring experiencing heavier pollution than summer and autumn, especially from TSP. SO_2 pollution is even more severe in the south-west, owing to the high sulphur content of the coal there. The area suffering from acid rain pollution is also increasing annually.

With the rapid increase in the number of motor vehicles, nitrous oxide and ozone levels in some large cities have been on the rise, resulting in pollution from a combination of coal smoke and motor vehicle exhaust.

Of the 95 cities that comprise the National Air Quality Monitoring Network, 72 % exceed Class II standards for TSP pollution, 45 % exceed Class II standards for SO_2 pollution, and 36 % exceed Class II standards for NOx pollution. Only 28 % of all cities fully meet national Class II air quality standards.

AMBIENT AIR QUALITY STANDARDS

In January 1996, national Ambient Air Quality Standard GB 3095-1996 was promulgated, replacing Ambient Air Quality Standard GB 3095-82 of August 1982.

- This Standard distinguishes three categories of air-quality zones: naturally protected areas, urban residential areas and industrial zones;
- It creates three corresponding standards and concentration limits for 10 pollutants;
- It sets annual, daily (24-hour) and hourly average values;
- It sets out methods for analysing all types of pollutants and principles for assessing data validity.

On the whole, this standard approaches standards used in other countries; with the exception of TSP, for which concentration levels are somewhat higher than international standards, concentration levels for pollutants such as SO_2, NOx and O_3 fall somewhat below international standards.

Most of China's cities will apply Class II standards of the national Ambient Air Quality Standard.

In May 1997 the National Environmental Protection Office (NEPA) established the Air Pollution Index, or API (also known as the Pollution Standard Index, or PSI) in an effort to classify the standards.

China's current API classifies standards using the 500 series; for API values below 200, the Class I, Class II and Class III standards set out in Ambient Air Quality Standard GB 3095-1996 are applied, while for values above 200, the concentrations of the United States Environmental Protection Agency (EPA) classification system are used.

After testing it was discovered that the API values falling in the 100-200 range were too low, causing the proportion of mid-level pollutants to go up when describing urban air quality.

When using the API targets to rank the main pollutants of urban air and the influence of the concentration limits set for all pollutants and the representativeness of monitoring sites is noticeable, particularly when the levels of some pollutants are relatively high, it is possible to come up with a picture that is somewhat less than precise

While no one system of indicators is perfect, this one is effective for the time being. However, to have efficient, rational and operable ambient air quality standards, the experience of other countries must be studied.

THE URBAN AIR QUALITY MONITORING NETWORK

China has a total of 666 cities (1996 figure), of which 220 are classified as cities directly under the central Government or at the provincial or municipal levels and 446 are at the county level. China has 46 key cities.

There are currently some 350 cities with environmental monitoring stations engaged in monitoring urban air quality, with a total of approximately 1,800 monitoring sites.

The National Air Quality Monitoring Network has a total of 103 air quality monitoring stations - 95 urban stations and 8 regional stations - which include approximately 400 monitoring sites. The Network monitors the ambient air quality. The National Acid Rain Monitoring Network is composed of 13 monitoring stations.

The Provincial Air Quality Monitoring Network is a network composed of 350 Chinese cities having air quality monitoring capacity organised separately at the provincial level.

The GEMS/China Network: China has five key cities and 20 monitoring sites that participate in the global air monitoring activities of WHO/UNEP-GEMS/Air.

Objectives of the Urban Air Quality Monitoring Network: to obtain a picture of the air quality situation and long-term changing trends for the country as a whole; to determine whether the air quality in individual cities meets national ambient air quality standards; to issue air quality reports for residents of urban areas; to assess the impact of air pollution on air quality; to evaluate the results of pollution control and management measures; and to provide a scientific basis for environmental policy-making and urban development planning.

From 1988 to 1993, the National Air Quality Monitoring Network urban monitoring sites conducted research and standardisation in order to improve the overall set-up of the network and make the monitoring sites more representative; however, with the rapid pace of urban development, the representativeness of its monitoring sites continues to pose a major problem for the networks existence as such.

