Statistical Journal of the United Nations ECE 22 (2005) 111–131
IOS Press

Integrated river basin accounting in the Netherlands and the European Water Framework Directive

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Abstract. The implementation of the European Water Framework Directive (WFD) has increased policy and decision-maker demand for integrated hydro-economic data, information and indicators at the level of river basins. In order to meet this increasing demand, a new integrated hydro-economic accounting system has been developed, called National Accounting Matrix including Water Accounts for River Basins (NAMWARiB). NAMWARiB provides information about the interactions between the physical water system and the economy at national and river basin scale. The main objective of this paper is to present and discuss the use and usefulness of the newly developed river basin information system for the implementation of the European WFD based upon the currently available time series data.

1. Introduction

Since a number of years, the demand for information about the economic value of water and the wider economic consequences of water policy and management has increased rapidly. In Europe, the introduction of the European Water Framework Directive (2000/60/EC) has given this demand an important impetus. The Water Framework Directive (WFD) is one of the first European directives in the domain of water, which explicitly acknowledges the important role of economics in water policy and management. One could say that the implementation of the WFD is one of the most important challenges facing water policy and management in the next decade.

According to the European Task Force on Water Satellite Accounts [8, p. 4], the implications of the WFD include:

- an increase in the demand for water-related data of various kinds (water supply and use, economic data, water quality etc.) that are integrated and consistent;
- an increase in the availability of data that are comparable across countries, not least to facilitate the consolidation of river basin district plans comprising several countries;
- better studies of the costs and prices of water services, including environmental and resource costs;

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– more focus on the geographical boundaries of the data, i.e. water bodies and river basin districts.

In order to meet this growing demand, the possibilities of linking existing water information systems to the economic accounting system have been investigated in the Netherlands [1,5,11]. This research has resulted in the creation of a new integrated water economics information system called the National Accounting Matrix including Water Accounts for River Basins (NAMWARiB).

NAMWARiB provides information about the interlinkages between the physical water system and the economy at national and river basin scale. The main objective of this paper is to present the newly developed river basin information system and discuss the use and usefulness for the implementation of the WFD.

2. Integrated hydro-economic accounting

NAMWARiB is an extension of the National Accounting Matrix (NAM), which is published annually in the Netherlands by Statistics Netherlands. The NAM presents the whole system of national accounts in one overall matrix framework. The NAM provides information about the flows of goods and services in the national economy in a particular year and the money flows that are related to these flows. As such, NAM provides an official account of the economic transactions in the Netherlands, in accordance with an internationally adopted methodology, i.e. the European System of Accounts (ESA) [2], which is based on the worldwide System of National Accounts (SNA) [9]. The use of such an internationally accepted methodology allows for international comparability.

In the beginning of the 1990s, Statistics Netherlands extended this National Accounting Matrix with a 'satellite account', which includes the environmental pressures related to the production of goods and services and the consumption of households. This resulted in the National Accounting Matrix including Environmental Accounts (NAMEA) [3,4,6]. In 1993 the United Nations published their first handbook on integrated environmental and economic accounting (SEEA), followed by an operational manual in 2000 and a revised handbook in 2003 [10], illustrating the international acknowledgement of the importance of integrated environmental and economic analysis.

NAMWARiB is a further specification of NAMEA for water, using the same basic structure as the NAMEA. Within this structure, each column represents the supply of a good or service, whereas the rows describe the demand for those goods and services. The monetary flows are in exactly the opposite direction: columns represent receipts and rows represent expenditures. The total of the columns equal the total of the rows. Together rows and corresponding columns make up an account for a specific good or service, reflecting where it comes from and where it goes.

Basically, the structure of NAMWARiB consists of three parts (Table 1):

– An economic account (the first 10 accounts, all in millions of euros per year);
– A water extraction and discharge account (account numbers 11 and 13 in millions of cubic metres per year); and
– An emission account (account numbers 12 and 14 in kilograms per year).

The first accounts for the emission of substances and water extraction and discharge, account numbers 11 and 12, represent the flows. The second account (account number 13) for water extraction and discharge describes changes in stocks, while the second account (account number 14) for emissions describes the contribution of various substances to the 'environmental themes' eutrophication, wastewater and the dispersion of heavy metals. Also this is significantly different than the flow accounts. To stress these differences, the accounts are not presented consecutively, but alternating in NAMWARiB (see Table 1). The various accounts will be discussed in more detail below.

Table 1
The basic structure of NAMWARiB

Account nr	1-10	11	12	13	14
1-10					
11					
12					
13	Water balance; mln m^3				
14	Emission balance; kg				

2.1. Economic accounts

The first ten accounts in NAMWARiB represent the traditional National Accounting Matrix (in millions of euros). In view of the fact that NAMWARiB focuses on water related issues, the 'not to water related issues' are summarised and included in the section "other". In this way, the totals in NAMWARiB correspond with those in NAMEA and NAM.

Account number 1 represents the supply (column) and demand (row) of goods and services (in purchaser prices) in the Netherlands for a particular year. Supply exists of production (in basic prices), product-related taxes less subsidies, and imports. Demand is broken down into consumption of households, government consumption, intermediate consumption, investments and exports. The types of goods and services distinguished in NAMWARiB are:

– Tap water (row 1a);
– Other goods and services (row 1b);
– External environmental services, excluding sewerage charges; e.g. collection of waste by environmental companies (row 1c1);
– Sewerage charges; taxes received by municipalities for use of the sewerage system (row 1c2);
– Internal environmental services related to water treatment; water related self-services (row 1d);
– Internal environmental services related to prevention of soil pollution (row 1e);
– Other internal environmental services; not water or soil related self-services (row 1f).

Account number 2 presents the budgets of households and how this is spent.

Account number 3 is the production account. This account presents in each row the production value (in basic prices). In the (sub)columns, the total production value is broken down into intermediate consumption, net value added, depreciation, and non-product related taxes less subsidies. This account is specified for nine sectors with a further breakdown of the sector Government into 4 subcategories, based on the importance of water in these specific sectors. The nine sectors are:

– Agriculture and fisheries (row 3a);
– Oil and gas mining (row 3b1);
– Other mining activities, including gravel mining (row 3b2);
– Industrial manufacturing (row 3c);
– Water extraction and distribution by drinking water companies (row 3d);
– Electricity generation and distribution and gas distribution (row 3e);
– Environmental services, including wastewater treatment (row 3f);
– Other services and construction, (excluding government, but including water boards) (row 3g);

- Government (3h):
  - ∗ Central government (row 3h1);
  - ∗ Municipalities (row 3h2);
  - ∗ Other government (row 3h3);
  - ∗ Defence (row 3h4).

Special attention is paid to 'Government'. In NAMWARiB, an important difference exists between the Government as an economic activity, described in account 3, and the Government as a sector, described in account 5. In account 3, Government is split into central government, municipalities, other government and defence. A further subdivision for these sub-sectors is not possible. As a result, no data for water use or various non-product related taxes can be presented for the sub-sector 'water boards'. On the other hand, water quality management by water boards, most importantly wastewater treatment, is included in row 3g.

Account number 4 describes the primary income generation. Net value added, value added tax not handed over to the government, and income generated abroad constitute net national income and income paid to other countries.

