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Analyzing the Data-Rich-But-Information-Poor Syndrome in Dutch Water Management in Historical Perspective

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Abstract Water quality monitoring has developed over the past century from an unplanned, isolated activity into an important discipline in water management. This development also brought about a discontent between information users and information producers about the usefulness and usability of information, in literature often referred to as the data-rich-but-information-poor syndrome. This article aims to gain a better understanding of this issue by studying the developments over some five decades of Dutch national water quality monitoring, by analyzing four studies in which the role and use of information are discussed from different perspectives, and by relating this to what is considered in literature as useful information. The article concludes that a "water information gap" exists which is rooted in different mutual perceptions and expectations between the two groups on what useful information is, that can be overcome by improving the communication. Such communication should be based on willingness to understand and deal with different mindframes and should be based on a methodology that guides and structures the interactions.

Keywords Science–policy interface · Environmental information · Information needs · Water-quality monitoring

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Abbreviations

IRC/ICPR	International Rhine Commission/International Commission for the Protection of the Rhine
MWTL	Dutch National Monitoring System
RIKZ	Institute for Marine and Coastal Research
RIZA	Institute for Inland Water Management and Waste Water Treatment (former Institute for Waste Water Treatment)
RWS	Rijkswaterstaat (Directorate-General for Public Works and Water Management)
V&W	Dutch Ministry of Transport, Public Works and Water Management
WFD	European Union Water framework Directive

Introduction

Over time, a steady increase in the need for information in support of water management can be discerned. In this article, water quality management will be taken as example. Water quality management was virtually non-existent up to approximately 1850, by which time locally poor environmental conditions with bad smelling, deoxygenated water were encountered as a result of industrialization (Perry and Vanderklein 1996). Regular water quality monitoring was however not established before the 1950s in the USA, the former USSR and in a few European countries and extended to Canada and most of Western Europe in the late 1960s and 1970s (Meybeck 1989). After their inception, water quality monitoring programs have evolved substantially owing to the identification of new environmental issues, illustrated by Meybeck and Helmer (1989) who give an overview of some of the major pollution problems arising over the years in industrialized countries, and the subsequent need to develop policies and keep track of the effectiveness thereof.

Nowadays each year a large amount of information is collected by water management organizations to support the evaluation and development of water management and water policy. At the same time, a discontent between information users and information producers about the usefulness of information grew. Ward and others (1986) called this the 'data-rich-but-information-poor' syndrome; a situation in which data is collected without a clear view of what information is to be produced out of it. They state that this follows from a situation where information expectations are insufficiently evaluated while on the other hand the expectations of information users may be higher that the monitoring system is capable of providing. Also, data are collected that are not used to produce useful information.

To tackle the data-rich-but-information-poor syndrome, much of the literature in monitoring network design emphasizes a process of determining about the water management problem and the information needs related to it as the fist step in the design (a.o. Boyle and others 2001; Giordano and others 2008; MacDonald 1994; Meybeck and others 1996; Timmerman and Langaas 2005). Other scholars emphasise the need to aggregate and present the information in an easy to understand form (a.o. de Jong and others 1996; Denisov and others 2004; Laane and Ten Brink 1990; McBride and Smith 1997). Besides this, some scholars emphasise the need for multidisciplinary or interdisciplinary information production that supports Integrated Water Resources Management (IWRM) to improve the situation (a.o. Giordano and others 2008; Gooch and Stålnacke 2006; Hisschemöller 2004).

Within the broad context of the use of environmental information of which water quality monitoring is only a small part, McNie (2007) notes that despite these approaches, policy makers from around the world are still calling for more 'useful' information. She states that this may be caused by scientists who produce too much information that is not considered relevant and useful by decision makers. Users on the other hand may have specific information needs that go unmet, or may not be aware of the existence of potentially useful information. In this context, information is considered useful when it is (1) salient and context-sensitive; responding to the specific information demands, (2) credible; perceived by the users to be accurate, valid and of high quality, and (3) legitimate; the production of information is perceived to be unbiased (Cash and others 2003; McNie 2007).

This article makes a retrospective analysis of a Dutch water quality programme with the objective to analyze the nature of the gap between users and producers of information. For this purpose, the article will analyze if data is produced with sufficient consideration of the needs of the information users, if the data that is collected is used to produce information, and if the information that is produced is considered useful (i.e., salient, credible and legitimate). Also, the article will investigate if the users have realistic expectations of information producing systems and are sufficiently aware of the existence of potentially useful information. The analysis will focus on a specific, rather straightforward situation, namely the Dutch National Water Monitoring Program (MWTL) where information supply and demand are both situated within one Ministry. The developments in the monitoring network and the involved organizations will be put in a historical context to identify the circumstances and conditions that have shaped the current situation. After a brief introduction to Dutch water policy, the developments over some five decades of Dutch national water quality monitoring are studied. Three studies on the use of monitoring information related to the Dutch national water monitoring program as well as one Dutch case study into the relationship between policy and monitoring are presented. These investigations enable us to address the abovementioned issues regarding the "water information gap" from the point of view of the scientists as designers of the programs and from the perceptions of decision makers as the users of information. The analysis shows that the water information gap is rooted in different views from science and policy on what useful and relevant information is, and that better communication is needed between science and policy to bridge the gap.

Dutch Water Policy

The Netherlands has a 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, where settlements were located that are currently known as the two largest towns of the Netherlands, Amsterdam and Rotterdam, respectively. Land-reclamation and construction of polders have led to a situation where large parts of the country are below mean sea level, with the lowest point at −6.7 m. These developments, together with a dense population and fast growth of economic interests, make good water management imperative. Moreover, the Netherlands are the downstream country of four international river basins, of which the rivers Rhine and Meuse are the most important. The Netherlands for instance draws around 65% of its freshwater supply from the Rhine River (Lindemann 2006). The quality of the Rhine River is therefore highly significant as is coordination with the upstream countries to secure the quality of the river water.

