# 3.5. Water Stress

**Main findings**

- Water stress is caused by activities in two sectors identified as priorities under the Fifth Environmental Action Programme, namely, agriculture and industry, and also by the household sector. Most progress has been achieved in the industrial sector, with some improvement for households, but little progress has been made by the agricultural sector.

- EU countries are, on average, abstracting around 21% of their renewable freshwater resources each year which is regarded as a sustainable position, although significant water loss occurs in southern countries – around 18% of the resource is lost each year in irrigation. Water abstraction will increase very slowly in the EU. Water pricing to promote conservation, re-use and leakage control is now an important consideration in the development of water policy.

- There are fewer heavily-polluted rivers due to reductions in organic matter discharges, phosphate-free detergents and improved waste-water treatment; implementation of the Urban Waste-water treatment Directive and upgrading of discharge can achieve further reductions of phosphorus and organic matter discharges but the quantity of contaminated sludge will increase accordingly. The concentration of nitrate in EU rivers has been approximately constant since 1980 leading to eutrophication in coastal areas. Nitrate contamination of aquifers also remains a problem, due to diffuse nutrient loads from agricultural areas.

## 1. Focus on major water stress problems

Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. It frequently occurs in areas with low rainfall and high population density or in areas where agricultural or industrial activities are intense. Even where sufficient long-term freshwater resources exist, seasonal or annual variations in the availability of freshwater may at times cause stress.

Water stress causes deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.). Such deterioration can result in health problems and have a negative influence on ecosystems.

At European level, various policy responses have been taken to address water stress and prevent the deterioration of water quality. Sustainable use of water is among the key objectives of the EU's Fifth Environmental Action Programme (5EAP), and is the subject of policy initiatives including the Groundwater Action Programme and Directives on Urban Waste-water treatment, Nitrate, Drinking-water and Bathing Waters. In February 1997, the European Commission adopted a Proposal for a Water Framework Directive, pursuing a generic approach to water management and providing a framework for the protection of water resources. Table 3.5.1 lists the EU objectives, targets and actions achieved in relation to water resources. Water stress is also affected by sectoral policies, notably the Common Agricultural Policy and its reform.

Water resources and water quality in Europe are affected mainly by the activities in three sectors: agriculture, industry and households. This chapter focuses on the influence these sectors have on the availability and demand for water and on water quality problems caused by discharges of organic matter, phosphorus and nitrogen into water bodies. Europe's water bodies are affected by many other factors creating water stress (see Table 3.5.2) but the issues selected for analysis in this chapter are the most prominent on a European scale. In addition, the relatively high amount of good quality information available on these issues provides a sound basis for analysis at European level.

**Table 3.5.1. EU objectives, targets and actions in relation to water resources**

| | Objectives | EC targets up to 2000 | Actions achieved (achievements by 1998) |
|---|---|---|---|
| **Quantitative aspects**<br><br>*Groundwater and surface fresh water* | Sustainable use of freshwater resources: demand for water should be in balance with its availability. | Prevent permanent overdraft. Integrate resource conservation and sustainable use criteria into other policies, including agriculture, planning and industry. Marked reduction in pollution of water bodies. | The approach on sustainable water use is now developed in the Water Framework Directive (1997/8 proposal, probable adoption 1999) which sets target of good ecological status (including minimum water flow conditions where relevant) for surface water, and good quantitative status for groundwater. These together define the sustainable limits for abstraction, and the Directive requires Member States (MS) to ensure that abstraction does not exceed this. This requires MS to integrate these constraints into controls on agriculture, industry and any other activity which could affect them. |
| **Qualitative aspects**<br><br>*Groundwater* | To maintain the quality of uncontaminated groundwater.<br><br>To prevent further contamination of contaminated groundwater.<br><br>To restore contaminated groundwater to a quality required for drinking-water production purposes. | To prevent all pollution from point sources and to reduce pollution from diffuse sources according to best environmental practices (BEP) and best available technology (BAT). | The main groundwater pollution problems were identified and legislated on in 1991 – nitrate (Directive on Protection of waters against nitrate pollution from agriculture) and pesticide contamination (Directive 91/414). Implementation of the Nitrate Directive has been unsatisfactory in the majority of Member States and proceedings have been initiated against those MS that have not yet complied. Progress on 91/414 has been glacially slow – seven years after adoption analysis is complete on only one active substance out of approximately 800.<br><br>The BEP and BAT measures are set out in the Groundwater Action Programme (GWAP, 1996) and implemented in the Water Framework Directive (1997/8 proposal, probable adoption 1999). They enforce existing quality objectives for pesticides, nitrate and biocides, and add two elements: a requirement to ensure that the quality is sufficient to support connected surface ecosystems; and a requirement to reverse increasing pollution trends. |
| **Qualitative aspects**<br><br>*Surface fresh waters* | To maintain a high standard of ecological quality with a biodiversity corresponding as much as possible to the unperturbed state of a given water. | Quality improvements towards a better ecological quality and safeguard of high quality where it exists. | The overall purpose of the proposed Water Framework Directive is to establish a framework for protection of water bodies to prevent further deterioration, and to protect and enhance the status of aquatic ecosystems and those terrestrial ecosystems directly dependent upon them. It requires the achievement of good surface water status by 2015 unless it is impossible or prohibitively expensive.<br><br>The Nitrate and Urban Waste-water treatment Directives address surface water pollution. Implementation of the Nitrate Directive is described above. Implementation of the Urban Waste-water treatment Directive since 1991 has been patchy but considerable investment programmes are in place in all Member States. |

## 2. How much water is available?

***2.1. Renewable resources***

The total renewable freshwater resource of a country is the amount of water flowing in rivers and aquifers, originating either from precipitation over the country itself (internal water resources), or from water received from neighbouring countries in transboundary rivers and aquifers (external water resources). In the EU, the average internal water resource is estimated to be approximately 1 190 km$^3$/year (EEA, 1999a), equivalent to 3 200 m$^3$/cap/year. Although this is significantly lower than the global average of 7 300 m$^3$/cap/year (WMO, 1997), EU countries appear to have sufficient water resources since average abstractions are estimated at 660 m$^3$/cap/year.

However, these resources are not evenly distributed. There are substantial imbalances between different regions. Map 3.5.1 illustrates the wide spatial variability of freshwater resources, with annual average runoff (water resource per unit of area) ranging from over 3 000 mm in western Norway to 100 mm over large areas of Eastern Europe and less than 50 mm in southern and central Spain.

Transboundary river flows make up a significant share of the resources in many countries. In Hungary, freshwater originating from upstream countries accounts for as much as 95% of the total resource. In the Netherlands and the Slovak Republic this proportion is over 80%; whilst Germany, Slovenia and Portugal all rely on imported water for over 40% of their resources. Although there are international agreements

**Other Water stress related factors** Table 3.5.2.

| **Water Stress Factor** | **Reference to Chapter** |
|---|---|
| Acidification | (no direct description of surface water acidification in *Chapter 3.4)* |
| | *Chapter 3.11* Acidification from sulphur and nitrogen polluted depositions |
| Biodiversity | *Chapter 3.11* Includes some description of biodiversity in relation to freshwater |
| Climate change | *Chapter 3.1* Vulnerability to climate change in Europe |
| | *Chapter 3.11* Foreseen impact of climate change by 2050 by habitat-type (running water, bogs, marshes and fens) |
| Desertification | *Chapter 3.6* Main impacts on resources |
| Eutrophication of coastal and marine waters | *Chapter 3.14* Environmental conditions in regional seas |
| Heavy metals | *Chapter 3.3* Heavy metals losses during production, use and waste treatment |
| Pesticides | *Chapter 3.3* Organochlorines dispersal in soil, groundwater and some global scale problems |
| Radiation | (No direct description of radiation in surface waters in *Chapter 3.8)* |
| River flooding | *Chapter 3.8* Occurrence of major floods |
| Soil-phosphorus | *Chapter 3.6* Analysis of phosphorus surplus |
| Sludge from waste-water treatment plants | *Chapter 3.7* Case study: Sewage sludge – a future waste problem? |
| Water management (urban areas) | *Chapter 3.12* Box: Water management in Europe: the pricing issue and Case study : Water flows in Barcelona |
| Water stress in mountain areas | *Chapter 3.15* Mountains are the water towers of the lowlands |
| Wetlands | *Chapter 3.11* Wetlands: where all environmental pressures meet |
| **Sectors** | |
| Aquaculture | *Chapter 3.14* Developments in aquaculture |
| Agriculture | *Chapter 2.2* Trends in agriculture (livestock, fertilisers and pesticides) |

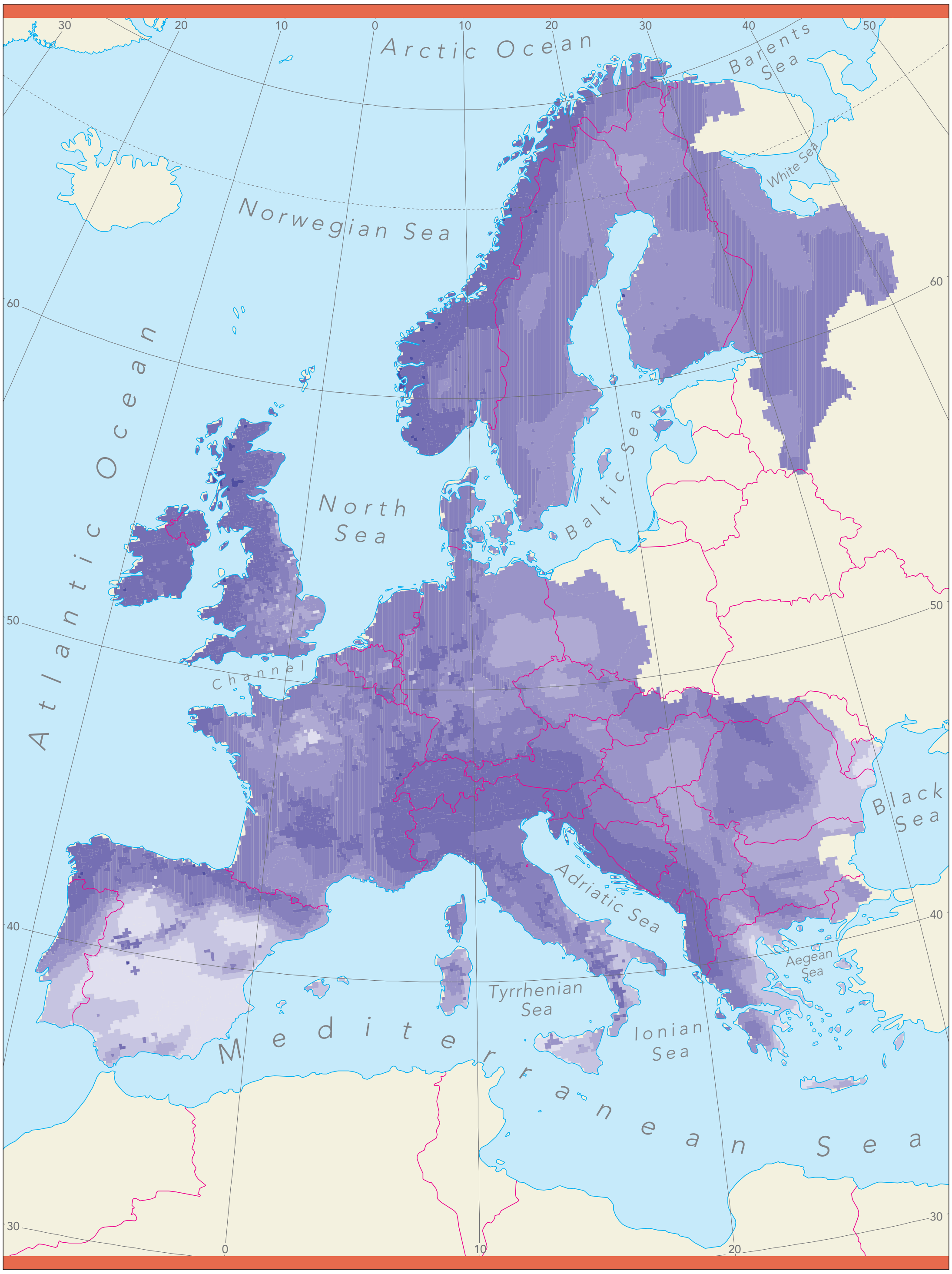
to control the quantity and quality of imported water, tensions inevitably can arise, especially where total water availability in the upstream country is less than in the downstream country.

***2.2 How much water is being used?***

Fortunately, in most European countries the amount of water available is far greater than demand. In the EU, EFTA and Accession Countries (excluding Cyprus), total internal resources amount to 1897 $km^3$/year, out of which 296 $km^3$/year are abstracted (16%) and 89 $km^3$/year consumed (5%).

With total abstraction at around 240 $km^3$/year (in 1995), the EU is using, on average, only 21% of its renewable resources (EEA, 1999a) which can be regarded as a sustainable position (OECD, 1998). The most stressed countries with respect to water quantity (highest ratios of abstraction per total resources) are Belgium and Luxembourg with high water stress and more than 40% of resources being abstracted and Germany, Italy and Spain, with medium-high water stress and values between 30% and 35% (Figure 3.5.1). Such country averages, however, may conceal enormous regional and temporal differences in the sustainability of usage within the country.

In order to meet their total needs for water for all purposes, most European countries rely more on surface water than on groundwater (EEA, 1998). For example, Finland, Slovenia and Lithuania take more than 90% of their total supply from surface waters, although groundwater is the predominant source in some countries, such as Denmark




**Map 3.5.1**

**Source:** EEA, 1998

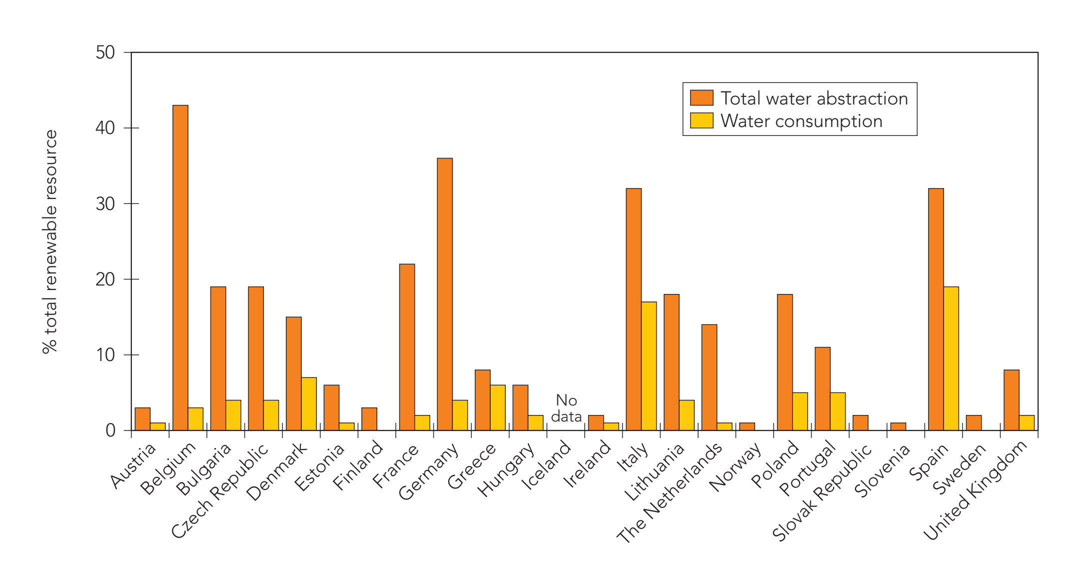
and Iceland, where it satisfies practically the entire demand. In many countries, groundwater is the main source for drinking-water supply, due to its easy (and low-cost) availability and its high quality (EEA, 1999a). It can, however, be an expensive and time-consuming resource to restore once it has been polluted or depleted, hence vigilance and regular monitoring are required.

