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Water quality of large rivers

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Executive summary

This report aims at assessing the environmental state of major rivers in the European Environment Agency (EEA) area and relating water quality variables to dominant human activities in river catchments. The report is based on a generally good quality data set of water quality variables while the information about human activities is more sparse and heterogeneous. This lack of information on human activities prevents a full assessment of the relationship between water quality variables and human activities. The assessment could have benefited from more detailed information about land-use characteristics (arable land, use of fertilizers, etc.) in the river catchments and information about the sources of pollutants (eg. sewage treatment plants) would have been valuable.

The report attempts as far as the information allows at giving a description of the large rivers in the EEA area, their water quality and the relationship between water quality and very broad descriptors of human activities in the river catchments such as population density and percentage of farmland.

Draining the EEA area there are 15 rivers with a catchment area greater than 50.000 km^2. The largest of these, the Danube, discharges into the Black Sea and only a small part of its catchment lies in the EEA area. Of the other 14 the most noticeable feature is the dominance of a westerly or northwesterly flow direction, with only three of the major rivers; ie. the Rhône, the Ebro and the Po discharging into the Mediterranean. In total, the report covers around 50 large rivers in the EEA area (the majority of rivers with a catchment area greater than 20 000 km^2 in addition some large rivers in the countries with only relatively small rivers have been included).

Large regional variation in the annual run-off was found. The large rivers with their source in the Alps as well as the rivers draining the north-western and northern part of the region generally have an annual run-off greater than 500 mm, while the rivers draining the southern part of Iberia have an annual run-off smaller than 200 mm.

In the catchment area of the large rivers in Norway, Sweden, and Finland the population density is generally less than 10 inhabitants per km^2. In the catchment areas of several of the large rivers in the south-western part of the region the population density ranges between 40 to 100 inhabitants per km^2. In the central part of the EEA area the catchment population density is generally greater than 100 inhabitants per km^2, with the highest densities being observed in the catchment areas of the rivers draining northern France and the Benelux countries, the Italian rivers, the river Rhine, and of the large rivers in the southern part of England. The volume of available water resource per inhabitants ranges from less than 1 000 m^3 per inhabitants per year in the most densely populated river catchments to more than 20 000 m^3 per inhabitant per year in the sparsely populated river catchments in the northern part of the EEA area.

Most of the catchment area of the large rivers in Norway, Sweden and Finland is dominated by natural landscape and forest, less than 10 % being agricultural land. In the central and southern part of the EEA area the catchment of the large rivers generally contain 40 to 60 % agricultural land, the percentage of forest and natural land (eg. mountains, wetlands, arid land) varying between 10 % and 50 %. A more detailed categorization of the agricultural land (eg. in arable land, rough grazing and permanent crops) has not been possible.

The large rivers have been divided into three regions: **the northern region**: large rivers draining Iceland, Norway, Sweden, Finland and Scotland; **the central region**: large rivers draining Denmark, Germany, the Benelux countries, northern France, Ireland, Northern Ireland, England and Wales; and **the southern region**: large rivers draining southern

France, the Iberian Peninsula, Italy, and Greece. The annual average water temperature was generally between 11–14°C in the large rivers in the central region and between 14–18°C in the rivers in the southern region (no temperature data from the rivers in the northern region). The pH was markedly lower in the northern rivers, while most of the rivers in the central and southern regions had annual average pH levels between 7,5 and 8. The conductivity levels were lowest in the northern rivers, medium in the southern rivers and highest in the rivers in the central region.

The level of organic matter (BOD_5) was quite similar in the large rivers of the central and southern part of the EEA area (no BOD_5 data from the northern region). The ammonium level is an order of magnitude lower in the northern rivers, medium in the southern rivers and highest in the rivers draining the central part of the EEA area. An increasing ammonium concentration was found with increasing population density in the river catchments.

During the last 15–20 years biological treatment of domestic and industrial waste waters has intensified, and organic matter loading has consequently decreased in many parts of Europe. This reduction in organic loading of the rivers is reflected in a similar reduction in the concentration of BOD_5 in many of the large rivers. A comparison of organic matter levels (BOD_5) at 101 river stations in large rivers in the EU12 Member States (no BOD_5 data from Norway, Sweden and Finland) reveals signs of improving conditions. From the period around 1980 to 1990–1992, the organic matter concentration decreased at almost 72 % of the river stations. The improvement was greatest in the rivers in the north-western Member States, while in the southern Member States 15 stations had decreasing concentration and 16 stations increasing BOD_5 levels. A similar reduction in the ammonium concentration was observed. The ammonium concentration decreased at 65 % of 130 stations at large rivers in the EEA area between the beginning of the 1980s and 1990–1992.

The levels of nutrients were an order of magnitude lower in the large rivers of the northern region compared to the other large river in the EEA area. The phosphorus concentrations were generally higher in the more densely populated central region than in the large southern rivers. A positive correlation was found between the population density and annual average river water phosphorus concentration.

A markedly higher nitrate concentration was observed in the large rivers of the central region compared to these of the southern region. The nitrate concentration is significantly correlated to the percentage of farmland in the river catchments. In rivers with the percentage of agricultural land greater than 40 % the nitrate level was about double in the large rivers draining the central part of the EEA area compared to the large rivers in the southern part. These regional differences in the nitrate levels can be explained by differences in agricultural intensification. In both the central and the southern region the percentage of farmland is around 60 %, however, in the central region the usage of nitrogen fertilizers is approximately double the usage in the southern region.

The concentration of phosphorus decreased between the beginning of the 1980s and 1990-1992 in the majority of the large rivers. In contrast, the nitrate level in the large rivers has generally been increasing the last l0–15 years. Thus, the nitrate levels increased between the beginning of the 1980s and 1990–1992 in nearly three quarters of 120 river stations.

1. Introduction

The European Environment Agency (EEA) was established under Council Regulation No.1210/90 and was given a task to:

"provide the Community and the Member States with objective, reliable comparable information at the European level enabling them to take the measures to protect the environment, to assess the results of measures and to ensure that the public is properly informed about the state of the environment."

To assist in this task, the EEA established five European Topic Centres (ETC) in December 1994 addressing media-oriented monitoring projects on air quality, air emissions, inland waters, marine waters and coastal zone management (scoping study only) and nature conservation. This report has been prepared by the European Topic Centre on Inland Waters (ETC/IW) as Task 15 of the 1994 subvention technical work programme.

The task description is as follows:

Once the river database (relating to the Exchange of Information Decision) has been updated (Task 12), the data will be analysed to produce a report relating water quality (in terms of the reported variables) in particular in large rivers to dominating human activities (e.g. agriculture, forestry, sewage discharges) in their catchments. The latter information should be available, and will need to be collated, from existing databases. Trend analysis will be undertaken on those data collected in a consistent way (e.g. in terms of methodology, limits of detection, frequency) over a long period. In terms of this project it should be possible to produce such a report on the most recently collected data. The draft report will be circulated for discussion and review by EEA, EIONET and other collaborators.

Part of this work also formed part of the successful Tender to DGXI mentioned in Task 12, the two successful organisations, NERI and WRc, will therefore take a full part in this task.

1.1. Aims and approach

This report aims at assessing the environmental state of major rivers in the European Environment Agency (EEA) area and relating water quality variables to dominant human activities in river catchments. The report is based on a generally good quality data set of water quality variables while the information about human activities is more sparse and heterogeneous. This lack of information on human activities prevents a full assessment of the relationship between water quality variables and human activities.

The report attempts, as far as the information allows, at giving a description of the large rivers in the EEA area, their water quality and the relationship between water quality and very broad descriptors of human activities in the river catchments such as population density and percentage of farmland. The primary focus is on frequently measured water quality variables (physical variables, organic pollution indicators and nutrients) since the wide-geographical coverage makes these variables well-suited to illustrate the general environmental state of large rivers in the EEA area. Many other pollutants and human activities affect the environmental state of large rivers (e.g. heavy metals, organic micropollutants, river regulation), however, it has not been possible to find comparable information to describe these problems at the EEA level.

1.2. Data and information sources

River water quality data on the majority of large rivers in the EEA area are generally available, while information about human activities in river catchment areas is sparse and very heterogeneous. A review of European sources (databases, report,s etc.) aimed at gathering information about human activities in the river catchment areas revealed only little relevant and useful information. The present study of human activities in the river catchment areas could not be based on available information from existing databases as planned, therefore it has been necessary to use large resources to collate information. A questionnaire asking for information about human activities in the major river catchments was distributed to the ETC/TW partners on 22 June 1995. During July and August information describing human activities in most of the large river catchments was received. In addition, information from various national state of the environment reports as well as Eurostat regional statistics (population, land-use, etc.) has been used (Eurostat 1995). The information provided was very heterogeneous and not always comparable.

Water quality data on major rivers in the EEA area

Exchange of information

Council Decision No. 77/795/EEC of 24 December 1977 established a common procedure for the exchange of information on the quality of surface fresh water. According to the Decision the Member States measure 18 specified physical, chemical, microbiological and biological parameters at 126 stations, located mainly in the large rivers of EU12 Member States, and report the information to the Commission each year. The database established for the Exchange of Information data includes data for the period 1977–1992. However, Greece and Italy started reporting data in 1982, whilst Portugal and Spain commenced in 1986. In total, data on 18 parameters are stored in the database: water flow, water temperature, pH, conductivity, chloride, nitrate, ammonium, dissolved oxygen, BOD_5, COD, total phosphorus, surfactants, cadmium, mercury, faecal coliform, total coliform, faecal streptococci, and salmonella. The measuring frequency has generally been monthly. The Commission of the European Communities has reported the results of the Decision in the form of three reports: the first report covered the period 1982 to 1986 (Commission of the European Communities, 1989), the second covered the period 1987 to 1989 (Commission of the European Communities, 1995), whilst the third report covering the period 1990 to 1992 exists in a draft form and has been put out to Member States for comments. The last report has in 1995 been prepared for the Commission by two partners of the ETC/IW – NERI and WRc. The report addresses the degree to which Member States have complied with the requirements of the Decision in the period 1990–1992 and describes, as far as the data allows, temporal and spatial trends in water quality. NERI and WRc are grateful to Ms. Kroll, DG XI D.l for her advice and ideas for preparation of the report.

In the current report the focus has been put on a more general characterization of the large rivers and especially water quality data from the downstream stations have been used. The Exchange of Information water quality data have been supplemented with information about human activities derived from the questionnaire sent to ETC/IW partners and a literature review.

EEA-TF database used for the Dobris Assessment

NERI has been responsible for preparation of the EEA report *European Rivers and Lakes* (Kristensen & Hansen, 1994) being used as a background document for the inland surface water section of the report *Europe’s Environment – the Dobris Assessment* (EEA, 1995). During the preparation of this report much information about large European rivers was collected and stored in a database. Only sparse information was reported by the EU12 Member States, however, from Iceland, Norway, Sweden, Finland and Austria some information about the large rivers was provided. For many large rivers water quality time series data for 1980–1992 as well as descriptions of the river catchments exist (eg.

catchment area, land-use category, population density). The relevant information about large rivers in the EEA area has been included into the present report.

Quality of data

The report is based on a generally good quality data set of water quality variables while the information about human activities is more sparse and heterogeneous. The quality of data on physical variables (e.g. water flow, temperature, pH and conductivity), organic pollution indicators (BOD_5 and ammonium) and nutrients (nitrogen and phosphorus) are generally high, i.e. measured frequently, at the majority of stations and by the use of generally comparable analytical methods, while the quality of data concerning surfactants, heavy metals and microbiological indicators generally is markedly lower. In particular, most of the observations for surfactants and heavy metals have been reported as values below the detection limit used, which has varied between river stations and within stations through time. This makes evaluation of trends of these variables problematic as well as regional comparisons between rivers very doubtful. The primary focus in the report is put on the physical variables, organic pollution indicators and nutrients since the generally high quality of these variables and the wide geographical coverage makes well-suited to illustrate the general environmental state and temporal trends in water quality of the major rivers in the EEA area.

The lack of information on human activities prevents a full assessment of the relationship between water quality variables and human activities. The assessment could have benefited from more detailed information about land-use characteristics (arable land, use of fertilizers etc.) in the river catchments as well as information about the sources of pollutants (eg. sewage treatment plants and industry).

The large rivers have been divided into three regions: **the northern region**: large rivers draining Iceland, Norway, Sweden, Finland and Scotland; **the central region**: large rivers draining Denmark, Germany, the Benelux countries, northern France, Ireland, Northern Ireland, England and Wales; and **the southern region**: large rivers draining southern France, the Iberian Peninsula, Italy, and Greece.

2. Major rivers in the European Environment Agency Area

Rivers are greatly influenced by the characteristics of the catchment area. The climatic conditions pertaining influence the water flow, as does the bedrock geology and soil type. The latter also affects the mineral content of the river water. Human activity affects river systems in numerous ways, for example through urbanization, agricultural development, land drainage, pollutant discharge, and flow regulation (dams, channelization, etc.).

The study covers large rivers in the seventeen countries in the EEA area: *Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom.* The total area covered by the seventeen countries is about 3,6 million square kilometres (km^2). The central region is dominated by a few large rivers whilst the peninsulas and islands are drained by numerous small rivers. Draining the EEA area there are 15 rivers with a catchment area greater than 50 000 km^2. The largest of these, the Danube, discharges into the Black Sea and only a small part of its catchment lies in the EEA area. Of the other 14 the most noticeable feature is the dominance of a westerly or northwesterly flow direction, with only three of the largest rivers, namely the Rhône, the Ebro and the Po discharging into the Mediterranean.

Rivers with catchment areas in excess of 10 000 km^2, of which there are approximately 60 in the EEA area, account for the majority of drainage from the region, only the Italian and Danish peninsula, the British Isles, western Norway and small islands display a different pattern being drained by a large number of relatively small river catchments and short rivers.

In this report the focus is on the largest rivers in the region (the majority of rivers with catchment area greater than 20 000 km^2). In addition the largest rivers in Denmark, Iceland, Ireland, and the United Kingdom as well as some large rivers in Norway, Italy and Greece have been included. In total the study covers 50 large rivers in the EEA area with information about the river catchment areas (eg. land-use and population density) as well as information about water quality variables (Table 2.1).

2.1. Characteristics of large rivers in the EEA area

Catchment area

The area a river system drains is known as the catchment. The size of the river catchment areas included in the study varies from approximately 2 500 km^2 in the two Danish rivers, the river Barrow in Ireland and the river Spey in Scotland to catchment areas greater than 75 000 km^2 in the rivers Rhine, Danube, Elbe, Loire, Duero, Rhône, Garonne, Ebro, Tajo and Seine (Figure 2.1). The Danube has a total catchment area of 817 000 km^2 but only the upstream 157 300 km^2 is located inside the EEA area, also the Rhine, the Elbe, the Rhône as well as some of the large Greek rivers have part of their upstream catchment area outside the EEA area. The total catchment area of the large rivers included in the study is app. 2,1 million km^2 or 60 % of the total area of the EEA region.

