National Environmental Research Institute
University of Aarhus · Denmark

DANISH MINISTRY
OF THE ENVIRONMENT

# Cleaner water in Denmark: Danish water management from the 1970s until today

*A story of strict enforcement of the regulations by local, regional and national authorities characterizes the four decades of Danish water management and the proof to show for it is the cleaner water over all in the country.*

In many respects, the story of improvement of the water quality in Denmark has been one of success. Since the first Environment Act came into force in the early 70s, a significant improvement in the quality of many water bodies has been seen.

A number of different sectors of Danish society have contributed to this development, with public authorities (mainly municipalities), industry and agriculture as the major drivers.

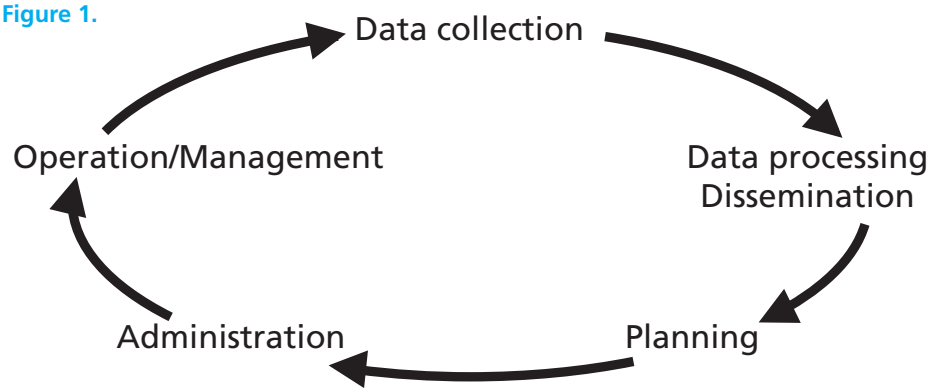
Efforts to reduce discharges of nutrients and organic matter in particular have resulted in significantly lower impacts on Danish water bodies. The main results from about 1990 up to now are shown in table 1, divided into different sectors.

**Table 1: Reduction in pollution load from 1990 until now from different sectors in Denmark**

| | Phosphorus | Nitrogen | Organic matter |
|---|---|---|---|
| Waste water treatment plants | 93% | 82% | 96% |
| Industry | 98% | 93% | 98% |
| Fish farms | 65% | 60% | 60% |
| Agriculture (diffuse load) | Not Significant | 40% (root zone) | Not relevant |
| Air pollution (Danish and European sources) | Not relevant | 20-25% (deposition) | Not relevant |

The same general approach to water management has been used in Denmark from very early on and it can be illustrated with a circle like that in figure 1. The starting point would normally be to collect information/data about status, load, sources etc. and use this information for planning and political decisions about the measures necessary. The circle is then closed again with an assessment of the status based on new data after the load has been reduced to see if the objective has been reached or if additional measures are required.

Figure 1.




This approach has been useful, no matter whether it has been used at local/regional level, or at national level, and in some cases it has been necessary to follow the circle several times before reaching the required status.

## Denmark: surrounded by water and protecting the groundwater

Denmark is surrounded by water with a large number of fjords, bays and small islands which give a coastline of more than 7,000 km. Many Danish waters are more or less closed and only have a minor water exchange with the open sea. This makes them very vulnerable to eutrophication due to nutrient load from the direct catchment, and many areas have suffered oxygen depletion with consequential fish deaths etc. Some of the more open sea areas, the Kattegat and the Baltic Sea, are also vulnerable because of the special hydrographical conditions, where low salinity water from the Baltic Sea meets the saline water from the North Sea, leading to stratification with the risk of oxygen depletion, as was seen in 1981.

Of course Denmark's geographical position has played a very important role in Danish environmental policy and management and it has been the driving force for a number of action plans. Some of the problems in coastal areas can be solved mainly by Denmark herself, but protection of the Kattegat and the Baltic Sea calls for close international cooperation, primarily with the other nations around the Baltic Sea, on issues such as modelling and the recently agreed action plan for the Baltic Sea.

