Ministerie van Verkeer en Waterstaat

Directoraat-Generaal Rijkswaterstaat

Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling RIZA

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Nation-wide water monitoring: the experience of the Netherlands

Presentation at the OECD/SEPA seminar on environmental monitoring Beijing, China. April 12-14,1999

ing. R.M.A. Breukel
Department of Information supply

RIZA document 2000.051X
Lelystad, March 2000

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Content

Preambule

In 1999, the Organisation for Economic Co-operation and Development (OECD, State of the Environnment Division, Paris, France) and the State Environmental Protection Aministration People's Republic of China (SEPA, Beijing, China) jointly organised a seminar on issues concerning environmental monitoring.
The seminar was part of the OECD's co-operative programme with China. It was held in Beijing, 12-14 April 1999.

The objectives of the seminar were to exchange information between China and OECD countries on practical experiences with environmental monitoring, in particular to water and air monitoring.

In this context particular attention was given to:

- the use of monitoring data to support decision-making and to inform public opinion,
- the collection, treatment and interpretation of monitoring data
- related institutional and financial issues.

The participants were:

- selected experts from China,
- Chinese delegates from SEPA, other ministries, provincial environmental protection bureaus and research institutes
- selected experts (11) from different OECD countries (US, Finland, France, Germany, Netherlands, Japan, UK, Mexico, Korea)
- delegates from OECD

This document contains the Dutch contribution wich concerned nation-wide water monitoring.

1 Introduction

Policy makers and managers need proper information to base decisions on and to improve the quality of the decisions and measures taken. Obviously, this is the case in any field in which policy is being made or evaluated, but especially with regard to environmental management, since the relation between measures and effects is such a strong and direct one. Measures taken in the field of environmental management can be very expensive and effects can have a large, sometimes even irreversible impact. In order to make the right decisions and to have good insight into the effects and cost-effectiveness of measures taken, information is essential.

However, information should not just be a large amount of data, but adequate, tailor-made information that gives clear and concise answers to the right questions.
The need for 'tailor-made' information in water management (as one of the most dynamic parts of environmental management) becomes more urgent with growing flows of information, since more data from different disciplines are combined and the exchange of water data between organisations increases. Also, policy makers and water management authorities are increasingly being challenged to cope with conflicting interests from pressures and functions of their waters [Ward, 1994].

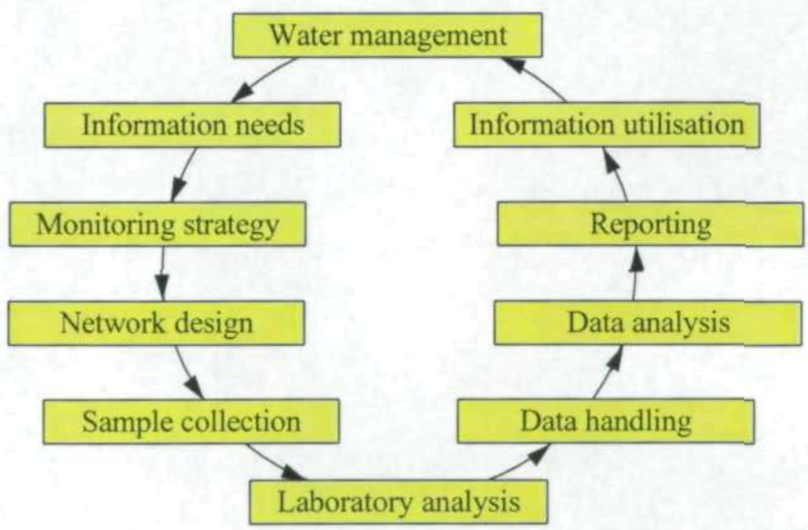

Figure 1: The Monitoring Cycle [UN/ECE, 1996

Based on experiences in the Netherlands, a new approach for the design of monitoring systems has evolved, and is presented in this paper as well as the implementation of this approach in the Netherlands. In this approach, careful and detailed specification of information needs is a major contributing factor to the effectiveness of information products.

The approach is illustrated by the "monitoring cycle" (figure 1). This is a general framework that describes the essential steps in the continuous monitoring process. The cyclic character provides a quantitative means of connecting the information expectations and/or products required by management with the monitoring system design and operations [Timmerman et al, subm.].

In this paper the 'monitoring cycle' is used to illustrate the different steps in the process of designing and operating monitoring systems in order to generate the information for water management.

2 Information needs

2.1 Three core-elements

Over the last two decades, European water management has changed from a focus on distinct sectors, dealing with one or two interests at a time, to integrated water management, interrelating different aspects of the water system like chemical aspects, physical planning, ecology and emissions. In addition, increasing knowledge of the complexity of processes in water systems has led to a growing demand for information.
This growing need to integrate disciplines also brings about the need to integrate large sets of data and information. Moreover, computers provide numerous possibilities to store, retrieve and analyse data, thus enlarging the availability of data and information. Nowadays, policy-makers and water managers are overwhelmed with data and information that may or may not be of use to them. Ward and others (1986) described this as the 'data-rich but information-poor syndrome'. Therefore, there is a call today for less quantity of information and more targeted, tailor-made, information.

The most critical step in developing a successful, tailor-made and cost-effective monitoring programme, is the clear definition of information needs. In specifying the information needs for integrated water management, it is suggested [UN/ECE, 1996] to approach the task from a triangle of core-elements: functions and use of the water, problems and threats for this use or function and measures that may be taken (figure 2). For example, a large part of the Dutch shore-line consists of dune that protects the land behind it against flooding (function). During storms, parts of these dunes are washed away (problem). The damage is repaired by supplying sand (measure). By elaborating problems and measures of all functions, a comprehensive analysis of the situation at hand is made.