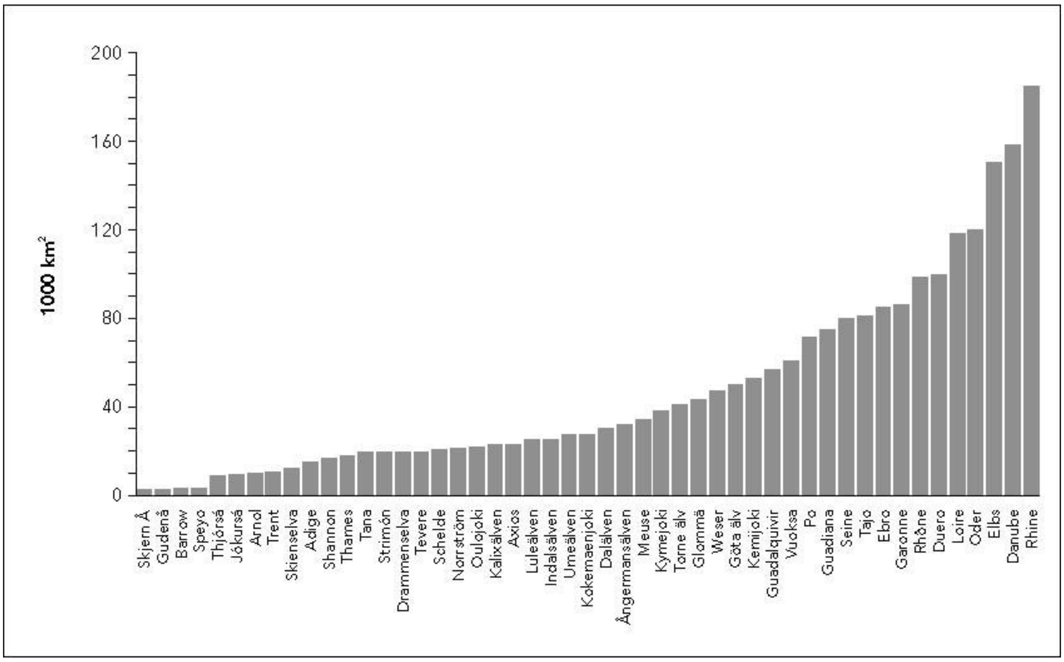
Table 2.1. Characteristics of major rivers in the EEA area

Country*	River	Catchment area Total	Catchment area Station	Length	Run-off	Population density	Agri-cultural land	Natural land	Fores
		1 000 km^2	1 000 km^2	Km	mm/ year	Inhabitants/km^2	%	%	%
IT	Adige	122,0	122	676	148	49		46	
SE	Ångerman älv	30,6		450	201	2	< 10	> 90	
IT	Arno	8,3	8,2	251	415	302	53		
GR, FYROM	Axios	23,8	21,6	420	225	82	~ 50		~
IR	Barrow	2,8		195	413	44	75		
SE	Dalälven	29,0		540	385	9	< 10	> 90	
AU, DE	Danube**	157,3	76,7	1 006	588	160	~ 45		~
NO	Drammenselva	170,0		302	591	16	10–50	50–90	
ES, PT	Douro/Duero	97,7	81,8	788	118	49	54	46	
ES	Ebro	84,2		930	177	33	49	51	
DE, CZ	Elbe	148,3	132,0	1 137	172	17	56		~
BE, FR, NL	Schelde/Escaut	20,3		430	166	577	~ 60		~
FR	Garonne	85,0	52,0	575	378	145	52		
NO	Glomma	41,9		601	540	53	10–50	50–90	
SE	Göta älv	50,1		720	322	36	10–50	50–90	
ES	Guadalquivir	56,5	49,4	675	126	77	59	41	
ES, PT	Guadiana	72,3	60,1	801	48	26	54	46	
DK	Gudenå	2,6	1,8	158	375	108	65		
SE	Indalsälven	25,8		430	558	4	< 10	> 90	
IS	Jökulsá	7,8		206	900	< 5	< 10	> 90	
SE	Kalixälven	23,6		450	381	2	< 10	> 90	
FI	Kemijoki	51,1		512	346	5	< 10	> 90	
FI	Kokemäenjoki	27,0		~ 400	274	10	10–50	50–90	
FI	Kymijoki	37,2		492	269	5	< 10	> 90	
FR	Loire	117,5	110,0	1 010	251	70	63		
SE	Luleälven	25,2		450	703	1	< 10	> 90	
FR, BE, NL	Meuse	36,0	30,0	890	258	400	~ 45		~
SE	Norrström	22,6			215	48	10–50	50–90	
DE, PL	Oder	118,9		854	143	129	~ 60		~
FI	Oulujoki	22,8		400	359	5	< 10	> 90	
IT	Po	69,4	68,7	672	675	228	47		
AU,DE,FR,NL,CH	Rhine	185,3	159,3	1 320	451	294	43		
FR, CH	Rhône	95,6	66,5	812	669	122	42		
FR	Seine	79,0	43,8	776	201	219	55		
IR	Shannon	14,1	10,6	260	528	26	63	30	
NO	Skienselva	10,8		251	843	11	< 10	> 90	
DK	Skjern Å	2,3	1,6	94	473	35	81		
UK	Spey	2,9			711	30	~ 60		~
GR, BG	Strimón	16,8	12,0	400	240	~ 60	~ 30		~
ES, PT	Tajo/Tejo	80,4	76,2	1 008	130	117	51	49	
FI, NO	Tana	163,0		318	370	1	< 10	> 90	
IT	Tevere	17,2		402	472	288	60		
UK	Thames	15,0	9,9	350	246	600	60	2	
IS	Thjórsá	7,5		230	1 600	< 5	< 10	> 90	
SE, FI	Torne älv	40,1		465	324	2	< 10	> 90	
UK	Trent	10,5	7,5	270	358	380	~ 70		<
SE	Umeälven	26,5		460	639	2	< 10	> 90	
FI	Vouksi	61,1		560	311	5	< 10	> 90	
DE	Weser	45,8	37,5	450	273	175	~ 50		~

* Only main countries: AU: Austria, BE: Belgium, BG: Bulgaria; CH Switzerland; CH: Czech Rep.; DE: Germany; DK: Denmark; FI: Finland; FR: France; GR: Greece; IS: Iceland; IT: Italy; LU: Luxembourg; NL: the Netherlands; NO: Norway; PL: Poland; PT: Portugal; ES: Spain; SE: Sweden; UK: the United Kingdom;

** Only the catchment area in Germany and Austria

Figure 2.1: Total catchment area of major rivers in the EEA area. For the river Danube only the catchment area inside the EEA area (Germany and Austria) is shown.



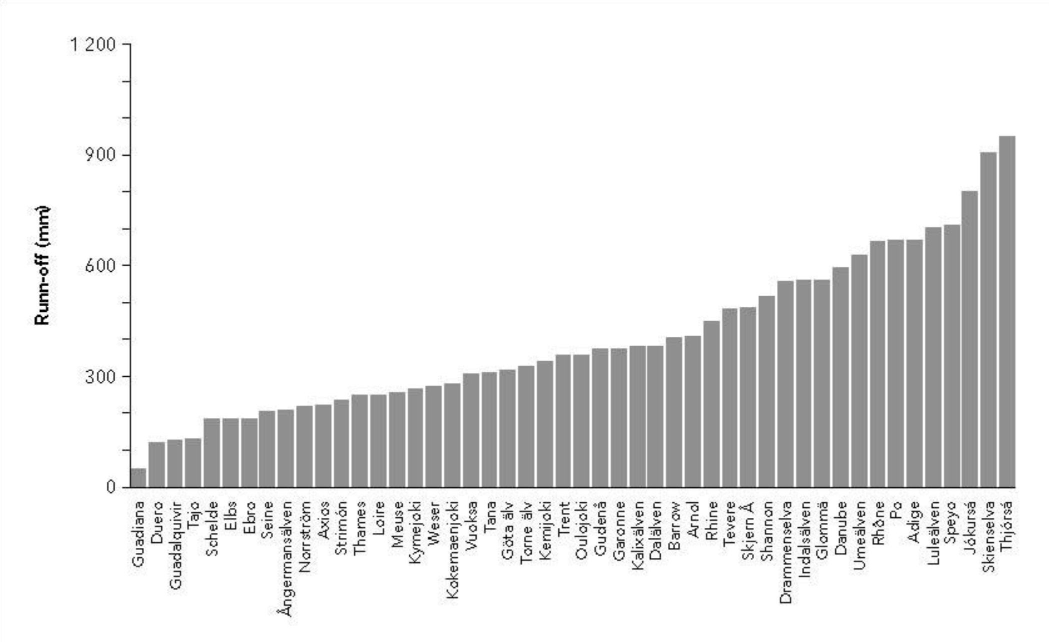
River flow

The pattern by which river flow varies during the year, i.e. the flow regime, is determined by the seasonal variation in climate, as well as the nature of the catchment (soil and bedrock permeability, land management, etc.). Flow regimes have their origin in the precipitation that falls over the catchment, in the form of rain or snow. Only a part of the precipitation runs off to the river since some water evaporates. However, annual run-off generally follows cumulative precipitation in the catchment quite closely. Because climatic and geological properties differ throughout the EEA area, the flow regimes of the large rivers in the EEA area vary considerably. Precipitation is highest in the west and mountain ranges like the Alps and lowest in the east, while evaporation is highest in the south and east. In the western and mountainous parts of Europe more than 70 % of the precipitation runs off to the rivers, only 25–-50 % becomes run-off in the lowland parts of central Europe, and less than l0–20 % in the arid regions (e.g. the southern part of the Iberian Peninsula) (EEA, 1995).

Annual run-off

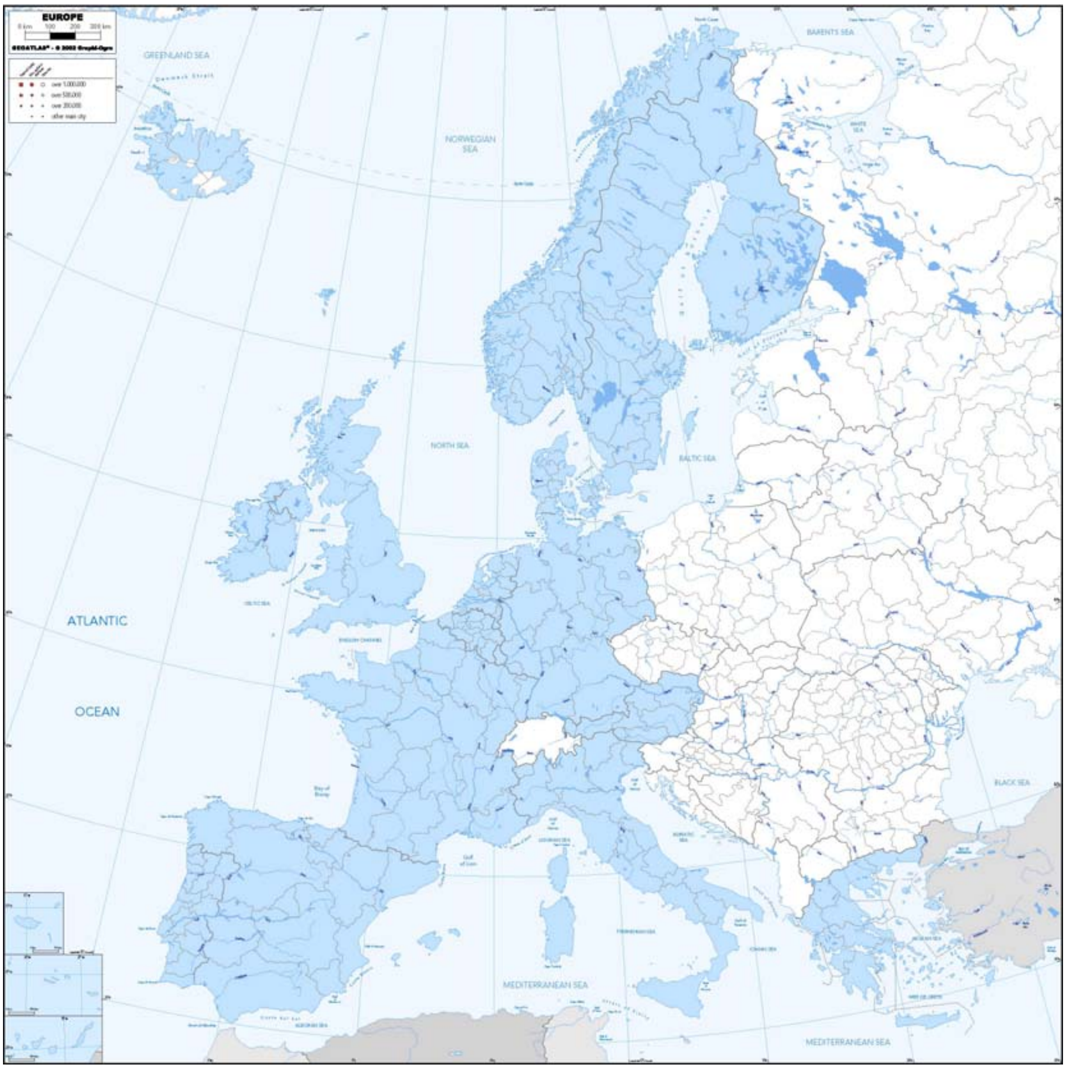
Annual run-off ranges from 50 mm in the river Guadiana in southern Iberia to more than 1 000 mm in Skienselva in southern Norway (Figure 2.2). The rivers with their source in the Alps (i.e. the Adige, Po, Rhône, Rhine, and Danube) as well as the rivers draining the north-western and northern part of the region (ie. the Icelandic and Norwegian rivers, river Shannon in Ireland, river Spey in Scotland and Lule and Ume Älv in northern Sweden) generally have annual run-off greater than 500 mm, while the rivers draining the southern part of the Iberian Peninsula have annual run-off less than 200 mm.

Figure 2.2: Run-off in millimetre (mm) per year in large rivers in the EEA area.



Seasonal differences in climate within the EEA area are also reflected by different flow regimes. In the northern part of the Nordic countries the period of high flow and river flooding occurs in the spring and summer with the thawing of snow and ice while the low water period occurs during late autumn and winter. Examples are the rivers Kemi in Finland and Glomma in Norway where high flows are observed in the period May to June, there being almost no flow during the winter months (Map 2.1). Similar flow regimes are seen in rivers in more southerly mountainous areas, an example being the river Rhine at Basel, which has a typically ‘Alpine’ flow regime, much like the northern rivers. Many of the large rivers in the central and western part of the EEA area have a much less fluctuating flow regime, although flow is generally highest during the winter half-year and lowest during the summer half-year. Examples being the rivers Shannon and Loire. The flow regime of many rivers in the Mediterranean is characterised by marked low water flow during the summer months, when watercourses in many catchment areas of up to 3 000–4 000 km^2 may become dry and even the main rivers may dwindle to small streams. The season of maximum run-off depends on the season of maximum rainfall but are in most southern rivers found in spring. An example being the river Guadalquivir. The lakes, reservoirs, and wetlands in a river system attenuate the fluctuation in discharge, the rivers Rhine, Rhône and Po are all examples of large rivers with large lakes upstream affecting the flow regime.

Map 2.1: **Examples of flow regime in major rivers in the EEA area (After EEA (1995); Arnell et al. (1993)).**

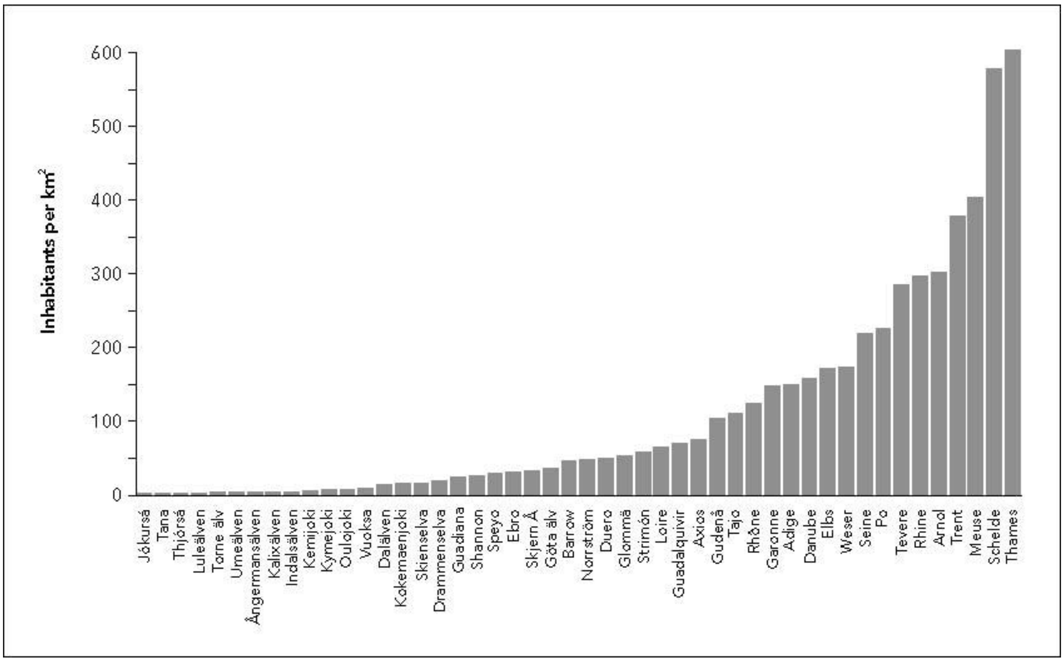


Most of the large rivers in the EEA area have now been regulated. The most important river regulation in large rivers is damming and construction of reservoirs. During the last two centuries there has been a marked increase in both reservoir size and number. In Spain, for example, the number of reservoirs increased at the rate of about two per year between 1900 and World War II, but at a rate of about 20 per year from 1950 to 1980, and today more than 1 000 Spanish reservoirs with surface area greater than 8 km^2 have been constructed at primarily large rivers (García de Jalón, 1987; Riera et al. 1992). Most other countries with large rivers suitable for damming and reservoir construction have observed a similar increase in their number of reservoirs (EEA, 1995). Reservoirs markedly affect the natural flow regime, as well as the transport of suspended matter. The ecological consequences can be manifold, one example being obstruction of faunal migration and a reduction in biological diversity in and downstream of the dam.

