Aquatic Environment 1999

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State of the Danish Aquatic Environment

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Danish Environmental Protection Agency
Ministry of Environment and Energy

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Preface

Aquatic Environment 1999 is the first state-of-the-environment report under the Danish Aquatic Monitoring and Assessment Programme 1998–2003, commonly referred to as NOVA-2003. The former aquatic environment reports (Aquatic Environment 1990 to 1998) were all based on the forerunners for NOVA-2003, namely the Nationwide Monitoring Programme 1988–1992 and 1993–1997 under the Action Plan on the Aquatic Environment.

In several respects, NOVA-2003 differs considerably from the previous monitoring programmes. The most obvious change is that virtually all the subprogrammes now encompass the monitoring of hazardous substances andheavy metals. In addition, the sampling strategy has been optimized within each of the subprogrammes. The monitoring programme has thereby developed from one specifically directed towards documenting the effects of the 1987 Action Plan on the Aquatic Environment to a general nationwide monitoring programme for groundwater and surface waters.

The purpose of Aquatic Environment 1999 is to document and report the effects of the Action Plans on the Aquatic Environment from 1987 and 1998, as well as the effects of other action plans, etc. aimed at improving the quality of the aquatic environment.

Aquatic Environment 1999 has been prepared by the National Forest and Nature Agency and the Danish Environmental Protection Agency. The National Forest and Nature Agency has prepared and been responsible for the sections on agriculture, freshwater fish farms, watercourses and lakes. The Danish EPA – in addition to being responsible for the overall coordination of the report – has prepared the sections on all the other sources of pollution and nutrient loading, as well as the sections on groundwater and marine areas. The chapters on water and weather, overall objectives and measures, and the summary and conclusions were prepared jointly by the two agencies.

PART 1: TECHNICAL STATUS – STATE AND PRESSURES

Aquatic Environment 1999 is subdivided into a technical part and a political/administrative part. Part 1, "Technical status – State and pressures" (Chapters 2, 3, 4 and 5), examines the main pressures on the aquatic environment, discharges and losses of nutrients, hazardous substances and heavy metals, and the resultant environmental quality.

PART 2: ACTION FOR A CLEANER AQUATIC ENVIRONMENT – STATUS AND PERSPECTIVES

Part 2, "Action for a cleaner aquatic environment – Status and perspectives ", (Chapters 6 and 7), examines the relevant action plans and fulfilment of their objectives, and assesses whether there is a correlation between the objectives stipulated and the measures it has been decided to implement.

1 Introduction

In connection with the adoption of the Action Plan on the Aquatic Environment in 1987, a monitoring programme was established to demonstrate the effects of the measures contained in the plan. The Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment has previously been revised in 1992. The latest revision of the monitoring programme was made in 1997–98 and resulted in the implementation of the National Programme for Monitoring the Aquatic Environment, commonly referred to as NOVA-2003.

General management of the monitoring programme is entrusted to a Programme Management Board. The members of the Committee are the Association of County Councils in Denmark, Copenhagen Municipality, the National Environmental Research Institute, the Geological Survey of Denmark and Greenland, the National Forest and Nature Agency, and the Danish EPA. The Danish EPA also holds the Chairmanship and runs the Secretariat.

1.1 What is NOVA-2003?

NATIONAL PROGRAMME FOR MONITORING THE STATE OF THE AQUATIC ENVIRONMENT 1998–2003

NOVA-2003 is a programme for monitoring the state of the Danish aquatic environment. The programme has been described in detail elsewhere (Danish EPA, 1999a).

The contents of NOVA-2003 are stipulated in the general programme description (Danish EPA 1999a). This is supplemented by a series of technical instructions in which all methods etc. are given together with a paradigm describing all the requirements as to data transfer and reporting.

With the implementation of NOVA-2003 in 1998, the monitoring programme has developed from one specifically directed towards demonstrating the effects of the Action Plan on the Aquatic Environment to one encompassing the environmental quality of Danish groundwater and surface waters in its broadest sense. This development is primarily attributable to greater priority having been accorded to monitoring of hazardous substances and heavy metals, but also to optimization of the sampling strategy within each of the subprogrammes.

In NOVA-2003, the term hazardous substance covers both man-made and naturally occurring substances. In strict terms, the latter are not hazardous but are included in the monitoring programme because they occur in concentrations exceeding the background level. Many of the hazardous substances are characterized as hazardous because their properties (toxicity, degradability or bioaccumulation) render them dangerous to the environment. In NOVA-2003, the term heavy metals encompasses both the metals and inorganic trace elements included in the programme over and above the substances and compounds included in the monitoring of nutrients, etc.

COUNTY-STATE COOPERATION

The majority of the monitoring is carried out by the county authorities. The state activities encompass measurements at the extensive marine stations, measurement and calculation of atmospheric deposition, and the operation of 27 stream stations for measuring water flow.

SUBPROGRAMMES UNDER NOVA-2003

During the preparation of NOVA-2003, a correlation was established between the programme's main/subsidiary objectives and the monitoring activities implemented. The programme encompasses the following subprogrammes:

- Point sources (inputs and discharges to water and soil)
- Atmospheric deposition (deposition on the sea)
- Agricultural monitoring catchments (pressures, transport and loss)
- Groundwater (state, pressures and resource balance)
- Lakes (state and pressures)
- Watercourses (state, pressures and pollutant transport)
- Marine waters (state, pressures and pollutant transport)

In order to be able to effectively document the effects of a given type of pollution and of the many plans and implemented measures it is necessary to be able to filter out the natural variation. It is therefore vital to know the natural variation in the weather and the factors involved in the water cycle – both short-term and long-term. This necessitates a good understanding of the factors involved in the water cycle and the availability of relatively long time series for the environmental variables encompassed by the aquatic environment monitoring programme.

The sampling frequencies for the many different analyses etc. included in NOVA-2003 have been planned so as to take natural variation into account to the extent necessary. In addition, many of the time series are now so comprehensive as to permit statistical analysis with a high degree of certainty.

Under NOVA-2003, emphasis is placed on the quality of the method etc. used to make the individual measurements, whether a chemical analysis or a measurement of physical or biological conditions. In connection with revision of the programme in 1997–98, it was observed that a number of hazardous substances are not yet encompassed by the laboratories' routine analyses. For this reason, a number of substances will not be encompassed by NOVA-2003 until the years 1999, 2000 and 2001.

FIGURE 1.1
THE NITROGEN CYCLE (ADAPTED FROM DANISH EPA 1984 AND 1990).

1.2 Reporting of NOVA-2003

The reporting of NOVA-2003 has been planned with a view to:

- Determining and describing the most important anthropogenic and natural pressures.
- Describing the current state of the aquatic environment, the overall trends and the causal relationships.

- Comparing the results of the monitoring with the overall political objectives for the state of the Danish aquatic environment and for limiting the pollution. Both the county reports and the national summary reports indicate what political and administrative measures can be taken to improve the aquatic environment.

Reporting of the monitoring programme over the period 1999–2004 consists of annual standard reports, oxygen deficiency reports and four cross-cutting theme reports. Annual standard reporting is made at three levels:

1. COUNTY TECHNICAL REPORTS
The regional reports by the county authorities encompass the following subprogrammes: agricultural monitoring catchments, groundwater, watercourses and spring brooks, lakes, point sources and marine waters. The county reports have to comprise a technical-scientific assessment of the results and wherever relevant, shall include an assessment of to what extent the regional quality objectives for the aquatic environment have been met.

2. NATIONWIDE TECHNICAL REPORTS
The nationwide technical reports encompass the following subprogrammes: Agricultural monitoring catchments, groundwater, watercourses and spring brooks, lakes, point sources, marine waters and atmospheric deposition. The reports contain technical assessments of the collected information on the aquatic environment.

FIGURE 1.2
THE PHOSPHORUS CYCLE (ADAPTED FROM DANISH EPA, 1984 AND 1990)

3. STATE OF THE DANISH AQUATIC ENVIRONMENT REPORT
The State of the Danish Aquatic Environment Report prepared by the National Forest and Nature Agency and the Danish EPA assesses the state of the aquatic environment and from a technical/administrative point of view assesses the results and effectiveness of the Action Plan on the Aquatic Environment I and II and other measures aimed at improving the aquatic environment.

Aquatic Environment 1999 is based on the activities carried out in each of the individual subprogrammes. However, as NOVA-2003 does not comprise a complete basis for assessing discharges and environmental state, the report also makes use of information from other supervision of the aquatic environment.

THEME REPORTS
During the programme period, the annual state-of-the-environment report will be supplemented by four independent theme reports in which the monitoring results will be evaluated across the individual subprogrammes. The following timetable has been agreed for the theme reports:
2001: The water cycle, nitrogen and phosphorus
2002: Hazardous substances, including heavy metals
2003: Biological state and developmental trends
2004: The results of 15 years of monitoring of the Danish aquatic environment.

OXYGEN DEFICIENCY REPORTS

Under NOVA-2003, regular oxygen deficiency reports are prepared during the "oxygen deficiency period" (August, September and October). The reports, which are prepared jointly by the Counties, the National Environmental Research Institute and the Danish EPA, are published as press releases and on the NOVA Internet homepage.

1.3 Where can I read more?

HTTP://WWW.MST.DK/NOVA

Further information on NOVA-2003 can be found on the programme's Internet homepage at address http://www.mst.dk/nova. In addition to the complete description of the programme, links are provided to the institutions participating in the monitoring of the Danish aquatic environment.

Aquatic Environment 1999 provides an overall summary of the monitoring results. More detailed assessments of the data can be found in the nationwide scientific reports for the individual subprogrammes (see References,

In addition, information on the state of the aquatic environment and the general endeavours to limit pollution can be found in the Government's 1999 Environmental Policy White Paper (Ministry of Environment and Energy, 1999).

All the reports mentioned can be ordered from the respective institutions or from Miljøbutikken for address and telephone number).

2 Water and climate

Because weather determines how and in what forms and in what amounts water is present on the Earth, it is of considerable importance for leaching of nutrients from the land and for nutrient loading of the aquatic environment, and hence for the state of the aquatic environment. Variation and shifts in the water cycle can often be explained by variation in the climate, as can variations in the chemical and biological conditions in the aquatic environment. In order to be able to demonstrate the effects of a given measure on the aquatic environment it is necessary to be able to filter out natural variations. It is therefore vital to know the natural variation in the weather and the factors involved in the water cycle – both short-term and long-term.

2.1 **The water cycle**

There are more than one thousand million cubic kilometres of water on the Earth. All the water in the World is part of the water cycle, whether freshwater or seawater, and whether it occurs in the form of water, water vapour or ice.

The driving force behind the water cycle is the sun. It evaporates water from open water bodies such as the sea, lakes and watercourses, and also drives the biological system and the evaporation that occurs from living organisms. Condensed water vapour in the atmosphere falls to the Earth as precipitation in the form of rain or snow. Part of the precipitation that falls on the landmass is subsequently transported to the sea – either by watercourses, in the groundwater or as ice in glaciers. Part of the water is used on the land in biological processes.

FIGURE 2.1
THE WATER CYCLE (FROM MINISTRY OF ENVIRONMENT AND ENERGY, 1999).

The gross precipitation is the term for the total amount of precipitation (both rain and snow) that falls on the landmass. The gross precipitation is around 113,000 km^3 – corresponding to 113,000,000,000,000 m^3 – per year for the whole World (GEUS, 1997).

A large part of this precipitation immediately returns to the atmosphere via evaporation from the water surface (e.g. lakes and watercourses), as well as via evaporation from the biological system – especially plants. Annual evaporation from the landmass totals around 72,000 km^3.

That part of the precipitation that remains on the landmass and is available for the lakes, watercourses and groundwater, etc., is called the net precipitation. Global net precipitation thus amounts to 41,000 km^3 per year. Of this, 29,000 km^3 flows out to the sea via watercourses, while "only" about 12,000 km^3 of the total precipitation seeps down into the ground and contributes to the formation of groundwater.

As part of the net precipitation is used to drive the hydrological system, it is only practically possible to exploit 10–30% for the water supply, etc.

If sustainable exploitation of the net precipitation is assumed to be 15%, the total global exploitable water resource will be approx. 6,000 km^3 per year. This should be seen in the context of global water consumption, which was 3,800 km^3 in 1995. Extrapolating the prognoses for development in the population and per capita consumption makes it clear that problems will arise with the water supply in a number of additional countries. From a global point of view the water supply is thus considered by some to be the most serious resource problem of the 21st Century.

2.2 Meteorological and hydrological conditions in 1998

TEMPERATURE

In Denmark, 1998 was a relatively warm year. The temperature data for 1998 thus show that February in particular was warm, while the summer was relatively cool. Figure 2.2 shows the temperature variation during the year together with the mean value for the period 1967–1998.

FIGURE 2.2
MEAN TEMPERATURE FOR DENMARK CALCULATED ON A WEEKLY BASIS. THE NORMAL REPRESENTS THE MONTHLY AVERAGE OF THE PERIOD 1961–90 (ADAPTED FROM GRANT ET AL., 1999).

WIND

1998 was a relatively windy year. The average wind speed was 7.6 metres per second at the coastal stations, somewhat above the normal of 6.6 metres per second (Bøgestrand et al., 1999).

IRRADIANCE

The sun only shone for 1,571 hours in 1998 compared with the normal of 1,670 hours (1971–90). A record low of 88 sunshine hours was recorded in September (Bøgestrand et al., 1998).

PRECIPITATION

Precipitation is unevenly distributed throughout Denmark. Thus southern Jutland and mid and western Jutland receive considerably more water than the country as a whole, while the western and southern parts of Zealand receive less. Variation in precipitation for the country as a whole during the monitoring period is shown in Figure 2.3 together with the average precipitation for the preceding normal period (1961–90).

FIGURE 2.3
ANNUAL PRECIPITATION IN DENMARK FOR THE PERIOD 1989–98 EXPRESSED RELATIVE TO THE NORMAL FOR 1961–90 (ADAPTED FROM BØGESTRAND ET AL., 1999).

1998 was a very wet year. With a national average of 860 mm precipitation, 1998 was the next wettest year since 1874.

Groundwater recharge

That part of the precipitation on the landmass that does not run off in the watercourses or evaporate from water bodies or living organisms seeps down to the groundwater and is termed the groundwater recharge. The magnitude of the groundwater recharge to a given aquifer depends not only on the magnitude of the net precipitation, but also on the geological conditions between the terrain and the groundwater aquifer and the characteristics of the aquifer.

In principle, the groundwater recharge is available for water abstraction. In practice, however, the geological and chemical conditions in the ground will limit the technical possibilities for abstraction. Politically determined concerns as to for example the amount of water in watercourses and lakes set other limits for the extent of groundwater abstraction.

Water abstraction

The water supply in Denmark is predominantly based on groundwater, with more than 98% of the water supply consisting of water abstracted from groundwater aquifers. Lake and/or watercourse water is only used for the water supply in very few places. In 1998, a total of 741 million m^3 groundwater was abstracted (GEUS, 1999).

The abstraction of groundwater in Denmark is very decentralized. As a consequence, the abstraction wells are distributed throughout most of the country. This is an advantage for nature and reduces the impact of abstraction on the environment of watercourses and lakes. The water supply is thus distributed between approx. 3,100 public common (i.e. waterworks supplying at least 10 properties) and approx. 2,750 private common plants. In addition, there are a number of local individual water supplies to institutions, industry, irrigation, sports grounds, market gardens, freshwater fish farms and households.

Groundwater table

Sounding of the groundwater table gives an idea of the amount of groundwater. The groundwater table is subject to natural seasonal variation with a maximum around April and a minimum around October. It is the winter precipitation in particular that determines the magnitude of the groundwater recharge. This is because evaporation and water uptake by plants are much lower in the winter period than in the summer, when the majority of the precipitation that falls on the landmass is taken up and evaporates via the vegetation. The variation in winter precipitation and the groundwater table are thus closely coupled, as illustrated in Figure 2.4.

FIGURE 2.4
VARIATION IN PRECIPITATION AND GROUNDWATER TABLE OVER THE PERIOD 1951–94 (ADAPTED FROM GEUS, 1999).

It can be seen that the groundwater table has varied considerably over the past few years. Because of the very dry winters in 1996 and 1997 the groundwater table fell to its lowest level during the past 25 or so years (Figure 2.4). In spring 1999, the high groundwater table re-established after the dry winters.

Runoff

Freshwater runoff to the sea consists of riverine runoff and surface runoff. Total runoff to the Danish marine waters in 1998 is estimated at approx. 16,000 million m^3 corresponding to 363 mm. Runoff in that year was therefore 11% above the normal for the period 1961–90 of 327 mm. The variation in runoff during the monitoring period is illustrated in Figure 2.5.

FIGURE 2.5
FRESHWATER RUNOFF FOR DENMARK OVER THE PERIOD 1989–98 EXPRESSED RELATIVE TO THE NORMAL FOR 1961–90 (ADAPTED FROM BØGESTRAND ET AL., 1999).

The runoff response to the very high level of precipitation has generally been less than expected due to the fact that the groundwater aquifers had become depleted in the preceding three years. In Bøgestrand et al. (1999), it is estimated that approx. 200 mm of the net precipitation in 1998 was used to recharge the groundwater aquifers.

HYDROGRAPHIC CONDITIONS

The description of the overall hydrographic conditions in Danish marine waters in 1998 is based on measurements from NOVA-2003 and meteorological observations etc. and subsequent calculations (DHI, 1999a and 1999b).

Due to a general inflow of water to the Baltic Sea, the salinity of Danish marine waters was relatively high during the first months of 1998, ranging from 33 PSU (approx. the same as 33‰) in the northern Kattegat to 10–22 PSU in the area around the Darss Shelf (between Gedser and Germany), where stratification occurred at a depth of approx. 10 m. The inflow, which amounted to approx. 200 km^3, was superseded in March and April by an outflow from the Baltic Sea of approx. 450 km^3. As there was only a weak net inflow of around 50 km^3 during May and June, the salinity of the inner Danish marine waters fell during early summer 1998 relative to that at the beginning of the year. The salinity varied from around 14 PSU in the surface waters of the Kattegat to around 28 PSU in the bottom water. At the Darss Shelf, the water column was homogenous with a salinity of 10–12 PSU.

From mid July until the beginning of October, there was a high level of outflow from the Baltic Sea. A total of approx. 360 km^3 water flowed out, and the salinity in the inner Danish marine waters therefore remained low during that period. In the last months of 1998 the situation fluctuated, with 200 km^3 water flowing into the Baltic Sea in October, 300 km^3 flowing out in November and a small amount flowing into the Baltic Sea again in December. The overall result of the varying current conditions was that the salinity in the Kattegat at the end of the year was low but increasing due to the inflow in December.

At the beginning of the year, the Jutland Coastal Current led water up past Hanstholm and northeast along the northwestern coast of Jutland. At the same time, circulation arose in the surface waters of the Skagerrak. This dissipated later in the year, though, and the Jutland Coastal Current concomitantly became weak. From July to the end of the year there was once again marked circulation in the Skagerrak, but the Jutland Coastal Current remained weak until the last months of the year, when it became stronger again.

WATER TRANSPORT

The accumulated transport of water and salt is calculated on the basis of model simulation of the hydrographic conditions (DHI, 1999c).

The accumulated transport between the Danish marine waters in 1998 is calculated to be an outflow from the Baltic Sea of approx. 317 km^3. This value is 152 km^3 less than the net input of freshwater to the Baltic Sea of 420 km^3 via runoff and 49 km^3 via net precipitation, approx. 469 km^3 in all. The difference is balanced by changes in the water mass in the Baltic Sea in that the sea level in the Baltic Sea was approx. 0.4 metres higher at the end of the period (1 January 1999) than at the start (1 January 1998). This difference in sea level calculated by the model is also seen in the measurements.

The distribution of the net transport between the Sound and the Femer Belt was 115 km^3: 210 km^3 or approx. 4:7, which is a little higher than the long-term relationship of 3:8 calculated in another context. The net transport of salt is towards the Skagerrak from the Baltic Sea corresponding to a reduction of the salinity of the inner Danish marine waters.

2.3 Water balance for Denmark

Drawing up a water balance for Denmark is no easy task, among other reasons because there are over 5 million people in Denmark who utilize and affect the water cycle in many ways, including abstraction for the supply of drinking water, irrigation, drainage and treatment of wastewater, and physical modification of the water bodies, first and foremost channelization of watercourses.

A water balance for Denmark has been established on several occasions (e.g. Schrøder, 1995) taking into account the Danish population's intervention in the natural water cycle. Figure 2.6 illustrates the water cycle in the early 1990s.

FIGURE 2.6

WATER BALANCE FOR DENMARK AT THE BEGINNING OF THE 1990S. THE FIGURES ARE IN MILLION M^3 WATER (ADAPTED FROM SCHRØDER, 1995).

As mentioned in the introduction, a cross-cutting theme report planned for publication in 2001 will in part focus on the water cycle. In connection with preparation of the theme report, attempts will be made to lay the foundation for an annual routine update of a national water balance that will also incorporate descriptions of water transport, including inflow, outflow and exchange of water between Danish marine waters.

3 Sources of pollution: Discharges, losses and emissions

According to the programme objective, NOVA-2003 has to quantify loading from the individual sources of pollution of the Danish aquatic environment. For practical reasons, a distinction is made between land-based point sources (Section 3.1), sea-based point sources (Section 3.2) and losses etc. from agricultural land (Section 3.3).

The calculations of discharges and losses are mainly based on NOVA-2003. In several cases, however, the results are supplemented with data from supervision work. The calculation of emissions to the atmosphere is not part of NOVA-2003, but for the sake of completeness is briefly discussed in Section 3.4.

3.1 **Land-based point sources**

Land-based point sources encompass the following types of source: Wastewater treatment plants, separate industrial discharges, stormwater outfalls, sparsely built-up areas, and freshwater fish farms. The percentage distribution of nutrient discharges for the various types of land-based sources with direct discharges is shown in Figure 3.1.

FIGURE 3.1
PERCENTAGE DISTRIBUTION OF DISCHARGES OF NITROGEN (TOTAL-N), PHOSPHORUS (TOTAL-P) AND ORGANIC MATTER (BOD_5) FROM LAND-BASED POINT SOURCES IN 1998.

3.1.1 **Wastewater treatment plants**

By a wastewater treatment plant is understood a plant that treats wastewater and discharges to watercourses, lakes or the sea. The majority of the treatment plants are public in the sense that one or more municipal councils are responsible for their operation and maintenance.

The calculations encompass all 1,475 treatment plants with a capacity exceeding 30 person equivalents (PE). For practical reasons, moreover, they encompass both public and private treatment plants. In 1998, there were 285 private plants that together treated less than 2% of all Danish wastewater. Municipal plants operated by private companies are included under public treatment plants since it is the municipal councils who are responsible for their operation and maintenance. The size distribution of wastewater treatment plants is shown in Table 3.1.

Table 3.1
Size distribution of wastewater treatment plants in 1998.

Capacity	PE
> 30	12,059,552
> 500	11,961,884
> 2,000	11,704,706
> 5,000	11,054,961
> 15,000	9,904,548
> 50,000	7,945,433
> 100,000	5,544,800

In 1998, 84% of all wastewater was treated to remove organic matter, nitrogen and phosphorus. The percentage reduction in organic matter, nitrogen and phosphorus at these plants is around 90%, which means that the majority of wastewater in Denmark is treated very effectively. In 1989 in comparison, only 10% of the wastewater was subjected to such treatment.

Total estimated discharge in 1998 was 5,166 tonnes nitrogen, 601 tonnes phosphorus and 3,525 tonnes organic matter measured as BOD_5, cf. Table 3.2.

Table 3.2
Distribution of wastewater treatment plants by type, capacity, discharge and degree of treatment in 1998.

Plant type	Treatment plants		Discharge			Degree of treatment		
	No.	1,000 PE	Tot-N	Tot-P	BOD_5	Tot-N	Tot-P	BOD_5
			tonnes			%		
No treatment	2	1	4	1	15	-	-	-
Mechanical	433	89	219	37	594	20	36	26
MC	24	150	123	7	286	48	81	85
MB	501	383	498	82	208	13	81	48
MBC	237	863	857	45	294	58	87	87
MBND	10	107	47	11	28	76	88	56
MBNDC	268	10,466	3,419	418	2,100	85	92	92
Total	1,475	12,059	5,166	601	3,525	-	-	-

The abbreviations represent the following treatment levels: MC –Mechanical-chemical; MB – Mechanical-biological; MBC – Mechanical-biological-chemical; MBND – Mechanical-biological with nitrogen removal; MBNDC – Mechanical-biological-chemical with nitrogen removal.

Relative to discharges in 1997, discharges of organic matter and nitrogen have increased by 2% and 6%, respectively. At the same time, the high level of precipitation increased the amount of wastewater by 26% relative to 1997. The increase in discharges of organic matter and nitrogen are largely attributable to the increase in the amount of wastewater as the treatment efficiency for these parameters depends on the hydraulic load to which the plants are subject.

Phosphorus discharges have fallen by 10% relative to 1997. That phosphorus discharges have fallen while discharges of organic matter and nitrogen have increased is attributable to the fact that phosphorus is removed from 98% of all wastewater by phosphorus stripping, a process that is less dependent on the hydraulic load on the plant.

In 1998, the total amount of effluent from the wastewater treatment plants was 2.2 million m^3 per day, corresponding to 802 million m^3 per year. In addition to household and industrial wastewater, the effluent also derived from rainwater and water infiltrating into the sewers. Based on the calculations of stormwater discharges (see section 3.1.3) it can be calculated that rainwater accounts for approx. 15% of all the wastewater passing through the treatment plants.

In 1998, data on water seeping into or out of sewers has been reported for 595 plants. Relative to the total wastewater input to the treatment plants for which infiltration into sewers has been estimated, total infiltration into sewers is calculated to be 29%.

The total treatment capacity is just over 12 million PE, cf. Table 3.2. The corresponding figure for total load on the plants in 1998 was 8.8 million PE. That plant capacity is greater than the load is attributable to the fact that the plants have to be able to provide effective treatment during peak load periods.

In 1998, the county authorities have reported data on industrial inputs to treatment plants based on information on wastewater or nutrient and organic matter discharges from industries in the catchment areas of the individual plants. In by far the majority of cases, the figures are rough estimates because the information on which the calculations are based is far from complete. In all, data have been reported on industrial wastewater inputs to 416 treatment plants that together treat approx. 40% of all wastewater. For the country as a whole, industrial wastewater is estimated to comprise 48% of all wastewater.

In 1998, 277 treatment plants were encompassed by the requirement of the Action Plan on the Aquatic Environment to undertake phosphorus treatment or phosphorus, nitrogen and organic matter treatment.

In 1998, 243 treatment plants were subject to a BOD_5 treatment requirement of 15 mg per litre or less. Only one plant was unable to comply with this criterion. BOD_5 effluent quality was 5 mg per litre or less at 220 of these plants. 276 plants were subject to a phosphorus treatment requirement of less than or equal to 1.5 mg P per litre. Of these, only one plant failed to comply with the criterion. Around half of the plants were subject to a more stringent requirement than the 1.5 mg per litre stipulated in the 1987 Action Plan on the Aquatic Environment. With regard to nitrogen, 215 plants were subject to a treatment requirement of 8 mg per litre or less. Of these, eight failed to comply with the nitrogen criterion.

The county authorities have provided the Danish EPA with various supplementary information for use in the preparation of special supervision reports. A total of 1,190 municipal treatment plants are registered. In 1998, county authorities carried out 2,728 site inspections at 1,135 of these plants, corresponding to an average of approx. 2.4 visits per plant per year. Among other things, the inspections encompass measurements of effluent concentrations and calculation of compliance with the discharge limit values stipulated in the discharge permits.

171 plants exceeded one or more discharge limit values in 1998, corresponding to 14% of all municipal treatment plants or 16% of the inspected plants.

Of the 171 plants that exceeded their discharge limit values in 1998, 89 had exceeded their discharge limit values for two or more years. This means that 82 plants only exceeded their discharge limit values in 1998 and not in 1997. Table 3.3 shows the number of treatment plants that have exceeded their discharge limit values for 2, 3, 4 and 5 or more years in a row. The number of plants having exceeded their discharge limit values on only a single occasion (i.e. in 1998) is also shown.

Table 3.3
Plants with exceedences for more than five years down to a single exceedence in 1998.

No. of years	No. of plants
1 yr (1998)	84
2 yr in a row	31
3 yr in a row	26
4 yr in a row	10
>5 yr in a row	20
Total	171

In 1998, county authorities took the following enforcement measures in reaction to the above-mentioned compliance failures: 69 plants have been served a recommendation, 5 plants have been served an order, 39 plants have been served an injunction and 31 plants have received *de facto* legalization. Finally, 2 plants have been reported to the police. The remaining 25 plants (corresponding to 15%) have been dealt with by other means. Some counties authorities have taken more than one enforcement measure against the same plant. The figures given above only include one enforcement measure per plant.

WASTEWATER CONTENT OF HEAVY METALS

In 1998, heavy metals concentrations were measured at 4 selected treatment plants. These treatment plants treat 10% of all Danish wastewater. The treatment plant Lynetten in Copenhagen is the largest in Denmark. The load here is typically of that for a large urban community. Lundtofte treatment plant in Lyngby-Tårbæk and Tårnby treatment plant are both medium-sized treatment plants receiving approx. 20% industrial wastewater. Grindsted treatment plant is a small plant receiving a medium-sized industrial load. All four plants are dimensioned for nitrogen and phosphorus removal, and effluent levels are generally better than the requirements. The Danish EPA considers these plants to be fairly representative as regards handling and composition of wastewater in Denmark. A greater than average percentage of the wastewater treated by the plants derives from industrial sources, however.

As yet the necessary analysis methods or documentation for the quality of the heavy metals analyses are not available. The mean values and deviation for the heavy metals content of inflow to and outflow from the four treatment plants in 1998 are shown in Table 3.4. Although the calculated discharges of heavy metals are subject to considerable uncertainty, it is nevertheless the Danish EPA's assessment that they provide a good idea of the magnitude of the discharges.

Table 3.4
Mean concentration and deviation for heavy metals in inflows and outflows in 1998.

Metal	Mean	Deviation	Mean	Deviation
	Inflow		Outflow	
	μg/l		μg/l	
Arsenic (As)	5.7	3.7	3.2	2.4
Lead (Pb)	33	51	2.5	1.0
Cadmium (Cd)	0.8	1.1	0.1	0.1
Chromium (Cr)	5.1	2.0	1.2	0.7
Copper (Cu)	40	16	17	10
Mercury (Hg)	0.5	0.7	0.2	0.1
Nickel (Ni)	5.9	2.5	5.0	2.3
Zinc (Zn)	390	381	168	177

With most of the heavy metals, the deviation is large relative to the mean values, cf. Table 3.4. This indicates inter-plant differences in the composition of the wastewater depending on which industries, etc. are connected to the individual plants. The large deviation in the monitoring results also reflect inaccuracy in the measurements, however. Relative to the measurements made by the Danish EPA in 1994 and 1996, the measured values in 1998 are of the same order.

The inflow values are typically slightly lower than previously while the outflow values for the individual heavy metals are slightly higher than previously. This is more an expression of a characteristic of the four plants investigated in 1998 than of a general increase or fall in the wastewater content of heavy metals.

DISCHARGE LIMIT VALUES FOR THE AQUATIC ENVIRONMENT

Comparison of the outflow concentrations of heavy metals with the discharge limit values for discharges to the aquatic environment reveals that the former are generally at a lower level than the discharge limit values stipulated in Ministry of Environment and Energy Statutory Order No. 921 of 8 October 1996. Thus the concentrations measured in the outflow from the treatment plants are not critical relative to the discharge limit values stipulated for the aquatic environment.

Estimated total discharges of heavy metals from wastewater treatment plants are shown in Table 3.5. The values have been arrived at by first extrapolating from the measurements at the four treatment plants investigated in 1998. These results were then compared with data from Aquatic Environment 1994 (Danish EPA, 1994a) and the total discharges thereafter estimated. The estimates are thus based on data from both studies. The total discharge was calculated by taking the average of all the measured outflow concentrations and multiplying by the total amount of wastewater effluent from all treatment plants in 1998.

Table 3.5
Heavy metal discharges

Metal	kg
Arsenic (As)	10,000
Lead (Pb)	1,700
Cadmium (Cd)	500
Chromium (Cr)	2,000
Copper (Cu)	9,000
Mercury (Ni)	500
Nickel (Ni)	11,000
Zinc (Zn)	90,000

Another method of estimating the total discharge could be to base the calculations on the amount of heavy metals discharged per PE for the four treatment plants investigated and thereafter multiplying by the total number of PE connected to all treatment plants. Such calculations yield discharges for 1998 that are 10–40% lower than the calculations based on the amount of wastewater. It is therefore believed that the figures in Table 3.5 are overestimated relative to the real discharges of heavy metals.

Comparison of discharge data for 1994 and 1998 reveals that for most heavy metals, total discharge is of the same order both years. The calculated discharges of arsenic, cadmium, mercury, chromium and nickel are lower than in 1994 while the discharges of zinc, lead and copper are higher than in 1994. The Danish EPA considers that this is more an expression of a characteristic of the four treatment plants investigated in 1998 than a general increase or fall in discharges of these heavy metals.

HEAVY METALS CONTENT OF SEWAGE SLUDGE

In 1998, a number of heavy metals were also measured in sewage sludge from the four treatment plants. The amount of sludge investigated in 1998 corresponds to approx. 10% of the total amount of sludge generated in Denmark. Of the sludge investigated, approx. 20% is applied to farmland. On a national basis, approx. 60% of all sewage sludge is applied to farmland. The sludge measured in 1998 thus represents a large part of the sludge that is not applied to farmland.

Each year, the Danish EPA collects data on sewage sludge from all Danish wastewater treatment plants. The data for 1997 are summarized in Danish EPA (1999b). Comparison of the data in that report and the figures in Table 3.6 shows that the measured values are of the same order. The values for cadmium and lead are a little higher than measured in 1997, though.

Table 3.6
Mean value and deviation for the heavy metal content of sewage sludge in 1997. DM: Dry matter

Metal	Total amount	Mean	Deviation
	kg	mg/kg DM	mg/kg DM
Arsenic (As)	-	6.0	3.2

Lead (Pb)	10,000	170	213
Cadmium (Cd)	300	3.3	3.5
Chromium (Cr)	5,000	24	7.7
Copper (Cu)	35,000	270	51
Mercury (Hg)	200	1.7	1.9
Nickel (Ni)	3,000	22	5.4
Zinc (Zn)	110,000	888	130

Sewage sludge intended for application to farmland has to meet certain requirements as to the content of heavy metals, etc. These requirements are stipulated in Statutory Order No. 823 of 16 September 1996 on the Application of Waste Products for Agricultural Purposes (Ministry of Environment and Energy, 1996). Relative to these requirements, the measured values for cadmium and lead are higher on a dry matter basis.

The total amount of heavy metals in sewage sludge was calculated from the Danish EPA's concentration measurements made in 1997. The calculations are based on approx. 90% of all sewage sludge generated in Denmark. It is thus believed that the calculated amounts for the total content of heavy metals in sewage sludge give a good impression of the magnitude of the resultant discharges.

TREND SINCE 1989

Since 1989, discharges from wastewater treatment plants have been reduced considerably. The total amount of organic matter discharged has been reduced by 90%, while discharges of nitrogen and phosphorus have been reduced by 71% and 87%, respectively. The trend in discharges of organic matter, nitrogen and phosphorus during this period is illustrated in Figure 3.2.

FIGURE 3.2.
TREND IN DISCHARGES FROM WASTEWATER TREATMENT PLANTS OVER THE PERIOD 1989–98.

FIGURE 3.3
TOTAL WASTEWATER DISCHARGE AND ANNUAL PRECIPITATION OVER THE PERIOD 1989–98.

Over the period 1989–98, inputs to the treatment plants varied from 8.2 to 9.4 million PE. The fluctuation in the magnitude of the loads is attributable to uncertainty in the calculation method, which is largely based on a relatively few measurements at the individual plants. The variation in plant capacity can be due to former uncertainty as to whether it was the physical capacity or the approved capacity that had to be reported. The total number of treatment plants continues to fall and wastewater treatment is being collected at larger and more advanced plants.

The number of exceedences of discharge limit values in percent of the total number of treatment plants with discharge limit values fell from 39% in 1989 to 25% in 1995, increased to 30% in 1996, fell to 20% in 1997 and fell further to 16% in 1998. The number of plants with controlled discharge limit values has been roughly constant for the past five years. Since the total number of municipal treatment plants has concomitantly fallen, the share of plants with controlled discharge limit values is increasing. The number of plants that have exceeded discharge limit values is the lowest recorded since 1989.

3.1.2 **Separate industrial discharges**

The calculations of separate industrial discharges encompass direct discharges to watercourses, lakes and the sea from enterprises that are required to have a discharge permit under the Environmental Protection Act. The calculations do not encompass discharges from enterprises etc. that discharge less than 30 PE or which solely discharge cooling water or uncontaminated surface water.

THE YEAR GONE BY

The calculations encompass a total of 109 enterprises etc. with one or more direct outfalls to watercourses, lakes or the sea. Of these, 32 are encompassed by the requirement of the Action Plan on the Aquatic Environment to reduce nutrient discharges (APAE-enterprises). Of the 109 enterprises, 87 discharge nitrogen, phosphorus and/or organic matter. Fifty-four are reported by the county authorities as discharging hazardous substances. Due to a lack of information, enterprises in Vestsjælland, Bornholm, Viborg and Nordjylland counties that might discharge hazardous substances are not included in the calculations.

The total amount of wastewater discharged via separate industrial discharges amounted to approx. 64 million m^3 in 1998, of which approx. 43 million m^3 was discharged from APAE-enterprises.