Water management of surface waters in the Netherlands is divided between Rijkswaterstaat (RWS), a part of the Dutch Ministry of Transport, Public Works and Water Management (V&W) and regional Water Boards. RWS holds responsibility for the large rivers, lakes and coastal waters, the so-called national waters. The Water Boards are responsible for management of the smaller waters within their respective region. Water management policy development is the responsibility of the Ministry of V&W. This article focuses on the national waters and will not discuss regional water management.

Fast developments in urbanization and industry after the Second World War in Western-Europe have led to deterioration of the quality of surface waters, which was especially apparent in the river Rhine. Here the load of inorganic and organic waste from the countries riparian to the river Rhine increased significantly in the 1950s and 1960s (RIZA 1965). The pollution situation of the river Rhine was at its worst in 1971 when the water lacked oxygen in the downstream sections and aquatic life was disappearing. This bad situation urged the riparian countries to take action leading to an improved water quality situation after 1971 (Huisman 1996).

Policy development was needed to face the challenges posed by this pollution. The first Dutch National Policy Document on Water Management that was published in 1968 addressed few water quality issues. The Pollution of Surface Water Act (1970) provided planning instruments for a water quality program. The major problem at that time was the emission of organic material; wastewater treatment plants were built to deal with this. Once major reductions in discharges of organic material had been achieved, the focus switched to heavy metals and organic micropollutants from industry. In the mean time, between 1975 and 1978, the European Union laid out legislation on surface waters describing lists of parameters to be monitored (Timmerman and others 2004). This is reflected in the second National Policy Document on Water Management (1984) which had an increased focus on water quality issues. The third National Policy Document on Water Management (1990) had a strong focus on water quality and contained a list of water quality standards and included attention for emissions from various sources: e.g. agriculture (phosphates, nitrates and pesticides), households (metals from gutters and water-pipes) and shipping (tar, oil and micropollutants). In the mid 1990s, the overall water quality situation had improved significantly as a result of an interaction between successful targeted policies and measures both nationally and international, and the related monitoring and research.

As a result of this improved situation, political attention towards water quality decreased. This is reflected in the fourth National Policy Document on Water Management (1998) that maintains the existing water quality policy but changes the focus towards socio-economic issues. Next to that, the EU Water Framework Directive (WFD) (European Commission 2000), that entered into force in 2000, has lead to substantial changes in Dutch water management, in particular by shifting the emphasis from the physical-chemical composition of water-bodies to ecological characteristics and by putting public participation more at the forefront.

Developments in Water Quality Monitoring

The Dutch National Monitoring Program (MWTL) is the program for the upkeep of a baseline set of information called ‘basic information’, encompassing hydromorphological, chemical and ecological characteristics of the so-called national waters. Collection of this ‘basic information’ is a task of Rijkswaterstaat (RWS). Two advisory and research institutes within RWS were, next to other tasks, responsible for managing the MWTL. The Institute for Waste Water Treatment (later Institute for Inland Water Management and Waste Water Treatment) (RIZA) was responsible for the freshwater part of the MWTL, the Institute for Marine and Coastal Research (RIKZ) for the salt and brackish parts. This article describes the developments in the MWTL network over the period from 1952 up to 2005 for the freshwater quality data.

The flow of the rivers Rhine and Meuse is not unidirectional to the sea. After entering the Netherlands at Lobith, the Rhine River splits up into several branches to the north and the west. The southernmost branch is again connected to the River Meuse. Furthermore, tidal movement influences freshwater flows upstream and flows are consequently complex. Water quality monitoring of these rivers is therefore not straightforward but requires a rather dense network of monitoring locations to be able to keep a good overview.

All water quality- and quantity-monitoring data collected by RWS are stored in the so-called DONAR database. The data presented in this section are selected from this database, including all inland chemical water quality data available from MWTL labeled as RIZAMON_LAN (the label for the national water-quality monitoring network) as the owner of the data. Literature (mainly in Dutch language) like RIZA year reports and monitoring optimization studies were used to further specify and explain the developments in locations, parameters and frequencies.

The growing importance and growing complexity of water management over the years (e.g., Rittel and Webber 1973) becomes visible in the increasing number of staff at RIZA. RIZA was founded in 1920 and started off with a staff of 5 people. By the year 2000, there were some 450 people employed by RIZA (Bosch and van der Ham 1998). This increase in number enabled employees to become more specialized. Meanwhile, an organizational divide grew as the monitoring people were organizationally separated from the policy people within RIZA through the creation of different departments. The physical distance to the policy people within the Ministry was extended when RIZA was moved to another town in 1975. Specialization together with physical and organizational separation reduced thus interactions between monitoring and policy.

Evaluation and Optimization of the Monitoring Network

The network design, that is the exact monitoring locations, choice of parameters, and sampling frequencies, is determined each year and put down in a monitoring schedule. Such schedules are based on the preceding years and usually include only minor changes, which can over time constitute substantial alterations compared to the original plan. Therefore, evaluation of the MWTL network has been carried out regularly to determine whether the actual information needs were still met and whether the network was designed and operated in an efficient manner.

Optimization and evaluation studies to improve the MWTL network were carried out in 1965 (RIZA 1966), between 1978 and 1981 (Schilperoort and others 1982), 1984 (Cappon 1984), 1991–1992 (Adriaanse 1992; Breukel and Schäfer 1991), and 1996 (Hesen and others 1998). All studies comprised a statistical optimization of the network to judge the efficiency of the network in terms of statistical correlations of results between locations and the quality of the information, leading to changes in frequencies and number of locations. Also, the lists of parameters were evaluated and adapted on the basis of new legislation.

From the optimization studies it becomes clear that the changes in the monitoring network are initiated and decided upon by the information producers. Decision-makers as information users were informed about the changes. In-between the optimization studies, sometimes, new analytical methods or changes in legislation led to changes in the network. Such changes are however sparsely documented.