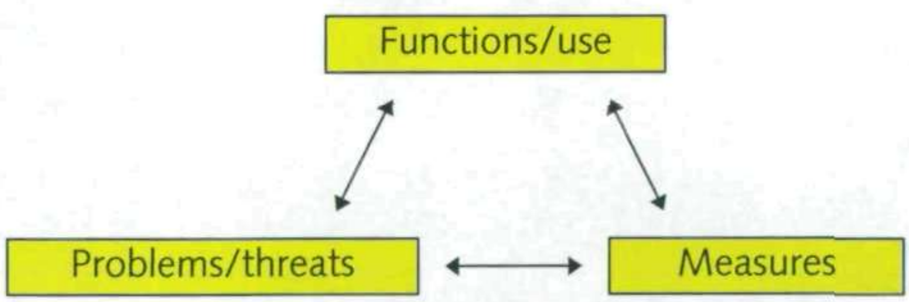

Figure 2. Core elements in water management (UN/ECE, 1996)

2.2 Dutch developments in specifying information needs

In the past few years, the Netherlands have been involved in the development of a structural approach towards water monitoring. This approach has evolved from (a.o.) from Dutch experiences with designing and optimising monitoring networks [Adriaanse, 1993 and Breukel et al, 1995], two international conferences on monitoring ('Monitoring Tailor-made' I and II in 1994 and 1996 respectively), an inventory of the experiences of many European countries and 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 specifying the information needs by the information 'users' to enable information 'producers' to produce tailor-made information.

A good example of changing information needs may be found in the development of water management policy in the Netherlands. In the first national policy document (published in 1968), water quantity was the central issue. The second document (1984) added a relation with economy and brought about attention to water quality aspects. The third national policy document (1989) portrayed water as a system and ecology was valued side by side with economy.
Nowadays the trend in water management is towards 'integrated water management' - a balance between economics, ecology and sociology. These aspects are integrated 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.].

2.3 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 or any feedback to resource managers, and contribute little or nothing to our understanding of the systems being monitored" [MacDonald, 1994].
The information objectives of monitoring networks should be identified by managers in consultation with technical staff, but management issues 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 'What will be the consequences of dry years for agriculture?'. These questions are not easily nor simply answered, and they even raise new questions. What is 'safe'? Maybe a statistical chance of one in ten-thousand years is safe? Does this count for the whole of the Netherlands or just for one polder? And against what cost? On the other hand, experts, scientists, and other 'information producers' that generate information, tend to provide answers like: 'The maximum water level is *34.6 m above mean sea level*' or '*pH is 7.8*'. *Many information users may* find it difficult to relate those answers to their questions [Timmerman et al, subm.].

These questions and answers reflect different 'worlds' of thinking. These two worlds need to be linked together through communication. A dialogue is needed between information users and information producers, to develop the 'connecting' questions - questions that are clearly articulated and understood by both information producers and users. Because only the right question will lead to the right information to make the right decisions [after Adriaanse, 1997].

2.4 Quantification of information needs

The right questions should also provide some quantitative aspects that are necessary for the next steps in the monitoring cycle such as the strategic choices in the phase 'monitoring strategy' and the step 'network lay-out'. This involves aspects such as 'significance', 'accuracy' and 'period of availability'. These more quantitative information needs make it possible for the information providers to formulate accurate monitoring objectives. Examples are:

1) for the Dutch monitoring network for water plants, the monitoring goal is formulated as: *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%.*

2) for the Dutch early-warning network, the monitoring goal is formulated as: *The continuous monitoring of water quality with a choice of instruments and communication-infrastructure, aimed to be able to warn interested parties within 24 hours after exceeding of determined water quality standards.*

Intermezzo

The optimisation of the Dutch national water monitoring network

The Dutch monitoring networks are optimised on a regular basis every few years. In the last optimisation of the chemical network, the starting point was to determine the objectives of the network to: the assessment of status and trends (surveillance monitoring), the assessment of loads/fluxes, and compliance testing (statutory monitoring; to meet legal obligations). This meant a limitation of the former objectives. Secondary objectives for the national network such as information collection for operational water management, research and development, and development and calibration of models were no longer taken into account [Ottens et al, 1998 and Breukel et al, 1995].

For these objectives the "information need" was specified per variable, per water system (lakes/rivers), and for different media (water/dissolves, suspended solids). The information need was determined to the detail of 'relevant margin' which is a range in information values that are still of interest to the information user [Breukel et al, 1991]. From this detailed information need, the sampling frequencies and the density of sampling locations can be determined. A statistical study was performed to check what measuring frequencies were needed to be able to detect trends or to calculate loads. A complicating factor in these studies was the availability of long term consistent historical series [Klavers, 1992].

Other factors that were taken into account in this optimisation were: cost effectiveness, expert judgement, new legal obligations and new water policy. The resulting national monitoring network ended up with:

- lower density in sampling locations (from 135 to 27),
- higher measurement frequencies,
- same costs as previous network,
- better link of monitoring data with objectives.