***2.3. Sectoral water use***

On average, 14% of total water abstraction in the EU is used for public water supply, 30% in agriculture, 10% in industry (excluding cooling water) and 46% as cooling water, mainly for power generation (EEA, 1999a). Mediterranean agriculture is the biggest water user: irrigation accounts for about 80% of total water demand in Greece, 60% in Spain, 52% in Portugal and more than 50% in Italy (the average figure in northern Europe is under 10%). For the Accession Countries, industry is the biggest user (Figure 3.5.2).

Most of the water abstracted is not consumed but returned to the water cycle, being

**Intensity of water abstraction and water consumption as a percentage of total renewable freshwater resources in the EU** — Figure 3.5.1




**Source**: ETC/IW

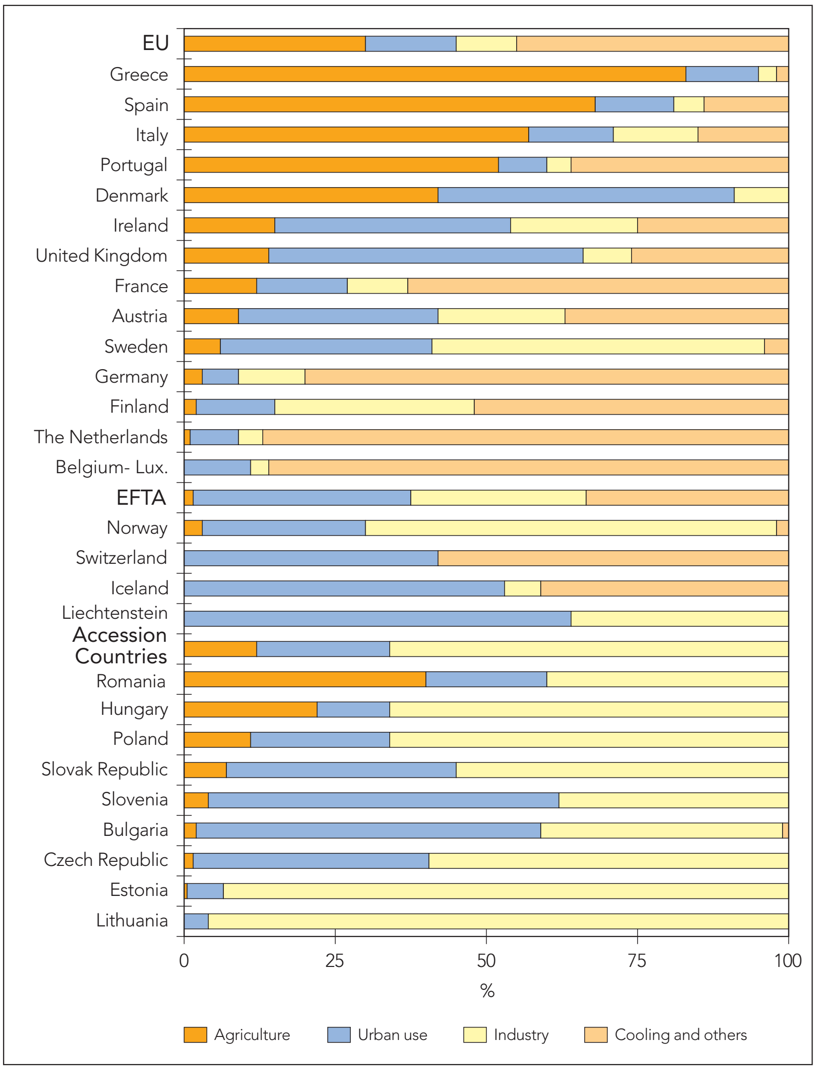
available, after proper treatment or natural purification, for subsequent use (see Box 3.5.1). Water consumption (principally evapotranspiration) in the EU is estimated to be 77 km$^3$/year, or around 32% of total abstractions, with 80% attributable to agriculture (mainly irrigation water), 20% to urban and industrial use and 10% to cooling and other uses.

The major water consumers are the Mediterranean countries, where irrigation is much greater than in central and northern Europe. Also, the highest levels of total water demand per capita occur in countries with agriculture systems which heavily depend on irrigation (e.g. Italy, Spain).

**Box 3.5.1: Definitions of water use**

Various concepts are used to describe the diverse aspects of water use. *Water abstraction* is the quantity of water physically removed from its natural source. *Water supply* refers to the share of abstraction which is supplied to users (excluding losses in storage, conveyance and distribution), and *water consumption* means the share of supply which in terms of a water balance actually is used (as evaporation) whilst the remainder is reintroduced into the source of abstraction. The term *water demand* is defined as the volume of water requested by users to satisfy their needs. In a simplified way it is often considered equal to water abstraction, although conceptually the two terms do not have the same meaning.

**Sectoral water use in Europe** — Figure 3.5.2




**Source**: EEA, 1999a

*2.3.1. Public water supply*
Public water supply (PWS) includes a wide range of users, most notably households, small industry, agriculture, commerce and public services. PWS is the major user in many western European and Nordic countries, but has a lower share in Mediterranean countries (see Figure 3.5.2).

Within public water supply, households tend to dominate, accounting for 44% of the total urban demand in the UK (DOE, 1999), 57% in the Netherlands, and 41% in Hungary (ICWS, 1996).

Large variations in PWS per capita are found in Europe, ranging from 50 $m^3$/capita/year in Germany to 140 $m^3$/capita/year in Italy, and from 30 $m^3$/capita/year in Romania to over 200 $m^3$/capita/year in Bulgaria. Iceland has the largest PWS volume supplied (310 $m^3$/capita/year).

Urban water demand rose steadily between the 1980s and 1990s in most countries, owing to growing population and the increased use of domestic appliances such as dishwashers (see also Chapter 3.12). Predictions indicate that population will continue to increase moderately over the next 15 years in most countries of the EU, with the total population reaching around 390 million in 2010, although the number of households is projected to increase, as household size declines (see Chapter 2.2). Pricing mechanisms and incentives to encourage improved efficiencies in water use by households will be important influences on future demand for PWS, and it is expected that future water demand for PWS will decline slightly in the EU (ETC/IW, 1998b).

Table 3.5.3. **Leakage rates in various European countries**

| Country | Leakage rate (%) |
|---|---|
| Austria[1] | 10 |
| Denmark[2] | 10 |
| Czech Replublic[1] | 33 |
| France[1] | 30 |
| Italy[1] | 15 |
| Slovak Replublic[1] | 23 |
| Spain[1] | 20 |
| UK (England and Wales)[3] | 28 |

[1] EEA, 1999a
[2] Danmark Statistik, 1998
[3] OFWAT, 1997

Loss of water from leakage in the distribution networks (still substantial in many countries) could be reduced by improved maintenance of the water distribution network. Comparisons of average leakage rates for eight countries (Table 3.5.3) shows that between 10% (for Austria and Denmark) and 33% (for the Czech Republic) of supplied water never reaches the final user. Individual cities and water companies can experience higher losses, for example, Bilbao and Thames Water report losses of up to 40% and 34% respectively (EEA, 1999a; DOE, 1999).

*2.3.2 Industrial water use*
The biggest industrial water users are the chemical industry, the steel, iron and metallurgy industries, and the pulp and paper industry, although in most European countries industrial abstractions have been declining since 1980. In western Europe this is due, primarily, to economic restructuring with closures in water-using industries such as textiles and steel, and a move towards less water-intensive industries. Technological improvements in water-using equipment and increased recycling and re-use have also contributed to the decline. In eastern Europe, abstractions seem to have diminished due to the serious decline in industrial activity across the whole sector.

Generally, pricing mechanisms have been used more extensively to encourage water use efficiencies in the industrial sector, where firms will adopt water-saving technologies if costs can be reduced, than in the household and agricultural sectors. Also charges for the discharge of contaminated water into the sewerage network are an important incentive for industries to improve process technologies and to reduce the amount of water used and discharged. Industrial sectors with the largest water needs are the chemical industry, steel, iron and metallurgy industries, and the pulp and paper industry.

In general, the quantities of water abstracted for cooling are far in excess of those used by the rest of industry (e.g. 95% of all industrial water use in Hungary is for cooling). However, cooling water is generally returned to the water cycle unchanged, apart from an increase in temperature and some possible contamination by biocides.

Forecasts of industrial water use in Europe are generally downwards because of increased efficiency in industrial processes, greater water re-use and the decline of resource intensive industries in Europe (ETC/IW, 1998b).

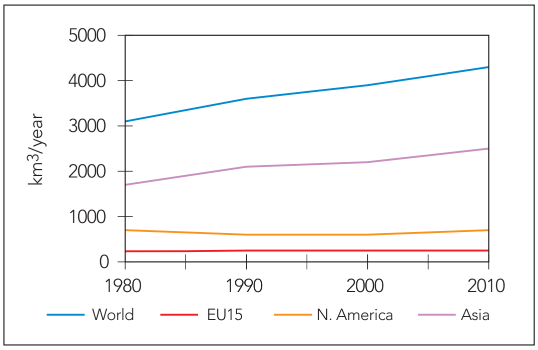
*2.3.3. Agricultural water use*

Over the past decades the trend in agricultural water use has, in general, been upwards, due to increasing use of water for irrigation. However, during recent years in several countries the rate of growth has slowed down. In Spain for example, the area under irrigation expanded from 1.5 to over 3 million hectares during the period from 1950 to 1980 and since then the irrigated area has been roughly stable.

In southern European countries, irrigation is necessary to secure crop growth each year whereas in central and western Europe it is only a means to maintain production in dry summers. The major irrigated areas in EU are in the Mediterranean countries and Romania and Bulgaria in the Accession Countries.

Reforms of Common Agricultural Policy (CAP – see Chapter 3.13) will lead to changes in types of crop being cultivated, the area irrigated and the amount of water used. In principle, two trends can be distinguished. On the one hand, if production is reduced, the demand for production inputs, such as water, is logically bound to diminish. On the other hand, there might be a switch towards more profitable crops, which at least in southern climates frequently require irrigation.

**Total water demand – trends and projections** Figure 3.5.3




**Source**: ETC/IW, 1998b; Shiklomanov, 1998

Unlike in the industrial sector, there remains scope for further improvements in the efficiency of water use by agriculture. Much of the improvement could be realised through changes in practice and behaviour, e.g. by undertaking irrigation more sparingly and when evaporation is less likely to occur, encouraged by the use of price mechanisms and other instruments.

*2.3.4. The overall demand for water in the future*

It is estimated, considering the present and future water demand sector by sector, that the total water demand in the EU will remain relatively stable until 2010 (Figure 3.5.3), although further growth is projected for other regions of the world, due to economic development and increased irrigation (Box 3.5.2).

**Box 3.5.2: The challenge of water resources in Mediterranean countries**

Water resources in the Mediterranean basin area, under increasing pressure, are about to be a major challenge regarding development and security over the next decades. Various figures on exploitation of the resources, analysed against the fast-growing population rate, notably in urban and coastal areas (see Chapter 3.14), lead to an estimate that around 50% of the population may face a water shortage of less than 500 $m^3$/cap/year available. According to a prospective analysis of water resources issues in the countries bordering the Mediterranean Sea (Blue Plan, 1996) it is projected that in 2025 more than 13 countries will be abstracting more than 50% of their renewable water resources and 6 countries more than 100%.

In this context, one should note that waters in the Mediterranean region are naturally of various qualities which hamper their exploitation; for instance, salinity in some places prevents the use of water for human consumption and irrigation in many southern countries. In addition, large pollution discharges and local overexploitation further degrade the quality. Every year, about 15 billion $m^3$ of discharges within the catchment area occur, a large part of which is not treated; 75% of these discharges come from northern Mediterranean countries. Loss of water resources, due to poor management, might represent 47% of the present demand (mainly from agriculture). Reversing that situation would contribute to 90% of the additional demand foreseen to 2010.

In spite of measures and actions, recourse to non-conventional sources of water is therefore expected to contribute to the challenge. Re-use/recycling of waste water, mainly for agriculture, is a key development; it is expected, in Cyprus, to triple the rate of re-use by 2010. Desalinisation is already in use in most islands but the high production costs limit production for human consumption and even for industrial processes. However, these non-conventional sources are estimated to account for less than 5% of water supply in the area by 2025.

**Source**: MAP/Blue Plan; Environment Institute, Cyprus

A similar analysis of the expected evolution of the total water demand in several regions of EU also shows only a slight increase of demand for water in all regions. This is because the rate of growth of the main driving forces is expected to slow and the efficiency of water use is expected to improve, as national water conservation policies and actions have an increasingly positive impact.

Such forecasts are best estimates based on current knowledge, and should be interpreted with caution. This is clearly demonstrated by the fact that the growth rates of water demand registered in some EU countries during the past decade were much lower than the forecasts made in the 1960s and 1970s and to bring the forecasts in line with reality they were on several occasions corrected downwards (Figures 3.5.4 and 3.5.5).

Figure 3.5.4 **Forecasts and actual growth of total water demand in Spain**

**Source**: Spanish Ministry for the Environment, 1998

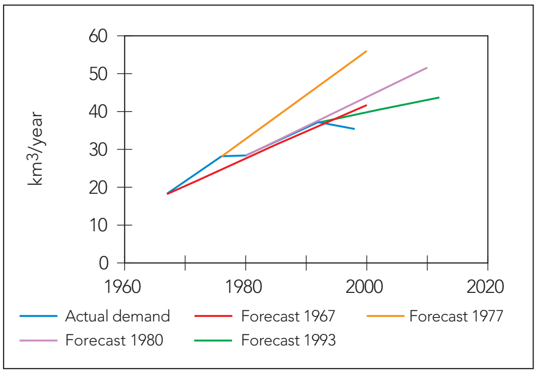
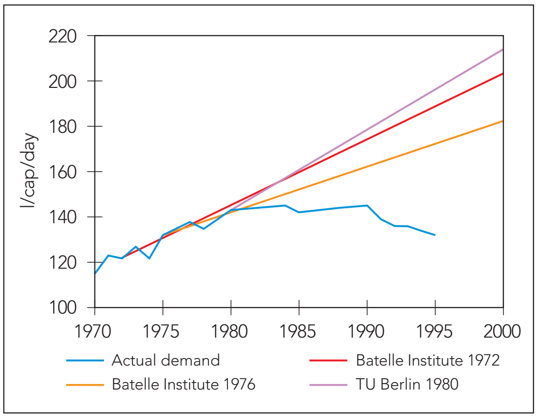



Figure 3.5.5 **Domestic water use per capita in the Federal Republic of Germany – projections and trends (per capita)**

**Source**: Gundermann, 1993




### *2.4. Water shortages*

Long-term water resources assessments do not take into account their irregular distribution in time. Even where there are sufficient long-term resources in an area, the seasonal or year-to-year variation of the resource will, at times, result in problems of water stress. For water resource planners, decisions on water supply are frequently based on the resource they can expect in dry periods and low river flow.

Recent years have shown how vulnerable countries can be to low precipitation. In several (mainly southern) European countries periodic droughts are a major environmental, social and economic problem (Box 3.5.3).

