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Environment and society

- a review of environmental development in Denmark

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Foreword

This review of environmental development in Denmark has been compiled by the National Environmental Research Institute (NERI) on behalf of, and in close collaboration with, the rest of the Ministry of the Environment. NERI has been responsible for the editing that has been undertaken, as well as for the final wording of the report.

The objective of the report is to collate the results of the research and monitoring that is being undertaken in the environmental area, and in that way establish a scientific basis for the overall political prioritization of environmental endeavours. In order to enable this to be regularly re-evaluated, it is intended to revise this status report at 4-year intervals.

The report can be considered a supplement to the large number of more specialized reports that describe individual problems in relation to the trend in the state of the environment and environmental endeavours. It is an attempt to meet the growing political desire to have a better basis with which to be able to undertake regular across-the-board evaluation of the objectives and impact of environmental policy. At the same time, it is an example of the Danish way of communicating environmental information to a broad political, public and scientific audience - a task that the European Environmental Agency shall undertake at the European level.

This is the first time that NERI and the Ministry of the Environment has prepared a status report of this character. It is not a traditional state of the environment report that just collates existing data on developments in the atmosphere, the aquatic environment, etc. Instead, the report attempts to couple developments in some of the central environmental topics with developments in those sectors of society having the greatest impact on the environment. The reason for this coupling is increasing awareness of the necessity of integrating environmental considerations in all sectors of society.

Many persons have been involved in the preparation of this report, which has materialized in an extremely short time. I would like to take this opportunity to thank all contributors for their efforts.

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1. Introduction

1 Introduction

We have entitled our report "Environment and society - a review of environmental development in Denmark". It summarizes existing knowledge concerning some of the central developmental trends in the state of Denmark's environment and nature, and links these trends with developments in those sectors of society having the greatest impact on the environment.

1.1 Idea and structure of the report

The subject of the report is the Danish environment and the Danish Society. However, as the Danish environment is affected by the world around us, and as Danish society affects the environment outside our national borders, the report attempts to see problems from the international perspective.

It is a difficult task to describe the complex interplay between man and the environment. The ecological processes and relationships in our surroundings are manifold and complex, as are developmental processes within society. The mutual interplay between these two systems is rather complex. A comprehensive description of this interplay must necessarily be an *edited* description where the authors' opinions of what is the central relationship characterize the wording. The information contained in this report is based on many years research and monitoring, as well as on verified statistical data. The National Environmental Research Institute (NERI) has been responsible for the editing that has been undertaken, i.e. of the picture that is painted of the situation. In our opinion it is as true a picture as our present knowledge allows. Nevertheless, we acknowledge that other authors could paint another picture. Debate and discussion of the "pictures" that are painted on the basis of data and statistics are an inevitable step in our seeking after a greater understanding.

When intending to describe the interplay between two systems - the environment on one hand and society on the other - the first question that arises is: what approach should one take?

One can start with the environment, i.e. with the atmosphere, the various segments of the aquatic environment or the terrestrial environment, and then make the connection to the various aspects of society to which the problems are attributable. Alternatively, one can start with society, i.e. with agriculture, industry, the energy sector, the transport sector, households - and then make the connection to the environment.

The first approach provides a good overview of the state of the environment - while the overview of the problems and their relationship to societal structure and development will be more diffuse. If, in contrast, one approaches the subject from the point of view of societal structure, one will obtain a good overview of the technological, economic and organizational correlations that are the basis for the environmental problems, and which environmental policies endeavour to regulate. However, the overview of the effects on the environment will be more unclear.

In this report we have endeavoured to create a synthesis between these two approaches:

In chapter 2, we approach the subject from the point of view of environmental problems - the condition of the environment - and draw connections to those aspects of society that are the cause of the problems. In chapter 3, the starting point is the various sectors of society. The chapter describes the correlation between technological and economic development in society, and the impact that this has on the environment.

As mentioned above, a comprehensive description such as the present is an *edited* description, where the focus is on selected problems and relationships. In the description of the relationship between environment and society, emphasis has been placed on a number of central *themes* that characterize the format of both chapters 2 and 3. The themes that have been emphasized are: Global air pollution; regional air pollution, with emphasis on acidification; the local environment, with emphasis on urban areas; nutrient loading; the groundwater resource; biodiversity; and finally, environmentally hazardous substances. *Figure 1.1* illustrates how the relationship between the various environmental media and the various

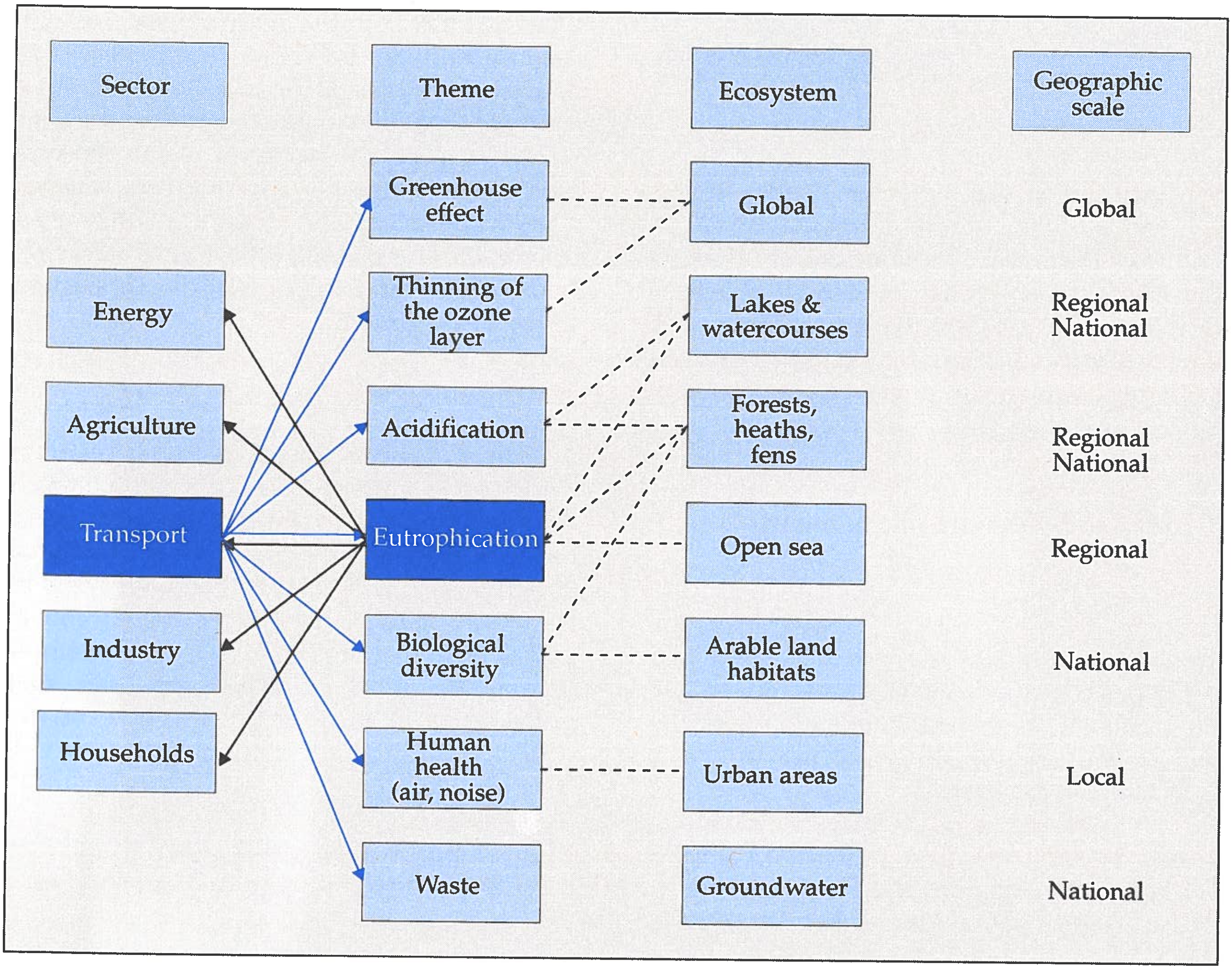


Figure 1.1. Schematic representation of the way that the report links the relationships between environmental ecosystems and sectors of society through selected themes. By way of example, the figure illustrates these mutual interrelationships for the sector transport and the theme eutrophication. (Source: National Environmental Research Institute).

sectors of society is connected through the selected themes.

The method here chosen of presenting the problems using two different approaches - the environment on one hand and society on the other - inevitably means that there is some repetition in the two chapters. On the other hand, we hope that the overall product will provide a more unified picture of the complex problem that the subject comprises.

1.2 Summary

The picture of the "environment and society" that is described in subtle detail in the subsequent chapters is briefly summarized below.

1.2.1 The environmental perspective

Climatic changes: Scientists engaged in climate research are agreed that the increased greenhouse effect is real, and that as a consequence, the Earth's average temperature will tend to increase. The result will be extensive changes in the Earth's climate, changes in the extent of the polar ice masses and an increase in sea level. Furthermore, it is also agreed that the cause of this effect is man's emission of greenhouse gasses, primarily CO_2, that are almost wholly attributable to the combustion of fossil fuels. The amount of greenhouse gasses in the atmosphere has increased by approx. 50% over the last 100 years, and the increase is continuing at the rate of about 0.5% per year. What is uncertain, however, is how great a temperature increase the greenhouse effect will bring about, and exactly what effects this will have.

The UN expert panel has estimated that the global temperature increase will lie between 1.5°C and 4.5°C during the 21st century.

The greenhouse effect lies high on the international political agenda, but it has not yet proved possible to achieve decisive progress in reducing the consumption of fossil fuels on the global level. Neither has it been possible within the EU to agree on a common EU tax on CO_2 emissions, despite the fact that the latter is considered to be a necessary measure to slow growth in the consumption of fossil fuels. Nevertheless, Denmark is still aiming at a 20% reduction in CO_2 emissions from 1988 to the year 2005. The realization of that target will require stricter measures, however.

Depletion of the protective stratospheric ozone layer is continuing, first and foremost in the polar and northern regions. The cause of this is the emission to the atmosphere of chlorofluorocarbons (CFCs). Through a number of increasingly strict amendments to the Montreal Protocol, the last of which was made in Copenhagen in 1992, the phase out of these emissions has been ensured. From the very beginning, Denmark has played a leading role in the endeavour to achieve this result. As a consequence, Danish industry is in the forefront as regards the technological switch over to CFC-free alternatives. Even if the agreements entered into are complied with, the effects now seen on the ozone layer will be detectable for at least 50 years to come.

Regional air pollution: In addition to having global climatic effects, the discharge of substances to the atmosphere also has regional and local effects. This is attributable to the discharge of acidifying substances, especially sulphur and nitrogen compounds, as well as other substances such as heavy metals, various hydrocarbons (VOCs), etc., many of which are harmful to health and the environment. While international agreements have successfully brought about a marked reduction in the emission of sulphur compounds in Europe, emissions of nitrogen compounds (NO_x and NH_3) has not yet been reduced. Total acidification has thus been reduced, but remains far above the level necessary to prevent it continuing to have a negative impact on sensitive ecosystems. Damage to Norwegian and Swedish lakes and to coniferous forests, especially those in central Europe, is therefore still widespread. Especially sensitive ecosystems are also affected by acidification and nutrient deposition in Denmark. This applies to lakes in limestone-poor mid and western Jutland, as well as to heathland and upland bogs, and to coniferous forests in sandy soil areas.

Heavy metal emissions from industry and power plants have been reduced considerably, and with regard to VOCs (volatile organic compounds), negotiations at the EU level have been concluded concerning a reduction plan. VOCs contribute to the formation of ozone at ground level, where it is harmful to health and the environment. The ozone concentration in central Europe is enhanced, and is tending to increase further.

The urban environment: Air pollution has previously had considerable local effects on health, not least in urban areas. The problem has by and large been curtailed by the implementation of stricter emission standards for enterprises and power plants, through regulations concerning smoke stack height, and through the migration of polluting industry out of urban areas. An exception from this general tendency, though, is the emission by traffic of NO_x, hydrocarbons and particulates, all of which have increased over the 1980s.

The introduction of stricter vehicle emission standards combined with natural replacement of older vehicles is expected to result in the halving of these emissions by the year 2010. Traffic will continue to cause environmental problems in urban areas, however, not least because continued growth in this sector is expected in the 1990s. Traffic has the effect of creating marked barriers to the inner life of towns, and is the cause of traffic accidents and most of the noise nuisance in urban areas. About 500,000 homes are subject to traffic noise exceeding 55 dB(A), a level at which approx. 15% feel bothered. The noise problem is politically acknowledged as being serious, and a large number of measures have been implemented over the last 10-15 years. These have markedly reduced the number of seriously affected homes, although it has been difficult to achieve decisive general improvements, not least because of traffic growth.

Another serious problem in urban areas is that of "the sins of the past", i.e. the many contaminated sites, most of which are located on former industrial areas. The groundwater (on which virtually all Danish drinking water supplies are based) is therefore threatened in some urban areas, and in certain places, has had to be abandoned, e.g. in some areas of Copenhagen. In addition, the contaminated sites limit land usage in urban areas. Endeavours so far undertaken have mainly concerned the registration of the extent of the problem, serious efforts to start remediation work having not yet been taken. The reason for this is partly that thorough remediation using current technology is extremely costly to society.

Another relevant aspect of urban areas is that they have been and still are the subject of many serious environmentally founded initiatives. Because people and enterprises congregate in urban areas, many environmental problems are associated with urban life; at the same time, however, that very same concentration provides the possibility to solve some of the problems. Thus Denmark's pioneering role with respect to reducing energy consumption is to a large extent the result of the endeavours made concerning the development of combined power/district heating plants in urban areas. The same applies to the development of sewage treatment and waste handling. These endeavours, which are mainly directed towards the urban area, can still be strengthened further. A more concerted focus on "urban ecology" experiments and initiatives in the 1990s would have the effect of providing further impetus to environmental endeavours in urban areas.

The aquatic environment - eutrophication: The aquatic environment has attracted considerable public attention over the last 10 years, with the focus having been directed at nutrient loading. The Action Plan on the Aquatic Environment was the most extensive environmental political initiative in Denmark in the 1980s. It aimed at correcting both the deteriorated environmental condition of Danish inner marine waters, which is primarily attributable to nitrogen discharge, as well as the poor condition of Danish lakes, which is primarily attributable to phosphorus discharge. The phosphorus concentration in the lakes *has* fallen during the 1980s, especially after the adoption of the Action Plan on the Aquatic Environment in 1987, first and foremost because of reductions in loading with urban waste water. However, the water quality targets set have not yet been achieved, the phosphorus concentrations still being too high. This is partly attributable to the release of phosphorus that accumulated in the sediment previously, but also to the fact that loading from sparsely built-up areas and from agriculture have not yet been reduced.

As far as concerns the coastal areas and the open sea, there are only sporadic indications of an improvement. While in some areas, e.g. Limfjorden, there are signs that submerged macrophytes have begun to recolonize areas where they were previously found, this is not a general tendency. Riverine nitrogen loading of the marine environment has not been reduced. About 70% of loading from the land is attributable to agriculture, and the Action Plan on the Aquatic Environment target that this should be halved is far from being fulfilled.

Groundwater: Denmark has a unique groundwater resource compared with other countries, both the quantity and quality being high and 99% of drinking water consumption being based on groundwater. This situation is subject to a number of threats, however. Thus nitrate concentrations exceeding the maximum admissible concentration of 50 mg/l have been detected in 13% of the groundwater resources, mainly in mid Jutland, Djursland and at Ålborg (this pattern being attributable to a combination of agricultural practice and soil conditions). In connection with the Action Plan for Sustainable Agriculture it has been decided to implement a special initiative in approx. 50,000 ha of these areas, the gist of which is that the farmers will be given compensation in return for reducing fertilizer and pesticide consumption.

In addition, pesticides have recently been detected in a number of groundwater monitoring boreholes, as well as at very low concentrations in certain water supply boreholes. It is still not completely clear how the pesticides are transported to and through the aquifers, nor from what sources they originate. In addition to nitrate and pesticides, the groundwater is also threatened by the leaching of organic compounds from point sources, especially contaminated sites. In certain localities contamination is so great that remedial measures such as the pumping of water from around the source have been inadequate. In such cases it has been necessary to shut down water supply abstraction boreholes, e.g. as at Esbjerg and in Greater Copenhagen.

For the country as a whole, there is still sufficient groundwater to satisfy current consumption. However, there is great local and regional differences in both groundwater regeneration and in the possibilities for water abstraction as determined by the geological conditions. In certain localities, e.g. on Zealand, water abstraction has caused the groundwater table to sink 5-10 m, the consequence being summer dry watercourses and a reduction in wetland area. In addition, this can lead to saline water penetrating into the freshwater aquifers from below or alongside, as well as to the formation of sulphate. It is therefore necessary to take a differentiated approach to the groundwater problem. In addition, the variation in precipitation that has been observed over the last century can have considerable impact on groundwater regeneration and hence on the magnitude of the groundwater resource. At present, we are in a period of relatively high precipitation as compared with earlier, but history teaches us that this can rapidly change. A few-year long period of low precipitation would have considerable impact on the magnitude of the groundwater resource.

Biodiversity: The proportion of cultivated land in Denmark has remained stable for most of this century, accounting for approx. 60% of the total land mass. During the same period, however, there has been a considerable increase in the urban area at the expense of natural ecosystems and less intensively utilized areas. Natural ecosystems such as freshwater meadows and saltwater meadows, commons, heaths, fens, ponds, small watercourses, hedgerows and thickets have therefore been on the decline. The result is a more homogenous landscape with fewer habitats for wild animals and plants. The more industrially oriented agriculture and the fragmentation of nature caused by the development of urban areas and the transport infrastructure exert further pressure on the fauna. The consequence has been that a number of plant and animal species have declined considerably, especially those associated with heaths and water bodies. It is estimated that 456 species are acutely threatened, 880 are vulnerable and 1,146 are rare. Since 1850, 353 species have disappeared from Denmark, of which 5 disappeared in the 1980s.

In order to counteract this trend - which is a reflection of the general international trend - both national and international agreements have been entered into and a number of measures have been implemented. Under the terms of the Biodiversity Convention, which arose from the UN Conference on Environment and Development in Rio de Janeiro in 1992, as well as of a number of more specific conventions, signatory countries are compelled to endeavour to preserve biological diversity. To this end, Denmark has established special protection of 10,000 km^2 aquatic areas of special significance to bird life; the Protection of Nature Act has been amended to include general protection of existing heaths, fens, water bodies, lakes, watercourses and similar habitats; reserves have been established covering 4% of the country, and a number of animals and plants have been assigned protected status. In addition to this defensive approach to protection, more offensive goals have been formulated concerning afforestation - a doubling of forest area over the next 80-100 years - and ecosystem restoration. Thus from 1989-92, DKK 130 million was used annually for the reestablishment of lakes, watercourses, ponds, etc.

Environmentally hazardous substances: About 20,000 chemical substances are in use in Denmark, and about 100,000 in the EU as a whole. The majority of these are only used in relatively limited quantities, however. About 2-3,000 of the substances are produced in amounts exceeding 1,000 tonnes per year in the OECD region. In the case of new substances released on the market, legally binding regulation is undertaken on the basis of laboratory investigations of the substances' characteristics, emphasis being placed on their toxicological properties, their degradability in the environment, and the extent to which they accumulate in biological material. For these substances, the provision of information about the above mentioned properties is legally mandatory. In the case of chemical substances that have been marketed since before 1981, no corresponding regulations are in force, and only a limited number of the substances have been investigated.

It is only possible to undertake systematic monitoring of the environmental occurrence of just a few of the substances. Such monitoring is to some extent carried out with certain heavy metals, organic environmentally hazardous substances and pesticides. In the case of the heavy metals lead, cadmium and mercury, there has been a marked decrease in discharge - especially to the air, and hence a corresponding decrease in airborne pollution with these substances. However, as heavy metals have accumulated in the environment, for example in marine sediment, a corresponding decrease in concentration is not seen in fish, etc. The same applies for a number of organic environmentally hazardous substances such as PCB, DDT and lindane, whose use has been prohibited, but which still circulate in the environment, albeit that concentrations are decreasing.

Pesticide consumption is currently less than at the end of the 1970s, but pesticide efficacy has increased. Thus when expressed in terms of their biological activity (the so-called treatment frequency factor), consumption of pesticides has not tended to decrease, and the objective of the Action Plan on Pesticides has not been fulfilled in this regard.

1.2.2 The societal perspective

General economic development: The value of society's total production expressed in fixed prices has increased from approx. DKK 500,000 million in 1970 to approx. DKK 780,000 million in 1992, a growth of 57%. The value of industrial production in fixed price terms has increased approx. 35% during the same period, while agricultural crop production in quantitative terms has increased 150%, pig production has increased by 60%, while milk and beef production have remained largely unchanged. Employment has fallen markedly in the agricultural sector, slightly in the industrial sector, and has grown in the public and private service sectors. This economic trend is described as a shift from an industry-oriented society to a service-oriented society. However, there is nothing to indicate that this service-oriented society is *per se* less demanding of resources or has less impact on the environment, the development of the service-oriented society so far having been accompanied by increasing material production.

Energy: Despite considerable growth in production over the last 20 years, it has proved possible to keep energy consumption approximately constant through specific political endeavours. The main reason is the reduction in household energy consumption for heating purposes, this having fallen 30% per m^2 housing area. On the other hand, household energy consumption for transport purposes and electricity consumption has increased. Commercial enterprises, which account for 2/3 of the country's energy consumption, have managed to become more energy effective. This applies particularly to the primary trades and industry, whereas the service sectors (which represents 50% of total energy consumption by commercial enterprises) have not increased energy effectiveness. Seen as a whole, growth in production has led to an increase in energy consumption by commercial enterprises despite the increased energy effectiveness. The Energy Action Plan from 1990 aims at a 30% reduction in CO_2 emissions associated with energy consumption (excl. transport fuels) by the year 2005, in relation to the level in 1988. As emissions from the transport sector are expected to increase, the total effect will be a reduction of approx. 20%. The latest assessment from the Ministry of Energy is that it will be extremely difficult to achieve these goals without the implementation of further measures. The Minister of Energy therefore introduced to parliament in November 1993 a number of bills intended to facilitate the achievement of these goals.

Transport: During the 1980s, traffic increased 40% expressed in terms of kilometres travelled, i.e. a rate of growth almost double that of the general economic growth. This is mainly attributable to the fact that passengers and goods are transported over longer distances. Because of this growth, the transport sector has accounted for an increasing share of CO_2, NO_x and hydrocarbon emissions. In the case of CO_2, this trend is expected to continue since transport emissions are expected to increase by 20%

between 1990 and 2010. A precondition, though, is a marked improvement in motor vehicle energy effectiveness. In the case of NO_x, hydrocarbons, particulates and CO, the inclusion of catalytic convertors on new vehicles is calculated to lead to a halving of emissions over the next 15 years or so.