It is not always easy to come to such strictly formulated information needs and monitoring goals, but there are many advantages. Not only will these strictly formulated monitoring goals enable water authorities to design their monitoring efforts, it also forces parties concerned to think very carefully about their information needs and the effects this has on size of the monitoring efforts.
An extra advantage is the fact that this quantitative formulation of monitoring goals enables an objective evaluation of the monitoring effort.

2.5 The use of indicators in specifying information needs

Indicators are useful to help further define the information needs in the communication between the different worlds of information users and information producers, because they can present information in a condensed/aggregated format and are often linked to specific problems or issues, which are in turn based on specific management needs.
Indicators are defined as observable or measurable quantity / variable / parameter, representing a process in the environment and having significance beyond its face value [Bakkes, 1994; OECD, 1993]. The construction of an indicator is a means of achieving reduction in data volume while retaining significance for particular questions. Suitable indicators provide for the three core elements (figure 2). When indicators are further aggregated the term index is used. This can be a set of aggregated or weighted variables or indicators describing a situation [OECD, 1993].

3 Monitoring strategy

When the information needs have been specified in enough detail, the next step will be to determine how and where the information will be gained. This step is called the 'monitoring strategy'. Monitoring, however, is not the only possibility to gather information.

3.1 Information strategy: different sources of information

Integrated water management requires integrated information. To provide such information, different sources are possible. However, in water management monitoring is still the method used most to collect data. Computer models are also used, to make predictions on the basis of the monitoring data. Surveys are used to provide insight into specific issues. Other sources of information may be literature studies and data from other disciplines such as agriculture, recreation, sociology, ecology and economics. Incorporated into the information cycle, different sources of information as well as different ways of collecting and analysing data are shown in figure 3. This paper is concerned with monitoring as a source of information only.

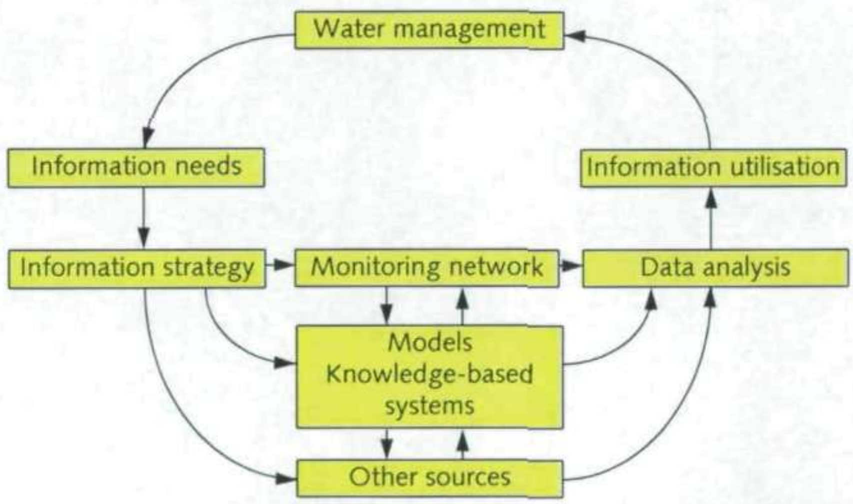

Figure 3. Different sources of information [UN/ECE, 1996]

3.2 Strategies of monitoring in Dutch national surface waters

When it has been decided that information is collected from monitoring, a strategy towards monitoring has to be chosen. In the Netherlands different approaches are persued, depending on the purpose and goals of the network (see table).
The Dutch monitoring effort for national surface waters is divided into three different strategies of monitoring (modules), each of which can be divided into several sub-modules on the basis of specified objectives. These modules are designed to supply for specific information needs and can be developed independently. This way it can be ensured that the monitoring

efforts will produce exactly the information needed. No more and no less. The modules, sub-modules and their purpose are:

<table>
<tr><th>MODULES</th><th colspan="3">SUB-MODULES</th></tr>
<tr><td><u>Ambient monitoring</u>

Ambient monitoring involves the observation of water systems with standardised methods, over a longer period (years), to establish status and trends for the purpose of enabling policy makers to make tactical and strategic decisions within water management, for the testing of standards and calculation of loads.</td><td>Nation-wide ambient monitoring

Answering 80-100% of all national and international information needs as well as 30-100% of the information needs from regional water authorities.</td><td colspan="2">Additional ambient monitoring

Answering to the specific (national / international) routine information needs, not covered by the nation-wide routine monitoring, with specific demands concerning variables, locations, frequencies, methods for sampling or analysis.</td></tr>
<tr><td><u>Operational monitoring</u>

Operational monitoring involves the continuous monitoring for the benefit of the safety and operational decisions within water management.</td><td>Early-warning

Early-warning in case of exceptional circumstances. The protection of functions and uses (drinking water, flood forecasting).</td><td colspan="2">Operational water management

Monitoring with high frequencies for the benefit of operational water management (agriculture, industrial use) and (inter-)national obligations.</td></tr>
<tr><td><u>Specific monitoring</u>

Specific monitoring involves the time-limited monitoring aimed at answering specific questions for the benefit of research and (method-) developments.</td><td>Specific monitoring, ambient

Specific monitoring for the sake of the research and development of the ambient monitoring.</td><td>Specific monitoring, operational

Specific monitoring for the benefit of the research and development of the operational monitoring.</td><td>Specific monitoring, others

Specific monitoring for the benefit of other requests, mainly scientific research and surveys or the development and calibration of models.</td></tr>
</table>

Note: effluent monitoring is not included, the table (and this paper) concerns surface water only.