Quality assurance and quality control programs targeting various parts of the monitoring cycle like sampling methods, chemical analysis methods and data assessment protocols have also been carried out to improve the credibility of the information. These lie outside the scope of this article.

Monitoring Locations in the Network

Figure 1 provides an overview of the monitoring locations in the network in the years 1952, 1961, 1972, 1978, 1990, and 1996. The river Rhine is under regular study on 4 locations in the Dutch part from 1952 onwards within the framework of the International Rhine Commission (IRC,in the late nineteen-nineties the commission was renamed into the ICPR, the International Commission for the Protection of the Rhine) (RIZA 1954). Between 1959 and 1961, the Dutch estuary (Nieuwe Maas - Nieuwe Waterweg) was added as well as locations along the river Meuse and in the Delta of both rivers. These additional locations were primarily selected to study the influence on the water quality of tributaries of the river Meuse (in the south-east part of The Netherlands) and the influence of industry around the harbor of Rotterdam (western part). In 1965, several existing regular studies were integrated into one routine monitoring program covering the whole network of the Dutch large rivers. The choice of the exact location was done largely on a logistical basis; the possibilities for transportation of samples like vicinity of a road or bridge and vicinity of suitable laboratory facilities were important qualifiers for the suitability of locations (RIZA 1972). It should be mentioned that most locations are merely sites where samples are taken and adding or deleting locations change the operational costs but do not include investments.

The number of monitoring locations increased to 61 in 1971. In this year, the expression “rijkswateren” (national waters) is used instead of “grote rivieren” (large rivers) in the yearly report, indicating that the water quality studies

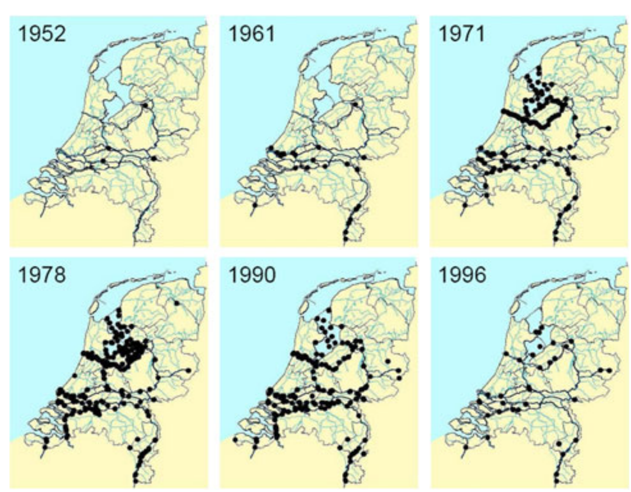

Fig. 1 Changes in monitoring locations in the network

of other national waters besides the large rivers has become urgent and consequently these other waters are included into the national inland monitoring network (RIZA 1973). In 1972, locations in the central lake area (Lake IJssel, Markermeer and the lakes bordering the Flevopolders) and the other national waters are included (RIZA 1975) and reaches a maximum of 224 locations in 1978 (RIZA 1979). On the basis of an optimization study, the monitoring network was reduced to 149 locations in 1982. The effects of the 1992 optimization study are remarkable; statistical analysis of the data showed that almost the same information could be derived from concentrating monitoring efforts on few locations because data from several locations showed high statistical correlations.

Choice of Parameters

The growing information need from newly arising water quality problems that come to the fore as reflected in the expanding regulations and policy documents is illustrated in the number of parameters included in the MWTL network. The number of individual and composed parameters has shown a tremendous increase over time, starting from 13 parameters in 1952 to over 285 in 1997. In Fig. 2 the number of different parameters included in the monitoring network is displayed, divided into several groups. Individual parameters within these groups are singular parameters like pH and cyanide, or BOD (Biological oxygen Demand) and DOC (Dissolved Organic Carbon), but also composite parameters such as the sum of 1,3 xylene and 1,4 xylene, or sum of several PAH's (Polycyclic Aromatic Hydrocarbon).

Until 1956, water quality analyses were carried out using general parameters like temperature, suspended solids, oxygen balance, and chloride. Between 1957 and 1971, the number of parameters slowly increased, starting with parameters to measure eutrophication and radioactivity, and later on, metals and organic pollution. Consecutive national Acts and European Directives led to the inclusion of additional groups of parameters like pesticides in 1972 (Pollution of Surface Waters Act 1970) and organic micropollutants in 1976 (Aquatic Environment Directive 1976). The third National Policy Document on Water Management (1990) and the Dutch Environmental Management Act (1993) led to an increase in, mostly, pesticides and (other) organic micropollutants. After 1999, in line with the WFD list of priority substances, additional organic micropollutants and pesticides are added to the network. Figure 2 in this way obviously links to the notion of Meybeck and Helmer (1989) that newly arising issues lead to new monitoring efforts.

The various optimization studies had effects on the number of parameters. Reconsideration of the parameters led to the conclusion that some parameters did not provide the information that was anticipated or were no longer required as a legal obligation. In 1967, 1982 and 1998,