Account number 5 presents the income distribution and describes the secondary distribution of national income across different sectors. Here, we focus mainly on the Government sector. The sector Government includes the economic activity Government, as described in account number 3, and parts of the Government that have been included in other economic activities, i.e. activities which have been carried out by other companies, such as health care or environmental services, including wastewater treatment by water boards. The various sectors specified in account number 5 include:

- Non-financial institutes;
- Financial institutes;
- Government:
  - ∗ Water related revenues by the central government;
  - ∗ Water related revenues by provinces (some provinces receive dividend on shares of drinking water companies);
  - ∗ Water related revenues by the regional water boards (water pollution levy and levy for water quantity management);
  - ∗ Water related revenues by municipalities (sewerage charges and other environmental taxes);
  - ∗ Other government.

Account number 6 describes the capital flows. Capital expenditures (rows) include investments in goods and services, national credits, and capital transfers to other countries. These expenditures equal the revenues (columns) consisting of depreciation, savings, and capital transfers from abroad.

Account number 7 describes the financial balance. This account presents the total of credits and debts with other countries. These are – by definition – each other's reciprocals.

Account number 8 describes taxes. Compared to NAMEA, NAMWARiB distinguishes the following water related taxes:

- Water related taxes (row 8a):
  - ∗ Water board levies (row 8a1);
  - ∗ Water pollution levies (row 8a2);
  - ∗ Sewerage charges (row 8a3);

  * Levies on wastewater discharged into large state-owned rivers (row 8a4);

- Levies on groundwater extraction (row 8b);
- Other environmental taxes (row 8c), including green taxes;
- Other taxes (row 8d).

These taxes are received as product related taxes, non-product related taxes, income taxes, property taxes or tax income from abroad (rows). In the columns, the associated expenditures are presented, i.e. non-paid value added taxes, taxes minus subsidies, and taxes paid to other countries.

Account number 9 describes the payments to and from abroad for non-capital goods and capital formation. These include, in the rows, revenues from abroad from exports, wages, income distribution, and taxes. The columns represent expenditures paid for imports, wages and taxes paid abroad and the balance of current transactions with other countries.

Finally, account number 10 presents the capital balance with other countries. Capital transfers, the financial balance, and the balance for current transactions finance the capital expenditures in other countries.

2.2. Emission accounts

Whereas the economic accounts are all in millions of euros, the emission accounts are expressed in physical units (kilograms). NAMWARiB describes the emissions of 78 substances to the aquatic environment originating from economic activities. The list with substances includes the most important substances identified in the WFD. The emission data for these substances are supplied by the Dutch National Emission Registration. The list with substances is shown in Table 2.

The emission balance consists of two accounts, account number 12, and account number 14. The columns of account number 12 present the emissions by consumers, by producers, and emissions of which the source is unknown (labelled 'transport difference'), and the import of transboundary pollution. Emissions to water through the air (atmospheric deposition) and through runoff from soils are attributed to the sources, which originally caused these emissions.

The rows of account number 12 describe the destination of the substances. Substances can be absorbed by producers (during the production process), environmental services (wastewater treatment), exported and/or contribute to environmental themes (cell 12, 14). This latter cell links account number 12, which describes water pollution, to account number 14, which describes the contribution of the various emitted substances to the various environmental themes, i.e. eutrophication, wastewater and dispersion of heavy metals.

The 'contribution to environmental themes' described in account number 14 presents the actual pressure on the environment caused by a particular substance in the environment. For example, excess amounts of nitrogen (N) and phosphorous (P) contribute to eutrophication, and emissions of heavy metals contribute to the dispersion of heavy metals in the environment.

It is important to point out that NAMWARiB only describes environmental pressures, not the extent to which these pressures actually result in environmental problems or damage (i.e. impacts). Furthermore, the level of detail in NAMWARiB is such that NAMWARiB can not be used to inform water managers about, for example, which lakes will be affected by eutrophication. NAMWARiB is a descriptive tool,

Table 2
List with substances included in NAMWARiB

Substance	Substance
SB	Chrysene
AS	Benzo(a)anthracene
CD	Benzo(a)pyrene
CR	Benzo(b)fluoranthene
CU	Benzo(k)fluoranthene
HG	Benzo(ghi)perylene
PB	Indeno(1,2,3-C,D)pyrene
NI	Organotin compounds
SE	Naphtalene
SN	CZV
V	Cloridbenzene
AG	Trichloridethane,1,1,1-
ZN	Dichloridethane,1,2-
Total P	Dichloridmethane
Total N	Dioxin and Phurane (I-TEQ)
Nitrates, Nitrites	Organic halogen compounds (total)
Kjeldahl-N	Hexachloridcyclohexane
CL	PCB AND PCT
CN	Tetrachloridethane (PER)
F	Tetrachloridmethane (TETRA)
SO4	Trichloridethane (TRI)
VOC	Trichloridmethane (Chloroform)
Carbohydrates	Chloridphenol
Non-halogenised carbohydrates (total)	Aliphatic halogenised carbohydrates
Aluiphatic non-halogenised carbohydrates (total)	Aromatic halogenised carbohydrates
Aromatic non-halogenised carbohydrates (total)	Diuron
Non-methane VOC (total)	Drins (Aldrin, Dieldrin, . . .)
Ethylbenzene	Dichloridbenzene,1,4-
Acrylaldehyde (Acroleine)	Trichloridbenzene, NNB
Benzene	Hexachloridbenzene
Ethene	Pentachloridphenol
Phenols, Phenolates	PCB
Formaldehyde	Dichloridethane 1,2-
Phtalaten, Phtaalesters	EOCL(extractable organic chlorid)
PAC (10), PAC (6)	
Tolueen	
Xylene (total)	
Mineral oils	
Isopropylbenzene	
Dibutylphtalate	
Phenanthrene	
Anthracene	
Fluoranthene	

presenting information about the pressures exerted on the water system in some past period, e.g. in which river basins excess amounts of nutrients have entered surface waters. An impact analysis of whether environmental pressures result in environmental problems would require the use of appropriate models. The data presented in NAMWARiB can be used as input into these models. On the other hand, NAMWARiB does offer opportunities for time series analyses on environmental pressures. This allows us to evaluate, for instance, the effectiveness of environmental policies aimed at reducing environmental pressures exerted by specific economic sectors or activities.

2.3. Water flow accounts

The water flow accounts, i.e. water extraction and discharge, in NAMWARiB are expressed in millions of cubic metres (m^3) per year and are, contrary to the emission accounts, not part of the NAMEA. The water flow accounts are currently available only for the years 1996 and 2001, as the necessary data are based on Statistics Netherlands' five yearly Water Survey. In this Water Survey approximately 7,500 companies are asked about their water consumption: how much fresh, brackish, and salt water they use and for which purpose (cooling water or other). The use of water by different economic activities is described in two accounts: water flows (account number 11) and changes in water stocks (account number 13).

Account number 11 describes the extraction from three types of water sources: groundwater, surface water and tap water. For groundwater a distinction is furthermore made between fresh and brackish groundwater and for surface water between fresh and salt water. The rows describe water consumption by households, different branches of industry and other sources including water losses as a result of evaporation. Water consumption is further broken down into water consumption for cooling water purposes and other purposes. Total freshwater use equals the use of drinking water, fresh groundwater and fresh surface water minus freshwater used for cooling purposes, as cooling water is only extracted temporarily and recycled again into surface water.