Discharge of nutrients from separate industrial discharges in 1998 amounted to 1,428 tonnes nitrogen and 124 tonnes phosphorus. Relative to 1997 this represents a 21% reduction in nitrogen discharge and a 14% reduction in phosphorus discharge. Of the 1,428 tonnes nitrogen discharged, 1,189 tonnes derived from APAE-enterprises and 239 tonnes from other enterprises. Of the 124 tonnes phosphorus discharged, 100 tonnes derived from APAE-enterprises and 24 tonnes from other enterprises.

Of the total land-based point-source discharges of nitrogen and phosphorus, separate industrial discharges accounted for around 14% and 9%, respectively, cf. Figure 3.1. The fish processing industry remains the main industrial source, accounting for 46% of the nitrogen discharge and 52% of the phosphorus discharge. The amount of organic matter discharged from separate industrial discharges in 1998 was approx. 10,700 tonnes BOD_5 or approx. 24,100 tonnes COD. Of this, discharges from APAE-enterprises comprised approx. 9,100 tonnes BOD_5 or 21,300 tonnes COD. Relative to 1997, this represents a reduction of 6% for BOD_5 and 23% for COD.

While the separate industrial discharges are of minor significance as regards nutrient loading, they are one of the main sources of organic matter loading, accounting for around 43% of total land-based point-source discharges calculated as BOD_5. Most of this derives from the sugar industry (61%) and the fish processing industry (32%).

The information reported by the Counties on the amount of hazardous substances discharged to water bodies in 1998 via separate industrial discharges is summarized in Tables 3.7 and 3.8. The calculations are based on enterprise in-house control and county supervision data. Data collection is thus not aimed at producing a nationwide estimate of discharges, neither with respect to the nature nor the amounts of the substances discharged. As already mentioned, moreover, such information is lacking from four of the 14 Danish counties. For the same reason, the amounts stated in Tables 3.7 and 3.8 are minimum values for the discharge.

Table 3.7
Discharges of heavy metals and inorganic trace elements via separate industrial discharges in 1998 (minimum values).

	kg
Aluminium (Al)	6
Arsenic (As)	10
Barium (Ba)	600
Lead (Pb)	66
Cadmium (Cd)	10
Chromium (Cr)	360
Cyanide	2
Copper (Cu)	454
Mercury (Hg)	2
Molybdenum (Mo)	252
Nickel (Ni)	397
Selenium (Se)	12
Strontium (Sr)	44,000
Silver (Ag)	2
Tin (Sn)	1
Vanadium (V)	33
Zinc (Zn)	670

Table 3.8
Discharges of xenobiotic substances via separate industrial discharges in 1998 (minimum values).

	kg
Pesticides	5
Aliphatic amines	8,787
Aromatic hydrocarbons	1,254
Phenolic compounds	86
Halogenated aliphatic hydrocarbons	30
Halogenated aromatic hydrocarbons	189
Chlorophenols	265
Polyaromatic hydrocarbons (PAH)	< 1
Anionic detergents	23
Ether	2
Aldehydes, am-	

ides, etc.	2,213
AOX	15

The majority of the hazardous substances and the heavy metals mentioned are included in the NOVA-2003 sampling programme. With many of the substances, however, the necessary analysis methods or documentation for the quality of the analyses are not yet available. As a consequence, the estimates given in the tables are subject to considerable uncertainty.

Other substances discharged in separate industrial discharges in 1998 are chlorine, formiat, acetate, iron, ferro-iron and oil.

Several of the hazardous substances reported on by the Counties in 1998, including mercury and cadmium, as well as chlorophenols, aromatic halogenated hydrocarbons and halogenated aliphatic hydrocarbons, are List I substances pursuant to Council Directive 76/464/EEC on Pollution caused by Certain Hazardous Substances Discharged into the Aquatic Environment of the Community, i.e. pollution with them should be terminated. The directive has been implemented in Danish legislation through Ministry of Environment and Energy Statutory Order No. 921 of 8 October 1996. In this connection, discharge limit values were stipulated for List I substances. The concentrations in the wastewater from the separate industrial discharges are not generally considered to be critical compared with these discharge limit values.

No information is available from the Counties on what concrete efforts are being made to terminate pollution by these substances.

TREND SINCE 1989

The total amount of wastewater discharged has fallen since 1989. Discharge peaked in 1991 at 100 million m^3 and thereafter fell until 1996, since when it has remained constant at just under 65 million m^3 per year. Total discharge from APAE-enterprises has remained roughly constant throughout the period at between 40 and 45 million m^3 per year except in 1991–92, when discharge amounted to 56 million m^3.

Total nitrogen discharge via separate industrial discharges fell by 37% alone from 1989 to 1990 and has generally been falling since then. The total reduction since 1989 is 78%, cf. Figure 3.4.

In the case of the APAE-enterprises alone, the percentage reduction in nitrogen discharge since 1989 is less than for all enterprises together, among other reasons because an increasing number of enterprises are falling in under the requirements of the Action Plan on the Aquatic Environment. It is therefore of interest to follow separately those APAE-enterprises for which data is available back to 1989. Total discharge from these enterprises has fallen steadily during the period from 2,065 tonnes to 839 tonnes except for the fact that an extraordinarily high discharge from the fishmeal industry in 1992 made that year's total discharge the period's greatest at 2.237 tonnes. The total reduction over the period 1989–98 was 59%.

The trend in phosphorus discharge via separate industrial discharges since 1989 is largely the same irrespective of whether the discharge is calculated for all enterprises (Figure 3.4), for all APAE-enterprises together, or for

APAE-enterprises for which information is available back to 1989. The total discharge fell markedly until the mid 1990s, since when it has remained relatively stable. Taking all enterprises together, the total discharge fell from 1,412 tonnes in 1989 to 124 tonnes in 1998, corresponding to 91%. In the case of APAE-enterprises for which information is available back to 1989, the total discharge has fallen from 810 tonnes to 48 tonnes, corresponding to 94%.

The total BOD_5 discharge via separate industrial discharges, which was 56,205 tonnes in 1989, fell steadily until 1996, whereafter it seems to have stabilized at around 10,000 tonnes BOD_5 per year. The reduction in the total discharges between 1989 and 1998 amounted to 81% (Figure 3.4).

FIGURE 3.4
TREND IN TOTAL DISCHARGE OF NITROGEN, PHOSPHORUS AND ORGANIC MATTER VIA SEPARATE INDUSTRIAL DISCHARGES OVER THE PERIOD 1989–98.

Total BOD_5 discharge from APAE-enterprises varied around 19,000 tonnes per year from 1989 to 1992, thereafter falling to around 6,400 tonnes in 1996, since when it has increased slightly again. This development to some extent reflects the fact that there are presently more APAE-enterprises than in 1989. In the case of the APAE-enterprises for which information is available back to 1989, the total discharge halved between 1989 and 1991–92, falling from 20,305 tonnes to around 10,000 tonnes. The reduction continued less steeply until 1996, whereafter the discharge increased slightly to 6,778 tonnes in 1998. The total reduction in BOD_5 discharge from these APAE-enterprises over the period 1989–98 was 67%.

With regard to hazardous substances, annual estimates of total discharges via separate industrial discharges have not previously been made. The Danish EPA (1994) has previously estimated the total discharge of the heavy metals lead, copper, chromium, nickel and zinc from separate industrial discharges to be 5 tonnes in 1993, while the corresponding discharge in 1998 was 2 tonnes. As with the present figures, the figures for 1993 are subject to considerable uncertainty, and there is no reason to believe that the difference in the two figures reflects a marked decrease in the discharges.

3.1.3 **Stormwater outfalls**

The calculations of stormwater outfalls encompass all stormwater discharges to watercourses, lakes and the sea from drained areas such as roofs, road surfaces, paths and paved surfaces to the extent that these are connected to the sewerage system. Stormwater discharges can be divided into:

- Separate discharges of surface runoff, and
- Stormwater overflows from combined sewerage systems, where the discharge consists of a mixture of surface runoff and wastewater.

THE YEAR GONE BY
The most important parameter for calculating the discharge from the stormwater outfalls is the precipitation. 1998 was a generally wet year. On average, 860 mm precipitation fell on the whole country, which is more than 20%

above normal. This led to correspondingly greater stormwater discharges from both separate and combined sewerage systems.

The number of stormwater outfalls and associated total and paved catchment areas is shown in Table 3.9. The total area serviced by sewerage systems is 241,300 ha. Of this, paved surfaces comprise 71,600 ha, corresponding to 5% of the total area. The paved area is virtually equally distributed between separate and combined systems, although with considerable regional variation. Thus 90% of Copenhagen municipality is serviced by combined systems while only approx. 30% of Copenhagen county is serviced by combined systems. A total of 5,395 stormwater overflows and 9,136 stormwater outfalls from separate systems are recorded. The total paved area has remained largely unchanged, but there is an increasing tendency for paved areas of both combined and separate systems to discharge via holding basins.

Table 3.9
No. of outfalls/overflows and total and paved catchment area for combined and separate sewerage systems with and without holding basins in 1998.

Sewerage system	No. of outfalls/overflows	Area (ha)	
		Total	Paved
Combined without basin	4,148	67,822	22,034
Combined with basin	1,247	41,236	11,969
Combined, total	5,395	109,058	34,003
Separate without basin	7,560	90,601	24,618
Separate with basin	1,576	41,649	12,945
Separate, total	9,136	132,250	37,563

Total discharge in 1998 was just under 20% greater than for a normal year, amounting to 244 million m^3 water containing 968 tonnes nitrogen, 253 tonnes phosphorus and 16,192 tonnes organic matter measured as COD. The higher discharge is due to the very high level of precipitation.

In 1998, an analysis was undertaken of stormwater overflows from wastewater treatment plants with a capacity exceeding 5,000 PE. The plants reported the total amount of overflow discharge from the whole of their catchment area serviced by combined systems. The analysis showed that despite the fact that the overflow discharges currently comprise less than 3–4% of the total load generated in the catchment areas of the treatment plants, in many cases they are of the same magnitude as the total discharge via the plants' outfalls. On average, though, they only comprise approx. 12% of the organic matter and nitrogen, and 30% of the phosphorus.

TREND SINCE 1989

The calculated discharges of nitrogen, phosphorus and organic matter during the period 1989–98 are shown in Figure 3.5 together with the precipitation for the same period. The figure shows that there has been little interannual variation in the discharges but that they follow the level of precipitation.

FIGURE 3.5

TREND IN THE TOTAL DISCHARGES OF NITROGEN, PHOSPHORUS AND ORGANIC MATTER (COD) FROM SEPARATE AND COMBINED SEWERAGE SYSTEMS.

Within the catchment areas of combined sewerage systems, the paved area from which discharge takes place via a holding basin increased by 34% over the period 1992–98, while the paved area where discharge does not take place via a holding basin decreased by 10%. The increase is attributable to the construction of new basins. In 1998, there were holding basins on the drainage systems from 35% of the paved area serviced by combined systems.

3.1.4 **Rural properties**

The rural areas typically represent ordinary dwellings. The properties lie outside the sewerage system catchment areas and discharge their wastewater via plants having a capacity of less than 30 person equivalents (PE). Most of the wastewater is ordinary domestic sewage.

THE YEAR GONE BY

In 1998, there were a total of approx. 346,500 properties in the rural areas. These comprise houses located in summer cottage districts, allotment cabin districts, sparsely built-up areas, and villages. The distribution by property type of all the properties in Denmark located outside the sewerage system catchment areas and discharging less than 30 PE is shown in Table 3.10.

By far the majority (60%) of the registered properties in rural areas are located in sparsely built-up areas. Summer cottages also comprise a large group, accounting for approx. 30% of the properties.

TREATMENT ESTABLISHED

Table 3.10 also shows the treatment that the wastewater from the rural properties undergoes. It can be seen that approx. half of all the properties discharge their wastewater via soakaways, i.e. that no discharge takes place to watercourses, lakes or the sea. It should be noted that approximately half of these soakaways are located in summer cottage districts. The treatment type "Other, with discharge" (cf. Table 3.10) is limited in extent since only 5% of the properties have established such systems. Thus just under half of all the properties in rural areas discharge wastewater to watercourses, lakes or the sea. Permanent residences account for 90% of these properties.

Table 3.10

Rural properties apportioned by property type and type of sewage treatment.

Treatment type	Summer cottages	Allotment cabins	Sparsely built-up areas	Villages	Other[1]	Total
Soakaways	86,753	2,233	76,234	4,435	179	169,834
Other without discharge	8,053	5,252	4,961	466	64	18,799
Mini treatment plants	23	0	82	36	8	149
Biological sand filters	2	0	357	120	2	481
Other with discharge	12,867	410	122,910	20,751	275	157,210
Total	107,698	7,895	204,544	25,808	528	346,473

Other[1] refers to properties with an atypical sewage load compared with ordinary dwellings, for example schools, institutions, office buildings, hotels, etc. Under treatment type, "Other without discharge" refers to other types of treatment plants that do not discharge effluent to watercourses, lakes or the sea.

Less than one percent of the properties in rural areas discharge their wastewater via mini treatment plants or biological sand filters, cf. Table 3.10. The remainder typically discharge into drains following mechanical treatment.

DISCHARGES IN 1998

The calculated discharges of nitrogen, phosphorus and organic matter from rural properties in 1998 are shown apportioned by property type in Table 3.11. There appears to have been a minor fall in discharges to water bodies relative to 1997. The registered change is probably also attributable to the fact that reporting as regards treatment method and hence degree of treatment is more detailed than previously.

The properties in rural areas outside the sewerage system catchment areas discharged treated effluent containing approx. 998 tonnes nitrogen, 228 tonnes phosphorus and 3,888 tonnes organic matter to watercourses, lakes or the sea. Approx. 98% of this input to the aquatic environment derives from permanent residences, with by far the majority coming from rural areas, cf. Table 3.11.

Table 3.11

Total discharges of nitrogen, phosphorus and organic matter from dwellings outside the sewerage system catchment areas.

	Total-N	Total-P	BOD_5
		Tonnes	
Summer cottages	16	4	70
Allotment cabins	<1	< 1	1
Sparsely built-up areas	830	189	3,231
Villages	145	33	554
Other	8	2	31
Total	998	228	3,888

In 1998, NOVA-2003 did not encompass measurements of hazardous substances in wastewater effluent from the properties in rural areas. In the coming years, measurements will be undertaken at a few selected treatment plants solely receiving domestic sewage. In future, it will thus be possible to use the measurements from these plants as a basis for estimating the total discharges of hazardous substances from properties in rural areas.

It is nevertheless already possible to provide a qualified estimate of the total discharges of heavy metals, cf. Table 3.12. The heavy metals discharges have been calculated as a combination of estimates based on two models (Danish EPA, 1997a and Danish EPA, 1999b), and are the best estimates that can be made at present. The calculated discharges are subject to considerable uncertainty, however. It is therefore not reasonable to discuss changes relative to previous years. The differences seen should rather be considered as reflecting improvement in the calculations.

Table 3.12

Calculated discharges of selected hazardous substances in 1998.

Substance	kg
Aluminium (Al)	1,000

Arsenic (As)	30
Lead (Pb)	200
Cadmium (Cd)	30
Chromium (Cr)	200
Copper (Cu)	1,000
Cobalt (Co)	60
Mercury (Hg)	20
Nickel (Ni)	500
Silver (Ag)	30
Zinc (Zn)	4,000

The future improvement in the treatment of the wastewater that can be expected to result from the initiatives in Act 325 of 14 May 1997 on Wastewater Treatment in Rural Areas (Ministry of Environment and Energy, 1997) must be presumed to have a positive effect as regards heavy metals. It can be expected that the trend will be towards a continual reduction in heavy metals discharges to the aquatic environment.

WASTEWATER TREATMENT PLANS

Based on the Regional Plans, which stipulate where treatment of wastewater from rural areas is to be improved, the municipal authorities plan a combination of connection to the sewerage system, soakaways and local treatment of a specified type etc. which will have to apply to the properties in rural areas.

At present, the municipal wastewater plans only encompass a few percent of the properties in rural areas. This is too slender a basis to create a picture of the future types of wastewater treatment for these properties.

The Counties that have a Regional Plan covering wastewater treatment in the rural areas have had difficulty in assessing whether the adopted municipal wastewater treatment plans are in accordance with the Regional Plans with respect to improvement of treatment. Often the Counties have reported that the plans are in accordance. Only in very few cases has it been reported that there is a lack of accordance between the Regional Plan and the wastewater treatment plan requirements as to treatment.

TREND IN DISCHARGES FROM PROPERTIES IN RURAL AREAS

The calculated discharges are subject to uncertainty. Hence it is not reasonable to discuss changes in the discharges relative to previous years. The changes hitherto observed should be considered as reflecting improvement in the calculations. There has been a real decrease in the discharge of phosphorus, however.

3.1.5 Freshwater fish farms

Freshwater fish farms raise salmonid fish, especially rainbow trout, and for this purpose utilize stream water that is subsequently discharged into watercourses, lakes or the sea.

THE YEAR GONE BY

In 1998, there were 423 freshwater fish farms in operation. Net production of fish was 32,585 tonnes. Total feed consumption was 31,607 tonnes, including feed for the mother fish. Just over 1 kg fish was thus produced for each kg feed used.

The calculations of discharges from freshwater fish farms indicate that 1,241 tonnes nitrogen, 92 tonnes phosphorus and 3,430 tonnes organic matter (BOD_5) were discharged in 1998. Based on information on water supply conditions at the fish farms, their total water consumption is estimated to be at least 4,300 million m^3 per year.

Relative to the total input of nutrients to the marine environment, the contribution from the freshwater fish farms is limited except in a few estuarine fjords in eastern Jutland (e.g. Mariager Fjord), where phosphorus discharge by freshwater fish farms accounts for a major part of the total load. Similarly, phosphorus loading from freshwater fish farms accounts for a major part of the phosphorus input to a number of lakes in mid Jutland.

The primary impact of the freshwater fish farms on the aquatic environment occurs locally in the watercourse reaches where the fish farms are located. This effect is associated with the discharge of organic matter derived, like the nutrients, from fish excreta and uneaten fish feed.

In connection with the freshwater fish farming, a large amount of medicine (antibiotics) and auxiliary substances are used to prevent and combat various parasites, bacterial diseases and viral diseases. In 1998, the three most used auxiliary substances were copper sulphate (10.2 tonnes), chloramine (10.4 tonnes) and formalin (164 m^3). It has not been possible to calculate the total consumption of medicine in 1998.

TREND SINCE 1989

Over the period 1989–98, a considerable reduction has taken place in the calculated discharges of nitrogen, phosphorus and organic matter, cf. Figure 3.6. Relative to 1997, the level of the three parameters is largely the same. Over the period 1989–98, the theoretically calculated discharge of organic matter (BOD_5) has decreased by 49%, while nitrogen has decreased by 43% and phosphorus by 61%.

FIGURE 3.6

DISCHARGES OF NITROGEN, PHOSPHORUS AND ORGANIC MATTER FROM FRESHWATER FISH FARMS (1993–98).

The decrease in discharges is primarily attributable to increasing compliance with the provisions of the Statutory Order on Freshwater Fish Farms concerning the establishment of treatment measures and setting annual feed consumption limits, as well as requirements on improved feed quality and better utilization of the feed.

The general reduction in the discharge of organic matter from freshwater fish farms has also been registered through measurements of BOD_5 in watercourses. By way of example, Figure 3.7 shows time series for the development in the BOD_5 level in two watercourses in Ribe County, where freshwater fish farms are the predominant point source. In accordance with the general reduction in organic matter loading by freshwater fish farms, the BOD_5 level in these two fish farm-affected watercourses has fallen considerably. The BOD_5 concentrations in watercourses affected by freshwater fish farms remain more than twice that in unaffected reference watercourses, however, cf. Bøgestrand et al., 1999.

FIGURE 3.7
TREND IN BOD_5 CONCENTRATION (FLOW-WEIGHTED AVERAGE) OVER THE PERIOD 1987–98 IN TWO WATERCOURSES IN RIBE COUNTY, WHERE FRESHWATER FISH FARMS ARE THE PREDOMINANT POINT SOURCE.

The trend is also reflected in the biological state of the watercourses downstream of the fish farms. In 1998, approx. 40% of watercourse reaches affected by fish farms had an acceptable biological state. This is a marked increase relative to 1989, when less than 15% of the affected reaches had an acceptable state (Danish EPA, 1999b).

The reported consumption of auxiliary substances has virtually doubled since 1997. It is uncertain whether the increase reflects a real increase in consumption or improved quality of data reporting. Clarification of this question and of the effects of these and other auxiliary substances downstream of the fish farms is a precondition for being able to identify how best to deal with the problem.

The heavy metals content of sludge from freshwater fish farms has attracted increasing attention in recent years. The results of one such study indicate that the majority, especially cadmium and nickel, derive from the river water (COWI, 1998).

3.2 Sea-based point sources

The sea-based point sources encompass mariculture, marine dumping of seabed material, offshore industry and ship-based pollution.

3.2.1 Mariculture

By mariculture is meant the farming of fish in sea-based fish farms or land-based fish farms fed by seawater. The latter are not strictly sea-based point sources, but are included here because they are subject to the same regulations as sea-based fish farms.

In Denmark, mariculture is mainly based on rainbow trout. The trout are usually released in the spring at a weight of 700–800 grammes and grow during the course of the summer half year to reach 3–5 kg by the time they are harvested in the autumn. Feeding the fish results in a loss of nutrients and organic matter to the aquatic environment – primarily in the form of excreta from the fish and uneaten feed.

THE YEAR GONE BY
The sea-based fish farms, of which 25 utilized their authorization permits in 1998, are mainly located in protected areas of the Little Belt, the northern Belt Sea, the sea south of Funen and the Great Belt. In 1998, sea-based mariculture used approx. 6,100 tonnes feed. Net production amounted to approx. 5,200 tonnes fish, of which approx. 300 tonnes was in the form of roe. The majority of the land-based mariculture farms, of which 13 were in operation in 1998, are of an elderly type (earth ponds) located alongside

Ringkøbing Fjord. A small number of modern land-based mariculture farms are located alongside the Great Belt and the Little Belt, as well as in northern Jutland out towards the Skagerrak. In 1998, land-based mariculture used approx. 2,500 tonnes feed resulting in the net production of 1,900 tonnes fish.

The total discharges from sea-based and land-based mariculture in 1998 were around 290 tonnes nitrogen, 33 tonnes phosphorus and 1,571 tonnes organic matter. The land-based mariculture farms used approx. 232 million m^3 water in 1998.

The total consumption of medicine and auxiliary substances in 1998 as reported by the county authorities was approx. 840 kg plus 16 m^3 formalin. The most used auxiliary substances were – apart from formalin – Tribrisin (338 kg) and Aquavet S/T (216 kg). The fate of the substances in the sea-based and land-based mariculture farms is relatively unknown, as are the environmental effects of the consumption of medicine and other auxiliary substances.

TREND SINCE 1987

Since 1987, total discharge from sea-based mariculture has decreased markedly in the case of phosphorus. Thus total discharge was around 40 tonnes in 1987, while less than 30 tonnes per year were discharged in recent years. The total nitrogen discharge from sea-based mariculture has fallen from 300 tonnes per year at the end of the 1980s to around 250 tonnes per year in recent years. Figures for land-based mariculture are only available from 1992 onwards. Total discharges have been relatively stable except for a slight fall in the case of nitrogen, cf. Figure 3.10. Expressed per tonne fish produced, discharges from both sea-based and land-based mariculture have fallen considerably.

FIGURE 3.8

DISCHARGES OF NITROGEN, PHOSPHORUS AND ORGANIC MATTER FROM SEABASED (A) AND LAND-BASED (B) MARICULTURE. NO INFORMATION IS AVAILABLE ON DISCHARGES OF ORGANIC MATTER (BOD_5) FROM LAND-BASED MARICULTURE NOR FOR SEA-BASED MARICULTURE IN 1994.

Based on the information presently available it is not possible to assess the trend in consumption of medicine and auxiliary substances.

3.2.2 Marine dumping of seabed material

Ship traffic, ferry traffic, fishing vessels and pleasure boats all need harbours and shipping channels of a known depth and width. Each year the county authorities issue permits to dump material from the necessary dredging and excavation operations at selected dumping sites within the County's area of jurisdiction. In some cases, though, the material is so contaminated that a permit for dumping at sea cannot be issued and the material is instead deposited in special deposits near the coast.

In 1998, approx. 4 million tonnes of dredged and excavated material from harbours and shipping channels were dumped at sea. As is apparent from Table 3.13, no trend can be seen over the period 1989–98. The amount of material very much depends on whether or not major construction projects involving dumping of seabed material have been undertaken during the year in question.

Table 3.13
Marine dumping of seabed material (million tonnes) over the period 1989-1998.

Year	Amount
1989	3.3
1990	4.6
1991	8.0
1992	7.0
1993	6.4
1994	5.4
1995	4.2
1996	3.5
1997	4.0
1998	3.7

An overview of how much dredged seabed material is deposited on land is not presently available. The material involved usually derives from particularly polluted sections of harbour and surface sediment. Not all the material excavated from harbours and shipping channels is dumped at sea or deposited. Whenever possible, excavated material is used in embankments, roadworks, etc. Another form of recycling is the use of clean seabed material for beach nourishment.

3.2.3 **Offshore industry**

The activities of the offshore industry result in the discharge of large amounts of substances into the sea, including hydrocarbons, a number of hazardous substances. The major sources of the discharges are:

- Drilling (discharge of drilling muds, cementing chemicals, etc.)
- Production water (discharge of residues of hydrocarbons, production chemicals, heavy metals, etc.)
- Well maintenance operations (discharge of chemicals), and
- Spillage (oils and chemicals).

The majority of the auxiliary substances and materials used and discharged are considered harmless to the marine environment as they are naturally occurring there or are natural products such as nutshells, cellulose fibres, etc.

Other substances and materials used and discharged into the marine environment are hazardous, however. Depending on the amounts discharged and the inherent properties of the individual substances and materials, including their toxicity, persistence and potential to accumulate in the food chain, the environmental hazard posed varies and will thus be able to affect the marine ecosystems to a varying extent.

THE YEAR GONE BY
According to the annual records submitted to the Danish EPA by the offshore operators, 185 tonnes of oil was discharged into the Danish sector of the North Sea in 1998. The discharge of production water containing oil resi-

dues accounted for 174 tonnes while spillage accounted for the remaining 11 tonnes.

The discharge of production water also contributes to heavy metals loading of the marine environment. The heavy metals in production water derive from the oil and gas reservoirs and partly from impurities in production chemicals that can end up in the production water. Barite and bentonite in the drilling muds contain impurities in the form of heavy metals, etc. The amounts of heavy metals discharged reflect the discharges of drilling muds and thus correlate with the number of wells drilled. The figures for heavy metals discharges given in Table 3.14 are based on measurements of production water from a single North Sea field. However, as there can be considerable inter-field variation, the figures are subject to some uncertainty and should be interpreted with caution.

Table 3.14
Marine discharges of heavy metals in connection with drilling (D) and discharge of process water (P), 1998.

Metal	D	P
	kg	
Mercury	53	33
Cadmium	52	7
Zinc	910	98
Lead	1,318	242
Chromium	209	52
Nickel	135	20
Copper	890	38

In 1998, 85,316 tonnes of chemical substances and materials were used, of which 41,216 tonnes (48%) are estimated to have been discharged to the sea. The remainder was disposed of in other ways, for example by injection into the seabed, by being taken ashore, or as chemicals mixed in the oil. In addition, part of the chemicals used is retained in the reservoirs during the operations. These might subsequently be retrieved and discharged in the production water. The extent of this is unknown at present, however.

TREND IN DISCHARGES

In 1998, oil-based muds (OBM), on which there had been a moratorium since 1991, were once again permitted for use in drilling certain sections of difficult wells if their use was deemed to be absolutely necessary. The waste OBM from these drilling operations were disposed of by injection into the seabed or by being taken ashore.

Discharge of oil to the sea in production water increased up through the 1990s (Figure 3.9) due to the general increase in the amount of production water generated. This in turn was partly attributable to increased production during the period and partly an effect of the general ageing of the existing oil and gas fields.

FIGURE 3.9

DISCHARGE OF OIL TO THE SEA FROM THE OFFSHORE INDUSTRY. THE DISCHARGES ARE DIVIDED INTO OIL-BASED MUDS (OBM), PRODUCTION WATER AND SPILLAGE. THE FIGURE DOES NOT INCLUDE DATA ON SPILLS FOR THE YEARS 1982–83, 1985–91 AND 1993, NOR FOR OBDF FOR THE PERIOD 1982–83.

The trend in discharges of products containing nonylphenolethoxylates (NPE) in connection with offshore activities is shown in Table 3.15. The development in the discharges of heavy metals from drilling operations is shown in Table 3.16.

Table 3.15
Annual discharges of products containing NPE.

Year	Discharge of products containing NPE[1]
	tonnes
1994	10.1
1995	8.4
1996	3.9
1997	0.5
1998	0.4

1) The values are the amount of product and not the total discharge of NPE.

Table 3.16
Annual discharges of heavy metals in connection with offshore drilling.

Year	Hg	Cd	Zn	Pb	Cr	Ni	Cu
				kg			
1991	6	6	541	1,121	94	1	636
1992	17	18	2,734	1,107	115	6	729
1993	12	14	1,051	2,258	162	27	1,257
1994	5	4	348	806	67	23	350
1995	7	6	550	1,280	97	29	646
1996	25	22	636	1,606	126	49	110
1997	31	34	651	785	155	103	470
1998	53	52	910	1,318	209	135	890

3.2.4 **Ship traffic**

Ship traffic can also have environmental effects. These are primarily associated with oil spills and the effects of antifouling agents.

OIL SPILLS FROM SHIPS

When oil pollutes our coasts and beaches the impact on their recreational value to the population is considerable, and can affect the tourist industry in the region.

In nature, oil can also cause considerable damage to ecosystems, animals and plants. The best known effect is on seabirds, whose plumage forms an effective water-repellent and insulating layer. When a bird comes in contact with oil this protective layer is destroyed. The feathers stick together.

In the winter, an oil spot the size of a large coin is sufficient to reduce a bird's insulation such that it dies. Seabirds can also suffer internal damage by consuming oil in the form of oil-contaminated food or when cleaning their oil-coated plumage. The damage is often so great that the birds have little chance of surviving. To avoid heat loss to the surrounding cold water, oil-coated birds often seek onto the coasts where they collect. This renders them very visible and can arouse attention.

Shallow-water areas, which are very productive during the summer and home to fish fry, are very vulnerable to oil pollution. In winter, moreover, the Danish marine waters house large populations of diving ducks etc., just at a time when they are most vulnerable to oil pollution. Bird deaths due to oil pollution are thus almost solely observed during the winter period from October to April. The pollution primarily affects eider ducks, common scoters, velvet ducks and long-tailed ducks.

Relative to the 1970s, when up to 100,000 birds possibly perished, the number of bird deaths as a result of oil pollution has fallen considerably up to the present time. Oil pollution is thus hardly likely to pose a threat to the populations any longer, but still poses an animal welfare problem.

It is not possible to give exact figures for the amount of oil illegally discharged into Danish marine waters. However, it is possible to illustrate the extent of the problem using examples of the number and distribution of oil pollution incidents over the years. A new investigation of the number of oil-coated birds during the period 1984 to 1995 shows a decrease in the Baltic Sea and the Kattegat, but no similar fall in the Skagerrak and the North Sea (Ornis Consult, 1996). In addition, the number of oil pollution incidents in Danish marine waters reported to the Naval Operations Command has remained rather constant over the past 5–10 years at around 400 reports per year – despite a general increase in ship traffic, cf. Table 3.17.

Table 3.17
Annual oil spill reports.

Year	No. of reports
1989	319
1990	345
1991	454
1992	356
1993	320
1994	354
1995	405
1996	393
1997	360
1998	476

The number of reported observations of oil pollution cannot be used directly as an indicator of whether or not there is a serious oil pollution problem in Denmark. As a rule, more than half of all observations concern either light oil/diesel, which evaporates, or mud or algae or current boundaries, i.e. false alarms. The Danish EPA considers that these figures indicate that the measures implemented to combat oil pollution have had a preventative effect. The environmental problem is greatest in the North Sea, where unlawful dumping of waste oil still takes place occasionally with resultant pollution of the Jutland west coast. On 1 August 1999, a new international ban on discharges of waste oil in the North Sea entered into force. A corresponding ban has existed for some years in the other Danish marine waters.

ANTIFOULING AGENTS

In order to hinder fouling of ship hulls they are coated with paint containing toxic substances. These have a broad spectrum of impact in the environment such that in addition to having effects on the organisms that cause fouling, they also have undesirable side effects on the environment.

The antifouling agent tributyl tin (TBT), which was introduced in the 1960s, is one of the most toxic substances deliberately released into the marine environment. It is toxic to a number of aquatic organisms, especially molluscs such as snails and mussels, which are affected at extremely low TBT levels right down to under 1 ng/l (Fent, 1996).

In the sea, TBT causes hormonal disturbances that can be registered as the so-called imposex phenomenon in whelks. Imposex is the development of male sexual characteristics in female snails and in extreme cases can lead to sterility and death. NOVA-2003 has encompassed monitoring of the effects of antifouling agents since 1998 (see Section 5.4).

3.3 Cultivated land

In Denmark, 62% of the country is agricultural land and of this, just over 90% is under crop rotation. No other country in Europe has such a high percentage of cultivated land. Agriculture and hence its structure, practices and land use thus have a decisive influence on the aquatic environment and nature in general.

Specialization and intensification of agriculture in Denmark has resulted in a development towards fewer but larger farms and intensively operated livestock farms. The overall livestock density has remained roughly constant, but the average herd size has increased six- to seven-fold over the period 1970–96 by six- to seven-fold in the case of pig herds and 4-fold in the case of dairy herds. The period up to the mid 1980s was characterized by increasing consumption of fertilizer and pesticides. Among other things, this led to loss and discharge of nutrients and hazardous substances, including pesticides etc. to the aquatic environment.

Agricultural pressure of the aquatic environment primarily encompasses ammonia volatilization, nitrogen and phosphorus losses, as well as pesticide losses.

Nitrogen and pesticide losses to the aquatic environment have been regulated for a number of years. Since the mid 1980s, a number of national strategies and action plans have formed the framework for this regulation. The individual plans and/or strategies are reviewed in Chapter 6.

3.3.1 Nitrogen

The latest Danish follow-up to achieve the target of a 50% reduction in nitrogen losses from agricultural sources is the Action Plan on the Aquatic Environment II. In 1987, total nitrogen discharge was calculated to be 260,000 tonnes N per year. The target was to reduce the farmyard load by approx. 30,000 tonnes N per year to a practical minimum and the nitrogen load from fields by approx. 100,000 tonnes N per year (Ministry of the Environment, 1987). The farmyard load encompasses discharges of seepage water from manure and silage stores, wastewater from livestock housing, etc., while the nitrogen load from fields largely encompasses nitrate leaching from cultivated land.

In March 1996, the Government estimated that the farmyard load had been reduced by 20–30,000 tonnes N per year. During preparation of the scientific foundation for the Action Plan on the Aquatic Environment II it was estimated that nitrogen leaching from the root zone had been reduced by approx. 17% over the period 1989/90 to 1995/96 (Iversen et al., 1998). As the nitrogen load from fields started at 230,000 tonnes N per year, this corresponds to a reduction of 35,000–40,000 tonnes per year. The analysis also encompassed assessment of the effect of the implemented and planned regulatory measures in agriculture. It was estimated that full implementation of the previously adopted agricultural measures by 1997, i.e. improved fodder utilization and changed norms for utilization of the nitrogen content of livestock manure, as well as changes in set-aside (from 1997 to 2003) and organic farming (leaching potential calculated from 1996 to 1997) would reduce nitrogen leaching by just over 60,000 tonnes N per year.

The measures in the Action Plan on the Aquatic Environment II were designed to ensure fulfilment of the original reduction target. The specific measures in the plan are described in Section 6.2.1 and is expected to further reduce nitrogen leaching by the remaining 37,000 tonnes N per year (Iversen et al., 1998).

The Danish Institute of Agricultural Sciences (1999) has calculated the total nitrogen balance for Danish agriculture from 1979/80 to 1996/97. The calculations are based on statistical information on purchases of commercial fertilizer and fodder and sales of animal and vegetable products. The balance revealed a total nitrogen surplus for Danish agriculture of approx. 510,000 tonnes N per year at the beginning of the 1990s. In 1996/97, the nitrogen surplus was approx. 415,000 tonnes, i.e. the surplus had been reduced by approx. 95,000 tonnes N per year up to 1996/97.

Ammonia volatilization accounts for a major part of the nitrogen load from agricultural sources – just under 93,000 tonnes N per year in 1996, which is the reference year for the scientific assessment of the Action Plan on the Aquatic Environment II (Andersen et al., 1999). According to the Statutory Order on Livestock Manure, liquid manure stores have to be tightly covered, either by a floating cap layer or by some other means. The aim is to reduce ammonia volatilization as well as to reduce the odour problem. It has been shown that compliance with this requirement is inadequate, especially on pig farms (COWI, 1999). Implementation of the Action Plan on the Aquatic Environment II will have a significant positive effect on ammonia volatilization from agriculture (Iversen et al., 1998), which is expected to be reduced by approx. 22% relative to the 1996 level. Most of this is expected to be achieved through a reduction in volatilization from livestock housing and in connection with manure application on fields.

At the end of the year 2000, the Minister for Environment and Energy and the Minister for Food, Agriculture and Fisheries will publish an action plan to reduce ammonia volatilization from agricultural sources together with the mid-term evaluation of the Action Plan on the Aquatic Environment II. The preparation for the mid-term evaluation includes revision of the calculation of the overall nitrogen balance for the agricultural sector, an assessment of the nitrogen balance being needed that integrates estimates of the various losses such as nitrate leaching, ammonia volatilization, farmyard load, gaseous loss via nitrification/denitrification and accumulation in the soil.