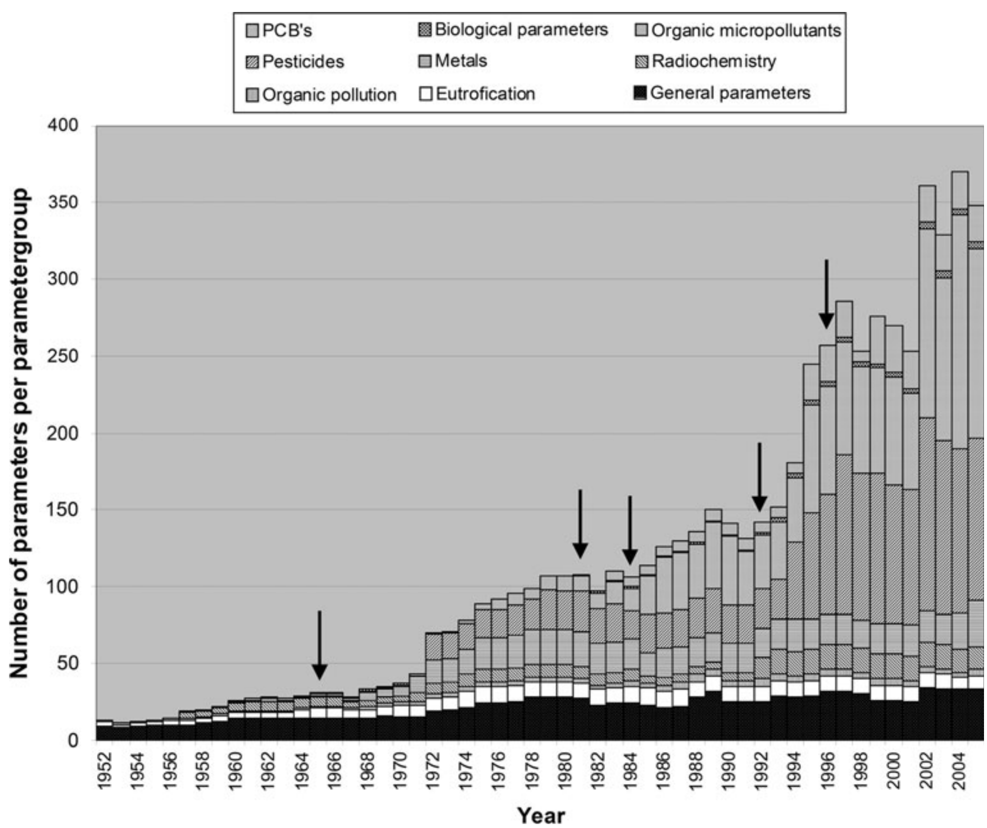

Fig. 2 Number of parameters per parameter-group included each year in the national monitoring network (*arrows* indicate the years that evaluation studies were performed) (the individual parameters and the grouping are detailed in Timmerman and others 2004)

after the evaluations, a reduction in number of parameters is effectuated. After the 1985 optimization study however, there is an increase in the number of different organic micropollutants and after 1993, next to other organic micropollutants, several new pesticides were added as described above. Sometimes parameters are added because new analysis techniques enabled the measurement of a wide spectrum of contaminants in addition to the target compounds at little additional costs.

Discussion of Trends in Dutch Monitoring

Developments in the Dutch national monitoring network can be described from the above as a period of growing awareness and try-outs, followed by a more critical view on the work. As can be derived from Figs. 1 and 2, roughly every decade there are substantial changes in number of monitoring locations and/or number and types of parameters included in the monitoring network that can be described as a phase in the development in the thinking about monitoring.

From the start of the monitoring network in 1952 until 1959, monitoring was performed to meet the objectives of the IRC. The network was largely driven by the international effort to improve the water quality situation, especially with regard to drinking water production.

As the monitoring network provides useful information, the monitoring network is slowly expanding from 1960 until 1971 to cover the large rivers. Few parameters are added.

From 1972 until 1981, the monitoring network is expanded to cover all the national inland waters of the Netherlands. The number of parameters rapidly increased to cover most of the pollutants present and known at that time. More knowledge about the importance and possibilities of monitoring is building up.

The monitoring network only slightly changes between 1982 and 1992. Ample attention is given to the goals of the network, and the frequencies and numbers of locations are optimized to meet the goals. Along with analytical possibilities, the number of parameters is slowly increasing.

From 1993 onwards, the goal of the monitoring network is restricted to the national status of the water quality. The monitoring network is reduced to what are considered the minimum requirements. Automated analytical instruments provide the opportunity to include many parameters relevant for policy and management, without adding (much) extra cost.

After 2000, the WFD influences the monitoring network. The definite network was not operational in 2005, but some of the parameters from this EU Directive were already included at that time.

From the overview of optimization and evaluation studies it becomes clear that the specification of information needs was done in a combination of regulatory/standard-driven and technical/scientific way. The choice of parameters was based on policy documents and regulations (legislation as well as (international) agreements). The number of monitoring locations is statistically optimized after a period of expansion and operation. The period of increase in the network can be labeled as a learning period. The optimization study of 1981 is a turning point; the availability of data for that study made it possible to (statistically) reduce the number of locations and frequencies enabling extension in terms of parameters without raising costs.

A study of the national and international legislation as well as international agreements was done to determine how many of the parameters included in MWTL were related to this legislation (Timmerman and others 2004). For each of the 364 parameters that had been measured in the period between 1952 and 2001 it was verified if there is a piece of legislation or international agreement for which the parameter was included. The study concluded that only some 10% of the selection of parameters is not directly attributed to a specific law or agreement. This 10% can be explained in terms of analysis methods that provide data on additional parameters that are presumably policy relevant and that are included at virtually no cost or parameters that are needed for data interpretation, for instance organic carbon in sediments. Few parameters that are included in legislation are not or no longer included in the monitoring network.

From the above it can be concluded that the information producers have put ample effort into producing useful information. Together with various quality assurance programs, the regular evaluation studies have promoted the credibility of the information; accurate, valid, and of high quality. Next to that, the information was legitimate in the sense that it was produced in a transparent way a.o. by describing the reasons for the information production and through yearly reports describing the network design as well as the results from the data collection. Both legitimacy and credibility are not challenged by information users.

The salience of the information is however not clear. On the one hand there is due consideration of information needs by the information producers. The information providers consider policies and regulations to infer the information demands of the information users. Decision-makers were however not involved in the design and evaluations of the network and it is consequently not clear if they consider the information salient. The following section will look into the degree to which the data and reports are used, which may provide answers about the salience of the information.