Another important factor for Danish water management has been the intention to protect the groundwater so that it can be abstracted as drinking water. This policy has meant that today nearly 100% of the drinking water in Denmark is abstracted from groundwater and undergoes only very simple treatment. The main threats to using the groundwater for drinking water have been and still are nitrates and pesticides. In certain areas of the country near the larger cities, abstraction of groundwater is so intense, that it is significantly lowering the groundwater table.

Denmark's position surrounded by water, as well as the size of the country, also mean that watercourses are generally small compared to the European continent because of the very short distance from the source to discharge into the sea. Actually there are only one or two real rivers in the country. The water flow in Danish watercourses is therefore also quite low, meaning that possible dilution of pollutants is limited. This has had an influence on the requirements for wastewater treatment in inland cities, for example.

Today the water quality in Danish watercourses is significantly better than 30 years ago. The main problem for Danish watercourses is no longer pollution, but poor physical conditions due to the fact that approximately 90% of all Danish watercourses have been channelized and maintained for many years to secure the drainage of agricultural areas.

Danish lakes are generally small (only 100 lakes exceed 100 ha) and shallow (max. depth app. 35 m). Because of the dense population and intensive farming, most Danish lakes have been heavily eutrophicated with massive blooms of blue-green algae. Reduction of the phosphorus load from waste water, either by deviation or improved treatment, has been the main measure used to improve the water quality in lakes. Today the phosphorus load from waste water to Danish lakes is very small compared to the situation in 1987, and the effect on the biological system has been seen in some lakes, but far from all because of the internal load with phosphorus and the ongoing diffuse load. So, it will take many years before the full effect of investment in better treatment will be detectable.

To understand Danish water policy and management, it is also necessary to look at the most important sources of pollution. Denmark is fairly densely populated, with an average of approximately 125 inhabitants/km², meaning the production of domestic waste water is large compared to the size of the watercourses and the vulnerability of lakes and coastal waters. Therefore it has been necessary to introduce very good treatment of the waste water. The other important fact is that the Danish agricultural sector has a very large livestock production and occupies around 2/3 of the total Danish area, meaning that pressure from this sector is intense and has called for extensive action through the years.

## Regional water quality plans: The basis of Danish water management

Danish water management over the last 30 years has involved three different public actors with well defined roles:

- National level (state) with general regulation and legislation.
- Regional level (self-governing counties until 2007) with the possibility to strengthen national regulation (only point sources).
- Local level (municipalities) with mainly operational responsibilities.

One of the turning points in Danish water policy has been the regional planning, including a plan for water quality. This planning has been the administrative basis for regional and local water management since the 70s, and the last regional water quality plan will be in force until it is substituted by the new water plan, issued according to the Water Framework Directive, in 2009.

The regional focus has changed during the years: pollution of watercourses with organic matter from waste water was the main focus in the 70s, reduction of the phosphorus load in lakes came into focus in the 80s and finally during the 90s the reduction of the nitrogen load in Danish coastal waters was the main issue.

One of the strengths of this regional approach is that it has been differentiated to take into account the specific needs for the individual water body instead of general requirements and objectives. Another strength has been that it has been locally anchored (also politically) in an open and transparent process.

One of the disadvantages in the Danish system so far has been the lack of coherence in the planning, because it has not been possible for regional authorities to regulate the agricultural load in a differentiated way. Pollution from agriculture of groundwater, lakes and coastal waters has been regulated in a parallel process at national level through action plans, mainly to protect the marine environment and the groundwater in general and without considering the needs to reduce the diffuse load running into individual water bodies.

With the introduction of the principles of the Water Framework Directive, coherent planning, taking all pollution sources into consideration at water-body level, will be a requirement from 2009 for all EU member states.

One lesson learnt from regional planning is that planning should be operated with very clear requirements, so that it is easy to implement for the authorities or the individual polluter. The same goes for the objectives; it must be easy to determine whether a objective has been reached or not.

## The Danish water infrastructure

The Danish water infrastructure is operated by approximately 2,700 non-profit companies. The primary functions of the water infrastructure and the non-profit water companies in Denmark are related to:

A. Abstraction, treatment and distribution of the groundwater
B. Collection and treatment of wastewater and "rainwater"

Most of the water infrastructures, including the non-profit companies, are "owned" by the municipalities. A small number are owned by the "end-users" – households and private companies.