3.3.2 **Phosphorus**

Phosphorus is not individually regulated within the agricultural sector, but is indirectly regulated through the regulations governing the application of nitrogen in the form of livestock manure. The harmony criteria, which are stipulated in the Statutory Order on Livestock Manure, restrict (at the time of writing) the amount of livestock manure that may be applied to 1.7 LU (livestock units) per hectare. In the case of cattle holdings meeting certain crop requirements, the application of livestock manure equivalent to 2.3 LU per hectare is permitted. The harmony criteria are based on the nitrogen content of the manure and hence do not hinder overfertilization with phosphorus. The main inputs of phosphorus take place on livestock farms. The more stringent harmony criteria stipulated in the Action Plan on the Aquatic Environment II for certain types of livestock farm will indirectly reduce the input of phosphorus.

When applying waste products (e.g. sewage sludge) for agricultural purposes the total input of phosphorus may not exceed 30 kg P per hectare per year (from 1 July 2000) according to the Statutory Order on the Application of Waste Products for Agricultural Purposes.

The phosphorus content of the livestock manure produced in Denmark is equivalent to the total phosphorus requirements of Danish crops. An additional approx. 20,000 tonnes P are applied in the form of commercial fertilizer. The problem with phosphorus is that livestock production in Denmark is concentrated in certain regions, primarily north and western Jutland, thus leading to overfertilization with phosphorus, which accumulates in the soil and might leach to the aquatic environment. Foreign studies indicate that when the phosphorus content of the soil is high, very high levels of leaching can occur.

The agricultural sector must therefore work for a more regionally homogenous distribution of the livestock manure, and use livestock manure on as many fields as possible on the individual farms. Similarly, efforts need to be made to reduce the amount of phosphorus in livestock manure through more effective feeding practices.

3.3.3 Monitoring of agricultural land

MONITORING OF THE SIGNIFICANCE OF FARMING PRACTICE FOR THE AQUATIC ENVIRONMENT

NOVA-2003 encompasses a subprogramme – the so-called agricultural catchment monitoring programme – to monitor agricultural losses and discharges of nutrients and hazardous substances. The programme is based on seven monitoring catchments ranging in size from 5 to 15 km^2 – three sandy soil catchments and four clayey soil catchments. The catchments have been selected to represent the country with respect to soil type, climate, size distribution, livestock density, farm mix and crop mix. The catchments differ in several respects from the national average. Until 1997, the most important difference was a higher livestock density relative to the national average. Inclusion of a new catchment in 1998 resulted in an average livestock density of 0.86 LU per hectare, slightly lower than for the country as a whole (0.96 LU per hectare).

The nitrogen balances and leaching, etc. reflect the agricultural practice used. Agricultural practice in the monitoring catchments – for example fertilizer consumption and yield – is assessed from interview surveys. On the national level, estimates of fertilizer consumption etc. are calculated from the relevant statistics. The data collection methods in the agricultural catchment monitoring programme and the national statistics therefore differ. As a consequence of this and other factors, the monitoring catchments differ from the national norm.

The most important results pertaining to the trend in agricultural practice in the agricultural monitoring catchments and in the country as a whole are summarized below.

CROPS AND LIVESTOCK HERDS

In the agricultural monitoring catchments, 71% of the cultivated land consists of winter green fields. Of this, grass including set-aside, winter rape and undersown cereals (e.g. cereals undersown with grass) accounts for 41% and winter cereals for 41%, with root crops, maize, fields with ploughed-in stubble, and Christmas trees accounting for the remaining 18%. Only the first groups and root crops (sugar beet) can be expected to take up significant amounts of nitrogen in the autumn and winter months. The percentage of winter green fields has increased from 67% in 1990 to 71% in 1998.

Important preconditions for being able to utilize livestock manure are rational handling of the manure, i.e. reduced loss from livestock housing and during storage, appropriate storage capacity, and application method and time. In 1998, 92% of the livestock units were located on farms with at least 9 months' manure storage capacity, an increase of 53 percentage points over the period 1991–98. In general, storage capacity is slightly greater in the monitoring catchments than the national average. Given that the storage capacity is now so good it should no longer limit the effective utilization of livestock manure.

The majority of the livestock manure is applied in the spring with the percentage applied in spring/summer having increased from 51% in 1990 to 81% in 1998. The increase was greatest from 1993 to 1994 since new regulations requiring farmers to have sufficient storage capacity had to be complied with by the end of 1994. From 1997 to 1998, the percentage of solid manure/deep litter increased with a consequent increase in autumn application.

FERTILIZER CONSUMPTION AND UTILIZATION

Average nitrogen fertilizer consumption in the monitoring catchments decreased over the period 1990–98. The consumption of commercial fertilizer has decreased so that the utilization of the N content of livestock manure has increased 42 percentage points (increase in utilization relative to the level in 1990). The livestock manure was applied in a more appropriate manner in 1994–98 than previously. The method used to apply liquid manure is of considerable importance with respect to utilization of its nitrogen content. Widespread use of trailing hoses can thus ensure better utilization of the nitrogen. The optimal method is subsurface injection as this reduces ammonia volatilization to a practical minimum.

In 1998, approx. 10% of the area of the agricultural monitoring catchments was overfertilized, although the extent of overfertilization has decreased considerably. Around 14% of the properties that used livestock manure in 1998 did not meet the minimum requirement on utilization of the nitrogen content of the manure.

The handling and storage of livestock manure and the method and time of application of the manure and supplementary commercial fertilizer are of central importance as regards utilization of livestock manure in crop production. Possibilities remain to further improve utilization of the nitrogen content of livestock manure, among other means by reducing volatilization of ammonia prior to application. In order to improve utilization of livestock manure, the consumption of commercial fertilizer needs to be reduced even further.

N-BALANCE FOR THE AGRICULTURAL MONITORING CATCHMENTS

The nitrogen surplus or net input of nitrogen to fields in the agricultural monitoring catchments increases with increasing livestock density. The nitrogen surplus has fallen from 128 kg nitrogen per hectare in 1991 to 91 kg nitrogen per hectare in 1998, corresponding to a reduction of approx. 29%. The nitrogen surplus in 1998 for crop farms, livestock farms with 0–1.7 LU per hectare and livestock farms with more than 1.7 LU per hectare was 49, 91 and 132 kg nitrogen per hectare, respectively.

FERTILIZER CONSUMPTION IN THE WHOLE COUNTRY

The total input of commercial fertilizer nitrogen at the national level has decreased from 392 million kg nitrogen in 1985 to 277 million kg in 1998. The amount of livestock manure applied (without binding, i.e. manure applied directly to fields) has fallen from approx. 12 million kg nitrogen during the period. The total decrease in nitrogen input (commercial fertilizer and unbound livestock manure) to cultivated fields amounts to 22%. During the same period, crop nitrogen requirements (the economically optimal level for the farmer) has fallen by 36 million kg nitrogen. In 1998, nitrogen requirements and inputs of effective nitrogen fertilizer balanced for the first time at the national level (Grant et al., 1999), cf. Figure 3.10.

FIGURE 3.10
TREND IN TOTAL AND EFFECTIVE NITROGEN INPUT, NITROGEN REQUIREMENT AND REQUIREMENT FOR COMMERCIAL FERTILIZER DURING THE PERIOD 1985–98 (ADAPTED FROM GRANT ET AL., 1999).

NITROGEN BALANCE FOR DANISH AGRICULTURAL LAND

Total nitrogen input (commercial fertilizer, livestock manure, fixation by leguminous plants and atmospheric deposition) to agricultural land in Denmark has fallen from 750 million kg nitrogen in 1985 to 613 million kg in 1998. Nitrogen removal in crops has varied between 308 and 408 million kg. The nitrogen surplus has thus been reduced from 380 million kg in 1985 to 247 million kg in 1998 (Grant et al., 1999).

The nitrogen surplus corresponds to the potential loss, which can take place via leaching, accumulation of organic matter pools in the soil, denitrification and ammonia volatilization.

The net input of nitrogen to agricultural land has fallen from 133 kg N per hectare in 1995 to 92 kg N per hectare in 1998, corresponding to a 27% reduction, cf. Table 3.18. It should be noted that the number of livestock expressed in terms of livestock units has been roughly stable with a tendency towards a weak increase since 1985. The ratio of cattle to pigs has changed markedly, however, such that pigs now account for 49% of all livestock units while cattle only account for 46%.

Table 3.18
Nitrogen balance calculated per unit area agricultural land (kg nitrogen per hectare) in Denmark in 1985, 1995, 1996, 1997 and 1998 (from Grant et al., 1999).

	1985	1995	1996	1997	1998
Commercial fertilizer	138	113	105	105	104
Applied livestock manure	91	92	93	85	87
Sewage sludge	-	2	3	2	2
Industrial waste	-	-	2	4	4
Total input (incl. atmospheric deposition)	263	239	234	227	229
N removed in harvest	130	131	127	135	137
Input minus harvest N content	133	108	107	92	92

NITROGEN LEACHING FROM THE ROOT ZONE

Under the monitoring programme, investigations of nutrient leaching from the root zone have been undertaken at 18 field stations in 3 clayey soil catchments and at 14 field stations in 2 sandy soil catchments (prior to 1998 there were a further 8 stations in a third sandy soil catchment). The study covered 9 hydrological years – 1989/90 to 1997/98.

Average leaching from the root zone during the study period (1989/90 to 1997/98) was 69 kg N per hectare per year for the 3 clayey soil catchments and 124 kg N per hectare per year for the 2 sandy soil catchments. Total nitrogen loss to the watercourses was approx. 25 kg N per hectare per year for clayey soils (36%) and approx. 11 kg N per hectare per year for sandy soils (10%). In comparison, leaching to watercourses from uncultivated areas was 0.6–4.3 kg N per hectare per year. Part of the nitrogen that leaches from the root zone will end up in the groundwater.

Leaching of nitrogen is greatest on cattle holdings. Average leaching over the period 1990/91–1995/96 was 63, 69 and 134 kg N per hectare per year, respectively, for crop farms, pig holdings and cattle holdings (Grant et al., 1998).

As there has been considerable climatically determined interannual variation in nitrogen leaching it is difficult to speak of a general trend. Nevertheless, statistical analysis for the period 1990/91–1996/97 shows a tendency towards a fall in the measured nitrogen concentrations in the soil water.

LOSS IN DRAINAGE WATER

Studies of drainage water in two clayey soil catchments have shown that approx. 42% of the nitrate leaching from the root zone is lost via drains.

MODEL CALCULATIONS OF NITRATE LEACHING FROM THE ROOT ZONE

Leaching of nitrate from the root zone depends on a complex interplay between soil, plants, cultivation practice and climate. This interplay is difficult to describe through the use of models, whether these are complex simulation models or more simple empirical equations such as the model used. Determinations of the magnitude of annual leaching are therefore subject to some uncertainty. The model employed is primarily used to describe the temporal developmental and effect of regulatory measures, i.e. it is the changes in nitrogen leaching that are of interest.

The calculations for leaching of nitrogen from the agricultural monitoring catchments have been made using an empirical model (Simmelsgaard, 1991). The calculations assume a normal climate for the farming years 1989/90–1997/98, thereby isolating the significance of climatic variation.

The average calculated leaching for the period 1990/91–1996/97 was 26% less than the measured value. It is believed that the difference is partly attributable to measurement inaccuracy and to the fact that the model is based on a small number of fields fertilized with livestock manure. The model is consequently unable to take into account the mineralization and after-effects of nitrogen resulting from many years of livestock manure application to several of the field stations.

The model calculations for all fields in the 6 catchments show that the change in agricultural practice from 1989/90 to 1997/98 will eventually reduce leaching from the root zone by approx. 25%. Expressed in terms of kg nitrogen per hectare, leaching has fallen most on sandy soils during the period, namely 20 kg N per hectare as compared with 13 kg N per hectare on clayey soils (see Figure 3.11). Among other things, the decrease in nitrogen leaching on sandy soils is attributable to improvements in the handling of livestock manure.

FIGURE 3.11
CALCULATED LEACHING UNDER NORMAL CLIMATIC CONDITIONS FOR THE SIX AGRICULTURAL MONITORING CATCHMENTS FOR THE FARMING YEARS 1989/90–1997/98 (ADAPTED FROM GRANT ET AL., 1999).

PHOSPHORUS BALANCE FOR THE AGRICULTURAL MONITORING CATCHMENTS

The greatest decrease in phosphorus input to the agricultural monitoring catchments took place from 1997 to 1998 and was primarily due to reduced use of commercial and animal fertilizer. The net input of phosphorus to agricultural land in the monitoring catchments has fallen from approx. 10.5 kg P per hectare in 1991–92 to 5.1 kg P per hectare in 1998.

PHOSPHORUS BALANCE FOR DANISH AGRICULTURAL LAND

The input of commercial fertilizer phosphorus per unit area agricultural land fell from 16.7 kg P per hectare in 1985 to 7.7 kg P per hectare in 1998. The input of phosphorus in livestock manure in 1998 was 20.9 kg per hectare. Phosphorus removal in crops has varied between 17 kg and 22 kg phosphorus per hectare. The net input of phosphorus to agricultural land has thus fallen from approx. 15 kg to 11 kg P per hectare over the period 1985 to 1998.

Phosphorus tends to accumulate in the soil, especially on livestock farms, thereby enhancing the soil's so-called phosphorus status. Thus in many areas where the livestock density and hence phosphorus input are high, the phosphorus binding capacity of the soil is very low. The phosphorus status in the form of a phosphorus index is an expression of the amount of soil phosphorus available to plants, and hence also of the risk of loss to the aquatic environment via erosion and leaching. In 1997, more than 50% of Danish soils had a phosphorus index exceeding 4.0. A phosphorus index of 2.0–3.5/4.0 is optimal for crop production.

PHOSPHORUS LEACHING FROM THE ROOT ZONE

Leaching of phosphorus from the root zone has been low at the majority of the monitoring stations encompassed by the monitoring programme, averaging 0.049 kg phosphorus per hectare per year during the nine-year measurement period. The concentrations were 0.011–0.015 mg phosphorus per litre. At a few monitoring stations, in contrast, high concentrations have been recorded ranging from 0.042–0.410 mg phosphorus per litre. These high phosphorus concentrations are an effect of the very high soil phosphorus index. The total phosphorus loss from cultivated land to watercourses during the measurement period averaged 0.32 kg P per hectare per year. In the watercourses of the cultivated catchments, the phosphorus concentrations are 3-fold higher than in the uncultivated catchments, therefore considerably affecting most of the lakes.

LOSS IN DRAINAGE WATER

Phosphorus loss via drains has lain at approx. 0.043 kg P per hectare per year. From the beginning of the runoff year 1998/99, drainage water studies have been extended to also encompass continuous sampling in order to facilitate more accurate determination of phosphorus loss via drains.

3.3.4 Hazardous substances

HAZARDOUS SUBSTANCES

As a part of NOVA-2003, monitoring of hazardous substances is undertaken in the agricultural monitoring catchments. Pesticides or pesticide residues have been detected in the groundwater at approx. 46% of the abstraction well filters investigated. In approx. 10% of these, moreover, the limit level was exceeded. Other hazardous substances have been detected at 5 wells, corresponding to 13% of those investigated. The substances detected are aromatic hydrocarbons, alkylphenol compounds and plasticizers. The groundwater content of hazardous substances is examined more closely in Section 5.1.

PESTICIDE CONSUMPTION IN DENMARK AND THE AGRICULTURAL MONITORING CATCHMENTS

The target of a 50% reduction in the consumption of pesticide active substance relative to the average for 1981–85 (see also Section 6.2.2) has been achieved for all pesticide groups except herbicides. The corresponding 50% reduction target for pesticide treatment frequency is far from being met, only an 8% reduction having so far been achieved, cf. Figure 3.12.

FIGURE 3.12
TREATMENT FREQUENCY AND PESTICIDE SALES (DANISH EPA, 1999D).

3.4 Emissions to the atmosphere

NITROGEN EMISSIONS

The aquatic environment and especially the sea receive considerable amounts of nitrogen from the atmosphere. The nitrogen thus deposited derives from both Danish and foreign sources.

Nitrogen emissions to the atmosphere from Danish sources encompass nitrogen oxides (NO_x) and ammonia (NH_3). The nitrogen oxides mainly derive from power stations, industry and traffic, while the ammonia mainly derives from agricultural sources (see Section 3.3.1). Due to flue gas abatement measures in power stations and industry and catalytic converters on cars, NO_x emissions are tending to decline. In 1997, approx. 248,000 tonnes nitrogen were emitted to the atmosphere as nitrogen oxides from Danish sources. Ammonia emissions the same year totalled 102,000 tonnes and have remained largely unchanged since 1989, cf. Figure 3.13.

FIGURE 3.13
DANISH EMISSIONS OF NITROGEN (DANISH EPA, 1999E).

HEAVY METALS EMISSIONS

Since the beginning of the 1990s, emissions of heavy metals to the atmosphere from Danish sources have decreased, especially in the case of lead, cf. Table 3.19.

Table 3.19

Heavy metals emissions (Danish EPA, 1999e and Illerup et al., in prep.).

Metal	1990	1994	1995	1996	1997[1)]
	kg				
Lead (Pb)	124,234	45,632	43,026	20,121	8,474
Cadmium (Cd)	1,123	1,156	1,120	1,085	847
Mercury (Hg)	3,171	8,196	8,485	2,677	2,126
Arsenic (As)	1,447	1,333	-	1,270	839
Chromium (Cr)	6,200	4,724	-	3,399	2,958
Copper (Cu)	9,669	14,972	-	10,447	8,755
Nickel (Ni)	26,479	27,464	-	25,396	21,098
Selenium (Se)	4,234	2,928	-	3,586	2,256
Zinc (Zn)	34,353	56,315	-	36,103	25,797

1) The emission factors for 1997 are updated in relation to previous years. Only 1990 and 1997 have so far been recalculated using the updated factors.

EMISSIONS OF HAZARDOUS SUBSTANCES TO THE AIR

The estimates of annual Danish emissions of hazardous substances to the atmosphere encompass dioxins and furans as well as polyaromatic hydrocarbons (PAH). In 1997, emissions of these substances amounted to 20 g and 1,125 g, respectively (Danish EPA, 1999e).

Emissions of the following substances were zero or close to zero in 1997: Hexachlorobenzene (HCB), hexachlorocyclohexane (HCH), DDT, polychlorobiphenyls (PCB), Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Hexabromobiphenyl, Mirex, Toxaphene, pentachlorophenol and short-chained chlorinated paraffins (Danish EPA, 1999e).

4 Inputs to inland and marine waters

This chapter examines inputs of pollutants to the various water bodies. Contrary to what one might believe, the magnitude of the inputs to the aquatic environment is not identical with the discharges from the sources of pollution examined in the previous chapter. This is due to the fact that removal or further addition of pollutants occurs at many places along the water cycle. In this connection it is worth remembering that the various parts of the aquatic environment and the pollutant cycles can change roles depending on the angle from which they are viewed. For example, a watercourse polluted by nutrients from a wastewater outfall itself becomes a source of pollution when considering inputs to the sea.

In order to be able to undertake effective environmental management it is necessary to know the amounts of pollutants input to the aquatic environment from the various sectors of society, thereby enabling political initiatives to be targeted appropriately. Not all types of pollution are easy to measure, however. In particular, it is difficult to measure nutrient losses from diffuse sources. The magnitude of these are instead typically calculated by measuring total nutrient output from a given catchment and total point-source inputs, and thereafter calculating the losses from diffuse sources as the difference.

On their route to the sea, the discharges and losses from the different sources intermingle. As a consequence, it is difficult to determine the magnitude of the contribution made by the individual sources. As mentioned earlier, it is necessary to take into account the conversion that takes place on route. The magnitude of this can be determined from knowledge of the conditions, e.g. the number and size of lakes in the individual catchment. The magnitude of diffuse losses to inland waters is assumed to equal riverine inputs to the sea minus point-source inputs to inland waters plus retention. In this chapter when referring to inputs to the sea, all the nutrient removal that takes place between the point of discharge and the final input to the sea or lake is solely applied to the diffuse losses. This consequently leads to slight underestimation of the significance of the diffuse sources relative to the point sources. The reason for doing so is partly because discharges from point sources usually occur far downstream along the watercourses. All other things being equal, the retention processes will therefore have less influence on the point-source discharges. The diffuse sources can be divided into sparsely built-up areas, agriculture and the natural background loss. The latter is calculated on the basis of measurements in a few catchments largely devoid of human activity. The size of this contribution at the national level is thus subject to some uncertainty.

The trend in inputs from the individual sources is naturally highly dependent on the specific measures implemented to combat the source in question. However, it is also very much dependent on natural conditions such as precipitation and temperature. The various types of source differ in "sensitivity" to climatic variation. For example, variation in precipitation affects inputs from cultivated land more than inputs from wastewater treatment plants. One must therefore be cautious when comparing trends in inputs from different types of source over a period of years.

4.1 Nitrogen inputs

This section examines inputs of nitrogen to the inland and marine waters. The most important parts of the nitrogen cycle are outlined in Figure 1.1. Apart from the types of source described in Chapter 3, the present section also examines nitrogen inputs of natural origin, the so-called background loading. The section is divided in two parts, a status report for 1998 and a description of the trend since 1989.

4.1.1 The year gone by

LAKES

NOVA-2003 encompasses 31 lakes selected so as to be representative of all Danish lake types ranging from completely pollution-free clearwater lakes to lakes that have long been affected by high levels of nutrient loading. The relative significance of the various sources of nitrogen inputs to the 31 lakes is illustrated in Figure 4.1.

The rural areas, which encompass the sources sparsely built-up areas, agriculture and background, accounted for most of the nitrogen inputs to the monitoring programme lakes in 1998. As mentioned above, these lakes encompass a very wide spectrum of lake types. As a consequence, calculations of the relative distribution of those source types that have not been directly measured are subject to considerable uncertainty. With this reservation, it is estimated that 60–80% of the inputs derive from agricultural sources. It can be seen that approx. 17% of the nitrogen inputs to lakes derives from the atmosphere. The origins of these inputs are largely to be found in the close vicinity of the lakes, with the main source being ammonia volatilization from agricultural sources.

WATERCOURSES

The relative significance of the various sources of nitrogen inputs to watercourses in 1998 is illustrated in Figure 4.2.

As with lakes, agriculture is by far the most important source of nitrogen inputs to watercourses.

FIGURE 4.1 (LEFT)
SOURCE APPORTIONMENT OF NITROGEN INPUTS TO THE LAKES IN 1998 (ADAPTED FROM JENSEN ET AL., 1999).

FIGURE 4.2 (RIGHT)
SOURCE APPORTIONMENT OF NITROGEN INPUTS TO DANISH WATERCOURSES IN 1998 (ADAPTED FROM BØGESTRAND ET AL., 1999).

THE SEA

Compared with inputs to inland waters, inputs to the sea differ in three important respects.

Firstly, it is the inputs from the atmosphere that are of greatest significance. The reason for this is simple, namely that the total area of the marine waters is many times greater than that of the inland waters. Secondly, the same area of sea can behave both as a source and as a recipient of nitrogen. In contrast to watercourses, there is no such thing as one-way flow in the sea. Some days the current runs from the Baltic Sea to the Kattegat while on other days it runs in the opposite direction. Finally, the nutrient retention mentioned in the introduction to this chapter is of greater significance in the case of inputs to marine waters, mainly because the water and hence the nutrients often take a long time to travel from the primary source to the sea. Considerable retention often takes place in lakes and other wetlands along the watercourses. These processes also occur in the coastal areas, where considerable retention and transformation can occur before the nutrients reach the open sea.

The marine environment receives nutrient inputs from a number of different sources. Quite a few wastewater treatment plants and industrial enterprises discharge directly to the sea via marine outfalls. Sources of this type are termed direct point sources. Discharges from land-based and sea-based mariculture, marine dumping of seabed material and discharges from the offshore industry are also encompassed by this category.

Finally, a considerable part of the nutrient inputs to Danish marine waters derives from the atmosphere and adjoining marine waters.

The relative significance of the various sources of nitrogen inputs to the sea in 1998 is illustrated in Figure 4.3.

FIGURE 4.3
SOURCE APPORTIONMENT OF NITROGEN INPUTS TO THE SEA VIA WATERCOURSES, THE ATMOSPHERE AND DIRECT DISCHARGES IN 1998 (ADAPTED FROM BØGESTRAND ET AL., 1999).

The figure encompasses several different input routes: Direct discharges, inputs via watercourses and inputs via the atmosphere. The inputs via the atmosphere encompass both Danish and foreign sources.

The inputs of nitrogen to Danish marine waters via watercourses in 1998 are calculated to be 96,000 tonnes. Inputs from direct discharges amounted to a further approx. 4,300 tonnes. The figures for source apportionment are based on measurements of discharges from point sources and knowledge of the "natural input" and retention.

Total atmospheric deposition of nitrogen on Danish marine waters is calculated to be approx. 104,500 tonnes. Taking all Danish marine waters as a whole, by far the majority of the deposited nitrogen derives from foreign sources. Thus only approx. 14% derives from Danish sources (Skov et al., 1999). In the coastal waters, however, a greater share (up to 50%) will be Danish in origin. The Danish contribution in percent of the total deposition from Danish and foreign sources is shown in Table 4.1. The converse also applies, however, and marine waters of other countries receive nitrogen from Danish sources.

Table 4.1
Contribution from Danish sources in percent of total nitrogen deposition on Danish marine waters in 1998 (Skov et al., 1999).

Marine water	%
North Sea	7
Skagerrak	20
Kattegat	27
Belt Sea (N)	29
Little Belt	23
Great Belt	21
The Sound	19
Belt Sea (S)	9
Baltic Sea	9
All marine waters	14

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Approximately 55% of the nitrogen deposition on the open Danish marine waters is estimated to derive from agricultural sources and the remainder from the combustion of fossil fuels (Frohn et al., 1998). This corresponds to an input of approx. 60,000 tonnes nitrogen from agricultural sources and 45,000 tonnes from industry, power stations and traffic. The latter derive almost exclusively from foreign sources.

Agriculture is clearly the predominant source of nitrogen inputs to the marine areas. Approx. 40% of the agricultural inputs takes place via the atmosphere while the remainder is input via watercourses. As mentioned earlier, only a small part of the total atmospheric deposition of nitrogen derives from Danish sources. It is estimated that approx. 15,000 tonnes of the nitrogen input to Danish marine waters via the atmosphere derives from Danish agriculture (O. Hertel, National Environmental Research Institute, personal communication).

Another important source is the nitrogen inputs from various forms of power production and transport. These inputs take place exclusively via the atmosphere.

POLLUTANT TRANSPORT IN THE SEA

As mentioned earlier, considerable amounts of nitrogen are transported to Danish marine waters from adjoining marine waters. In connection with NOVA-2003, a model has been established to describe the exchange of nutrients between the various Danish marine waters.

Based on model simulations of water and salinity conditions during the year 1998, the transport of nitrogen has been calculated for the following three control transects (DHI, 1999c):

- The Sound/Arkona Sea: Dragør–Limhamn
- Femer Belt/Arkona Sea: Gedser–Darss
- Kattegat/Skagerrak: Vorså–Kungsbacka (over Læsø).

The calculations show that:

- The net transport of total and inorganic nitrogen from the Baltic Sea to the Sound in 1998 was in a northerly direction (approx. 33,600 tonnes total-N and 406 tonnes inorganic N)
- The net transport of nitrogen from the Baltic Sea to the Femer Belt in 1998 was in the direction out of the Baltic Sea (approx. 32,000 tonnes)
- Total transport of nitrogen through the transects in the northern Kattegat in 1998 was northerly in direction (approx. 77,000 tonnes).

4.1.2 **The trend**

INLAND WATERS

The trend in point-source inputs of nitrogen to inland waters since 1989 is illustrated in Figure 4.4. Wastewater treatment plants still comprise the main point source of nitrogen inputs to inland waters, despite the fact that these have fallen to a third of the original level in 1989. Inputs from industry and freshwater fish farms have also fallen. It is worth noting that for the first time in 10 years, inputs from point sources have increased. The increase, although modest, is seen for both nitrogen, phosphorus and organic matter and is accounted for by discharges from wastewater treatment plants, industry and stormwater overflows. The reason for the increase is that 1998 was a relatively wet year thus placing more pressure on the wastewater treatment plants than in the two preceding very dry years.

FIGURE 4.4
TREND IN POINT-SOURCE NITROGEN INPUTS TO DANISH INLAND WATERS (ADAPTED FROM DANISH EPA, 1999b).

The trend in nitrogen inputs to inland waters from all sources since 1989 is illustrated in Figure 4.5. As the trend in inputs to the lakes and watercourses largely follows the same pattern, only the data for the watercourses is presented here as in contrast to the lakes, the watercourses are representative of the whole country. Inputs from the atmosphere, which only account for less than one tenth of a percent, are not included.

FIGURE 4.5
TREND IN NITROGEN INPUTS TO DANISH INLAND WATERS FROM ALL SOURCES EXCEPT THE ATMOSPHERE (ADAPTED FROM BØGESTRAND ET AL., 1999).

The trend for inputs from all sources is rather different from that for point sources alone. The most obvious feature is that the virtually constant fall in point-source inputs is masked by the great variation in inputs from the diffuse sources.

Since 1989 the agricultural sector has remained the main source of nitrogen inputs to watercourses. If one compares the trend in inputs from agriculture and the background load with the trend in runoff, a close correlation can be seen. This has been tested statistically and it transpires that 90% of the variation in the trend in diffuse sources can be explained by the variation in runoff (Bøgestrand et al., 1999). However, there is a tendency towards a nonstatistically significant fall in the total diffuse (sparsely built-up areas, agriculture and background) inputs of nitrogen to the inland waters. While the uncertainty makes it difficult to pinpoint the reason, a clear fall can be seen in inputs from sparsely built-up areas. This fall is probably attributable to changes in the calculation methods (see Chapter 3). No clear trend can be detected in inputs of nitrogen from the agricultural sector.

When preparing the first report of the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment in 1990 (Danish EPA, 1990), the conclusion was reached that nitrogen was also being lost to the aquatic environment in the form of the so-called farmyard load. As a result of the action plan's requirements on better manure storage etc., it is assumed that this source of nitrogen input is now negligible. The trend in inputs to watercourses and the onwards transport to the marine waters does not reflect this, however, possibly due to uncertainty in the calculations or due to initial overestimation of the farmyard load.

THE SEA
The trend in direct point-source inputs of nitrogen to Danish marine waters is illustrated in Figure 4.6. Nitrogen inputs to the sea from point sources have decreased considerably and are now approximately one quarter of the level in

1989. The fall is mainly accounted for by the wastewater treatment plants. These still represent the dominant point source of nitrogen, however.

FIGURE 4.6
TREND IN DIRECT POINT-SOURCE DISCHARGES OF NITROGEN TO THE SEA (ADAPTED FROM DANISH EPA, 1999B).

Total inputs of nitrogen to Danish marine waters from direct point sources, watercourses and the atmosphere are given in Table 4.2. This form of presentation corresponds to the way that the data has to be reported annually to the international conventions OSPAR and HELCOM. The information is combined here in a single table to provide a nationwide impression.

Table 4.2
Discharges and inputs of nitrogen to Danish marine waters via direct discharges, watercourses and the atmosphere over the period 1989–1998. Abbreviations: WTP – Wastewater treatment plants, SID– Separate industrial discharges; SWO – Stormwater outfalls; SBA – Sparsely built-up areas; MFF – Marine fish farms; DD –Direct discharges; WC – watercourses; AD –atmospheric deposition.

	WTP	SID	SWO	SBA	MFF	DD	WC	AD	Total
	tonnes					tonnes			
1989	11,300	4,700	240	12	320	16,700	61,900	98,000	176,600
1990	10,500	3,900	230	12	330	15,000	97,000	116,000	228,000
1991	9,100	3,800	240	12	270	13,500	78,500	108,000	200,000
1992	7,800	4,100	260	12	360	12,500	91,700	101,000	205,200
1993	6,700	2,500	310	12	370	9,800	98,200	87,000	195,000
1994	6,300	2,600	370	12	300	9,600	119,100	99,000	227,600
1995	5,500	2,400	250	4	350	8,400	84,400	96,000	188,800
1996	3,600	1,600	190	3	330	5,800	42,500	97,000	145,300
1997	2,400	1,700	230	1	270	4,700	45,400	96,000	146,100
1998	2,500	1,400	240	3	290	4,400	96,600	105,000	205,900

No statistically significant trend is apparent in the calculated atmospheric deposition of nitrogen on the Danish marine waters since 1989. There has been a tendency towards a weak fall, however, although this is not statistically significant (Skov et al., 1999). Measurements of the concentration of nitrogen compounds in the air show a statistically significant fall, however.

The trend in the total inputs of nitrogen to the sea from all sources is illustrated in Figure 4.7. As no trend could be detected in inputs from the atmosphere (see above), these are not included in the figure.

FIGURE 4.7
TREND IN NITROGEN INPUTS TO THE SEA FROM ALL SOURCES EXCEPT THE ATMOSPHERE (ADAPTED FROM BØGESTRAND ET AL., 1999).

The trend in the total inputs of nitrogen to the sea is particularly characterized by the variation in the diffuse inputs, especially from agricultural sources. As with the inputs to inland waters, there is a clear correlation between runoff and the inputs. Even though it is largely the runoff that influences the trend, a statistically significant downward trend in total inputs can nevertheless be detected (Bøgestrand, et al., 1999). Taking the individual marine waters, a statistically significant fall in total inputs of nitrogen via watercourses and direct point sources is seen for all marine waters except the North Sea, the

Kattegat and the northern Belt Sea. In contrast, no statistically significant trend is detectable in diffuse loading (Bøgestrand et al., 1999). In those places where a fall in inputs of nitrogen is detectable, this can almost always be attributed to improved wastewater treatment.

4.2 Phosphorus inputs

This section reviews phosphorus inputs to Danish inland and marine waters, examining the same topics as the section on nitrogen. Moreover, it is organized in the same manner, starting with a status report for the year 1998 and thereafter a description of the trend since 1989.

The most important parts of the phosphorus cycle are outlined in Figure 1.2. As with nitrogen, phosphorus can be divided into organic and inorganic compounds. Some phosphorus compounds can easily bind to the soil or other material. Thus in several parts of the phosphorus cycle, large amounts of phosphorus will be stored that under certain conditions can be released into the aquatic environment.

It is also worth noting that phosphorus is not transported around by the air to anything like the same degree as nitrogen.

4.2.1 The year gone by

LAKES
The relative significance of the various sources of phosphorus inputs to the monitoring programme lakes in 1998 is illustrated in Figure 4.8.

As mentioned earlier, the NOVA lakes encompass a wide spectrum of different lake types. For this reason it is not yet possible to undertake complete subdivision of the diffuse sources. It is estimated, though, that agriculture is the dominant phosphorus source in the majority of the lakes. It can be seen that approx. 12% of the phosphorus input to lakes derives from the atmosphere. These inputs originate in the vicinity of the lakes, but it is not possible to apportion them by source either.

WATERCOURSES
The relative significance of the various sources of phosphorus inputs to watercourses is illustrated in Figure 4.9. As with nitrogen, agriculture is the most important source of phosphorus input to watercourses.

FIGURE 4.8 (LEFT)
SOURCE APPORTIONMENT OF PHOSPHORUS INPUTS TO THE NOVA LAKES IN 1998 (ADAPTED FROM JENSEN ET AL., 1999).

FIGURE 4.9 (RIGHT)
SOURCE APPORTIONMENT OF PHOSPHORUS INPUTS TO DANISH WATERCOURSES IN 1998 (ADAPTED FROM BØGESTRAND ET AL., 1999).

THE SEA
The relative significance of the various sources of phosphorus inputs to the sea in 1998 is illustrated in Figure 4.10.

FIGURE 4.10
SOURCE APPORTIONMENT (APART FROM THE ATMOSPHERE) OF PHOSPHORUS INPUTS TO THE SEA IN 1998 (ADAPTED FROM BØGESTRAND ET AL., 1999).

The phosphorus inputs are roughly equally divided between wastewater (point sources and sparsely built-up areas) and agriculture. This is the first time during the monitoring period that inputs from agriculture exceed the point-source inputs. As the origins and the bioavailability of the atmospheric inputs of phosphorus are largely unknown, these inputs are not included in the figure.

The calculated inputs of phosphorus via watercourses in 1998 are approx. 2,090 tonnes.

PHOSPHORUS DEPOSITION ON THE SEA

The deposition of phosphorus on the Kattegat, the northern Belt Sea, the Little Belt, the Great Belt, the Sound and the southern Belt Sea is estimated to be approx. 8 kg phosphorus per km^2, corresponding to approx. 280 tonnes phosphorus per year. This estimate is the upper limit for phosphorus deposition. Based on this it is estimated that total phosphorus deposition on all Danish marine waters can be no more than 1,000 tonnes per year. The estimated deposition of phosphorus is subject to considerable uncertainty. A large part of the phosphorus deposition probably derives from biological sources or geological, among other things small soil particles (Ellermann et al., 1997). A very large part of the phosphorus that is input from the air is probably not biologically available.

PHOSPHORUS TRANSPORT IN DANISH MARINE WATERS

The Danish marine waters also receive large amounts of phosphorus from the adjoining marine waters. Calculations of phosphorus transport based on model simulations of water and salinity conditions during the year 1998 (DHI, 1999c) show that:

- Net transport of total phosphorus took place from the Baltic Sea to the Sound (approx. 1,600 tonnes), while the transport of inorganic phosphorus was in the direction of the Baltic Sea (approx. 155 tonnes).
- Net transport of both total phosphorus and inorganic phosphorus took place towards the Baltic Sea from the Femer Belt (approx. 5,600 tonnes total-P and approx. 2,200 tonnes inorganic P).
- Total transport of phosphorus through the transects in the northern Kattegat in 1998 was southerly in direction (approx. 1,460 tonnes).

4.2.2 **The trend**

INLAND WATERS

The trend in point-source inputs of phosphorus to inland waters since 1989 is illustrated in Figure 4.11.