Population density

In the catchment area of the large rivers in Iceland, Norway, Sweden, and Finland the population density is generally less than 10 inhabitants per km^2, however, in the catchments of the large rivers in the southern part of these countries the population density is between 10 to 50 inhabitants per km^2 (Figure 2.3). Similar population densities are found in the catchment areas of the large rivers in Ireland and Scotland. In the catchment areas of several of the large rivers in the south-western part of the region the population density range is between 40 to 100 inhabitants per km^2 (eg. the rivers Guadiana, Ebro, Duero, and Loire). In the central part of the EEA area the catchment population density is generally greater than 100 inhabitants per km^2, with the highest densities being observed in the catchment areas of the rivers draining northern France and the Benelux countries (ie. the rivers Schelde, Meuse, and Seine), the rivers draining northern Italy (Arno, Tevere, and Po), in the river Rhine, and the large rivers of southern England (Thames and Trent).

Figure 2.3: Population density (inhabitants per km^2) in the catchment areas of the major rivers in the EEA area. Hatched bars the population density is estimated by NERI.



Land-use

In the EEA area there is large geographical variation in the land-use pattern, going from dominating forest and tundra in the north to dominating intensive arable agricultural land in the central part, and less intensive, arid agricultural land in the southern part of the EEA area. This, of course, is also reflected in the land-use characteristics of the river catchments. Most of the catchment of the large rivers in Iceland, Norway, Sweden and Finland is dominated by natural landscape and forest, less than 10 % being agricultural land (Table 2.1). In the central and southern part of the EEA area the catchment of the large rivers generally contain 40 % to 60 % agricultural land, the percentage of forest and natural land (eg. mountains, wetlands, arid land) varying between 10 % and 50 %. A more detailed categorization of the agricultural land (eg. in arable land, rough grazing and permanent crops) has not been possible. The large regional differences in farming intensity and the types of crops grown are not reflected in this comparison of the percentage of agricultural land in the river catchments. For example, agricultural land constitutes about 65 % of the total land area in Denmark and 81 % in Ireland, while 60 % of the total land area is arable in Denmark, only 18 % is arable land in Ireland, most of the agricultural land being used for grazing (Eurostat, 1995).

Flood plains and natural riparian wetlands are highly productive ecosystems. Undisturbed they provide habitat for a wealth of animal and plant species, thus contributing to the overall biodiversity. At the same time they function as temporary sinks for water, thus reducing downstream floods. They also serve as sinks for nutrient thus reducing the nutrient loading into downstream lakes and marine areas. Urbanization and cultivation of flood plains have resulted in loss of numerous habitats and reduced the sinks for water and nutrients thus increasing the human impact on the aquatic ecosystems. Most of the large rivers in central Europe have, during the last centuries, observed a marked reduction in the flood plains and riparians wetlands. Navigation and agricultural development have led to clearance of the riparian forest cover, channelization, straightening of meanders, and construction of embankments for flood protection led to decreased riparian influences. Comparable data on the reduction of flood plains and riparian wetlands along the major rivers have not been available for this study. In 1996 an ETCAW project will focus more on the different types of human interventions on river hydrology and geomorphology.

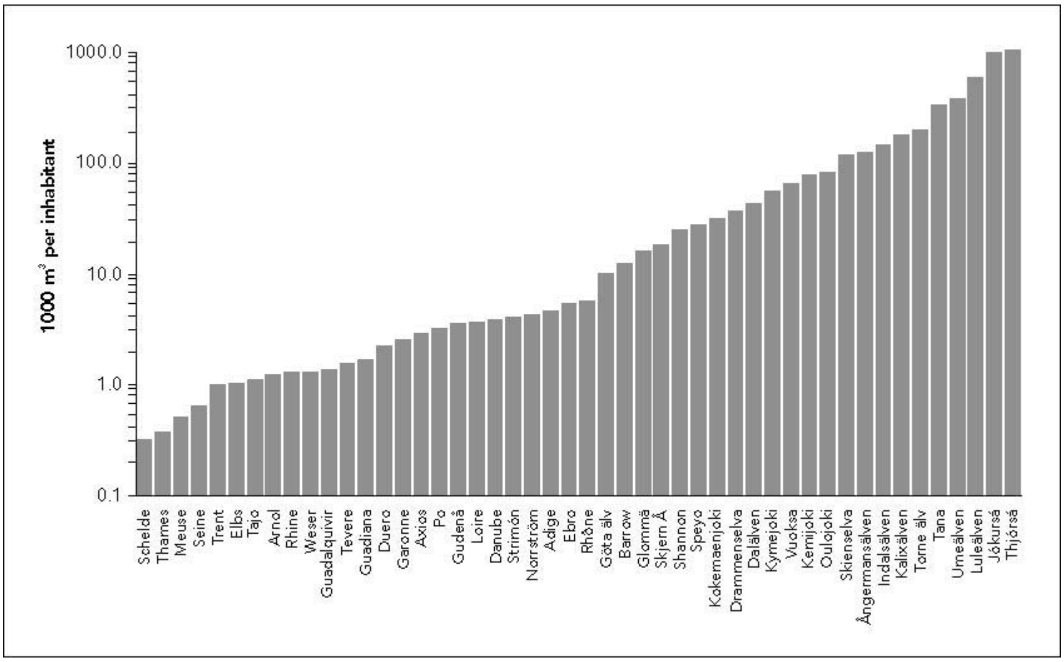
Pollution

The environmental effect of a pollutant depends mainly on its concentration or the total loading. The amount of water into which a certain amount of pollutant is discharged and hence diluted determines its concentration. If an identical amount of a pollutant is discharged into a large and a small river, the effects will generally be most harmful in the small river. Another aspect to be considered is the seasonal variation in flow, thus, as the dilution of a pollutant is minimal when the water flow is low, it will have a more serious negative impact than when water flow is high. The discharge of many pollutants are directly related to the population density in the river catchments (eg. phosphorus and organic matter), loading by other pollutants may be more dependent on the nature of industrial and agricultural sector in the catchment. In catchment, for instance, with intensive agricultural production with high use of fertilizers and pesticides the pollution with these substances will also generally be high.

Potential available water resource
As both the population density in the river catchment areas and the run-off differ between the various large rivers one possible way to illustrate how the population in the river catchment may affect the water quality is to calculate the **available water resource per inhabitant** (the annual run-off divided by the population in the catchment areas).

The available water resource ranges from less than 1 000 m^3 per inhabitant per year in the most densely populated rivers to more than 20 000 m^3 per inhabitant per year in the sparsely populated rivers in northern part of the EEA area. In the rivers Schelde, Thames, Meuse, Seine, Trent and Elbe the available water resource are particularly low (< 1 000 m^3 per inhabitant per year). The European average water abstraction is approximately 700 m^3 per capita per year (EEA, 1995),
consequently, in the most densely populated river catchments the major part of the annual run-off is used by humans. At the moment, for instance, nearly 6 million people are depending on the river Meuse for their drinking water supply, and large volumes of water are abstracted from the river Thames to supply London, consequently, the populations in these river catchments are very dependant on the quality of the river water.

Figure 2.4: Available water resource in major rivers in the EEA area (runoff divided by population density).



The potential pollution can be assessed if the annual contribution per inhabitant of various polluting substances is known. In western European countries the annual production of organic matter and phosphorus per capita is app. 18 kg of BOD_5, and 1 kg of phosphorus, respectively (Meybeck et al. 1989). If the available water resource per inhabitant and the production of a pollutant are known, the maximum river water concentration can be calculated (amount of pollution substance divided by the available water resource). In a river with an available water resource of 1 000 m^3 per inhabitant and no waste water treatment the river water total phosphorus concentration will be app. 1 mg P/l, while in a river with an available water resource of 20 000 m^3 per inhabitant the river water total phosphorus concentration will be app. 0,05 mg P/l (Table 2.2). In large river systems much of the organic matter discharged upstream is decomposed before, reaching the downstream part of the river system. Some of the phosphorus discharged upstream may also be retained in lakes and reservoirs. Nevertheless from an ecological point of view there is an increasing need for reduced loading (waste water treatment, cleaner technology, etc.) with decreasing available water resource.

Table 2.2: Estimated river water concentration of organic matter (BOD_5) and phosphorus in rivers with different available water resource and discharge of pollutants without any sewage water treatment

Available water resource (run-off divided by population) (m^3/inh. yr.)	**Production per inhabitant per year**	
	Organic matter (BOD_5) (18 Kg O_2)	**Phosphorus (1 Kg P)**
1 000	18 mg O_2/l	1 mg P/l
2 000	0,9 mg O_2/l	0,05 mg P/l

2.2. Description of major rivers in the EEA area

In the following is listed a brief description of the major rivers in various regions of the EEA area.

Major rivers draining into the Mediterranean and Black Sea

The European Mediterranean is remarkable for the smallness of its river catchment areas that are generally short and steep. Only the Ebro, Rhône and Po rise any distance inland. In addition, the Spanish rivers Jucar and Segura, the Italian rivers Tevere, Adige and Arno, and the Greek rivers are important. The Danube is the primary fresh water input to the Black Sea.

Ebro River

The river Ebro, Spain's longest river, rises in north-western Spain and flows mainly south-east before discharging into the western Mediterranean. Although its catchment area is the largest in Spain, 85 500 km^2, the land is arid, poor and generally sparsely populated. About 2,8 million inhabit the Ebro catchment area (33 inh./km^2) with 0,6 million living in the city of Zaragoza. The most powerful tributaries have been utilised for hydroelectric power and irrigation, especially in the middle reaches of the Ebro basin.

Rhône River

The river Rhône rises in the Swiss Alps runs through Lac Léman and then generally south before discharging into the Mediterranean. A major tributary is the river Saone. The high precipitation in the Alps is reflected in a high annual run-off in the river Rhône (670 mm). The Rhône catchment area is with its 95 500 km^2 the second largest in France after the river Loire. The population in the French part of the catchment area is 8,1 million (around 100 inh./km^2).

Po River

The river Po is the longest river in Italy. It rises in the Alps in north-western Italy and empties in the Adriatic Sea after a course of 652 km. Its catchment area covers 70 000 km^2, forming Italy's widest and most fertile plain. The total population is 15,7 million (27 % of Italy's population; 228 inh./km^2) including several of the major cities (eg. Turin, Milan) and most the country's industry and agriculture.

Adige River

The river Adige is the second longest river in Italy. It rises in the Alps in north-eastern Italy and flows south and east and enters the Adriatic Sea just north of the Po delta. The Adige passes the cities of Bolzano, Trento and Verona, and the total population in its catchment area is 1,2 million people. The Adige supplies energy for hydroelectric power plants in its upper Alpine and water for irrigation m its lower course.

Arno River
The river Arno is the principal stream of the Tuscany region in central Italy. Rising in the Tuscan Appennines, it flows 240 km to the Ligurian Sea. About 2,5 million people inhabit the 8 228 km^2 large catchment area (302 inh./km^2) with 0,4 million living in the city of Florence.
Tevere River
The river Tevere (Tiber) raises in central Italy in the Etruscan Appennines and flows generally south and west for 400 km before it discharges into the Mediterranean near Rome. The catchment area is 17 156 km^2 with 4,9 million inhabitants (288 inh./km^2) of which 2,7 million live in the city of Rome.
Greek rivers
The irregular, deeply penetrated Greek coastline means river courses are short. The Axios and the Strimón that cross Greek Macedonia and Thaki to enter the northern Aegean are the major rivers — but only because they drain large regions beyond the Greek frontier. The river Axios has more than 80 % of its catchment in FYROM and the river Strimón/Strymon has app. two thirds of its catchment in Bulgaria.
Danube River
The Danube catchment is the second largest in Europe and spreads through 17 countries. The river rises in southern Germany and drains more than 96 % of Austria, flowing southeast and discharging into the Black Sea. The catchment area in the EEA area is app. 157 300 km^2. Many large cities lie within the catchment, including München and Wien. About 15 and 7,8 million inhabit the German and Austrian part of the catchment area, app. 160 inhabitants per km^2.

Major rivers draining into the north-west Atlantic

France and the Iberian Peninsula are mainly drained by rivers running from east to west into the Atlantic. The British Isles are drained by a large number of relatively small river catchments and short rivers.

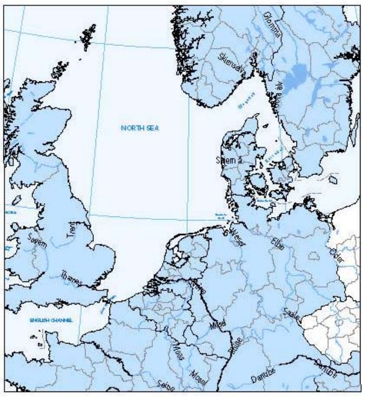
Iberian Peninsula
Guadalquivir River
The river Guadalquivir is the major watercourse of southern Spain. Rising in the mountain of the Jaen Province, it flows in a generally westward direction for 657 km before emptying into the Atlantic. Its catchment area is 56 500 km^2 with 4 million inhabitants (77 inh./km^2) with the cities of Sevilla, Cordoba and Granada being the most important.
Guadiana River
The river Guadiana is flowing generally westward through south of Spain and south eastern Portugal to the Gulf of Cadiz and the Atlantic Ocean. The river has a catchment area of 72 300 km^2 and a length of 801 km. The flow is relatively meager because the catchment drains the low rainfall area of the southern Iberian Peninsula. The catchment area is sparsely populated with app. 1,5 million inhabitants, 25 inhabitants per km^2.
Tejo River (Spanish Tajo)
The river Tajo rises in central Spain and flows westward for 1 008 km before it discharges into the Atlantic near Lisboa. The catchment area is 80 400 km^2, with 8,9 million inhabitants (117 inh./km^2) including the cities of Madrid and Lisboa. *Douro River (Spanish Duero)*
The Douro River is the third longest stream of the Iberian Peninsula, draining a catchment area of 97 800 km^2. Rising in the Sierra da Urbion (mountains) the river flows generally westward for 895 km across Spain and northern Portugal to the Atlantic Ocean near the city of Porto. About 4 million people live in the catchment area (49 inh./km^2), with the largest city being Porto near its mouth.

France
Garonne River
The Garonne River is the most important river of southwest France rising in the Spanish central Pyrenees and flowing into the Atlantic along the estuary called the Gironde Estuary (72 km). App. 7,5 million people live in the 85 000 km^2 large catchment area (88 inh./km^2) with the largest cities being Toulouse and Bordeaux.
Loire River
The Loire River is the longest river in France. It rises in the southern Massif Central, flows first in a north-westerly and then it curves westward towards the Atlantic, which it enters after a course of 1 020 km. The catchment area is 117 500 km^2, with 7,7 million inhabitants (66 inh./km^2). The largest cities being Nantes and St. Etienne.

United Kingdom
Severn River
The source of the Severn lies in the eastern hills of Wales and is the third longest river (354 km) with the fifth largest catchment area (11 600 km^2) in the UK. The river initially flows eastwards and then southwards passing through major towns such as Shrewsbury, Worcester and Gloucester before discharging into the Severn estuary on the south west coast of England. The catchment is not heavily industrialised and is mainly agricultural: the river is an important source of drinking water.

Ireland
Shannon River
The river Shannon, the largest Irish river, originates close to the north west coast of Ireland and flows south to discharge close to Limerick on the west coast of Ireland. The length is 260 km and the catchment area is 14 100 km^2. The river passes through several large lakes along its course and has a largely rural, low population density catchment area with no major towns.
Barrow, Nore, and Suir rivers
The next largest Irish river system is that of the Barrow, Nore and Suir rivers. The rivers arise in central Ireland and flow southwards to discharge along the southern Irish coast close to Waterford. The Barrow and Suir rivers having significant estuaries. The area of

the combined catchment of this river system is 9 100 km^2. The catchment area is sparsely populated and has no major towns.



Major rivers draining into the North Sea

The borders of the North Sea are defined as the North Sea south of-latitude 62°N, the Skagerrak and the English Channel and its approaches eastwards of longitude 5°W(North Sea Conference, 1990). The major rivers discharging into the North Sea are the rivers discharging from northern France, the Benelux Countries, western Germany and Denmark, southern Norway, and eastern England and Scotland.