Account number 13, which describes the changes in stocks, is further specified into groundwater and fresh surface water. The rows present the extraction from these sources and the columns reflect additions to groundwater and surface water resources through replenishment by rivers or rainfall.

3. Aggregation of environmental and economic data to river basins

NAMWARiB presents information at the level of the four main river basin districts in the Netherlands: Rhine, Meuse, Scheldt and Ems. In view of the fact that the Rhine basin covers approximately 70 percent of the entire Dutch territory – making it difficult to carry out any meaningful analysis – this basin is furthermore split up into four different subregions: Rhine North, Rhine West, Rhine East and Rhine Centre (Fig. 1). As mentioned, NAMWARiB combines three different types of data and includes an economic account, an emission account and a water extraction and discharge account. The data from the economic and water flow accounts are aggregated to the level of the seven river basins in the same way. The economic data are based on the regional accounts (see below), whereas regional water flow data are based on the National Water Survey conducted by Statistics Netherlands once every five years. This survey comprises business level data as in the regional accounts on water use by industry, mining and electricity companies. Additional information about water use in agriculture is supplied by the Dutch Agricultural-Economic Institute (LEI). The regional water flows add up to the total of the national water flow. Emission data are available at the level of individual plants, including their x and y coordinates, making it relatively easy to attribute these emissions to one of the river basin districts.

Regional accounts are composed at the level of 40 so-called COROP areas (see Fig. 1). The regional accounting system focuses on the production processes in each business unit in the various regions [7]. COROP areas are the official regional economic units distinguished by Statistics Netherlands. The regional economic accounting system at COROP level provides the basis for the compilation of NAMWARiB.

The economic data at the level of the 40 COROPs are aggregated to the seven river basins in a number of steps. In a first step, data for COROPs which are situated entirely in one river basin are allocated

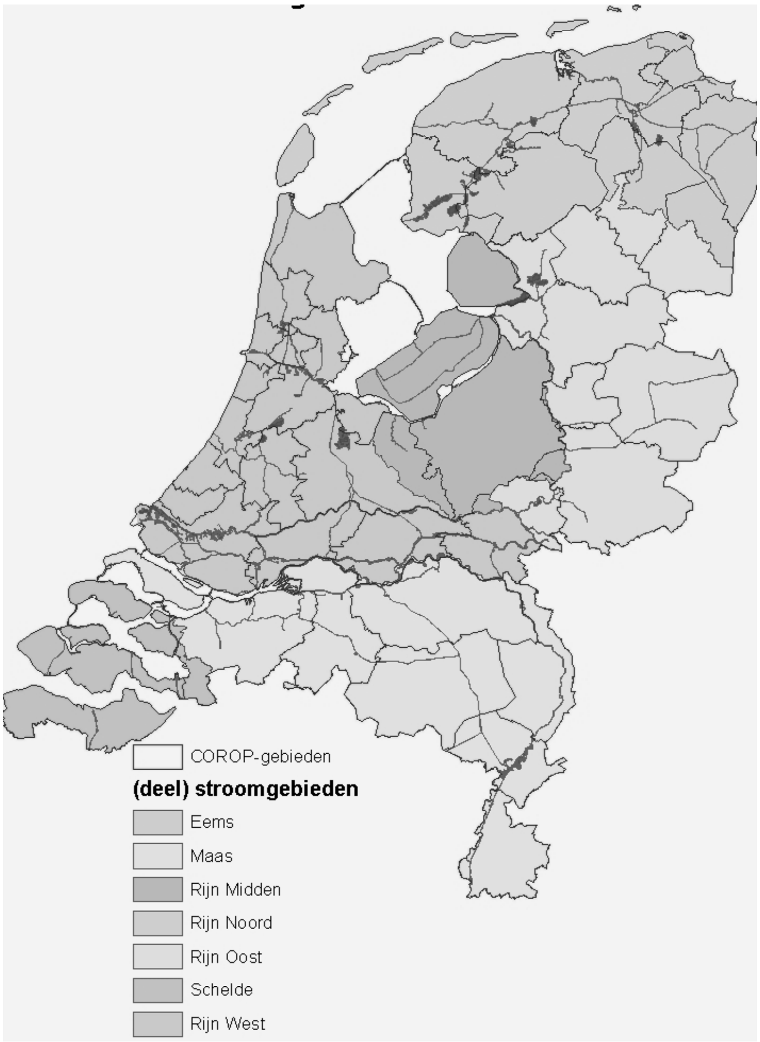


Fig. 1. The Netherlands split up in the seven river basins distinguished in the WFD and the underlying 40 geographical economic units (COROPs).

directly to this river basin. This is the case for 23 of the 40 COROPs in total. For the remaining 17 COROPs, data are allocated in subsequent steps on the basis of the distribution of employees in the specific branches of industry in these 17 COROPs. The economic data are allocated to two or more river basin districts with the help of the estimated percentage of employees working in a specific river basin. These percentages are estimated by identifying:

(1) the specific branches of industry in the 17 COROPs;
(2) the total number of employees working in these branches of industry;
(3) the municipalities in which the business units in these branches of industry are located;
(4) which of these municipalities fall entirely in one specific river basin, and which municipalities overlap with other river basins.

After the specific branches of industry have been identified in these 17 COROPs, these branches of industry and the number of employees working in them are linked to the municipalities in which the underlying business units are found. These municipalities are linked again to the specific river basin districts in which they fall. Business units and their number of employees in municipalities falling entirely inside a specific river basin district are allocated directly to that specific district. For those municipalities located partly in one and partly in another river basin district, the identified business units are linked in a next step to the postal codes within these municipalities. Also these postal codes are allocated to river basin districts. Business units falling entirely in postal code areas within one specific river basin district are allocated directly to that district. For the remaining postal codes found in two or more river basins, business units and their employees are allocated to a specific river basin on the basis of the area of the postal code falling in that river basin district.

4. The usefulness of integrated river basin indicators for the WFD

The WFD requires that river basins across Europe are described in both physical and economic terms. According to Article 5, the economic characterisation of river basins should include an assessment of [12]:

- the economic significance of current water use;
- future water use up to 2015;
- current levels of cost recovery of water services.

The WATECO guidance document[1] provides some first guidelines on how to prepare an economic analysis of current water use and their economic importance. According to the WATECO guidance, this step will require a high level of coordination with other experts and stakeholders to build a common knowledge and representation of the river basin. First, water uses and services should be identified by socio-economic sector (agriculture, industry and households). Secondly, one should assess the relative socio-economic importance of the identified water uses. Potential indicators are production volume, value added and employment. The main outputs of this step in the economic analysis are key indicators of the economic significance of water uses. It is important to collect information that is relevant to water management issues in the river basin and economic sectors likely to be affected by the implementation of the Directive. The combination of biophysical and economic information requires agreement on one common spatial scale of analysis and reporting.

Essentially, the economic significance of water use in the different river basins is measured in two different ways. Economic significance is measured through production and value added generated in river basins per sector (expressed in euros). Water use is measured through water extraction (expressed in cubic metres) by economic activities and the emission of polluting substances (expressed in kilograms) per sector. Water use can furthermore be measured through wastewater discharge per sector in each river basin (expressed in inhabitant equivalents). In the next sections, we will give examples of the type of information derived from NAMWRiB related to the economic-environmental characterization of river basins and trend analysis.