Studies Into the Use of Monitoring Results

Four studies will be discussed here that have looked at the role and use of information from different perspectives and show different aspects of the water information gap. The study by Sam and Smit (1996) started from the hypothesis that there is a gap between information needs as described in policy documents and information produced by monitoring. The study tries to quantify this gap in a specific region. The study by van Kerkhoff and van Riel (1996) took the information user's satisfaction as a starting point and tried to specify the reasons why information users are not satisfied. The study by RIKZ (RIKZ 2000) was done from a monitoring perspective and looked at the use of monitoring data in reporting. The study by Stevers (2003) finally examined the perceptions of the different actors to define appropriate action to improve the monitoring.

Policy and Monitoring in the Wadden Sea

Sam and Smit (1996) conducted a desk-study to determine if monitoring in the Dutch Wadden Sea satisfied the information needs of the policy makers for that area. Their hypothesis was that there is a discrepancy between the policy information needs, the possibilities of monitoring, the design of the monitoring networks, and the actual realization.

The study comprised an inventory of policy- and management plans for the Wadden Sea and the policy statements included in these plans. The plans included in the study were national policy- and management reports as produced by the Dutch Ministry of Defense, the Ministry of Spatial Planning and Environment, the Ministry of Transport, Public Works and Water Management, and the Ministry of Agriculture, Nature and Fisheries. In total, 27 reports were selected. From these reports an inventory was made of policy statements that were relevant for monitoring. 135 policy statements were identified in total. These policy statements were divided into three categories, namely clear statements like 'no more than' and 'constant', vague statements like 'sufficient' and 'possibly', and unclear statements like 'pursue' and 'in principle'. Next, the monitoring networks in the Wadden Sea, the Dutch MWTL program, the Trilateral Monitoring and Assessment Program agreed between Denmark, Germany and The Netherlands, and the OSPAR Joint Monitoring Program, were studied and the parameters measured were listed. Then, a comparison was made between policy statements that could be related to parameters and the actually measured parameters. The MWTL network is predominantly based on legislation as described above. The two other networks are the result of international agreements. The monitoring networks can therefore be considered to be entirely based on regulations.

Sam and Smit concluded that 35% of the policy statements are unclear and can consequently not be evaluated through monitoring in a meaningful way. No parameters are measured for 36% of the policy statements in the categories clear and vague that can be evaluated and for which monitoring is possible. That leaves 29% of the policy statements that are supported by information (also see Fig. 3). If the statements labeled as unclear are excluded from the total number of policy statements, the percentage of policy statements supported by information rises to approximately 46%.

The assumptions in the study of Sam and Smit are that information needs of decision-makers are put down in policy statements and that all policy statements should be evaluated through monitoring. This is the similar regulatory/standard-driven approach that is followed in the design of the national monitoring network. They consider information to be useful if it can be linked to policy documents and (inter)national agreements. Although these assumptions are debatable, Sam and Smit make a point that apparently of all policies that can potentially be monitored only one third is actually monitored. As decision-makers were not involved in the study it is not clear if they would also consider the information useful. Nevertheless, from this study it is concluded that decision-makers can be right to say that they do not get all the information they need.

Customer Satisfaction of Monitoring Products

Van Kerkhoff and van Riel (1996) performed a study on the satisfaction of users of monitoring products, termed 'customers' in the study. They focused on the appreciation of products and services (do they satisfy the user?) of three specialist departments of RWS, thus aiming to determine about the usefulness of the information coming from the

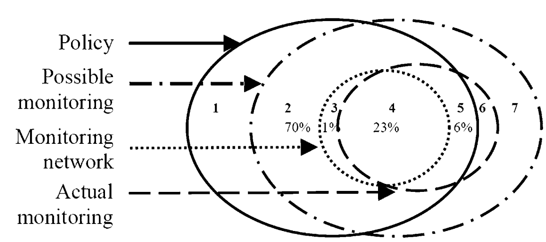

Fig. 3 The differences between the policy information needs, the possible monitoring, the design of the monitoring networks, and the actual monitoring. *1* Policy for which no monitoring is possible, *2* policy for which monitoring is possible, *3* policy supported by a monitoring program, *4* monitoring executed based on a monitoring program, *5* monitoring executed that was not originally designed in the monitoring program but that is usable for policy, *6* monitoring executed that cannot (yet) be used for policy because the information does not fit into the existing policy, and *7* all other possible monitoring (redrafted from Sam and Smit 1996)

MWTL network. The products and services included yearly data-overviews, water quality reports, compliance reports, reporting of data to national and international organizations, daily reports about water levels and navigation, and various thematic reports. Issues that were discussed in determining the appreciation of the customers were related to aspects like quality, timeliness, frequency, presentation, reliability, and flexibility of the products and services of the departments.

The study focused largely on customers within RWS. The study comprised 300 questionnaires, 35% of which were returned. The response group was heterogeneous, ranging from decision makers to researchers in specialist departments. The answers to the questionnaires were clarified in more detail through 25 interviews with a similar mixture of interviewees, both group-wise and with individuals.

From the study it was concluded that the customers were positive about the expertise and knowledge of the specialist departments, thus acknowledging the credibility of the information. Next to that, the legitimacy of the information was not questioned. They were, however, not satisfied with the products. The main criticisms derived from the study, in aggregated form (qualitative, the report does not give any quantification), were:

- The information is too much aggregated.
- The amount of information is too much and too general.
- The information is not presented aiming at a region or target group.
- Trends and well-founded predictions are missing.
- Delivery of information is slow.
- The underlying (analytical) data are not accessible.
- Employees are hard to contact.
- Agreements are not met.
- Communication with the customer before, during and after activities is insufficient.

Information products were accepted because they contained enough information for the customers, although they sometimes had to further process the data, or because there are no alternatives to get the information. The first four bullets indicate that the information is not salient, not tailor-made to the needs of the information user or context-specific enough. The last five bullets are not so much related to the content of the information as produced, but indicate insufficient customer orientation of the information producers in the process of bringing the information to the users.

The assumption of van Kerkhoff and van Riel in this study is that if the information user is satisfied, the information brought to him/her is the right information. From this study it can be concluded that the data that is collected is used to produce a range of information products but that the information in these products is often not considered salient although users are able to produce their own (salient) information from the data and information provided. The monitoring network does not target individual users and if different information users use different parts of the information presented they may all feel that there is too much information, but it may well be that overall all of the information is used. The institutional embedding of the monitoring organization implies that the network does not target one specific user.