The total annual turnover of the water infrastructure companies is €1.5 billion, and app. 5,000 people are employed in the sector. The sector is financed by the users. The fees paid by the users are closely related to water consumption, so the more water you use, the more you have to pay. This pricing policy has been the main driver for the reduction in the abstraction of groundwater by 35-40% over the last 20 years. In Denmark there are approximately 145 private companies producing services, products and technologies for managing and protecting water in Denmark and abroad. The companies had a turn-over of €2.2 billion in 2005, of which around €1 billion from exports. Besides the above water companies, there is a broad group of Danish companies that deliver services, products and technologies to a market where, to a large extent, demand is determined by the intention to reduce pressure on the aquatic environment and optimize the use of water resources. Good examples are producers of enzymes that replace potential pollutants in detergents; or providers of equipment for the agricultural sector that is designed to reduce the loss of nitrogen to the atmosphere and the aquatic environment. Between 1,200 and 1,500 people are employed

in aquatic research at universities and at institutions authorized by the government to facilitate transfer of knowledge and technology to private companies.

The private water companies also support and perform research and development (R&D). About 13% of the private water companies spend more than 25% of their total revenue on R&D activities, and about 61% of the companies are collaborating with Danish research institutions. Other cleantec companies spend an even higher percentage of their total revenues on development.

In 1989 the Ministry of Environment established the National Environmental Research Institute (NERI) as a fusion of five small laboratories under the Environmental Protection Agency. It was a result of an international evaluation of Danish environmental research and the evaluation's recommendation to strengthen internationalization and increase interdisciplinary environmental research. By adding new activities and increasing external funding, NERI has grown from a staff of about 235 in 1990 to about 430 in 2008, when NERI is now part of the University of Aarhus.

Another outcome of the international evaluation of environmental research in Denmark was the establishment of strategic research programmes. These programmes have significantly increased cooperation between relatively small institutes, thus increasing critical mass and they have increased the cooperation between different sectors.

## National action plans for the aquatic environment: from beneficial nutrients to dead fish

In the 1970s general opinion held that excess nutrients in open marine waters in Denmark were not an environmental issue, but they actually benefited fish production. However significant oxygen deficiency in 1981 due to very large landbased discharges of water and nutrients indicated for the first time that this perception was wrong.

Political pressure to do something increased during the 1980s. The NPo-report in 1984 tried to quantify the different sources of nitrogen (N), phosphorus (P) and organic matter, but there was much debate, especially about the agricultural sources.

A TV news report about dead Norwegian lobsters caused by severe oxygen deficiency in large parts of Kattegat in 1986 initiated a period of political discussion, which ended with a parliament decision on the Action Plan for the Aquatic Environment on 10 June 1987.The 1987 Action Plan had an overall objective to reduce emissions of nitrogen to groundwater and surface water by 50% and emissions of phosphorus by 80% within 3-6 years. The plan recognized that agriculture, municipal waste water and industry were by far the main sources of nutrients, and specific reduction targets were established for these sectors (Table 1 and 2).

**Table 2. Nitrogen emissions and emission reductions in the 1987 Action Plan for the Aquatic Environment.**

| Source | Estimated emissions N | Reductions | | Estimated emissions after reduction |
|---|---|---|---|---|
| | t N | t N | % | t N |
| Agriculture | 260,000 | 127,000 | 49 | 133,00 |
| Municipal waste water | 25,000 | 15,000 | 60 | 10,000 |
| Industrial waste water | 5,000 | 3,000 | 60 | 2,000 |
| Total | 290,000 | 145,000 | 50 | 145,000 |

**Table 3. Phosphorus emissions and emission reductions in the 1987 Action Plan for the Aquatic Environment.**

| Source | Estimated emissions P | Reductions | | Estimated emissions after reduction |
|---|---|---|---|---|
| | t P | t P | % | t P |
| Agriculture | 4,400 | 4,000 | 91 | 400 |
| Municipal waste water | 7,200 | 5,200 | 72 | 2,000 |
| Industrial waste water | 3,400 | 2,800 | 82 | 600 |
| Total | 15,000 | 12,000 | 80 | 3,000 |

A national environmental monitoring programme was established in order to document the effect of the measures implemented. Work on common methods for data collection, data storage and data processing was to be intensified by the National Topic Centres in order to prepare technical guidelines. This reflected the need for comparable, standardized data which had become evident in the preparatory work prior to the Action Plan.