3.3 Different monitoring networks in Dutch national surface waters

Based on the above mentioned strategies for monitoring, different networks can be designed to gather the information needed. For pragmatic reasons these networks are divided according to their discipline. The Dutch nation-wide monitoring includes the following disciplines: hydrological (physical) monitoring networks; chemical monitoring networks; biological monitoring networks; operational water quality monitoring network.

For each of the monitoring networks, one or more monitoring programmes is/are published every year, depending on and taking into account the demands from the different modules and sub-modules.

Within these programmes are specified: the results to be achieved, the lay-out of the network, the necessary means and the yearly evaluation in order to fine-tune the programme for the next year.

If the evaluation shows a change of information needs, several different options for adjustment of the monitoring programmes are specified including the financial consequences and discussed with the parties concerned. The option agreed upon will be integrated in next year's programme.

4 Network lay-out

Based on the different monitoring strategies (ambient, operational and specific) and the different monitoring disciplines (hydrological, chemical, biological and operational) the following Dutch monitoring networks are operational in the inland national waters. The information in this section is mainly derived from [RIZA, 1999].

4.1 Hydrological monitoring networks

4.1.1 General objectives

- Information supply for the benefit of (inter-)national water policy. Establishing status and trends of the hydrological characteristics of the Dutch national water systems;
- Information supply for the benefit of national operational water management.
- Objectives that have recently been developed and for which adjustments of the monitoring programmes are necessary:
- the 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.
- increase of the demand for physical and hydrological data due to the increased research on measures and policy plans in connection with the floods and safety problems as a result of the high water levels in the large transboundary rivers in the last few years.

4.1.2 Objectives per (sub)module

<u>Ambient monitoring</u>
Nation-wide ambient monitoring: Ambient monitoring of the river's regime supplies the data necessary to establish status and trend on hydrological characteristics. The data are also necessary for load calculations on transport of sediments and pollutants and for interpretation of the data from chemical and biological monitoring.

<u>Operational monitoring</u>
Early-warning (flood forecasting): Early-warning monitoring supplies the current water levels and other relevant data at times of floods (high discharge or water levels) The data are essential for making predictions with computer model.
Operational water management and (inter-)national agreements: The on-line available data are used to operate the nationally important bridges, sluices and other water works, to establish the water depth en other criteria relevant for shipping and to support decision makers in operational water management.

4.1.3 Hydrological network lay-out

<u>National water level network</u>
The national water level network consists of 69 locations in the inland waters. The spatial coverage is based on the risks in case of a

breach in a dike and obstacles for shipping. Most locations are situated near cities, weak spots in dikes, bridges and rims in the water-bed.
An extra demand is that in case of a break-down of the equipment at one of the locations, 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 10 seconds but transformed to average-values of 10 minutes. The data are recorded and transmitted on-line.

National flow monitoring network

The national flow monitoring network consists of 16 locations. The spatial coverage is determined by the national distribution of water flows and the policy relevant information needs.
The discharge is determined with different methods: an acoustic flow meter (ADM), determination by means of a discharge-water level graph, calculation from other discharge data or through spillage data from sluices, locks and weirs.
The aim of the network is to determine the flow with an accuracy of 90%. The data gathering with ADM's is carried out on-line. The other data sources do not deliver on-line data.

4.2 Chemical monitoring networks

4.2.1 General objectives

The general objectives of the national chemical networks are:

- evaluation of national water quality policy, testing of standards;
- establishing status and trends in concentrations and loads of pollutants;
- complying to (inter-)national obligations and agreements related to water quality monitoring;
- surveying for or detection of relevant new water quality developments or problems.

4.2.2 Objectives per (sub-)module

Ambient monitoring

Nation-wide ambient monitoring. Policy preparation and evaluation is the first key-objective. Establishing status and trends (trends of 20% or more over a period of five years) is the next. A secondary objective is to serve as a reference for other monitoring programmes.

International agreements. International agreements are becoming increasingly important for integral water management. The water system approach will in case of transboundary waters, ask for more and more international co-operation. Agreements made in international context may well be (partly) incompatible with the national programmes. This specific programme will generate the missing information.

Specific monitoring

Specific monitoring ambient. The projects in this sub-module have been started to develop and optimise the ambient monitoring.

Specific monitoring operational. Several inventories, surveys and screenings have been conducted in order to generate new monitoring or assessment methods and techniques.

Specific monitoring others. Several inventories, surveys and screenings have been conducted in order to generate information on 'new' substances, to generate new monitoring or assessment methods (e.g. load-calculations).

4.2.3 Chemical network lay-out

Nation-wide ambient monitoring programme

The ambient monitoring is carried out in one monitoring network. There are 27 locations, chosen to be representative for 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 / parameters as well as a limited amount of effect indicators. The variables include field parameters, general parameters, non-organic pollutants (a.o. heavy metals), organic pollutants, ecotoxicology (a.o. Ames-test), radioactivity and microbiology.

The media covered by the monitoring programme 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 the RIZA-laboratories or delegated to other laboratories under responsibility of the RIZA-labs.

Specific project networks

The specific monitoring is carried out in a large number of project-related networks, each with their own duration, selection of locations, variables and media. The lay-out of the network is decided by the relevant project manager in close co-operation with the monitoring department that controls the larger national networks. Obviously, the specific programmes will aim at the information not provided by the national regular networks. These specific monitoring programmes will not be further described in this paper.