Extended or recurrent periods of drought can intensify the desertification process, which is caused by over-use of soil and water (see Chapter 3.6) leading to deterioration in the natural vegetation cover. The result is a reduction of infiltration into the soil and increased surface flow; furthermore the soil is unprotected and the risk of erosion becomes greater.

Semi-arid Mediterranean countries are the most susceptible to the effects of desertification because of – for example – their mountainous morphology with steep slopes (see Chapter 3.15), rainfall with considerable erosion capacity and over-exploited systems due to the imbalance between resources and abstractions (EEA, 1997).

Intensive exploitation of aquifers can give rise to over-exploitation problems. Aquifer over-exploitation mainly depends on the balance between abstraction and renewable resources. In Mediterranean countries the over-exploitation commonly arises from excessive abstraction for irrigation. The resulting increase in productivity and change in land use can establish a cycle of unsustainable socio-economic development within an irrigated region. Additional resources are exploited to satisfy the increased demand from the population and agriculture, exacerbating the already fragile environment by reducing groundwater levels and, in some circumstances, accelerating the desertification processes (EEA, 1997). Wetlands or wet ecosystems are also damaged when the aquifer water table drops (Box 3.5.4). It is estimated (EEA, 1999b) that about 50% of major wetlands in Europe have 'endangered status' due to groundwater over-exploitation (see also Chapter 3.11).

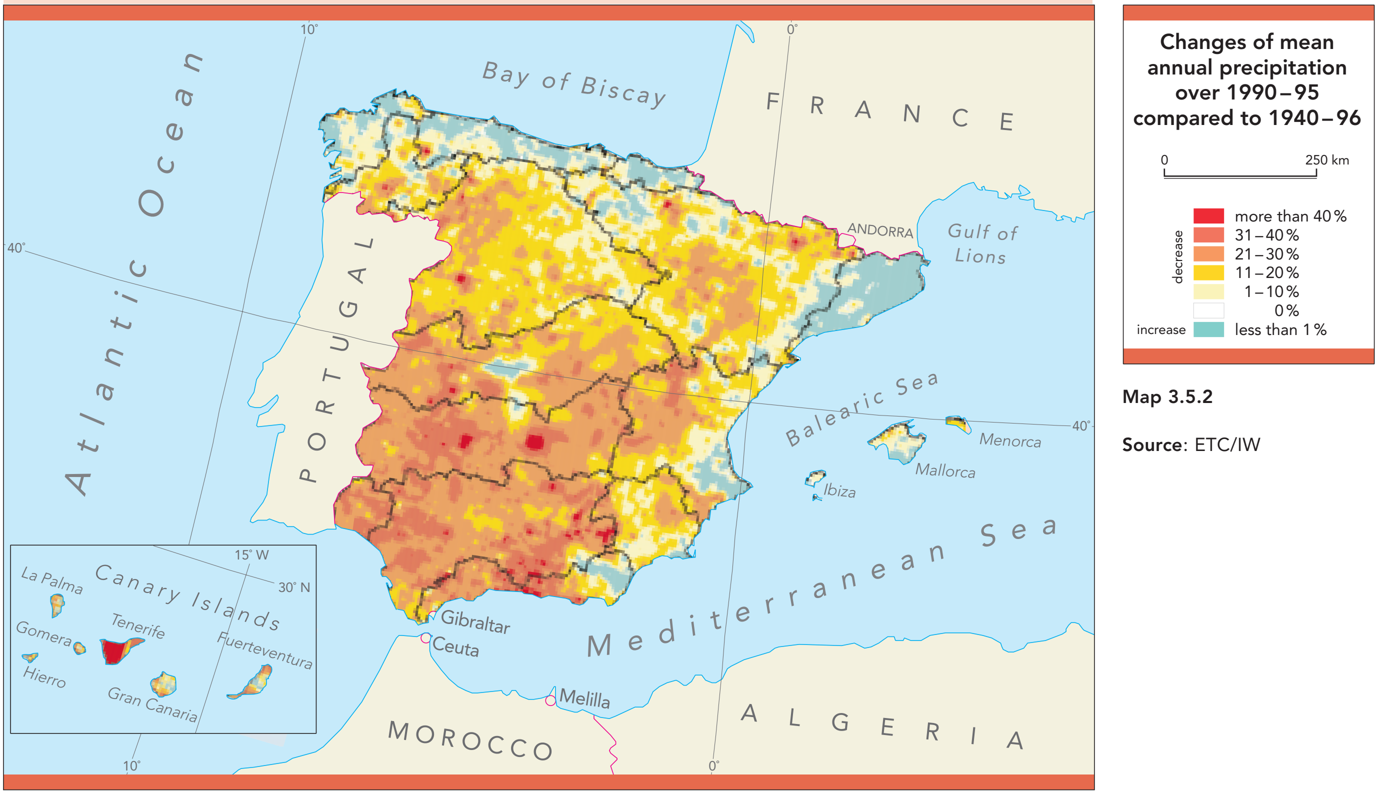
**Box 3.5.3 Droughts in Cyprus and Spain**

*Cyprus*
In Cyprus, water scarcity is creating serious problems and constraining infrastructural development, not only of agriculture, but more significantly of other activities, including tourism, a water- intensive activity. In recent years annual precipitation has fallen well below its historical average. The country is suffering the third-worst three-year drought period of this century, and water in the reservoirs is down to only 10% of total capacity. As a result, and despite many resources being invested in water storage capacity, the quantities of water available for drinking and irrigation purposes have not been adequate.

The present water situation is not sustainable. Development of conventional surface water resources in the past two decades has proved insufficient to respond successfully to the extreme climatic conditions of the past three years.

*The 1990-95 drought in Spain*
Low rainfall during 1990-95 led to a significant reduction in run off and to a spectacular decrease in most of the country's water reservoirs. This adversely affected aquatic life and landscapes in many regions (dry rivers, impact on ecosystems, deterioration of water quality, etc.). Although the drought struck almost the entire territory, it especially increased the problems related to water stress in regions where water resources were already under pressure (Map 3.5.2).

The strategies to confront the situation included a variety of emergency measures to develop new sources of supply (increased use of groundwater, water transfer, use of water of poor quality). The increased use of existing groundwater resources was a major source of additional supply. In total 270 new wells with a pumping capacity of more than 16 $m^3/s$ were opened during the period 1990-95. Also a number of measures aimed at reducing demand were applied (information campaigns, assignment of priorities, restrictions of urban supply). At one time during the period 1990-95, 25% of the population in Spain, especially in the south of the country, was suffering restrictions of domestic water supply.




Map 3.5.2

**Source**: ETC/IW

Salt-water intrusion in aquifers can result from groundwater exploitation along the coast, where urban, tourist and industrial centres are commonly located. The intrusion of salt water is a problem in many coastal European regions, but especially along the Mediterranean, Baltic and Black Sea coasts (EEA, 1995).

## 3. Just using water pollutes it

### *3.1. Agriculture*

Over the past 50 years, more intensive farm management practices, have meant that the use of commercial inorganic fertilizer has increased dramatically. Increased livestock densities have resulted in the production and application of greater loads of manure to cultivated land. Together these trends have contributed to excessive amounts of nutrients, in particular nitrogen, being applied to the soil. Under these conditions, the nutrient load can exceed the removal capacity of the crops and of the soil and leaching of nutrients to water bodies may increase.

In many areas, much of the agricultural land has been drained to enhance production.

**Box 3.5.4 An example of wetland deterioration**

Maintenance of wetlands is dependent on a natural hydrological regime (see Chapter 3.11). In Spain, for the past two or three decades, the 'la Mancha Occidental' aquifer (5 500 $km^2$) has been exploited for irrigation purposes. The abstraction, made by private farmers, has established more than 100 000 ha of new irrigation land. This abstraction (more than 600 M $m^3$/year a few years ago) was higher than the recharge (between 200 and 500 M $m^3$/year, depending on the meteorological year) and had two consequences: economic development of the region and the exploitation of the aquifer.

The decline of the aquifer water level produced serious ecological impacts on some wetlands of La Mancha Humeda, the most important in the National Park "Las Tablas de Daimiel".

The Spanish administration declared the aquifer provisionally over-exploited in 1987, and in 1995 the administration produced its final declaration of over-exploitation. Together with this measure, the administration designed a programme to plan the abstractions. In 1993 a five-year programme was established to compensate for the loss of farmer's income (PCR) when reducing their abstractions. A large part of the compensation (75%) came from the EU. The PCR programme gave rise to the 'Groundwater Users' Community' (the farmers receive compensation through this organisation) and had the effect of reducing the abstractions, but the economic impact was negative for the region, with a loss of jobs in agriculture and small industries (Llamas, 1996).

However, as a result, many of Europe's marshes, wetlands, ponds and lakes have disappeared. This has considerably reduced the capacity of freshwater ecosystems to store and remove many pollutants including nitrogen.

*3.1.1. Nitrogen load*

Agriculture is the main source of nitrogen loading to water bodies. High inputs of nitrogen to water bodies can cause significant ecological changes, especially in coastal areas. At excessive concentrations nitrate in drinking-water is considered to be a human health problem (see Chapter 3.10).

In the five areas (Figure 3.5.6) with the largest nitrogen export coefficient (i.e. Poland, the European part of the Mediterranean basin, Danube basin, North Sea basin and western European countries) there are only small differences in the percentage of arable and total agricultural land. The marked increase in load, i.e. from 6.5 kg N/ha in Poland to around 28 kg N/ha in the western European countries, can generally be explained by more intensive agricultural production, here illustrated by higher nitrogen fertiliser application.

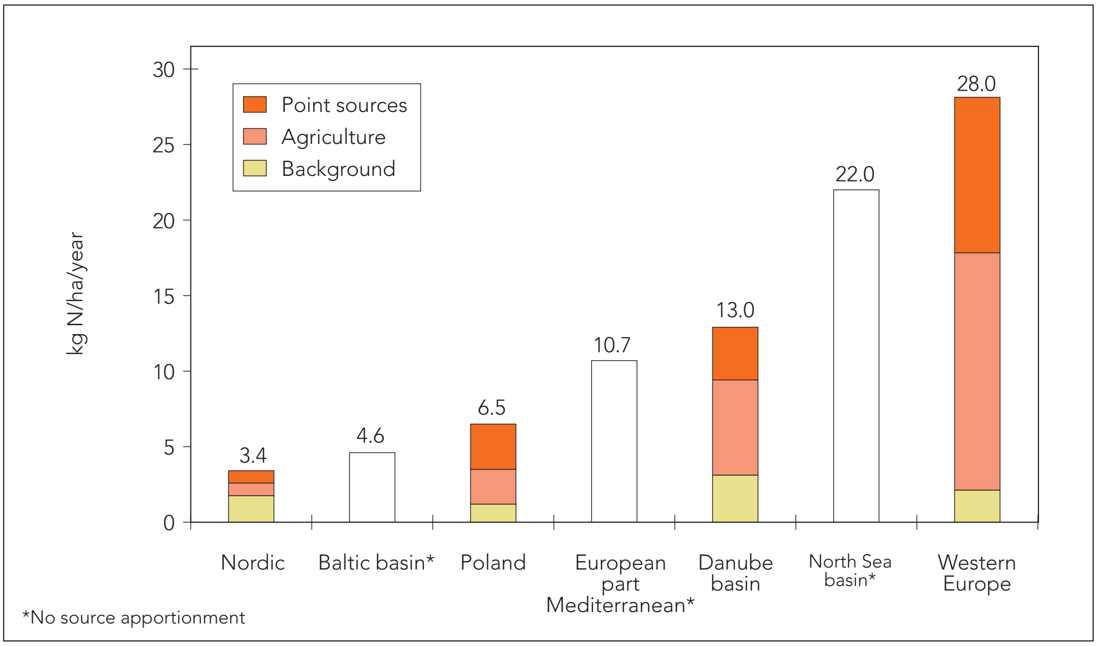
*3.1.2. Nutrient surpluses are highest in regions with intensive livestock production*

Despite documented decreases in fertiliser use, livestock numbers and manure production (Chapter 2.2), European agriculture still adds much more nitrogen to the soil than is

Figure 3.5.6 **Sources of N in selected larger areas (> 300 000 km²)**

Annual nitrogen load per hectare (export coefficient) compared with the percentage of agricultural land, and the application of fertilisers per hectare of *total land* area. No source apportionment for the Baltic Sea catchment, the European part of the Mediterranean catchment and the North Sea. *Nordic:* Norway, Sweden, & Finland. *Eur. Medd.:* European part of the Mediterranean basin *W. Europe:* Germany, the Netherlands, Flemish part of Belgium, Denmark, & Austria.

**Source**: ETC/IW based on 12 different sources



required for crop growth. When this surplus of nitrogen leaches out of the soil and reaches a water body it can create pollution problems. Field balance studies show that countries in north-western Europe generally have the largest nitrogen surplus. In the Netherlands and Belgium the country average nitrogen surplus is around 300 and 180 kg N/ha of agricultural land, respectively, while in Luxembourg, Germany, Denmark and the United Kingdom the surplus is around 100 kg N/ha (Figure 3.5.7). In southern countries, the country average surplus is generally less than 50 kg N/ha.

Even in countries with a relatively low average nitrogen surplus, there may be regions where the surplus is high; they are generally also the regions with high concentration of intensive livestock production (in particular pigs and poultry).

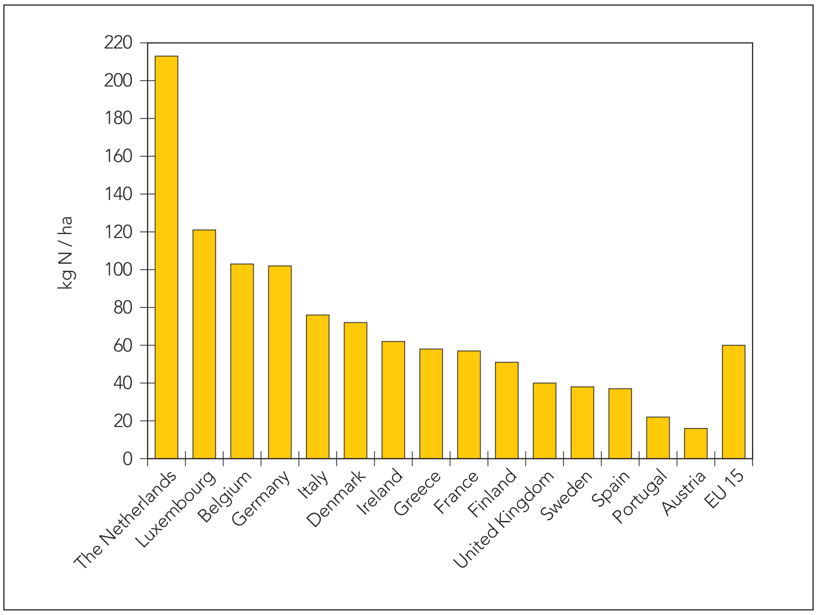
***3.2. Marked reduction in discharge from industry***
Only a small part of the European industrial sector is responsible for the majority of organic matter and nutrients in waste water, in particular the pulp and paper, food processing and fertiliser industries.

Over the past 25 years, emissions of oxygen-consuming substances from the pulp and paper industry have been radically reduced because of the introduction of new techniques and various measures to clean processes. In Sweden and Finland, which account for 60% of the EU production of woodpulp for paper production, the organic matter load has been reduced by around 75% during over the past 15 years, even though production has increased by 20%.