Agriculture and forestry: Since the 1970s, agricultural production has been characterized by: a markedly increasing production, especially of plant products and pork; a marked fall in the number of farms, especially the smallest; a fall in employment; an increase in farm size; considerable specialization of farms; and the geographic concentration of crop farms in eastern Denmark and cattle farms in western Denmark. The increasing quantitative production has been accompanied by falling prices, the result being that agriculture's share of gross domestic product at factor cost has fallen from 6% to 3% since the 1970s. The basis for the increasing production has been partly attributable to increasing consumption of commercial fertilizer, especially in the 1970s. At the same time, the increasing pork production has led to a growing amount of animal manure. Calculations indicate that the nitrogen utilization rate is low, especially on farms with large livestock herds. Animal manure is not used effectively and leaching of nitrogen from agriculture is not falling. The goal stipulated in the Action Plan on the Aquatic Environment was a reduction of 127,000 tonnes. The initiatives already implemented, including the EU agricultural reform, are only estimated to reduce loading by approx. 50,000 tonnes.

The marked growth in agricultural production has caused problems with food surplus in the EU. Thus the future trend in EU agricultural policy will be to curb growth in production. One means of achieving this aim is to transfer agricultural land to other uses, including forestry. In Denmark, it is intended to double the area of forest over the next 80-100 years, among other reasons, because of the positive impact that forests have on nature and the environment - as well as their value as recreational areas. However, there is a financial problem associated with achieving this goal, falling world prices for wood and cellulose having made afforestation currently less attractive. A doubling of the area of forest over the next 80-100 years is equivalent to the planting of approx. 5,000 ha per year. In the last few years, total state and private afforestation has amounted to less than 2,000 ha per year.

Industry: As mentioned previously, the value of industrial production in fixed price terms increased by 35% between 1970 and 1992. This was achieved with a work force that concomitantly fell from 560,000 to approx. 500,000. The food, drink and tobacco industry, metals industry and chemicals industry are the dominant industries, together accounting for 75% of production value. Industrial discharge of environmentally hazardous substances derived from production processes has been reduced considerably over the last 10 years. This is mainly attributable to the installation of purification equipment, better process control and, to some extent, the implementation of newer and cleaner technology. Even though there are still problems with discharges from industrial enterprises, interest is more and more centred on industrial consumption of resources - including energy - as well as on the further fate of the products, including associated waste problems.

Households: From 1981-91, household consumption increased by approx. 20% expressed in fixed price terms. The most marked growth has been in areas such as medicine, transport, leisure goods and foreign travel. As far as concerns energy, households have reduced consumption for heating purposes but have increased consumption for transport and electricity. Water consumption has been stagnant, or slightly decreasing. As many as 93% of households are currently connected to sewage treatment plants; when the Action Plan on the Aquatic Environment is fully implemented, the plants will employ mechanical, biological and chemical treatment methods. Household waste production is still increasing, but is increasingly being incinerated or recycled. According to the government's Action Plan on Waste and Recycling, the goal is to increase the recycling of household waste from the current level of 16% to 50% by the year 2000. Households use large amounts of environmentally foreign substances for washing, cleaning, house and car maintenance, etc.

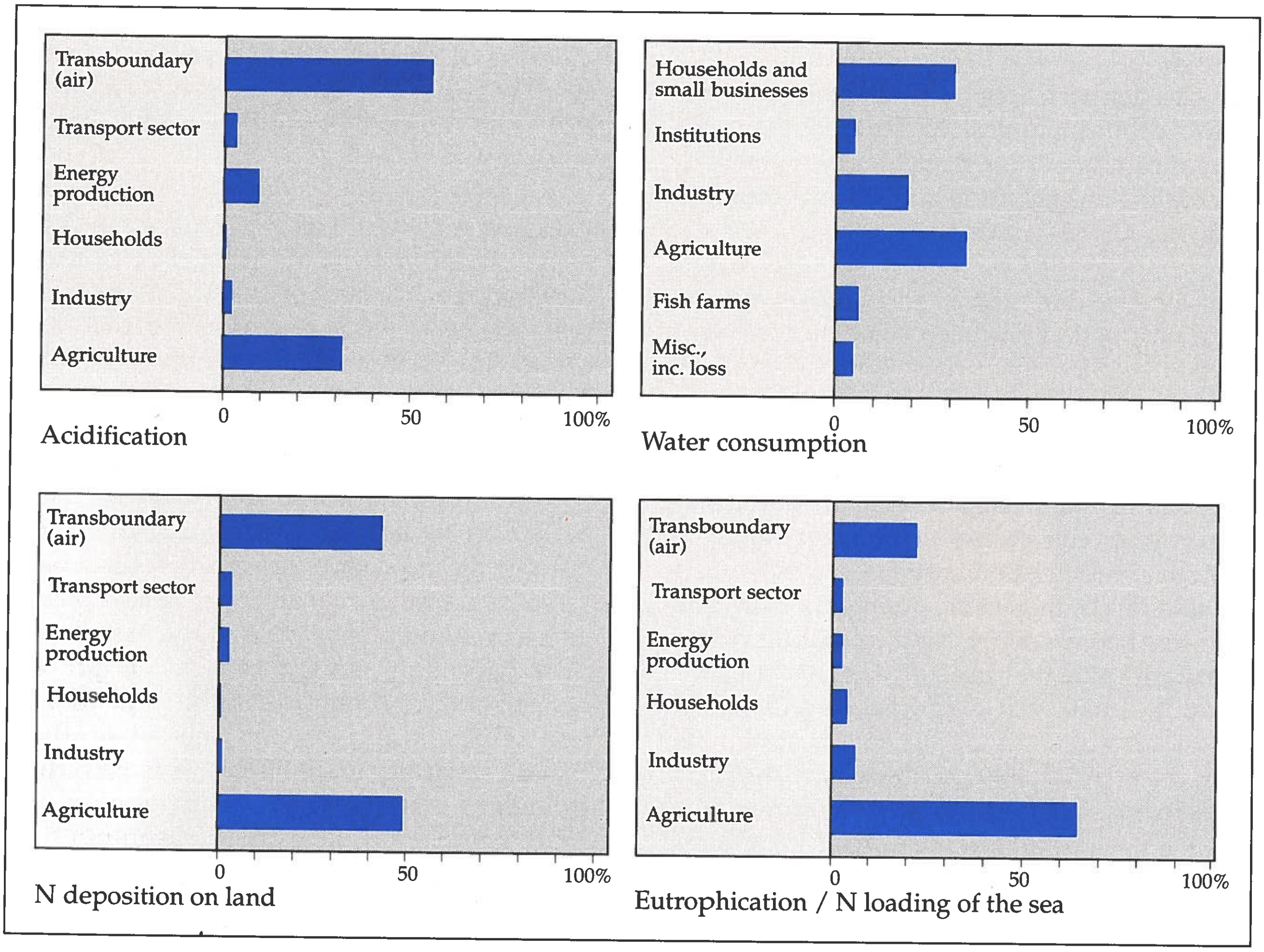


Figure 1.2. Sector profiles showing the relative contribution made by different sectors of society and transboundary import to environmental impact within selected environmental themes. (Source: National Environmental Research Institute).

General summary

With a number of the environmental themes that are described in section 1.2.1, the effects observed are attributable to simultaneous impact from several sectors of society. In a number of cases, in which there is a simple relationship between cause and effect, it is possible to quantify the individual sectors' relative contribution to total environmental impact. This applies to contribution made by the different sectors to acidification, eutrophication of the terrestrial and marine environments, as well as exploitation of the water resources. Sector profiles showing the relative contribution of the above mentioned sectors together with transboundary import are depicted for these themes in *Figure 1.2*.

As is apparent from these sector profiles, transboundary "import" accounts for a considerable part of total acidification of and nitrogen deposition on the Danish environment. However, it should be remembered that Denmark's "export" of these problems is also considerable.

The overall picture that can be painted of the development in the relationship between society and the environment is that the efforts made on the environmental front over the last 10-20 years have had considerable influence on the way society has developed, as well as on the environmental impact of society. Direct discharges from industry and households have largely been brought under control. A number of environmentally hazardous substances have been prohibited or their use markedly curtailed. To a certain extent, it has been possible to uncouple economic development and energy consumption such that the latter has been stabilized despite increasing production. Throughout society, processes and activities have been implemented that aim to reduce the environmental impact and resource consumption; in many cases, the effects of these initiatives are apparent in the environment. For example, airborne pollution with sulphur and heavy metals has been considerably reduced, phosphorus loading of Danish lakes has fallen markedly and a number of environmentally hazardous organic substances are in the process of being phased out. In the case of some of these improvements, however, it will be many years before a real effect on the environment will be detectable. This is because the compounds have previously accumulated in the environment's various compartments, and will therefore take many years to remove by natural means. Examples include CFCs in the stratosphere, phosphorus in the lakes, heavy metals in marine sediment, PCB in the sea, etc.

In other areas, however, it is very difficult to identify any progress. This applies to nitrogen loading of the aquatic environment, as well as to the safeguarding of a varied landscape with a diverse flora and fauna. It applies to the growth in traffic and in waste production, as well as to a general noticeable reduction in resource consumption by society. As far as concerns energy, it has proved possible to become more energy-effective and, especially with respect to household heating, to actually reduce consumption. However, the general economic growth offsets the increased effectiveness, and it has become apparent that it will be extremely difficult to achieve a real reduction with the measures hitherto implemented. It is characteristic of those areas for which it is difficult to identify any progress that they are exactly those areas where man and society are faced with the fundamental choice between on one hand, our present pattern of consumption and production, and on the other hand, nature and the environment.

2. State of the environment

2.1 Air pollution - global effects

2.1.1 Introduction

Mankind's activities have now grown to such a level that they markedly affect the composition of the atmosphere. The presence in the atmosphere of a number of anthropogenic gasses can both affect the climate, by enhancing the greenhouse effect, and lead to depletion of the atmospheric ozone layer, that protects life on Earth against ultraviolet radiation from the sun.

The greenhouse effect is *per se* a natural phenomenon, and a necessary precondition for the maintenance of life on Earth. So what is meant by the "greenhouse effect" in this context is the *enhancement of the greenhouse effect* as a result of anthropogenic gas emissions. The question is no longer whether the Earth's mean temperature has increased over the last 100 years, but more to what extent that increase is attributable to mankind or is caused by natural climatic variation, and how serious the consequences of a continued temperature increase will be for the various parts of the world.

The *greenhouse effect* and *depletion of the ozone layer* should be considered together since they are partly coupled through a number of physical and chemical processes in the atmosphere and by the fact that some gaseous compounds affect both the greenhouse effect and the ozone layer, e.g. the so-called CFCs (chlorofluorocarbons and halons). While it is unanimously agreed that CFCs both enhance the greenhouse effect and deplete the ozone layer in the upper part of the atmosphere (the stratosphere), it is less certain how these two phenomena interact.

It is likely that depletion of the ozone layer can reduce the global warming at the Earth's surface caused by the greenhouse effect. In that case, the effective greenhouse effect of CFCs will be less than previously expected. Concomitant with the depletion of the stratospheric ozone layer, increasing concentrations of ozone have been registered in the lower atmosphere (the troposphere), this being attributable to increased emissions of nitrogen oxides and hydrocarbons. It is known that ozone is a greenhouse gas, but its efficacy relative to CO_2 has not yet been determined.

2.1.2 The greenhouse effect

The UN Intergovernmental Panel on Climate Change (IPCC) is of the view that the enhanced greenhouse effect can lead to climatic changes on Earth; however, proof is lacking that the 0.3-0.6°C temperature increase recorded over the last hundred years is attributable to human activity. Moreover, since natural variation in global mean temperature is so great, it is unlikely that such proof will be forthcoming within the next 10 years. Current decisions to reduce emissions of greenhouse gasses have thus to be made not on the basis of proof, but more as a safety measure.

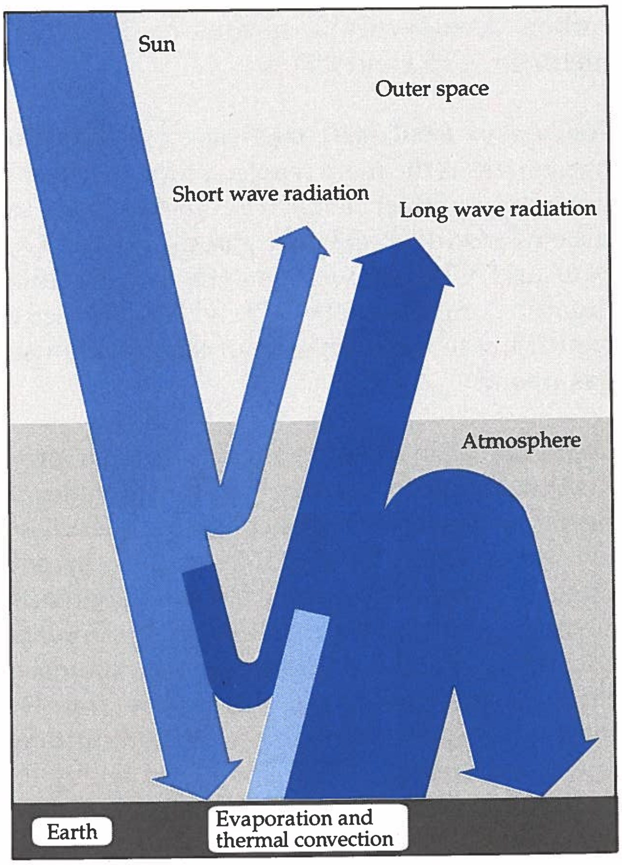


Figure 2.1.1. Global energy balance. Approximately 2/3 of the short wave solar radiation is absorbed by the Earth and its atmosphere, subsequently to be reflected as long wave radiation. Greenhouse gasses are able to effectively absorb the long wave radiation emanating from the Earth. If the gas concentration is increased, a new energy equilibrium will be reached at a higher temperature, i.e. the Earth will be warmed up. (Source: National Environmental Research Institute).

Causes of the greenhouse effect

The Earth's climate, and hence its temperature, are determined by the global energy balance. Only about 1/3 of the short wave radiation reaching the Earth's atmosphere is reflected back to space as short wave radiation, the rest being absorbed by the atmosphere, the oceans and the land masses (*Figure 2.1.1*). While the incoming solar radiation easily penetrates the atmosphere, most of the reflected or emitted radiation is long wave radiation that is to a greater extent absorbed by gasses in the atmosphere - including greenhouse gasses deriving from man's activities. The net effect, which is warming of the Earth, is termed the greenhouse effect. If the Earth were completely without an atmosphere, it would be approx. 35°C colder than it is.

Greenhouse gasses

The most important greenhouse gasses are carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and CFCs.

The use of fossil fuels such as coal, oil and natural gas is the main reason for the increased greenhouse effect. Their combustion leads to the emission of greenhouse gasses such as CO_2, N_2O and CH_4, as well as NO_x and volatile organic compounds (VOC), which indirectly contribute to the formation of the greenhouse gas ozone.

Deforestation in order to increase timber production and provide more land for agricultural purposes is another major cause, being estimated to account for 15-25% of the current increase in the CO_2 concentration, and perhaps as much as 10% of the increase in CH_4. Forests consume CO_2 while building up their biomass through photosynthesis. In mature forests, there is an equilibrium between the production and consumption of CO_2. However, felling or burning forests leads to the net release of CO_2 from the cleared areas.

Foodstuff production, which is a third major cause, is estimated to account for approximately half of the anthropogenic CH_4 emissions and a significant part of the N_2O emissions. These emissions have increased concomitantly with the increase in the total area cultivated with rice, the increase in livestock herds and the increased utilization of nitrogen fertilizers. Methane is formed by the degradation of organic matter under anaerobic conditions, e.g. in paddy fields, and by ruminating animals. Nitrous oxide forms when nitrogen fertilizers increase the nitrate content of the soil; under anoxic conditions, the nitrate can be converted to gaseous N_2O (denitrification).

Industrial use of CFCs for various purposes is a fourth major cause (cf. 2.1.3 below). CFCs are purely anthropogenic greenhouse gasses, and are not naturally occurring in the atmosphere.

Global emissions

The various greenhouse gasses do not have the same impact per kg emitted. Of decisive importance is their concentration in the atmosphere as well as their ability to absorb long wave radiation. Just as important is their lifetime in the atmosphere, as this determines how great a concentration can be built up within a given time horizon.

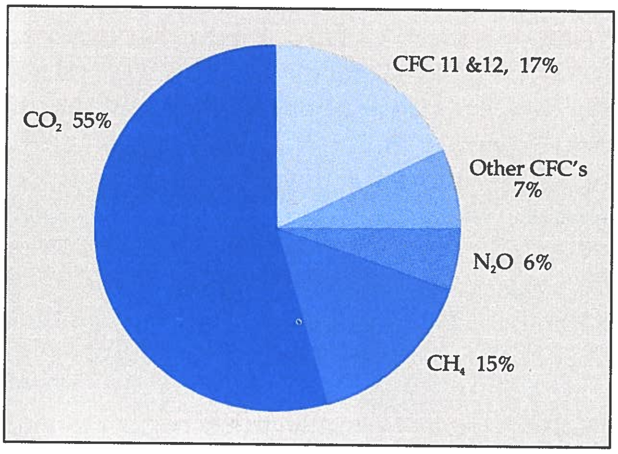


Figure 2.1.2. The most important greenhouse gasses shown apportioned according to their relative contribution to the increase in the greenhouse effect, expressed in terms of CO_2 equivalents (global warming potential). (Source: IPCC, 1990).

The lifetime of a gas in the atmosphere is determined by the balance between the most important sources and the most important sinks. In the case of CO_2, the latter comprises the oceans, the atmosphere and the whole biosphere. CO_2, CFCs and N_2O all have a long lifetime, and are only slowly removed from the atmosphere. If the emission of these gasses is changed, it can therefore take from tens to hundreds of years before the atmospheric concentration has fully adjusted to the new equilibrium. If anthropogenic CO_2 emissions

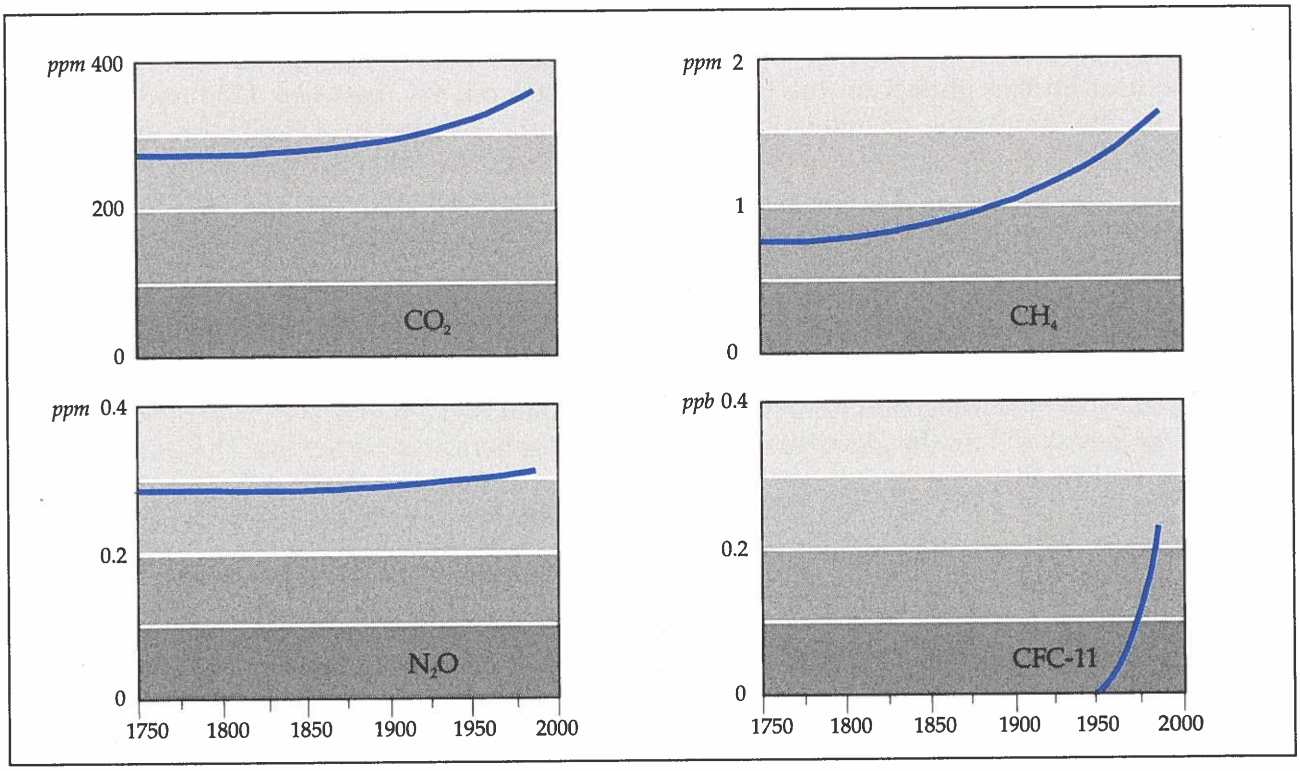


Figure 2.1.3. Trend in the atmospheric concentration of the most important greenhouse gasses. (Source: IPCC, 1990).

- CO_2 concentration is currently increasing by 0.5% per year, and accounted for approx. 55% of the increase in the greenhouse effect during the 1980s.
- CH_4 is currently increasing by approx. 0.75% per year, and accounted for approx. 15% of the increase in the greenhouse effect during the 1980s.
- N_2O is increasing by 0.2-0.3% per year, and accounted for approx. 6% of the increase in the greenhouse effect during the 1980s.
- CFC gasses increased by approx. 4% per year until 1990, and accounted for approx. 24% of the increase in the greenhouse effect during the 1980s. Since 1990 the rate of increase has declined.

Box 2.1.1. Growth in the atmospheric concentration of the most important greenhouse gasses.

were reduced to zero now, approx. 50% of the increase attributable to previous emissions would still be detectable in the year 2100.

The contribution of the various substances to global warming is normally compared over a horizon of 100 years expressed as CO_2 equivalents on the basis of their global warming potential (GWP) (*Figure 2.1.2*). It should be noted that the calculations in *Figure 2.1.2* are based on the GWPs given by the IPCC in 1990, GWPs which have subsequently proved to be subject to considerable uncertainty (IPCC, 1992).

Since the start of industrialization in the last century, the atmospheric concentration of greenhouse gasses has increased by 50% expressed in terms of CO_2 equivalents, even though CO_2 itself has only increased by 25%, i.e. the level of other greenhouse gasses has increased more rapidly. The atmospheric concentration of most greenhouse gasses is currently increasing (*Figure 2.1.3 and Box 2.1.1*). The same applies to CFCs, although emissions are expected to fall to almost zero around the year 2000 as a result of international agreements to phase out these substances in order to protect the ozone layer (cf. section 2.1.3).

Climatic changes - scenarios

Assessment of human impact on the Earth's climate and the forecasting of trends involve three steps:

- prediction of growth in the population, energy consumption, foodstuff production, etc., and calculation of the consequent greenhouse gas emissions (scenarios),
- evaluation of the future composition of the atmosphere based on the global chemical cycle, and finally,
- mathematical modelling of the climate using large computers.

The climatic models currently used for this purpose are exceedingly complex, and are based on a number of questionable assumptions that are extremely simplified in relation to the world that they are supposed to describe.