[1]The Water Economics working group WATECO was one of the European working groups set up under the Common Implementation Strategy of the Water Framework Directive (WFD) with an aim to provide guidelines for the economic analysis in the WFD. This resulted in 2002 in the WATECO guidance document.

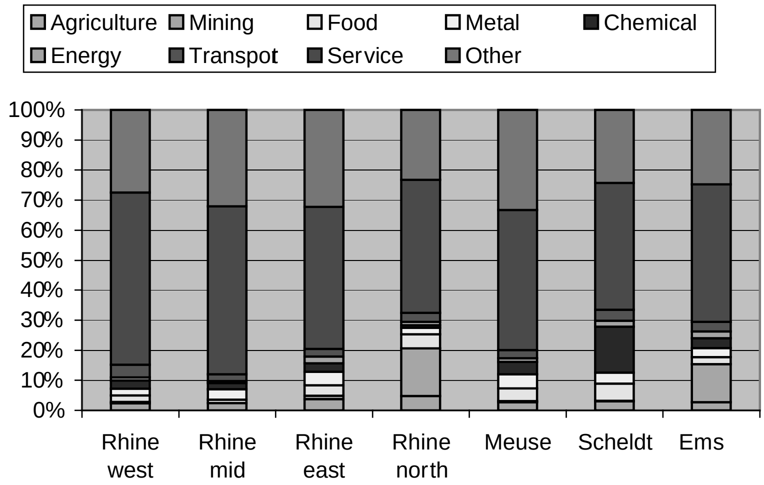


Fig. 2. Economic structure in each river basin in the Netherlands in 2000 (measured as the share of different sectors in total value added).

4.1. *Economic river basin indicators*

The allocation of economic data to river basins enables a detailed description of the economic structure of these river basins. Most economic value is currently (2000) generated in the river basin Rhine West (50%), followed by the Meuse (21%) and Rhine East (10%). The most important reason for this is that these are the three largest river basins in the Netherlands (see Fig. 1). Rhine West is economically speaking a very important area in the Netherlands and the most densely populated. The contribution of three of the four other basins in total Gross Domestic Product (GDP) (i.e. sum of gross value added across the various river basins) is less than 5 percent each. In 2000, total GDP was 402 billion euros.

The economic structure per river basin is presented in Fig. 2 (based on the value added generated in 2000). Overall, the river basins show a fairly similar structure. The service sector dominates in each river basin, but most importantly in the river basins Rhine West and Rhine Centre (Rhine Mid). Almost 60 percent of total value added is generated in the service sector in these river basins, compared to approximately 50 percent in the rest of the Netherlands.

The share of agriculture in total value added is relatively low compared to other sectors. Agriculture is especially important in Rhine North and Rhine East. Industry consists of many sub-sectors. Those sectors, which are generally believed to have an important relationship with water (mining, food, chemical, metal, energy) are shown explicitly in Fig. 2. Mining (oil and gas) is particularly important in Rhine North and Ems, while the share of the chemical and food industry are relatively high in the Scheldt basin. No substantial differences can be found in the case of the energy sector. The metal industry is slightly more important in the Meuse basin compared to the rest of the Netherlands.

4.2. *Water use indicators: Water extraction*

Total water use from tap water, groundwater and (salt and fresh) surface water is highest in the river basin Rhine West (where also most people live in the Netherlands), followed by Meuse and Rhine East (Fig. 3). Total water consumption in Rhine West was about 8 billion cubic metres in 2001 (45 percent of the total water use in the Netherlands in that year). Total water use in the Meuse was 3.8 billion cubic metres and in Rhine East 2 billion.

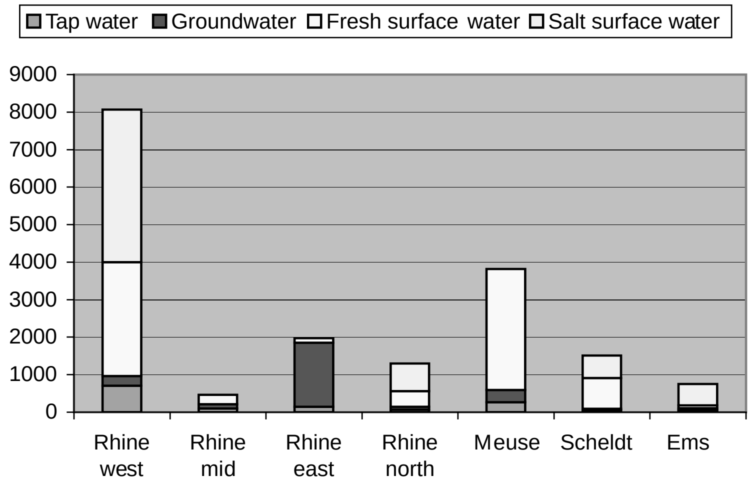


Fig. 3. Total water use from different water sources per river basin in 2001 (in million m^3).

The source of water varies significantly across river basins. Overall, most water is extracted from fresh surface waters (40% of the total water consumption). Across all river basins, about a third of all water is extracted from the sea whilst 20 percent of all water consumption is based on groundwater. The remainder (about 10 percent) consists of tap water.

Salt water is (for obvious reasons) only extracted in those river basins, which are bordered by the sea (i.e. Rhine West, Rhine North, Ems and Scheldt). In Rhine West, 50 percent of all water use consists of salt water, in Rhine North 60 percent, in the Ems 75 percent and in the Scheldt 40 percent. Almost sixty percent of all water use in these river basins is used as cooling water and discharged again into surface water after use. The same applies to the Meuse. Relatively much tap water is used in Rhine Mid (20 percent compared to 10 percent in the rest of the country). Rhine East depends for its water consumption relatively heavily on groundwater (85% of all water use comes from groundwater) and the Meuse basin on fresh surface water (also 85%). Relatively small amounts of groundwater are used in Rhine West and the Scheldt.

When comparing water consumption across sectors in the two largest water consuming river basins in the Netherlands (Rhine West and Meuse), the energy sector appears to be one of the most important water users in these two river basins. In Rhine West, more than half (54%) of all water is used in this sector and in the Meuse river basin around 80 percent (Fig. 4).

All water used in the energy sector in the Meuse river basin is extracted from fresh surface waters. In the river basin Rhine West, 65 percent of all cooling water used in the energy sector is extracted from the sea. After the energy sector, the service sector follows as the second largest water user in the two river basins with a share of 20 and 10 percent in Rhine West and the Meuse basin respectively. Approximately 4 percent of all water use is related to households. In Rhine West, the chemical industry and other industrial activities appear to have relatively much higher water consumption than the same sectors in the Meuse river basin.