Similarly, because of improved technology there has been a marked reduction in industrial phosphorus discharges in many western European countries. In the Netherlands, the industrial phosphorus discharge was reduced from 14 to 3 ktonnes between 1985 and 1993 (RIVM, 1995) mainly due to discharge reductions at fertiliser plants in Rotterdam harbour.

The phosphorus emission from two major European fertiliser companies (Hydro and Kemira) fell from 15.6 ktonnes in 1990 to 2.6 ktonnes in 1996 (Figure 3.5.8). For comparison, the total annual discharge from Denmark is around 5 ktonnes. In the same period the phosphorus discharged from the pulp and paper industry in Sweden and Finland was halved from 1.2 to 0.6 ktonnes.

**Average nitrogen surplus (difference between input by atmospheric deposition, fertiliser and manure and output by harvested crops)** Figure 3.5.7



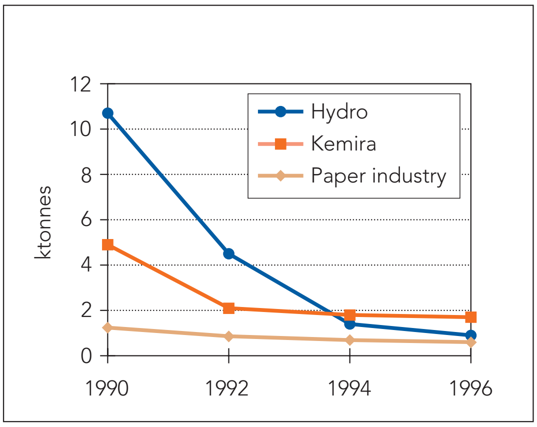

**Source**: Eurostat

***3.3. Phosphorus loads***

*3.3.1. Regional loads*
Excessive input of nutrients to water bodies can result in eutrophication. Households and industry are the most important contributors to phosphorus pollution (Figure 3.5.8). Agricultural activities also contribute to phosphorus loading. In Nordic countries the contribution from uncultivated land and forested areas is proportionally high as inputs from other sources are low.

With increasing population density and human activity phosphorus loading from the area increases. In the Baltic Sea catchment area, for instance, the phosphorus export

**Phosphorus emissions from large industries** Figure 3.5.8



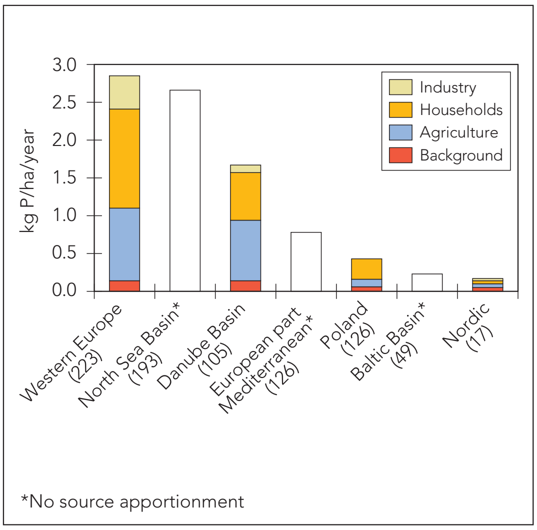

**Source**: Hydro, 1995, 1996; Kemira, 1996; Wahlström, 1996; Statistics Sweden 1990; 1996

Figure 3.5.9

**Sources of phosphorus discharges in selected larger areas (> 300 000 km²)**

Annual phosphorus load per hectare (P export coefficient) compared with population density (inhabitants per km²). No source apportionment for the Baltic, the European part of the Mediterranean catchment and the North Sea. *Nordic*: Norway, Sweden, and Finland; *Eur. Med.*: European part of the Mediterranean basin; *W. Europe*: Germany, the Netherlands, Flemish part of Belgium, Denmark, and Austria.

**Source**: ETC/IW based on 12 different sources




coefficient is 0.23 kg P/ha per year, increasing to 2.7 kg P/ha per year in the North Sea catchment area. The results can be related to increasing population density from less than 50 persons per km² in the Baltic Sea catchment to around 200 persons per km² in the North Sea catchment area.

If there were no human activity (the background level at Figure 3.5.9), phosphorus loads would only be 5% to 10% of the current loads in densely populated areas. In densely populated areas, 50 to 75% or even more of the phosphorus load to surface waters is derived from households and industry, while agricultural activity generally accounts for the remainder. In these densely populated areas, municipal sewage discharge generally accounts for the major part of the point source discharge. However, in some countries, e.g. the Netherlands (because of fertiliser production) and Finland and Sweden (because of the pulp and paper industry), industrial effluents may account for most of the point sources discharge. Diffuse phosphorus loads from agriculture are in some countries quite significant. In the UK, for example, the agricultural contribution is as high as 43% (Environment Agency, 1998), in Germany 46% (Umweltbundesamt, 1997), in Switzerland 50% (Siegrist and Boller, 1999) and in Denmark 38% (Danmarks Miljøundersøgelser, 1997). In Norway, fish farms account for around half of the total phosphorus discharged (see Box 3.5.5).

### *3.3.2. Phosphate-free detergents have reduced the phosphorus produced per capita*

The organic matter and nutrient content of waste water is primarily determined by excreta from humans, by phosphorus from detergents and by the type of industries connected to sewers. Over the past 10-15 years the most marked change in the phosphorus content of waste water in many European countries has been due to nationally imposed reductions in the phosphate content of detergents. Today, in many countries phosphate-free detergents constitute the majority of detergents being sold.

The downward trend in consumption of detergents containing phosphate occurred especially from the late 1980s to 1992/93 with a more than 50% reduction in the use of phosphate in detergents in many countries. In 1992, the average detergent-phosphorus consumption per capita was between 0.1-0.4 kg P/year. Phosphate-free detergents are used much less in the Accession Countries (Ijjas, 1996).

The marked reduction in the phosphorus content of detergents is also reflected in the waste water flowing to waste-water treatment plants. In Denmark, Finland and Switzerland, for instance, the phosphorus being produced per person was reduced from around 1.2-1.7 kg P/year in the 1980s to less than 1 kg/year in the 1990s. Much smaller changes have occurred in the per capita production of organic matter and nitrogen.

## 4. Waste-water treatment

Industry and households produce waste water containing all sorts of pollutants including organic matter and nutrients (mainly phosphorus). The extent to which the pollutants in waste water are discharged into surface waters depends on the waste-water treatment facilities available. Similarly, agricultural activities lead to the discharge of a variety of pollutants to water bodies, the most important being nitrogen resulting from the excess application of artificial fertilisers and manure. At a local level, the accidental spills of oxygen consuming liquid manure and silage juice to small streams can severely threaten the natural fauna dependent on good oxygen conditions in the water thus reversing the improved conditions resulting from waste-water treatment.

## Box 3.5.5: Fish farms: one of the fastest-growing food industries

From 1984 to 1996, the production in Europe's fish farms increased by more than 250%, making it one of the fastest-growing food production activities. In Europe, about 5% of all fish production in 1995 was attributable to fish farms. Yet this industry's contribution to the human diet is actually greater than the numbers imply. Whereas a proportion of the conventional fish catch is used to make fishmeal and oil, virtually all farmed fish is used as human food.

**Salmon from west – carp from east**
Europe's fish farms fall into two distinct groups: in western Europe the fish farms grow high-value species such as salmon and rainbow trout, frequently for export, whereas in central and eastern Europe the fish farms grow lower-value species such as carp that are mainly consumed locally (Figure 3.5.10).

In the period 1984 to 1996, European production of Atlantic salmon increased 15 fold (Figure 3.5.11). Since 1987 the growth has been 40 to 60 ktonnes per year, except for a period of consolidation in the early 1990s, because of problems of marketing and control of parasites and diseases. In 1984 the production of rainbow trout was five times the salmon production, and has nearly doubled over the last 13 years. The production of common carp was nearly constant between 1984 to 1991 and declined thereafter by 35%. The reduction was most significant in Romania and Hungary (60-70%).

As currently practised, fish farming also causes environmental damage. The farmed fish need artificial feeding and in many cases treatment with chemicals; these and the surplus of food and the faeces may be discharged to the surrounding waters. It is inevitable that fish escape from fish farms. The escapees may be of completely different genetic stock from native and the long-term effects on native stocks are unknown.

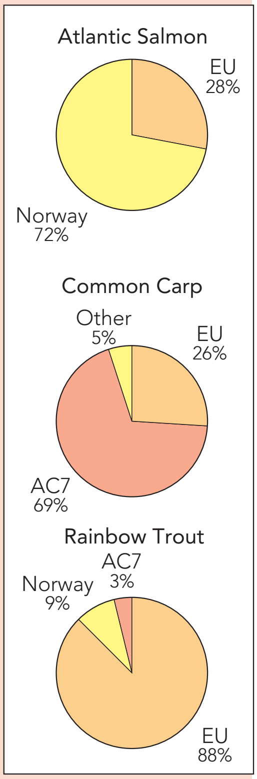
**Chemicals in fish farming**
Chemicals, particularly formalin and malachite green, are used in freshwater farms to control fungal and bacterial diseases. In marine farms antibiotics are used for disease control but amounts have been drastically reduced in the past years following the introduction of vaccines.

**Fish farms' discharge is equal to untreated waste water discharge from five million persons**
In marine areas the fish are reared in large cages or net enclosures in sheltered coastal areas. When they are fed, the situation is the same as it would be if a farmer threw some of his fertiliser or manure straight into the water. Inland fish are generally reared in artificial ponds, from which outflows of organic matter and nutrients are easier to control. Annually, around 3 to 8 ktonnes of phosphorus and 30 to 60 ktonnes of nitrogen are discharged from European fish farms. The amount of nutrients being discharged is equal to untreated waste water from five million persons.

The comprehensive development of the feed composition and the feeding technology have over the past years resulted in reduced load of nutrients from fish farms, calculated per tonne of fish produced. The effect of the technology improvement on the total nutrient loading has partly been halted by the marked increase in production.

**Big production increase still expected**
In the long term, there is a real possibility that production of farm fish will still continue to increase. This will probably result in rising discharges of nutrients, organic matter and chemicals. The choice of technology for fish farms will be one factor that affects the extent of the increase. Fish farms should increasingly take account of pollution problems. In addition, the concept of integrated coastal management and planning provides an appropriate framework for assessing environmental effects of fish farms.

**Fish-farming by European regions in 1996** Figure 3.5.10

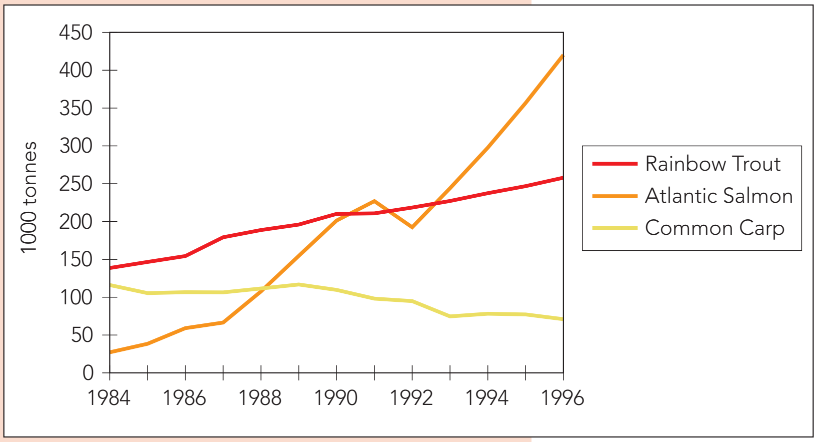



Total Atlantic salmon, rainbow trout and common carp production are 420 258 and 71 ktonnes, respectively.

**Source**: FAO Aquacult PC, 1998

AC7: Bulgaria, Czech Rep. & Slovak Rep. (Czechoslovakia ), Hungary, Poland, Slovenia & Romania.

**Main fish-farming productions, 1984-96** Figure 3.5.11



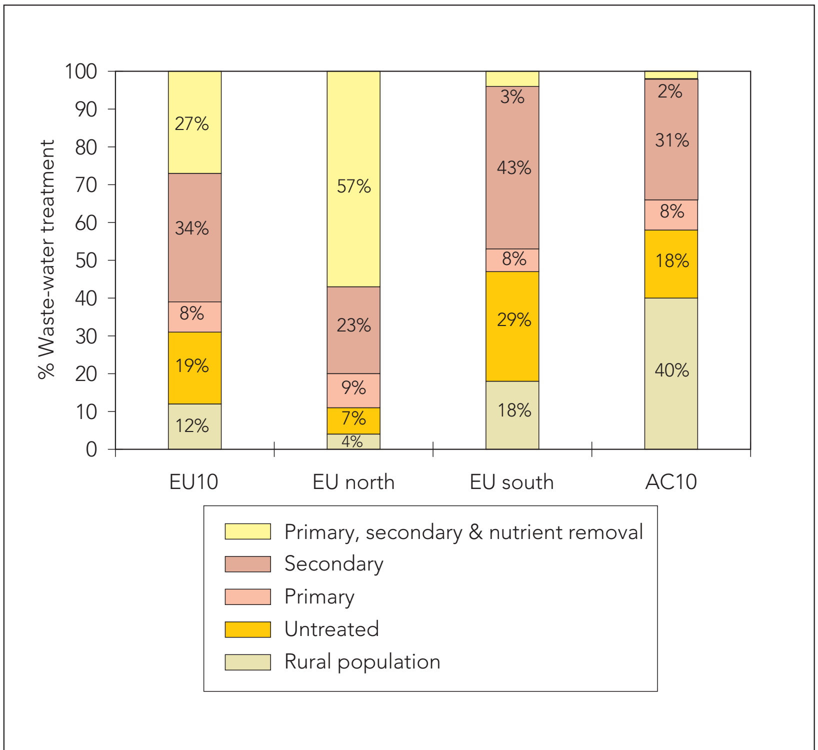

**Source**: FAO Aquacult PC, 1998

### *4.1. Better waste-water treatment in Northern Europe*

Around 90% of the EU population is connected to sewers and around 70% to municipal waste-water treatment plants (Figure 3.5.12). However, some regional differences do exist. In northern countries generally more than 90% of the population is connected to waste-water treatment plants, while the percentage in southern Europe varies between 50% and 80%. The absence of a sewer connection does not necessarily imply inadequate sewage treatment, because rural populations not connected to sewers may have efficient individual treatment systems.

The more advanced waste-water treatment is found in the northern Member States with 57% of the waste water treated in plants with nutrient removal (tertiary treatment) and a further 23% treated in plants with biological removal of organic matter (secondary treatment). Tertiary treatment is found in the Nordic countries, Austria, Germany and the Netherlands, while most of the waste water in the United Kingdom and Luxembourg is treated in plants with secondary treatment.

Figure 3.5.12 **Population served by different treatment levels in three European regions**




Rural population is the population not connected to sewers; EU north: DE, FI, NL, LU, UK; EU south: FR, IT, GR, ES, PT; AC10: Accession Countries minus Cyprus

**Source**: Compiled on basis of information from European Waste Water Group (1997) and other sources (ETC/IW, 1998a).

In the southern Member States 29% of waste water is discharged without any treatment and only 43% of the waste water is treated in secondary treatment plants. Here the highest level of treatment is generally found in France and Italy, where more than half of the waste water was secondarily treated.

In the Accession Countries (excluding Cyprus; AC10) 40% of the population is not connected to sewers and from 18% the waste water is discharged without any waste-water treatment (untreated). The remaining 42% of the waste water receives treatment before being discharged into surface waters, with most waste water receiving secondary treatment.