4.3 Biological monitoring networks

After a period of biological monitoring in several specific projects, the ambient monitoring of biological variables on a routine basis started in 1992. The network aims to monitor the effects of national policy with respect to ecological effects of pollution, eutrophication and (re-)construction of water systems design. There is also a strong growing use of and demand from international river commissions and agreements.

The network has been designed based on existing networks (chemical, operational) within RIZA, but also in accordance with the biological networks of other national institutes in order to improve the quality of the derived information and reduce costs. Also, in present day operation, several parts of the biological monitoring are performed in co-operation with, or completely by other institutes and organisations.

4.3.1 General objectives

The general objectives of the national biological networks are:

- detecting the ecological effects in the eco-systems, resulting from changes in water quality, water management and/or (re-) construction of the national water systems;
- collection of the ecological data to be used for policy evaluation and preparation to ensure a sustainable use from an ecological perspective;
- preparation of and commitment to international agreements for the benefit of the international co-operation in river basin committees (a.o. International Rhine Commission) as well as European and United Nations regulations.

4.3.2 Biological network lay-out

Biological monitoring covers a wide area of different 'variables', each in need of specific monitoring and assessment techniques. However, it is necessary to integrate the information from these different fields to one general assessment of the ecological status. This has always been an important criterion when designing the biological networks.

Biological monitoring asks for a completely different monitoring strategy than used for chemical or hydrological monitoring. The monitoring frequencies for example are determined completely differently. Therefore the (basic) biological monitoring is carried out on a yearly basis. However, every four years a more thorough inventory is made per water system. These years of more intensive monitoring (inventory-years) are carried out according to a four-year rotating planning.

The frequencies necessary in monitoring ecological variables varies very much. Plankton, for example, is monitored once/month, water plants once/year and border vegetation once/4 years. Obviously, these frequencies are in line with the expected time-scale of possible changes in relation to those ecological variables. Another important aspect in designing these networks is seasonal dynamics that occur with almost any biological variable.
The biological ambient monitoring network consists of nine different groups of variables that all require a different measure planning. These are the following:

Phyto- en zooplankton

This network for plankton is carried out in all national water systems en strongly connected with the chemical ambient network. Chlorophyll-a, phytoplankton and zooplankton, including length measures of *Daphnia'* (water fleas) are monitored every 2 - 4 weeks in spring and summer.

In the inventory-years (once every four years) both phyto- and zoo-plankton are analysed to a deeper level than the basic analyses (down to individual species and biovolume).

Macro-invertebrates

The measure planning for macro-invertebrates has three parts:

- Yearly sampling of rocks and stones in the river IJssel (in addition to a long series of monitoring that was already available) and of standardised artificial substrate (a metal box filled with marbles) in *all* national surface waters.
- In the inventory-years, a one-off sampling in the autumn of macro-invertebrates in the most relevant ecotopes such as: lithorale (shallow) and profundale (deep) water, sediments, stones, water plants, border plants and dead wood;
- Once / eight years an inventory of zebra mussel (*Dreissena*) in a selection of water systems.

Water plants

Water plants are inventoried in the field every year in the stagnant waters, always at the same locations. In addition air-photography is used for inventories, carried out from aeroplanes every inventory-year (see ecotope charts).

Fish

The fish monitoring network has two parts: active and passive monitoring.
The passive monitoring is aiming to gather information about diversity of species and the occurrence of rare species. The information is derived from professional fisher men that report their catches with a frequency of 1-3 times a week in the period May-October.
The active monitoring, with fishing boat and (electrical) net, is concentrated in a few areas. In these areas the same ecotopes are sampled every year. Distinction is being made in deep summer bed, shallow summer bed and river arms.

Water birds

The spotting and counting of water birds is performed frequently (once a month or more often) in all national water systems. A large part of this work is done by volunteers and organisations that own and/or manage the area in question. The programme is designed in accordance with the counts in January in the 'West-Pelearctic area', for the benefit of the "Wetlands International".
The co-ordination is not carried out by RIZA, but by an organisation of the volunteers.

River bank vegetation

The river bank flora is monitored every four years (inventory-years). These inventories cover approximately 25% of the area. The data support the detection of trends in the floristic quality of the several types of ecosystems. The co-ordination is not carried out by RIZA, but by a specific foundation working in this field.

River bank fauna

In relation to the increased interest in (re-)creation and restoration of different habitats by rehabilitation works, having a large impact on ecotopes, this network monitors the fauna. The restoration projects are aimed at the sustainable development of natural values. To monitor the effects of these measures, information is necessary. Until now there has been no structural input of such data. Since 1999, this part of the biological monitoring has started in co-operation with national programmes from other ministries and organisations. So far, programmes for breeding birds and amphibians have been set up.

Ecotoxicological variables

Ecotoxicological monitoring consists of the following parts:

- accumulation of micro pollutants in eel and in zebra mussel;
- determination of toxicity of sediments and pore water using bio-assays;
- determination of toxicity of surface waters.

The locations are in accordance with those of the chemical monitoring network and the four year rotation of the 'inventory-years'.

Ecotope charts

Once every eight years an ecotope chart is produced of the individual water systems. This cycle is in line with the 'inventory-years'. These maps, covering the full water system, are based on true-colour air photos (scale 1:10,000) with extra information from depth-charts and groundwater charts. A standardised system is used to make the charts compatible. The charts are presented in a geographical information system (GIS) enabling further interpretation and research.