Seine River

The river Seine rises in north-eastern France, runs generally western for 775 km, passing the cities of Paris and Rouen before it discharges in the Channel south of le Havre. The catchment area is with its 79 000 km^2 the fourth largest in France and is densely populated with a population density of more than 200 inhabitants per km^2.

Schelde River

The source of the river Schelde is situated in northern France. The river, which is 350 km long, flows through France, Belgium and the Netherlands and debouches in the North Sea. The estuarine part is situated downstream Gent (length 160 km). The area of the catchment is 20 131 km^2 divided by France 33 %, Belgium 63 % and the Netherlands 4 %. The Scheldt catchment is densely populated, about 11 million people live in the catchment, the population density being 550 inhabitants per km^2.

Meuse River

The river Meuse rises in northern France and is generally flowing northward for 950 km through Belgium and the Netherlands to the North Sea. The % catchment covers 36 000 km^2 (France (28 %), Belgium (36 %), Germany (11 %) and the Netherlands (16 %)). The catchment is densely populated with high industrial production and intensive agricultural areas. Nearly 6 million people depend on the river water for their drinking water supply.

Rhine River

With its 185 000 km^2 the Rhine catchment is the largest in the EEA area, but only the 11th largest in Europe. The Rhine rises in the Swiss Alps. It flows northwards through five countries, the catchment being spread over eight countries and in the Netherlands the Rhine branches into three main rivers before emptying into the North Sea. The mean population density in the catchment is 294 inhabitants per km^2. The larger cities include Zürich, Strasbourg, Frankfurt, Düsseldorf, Köln and Amsterdam. The Rhine catchment has become the most important industrial agglomeration in Europe. It accounts for 20 % of the world's chemical production, and boast several steel industries, coal mines, power stations, etc (Lelek, 1989).

Ems River

The river Ems rises in Teutoburger Forest and flows north-west and north for 370 km through the Länder of North Rhine-Westphalia and Lower Saxony to the Dollart Estuary and-the North Sea. The catchment area is 13 131 km^2 and densely populated.

Weser River

The river Weser is formed by the two rivers Fulda and Werra draining the central part of Germany. It runs primarily northwards and discharges into the North Sea through the Weser estuary at Bremerhaven. The catchment area is 45 800 km^2 and densely populated with main cities of Bremen and Hannover.

Elbe River

The river Elbe runs from the Czech Republic through Germany to the North Sea at Cuxhaven. The total length of the Elbe is 1 165 km, of which one-third flows through the Czech Republic and two-thirds through Germany. The total catchment area is 148 300 km^2, densely populated with high industrial and agricultural production.

Thames River

The river Thames is the longest river (350 km) and has the largest catchment area (15 000 km^2) in the UK. The Thames' source lies to the west of London and initially flows through largely agricultural land. It flows eastwards towards London passing through the major towns of Oxford and Reading before reaching its tidal limit at Teddington at the western the Greater London conurbation. The river flow has been regulated and controlled for many decades and is a major source of drinking water. It is also widely used for pleasure boating and angling. Improvements in water quality and physical structures (both in the river and estuary) over the last 20 years have lead to the successful reintroduction of the Atlantic salmon.

Trent river

The River Trent has the second largest catchment area (10 500 km^2) in the UK. Its source lies in the Midlands of England and flows initially in an eastward direction passing through the major towns of Stoke and Nottingham before flowing northwards to discharge into the Humber estuary on the east coast of England. The Trent also has Birmingham in its catchment. There are many industrial and domestic uses of the water and it is also an important source of drinking water.

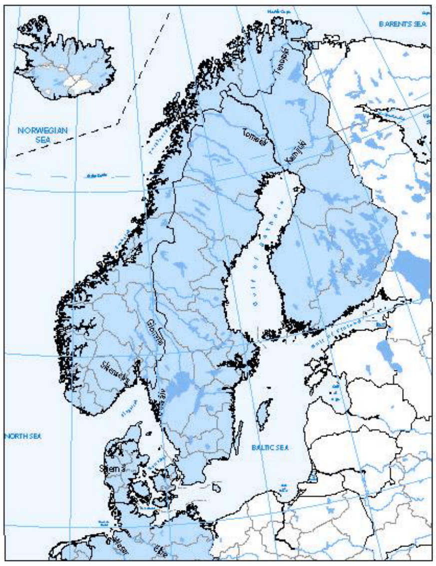
Spey River

The Spey originates in the Grampian Mountains of Northern Scotland and has a sparsely populated, largely rural/natural catchment with no major towns. It flows north eastwards to discharge into the North Sea along the north east coast of Scotland. It is one of the prime salmon rivers in the UK.

Denmark

The Danish North Sea catchment area is 10 900 km^2 (25 % of the total land area) and compared to the other large rivers discharging into the North Sea the Danish rivers are small. The largest river being the river Skjern with a catchment area of 2 600 km^2.

Norway
Three Norwegian rivers with a catchment area greater than 10 000 km^2 drain into the North Sea (described on next page).



Major rivers draining the Nordic countries and into the Baltic Sea

The Nordic countries are Denmark, Finland, Iceland, Norway and Sweden with a total area of 1,3 million km^2 or about one third of the EEA area. The length going from the southern part of Denmark to the northern part of Norway is 1 600 km. The geology of the Nordic countries can be divided in three regions: Denmark and the southern tip of Sweden consist of glacial moraine deposits; Norway, Sweden and Finland consist of Archean crystalline rocks; and the geology of Iceland is characterized by volcanic activity. The EEA countries, ie. Sweden, Finland, Denmark and Germany, comprise app. half of the 1,6 million km^2 big Baltic Sea catchment area.

Sweden
Sweden has 12 river systems with a catchment area greater than l0 000 km^2. In the north of Sweden a number of relatively large parallel rivers run from the western mountain range to the Gulf of Bothnia in the east. The rivers of the southern part of the country are generally small. The greatest river is Göta älv, on the west coast of Sweden, with a catchment area of 50 100 km^2. Sweden is generally sparsely populated, most major towns being located along the coast and only 6–7 % of the land is cultivated. The majority of the inhabitants live in the south and around the great lakes, and the major part of agricultural land also lies in the southern part of Sweden.

River	Catchment 1 000 km^2	Length km
Göta älv	50,1	360
Torneälven*	40,2	310
Angermans älven	31,9	490
Dalälven	29,0	380
Umeälven	26,8	520
Indalsälven	26,7	530
Luleälven	25,4	610
Norrström	22,7	230
Ljusnan	19,8	360
Kalixäven	18,1	500
Motala ström	15,6	190
Ljungan	12,9	330

* Including the Finnish part of Torneälven

Finland

Finland has six river systems with a catchment area greater than 20 000 km^2, the Torneälv (Tornionjoki) forming part of the borderline between Sweden and Finland, and the rivers Kemijoki and Oulujoki all discharging into the northern part of the Gulf of Bothnia. The river Vuoksi runs from the large lakes in central Finland into the northwestern part of Russia where it discharges into lake Ladoga (Europe's largest lake). The river Kymijoki and Kokemäenjoki drain the southern and south-western part of Finland. Finland is generally sparsely populated and less than 10 % of the land area is used for agricultural purposes. Most of the population is concentrated in the south-west and southern parts of the country.

River	Catchment 1 000 Km^2	Length km
Vuoksi*	61,1	560
Kemijoki	51,1	512
Tornionjoki**	40,2	310
Kymijoki	37,2	492
Kokemäenjoki	27,0	400
Oulujoki	22,8	400

* Including the Russian part; ** Including the Swedish part

Norway

The largest Norwegian rivers are generally found in the south-east and southern part of the country. In the northern part the rivers are relatively small, excepting the rivers Alta and Tana (borderline with Finland). The four largest Norwegian rivers, all with a catchment area greater than 10 000 km^2, cover about a quarter of the Norwegian territory. The river Glomma is the largest Norwegian river. It drains the south- eastern part of the country, runs generally southwards and discharges close to the mouth of the Oslo Fjord. The rivers Drammenselva and Skienselva also drain the south-eastern part of the country. The national population density is 13 inhabitants per km^2, however there are large regional differences, most of the population being located in the south-eastern part of the country and in the cities along the coast. This is reflected in the population density of the catchment area of the large rivers. The density in the Glomma catchment area is app. 50 inhabitants per km^2, in the Drammenselva and Skienselva the density is 16 and 11 inhabitants per km^2, while the catchment area of the river Tana in the north has less than 1 inhabitant per km^2.

River	Catchment 1 000 Km^2	Length km
Glomma	41,9	601
Drammmenselva	17,0	302
Tana	16,3	348
Skienselva	10,8	251

Denmark

The fact that Denmark comprises the Jutland Peninsula and more than 160 islands means that it is dominated by a large number of river catchments and small rivers. The three largest rivers (the rivers Gudenå, Skjern and Storå) all with length around 100 km and catchment area smaller than 3 500 km^2 only drain about 14 % of the land area. Compared to the other Nordic countries Denmark is densely populated (120 inh./km^2) and has one of the highest percentages of agricultural and arable land in Europe.

Poland — Germany

Oder River

The river Oder rises in the northern part of the Czech Republic and flows northwards to the Baltic Sea. For a distance of 185 km it constitute the boundary between Poland and Germany. The river catchment area is 119 000 km^2 of which 95 % drains the western part of Poland and only 5 500 km^2 drains the eastern part of Germany.

3. Water quality in large rivers

The general water quality of the large rivers in the EEA area is characterised on the basis of information about the annual average of water quality variables at downstream stations in the large rivers described in the previous section. The quality of data on physical variables (eg. water flow, temperature, pH and conductivity), organic pollution indicators (BOD_5 and ammonium) and nutrients (nitrogen and phosphorus) is generally high, ie. measured frequently, at the majority of stations and by the use of generally comparable analytical methods. The quality of data concerning surfactants, heavy metals and microbiological indicators generally is markedly lower. In particular, most of the observations for surfactants and heavy metals have been reported as values below the detection limit used, which has varied between river stations and within stations through time. This makes evaluation of trends in water quality of these variables problematic as well as regional comparisons between rivers are very doubtful. The primary focus in the report is put on the physical variables, organic pollution indicators and nutrients since the general high quality of these variables and the wide geographical coverage makes them well-suited to illustrate the general environmental state and temporal trends in water quality of the major rivers in the EEA area. For most of the rivers information about water quality variables exist for the years around 1990 as well as information about human activities in the river catchments (eg. population density, percentage of agricultural land).

Time series data for the period 1977–1992 concerning annual average BOD_5, ammonium, nitrate and total phosphorus concentrations at more than 150 river stations in large rivers in the EEA area has also been used for this section. The data was obtained from the database established for the data in relation to Council Decision No. 77/795/EEC of 24 December 1977 ‘Establishing a common procedure for the exchange of information on the quality of fresh water’ supplemented with time series data from some rivers in Austria, Finland, Norway and Sweden. The evaluation of temporal trends in the selected variables is based on the period from 1977 to 1992. However, Greece and Italy only started reporting data in 1982, whilst Portugal and Spain commenced in 1986.

Calculation of trends

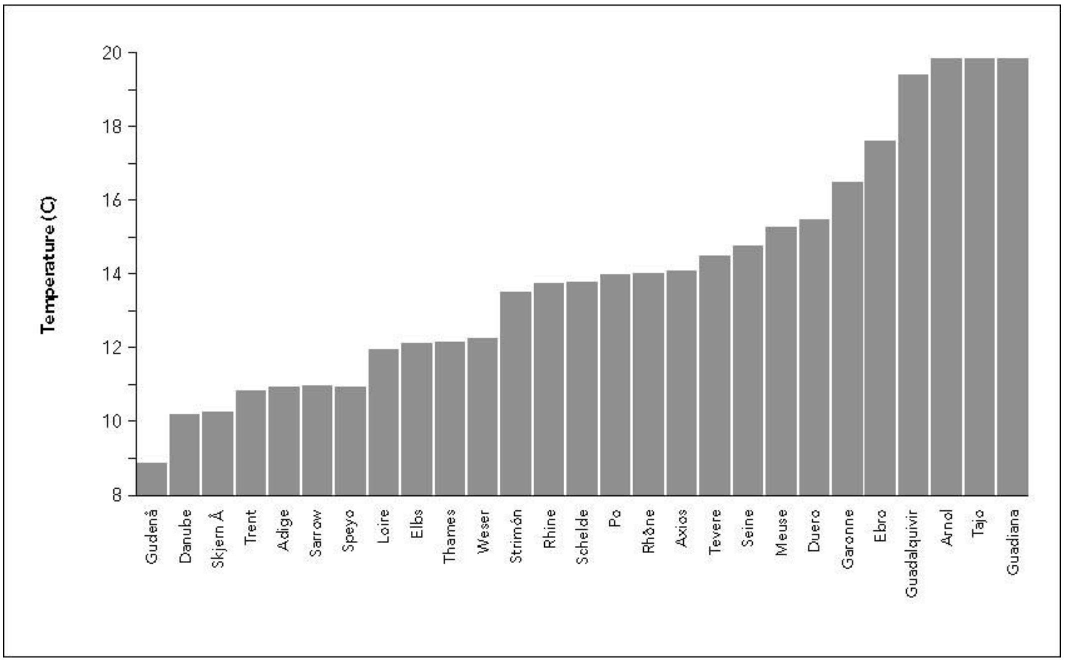
Temporal trends in the concentration of BOD_5, ammonium, total phosphorus and nitrate were evaluated. For each station and each of the selected variables the average concentration in the period 1990–1992 was compared with the average concentration in the period 1977–1982 (Greece and Italy the period 1982–1987, and Portugal and Spain the period 1986–1987) and the percentage increase or decrease in concentration was calculated (l00*difference in concentration divided by the average concentration in the first period). In the river Loire (station La Possoniere), for instance, the average concentration of nitrate rose from 2,1 mg N/l in the period 1977–1982 to 3,6 mg N/l in the period 1990–1992, an increase by 72 %. The number and percentage of stations with increasing or decreasing concentration were calculated, and the stations were grouped according to the rate of increase or decrease, ie. 0–25 %, 25–50 % and > 50 % increase or decrease, respectively.

3.1. Physical variables

Water temperature

The annual average water temperature ranges from around 8–12°C in the north-western rivers and in the rivers Danube and Adige originating in the Alps up to 16–20°C in the rivers in southern Europe (Figure 3.1).

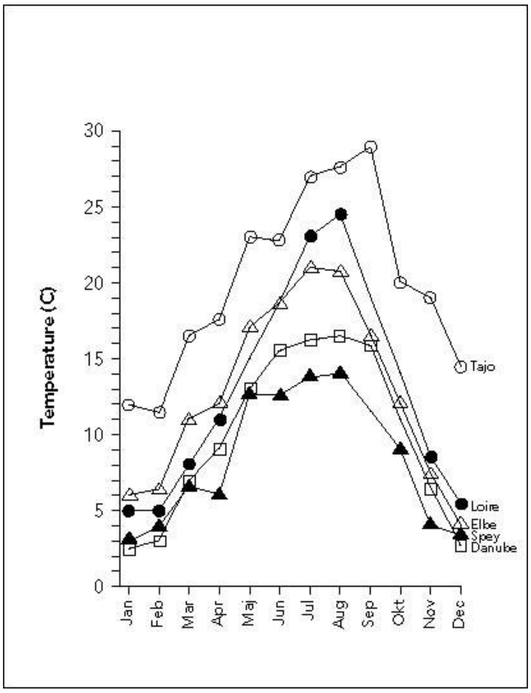
Figure 3.1: Annual average water temperature (1990-1992) at downstream stations in large rivers in the EEA area.



Note that there is no water temperature data from rivers in Iceland, Norway, Sweden and Finland.

Seasonally the water temperature varies from between 3 and 12°C in the winter months to between 12 and 30°C in the warmest months. There were large differences in the water temperature going from north to south especially during the summer period. The river Spey being an example of a large northern river, the river Danube at the German-Austrian border being an example of a large river draining the Alps, the river Elbe and Loire being examples of large lowland rivers from the central part of the European mainland, the river Tajo illustrating the seasonal variation in temperature at downstream reaches of large southern European rivers (Figure 3.2).

Figure 3.2: Seasonal variation in water temperature (1990-1992) in the river Spey, Scotland (+); the river Danube at the German-Austrian border (Square), the river Elbe, Germany (dot), the river Loire, France (triangle) and the river Tajo at the Spanish-Portuguese border (circle).