The description of the global climate system is particularly subject to uncertainty. The large oceans can absorb large amounts of heat energy and CO_2, which is the most important greenhouse gas. Perhaps half of all anthropogenic CO_2 emissions can be absorbed by the oceans and the terrestrial part of the biosphere over the next 100 years. However, warming of the oceans will increase the evaporation of water (which then also serves as a greenhouse gas), and the warming of the polar tundra might increase CH_4 emissions, and thereby enhance the greenhouse effect. Increased cloud cover can also influence any temperature increase, although the magnitude and even the direction of the temperature change is uncertain. The effect will depend on such factors as cloud height, the time at which the clouds appear, etc.

The first report of the IPCC, issued in August 1990, described future trends with the aid of various scenarios. In the baseline scenario, the so-called "business-as-usual" scenario, the trend is projected up to the year 2010 on the basis of continued coal-intensive energy production and without control being imposed on agricultural emissions of nitrous oxide and methane.

These model calculations showed that the mean temperature of the Earth could increase by approx. 4°C between 1850 and 2100; the forecast is subject to considerable uncertainty, however. In other scenarios, in which it is assumed that more or less drastic measures will be implemented to curtail greenhouse gas emissions, the temperature increase is delayed, but not completely avoided.

In the latest model calculations, greater consideration is given to heat exchange between the atmosphere and the oceans. These calculations indicate that the Earth will warm up more slowly than previously predicted, and that by the year 2100, mean temperature will only have increased by 3°C in relation to the present temperature (*Figure 2.1.4*).

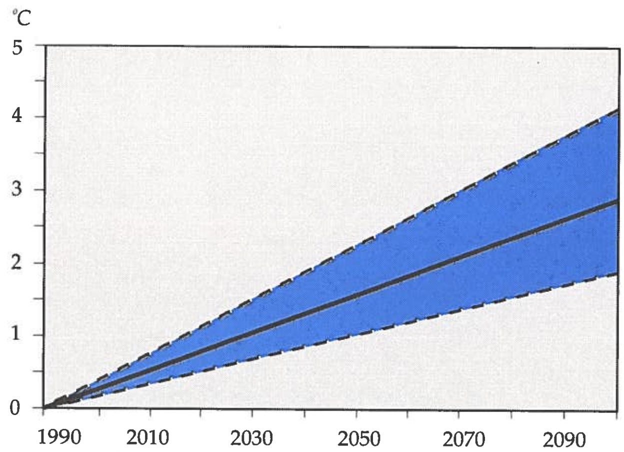


Figure 2.1.4. Calculated increase in the Earth's mean temperature under the "business-as-usual" scenario. The solid line indicates the most probable course. The blue field indicates model uncertainty. (Source: IPCC, 1992).

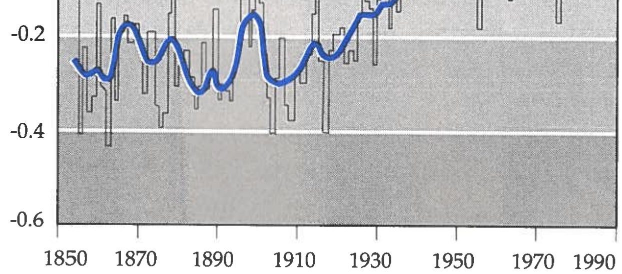


Figure 2.1.5. Change in the Earth's temperature since 1850 expressed as deviation from the mean temperature for the period 1951-80. (Source: Fenger & Torp, 1992).

It appears that the global temperature *has* already increased by about 0.5°C (*Figure 2.1.5*). While this is in good overall agreement with the model calculations, it could also be due to climatic variation. In Denmark, in contrast, the temperature has not increased since 1940 (Figure 2.1.6).

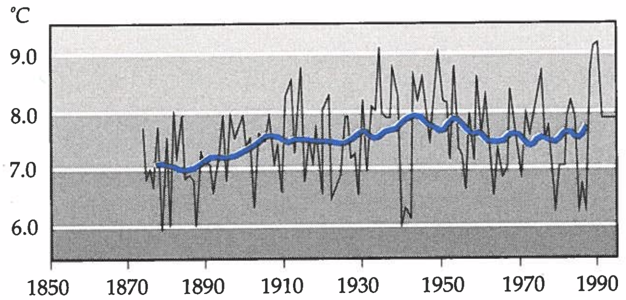


Figure 2.1.6. Change in temperature in Denmark over the last 100 years expressed as both the annual mean and the sliding 20 year mean. (Source: Fenger & Torp, 1992).

Effects of climatic changes

The calculated increase in temperature will be accompanied by changes in wind and precipitation patterns that together may affect agriculture, forestry, fishery and nature. Studies undertaken by the International Institute for Applied Systems Analysis in Austria thus show that the great European vegetation belts will be displaced approx. 1,100 km north if there is an average temperature increase of 5°C and a 10% increase in precipitation. For Danish agriculture, this will provide the advantage of a prolonged growth season. For example, the boundary of the area in which maize can ripen will move from northern Germany to central Scandinavia. There are also disadvantages, though, such as increased distribution of insect pests and plant diseases.

Even if the net result is advantageous to certain countries, including Denmark, it is feared that the calculated changes in climate will be detrimental to foodstuff production in general - especially in central areas of the large continents such as USA, which risk being hit by drought.

Although it will be possible to counteract many of the disadvantages, e.g. by artificial irrigation of crops or changes in crop selection, human intervention will be more difficult in the case of natural ecosystems and forests. Moreover, it is doubtful that the possible climatic changes will be slow enough to enable continuous adaptation to take place as the vegetation belts move north.

Climatic changes will not only affect the environment *per se*, but will also be able to modify environmental effects of other types. Thus a warmer, more humid climate will accelerate degradation of materials by air pollutants, increase the sensitivity of vegetation to air pollution, and will even be able to affect nutrient leaching.

An increasing sea level could lead to problems such as increased coastal erosion, straining of dyke systems and direct flooding of unprotected, low lying areas. Encroachment by salt water could also threaten the drinking water supply and sensitive ecological systems in coastal areas. A number of European river deltas are vulnerable, but the greatest problems will probably arise in the third world countries, which do not have the technology necessary to defend the coastline. A coral reef nation such as the Maldives, where 200,000 people inhabit 200 islands lying an average of 1-1.5 m above sea level, is directly threatened with total obliteration.

With countries like Denmark, which in addition to being small lies on a border zone between ocean and continent, evaluation of climatic changes is extremely uncertain. Nevertheless, the most recent calculations indicate that summer temperature will increase by only 1-3 °C during the next 100 years, while winter temperature will increase by 2-5°C and precipitation by between 0 and 20%.

Summary of Danish greenhouse gas emissions

Total Danish emissions of the most important primary greenhouse gasses have been reckoned up for 1989, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the two most important CFCs, CFC-11 and CFC-12 (*Table 2.1.1*).

Total emissions from both natural and anthropogenic sources have only been estimated in the case of CH_4 and N_2O. In the case of the CFCs, current net consumption has been listed

Sector	CO_2	CH_4	N_2O	CFC-11	CFC-12
Power stations	20,704	0.06	0.66		
Coal storage		16.00			
District heating	4,315	0.01	0.13		
Process energy (industry)	10,160	0.07	0.38		
Individual heating	7,683	1.78	0.29		
Transport (national)	10,223	6.93	4.28		
Biomass utilization	-2,389				
Gas supply		8.45			
Industry	917	0.04		1.359	0.450
Landfills		310.00			
Sewage		1.60			
Agriculture (biological)	3,500	262.00	14.60		
Forestry	-2,600	-3.00	0.60		
Natural ecosystems		350.00	4.20		
Total national emissions	52,513	953.94	25.14	1.359	0.450
Transport (international)	4,777	0.61	2.49		
Global emissions x 10^{-3}	26,000	300	6.00	0.300	0.400
Danish national share (‰)	2.0	3.2	4.2	4.500	1.100
Transport (international) (‰)	0.2	0.2	0.4		

Table 2.1.1. Summary of total estimated Danish emissions and uptakes of the most important greenhouse gasses in 1989, apportioned by source and sink. All values are 1,000 tonnes per year. Emissions of methane (CH_4) and nitrous oxide (N_2O) are subject to considerable uncertainty. Emissions from landfills and waste dumps are almost certainly overestimated. (Source: Fenger et al, 1991).

as emission, even though actual emission is delayed in relation to consumption. In the case of CO_2, it is only possible to estimate net emissions from anthropogenic sources.

Carbon dioxide is the most important of the anthropogenic greenhouse gasses, with the energy sector accounting for the greatest part (cf. section 3.2). Danish annual CO_2 emissions have remained almost constant at approx. 60 million tonnes over the last 15 years; although there has been some slight variation, this is primarily attributable to variable energy requirements for heating, and the import/export of electricity between Denmark and other countries. Because electricity imports were particularly high in the year that emissions were reckoned (1989), CO_2 emissions were particularly low. The CO_2 emissions listed under industry (*Table 2.1.1*) almost exclusively comprise approx. 1 million tonnes a year from cement production; emissions from process energy, which primarily derive from industry, are listed separately.

The figure given for the so-called biological CO_2 sources and sinks (biomass utilization, agriculture, forestry and natural ecosystems) are uncertain estimates. They primarily comprise an estimation of total photosynthetic binding of CO_2 during biomass growth, and CO_2 release by burning of biomass or the degradation of organic matter in the soil.

The total "biological" emissions from agriculture thus amount to about 3.5 million tonnes per year, while carbon equivalent to 2.6 million tonnes CO_2 per year is bound in the forests, primarily as a result of the expanding area of forest. While the current afforestation programme will result in the binding of approx. 4% of the CO_2 derived from anthropogenic sources over the next many years, it will not be a permanent contribution, however.

It should be noted that the agricultural CO_2 emissions do not include emissions attributable to direct energy consumption - these are given under the relevant energy sectors, just as the emissions associated with indirect energy consumption for the production of commercial fertilizers, etc. (cf. section 3.4).

Methane is largely of organic origin, whether emitted from anthropogenic or natural sources. Emissions from natural and agriculture-related sources are far greater than emissions from the energy and industry sectors. The greatest part derive from non-agricultural countryside, for which total annual emissions are estimated to be about 350,000 tonnes.

Emissions from agriculture are large, ruminating livestock and vaporization from manure together accounting for 260,000 tonnes. Calculated methane emissions from landfills and waste dumps are also large, amounting to 310,000 tonnes (although this is probably an overestimate).

Nitrous oxide forms upon the combustion of coal and oil products, with the transport sector being the main source. It is also emitted by various biological sources such as agriculture, forestry and natural ecosystems, denitrification of nitrate in the soil associated with agricultural use of nitrogen fertilizers accounting for the major part of N_2O emissions.

The chlorinated hydrocarbons, and in particular the *CFCs*, are discussed later (cf. section 2.1.3).

The most important emissions are shown in Table 2.1.2, expressed in terms of CO_2 equivalents (calculated over a time horizon of 100 years) and apportioned by sector. The calculations are based on the global warming potentials given by the IPCC in 1990.

From the *Table 2.1.2.* it is apparent that *energy-related activities* such as room heating and electricity production together account for almost 40% of emissions, while the *transport sector* accounts for about 20%.

Industry-related emissions (from process energy, etc.), which also encompass CFCs, account for almost a quarter of total emissions. The planned phasing out of CFCs will alone halve emissions from this sector.

Biogenic emissions from agriculture are an uncertain estimate, although it is indisputable that methane derived from livestock herds is a major source that could be reduced by increased use of animal manure for biogas production.

Source	Emission	Percentage
Electricity production	23	24
Room heating	14	15
Process energy (inc. industry)	23	24
Transport (national)	20	21
Agriculture (biological)	11	12
Waste	7	7
Forestry (biological)	-3	-3
Total CO_2 equivalents	95	100

Table 2.1.2. Summary of Danish greenhouse gas emissions of anthropogenic origin. Units: million tonnes CO_2 per year. (Source: Fenger et al., 1991).

Political intervention

UN Climate Convention: In connection with the UN World Conference on the Environment and Development in June 1992, 154 countries, among them Denmark, were signatories to the UN Climate Convention under which signatory countries are bound to stabilize emissions of CO_2 and other greenhouse gasses. The objective is to curtail mankind's impact on the climate systems and to bring to an end the present rate of increase in the atmospheric concentration of greenhouse gasses derived from anthropogenic sources.

Danish endeavours to limit emissions have so far concentrated on CO_2, and mainly comprise the measures stipulated in the Ministry of Energy's action plan "Energy 2000" and the Ministry of Transport's action plan on transport (cf. sections 3.2 and 3.3).

If the goals stipulated in these plans are realized, it will ensure that Denmark fulfils its target of reducing CO_2 emissions by 20% in relation to 1988 levels by the year 2005. As a signatory to the Climate Convention, Denmark has also committed itself to fulfilling the Convention's stipulations that industrialized countries should stabilize their emissions of CO_2 and other greenhouse gasses not covered by the Montreal Protocol (CFCs) at 1990 levels before the year 2000. The national goals are expected to "automatically" fulfil this obligation. Finally, it will also be an important step towards fulfilling the EU goal of stabilizing total EU CO_2 emissions at the 1990 level by the year 2000.

The Danish targets for reducing CO_2 emissions do not take into account the binding of CO_2 in the biomass that can be expected as a result of the ongoing expansion of forest area. As a consequence of the EU decision to reduce the amount of agricultural land (cf. section 3.4), the decision has been taken to double the amount of forest in Denmark within a rotation age, i.e. in the course of 80-100 years. When CO_2 binding is at its maximum, the increase in forest will correspond to 5% of annual anthropogenic CO_2 emissions; however, after about 150 years, this will be offset by the CO_2 produced by the forest. Although the effect will therefore be temporary, it will provide a respite to allow more permanent measures to be implemented. An additional environmental benefit of increasing the forest area is that it increases the prospects for substituting fossil fuels with greenhouse gas neutral biofuels.

As far as concerns the other greenhouse gasses, methane and nitrous oxide, specific targets have not yet been stipulated. However, consideration is currently being given to whether measures implemented in other contexts can fulfil Denmark's obligations under the Climate Convention to stabilize emissions before the year 2000.

One of the main sources of methane emissions is methane formation by landfills. Implementation of the Ministry of the Environment's Action Plan on Waste and Recycling will considerably reduce the dumping of organic waste, and thereby the potential for methane formation. Increased endeavours aimed at the ventilation of landfills and the collection of waste gas for energy production will also reduce emissions, as will increased use of animal manure and organic waste for biogas production. The overall effect is expected to be that Denmark's obligations under the Climate Convention in this respect can easily be fulfilled.

2.1.3 Depletion of the ozone layer

The so-called ozone layer, which contains about 90% of all atmospheric ozone, is located in the stratosphere, between 20 and 40 km above the surface of the Earth (*Figure 2.1.7*). It has long been known that ozone filters out harmful ultraviolet radiation (UV radiation) from the sun, and that the ozone layer periodically thins, but until the 1970s, it was thought that the ozone layer regenerated naturally and that the ozone concentration was constant when viewed over a period of several years.

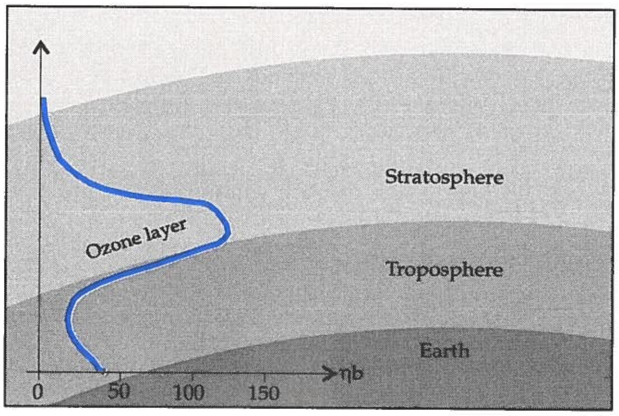


Figure 2.1.7. Ozone concentration through a cross section of the atmosphere showing that 90% of atmospheric ozone is located in the ozone layer in the stratosphere. Units: partial pressure in nannobar. (Source: National Environmental Research Institute).

However, since the mid 1970s, several extreme incidents of ozone layer thinning (holes in the ozone layer) have been recorded over the Antarctic. In October 1987, 1989, 1990, 1991 and 1992 (i.e. during spring in the southern hemisphere), a reduction of around 50% or more was recorded. A decrease in the ozone layer over Europe of 6-7% has been observed over the last 10 years. The decrease is greatest in the winter and early spring, during which time UV radiation from the sun is least.

In 1991, the World Meteorological Organization (WMO) declared that there is now documented

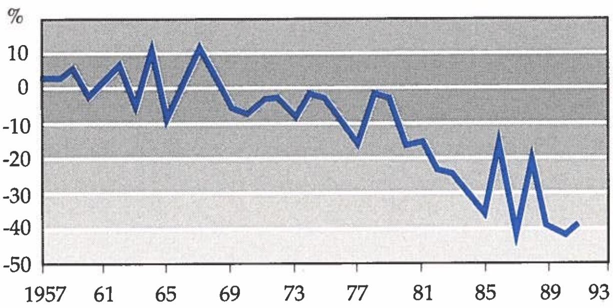


Figure 2.1.8. Decrease in the ozone content of the stratosphere over the Antarctic from the beginning of the 1960s, expressed as the relative fall in percent of the mean value for the period 1957-78. (Source: WMO, 1992).

evidence for ozone layer thinning in the spring and summer months over temperate and polar latitudes in both the northern and southern hemispheres, as well as for thinning during the winter period in the southern hemisphere, where the tendency is strongest (Figure 2.1.8), and where the ozone layer thinned even more in 1992 and 1993.

Effects of increased UV radiation

The amount of UV radiation that reaches the surface of the Earth is determined by the amount of ozone through which the sunlight passes. It has been shown that a 1% reduction in the ozone layer results in a 2% increase in that form of radiation which is the most critical - UVB radiation.

UV radiation is known to have a number of harmful effects on man. Even short-term exposure can cause sunburn and snow blindness. Longer exposure can lead to ageing of the skin, skin cancer, cataracts and immunosuppression.

An increase in UV radiation will also affect both terrestrial and aquatic ecosystems. A particular risk is reduced phytoplankton production in the sea, phytoplankton comprising more than half of world total biomass production. An indirect detrimental effect of increased UV radiation near the surface of the Earth is increased photochemical activity and a resultant increase in the formation of ozone, etc.

Causes of the depletion

It has been established that anthropogenic emissions of chlorinated and brominated compounds (CFCs and halons) are one of the main causes of the thinning of the ozone layer, and that this phenomenon will continue as long as the atmospheric concentration of these compounds continues to increase (cf. *Figure 2.1.3*). An atmospheric chlorine concentration of 2 ppb, which was the concentration before this trend started, is considered to be the critical level, and is the long-term goal of the international agreements to reduce CFC emissions.

Ozone-depleting compounds include halons, CFCs, tetrachloromethane, 1,1,1-trichloroethane, methyl bromide, etc. The halons are used for fire fighting and the CFCs in plastic foam, refrigerators and solvents. Tetrachloromethane and trichloroethane are used in industry as degreasing agents and solvents, while methyl bromide is used as a disinfectant. HCFCs, which have to some extent replaced CFCs, also deplete ozone, but to a lesser extent.

Ozone-depleting compounds are typically characterized by their chemical stability and long lifetime in the atmosphere. They do not all have the same effect, and in order to be able to compare them it is necessary to express their effects in terms of their ozone depletion potential (ODP). This is a measure of their long-term effects on the ozone layer in relation to CFC-11, which has been assigned the ODP of 1.

Political intervention

The use of CFCs in most aerosol sprays has been prohibited in Denmark since 1987. A plan has been drawn up for phasing out the various uses of CFCs and other ozone-depleting substances during the 1990s. The goal is to phase out the use of these substances as rapidly as possible, and in most cases the planned phase out is quicker than required by the latest revision of the Montreal Protocol, as well as by the EU. For example, methyl bromide and HCFCs are to be phased out by 1998 and 2002, respectively. As depicted in *Figure 2.1.9*, Danish total consumption of ozone-depleting substances expressed as tonnes CFC-11 equivalents fell by more than 60% over the period 1986-92.

Many of the ozone layer neutral alternatives to CFCs, halons, etc. have been developed by

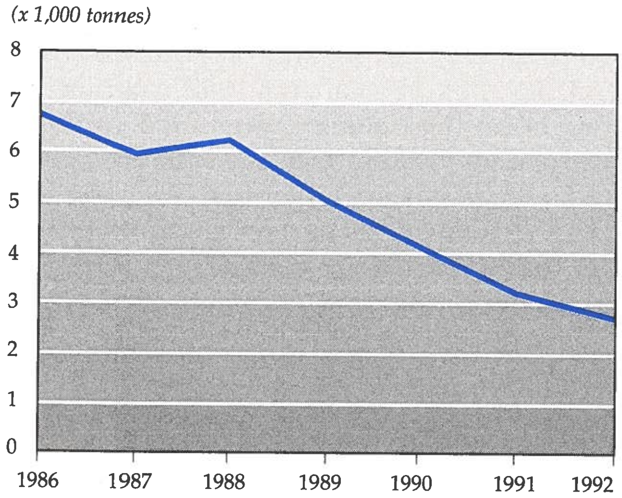


Figure 2.1.9. Trend in Danish total consumption of ozone-depleting substances over the period 1986-92, expressed as tonnes CFC-11 equivalents (ODP-weighted). (Source: Danish Environmental Protection Agency).

Danish industry in collaboration with technological institutes and the Danish Environmental Protection Agency. In many cases economic support was provided by the National Development Programme for the Reduction in CFC Consumption, a Danish programme administered by the Danish Environmental Protection Agency.

International agreements: The original *Montreal Protocol* from 1987, which extends the original Vienna Convention for the protection of the ozone layer, binds signatory countries to halve consumption of the 5 main CFCs by 1998, and to stabilize consumption of 3 halons by 1992, in both cases in relation to consumption in 1986. As per September 1, 1993, the protocol had been ratified by 112 countries, including Denmark and the EU.

The original protocol was revised in *London* in 1990, and the regulation of these substances sharpened considerably. New CFCs and other ozone-depleting substances were included, and the phase-out rate of the substances encompassed by the 1987 protocol was accelerated. As per September 1, 1993, the 1990 protocol had been ratified by 67 countries, including Denmark and the EU.

Even more stringent regulation of these substances was agreed upon in *Copenhagen* in 1992. In addition, HCFCs, HBFCs and methyl bromide were included in the protocol. All known ozone-depleting substances of consequence are now encompassed by the protocol. The phase-out targets for the various ozone-depleting substances as stipulated in the 1992 revision of the Montreal protocol are listed in *Table 2.1.3*.

CFC	75% in 1994 100% in 1996
Halons	100% in 1994
1,1,1-trichloroethane	50% in 1994 100% in 1996
Tetrachloromethane	85% in 1995 100% in 1996
Methyl bromide	stabilized in 1995
HCFC	stabilized in 1996 35% in 2004 65% in 2010 90% in 2015 99.5% in 2020 100% in 2030
HBFC	100% in 1996

Table 2.1.3. Phase-out targets for ozone-depleting substances as agreed in the 1992 Copenhagen revision of the Montreal protocol. (Source: Danish Environmental Protection Agency).