Use of Monitoring Data in Policy Documents

RIKZ (Institute for Marine and Coastal Research, part of RWS) conducted a study in 1999 to determine to what extent data and information from the MWTL network is used in policy documents, management plans, vision reports, brochures, atlases, and policy- and management reports (RIKZ 2000). An inventory was made of a set of documents from these categories issued between 1992 and 1999, and these were analyzed for their use of monitoring data. In this way, the study provides insight into the usefulness of the information that is produced in the MWTL network. In total, 95 documents were analyzed.

The study showed that in 75 out of the 95 reports data from the MWTL-network was used. In many reports however, the source of the data was not referenced in the report. Interviews with authors of the reports were conducted to reveal the source of the data. From these interviews it was concluded that the MWTL network was considered useful, sensible and of high quality, not in the least because of its long-term history of data. The interviewees however considered the accessibility of the data to be low and suggested that this was to be improved. They also noted that the network was not widely known, and improved communication about the existence and contents of the program was advised.

The assumption in this study by RIKZ was that information from the MWTL network is widely used but that this is not always acknowledged. This assumption proved to be correct for many of the studied reports. The MWTL network provides a substantial amount of information that is used in many different reports. The authors of the reports studied consider the information useful and include it into their work. From the interviews it followed that the interviewees were little aware of the source of the information. They did not realize that they make use of the monitoring programs, which may lead to low appreciation of such programs. Moreover, this lack of awareness can also lead to a situation in which users are not making use of existing information that could lead to improved decisions as Callahan and others (1999) documented for regional hydrological forecasts (also see McNie and others 2007).

The Organization of the Information Market

The final study that will be discussed in this context is a short study by Stevers (2003), who examined the implementation of the long-term vision document on the RWS program 'basic information', three and a half year after finalization of this strategic document. The RWS program is responsible for providing information in support of policy evaluation and development and is largely realized through the MWTL network. The vision document was intended to improve the organizational structure around the production of 'basic information' in order to increase the effectiveness and efficiency in terms of management, costs and organization. There was general disappointment about the yields of the organizational changes, and Stevers performed the study to determine the reasons for this disappointment and to decide about the way forward. The study was based on one meeting and interviews with, in total, 15 people involved in the program.

Stevers (2003) in his study discerns four actors in the process that each apparently fail to improve the existing situation; (1) the demand side (users) of the information, the decision-makers who take basic information as a constant factor that just "has to be there" and does not need much attention from them, (2) the supply side (producers) of the information, the operational measuring services in the regional departments within RWS that are, according to Stevers, generally not much inclined to change their practice, (3) the commissioners for the program, that are expected to actively connect the demand and supply but do not feel this responsibility themselves, and (4) the high level management of the various departments that, according to Stevers, are not addressed at the right level and in the right, 'management' language.

Stevers concludes that the vision document and its continuation were not discussed or embedded at the correct management level and were not formulated in the language of the higher management, leading to minimal attention from the higher management. Also, the demand side values basic information as unimportant and does not see its role as steering or determining the type of information produced. The supply side on the other hand is introverted, working from their own mindframes, while the commissioners are not able to change this situation. Stevers calls this situation the 'dynamics of stagnation' that should be broken. He advises to do this in an organizational/managerial way by appointing a high-ranking, authoritative official not coming from the information production sector to lead the process. The focus in the process should be on the interface between demand and supply. The supply side should direct their attention towards data accessibility, data presentation and data mining. The commissioners should try to define their own role. The top-managers should reflect on paying proper attention to the process. The demand side finally should become a party in the process.

Stevers assumes that information production is a market in which there is demand from decision makers and supply from information producers. He however overlooks the fact that this is not a free market, but that decision makers decide about budgets for information production and in that capacity carry responsibility for the information that is produced. Decision makers mostly view expressing their information needs not as a high priority issue, which leaves their demands and needs diffuse. They have unrealistic expectations when they state that 'the information just has to be there' without any input from their side. The information producers follow the route of basing their work on regulations and policies, including reporting obligations as documented, and there is insufficient consideration of the information needs of the users. The mutual frustration in this situation stays in place.

Discussion and Conclusions

In the field of environmental information, information users are usually not satisfied with the information that is produced and information producers are criticized for producing too much data that yields little information that is of use. The discussion focuses on what makes information useful. Useful information is defined by McNie (2007) as information that is credible, legitimate and salient. This article aims at analyzing the water information gap, the basis for the dissatisfaction in the field of water quality information, building on literature and several studies that were done related to the Dutch National Water Monitoring Program (MWTL) and reviewed the studies in light of these three characteristics.

From the studies described in this article it follows that the credibility of the information from the MWTL network is not disputed. Ample efforts through quality assurance programs and regular evaluations are undertaken to produce high quality data. These efforts are generally acknowledged in the studies, where information users state that the information is of high quality and the information producers are considered to have sufficient expertise. Also, the legitimacy of the information is not disputed; the information from the MWTL network is not perceived as biased or providing only part of the relevant information. The discussion therefore concentrates on the salience of the information; does the information respond to the needs of the users?

This question can be divided into the question if information that is produced is used and the question if information users have information needs that are not met. The

RIKZ study (RIKZ 2000) and the study by van Kerkhof and van Riel (1996) showed that information coming from the MWTL network is used in a range of reports. The study by Sam and Smit (1996) suggests that information users may have questions that are not included in monitoring networks. This leads us to the question why this information is not produced.

From the description in the previous section, it becomes clear that there are regular evaluations of the network and that these evaluations include considerations of information needs. This is however done with little or no involvement of information users. Stevers (2003) states that the demand side should be more involved but immediately asks the question: "Maar kan dat van jullie gevraagd worden? (*But can this be asked from you?*)". He thus illustrates that decision makers that need information are little inclined to invest into what they believe to be uninteresting 'technical details'. As a consequence, the monitoring network is designed with little consideration of the needs of information users.