4.3. Water use indicators: Wastewater production

Most wastewater is produced in Rhine West, followed by the Meuse and Rhine East. Total wastewater production in 2000 was 27 million inhabitant equivalents (IE). This is slightly lower than in 1996

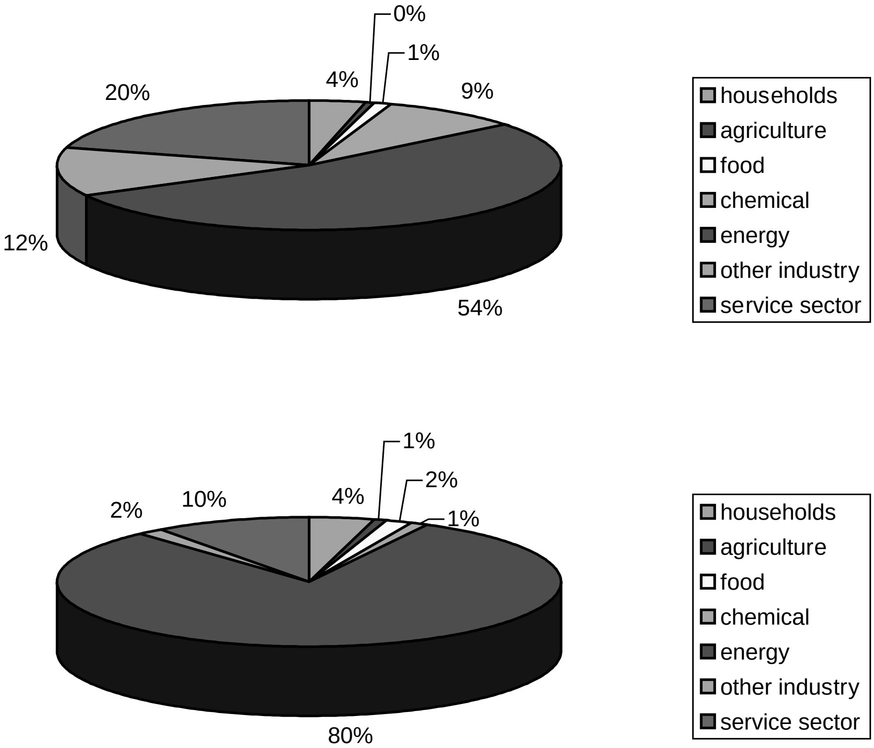


Fig. 4. Share of different sectors in total water use in Rhine West (top) and Meuse (bottom) in 2001.

(−0.5%). When relating wastewater production to the total number of inhabitants in the river basins, the highest wastewater production per capita ratio in 2000 is found in the Scheldt (2.4 IE/inhabitant), followed by Rhine East (2.0 IE/inhabitant) and Ems (1.9 IE/inhabitant). Average wastewater production per capita in the Netherlands is 1.8 IE. Obviously, this indicator has to be interpreted with the necessary care in view of the fact that not only households, but also industry is responsible for the amount of wastewater produced in a specific basin.

Wastewater discharge per sector does not significantly differ across the river basins. Most wastewater is produced by households (about 60%) (Fig. 5). The food and transport sector contribute each for about 7–8 percent. The contribution from agriculture, the metal industry and the service sector is relatively low (less than 1%). For about 15 percent of all wastewater, the exact source is unknown.

4.4. Water use indicators: Emission of pollutants

Although emission data are available for 78 substances, a complete emission balance only exists for the nutrients total phosphorous (P) and total nitrogen (N) and the metals As, Cd, Cr, Cu, Hg, Ni, Pb and Zn. For the other substances, information about influents, import and export by rivers or runoff from agricultural land is missing.

In 2000, the total emission of N was 285 thousand tonnes and 28 thousand for P. More than half of all N and P (55–60%) are emitted in the largest river basins Rhine West and Meuse, followed by Scheldt and Rhine East (Fig. 6).

When relating nutrient emissions to the area size of the river basins, a slightly different picture emerges. The highest emission-land ratio for both N and P is found in the Scheldt basin (236 kg/ha for N and

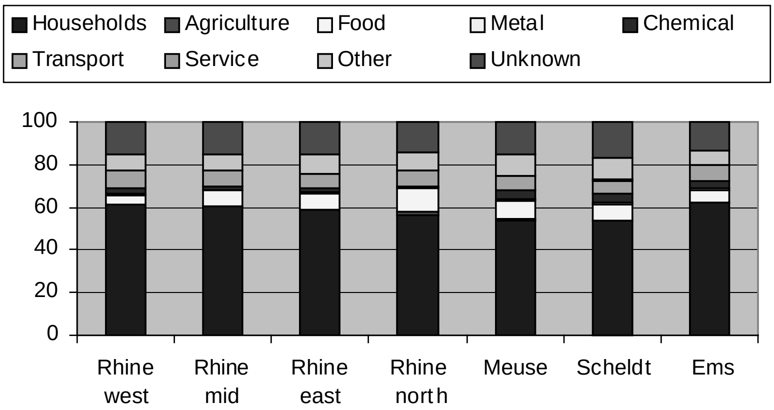


Fig. 5. Relative contribution of different sectors to total wastewater production in 2000 (in %).

19 kg/ha for P in 2000), followed by Rhine West (96 kg/ha for N and 14 kg/ha for P) and Meuse (117 kg/ha for N and 10 kg/ha for P). On average, nutrient emissions per hectare in the Netherlands in 2000 were 93 kg for N and 8 kg for P.

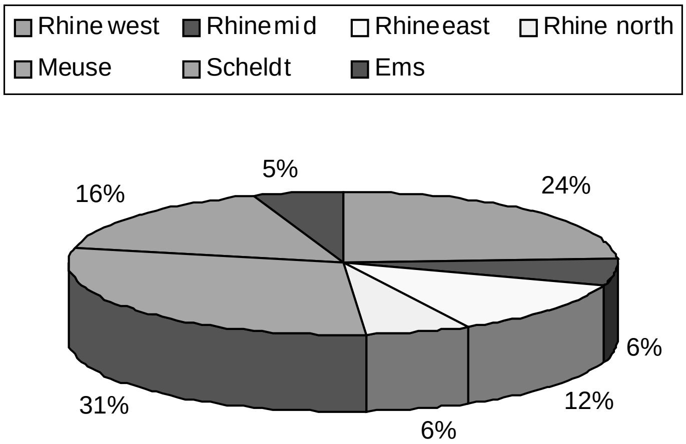
Most nutrients enter the Dutch water systems through the large international rivers Rhine, Meuse and Scheldt. On average, 43 percent of all P and 57 percent of all N emissions have their origins abroad. In some river basins, the relative contribution from abroad can be as high as 80 percent for N and 70 percent for P (see Figs 7 and 8). Numbers like these immediately make clear the necessity of an international river basin approach, as advocated in the WFD, in tackling current and future water quality management problems.

Considering domestic emissions only, agriculture is the largest source of N emissions, followed by private households (approximately 20 respectively 10 percent on average across all river basins). In the case of P, a relatively large share of the total amount emitted cannot be attributed to one specific emission source (17 percent), but is the result of diffuse pollution. For N, the share of diffuse pollution is about 7 percent. In the case of P, about 15 percent originates from households and 12 percent from agriculture.

The emission quantities above do not necessarily correspond with the quantities, which eventually enter into the water system. Excluding emissions from abroad and unknown diffuse pollution, on average across all river basins about 85 percent of all P and 50 percent of all N emissions from households, industry and the service sector were treated in 2000 by wastewater treatment plants (WWTP). The Meuse has the highest P absorption rate (91%), followed by the Ems (89%) and Scheldt (74%).[2] There is no information about nutrient absorption rates in the Rhine and its different sub-basins. In the case of N, the Scheldt has the highest absorption rate (60%) and the Ems the lowest (37%), suggesting that a relatively high percentage of N in the Ems basin originates from diffuse sources.