In many areas of Europe, but in particular in AC10, many of the sewer systems are old, overloaded and leaking, potentially affecting groundwater quality. In addition, many sewer systems have an inflow of groundwater, diluting the waste water and resulting in more water going to treatment plants. At many of the waste-water treatment plants operational problems and low level of efficiency are frequent problems and some are heavily overloaded.

#### *4.1.1. Marked improvement in waste-water treatment*

Over the past 15 years marked changes have occurred in the proportion of the population connected to waste-water treatment as well as in the waste-water treatment technology involved (Figure 3.5.13).

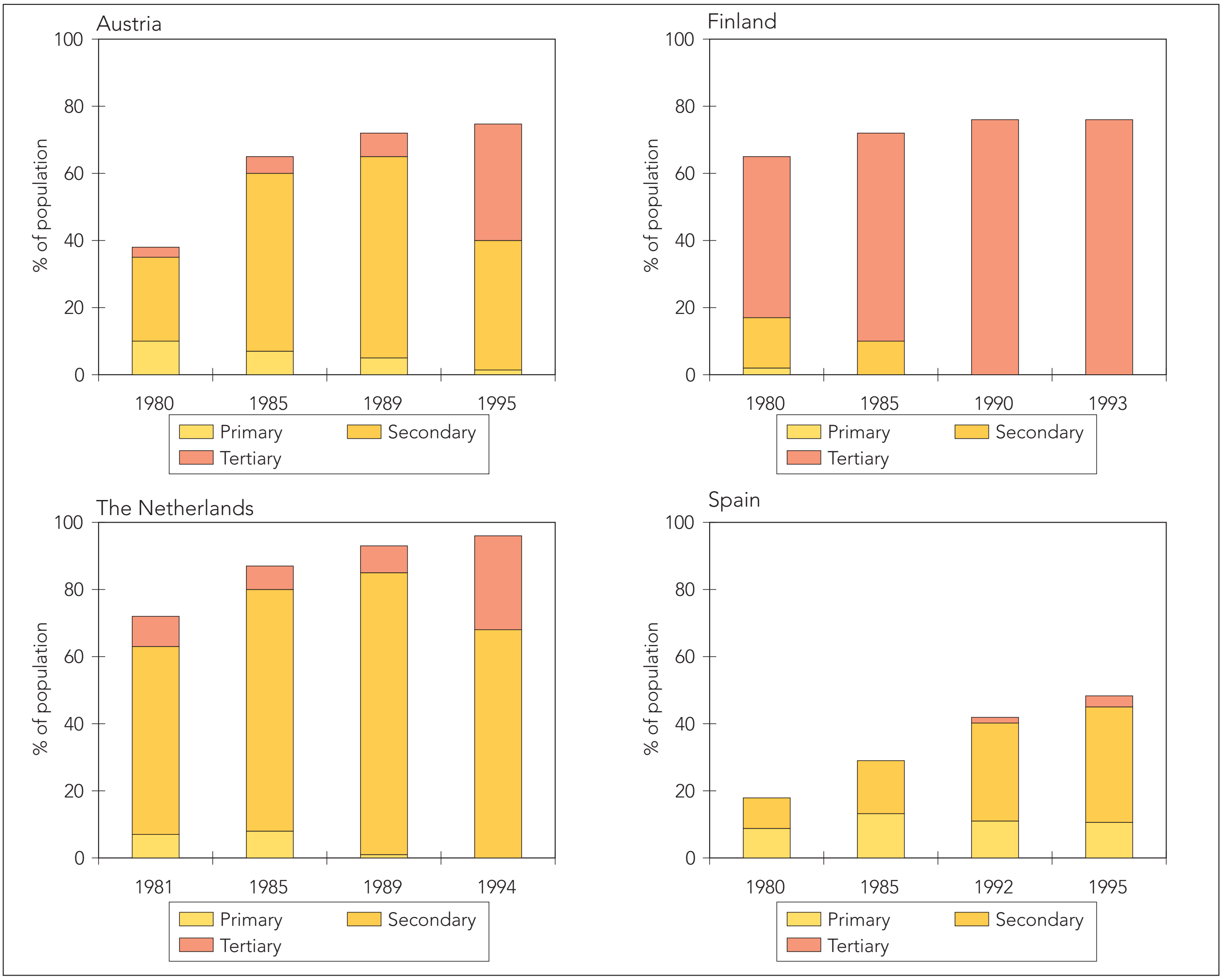
There has been a dramatic increase in sewer connections in those EU countries where the connection rates were comparatively low: in Austria and Spain, it has nearly doubled over the past 15 years. However, there is still some way to go: in 1995 only half of Spain's population had their waste water treated in treatment plants, and some of the waste water going to sewers was discharged untreated.

In the late 1980s and in the 1990s many of the western countries constructed treatment plants with nutrient removal, e.g. there was a marked increase in tertiary treatment in Austria and the Netherlands from 1990 to the mid-1990s.

#### *4.1.2. Marked reductions in emissions from urban waste-water treatment plants*

Over the past 15 years reductions of 50-80% in organic matter discharges and 60-80% in phosphorus discharges have been observed

Development in waste-water treatment in selected EU countries | Figure 3.5.13




Only data for untreated waste water for the last year

**Source**: OECD 1997

in many of the northern EU countries. Part of the reduction in phosphorus discharges can be explained by the shift to use phosphate-free detergents (see above).

Compared to the marked reduction in discharges of organic matter and phosphorus, there have only been small reductions in the discharge of nitrogen. Only a few countries have upgraded their waste-water treatment plants to include nitrogen removal: for instance in Denmark 73% of the waste water is treated in plants with nitrogen removal and current nitrogen emissions from waste-water treatment plants are around 40% of the discharges in the mid-1980s.

### *4.2. Future waste-water treatment*

*4.2.1. EU Member States*

Under the baseline scenario, the existing waste water facilities in 10 EU Member States, covering 90% of the EU population, are assumed to have been upgraded fully to implement the requirements of the Urban Waste-water treatment Directive (UWWT, see Box 3.5.6). The scenario is based on results reported by national contacts to the European Waste Water Group (1997).

Full implementation of the UWWT Directive, which is expected before 2010, should halve the population not connected to sewers (from 64 to 29 million persons). This would mean that 95% of the total waste water is discharged to sewers (Figure 3.5.14).

With a marked upgrading in waste-water treatment, most waste water would either receive secondary treatment or secondary treatment plus nutrient removal. Sweden and Denmark currently have most of their waste water treated in plants with nutrient removal, while major upgrading of the waste-

**Box 3.5.6 Urban Waste-water treatment Directive (UWWTD)**

The UWWTD obliges Member States to provide all agglomerations of more than 2 000 population equivalents (p.e.) with collecting systems, and secondary treatment (i.e. biological treatment) for all agglomerations of more than 2 000 population equivalent (p.e.) discharging into fresh waters and estuaries and for all agglomerations of more than 10 000 p.e. discharging into coastal waters.

Member States have to identify water bodies as sensitive areas in accordance with the criteria of the Directive (eutrophication, high concentration of nitrates in surface waters intended for abstraction of drinking water, areas where further treatment is necessary to fulfil other directives). In sensitive areas and catchment of sensitive areas Member States have to ensure the provision of more advanced treatment.

For agglomerations smaller than those described above and which are equipped with a collecting system the treatment must be appropriate, which means that the discharge allows the receiving waters to meet the relevant quality objectives.

The deadline for the implementation of these collection and treatment systems is 31 December 1998, 31 December 2000 or 31 December 2005, depending on the size of the agglomeration and the identification of the receiving waters.

Member States have to ensure that by 31/12/1998 the disposal of sludge from urban waste-water treatment plants is subject to general rules or registration or authorisation in order to minimise the adverse effects on the environment. The disposal of sludge to surface waters has to be phased out by this deadline.

The Directive also contains requirements concerning the discharge of biodegradable industrial waste water from plant representing 4000 p.e. or more. The deadline for this application is 31 December 2000.

water treatment plants is planned in Austria, Belgium and Ireland.

Some countries, such as Spain, Italy, Portugal and the UK, have decided that most waste water should receive secondary treatment, while in the other EU countries most of the water bodies have been classified as sensitive and the waste-water would therefore be treated in plants with nutrient removal.

With full implementation of the UWWT Directive, the discharge of organic matter after implementation of the UWWT Directive is expected to fall from 3.4 to 1.2 Mtonnes $BOD_5$, a reduction of 65% from current levels. In addition, phosphorus and nitrogen discharges should decrease by 31% and 21% respectively; from 210 to 145 ktonnes P, and from 1030 to 810 ktonnes N.

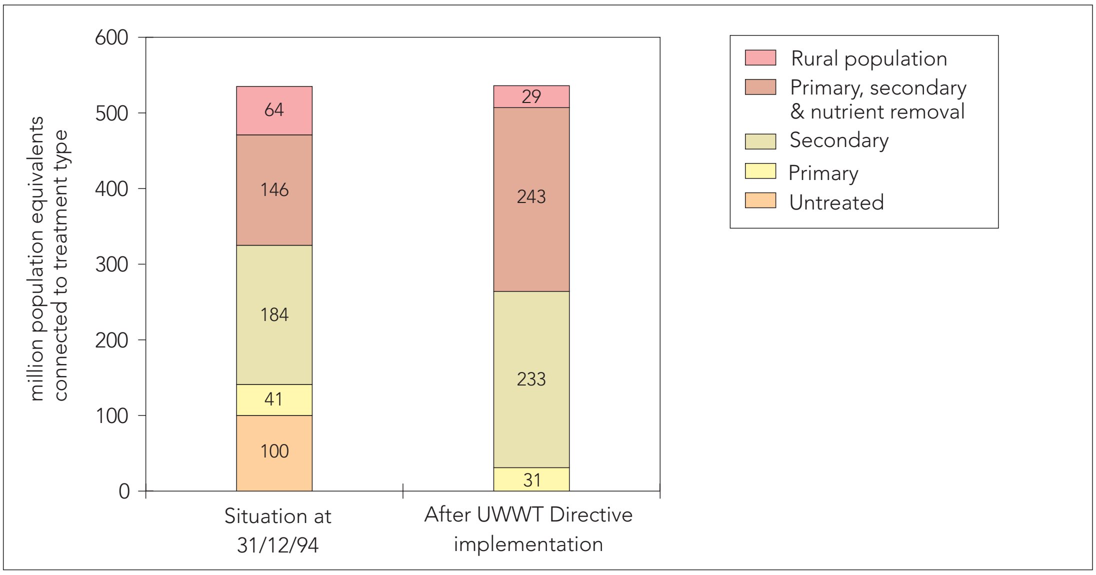
The investment cost of implementing the UWWT Directive in the EU has been estimated at 140 EUR per capita for waste-water treatment alone and 300 EUR per capita for waste-water treatment and collecting systems together. Beside, the intensification of waste-water treatment will increase the quantity of contaminated sludge generated by the treatment process (see Chapter 3.7).

Construction of waste-water treatment plants will be concentrated in the catchment areas of heavily polluted rivers, and so the improvement in water quality should be even greater than suggested by the emission reductions. Thus, the number of river stretches heavily polluted by organic matter should be mark-

Figure 3.5.14 **Development in the number of population equivalents connected to different types of waste-water treatment (EU10)**

Person equivalents (p.e)
EU10: DE, ES, FI, FR, GR, IT, LU, NL, PT, UK.

**Source**: Compiled from European Waste Water Group, 1997



edly reduced, especially in southern and eastern parts of the EU, where the current waste-water treatment level is low.

Reduced discharges of nutrients from point sources are also expected to reduce eutrophication effects, especially in water bodies with current high concentrations. For these and other water bodies, nutrient concentrations will be largely determined by the diffuse loads from agricultural activities.

The baseline scenario, with full implementation of the UWWT Directive, has been applied to estimate the downstream concentration of nutrients in large EU rivers (European Commission, 1999). The results demonstrate that overall river phosphorus concentrations could decrease by 0.1-0.2 mg P/l in the period 1990 to 2010, while the nitrate concentrations are likely to remain unchanged in most rivers. In many rivers in north-western Europe, phosphorus concentrations have already decreased by around 0.1 mg P/l during the first half of the 1990s.

*4.2.2. Accession Countries*

Similar baseline scenarios have also been developed for the implementation of the UWWT Directive in the AC10. In these countries around 40% of the population is not currently connected to sewers. Thus the effect of implementation of the Directive will depend significantly on the development of sewerage in the coming years. Three possible 'what if' scenarios for the period 1995 to 2010 have been assessed (EEA, 1999):

A: Moderate development of sewerage and waste-water treatment as a requirement for normal areas (secondary treatment);
B: High effort on sewerage development and waste-water treatment as a requirement for normal areas (secondary treatment);
C: High effort on sewerage development and waste-water treatment as a requirement for sensitive areas (secondary treatment plus nutrient removal).

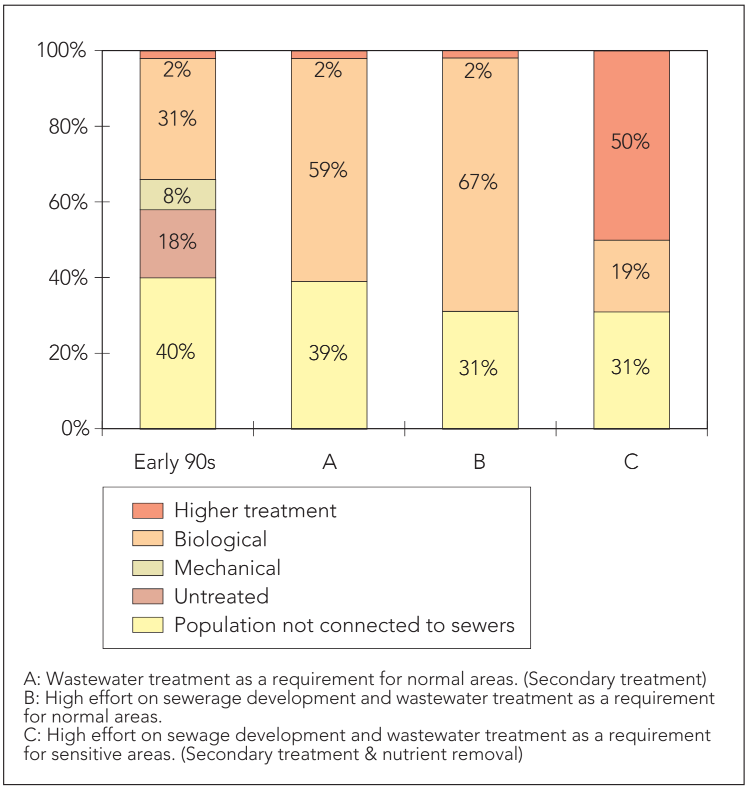
The predicted changes in waste-water treatment are illustrated in Figure 3.5.14. The proportion of the population not connected to waste-water treatment is expected to decrease from the current 40% to around 31% under scenarios B and C.

Waste-water treatment will also improve. Currently most discharges are untreated or mechanically treated. In the future waste water will be either treated biologically, as in scenarios A and B; or biologically with nutrient removal, as in scenario C. Scenario C is similar to the expected situation in the present EU following implementation of UWWT Directive, except that the proportion of population not connected to sewers is higher in the Accession Countries.

Under scenarios A and B, the extent of biological treatment of waste water is expected to increase from the current 31% to 59% and 67%, respectively by 2010. If realised, this should result in a reduction of organic matter being discharged from the current value of 1.1 Mtonnes to around 0.45 Mtonnes, that is a 60% reduction (Figure 3.5.16). Implementation of scenario C should result in a small additional reduction (5%) in the amount of organic matter discharged to about one third of the current loads.