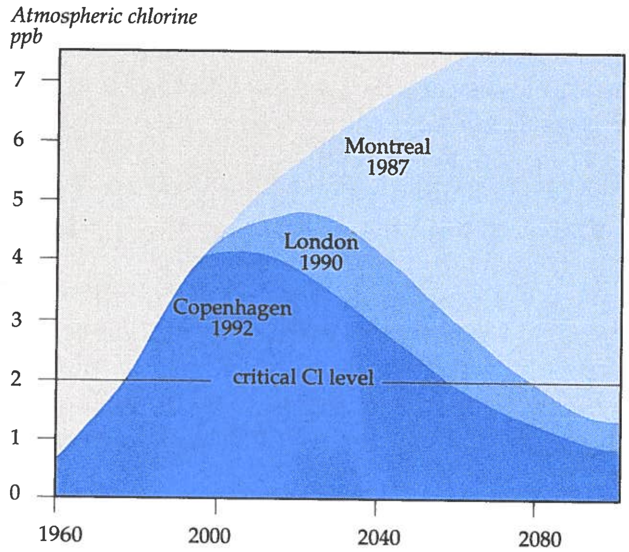


Figure 2.1.10. Calculated effect of the various international agreements on the atmospheric concentration of chlorine. (Source: WMO, 1992).

The more stringent regulation of the substances already encompassed by the 1990 protocol applies to all countries that have ratified the

1990 protocol. As of September 1, 1993, 6 countries had ratified the 1992 protocol.

The decision made at the 1992 meeting in Copenhagen to accelerate the phase-out of CFCs and halons is particularly important since these two substances are together responsible for most emissions of chlorinated and brominated compounds. The current atmospheric concentration of chlorine is more than 3.6 ppb, and is expected to increase further over the next 10 years. As is apparent from *Figure 2.1.10*, only the more stringent measures agreed upon in Copenhagen will be able to prevent the concentration reaching a level of perhaps 5 ppb, and enable it to decline to the critical level of 2 ppb sometime in the middle of the next century.

2.2 Air pollution - regional effects

2.2.1 Introduction

The increasing consumption of fossil fuels such as coal and oil is an important cause of air pollution. While the impact of such pollution is sometimes limited to the densely populated urban areas close to the sources of the pollution (cf. section 2.3), air pollutants can also spread across national borders to a greater geographic area, and thereby become part of the so-called transboundary air pollution.

Sulphur dioxide (SO_2) and the nitrogen oxides NO and NO_2, which are examples of so-called primary pollutants, can exist in the air for periods of up to a few days, and while being transported over several thousand kilometres, can be converted to sulphuric acid and nitric acid.

Another primary pollutant is ammonia (NH_3). This is rapidly converted to ammonium and, upon deposition on the soil, can be converted to nitric acid by nitrification.

The effect that these primary pollutants and their reaction products have when deposited on lakes and forests is known as "acidification". Forest die back such as recorded in central and eastern Europe, and lake "mortality" such as recorded in Scandinavia and Canada, are examples where acidification has at least been partly responsible. The intensive silviculture used in modern European forestry also contributes to the acidification of the forest floor.

Some of the air pollutants play a role in more than one environmental problem. For example, nitrogen oxides contribute to the formation of ozone which, apart from being a greenhouse gas, can also damage forest trees and other vegetation, as well as affect the health of man. In the presence of sunlight, NO_2 reacts with atmospheric oxygen and volatile organic compounds (VOCs) to form ozone (O_3).

Finally, the nitrogen oxides, together with ammonia from agriculture, contribute to eutrophication of forests and many natural oligotrophic ecosystems, and together with phosphorus, contribute to the eutrophication of the aquatic environment (cf. section 2.4).

The complex of atmospheric chemical reactions and environmental effects in which acidifying pollutants participate is illustrated in *Figure 2.2.1*.

At the end of the 1970s, acidification became widely acknowledged as a serious regional environmental problem in Europe and North America. As a result, major research and monitoring programmes were implemented to determine the whole chain of events between the emission of acidifying pollutants to their effects on the environment. These endeavours became the basis for international negotiations and agreements to reduce primary pollutant emissions in order to reduce total pollution to what is considered to be the critical limit for the environment, i.e. a level of pollution at which the impact of the pollutant on a given ecosystem can be tolerated without permanent damage being caused.

2.2.2 Effects on the environment

The regional effects of air pollution can be roughly divided into *direct effects*, that arise from direct contact with the airborne pollutants, and *indirect effects*, that first develop after the pollutants have been deposited on the terrestrial or aquatic environments. Direct effects manifest themselves as, for example, damage to trees and crops caused by the uptake of high concentrations of gaseous air pollutants through stomata. The indirect effects usually manifest themselves as the effects of *acidification* or *eutrophication*.

The effects of acidification depend on the combination of two factors - the magnitude of acid deposition and the natural capacity of the terrestrial or aquatic environment in question to counteract acidification (the system's buffering capacity). Thus in areas with a soil in which the minerals easily weather or which has a high limestone content, acid deposition will be fairly easily neutralized. The southern Scandinavian lakes in which the effects of acidification were first observed were located in areas where both deposition and sensitivity were high.

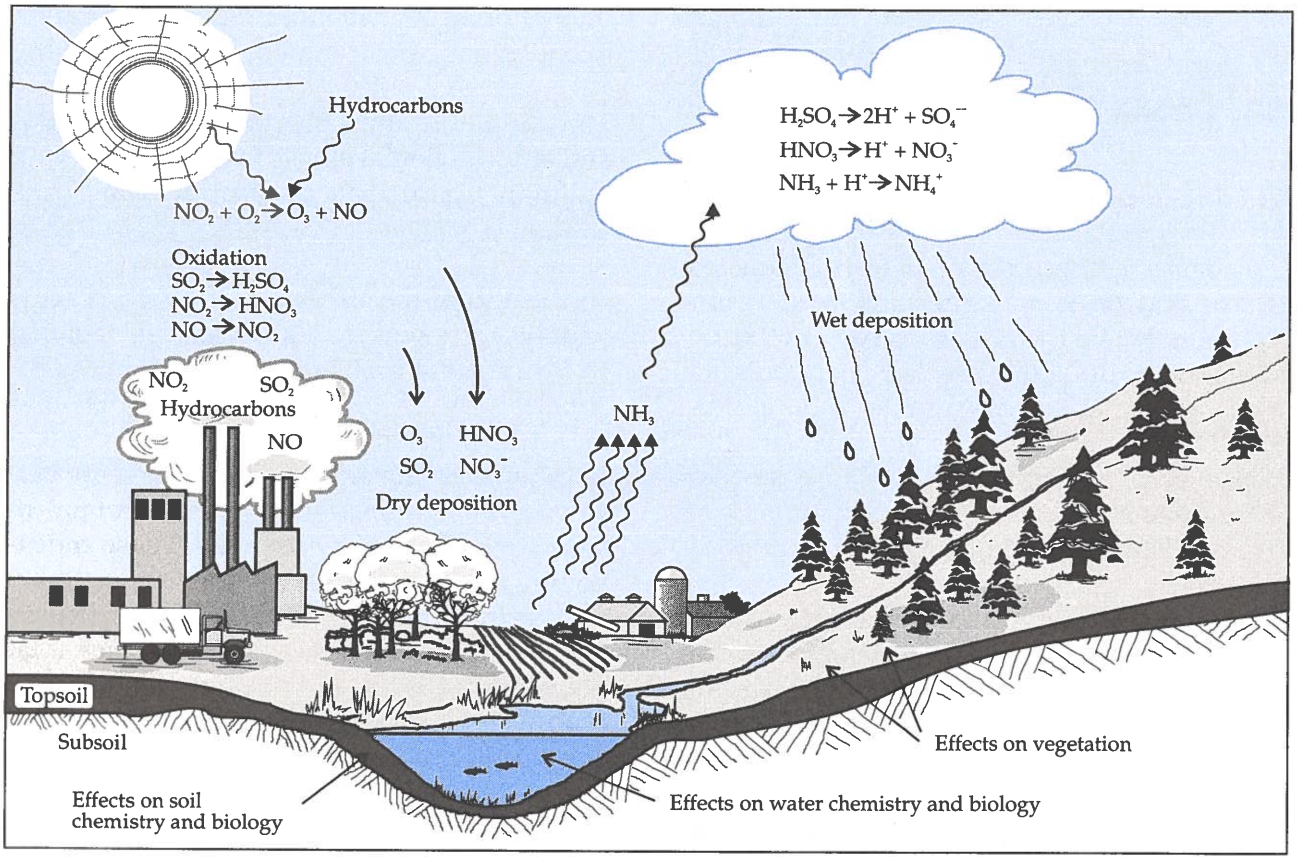


Figure 2.2.1 Diagrammatic representation of the complex of atmospheric chemical reactions and environmental effects in which acidifying pollutants participate. As a result of their dispersal, conversion and deposition, sulphur dioxide, nitrogen oxides and ammonia emissions can affect the environment in a large regional area. (Source: Nygaard, 1989).

The effects of air pollution on lakes and watercourses, forests, natural vegetation and cultivated land are discussed below.

Acidification of lakes and watercourses

Increasing acidification of watercourses and lakes and a number of drastic biological changes have been observed in much of northern Europe and North America over the last 20-30 years. A major cause of these effects is now known to be the increasing atmospheric deposition of acidic sulphur and nitrogen compounds.

Other characteristics of lake and watercourse catchments are also significant determinants of whether or not the water acidifies, however, including the ease with which the soil weathers, the total foliage surface area (as this determines the magnitude of dry deposition), as well as the way in which the land is used, and changes in it. Increased afforestation on former agricultural land will lead to acidification of the soil because logging results in the removal of basic nutrient salts. The soil's base saturation falls, and runoff becomes acidic because soil neutrality is no longer maintained by the routine spreading of agricultural limestone.

Acidification of lakes and watercourses is a progressive process that can be divided into three stages.

1. If the catchment area subsoil minerals are easily weathered, runoff will initially have a high bicarbonate content. This will act as a buffer against acidification. The bicarbonate concentration and hence buffering capacity will eventually decline, but no biological changes will be apparent at this stage.

2. In the second stage, the bicarbonate concentration has fallen to such a low level that large inputs of hydrogen ions in runoff cannot be neutralized, and pH falls. Periods of heavy rain or sudden thaws will be accompanied by great variations in pH that can directly provoke

mass mortality of fish or interfere with their reproduction. Characteristic of this moderate acidification stage is that the pH is never below 5.5.

3. In the third stage the pH has stabilized at around 4.5 and dissolved humus and aluminium compounds begin to function as a buffer against further acidification. As a result, the concentration of ionic aluminium attains a level that is toxic for many living organisms and virtually all fish life disappears. At the same time, acidophilic mosses start to colonize the lake bed at the expense of other submerged macrophytes. Many important invertebrates and algae have disappeared and the degradation of organic matter proceeds more slowly, the net result being that the lake becomes impoverished of species and less productive.

Most of the water flowing into the majority of Danish lakes and watercourses derives from groundwater. Since this has a high pH and a high bicarbonate concentration because of the high limestone content of the soil, most Danish inland water bodies are not threatened by acidification. Nevertheless, it has been shown that some low buffering capacity lakes in the limestone-poor heath, forest and dune areas in mid and western Jutland are acidified or threatened by acidification, pH levels being around 5 or less, and there being evidence of more or less marked biological changes. An example is lake Grane Langsø (*Figure 2.2.2*). Because old time-series of pH measurements are available for this lake, it has been possible to demonstrate a clear trend towards acidification.

Acidification has also been demonstrated in several watercourses in mid Jutland. For example, the pH of the stream Skærbækken, which drains a heath area without other significant sources of acidification than the air, has fallen from approx. pH 5.8 to 5.5 over a 12 year period.

In Norway and Sweden, the soil layers are generally thinner and limestone-poor, and a significantly greater part of the precipitation is delivered direct to lakes and watercourses as surface runoff. These are the main reasons why atmospheric deposition of acidifying pol-

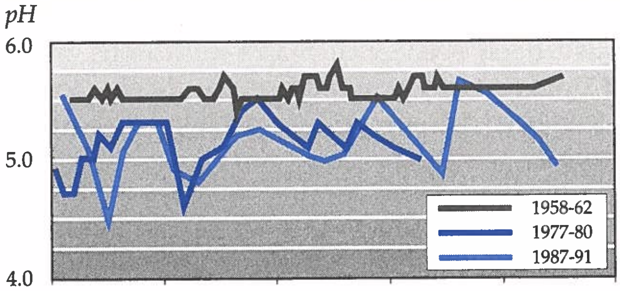


Figure 2.2.2. Time-series of pH measurements in lake Grane Langsø covering 5 year periods starting around 1960, 1980 and 1990. (Source: National Environmental Research Institute; Århus County).

lutants is now estimated to have acidified about 14,000 of the 85,000 lakes in Sweden that have a surface area greater than 1 ha. Moreover, it has been calculated that if atmospheric deposition of acidifying pollutants is not reduced by at least 50%, a further 20,000 Swedish lakes will be affected by acidification in the next decades. As regards Norway, it is estimated that approx. 2,000 fish populations are already on the verge of extinction as a result of acidification.

Effects on forests

One of the most discussed effects of regional air pollution is the extensive damage caused to forests in much of Europe and North America over the last 10-20 years. Poor condition and misgrowth have been known for centuries, and has previously been ascribed to natural causes such as extreme weather conditions and insect plagues, or to anthropogenic effects such as intensification of silvicultural practice and local emission of air pollutants.

The damage sustained in recent years differs from that seen earlier in that it develops more rapidly and involves greater areas and more tree species. In addition, the damage occurs in areas of quite different climate, height and soil characteristics, and the symptoms can vary in nature and strength within the same stand of trees, with the older trees and those on the edge of the stand seemingly being most susceptible.

The damaged trees are characterized by symptoms such as discolouration and loss of needles and leaves, misgrowth of roots, trunks and branches, and complete death. The damage has been most marked with conifers, but has also been seen with many deciduous trees. Conifers are generally more likely to be damaged by air pollutants than deciduous trees.

Since the beginning of the 1980s, the condition of forests has been monitored annually in a number of European countries. This monitoring, which currently encompasses approx. 80% of Europe's forests spread over 28 countries, is based on standardized assessment of discolouration and needle/leaf loss in selected trees in selected forests. Trees are considered to be damaged if needle/leaf loss is 25% or more, and healthy if needle/leaf loss is under 25%. In 1991, monitoring revealed that approximately one fifth of all coniferous and deciduous trees in Europe were damaged, i.e. needle/leaf loss exceeded 25%. The results of monitoring in Denmark are illustrated in *Figure 2.2.3*.

Needle loss and discolouration are not specific effects of air pollution, and monitoring cannot usually give any indication as to the cause of the changes in tree condition. The sensitivity of the forests to acidification depends on a number of factors such as the selection of tree species, silvicultural practice and various factors relating to the soil, as well as climate and the stress caused by climatic changes.

The damage to European forests cannot be solely attributed to any one of the above mentioned factors or to any one type of air pollution, because these will vary from place to place. Nevertheless, it is generally agreed that *acid precipitation, increased nitrogen deposition* and *photochemical oxidants (ozone)* are of great significance to European forests. The effects of these factors are discussed below.

Acidification of the soil: In Europe, the acid that coniferous forests naturally produce will normally be neutralized by the buffering effect of weathering processes. However, as atmospheric acid deposition can equal or even exceed the amount of acid produced by a forest, this will increase the risk of exceeding the buffering capacity. The result will be a lowering of soil pH, a falling base saturation and an increased leaching of basic buffer salts such as potassium, calcium and magnesium salts, as well as a corresponding reduction in

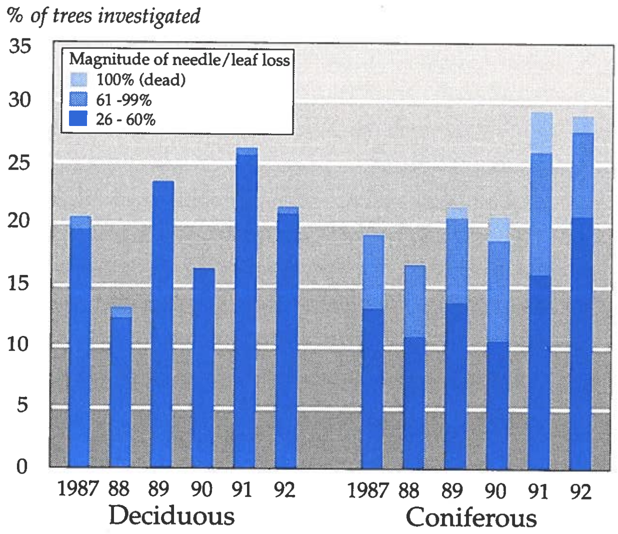


Figure 2.2.3. Health of Danish forests during the years 1987-92. While there is no clear trend in the case of deciduous trees, the condition of conifers seems to have improved slightly in 1992 as compared with the negative trend that has characterized most of the period. (Source: National Forest and Nature Agency, 1992).

the soil store of nutrient salts of these elements.

Soil acidification is a progressive process, the final stages of which result in aluminium being leached out and led to lakes and watercourses in toxic concentrations. The increased concentration of aluminium will also affect the fine roots of trees.

In the Scandinavian countries, including Denmark, acidification is primarily caused by sulphur deposition. Sulphate-sulphur is not retained in the soil but is leached out, accompanied by potassium, calcium and other cations in amounts proportional to the amount of sulphate leached.

The maximum level of sulphur deposition that can just be offset by weathering is termed the *critical sulphur load*. This is thought to be 300-800 mg sulphur per m^2 in the vulnerable granite and gneiss areas that characterize Nordic mountain areas, and where the load is exceeded by 75% or more. The critical load is in the same range in the sandy-soil coniferous forests in southwestern Denmark, but deposition in these areas is almost twice that amount (cf. *Figure 2.2.14*).

Nitrogen saturation: Nitrogen has previously been considered to be the most important growth-limiting factor in forestry, and still is in northern Scandinavia, where increased atmospheric deposition has led to increased growth. If nitrogen loading is increased above a certain limit, the forest will cease to respond with an increased growth; instead nitrogen will be released in the form of increased nitrate leaching, thus entailing the risk of soil and freshwater acidification.

Before that level is attained, disturbances can arise in the form of nitrogen induced deficiency in nutrients such as potassium, phosphorus, magnesium and micronutrients. As a result, these become limiting for growth. For example, nitrogen- or acidification-induced magnesium deficiency causes yellow discolouration of older needle generations, this being one of the main symptoms of damaged conifers in central Europe. Other symptoms of "nitrogen saturation" are reduced resistance to drought and frost, increased sensitivity to insect plagues and a shift in the forest floor flora towards more nitrophilic species.

Nitrogen plays an important role in acidification of the soil in many areas of central Europe and in countries such as Holland. In Denmark, as well as in southern and mid Sweden, nitrogen loading from the atmosphere has approached the critical load for coniferous forests. The critical load for forest *eutrophication*, which is estimated to be 15-20 kg N/ha/y (*Table 2.2.1*), is attained or exceeded in several parts of these areas. The critical load for *acidification* is determined on the basis of the combined impact of nitrogen and sulphur, and will in some cases entail an even lower critical load for nitrogen loading.

A warning that the coniferous forests in sandy-soil areas of Denmark are attaining the limit for how much nitrogen they can take up is provided by studies of wood production in heathland forests. Until the end of the 1970s, nitrogen was the most important growth-limiting factor. Thereafter, the forests reacted to the input of nitrogen fertilizer with an increasingly negative growth response. This backlash is interpreted as reflecting potassium deficiency induced by an increased leaching of potassium and a decreased potassium concentration in the soil - a condition that has been recorded for both fertilized and unfertilized reference areas over a period of 30 years (*Figure 2.2.4*).

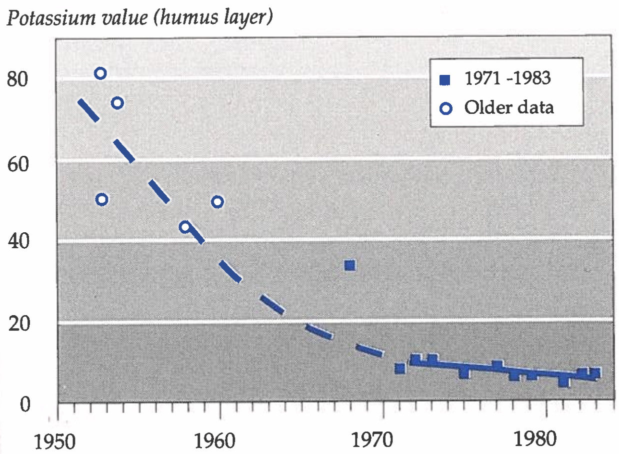


Figure 2.2.4. Trend in soil potassium content over the period 1971-83 expressed as the potassium value in unfertilized reference areas, shown together with older analysis results from heathland forests. (Source: Lundberg & Ravnsbæk, 1992).

Direct effects of air pollution: Gaseous air pollutants such as ozone, sulphur dioxide and nitrogen oxides directly affect tree leaves and needles. Moreover, when present simultaneously, they can reinforce each other's effects (combination effects). Under controlled experimental conditions, it has been possible to provoke symptoms similar to those observed in the forests by exposing trees to gaseous air pollutants. However, as the trees used in such experiments are almost never comparable with forest trees, the results cannot be used to evaluate the general significance of the gasses with respect to the damage seen in the forests. In Denmark, ozone undoubtedly has direct effects on forests since the concentrations measured each year during the growth season are above the limit at which it has direct effects on trees (cf. 2.2.3 below).

The natural vegetation

A number of oligotrophic ecosystems such as heaths and upland bogs are especially sensitive to changes in atmospheric deposition, the main reason being that water and nutrient input to such systems is almost exclusively derived from the atmosphere, and that the vegetation has adapted to the low availability of nutrients. According to the latest assessment, as many as 80% of the plant species threatened with extinction in Europe are associated with oligotrophic localities.

Ecosystem	Critical load	Indication
Forest:		
Acidic (managed) coniferous forest	15 -20, #	Changes in ground flora, inc. fungi
Acidic (managed) deciduous forest	< 15 - 20, #	
Calcareous forest/Acidic unmanaged forest	?	?
Heath:		
Lowland dry heath	15 - 20, ##	Decline in sensitive species, invasion of grasses
Lowland wet heath	17 - 22, ##	
Species-rich heath/acidic grassland	< 20, #	
Arctic and alpine heath	5 - 15, (#)	
Meadows/commons:		
Calcareous species-rich grassland	14 - 25, ##	Decreased species diversity, invasion of grasses
Neutral/acidic species-rich grassland	20 - 30, #	
Montane/subalpine grassland	10 - 15, (#)	
Wetland ecosystems:		
Shallow soft-water bodies (lakes and rivers)	5 - 15, ##	Decline in submerged macrophytes
Fens	20 - 35, #	Decreased species diversity, invasion of grasses
Upland bogs	5 - 10, #	

Table 2.2.1. Critical loads for nitrogen (kg N/ha/y) in terrestrial and aquatic ecosystems; ## reliable, # relatively reliable, (#) best guess. (Source: Grennfelt & Thörnelöf, 1992).