Of all heavy metals, Zinc (Zn) is emitted in the largest quantities in the Netherlands. Total Zinc emission was about 1,500 tonnes in 2000. Copper (Cu), Lead (Pb) and Nickel (Ni) are also emitted in relatively large quantities (350, 265 and 130 tonnes respectively in 2000). Chromium (Cr), Arsenic (As), Cadmium (Cd) and Mercury (Hg) are emitted in relatively smaller quantities (which does of course not mean that they are therefore less harmful to the water environment). Total Chromium emission in 2000 was 62 tonnes, Arsenic 24 tonnes, Cadmium 7 tonnes and Mercury 1.2 tonnes.

[2]The absorption rate is defined here as the percentage of all emissions treated in WWTP (influents). This absorption rate should not be confused with the WWTP treatment efficiency.



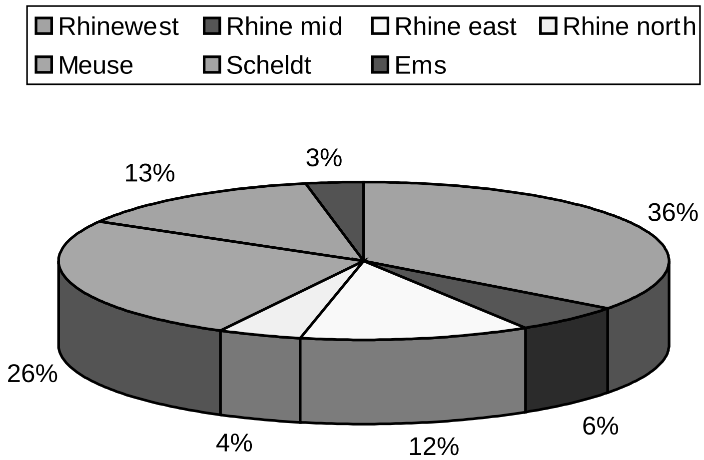


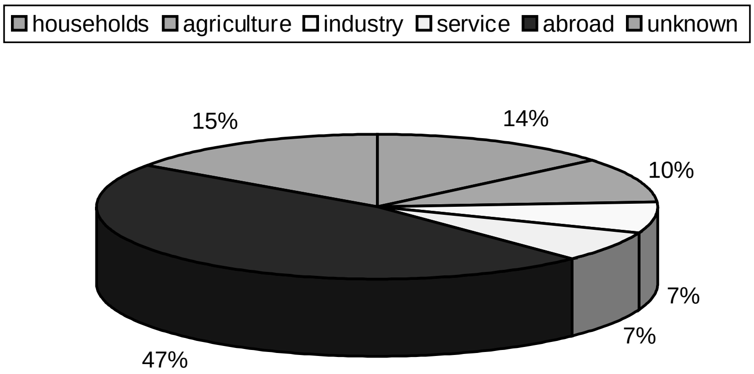
Fig. 6. Relative contribution of different river basins to the total emission of nitrogen (N) (top) and phosphorus (P) (bottom) in 2000.

Most metals enter the water system in the Meuse river basin (Fig. 9).[3] On average, about 35 percent of all the metals entering the water system do so within the boundaries of the Meuse. Scheldt and Rhine West follow, each with a share of about 25 percent. Hence, on average, approximately 85 percent of all metals are emitted in the river basins Meuse, Scheldt and Rhine West. The contribution of the other river basins is relatively low, usually not exceeding more than 5 percent of the total emission of a specific metal.

As for nutrients, most heavy metal emissions have their origins abroad (Fig. 10).[4] On average across all river basins in the Netherlands, 65 percent of total metal emissions come from abroad. The share from abroad in total emissions is largest in the Scheldt river basin (86% in 2000) and lowest in the Ems

[3]The Rhine is split up in four sub-basins. When represented as a whole, heavy metal emissions would be highest for the Rhine except for Cadmium, Chromium and Nickel.

[4]No import information is available for the four Rhine sub-basins separately, only for the whole Rhine river basin (i.e. heavy metals entering the Netherlands via the Rhine at Lobith).



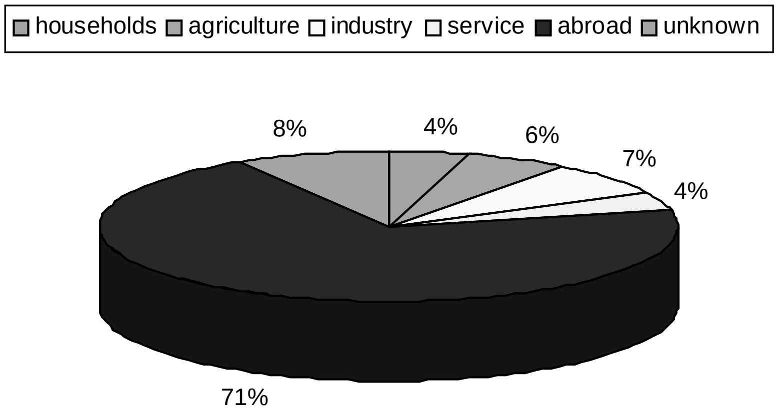


Fig. 7. Share of different sources in total P emissions in 2000 in the Rhine (top) and Scheldt basin (bottom).

basin (32% in 2000).

Households and the service sector (including wastewater treatment plants) are generally the most important domestic emission sources, followed by industry. However, different sources may be more or less important in different river basins depending on the specific metal.

Not all emissions enter into the water system. On average, about 40 percent of all domestic emissions, i.e. excluding emissions from abroad (which are essentially outside the control of water managers), are treated by WWTP and do not enter the water system.

Average absorption rates across all river basins are highest for Copper and Mercury (51 and 52% respectively) and lowest for Cadmium and Lead (21 and 26% respectively). There exist large differences between river basins though (Fig. 11). In the case of Cadmium, for example, the domestic absorption rate was as low as 12 percent in the Scheldt and 50 percent in the Meuse river basin. For Chromium, the absorption rate in 2000 was only 20 percent in the Ems and 70 percent in the Meuse basin.