4.4 Operational water quality monitoring network

The operational water quality monitoring network has been designed to survey the water quality and to be able to inform interested parties such as drinking water companies, in time about accidental pollution. In the seventies, as a reaction to several serious incidents, it was decided to build seven monitoring stations on the main Dutch rivers. From a few relatively simple variables (oxygen, temperature etc.) at first, the stations now carry a variable package that includes many organic variables, as well as several biological warning systems (with fish, water fleas and mussels). The system and its functions will be optimised again in 1999.

4.4.1 General objectives

The general objectives of the operational network are:

- continuous surveillance of the water quality enabling early warning;
- gathering data for the benefit of operational water management and (inter-)national agreements;
- gathering, storing and presenting of on-line data of the water quality;
- information supply for the benefit of trend research and models.

4.4.2 Objectives per (sub-)module

Operational monitoring

Early-warning in case of exceptional circumstances (water quality)
Operational monitoring is used to facilitate the surveillance of the water quality. Acute changes of the water quality due to discharges of 10-100 kg of polluting substance can be traced. In case of an acute water quality problem (monitored and signalled on-line) a procedure will be started automatically. As a first action a member of a specific group of specialists (who can be reached 24 hours per day) will be alarmed and will take charge of the co-ordination in dealing with the incident. This involves consulting several specialists, computer models and data banks to generate the information necessary for several users of the water systems such as drinking water companies, water authorities and many others.

Operational water management and (inter-)national agreements
This involves the monitoring of water quality with high frequencies for the benefit of operational water management and (inter-)national agreements. The water quality measurements are stored in the AQUALARM system and are available on-line (also via internet).

Specific monitoring

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

4.4.3 Operational water quality network lay-out

The present day system consists of four stations. Two of these are highly developed carrying equipment for sampling, analysis and communication, with a crew of four employees and an extensive variable package. These two stations are situated at the borders of the most important transboundary rivers in the Netherlands (Rhine and Meuse); the two 'inns' of the Netherlands. The two other locations, with smaller monitoring programmes are situated at the 'outs' of the Netherlands 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). A response time of two hours is used. Quantification of unknown substances will take place within 24 hours.
The analytic equipment for organic pollutants at the stations must function properly at least 98% of the time and for the other pollutants at 80-90% of the time. The maximum period of non-operational is 1-3 days, depending of the relevance of the variable.

5 Data handling

5.1 Data storage and management

The data from the different monitoring programmes have to be stored to enable further processing.
In the Netherlands data from the national hydrological and chemical monitoring programmes are stored in one database (Donar).
The data from the biological networks are gathered in co-operation with other institutes. Part of the data are stored at those institutes. Plans are in progress to ensure that all the biological data are stored in the same national database (Donar). An exception will be made for the geographical data from the ecotope charts and water plants monitoring. These GIS-files are 'Arcview-shapefiles' and 'Arc/info-export files' 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 are available for presentation on-line at any location in the Netherlands with access to the company's network. These data are also available on the Internet (http://www.waterland.net/riza/aqualarm). The monitoring data of 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 a longer period (6-24 hour averages) and stored in Donar.

Proper data management is very important, often underestimated in the process of monitoring and assessment. To enable proper use of the data, it is not sufficient to just record the location, date and time and the result of the measurement. A lot of extra information about the monitoring data is necessary to support good data management. This extra information is often referred to as "meta-information". Of all the data from all the different monitoring programmes, at least the following characteristics are recorded:

WHO	ordering organisation data managing organisation analysing organisation sampling organisation	**WHERE**	location area
WHAT	variable compartment (media) unit domain entity organ species biotic taxon	**HOW**	analytic method sampling method sample treatment method sampling equipment

The meta-information can only be changed by dedicated employees. This way a certain quality in data management, unity and comparability of data is ensured.

5.2 Data quality management

Every year, as soon as all data from the previous monitoring year are available, a co-ordinated plausibility check takes place. First step is to signal all 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 employees of the RIZA will manually assess the data and the 'outliers' in them. They form an expert judgement on whether or not the values should be considered an outlier or a regular value. 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 specific quality code.

5.3 Data availability

The monitoring data from RIZA are not available to the public before this assessment has been made, but as soon as this yearly check has been carried out, the data are freely accessible to anyone, partly (a.o. data from the operational network) even by Internet
(http://www.waterland.net/riza/aqualarm).
The data can be derived straight from the Donar database (for employees of 'Rijkswaterstaat') or with the assistance of the 'help-desk'. There are several other products that make the data available for scientists, research-employees and other users (management, politicians, public).

6 Information utilisation

The data from the monitoring networks serve many purposes. Depending on the objectives of the network, the data users and the possibilities of the technical infrastructure a wide range of products is being generated. Sometimes these are just the raw data and sometimes highly aggregated information that require a thorough assessment of the data.
In all these situations the most important goal of the data utilisation is to provide the information that is of interest to the users: not an over-flow of data, no answers to questions never asked, but exactly the 'tailor-made' information necessary. This demands for a continuous dialogue between ' information providers' and 'information users', since fine-tuning the information products to the changing information needs is a continuous task. The different types of monitoring data, networks and users ask for many different products each designed for a specific use.

6.1 Data utilisation for operational water management

It is obvious that for operational water management the data from operational networks are used. In general this means that the raw data, such as water levels, flows or temperature, are available on-line for the relevant water authorities. The data are available via the companies network.
The operational monitoring also provides the data for dealing with exceptional situations. This includes water quantity problems such as flooding or water shortage, but also water quality accidents such as accidental discharges from industry or shipping accidents. Not only will the operational networks detect such increases of pollution, it will also be able to identify and quantify the substances involved.