The reductions in N and P emissions in urban waste-water treatment plants were implemented by biological treatment with nitrogen removal in plants >5,000 PE to 8 mg N/l and phosphorus removal to 1.5 mg P/l. The monitoring programme documented that the targets had been reached by the mid 1990s and that today emissions are far below these targets. Similarly, the targets for industrial waste water had been achieved by the mid 1990'ies.

## Action Plans II and III

For agriculture, the annual monitoring reports in the mid 1990s concluded that the agricultural measures in the 1987 Action Plan and the Action Plan on sustainable agriculture were insufficient to reach the objective of a 49% reduction in agricultural nitrate leaching.

In 1997 the two research institutes, the National Environmental Research Institute and the Danish Institute of Agricultural Sciences, were asked to evaluate the potential of a number of measures. Based on this evaluation, Action Plan for the Aquatic Environment II, 1998-2003 was decided. The nitrate leaching reduction target was maintained and for the first time Action Plan II included tabled evaluations. The plan contained two types of measures: area-related and nutrient-related and the main effect was due to the nutrient-related measures (Table 3). In particular the 10% reduction in maximum limits for N was an efficient, but also expensive, measure.

**Table 4. Summary of regulatory agricultural measures in Danish Action Plans for the Aquatic Environment**

- Slurry storage capacity
- Slurry spreading regulations
- Mandatory fertilizer plans
- Mandatory wintergreen crops
- Norms for using N in a mal manure
- Improved animal feeding practises
- Catch crops
- Maximum limits for N in different crops
- 10% reduction in maximum limits for N below the economic limit

The evaluation in 2001 demonstrated the need to strengthen some measures, whereas the evaluation in 2003 concluded, that the overall objective of the Action Plan II had been achieved.

To continue the positive development in nitrogen loss and to facilitate the process of implementation of the Water Framework Directive, the Danish Parliament launched a third action plan in 2004, with among other things the goal to reduce the nitrogen loss from agriculture by a further 13% before 2015. So the circle has to be travelled for a third time if Denmark is to live up to the new requirements. Furthermore targets for phosphorus were introduced. The surplus of P in Danish agriculture has to be halved by 2015 compared to 2001/2002 and in order to reduce the diffuse agricultural P losses, 50,000 ha of riparian zones have to be established. Scientific evaluations in 2008 and 2011 were scheduled.

## Monitoring and research: ecological effects on the aquatic environment

The purpose of the national monitoring programme was systematically to collect data in order to assess changes in nitrogen and phosphorus emissions from different sources and sectors to groundwater, lakes, rivers and marine areas and to monitor the ecological effects on the aquatic environment of reduced emissions.

This monitoring programme was to secure collection of standardized and comparable data and make it possible nationwide to report on the state of the aquatic environment.

As an example, leaching models developed through research were used on leaching data provided by the monitoring programme to assess the changes in nitrate leaching from agricultural fields. Later on these models constituted the basis for management systems for approval of livestock farms in a form that is easily operated by municipal staff. This is just one example of how monitoring data is used for other purposes than were originally intended.

The national monitoring programme was revised in 1998 and 2004. In the first ten years, priority was given to NPo-related issues. In 1998 hazardous and toxic substances in the aquatic environment were given priority and since 2004 monitoring of species and habitats as well as ambient air pollution in large cities have been included. In recent years increased focus has been given to EU obligations for data collection and reporting in EU Directives such as

the Habitats Directive, the Nitrates Directive, the Framework Directive on Air Quality and the recent Water Framework Directive.