On Danish heaths, which are richly vegetated with reindeer moss (various lichen species) and heather, it has been found that the lichens are damaged and that there is increasing encroachment by grasses and woody plants. This encroachment has occurred at the expense of both the slowly growing lichens and the heather, and has proved to coincide with increased nitrogen concentrations in the mosses and in the soil. The trend is the same on Dutch heaths, two thirds of which are currently overgrown with grass. Direct effects of ozone are also thought to influence the shift in heathland species composition.

It has been calculated that if the characteristic flora on the heaths is to remain unchanged in the long run, atmospheric deposition of nitrogen should not exceed 15-20 kg N/ha/y. That load has already been attained or exceeded in several areas of southern Scandinavia, as well as in much of the rest of Europe (*Table 2.2.1*).

Studies of plant species composition in 21 Danish upland bogs have demonstrated colonization by non-native and more nitrophilic species such as grasses, birch and willow. It has been calculated that if such changes in vegetation are to be avoided, nitrogen deposition in upland bogs should not exceed 5-10 kg N/ha/y (*Table 2.2.1*), a critical load that is already exceeded in much of Europe, including the whole of Denmark.

Cultivated land

Air pollution also affects cultivated agricultural land, but loading of the soil is of little importance. Of the total acid production in the soil, 80-90% is attributable to the addition of commercial fertilizer and animal manure. This is normally offset by the routine spreading of agricultural limestone, however.

The nitrogen input to agricultural land by atmospheric deposition is of little practical significance to agricultural production as it amounts to only a minor part of the plants' total nitrogen requirements. Sulphur has proved to be an exception, however. When sulphur pollution was at its peak in Denmark, the sulphur requirements of sulphur-requiring crops such as rape and cabbage were met without the need for supplementary sulphur fertilizers. However, the atmospheric deposition of sulphur in Denmark has now fallen so much that it has once again become necessary to provide sulphur to the crops.

In contrast, *the direct effects* of gaseous air pollutants on agricultural crops are estimated to be of much greater significance to agricultural production. In Danish agricultural land, the main air pollutant during the plant growth season is ozone, as is also the case in much of the rest of Europe and North America. Ozone is extremely toxic to many crops and other plants, typical symptoms being withered leaves and reduced growth of roots and fruit. The toxicity is further enhanced by the fact that ozone is present in the highest concentrations in full daylight during the summer, i.e. just when the plants are most active. Moreover, crops such as beans, oats, potatoes and spinach are extremely ozone-sensitive and leaf damage occurs even at relatively low concentrations.

Impact assessment studies indicate that the ozone concentrations seen in Denmark are able to reduce the harvest of common crops by up to 10%. In addition, it has been found that ozone can enhance plant sensitivity to drought and attacks by aphids, thereby further reducing the harvest. While the economic consequences have not yet been determined for Denmark, the Swedes have calculated that ozone reduces the value of their annual national harvest by more than SEK 1,000 million (at world market prices).

In contrast to the situation in central Europe, gaseous sulphur and nitrogen compounds are only present in herbitoxic concentrations close to major sources, e.g. motorways, factories and power plants. The concentration of these gasses in Danish rural areas is so low (on average less than 5-10 ppb during the day) as to be unlikely to cause direct damage to crops.

2.2.3 Pollutant emissions

Photochemical oxidants (ozone)

From the chemical perspective, the formation of ozone is a considerably more complex process than the formation of acidifying sulphur and nitrogen compounds. Under the influence of sunlight, NO_2 reacts with compounds such as volatile organic compounds (VOCs), methane and carbon monoxide to form ozone.

The WHO short-term critical limit (maximum hourly ozone concentration) of 75-100 ppb for man is exceeded in many parts of central Europe, as is the growth season long-term critical limit of 25 ppb for plants. Over the last 100 years the background ozone concentration has increased from about 10 ppb to 25 ppb, with peak values of 100 ppb or more being common over central Europe (*Figure 2.2.5*).

Such episodes seldom occur in northern Europe, and when they do occur it is usually in connection with long-range transboundary transport from the south, or under high pressure weather conditions. Under such circumstances, concentrations of 100-150 ppb have been measured in Denmark. The background level of ozone in Denmark averages 20 ppb in the winter and 30 ppb in the summer, the corresponding peak hourly levels being approx. 40 ppb and 65 ppb (98% percentile), respectively.

VOCs are a major contributory cause of ozone formation. They are emitted by a number of natural sources, in particular conifers, but also by other types of vegetation. Of anthropogenic emissions, road traffic accounts for approximately half, with the remainder mainly being derived from various activities in the industrial and private sectors. Emissions have hitherto been growing in Europe, but the introduction of catalytic convertors on cars and the introduction of cleaner technology in industry will probably change this tendency.

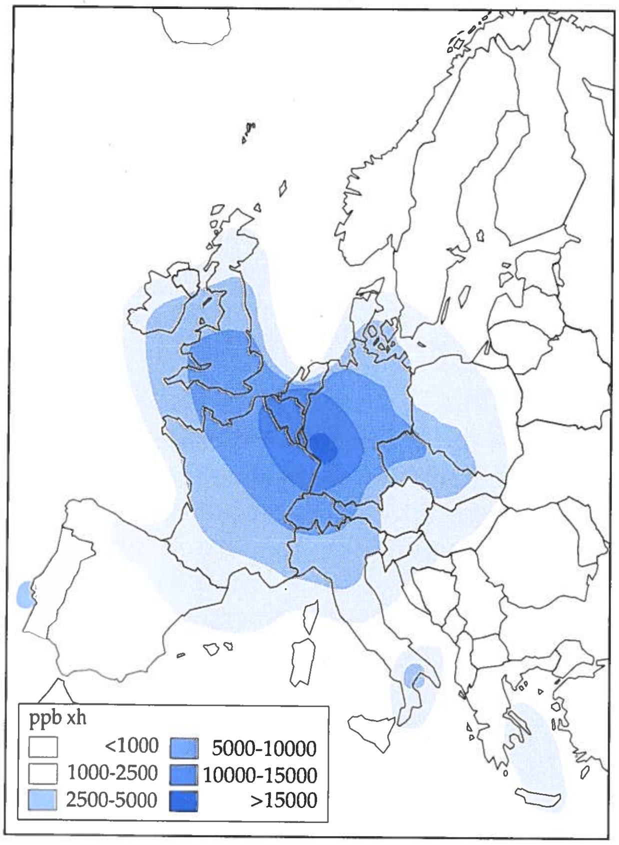


Figure 2.2.5. Distribution of enhanced ozone concentrations over Europe. The values shown are the sum total for the whole summer period of all hourly average values exceeding 75 ppb. (Source: Simpson, 1991).

Trends in pollutant emissions

The dominant sources of the air pollutants that comprise transboundary air pollution are all associated with the combustion of fossil fuels. Ammonium is an exception, being mainly derived from agricultural production and spreading of animal manure. Moreover, in contrast to sulphur dioxide and nitrogen oxides and their reaction products, ammonium is mainly deposited relatively close to the sources.

European coal and oil consumption, and hence sulphur dioxide emissions, were relatively constant during the first half of the century, but grew to almost the double by the 1970s. In recent years, however, emissions have generally fallen, this being attributable to stricter regulations concerning the sulphur content of fuels, a shift from oil and coal to sulphur-free energy sources (natural gas and atomic energy) and increasing implementation of flue gas desulphurization.

It is expected that total sulphur emissions in Eastern and Western Europe will be 20% lower in 1993 than in 1980, but with considerable variation between individual countries. By 1991, for example, emissions had been more than halved in France and reduced to around a third in former West Germany (Figure 2.2.6).

When evaluating the prospects for further reductions, it is necessary to take into account the fact that current energy consumption per inhabitant varies considerably in European countries. Thus while energy consumption expressed in tonnes oil equivalents per inhabitant averages 3.3 in Europe, it is almost 6 in former East Germany, but under 3 in France. Even if the differences in energy requirements due to differences in national infrastructure, etc., are taken into account, there is still an unexploited potential for more effective energy consumption.

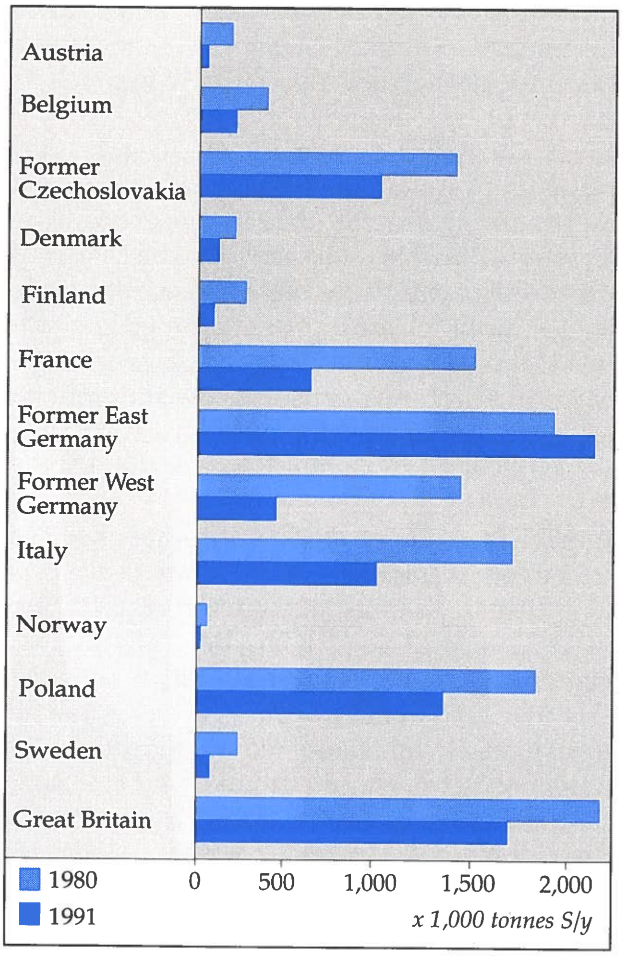


Figure 2.2.6. National emissions of sulphur dioxide in selected European countries in 1980 and 1991. German emissions are shown separately for former East and West Germany. (Source: The European Monitoring and Evaluation Programme (EMEP)).

Danish sulphur dioxide emissions increased up to 1977, but then fell (cf. *Figure 3.2.10*, section 3.2) as a consequence of stricter legislation concerning the composition of fossil fuels, fuel substitution and increased energy intensity (cf. section 3.2).

With regard to *European NO_x emissions*, there does not seem to have been any overall trend, total European emissions having only varied a few percent over the period 1980-91. NO_x emissions from traffic are increasing, however, and this trend is expected to continue due to the increasing amount of transport.

As is apparent from *Figure 2.2.7*, *Danish NO_x emissions* tended to increase over the period 1975-91, total emissions having increased a good 50% since 1972. The main sources of NO_x emissions are power plants and the transport sector, each of which accounts for a good 45% of the total, with the increase in emissions being attributable to the marked increase in consumption of electricity and transport energy (cf. *Figure 3.2.10* and section 3.2).

As with NO_x emissions, no clear trend is apparent in *European ammonia emissions*, the total of which amounts to only 12% of total NO_x emissions expressed in terms of nitrogen. Countries such as Holland and Denmark, where there are large cattle and pig herds, emit more NH_3-N than NO_x-N. Thus Danish emissions in 1991 amounted to 130,000 tonnes NH_3-N, as compared to 100.000 tonnes NO_x-N.

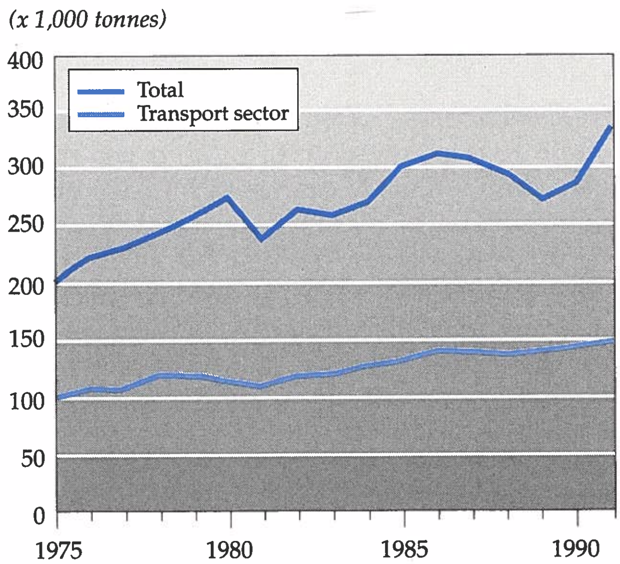


Figure 2.2.7. Trend in Danish NO_x emissions over the period 1975-91. (Source: Fenhann & Kilde, Risø National Laboratory, 1993).

Atmospheric deposition

Sulphur deposition. Sulphur emissions in Europe mainly occur in a belt stretching from the industrial areas of the central England through Holland/Belgium and the Ruhr district to eastern Germany and Poland. Emissions are low at the extremities of Europe, especially in northern Scandinavia. To some extent, the same pattern also applies to sulphur deposition (*Figure 2.2.14*), although it is markedly affected by the weather in Europe, which is dominated by a westerly wind. In Denmark, westerly winds are twice as frequent as northerly winds, and are generally stronger too.

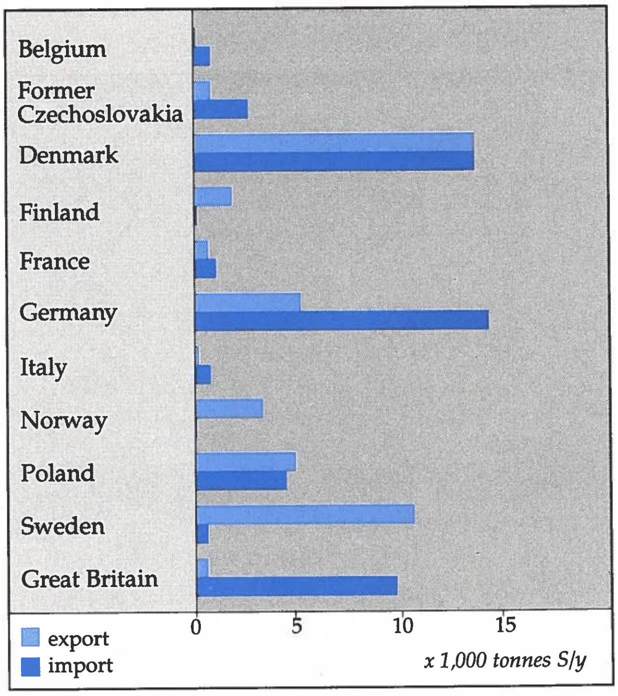


Figure 2.2.8. Total Danish exports and imports of airborne sulphur from selected European countries. The columns representing Denmark's export to and import from Denmark should be understood to represent that part of the total Danish emissions which is deposited in Denmark. This amounts to 13% of the total emissions of approx. 100,000 tonnes S/y. (Source: The European Monitoring and Evaluation Programme (EMEP)).

One of the consequences of this is that deposition of sulphur compounds in Great Britain only amounts to 30% of national emissions. In Norway, in contrast, transboundary deposition is more that fourfold greater than national emissions, and of this, more is derived from Great Britain than from all the other Scandinavian countries put together. This illustrates the fact that a common Nordic endeavour to reduce mutual transboundary air pollution will be of little significance.

In Denmark, approx. 25% of sulphur deposition is derived from Danish sources, the rest being attributable to transboundary import, mainly from Great Britain and Germany, but also from other countries, e.g. Poland. The sulphur *emitted from Denmark* is mainly deposited in Sweden, Germany, Poland and the former Soviet Union.

Nitrogen deposition. The geographic pattern of nitrogen emission and deposition in Europe is basically the same as that for sulphur compounds, although emissions are relatively smaller in Eastern Europe because there is less motor vehicle traffic. The calculated deposition comprising both nitrogen oxides and ammonia is illustrated in *Figure 2.2.9*.

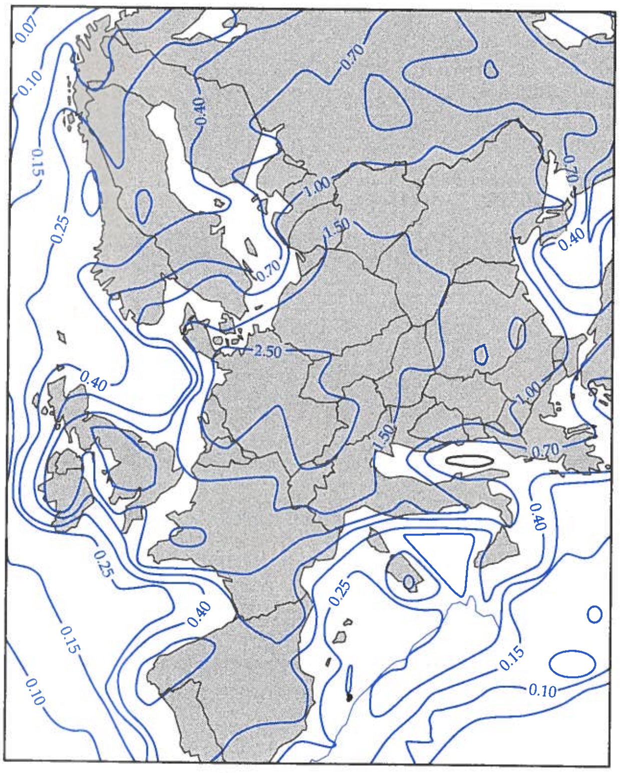


Figure 2.2.9. Calculated nitrogen deposition (g N/m^2/y) in Europe in 1991, comprising nitrate-N and ammonia-N. (Source: Sandnes, 1993).

As can be seen, deposition is clearly maximal in central Europe. In contrast to sulphur deposition, nitrogen deposition has not declined in recent years, and in southern Norway and central Sweden, deposition actually increased during the 1980s. That part of acid deposition in southern Scandinavia that is attributable to nitrogen compounds has therefore increased at the expense of sulphur compounds, and now accounts for about one third.

Total calculated nitrogen deposition on the Danish landmass during recent years has remained relatively constant at approx. 80,000 tonnes per year (*Figure 2.2.10*), i.e. approx. 20 kg N/ha/y. Total Danish emissions of NO_x-N and NH_3-N are of approximately the same magnitude. However, since ammonia and ammonium have a relatively short lifetime in the air, almost 80% of NH_3-N deposition derives from Danish sources, while less than 10% of NO_x deposition (expressed as nitrate-N) derives from Danish sources, the majority being attributable to transboundary atmospheric import.

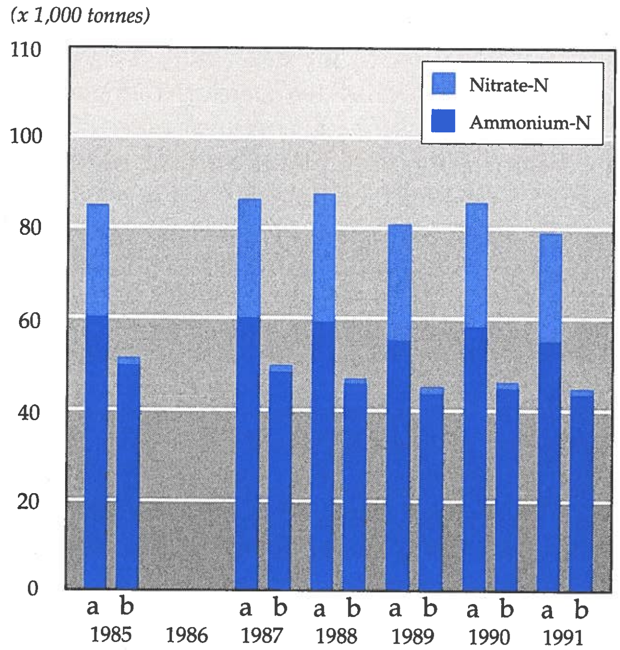


Figure 2.2.10. Total deposition of nitrogen compounds in Denmark (a) and deposition derived from national sources (b), expressed as nitrate-N and ammonium-N. (Source: The European Monitoring and Evaluation Programme (EMEP)).

National sources - sector profile. The magnitude and trends in emissions of sulphur and nitrogen compounds are discussed for each of the main sectors of society in chapter 3 of this report. Source apportionment of total nitrogen deposition (*Figure 2.2.11*) can be used to indicate the relative importance of sectors such as agriculture, energy and transport with respect to the eutrophication of Danish oligotrophic habitats.

Similarly, by combining nitrogen and sulphur emissions from energy production, industry, households, etc., and expressing sulphate-S, ammonium-N and nitrate-N in terms of acid equivalents, the relative contribution of the

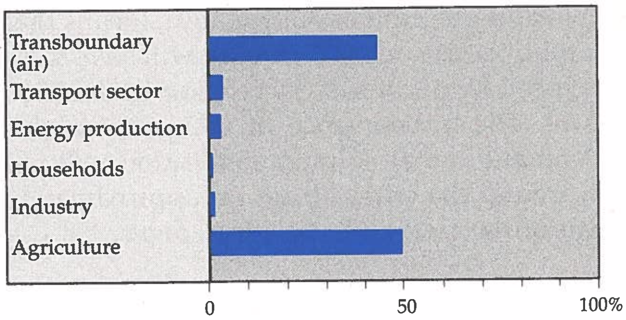


Figure 2.2.11. Sector profile of the relative contribution made to total nitrogen deposition in Denmark by transboundary import and the main sectors of society (transport, energy production, households (room heating), industry (process energy) and agriculture). (Source: National Environmental Research Institute).

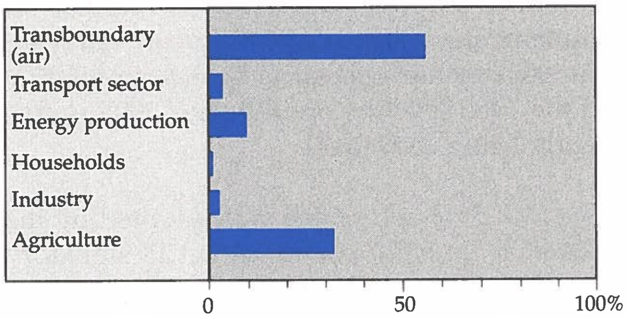


Figure 2.2.12. Sector profile of the relative contribution made to total acid deposition in Denmark by transboundary import and the main sectors of society (transport, energy production, households (room heating), industry (process energy) and agriculture). (Source: National Environmental Research Institute).

different sectors to acid deposition can be determined (potential acidity) (*Figure 2.2.12*).

As is apparent from these figures, the agricultural sector accounts for approx. 50% of total nitrogen deposition, while transboundary import accounts for most of the rest. The agricultural sector also accounts for much of total acid deposition (approx. 30%), while transboundary import accounts for even more (approx. 55%) with the energy sector accounting for less than 10%.

2.2.4 Political intervention

Critical limits

Critical limits are relatively new tools in the international endeavour to combat the impact of transboundary air pollution. A critical limit for a pollutant refers to either the concentration in air (critical level) or magnitude of deposition (critical load) at which the impact of the pollutant on a given ecosystem can be tolerated for long periods of time without permanent damage being caused.

Since the capacity of ecosystems to endure the effects of air pollutants varies from ecosystem to ecosystem, and from area to area, special methods of measurement and mathematical analysis are needed in order to be able to calculate the critical limits. When fixing the critical limits for a pollutant, the effects of other air pollutants are also taken into account. The critical limit for atmospheric input of acid can therefore be expressed as the critical limit for sulphur using specific assumptions about acidity of nitrogen compounds. The critical limits are regularly revised so that they always reflect the latest knowledge in the area (cf. *Table 2.2.1*).