Other information is assessed and transformed into useful information, for example the water levels in the rivers and the heights of bridges are transformed into information for shipping (e.g. the maximum height of ships that can pass under the bridge) and an estimation for the next few days (derived from computer models) is included. This and other relevant information for shipping is available by means of a daily updated service-channel on regular television allowing every ship -and anyone else for that matter- to have this information. The same information is faxed or e-mailed to the shipping firms or even to the ships themselves allowing a more up-to-date service.

6.2 Data assessment

As mentioned before (data availability), the original (raw) data from the different monitoring networks are freely accessible to both employees of 'Rijkswaterstaat' and the public.
However, in order to use data to support the evaluation and preparation of water policy and management, a more thorough assessment of the raw data is generally necessary. The techniques and methods used and the assumptions and decisions made in this assessment must be agreed upon

and documented. That way different and/or successive assessments will be comparable and exchangeable. In the Netherlands a set of standards has been agreed upon for:

- dealing with values at the detection limit,
- dealing with outliers in the time series
- calculation methods for loads
- calculation methods for trends
- calculation methods for the testing of standards

These agreements have also been used when designing and building the computer tools used for the different assessments.
Of course it is possible to use different methods if suitable, but these standards are applied in all the standard products based on the monitoring data. An exception to this rule are the information products made for international river or sea commissions. Most international commissions will state their own policy on the above mentioned issues and they are not always identical to the national ones or to each other. Therefore, it is unavoidable that different methods are used in national or international products. Important is that these differences are recognised and understood. This is another reason why the standards must be carefully documented and regularly up-dated.

6.3 Data utilisation for water management/policy and for the public

Some of the information products for water policy evaluation and preparation are produced on a regular (yearly) basis, others are upon request on an ad-hoc basis. The information in these products varies from almost raw data to highly assessed and processed information. All products are freely accessible to employees and the public. Some of the main reports are mentioned here.

Yearbook Monitoring National Waters
Maybe the oldest information product of environmental monitoring data in the Netherlands is the Yearbook Monitoring National Waters that has been produced every year for the last 145 years. The first, hand written (!) issue, dates from 1853 and contains a report of the recorded water levels and ice conditions at relevant locations in the main national rivers.

Nowadays the yearbook consists of three parts: a small report (the Cronicle) describing specific developments in the national waters that have been recorded by the national monitoring programmes and two other parts (Numbers and Presenter) that contain the main features of the time series of the last 10-15 years of monitoring from most of the monitoring locations and variables. This includes the information from all the main national monitoring networks (hydrological, chemical, biological and operational).
The product 'Numbers' presents this information on paper, the 'Presenter' does this in a digital form (CD-ROM including selection and presentation facilities). The possibilities to distribute this data by the Internet are subject to studies. This product can provide for a large part of the every day information needs from scientists, experts, advisors and water managers.

Several regular reports based on the monitoring data are produced on a yearly basis, containing more thoroughly assessed information, giving answers to more complicated information needs.

Monitoring newspaper
As soon as the time series of the last monitoring year are available, a general impression of the developments is made by a group of experts. On the basis of this assessment a 'newspaper' is developed with a short, up-to-date and popular explanation of developments in the water quality and the ecosystems of the national waters. This newspaper is intended for the broader public, rather than the expert.

Annual reports on assessed information
Since 1992, a series of 'water system reports' have been published. In a rotating schedule of four years, all national water systems are described integrally in these reports, giving an accurate 'status and trends' insight. These reports contain the description of long-term developments in water quality and ecology and makes the integral assessment linking these developments to the problems and measures relevant for the water system in question. It supports the water authorities in the development and evaluation of their water management and policy.

Additional 'thematic' reports
Information needs are not fixed; they vary as much as developments in water management do. This means that standard reports can only provide answers for a part of the information needs. Often, water managers will have specific questions that ask for 'tailor-made' answers. For this purpose many thematic reports have been (and will be) produced. These reports focus on a specific subject or question. Reports have been written on subjects such as: high water levels and floods, quality of the suspended solids, drinking water production from surface waters, pesticides, quality standards for fish and many others.

Derived uses of monitoring data
Of course, the monitoring data are used for many other purposes than just the ones mentioned above. One of the most important ones is the construction and calibration of computer models. Monitoring data are a necessity when developing and/or calibrating computer models for flood forecasting, water quality developments and other purposes. With models being an important source of information for long term policy plans, this use of monitoring data is very important. However, the ambient monitoring networks are not designed for this purpose, so additional specific -project- monitoring is often necessary.

There are several yearly reports on the state of the environment made by other Dutch ministries and/or by the European Commission. The data reported in above mentioned products are frequently used for the 'Water-chapter' in such integral environmental reports.

7 Quality assurance

To achieve and maintain a high quality standard in monitoring, several quality assurance measures have been taken. For example in the fields of:

7.1 Determination and updating of information needs

For the determination in information needs, a method (five-step plan) has been developed, translating policy goals and targets to monitoring objectives and network criteria. This method enables a rapid and thorough determination of information needs in close co-operation between information user and information supplier.
The monitoring programmes are evaluated every year. If the evaluation shows a change of information needs, several different options for adjustment of the monitoring programmes are specified, including the financial consequences and discussed with the parties concerned. The option agreed upon will be integrated in next year's programme.