Only small changes are expected in the future amount of nutrients discharged under the two first scenarios, namely a reduction of 12% and 10% for phosphorus and nitrogen respectively. In scenario C with half of the waste water being treated in

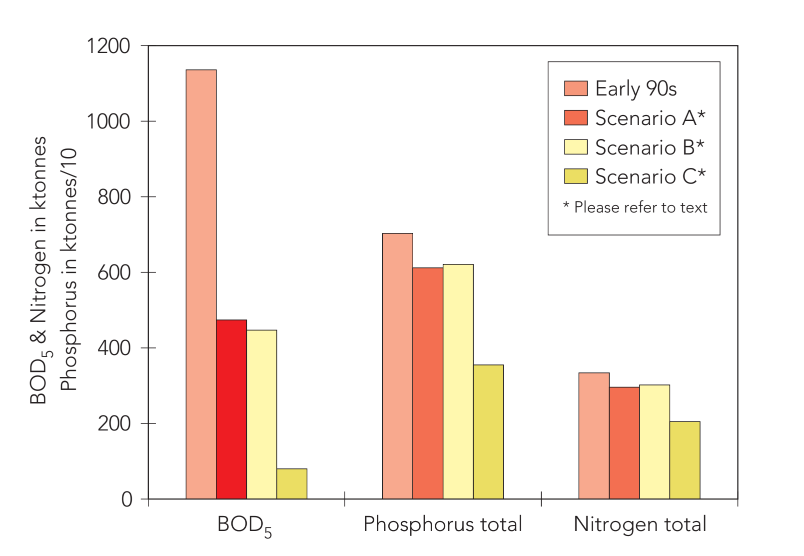
**Development in waste-water treatment in the Accession Countries (excluding Cyprus)** Figure 3.5.15




**Source**: EEA, 1999

Figure 3.5.16

**Change in emissions from urban waste-water treatment plants as result of three scenarios, Accession Countries**




Phosphorus discharges should be divided by 10

**Source**: EEA, 1999

plants with nutrient removal, a 50% reduction in phosphorus discharges and a 40% reduction in nitrogen discharges would be expected by 2010 compared to the current loads. This would potentially reduce the nitrate and phosphorus loading from rivers in the Accession Countries to both the Baltic and Black seas by around 15% and 28% respectively.

The cost for the most radical implementation of the UWWT Directive in the Accession Countries as in scenario C is estimated at 9 billion EUR (around 100 EUR per capita), for the construction of treatment plants (van Driel, 1998); this does not include costs of additional sewer construction and sludge treatment and disposal.

## 5. Trends in quality

### *5.1. Improvement in oxygen conditions and river quality*

*5.1.1 Organic pollution, a success story*

The most important sources of the organic waste load are: household waste water, industries such as the paper industry or food processing industry, and silage effluent and slurry from agriculture. Severe organic pollution may lead to rapid deoxygenation of river water and disappearance of fish and aquatic invertebrates.

Increased industrial and agricultural production coupled with more of the population being connected to sewerage meant that the discharge of organic waste into surface water increased in most European countries from the 1940s onwards. Over the past 15-30 years however, biological treatment of waste water has increased, and the organic loading has consequently decreased in many parts of Europe. The result is that many rivers are now well oxygenated.

The changes in the river Rhine is an illustrative example (Figure 3.5.17). Up to the early 1970s, the Rhine was polluted with such excessive amounts of organic matter that the oxygen depletion was so serious in the central and lower reaches that the river was virtually dead. Since then, the oxygen conditions have markedly improved, and as a result the number of invertebrate species has nearly reached the numbers observed early this century.

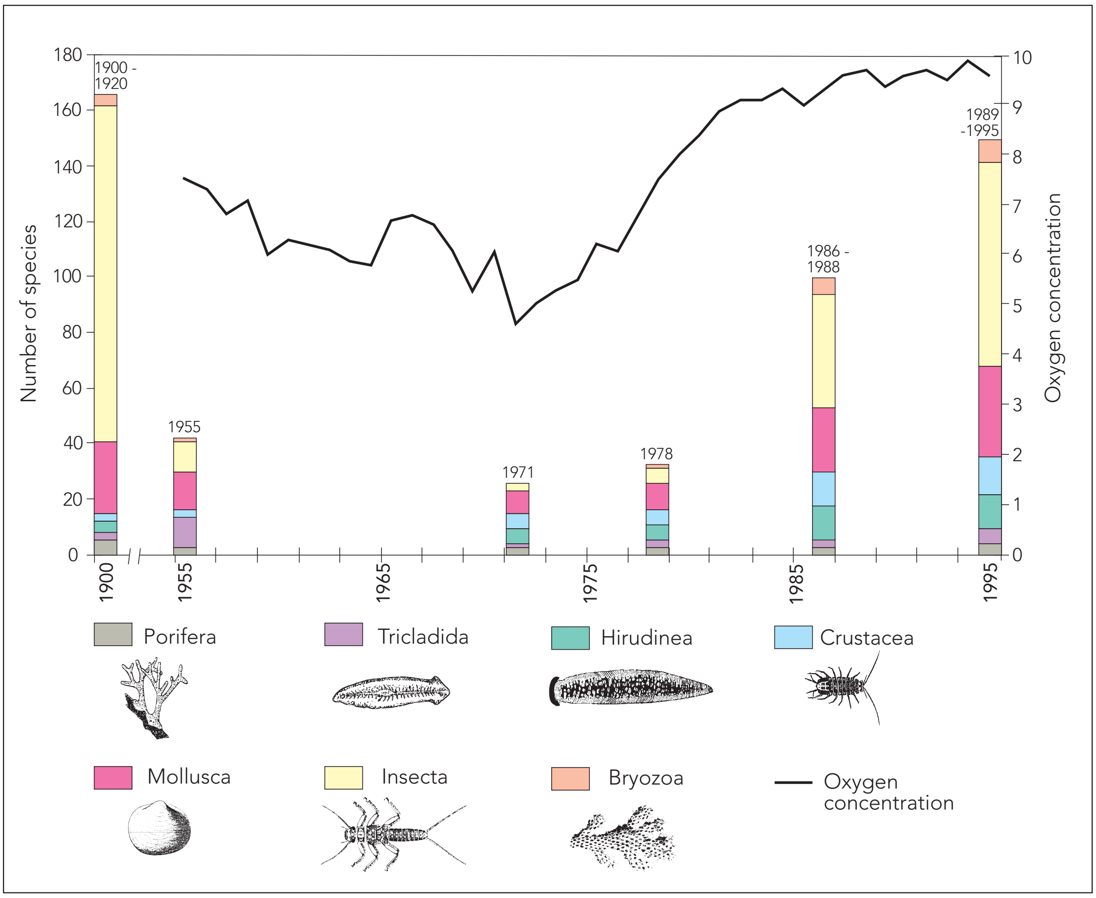
Information from about 1 000 river sites across Europe shows that in the mid-1990s, 35% of the sites had an annual average concentration of organic matter measured as BOD (Biochemical Oxygen Demand) below 2 mg $O_2$/l (the typical value for unpolluted rivers) while 11% were heavily polluted and had an average BOD greater than 5 mg $O_2$/l. Rivers with high BOD levels are generally subject to high human and industrial use. In the Nordic countries and western Europe less than 10% of the rivers have BOD levels higher than 5 mg $O_2$/l, while around 25% of the rivers in southern and eastern Europe are heavily polluted with organic matter (Figure 3.5.18).

Generally, the concentration of organic matter in European rivers has fallen over the past 10 to 20 years, particularly in the most polluted rivers. In western Europe there has since the late 1970s been a marked decrease in the number of heavily polluted rivers from 24% in the late 1970s to 6% in the 1990s, while the decrease in southern and eastern Europe started in the 1980s and are less significant. The decrease reflects improvements in the treatment of domestic sewage and industrial waste water.

Improvements in the oxygen conditions of European rivers are consistent with the reduction in concentrations of organic matter. The oxygen concentration in the river Rhine has, for instance, increased from an annual average value around 5 mg $O_2$/l in the 1970s to current values around 10 mg $O_2$/l (see Figure 3.5.17).

**Development of biotic community of the Rhine (selected animal groups) and oxygen concentration (at Bimmen)**

Figure 3.5.17




**Source**: German Federal Ministry of the Environment, 1998

*5.1.2. Ecological impacts*

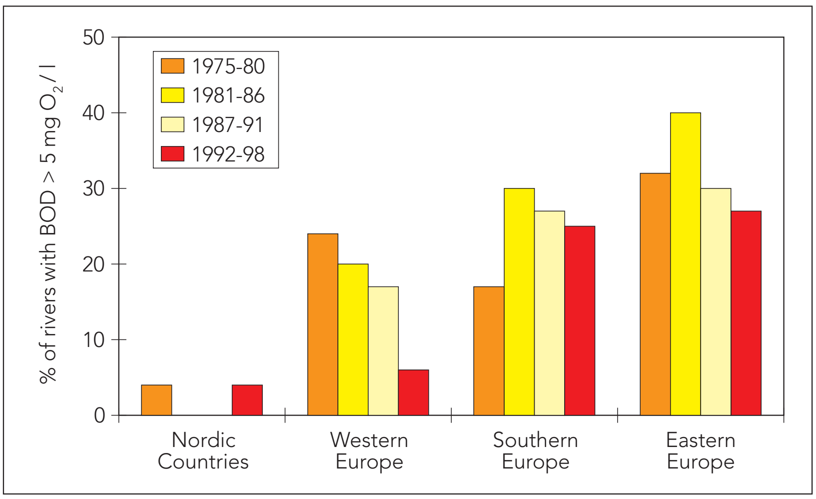
The oxygen consumption caused by organic matter pollution has a strong impact on the riverine fauna. Heavily polluted rivers have a low biodiversity and an invertebrate fauna dominated by species tolerant to low oxygen concentrations. Many European countries use either biochemical organic pollution indicators (e.g. oxygen levels, BOD and ammonium concentrations) or invertebrate indices for classification of river quality.

In general, most of the countries classify 80% to 95% of the river stretches as having good and fair quality. However, in some countries such as Belgium, Bulgaria, the Czech Republic, Denmark, Lithuania and Poland more than 25% of the river stretches surveyed have been classified as poor or bad quality. The rivers with poor or bad quality are generally rivers polluted by waste-water discharges and are in regions of high population density and intensive farming.

An illustration of the bad quality of some of the rivers in eastern Europe, also to illustrate that the measures to improve quality are

**Percentage of heavily polluted rivers (i.e. rivers with BOD concentration levels greater than 5 mg $O_2$/l)**

Figure 3.5.18



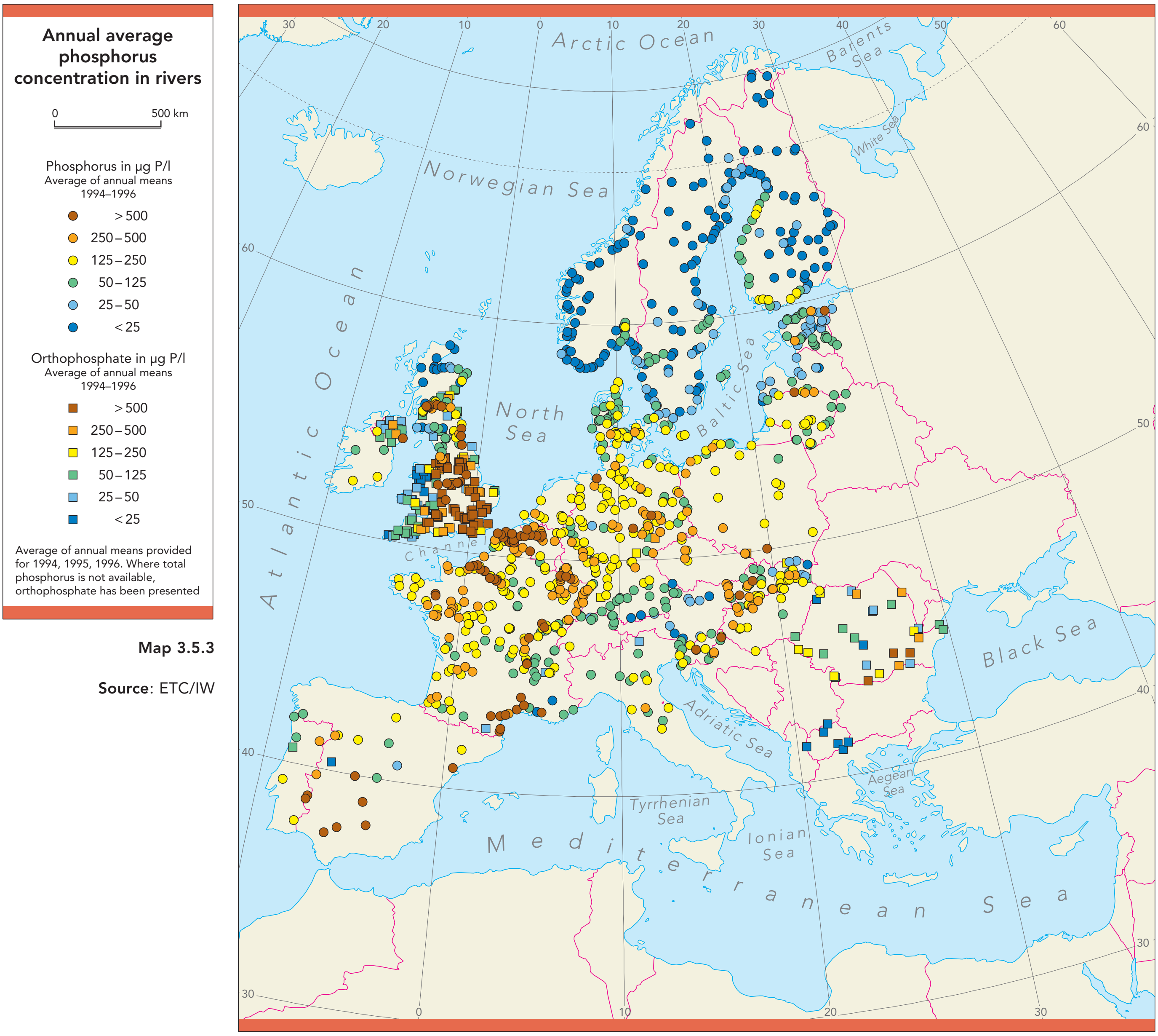

**Source**: ETC/IW

rather straightforward, could be the situation in the river Elbe after the reunification of Germany in 1990. Here it proved necessary to introduce a new water quality class 'ecologically destroyed' to describe the water quality of some stretches of the river. In 1995, because of the closure of major industries and the construction of new waste-water treatment plants, especially in the New Länder and the Czech Republic, water quality in the Elbe has markedly improved. In the catchment area of the Elbe more than 125 waste-water treatment plants are being built at a cost of DM 14 billion (German Federal Ministry of the Environment, 1997).

### *5.2. Phosphorus levels are declining in rivers and lakes*

Information from about 1 000 river stations in Europe shows that 90% of the stations had a mean concentration of total phosphorus exceeding 50 µg/l (Map 3.5.3). The concentration in rivers unaffected by human activities are for comparison generally less than 25 µg/l. The lowest concentrations are found in the Nordic countries, whereas the river stations in a band stretching from southern England across western and central Europe to Romania have relatively high concentrations.