The calculations hitherto made show that the critical limits are exceeded in many areas of Europe (cf. section 2.2.2), and that major reductions in atmospheric emissions of acidifying compounds are required if the critical limits are not to be exceeded (*Figures 2.2.13 and 2.2.14*).

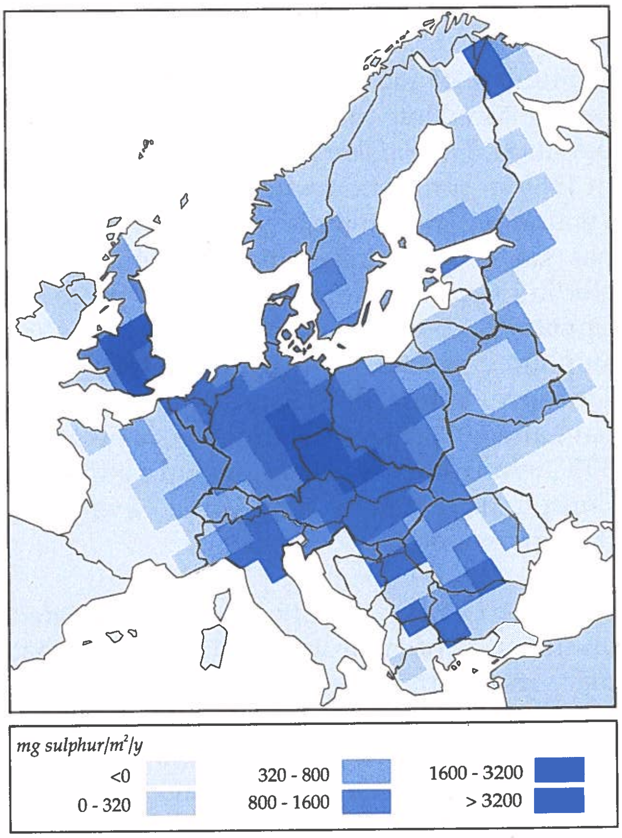


Figure 2.2.13. Magnitude by which the critical load for sulphur deposition was exceeded in different areas of Europe in 1990. (Source: UN-ECE, 1993).

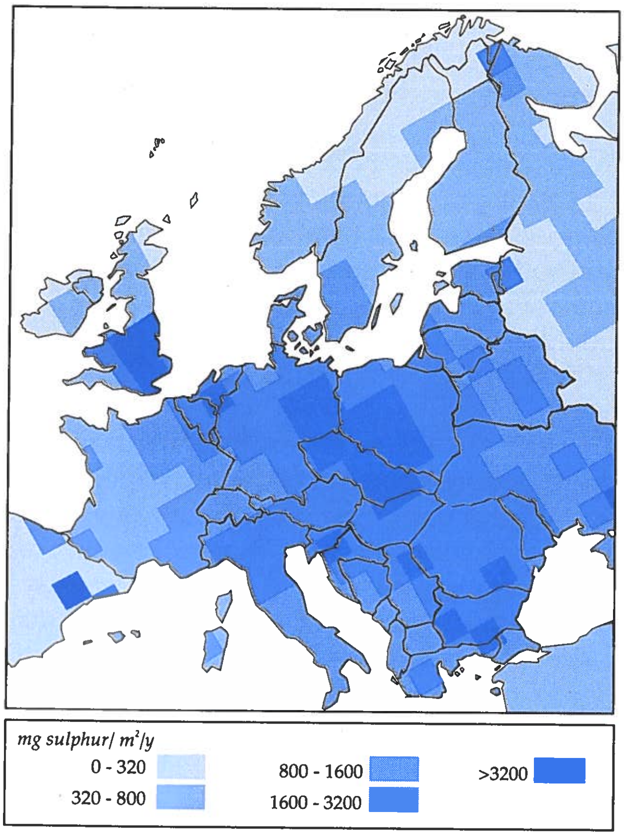


Figure 2.2.14. Sulphur deposition in different areas of Europe in 1990. (Source: UN-ECE, 1993).

International agreements

A number of international agreements have been entered into to reduce transboundary air pollution. The *Sulphur Protocol* was formulated in 1985 in connection with the UN-ECE Convention on Transboundary Air Pollution, and has since been signed by 18 countries, including Canada. According to this protocol, signatory countries are bound to reduce sulphur emissions by 30% in relation to the 1980 level before 1993. Some of the countries have already achieved a reduction greater than 30%, while other countries, including Eastern Europe, have not yet been able to live up to the agreement.

The Protocol is currently being renegotiated on the basis of environmental objectives that place more emphasis on the critical load, as well as on regional variation in acidification caused by sulphur and nitrogen. The basic proposal is to reduce sulphur loading by an average of 60% for Europe as a whole. The proposal, which builds on the principle of reducing emissions in those areas where the effect will be greatest, and where the sulphur reduction per unit cost is greatest, means that sulphur emissions in Denmark will have to be reduced by all of 87% in relation to the 1980 level. The consequence of the proposal for Denmark is that sulphur deposition will fall to around the critical load, i.e. approximately half of the present deposition (*Figure 2.2.14*).

If the Ministry of Energy's action plan on energy "Energy 2000" (cf. section 3.2) is implemented, sulphur emissions will be 75% lower in the year 2000 than in 1980. The plans for achieving that target have not yet been finalized, however. If the proposal of an 87% reduction is to be fulfilled, further measures to reduce sulphur emissions will need to be implemented. The feasibility of reducing Danish sulphur emissions by 80% in relation to the 1980 level before the year 2005 is currently being examined.

The *NO_x Protocol*, which was adopted by the UN-ECE in 1988, commits the 25 signatory countries (inc. the USA and Canada) to by 1994 have frozen NO_x emissions at a level corresponding to that in a year of their choice between 1980 and 1986. Many of these countries, including the Nordic countries, have declared that they will reduce their NO_x emissions by a further 30%.

A *VOC Protocol* has also been adopted under the UN-ECE. This stipulates that signatory countries have to reduce VOC emissions by 30% in relation to the 1985 level before the year 2000. Denmark has taken the decision to fulfil that target, but none of the signatory countries have yet ratified the protocol.

A special protocol, which concerns the monitoring of air quality in Europe through a network of 100 monitoring stations in 25 countries, and which was formulated by the European Monitoring and Evaluation Programme (EMEP) under the auspices of the UN-ECE, has been signed by 30 countries. The aim is to enable the effects of the various international agreements on transboundary air pollution to be monitored.

2.3 The urban environment

2.3.1 Introduction

Encompassing 4% of the country's area and approx. 85% of the population, Denmark's urban areas, with their concentration of buildings, roads and other transport and supply facilities, represent a considerable economic asset. In addition, urban areas form the framework for a number of important societal functions such as housing, leisure activities, transport and production enterprises - activities that each make demands on and affect the urban environment. For this reason, the term "urban environment" also encompasses a number of qualitative assets that are difficult to weigh up, and which are not treated separately in this section, but which nevertheless are experienced and appreciated by the people who inhabit or frequent urban areas.

Societal turnover of a number of important resources is concentrated in the urban areas, e.g. drinking water, energy and raw materials for trade and industry. Through their conversion to products and subsequent consumption by the population, these resources are partly returned to the surroundings in the form of pollution and waste. It is for this reason that it was in the urban areas of Europe that environmental deterioration was first acknowledged, and where the impact of pollution first became apparent. Thus until a few decades ago, air pollution was considered a purely urban phenomenon, and one which could be solved by dispersing the pollution from sufficiently high chimneys.

According to the UN's population census, the percentage of the world population that inhabits urban areas increased threefold during the period 1950-90. This trend is expected to continue for the remainder of the century, especially in developing countries, where the UN forecasts that 45% of the population will inhabit urban areas by the year 2000, as compared with 75% of the population in the industrialized part of the world.

Urban areas, with their high concentration of people and economic activities, can therefore be increasingly considered a major contributor to local, regional and global environmental problems.

Regional and global environmental problems have been discussed in the preceding sections. This section examines those environmental problems that originate in and affect the urban environment *per se*.

2.3.2 Urban structure and function

Urban development in Denmark over the last 50 years has been based on functional planning and urban compartmentalization, whereby areas for housing and production were partitioned in independent districts. After 1960, when the motor vehicle became the dominant form of transport, partitioning became even more marked, and the character of individual districts as housing districts, industrial districts, shopping centres and leisure areas became strengthened.

The economic and environmental advantages that such urban development provided led, however, to a number of unintentional new problems, e.g. increased needs for transportation between home and work, deserted industrial and commercial districts in the evening and night-time, as well as housing districts devoid of life during the daytime and offering only a poor selection of social and cultural activities.

In recent decades there has been a tendency for urban expansion to slow down, instead to be replaced by renewal within the existing urban areas. Urban growth has continued in many coastal towns, however, an example being Århus (*Figure 2.3.1*), whereas the population of Copenhagen is on the decline.

2.3.3 Urban trade and industry

Over the last 50 years there has been considerable migration of industrial production away from the centre of large urban areas, and there has been a national trend to migrate from the east of Denmark to the west. Thus whereas 20-30 years ago the industrial centre of gravity was in Greater Copenhagen and the larger towns, it has now moved to the west, taking with it the environmental problems that previously mainly affected Greater Copenhagen (cf. section 3.5).

While one of the reasons for this migration has been the rather limited possibilities for expansion offered by the urban areas, the environmental problems sometimes associated with being neighbour to housing districts have also played a role. The enterprises previously migrated to industrial districts on the outskirts of large urban areas. However, because of the considerable urban growth in the intervening period, housing districts have followed after. As a result, industrial districts containing polluting enterprises have sometimes come to be surrounded by housing districts.

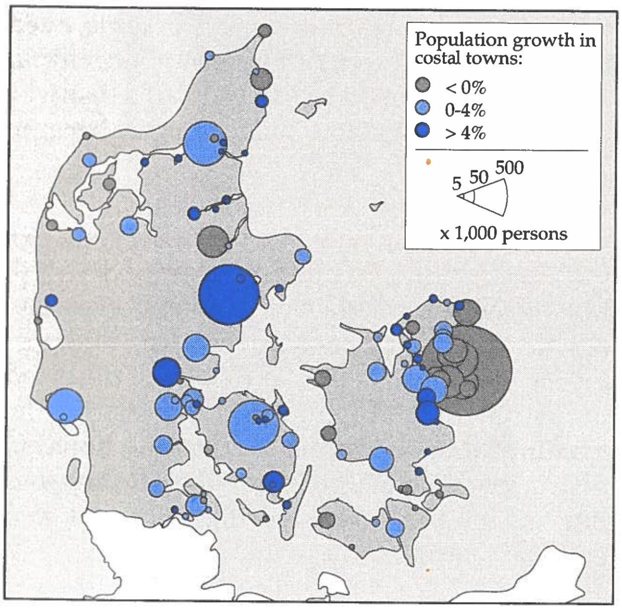


Figure 2.3.1. Population in 1992 and population growth from 1986-92 in selected coastal Danish towns. (Source: Danmarks Statistik; Ministry of the Environment).

Cleaner production technology and better treatment/purification technology will to some extent be able to solve such conflicts in the future, but there will still be enterprises that it would be inappropriate to locate in areas sensitive to pollution.

Contaminated sites

Industrial migration has revealed that many of the abandoned sites are so contaminated that they cannot be used for other purposes without extensive and costly remediation.

The sites are mainly contaminated with organic compounds such as chlorinated solvents, tar residues, pesticides and oil and petrol, but also with heavy metals and cyanides. In several cases, leaching of such compounds to the groundwater has precluded basing the water supply on water abstracted in or within the vicinity of an urban area. Although the total number of water supply boreholes that have been closed as a result of such point-source contamination has not been reckoned, the number is considerable and growing - especially in Greater Copenhagen (cf. section 2.5).

There are at present 2,600 contaminated sites registered in the country as a whole, approximately half of which are former landfills and half are former industrial sites. During the next 5-10 years, by which time the county authorities will have finished their ongoing investigation, the figure is expected to approach 10,000 contaminated sites. Of these, approximately two thirds are expected to be industrial sites, the majority of which will be located in or near urban areas, often near the coast.

The state and the county authorities are currently expending approx. DKK 150 million annually on contaminated site remediation. This is undertaken partly to safeguard current site usage, partly to protect the groundwater, and in certain cases to protect the aquatic environment in general.

2.3.4 Urban traffic

Traffic facilities for both private and collective transport occupy approx. 1/4 of the total urban area, most of this being accounted for by small urban roads. The main thoroughfares, which are planned to cope with the rush hour traffic, only account for a minor part of the area. Traffic between home and work in Denmark is characterized by there being an average of less than 2 persons per car. Moreover, this relatively low capacity utilization has tended to fall in recent years (cf. section 3.3).

Road traffic in Denmark has increased markedly, especially during the last 10 years, and now accounts for the majority of transport. For the country as a whole, 40% of traffic takes place in urban areas. Comparison of the trend in

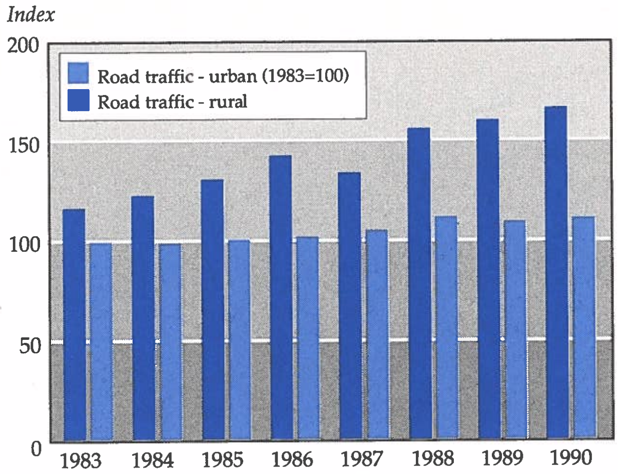


Figure 2.3.2. Trend in rural and urban traffic over the period 1983-90. (Source: Ministry of Transport; Ministry of the Environment).

traffic in urban and rural areas over the last 10 years reveals that growth has been greater in rural than in urban areas (*Figure 2.3.2*).

Urban traffic is considered to be the factor having the greatest impact on the urban environment, with the list of its adverse effects including noise, air pollution, insecurity, barrier effects and deterioration of the visual environment. Several of these effects are discussed below.

Noise

Traffic is by far the greatest source of noise nuisance. Road traffic noise is the most dominant form, but noise from air and rail traffic can also cause problems. Traffic noise is not usually so high that it causes damage to hearing, but it can be a nuisance to many people in and around their homes. For example,

- their activities can be affected, e.g. they open windows less often, go outdoors less often, have their conversations disturbed, and have difficulty in falling asleep,

- their health can be affected, in some cases general well-being lessens, others seek medical help or are admitted to hospital with a nervous breakdown, while others take sedatives or sleeping pills,

- they change their behaviour to offset the noise, e.g. by changing the interior arrangement of their homes, soundproofing their homes, or moving away.

Noise is measured in decibels (dB(A)), a unit whereby noise is weighted according to the sensitivity of the human ear to different sound frequencies. Studies of road noise show that noise levels of around 55 dB(A), which is what is considered acceptable for planning purposes, bother between 10 and 25% of nearby residents. At noise levels above 65 dB(A), which is considered unacceptable for planning purposes, general well-being is affected in 25-50% of residents. In the case of noise from rail traffic, the corresponding levels are 5 dB(A) higher.

It has been found that the impact of road traffic noise varies in different urban areas. The larger the town, the greater the percentage of homes that are affected. Thus 75% of the homes in Copenhagen Municipality are subject to noise levels exceeding 55 dB(A), while in the countryside and in country towns, the figure is only about 10%. A recent study has shown that about 34% of the inhabitants of Copenhagen are bothered by traffic noise in their homes. According to the study, traffic noise is the most frequent form of nuisance in the home.

Noise levels exceeding 65 dB(A) have been recorded alongside nearly all central urban roads with through traffic. Noise levels are particulary high alongside the old approach roads to towns, where built-up areas from earlier times lie spread along the road and traffic is still very heavy. In addition, noise levels are high alongside through roads in town centres and in dense housing districts from the beginning of the century.

Estimates of the impact of noise are subject to considerable uncertainty. The latest assessments indicate that there has been a fall in the number of homes affected by road traffic noise over the last 15 years. Thus the number of homes subjected to noise levels exceeding 65 dB(A) is now estimated to be approx. 145,000, as compared with approx. 225,000 previously. The total number of homes subjected to road traffic noise levels exceeding 55 dB(A) is estimated to be just under 500,000.

A number of the changes made in the area of traffic in recent decades have undoubtedly helped to reduce the nuisances. These include the introduction of speed limits in the 1980s, as well as the implementation of traffic rationalization measures in the most noise-plagued areas of towns.

A thorough assessment is currently being undertaken of road traffic nuisances as they are expected to develop in future.

In addition to road traffic, a large number of people are also bothered by noise from aircraft and trains. Recent studies show that approx. 40,000 homes are subjected to noise levels exceeding 60 dB(A) from trains, and that aircraft noise affects a further 40,000 homes in the vicinity of large airports and aerodromes. An analysis of the possibilities for reducing noise around Copenhagen Airport at Kastrup, which is where by far the majority of noise-plagued homes lie, has just been completed.

Traffic safety

The number of accidents and the number of traffic fatalities and injuries have been on the decline for some years. The official statistics for 1991 are that 606 persons were killed in road traffic accidents, 6,231 suffered serious injuries, and 4,031 suffered minor injuries. These figures only represent accidents reported by the police. Studies undertaken at hospital casualty rooms indicate that only around 20% of the injuries necessitating a visit to a casualty room are included in the official statistics. However, the statistics for serious injuries and fatalities are undoubtedly much more correct.

The pattern of accidents in urban and rural areas differs considerably, 57% of all personal injuries occurring in the towns as opposed to only 43% outside the towns. This is mainly attributable to the many possibilities for conflict that the mixed urban traffic presents. In contrast, only 36% of traffic fatalities occur in towns. The lower speed is an important reason why the accidents that occur in urban areas are less serious. Pedestrians and cyclists are much more likely to suffer injuries in urban areas than are car drivers and passengers (*Figures 2.3.3 and 2.3.4*).

The number of traffic accidents in Denmark is somewhat different from that in the other northern European countries. The number of traffic fatalities per million inhabitants is lower

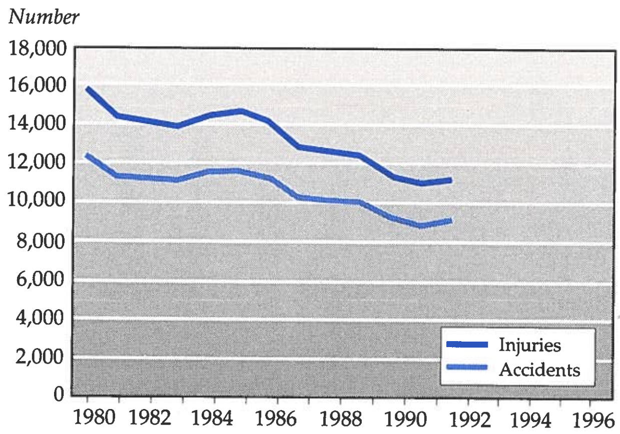


Figure 2.3.3. Trend in the number of traffic accidents and personal injuries in Denmark over the period 1980-91. (Source: Danmarks Statistik).

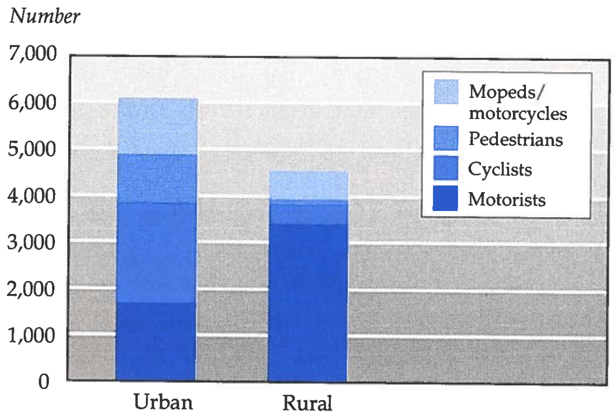


Figure 2.3.4. Pattern of urban and rural traffic accidents in Denmark. (Source: Danmarks Statistik).

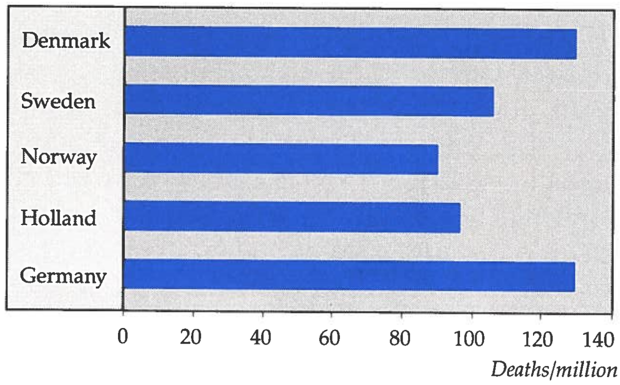


Figure 2.3.5. Traffic fatalities per million inhabitants in selected northern European countries in 1989. (Source: Danmarks Statistik).

in the other countries, being only 2/3 of the Danish level in Norway and 3/4 of the Danish level in Sweden and Holland. Germany (West) lies at the same level as Denmark (*Figure 2.3.5*). On the other hand, the total number of accidents leading to personal injuries is lower in Denmark than in the other countries (*Figure 2.3.6*). No unambiguous explanation for these differences is available. There could be differ-

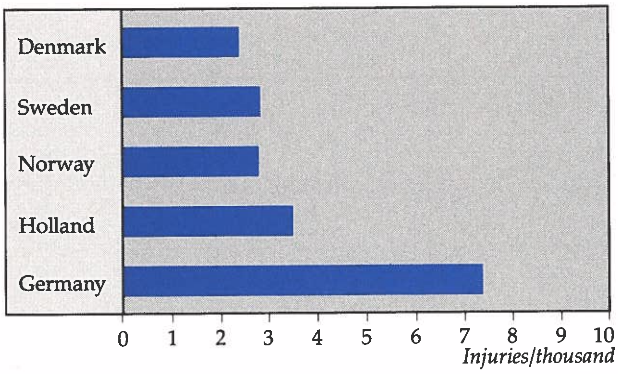


Figure 2.3.6. Traffic personal injuries per 1,000 inhabitants in selected northern European countries in 1989. (Source: Danmarks Statistik).

ences in the data collected, although statistics for traffic fatalities is usually considered to be more reliable than those concerning less serious personal injuries.

2.3.5 Urban air pollution

Air pollution in the largest Danish towns is investigated by the National Environmental Research Institute through the so-called National Urban Air Quality Monitoring Programme, which was initiated in its present form in 1981. At present (1993), air pollution is being monitored in 6 Danish urban areas: Greater Copenhagen, Odense, Fredericia, Esbjerg, Århus and Ålborg.

Sources of pollution

Urban air pollution is mainly determined by the sum of pollution derived from three main sources:

- traffic,
- other local pollution,
- transboundary air pollution.