4.5. Prediction of trends in future water use

Based on time series analysis, possible trends can be identified. In NAMWARiB, trends in economic driving forces can be linked to pressures such as water consumption, wastewater production and the

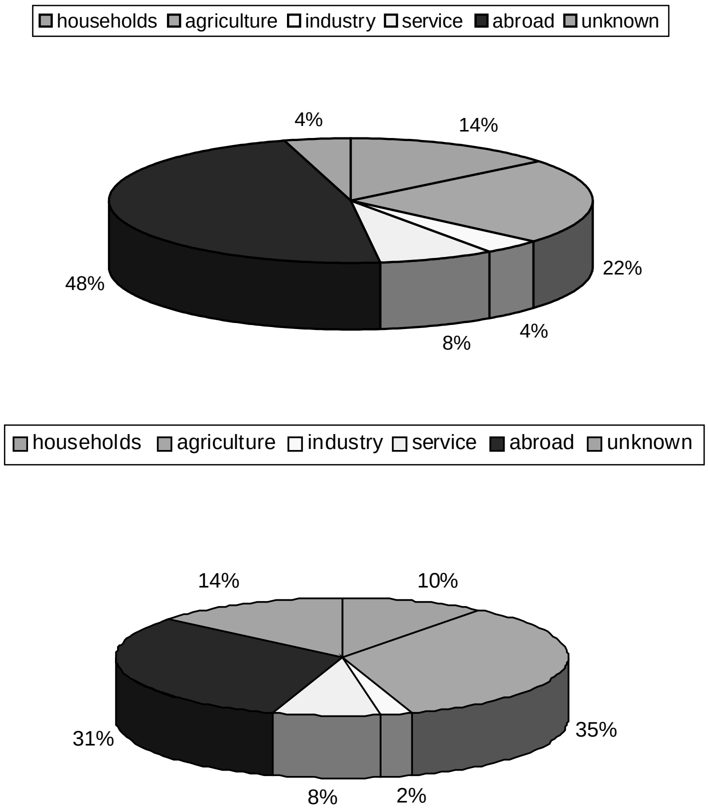


Fig. 8. Share of different sources in total N emissions in 2000 in the Meuse (top) and Ems basin (bottom).

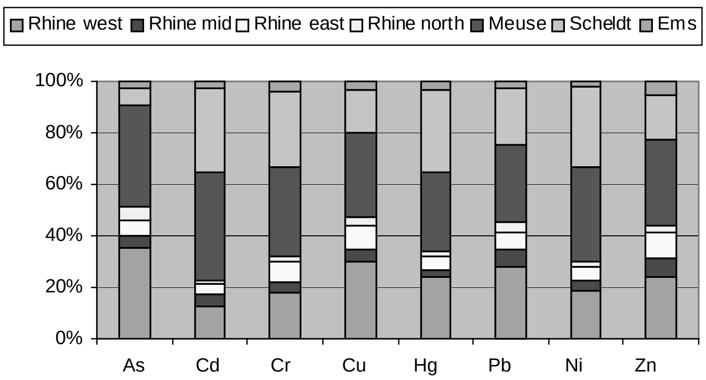


Fig. 9. Share of different river basins in the total emission of specific metals in the Netherlands in 2000.

emission of polluting substances (nutrients, metals etc.). An example is given in Fig. 12.[5] At the national level, real economic growth (in terms of GDP in constant prices) over the period 1996–2001 was 18

[5]In Fig. 12 (and later also Figs 13 and 14), nutrients and metals refer to the environmental themes eutrophication and dispersion of metals.

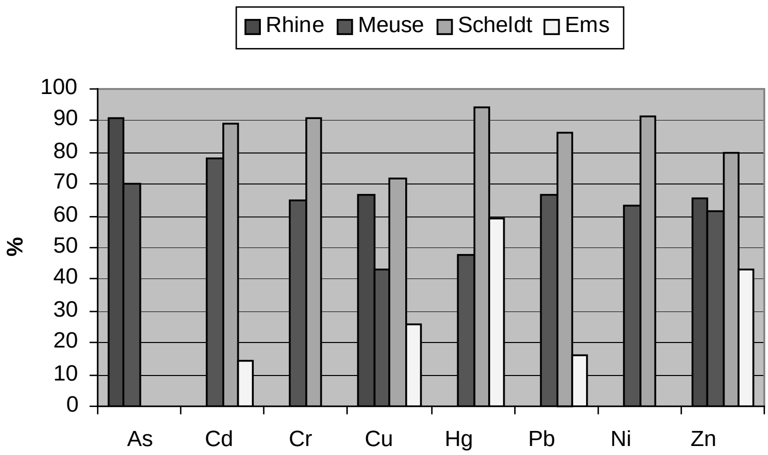


Fig. 10. Percentage of total metal emissions from abroad in different river basins in 2000.

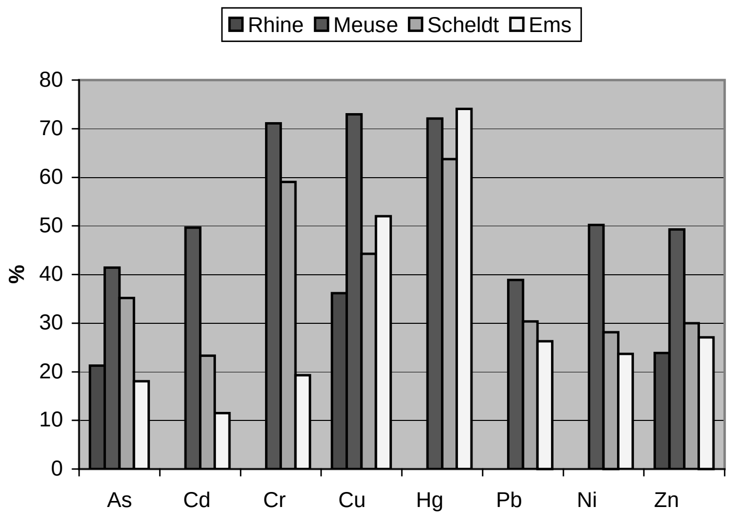


Fig. 11. Absorption rates of different metals across river basins in 2000 (excluding emissions from abroad).

percent (on average 3 percent per year). Total wastewater production remained more or less the same over that same period, whereas the emission of nutrients decreased significantly by approximately 15 percent and the emission of metals by about 10 percent. Figure 12 hence seems to suggest that economic activities use the water environment in a more efficient way.

Diagrams like these have to be interpreted with the necessary care. They provide, for instance, no hard evidence of a direct link between production and water use, such as wastewater production or emission of pollutants. These types of indicators are helpful in assessing the success (or failure) of environmental (sector) policy, as they provide important insight in the environmental efficiency of economic activities (i.e. the relationship between production output and the use of the environment or environmental inputs). They may also provide a basis for trend analysis. Based upon the observed development of economic activities within sectors and corresponding water use over the past 5 or 10 years, one can extrapolate this

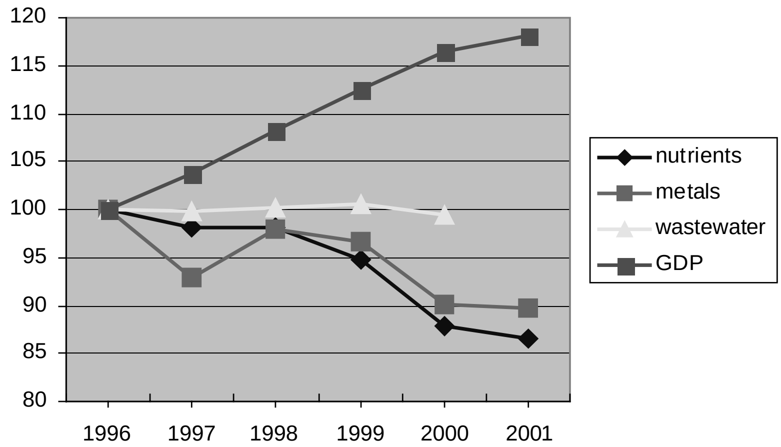


Fig. 12. Economic growth, wastewater production, emission of nutrients and metals (excluding import) in the Netherlands over the period 1996–2001 (indices, 1996 = 100).