FIGURE 4.11
TREND IN POINT-SOURCE PHOSPHORUS INPUTS TO DANISH INLAND WATERS (ADAPTED FROM DANISH EPA, 1999B).

Point-source inputs of phosphorus to inland waters mainly derive from the wastewater treatment plants, which have been the dominant source throughout the whole period. The inputs have fallen by around 80%, however. Inputs from freshwater fish farms have also decreased markedly to approx. one third of the level in 1989.

As with nitrogen, this is the first time that inputs from point sources have increased. The reasons are considered to be the same as those for nitrogen (see Section 4.1.2).

The trend in phosphorus inputs to inland waters from all sources since 1989 is illustrated in Figure 4.12. As the trend in inputs to the NOVA lakes and watercourses largely follows the same pattern, only the data for the watercourses is presented here as in contrast to the 31 NOVA lakes, the watercourses are representative of the whole country. Inputs from the atmosphere, which only account for less than one tenth of a percent, are not included.

FIGURE 4.12
TREND IN PHOSPHORUS INPUTS TO DANISH INLAND WATERS FROM ALL SOURCES EXCEPT THE ATMOSPHERE (ADAPTED FROM BØGESTRAND ET AL., 1999).

The trend for inputs from all sources is very different from that for inputs from point sources alone. The most obvious feature is that the virtually constant fall in point-source inputs is masked by the great variations in inputs from the diffuse sources. The inputs of phosphorus from diffuse sources are also closely coupled to the runoff, with almost 85% of the variation being explicable in this way. Thus in this case too, no statistically significant trend is apparent.

THE SEA

The trend in direct point-source inputs of phosphorus to Danish marine waters is illustrated in Figure 4.13.

FIGURE 4.13
TREND IN DIRECT POINT-SOURCE DISCHARGES OF PHOSPHORUS TO DANISH MARINE WATERS (ADAPTED FROM DANISH EPA, 1999B).

The slight increase in point-source inputs to inland waters seen since last year is not reflected in the direct point-source discharges to the sea. One of the reasons is a concomitant major improvement in treatment at Denmark's largest wastewater treatment plant, Lynetten.

As mentioned earlier, atmospheric deposition of phosphorus on Danish marine waters amounts to around 1,000 tonnes per year. There are no signs of any trend as regards inputs from this source. Total inputs of phosphorus to Danish marine waters from direct point sources, watercourses and the atmosphere are given in Table 4.3.

Table 4.3
Discharges and inputs of phosphorus to Danish marine waters via direct discharges, watercourses and the atmosphere over the period 1989–1998. Abbreviations: WTP – Wastewater treatment plants, SID – Separate industrial discharges; SWO – Stormwater outfalls; SBA – Sparsely built-up areas; MFF – Marine fish farms; DD –Direct discharges; WC – watercourses; AD –atmospheric deposition.

	WTP	SID	SWO	SBA	MFF	DD	WC	AD	Total
	tonnes					tonnes			
1989	2,700	1,200	59	5	44	4,000	2,800	1,000	7,800
1990	2,400	630	56	5	40	3,100	3,600	1,000	7,700
1991	1,800	560	62	3	36	2,500	2,300	1,000	5,800
1992	1,500	420	67	3	37	2,000	2,000	1,000	5,000
1993	1,200	240	78	3	39	1,600	2,000	1,000	4,600
1994	1,100	310	94	3	32	1,600	3,000	1,000	5,000
1995	830	200	65	1	37	1,300	2,200	1,000	3,500
1996	580	120	47	0	35	800	1,200	1,000	3,000
1997	400	140	57	0	30	600	1,200	1,000	2,800
1998	330	120	62	0	33	500	2,100	1,000	2,700

The trend in inputs of phosphorus to the sea from all sources is illustrated in Figure 4.14. Even though total phosphorus inputs to the sea vary markedly in line with the runoff, a clear downward trend can be demonstrated. This is attributable to a downward trend in inputs from point sources. A statistically significant downward trend in inputs from point sources is seen for all the individual marine waters. In the case of the diffuse inputs, a statistically significant fall in inputs can only be demonstrated for the Little Belt, while there is a tendency towards an increase in the other marine waters. On the figure it can be seen that there were no inputs of phosphorus to the sea from agricultural sources in 1989. The reason for this is that the phosphorus removal and retention that took place on route to the sea was greater than the inputs from agricultural sources. This is an example of the relative underestimation associated with calculation of the diffuse sources.

FIGURE 4.14
TREND IN PHOSPHORUS INPUTS TO DANISH MARINE WATERS FROM ALL SOURCES EXCEPT THE ATMOSPHERE (ADAPTED FROM BØGESTRAND ET AL., 1999).

4.3 Organic matter

The estimates of organic matter inputs to the various water bodies only encompass inputs from point sources and sparsely built-up areas. In addition, the inputs to the sea via watercourses are calculated. The inputs from sparsely built-up areas are usually calculated as part of the diffuse sources. In NOVA-2003, however, inputs of organic matter from other diffuse sources are not determined. Thus inputs from sparsely built-up areas are examined here together with the point-source inputs.

4.3.1 The year gone by

The relative significance of the various sources of organic matter inputs to inland waters is illustrated in Figure 4.15. The main sources are freshwater fish farms and sparsely built-up areas. The relative significance of the various sources of organic matter inputs to the sea is illustrated in Figure 4.16. By far the dominant point source of organic matter inputs to the sea is industry.

FIGURE 4.15 (LEFT)

SOURCE APPORTIONMENT OF ORGANIC MATTER INPUTS TO INLAND WATERS FROM POINT SOURCES (ADAPTED FROM DANISH EPA, 1999B).

FIGURE 4.16 (RIGHT)
SOURCE APPORTIONMENT OF ORGANIC MATTER INPUTS TO THE SEA FROM POINT SOURCES (ADAPTED FROM DANISH EPA, 1999B).

Inputs of organic matter to the sea via watercourses in 1998 are calculated to be 26,700 tonnes. The majority of this is attributable to natural sources such as algal growth, dead leaves, etc. In 1998, the Danish marine waters thus received a total of approx. 41,000 tonnes organic matter via watercourses and direct point sources.

4.3.2 The trend

The trend in organic matter inputs to inland waters from point sources and sparsely built-up areas is illustrated in Figure 4.17.

FIGURE 4.17
TREND IN ORGANIC MATTER INPUTS TO INLAND WATERS FROM POINT SOURCES AND SPARSELY BUILT-UP AREAS (ADAPTED FROM DANISH EPA, 1999B).

Whereas wastewater treatment plants used to be by far the most important point source of organic matter, inputs from this source have fallen by approx. 80% since 1989. Inputs from freshwater fish farms have also fallen markedly to approx. half of the original level in 1989. Excluding sparsely built-up areas, freshwater fish farms still comprise the most significant source of organic matter inputs to inland waters, however.

It can be seen that sparsely built-up areas have become the greatest single source of organic matter inputs to inland waters. The inputs have only fallen slightly by approx. 20–25% over the period 1989–1998.

The trend in organic matter inputs to the sea from point sources and sparsely built-up areas is illustrated in Figure 4.18. It can be seen that inputs from all sources have fallen since 1989. Inputs from wastewater treatment plants have fallen particularly much and now only comprise just over 10% of the total as compared with just under half at the beginning of the period. Despite a marked downward trend, inputs from separate industrial discharges are still the dominant direct point source of organic matter inputs to the sea.

FIGURE 4.18
TREND IN ORGANIC MATTER INPUTS TO THE SEA FROM POINT SOURCES AND SPARSELY BUILT-UP AREAS (ADAPTED FROM DANISH EPA, 1999B).

In the northern Belt Sea and the Little Belt, inputs from sea-based and land-based mariculture are the main sources of organic matter inputs (Danish EPA, 1999b).

4.4 Hazardous substances

Determination of discharges of hazardous substances is one of the new areas encompassed by NOVA-2003 as compared with the earlier monitoring programmes. Moreover, the measurements are made with a lower frequency and with less geographic coverage than the remainder of the programme. The data foundation in this area is therefore not yet of the same quality as for nutrients.

Monitoring of inputs of heavy metals to the aquatic environment under NOVA-2003 encompasses inputs from point sources including sparsely built-up areas, transport in watercourses and deposition from the atmosphere. As yet it is only possible to present data concerning point sources, sparsely built-up areas and atmospheric deposition.

As is apparent from their name, heavy metals are metals and hence elements. They are therefore naturally occurring in the environment in low concentrations. However, human activity has resulted in the dispersal of a number of heavy metals into the environment in concentrations known to cause harmful effects to man or the environment. As with all other elements, heavy metals are by definition nondegradable. Thus there is no such thing as "gone" when it comes to heavy metals. The removal processes that make nutrients disappear on route from the source to the aquatic environment are thus without effect as regards heavy metals. At best they can be delayed on route. Some of the hazardous substances are so persistent that the same also applies to them.

Discharges of hazardous substances have been examined in Chapter 3. The present section provides a short review of the various transport pathways and types of source.

POINT SOURCES

In addition to the sources encompassed by NOVA-2003, heavy metals are input to the aquatic environment from a number of other point sources. These include offshore activities and marine dumping of seabed material such as harbour sediments, etc. It is open to question whether marine dumping of seabed material comprises an actual source, or whether it is really just represents redistribution of material previously input to the aquatic environment. Moreover, from the available data it is very difficult to determine the total inputs of heavy metals from this source. As a consequence, inputs of heavy metals via marine dumping of seabed material are not included here.

The total inputs to the aquatic environment via wastewater treatment plants, separate industrial discharges and the offshore industry are included under point sources in Table 4.4. Sparsely built-up areas are given as an independent source. The figures for inputs from point sources and sparsely built-up areas have been determined in different ways and hence are not fully comparable.

Table 4.4

Heavy metals inputs to the aquatic environment from point sources, sparsely built-up areas and the atmosphere in 1998 (data from Chapter 3 and Hovmand & Kemp, in prep.).

	Point sources	Sparsely built-up areas	Atmospheric deposition

Metal	kg		
Arsenic (As)	10,000	30	7,300
Lead (Pb)	3,300	200	45,000
Cadmium (Cd)	720	30	1,500
Copper (Cu)	10,300	1,000	33,000
Chromium (Cr)	2,600	200	5,300
Mercury (Hg)	590	20	-
Nickel (Ni)	11,600	500	12,000
Zinc (Zn)	91,700	4,000	352,000

There is probably quite a lot of mercury accumulated in the sewerage systems that is slowly being discharged via the wastewater treatment plants despite the marked reduction there has been in mercury consumption.

Heavy metals are also input to the aquatic environment from a number of other diffuse sources. Wastewater treatment generates a large amount of sewage sludge in which a large part of the heavy metals content of the wastewater will be retained. The majority of the sludge is disposed of by being used as fertilizer on agricultural land, with the remainder being incinerated or deposited at a waste depository. The total amount of heavy metals in sewage sludge is given in Table 3.6. It is known that the heavy metals are strongly bound to the sludge and that very little release to the aquatic environment is likely. Nevertheless, it must be expected that some release will occur in the span of years. In connection with rust protection of harbour structures, bridges, ships, etc., large amounts of zinc are released that may contain traces of other metals such as cadmium. Heavy metals are also released from the antifouling paints used on ship hulls.

DEPOSITION FROM THE ATMOSPHERE

A large part of the total inputs of heavy metals to the aquatic environment derives from the atmosphere, cf. Section 3.4. Heavy metals inputs to Danish marine waters from this source (Table 4.4) have been determined on the basis of measurements of their concentrations in the air (Hovmand & Kemp, in preparation).

TRANSPORT IN WATERCOURSES

In connection with the submission of data to OSPAR in 1990, measurements were made of heavy metals transport to the North Sea and the Skagerrak via a number of watercourses. It has subsequently been estimated that inputs to these marine areas via watercourses comprise 20% of total riverine loading. The total inputs of heavy metals to the sea via watercourses in 1990 estimated on this basis are given in Table 4.5.

Table 4.5

Heavy metal inputs to the marine environment via watercourses in 1990 (based on OSPAR, 1998).

Metal	kg
Lead (Pb)	14,500
Cadmium (Cd)	1,950
Copper (Cu)	32,000
Mercury (Hg)	110
Zinc (Zn)	269,000

As the total inputs are estimated on the basis of measurements in just a few watercourses, the figures are subject to considerable uncertainty. Moreover, the analysis methods used were less sensitive than those in use today. The figures should therefore be interpreted as giving only a very rough picture of the general conditions at the end of the 1980s and beginning of the 1990s.

Inputs of heavy metals to Danish marine waters via watercourses in 1998 are not reported.

HAZARDOUS SUBSTANCES

Due to analytical problems etc., the data foundation for calculating inputs of hazardous substances to the aquatic environment is far from adequate. It is anticipated that the first analysis of this area will be undertaken in connection with preparation of the theme report in 2002.

5 State of the aquatic environment – status and trends

The following sections review the environmental state of the groundwater (Section 5.1), watercourses (Section 5.2), lakes (Section 5.3) and the sea (Section 5.4) based on the activities conducted under NOVA-2003. As a consequence of the fact that the monitoring programme does not fully cover all areas, information has also been incorporated from other sources, for example data from county and state supervision activities.

5.1 Groundwater

Systematic monitoring of the Danish groundwater encompasses three main elements: 1) County monitoring in connection with NOVA-2003 (the GRUMO programme), 2) The agricultural catchment monitoring programme under NOVA-2003 (LOOP), and 3) Waterworks statutory routine control of abstraction wells, cf. Statutory Order No. 515 of 29 August 1988 on Water Quality and Supervision of Water Supply Plants (Ministry of the Environment, 1988) and associated official Danish EPA Guidelines.

The present overview of the state and overall trend in groundwater quality over the monitoring period is based on the 1998 nationwide scientific report on the combined systematic groundwater monitoring programme (GEUS, 1999).

Groundwater monitoring under NOVA-2003 is conducted in so-called groundwater monitoring areas (GRUMO areas) and in the six agricultural monitoring catchments (designated LOOP), where the focus is on newly formed subsurface groundwater. In the GRUMO programme, samples are collected from both the upper "secondary" aquifers (point-monitored filters) and in the deeper-lying "primary" aquifers (serial or volume-monitored filters), thereby enabling assessment of the quality of both young and old groundwater.

5.1.1 The year gone by

MAIN CONSTITUENTS OF GROUNDWATER
The following section examines the 1998 results concerning the groundwater content of nitrate and phosphorus. The other main constituents (e.g. chloride and sulphate) have been examined in detail in the Theme Report on groundwater (GEUS, 1995). The situation regarding these substances has not changed significantly since then.

NITRATE
The results of the agricultural catchment monitoring show that the water that is on its way to the aquifers in sandy areas contains high concentrations of nitrate. The average concentration measured in the filters is around 50 mg per litre. This corresponds to the limit value in drinking water. In clayey ar-

eas, the nitrate concentration in the newly formed groundwater averaged 25 mg per litre.

Deeper down in the ground one finds groundwater aquifers with an unconfined water table, which is the type of aquifer that is most vulnerable with respect to nitrate leaching. In 1998, the nitrate concentration in this type of groundwater aquifer – which is widespread in western Jutland – averaged approx. 50 mg per litre in those filters in which nitrate was detected. In general, the nitrate concentration decreases with increasing age of the water. In all, approx. 60% of the filters encompassed by the groundwater monitoring programme are nitrate-free.

The results of the waterworks routine control of abstraction wells show that approx. 3% of the abstracted water exceeds the limit value for nitrate in drinking water, while approx. 6% exceeds the guide level of 25 mg per litre. Two thirds of the wells do not contain nitrate, however. The findings demonstrate clear regional differences in nitrate contamination of the drinking water. The highest levels are found in the so-called nitrate belt across Jutland (Nordjylland, Viborg and Aarhus counties), cf. Figure 5.1. Nitrate comprises a serious problem for the water supply, especially in the western part of the country where there is intensive livestock production and little or no clay cover bed over the groundwater aquifers, and hence considerable vulnerability to nitrate leaching.

FIGURE 5.1
NITRATE CONCENTRATIONS IN WATERWORKS ABSTRACTION WELLS FOR THE PERIOD 1990–98. ONLY WELLS WHERE THE NITRATE CONCENTRATION EXCEEDS 25 MG PER LITRE ARE INCLUDED (ADAPTED FROM GEUS, 1999).

PHOSPHORUS

The phosphorus concentration in the newly formed groundwater measured in the agricultural monitoring catchments was unchanged and low in 1998, although with slightly higher levels in the sandy areas. Under the groundwater monitoring programme, phosphorus was detected in concentrations exceeding the limit value for drinking water of 0.15 mg per litre in 14% of the filters in 1998. Control of the water supply abstraction wells revealed that around 20% exceed this limit. As the majority of the phosphorus is removed from the water during routine treatment it does not generally comprise a problem for the drinking water supply. The enhanced phosphorus concentration in the groundwater is often attributable to the geological conditions.

AGE OF THE GROUNDWATER

Dating of the groundwater from some of the wells encompassed by the monitoring programme was undertaken in 1997–98. This revealed:

- that no more than 10% of the water analysed under the groundwater monitoring programme was formed after the adoption of the Action Plan on the Aquatic Environment in 1987,
- that the majority of the groundwater that is monitored was formed between 1940 and 1990,
- that in Copenhagen, Vestsjælland and Funen counties, a large part of the groundwater was formed prior to 1970,
- that in Ribe and Nordjylland counties, a large part of the groundwater was formed after 1980, and

- that 10% of the water investigated was formed before 1940.

HEAVY METALS AND INORGANIC TRACE ELEMENTS

The heavy metals and trace elements encompassed by the monitoring programme include aluminium, arsenic, barium, lead, cadmium, copper, nickel, selenium and zinc. The monitoring results for the upper groundwater in the agricultural monitoring catchments in 1998 indicate that heavy metals and inorganic trace elements are retained and accumulated in the root zone.

Under the groundwater monitoring programme, one or more heavy metals or inorganic trace elements were found at one time or another in all the filters investigated during the period 1993–98. In more than 30% of the analyses for the trace element barium, the concentration detected exceeded the guide level for drinking water of 100 microgrammes per litre. Barium is naturally occurring but its presence can also be due to local pollution around the well, possibly in conjunction with the establishment of the well. Thereafter follow aluminium, nickel and zinc, where the concentration in the groundwater exceeds the limit values for drinking water of 0.2 mg/l, 50 mg/l and 5 mg/l, respectively, in 8%, 4% and 4% of the analyses.

Of the above-mentioned substances, only nickel and aluminium were encompassed by the majority of the analyses conducted under the waterworks routine well control, cf. the requirements stipulated in the Statutory Order on Water Quality and Supervision of Water Supply Plants. Up to 1998, though, heavy metals and/or inorganic trace elements had been detected in 40% of the abstraction wells investigated. The concentration exceeds the limit value for drinking water in approx. 4% of the wells – in the majority of cases due to nickel contamination. Enhanced nickel concentrations are often seen in cases where water abstraction has lowered the groundwater table. Other substances, for example zinc, aluminium and arsenic, are also occasionally found in waterworks wells in concentrations exceeding the limit value for drinking water. Common for this group of substances, though, is the fact that they are largely removed from the water during ordinary simple treatment at the waterworks.

ORGANIC MICROPOLLUTANTS

The organic micropollutants can be subdivided into chlorinated hydrocarbons, aromatic hydrocarbons, phenols and chlorophenols, detergents, and miscellaneous organic micropollutants.

The chlorinated hydrocarbons chiefly derive from industry, where they are used as solvents and degreasing agents etc., as well as coolants. Thus they are mainly present in the groundwater in connection with waste depositories and contaminated sites. Under the groundwater monitoring programme in 1998, one or more chlorinated hydrocarbons were detected in 29% of the wells analysed. The substances most frequently detected were chloroform, 1,1,1-trichloroethane and trichloroethylene. Chloroform can be formed naturally, for example under coniferous forest, while the other substances derive from human activities. The chlorinated hydrocarbons most frequently detected in waterworks wells are vinyl chloride and trichloroethylene: Over the period 1987–98, these were detected in 15% and 13% of the wells, respectively.

Aromatic hydrocarbons are mainly oil products such as petrol. During the period 1989–98, aromatic hydrocarbons were detected in 24% of the well filters in the groundwater monitoring areas. Those most frequently detected were the petrol constituents benzene and toluene. The median concentration of these two substances in groundwater is approx. 0.1 microgramme per litre as compared with the limit value for drinking water of 1 microgramme per litre. Of the waterworks wells investigated during the same period, aromatic hydrocarbons were detected in 14%. The substances are present in the waterworks wells at approximately the same frequency – and in the same concentrations – as in the groundwater monitoring wells.

Phenols and chlorophenols were detected in approx. 25% of the groundwater monitoring wells at low concentrations near the detection limit, while they were found in 6% of the waterworks wells – likewise at concentrations that generally lie well below the limit values for drinking water (0.5 microgrammes per litre for phenols and 1 microgramme per litre for chlorophenols). A possible source of the chlorinated phenols is the degradation of natural organic matter (e.g. livestock manure), while the phenols can stem from pesticides. The chlorinated phenol pentachlorophenol, which is used in the impregnation of wood, is detected in approx. 1% of the wells. Nonylphenols, which are found in cleaning agents, cosmetics, paints and plastics, are discussed below in connection with the hormone-like substances. The few available analysis results indicate that the nonylphenols are present at a high frequency and in relatively high concentrations. Attempts will be made to confirm these findings in the future groundwater monitoring work.

Detergents can also be naturally occurring, but probably mainly stem from washing powders and cleaning agents. In addition, detergents are used in pesticide products. Detergents are widely detected – also in the deeper groundwater. Under the groundwater monitoring programme, detergents were detected in 87% of the wells analysed during the period 1989–97. In 1998, detergents were detected in just over half of the waterworks wells at a median concentration of 6 microgrammes per litre, i.e. well below the limit value for drinking water of 100 microgrammes per litre. The limit value for detergents is based not on possible health effects, but on their foaming properties.

As regards the miscellaneous organic micropollutants, plasticizers were detected in 39% of the groundwater monitoring wells analysed. Of the only 37 waterworks wells investigated for plasticizers in 1998, 9% proved positive. No limit value has been set for plasticizers in drinking water. With respect to the percentages given here it should be noted that the analysis methods for plasticizers are subject to relatively great uncertainty and that false “positives” can occur due to contamination from plastic tubing during sample collection if the tubing contains plasticizers.

The petrol additive MTBE has not been detected in any of the 12 groundwater monitoring wells investigated in 1998. Of the waterworks wells investigated, MTBE was detected in approx. 10% in an average concentration of 0.33 microgrammes per litre (the preliminary limit level for drinking water announced in connection with the MTBE Action Plan is 30 microgrammes per litre).

All in all, organic micropollutants have been detected in 94% of the filters investigated up to 1998. Under the waterworks routine well control, micropollutants were detected in 29% of the filters investigated in 1998. In general, the concentrations of organic micropollutants are greatest in the uppermost part of the groundwater aquifers. Aromatic hydrocarbons and phenols also occur in the deeper-lying parts of the aquifers, however.

PESTICIDES AND PESTICIDE RESIDUES

Although pesticides is a generic term for herbicides, fungicides and insecticides, in the groundwater context the term pesticides is generally used synonymously with herbicides. Thus no other pesticides than herbicides have been detected in groundwater in concentrations exceeding the limit value for drinking water.

As regards the pesticide content of the upper groundwater, the agricultural catchment monitoring revealed pesticides and/or pesticide residues in 40% of the filters investigated. Those detected in the upper groundwater are mainly of the atrazine family and their degradation products. The detection percentage is comparable with that for the subsurface groundwater in the groundwater monitoring areas.

Under the groundwater monitoring programme, pesticides were detected in 29% of the wells in 1998, with the concentrations exceeding the limit value for drinking water (0.1 microgramme per litre) in 8% of the wells. The detection frequency decreases almost linearly with depth, cf. Figure 5.2. The high detection frequency in the upper groundwater is largely attributable to the presence of BAM, a degradation product of dichlobenil and chlorothiamide. The pesticides most frequently detected are atrazine, dichlorprop and mecoprop.

FIGURE 5.2

PESTICIDE DETECTION FREQUENCY (TOTAL AND ABOVE LIMIT VALUE) IN GROUNDWATER AT DIFFERENT DEPTHS (ADAPTED FROM GEUS, 1999).

In step with the phase-out of pesticides able to leach into the groundwater, consumption of the product Round-up has increased. The active substance glyphosat and the degradation product AMPA were detected in a couple of low wells on agricultural land in 1998. The substances might occur as a result of very localized contamination around the well, though, either as a result of the so-called chimney effect, whereby the substances seep down to the sampling filters along the well wall, or as a result of contamination with water that has run into the well from above. Attempts will be made to confirm these findings in the future groundwater monitoring work.

Routine control of waterworks wells in 1998 revealed pesticides in 32% of the wells – with the concentration exceeding the limit value for drinking water in 12% of the waterworks wells. BAM is the substance most frequently detected, followed by the atrazine family of pesticides and their residues, cf. Figure 5.3. The pesticides found in the greatest concentrations in drinking water are thus substances (or their residues) whose use is already prohibited.

FIGURE 5.3

PESTICIDES DETECTED IN WATERWORKS WELLS DURING THE PERIOD 1989–98 IN CONCENTRATIONS EXCEEDING THE LIMIT VALUE FOR DRINKING WATER (ADAPTED FROM GEUS, 1999).

GROUNDWATER POTENTIAL
The groundwater table was generally low in 1998 due to the dry winters of 1996/97 and 1997/98. The wet autumn in 1998 has recharged the groundwater table to a more normal level, however.

GROUNDWATER ABSTRACTION
In 1998, groundwater abstraction totalled 741 million m^3. Of this, approx. 60% was abstracted by common waterworks (primarily for household use), approx. 30% by commercial users (irrigation) and approx. 10% by industry.

CLOSURE OF CONTAMINATED WELLS
Notifications from the municipal authorities show that 28 abstraction wells were closed down in 1998 as a result of anthropogenic pollution with pesticides, other hazardous substances or nitrate. Pesticides are currently by far the most frequent cause of contamination-related closure of abstraction wells, accounting for 25 (89%) of the closures. Of the remaining three wells, two were closed down because of contamination with other hazardous substances while one was closed down because of nitrate contamination.

GROUNDWATER MODELLING
For the second year in a row, the 1998 monitoring reports contain a description of the groundwater models established by the county authorities. The models are used by them in connection with assessments of the size of the groundwater resource, remedial measures against groundwater contamination, etc. The groundwater models for each area contain information on geological conditions such as the number of geological layers, etc. For each geological layer, figures are given describing its water conductance. The groundwater models also contain information on the hydrological conditions such as precipitation, watercourses and lakes. The model established for each area can be fed into a computer programme and used to predict how groundwater flow and the groundwater table will change in response to various measures, for example the abstraction of groundwater in a specific part of the model area.

5.1.2 **Trend over the period 1989 - 98**

NITRATE
The variation in the nitrate content of the upper groundwater is primarily a function of the variations in precipitation and harvest yield. Thus no clear trend can be seen in the data from the agricultural monitoring catchments (LOOP) over the monitoring period and hence it is not possible to identify any effect of the reduced nitrogen losses from agricultural sources on the newly formed groundwater. The average nitrate concentration in the approx. 40% of the well filters in which nitrate has been detected is shown in Figure 5.4.

FIGURE 5.4
TREND IN GROUNDWATER NITRATE CONCENTRATION IN FILTERS WITH MORE THAN 1 mg/l IN THE GROUNDWATER MONITORING AREAS (GRUMO) AND AGRICULTURAL MONITORING CATCHMENTS (LOOP) IN SANDY AND CLAYEY AREAS (ADAPTED FROM GEUS, 1999).

Neither can a clear trend be identified in the deeper-lying groundwater (GRUMO), although a slight increase in nitrate concentration can be seen in the unconfined aquifers of the sandy areas.

The groundwater dating studies reveal that only a minor part of the groundwater analysed for nitrate stems from after implementation of the Action Plan on the Aquatic Environment. Thus one cannot yet expect to see an effect of the Action Plan measures on groundwater quality.

The nitrate concentration in the water supply wells has remained roughly stable during the period 1990–98. The distribution according to nitrate concentration is shown in Table 5.1.

Table 5.1
Water supply abstraction wells apportioned by nitrate content.

Conc. mg/l	No.	%
>50	251	2.9
25–50	544	6.3
1–25	2,134	24.7
<1	5,711	66.1
Total	8,640	100.0

PHOSPHORUS

The presence of phosphorus in groundwater is primarily determined by the geological conditions. Thus the groundwater monitoring programme cannot be expected to reveal marked changes. In accordance with this, the phosphorus concentration appears to have remained stable during the period 1990–98.

ORGANIC MICROPOLLUTANTS

The trend over the monitoring period 1989–98 for a couple of the substances examined in Section 5.1.1 is outlined below.

The average concentration of the chlorinated hydrocarbons detected in the highest concentrations in the groundwater monitoring wells is about half of the limit level for drinking water. The same is true for the substances most frequently detected in the waterworks wells. Vinyl chloride has been detected in 40 (15%) out of the 268 wells investigated. The concentration of vinyl chloride in the waterworks wells investigated during the period has increased to an average of 0.6 microgrammes per litre. Vinyl chloride is a stable degradation product of the other chlorinated hydrocarbons and it is therefore not surprising that some accumulation of it has taken place in the groundwater.

As regards detergents in drinking water, these have been detected in between 50% and 60% of waterworks wells since 1993 with no evidence of any clear trend over the period.

PESTICIDES AND PESTICIDE RESIDUES

The groundwater monitoring programme previously encompassed 8 pesticides. Since 1998 under NOVA-2003 it has encompassed approx. 50 pesticides and pesticide residues.

In the agricultural catchment monitoring programme, pesticides and/or pesticide residues have been detected in 46% of the filters over the period 1990–99, with the concentration exceeding the limit value for drinking water in 10% of the filters. It is particularly pesticides of the atrazine family that are detected in high concentrations. The concentration has fallen during the period, which is as would be expected since the sale of atrazine ceased in 1994.

In the groundwater monitoring programme, pesticides and/or pesticide residues have been detected in 30% of the filters over the period 1989–98, with the concentration exceeding the limit value for drinking water in 10% of the filters.

The detection frequency fell slightly from 1990 to 1992, cf. Figure 5.5. This is mainly attributable to the fact that the county authorities previously collected the samples from high-lying filters. The increase between 1994 and 1998 is due to the fact that since the detection of atrazine at Ejstrupholm, the counties now analyse for a far greater number of substances. Finally, the increase is also attributable to BAM.

Routine control at the waterworks revealed pesticides and/or pesticide residues in an average of 23% of the wells over the period 1989–98, with the concentration exceeding the limit value for drinking water in 9% of the filters.

FIGURE 5.5
NUMBER AND PERCENTAGE OF GROUNDWATER MONITORING WELLS CONTAINING PESTICIDES (ADAPTED FROM GEUS, 1999).

GROUNDWATER POTENTIAL

The variation in the groundwater table over the period 1989–98 is illustrated in Figure 2.5. As a result of the dry winters of 1996/96 and 1997/98, the groundwater table at the end of the monitoring period was the lowest in 20 years.

WATER ABSTRACTION

Total groundwater abstraction in 1998 amounted to approx. 741 million m^3. Since 1989, total abstraction has decreased by approx. 30%, cf. Figure 5.6.

FIGURE 5.6
TREND IN GROUNDWATER ABSTRACTION APPORTIONED BY CATEGORY OVER THE PERIOD 1989–98 (ADAPTED FROM GEUS,1999).

The fall in abstraction by the public waterworks over the period is attributable to water economy measures and levies on water. The marked variation in water abstraction for irrigation reflects the variation in precipitation since this category also encompasses the sprinkling of agricultural crops.

CLOSURE OF CONTAMINATED WELLS

Notifications from the municipal authorities show that 478 abstraction wells were closed down over the period 1987–98 as a result of anthropogenic pollution. Pesticides are the most frequent cause of contamination-related closure of abstraction wells, accounting for 47% of the closures. The corresponding figures for other hazardous substances and nitrate are 22% and 31%, respectively. Some clear trends are apparent regarding the type of substance that contaminates the water supply:

- The number of wells closed down because of contamination with pesticides and/or pesticide residues has increased markedly since 1993 when the waterworks seriously started to analyse for pesticides.
- The number of wells closed down as a result of contamination with nitrate and other hazardous substances has remained roughly constant during the period.

GROUNDWATER MODELLING

The use of groundwater models has increased markedly during the period 1989–98 in line with enhanced legislative requirements as to county planning and management of the groundwater resource, among other things the Danish EPA's forthcoming zoning guidelines. Moreover, the trend within information technology, which has enabled groundwater models to be used on ordinary computers, has made it more common to use groundwater models as a tool in routine administration of groundwater resources.

5.2 Watercourses and springbrooks

The majority of the monitoring and supervision of the Danish watercourses and springbrooks is undertaken by the county authorities.

The selection of stations in the former monitoring period (1989–97) was primarily based on the need to calculate nutrient loading of lakes and marine waters. In general, therefore, most of the watercourses included in the station network were large or medium-sized. The majority of the approx. 64,000 km of watercourse in Denmark are small watercourses less than 2.5 metres wide, cf. Table 5.2. The small watercourses were thus clearly underrepresented in the station network relative to their total length. This imbalance has now been redressed in the revised station network for assessment of biological watercourse quality. Thus the stations for the monitoring period 1998–2003 have been selected so as to be more representative of the Danish watercourses as a whole, both with respect to watercourse size and general environmental state.

Table 5.2
Estimated length of Danish watercourses (Windolf et al., 1997).

Watercourse width	Length (km)
0–2.5 m	48,000
2.5–8.0 m	14,500
>8.0 m	1,500

Total	64,000

NOVA-2003 also encompasses water chemistry monitoring stations and springbrook stations carried forward from the previous programme period with minor adjustments. A completely new element of the programme is the monitoring of hazardous substances. A further new element is the establishment of an extended biology programme to elucidate the relationship between the biological state of the watercourses and various pressures.

The results are reported both independently by the county authorities and in the form of nationwide scientific reports based on the results of the county and state monitoring. The following description of the current environmental state of Danish watercourses and the overall trends is based on the report "Watercourses and springs" (Bøgestrand et al., 1999), supplemented by information from the county regional supervision of watercourses (Danish EPA & National Forest and Nature Agency, in preparation).

5.2.1 **The year gone by**

SPRINGBROOKS

NOVA-2003 encompasses the monitoring of 58 springbrooks for various selected water chemistry variables in order to follow the quality of and overall trend in the groundwater that naturally flows into the watercourses.

PHOSPHORUS AND NITROGEN IN SPRINGBROOKS IN 1998

No significant changes were observed in the phosphorus concentration in the springbrooks in 1998 relative to preceding years. Thus the total phosphorus concentration in 1998 was 0.074 mg P per litre in springs in cultivated catchments and 0.054 mg P per litre in springs in uncultivated rural catchments. The corresponding values for 1997 were 0.073 mg P per litre and 0.048 mg P per litre, respectively.

As in the preceding years, an increase in the nitrate concentration of spring water was observed in cultivated catchments. Thus the nitrate concentration increased from 6.21 mg N per litre in 1997 to 6.83 mg N per litre in 1998. No such increase was detected in springs located in uncultivated rural catchments.

NITROGEN IN WATERCOURSES

The 1998 results show that as was the case in the preceding years, the concentration of total nitrogen was highest in watercourses draining cultivated catchments. Thereafter follow the watercourses in catchments with point-source discharges, watercourses affected by wastewater from freshwater fish farms and finally, watercourses in uncultivated rural catchments.

1998 was characterized by a high level of runoff and hence a relatively high level of nitrogen leaching. Area-specific nitrogen runoff was greatest in the watercourses in cultivated catchments. Because of the high level of runoff in 1998, nitrogen loading from fish farms in some of the watercourses traditionally considered to be "fish farm watercourses" was 30% less than in the low-precipitation years 1996 and 1997.

PHOSPHORUS IN WATERCOURSES

As in the preceding years, the concentration of total-P in watercourses was highest in catchments with point-source discharges, followed by watercourses in the cultivated catchments, after which follow watercourses with wastewater discharges from fish farms, with the lowest concentrations in watercourses in uncultivated rural catchments.

Agriculture was the chief source of phosphorus transport in both the cultivated catchments and the catchments with point-source discharges. Discharges from sparsely built-up areas also accounted for a considerable part of the phosphorus transport in watercourses in cultivated catchments. In watercourses in catchments with point-source discharges, wastewater discharges comprised the second-largest share of the phosphorus transport.

ORGANIC MATTER IN WATERCOURSES

The organic matter concentration in watercourses in 1998 was highest in watercourses affected by wastewater discharges and in "fish farm watercourses", and least in watercourses in uncultivated rural catchments. There is a significant difference in the organic matter content of watercourses located east and west of the Great Belt, with the organic matter content being highest east of the Great Belt. The difference is not sufficient to explain the marked difference in watercourse environmental quality between the two regions of Denmark, however.

HAZARDOUS SUBSTANCES

Because of methodological problems with the analyses, monitoring of hazardous substances will not be initiated until the year 2000. Similarly, very little data is available concerning heavy metals.

PHYSICAL CONDITIONS AND WATERCOURSE MAINTENANCE

The objects clause of the Watercourse Act stipulates that it is permissible to use watercourses for drainage of water, but that this must be done in deference to stipulations concerning watercourse environmental quality laid down in other legislation (Ministry of Environment, 1992). The drainage capacity of watercourses can be improved, for example by channelization and weed clearance. Weed clearance practice can be classified as "no weed clearance", "gentle weed clearance", where a minor part of the watercourse vegetation is cleared and "hard-handed weed clearance", where all the watercourse vegetation is cleared. The weed clearance method influences the physical variation in the watercourses. In watercourses that are not maintained or are maintained gently, hard substrates such as stones and gravel comprise a larger part of the stream bed.