ROUTINE MONITORING OF URBAN AIR QUALITY

Analytical methods and technical standards

Analytical methods are the product of many years of research in China and draw on long-established international methods such as those of the United States EPA, the ISO-TC 146 of the International Organisation for Standardisation (ISO), the Japanese JIS, etc.

In 1990 the National Environmental Protection Agency (NEPA) issued a revised edition of its "Methods for Analysing Air and Gases", listing a total of 81 categories covering 149 analytical methods, including 49 categories for 79 methods applicable to air pollution monitoring. This is basically sufficient for pollution control in its current stage.

However, the analytical methods currently in use are not comprehensive enough, especially sampling methods, and the methods for sample pre-treatment are relatively weak. In addition, the number of methods is inadequate, particularly in view of the even greater number of organic pollutants. For example, the United States EPA focuses on controlling 174 organic pollutants, whereas Chinas analytical methods include only 30 methods for 22 organic pollutants.

In November 1986, NEPA promulgated the Technical Standards for Environmental Monitoring, including the volume II, °Air and Waste Gases, which is used in monitoring urban ambient air quality. The content and thoroughness of these standards are still rudimentary after more than a decade of use; they are currently undergoing a thorough revision, and it is hoped that the revised edition will be issued soon.

Mode of operation

Three operational modes are used in monitoring ambient air quality in China:

Continuous automatic monitoring

Substances monitored and analytical method:

SO_2	Ultraviolet fluorescence
$NO/NO_3/NOx$	Chemical luminescence
TSP/IP_{10}	High and medium volume sampling, Beta-ray absorption, TEOM
CO	Infrared (undispersed) method
O_3	Ultraviolet absorption

In addition, a small number of cities use the DOAS to monitor SO_2, NO_2, O_3 and organic pollutants.

Average values can be obtained for 5-minute, 1-hour and 24-hour intervals, with significant data obtainable for ratios 5,000 hr/yr.

Continuous automatic (24-hr) sampling with laboratory analysis

Substances monitored and analytical methods:

SO_3/NOx	Spectral luminosity
TSP	High and medium volume sampling

Rough daily averages can be obtained, with significant data obtainable for SO_2 and NOx ratios:

- 12 days/mo on average (evenly distributed) and
- 144 days/yr on average (evenly distributed); TSP
- 5 days/mo on average (evenly distributed) and
- 60 days/yr (evenly distributed).

Manual (intermittent) sampling with laboratory analysis

Substances monitored and analytical methods are the same as above.

Rough daily averages can be obtained, with significant data obtainable for ratios of:

- 5 days/season on average,
- 20 days/yr on average.

Statistics for urban air quality routine monitoring, by operational mode:

- In 1998, in 46 key cities around the country, 46% of all monitoring was carried out by automatic monitoring sites, 54% by continuous sampling sites, and 0 % by manual sampling sites;
- In 1998, in the 95 cities making up the National Monitoring Network, 27% of all monitoring was carried out by automatic monitoring sites, 42% by continuous sampling sites and 31 % by manual sampling sites;
- In 1998, in the 353 cities making up the Provincial Monitoring Network, 8% of all monitoring was carried out by automatic monitoring sites, 34% by automatic sampling sites and 58 % by manual sampling sites;
- Through the year 2000, automatic monitoring will account for 97% of monitoring done in key cities, 60% of monitoring done by the National Network and 16% of monitoring done by the Provincial Network.

The choice of operational method for routine monitoring depends on monitoring objectives and the local level of economic and technological development. It is thought that these three operational methods will coexist for some time to come; however, when making a comprehensive evaluation of the ambient air quality situation and trends, problems of data consistency and comparability may arise.

QUALITY ASSURANCE (QA) IN AIR QUALITY MONITORING

Environmental monitoring stations at all levels have established QA structures and administrative systems. They have also developed a series of basic works on QA, including the Handbook for Quality Assurance in Ambient Air Monitoring, Technical Regulations for Quality Assurance in Ambient Air Monitoring and Training Materials for Quality Assurance in Environmental Monitoring.

Continuous automatic monitoring systems and continuous sampling have all developed a series of QA activities such as calibration, standards transmission, quality control inside and outside the laboratory and data verification.