But is this a typical Dutch situation or is the situation comparable to other countries? Some studies looking at the use of information in several international commissions in Europe showed that the information needs for these international commissions are usually based on treaties that regulate the work of that commission while the monitoring networks are largely based on national legislation from the respective countries. In all of the cases little attention is given to ensure that the information collection is linked to the actual priorities and needs of the decision-makers or stakeholders and improved communication between information producers and users is recommended (Langaas and others 2002; Nilsson 2006). The Dutch situation is consequently not unique and can act as an example for a general problem.

The analysis in this article showed that due consideration of information needs takes place in designing monitoring networks. These information needs are largely based on existing regulatory reporting obligations. Also, vast efforts are regularly carried out to make the information production efficient by optimizing and reducing the networks to avoid producing too much information. Then, information from the MWTL network is used by a variety of users in several ways. However, policy objectives can be distinguished about which no information is produced. Also, information users consider the information as produced not salient.

This situation has developed as information users are hardly involved in the specification of information needs. An essential reason for this is that information producers have a limited insight in the work and needs of information users and vice versa. As both groups have a task to fulfill, this unawareness leads to reluctance when it comes to investing efforts in communicating about mutual needs and interests, a process that can be time-consuming and troublesome.

To bridge this "water information gap", the link between users and producers of information needs to be managed (McNie 2007) through close interaction (Sarewitz and Pielke 2007). Better communication between the two groups is needed. However, better communication does not equal more communication. Investing only in more communication runs the risk to strengthen the 'dynamics of stagnation'. Instead, respectful interactions are needed between policymakers and scientists in which they are willing to learn from and deal with their different interpretations that are rooted in different mindframes (Timmerman and Langaas 2005). It also implies that users' information needs must be identified prior to producing information (also see Timmerman and others 2000).

To manage this improved communication between policy and science, a methodology is needed that guides and structures the interactions in order to come to meaningful information production. On the basis of the analysis of the water information gap as described in this article, such a methodology is developed (Timmerman and others submitted) and tested (a.o., Timmerman and others in preparation). Results show that a methodology guiding the communication is an efficient way to manage the link and improve the interaction between science and policy and supports narrowing the water information gap.

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References

Boyle M, Kay J, Pond B (2001) Monitoring in support of policy: an adaptive ecosystem approach. In: Munn T (ed) Encyclopedia of global environmental change, vol 4. Wiley, New York, pp 116–137

Callahan B, Miles E, Fluharty D (1999) Policy implications of climate forecasts for water resources management in the Pacific Northwest. Policy Sciences 32:269–293

Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH, Jäger J, Mitchell RB (2003) Knowledge systems for sustainable development. Proceedings of the National Academy of Science 100(14):8086–8091

de Jong J, van Buuren JT, Luiten JPA (1996) Systematic approaches in water management: aquatic outlook and decision support systems combining monitoring, research, policy analysis and information technology. Water Science and Technology 34(12):9–16

Denisov N, Rucevska I, Lucas B, Simonett O, Heberlein C, Ahlenius H (2004) Addressing environmental information efforts: the impact-of-information chain. In: Timmerman JG, Langaas S (eds) Environmental information in European transboundary water management. IWA Publishing, London, pp 125–134

Giordano R, Uricchio VF, Vurro M (2008) Monitoring information systems to support integrated decisionmaking. In: Timmerman JG, Pahl-Wostl C, Möltgen J (eds) The adaptiveness of IWRM; analysing European IWRM research. IWA Publishing, London, pp 113–128

Gooch GD, Stålnacke P (2006) Introduction: identifying and solving problems in an integrated approach. In: Gooch GD, Stålnacke P (eds) Integrated transboundary water management in theory and practice: experiences from the new EU Eastern borders. IWA Publishing, London, pp 1–24

Hisschemöller M (2004) Integrated assessment in transboundary water management: a tentative framework. In: Timmerman JG, Langaas S (eds) Environmental information in European transboundary water management. IWA Publishing, London, pp 168–183

Huisman P (1996) Water management in the Rhine delta. The river Rhine: development and management. Deutsches IHP/OHP-Nationalkomitee, Koblenz, pp 79–96

Laane RWPM, Ten Brink BJE (1990) Data-rich, information-poor. The modern monitoring syndrome? Land & Water International 68:12–16

Langaas S, Aliakseyeva N, Gooch GD, Lopman E, Nilsson S, Timmerman JG (2002) Environmental information in transboundary river basin policy-making and management: Selected European case studies. MANTRA-East working paper, Stockholm, Sweden

Lindemann S (2006) Water regime formation in Europe. A research framework with lessons from the Rhine and Elbe river basins. FFU-report 04-2006. Freie Universitaet Berlin, Berlin

MacDonald LH (1994) Developing a monitoring project. Journal of Soil and Water Conservation 1994:221–227

McBride GB, Smith DG (1997) Results of a trend assessment of New Zealand's National River Water Quality Network. In: Ottens JJ, Claessen FAM, Stoks PG, Timmerman JG, Ward RC (eds) Proceedings of the international workshop on information strategies in water management. RIZA, Lelystad, pp 135–142

McNie EC (2007) Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. Environmental Science and Policy 10:17–38

McNie EC, Pielke RA, Sarewitz D (2007) Climate science policy lessons from the RISAs. Consortium for Science, Policy, and Outcomes (CSPO). Arizona State University, Tempe

Meybeck M (1989) Surface water quality: global assessment and perspectives. In: Zebidi H (ed) Proceedings of the international conference on world water resources at the beginning of the 21st century, pp 173–185

Meybeck M, Helmer R (1989) The quality of rivers: from pristine state to global pollution. Paleogeography Paleoclimatology Paleoecology (Global and Planetary Change Section) 75:283–309