NOVA-2003 shows that hard-handed maintenance is chiefly employed in watercourses where the adjoining land is cultivated. The land alongside watercourses where no or gentle weed clearance is employed encompasses both intensively cultivated, extensively cultivated and uncultivated land. Of the watercourses encompassed by the monitoring programme, the majority of the affected watercourses are cleared of weeds 1-2 times yearly (56%), while 11% are cleared more than twice yearly. The majority of the affected watercourses are cleared using scythes (64%), while a relatively large percentage are cleared using mechanical weed cutters (36%).

Another important element as regards watercourse physical quality is obstructions such as falls in connection with road underpasses etc,. and dams in connection with fish farms.

EXTENSIVE BIOLOGICAL MONITORING PROGRAMME

A total of 444 watercourse stations were included in the extensive biological monitoring programme in 1998. The results show that the dominant state in Danish watercourses is fauna class 4. This corresponds to a moderately effected fauna, where the majority of the more demanding macroinvertebrates are either absent or only present in very small numbers. The watercourses at 43% of the stations are rated as fauna class 4. At 37% of the stations the watercourses are either unaffected or only slightly affected (fauna classes 5, 6 and 7). At the remaining 20% of the stations the watercourses are markedly or severely affected (fauna classes 1, 2 and 3).

Subdividing the watercourses into 5 size classes based on watercourse width reveals that fauna class 4 is the most frequent state in all 5 classes. There is nevertheless a clear tendency for the large watercourses (more than 5 m wide) to have a better general state than the small watercourses (less than 2 m wide). Fauna classes 1, 2 and 3 (severely affected) are found at 25% of the stations in small watercourses as opposed to only 7.5% of the stations in large watercourses.

The state of the watercourses in 1998 is significantly better in Jutland and on Funen than in the remainder of the country. Thus the state of the watercourse is good or very good (fauna classes 5, 6 and 7) at 44% of the stations in Jutland and on Funen and bad or very bad at 14%. The corresponding figures for the remainder of the country (Zealand, Lolland and Falster) are 12% and 42%.

EXTENDED BIOLOGICAL MONITORING PROGRAMME

The programme encompasses a total of 80 watercourse stations nationwide, all of which are located in small watercourses in rural areas. 15 of the watercourse stations are reference stations characterized by being unaffected as regards physical variation, fauna and/or flora. Land use at the stations is usually extensive (meadows, reed swamps). Cultivated land is far more frequent along the affected watercourses, which are also far more frequently channelized. Watercourses with undercut banks are present in both watercourse types, just as there is no significant difference in the nature of the bed substrate. The water temperature is higher in the affected watercourses.

The monitoring results reveal that there are significant differences in the plant, macroinvertebrate and fish communities in the two types of watercourse. Weed clearance thus has a considerable influence on plant distribution in the watercourses. The percentage of bed substrate comprised of sediment is of great significance as regards plant distribution, while the percentage of fine gravel is of less significance. The impact of the method and frequency of weed clearance and the implements used on the current velocity and bed substrate affect the competitiveness of the various plant species, thereby changing the plant communities. The total number of plant species, the species composition and the percentage of watercourses where one plant species comprises more than 50% of the total plant cover shows that watercourses subject to hard-handed or partly gentle maintenance are impoverished relative to watercourses in which weed clearance is not undertaken.

The number of macroinvertebrates is lower in the affected watercourses than in the reference watercourses. The Danish Stream Fauna Index for spring and summer is 4 (moderately affected fauna) in the affected watercourses while it is 6 and 5 (mildly affected fauna), respectively, in the reference watercourses. In the late summer, the mocroinvertebrate communities are also more diverse in the reference watercourses.

There is no significant difference in the number of fish species in the two types of watercourse. Trout make more specific demands on watercourse quality than for example pike, eel and 3-spined and 9-spined sticklebacks. There is a tendency for the number of trout to be greater in the reference watercourses than in the affected watercourses, but the difference is not statistically significant. This tendency is enhanced if only watercourses in which trout stocking is not undertaken are included.

QUALITY OBJECTIVE COMPLIANCE

According to the county regional supervision reports, only 44% of the watercourses complied with their quality objectives as stipulated in the county Regional Plans (Danish EPA & National Forest and Nature Agency, in preparation).

5.2.2 Trend in watercourse environmental state

SPRINGBROOKS

During the period 1989–98, the nitrate concentration in springs in cultivated catchments has been 10-fold higher than in springs in uncultivated rural catchments. Moreover, the nitrate concentration in springs in cultivated catchments has been increasing since 1994. In contrast, there has been no evidence of any changes in phosphorus and nitrogen concentrations in springs in uncultivated rural catchments.

NITROGEN IN WATERCOURSES

The pattern of watercourse nitrogen transport since 1989 has largely followed that of runoff, high levels of runoff thus being accompanied by high nitrogen transport. The great variation in runoff in recent years therefore makes it difficult to draw any general conclusions as to the overall trend and hence to assess the effect of the environmental measures implemented.

When taking the variation in water flow into account, the calculations show that the nitrogen concentration has fallen 9% in the majority of the watercourses over the period 1989–99. The fall is statistically significant at 35 out of 116 stations at which a fall in concentration was detected. The variation is considerable, however. In sandy soil areas, there is a weak tendency towards an increase in watercourse nitrogen concentration.

PHOSPHORUS IN WATERCOURSES

The pattern of phosphorus transport in watercourses in uncultivated rural catchments without point-source loading since 1989 has generally followed the variation in runoff. Thus water flow and phosphorus transport were higher in 1998 than in the dry years 1996 and 1997. The flow-weighted phosphorus concentrations, which are less affected by runoff, do not reveal any general trend in watercourses in uncultivated rural catchments. In watercourses in cultivated catchments, in contrast, the flow-weighted concentrations have fallen from a level of 0.13–0.15 mg P per litre in 1989–91 to 0.11–0.13 mg P per litre in 1994–98.

Phosphorus discharges to watercourses in catchments with wastewater discharges from point sources and freshwater fish farms have fallen markedly due to a fall in phosphorus discharges from wastewater treatment plants and fish farms.

ORGANIC MATTER IN WATERCOURSES

As long time series of organic matter data are only available for a small number of stations, no analysis has been made of the general trend.

One of the chief sources of organic matter in several watercourses in Jutland is freshwater fish farms, discharges from which have often been the cause of an unacceptable environmental state in watercourse reaches affected by fish farms.

Since 1989, organic matter discharges from freshwater fish farms have been reduced considerably from more than 6,000 tonnes in 1989 to 3,500 tonnes in 1998. The measurements of organic matter in watercourses made under NOVA-2003 – especially in the catchments where the wastewater from freshwater fish farms accounts for a considerable part of the point-source load – documents the reduction in discharges of organic matter from fish farms.

HAZARDOUS SUBSTANCES

As mentioned above, the basis for assessing the occurrence and transport of hazardous substances in watercourses is presently too inadequate to enable such assessment of these factors.

Over the period 1994–97, Funen County conducted screening for the occurrence of pesticides in selected watercourses, springs and drains (Funen County, 1999). The investigations encompassed 237 water samples analysed for 99 different substances and 6 stream bed sediment samples analysed for 22 different substances. The pesticides analysed for are currently or previously used by farmers, public institutions and the general public. The background for the pesticide investigation by Funen County was that the County's routine studies of stream macroinvertebrates in the early 1990s revealed a disquieting increase in the number of watercourses that were acutely affected by toxic discharges. Crustaceans and aquatic insects had been killed in large numbers.

The investigation revealed 33 pesticides in watercourses and 21 pesticides in drainage water, comprising 27 herbicides, 2 fungicides and 4 insecticides. Of the 33 different pesticides, 26 are currently approved for use in Denmark. The most frequently detected mother substances were isoproturon and glyphosat. Both substances are approved and are the most used pesticides in Denmark. On the basis of the investigation, Funen County concluded that it is highly probable that a major part of the pesticides in the watercourses are input in drainage water, especially in the spraying season. Pesticide input to the watercourses via wind drift seems to be of little significance for the occurrence of pesticides in the water.

The analyses of stream bed sediment from Lillebæk stream and the river Odense in 1997 revealed the presence of 5 and 4, respectively, out of the 22 pesticides investigated, cf. Table 5.3. The substances detected comprise four insecticides and one fungicide. DDE is a degradation product of DDT, which is extremely toxic, and which was banned in Denmark back in 1984. Thirteen years after the ban entered into force, its degradation product is still detectable in both the river Odense and Lillebæk stream. The sediment investigated is the loose subsurface fraction that is transported downstream to lakes or coastal waters during periods of high stream flow. The sediment deposits on the stream bed during periods of low stream flow, typically in the summer, and resuspends in the water phase when stream flow increases in the autumn.

Table 5.3
Maximum concentrations of pesticides detected in watercourse sediment (Funen County, 1999). DM: Dry matter.

Pesticide	µg/g DM
α-cypermethrin	0.003
DDE	0.02
Esfenvalerat	0.003
Permethrin	0.03
Vinclozolin	0.002

In the Funen County investigation, it was concluded that if the pesticide contamination had not occurred, the number of watercourses with a satisfactory environmental state would have been 10% greater.

Aarhus County also undertook a similar investigation in 1997, collecting 26 water samples for pesticide analysis from 3 watercourses and 4 springs in agricultural catchments (Aarhus County, 1999a). The substances most frequently detected in the investigation are typically substances that are commonly detected in other pesticide studies.

WATERCOURSE MAINTENANCE

The method and frequency of weed clearance and the implements used are of great significance for the watercourse plant communities. In 67% of the watercourses encompassed by the monitoring programme, the weeds are cleared at least once yearly. The weed clearance pattern is the same for the large Danish watercourses.

Former weed clearance practices affect the plant communities for a long time. Thus it can take many years for the plant communities to re-establish once weed clearance is stopped.

EXTENSIVE BIOLOGICAL MONITORING PROGRAMME

When comparing the fauna class data for 1998 with the data for the monitoring period 1993–97, it is necessary to take into account that the small, affected watercourses were previously underrepresented. On the basis of the recalculated data and county regional watercourse supervision data for the period 1993–96 it is estimated that the state of the watercourses during that period is in relatively good agreement with the state determined in 1998 using the Danish Stream Fauna Index, where fauna class 4 dominates (moderately affected fauna).

Based on data from the national monitoring stations it has previously been concluded that watercourse environmental state was generally better in Jutland and on Funen than in the remainder of the country. The county regional watercourse supervision data for the period 1993–96 leads to the same conclusion.

The BOD_5 content of the watercourses in eastern Denmark was found to be slightly but significantly greater than in western Denmark. The difference in BOD_5 cannot explain the marked difference in environmental quality between the two regions, however. It must further be concluded that stream bed conditions do not differ and hence cannot explain the difference in environmental state either.

EXTENDED BIOLOGICAL MONITORING PROGRAMME
The extended biological monitoring programme is undertaken a total of three times during the monitoring period 1998–2003 – in the years 1998, 2000 and 2003 – thereby enabling watercourse biological state to be followed for a 6-year period. The first two reports will focus on describing and characterizing the factors of significance for the various groups of watercourse organisms and the interactions between the animal and plant communities. The final report will focus on the overall trend in the biological communities.

QUALITY OBJECTIVE COMPLIANCE
At the national level, the watercourse quality objectives were met at 39% of the monitoring stations in 1996 as compared with 43% in 1997 and 44% in 1998. The increase is not necessarily an expression of an improvement in state, but could be due to the fact that different stations were investigated in the three years (Danish EPA, 1999f).

5.3 Lakes

In Denmark, there are around 120,000 lakes greater than 0.01 hectare (100 m^2), the majority of which are ponds and small lakes. Only 2,762 of the lakes are larger than 1 hectare (10,000 m^2). The total lake area is approx. 58,000 hectares, which corresponds to around 1.4% of the Danish landmass.

NOVA-2003 encompasses a total of 31 lakes, of which 4 are brackish. The lakes span from completely pure clearwater lakes to lakes that are strongly polluted. The environmental state of these lakes is estimated on the basis of chemical, physical and biological measurements on the lake water and measurements of nutrient inputs and outputs.

The following description of the environmental state of Danish lakes and the overall trend is primarily based on the report “Lakes 1998” (Jensen et al., 1999). As the investigations in the 31 lakes are inadequate to provide a general and representative description of the current state and overall trend in the environmental quality of Danish lakes, the description is supplemented with information from county regional supervision of lakes (Danish EPA & National Forest and Nature Agency, in preparation).

5.3.1 The year gone by

The environmental state of the 31 monitoring programme lakes is investigated each year and the overall trend assessed. No results are available for one of the four brackish lakes in 1998, however, as sample collection was not initiated until 1999. Data from the other three brackish lakes are included for the first time. Time series for use in an assessment of the overall trend in environmental state are thus only available for the remaining 27 lakes.

WATER BALANCE
It has been possible to establish reasonably accurate water and nutrient balances that include exchange with the groundwater for 16 of the 31 lakes. 1998 was a wet year, cf. Figure 2.4, and water input to the lakes was greater

than normal. The residence time in lakes was thus shorter than normal, though not as short as in the hitherto wettest year of the monitoring period, namely 1994.

PHOSPHORUS AND PHOSPHORUS BALANCE

Phosphorus retention increases with increasing residence time in the lakes. In 1998, retention was greater than 12% in half of the lakes. The phosphorus balance was negative in a number of the lakes, however, i.e. phosphorus output exceeded phosphorus input due to phosphorus release from the lake sediment after external loading has been reduced.

NITROGEN AND NITROGEN BALANCE

Nitrogen retention in the 16 lakes also increases with increasing residence time. In addition, nitrogen retention has increased in some of the monitoring programme lakes after the restoration of a clearwater state following changes in the fish stock. Nitrogen retention exceeded 29% in half of the lakes in 1998.

SECCHI DEPTH AND CHLOROPHYLL *A*

In the majority of the lakes in which the Secchi depth or chlorophyll *a* concentration have changed significantly, the change has involved an increase in Secchi depth and a decrease in the chlorophyll *a* concentration. The annual mean Secchi depth has thus increased in 12 lakes and only decreased in one. Correspondingly, chlorophyll *a* concentration has decreased in 11 lakes and only increased in 2. Similar changes were also seen in the summer levels. Summer mean Secchi depth has increased in 11 lakes and the summer mean chlorophyll *a* concentration has decreased in 8 lakes.

PHYTOPLANKTON

Phytoplankton biomass has fallen significantly in 6 of the 27 freshwater lakes and increased in 2 lakes. The changes are mainly seen in the bluegreen algae and green algae, as well as in diatoms and dinoflagellates. The composition of the phytoplankton community has also changed in many lakes, among other things the percentage of bluegreen algae having increased in 3 lakes and fallen in 6.

ZOOPLANKTON

For the zooplankton community as a whole, no significant changes in biomass have occurred during the 10-year monitoring period. Changes have taken place in a few lakes, however, with total biomass having decreased in 4 lakes and increased in 5.

SUBMERGED MACROPHYTES

Relative to the preceding years, there were very few general changes in submerged macropyhyte distribution and composition, although there was a tendency towards increased distribution in the investigated lakes.

FISH FRY SURVEYS

Fish fry surveys in the monitoring programme lakes are a new element of the monitoring programme. The surveys have provided a good impression of the number and composition of the fish fry, just as their impact on the zooplankton can be described.

The most abundant species are roach and perch, but bream and ruffe are also frequently found in the surveys. The density of fish fry is very variable, both between lakes and within the individual lakes. Average density was highest for roach by the banks (3.7 per m^3) and in the open water (1.3 per m^3), with the corresponding figures for perch being 0.6 and 0.7 per m^3, respectively.

HAZARDOUS SUBSTANCES

In 1998, no data on hazardous substances was reported for the 8 selected lakes included in the monitoring programme.

A few individual Counties have investigated the occurrence of pesticides in fresh waters. Aarhus County has thus detected a number of herbicides and their residues in a single lake (Aarhus County, 1999). The substance present in the greatest quantity was BAM, a degradation product of dichlobenil, which is used in Christmas tree plantations and for eliminating vegetation in courtyards, etc. Other substances detected include hexazinon, which has been prohibited since 1994, and isoproturon.

Of the pesticides detected in two ponds, those present in the greatest quantities were herbicides used on cereals – including isoproturon. AMPA was also detected in both ponds and glyphosat in one of the ponds. The substances most frequently detected in the ponds investigated are typically substances that are commonly detected in other pesticide investigations. A number of these substances are presently prohibited or their use is subject to restrictions.

Among other things, Aarhus County concluded that the long-term effects of the substances detected are generally unknown. The overall effect of the many substances at the ecosystem level has not been investigated either. Finally, the County concluded that as the possibility cannot be excluded that the pesticides will have environmental effects in the aquatic environment, attempts should be made to limit inputs to surface waters.

QUALITY OBJECTIVE COMPLIANCE

In connection with the Counties' regional supervision work in 1998, the environmental state of 222 lakes was investigated. Of these, quality objectives have been stipulated for 217. The lake supervision programme encompasses biological and chemical conditions, including such factors as summer Secchi depth, which provides an impression of the environmental state of the lake.

The lake supervision work has primarily been directed at investigating compliance with lake quality objectives. For a given lake to comply with its quality objective, it must meet a set minimum requirement as to Secchi depth, etc. In the great majority of the lakes hitherto investigated, the Secchi depth is still unsatisfactory. At the national level it is estimated that only 32% of the investigated lakes comply with the quality objective set for them in each county's Regional Plan.

One of the priorities of regional lake supervision in several areas has been to investigate the effect of lake restoration projects, in particular investigations of the effect of biomanipulation on the fish stock. Positive effects in the form of clearer water than in the period prior to depletion of the fish stock have been reported in several places, and in a few cases submerged macrophyte communities have become established. The long-term effect of the restoration measures implemented will be investigated in the coming years.

The brackish lakes have not hitherto been studied to any great extent, and were not included in the monitoring programme until after the latest revision. The three brackish lakes investigated in 1998 are all shallow lakes. The nutrient levels are relatively high in all three lakes, the total-P concentration thus being over 0.1 mg P per litre and the total-N concentration being between 2 and 4 mg N per litre. The Secchi depth is therefore also low (under 1 m) and the chlorophyll concentration is correspondingly high.

5.3.2 **Trend in lake environmental state**

As mentioned above, this is the first time that the brackish lakes are included in the monitoring programme. As a consequence, the trends in lake quality are solely determined on the basis of the time series for the remaining 27 monitoring programme lakes.

BRACKISH LAKES

As Danish lakes are generally small and have a low water volume, the residence time is highly affected by runoff conditions in the individual years. Almost 3/4 of the 30 monitoring programme lakes have a residence time of less than one year, i.e. all the water in these lakes is renewed once to several times yearly.

Interannual variation in residence time and water inputs for the 16 monitoring programme lakes for which detailed water balances have been established also change markedly from year to year depending on the precipitation conditions. Residence times were longest in 1996, but were also long in 1997. In the wet year 1994, the residence times were considerably shorter than in the other years. The residence times were also short in 1998, but not so distinctly as in 1994. Water inputs to the monitoring programme lakes were highest in 1994, high in 1998, and lowest in 1996 and 1997.

PHOSPHORUS AND PHOSPHORUS BALANCE

Phosphorus input to the 16 lakes has decreased during the 10-year monitoring period. Following two dry years with low phosphorus input it is now back at the 1995 level. Total phosphorus input has decreased significantly in 6 of the 16 lakes, in particular in lakes where the level of phosphorus input used to be very high. The inflow concentration of total-P has decreased markedly during the period 1989–98, with the decrease being significant in 8 of the 16 lakes.

Correspondingly, the annual mean total-P concentration in the 27 freshwater lakes has almost halved from 0.204 mg P per litre in 1989 to 0.104 mg P per litre in 1998. The outflow phosphorus concentration has decreased in roughly the same number of lakes as for the inflow concentration, although not to the same extent as a result of internal phosphorus loading from the sediment in many of the lakes.

NITROGEN AND NITROGEN BALANCE

Nitrogen input to the 16 lakes was higher in 1998 than in the two preceding dry years. The median input was lower in 1998, however, namely 385 mg N per m^2 per day, which corresponds to the inputs recorded at the beginning of the 1990s. Nitrogen input to two of the lakes has reduced significantly over the period 1989–98. The inflow concentration has decreased significantly in four of the 16 lakes, the average concentration being higher than in the preceding dry years, though.

Both absolute and relative nitrogen retention in 1998 were equivalent to the mean values for 1989–97. The variation in the relatively low level of retention is largely determined by the residence time of the water in the lakes. All other things being equal, relative nitrogen retention is always less when residence time is short than when residence time is long because there is too little time for much nitrogen to be converted and released to the air.

SECCHI DEPTH AND CHLOROPHYLL *A*

The changes in the average Secchi depth and chlorophyll *a* concentration in the monitoring programme lakes are relatively small compared with the changes in the concentration of nutrients and especially of total-P. The Secchi depth has generally been increasing over the period 1989–98, though, while the chlorophyll *a* concentration has decreased. The annual mean Secchi depth has varied from 1.7 to 2.0 m. If the lakes are subdivided into four equal groups according to Secchi depth it transpires that the Secchi depth of the most turbid quarter has increased from 0.6 m in 1989 to 1.0 m in 1998. The Secchi depth of the next group has increased from 1.5 to 1.9 m, while the chlorophyll *a* concentration in this group has fallen correspondingly from 108 to 38 microgrammes per litre.

The overall trend is thus that the most unclear lakes are becoming clearer at the annual level. At the summer level the trend is not so clear, and the Secchi depth for the most turbid quarter has only increased from 0.5 to 0.7 m over the period 1989–98.

PHYTOPLANKTON

As is apparent from the Secchi depth and the chlorophyll *a* concentrations, the majority of the monitoring programme lakes are characterized by a high phytoplankton biomass. In the most of the lakes, the phytoplankton community is dominated by species characteristic of nutrient-rich lakes. The majority of the biomass is thus accounted for by bluegreen algae and green algae. The summer mean total biomass has decreased from 18.7 mg per litre in 1989 to 8.1 mg per litre in 1998. The summer median has decreased from 11.7 mg per litre in 1989 to 3.6 mg per litre in 1998.

ZOOPLANKTON

Neither the total biomass nor the biomass of the various types of zooplankton has changed much in the lakes as a whole since 1989. There is thus little overall indication that the capacity of the zooplankton to graze down the phytoplankton has increased in the monitoring programme lakes despite the fall in input of total-P in many lakes.

As with the other variables, the general picture hides a number of differences in the individual lakes. The total zooplankton biomass has thus declined significantly in 4 lakes and increased in 5. A change in the total biomass can be an expression of a change in grazing pressure from carnivorous fish, but it can also be due to changes in the amount of food in the form of phytoplankton.

No clear trend is apparent in the average size of the zooplankton. However, significant changes in the average biomass have been found in a few lakes, although this is not reflected in the total grazing pressure in the individual lakes. Overall, though, there is a tendency towards a slight increase in the grazing pressure throughout the monitoring period.

SUBMERGED MACROPHYTES

The distribution of submerged macrophytes has been investigated once yearly since 1993 in 14 of the 27 freshwater lakes. The average vegetated area has remained largely unchanged throughout the period, although with a tendency towards an increase. The relative plant-filled water volume has generally been increasing slightly in the 14 lakes over the period 1993–98. The depth distribution has generally increased correspondingly in the 14 lakes, although not as markedly as the overall percentage cover and the relative plant-filled volume.

QUALITY OBJECTIVE COMPLIANCE

There does not seem to have been any improvement in quality objective compliance since 1989. Thus the number of lakes meeting their quality objective has remained at about 30% throughout the period. In the majority of cases the failure to meet the quality objective is attributable to excessive nutrient loading. Point-source loading and diffuse phosphorus loading from agriculture and sparsely built-up areas are considered to be of decisive significance for lake environmental state.

Even when external nutrient loading of the lakes has been successfully reduced, there is often no immediately detectable effect on water quality. In many cases, this is due to built-in resilience, which prevents improvement from taking place despite the reduction in loading. This can either be due to chemical resilience as a result of a large pool of phosphorus accumulated in the lake sediment or to biological resilience because the fish stock remains unchanged after a reduction in loading.

In order to accelerate improvement, various lake restoration methods have been developed. The most widespread form of lake restoration in Denmark is depletion of planktivorous fish, especially roach and bream. Among other things, these fish graze down the number of zooplankton, especially the number of large and effective filter-feeding daphnia species. This method has been employed in more than 20 Danish lakes and the results so far have been collated by Søndergaard et al. (1998).

The effect of fish removal has generally been good, although primarily in lakes in which a large part of the fish stock has been removed over a period of a few years. The fish stock should preferably be reduced to under 100 kg per hectare over 1–2 years. The long-term effect of the fish stock manipulations so far undertaken is not yet well-documented as the majority of the projects has been undertaken within the past 4–6 years.

5.4 Marine waters

Monitoring of the Danish marine waters is divided between the county and state authorities such that the Counties monitor the coastal waters and the State monitors the open marine waters.

The following description of the environmental state of Danish marine waters and the overall trend is primarily based on the report “Marine waters. Environmental state in 1998” (Markager et al., 1999). The description is supplemented with information from county supervision of the environmental state of the coastal waters.

5.4.1 The year gone by

The main climatic factors affecting the environmental state of the sea are precipitation, wind and the amount of light. The precipitation affects the magnitude of nutrient loading from the land. The wind stirs up the water, counteracting oxygen deficiency at the seafloor, etc., while light is of importance for plant growth. The temperature in 1998 was higher than the normal for the period 1961–90 during the first quarter of the year, while the summer months were cooler than normal, cf. Chapter 2.

HYDROGRAPHIC CONDITIONS

Relative to the normal, the surface water temperature was higher in the spring but lower in the summer months. Combined with the windy weather this resulted in less frequent incidents of temperature stratification of the water, especially in shallow areas.

On the other hand, springtime salinity was markedly higher than normal in the inner marine waters. In April, outflow of water from the Baltic Sea resulted in marked stratification of the water in the southern part of the Little Belt, where the bottom water was not renewed until in October, with resultant severe oxygen deficiency.

NUTRIENTS

Nutrient concentrations in the estuarine fjords, in the coastal waters and in the inner marine waters were generally average in 1998, although they were above average in several fjords in October and November due to the fact that precipitation was twice as great as normal in October.

The exchange of nutrients between estuarine fjords and individual segments of marine waters has been calculated for four fjords – Roskilde Fjord, Odense Fjord, Limfjorden and Ringkøbing Fjord. The results show that nitrogen (total-N) export from the fjords in 1998 was of the same magnitude as in the preceding years.

The magnitude of phosphorus (total-P) exchange between fjord and sea largely depends on the individual fjord. Thus in Limfjorden, export of phosphorus to the North Sea took place for the first time in the 1990s. In Ringkøbing Fjord, the sluice practice was changed in 1996 so that seawater is only let into the fjord when it is windy, thereby hindering stratification of the fjord. As a result, incidents of oxygen deficiency are now exceptional and short lasting, and hence so too is the occurrence of conditions conducive to phosphorus release from the sediment. Phosphorus export from Ringkøbing Fjord has therefore been reduced markedly relative to previous years.

The calculations from Limfjorden and Ringkøbing Fjord further show that less phosphorus is released from the marine sediment than at the beginning of the 1990s.

Oxygen conditions

In 1998, oxygen deficiency in the marine waters was extensive, cf. Figure 5.7. Based on the nitrogen inputs it can be assumed that oxygen consumption at the seafloor in 1998 was around or above the average for the period 1989–97.

Figure 5.7
Stations where oxygen was measured in 1998 and where oxygen deficiency (<4 mg/l) or severe oxygen deficiency (<2 mg/l) was observed (adapted from Markager et al., 1999).

The windy, cool weather in summer 1998 was beneficial to the open shallow waters. In the shallow estuarine fjords, the water was frequently stirred up so that the bristle worms and mussels that obtain their food by filtering the water were able to partially control the amount of phytoplankton in the water column (Markager et al., 1999). The animals are able to filter the total water volume of the fjords between approx. three times daily (e.g. Ringkøbing, Roskilde and Skive Fjords) and approx. 14 times daily (Odense Inner Fjord).

In the deep stratified areas of the southern Little Belt, Åbenrå Fjord and Flensborg Outer Fjord, a very long-lasting, severe oxygen deficiency developed. This was partly attributable to a relatively large phytoplankton spring bloom and a subsequent resultant high level of oxygen consumption at the seafloor in connection with decomposition of the sedimented dead algae, and partly attributable to the outflow of water from the Baltic Sea in April, which in these areas caused a marked pycnocline above a layer of standing bottom water. In the open marine waters, widespread oxygen deficiency developed in the southern Kattegat and the Sound, as well as in the Great Belt during the course of the late summer.

Phytoplankton

In 1998, the seawater was clearer than normal. Secchi depth was approx. 23% greater than average for the period 1977-88 and 7% greater than the average for the period 1989–97. The clarity of the water was thus roughly the same as in the low-precipitation years 1996 and 1997.

In 1998, the phytoplankton biomass was generally lower than the average for the period 1989–97, and was only higher than the average for the preceding 10-year period in the southern Kattegat, in Hevring Bay off Randers Fjord, and in Mariager Fjord. In the case of Ringkøbing Fjord, the changed sluice practice is now clearly apparent. The average biomass in 1998 was less than 10% of the biomass in 1995, and the bluegreen algae that previously dominated have now been replaced by other types. No algal blooms were recorded in 1998.

The severe incident of oxygen deficiency with the development of hydrogen sulphide which eradicated the fauna in Mariager Fjord in August 1997 clearly influenced conditions in the fjord in 1998. Many of the predator-prey relationships had not yet been restored and this enabled the unhindered growth of phytoplankton. Seven algal blooms thus occurred during the course of the year.

Apart from this, only few other algal blooms were recorded in 1998 and their effects were limited.

TOXIC ALGAE

In the beginning of May there was a major bloom of a toxic planktonic algae of the *Chattonella* family, which is otherwise best known from the marine waters around Japan. The bloom comprised up to 12 million cells per litre and involved large parts of the Skagerrak, the North Sea along the west coast of Jutland, the Kattegat and down to Aarhus Bay and Odense Fjord. The algae were toxic and caused fish mortality (garfish) in an area from Hanstholm to Skagen and in the western part of Limfjorden. In addition, salmon mortality occurred along the Norwegian Skagerrak coast.

In all, around 20 potential toxic species of phytoplankton were recorded in the marine waters and estuarine fjords in 1998. These did not cause any known effects. A few mussel fishing areas along the east coast of Jutland were briefly closed for mussel fishing because the number of toxic dinoflagellates exceeded the limit level of 500 cells per litre. At no point were algal toxins detected in the mussels, however.

BENTHIC VEGETATION

In 1998, the depth distribution for eelgrass increased in 27% of the waters, decreased in 17% and remained unchanged in 47% (or information is unavailable) (Table 5.4). The tendency towards increasing depth distribution is especially apparent in the outer sections of the estuarine fjords and along open coasts such as in the Little Belt, the sea south of Funen and the outer part of Kalundborg Fjord. The tendency towards a decreasing depth distribution has been recorded in a number of closed fjords, among others Mariager Fjord, Randers Fjord, Odense Fjord and in the western part of Limfjorden.

Table 5.4
Trend in eelgrass depth distribution and coverage and the coverage of eutrophication-dependent algae in 1998 relative to the preceding years. Based on county environmental data. The trend is described as either increasing (I), falling (F), status quo (O), or unknown (-) (adapted from Markager et al., 1999).

Marine area	Eelgrass		Eutrophic algae
	Depth distribution	Coverage	Coverage
Odense Fjord	F	I	I
Sea south of Funen	I	-	O
Kertinge Cove	I	I	-
Århus Bay, Kalø Cove	O	-	-
Mariager Fjord	O	F	I
Randers Fjord	F	F	-
Roskilde Fjord	O	F	O
Ringkøbing Fjord	I	F	O
Nissum Fjord	I	I	-
Karrebæksminde Bay	O	O	-
Dybsø Fjord	O	-	I
Karrebæksminde Fjord	O	-	I
Præstø Fjord	O	-	I
Isefjord	O	-	F
Little Belt (N)	I	I	O
Little Belt (S)	I	-	O
Limfjorden (W)	F	F	I
Grådyb tidal flats	-	-	I
Lister Deep	-	-	O
Aabenraa Fjord	O	I	I
Augustenborg Fjord	O	F	I
Flensborg Fjord	F	F	O
Kolding Fjord	I	-	O
Vejle Fjord	O	-	O
Horsens Fjord	F	-	O
Kalundborg fjord	I	-	I
Korsør Cove	O	-	I
Nivå Bay	-	-	F
The Sound	O	-	F
Køge Bay	O	-	F
Falling tendency (%)	17	23	13
Increasing tendency (%)	27	13	37
Status quo (%)	47	3	33
Unknown (%)	10	60	17

The distribution of drifting eutrophication-dependent macroalgae such as filamentous brown algae (*Ectocarpus*), silkweed (*Cladophora*) and sea lettuce (*Ulva*) has been systematically monitored since 1994. In 1998, increasing abundance of these algae was recorded in a number of enclosed fjords, including Karrebæksminde Bay and Dybsø, Præstø, Ringkøbing, Nissum and Mariager Fjords. Decreasing abundance has only been observed in open waters such as Nivå Bay and Isefjord.

BENTHIC FAUNA

In contrast to previous years, the benthic fauna in quite a few of the Danish estuarine fjords displayed common features in the form of low biomass and number of individuals. This is in line with the improved environmental conditions detected, particularly along the west coast of Jutland and in the Sound.

The trend in the benthic fauna is thus as expected, with the occurrence of benthic fauna one year being related to nutrient inputs the preceding year (Ærtebjerg et al., 1998). In 1997, nutrient inputs to the sea were low due to the low runoff from the land, thus accounting for the low benthic faunal abundance in 1998.

Marked deviation from the general trend was recorded in Mariager Fjord and Ringkøbing Fjord. In Mariager Fjord, considerable recolonization by benthic fauna was recorded in 1998 following the extensive benthic faunal mortality in August 1997. In Ringkøbing Fjord, changes in sluice practice have resulted in a marked increase in benthic faunal biomass. Sand mussels in particular have returned in great numbers.

HAZARDOUS SUBSTANCES

Monitoring of hazardous substances in the marine environment, which was added to NOVA-2003 in 1998, is usually based on measurement of the concentration in plants or animals or sediment. The highest concentrations of hazardous substances are expected to occur in our estuarine fjords and the more inshore waters, where dilution of discharges is least. It is also here that one can expect the greatest effect of a reduction in the discharge of a given substance. The monitoring work thus mainly focuses on the fjords and coastal waters.

HAZARDOUS SUBSTANCE GROUPS

In evaluating the results, the hazardous substances are dealt with in the following main groups:
PCB (polychlorinated biphenyls): the sum of the concentration of 10 selected representatives of the PCBs,
HCH: the sum of α-HCH, β-HCH and γ-HCH (lindane),
DDT: the sum of pp'-DDE, pp'-DDD and pp'-DDT, and
PAH (polyaromatic hydrocarbons): the sum of the concentration of PAHs and the other aromatic hydrocarbons.

OSPAR has developed ecotoxicological evaluation criteria for the hazardous substances encompassed by the marine part of NOVA-2003. These criteria give the concentration intervals below which effects on marine organisms are unlikely. In addition, OSPAR and others have established various background/reference levels for the occurrence of a number of hazardous substances in mussels. In general, though, the basis for evaluating the occurrence of hazardous substances in marine sediment and biota is very limited.

ASSESSMENT OF HEAVY METALS

In 1998, the measured concentrations of heavy metals in common mussels and fish were relatively low, which means that the environmental quality objectives were met in the majority of the areas investigated. In the areas where raised concentrations of mercury and/or some of the other heavy metals have been detected in mussels and fish the presence of the metals was probably due to contamination from local sources. In the Sound, raised concentration levels were detected for all the heavy metals investigated except nickel. Raised levels of both zinc and copper were detected in Roskilde Fjord and Odense Fjord, while raised levels of mercury were detected in Odense Fjord and the Wadden Sea.

In general, the concentrations of heavy metals in fish decrease as one moves from the Sound through the Great Belt to Hvide Sande. In 1998, mercury levels in fish were only investigated in the Sound. The results indicate that the levels are lower than the limit value for food (Frederiksborg County, 1999).

Assessment of organotin

The highest concentrations of tributyl tin (TBT) in mussels were detected in Odense Fjord, Aarhus Bay and in the Sound. The concentrations are also relatively high in the Great Belt compared with other marine waters. These marine waters are all characterized by a high level of ship traffic and other ship-related activities that can comprise a source of TBT. The distribution of TBT and its degradation products in mussels indicates that the mussels have recently been exposed to TBT. The other organotin compound – triphenyl tin – has only been found in detectable levels in a few samples from Horsens and Odense Fjords.

The TBT concentrations in mussels are high at all stations. The level ranges from approx. two to 120 times greater than OSPAR's evaluation criteria. Studies of the biological effects of TBT concentrations have thus shown that all the red whelk and a considerable fraction of the pygmy whelk and common whelk in the inner Danish marine waters exhibited hormonal disturbances with the development of male genitalia in females. Nearly all the female periwinkles collected in Copenhagen harbour and 40% of the female snails collected near the Lindø Shipyard in Odense Fjord exhibited intersex characteristics to an extent that has caused sterility.

Chlorinated organic compounds

The PCB concentration in all marine waters is at a level where the possibility of ecological effects cannot be excluded according to OSPAR's evaluation criteria. The only exception is Ringkøbing Fjord, where the level is low. Uncharacteristically high levels have been detected in a few samples from Horsens harbour and from Roskilde Fjord. This issue should be examined more closely over the next few years of monitoring.

At the present time, there is insufficient data to be able to evaluate whether the levels of DDT and HCH in mussels and fish pose a problem.

Evaluation of PAHs

In general, it can be concluded that the PAH concentration in Danish coastal waters is at the same level as in relatively unpolluted marine waters. High values have been detected in a few estuarine fjords, especially in areas with little water exchange and/or potent point-source discharges.