Traffic: A common feature of both petrol and diesel driven vehicles is that they both use light fuels with a relatively low sulphur content and that combustion in the engines takes place at relatively high temperature. During this process, some of the nitrogen in the air is oxidized to nitrogen oxides (NO_x), especially nitrogen monoxide (NO). The latter is rapidly oxidized further to nitrogen dioxide (NO_2), which is more hazardous to health than NO. Vehicles driven with badly tuned engines or incomplete combustion also emit carbon monoxide (CO) and hydrocarbons (CH). Volatile organic compounds (VOCs) are emitted from traffic in amounts corresponding to approx. 50% of total anthropogenic emissions. The combustion of petrol containing tetraalkyl lead additives results in the emission of lead.

Other local pollution: Another anthropogenic source of pollution in urban areas is the com-

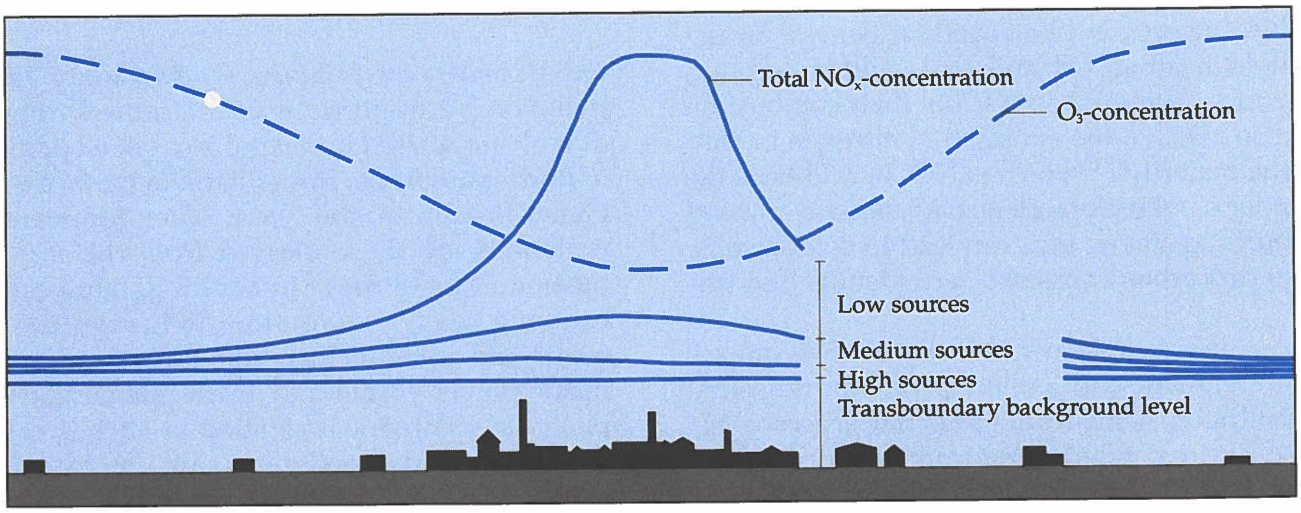


Figure 2.3.7. Diagrammatic representation of the concentration of nitrogen oxides (NO_x = NO + NO_2) in rural and urban areas. The level of pollution is high in urban areas, with the dominant contribution being from low sources (motor vehicles), and much lower in rural areas, where the dominant source is transboundary transport from abroad. The concentration of ozone (O_3), which is broken down by NO during the formation of NO_2, is lower in urban areas than in rural areas. (Source: Fenger, 1991).

Substance	Measurement period (h)	Statistic	Limit value ($\mu g/m^3$)	Period of calculation	Source
SO_2	24	50-perc.	80	1/4 -31/3	(1)
		98-perc.	250		
		50-perc.	130	1/10 - 31/3	
Total suspended particulates (TSP)	24	Mean	150	1/4 - 31/3	(1)
		95-perc.	300		
Lead		Mean	2	1/1 - 31/12	(2)
NO_2	1	98-perc.	200	1/1 - 31/12	(3)
		50-perc.	50 (*)		
		98-perc.	135 (*)		

(*) recommended level

Table 2.3.1. Air pollutant limit values currently in force in Denmark. Sources: (1) Ministry of the Environment Statutory Order No. 836 of December 10, 1986; (2) EU Directive 82/884/EC of December 3, 1982; (3) Ministry of the Environment Statutory Order No. 119 of March 12, 1987. (Source: Kemp & Palmgren Jensen, 1994).

	Ozone ($\mu g/m^3$)			Carbon monoxide ($mg(CO)/m^3$)		
Station	Median	Max. 8 hr	Max. 1 hr	Median	Max. 8 hr	Max. 1 hr
1103	11	52	62	2.2	9.4	28
3003	27	88	97			
WHO		100-120	150-200		10	30

Table 2.3.2. Yearly mean ozone and carbon monoxide concentrations measured in Copenhagen (H.C. Andersens Boulevard: station 1103) and Skovbo (station 3003) shown together with the corresponding WHO guidelines. (Source: Kemp & Palmgren Jensen, 1994).

bustion of natural gas, coal and oil products in industry, coal-fired combined district heating/power plants and for general household heating. Oil and coal contain sulphur, which is emitted as SO_2, but their combustion also leads to the emission of nitrogen oxides, the majority of which is NO. In addition, the poor combustion often characteristic of wood burning stoves, etc., can lead to considerable hydrocarbon emissions in residential districts.

As there is no heavy industry of consequence in Denmark, only a minor part of the industrial pollution stems from industrial processes *per se* - the major part stems from industry-related energy production and heating. Heavy metal emissions do not therefore pose any general problem in Denmark, although this does not preclude the possibility of local problems around industrial point sources.

Transboundary air pollution: Quite a lot of air pollution is transported in over Denmark from densely populated industrial areas in all parts of northern Europe, from Russia in the east to Great Britain in the west. The dominant pollutants are those derived from the combustion of fossil fuels. In addition, there can be some heavy metals from industrial processes and waste incineration. Pollution from major power plants and waste incineration plants in Denmark is emitted at such great heights that the pollutants are effectively dispersed. Thus as far as concerns urban areas, such pollution will behave in the same way as transboundary pollution.

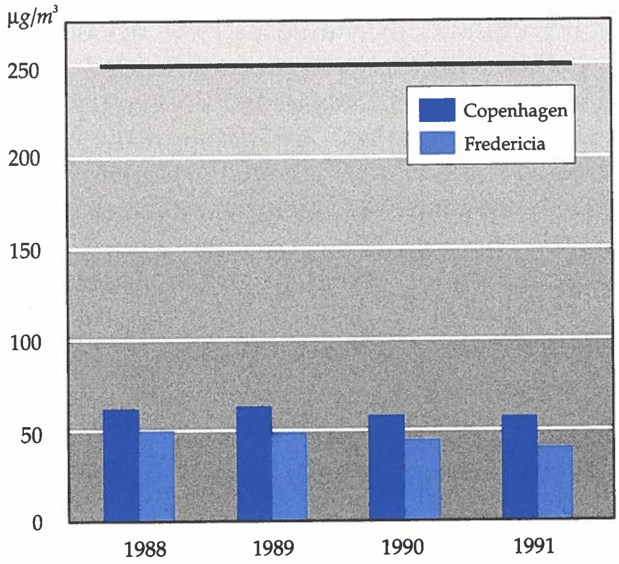


Figure 2.3.8. Concentration of SO_2 (annual 98 percentile of one-hour averages) measured in Copenhagen and Fredericia. The horizontal line represents the mandatory limit value (98 percentile). (Source: Kemp & Palmgren Jensen, 1994).

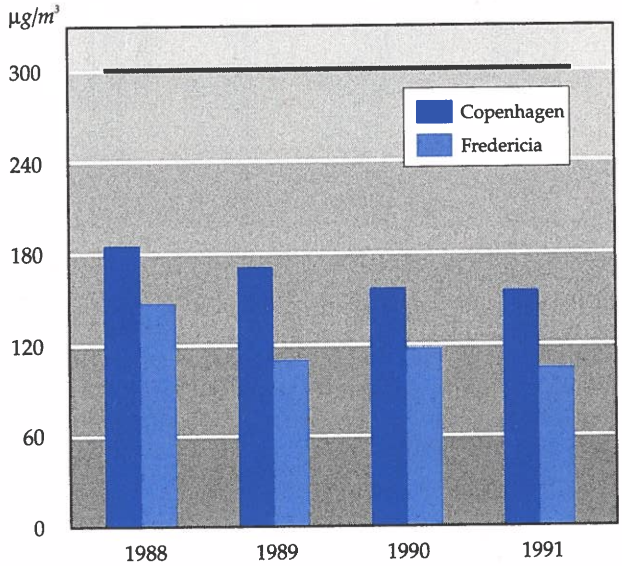


Figure 2.3.9. Concentration of suspended particulates (annual 98 percentile of one-hour averages) measured in Copenhagen and Fredericia. The horizontal line represents the mandatory limit value (95 percentile). (Source: Kemp & Palmgren Jensen, 1994).

The overall level of nitrogen oxides and hydrocarbon pollution in northern Europe determines the regional ozone concentration and hence the background level measured in Denmark. In urban areas, this ozone level will determine the amount of NO_2 formation, the reason for this being that ozone reacts with NO from vehicle exhaust gasses and forms NO_2 (*Figure 2.3.7*). The effect on the NO_2 concentration of the introduction of catalytic convertors on cars will therefore also depend on international endeavours to regulate these pollutants.

Effects and limit values

The general level of air pollution in selected urban areas is monitored by means of the National Urban Air Quality Monitoring Programme. The aim of the programme is to determine the concentration of potentially toxic substances so that their effects on man, animals and plants can be judged. However, it is the significance of the pollutants for human health on which the limit levels for the individual substances are based.

The limit levels are usually fixed by dividing the lowest concentrations that can cause demonstrable damage to health by a safety factor of between 2 and 10. The most comprehensive and frequently used recommendations for limit levels have been drawn up by the WHO. Both the EU and Denmark have used these as the basis for setting mandatory and recommended limit levels. The limit levels currently in force are summarized in *Table 2.3.1*. Limit values for ozone will be introduced in 1994.

The limit levels for substances that have acute effects on man, e.g., NO_2, are typically given as short-term mean values that may only seldom be exceeded. In the case of NO_2, the 98 percentile is therefore a mandatory limit value (200 $\mu g/m^3$) that signifies that 98% of the hourly mean values over a period of 1 year are less than the limit value, which consequently may only be exceeded 2% of the time.

Level of pollution - trends

The following overview of selected pollutants is based on the results of the National Urban Air Quality Monitoring Programme. The measurement results on which the overview is based, and which are compared with limit values, are from monitoring stations in Copenhagen and Fredericia. These stations represent relatively high and relatively low levels of pollution, respectively. Evaluation of the trends is primarily based on the results from stations for which long time-series are available.

Sulphur dioxide: As is apparent from *Figure 2.3.8*, the concentrations measured are low, and do not exceed the current limit levels. Since the first energy crisis at the beginning of the 1970s, sulphur dioxide pollution of the air has been falling because of a reduction in emissions, despite an increasing energy consumption during the whole period. This is attributable to more efficient utilization of energy and heat production, improved utilization of the fuel, the introduction of natural gas, and better regulative control of the sources of pollution.

Suspended particulates: As is apparent from *Figure 2.3.9*, the limit value is not exceeded. Nevertheless, suspended particulates are the pollutant that, second only to NO_2, come closest to the limit value. The suspended particulates measured represent an unspecific mixture from a number of different sources, the most significant of which is whirled-up soil particles. The latter hardly present a health risk, however.

Nitrogen oxides: As is apparent from *Figure 2.3.10*, there is no problem of compliance with the mandatory limit level of 200 µg NO_2/m^3. However, the recommended limit levels are reached at several stations in areas of heavy pollution. In 1991, though, the values only approached the recommended limit levels in Copenhagen; nevertheless, they were probably high enough to be a bother to predisposed persons, e.g. asthma patients.

Lead: The air concentration of lead has fallen by a factor of 10 over the last 15 years (*Figure 2.3.11*). Road traffic has been the major source, and emissions have fallen markedly in step with the implementation of a fuel tax differential in favour of unleaded petrol. In 1978, the lead content of petrol was limited to 0.40 g/litre. In 1984, the limit was further reduced to 0.15 g/litre for all types of petrol. In 1986, a DKK 0.25 fuel tax differential in favour of unleaded petrol was introduced. This was widened to DKK 0.65 in 1990, and the differential is now greater in Denmark than in most other countries. Unleaded petrol currently accounts for 80% of all petrol sales. The trend in lead emissions shows the result of this policy.

Other substances: Carbon monoxide and ozone concentrations measured in 1990 are shown together with the WHO recommended limit levels in *Table 2.3.2*. It should be noted that the ozone concentrations are higher at the background station (Skovbo) outside Copenhagen than in the centre of Copenhagen (H.C. Andersens Boulevard). This shows that there is a net degradation of ozone in urban areas, the conversion of NO and O_3 to NO_2 probably being the most important process.

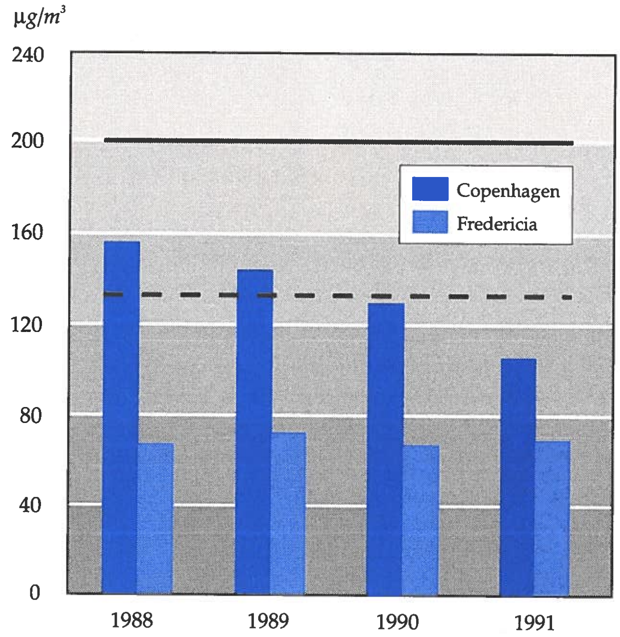


Figure 2.3.10. Concentration of NO_2 (annual 98 percentile of one-hour averages) measured in Copenhagen and Fredericia. The unbroken horizontal line represents the mandatory limit value and the broken line the recommended limit level (98 percentiles). (Source: Kemp & Palmgren Jensen, 1994).

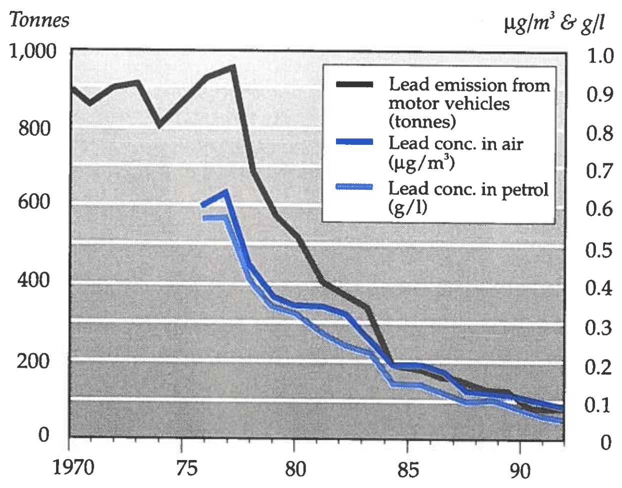


Figure 2.3.11. Trend in the lead concentration in the air, the lead content of petrol and total lead emissions over the period 1970-92. (Source: National Environmental Research Institute).

2.3.6 Environmental endeavours in urban areas

A number of initiatives have been implemented to counteract environmental deterioration in urban areas, as well as to promote more appropriate exploitation of resources. This applies both at the local and at the state level, and involves the environmental conditions associated with both trade and industry, traffic and housing districts.

As regards the nuisances caused by traffic, many municipalities are in the process of undertaking concrete measures to reduce the nuisances as part of their involvement in national action plans concerning traffic and the environment. The state supports these endeavours by providing advice, instruction, and financial help, among other means from the Ministry of the Environment's Traffic and Environment Fund. Emphasis is placed on considering urban traffic and the problems associated with it as an entity that has to be seen in the context of overall urban development. It is the goal that all municipalities with more than 10,000 inhabitants shall, as part of their routine planning, draw up and put into effect local action plans to improve traffic safety, air quality, noise, etc. A large number of municipalities have already started this work.

Noise: The government's 1990 Action Plan on Transport stipulates that the number of homes subjected to noise levels exceeding 55 dB(A) shall be reduced. In addition, specific targets have been set for the reduction in the number of homes subjected to noise levels exceeding 65 dB(A). In 1990, the target was equivalent to a halving of the number of homes reckoned to be affected at that time. Since then a number of initiatives have been implemented that should help to reduce the noise nuisance, e.g. a programme of noise abatement alongside the main state road net (cf. section 3.3).

Air pollution: In the long term, it is expected that car catalytic convertors will considerably reduce NO emissions from traffic. However, effective reduction in NO_2 concentrations can only be brought about by means of a coordinated international effort to reduce emissions of NO, as well as of the components (VOCs) that lead to the formation of ozone. As is the case with SO_2, there is an international agreement to reduce NO_x emissions from power plants. A VOC protocol has also been adopted internationally according to which VOC emissions from all national sources have to be reduced by 30% in relation to the 1985 level before the year 2000 (cf. sections 2.2 and 3.2).

In 1987, as a trial measure, a national smog warning system was initiated. A smog episode is when an unfortunate coming together of special meteorological conditions leads to extremely high concentrations of individual substances such that it is necessary to warn people against frequenting particularly affected areas of towns. The trial measure is expected to be made permanent, and will encompass SO_2, NO_2 and ozone (O_3).

Initiatives relating to urban ecology: Increased awareness of overall consumption of resources in urban areas has led to the implementation of a large number of urban ecology projects. Urban ecology expresses a comprehensive and multidisciplinary way of thinking in which the urban area is considered as an entity from the environmental point of view. One of the main objectives is to reduce urban consumption of physical resources, while at the same time reducing the amount of waste. In addition, urban ecology strives to promote the use of healthy materials in buildings and to promote the green character of urban areas. The projects carried out have typically been aimed at the improvement of individual buildings, water conservation, renewable energy, waste disposal solutions, etc. An advisory committee on urban ecology has been established under the Ministry of the Environment whose function is to evaluate urban ecology initiatives as a whole. Among other things, the committee shall evaluate whether there are urban ecological considerations that are currently inadequately attended to through existing sectorial measures, as well as whether there is a need for particular urban ecological initiatives. In addition, projects have been initiated in selected municipalities to develop municipal planning strategy aimed at ensuring more cohesive safeguarding of the environmental aspects of urban areas.

2.4 Eutrophication

2.4.1 Introduction

Water bodies - watercourses (mainly streams), lakes, fjords, coastal waters and open marine waters - are an important part of the Danish nature. In recent decades the environmental condition of these areas has been found to have deteriorated in several respects, as manifested by enhanced algal growth, periods of oxygen deficit, fish kill, etc. The poor environmental condition is mainly attributable to enhanced nitrogen and phosphorus loading of the aquatic environment (eutrophication).

The growth of phytoplankton and other plants in the aquatic environment is mainly controlled by the nutrients nitrogen (N) and phosphorus (P). Under natural conditions both nutrient loading and algal growth are relatively modest, and there is a diverse and stable plant and animal community. With enhanced nutrient loading that stable community can be brought out of balance. In many coastal areas enhanced nutrient loading leads to increased growth of annual macrophytes, and in some cases to mass occurrence of filamentous algae. The latter deteriorates the living conditions for benthic invertebrates and spawning and nursery areas for fish. At even higher levels of nutrient loading the amount of phytoplankton increases markedly, and the water becomes turbid such that conditions for plants and animals deteriorate further. The turbid water prevents the sunlight from penetrating down to the submerged macrophytes and they therefore disappear. The composition of the fish stock changes towards species that are favoured by the turbid water, this leading to the mass occurrence of roach and bream in the case of lakes, and of sticklebacks and gobies in the case of coastal waters. These fish eat the zooplankton in the water, thereby causing a further increase in the amount of phytoplankton. In deep lakes and open marine waters, large amounts of phytoplankton will sediment out and oxygen consumption will consequently increase, possibly resulting in oxygen deficit and fish kill.

Eutrophication is defined here to mean: "*An enrichment of the aquatic environment with nutrients that leads to increased production of phytoplankton and higher aquatic plants that in turn leads to deterioration of water quality and a reduction in the utility of the aquatic area*". The negative effects of eutrophication are generally greatest in Danish lakes and fjords, as well as coastal and open marine areas.

Nutrient loading generally increases with increasing human activity in the catchment area. During this century the urban population has increased from around 2/5 to more than 4/5 of the population. In addition, sewerage systems have been laid and both industrial production and household consumption have increased dramatically. This has resulted in extremely large quantities of waste water and hence also of nutrients. Because of our effective sewerage systems, the majority of the waste water is now led directly out into water bodies. An important use of water bodies in this century has therefore been for the disposal of waste water. Similarly, the structure of the agricultural sector has changed and effectiveness has increased markedly. Much of the agricultural land is drained and many of Denmark's marshes, wetlands, ponds and lakes have disappeared. This has considerably reduced the possibility for nutrients to be retained on land prior to their being led out into the water bodies.

The most important change in agricultural practice is the marked increase in the use of fertilizer (cf. section 3.4). Fertilizer input to agricultural land has almost doubled over the last 30 years, the result being that leaching of nutrients has increased markedly. Agriculture is now the most significant source of nitrogen loading of water bodies. The following section reviews the current state and development of the environmental condition of Danish watercourses, lakes, fjords and coastal areas, as well as the open marine waters.

2.4.2 Environmental condition of Danish watercourses

Although the environmental condition of watercourses is affected by nutrient discharge, other factors such as the discharge of organic matter and the physical condition of the watercourse are generally of more importance. For a detailed description of the environmental condition of watercourses the reader is referred to e.g. Ministry of the Environment (1993) and Svendsen et al. (1993).