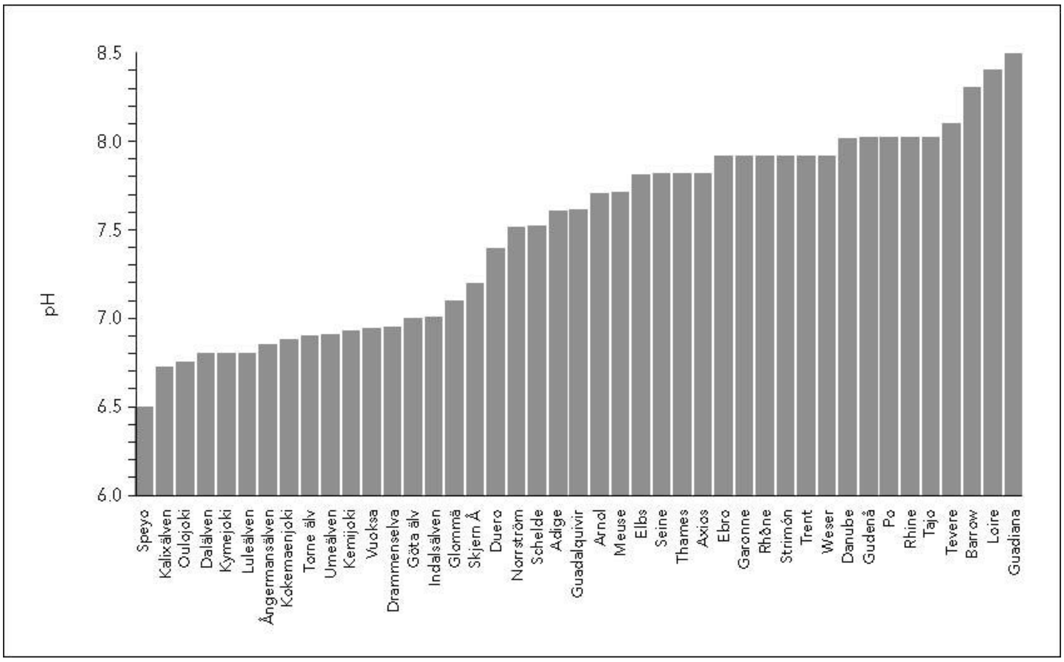


pH

The annual average pH ranges generally between 6,5–7 in the rivers in northern Scandinavia, in the river Spey in Scotland and the river Minho in north-western Iberia, while in the majority of rivers the average pH vary between 7,5 and 8 (Figure 3.3). Generally there was little seasonal variation in pH in many of the large rivers although a pH maximum was observed in the spring or summer, an indication of high primary production, especially by phytoplankton.

The temporal trend of pH for the period I977 to 1992 was analysed. As would be expected, no general trend in annual average pH values could be observed. The large rivers are generally well buffered, while acidification trends are generally observed in small streams and lakes with catchment soils and bedrock that are poor in lime and other easily weatherable minerals (which buffers against acid precipitation).

Figure 3.3: Annual average pH (1990–1992) at downstream stations in major rivers in the EEA area.

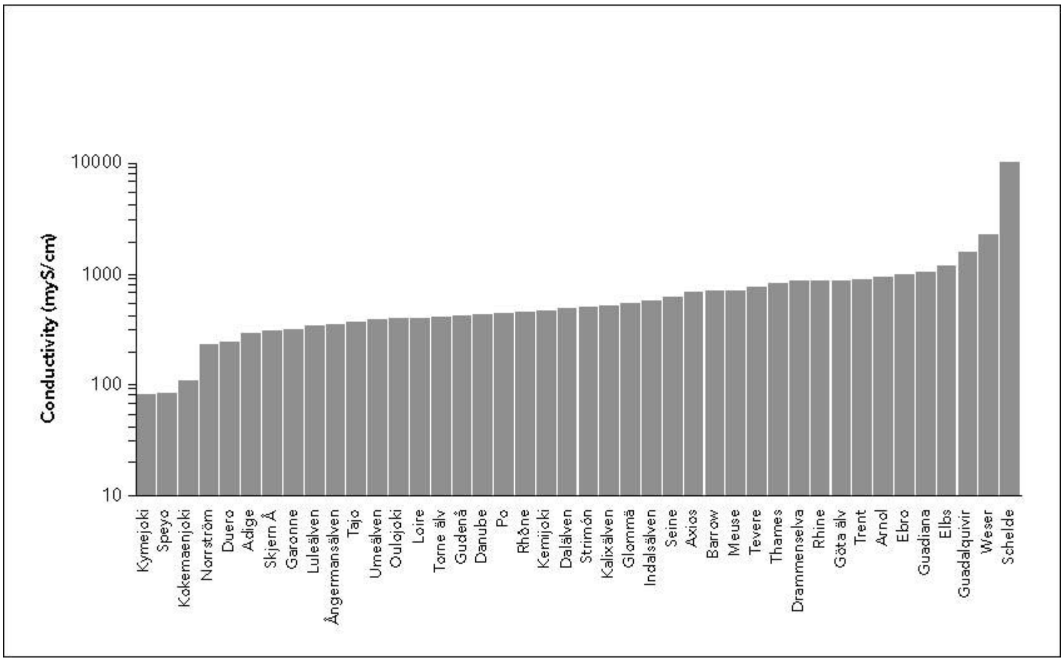


Conductivity

High concentrations of dissolved salts, as reflected by high conductivity impair the use of water for human consumption, livestock watering, irrigation and industry. High conductivity may also affect the ecological state of the river.

The annual average conductivity at the downstream station in the large rivers vary from less than 200 to more than 15 000 µS/cm. Stations with extreme high conductivity values were found at downstream reaches of rivers that were affected by tidal intrusion of marine water.

Figure 3.4: Annual average conductivity (μS/cm) at downstream stations in major rivers in the EEA area.



Regional differences in physical variables

The major rivers in the EEA area have been divided into three broad regions; the northern, the central and the southern region (Table 3.1). The regional variation in the three physical variables is described in Figure 3.5. The annual average water temperature was generally between 1l–14°C in the large rivers in the central region and between 14–18°C in the rivers in the southern region. The pH was markedly lower in the northern rivers, while most of the rivers in the central and southern regions had annual average pH levels between 7,5 and 8. The conductivity levels were lowest in the northern rivers, medium in the southern rivers and highest in the rivers in the central region.

Figure 3.5: Annual average of A) Water temperature B) pH and C) Conductivity in major rivers draining three regions of the EEA area. Median, upper and lower quartiles are shown.

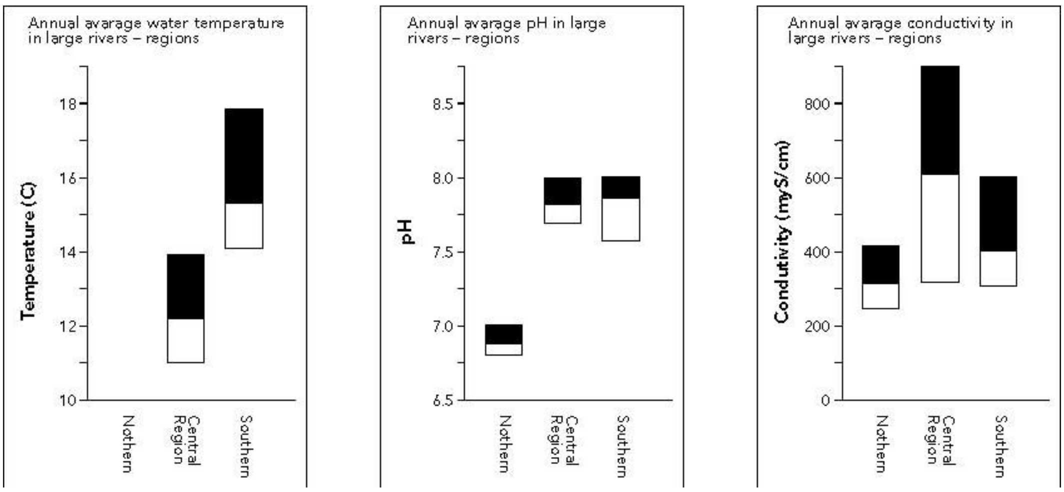


Table 3.1: The large rivers divided in the three regions used in this section.

Northern region	Central region	Southern region
Spey Kemijoki Vuoksi Torne Älv Kokemäenjoki Kymijoki Oulujoki Glomma Drammenselva Tana Skienselva Göta älv Ångermans älven Dalälven Indalsälven Kalixälven Luleälven Norrström Umeälven	Schelde Meuse Gudenå Skjern å Seine Loire Garonne Weser Elbe Rhine Shannon Barrow Thames Trent	Guadalquivir Ebro Duero Tajo Guadiana Rhône Arno Tevere Adige Po Strimón Axios

3.2. Organic pollution of large rivers

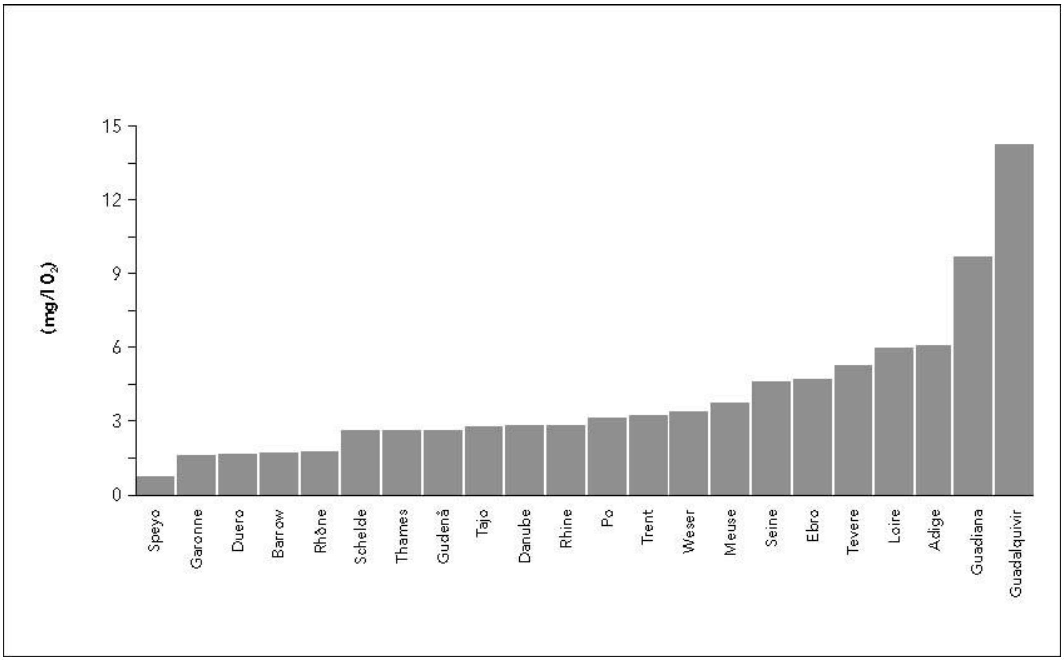
Input of organic waste into rivers results in oxygen consumption due to breakdown of organic matter. Severe organic pollution may lead to rapid deoxygenation of river water and the disappearance of fish and aquatic invertebrates. Decomposition of organic matter also results in the release of ammonium, which at high concentrations and under certain conditions may be toxic to aquatic organisms. Organic pollution is generally assessed by measurements of the concentration of Biochemical Oxygen Demand over 5 days (BOD_5) and the concentration of ammonium.

In large rivers the concentration of organic matter at downstream stations does not directly reflect the input of organic matter in the catchment area. Immediately downstream of a sewage effluent the highest concentration of organic matter will be observed, while downstream the concentration of organic matter decreases as a result of dilution and decomposition. In large rivers much of the organic matter discharged at the upstream reaches has been decomposed when it reaches the downstream part of the river, especially in rivers with many reservoirs and lakes. The organic matter concentration at the downstream reaches will only indicate the organic pollution load of a certain distance upstream.

BOD_5

In Norway, Sweden and Finland the organic matter concentration of rivers is generally assessed by measurement of Chemical Oxygen Demand (COD) and COD results are not directly comparable to BOD_5 measurements. However, the concentration of organic matter in the large rivers of these countries is generally low compared to the organic matter concentration of the other large rivers of the EEA area (EEA, 1995). At present, the annual average concentration of BOD_5 is relatively low (< 3 mg/l O_2) at the downstream stations of most large rivers (Figure 3.6), reflecting the fact that many countries took measures to reduce the discharge of organic waste water to large rivers during the 1970s and 1980s. However, in some of the rivers many upstream parts still suffer from organic pollution. In the rivers Guadiana and Guadalquivir in the southern part of Iberian Peninsula the highest concentration of BOD_5 was observed, but also other rivers in southern Europe (the rivers Adige, Tevere and Ebro) as well as some of the rivers in the densely populated western part of central Europe (the rivers Seine, Meuse, Weser, and Trent) had high concentrations of organic matter.

Figure 3.6: Annual average BOD5 concentration (1990-1992) at downstream stations in large rivers in the EEA area.

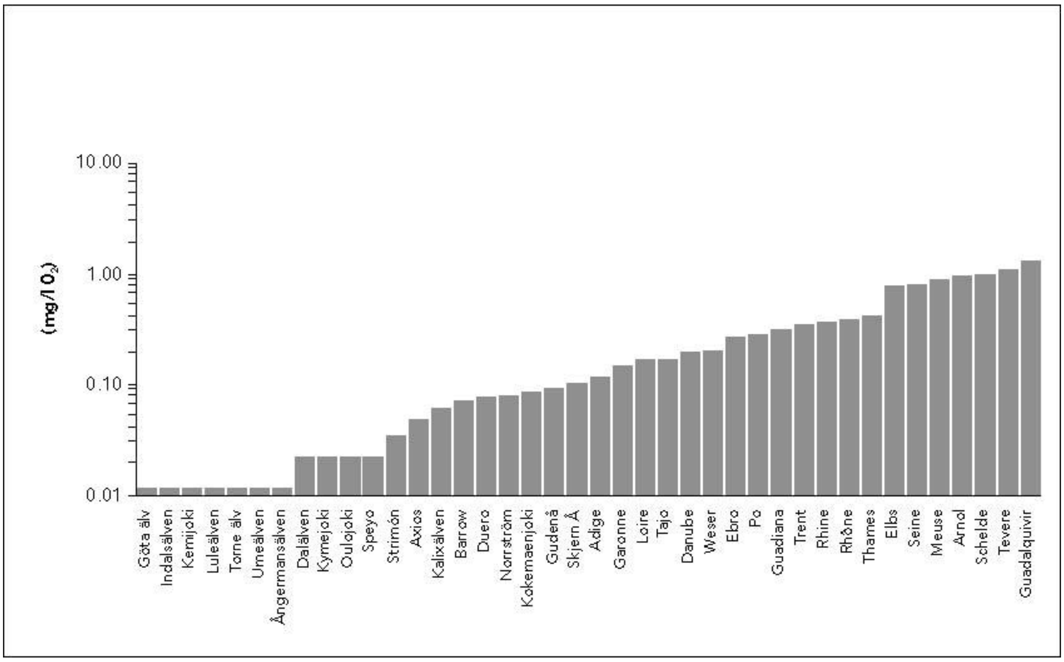


Note that there are no BOD_5 data from rivers in Norway, Sweden and Finland.