In the mid 1980s it was realized that agricultural production in Denmark was a dominant source of nitrogen, but that the scientific basis was insufficient to provide a reliable evaluation of different measures to reduce nitrogen emissions. Therefore in the spring of 1986 the NPo research programme was initiated to provide a multidisciplinary and comprehensive study of the entire transport and transformation cycle of nitrogen and phosphorus. In the 1987 Action Plan the need for further marine research was recognized and several research programmes were launched in the following years, the latest being the Action Plan III research programme. New technologies and techniques significantly reduced pollution.

The combined efforts of the regional planning and the action plans to reduce the load of organic matter, nitrogen and phosphorus have been visible in different ways:

- the number of the watercourses with a good biological status has increased from 42% in 1994 to 53% in 2006
- the total load of phosphorus from waste water was reduced by approximately 90% from 1989 to 2005 (see Figure 2)
- the concentration of nitrogen in watercourses was reduced by approximately 30% from 1989 to 2005 (see Figure 3).

These results have been reached despite a growing standard of living in general and increased livestock production in Denmark. This may seem contradictory, but part of the story is that the requirements have forced Danish industries, farmers etc. to develop new techniques and new, less polluting production methods to live up to the stricter standards. On top of that, this has provided Danish industry with a strong position in the international market for environmental equipment and consultancy.

**Figure 2. Development in phosphorus load.**

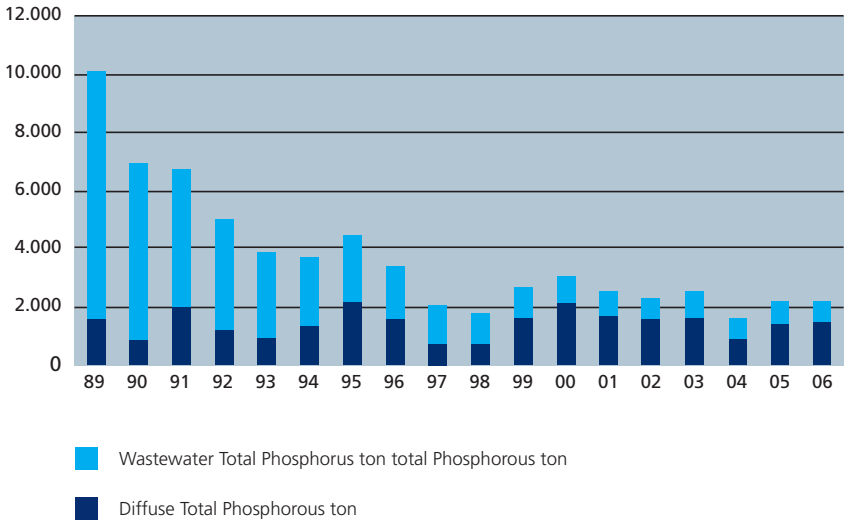
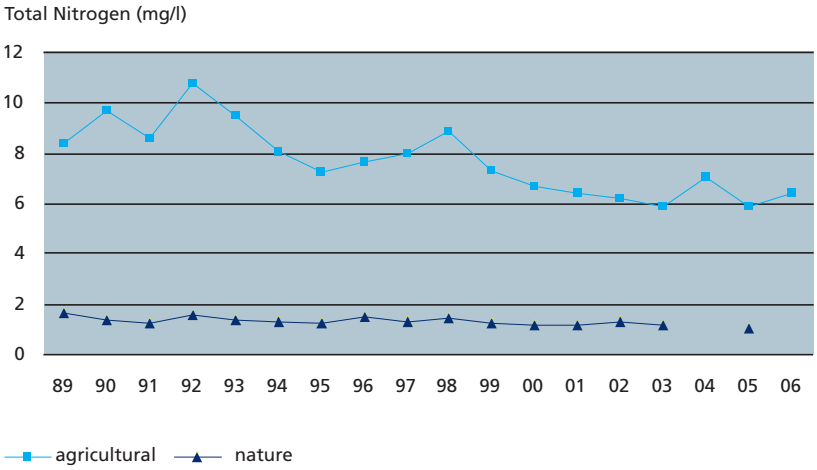


**Figure 3. Development in nitrogen concentration in Danish watercourses.**




Even though the pressure on surface water and groundwater has been reduced significantly over the last 20 years, there are still unacceptable conditions in many aquatic areas and in some areas there is still a long way to go to achieve a good ecological status or groundwater status. For example, it has been estimated, that in addition to Action Plan III a further significant reduction in nitrogen load is needed to meet the requirements for coastal surface water of the Water Framework Directive. So there is still an incentive to develop techniques to improve the utilisation of nitrogen in order to be able to maintain agricultural production with a reduced loss to the environment.