7.2 Sampling, field measures and analyses

Sampling and field measures are conducted according to strict regulations. The employees in charge are instructed and trained in these regulations. These procedures and regulations are checked by audits.
All the laboratory analyses are performed by laboratories with quality assurance systems. This is not only the case for RIZA laboratories, but also for external labs. The system for quality assurance complies with the standards for certification and is checked and supervised by an independent national institute.
Every year a report is published containing the validation of all analytical methods and their characteristics such as recovery, detection limits etc.

8 Related institutional and financial issues

8.1 Institutional aspects

The Netherlands have a very long history of water management. The first dikes and dams were built in this country more than 2000 years ago. Many dikes and other water works followed such as the dams in the rivers Amstel and Rotte, now known as the two largest towns of the Netherlands (Amsterdam and Rotterdam).
Because of land-reclamation and impoldering large parts of the country are below sea-level, the lowest point as much as 6.7 meters. With these developments and increasing growth of population, towns and economic interests, water management became more and more important. In the last 500 years water management has become more than an interest of individuals and the organisation of this task was institutionalised. This was organised in accordance with the administrative situation of that time with numerous different authorities each in charge of relative small areas. At a certain point of time the Netherlands had more than 600 different -and relatively independent- water authorities. And that for a country with a territorial area of no more than 41,000 km^2 !

Although the number of organisations involved in water management has decreased steadily, the Netherlands still have a very complex water management organisation.

- There are still 66 different water authorities for the -smaller- regional waters, 39 of them for water quantity only, 27 for quantity and/or quality management.
- The provinces (12) are responsible for the development and evaluation of the strategic (surface)water management policy and for groundwater management.
- Water management and policy in the -larger- national waters is performed by the national organisation 'Rijkswaterstaat' which is divided into nine operational directorates and is supported by scientific research and advisory institutes such as RIZA.

So, together almost 100 organisations are involved in water management. This is an aspect that is under study and adjustments in both organisation and financial structures may be expected.

However, the almost 100 different organisations involved in water management are not the only players in the Dutch field of environmental monitoring. With water management growing more and more towards an integral assessment of water systems including river banks, flood plains, natural restoration, economic aspects and many other aspects, the situation is becoming even more complex. Many of these aspects are within the competence of different ministries, organisations and institutes from the fields of agriculture, industry, recreation, nature and environment, shipping and transport and many others. It is obvious that this complex organisation makes communication, co-operation and information supply and availability very important.

8.2 Monitoring by regional water authorities

The monitoring activities described in this paper are carried out by the national organisation 'Rijkswaterstaat' in the (inland) national water systems and for the benefit of national water management. As described above, regional water management is carried out by water authorities who usually have their own monitoring. The monitoring in the regional waters will more or less, be developed according to the same strategies used for national water monitoring. In general, monitoring efforts in regional waters will include at least ambient water quality monitoring for status and trend detection and the testing of standards. Other types of monitoring are performed according to the functions and uses in the water system concerned. The water authorities with a task in water quantity management perform hydrological monitoring partly ambient, partly operational.

A part of the results from regional water monitoring are gathered by RIZA, by means of a yearly inquiry. The water authorities send in the monitoring data from their main locations. This data from the regional locations are used for national policy evaluation and the testing of standards.

The monitoring activities of the regional water authorities are not described further in this paper, however, they are not essentially different from the national monitoring programmes.

8.3 Financial aspects

The costs for Dutch regional water management and sewage treatment performed by the (66) water authorities are directly related to specific taxes that are paid by land- and house owners and users such as industry, farmers and house holds. As mentioned above this system is under reconstruction at the moment. It can be expected that the future situation will be as follows. The costs for water management of the regional waters (water quality management, infrastructurel management and safety) will be paid by the users and owners of land and property in proportion to its economic value. The costs for sewage treatment are paid by the dischargers (house holds), based on a fixed price per inhabitant or based on the use of drinking water. The water authorities will have the possibility to make specific deals with large dischargers in order to optimise the influence of the free market principle.

In 1998 the cost of water management by the water authorities was approximately 1725 mln.$. About 65% of these costs are related to the water quality tasks (sewage treatment), the rest for water quantity tasks and dikes etc. The costs of the national water management tasks are an additional 1050 mln.$. The costs of water management and the development of the taxes that cover these costs are published yearly in several policy plans that are freely accessible.

The total cost of monitoring for the national waters is approximately 45 mln.$, which includes all the monitoring activities for national water management. For the networks described in this paper (inland waters only) the total cost is approximately 14 mln.$ including the costs of personnel. In general the cost of monitoring is estimated at 4-5% of the total cost of water management.

9 Dutch nation-wide monitoring: Strengths and weaknesses

Water monitoring in the Netherlands has a long tradition. In certain aspects this is an advantage; the knowledge on water monitoring (and water management in general) is highly developed. Sometimes, however, an advantage in knowledge, methods or techniques may become a disadvantage if other developments are not noticed, assessed or implemented. In the Netherlands this is called: 'the law of the slowing down advantage'. For instance, the development of water authorities several hundreds of years ago was very modern at its time, but now it is a strong disadvantage.
Some of the strong and weak points in Dutch water monitoring are listed below.

Strong

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

Weak

- Extensive communication necessary between parties (national, provinces, water authorities)
- Organisations designed according to administrative boundaries instead of water-sheds or water systems
- Differences between methods and/or techniques between different parties
- Lack of useful indicators, e.g. in relation to habitat aspects in biological / hydrological monitoring
- To many variables in programmes, not all of them are used for relevant products

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