Ammonium

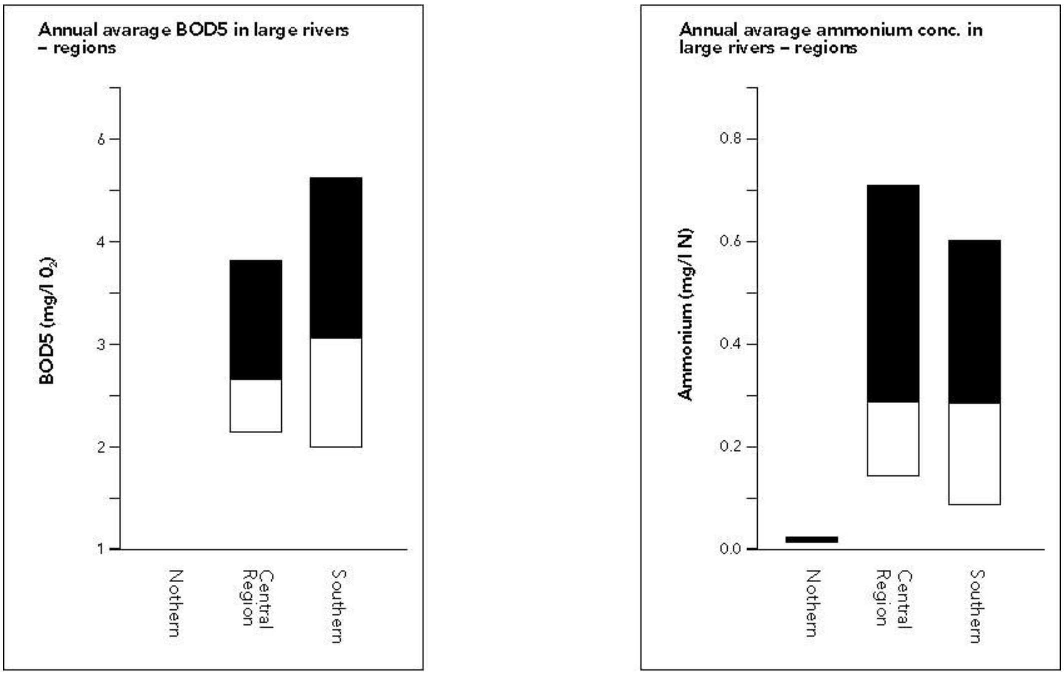
The annual average concentration of ammonium varied from less than 0,01 mg N/l to more than 1 mg N/1 in the most heavily poiluted rivers (Figure 3.7). Generally, the ammonium concentration in rivers in the sparsely populated areas (Sweden, Finland, Greece, Scotland and Ireland) was below 0.1 mg N/l. In many of the rivers in the central part of the EEA area the concentration ranged between 0,l–0,5 mg N/l, while in some rivers in the densely populated areas the annual average ammonium concentration was around 1 mg N/l (the rivers Elbe, Seine, Meuse, Schelde, Arno and Tevere).

Figure 3.7: Annual average ammonium concentration (1990–1992) at downstream stations in large rivers in the EEA area.



Regional differences in organic pollution indicators

Figure 3.8: Annual average concentration of A) BOD_5 and B) Ammonium in large rivers draining three regions of the EEA area. Median, upper and lower quartiles are shown.



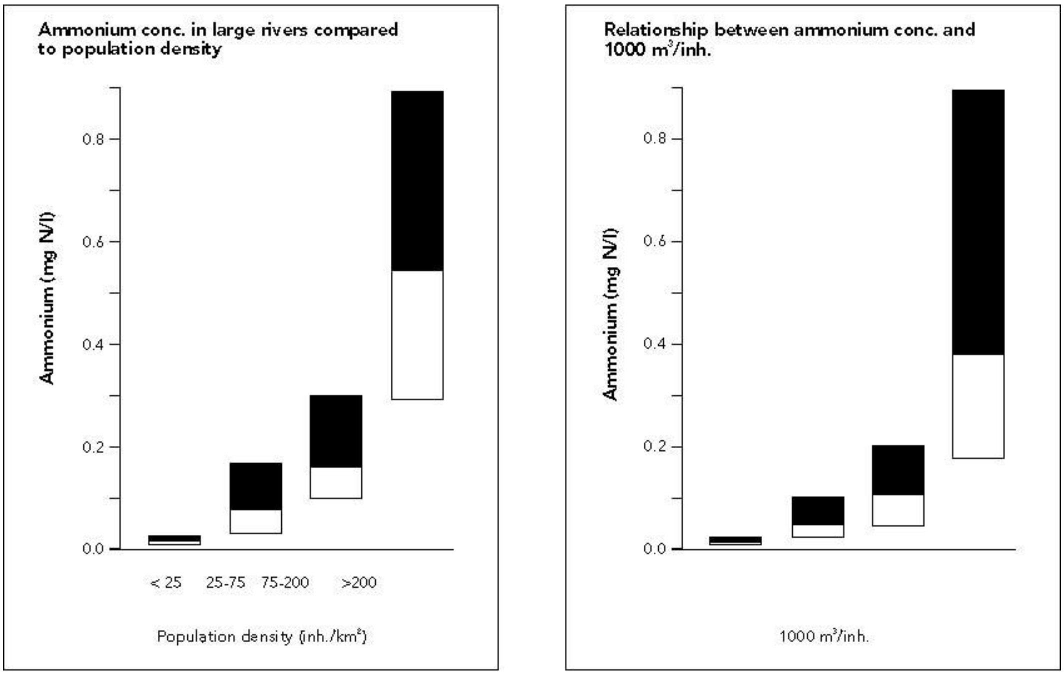
Bearing in mind the differences between individual rivers described above, the EEA can be divided into three main regions, the BOD_5 and ammonium levels of which are shown in Figure 3.8. The level of BOD_5 is quite similar in the central and southern rivers. The ammonium level is an order of magnitude lower in the northern rivers, medium in the southern rivers and highest in the rivers draining the central part of the EEA area.

Organic Pollution Indicators in relation to population density in the river catchment

The annual average concentration of ammonium increases with increasing population density in the river catchment (Figure 3.9). Thus, while the ammonium concentration is lower than 0,02 mg/l N in catchments with less than 25 inhabitants per km^2, it generally ranges between 0,1 and 0,3 mg N/l in catchments with a population density of 75–200 inhabitants per km^2, and generally exceeds 0,3 mg N/l in catchments with more than 200 inhabitants per km^2. A similar relationship between the annual average ammonium concentration and the available water resource was found, the ammonium concentration being low in rivers with more than 10 000 m^3 per inhabitants per year and high especially in rivers with less than 2 000 m^3 per inhabitants per year.

A similar relationship between BOD_5 levels and population density could not be found for large rivers. However, Kristensen and Hansen (1994) had found a positive relationship between the BOD_5 concentration and population density in generally smaller European rivers.

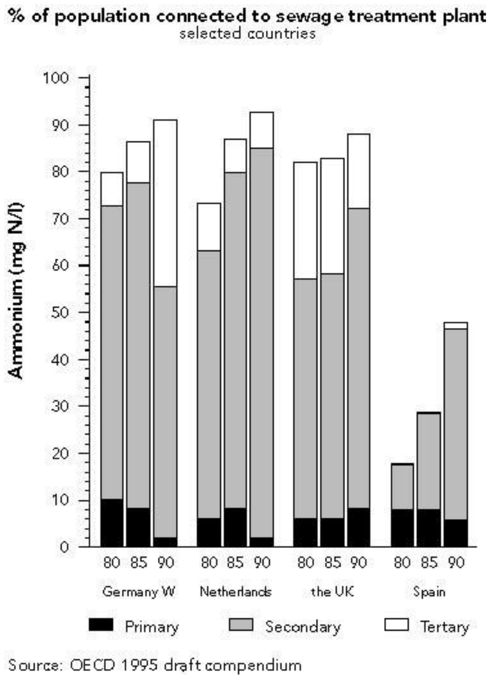
Figure 3.9: Annual average ammonium concentration in relation to A) population density and B) available water resource (1 000 m^3 per inhabitant). Median, upper and lower quartiles are shown.



Trends in organic pollution of rivers

After World War II discharge of organic waste into surface waters increased in many European countries with resultant severe oxygen depletion. During the last 15-–20 years, however, biological treatment of domestic and industrial waste waters has intensified, and organic matter loading has consequently decreased in many parts of Europe. During the 1980s the percentage of the population connected to municipal waste water treatment plants has increased (Figure 3.10). In the northern Member States generally more than 75 % and the southern Member States app. 50 % of the population is connected to sewage treatment plants with minimum secondary treatment with removal of organic matter (EWPCA, 1995), while only a minor proportion of the waste water undergoes tertiary treatment (eg. phosphorus or nitrogen removal).

Figure 3.10: Percentual development of the population connected to primary, secondary and tertiary sewage treatment plants in Germany (West), the Netherlands, the United Kingdom and Spain.

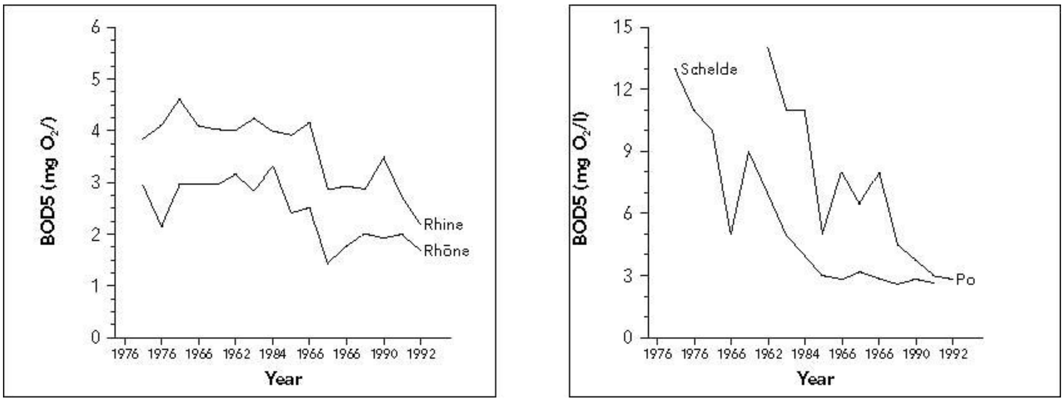


BOD_5

This reduction in organic loading of the rivers is reflected in a similar reduction in the concentration of BOD_5 in many of the large rivers. In the rivers Rhine, Rhône, Schelde, and Po, for instance, a marked reduction in the annual average concentration of BOD_5 during the 1980s has been observed (Figure 3.11). The concentration of BOD_5 in the river Rhine at the German-Dutch border fell from

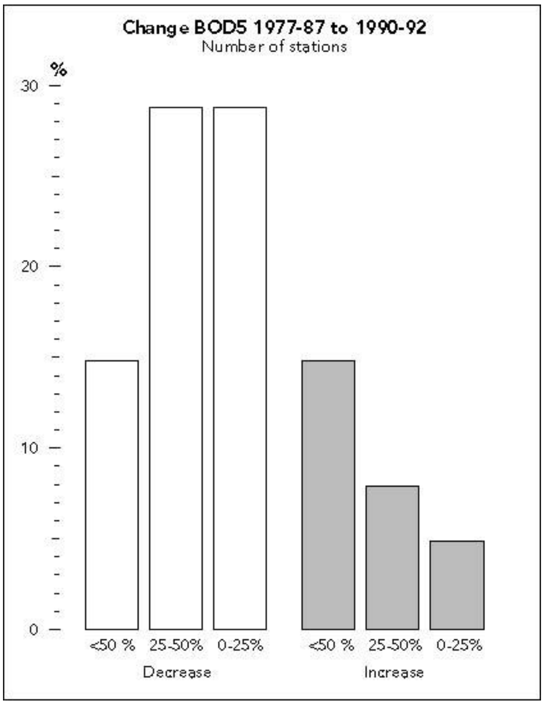
4,2 mg O_2/l in the period 1977–1982 to 2,8 mg O_2/l in the period 1990–1992 a reduction by 32 %, similarly a reduction of 36 %, 81 % and 69 % was observed in the rivers Rhône, Schelde, and Po, respectively.

Figure 3.11: Trend in annual average BOD5 concentration in the rivers A) Rhine and Rhône, and B) the rivers Schelde and Po.



A similar comparison of organic matter levels (BOD_5) at 101 river stations in large rivers in the EU12 Member States (no BOD_5 data from Norway, Sweden and Finland) reveals signs of improving conditions. From the period around 1980 to 1990–1992, the organic matter concentration decreased at almost, 72 % of the river stations (Figure 3.12), the reduction in concentration level being greater than 25 % and 50 %, at 44 % and 15 % of the stations, respectively. The improvement was greatest in the rivers in the north-western Member States, more than 83 % of the stations having decreasing concentrations, while in the southern Member States 15 stations had decreasing concentrations and 16 stations increasing BOD_5 levels.

Figure 3.12: Percentage of river stations in which the river BOD_5 concentration decreased (empty) or in-creased (hatched) between the periods 1977–82 (IT & GR 1982–87; ES & PT 1986–87) and 1990–92.

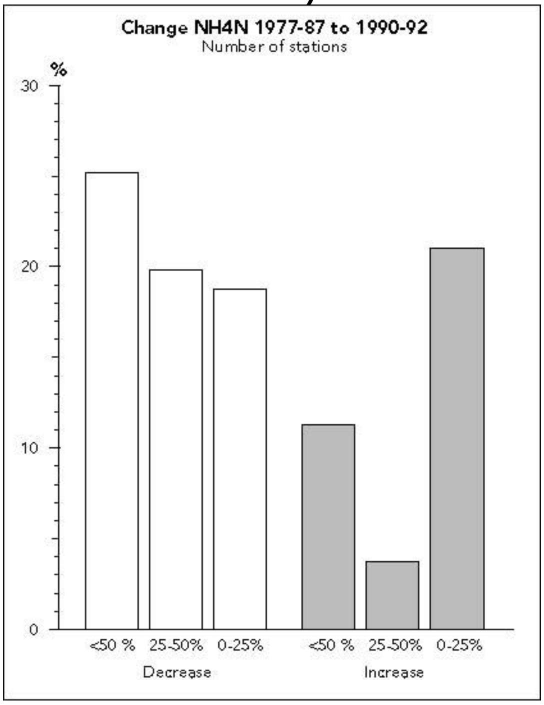


The percentual change in concentrations is shown. Data from Italy (IT), Greece (GR), Portugal (PT), and Spain (ES) are shown above bar lines.

Ammonium

A similar reduction in the ammonium concentration was observed. The ammonium concentration at 65 % of 130 river stations in large rivers in the EEA area decreased between the beginning of the 1980s and 1990–1992, with the concentration decreasing by more than 25 % at 45 % of the stations (Figure 3.13).

Figure 3.13: Percentage of river stations in which the river ammonium concentration decreased (empty) or increased (hatched) between the periods 1977–82 (IT & GR 1982–87; ES & PT 1986–87) and 1990–92.



The percentual change in concentrations is shown. Data from Italy (IT), Greece (GR), Portugal (PT), and Spain (ES) are shown above bar lines.

Biological river quality

Coincident with the reduction in organic loading and organic matter concentration of many of the large rivers an improvement in the conditions for the aquatic fauna has occurred. At the start of this century the number of invertebrate species in the river Rhine was 165. As a consequence of, primarily, the high organic loading and bad oxygen conditions the number of species in the period 1955–1978 was reduced to 27–41. In the periods 1986–88 and 1989–92 the number of species increased to 97 and 155, respectively (Umweltbundesamt,
1994). In the Austrian part of the Danube catchment 61 %, 20 %, and 19 % of the river stretches were in 1979 classified as having good and fair, poor, and bad biological river quality, respectively. In 1992 the percentage of stretches having good and fair quality increased to 72 %, and the percentage with bad quality decreased to 8 % (BMLF, 1994).

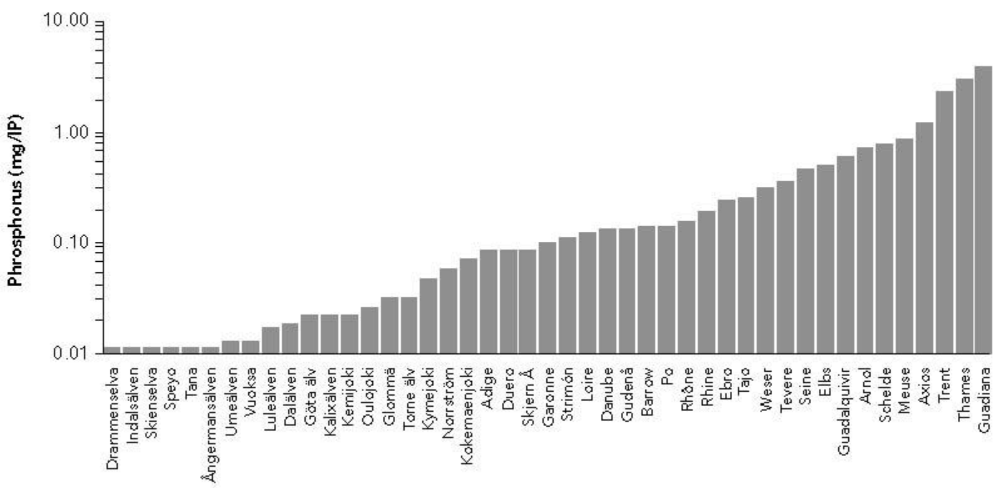
3.3. Eutrophication and nutrients

Eutrophication may be defined as the excessive enrichment of a water body with nutrients, particularly nitrogen and phosphorus. This stimulates the growth of aquatic plants, thereby causing a variety of adverse effects (eg. toxic blue-green algae, extensive treatment prior to use as drinking water). These effects are generally most apparent in lakes, reservoirs and coastal areas, as well as in large, slow-flowing rivers. Much of the excessive phosphorus loading to inland surface waters is attributable to discharge from point sources, especially municipal waste water and industrial effluent, although inputs from agricultural land can also be significant, especially in areas with intensive agriculture. Nitrogen loading is primarily derived from agricultural activity, especially from the use of nitrogen fertilizers and manure.