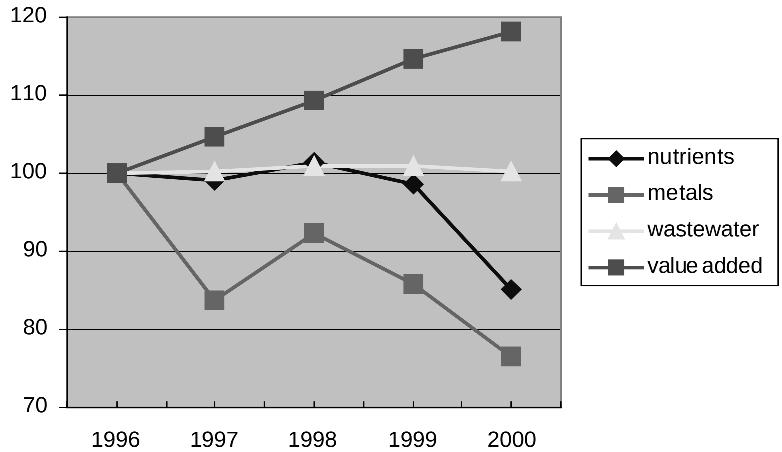


Fig. 13. Economic growth, wastewater production, emission of nutrients and metals (excluding import) in Rhine West over the period 1996–2000 (indices, 1996 = 100).

development into the future.[6] An important condition is that one has to be able to identify the trend first. Based on the average growth rates in Fig. 12 and assuming that the observed trend of a more efficient water use will continue into the future, economic driving forces (production volumes) and corresponding water pressures can be calculated. Needless to say that these numbers have to be used very carefully in any analysis and should, if possible, be supplemented with more 'qualitative data' regarding expected regional, national or international (sector) policies and/or technological change.

NAMWARiB allows detailed trend analysis of specific substances per sector at river basin level. The trends identified at national level, are also found in Rhine West (Fig. 13), but in the Meuse river

[6] It has to be pointed out that a longer time period than the past 5 years is preferred when trying to detect trends in economic driving forces and associated pressures. This will be the case in the next few years when NAMWARiB will be extended to also include more recent years (2001–2003) and possibly a few more years in the past as well (1990–1995).

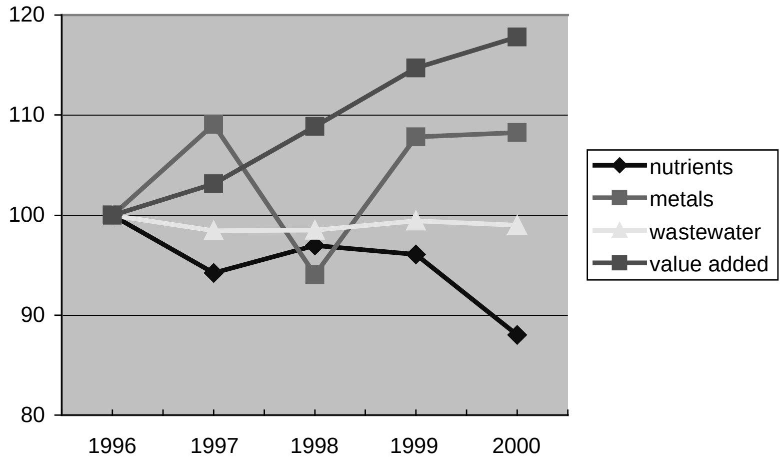


Fig. 14. Economic growth, wastewater production, emission of nutrients and metals (excluding import) in the Meuse river basin over the period 1996–2000 (indices, 1996 = 100).

basin metals show a more fluctuating development, with an actual increase over the period 1998–2000 (Fig. 14).[7]

5. Discussion and conclusions

In this paper, we presented a new integrated hydro-economic river basin accounting system for the implementation of the European Water Framework Directive. Linking available environmental data to economic data and the aggregation of both types of data to river basin level were the two most important challenges faced during the development of NAMWARiB. In-depth research was needed to assess the compatibility of different types of data at different levels of detail and in some cases also at different levels of confidence. Some of the main problems encountered include the use of different statistics:

- from different sources;
- with different classifications;
- with different monitoring scales;
- with different sampling and aggregation procedures;
- with different confidentiality procedures;
- from observations, calculations and model simulations.

It is important to clarify to water policy and decision-makers how to use NAMWARiB and how to interpret the information supplied by this information system. Relating NAMWARiB to the Driving forces-Pressure-State-Impact-Response (DPSIR) framework, NAMWARiB describes the driving forces related to the water system, such as specific economic activities and sectors. These driving forces exert different types of pressures on the water system, such as water extraction and emissions to ground and surface water. NAMWARiB also contains a water balance, showing the quantitative input and output

[7] At river basin level we only show the development of the indicators over the period 1996–2000 as two of the four indicators (value added and wastewater) are not yet available for the year 2001.

flows of ground and surface water, but only in a limited way based on a Water Survey, which is carried out only once every five years.

In some cases, pressures, such as the emission of phosphorous or nitrogen, organic pollution and heavy metals, are linked to state variables, based on their contribution to environmental themes such as eutrophication, wastewater, and the dispersion of heavy metals in the environment. The impact of water policy and management responses on water use and their effectiveness can be derived from NAMWARiB through time series analysis of water use and emissions to the water system. In short, NAMWARiB describes the pressures exerted on the water system, not the state of the water system or the impact of emissions on this state. Based on time series analysis, one can get an idea about the impact of policy and management responses on these pressures though, but this type of analysis usually requires a more in-depth assessment of the various factors that may have played a role in the observed trend.

Based on time series, trends can be identified, which can provide an important input in the scenarios that have to be developed for the WFD, e.g. in order to select a cost-effective programme of measures. More specifically, the trend analysis can be used to assess whether water bodies are at risk of not achieving good water status at some point in time. The description of the economic situation in river basins helps to determine the economic interests involved in water use and emissions, which in turn plays an important role in the determination of issues in the WFD such as disproportionality and derogation. Although NAMWARiB provides information about the use of different water services and the associated financial transfers and transactions, the calculation of cost recovery rates for water services for the WFD requires additional information. Moreover, calculating these rates at river basin level also still proofs to be difficult, mainly because of lack of sufficient information.

In conclusion, linking water and substance flows to economic flows and doing this systematically for a number of years, gives insight into the relationship between our physical water system and the economy. The integration of physical and economic information also allows for the construction of integrated indicators. For instance, water use by various economic sectors can be related to the economic interests involved. It is this integration of water and economy at river basin level, which makes NAMWARiB an important information tool to support policy and decision-making in the field of integrated water management as advocated by the WFD. By linking information about the physical pressures exerted on the water system by economic agents and the associated economic interests, NAMWARiB enables policy makers and water managers at national and river basin scale to assess in a consistent way the necessary measures to reduce these pressures and meet the environmental objectives in the WFD in an integrated manner. NAMWARiB offers opportunities to analyse the trade-offs between environmental goals and the economic interests involved at the relevant level of analysis, i.e. river basins.

Acknowledgements

The work presented in this paper was funded by the Directorate-General Water of the Dutch Ministry for Transport, Public Works and Water Management. The authors are grateful to the following persons from Statistics Netherlands for their valuable contributions to the development of NAMWARiB: Mark de Haan, Marret Smekens, Ronald van der Stegen and Henk Verduin.

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