Quality objective criteria

Quality objectives for coastal marine waters are set by the County Councils in their Regional Plans. The quality objective set for most marine waters is the General Quality Objective, i.e. only slight human impact on the environment is permissible and the hygienic standard of the water body has to be good. The characteristics that the County Council decides to focus on when defining the quality objectives depends on the nature of the marine water in question.

In order to make assessment of the extent to which a given marine water complies with its quality objective as clear as possible, parameters are often chosen that are easy to measure and quantify. Knowledge of how these parameters vary in line with changes in environmental state is also necessary. The final decision will nevertheless often depend on a judgement of the overall situation, among other reasons because our knowledge of the mechanisms that determine the development of the selected parameters is incomplete.

In the majority of marine waters it is inputs of nutrients and organic matter that are of interest. The occurrence of oxygen deficiency is often used in such assessments, partly because oxygen deficiency reflects the extent of present or past nutrient and organic matter loading, partly because oxygen deficiency is of great significance for the whole ecosystem.

The depth distribution of the vegetation, which particularly reflects the transparency of the water, is also an indicator of the longer-term environmental state. The composition and abundance of the benthic fauna is also used as an evaluation criterion. In this case, it is the dependence of the fauna on good oxygen conditions and an ample food supply that determines the state. In marine waters that are affected by high levels of nutrient loading, filamentous algae or annual green algae (eutrophication-dependent macroalgae) are often favoured at the expense of other types of vegetation. Enhanced occurrence of such organisms can therefore often be employed as an indicator of an unacceptable state. Finally, enhanced phytoplankton abundance or production are well-known indicators of nutrient loading.

QUALITY OBJECTIVE COMPLIANCE

As is apparent from the 1996 and 1998 reports on the state of the Danish aquatic environment (Danish EPA, 1997 and 1998) and the county technical reports, the environmental state of the majority of the coastal waters fails to comply with the quality objectives set for them, and efforts to deal with land-based nutrient loading are necessary if the desired quality objectives are to be met. Table 5.5 summarizes the county assessments of the current (1998) state of coastal waters relative to their quality objectives. The table only considers whole water bodies, and there can be local divergences that are not fully reflected in the table.

Table 5.5

State of the environment in 1998 relative to the quality objectives for the coastal waters. Based on county environmental data. Under "State", " –" indicates lack of compliance with the quality objective, "+" indicates compliance with the quality objective and "?" indicates that the quality objective is threatened. The column "Parameters" lists the parameters used for assessing the environmental state as: NC – Nutrient concentrations; PAB – Planktonic algal blooms; TA – presence of toxic algae; OD – Oxygen deficiency; OP – Oil pollution; EM: Mass occurrence of eutrophication-dependent macroalgae; BMB – Benthic macroinvertebrate biomass; SD – Secchi depth; PE – Physical effect; BVC – Benthic vegetation coverage: M – Miscellaneous. The column "Causes" describes the types of sources that the county authorities consider to be of greatest significance and where further measures to reduce loading would be highly appropriate.

Area	State	Parameters	Causes
North Sea – coastal regions	-	NC, PAB, TA, OP	Discharges from rivers and Danish streams
Wadden Sea	-	NC, EM, BMB	Discharge of nitrogen in particular

Ringkøbing Fjord /Nissum Fjord	-	NC, SD, M	Input of nutrients, especially nitrogen
Skagerrak – coastal regions	+	NC	-
Limfjorden	-	NC, PE	Nitrogen loading from agriculture Scraping with fishing equipment
Kattegat (W)	-	EM, BMB	Nitrogen loading, especially from the open country-side
Randers Fjord	-	NC, BVC	Nutrient loading
Mariager Fjord	-	NC, BVC, BMB	Nutrient loading from land, limited water exchange with the Kattegat
Kattegat (S) – coastal regions	+		-
Isefjord	-	OD, EM, M	Nitrogen loading
Roskilde Fjord	-	Not given	Not given
Århus Bay	-	OD, BVC, PAB	Nitrogen loading but also phosphorus loading from cultivated land. Nutrient input from the atmosphere, the Kattegat and the sediment.
Horsens Fjord	-	BVC, BMB	Mussel trawling Nutrient loading
Sejrø Bay	-/?	OD, EM, M	Nitrogen loading
Odense Fjord	-	PAB, EM	Enhanced nutrient concentrations Xenobiotic substances
Vejle Fjord	?	-	Conditions seem good in 1998
Kolding Fjord	-	BMB	Nutrient loading
Augustenborg Fjord	-	EM, BVC, M	Nutrient loading
Åbenrå Fjord	-	OD, EM, BVC	Nutrient loading
Flensborg Fjord	-	OD, BVC, M	Nutrient loading
Helnæs Bay	-	EM	Nutrient loading
Little Belt (S)	-	OD, BMB	Nutrient loading
Great Belt	-	OD	Nutrient loading
Sea south of Funen	-	PAB, EM	Nutrient loading
Holckenhavn Fjord	-	BVC, EM, M	Nutrient loading and water exchange
Kertinge Cove	-	EM	Nutrient loading
Kalundborg Fjord	-	OD, EM, M	Nitrogen loading
Korsør Cove	-	OD, EM	Nitrogen loading
Karrebæksminde Bay	+	SD, BVC, OD	-
Karrebæk Fjord – inner part	+	Not given	-
Karrebæk Fjord – outer part	-	EM	Nutrient loading
Dybsø Fjord	-	EM, M	Nutrient loading
Belt Sea (S) (Storstrøm County)	+	SD, OD	-
The Sound (N)	-	EM, BVC, BMB, M	Nitrogen loading
The Sound (open regions)	+	SD	-
Køge Bay	+/-	OD, EM	Nitrogen loading
Baltic Sea – coastal regions	-	NC, EM	Nutrient loading

HAZARDOUS SUBSTANCES IN RELATION TO QUALITY OBJECTIVES

It is difficult to assess to what extent the hazardous substances investigated have effects that hinder compliance with the General Quality Objectives. This is partly because the quality objectives are only loosely defined and partly because the technical/scientific basis for them needs to be developed. In view of the uncertainty associated with the monitoring of hazardous substances and the limited basis for assessment, an actual assessment of whether the quality objectives have been met must await the monitoring results for the coming years. A single exception is TBT, where effects can clearly be demonstrated in the sea.

Based on this year's results it seems that for most marine waters, the General Quality Objective can probably be met for heavy metals and PAHs, but not for TBT. With the other hazardous substances it is too early to be able to assess whether the quality objectives have been met.

5.4.2 **Trend in the environmental state of the sea**

NUTRIENTS

Transport of nutrients from the estuarine fjords to the open marine waters has been partly investigated in four fjords, namely Ringkøbing Fjord, Limfjorden, Odense Fjord and Roskilde Fjord.

Based on calculations for 1985, 1992 and 1998, export of nutrients from Roskilde Fjord to Isefjorden has decreased by approx. 54% for nitrogen and approx. 75% for phosphorus. The decrease in nitrogen export is unrelated to the trend in nitrogen loading from the land. Due to the small number of years for which calculations are available the conclusions are not unambiguous, however.

Limfjorden generally exports more nutrients to the Kattegat than it receives from the North Sea. The calculations of transport conditions since 1990 show no indication of any trend in nitrogen export, but the export of phosphorus to the Kattegat has fallen since 1990. Exceptions to this are 1994 and 1997, when there was extensive oxygen deficiency and hence enhanced release of phosphorus from the fjord sediment.

The decrease in the concentration of phosphate and total-P in the open inner marine waters continued in 1998. However, the observed decreases are too great to be solely attributable to improved wastewater treatment as a result of implementation of the 1987 Action Plan on the Aquatic Environment. The fall might be caused by changes in water exchange between the North Sea/Skagerrak and the Baltic Sea. The issue has not yet been elucidated in detail.

An analysis of the time-weighted concentrations of nitrate+nitrite-N in the winter period reveals a tendency towards a slight fall over the period 1989–98 in 10 out of 12 stations in the Kattegat, but no significant change in the Belt Sea and the Sound.

NUTRIENT LIMITATION

Evaluation of the number of days when growth is nutrient-limited (irrespective of whether nitrogen or phosphorus is the limiting factor) reveals that this primarily depends on the pollutional state of the area. Thus the most strongly polluted areas have the fewest days with nutrient-limited growth, while the least polluted areas have the most days with nutrient-limited growth. In the Belt Sea, the number of nutrient-limited days varies from approx. 100 to 180 days per year, while it is somewhat higher in the Kattegat at 220–250 days per year (Markager et al., 1999).

In Odense Fjord, the annual number of days with nutrient limitation was approx. 40 in the innermost part and 180 in the outermost part of the fjord. The number of days with nutrient limitation has increased markedly since 1990, this being attributable to the decrease in nutrient loading throughout the period.

In the Kattegat, there is no evidence of any change in the number of days that growth has been nutrient-limited. There has been a change in the balance of nutrient loading, however, as reflected by an increase in the number of days when both nutrients are limiting for growth. The reason for the change in the balance between nutrients is the general decrease in the phosphate concentration, cf. Figure 5.8. An assessment of which nutrient phytoplankton growth is limited by in the estuarine fjords revealed that growth is generally phosphate-limited in the spring and nitrate-limited from the early summer to the end of the year (Markager et al., 1999). Due to the marked reduction in phosphorus inputs from urban wastewater treatment plants, the number of days on which phosphate is the potential limiting nutrient has increased in recent years in most estuarine fjords, in the coastal waters and in the inner open marine waters. This is in accordance with experimental studies showing that nitrogen is the primary limiting nutrient in open parts of the inner Danish marine waters (Graneli et al., 1990).

FIGURE 5.8
NUMBER OF DAYS WITH POTENTIAL NITRATE LIMITATION, POTENTIAL PHOSPHATE LIMITATION AND POTENTIAL LIMITATION BY BOTH NITRATE AND PHOSPHATE AT STATION 925 AT ANHOLT IN THE KATTEGAT FOR THE PERIOD 1989–98 (ADAPTED FROM MARKAGER ET AL., 1999).

PHYTOPLANKTON

The amount of phytoplankton expressed in terms of the amount of chlorophyll *a* was low in the inner open Danish marine waters in 1998, cf. Figure 5.9. On average it was 14% below the level for the period 1977–98 and 21% under the level for the period 1989–98. The picture in the estuarine fjords and in the coastal waters is virtually the same, but not quite so pronounced. A statistical analysis shows that there has been a statistically significant decrease over the period 1989–98, but that the trend is primarily attributable to the two dry years 1996 and 1997. On the other hand, the trend is significant if the period 1977–98 is analysed.

FIGURE 5.9
TEMPORAL DEVELOPMENT IN CHLOROPHYLL *A* INDEX AT MARINE STATIONS DEFINED AS STATIONS WHERE THE WATER IS MORE THAN 10 M DEEP AND WHICH ARE NOT LOCATED IN ESTUARINE FJORDS (ADAPTED FROM MARKAGER ET AL., 1999).

TOXIC ALGAE

Toxic algae normally do not pose a problem until they occur in blooms. The number of known toxic planktonic algae has increased considerably in the past 20 years and new species keep ducking up that have not previously caused problems. The reasons for this are unknown.

A particular problem is posed by ship ballast water, which is presently considered to be a major route of dispersal for toxic algae. In many cases, the algae have been traced back to the eastern part of Asia. Many planktonic algae have a cystic resting stage in their life cycle and hence can survive for as long as several years in the dark, for example in the ballast tank of a ship. If the tank is emptied, the cysts can germinate providing growth conditions in the new location are favourable. The International Maritime Organization (IMO) has therefore drawn up a number of recommendations aimed at reducing this unintended dispersal (Kaas et al., 1999).

BENTHIC FAUNA

Crustacean abundance has more than halved since the beginning of the 1980s, while bristle worms, mussels and echinoderms were very abundant at the beginning of the 1990s, but have since fallen to the same level as in the 1980s. The most significant change is the decrease in the number of crustaceans. In the same period, there was an increase in the number of soft-bodied animals, which have been on the decline again since 1995. The reasons for these swings are unknown.

The inter-annual variation at four stations located in the Kattegat, the Great Belt, the Sound and the Arkona Sea, for which long time series are available, reveals a time delay of 1–2 years relative to the variation in nutrient inputs from the land. The relationships have not changed significantly through the monitoring period and the environmental state of the benthic fauna is therefore considered to be largely unchanged in the open marine waters over the period 1989–98.

BENTHIC VEGETATION

For the nation as a whole there has not been any significant change in the depth distribution of eelgrass during the period 1989–97. However, marked inter-annual variation has been recorded, cf. Figure 5.10. The depth distribution was unchanged during the first half of the 1990s. In 1996 and 1996, however, the average depth distribution increased by 0.5 to 1 m compared with that in 1995 as a result of enhanced Secchi depth and improved light conditions. In 1998, the depth distribution had returned to the same level as in 1995. Compared to the situation at the beginning of the Century, the depth distribution of eelgrass is now considerably lower.

FIGURE 5.10
EELGRASS MAXIMUM DEPTH DISTRIBUTION (ADAPTED FROM MARKAGER ET AL., 1999).

The decisive determinant of the trend in the distribution of eelgrass and drifting eutrophication-dependant macroalgae during the period 1989–98 was the magnitude of nutrient inputs.

By influencing planktonic algal growth, nutrients also affect light conditions for the benthic vegetation. An analysis of the inter-annual variation in nutrient concentrations reveals that the high concentrations of total-N in the period 1993–95 coincide with low eelgrass coverage during the same period. In the two dry years 1996 and 1997, the concentration of total-N fell while the eelgrass depth distribution increased during the same period. In 1998, the concentration of total-N increased again, this being matched by a decrease in the depth distribution of eelgrass.

OXYGEN DEFICIENCY

In general, no clear trend can be detected as to the occurrence or frequency of oxygen deficiency in the marine waters around Denmark. Serious incidents of oxygen deficiency occurred in the southern Kattegat in 1981, 1986, 1987 and 1988, cf. Figure 5.11. In the southern Belt Sea, oxygen deficiency was so severe in 1981 and 1985 that hydrogen sulphide formed at the sea floor.

FIGURE 5.11
EXTENT OF OXYGEN DEFICIENCY IN 1981, 1986, 1987 AND 1988.

Model calculations have shown that the oxygen concentration in the bottom water of the inner Danish marine waters is coupled to nitrogen loading from the land, and that a permanent reduction in loading would improve conditions considerably (Ærtebjerg et al., 1998).

The long-term trend (since the 1970s or 1980s) in oxygen conditions has been investigated in the Belt Sea and adjoining fjords (Markager et al., 1999). Improved oxygen conditions were detected at seven out of nine stations in the spring, while deteriorated oxygen conditions were detected at seven out of eight stations in the autumn, cf. Table 5.6.

Table 5.6
Stations where a significant (5%) change has been detected in spring (April-June) or autumn (July-October) minimum oxygen concentration (from Markager et al., 1999).

Marine area	Season	Period	Trend
Odense Fjord	Spring	1997-98	↓
Odense Fjord	Spring	1989-98	↓
Little Belt (N)	Spring	1977-98	↑
Åbenrå Fjord	Spring	1988-98	↑
Augustenborg Fjord	Spring	1988-98	↑
Flensborg Inner Fjord	Spring	1987-98	↑
Flensborg Outer Fjord	Spring	1987-98	↑
Sea south of Funen	Spring	1989-98	↑
Svendborg Sound	Spring	1989-98	↑
Odense Fjord	Autumn	1977-98	↓
Snævringen	Autumn	1976-98	↓
Little Belt (S)	Autumn	1975-98	↓
Flensborg Outer Fjord	Autumn	1987-98	↑
Sea south of Funen	Autumn	1977-98	↓
Langeland Sound	Autumn	1979-98	↓
The Sound	Autumn	1970-98	↓
Køge Bay	Autumn	1985-98	↓

HAZARDOUS SUBSTANCES
Because of the limited knowledge concerning the occurrence of hazardous substances in 1998, it is not possible to assess the overall trend in their concentrations in the marine environment. The mercury content of flounder in the waters of the Sound has fallen by a factor of four over the period 1973–98 at Copenhagen and by a factor of three at Vedbæk (Frederiksborg County, 1999). The concentrations of all the heavy metals investigated are now at the same levels as when the Danish Foods Agency investigated the

concentrations of heavy metals in Danish coastal fish in the period 1979–82 (Danish Foods Agency, 1994).

The general trend in the North Sea is towards decreasing heavy metals concentrations over the past 10 years. In the case of hazardous substances, the trend is less clear (OSPAR, in preparation).

MONITORING OF EFFECTS AROUND OFFSHORE RIGS

Monitoring was undertaken in the vicinity of selected oil rigs in the Danish part of the North Sea during the period 1989–98 in accordance with applicable Danish guidelines. The main purpose of the investigations was to map changes in sediment and benthic faunal composition and identify the most important factors to which the observed changes can be ascribed.

The investigations revealed that discharges in connection with drilling and the operation of offshore oilrigs clearly affect bottom conditions around the rigs. The discharge of drilling muds is considered to be the main cause of the changes detected.

Thus discharges from drilling rigs in the Gorm, Kraka and Harald oil fields markedly affected the conditions at the seafloor in areas up to 250 m from the oilrigs. Less severe changes were detected at distances of up to 1,500 metres. The effects include enhanced levels of such substances as hydrocarbons, barium and heavy metals in the sediments and a reduction in the biomass and number of benthic faunal species present. The variation in benthic faunal biomass could be correlated with the sediment content of hydrocarbons and barium.

A reduction in discharges in connection with the cessation of drilling activity diminished the impact on the benthic fauna, while certain species, including the brittle star *Amphiura filiformis*, which is an abundant member of the benthic faunal communities in the central North Sea, have not re-established themselves up to 2–3 years after cessation of drilling.

QUALITY OBJECTIVE COMPLIANCE

Despite a series of positive tendencies, the environmental state of the Danish marine waters does not fully comply with the quality objectives set for them. The effects of the efforts to reduce agricultural discharges are not yet reflected by an improvement in environmental quality, and national implementation of a series of international action plans is not yet fully complete. It can be expected that when these measures have been fully implemented, this will be reflected in the level of quality objective compliance.

6 Objectives and measures

Protection of the aquatic environment, especially the marine areas, requires a coordinated effort both nationally and internationally. Denmark participates actively in the international cooperation to protect groundwater and drinking water resources as well as inland and marine waters. Denmark has ratified a large number of binding agreements on protection of the aquatic environment at the regional, European and global levels – international agreements that form the foundation for Danish legislation and regulation of pollution and hence for protection of the Danish groundwater and surface waters.

This chapter presents the Government's overall political objectives and policy measures for the Danish aquatic environment. The Danish reduction targets for nutrients and hazardous substances etc. are outlined, and the central planning of Danish water body quality is examined.

6.1 **Pure water**

The quality and protection of the groundwater and the aquatic environment – both nationally and internationally – continues to be accorded high priority in the Government's work, as is apparent from the Government's Policy Statement of March 1998.

The Government's overall goal is to ensure that the water in Denmark is clean. The Government's endeavours in this respect are described in the Environmental Policy White Paper (Ministry of Environment and Energy, 1999). This states that the Government will work towards ensuring:

- that Danish watercourses, lakes and marine waters are clean and of a satisfactory quality as regards health and hygiene,
- that exploitation of the water bodies and associated resources takes place in a sustainable manner,
- that the groundwater resource remains unpolluted, and
- that groundwater abstraction and groundwater recharge balance.

In addition, the Government will fulfil the objectives of relevant international agreements, i.e. the objectives that aim to prevent and remove pollution of the aquatic environment in the long term, especially the objectives aiming at a progressive reduction of discharges and losses of pollutants to the aquatic environment.

The Government's objectives entail that only insignificant or minor anthropogenic changes in the state of the aquatic environment can be accepted. Unfortunately, though, some water bodies currently have an environmental state that does not live up to these objectives. In special situations and in particularly vulnerable areas, a poor or very low environmental state sometimes has to be accepted.

GROUNDWATER

With regard to groundwater in Denmark, the Government's objectives entail:

- that groundwater has to comprise a safe and permanent source for the drinking water supply,
- that drinking water quality and the drinking water resource must not be deteriorated by pollution and water abstraction, and
- that the quality of groundwater swell has to be of such a quality as to ensure a good environmental state in watercourses and lakes.

Commercial and other types of groundwater exploitation thus have to be conducted in a manner that respects environmental and natural wealth and is sustainable. Further detail can be found in "Denmark's groundwater and drinking water" (Danish EPA, 1994) and in the Environmental Policy White Paper (Ministry of Environment and Energy, 1999).

WATERCOURSES

With regard to Danish watercourses, the Government's overall objectives as stated among other places in the Watercourse Act (Ministry of the Environment, 1992) and the Environmental Policy White Paper (Ministry of Environment and Energy, 1999) entail:

- that water flow has to be adequate,
- that obstructions must not be present that hinder the dispersal of fish and macroinvertebrates,
- that the watercourses have to exhibit physical variation and have good oxygen conditions, and
- that the watercourses have to contain a varied and natural fauna and flora.

Commercial exploitation, i.e. fishery, navigation, drainage, etc. and recreational activities such as pleasure boat sailing, angling and bathing and other uses of watercourses have to be conducted in a manner that respects environmental and natural wealth and is sustainable – both in the watercourses themselves and on the adjacent land.

LAKES

With regard to Danish lakes, the Government's overall objectives as stated among other places in the Environmental Policy White Paper (Ministry of Environment and Energy, 1999) entail:

- that animal and plant communities have to be natural and in equilibrium, and
- that the water has to be clear and submerged macrophytes have to be present in the shallow parts of the lakes.

Commercial exploitation, recreational activities and other uses of the lakes also have to be conducted in a manner that respects environmental and natural wealth and is sustainable.

MARINE WATERS

The Government's overall objectives for the environmental state of Danish marine waters are based among other things on the 1992 Helsinki Convention on Protection of the Marine Environment in the Baltic Sea Region, the 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) and the 1995 Declaration of the 4th International Conference on the Protection of the North Sea (Esbjerg Declaration) (Danish EPA, 1995). This means:

- that the fauna and flora may only be insignificantly or slightly affected by anthropogenic pollution and human activities,
- that nutrient levels have to be at a natural level, the clarity of the water has to be normal, unnatural blooms of toxic planktonic algae or pollution-dependent macroalgae must not occur, and oxygen deficiency may only occur in areas where this is natural, and
- that the levels of hazardous substances have to be at background levels in the case of naturally occurring substances and close to zero in the case of hazardous substances.

Commercial exploitation such as fishery, navigation, offshore industry, minerals extraction, marine dumping of seabed material, etc., and recreational activities such as pleasure boat sailing, angling and bathing, and other uses of the sea have to be conducted in a manner that respects environmental and natural wealth.

6.2 Nutrient reduction targets and measures

The primary means of achieving the objectives for both groundwater and surface waters is a reduction in nutrient discharges and emissions. This section briefly examines the strategic targets for preventing and combating nutrient pollution.

6.2.1 Strategic reduction targets for nutrients

ACTION PLAN ON THE AQUATIC ENVIRONMENT 1987

In the January 1987 Action Plan on the Aquatic Environment and the April 1987 Report on the Action Plan on the Aquatic Environment, the reduction targets for nitrogen and phosphorus were 50% and 80%, respectively. This corresponds to a reduction in annual discharges and losses from a level of around 283,000 tonnes nitrogen and 9,120 tonnes phosphorus at the time the plan was adopted to a level of approx. 141,600 tonnes nitrogen and approx. 1,820 tonnes phosphorus. As agriculture, municipal wastewater treatment plants and separate industrial discharges are the main sources of nutrient pollution of the aquatic environment, only these three sources are included in the calculations of whether the reduction targets stipulated in the Action Plan on the Aquatic Environment have been met, cf. Table 6.1.

Table 6.1

Sector-specific reduction targets for annual discharges etc. (in tonnes) of nitrogen and phosphorus to the aquatic environment (Ministry of the Environment, 1987 and Danish EPA, 1990). The reductions and target levels are described in detail below in the section on agriculture, municipal wastewater treatment plants and separate industrial discharges.

	Nitrogen					Phosphorus				
	1987	–	Reduction	=	Target	1987	–	Reduction	=	Target
Agriculture	260,000	–	127,000	=	133,000	4,400 [1]	–	4,000	=	400
Municipal wastewater treatment plants	18,000	–	11,400	=	6,600	4,470	–	3,250	=	1,220
Separate industrial discharges	5,000	–	3,000	=	2,000	1,250 [2]	–	1,050[2]	=	200[2]
Total	283,000	–	141,400	=	141,600	9,120	-	8,050	=	1,820

1) Only encompasses the farmyard load i.e. does not include loss of phosphorus from fields. 2) See page ???100 for explanation.

Pollution of the sea is transboundary in nature and the countries in the North Sea and Baltic Sea regions have therefore adopted similar reduction targets:

- At the North Sea Conference in London in November 1987, the countries of the North Sea region excluding the United Kingdom adopted the goal of reducing nitrogen and phosphorus inputs to the sea by 50% over the period 1985–95 in areas where these could cause pollution. At the conferences in The Hague (1990) and Esbjerg (1995), these reduction targets were reiterated and the need to take action against wastewater discharges and losses from agriculture was specified.
- In June 1988, the Paris Commission adopted a 50% reduction target for nutrient inputs to marine waters susceptible to eutrophication and also adopted a programme to achieve the reductions. In 1992, it was decided to integrate the Oslo and Paris Conventions, both of which aimed to prevent marine pollution from dumping and land-based sources of pollution. The objective of the successor – the OSPAR Convention – is to protect the marine environment of the Northeast Atlantic region. In 1989, the reduction target was specified in relation to the specific sectors. As a follow-up on the 1988 decision, the 1998 OSPAR Ministerial Meeting adopted a strategy to combat eutrophication.
- At a ministerial meeting in February 1988, HELCOM adopted a declaration specifying a 50% reduction target for discharges of nutrients etc. over a 10-year period. In the Communiqué from the ministerial meeting in 1998, the ministers confirm that they have committed themselves to attaining the strategic goal from 1988 and to defining specific objectives that have to be achieved before the year 2005.

The sections that follow examine the measures that Denmark has decided to employ to achieve the reduction targets – both for the three sectors encompassed by the Action Plan on the Aquatic Environment I (i.e. agriculture, industry and wastewater treatment plants) and for a number of other sectors for which specific reduction targets were not specified in the Action Plan on the Aquatic Environment.

6.2.2 **Sector-specific reduction targets**

SPECIFIC REDUCTION TARGETS FOR THE AGRICULTURAL SECTOR

Since agriculture is one of the main sources of pollution of the aquatic environment, Parliament has adopted goals for reducing nitrogen pollution from agricultural sources. Since the mid 1980s, a number of action plans and strategies have been adopted to regulate development of the agricultural sector and its impact on the aquatic environment:

- The NPo (Nitrogen, phosphorus and organic matter) Action Plan (1985),
- The Action Plan against Pollution of the Danish Aquatic Environment with Nutrients (Action Plan on the Aquatic Environment) (1987),
- The Action Plan for Sustainable Agriculture (1991),
- Parts of the Government's 10-Point Programme for Protection of the Groundwater and Drinking Water (1994),
- Follow-up on the Action Plan for Sustainable Agriculture (1996), and
- The Action Plan on the Aquatic Environment II (1998).

The reduction targets for nitrogen and phosphorus stipulated in the Action Plan on the Aquatic Environment I are an approximate halving (49%) of nitrogen losses and the elimination of the phosphorus farmyard load. Nitrogen losses are to be reduced from around 260,000 tonnes to a level of approx. 133,000 tonnes per year, corresponding to a reduction in losses of 127,000 tonnes nitrogen per year, cf. Tables 6.1 and 6.2. The Action Plan on the Aquatic Environment I further stipulates the magnitude of the nitrogen and phosphorus reduction necessary to avoid unintended pollution of the aquatic environment. The reduction targets were to be attained by 1993 through the following measures:

- The agricultural sector has to establish sufficient capacity to store 9 months of manure production (6 months on certain farms) so that the manure can be stored until the crop growth season starts.
- The agricultural sector has to establish crop rotation and fertilization plans to ensure that the nitrogen content of the fertilizer is optimally exploited.
- Fields have to have green cover during the winter period so that nitrogen can also be taken up during the autumn.
- Manure has to be ploughed in or in some other way deployed into the soil within 12 hours.
- Limits on how much livestock manure may be applied to fields.

It soon became clear that it would not be possible to attain the reduction targets by 1993 (Ministry of Agriculture, 1991). The measures stipulated in the Action Plan on the Aquatic Environment I were therefore tightened in 1991 in the Action Plan for Sustainable Agriculture. The reduction target was maintained but the time frame was extended to the year 2000. The measures were:

- Fertilization accounts so that fertilizer application can be documented.
- More stringent and fixed requirements on utilization of the N content of livestock manure.
- All farms must establish sufficient capacity to store 9 months of manure production (6 months for certain farms).
- Ban on the application of liquid manure between harvest time and February except on fields cultivated with winter rape or grass.

After the Action Plan for Sustainable Agriculture there have been a number of follow-up plans for reducing the impact of the agricultural sector on the aquatic environment, including the Government's 1994 10-Point Programme for Protection of the Groundwater and Drinking Water in Denmark. Among other things this entails the selection of areas of the country on which the water supply is to be chiefly based.

The need to further tighten the regulation of agricultural losses of nitrogen has become even more necessary because Denmark has to comply with the EU Nitrates Directive by the year 2003. The directive restricts the application of livestock manure to 170 kg N per hectare per year. In the case of some types of farm this is less than the levels currently permitted. Denmark has sought permission to derogate from the 170 kg N per hectare rule on cattle holdings so as to enable the application of up to 230 kg N per hectare per year on a small number of these holdings.

In February 1998, Parliament adopted several new instruments aimed at achieving the reduction targets stipulated in the Action Plan on the Aquatic Environment I. As a supplement to the Action Plan on the Aquatic Environment I, the Action Plan on the Aquatic Environment II will reduce nitrogen leaching by a further approx. 37,000 tonnes N per year so as to enable the reduction target of 100,000 tonnes N per year to be achieved no later than the end of the year 2003. The following measures have been implemented under the Action Plan on the Aquatic Environment II:

- Re-establishment of wetlands. This will help reduce nitrogen leaching to the aquatic environment due to their ability to convert nitrate to free nitrogen. Assuming that one hectare of wet meadow can remove an average of approx. 350 kg nitrate per year, the re-establishment of 16,000 hectares of wet meadow will reduce nitrogen leaching to inland and marine waters by about 5,600 tonnes N per year.
- Afforestation in Denmark. Among other things this is founded on the idea that in general, little nitrate is washed out of forest soils. Planting 20,000 hectares forest before the year 2002 is expected to reduce nitrogen leaching by around 1,100 tonnes N per year.
- Agri-environmental measures. Financial support to farmers willing to cultivate sensitive agricultural areas in a more environmentally sound manner, among other things by using less fertilizer or by completely refraining from cultivating the land. There has hitherto been very little interest in this scheme. Conversion of 90,000 hectares to the scheme is expected to reduce nitrogen leaching by 1,900 tonnes N per year.
- Improved fodder utilization. The agreement on which the Action Plan on the Aquatic Environment II is based assumes that fodder utilization will be improved. Changes in feeding practice are expected to reduce nitrogen leaching by 2,400 tonnes N per year.
- Stricter harmony criteria. Implementation of stricter harmony criteria governing livestock density is expected to reduce nitrogen leaching by a further 300 tonnes N per year.
- Stricter requirements on utilization of the N content of livestock manure. It should be possible to get the crops to use even more of the nitrogen in livestock manure than is presently the case. This is expected to reduce nitrogen leaching by 10,600 tonnes N per year.
- Organic farming. Organic farming can help reduce total nitrogen leaching from the agricultural sector. If 170,000 hectares are converted to organic farming, nitrogen leaching will be reduced by 1,700 tonnes N per year.
- Catch crops on a further 6% of a farmer's land. Catch crops can take up nitrogen in the autumn. The additional acreage with catch crops is expected to reduce nitrogen leaching by 3,000 tonnes N per year.
- Nitrogen norm reduced by 10%. A new element in the regulation of the agricultural sector is that farmers may now only apply nitrogen in amounts corresponding to 90% of the economically optimal level. The reduced nitrogen norm is expected to reduce nitrogen leaching by 10,500 tonnes N per year.

The requirement for the 10% reduction in the nitrogen norm entered into force on 1 August 1998. The requirement for catch crops on a further 6% of each farmer's land entered into force in autumn 1998. The requirement for improved utilization of livestock manure is being implemented in two steps: 5% from 1 August 1999 and a further 5% from 1 August 2001.

The harmony criteria (number of LU/ha) have been tightened for cattle holdings as per 18 August 1998. The criteria for all livestock holdings will be further tightened in the year 2002 (1.4 LU/ha for pig holdings and 1.7 LU/ha for cattle holdings).

If the measures in the Action Plan on the Aquatic Environment II are implemented as changes in agricultural practice, 20 years of nitrate policy (1985–2003) will result in a 100,000 tonnes N per year reduction in leaching from agricultural land. Moreover, nitrogen consumption in the form of commercial fertilizer will decrease from approx. 400,000 tonnes N per year in 1985 to approx. 200,000 tonnes N per year in 2003 (Iversen et al., 1998).

The measures and targets for reducing nitrogen pollution from agricultural sources are summarized in Table 6.2. In connection with the Action Plan on the Aquatic Environment I it was estimated that nitrogen losses could be reduced by a total of 127,000 tonnes N per year by 1993. The reduction targets were approx. 100,000 tonnes N per year for the nitrogen load from fields and approx. 27,000 tonnes N per year for the farmyard load. In the Action Plan for Sustainable Agriculture it was estimated that by the year 2000, the measures stipulated in the Action Plan on the Aquatic Environment I would only have reduced nitrogen losses by 50,000 tonnes N per year and that further measures were therefore needed to achieve the total reduction of 127,000 tonnes N per year. The existing measures and targets under the Action Plan on the Aquatic Environment I and the Action Plan for Sustainable Agriculture were re-evaluated in 1998 in connection with the preparation of the Action Plan on the Aquatic Environment II and it concluded that by the year 2003, the existing measures will reduce nitrogen losses by 89,900 tonnes N per year. Together with the expected reduction under the Action Plan on the Aquatic Environment II, it was concluded that nitrogen losses would be reduced by 127,000 tonnes N per year by 2003. Not all the measures in the Action Plan on the Aquatic Environment II will have taken full effect by 2003, however.

Table 6.2
Summary of measures and estimated reductions (in tonnes N per year) in nitrogen loading from agricultural sources, cf. Action Plan on the Aquatic Environment I, Action Plan for Sustainable Agricultural Development, follow-ups hereto, and Action Plan on the Aquatic Environment II.

	1993	2000	2003
1. Action Plan on the Aquatic Environment I (1987):			
I. Optimal utilization of livestock manure			
A. NPo Action Plan	55,000		
B. NPo Subsidy Act	5,000		
C. Further initiatives	10,000		
II. Programme for improved utilization of fertilizer			
A. Systematic fertilization plans	15,000		
B. Improved application methods	5,000		
C. Winter green fields – catch crops and ploughing down of straw	20,000		
D. Winter green fields – further initiatives	8,000		
III. Structural measures	9,000	↓	
Total	127,000	50,000	
2. Action Plan for Sustainable Agricultural Development (1991):			
• Improved utilization of livestock manure		20,000-40,000	
• Reduction in commercial fertilizer consumption		8,000-15,000	
• Protection of groundwater in particularly vulnerable areas		1,000-2,000	
• Reduction in agricultural acreage		17,000-20,000	
• Structural development, other measures		15,000	↓
Total		77,000	89,900
3. Action Plan on the Aquatic Environment II (1998):			
• Wetlands			5,600
• Sensitive agricultural areas			1,900
• Afforestation			1,100
• Improved fodder utilization			2,400
• Stricter harmony criteria			300
• Stricter requirements on utilization of N content of manure			10,600
• Organic farming			1,700
• Catch crops on a further 6% of the land			3,000
• 10% reduction in N norm			10,500
I alt			37,100
Total:	127,000	127,000	127,000

Table 6.2 is also an example of strategic environmental planning, i.e. the process whereby a target is set, measures are implemented, the effects are monitored and evaluated and supplementary measures are implemented if – as in the present case – the original target is not attained as expected.

Conversion to organic farming has hitherto been taking place faster than presumed in the Action Plan on the Aquatic Environment II. Thus in 1998 and 1999, the area under organic farming increased by a net 90,000 hectares corresponding to just over 50% of the target of 170,000 hectares. With respect to the Action Plan on the Aquatic Environment II's target for conversion of farmland to agri-environmental measures, more acreage needs to be converted. It is estimated that new agreements have been signed covering 21,000 hectares while agreements on 23,000 hectares are soon to run out. The total area of farmland encompassed by the agri-environmental measures scheme has thus decreased.

With regard to the establishment of wetlands under the Action Plan on the Aquatic Environment II, a large number of project applications have been submitted during the first half of 1999. As of 1 October 1999, funds had been allocated to enable full implementation of 6 projects encompassing a total of 650 hectares and for pilot studies on a further 3,700 hectares. This corresponds to the average number of hectares that need to be converted to wetlands annually to reach the target of 16,000 hectares.

With regard to afforestation under the Action Plan on the Aquatic Environment II, private afforestation, which accounts for the majority of the 20,000 hectares planned, is progressing according to plan. Expectations as to state afforestation are currently lessened.

The Action Plan on the Aquatic Environment II also encompasses so-called regional measures. These represent implementation of the recommendations of the Drinking Water Committee concerning the protection of groundwater resources considered particularly vulnerable to nitrate pollution.

SPECIFIC REDUCTION TARGETS FOR MUNICIPAL WASTEWATER TREATMENT PLANTS

In general, discharges from municipal wastewater treatment plants are regulated by the Environmental Protection Act, the Urban Wastewater Directive and derivative statutory orders and official guidelines.