At the national level, the continued lack of unified regulations for QA in environmental monitoring, including systems for DQO, sampling control, and systematic and functional verification of monitoring systems, is a relative weakness.

From a national standpoint, QA/QC is developed to differing degrees in different localities; the more successful facilities approximate the QA/QC regulations of the U.S. EPA which are nearing completion, while those that are somewhat behind do not even done flow calibraton for the whole sampling process.

URBAN AIR QUALITY PUBLIC INFORMATION SYSTEM

In June 1997, 46 key Chinese cities began issuing reports on their air quality to the entire country (there are currently 65 reporting cities, 46 of which issue their reports nationally and 19 which issue them locally). The reports use the urban API to determine current SO2, NOx and TSP levels; they are disseminated through the news media (television, radio and the press) and hotlines.

At present, air quality reports are issued to the public on a weekly basis: five reports a week covering the urban air quality of the past week. These retrospective reports are intended to inform urban residents of the approximate current air quality level. This public information has strengthened city-dwellers' sense of control and participation in environmental protection and also promotes the pace of management of environmental quality and pollution control by government at all levels.

The country's 46 key cities are currently endeavouring to issue same-day and next-day API urban air pollution forecasts by the year 2000. A few relatively heavily polluted cities are also studying and setting up systems for air pollution alerts and environmental quality management.

MONITORING AND MANAGEMENT OF AIR QUALITY IN BEIJING

Beijing has a total surface area of 16,808 km^2, an urban area of 1,040 km^2 and a population of 11 million; its energy is derived chiefly from coal, with an annual consumption of 28 million tons. There are approximately 1.4 million motor vehicles. Beijing is located in an area of transition from mountains to plains; it has a temperate continental monsoon climate and four distinct seasons - winter and spring are dry, with much wind-borne sand.

The main feature of Beijing's air pollution is a smoky combination of coal soot and motor vehicle exhaust. Over the years the three main pollutants, TSP, SO2, NOx, have stabilised at relatively high levels, with NOx pollution showing a marked increase.

In 1984, Beijing established the Beijing Municipal Air Quality Automatic Monitoring System, which has gone from an original 143 manual monitoring sites to an optimal 8 sites carrying out long-term continuous automatic monitoring of such substances as SO2, NO/NO2/NOx, CO, O3, TSP/PM-10 and such meteorological parameters as wind direction, wind velocity, temperature, humidity, etc. These 8 monitoring sites also come under the jurisdiction of the NEPA National Air Quality Monitoring Network, and 4 are still part of the GEMS/AIR/Beijing site. In 1998 the Beijing Municipal Air Quality Monitoring System expanded to 12 monitoring stations, and it is planned that by the year 2000 it will expand to 24 stations. Currently each Beijing district and county still has 27 manual intermittent sampling stations to monitor SO3 and traffic-related atmospheric pollutants such as NOx and CO.

The Beijing Air Quality Automatic Monitoring System has been in continuous operation for 10 years. Annual data are consistently obtained for more than 7,500 hr/yr. The system operates in accordance with the relevant QA regulations of the U.S. EPA and its data have a high degree of accuracy and comparability. It is the chief tool of the Beijing Municipal Environmental Management Authority.

In 1998, Beijing began using the API to issue weekly comprehensive municipal air quality reports. It is currently testing a statistical forecast and preparing to study models to develop a numerical forecast. It is planned that municipal air quality forecasts will be issued by 2000 and that a pollution-alert system and a municipal air quality management system will be in place.

In the light of Beijing's air quality situation, a policy of "Manage All Three Together" has been adopted to control the three main pollutants. The Beijing Municipal Government, as part of its implementation of a long-term pollution reduction policy, plans to introduce priority stabilisation measures in the near future for the control of 19 major pollutants, including modification of energy source structures, bringing four city districts inside the ring road under control, controlling smoky emissions from primitive coal-fuelled boilers, controlling motor vehicle exhaust and dust emissions from construction sites, etc. This effort to effect a significant improvement in Beijing's ambient air quality will require a sustained, intense effort.

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