Phosphorus

The total phosphorus concentration in relatively unpolluted streams is generally below 0,025 mg P/l (EEA, 1995). Phosphorus levels exceeding 0,05 mg P/l indicate anthropogenic influence, such as from sewage effluent or intensive agriculture. The large rivers in Norway, Finland and Sweden as well as the river Spey (Scotland) generally had phosphorus levels below 0,05 mg/l P, while the other large rivers generally had phosphorus concentration higher than 0,1 mg P/l with the levels exceeding 0,3 mg P/l in the large rivers draining the more densely populated catchments (Figure 3.14) These latter levels indicate heavy pollution, particularly by sewage effluent.

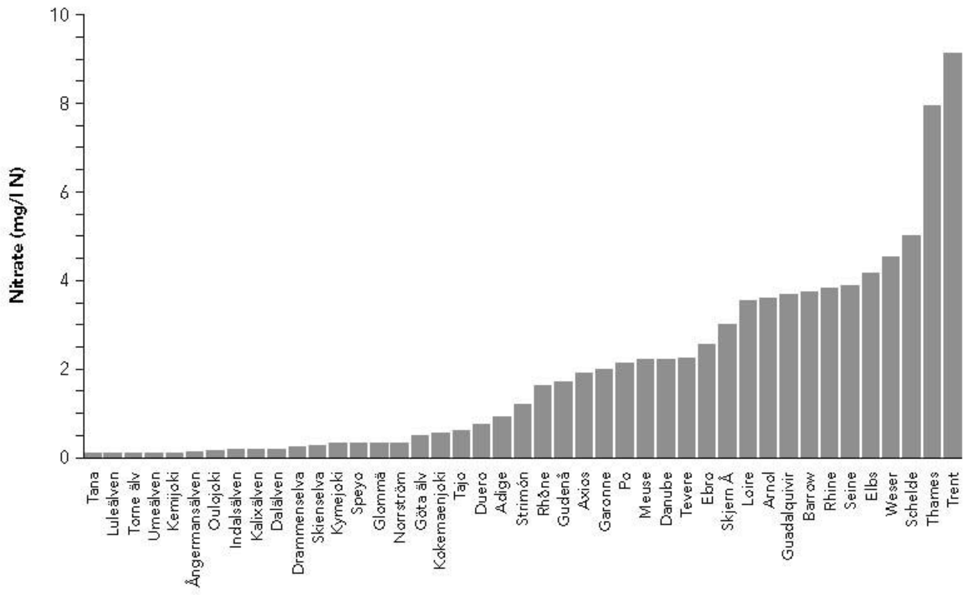
Figure 3.14: Annual average phosphorus concentration (1990–1992) at downstream stations in large rivers in the EEA area. Soluble reactive phosphorus: empty bars; total phosphorus = hatched bars.



Nitrate

The nitrate concentration in relatively unpolluted streams is generally below 0,3 mg N/l. Nitrate levels exceeding 1 mg N /l indicate anthropogenic influence, eg. agricultural run-off (EEA, 1995). Generally the rivers in the north-western part of the European Union (in northern France, the Benelux countries, Germany, Denmark and the southern UK) had nitrate concentrations greater than 2,5 mg/l N. The rivers in southern Europe (Portugal, Spain, southern France, Italy, and Greece) and Norway, Sweden and Finland, as well as some stations in Ireland, and Scotland, generally had nitrate concentrations below 2,5 mg N/l (Figure 3.15). The high level of nitrate at river stations in north-western Member States can be related to the high degree of agricultural intensification, with high application of nitrogen fertilizers and manure from large number of livestock.

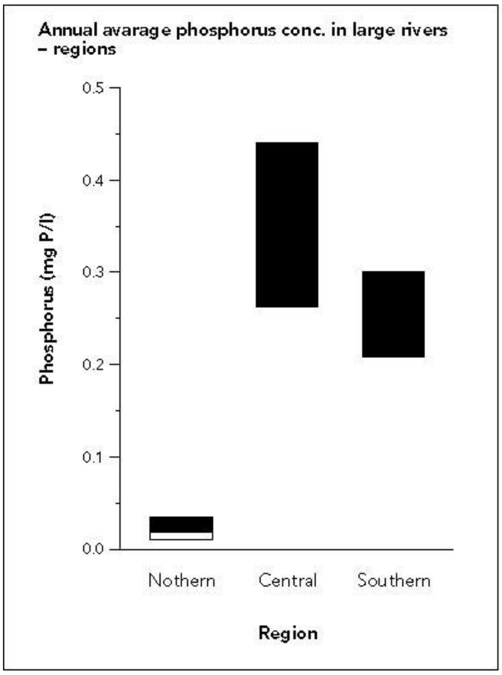
Figure 3.15: Annual average nitrate concentration (1990–992) at downstream stations in large rivers in the EEA area.

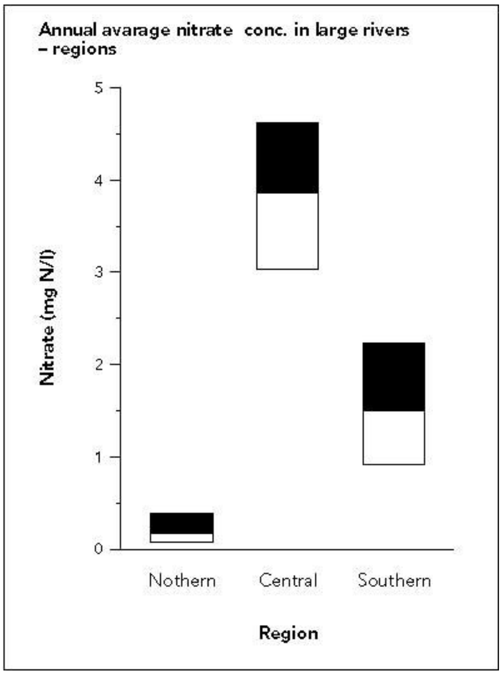


Regional differences in nutrient concentration

The annual average phosphorus and nitrate levels in the three regions are shown on Figure 3.16. The levels of nutrients were an order of magnitude lower in the large rivers of the northern region compared to the other large river in the EEA area. The phosphorus concentrations were generally higher in the more densely populated central region than in the large southern rivers. A markedly higher nitrate concentration was observed in the large rivers of the central region compared to the large rivers of the southern region reflecting the differences in agricultural intensification.

Figure 3.16: Annual average concentration of A) phosphorus and B) nitrate in large rivers draining three regions of the EEA area. Median, upper and lower quartiles are shown.



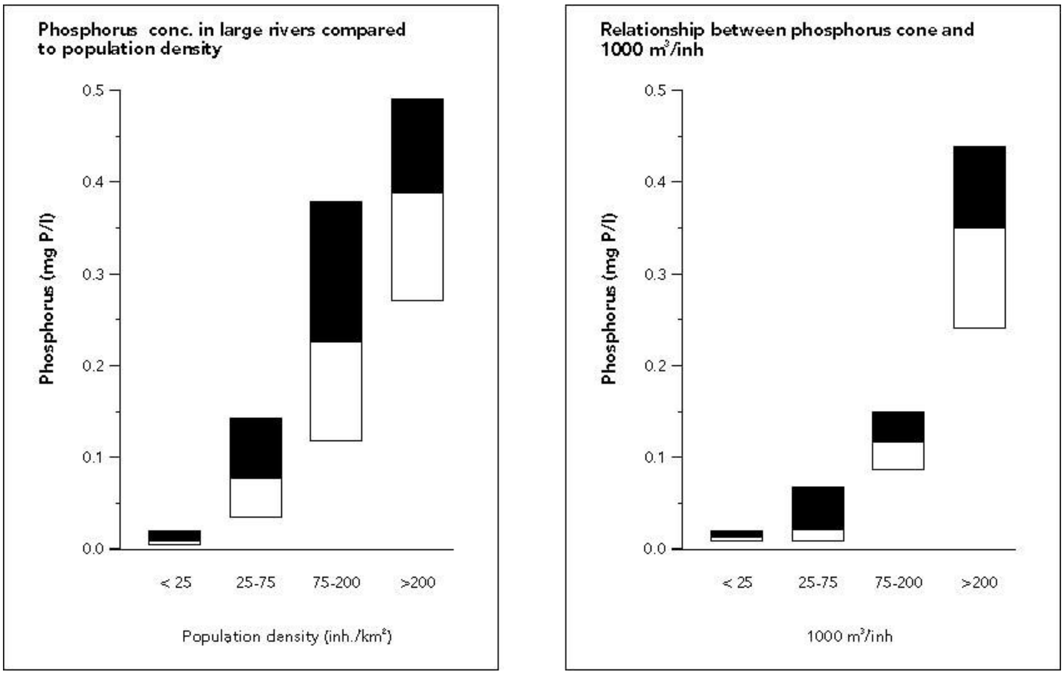


Phosphorus in relation to human activity

There is a positive correlation between population density and annual average river water phosphorus concentration (Figure 3.17). The phosphorus concentration is generally lower than 0,02 mg P/l in rivers draining catchment areas with less than 25 inhabitants per km^2, between 0,05 and 0,15 mg P/l in catchments with 25–75 inhabitants per km^2, between 0,15 and 0,35 mg P/l in catchments with 25–75 inhabitants per km^2, while the phosphorus concentration in rivers draining the most densely populated catchments (> 200 inhabitants per km^2) is generally higher than 0,25 mg P/l.

A similar relationship is found between the phosphorus level and the available water resource (Figure 3.17), in rivers with more than 10 000 m^3 per inhabitant the phosphorus concentration is generally lower than 0,05 mg P/l while in rivers with less than 2,000 m^3 per inhabitant the phosphorus concentration is generally higher than 0,25 mg P/l. In rivers with an available water resource of 1 000 and 2 000 m^3 per inhabitant and an annual 'production' of 1 kg P per inhabitant the river water phosphorus concentration without any treatment in sewage plants would be expected to be around 1 mg P/l and 0,5 mg P/l, respectively. The general range of the observed values was between 0,25–0,45 mg P/l and is generally below the above expected values, mainly due to that some phosphorus reduction in sewage treatment plants and retention of phosphorus in upstream lakes, reservoirs and wetlands. Sewage treatment plants with chemical precipitation of phosphorus may remove more than 95 % of the phosphorus, however, at the moment only a small part of waste water (< 20 %) is treated by phosphorus precipitation (EWPCA, 1995). If all waste water in sewage treatment plants was treated by chemical phosphorus precipitation, the water phosphorus levels in those rivers with an available water resource of less than 2 000 m^3 per inhabitant would be in the range of 0,1–0,2 mg P/l much lower than the observed concentrations, that is at present.

Figure 3.17: Annual average phosphorus concentration in relation to A) population density and B) dilution potential (1 000 m^3 per inhabitant). Median, upper and lower quartiles are shown.



In sparsely populated areas with very low agricultural activity such as the Swedish catchment draining to the Gulf of Bothnia (including the large rivers Tome älv, Kalixälven and Luleälven), only a small part of the phosphorus loading is related to human activities (point sources and agriculture) (Table 3.1). The loading is primarily derived from diffuse run-off from the countryside (natural land). With increasing human activity the phosphorus loading from the catchment areas increases. In the Göta älv catchment, for instance, 60 % of the phosphorus loading derives from human activities with the loading from point sources being the main source. The Göta älv catchment includes many large lakes (the area of inland waters constitute 17,8 % of the total area) consequently the phosphorus deposition on inland surface waters is relatively high. In densely populated areas, such as the remaining catchment areas, mentioned in Table 3.1, 50–96 % of the phosphorus discharged to inland waters is derived from point sources, while agricultural activity generally accounts for 20–40 %. If there was no human activity, the phosphorus levels would only be 5–10 % of the current levels. In these densely populated catchments municipal sewage discharge generally accounts for the major part of the point source load. However, in the Dutch part of the Rhine catchment, industrial effluents account for more than 75 % of the point source discharge (RIVM, 1992).

Table 3.1: Sources of phosphorus discharge to selected catchment areas.

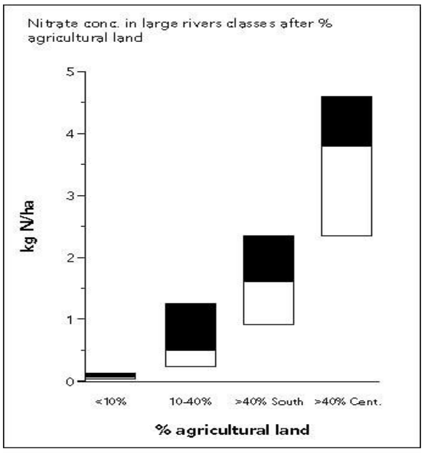
	Catchment area; annual loading; areal run-off in KgP/ha/yr	Point sources (household, industry, etc.)	Agriculture	Natural run-off (forest, mountains, etc.)	Atmospheric deposition on surface waters
Swedish catchment area to the Gulf of Bothnia 1982–1989[1]	116 103 km^2 1 599 tP/yr 0,14 kgP/ha/yr	3 %	1 %	**93 %**	3 %
Göta älv, Sweden 1982-–1987[1]	50 181 km^2 777 tP/yr 0,15 kgP/ha/yr	**47 %**	12 %	**31 %**	9 %
Austrian part of the Danube catchment 1994[2]	80 731 km^2 5 619 tP/yr 0,7 kgP/ha/yr	**71 %**	24 %	5 %	
Germany 1987–1991[3]	356 950 km^2 100 000 tP/yr 2,8 kgP/ha/yr	**52 %**	**42 %**	6 %	
The river Po, Italy 1989[4]	69 400 km^2 23 050 tP/yr 3,3 kgP/ha/yr	**67 %**	**32 %**	1 %	
The Dutch part of the Rhine catchment 1989[5]	-- km^2 14 400 tP/yr -- kgP/ha/yr	**96 %**	4 % *		
The Dutch part of the Meuse catchment 1989[5]	-- km^2 2 900 tP/yr -- kgP/ha/yr	**59 %**	**41 % ***		
Denmark 1993[6]	43 200 km^2 2 040 tP/yr 0,47 kgP/ha/yr	**51 %**	**39 %**	10 %	

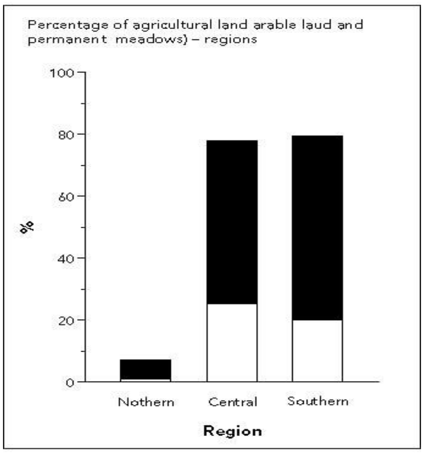
* Includes run-off from natural land (<5 %)
Source: revised from [1)]Löfgren & Olsson, 1990; [2)]BMLF, 1995; [3)]Umweltbundesamt, 1994; [4)]Italian Ministry of the Environment, 1989; [5)]RIVM, 1992; [6)]Græsbøll et al. 1994.

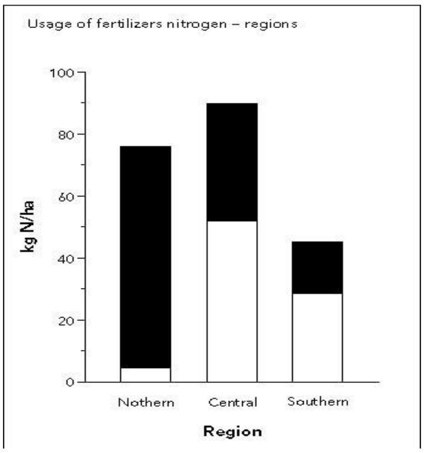
Nitrate concentration in relation to percentage of agricultural land

The nitrate concentration is significantly correlated to the percentage of farmland in the river catchments (Figure 3.18A). River nitrate levels in rivers draining catchments with less than 10 % agricultural land are below 0,15 mg N/l, whereas those in catchments with 10–40 % agricultural land lie between 0,3 and 1,2 mg N/l. In rivers draining catchments with percentages of agricultural land greater than 40 % nitrate levels are even higher. In the large southern European rivers the nitrate concentrations generally range between 0,9–2,2 mg N/l, while the nitrate levels in the large rivers draining the central region generally range between 2,5–4,8 mg N/l. These regional differences in the nitrate levels can be explained by differences in agricultural intensification in the three regions. In the northern region only around 7 % of the total land area is used for agricultural purposes, while in the central and southern region the percentage of farmland is around 60 % (Figure 3.18B). In the central region the usage of nitrogen fertilizers (average 91 kg N per hectare of agricultural land and 53 kg N per hectare of total land) is about double the usage in the southern region (average 48 kg N per hectare of agricultural land and 28 kg N per hectare of total land). In the northern region the usage per hectare of agricultural land is relatively high, however, the usage per hectare of total land area is low (average 5 kg N per hectare).