Council Directive 91/271/EEC of 21 May 1991 concerning Urban Wastewater Treatment as amended by Commission Directive 98/15/EU of 27 February 1998 – commonly referred to as the Urban Wastewater Directive – is one of the most important legal documents in the EU legislation on the aquatic environment. The purpose of the directive is to protect the environment against the negative effects associated with the discharge of inadequately treated urban wastewater and discharges of biologically degradable industrial wastewater from enterprises within the food processing industry. The directive therefore requires that Denmark implement regulations on the collection and treatment of these forms of wastewater. According to the directive, wastewater discharges have to be subjected to a level of treatment appropriate to the environment at the place in question and the use to which the recipient water bodies in question are put. Denmark implemented the provisions of the directive in Danish legislation in 1994.

The Action Plan on the Aquatic Environment's reduction targets for municipal wastewater treatment plants were adjusted in 1990 on the basis of the results of the Nationwide Monitoring Programme (Danish EPA, 1990). In the case of nitrogen, annual discharges in treated wastewater are to be reduced from approx. 18,000 tonnes N to approx. 6,600 tonnes N. Phosphorus discharges are to be reduced from approx. 4,470 tonnes P to approx. 1,220 tonnes P. The reduction in nitrogen discharges from municipal wastewater treatment plants corresponds to all new or upgraded plants exceeding 5,000 PE and all existing plants exceeding 1,000 PE having to implement biological treatment with nitrogen removal down to an annual average of 8 mg N per litre. In 1987 this was considered as low as it is practically possible to reach with biological nitrogen removal. As regards phosphorus, municipal wastewater treatment plants exceeding 5,000 PE have to remove phosphorus down to an annual average of 1.5 mg phosphorus per litre.

The Action Plan on the Aquatic Environment's reduction targets for discharges from municipal wastewater treatment plants should originally have been met within three years, i.e. by 1 February 1990 at the latest. A number of plants were granted a deadline extension for technical reasons, however. The reduction target for nitrogen of 6,600 tonnes N per year was achieved in 1996, as was the reduction target for phosphorus of 1,200 tonnes P per year.

SPECIFIC REDUCTION TARGETS FOR SEPARATE INDUSTRIAL DISCHARGES

In general, separate industrial discharges are regulated by among other things the Environmental Protection Act and the EU Directive on Pollution Prevention and Control (IPPC Directive) and derivative statutory orders and official guidelines.

The IPPC Directive aims at integrated prevention and control of pollution by major industrial companies. The directive specifically regulates the energy industry (power stations and refineries, etc.), production and processing of metals, the mineral industry, the chemical industry, waste management plus a number of other activities such as paper manufacturers, textiles pretreatment and dyeing, slaughterhouses and dairies, as well as installations for intensive rearing of poultry and pigs exceeding a certain capacity. The IPPC Directive contains measures designed to prevent or, where that is not practicable, to reduce emissions to the air, water and land from the abovementioned activities.

As with the reduction targets for municipal wastewater treatment plants, the Action Plan on the Aquatic Environment's reduction targets for separate industrial discharges were revised on the basis of the results of the Nationwide Monitoring Programme. Back in 1986/87, industrial discharges of phosphorus were largely attributable to a few individual enterprises that had already planned treatment measures to reduce discharges to a total of 350 tonnes P per year. It was therefore considered that the implementation of the best available technique (BAT) could reduce industrial discharges of phosphorus to a level below the original target of 600 tonnes P per year. The original starting point was 3,400 tonnes P per year, but this has now been adjusted to 1,125 tonnes P per year. As the percentage reduction has remained unchanged, the new target is a total annual discharge of approx. 200 tonnes P per year.

Because of the large differences between the individual enterprises and their discharges of wastewater, the Action Plan on the Aquatic Environment I did not stipulate general discharge requirements for industry as for the wastewater treatment plants. Industry was to reduce its discharges through the application of BAT understood as the level of treatment that is technically attainable and economically viable for the industry in question.

Discharges of nutrients via separate industrial discharges should originally have been reduced within three years as stipulated in the Action Plan on the Aquatic Environment, i.e. by 1 February 1990 at the latest. The reduction targets for nitrogen (2,000 tonnes) and phosphorus (200 tonnes) were attained at the end of 1995.

SPECIFIC REDUCTION TARGETS FOR OTHER SECTORS

The Action Plans on the Aquatic Environment focus on the major sources of nutrient pollution. A number of other sectors and types of source also contribute to pollution of the aquatic environment, including freshwater fish farms, marine fish farms, transport, combustion plants (heat and power production), sparsely built-up areas and stormwater outfalls. The plans did not specify specific reduction targets for these sectors and types of source but instead describes a number of other measures.

FRESHWATER FISH FARMS

As regards freshwater fish farms, the Action Plan on the Aquatic Environment presumed that a statutory order would be issued stipulating detailed guidelines for the design and operation of the farms. The statutory order was to ensure a satisfactory water quality in the associated watercourses and to considerably reduce nutrient loading. On 5 April 1989 the Ministry of Environment thus issued the Statutory Order on Freshwater Fish Farms. The statutory order provided for general regulation of the industry with guidelines for the county authorities to stipulate the maximal permitted feed consumption at the individual fish farms, minimum requirements as to treatment measures on the fish farms as well as minimum requirements as to utilization and quality of the fish feed.

MARICULTURE

As regards mariculture (seawater-based fish farming), a 1-year moratorium was placed on the establishment of new farms and the expansion of existing farms. The moratorium was raised in connection with issuance of Statutory Order No. 640 in 1990 on mariculture. This stipulated general regulations on feed quality and consumption as well as consumption of feed relative to production. In addition, upper limits were placed on nutrient discharges to the surrounding aquatic environment from each individual farm. However, in early 1996, the Danish EPA requested the Counties not to issue any permits for new sea-based or land-based mariculture farms or for extensions of existing farms. The Counties were simultaneously urged to assess whether environmental or operational benefits could be obtained by moving or merge the existing farms.

EMISSIONS TO THE AIR

When the Action Plan on the Aquatic Environment was adopted in 1987, the Danish EPA was instructed to prepare a report containing a specific reduction programme for power station NO_x emissions. This was done in continuation of earlier reports on limitation of NO_x emissions from power stations. In connection with the Action Plan on the Aquatic Environment I in 1987 it was also decided to investigate the possibilities for promoting the use of catalytic converters through changes to the car taxation system.

Regulation of NO_x emissions in Denmark has concentrated on improved combustion technology and flue gas abatement at power stations (cf. Statutory Order No. 885 of 18 December 1991 on Limitation of Emissions of Sulphur Dioxide and Nitrogen Oxides from Power Stations), enhanced use of natural gas and renewable energy (cf., the Government's 1990 Energy Action Plan) as well as implementation of the requirement for catalytic converters on cars (cf. Ministry of Justice Statutory Order on Detailed Regulations for the Motor Vehicle Design and Equipment from 1990).

Under the EEC Convention on Transboundary Air Pollution, Denmark has entered into an international agreement to reduce emissions of NO_x by 30% over the period 1986–98. However, the measures needed to meet this goal are inadequate in Europe as regards acidification and eutrophication. In June 1999, the EU Commission therefore issued proposals for two directives on acidification and ozone formation at ground level (Proposal for a Directive on National Emission Limits for Certain Polluting Substances and Proposal for a Directive on the Ozone Content of the Air). These two directives stipulate national limits for emissions of NH_3 and NO_x, etc. In the case of Denmark, the proposed directives will limit ammonia (NH_3) emissions to 71,000 tonnes per year and nitrogen oxide (NO_x) emissions to 127,000 tonnes per year from 2010.

SPARSELY BUILT-UP AREAS

In step with the reduction in discharges from wastewater treatment plants and industry over the past 10 years, the relative impact of sparsely built up areas (see Section 3.1.4) and stormwater outfalls (see Section 3.1.3) on watercourses and lakes has increased.

It can be assumed that the expected future improvements in the treatment of wastewater from sparsely built-up areas resulting from the initiatives in connection with the amendment of the Environmental Protection Act concerning wastewater treatment in rural areas (Ministry of Environment and Energy, 1997) will have a positive effect.

According to state instructions to the Counties concerning revision of the Regional Plans in 2001 (Ministry of Environment and Energy, 1998), the County will have to specify in the Regional Plan or an annex to it the areas in which the treatment of wastewater from properties in rural areas is to be improved. In consultation with the municipal authorities, the County Council has to stipulate quality objectives for the individual recipient waters in its Regional Plan. The County Council has to identify watercourses and lakes that are vulnerable to pollution and based on its knowledge of the environmental state and pollutional load on the individual recipient waters, has to assign each individual recipient a maximal environmentally permissible level of pollution.

The Danish EPA estimates that there are approx. 67,000 properties in rural areas nationwide that currently have individual discharges and which will have to improve wastewater disposal in the near future. The remaining properties can maintain the existing means of wastewater disposal without further improvement.

STORMWATER OUTFALLS

As mentioned above, stormwater outfalls are one of the contributory reasons for the failure of many watercourses and lakes to meet their quality objectives as stipulated in the Regional Plan. Knowledge of how best to regulate stormwater overflows is lacking, however. The Wastewater Committee under the Danish Engineering Association has established a working group to investigate how to draw up appropriate discharge requirements for stormwater overflows. The Danish EPA is participating in the Working Group's work, which is intended to result in proposals for guidelines that can be incorporated in official Danish EPA Guidelines. The Working Group is expected to complete its task at the end of 2001.

6.3 Reduction targets and measures for hazardous substances

The overall objective of reducing pollution of the groundwater and surface waters by hazardous substances is to be attained through a progressive reduction in discharges and emissions.

An important breakthrough in the efforts to reduce pollution of the aquatic environment with hazardous substances came in 1995 at the North Sea Conference in Esbjerg. At the beginning of the 1990s it was acknowledged that measures need to be directed at a greater range of substances than had hitherto been in focus. The Esbjerg Declaration therefore reiterated the objective of reducing discharges, emissions and losses of hazardous substances by 50% but at the same time emphasized the application of the precautionary principle in order to ensure a sustainable, sound and healthy North Sea ecosystem. Part 17 of the Esbjerg Declaration (Danish EPA, 1995) expresses this as follows:

The guiding principle for achieving this objective is the precautionary principle. This implies the prevention of the pollution of the North Sea by continuously reducing discharges, emissions and losses of hazardous substances thereby moving towards the target of their cessation within one generation (25 years) with the ultimate aim of concentrations in the environment near background values for naturally occurring substances and close to zero concentrations for man-made synthetic substances.

The Esbjerg Declaration concomitantly identifies the need for an overall strategy to implement this goal. By involving competent national and international authorities, the strategy should contain a number of more closely specified elements. OSPAR and the EU Commission are specifically invited to undertake the follow-up work.

At ministerial meetings in 1998, OSPAR and HELCOM adopted a corresponding objective and more specific strategies to follow up the initiative. The European Community and OSPAR are presently cooperating on concretizing prioritized endeavours against the substances that are of greatest significance as regards pollution of the marine environment. With the adoption of the UNEP's Global Action Plan for the Sea in Washington in 1995, the initiative has been taken for global regulation of the persistent organic pollutants (POPs).

The Danish objectives regarding prevention and control of pollution of the aquatic environment with hazardous substances, including pesticides, chemicals and oil pollution, are briefly described in the following three sections.

6.3.1 Strategy for reducing pesticide consumption

ACTION PLAN FOR REDUCING CONSUMPTION OF PESTICIDES

The purpose of the 1986 Pesticide Action Plan was to reduce pesticide consumption in order:

- to protect human beings from the health risks and harmful effects associated with the use of pesticides – both users of the substances and the population in general – and in particular to protect the latter against the intake of pesticides in foods and drinking water, as well as
- to protect the environment – i.e. both harmless organisms and useful organisms among the flora and fauna in the terrestrial and aquatic environments.

The Pesticide Action Plan therefore stipulated that total consumption was to be reduced and consumption steered towards the use of less harmful pesticides.

MAIN OBJECTIVES

One of the two main objectives of the Pesticide Action Plan was that total pesticide consumption should be halved by 1 January 1997. The halving of pesticide consumption was to encompass both 1) the amount of active substances and products sold, and 2) the spraying intensity expressed in terms of treatment frequency. The second main objective was to ensure a switch to the use of less harmful pesticides.

STATUS IN 1997

The Danish EPA published a status report on the Pesticide Action Plan in 1997. The conclusions were:

- that the action plan objective of tightening the approval procedure has been achieved,
- that total sales of active substances have been falling steadily throughout the whole period encompassed by the action plan and as of 1997 have been reduced by approx. 36% relative to the reference period 1981–85. The agricultural sector accounts for 90% of the total consumption of active substances. The reduction achieved in the agricultural sector is approx. 40%. Part of the reduction is due to the fact that the area of agricultural land under crop rotation has decreased by approx. 11% while some of the remainder is due to increasing use of more high-potency products,
- that the treatment frequency within the agricultural sector has not decreased as expected in the action plan, cf. Figure 3.12. The total application frequency is largely unchanged relative to the reference period. The average crop-specific treatment frequency has fallen by 15–20% in recent years, but this is counterbalanced by an increase in the acreage of crops that are sprayed frequently. The decrease in the crop-specific treatment frequency is largely attributable to a marked fall in the application of fungicides,
- that the impact factor (consumption weighted by the substance's toxicity) has decreased markedly as regards acute and chronic toxicity towards mammals. The impact factors for acute toxicity to birds and crustaceans have also fallen, while that for fish is unchanged. Sales of pesticides suspected of being carcinogenic lie at the same level as during the reference period,
- that the use of pesticides entails pollution of the environment and that pesticides can be detected in the groundwater, surface waters and precipitation. Set-aside has resulted in a reduction in the environmental impact of pesticides.

BICHEL COMMITTEE

Prompted by the detection of a number of pesticides in the groundwater, Parliament adopted Motion D105 of 15 May 1997 urging the Government to establish an independent committee to assess the overall consequences of a phase-out of agricultural use of pesticides. The committee, named the Bichel Committee after the Chairman, was established in autumn 1997 and submitted its report in March 1999.

FOLLOW-UP ON THE BICHEL COMMITTEE

On the basis of the Bichel report a parliamentary discussion of the Committee's work was held on 20 May 1999. This resulted in the adoption of Resolution V88 of 21 May 1999 urging the Minister for Environment and Energy to submit a proposal at the beginning of the next parliamentary year implementing the Bichel Committee's work or part thereof, including proposals for a new pesticide action plan.

The Pesticide Action Plan II is currently being drawn up. The Bichel Committee has recommended the following three-pronged strategy to reduce pesticide consumption:

1. A general reduction in the use of pesticides.
2. Protection of certain areas.
3. Enhanced conversion to organic farming.

The Bichel Committee also recommends establishing pesticide-free border zones alongside watercourses for which a quality objective has been set, and around lakes exceeding 100 m^2 in area. To the extent that the border zones are established in connection with set-aside they will be both pesticide-free and fertilizer-free, which will further enhance the positive effect on the environment.

6.3.2 Strategy for intensified action in the chemicals area

In December 1996, the Danish EPA submitted the Discussion Paper "Chemicals – Status and Perspectives" for hearing and in May 1997, the Minister for Environment and Energy submitted a report to Parliament on coming initiatives in the chemicals area. In addition, the Government's March 1998 Policy Statement highlighted the necessity to enhance efforts to deal with the problems posed by hazardous chemicals. It was emphasized that both control measures and regulations need to be tightened.

GOVERNMENT STRATEGY FOR INTENSIFIED ACTION IN DENMARK, THE EU AND GLOBALLY

In January 1999, as a follow-up on its Policy Statement, the Government published a strategy for intensified action in the chemicals area in Denmark, the EU and globally. The background for this three-tier subdivision of the strategy is that the chemical problem is dealt with and regulated at these three levels, and that Denmark therefore has to assess at what level it will be possible and relevant to attempt to influence the decision-making process.

OVERALL STRATEGY OBJECTIVES

The overall objectives of the strategy are to limit the consumption of hazardous chemicals to the greatest extent possible and to ensure that the production, use and disposal of chemical substances do not cause unacceptable effects on man and the environment. The strategy therefore argues that more specific objectives should be specified for the efforts in the chemicals area. Moreover, efforts should be made to ensure that special consideration is shown to children and other vulnerable groups such as expectant mothers, allergy sufferers and the chronically ill, as well as to particularly vulnerable ecosystems. The efforts should be graduated according to how hazardous the chemical substances are. Greatest attention should be paid to substances that are persistent or highly bioaccumulable, i.e. can accumulate in the environment, as well as to substances that cause irreparable damage (carcinogenic and mutagenic effects, reproductive damage, hormonal disturbances, etc.). With other substances the action taken will depend on a specific assessment of the substance's toxcicity, its uses and dispersal in the environment.

STRENGTHENED EFFORTS AT THE NATIONAL LEVEL

At the national level, there are plans to tighten the regulations requiring producers and importers to submit information documenting the risks associated with the use of a product.

One of the Annexes to the 1996 Discussion Paper "Chemicals – Status and Perspectives" was a blacklist of approx. 100 undesirable substances or groups of substances. The list does not represent a ban but rather a signal to companies and product developers indicating substances whose use should be limited. The Danish EPA published the final list in 1998 and in this connection also identified 26 of the substances or groups of substances selected for special attention. Since the information on chemicals classification and registered consumption in the Chemical Products Register has probably changed, a proposal for a revised list of undesirable substances is currently being drawn up.

On the basis of new computer calculations of the hazard posed by 165,000 chemical substances, the Danish EPA also plans to publish an official Danish EPA Guideline on the classification of chemical substances that do not have an official EU classification, i.e. are not on the list of hazardous substances.

Special efforts are to be made to limit the use of the priority substances on the list of undesirable substances. Apart from bans, the means to regulate their use will encompass economic instruments, voluntary agreements, ecolabelling, environmental guidelines, etc.

In order to improve our knowledge about the use and dispersal of chemical substances in Danish society, the strategy proposes to extend the duty of companies to submit information to the Chemical Products Register so as to also encompass chemical substances used in consumer products. Control of the chemicals area is to be strengthened through information to the pertinent companies and effective control of compliance with the regulations. In addition, the strategy points out the need to strengthen the control activities. Finally, efforts are to be made to improve the provision of information on the chemicals area to the general public.

MTBE ACTION PLAN

In 1998, the Danish EPA drew up an action plan for MTBE. MTBE is added to petrol in order to raise the octane rating as a replacement for lead, which was phased out at the end of the 1980s. At present no environmentally more sound alternatives to MTBE are available. The problem with MTBE is that it can rapidly disperse in the soil and groundwater from leaky petrol station installations. A central element in the action plan is stricter environmental regulations for petrol stations aimed at preventing spillage of petrol – and hence MTBE – or other oil products.

EFFORTS AT THE EUROPEAN LEVEL

As Danish chemicals legislation is largely based on EU directives, efforts will have to be made at the European level to introduce regulations placing clear responsibility on the producer/importer to ensure that a substance or product does not comprise any risk under normal use.

Assessment of the 100,000 substances that may currently be used on the European market is a comprehensive and extremely time- and resource-consuming task. In order to promote the process, Denmark will work towards an understanding and acknowledgement of the fact that particularly hazardous substances should not be used at all. Examples are substances with irreparable health effects or substances that are bioaccumulable and persistent. In addition, Denmark will work for greater use of group classifications based on computer model assessments in the work on classifying and labelling hazardous substances. Correspondingly, consideration will be given to how the work on risk assessment of existing substances can be simplified and rendered more pragmatic so as to be able to facilitate more rapid decisions on whether the use of a substance should be limited.

EFFORTS AT THE GLOBAL LEVEL

Denmark will work actively to strengthen global efforts in the chemicals area in international decision-making fora with the participation of countries from all parts of the world, it being important that all countries contribute to the phase-out of the substances that are most harmful to health and the environment. Among other things, this encompasses phase-out of the use of ozone-depleting substances and the so-called persistent organic pollutants (POPs), the introduction of procedures committing the exporting industrial nations to inform the importing developing countries about the nature of the chemical substances being imported, and support for the Baltic countries to meet the reduction targets stipulated in the Helsinki Convention.

In the aid area, aid is to be given to facilitate the build-up of expertise among the authorities in the recipient countries so as to establish a foundation whereby they can draw up and enforce their own legislation in the chemicals area and comply with international conventions.

Since 1991, a ban has been in effect in Denmark on the sale of TBT-containing hull paints for use on boats shorter than 25 metres (cf. Statutory Order No. 1042 of 17 December 1997). In the International Maritime Organization (IMO) under the UN it has been agreed to adopt a convention in 2001 prohibiting the application of TBT-containing hull paints from 1 January 2003 and the presence of TBT-containing hull paints on ship hulls from 1 January 2008.

The Biocide Directive contains a special transitional scheme for antifouling agents. Until 2008, Member States will be able to permit the use of antifouling agents (e.g. TBT) irrespective of whether or not the active substances meet the conditions for inclusion on the directive's positive list. During the transitional period, Member States have to comply with IMO resolutions and recommendations.

6.3.3 **Strategy for prevention and control of oil pollution**

Effective efforts to counter oil pollution at sea need to encompass both preventative efforts at the national and international levels and specific measures to combat the oil pollution that occurs in the open sea and along the coasts.

The efforts to counter oil pollution are based on an overall assessment of all relevant elements such as national and international regulations, reception facilities for waste oil from ships, monitoring of whether ships comply with regulations in the Marine Environment Act, etc., and enforcement of regulations, including penal and compensation cases. In addition, there is a need for a contingency task force to combat oil pollution at sea and to clean up the oil that washes ashore.

DANISH INITIATIVES

Prompted by increasing awareness of oil pollution in Danish marine waters, the Government and Parliament have initiated a number of new initiatives aimed at ensuring that the Danish Oil Pollution Contingency Task Force remains satisfactory and on full par with that of our neighbouring countries. Among other things, the political and financial responsibility for the Danish Oil Pollution Contingency Task Force was transferred to the Ministry of Defence from 1 January 2000.

In addition, an intensified information campaign directed at ship traffic has been initiated concerning the delivery of waste oil to port reception facilities and concerning the duty to notify oil pollution incidents, etc. The objective has been to make sure that everyone is aware of oil pollution and that they notify such incidents to the relevant authorities.

Finally, the procedures for collection of evidence in connection with oil pollution in Danish marine waters will be tightened, and coordination between the various authorities will be strengthened.

In June 1998, in addition, a legislative working group was established to examine the possibilities for introducing administrative fines and to submit concrete proposals for legislation in the area. In its report, the working group recommends that the Marine Environment Act and Safety at Sea Act are amended to encompass the powers:

- to impose administrative fines for unlawful discharge of waste oil and for failing to or inadequately keeping oil, cargo and waste records, and
- to detain a ship as surety for the fine, legal costs and confiscation value until other surety is posted.

The report also proposes higher fines.

INTERNATIONAL INITIATIVES

International preventative efforts are the most important step in the fight against oil pollution. Denmark therefore works actively in the international fora to strengthen preventative efforts against oil pollution.

International agreement has been reached on the implementation of a total ban on discharges of oil in the North Sea with effect from August 1999. A corresponding international complete ban on the discharge of oil from ships has been in effect in the Baltic Sea region since 1983. In July 1999, in addition, Denmark established an exclusive economic zone around the country and in May 1999, extended the Danish marine territory from 3 sea miles to 12 sea miles. With the new international regulations, the possibilities to prevent pollution and to implement sanctions against future oil polluters have been considerably improved.

Denmark has also worked actively to ensure adoption of regional regulations on obligatory delivery of waste oil at all ports in the Baltic Sea region. These regulations enter into force in mid 2000.

In addition, a proposal has been drawn up for an EU directive on port reception facilities that – upon the urging of Denmark and the other Baltic Sea nations – contains similar regulations on obligatory delivery of waste oil at all EU ports.

DISCHARGES FROM OFFSHORE ACTIVITIES

The Esbjerg Declaration urged OSPAR to implement measures to considerably reduce discharges of PAHs, including those accompanying oil discharges from offshore activities. Denmark is working in OSPAR for a reduction in discharges of oil in production water so that the measured and expected growth in the amount of oil discharged to the sea from this source can be limited and preferably stopped.

The objective is to ensure that prior to being discharged into the sea, production water in the offshore industry is treated using the best available technique (BAT). To promote the use of BAT, efforts are being made to ensure a reduction in the current limit level of 40 mg oil per litre water.

6.4 Water body quality plans - now and in the future

QUALITY OBJECTIVES FOR WATERCOURSES, LAKES AND THE SEA

A central aspect of Danish planning of water body quality is the setting of quality objectives for the individual water bodies. Quality objective systems have been in operation for watercourses, lakes and coastal waters since 1983. In principle, these are based on a three-tier system encompassing stringent quality objectives, basic quality objectives and eased quality objectives, as stipulated in the Danish EPA's Guidelines on Recipient Quality Planning. The basic quality objectives for watercourses and lakes are based on EU Directive 78/659/EEC on the Quality of Fresh Waters needing Protection or Improvement in order to Support Fish Life, while the basic quality objectives for coastal waters cover the requirements in EU Directive 79/923/EEC on Crustacean Waters.

Until 1989, the quality objectives were binding for the administration of cases under the Environmental Protection Act. Until the Act was amended in 1992, the quality plans for water bodies had to include quality objectives and state when the quality objectives and associated quality requirements were expected to be met. The official remarks accompanying the amendment state that it is only the formal requirements on planning that are rescinded while it is presumed that the county authorities will continue to undertake comprehensive charting and planning as preventative environmental measures, including ensuring the foundation for administration of the Environmental Protection Act according to the previously described principles.

The official guidelines for the Regional Plans still require the Counties to set objectives for the quality and use of water bodies, just as their Regional Plan has to be accompanied by a review of the assumptions on which it is based, including the presumed order in which the plan is to be implemented.

QUALITY OBJECTIVES FOR GROUNDWATER

With regard to groundwater there are presently no corresponding regulations requiring the setting of quality objectives. Indirectly, though, the general objective applies that groundwater has to be of a quality that renders it suitable for the production of drinking water following the simple level of water treatment that is usual in Denmark.

Based on the Danish EPA's Guidelines No. 4, 1995, all the Danish Counties and Frederiksberg and Copenhagen Municipalities have identified areas of high, low and normal value for the drinking water supply. The Counties have thereby set objectives for the use of the groundwater resource, and hence indirectly also for the groundwater's quality.

Identification of these areas provides the Counties with the possibility to impose restrictions on future land use within the framework of the Regional Plans. The subdivision into areas of different value as drinking water resources and the associated requirements on protection of the groundwater correspond to the quality objectives known from recipient waters such as watercourses. The objectives for – and protection of – the groundwater are to be described in greater detail on the basis of new geological surveys. This will enable very specific protection, for example of areas that are vulnerable to nitrate pollution.

With regard to drinking water, the quality criteria are stipulated in the 1998 EU Drinking Water Directive, which has to be implemented in Danish law no later than December 2001. The directive solely concerns drinking water (as opposed to groundwater), and stipulates quality criteria regarding the concentration of various substances and microorganisms.

FUTURE WATER BODY PLANNING

There has long been a general wish for a revision of the existing guidelines on water body planning. Technical/scientific development has improved the knowledge base for water body planning and the quality objective definitions that the Counties have drawn up on the basis of the guidelines are far from as operational and unambiguous as could be wished. They involve a considerable element of judgement and hence heterogeneity when the state of a given water body is assessed relative to the quality objective. It is therefore necessary to link a qualitative and operational description of the determining parameters to each quality objective in order to be able to indicate what anthropogenic impacts are acceptable.

In this connection, efforts will be made to develop an operational quality objective system in connection with the implementation of the coming EU Directive Establishing a Framework for Community Action in the Field of Water Policy (the Water Framework Directive).

THE FORTHCOMING DIRECTIVE ESTABLISHING A FRAMEWORK FOR COMMUNITY ACTION IN THE FIELD OF WATER POLICY

The overall purpose of the Water Framework Directive is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which a) prevents further deterioration and protects and enhances the status of aquatic ecosystems and b) promotes sustainable water use based on long-term protection of available water resources. The directive thereby contributes to the provision of the sufficient supply of good quality surface water and groundwater to achieve the objectives in international agreements, including targets aimed at preventing and eliminating pollution of the marine environment, and to the progressive reduction of emissions of hazardous substances.

According to the Water Framework Directive, water bodies have to be managed at the river basin level within River Basin Districts encompassing one or more neighbouring river basins together with their associated groundwaters and coastal waters. Appropriate administrative arrangements have to be made, including the designation of appropriate competent authorities to coordinate and oversee the application of the directive's rules. For each River Basin District a comprehensive River Basin Management Plan has to be drawn up on the basis of an analysis of the characteristics of the River Basin District, a review of the impact of human activity on the status of the surface waters and groundwater and an economic analysis of water use within the River Basin District.

The directive requires the identification of all significant bodies of water which are presently or may in future be used for the abstraction of water intended for human consumption. In addition it requires that following treatment, the water has to meet the requirements of the Drinking Water Directive.

The Water Framework Directive also contains provisions on monitoring of the aquatic environment. The monitoring programmes have to ensure the establishment of a coherent and comprehensive overview of water status within each River Basin District as well as for the adjoining maritime areas.

Within each River Basin District the necessary measures have to be implemented to achieve the following environmental objectives:

- to prevent deterioration in the status of the surface waters and groundwater,
- to restore surface waters and bodies of groundwater with the aim of achieving good water status,
- to improve heavily modified and artificial water bodies with the aim of achieving good ecological potential and good surface water chemical status,
- to reverse any significant and sustained upward trend in the concentration of any pollutant in groundwater resulting from the impact of human activity in the direction of an insignificant level of anthropogenic pollution, and
- to comply with all standards and objectives relating to protected areas.

The preliminary general deadline of 16 years for achieving the environmental objectives can only be extended under special circumstances. Less stringent objectives can be established if the water body is severely affected by human activity and improvements in status are proven to be impossible or prohibitively expensive.

In order to achieve the environmental objectives, programmes of basic and (if necessary) supplementary measures have to be designed and implemented within the River Basin Management Plans.

The basic measures are compulsory and shall among other things ensure implementation of existing legislation of relevance to water policy. Among other things, pollutant emissions have to be reduced using a combined approach including emission controls based on best available techniques and the setting of environmental quality objectives or environmental quality standards. The basic measures also include implementation of the principle of full cost recovery, controls over the abstraction of fresh surface water and groundwater, a prohibition on the direct discharge into groundwater of certain pollutants, and a requirement for prior authorization of pollutant discharges and all activities having a potentially adverse impact upon the aquatic environment. Supplementary measures can be implemented if the basic measures alone cannot ensure achievement of the objectives.

It is expected that agreement on the Water Framework Directive will be reached between the European Council and the European Parliament during 2000 such that the directive can be adopted before the end of the year. Implementation of the directive in national legislation must take place within a period of three years thereafter.

7 Summary and conclusions

Through the national programme for monitoring of the aquatic environment 1998–2003 (NOVA-2003), a comprehensive programme has been implemented for the period 1998–2003 whereby discharges, transport and effects of nutrients, heavy metals and hazardous substances will be monitored in the various parts of the aquatic environment.

Aquatic Environment 1999 is the first report to summarize the results of NOVA-2003. It assesses:

- Discharges of pollutants to the aquatic environment
- The current state of the environment and the overall trends
- The reduction targets and quality objectives set, and the measures implemented to achieve the various targets.

Discharges and inputs of pollutants to the aquatic environment are described in Chapters 3 and 4, with a brief summary being given here in Section 7.1. The current environmental state of the groundwater, watercourses, lakes and Danish marine waters is described in Chapter 5, with a brief summary being given here in Section 7.2.

7.1 Discharges and reduction targets - status and trends

The magnitude of nutrient inputs from most sources depends on the runoff. It is therefore not surprising that the total input of nutrients to the aquatic environment was high in 1998, as this was the second-wettest year since 1874.

NUTRIENT INPUTS IN 1998

Total nutrient inputs to inland waters in 1998 amounted to approx. 110,000 tonnes nitrogen and approx. 2,100 tonnes phosphorus, cf. Table 7.1. Inputs to Danish marine waters in 1998 amounted to approx. 200,000 tonnes nitrogen and approx. 2,500 tonnes phosphorus, cf. Table 7.2.

Table 7.1
Sector discharges of nitrogen and phosphorus (in tonnes) to inland waters.

	Nitrogen	Phosphorus
• Wastewater treatment plants	2,710	274
• Separate industrial discharges	66	4
• Stormwater outfalls	723	190
• Freshwater fish farms	1,241	92
Point sources, total	4,740	560
• Agriculture and background[1)]	102,744	1,366
• Sparsely built-up areas	989	226
Diffuse sources etc, total	103,733	1,592
Total	108,473	2,152

1) Atmospheric deposition on open water bodies is included, but comprises only a few tenths of a percent.

Table 7.2
Sector discharges of nitrogen and phosphorus (in tonnes) to marine waters.

	Nitrogen	Phosphorus
• Wastewater treatment plants	5,163	600
• Separate industrial discharges	1,427	124
• Stormwater outfalls	968	252
• Fish farming (freshwater and mariculture)	1,508	121
Point sources, total	9,066	1,097
• Background[1)]	12,536	311
• Agriculture	135,783	990
• Sparsely built-up areas	989	226
• Traffic and power	47,025	0
Diffuse sources etc., total	196,333	1,527
Total	205,399	2,624

1) Excluding inputs from adjoining marine waters and biological fixation of atmospheric nitrogen (N_2).

THE TREND 1989–98

Since 1989, inputs of both nitrogen and especially phosphorus to the aquatic environment have decreased. This trend is attributable to improved treatment of wastewater. In the case of the point sources, the fall seen in the preceding years was superseded by a slight increase in inputs to inland waters in 1998, primarily due to the large amount of precipitation that fell in 1998. The increase is thus not expected to continue under normal climatic conditions.

The relative development in total inputs of nutrients to the aquatic environment relative to the level at the end of the 1980s is illustrated in Figure 7.1.

FIGURE 7.1

RELATIVE DEVELOPMENT IN INPUTS OF NITROGEN (A) AND PHOSPHORUS (B) TO THE AQUATIC ENVIRONMENT (INLAND AND MARINE WATERS) FROM CULTIVATED LAND, WASTEWATER TREATMENT PLANTS, INDUSTRY AND THE ATMOSPHERE DURING THE PERIOD 1989–98. THE 1989 INPUTS FROM THE ATMOSPHERE, WASTEWATER TREATMENT PLANTS AND INDUSTRY HAVE BEEN SET TO 100. AS 1989 WAS A VERY DRY YEAR, THE FIGURES FOR RUNOFF AND INPUTS FROM AGRICULTURE ARE INSTEAD EXPRESSED RELATIVE TO THE AVERAGE FOR THE PERIOD 1981–88.

A tendency towards a slight fall in the diffuse losses of nitrogen to inland waters is apparent. Whether or not this statistically nonsignificant fall is due to reduced inputs from agriculture, sparsely built-up areas or background loss is unclear.

The marked fall in inputs from point sources has not been accompanied by a corresponding fall in inputs from agriculture. Model calculations of the leaching of nitrogen from the root zone indicate a fall of approx. 25% since 1989/90, cf. Section 3.3. This corresponds to a reduction in annual nitrogen leaching from agricultural land of 57,500 tonnes nitrogen per year. This assessment is in good accordance with the assessments made as the foundation for the Action Plan on the Aquatic Environment II, where it was concluded that the regulations implemented up to summer 1998 would reduce nitrogen loading from agriculture by 60,000 tonnes nitrogen per year.

The calculated fall in leaching of nitrogen from fields, however, is not yet reflected in the transport of nitrogen in watercourses and hence in nitrogen input to the marine waters.

In contrast to the calculations, measurements of the atmospheric deposition of nitrogen compounds on the sea reveal a statistically significant fall.

INPUTS OF HAZARDOUS SUBSTANCES

At the present time it is not possible to draw any general conclusions regarding the magnitude and overall trend in inputs of hazardous substances. This is expected to be done in connection with the theme report on hazardous substances planned for publication in 2002.

AGRICULTURE

According to the Action Plan on the Aquatic Environment I, nitrogen losses from agricultural sources should be reduced by a total of 127,000 tonnes N per year from approx. 260,000 tonnes N per year to 130,000 tonnes N per year. The target was divided into 100,000 tonnes N reduction in the nitrogen load from fields and an approx. 27,000 tonnes N reduction in the farmyard load. In addition, farmyard phosphorus load was to be reduced from approx. 4,400 tonnes P per year in 1987 to a level of around 400 tonnes P per year.

Based among other things on NOVA-2003, it can be ascertained that:

- Model calculations of the actual cultivation practice during the period 1990–98 estimate that nitrogen leaching from fields will be reduced by approx. 25% within a period of years.
- The total nitrogen input to agricultural land has decreased 22% since 1985 as a result of improvements in agricultural practice during the monitoring period (1989–98).
- The surplus on the field nitrogen balances for the agricultural monitoring catchments and the country as a whole has decreased by 27–29%, and amounted to approx. 90 kg N per hectare in 1998.
- The phosphorus surplus has decreased correspondingly.
- 1998 was the first year in which there was concordance between crop nitrogen requirements (commercially optimal) and the amount of effective nitrogen fertilizer applied (on average) at the national level (cf. Grant et al., 1999). This reflects a positive general trend, although it still encompasses both underfertilization of some fields, e.g. grass, and overfertilization of others.
- The farmyard load has been reduced to a practical minimum corresponding to approx. 5,000 tonnes N and approx. 400 tonnes P per year.

The expected reduction in the groundwater nitrate concentration in the 6 agricultural monitoring catchments as a result of the decreasing nitrogen input to agricultural land is not yet detectable in the upper groundwater. One explanation might be that the groundwater is old and that the nitrate it contains thus derives from the period prior to adoption of the Action Plan on the Aquatic Environment I.