## Legislation and dialogue have achieved results

Nearly all the results have been achieved through some kind of regulation – either general, national regulation or a specific regulation laid down in a licence based on more general national legislation. A very important aspect in all the regulations is the obligation for the authorities both to inspect the installation and, where relevant, to check emissions standards and to enforce legislation etc.

An important part of inspection in Denmark is to establish a dialog with those responsible for the installation to improve the environmental performance of the installation and in this way to avoid further enforcement. In most cases, environmental problems are solved in such a dialog between the authority and those responsible for the installation with the benefit that both parties share ownership of the solution and that it is adjusted to the particular installation. Of course it is not possible in all situations to solve an environmental problem in a dialog, and here it is important that the inspecting authority has the necessary enforcement tools, including the possibility to prosecute the polluter.

A short description of the regulation, enforcement, inspection and financing of the main sectors for water pollution is as follows.

### *Municipal wastewater treatment*

The main steps forward in this area have been achieved through new and more efficient technology for wastewater treatment. The requirements for better treatment over the last 20-30 years have meant a significant change in the infrastructure for wastewater treatment from many small plants with no treatment or only mechanical/biological treatment, to fewer plants with advanced treatment with removal of phosphorus and nitrogen as shown in table 5.

**Table 5: Amount of waste water divided between different kinds of treatment**

| | Without any treatment | Mechanical | Mechanical chemical | Mechanical biological | Mech./biol./chem | Mech. biol., N and P removal |
|---|---|---|---|---|---|---|
| Before 1989 | 10% | 20% | 0,5% | 67% | 2% | 0,5% |
| 2005 | 0 | 0,4% | 0,1% | 3% | 5,3% | 91,2% |

General environmental standards for discharges (EU standards) are laid down in a statutory order, but for most treatment plants, especially for phosphorus and organic matter, the standards are strengthened by the regional authority which ensures fulfilment of objectives in the regional plans. The area is mainly controlled by analysis of the emissions (internal control) and inspection by a national authority.

### *Industry*

Environmental improvement in industry in general and also for wastewater is mainly based on the BAT principle, where the Best Available Techniques can cover the whole process from the selection of raw materials to treatment or pretreatment of the wastewater, with the overall goal to minimize the emissions.

Most industrial facilities producing wastewater are now discharging into a municipal wastewater treatment plant and are ultimately covered by the licences issued to the particular treatment plant. The user-pays principle also applies to this situation. Individual discharges from an industry are also regulated by a licence and the installation pays for investment and operation. Emissions of wastewater are controlled through analysis (internal control) and inspected by national or local authorities, depending of the nature of the production.

### *Agriculture*

The reduction in nitrogen loss to the atmosphere and the aquatic environment from the agricultural sector has been achieved in a number of different ways:

- Technological solutions for storage and management of manure. Regulated through national legislation.
- Measures to change farming methods like catch crops, reduced P application and reduced N standards. Regulated through national legislation.
- Change in land use like buffer zones along watercourses, afforestation and restoration of wetlands. Individual projects carried out by a public institution and with full compensation to the land owner.
- New technologies like biogas production and/or incineration of manure.

Supervision of the agricultural regulation is divided between the local authorities (mainly the actual installations), and a national agency (measures to change farming methods through the fertilizer plans).