The phosphorus concentration in European lakes and reservoirs is similar to the state of the rivers. In the Nordic countries more than half the lakes have a concentration below 10 µg/l, whereas in most other countries, a large proportion of the lakes have phosphorus concentrations far exceeding a near natural state, in this context considered as below 25 µg/l.




Map 3.5.3

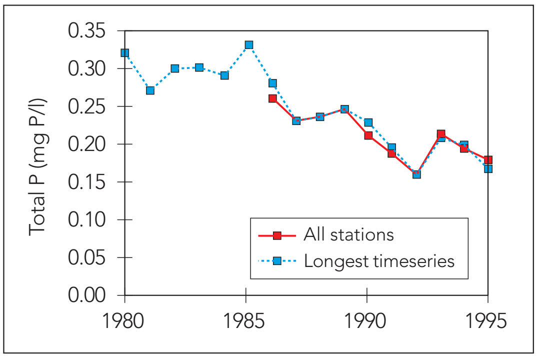
**Source:** ETC/IW

The concentration of phosphorus in EU rivers has decreased since the mid-1980s, particularly in the most polluted rivers. The long time-series available for some river stations reported under Council Decision (77/795/EEC) on Exchange of Information, indicates roughly a 25% reduction of the concentrations (Figure 3.5.19), from the early 1980s the early 1990s. The changes have been most pronounced in the previously most polluted rivers.

Similar changes have been observed in many lakes (e.g. lake Constance; Figure 3.5.20). Here the phosphorus level increased in the 1960s, but since the mid-1970s, when measures were taken to reduce the phosphorus load, the lake phosphorus concentration has decreased. Although the phosphorus level of European lakes has decreased markedly, water quality in many lakes in large parts of Europe is still poor and below that of lakes in good ecological state.

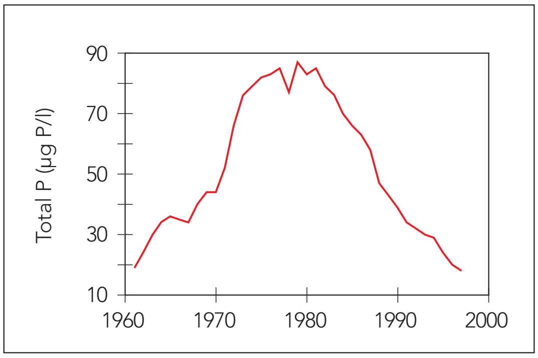
The declining concentrations of phosphorus results from improved waste-water treatment and reduced content of phosphorus in detergents. Having reduced the pollution from the point sources it may, in many cases, also be necessary to take measures to reduce the diffuse load of phosphorus from agricultural areas, particularly where the absorption capacity of the soil may be exceeded, for example, in parts of Ireland, where such measures are being introduced.

**Development in river phosphorus concentration in 126 large river stations – median of annual averages** — Figure 3.5.19




**Source**: Codling and Bøgestrand, 1998

**Development in lake Constance phosphorus concentration** — Figure 3.5.20




Volume-weighted annual averages of phosphorus (in epilimnion)

**Source**: IGBK, 1998

### *5.3. Nitrate in European waters*

*5.3.1. Why worry about nitrate?*

Nitrate in drinking-water is considered to be a public health problem because nitrate rapidly reduces to nitrite in the body. The major effect of nitrite is that it reduces the capacity of the blood to transport oxygen. This phenomenon has only been observed at nitrate levels significantly above the 50 mg/l level therefore this level delivers sufficient protection against this occurring. In addition, nitrite reacts with compounds in the stomach to form products which have been found to be carcinogenic in many animal species, although the link to cancer in humans is at the moment suggestive. Nevertheless, these two factors together totally justify a precautionary approach being taken in the establishment of this parameter.

*5.3.2. Drinking water*

In Europe, most people are served with drinking-water taken from groundwater sources (EEA, 1999b). Most groundwater supplies in the EU are generally from deep wells not affected by high nitrate levels, although private and small communal supplies are usually derived from shallow groundwater sources, and if these are contaminated with nitrate the population is at risk.

In the EU, the concentration of nitrate in drinking-water has been regulated since 1980 by the Drinking-water Directive. This establishes a guide level of nitrate of 25 mg/l and a Maximum Allowable Concentration (MAC) of 50 mg/l. No complete overview of nitrate in drinking-water exists in the EU, only information from selected national surveys. A study of more than 5 000 samples from private well waters throughout Belgium has shown that 29% exceed the MAC of 50 mg $NO_3$/l (Verbruggen, 1997). Thirteen percent of the Finnish population has water supply from private wells, of which 12% has a nitrate content exceeding 25 mg $NO_3$/l (Wahlström *et al.*, 1996).

Nitrate levels were evaluated at more than 3 000 sampling sites in France in 1992-93 (IFEN, 1996). The sampling sites were mainly abstraction points for supplying drinking-water from both groundwater and surface water. In all, water in 25% of the sampling sites had nitrate concentration over 40 mg/l. In addition, the nitrate concentration exceeded 50 mg $NO_3$/l at 12% of the water abstraction points sampled. The most serious situation was observed in regions where intensive livestock and arable farming takes place (e.g. Brittany, Paris basin, and Rhone valley).

In many countries the main measure to combat the nitrate problem has been closing the nitrate-affected shallow wells and taking groundwater from deeper wells. Taking water supplies from deeper aquifers is a short term solution and is not sustainable in the long run. A reduction in the pollution of groundwater and surface waters can only be achieved if there is a substantial reduction in the nitrogen surplus in the agricultural sector and hence in nitrogen inputs to water.

In the Accession Countries agricultural activities are generally less intensive compared to the EU, however, some regions are affected by high nitrate levels. This is especially of concern because of the relatively high proportion of rural population in the AC10. The rural population is more at risk because of the use the more heavily polluted shallow wells for drinking water. In 10 different regions in Bulgaria, an average of 35-45% of the population is exposed to elevated nitrate levels (OECD, 1993). In Lithuania in 1996, 37% of samples from private groundwater water supplies contained concentrations of nitrate exceeding the MAC (EEA/WHO, 1999). Elevated nitrate levels are also found in local water supplies in all but two of the 41 districts of Romania. According to a 1990 survey of water supplies in the countryside, 7% were above 200 mg $NO_3$/l, 10% were between 100-200 mg $NO_3$/l, and a further 19% were between 45-100 mg $NO_3$/l (OECD, 1993).

*5.3.3. Nitrate in rivers and coastal areas*

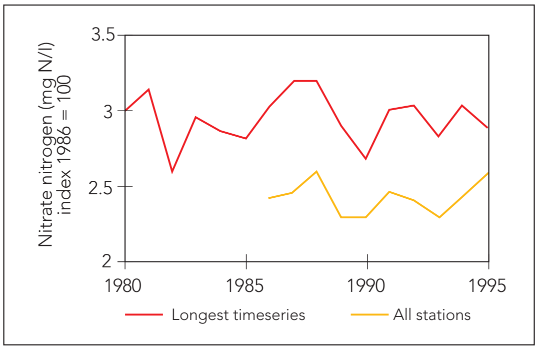
Apart from Nordic rivers, 68% of the river stations (Map 3.5.4) had mean nitrate concentrations exceeding 1 mg/l. The concentration in unaffected rivers is 0.1-0.5 mg/l. The highest concentrations were found in rivers in the intensive agricultural regions in the northern part of western Europe. In the Nordic countries, concentrations are low, 70% of the sites have levels below 0.3 mg/l.

The concentration of nitrate in EU rivers has been approximately constant since 1980 (Figure 3.5.21) and there is no overall indication that the reduced application of nitrogen fertilisers to agricultural land (see Chapter 2.2) has resulted in lower levels of nitrate in the 1990s.

The impact of nitrate is more significant in coastal and marine waters than in inland surface waters. In many coastal areas enhanced nitrogen loading leads to increased growth of annual macrophytes and in some cases mass occurrence of filamentous algae. At even higher nitrogen loading the amount of phytoplankton (algae) increases markedly, and the water becomes turbid. In enclosed or semi-enclosed marine waters (for instance the Baltic Sea), large amounts of phytoplankton will sediment out and oxygen consumption will consequently increase, possibly resulting in oxygen deficits and kills of animals unable to escape the area affected by low oxygen content (see chapter 3.14).

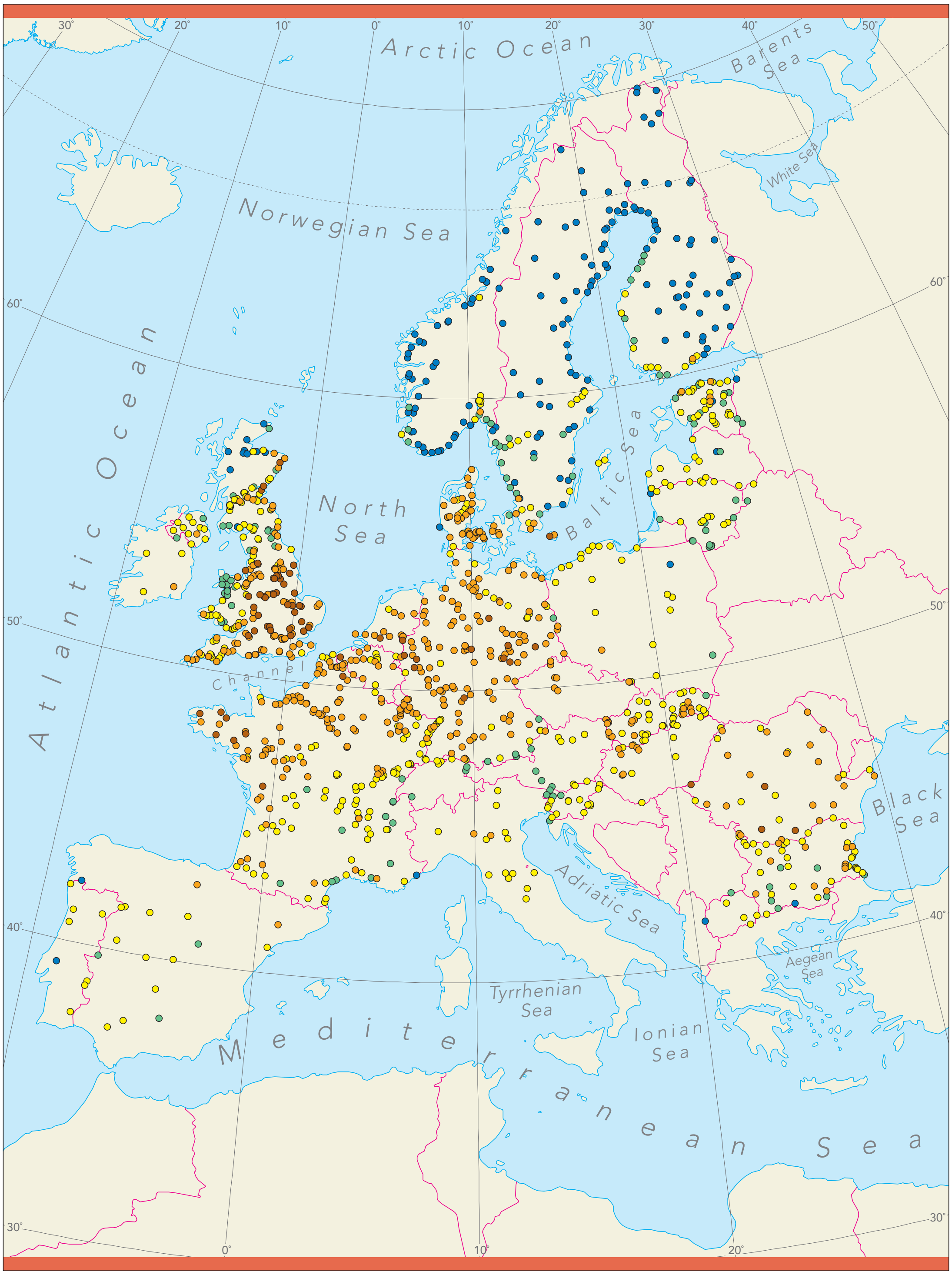
**Figure 3.5.21** **Development in river nitrogen concentration in 126 large river stations – median of annual averages**

**Source**: Codling and Bøgestrand, 1998




## 6. Policy responses to alleviate water stress

Over the past 25 years, the EU has developed and adopted a number of directives concerning water quality, aimed at specific processes or industries (e.g. chlor-alkali, titanium, dioxide), specific substances (e.g. dangerous substances, nutrients) or specific uses of water (e.g. drinking water, fish, bathing). The majority of these Directives have been transferred to national law, and their application is leading to improvements in many areas. In contrast to the many initiatives on water quality in the European Union, there has been much less activity concerning water quantity, and until recently there has been no policy in place, which integrated water quality and quantity.




**Annual average nitrate concentration in rivers**

0 500 km

Nitrate in mg N/l
Average of annual means
1994–1996

- more than 7.5
- 2.5–7.5
- 0.75–2.5
- 0.3–0.75
- less than 0.3

**Map 3.5.4**

**Source**: ETC/IW

The proposed Water Framework Directive (see below) seeks to address these deficiencies by an integrated approach covering all aspects of water management (including groundwater) under one framework document. It is also intended to integrate conservation and sustainable use criteria into other policy areas, such as agriculture, land-use planning, industrial production processes and economic development.

Another initiative towards an integrated management of water resources is the EU groundwater action programme, which establishes objectives related to groundwater quality and the over-exploitation of aquifers. However, these initiatives are relatively recent and there are no parameters yet available to measure the progress in pursuing the targets established.

The EU regulation 2078/92 on agri-environmental measures (see Chapter 3.13) has co-funded actions for the protection of rivers and water extraction areas. The expansion of agri-environmental measures is the central element of a strategy to integrate environmental considerations into agricultural policy. However, the pace and extent of integration will need to be considered in future adjustments of the CAP.

***6.1 Water quality: what do the trends tell us about the effectiveness of current policies?***

The assessments in this chapter illustrate that the measures to reduce pollution and hence improve water quality have been implemented with varying degrees of success. Organic matter and phosphorus discharges into surface waters have been reduced markedly in several areas over the past 20 years and have lead to lower concentrations. In contrast, nitrate levels in rivers have remained high. For groundwater no firm conclusions about state and trends of pollution can be drawn. This is partly due to a lack of comparable data on groundwater pollution and to the fact that the time lag for pollutants to reach groundwater may be up to 20 to 30 years.

Although many large rivers have improving quality, there is little evidence that this trend is being observed in smaller rivers, to which national regulatory authorities often give a lower priority in terms of monitoring and improvement measures. Small rivers and headwaters are ecologically important, providing diverse habitats for aquatic biota. For example, they provide important spawning grounds for many fish species. Because of their physical size, and often low flows, providing only limited dilution of pollutants, they are particularly susceptible to human pressures and activities. Channel modifications, discharges of inadequately treated sewage and run-off from agricultural land are all important pressures on small rivers.

Generally, control of discharges has been most effective for point sources such as urban waste water and industrial effluents, and in the case of pollutants like phosphate from detergents, where the use has been restricted or completely banned. Nevertheless, control of point source discharges varies, and most Member States have room for improvement. In the Accession Countries, the construction and upgrading of waste-water treatment plants to north-western European standards would result in considerable reductions in pollutant discharges.

In the case of diffuse sources, such as nitrate runoff from agriculture, effective control has rarely been achieved. Today, the use of fertilisers and the load of nutrients spread in manure has decreased compared to maximum levels in the 1980s. This is mainly because of the effect of the CAP reform (decoupling of payments from production aids to direct aids linked to farming area with price reductions), and a reduction in cattle livestock, but also due to economic recession in the AC10. However, the nutrient input from agriculture is still too high. In addition, when agriculture in the AC10 regains some of its former production levels, major problems with diffuse source pollution may occur in this region.