In addition it can be concluded that:

- Overfertilization has been reduced and now takes place on approx. 10% of the land in the 6 agricultural monitoring catchments.
- Approx. 14% of the farms that used livestock manure in 1998 did not comply with the requirements on utilization of the N content of livestock manure.

The nitrogen surplus in the monitoring catchments and the country as a whole entails a considerable potential for leaching. It should be noted that the above-mentioned results are from 1998, which is before the Action Plan on the Aquatic Environment II entered into force. Implementation of the Action Plan on the Aquatic Environment II will further reduce nitrogen inputs. Utilization of the nutrient content of livestock manure is to be further improved and wetlands are to be re-established in order to enhance nitrogen turnover and retention.

The effects of the Action Plan on the Aquatic Environment II are not yet detectable, but the measures will be reflected in measurements and calculations of nitrogen leaching etc. in the coming years. It is expected that full compliance with the regulations already in force and fulfilment of the targets stipulated in the Action Plan on the Aquatic Environment II will enable the goal of a 50% reduction in nitrogen losses to be met. It will take some years past 2003, though, before the full effect of the measures and instruments implemented will be detectable and nitrogen leaching is halved in practice.

The use of commercial and animal fertilizer by the agricultural sector results in an annual phosphorus surplus on the livestock farms because only part of the phosphorus applied is removed in the crops. Thus in 1998, an average of 11 kg phosphorus was applied per hectare and the phosphorus pool in the soil is thus being continually built up. Through the 1990s, the surplus input of phosphorus at field level has been halved. However, it is of vital significance as regards phosphorus loss to the aquatic environment that farmers continue the positive trend and further reduce the amount of phosphorus inputs to the soil. This is rendered difficult by the fact that livestock production is unequally distributed though the country, thus resulting in local and regional phosphorus surpluses. On many livestock holdings, the application of livestock manure alone will result in a phosphorus surplus. In order to reduce the surplus it is important that the livestock manure is distributed optimally and that efforts are continued to reduce the amount of phosphorus in livestock manure through more effective feeding practices.

The loss of phosphorus from cultivated land is of great significance for the environmental state of the lakes and coastal waters in particular. It is therefore necessary to further improve agricultural practice so as to ensure that the amount of phosphorus applied corresponds to the needs of the crop. This will enhance the possibilities for attaining the environmental quality objectives in many Danish lakes and certain coastal waters.

MUNICIPAL WASTEWATER TREATMENT PLANTS

According to the 1987 Action Plan on the Aquatic Environment, nitrogen discharges from municipal wastewater treatment plants were to be reduced from a level of 18,000 tonnes N per year to 6,600 tonnes N per year. Phosphorus discharges were to be reduced from 4,470 tonnes P per year to 1,220 tonnes P per year.

The Action Plan on the Aquatic Environment's reduction targets for discharges from municipal wastewater treatment plants were attained in 1996 for both nitrogen and phosphorus. Monitoring of discharges from treatment plants shows that:

- 5,166 tonnes N, 601 tonnes P and 3,525 tonnes organic matter (BOD_5) were discharged in 1998.
- Discharges of nitrogen, phosphorus and organic matter have been reduced by 74%, 90% and 94%, respectively, relative to discharge levels at the time the Action Plan on the Aquatic Environment was adopted. The reduction targets for nitrogen and phosphorus were 60% and 72%, respectively.
- The measured concentrations of heavy metals in the effluent from 4 wastewater treatment plants where measurements were made in 1998 were generally lower than the quality criteria for the recipient waters and hence were not critical relative to the criteria.

INDUSTRIAL DISCHARGES

When the Action Plan on the Aquatic Environment was adopted in 1987 it was decided that separate industrial discharges were to be reduced by 3,000 tonnes N and 1,050 tonnes P, cf. Table 6.1. Nitrogen was to be reduced from 5,000 tonnes N per year to 2,000 tonnes N per year while phosphorus was to be reduced from approx. 1,250 tonne P per year to approx. 200 tonnes P per year.

From the monitoring results it is apparent that the reduction targets stipulated in the Action Plan on the Aquatic Environment for separate industrial discharges have been met. Thus:

- separate industrial discharges in 1998 amounted to 1,248 tonnes nitrogen, 124 tonnes phosphorus and 10,700 tonnes organic matter (BOD_5), and
- discharges of nitrogen and phosphorus have been reduced by 71% and 90%, respectively, since adoption of the Action Plan on the Aquatic Environment, as compared with the reduction targets of 60% and 82%, respectively.

The discharge figures for hazardous substances are based on company in-house control data and county supervision data. The relevant information is lacking for 4 of the 14 Danish counties. There is therefore some uncertainty as to the actual amounts of hazardous substances discharged via separate industrial discharges, both as regards individual outfalls and on a national level. The monitoring work under NOVA-2003 planned for the next few years is intended to determine the magnitude of the problem. Thus from the year 2000, in-house control and county supervision will be supplemented with measurements at 17 selected companies with separate industrial discharges.

REDUCTION TARGET STATUS

With regard to the sector-specific reduction targets stipulated in the Action Plan on the Aquatic Environment I it can be concluded that:

- discharges of both nitrogen and phosphorus from wastewater treatment plants and industry have been reduced by more than stipulated in the Action Plan on the Aquatic Environment I,
- agriculture has attained the reduction target for the farmyard phosphorus load,
- agriculture has reduced the farmyard load for nitrogen by approx. 20–30,000 tonnes N per year to a practical minimum of approx. 5,000 tonnes N per year, and
- model calculations of actual cultivation practices during the period 1990–98 show that nitrogen leaching as a whole is expected to decrease by 25% over a period of years, corresponding to a potential reduction in the nitrogen load from fields of approx. 57,500 tonnes N per year (260,000 - 30,000) x 25%).

The present situation is thus that the targets stipulated in the Action Plans on the Aquatic Environment have not yet been fully attained, among other reasons because the Action Plan on the Aquatic Environment II will not have been fully implemented until 2003.

FIGURE 7.2
REDUCTIONS ATTAINED AS PER 1998 RELATIVE TO THE REDUCTION TARGETS STIPULATED IN THE ACTION PLAN ON THE AQUATIC ENVIRONMENT I. IF THE STATUS COLUMN IS HIGHER THAN THE TARGET COLUMN, THE DISCHARGE HAS BEEN REDUCED MORE THAN EXPECTED. WASTEWATER TREATMENT PLANTS AND INDUSTRY ARE ASSESSED ON THE BASIS OF THE ACTUAL DISCHARGES IN 1998. THE ESTIMATED REDUCTION IN AGRICULTURAL DISCHARGES OF NITROGEN IS 57,500 + 25,000 = 82,500 TONNES PER YEAR.

OTHER SOURCES OF POLLUTION OF THE AQUATIC ENVIRONMENT

The Action Plan on the Aquatic Environment I did not stipulate specific reduction targets for sources such as freshwater fish farms, mariculture, stormwater outfalls and sparsely built-up areas.

FRESHWATER FISH FARMS

The total discharge of nutrients from freshwater fish farms in 1998 was roughly the same as in the preceding four years – 1,250 tonnes N per year and 100 tonnes P per year. Since 1989, when the statutory order governing the organization and operation of freshwater fish farms entered into force, discharges have fallen considerably. The requirements of the statutory order that discharges be reduced seem to have had the desired effect. Further significant reductions in discharges as a result of the statutory order cannot be expected.

Consumption by fish farms of certain auxiliary substances seems to have increased relative to earlier years. Future attention will be focused on their consumption of medicines and auxiliary substances, in particular the magnitude of discharges and possible effects on the aquatic environment. In addition, consumption of these substances needs to be more closely coupled to the actual need for them.

MARICULTURE

Total discharges of nutrients from mariculture – both sea-based and land-based seawater fish farms – in 1998 were largely the same as in earlier years, i.e. approx. 300 tonnes N per year and just under 35 tonnes P per year. Even though discharges from mariculture are small relatively speaking, they can have significant effects locally.

STORMWATER OUTFALLS

Stormwater overflows are currently one of the reasons why many watercourses and lakes do not meet their quality objectives. In step with the reduction in discharges to inland waters from wastewater treatment plants and industry over the past 10 years, the impact of stormwater overflows on watercourses and lakes has become more apparent.

In 1998, discharges from stormwater outfalls amounted to approx. 968 tonnes nitrogen and 253 tonnes phosphorus. No general trend can be detected in discharges from stormwater outfalls.

Very little is known regarding how best to regulate stormwater outfalls. The Danish EPA is therefore participating in work that will result in proposals for guidelines that can be incorporated in official Danish EPA Guidelines. The work is expected to be completed in 2001.

SPARSELY BUILT-UP AREAS

As with stormwater outfalls, the relative significance of discharges from sparsely built-up areas has increased in step with the reduction in discharges from wastewater treatment plants. The discharges from sparsely built-up areas – especially of organic matter and phosphorus – are responsible for many watercourses and lakes failing to meet their quality objectives.

Discharges from sparsely built-up areas in 1998 amounted to approx. 998 tonnes nitrogen and 228 tonnes phosphorus with the tendency being towards a decrease.

In the country as a whole, there are presently approx. 67,000 properties in rural areas that have individual discharges. As a result of a 1997 amendment of the Environmental Protection Act concerning wastewater treatment in rural areas these properties will have to improve sewerage and discharge conditions within the coming years. This will help improve the environmental state of inland waters, especially that of the small watercourses.

HAZARDOUS SUBSTANCES, ETC.

It can also be concluded that the work on implementation of the Esbjerg Declaration's goal that the levels of hazardous substances etc. in the aquatic environment should be reduced to background levels in the case of naturally occurring substances and close to zero for true hazardous substances is still in its initial phase. The current status is that:

- the Pesticide Action Plan goal of halving consumption of pesticide active substance has for all intents and purposes been attained since sales of active substance have been reduced by 48%,
- the Pesticide Action Plan's goal of reducing pesticide treatment frequency has not been attained, and

- national strategies etc. for reducing pollution of the aquatic environment with hazardous substances etc. have already been adopted or are in the process of being adopted.

FUTURE ENDEAVOURS FOR A CLEANER AQUATIC ENVIRONMENT

In connection with the political agreement behind the Action Plan on the Aquatic Environment II it was agreed that a status report on the plan should be prepared at the end of the year 2000. This status report will focus on:

- an overall assessment of nitrogen balances, losses and the uncertainty associated with them,
- an assessment of the effects of the measures adopted, and
- means to reduce ammonia volatilization from agriculture.

As far as concerns further reductions in discharges from point sources, special emphasis will be placed on ensuring that:

- discharges of hazardous substances are limited through revision of discharge permits issued to wastewater treatment plants and industrial companies and permits for the connection of industrial discharges to municipal wastewater treatment plants,
- county and municipal authorities actually enforce the discharge permits issued in practice,
- in connection with their wastewater treatment plans, the Municipalities draw up targets and prioritized plans for renovating the municipal sewers in accordance with the Government's 1994 agreement with the National Association of Local Authorities in Denmark on renovation of the sewer network,
- all Counties submit information on discharges of hazardous substances from industrial enterprises etc., in the year 2000, and
- discharges of nutrients, auxiliary substances and medicines from freshwater fish farms and mariculture are reduced.

7.2 State of the aquatic environment - status and trend

The general state of the aquatic environment in Denmark has not changed significantly relative to previous years (1989–97).

GROUNDWATER

After a couple of dry years, when the groundwater table was unusually low, it returned to a more normal level during the course of 1998, when the autumn in particular was very wet. Water abstraction in 1998 was extremely low: 741 million m^3. The total abstraction has fallen by approx. 30% from 1989 to 1998, among other reasons because of water taxes and water-saving measures.

The groundwater monitoring shows that:

- nitrate continues to comprise a problem – especially in sandy-soil areas of Jutland. No clear trend can be detected during the monitoring period (1990–1998),
- in several localities, heavy metals and inorganic trace elements such as barium, aluminium, nickel and zinc are present in the groundwater in concentrations exceeding the limit value for drinking water. Several of the substances are naturally occurring in the groundwater and are to a large

extent removed by ordinary water treatment at the waterworks. No clear trend is apparent in the occurrence of the substances during the monitoring period (1990–1998),

- organic micropollutants have been detected in nearly all abstraction wells at one time or another. The organic micropollutants comprise a large group of substances that can derive both from industry (e.g. chlorinated hydrocarbons) and from households (e.g. detergents), and which can also be formed naturally (e.g. chloroform). The majority occur in the groundwater in concentrations well under the limit values for drinking water. No clear trend is apparent during the monitoring period (1990–98),
- pesticides and pesticide residues are found in the upper groundwater in 40% of the abstraction filters investigated. In the deeper groundwater, pesticides are found in approx. 29% of the wells, with the pesticide content exceeding the limit value for drinking water in approx. 8%. The trend over the period 1994–98 is towards increasing detection of pesticides and pesticide residues – also at levels exceeding the limit value for drinking water. This is considered to be largely attributable to the fact that more substances are measured now than previously, and
- a decrease in the concentration of atrazine has been detected in the upper groundwater in the agricultural monitoring catchments.

It should be noted that all the pesticides or pesticide residues detected most frequently and in the highest concentrations are currently either prohibited or strictly regulated.

A general finding with regard to the groundwater monitoring is that with few exceptions, no clear trends are detectable for the substances analysed during the monitoring period (1990–98). Among other reasons this is attributable to the fact that the majority of the groundwater analysed was formed prior to adoption of the Action Plan on the Aquatic Environment.

The further work on ensuring clean groundwater will be based on the Government's 1994 10-point Programme for protection of the groundwater and drinking water and the Drinking Water Committee's 1997 report. Emphasis will be placed on:

- preserving the Danish water supply structure, which is based on decentralized abstraction of pure groundwater, and
- ensuring that curtailment of nutrient discharges to the groundwater takes place through promotion of organic farming, protection of particularly vulnerable groundwater abstraction areas, enhanced afforestation, and nature restoration, cf. the Government's 10-point Programme.

The recommendations of the Drinking Water Committee have been implemented in legislation in connection with the Action Plan on the Aquatic Environment II, which introduces the possibility to protect vulnerable areas through agreements with the agricultural sector, etc. With respect to pesticides, though, this necessitates building up the scientific foundation for identification of areas that are particularly vulnerable to pesticide leaching. A new measure is the power to impose restrictions on land use in return for full compensation. Regulations governing cooperation between county and municipal authorities and the waterworks have also been established and the possibility has been introduced to finance groundwater protection through water charges.

The recommendations of the Drinking Water Committee concerning safeguarding the groundwater resource against pollution by hazardous substances has, as with nutrients, led to the implementation of new measures. The county authorities identify sensitive agricultural areas where there is a need for special efforts to safeguard drinking water interests.

The overall framework for implementing goal-oriented, prioritized protection of the groundwater has now been established. However, considerable work remains on preparing official guidelines, statutory orders, etc. stipulating in detail the technical and administrative requirements pertaining to protection of the groundwater. It will therefore be several years before the work on drawing up official guidelines and statutory orders etc. is completed.

WATERCOURSES AND SPRINGBROOKS

The watercourse monitoring shows that:

- the concentration of nitrogen in watercourses in cultivated catchments has fallen approx. 5% since 1989 when corrected for inter-annual variation in runoff. The fall is not statistically significant, however,
- there has been a corresponding marked fall in the concentration of total-P in the watercourses that were previously highly affected by wastewater from freshwater fish farms and treatment plants when corrected for the variation in runoff,
- discharges of phosphorus from sparsely built-up areas still comprise a major part of the total-P input to watercourses, and
- the concentrations of phosphorus in watercourses in cultivated catchments are still 3-fold greater than in watercourses in uncultivated catchments.

In addition, it can be concluded that the nitrate concentration of springs in cultivated areas is increasing, but that the increase does not correlate with the tendency towards a falling nitrogen concentration in many watercourses. One explanation could be that the groundwater in the springs is relatively old and hence might reflect agricultural practice in the years prior to adoption of the Action Plan on the Aquatic Environment.

NOVA-2003 and county watercourse supervision show that environmental quality is only acceptable in approx. 40% of watercourse reaches. The unacceptable state of the remaining 60% of watercourse reaches is often due to poor physical variation, for example as a result of channelization and hard-handed maintenance practices. Nevertheless, there are still some watercourses where the unacceptable environmental state is attributable to pollution from point sources and sparsely built-up areas.

Assessment of the environmental state of watercourses is not undertaken in the same manner in NOVA-2003 and the county watercourse supervision. This gives an inhomogeneous basis for a nationwide assessment of the current state and overall trend in watercourse quality. The recommended method – the Danish Stream Fauna Index – therefore needs to be used more widely as the assessment method.

The future endeavours to improve the environmental state of Danish watercourses will focus on ensuring that:

- efforts to create better physical conditions in the watercourses are enhanced and that restoration work is continued,
- watercourse authorities enforce the provisions of the Watercourse Act stipulating a 2-m wide pesticide-free border zone alongside all natural watercourses or watercourses with a high quality objective,
- the Counties in future employ the Danish Stream Fauna Index to such an extent and manner as to enable the county watercourse supervision data and NOVA-2003 to together provide a nationwide assessment of the environmental state of Danish watercourses, and
- measures are taken to re-establish good natural and environmental quality in watercourses where obstructions have a major negative impact on watercourse quality and hinder fulfilment of the quality objective.

LAKES

As a result of eutrophication, many Danish lakes have become so nutrient-rich that they have switched from a clearwater to a turbid state. Eutrophication has a number of negative effects on lake environmental quality. As a general rule, increasing eutrophication leads to impoverishment in the direction of fewer plant and animal species. Two important examples are the submerged macrophytes, which often disappear or markedly regress in the turbid water, and the fish stock, which becomes dominated by large populations of just a few species. In order to rectify these undesirable conditions, efforts have been going on for many years to reduce nutrient inputs to the lakes.

The lake monitoring results reveal that the majority of the investigated lakes are improving as a result of the reduction in nutrient inputs. Among other things this is reflected in:
- an increase in the water's Secchi depth,
- a decrease in planktonic algal biomass, and
- a tendency towards a greater depth distribution of submerged macrophytes.

It can also be ascertained, however, that:
- on the national scale, only 32% of lakes investigated fulfil their quality criteria, and
- there has not been any detectable improvement in compliance with quality objectives during the monitoring period (1989–1998).

The failure of Danish lakes to meet their quality objectives is largely attributable to the fact that nutrient discharges have not yet been reduced sufficiently. The main sources of this loading are probably diffuse inputs from cultivated land, point sources and sparsely built-up areas.

A basic premise for being able to improve water quality is that external nutrient inputs have to be reduced sufficiently. This means that the lake water concentration has to be reduced below an equilibrium concentration of 0.05–0.10 mg phosphorus per litre in shallow lakes and 0.02–0.05 mg phosphorus per litre in deep lakes. This can only be achieved by reducing nutrient inputs, especially phosphorus inputs, from cultivated land and sparsely built-up areas. Due to the resilience of lake ecosystems, the reduction in nutrient loading will not always lead to an immediate improvement. In the lakes where external nutrient loading has been reduced sufficiently, an improvement in environmental state can sometimes be promoted through lake restoration methods.

MARINE WATERS

Monitoring of the marine waters shows that:

- the concentrations of phosphorus in the sea are still falling.
- there is a weak tendency towards a fall in the concentration of nitrogen.
- the incidents of oxygen deficiency in 1998 were limited in extent in the shallow estuarine fjords and coastal waters. In the deep marine waters with a stratified water column, it was mainly the areas that naturally suffer from oxygen deficiency that were affected.
- the concentrations of PAHs and heavy metals (with the exception of organotin compounds) in fish and mussels are less than the concentrations considered critical in an international context, and
- the concentrations of hazardous substances in fish and mussels are generally at a level considered to be of no significance.

The monitoring results also show that:

- the environmental state is very rarely satisfactory, largely due to high nutrient concentrations in the water, restricted distribution of perennial submerged macrophytes, oxygen deficiency, or the occurrence of undesirable, pollution-dependent plant growths,
- extremely high concentrations of hazardous substances can occur locally,
- the TBT concentration in fish and mussels is between 2- and 100-fold greater than the recommended international evaluation criteria,
- TBT-induced hormonal disturbances have been detected in the majority of snails in the inner Danish marine waters, and
- the PCB concentration in fish and mussels is at a level where the occurrence of ecological effects cannot be excluded.

The progress so far made in reducing nutrient inputs to the sea have been insufficient to lead to a general improvement in environmental state. In the two dry years 1996 and 1997, inputs of nutrients to the sea were so low as to correspond to the expected effect of the Action Plans on the Aquatic Environment. The environmental state of the marine waters improved considerably during these two years. Among other things this was reflected in enhanced Secchi depth, enhanced depth distribution of eelgrass, less filamentous brown algae and sea lettuce, as well as less frequent and less severe oxygen deficiency.

The clear effects of tributyl tin presently detected in sea snails will presumably decrease considerably in step with implementation of the newly adopted international ban on its application (2003) and use (2008).

Pollution of the sea is a transboundary problem. It is therefore important that the reduction targets are achieved both nationally and by our neighbouring countries.

7.3 Overall conclusion

Progress towards improving the Danish aquatic environment is being made on many fronts. Discharges etc. of pollutants are decreasing as expected. It can thus be ascertained that:

- wastewater treatment plants and industry have reduced discharges of nitrogen and phosphorus by more than stipulated in the Action Plan on the Aquatic Environment I,
- the farmyard load has been reduced to a practical minimum corresponding to approx. 5,000 tonnes N per year and approx. 400 tonnes P per year,
- the nitrogen load from fields could be reduced by 25% within the space of some years, corresponding to 57.500 tonnes N per year,
- measured atmospheric deposition of nitrogen on marine waters is decreasing slightly, and
- pesticide sales to agriculture (measured in tonnes active substance) have been reduced by 48% and than the use of a number of pesticides, including those that most threaten the groundwater, has been prohibited or strictly regulated.

The general state of the aquatic environment in Denmark has not changed significantly relative to previous years, however. The nitrogen surplus still comprises a major problem, among other things in the form of nitrate contamination of the groundwater and springs. In the sea, it results in enhanced plant growth and unnaturally expansive and severe incidents of oxygen deficiency. The phosphorus surplus is also a considerable problem, especially in the lakes and certain coastal waters. The detection of hazardous substances in abstraction wells and in many watercourses and lakes and the sea is worrying.

There is no doubt, though, that with the existing action plans, strategies and international agreements Denmark is on the right track, and that once they have had time to take effect, improvement in the state of the aquatic environment will follow.

References

Amternes Vadehavssamarbejde (1999): Vandmiljøovervågning - Marine områder – Vadehavet (in Danish), 51 pp. + annexes.

Andersen, J.M., S.G. Sommer, N.J. Hutchings & H. Damgaard Poulsen (1999): Emission af ammoniak fra landbruget - status og kilder. I: Ammoniak-fordampning (in Danish). Redegørelse nr. 1 fra Danmarks JordbrugsForskning, 1999. Danish Institute of Agricultural Sciences and National Environmental Research Institute.

Bornholm County (1999): Vandmiljøovervågning - Kystvande 1998 (in Danish), 14 pp.

Bøgestrand, J. (ed.) (1999): Vandløb og kilder 1998. NOVA 2003 (in Danish). National Environmental Research Institute, Technical Report No. 292, 132 pp.

COWI (1998): Tungmetalforurening af slam fra dambrug. Kilder og afhjælpningsforanstaltninger (in Danish).

COWI (1999): Undersøgelse af flydelag i gyllebeholdere og kommunernes tilsyn hermed (in Danish), 40 pp + annexes.

Danish Environmental Protection Agency (1984): NPo-redegørelsen (in Danish), 218 pp.

Danish Environmental Protection Agency (1990): Vandmiljø-90. Samlet status over vandmiljøet i Danmark (in Danish). Redegørelse fra Miljøstyrelsen, 1/1990, 204 pp. Translated as "Environmental impacts of nutrient emissions in Denmark, Redegørelse fra Miljøstyrelsen 1/1991.

Danish Environmental Protection Agency (1994a): Vandmiljø-94 (in Danish). Redegørelse fra Miljøstyrelsen 2/1994, 150 pp. Translated as "Aquatic Environment 1994", Redegørelse fra Miljøstyrelsen 1/1996.

Danish Environmental Protection Agency (1994b): Notat om udledninger af tungmetaller fra beboelse i det åbne land (in Danish), 3 pp.

Danish Environmental Protection Agency (1994c): Danmarks grundvand og drikkevand (in Danish). Redegørelse fra Miljøstyrelsen 4/1994, 37 pp.

Danish EPA (1995): Progress Report. 4th International Conference on the Protection of the North Sea. Esbjerg, Denmark, 8-9 June 1995. Danish Environmental Protection Agency, 247 pp.

Danish Environmental Protection Agency (1997a) Miljøfremmede stoffer i husholdningsspildevand (in Danish), Environmental Project 357.

Danish Environmental Protection Agency (1997b): Vandmiljø-97 (in Danish). Redegørelse fra Miljøstyrelsen 4/1997, 172 pp.

Danish Environmental Protection Agency (1998): Vandmiljø-98 (in Danish). Redegørelse fra Miljøstyrelsen 2/1998, 114 pp.

Danish Environmental Protection Agency (1999a): NOVA-2003. Nationalt program for overvågning af vandmiljøet 1998-2003. Programbeskrivelse. Del 1: Tekst. Del 2: Annexes (in Danish). September 1999, 200 pp + 215 pp.

Danish Environmental Protection Agency (1999b): Punktkilder-98 (in Danish). Orientering fra Miljøstyrelsen 151/1999, 136 pp.

Danish Environmental Protection Agency (1999c): Spildevandsslam fra kommunale og private renseanlæg i 1997 (in Danish). Environmental Project 473.

Danish Environmental Protection Agency (1999d): Bekæmpelsesmiddelstatistik (in Danish).

Danish Environmental Protection Agency (1999e): Indberetning til Convention on long-range Transboundary Air Pollution om nationale emissioner af NO_x, NH_3, tungmetaller og udvalgte POPer (in Danish), 5 pp.

Danish Environmental Protection Agency (1999f): Tilsyn 1998 (in Danish). Orientering fra Miljøstyrelsen.

Danish Environmental Protection Agency & National Forest and Nature Agency (in preparation): Tilsyn 1999. Orientering fra Miljøstyrelsen.

Danish Foods Agency (1994): Forurening i fisk fra Øresund 1993: Kviksølv i torsk og skrubber (in Danish).

Danish Institute of Agricultural Sciences (1999): Kvælstofbalancer i landbruget. Ministry of Food, Agriculture and Fisheries (in Danish), Danish Institute of Agricultural Sciences, 1999.

DHI Water and Environment (1999a): Farvandsmodellen - Modeletablering (in Danish). 84 pp + annexes.

DHI Water and Environment (1999b): Farvandsmodellen - Hydrografi og stoftransport: 1998 (in Danish). 31 pp + annexes.

DHI Water and Environment (1999c): Farvandsmodellen - Akkumulerede transporter, 1998 (in Danish). Memorandum of 21 November 1999. 8 pp.

Ellermann, T., O. Hertel, K. Kemp, O.H. Mancher & H. Skov (1997): Atmosfærisk deposition af kvælstof. Vandmiljøplanens Overvågningsprogram 1996 (in Danish). National Environmental Research Institute, Technical Report No. 212, 87 pp.

Fent, K. (1996): Ecotoxicology of Organotin Compounds. Critical Reviews in Toxicology 26(1). 117 pp.

Frederiksborg County (1999): Overvågning af det sydlige Kattegat 1998 (in Danish). Vandmiljøovervågning 59, 26 pp + annexes.

Frederiksborg County (1999): Overvågning af Øresund 1998 (in Danish). Vandmiljøovervågning 58, 67 pp + annexes.

Frohn, L., H. Skov & O. Hertel (1998): Atmosfærisk deposition af kvælstof. Vandmiljøplanens Overvågningsprogram 1997 (in Danish). National Environmental Research Institute, Technical Report No. 255, 97 pp.

Funen County (1999): Kystvande 1998 (in Danish). Vandmiljøovervågning. 187 pp.

Funen County (1999): Pesticidundersøgelser i vandløb, kildevæld og dræn (in Danish). Memorandum by the Nature and Aquatic Environment Division, 9 pp.

GEUS Geological Survey of Denmark and Greenland (1995): Grundvandsovervågning 1995 (in Danish). Særudgivelse fra Danmarks og Grønlands Geologiske Undersøgelse. 209 pp + annexes.

GEUS Geological Survey of Denmark and Greenland (1997): Vandressourcer. Ferskvand! Det 21. århundredes hovedproblem? (in Danish) Geologi. Nyt fra GEUS 2/1997. 16 pp.

GEUS Geological Survey of Denmark and Greenland (1999): Grundvandsovervågning 1999 (in Danish). Særudgivelse fra Danmarks og Grønlands Geologiske Undersøgelse. 114 pp.

Graneli, E., K. Wallström & U. Larssen (1990): Nutrient Limitation of Primary Production in the Baltic Sea Area. Ambio 19: 142-151.

Grant, R., G. Blicher-Mathiesen, H.E. Andersen, A.R. Laubel, I. Paulsen, P.G. Jensen. & P. Rasmussen (1998): Landovervågningsoplande, Vandmiljøplanens Overvågningsprogram 1997 (in Danish). National Environmental Research Institute, Technical Report.

Grant, R., I. Paulsen, H.E. Andersen, A.R. Laubel, J.O. Jørgensen, P.G. Jensen1, M. Pedersen & P. Rasmussen (1999): Landovervågningsoplande 1998. NOVA 2003 (in Danish). National Environmental Research Institute. – Technical Report No. 293.

Hovmand, M.F. & K. Kemp (in prep.): Tungmetalnedfald i Danmark 1998 (in Danish). National Environmental Research Institute, Technical Report.

Illerup, J.B., A. Geertinger, L. Hoffmann, & K. Christensen (in prep.): Emissionsfaktorer for tungmetaller, 1990-1997 (in Danish). National Environmental Research Institute, Technical Report.

Iversen, T.M., R. Grant, G. Blicher-Mathiesen, H.E. Andersen, E. Skop, J.J. Jensen, B. Hasler, J. Andersen, C.C. Hoffmann, B. Kronvand, H.E. Mikkelsen, J. Wagepetersen, A. Kyllingsbæk, H.D. Poulsen & V.F. Kristensen (1998): Vandmiljøplan II – faglig vurdering (in Danish). National Environmental Research Institute, 44 pp.

Jensen, J.P., M. Søndergaard, E. Jeppesen, T.L. Lauridsen & L. Sortkjær (1999): Søer 1998. NOVA 2003 (in Danish). National Environmental Research Institute, Technical Report No. 291, 104 pp.

Kaas, H., Ø. Moestrup, J. Larsen & P. Henriksen (1999): Giftige alger og algeopblomstringer (in Danish). National Environmental Research Institute, TEMA-rapport 27/1999, 64 pp.

Ministry of Agriculture (1991): Action Plan for sustainable Agriculture (Translation).

Markager, S., T.G. Nielsen, J. Carstensen, D. Conley, K. Dahl, J. Hansen, P. Henriksen, A. Josefson, M.M. Larsen, B. Pedersen, B. Rasmussen, J. Strand, G. Ærtebjerg, H. Fossing, J.S. Lauersen, O. Hertel, H. Skov, L.M. Svendsen, M. Cleemann, & G. Pritzl (1999): Marine områder. Status over miljøtilstanden i 1998. NOVA 2003 (in Danish). National Environmental Research Institute, Technical Report No. 290, 164 pp.

Ministry of Environment and Energy (1992): Watercourse Act (Translation).

Ministry of Environment and Energy (1996): Statutory Order No. 823 of 16 September 1996 on Application of waste products for agricultural purposes (Translation).

Ministry of Environment and Energy (1997): Act No. 325 of 14 May 1997 on wastewater treatment in rural areas (in Danish).

Ministry of Environment and Energy (1998): Statslig udmelding til regionplan-revision 2001 (in Danish).

Ministry of Environment and Energy (1999): Environmental Policy White Paper 1999 (in Danish), 664 pp.

Ministry of the Environment (1987): Handlingsplan mod forurening af det danske vandmiljø med næringssalte af 31. januar 1987 (in Danish). 13 pp.

Ministry of the Environment (1988): Statutory Order No. 515 of 29 August 1988 on water quality and supervision of water supply plants (Translation).

Nordjylland County, Ribe County & Ringkøbing County (1999): Åbne farvande langs Vestkysten 1998 (in Danish), 97 pp.

Ornis Consult (1987): Trends in Marine Oil Pollution 1984-1997. Working Report from the Danish Environmental Protection Agency, 62 pp + annexes.

OSPAR (1998): Summary Report of the Comprehensive Study on Riverine Inputs and Direct Discharges (RID) in 1990 - 1995.

OSPAR (in prep.): Regional Quality Status Report 2000. Greater North Sea.

Ribe County (1999): Vandløb og kilder (in Danish). Vandmiljøovervågning, 153 pp.

Ringkøbing County (1999). Ringkøbing Fjord og Nissum Fjord 1998 (in Danish). Vandmiljøovervågning. 141 pp.

Roskilde County & Frederiksborg County (1999): Overvågning af Roskilde Fjord 1998 (in Danish). Vandmiljøovervågning 60. 48 pp + annexes.

Schrøder, H. (1995): Vandbalance for Danmark. Vand & Jord, 4/1995:162-165. 4 pp.

Simmelsgård, S.E. (1991): Estimering af funktioner for kvælstofudvaskning. In: Rude, S.: Kvælstofgødning i landbruget - behov og udvaskning nu og i fremtiden (in Danish). Danish Institute of Agricultural Economics, Report No. 62.

Skov, H., O. Hertel, T. Ellermann & C.A. Skjøth (1999): Atmosfærisk deposition af kvælstof (in Danish). National Environmental Research Institute, Technical Report No. 289, 102 pp.

Storstrøm County (1999): Havmiljø 1998 (in Danish), 126 pp.

Søndergaard, M, E. Jeppesen, J.P. Jensen, T.L. Lauridsen, J.P. Müller, H.J. Jensen, S. Berg & C. Hvidt m.fl. (1998): Sørestaurering i Danmark (in Danish). Miljønyt 28/1998, Danish Environmental Protection Agency, 283 pp.

Sønderjylland County (1999): NOVA, Vandmiljøovervågning, 1998, Aabenrå Fjord, Augustenborg Fjord, Flensborg Fjord (in Danish). 47 pp + annexes.

Vejle County (1999): Overvågning af kystvande 1998 (in Danish). 91 pp + annexes.

Vestsjælland County (1999): Fjorde, kystnære områder og åbne farvande 1998 (in Danish). Vandmiljøovervågning, 39 pp.

Vestsjælland County (1999): Isefjord 1998. Vandmiljøovervågning (in Danish). 20 pp.

Viborg County, Nordjyllands County & Ringkøbing County (1999): Vandmiljø i Limfjorden 1998. NOVA 2003 (in Danish). 101 pp + annexes.

Windolf, J., L.M. Svendsen, B. Kronvang, J. Skriver, N.B. Ovesen, S.E. Larsen, A. Baattrup-Pedersen, H.L. Iversen, J. Erfurt, D. Müller-Wohlfeil & J.P. Jensen (1997): Ferske vandområder – vandløb og kilder. Vandmiljøplanens Overvågningsprogram 1996 (in Danish). National Environmental Research Institute, Technical Report No. 214, 1997. 112 pp.

Ærtebjerg, G., J. Carstensen, D. Conley, K. Dahl, J. Hansen, A. Josefson, H. Kaas, S. Markager, T.G. Nielsen, B. Rasmussen, D. Krause-Jensen, O. Hertel, H. Skov & L.M. Svendsen (1998): Marine områder. Åbne farvande - status over miljøtilstand, årsagssammenhænge og udvikling. Vandmiljøplanens Overvågningsprogram 1997 (in Danish). National Environmental Research Institute. - Technical Report No. fra DMU, nr. 254. 248 pp.

Aarhus County & Nordjylland County (1999): Vestlige Kattegat og tilstødende fjorde 1998. Tilstand og udvikling (in Danish). 77 pp + annexes.

Aarhus County (1999): Pesticider i vandløb, kilder og søer i Århus Amt (in Danish).

Aarhus County (1999): Århus Bugt 1998 (in Danish). 27 pp + annexes.

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Vandmiljø-99 er den første samlede rapportering af NOVA-2003, det nationale program for overvågning af vandmiljøet 1998-2003. Del 1: “Faglig status - miljøtilstand og påvirkninger”, indeholder en opgørelse af udledninger og tab af forurenende stoffer til vandmiljøet samt en beskrivelse af den resulterende miljøtilstand. I del 2: “Status og perspektiver for indsatsen for et renere vandmiljø”, bliver der gjort status for opfyldelsen af reduktions- og kvalitetsmålene for vandmiljøet. Der bliver desuden peget på, hvordan der kan arbejdes videre for at sikre et renere vandmiljø.

Emneord:
vandmiljøplanen; miljøtilstandsbeskrivelser; grundvand; vandløb; søer; hav; belastningstal; spildevand; udledning; dambrug; havbrug; jordbrug; regnvand

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På dansk er udgivet "Vandmiljø-90", "Vandmiljø-92", "Vandmiljø-93", "Vandmiljø-94", "Vandmiljø-95", "Vandmiljø-96", "Vandmiljø-97" og "Vandmiljø-98" som Redegørelse fra Miljøstyrelsen 1/1990, 2/1992, 4/1993, 2/1994, 3/1995, 3/1997, 4/1997 og 2/1998

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Aquatic Environment 1999 is the first state-of-the-environment report under NOVA-2003, the Danish Aquatic Monitoring and Assessment Programme 1998–2003. Part 1: “Technical status – State and pressures” quantifies discharges, losses and emissions of pollutants to the aquatic environment and describes the resultant environmental state. Part 2: “Action for a cleaner aquatic environment – Status and perspectives” reviews current progress towards fulfilment of pollutant reduction targets and aquatic environment quality objectives, and examines how best to continue the efforts to ensure a cleaner aquatic environment.

Terms:
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