## Challenges for the future

A number of challenges lie ahead for the Danish water sector, most of which are connected to the European Union legislation, including

- Implementation of the Water Framework Directive is in focus, and central questions include how do we achieve the objectives? What are the necessary measures to take? How much does it cost? And last but not least, who is going to pay? These questions are being asked all over Europe, and it is certain, that some of the technical solutions we have invented and are using in Denmark to stop or to reduce the pollution are also applicable for other countries. But to reach the objectives in the Directive and still have significant agricultural production requires continued technical development of measures to reduce losses of nitrogen and phosphorus to the Danish aquatic environment.
- Research and development of improved methods for treatment of wastewater and storm flow will probably also be necessary to contribute to the reduction in nutrients required.
- The physical conditions in watercourses. Improvement of the physical conditions in watercourses is vital to living up to the requirements of the Water Framework Directive. Research is needed to describe the measures necessary and to describe the effects and consequences for riparian areas, agricultural land use, protected habitats etc.
- Occurrence and effect of hazardous substances and how to deal with these in the context of the Water Framework Directive. The Danish monitoring programme has shown that a number of biological effects, like change of sex of aquatic snails, may be related to the occurrence of certain hazardous substances. The programme has also generated evidence of the occurrence of pesticides in the upper groundwater, which in the long run could be a threat to the supply of clean, untreated drinking water. The challenge is to reduce the load of hazardous substances either by phasing out the substances or by treatment of wastewater.
- To secure the continued delivery of clean, untreated groundwater for drinking water and water for irrigation and at the same time to secure the necessary amount of water in watercourses to achieve/maintain a good ecological status in watercourses.
- To incorporate the effects of climate change into the context of the Water Framework Directive. There is no doubt that changes in climate like increasing temperature or increasing precipitation (more concentrated and heavy rain) will increase the pressure and have an impact on the status of our water bodies. These effects have to be considered when setting requirements for wastewater discharges or diffuse load from agriculture.

## Danish lessons learnt

Protection of surface water and groundwater has a long tradition in Denmark and many lessons have been learnt – both good and bad. In the following, a number of these lessons are commented.

- Point sources. The pollution load from wastewater – both domestic and industrial - has been reduced dramatically over the last 20-30 years through investment in advanced treatment technology. This has meant a significant change in the infrastructure from many small and insufficient treatment plants to few plants with high technology and advanced treatment.

- Diffuse pollution. Compared to point sources, abatement of diffuse pollution needs different instruments and different controlling measures. It has been possible to reduce the load of nitrogen in particular from the agricultural sector in Denmark, even though the sector has expanded at the same time. The instruments used have been regulation concerning land use and agricultural practise and development of and investment in technology.
- Air pollution. The deposition of nitrogen has been reduced by 20-25% since 1989 due to regulation both in Denmark and in other European countries.
- State of the environment. The load of nutrients and organic matter in Danish water bodies has been reduced significantly over the past 20-30 years, and many water bodies have responded to the reduced load with an improved state. Despite these improvements, there is still a need for further efforts to reduce the load before the Danish water bodies can live up to EU standards.
- Knowledgebased planning and decisions. This is probably the most important lesson, where data is collected both for decision-making and for controlling the effect, including providing the necessary evidence for additional measures to be taken. This is important for national plans like the Action Plans I-III and for plans for individual water bodies.
- Holistic planning, where all sources are taken into consideration at the same time, and not like the Danish approach up to now, with two parallel processes and in two different administrative systems.
- Planning is to a great extend an iterative process, where new knowledge and/or new objectives require new targets. The "management circle" has to be travelled several times.
- A strong connection between a general monitoring programme and researchers, so the monitoring programme is based on scientific principles and the data generated from the programme can also be used for research purposes like developing management models.
- Objectives for water bodies should be individual and reflect the local structural, economic and technical conditions.
- Objectives and requirements should be clear and practicable, so they are easy to implement and easy to control.
- To a certain degree, requirements can be general at national level, but ultimately requirements should be targeted towards the actual needs for the individual water body and the objective laid down. This will ensure that the objective is reached cost-effectively.

- Legally binding requirements are one of the driving forces for innovation and development of new techniques, whether in the agricultural, water-treatment or industrial sector. The necessary public funding should be available for research and technical testing to facilitate this process.
- The advantage of the dialogue between the authority and the person responsible for an installation with their mutual knowledge and the necessary tools for enforcement must be available.
- The necessity to cooperate internationally and to be committed to solving pollution problems in open marine areas.
- Multi-discipline management, where all relevant skills such as engineering, agricultural and biological expertise contribute to the proposals and solutions.

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