Meybeck M, Kimstach V, Helmer R (1996) Strategies for water quality assessment. In: Chapman D (ed) Water quality assessment—a guide to the use of biota, sediments and water in environmental monitoring. Chapman & Hall, London, pp 19–50

Nilsson S (2006) Managing water according to river basins. Information management, institutional arrangements and strategic policy support—with focus on the EU Water Framework Directive. Royal Institute of Technology, Stockholm

Perry JA, Vanderklein E (1996) Water quality: management of a natural resource. Blackwell Science, Cambridge

Rittel HWJ, Webber MM (1973) Dilemmas in a general theory of planning. Policy Science 4:155–169

Sarewitz D, Pielke RA (2007) The neglected heart of science policy: reconciling supply of and demand for science. Environmental Science and Policy 10:5–16

Timmerman JG, Langaas S (2005) Water information—what is it good for? On the use of information in transboundary water management. Regional Environmental Change 5(4):177–187

Timmerman JG, Ottens JJ, Ward RC (2000) The information cycle as a framework for defining information goals for water-quality monitoring. Environmental Management 25(3):229–239

Timmerman JG, Beinat E, Termeer CJAM, Cofino WP (submitted) A methodology for specification of information needs. Water Science and Technology

Timmerman JG, Beinat E, Termeer CJAM, Cofino WP (in preparation) Testing a methodology for specification of information needs; the Dutch national policy evaluation case

Ward RC, Loftis JC, McBride GB (1986) The "Data-rich but Information-poor" syndrome in water quality monitoring. Environmental Management 10(3):291–297

Other Literature Used for the Analysis (Mainly in Dutch Language)

Adriaanse M (1992) Optimalisatie routinematig onderzoek kwaliteit rijksbinnenwateren. Deel 1: Hoofdrapport. (Optimisation of routine investigation of the quality of national inland waters. Part 1: main report). Nota nr. 92.055 RIZA, Lelystad (in Dutch)

Bosch A, van der Ham W (1998) Twee eeuwen Rijkwaterstaat (Two ages of Rijkswaterstaat) 1798–1998. Rijkswaterstaat (Den Haag)/Stichting Historie der Techniek (Eindhoven), Europese bibliotheek, Zaltbommel (in Dutch)

Breukel RMA, Schäfer AJ (1991) Optimalisatie routinematig onderzoek kwaliteit rijksbinnenwateren. Deel 2: Informatiebehoefte waterkwaliteit. (Optimisation routine investigation of the quality of national inland waters. Part 2: information needs for water quality). Nota nr. 91.012 RIZA, Lelystad (in Dutch)

Cappon JJ (1984) Herziening routineprogramma kwaliteit Rijkswateren 1985 (Revision of the routine program quality of the national waters 1985). letter 16 October 1985 (in Dutch)

European Commission (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities 22.12.2000, L 327/1-L 327/72

Hesen PLGM, Gilde LJ, van Helmond CAM (1998) Actualisatie van het landelijk chemisch meetnet voor zoete rijkswateren (Actualisation of the national chemical monitoring network for national inland waters). H2O 22, 27–29 (in Dutch)

RIKZ (2000) Gebruik van MWTL-gegevens van de zoute Rijkswateren (Use of MWTL-data of the salt National Water Systems). RIKZ; Alkyon; Witteveen + Bos, The Hague (in Dutch)

RIZA (1954) Jaarverslag 1952–1953 (Yearreport 1952–1953). Rijkswaterstaat, The Hague (in Dutch)

RIZA (1965) Jaarverslag 1964 (Yearreport 1964). RIZA mededeling nr. 1 Staatsuitgeverij, The Hague (in Dutch)

RIZA (1966) Jaarverslag 1965 (Yearreport 1965). RIZA mededeling nr. 3 Staatsuitgeverij, The Hague (in Dutch)

RIZA (1972) Jaarboek der waterkwaliteit van de Rijkswateren 1965; Rijntakken en Maas. (Yearbook of the water quality of the national waters 1965; Rhine and its branches and Meuse). RIZA mededeling nr. 11 Staatsuitgeverij, The Hague (in Dutch)

RIZA (1973) Jaarverslag 1971 (Yearreport 1971). RIZA mededeling nr. 17 Staatsuitgeverij, The Hague (in Dutch)

RIZA (1975) Jaarverslag 1972–1973 (Yearreport 1972–1973). RIZA mededeling nr. 19 Staatsuitgeverij, The Hague (in Dutch)

RIZA (1979) Jaarverslag 1977 (Yearreport 1977). RIZA mededeling nr. 24 Staatsuitgeverij, The Hague (in Dutch)

Sam R, Smit J (1996) Wad monitoren: een onderzoek naar de afstemming tussen beleid m.b.t. de Waddenzee en de monitoringsaktiviteiten (Wad monitoring: a study into the relation between policy for the Wadden Sea and monitoring activities).

RIKZ/AB-96.602X Ministry of Transport, Public Works and Water Management. Institute for Marine and Coastal Zone Management, The Hague (in Dutch)

Schilperoort T, Groot S, van de Wetering BGM, Dijkman F (1982) Optimization of the sampling frequency of water quality monitoring networks. Publication nr. 261. RIZA, Lelystad

Stevers R (2003) Beeld SvZ Langetermijnvisie Basisinformatie nat en advies voor vervolg (Analysis of long-term vision for basic information on water and advice for follow-up) (internal report) (in Dutch)

Timmerman JG, Houben A, van Steenwijk J, van der Weijden M (2004) Legal obligations for Dutch national water quality monitoring. RIZA/2004.131X. RIZA, Lelystad

van Kerkhoff JJB, van Riel MA (1996) RWS: RIZA, RIKZ, MD. Informatiebehoefte monitoring. "Beter meten? De klant niet vergeten!" (RWS: RIZA, RIKZ, MD. Information need monitoring. "Better measuring? Do not forget the customer!"). rwdh-237/riza9.jke Twijstra Gudde, The Netherlands (in Dutch)