The implementation of the Nitrate Directive has been unsatisfactory in the majority of Member States (European Commission, 1998) and proceedings have been initiated against those Member States that have not yet complied. Implementation of the Urban Waste-water treatment Directive has likewise been patchy and slow but considerable investment programmes are in place in all Member States to comply with the Directive's objectives. Achievement of these objectives should have a great impact on the future state of the EU's waters.

***6.2 Water quantity – supply-side and demand-side strategies***

*6.2.1. Supply-side*

Supply-side strategies, which focus on measures (reservoirs, new wells, water transfers, etc.) that increase or assure supply, have traditionally been used for addressing the water quantity problems associated with water stress.

At present about 3 500 major reservoirs with a total gross capacity of approximately 150 $km^3$ are in operation in the European Union (EEA, 1999c). The greatest storage capacities exist in Spain (52 $km^3$), Sweden (21 $km^3$) and Finland (18 $km^3$). Despite its large reservoir storage capacity, Spain still experiences periods of severe drought, indicating that more than just supply-side measures are needed for efficient water resource management. Reservoirs are expensive to build and can cause problems like sedimentation, eutrophication, reduction of the biodiversity downstream, interruption of fish migration, etc. The establishment of a common policy for ecological quality and minimum flows to be guaranteed by reservoir management is a key question, for instance, in order to maintain the aquatic biodiversity (EEA, 1999c).

Water transfer schemes are used (for example in France, Spain and Greece) to over-come the uneven geographical distribution of resources, and they constitute an essential element of water resource planning. Water transfer can, however, have several disadvantages, such as the need for major investment in construction works, losses through leaks and evaporation and possible negative environmental impacts, for example through the introduction of alien species. Water quality problems can also arise because of mixing of water from different sources during a water transfer.

Increasingly, non-conventional sources such as desalination and water re-use are playing an increasingly important role in Mediterranean areas which face acute problems of water stress (see Box 3.5.7).

*6.2.2. Demand-side*

Demand-side strategies focus on water conservation and waste prevention measures. In general, demand-management measures tend to be especially promising under circumstances where either water is very scarce or environmental consciousness very high.

In order to achieve reduction or prevention of water stress by demand-based strategies, policy must rely on economic principles and particularly on pricing (Box 3.5.8). Nowadays prices do not always cover the full cost of water services and therefore users do not pay the real cost of the water they use. One aim of a future water policy could be to implement the (full) cost recovery principle (CRP). The main question is to determine which services and costs have to be covered by each particular tariff system and how it impacts on the economic situation of users. The main consequence of the implementation of the CRP is that most subsidies will be removed and the revenues will have to be provided by higher tariffs, which should tend to reduce water demand. This type of policy can produce negative impacts on some regions where water is crucial for their economic or social development. As a benefit, the CRP implementation will reflect the “real value” of water, and the need for efficient management of water resources.

### *6.3. The Water Framework Directive – a new approach?*

Pressure for a fundamental rethink of EU water policy came to a head in mid-1995. There was a need for a more global and coherent approach to water policy to replace what many saw as a piecemeal and sometimes inconsistent approach that had been put into place. As a result the requirements of the proposed directive on the ecological quality of surface waters were incorporated into a proposed framework directive that aimed to be the cornerstone of a new water policy. This proposed Water Framework Directive will rationalise the Community’s water legislation by replacing six of the ‘first generation’ directives. The aims of these directives will be taken into in the Framework Directive, allowing them to be repealed.

The overall purpose of the proposed Directive is to establish a framework for the protec-

**Box 3.5.7 The role of non conventional water resources in Europe**

**Desalination**

Initially sea-water desalination technologies were based on distillation and hence energy consumption was very high. The development of more efficient technologies (such as inverse osmosis) has reduced the cost of desalination considerably (below 1 EUR/m$^3$). However, this technique still tends to be considerably more expensive than supply from conventional (surface water and groundwater) sources. Desalination of sea water or brackish groundwater is therefore mainly applied in places where no other sources are available.

Sea-water desalination in Spain accounts for about 0.22 km$^3$/year. Although this volume is small in comparison to the country’s total renewable water resources (111 km$^3$/year), it represents a significant share of resources in the areas where this technology is applied (mainly the Canary and Balearic Islands). In Greece five desalination plants are in operation, all of them on islands.

**Water re-use**

The term ‘water re-use’ refers to supplying wastewater for a secondary use. The main applications of this technique are irrigation in agriculture, parks, recreational areas, golf courses, etc. Usually, simplified water treatment is carried out, in order to guarantee minimum quality standards of the water to be re-used. Few studies and data about the re-use of waste-water are available, and further research is needed to assess the long-term effects of irrigation with treated waste-water on soils and agriculture.

In France, waste-water re-use has become a part of regional water resources management policies. It is practised mostly in the southern part of the country and in coastal areas, compensating local water deficiencies.

In Portugal it is expected that by the year 2 000 the volume of treated waste-water will be around 10% of the water needs for irrigation in dry years. It is estimated that between 35 000 and 100 000 ha could be irrigated with treated waste-water.

In Spain, the total volume of waste-water reclaimed amounts to 0.23 km$^3$/year, being used mainly for irrigation in agriculture (89%), recreational areas and golf courses (6%), municipal use (2%), environmental uses (2%) and industry (1%).

**Box 3.5.8 Water prices and subsidies**

A study being carried out (Planistat, 1998) for the European Commission shows what is the current situation of pricing in four different European basins and what have been the main obstacles for the implementation of the cost recovery principle (CRP). The basins that have been studied are: the Adour-Garonne in France, the Henares in Spain, the Tavy in UK and the whole territory in the Netherlands.

In England and Wales, the costs of providing public water supplies are covered solely by the charges that the water companies make on their customers. These charges are under the control of an independent regulator who conducts periodic reviews of the price limits which apply to each company. These reviews are conducted with full consultation and the outcome is available for public scrutiny, subject only to genuine needs for commercial confidentiality. Water abstraction charges, whether by water companies or other abstractors such as irrigators, are limited to recover only the costs the Environment Agency incurs in managing water recourses.

In the Netherlands, the collective water supply is self-financing. There are not known government grants for collective drinking-water services. There is no collective irrigation thus no tariffs are applicable. As in the UK, problems of data availability have been found when trying to assess how the CRP is implemented.

In the Spanish Henares basin, different rates of cost recovery have been found, depending on the high, medium or low section along the river. In the highlands, the tariff system applied for the regulation and distribution of water result in a low rate of cost recovery (46% for agriculture and 58% for urban use). In the middle and low section, the rate is close to the CRP, varying between 99% and 74%, depending on the approach used for assessing the revenues to be got from the tariff system.

In the French Adour-Garonne basin the drinking-water supply is almost entirely self-financing (about 98%), but the irrigation tariff only covers from 30% to 40% of the total cost of the services.

tion of inland surface water, transitional waters, coastal waters and groundwater in order to prevent further deterioration, and to protect and enhance the status of aquatic ecosystems and those terrestrial ecosystems directly dependent upon them;

- It requires the achievement of 'good' surface water and groundwater status by 2015 unless it is impossible or prohibitively expensive.
- It also promotes the concept of sustainable water use based on the long-term protection of available water resources and also contributes to mitigating the effects of floods and droughts. The Framework Water Directive will, therefore, contribute to the provision of a supply of water of the quality and in the quantity needed, for sustainable, balanced and equitable use of the resource.
- It supports the protection of transboundary, territorial and marine waters and the achievement of the objectives of international agreements to prevent and eliminate pollution of the marine environment.
- The proposal also stimulates the progress reduction of pollution by hazardous substances.

A key feature of the proposed Directive is that it requires Member States to manage and co-ordinate administrative arrangements at the River Basin level (or, where appropriate, e.g. in the case of small River Basins) to aggregate into River Basin Districts. This applies to groundwater as well as surface waters. The more integrated approach to protect the aquatic environment together with integration of environmental considerations into sectoral policies should help to alleviate water stress in the future.

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**References**

Blue Plan, 1996. *Water in the Mediterranean region. Situations, perspectives and strategies for sustainable water resources management.* Euro-Mediterranean Conference on local water management. Marseilles, 25-26 November 1996.

Codling, I.D. and Bøgestrand, J., 1998. *Quality of surface fresh water. – Common procedure for the Exchange of Information – 1993-1995.* Synthesis Report to the European Commission, Brussels.

Danmarks Miljøundersøgelser, 1997. *Vandmiljøplanens Overvågningsprogram.Ferske vandområder – vandløb og kilder.* Faglig rapport fra DMU, nr. 214. (in Danish)

Danmarks Statistik, 1998. *Miljøstatistik.* Copenhagen. (in Danish).

DOE, 1999. Personal Communication, Department of Environment, UK.

EEA, 1995. *Europe's Environment. The Dobris Assessment.* D. Stanners and P. Bourdeau (Eds). Office for Official Publications of the European Communities. European Environment Agency, Copenhagen.

EEA, 1997. *Water resources problems in Southern Europe – An overview report.* Topic Report 15, Inland Waters. European Environment Agency. Copenhagen.

EEA, 1998. *Europe's Environment. The Second Assessment.* Office for Official publications of the European Communities & Elsevier Science Ltd.

EEA, 1999a. *Sustainable Water Use in Europe – Sectoral Use of Water.* Topic Report 1, Inland Waters. European Environment Agency. Copenhagen.

EEA, 1999b. *Groundwater quality and quantity in Europe*. Environmental Issues Series,. European Environment Agency. Copenhagen. (in press).

EEA, 1999c. *Lakes and reservoirs in the EEA area.* Topic Report 2, Inland Waters. European Environment Agency. Copenhagen. (in press).

ETC/IW, 1998a. *Nutrient discharges from point (industry and consumers) in the 10 Accession countries.* Technical Report to the EEA from the European Topic Centre on Inland Waters. December 1998.

ETC/IW, 1998b. *Contribution from the European Topic Centre on Inland Waters to RIVM's study on priorities, Water demands in Europe*. European Topic Centre on Inland Waters. Report for European Environment Agency.

EEA (forthcoming), 1999. Environment and European enlargement - Appraisal of future trends: *Implementation of the Urban Waste-water treatment Directive*. Scenarios and projects n° 3. Environmental issues n°. 8. European Environment Agency, Copenhagen. Office for Official Publications of the European Communities, Luxembourg.

EEA/WHO, 1999. *Water resources and human health in Europe*. Environmental Issues Series (in press).

Environment Agency, 1998. *Aquatic eutrophication in England and Wales. A proposed management strategy.* Environmental Issues Series, UK Environment Agency.

European Commission, 1998. *The implementation of Council Directive 91/676/EEC concerning the Protection of Waters against Pollution caused by Nitrates from Agricultural Sources.* Report of the Commission to the Council and European Parliament. COM(97) 473 final.

European Commission, 1999 (fortcoming). *Economic assessment of priorities for a European Environmental Policy Plan (working title).* Report prepared by RIVM, EFTEC, NTUA and IIASA for Directorate General XI (environment, nuclear safety and civil protection).

European Waste Water Group, 1997. *Urban waste-water treatment in the EU*. Report from the European Waste Water Group.

FAO Aquacult PC, 1998. AQUACULT PC – *Time Series of Aquaculture and Capture Fishery Production*. http://www.fao.org/WAICENT/FAOINFO/FISHERY/statist/fisoft/AQUACULT.HTM

German Federal Ministry of the Environment, 1997. *Towards Sustainable Development in Germany*.http://www.bmu.de/englisch/index.htm

German Federal Ministry of the Environment, 1998. *Water Resources Management in Germany*. http://www.bmu.de/englisch/index.htm

Gundermann, H., 1993. *An estimate of the future demand for water in a region – Forecasting techniques*, in La economía del agua, Sociedad General de Aguas de Barcelona (ed.).

Hydro, 1995-1996. *State of the Environment report 1995, & 1996.* Http://www.hydro.com/

ICWS, 1996. *Long range study on water supply and demand in Europe – Integrated Report*, International Centre of Water Studies. Amsterdam, the Netherlands, Report 96.05 to the EC Forward Studies Unit.

IFEN, 1996. *Environmental Performance Indicators in France – 1996-1997 edition*. Report from the French Institute for the Environment (IFEN).

Ijjas, I., 1996. *Removal of Phosphate from Detergents in the Danube Basin. Executive Summary*. Report from PHARE Project No: EU/AR/205/91, Contract No: 95-0036.00.

IGBK, 1998. *Langjährig Entwicklung chemischer Parameter im Bodensee-Obersee*. Internationale Gewässerschutzkommission für den Bodensee Bericht 48.

Kemira, 1996. *State of the Environment report.* http://www.kemira.com/environment.html

Llamas, M.R., M. Casado, A. de la Hera, J. Cruces and L. Martinez, 1996. *El desarrollo sostenible de la cuenca alta del río Guadiana: aspectos socio-económicos y ecológicos.* Medio Ambiente. Páginas 66-74. Sept.-Oct. 1996.

OECD, 1993. *Environmental Action Programme (EAP) for the Central and Eastern European Countries*. Document endorsed by the Ministerial Conference 'Environment for Europe', 28-30 April 1993 in Lucerne, Switzerland http://www.oecd.org/env/eap/docs/eap-cont.htm

OECD, 1997. *OECD Environmental Data – Compendium 1997*. Paris.

OECD, 1998. *Towards sustainable development – Environmental indicators.* Paris.

OFWAT, 1997. *1996-97 Report on leakage and water efficiency*. Office of Water Services. Birmingham.

PLANISTAT, 1998. *A study on water economics – Integrated Report.* A study for the European Commission – DG XI.B.1. September 1998.

RIVM/NTUA/IIASA, 1998. *Integrated environmental assessment of the baseline scenario for the EU state of the environment 1998 report*. Report prepared for EEA.

RIVM, 1995. *Milieubalans 95.* Http://www.Milieubalans.rivm.nl/body.htm.

Shiklomanov, I., 1998. *World water resources – A new appraisal and assessment for the 21st century.* UNESCO.

Siegrist, H. and M. Boller, 1999. *Auswirkungen des Phosphatverbots in den Waschmitteln auf die Abwasserreinigung in der Schweiz.* Korrespondenz Abwasser 46: 57-65.

Spanish Ministry for the Environment, 1998. *Spanish White Paper on Water.* Madrid.

Statistics Sweden, 1990. Naturmiljön I siffror – tredie udgave 1990. Report from Statistics Sweden (in Swedish).

Statistics Sweden, 1996. *Naturmiljön i siffror – femte udgave 1996*. Report from Statistics Sweden (in Swedish).

Umweltbundesamt, 1997. *Daten zur Umwelt, Der Zustand der Umwelt in Deutschland*. Erich Schmidt Verlag.

van Driel, 1998. *Costs for upgrading waste-water treatment to EU standards in ten Accession Countries*. Draft, RIZA, the Netherlands.

Verbruggen, A., 1997. *Report on the Environment and Nature in Flanders 1996*. Report from the Flemish Environment Agency, Ostende.

Wahlström E., E.-l. Hallanaro, & S. Manninen, 1996. *Miljöns framtid i Finland*. Report from Edita & Finlands Miljöcentral.

WMO, 1997. *General evaluation of world freshwater resources.* Stockholm Environment Institute (ed.). World Meteorological Organisation. 1997.