Figure 3.18: A) Annual average nitrate concentration in relation to the percentage of catchment area used for agricultural land. Median, upper and lower quartiles are shown.
B) Percentage of total land area used for agricultural purposes (arable land and permanent crops (dark hatched); permanent meadows and pastures (light hatched)). Source: Eurostat (1995).
C) Usage of nitrogen fertilizers: light bar: kg N per hectare of total area; dark bar: kg N per hectare of agricultural land. Source: Eurostat (1995).







In the river systems draining catchments in the central and western part of the EEA area, 46–87 % of the nitrogen discharge to inland waters is related to agricultural activity (Table 3.2). In some catchments point source nitrogen discharge also play an important role, accounting for 35–43 % of the total discharges, of this, most is attributable to municipal sewage discharge. In the two Swedish catchments the differences in percentage of agricultural land and population density are reflected in the sources of nitrogen discharge. In the Göta älv catchment area, where approximately 10 % of the land is cultivated and the population density is approximately 30 inhabitants per km^2, human activities account for 41 % of the nitrogen discharge (some of the atmospheric deposition can also be related to human activities). In contrast in the catchment draining to the Gulf of Bothnia, where approximately 1 % of the land is cultivated and the population density is l–3 inhabitants per km^2, most of the nitrogen discharge comes from diffuse run-off from forested and uncultivated areas.

Table 3.2: Sources of nitrogen discharge to inland surface waters in selected catchment areas.

	Catchment area; annual loading; areal run-off in KgN/ha/yr	Point sources (household, industry, etc.)	Agriculture	Natural run-off (forest, mountains, etc.)	Atmospheric deposition on surface waters
Swedish catchment area to the Gulf of Bothnia 1982–1989[1]	116 103 km^2 24 434 tN/yr 2,1 kgN/ha/yr	3 %	1 %	**88 %**	7 %
Göta älv, Sweden 1982–1987[1]	50 181 km^2 21 578 tN/yr 4,3 kgN/ha/yr	19 %	22 %	**33 %**	**26 %**
Austrian part of the Danube catchment 1994[2]	80 731 km^2 9 987 tN/yr 9,9 kgN/ha/yr	**36 %**	**46 %**	18 %	
Germany 1987–1991[3]	356 950 km^2 1 040 000 tN/yr 29 kgN/ha/yr	**39 %**	**53 %**	86 %	
The river Po, Italy 1989[4]	69 400 km^2 243 630 tN/yr 35 kgN/ha/yr	**43 %**	**54 %**	3 %	
The Dutch part of the Rhine catchment 1989[5]	-- km^2 40 600 tN/yr -- kgN/ha/yr	**35 %**	**62 % ***		3 %
The Dutch part of the Meuse catchment 1989[5]	-- km^2 44 000 tN/yr -- kgN/ha/yr	25 %	**75 % ***		1 %
Denmark 1993[6]	43 200 km^2 98 000 tN/yr 23 kgN/ha/yr	7 %	**87 %**	6 %	

* Includes run-off from natural land (<10 %)

Source: revised from [1)]Löfgren & Olsson, 1990; [2)]BMLF, 1995; [3)]Umweltbundesamt, 1994; [4)]Italian Ministry of the Environment, 1989; [5)]RIVM, 1992; [6)]Græsbøll et al., 1994.

Trends in nutrient concentrations

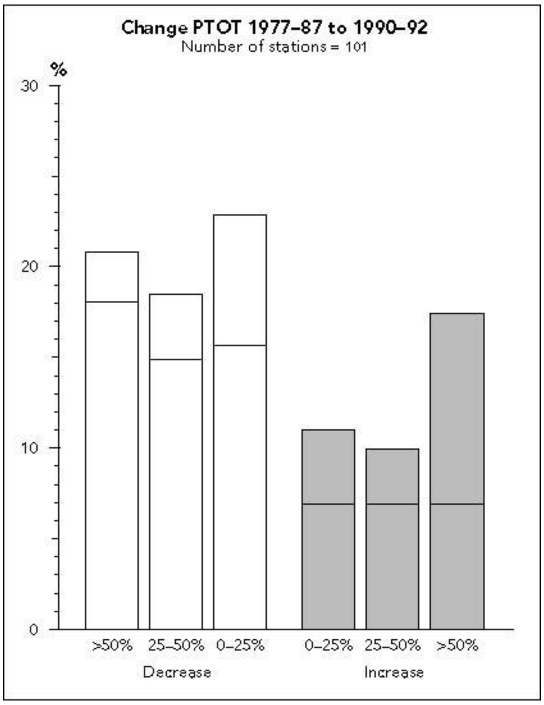
Phosphorus

The increase in phosphorus levels that occurred in many European inland surface waters during the 1960s and 1970s caused severe eutrophication problems and led several countries to take measures to reduce phosphorus loadings to rivers. This was primarily achieved by improving sewage water treatment and by reducing the phosphorus content in detergents. In Denmark, for instance, the percentage of the population connected to sewage treatment plants with phosphorus precipitation increased from less 5 % in the 1980s to more than 60 % in the 1990s (Miljøstyrelsen, 1994). In West-Germany the usage of polyphosphate in households was reduced from 200 000–270 000 tonnes in the period 1975–1980 to 16 000–20 000 tonnes in the years 1989–1990 (Umweltbundesamt, 1994). The reduction in phosphorus loading is reflected by a marked decrease in the phosphorus levels of many European rivers.

Data from 101 river stations show that the total phosphorus concentration at the majority of river stations (63 %) decreased between the beginning of the 1980s and 1990–1992 (Figure 3.20). In 40 % of the rivers, the reduction in phosphorus levels was greater than 25 %.

The percentage of river stations with a total phosphorus concentration below 0,3 mg/l P increased from 67 % in the 1980s to 80 % in the period 1990–1992. In addition, the percentage of stations with concentrations higher than 0,5 mg/l P decreased from 18 % to 7 %.

Figure 3.20: Percentage of river stations in which the river total phosphorus concentration decreased (empty) or increased (hatched) between the periods 1977–1982 (IT & GR 1982–87; ES & PT 1986–87) and 1990–92.

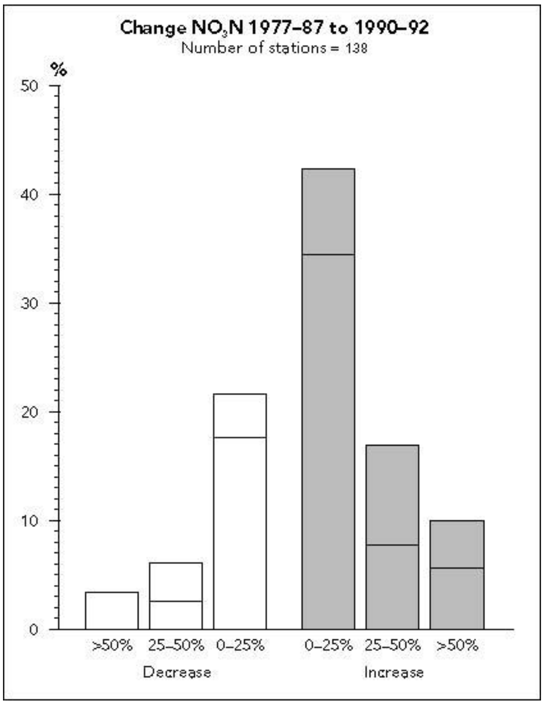


The percentual change in concentrations is shown. Data from Italy (IT), Greece (GR), Portugal (PT), and Spain (ES) are shown above bar lines.

Nitrate

In contrast to phosphorus, organic matter and ammonium levels, the nitrate levels in the large rivers have increased during the last 10–15 years. Thus, nitrate levels increased between the beginning of the 1980s and 1990–1992 at nearly three quarters of 120 river stations (Figure 3.21). In 30 % of the river stations the increase in nitrate concentration was greater than 25 %.

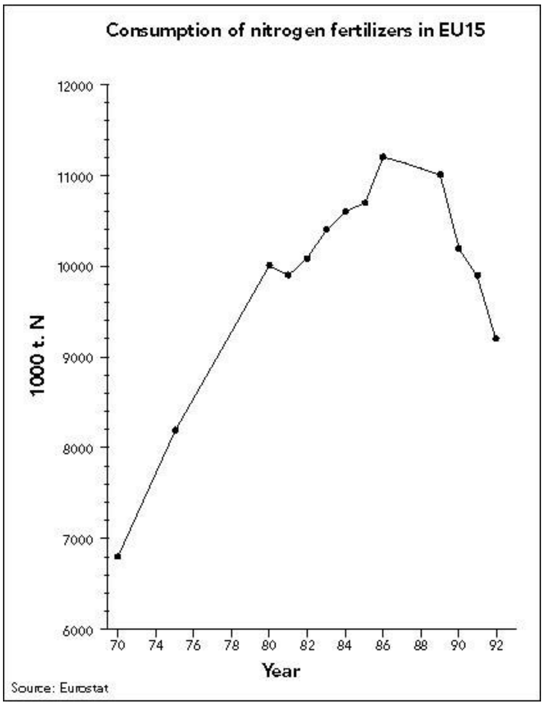
Figure 3.21: Percentage of river stations in which the river nitrate concentration decreased (empty) or in-creased (hatched) between the periods 1977–82 (IT & GR 1982–87; ES & PT 1986–87) and 1990–92.



The percentual change in concentrations is shown. Data from Italy (IT), Greece (GR), Portugal (PT), and Spain (ES) are shown above bar lines.

The increase in river nitrate levels is mainly attributable to a corresponding increase in the use of nitrogen fertilisers. The use of artificial nitrogen fertilisers in the EU15 Member States increased from the beginning of the 1970s until the late 1980s (Figure 3.22). Use has been decreasing in the period 1990–1992 and in 1992 the overall use was approximately 90 % of the use in 1980. However, a similar decrease in river concentration over the recent years cannot be found. The increase in use at the beginning of this period was driven by supply-side orientated agricultural policies with over-emphasis on price support mechanisms, which made the over-use of fertilizers more profitable. The more recent decreasing trend is likely to be due to the overly high level of application already reached in some countries and the awareness of environmental consequences (EEA, 1995b).

Figure 3.22: Development in the consumption of artificial nitrogen fertilizers in the EU15 Member States.



Source: Eurosat/FAO.

4. Conclusions

This report aims at assessing the environmental state of the major rivers in the EEA area and to relate water quality variables to the dominant human activities in their catchments. The report is based on a generally good quality data set of water quality variables, while the information about human activities is sparse and heterogeneous. This lack of information on human activities prevents a full assessment of the relationship between water quality variables and human activities. The assessment could have benefited from more detailed information about land-use characteristics (arable land, use of fertilisers, etc.) in the river catchments and information about the sources of pollutants (eg. sewage treatment plants, industry) would have been valuable.

The countries or the local authorities generally produce and collate much information about human activities in the river catchments and make inventories of pollutant emissions from point sources into the rivers. However, this information may be hard to obtain (reported in specific reports), and as the methods used for assessing pollution loads differ the information may not be directly comparable. In the coming working period (1996) one of the ETC/IW projects will be to produce guidelines for inventories of pollutant emissions into surface waters. In addition, the Topic Centre for Land Cover as well as Eurostat will, hopefully, in the years to come be able to collate more detailed and comparable information about land-use and agricultural activities in the large river catchments areas.

The report attempts, as far as the information allows, to give a description of the major rivers in the EEA area, their water quality and the relationship between water quality and very broad descriptors of human activities in the river catchments such as ‘population density and percentage of farmland.

There are 15 rivers with a catchment area greater than 50 000 km^2 draining the EEA area. The largest of these, the Danube, discharges into the Black Sea and only a small part of its catchment lies in the EEA area. Of the other 14 the most noticeable feature is the dominance of a westerly or northwesterly flow direction, with only three of the major rivers; i.e. the Rhône, the Ebro and the Po discharging into the Mediterranean. In total, the report covers around 50 large rivers in the EEA area.

Large regional variations in the annual run-off were found. The large rivers with their source in the Alps and the rivers draining the north-western and northern part of the EEA area generally have an annual run-off greater than 500 mm, while the rivers draining the southern part of the Iberian Peninsula have an annual run-off smaller than 200 mm.

In the catchments of the large rivers in Norway, Sweden, and Finland the population density is generally less than 10 inhabitants per km^2. In the catchments of several of the large rivers in the south-western part of the region the population density ranges between 40 to 100 inhabitants per km^2. In the central part of the EEA area the catchment population density is generally greater than 100 inhabitants per km^2, with the highest densities being observed in the catchment areas of the rivers draining northern France and the Benelux countries, Italian rivers, the river Rhine, and the large rivers in the southern part of England. The volume of available water resource per inhabitant ranges from less than 1 000 m^3 per inhabitants per year in the most densely populated river catchments to more than 20 000 m^3 per inhabitant per year in the sparsely populated river catchments in northern part of the EEA area.

Most of the catchments of the large rivers in Norway, Sweden and Finland are dominated by natural landscape and forest, with less than 10 % being agricultural land. In the central and southern part of the EEA area the catchments of the large rivers generally contain 40 to 60 % agricultural land with the percentage of forest and natural land (eg. mountains, wetlands, arid land) varying between 10 % and 50 %. A more detailed categorisation of the agricultural land (eg. in arable land, rough grassing and permanent crops) has not been possible.

The level of organic matter (BOD_5) was quite similar in the large rivers of the central and southern part of the EEA area (there are no BOD_5 data from the northern region). Ammonium levels are an order of magnitude lower in the northern rivers, medium in the southern rivers and highest in the rivers draining the central part of the EEA area. An increasing ammonium concentration was found with increasing population density in the river catchments.

During the last 15–20 years biological treatment of domestic and industrial waste waters has intensified, and organic matter loading has consequently decreased in many parts of Europe. This reduction in organic loading of the rivers is reflected in a similar reduction in the concentration of BOD_5 in many of the large rivers. A comparison of organic matter levels (BOD_5) at 101 river stations in large rivers in the EU12 Member States (there are no BOD_5 data from Norway, Sweden and Finland) reveals a sign of improving conditions. From the period around 1980 to
1990–1992, the organic matter concentration decreased at almost 72 % of the river stations. A similar reduction in the ammonium concentration was also observed.

The levels of nutrients were an order of magnitude lower in the large rivers of the northern region compared to the other large rivers in the EEA area. The phosphorus concentrations were generally higher in the more densely populated central region than in the large southern rivers. A positive correlation between the population density and annual average river water phosphorus concentration was found.

A markedly higher nitrate concentration was observed in the large rivers of the central region compared to the large rivers of the southern region. The nitrate concentration is significantly correlated to the percentage of farmland in the river catchments. In rivers with the percentage of agricultural land greater than 40 % nitrate levels were about double in those large rivers draining the central part of the EEA area compared to those draining the southern part. These regional differences in nitrate level can be explained by differences in agricultural intensification. In both the central and the southern region the percentage of farmland is around 60 %. However, in the central region the usage of nitrogen fertilisers is approximately double the usage in the southern region.

In the majority of the large rivers the concentration of phosphorus decreased between the beginning of the 1980s and 1990–1992. In contrast, the nitrate level in the large rivers has generally been increasing over the last l0–15 years with increases occurring at nearly three quarters of 120 river stations.

When assessing river characteristics and water quality at downstream stations in the large rivers in the EEA area, it is important to bear in mind, that a river comprises not only the main course, but also a vast number of tributaries. Each tributary includes several streams, each with its own characteristics and water quality. A report on the large rivers will only describe the general water quality of these rivers, while the proposed EEA monitoring network covering both small streams and large rivers will when fully implemented give a more detailed and precise overview of the overall environmental state of rivers in the EEA area.

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