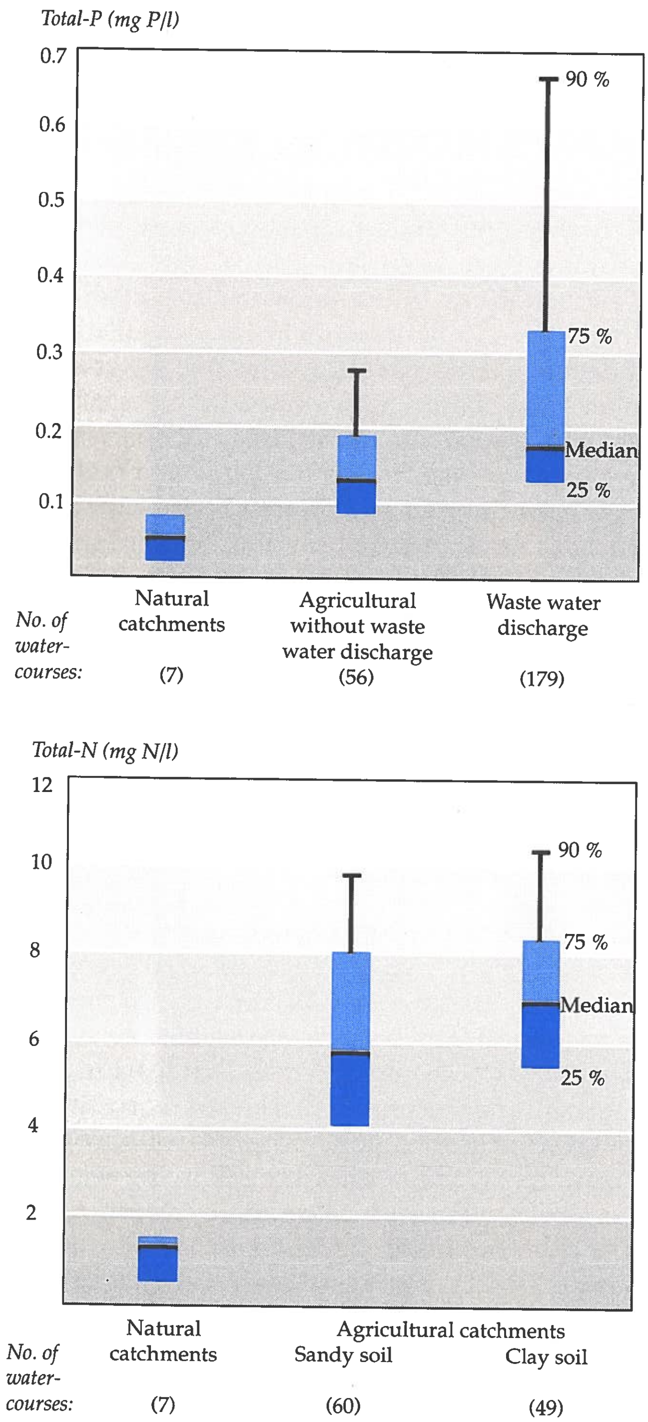


Figure 2.4.1. Yearly mean concentration of phosphorus (tot-P) and nitrogen (tot-N) in watercourses draining natural catchments, agricultural catchments without point sources, and catchments with point sources. 25%, median, 75% and 90 % mean that 25 %, 50%, 75% and 90% of the watercourses have a yearly mean concentration less than the level indicated. (Source: National Environmental Research Institute).

Nutrients in watercourses

Nutrient loading of lakes and coastal areas is mainly attributable to riverine transport. The nutrient concentration in a watercourse is a function of the various human activities taking place in the catchment area. Thus the concentration of nutrients is lower in watercourses that drain natural catchments (non-agricultural) than in those that drain agricultural catchments without point-source discharges (*Figure 2.4.1*). In catchments with point-source discharges, i.e. municipal sewage treatment plants, individual industrial outfalls or fish farms, the concentration of nutrients is extremely dependent on the relative size of the point source.

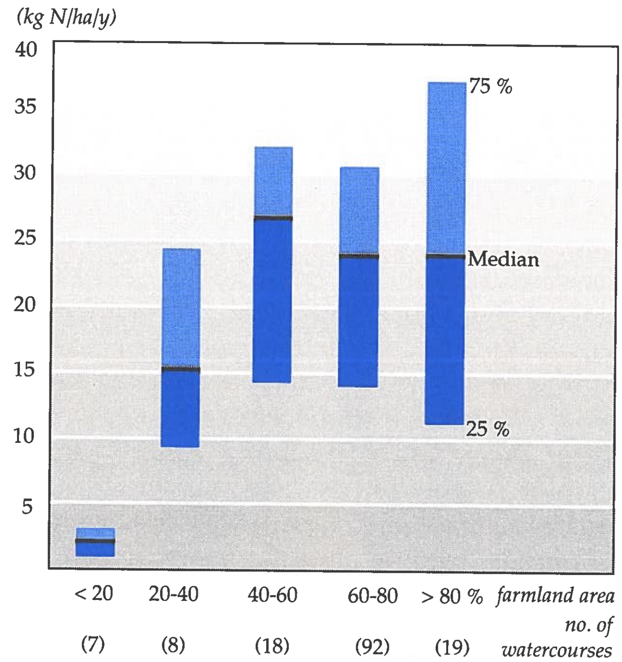


Figure 2.4.2. Relationship between the export coefficient of nitrate-nitrogen and the percentage of the catchment that is cultivated (Source: National Environmental Research Institute).

The phosphorus concentration in watercourses draining agricultural catchments is therefore 2.5 times greater than that in watercourses draining natural catchments, and can be extremely high in point-source loaded watercourses (1-5 mg P/l).

The nitrogen concentration and export in watercourses is especially dependent on the percentage of the catchment that is cultivated (*Figure 2.4.2*). Thus in areas with a low percentage of cultivated land the export coefficient

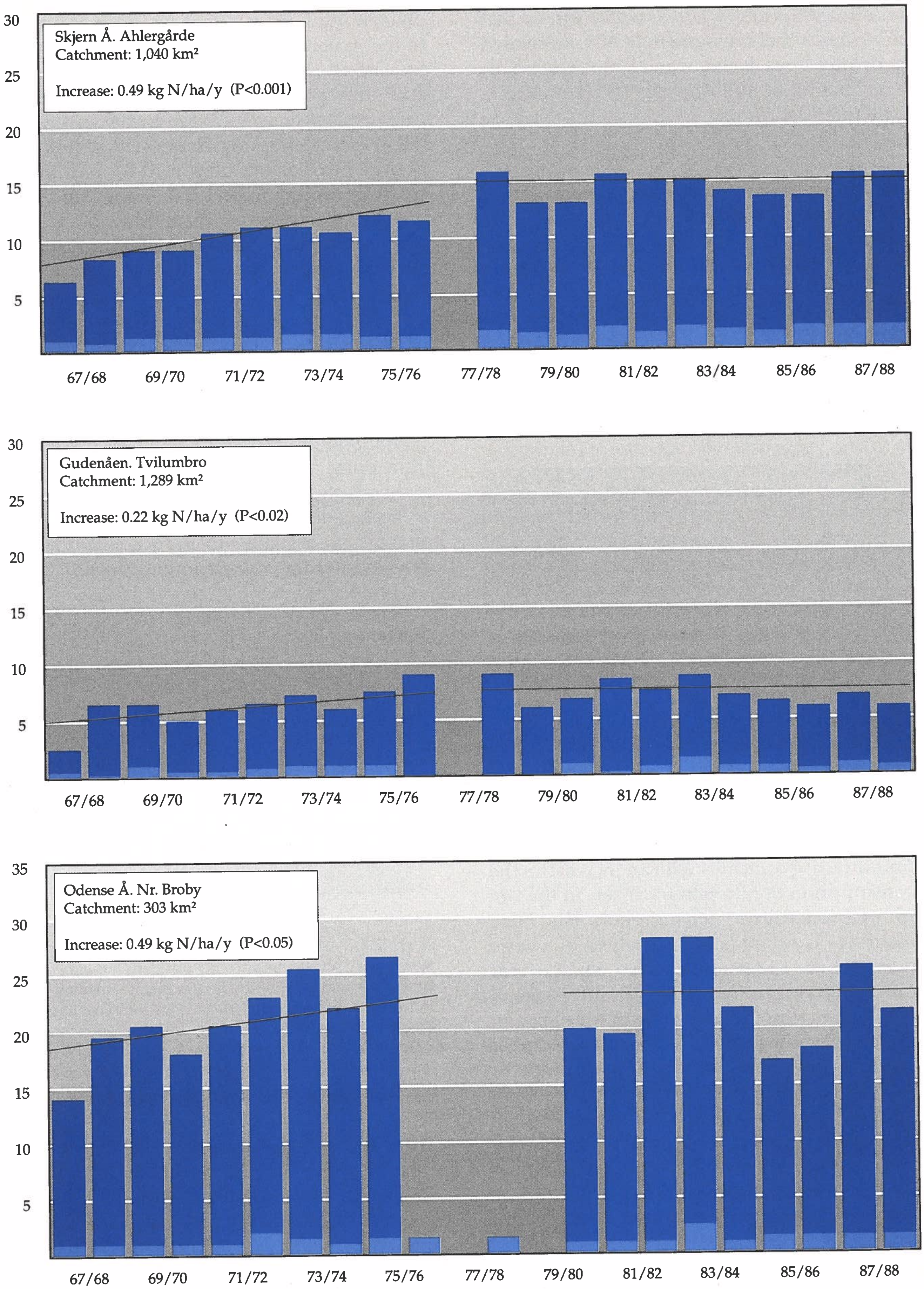


Figure 2.4.3. Discharge-weighted export coefficient of nitrate-nitrogen in the rivers Skjern Å, Gudenå and Odense Å during the period 1967-89. Units: kg/ha/y. Light blue represents nitrogen export during the summer months. (Source: Kristensen et al., 1990).

for nitrogen is low, whereas watercourses that drain areas that are more than 60% cultivated generally have a considerably higher export coefficient (on average 65% of Denmark is cultivated land).

Trends in watercourse nitrogen and phosphorus concentrations

At the end of the last century the concentration of nitrogen was measured in six large rivers - Suså, Odense Å, Storå, Skjern Å, Konge Å and Gudenå (Westermann, 1898). Comparison of these concentrations with the concentration in 1991 reveals that the nitrogen concentration in these rivers has doubled.

Region	1979-1987 (kg N/ha/y)	1988-1992
Western Jutland	12.7	13.3
Eastern Jutland	16.0	17.7
Funen	18.8	19.5

Table 2.4.1. Discharge-weighted export coefficient of nitrogen in the periods prior to and following adoption of the Action Plan on the Aquatic Environment in 1987. (Source: Kronvang et al., 1992).

The nitrogen concentration in Skjern Å, Gudenå and Odense Å has been measured since 1967. During the period 1967-78 there was a significant increase in the export coefficient of nitrogen of about 3% per year (*Figure 2.4.3*). This increase coincides with an increase in the consumption of nitrogen fertilizer. In the last 15 years fertilizer consumption has been relatively constant, and an analysis of a large number of watercourses also shows that nitrogen transport (corrected for inter-annual variation in runoff) has been both constant and high during the period 1978-92. Evaluation of nitrogen transport in the watercourses of Jutland and Funen in the nine year period preceding the adoption of the Action Plan on the Aquatic Environment in 1987 and in the five years thereafter reveals a somewhat higher level in the last five years (*Table 2.4.1*). Thus there is no sign that nitrogen leaching has decreased.

The concentration of phosphorus in Danish watercourses generally increased until the end of the 1970s. Thereafter a marked decrease in phosphorus concentration has been observed in the majority of Danish watercourses over the last 10-15 years. Comparison of the 1978 and 1991 phosphorus concentration in 109 watercourses revealed a statistically significant fall in 64% of the watercourses, no significant change in concentration in 31%, and an increase in concentration in 5%. The fall in phosphorus concentration in another 50 watercourses for which measurements are available for each year from 1978 to 1992 is shown in *Figure 2.4.4*.

In general, the decrease in phosphorus concentration has been greatest in the large watercourses. The observed decrease in the phosphorus concentration is almost wholly attributable to reduced phosphorus discharge from point sources, especially sewage treatment plants, and is therefore a consequence of the Action Plan on the Aquatic Environment and other measures to reduce phosphorus discharge to the aquatic environment.

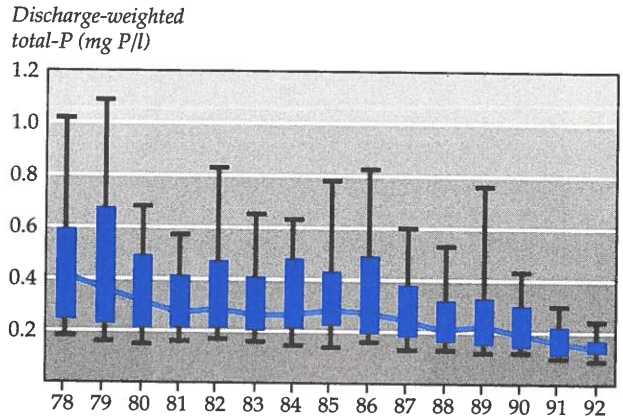


Figure 2.4.4. Changes in the discharge-weighted concentration of phosphorus (tot-P) in 50 Danish watercourses during the period 1978-92. The 10-, 25-, 50- (median line), 75- and 90 percentiles are indicated for each year. (Source: Svendsen et al., 1993).

2.4.3 Environmental condition of Danish lakes

There are approximately 470 lakes larger than 5 ha (50,000 m^2) in Denmark. The majority of Danish lakes are shallow with an average depth of less than 3 metres. In its natural state this type of lake is characterized by having widespread coverage of submerged macrophytes since in the clearwater lakes, sunlight is able to reach much of the bottom. The fish stock is comprised of the predators perch and

Lake name	Depth distribution (m)	Source	Total-P(µg P/l) 1895-1912	1980s
Brabrand Sø	to bottom > 1.5	1	<< 100	920
Silkeborg søer	2-3(4)	1	< 20-75	115-175
Bagsværd sø	2	2	< 75	250
Lyngby sø	3.5	2	< 20-50	140
Gundsømagle sø	to bottom >2	3	<< 75	1280
Sjælsø	3-3.5	3	< 20-50	225
Vejle sø	2.5	3	< 50-75	600
Farum sø	6.5-7	2	< 10-30	120
Søllerød sø	5.4	3	< 20-40	950
Furesø	7-7.5	2	< 10-30	90

Table 2.4.2. Measured depth distribution of submerged macrophytes and phosphorus concentration in a number of lakes at the beginning of the century (estimated) and in the 1980s (measured). (Source 1: Baagøe and Kølpin Ravn, 1895; 2: Boye-Petersen, 1917; 3: CowiConsult, 1990).

pike, while the relative number of roach and bream is low.

Today the environmental condition of many Danish lakes is poor. The lakes are generally extremely nutrient-rich with high concentrations of phosphorus and nitrogen, large amounts of phytoplankton, and turbid water. The environmental condition of the lakes is mainly determined by the phosphorus concentration. The majority of the lakes currently have a phosphorus concentration greater than 100 µg P/l and a nitrogen concentration greater than 2 mg N/l. The transparency of the water is poor, Secchi depth in the summer period generally being less than 1 m. Few of the lakes have a widespread distribution of submerged macrophytes, and the majority of the lakes have a fish stock dominated by roach and bream. Algal blooms of blue-green algae occur in a large part of the lakes during the summer period and can lead to the formation of a green paint-like layer on the surface of the water, and in some cases the algae can be toxic to cattle, dogs and man.

Trends in lake environmental condition

Measurements of the nutrient concentration of lake water at the beginning of the century are not available. However, by comparing botanical studies of Danish lakes with their current environmental condition it is possible to get an idea of how their condition has changed; similarly, plant remains in a lake sediment can also give an idea of the lake's previous environmental condition (*Box 2.4.1*). Around the beginning of the century the majority of Danish lakes had extensive coverage with submerged macrophytes to a depth of 3 m or more (*Table 2.4.2*). Today the majority of the lakes have little or no submerged macrophytes. For example, following an excursion to watercourses and lakes in Jutland in 1895 Baagøe and Kølpin Ravn (1895) (although the charm of the old fashioned Danish is lost in the translation) wrote:

"Concerning the depth distribution of different types of vegetation, we can report the following figures from the Silkeborg lakes. The reeds reach out to a depth of 2 m; this applies both to *Scirpus* and *Phragmites*, when growing as pure populations. *Myriophyllum* and *Ceratophyllum* go 1 m deeper. Depths deeper than 3 m are vegetation free.... At a single location in the eastern end of lake Silkeborg Langsø we found *Elodea canadensis*, *Ceratophyllum demersum*, *Potamogeton crispus* and *lucens* on silt at a depth of 4 m."

Today the environmental condition is rather deteriorated, and very few of the "Silkeborg lakes" have submerged macrophytes. The distribution of submerged macrophytes can be converted to an estimated phosphorus concentration in the lake water in the period around the turn of the century, and compared with the measured phosphorus concentrations in the 1980s (*Table 2.4.2*). This indicates that the lakes have previously had a phosphorus con-

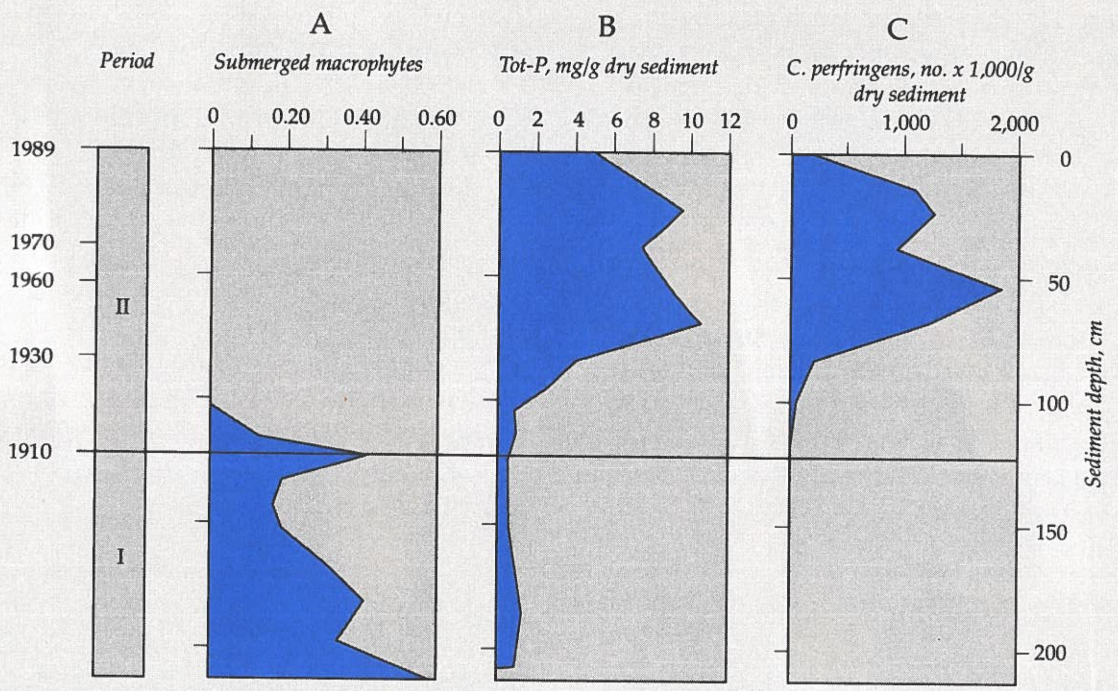
Søllerød Sø, a lake in northern Zealand, well illustrates how the environmental condition of Danish lakes has developed. Sewage water has been led into the lake for the whole of this century and as a consequence, the lake is currently extremely eutrophic. Prior to 1924, the sewage led into the lake was untreated. The Kirkeskoven sewage treatment plant then came into operation and the sewage was thereafter treated both mechanically and biologically. Although the treatment plant ceased discharging waste water into Søllerød Sø in 1975, the lake occasionally still receives waste water from overflow outfalls. The lake currently has a high phosphorus concentration and its environmental condition is generally poor.

An approximately 1 cm thick layer of new sediment forms on the lake bed each year. Analysis of a core through the lake bed can therefore be used to illustrate the lake's development. Such an analysis was undertaken by the Greater Copenhagen Council and COWI consult in 1989. The main findings are summarized below.

The layers originating from before 1910 contain numerous remains of submerged macrophytes (A) - a clear indication that submerged macrophytes were previously widespread in the lake. In later layers, the remains of submerged macrophytes are absent.

The lake sediment content of phosphorus (tot-P) increases markedly after 1930, and is particularly high from 1950 onwards. In the uppermost layers it decreases slightly, this being attributable to a decrease in phosphorus loading as a result of the almost complete cessation of waste water discharge into the lake from 1975 onwards (B).

The lake sediment content of spores of the human digestive tract bacterium *Clostridium perfringens* shows a similar development as that of phosphorus - and for the same reason (C).



Box 2.4.1. Development in the environmental condition of the lake Søllerød Sø during this century. (Source: Copenhagen County, Frederiksborg County and Roskilde County).

centration of less than 50 µg P/l. Current conditions in the majority of the lakes therefore represent a many-fold increase in the phosphorus concentration.

The deterioration in environmental condition has taken place gradually from the turn of the century up to the mid 1970s, though especially from the beginning of the 1950s, when phosphate-containing washing powders were introduced for household use and the amount of waste water increased markedly. In the 1970s and 1980s phosphorus input to a number of lakes was reduced, either by the cessation of waste water discharge, or by the implementation of phosphorus removal in the sewage treatment plants.

An analysis of the trend in 55 lakes from the 1970s until the end of the 1980s showed a marked general reduction in the phosphorus concentration, the median concentration falling from 240 µg P/l in 1972-79 to 180 µg P/l in 1985-89. Since 1989 the environmental condition of 37 representative Danish lakes has been followed in connection with the Action Plan on the Aquatic Environment Nationwide Monitoring Programme (cf. Kronvang et al., 1993). The results of these standardized investigations show that the phosphorus concentration in the lakes has further decreased between 1989 and 1991.

In many cases, however, the phosphorus concentration has not been reduced sufficiently to allow a satisfactory environmental condition to be obtained. Many Danish lakes currently have a phosphorus concentration greater than 125 µg P/l, whereas the concentration generally has to be brought below 80-100 µg P/l if the environmental condition is to improve significantly in the direction of fewer phytoplankton, including blue-green algae, and hence clear water and a greater abundance of submerged macrophytes, as well as a better balance between predators and planktivorous fish. In the deeper lakes the phosphorus concentration has to be considerably lower - around 20-40 µg P/l - in order to achieve the same degree of improvement in environmental condition as in the shallow water lakes.

2.4.4 Environmental condition of Danish fjords and coastal areas

Denmark's long coastline and many fjords make these water bodies a characteristic and important part of the Danish nature. The Danish coastal areas can be described as shallow water, open coastal ecosystems. Tides, waves, wind-induced water circulation and the input of freshwater via watercourses ensure that water exchange is great. Nutrient input is mainly attributable to freshwater runoff, inflow from adjacent marine waters and atmospheric deposition.

In the shallow coastal areas where nutrient concentrations are low, perennial submerged macrophytes are of great significance, e.g. eelgrass and macroalgae (*Figure 2.4.5*). These areas are important as spawning and nursery grounds for fish. With enhanced nutrient levels the benthic vegetation shifts to annual filamentous algae, sometimes as mass occurrences. These mass occurrences considerably deteriorate conditions for benthic invertebrates and fish, and in relatively shallow water can lead to episodes of oxygen deficit and the occurrence of sulphurous bacteria on the sediment surface. The filamentous algae hinder coastal fishery, cause problems of odour and give a generally unpleasant impression of the coasts.

Trends in the environmental condition of coastal waters

The environmental condition of Denmark's fjords and coastal areas has deteriorated markedly during this century. For example, the eelgrass depth distribution limit in Århus Bay was about 11.5 m at the beginning of the century, whereas in 1991 eelgrass was absent at depths greater than 6.5 m. In the Little Belt the area covered by eelgrass has more than halved and the depth distribution limit has reduced to 2-4 m. The benthic vegetation in some fjords has nearly completely disappeared. For example, in Limfjorden, Nissum Fjord and Ringkøbing Fjord a marked decrease in the distribution of benthic vegetation has been observed through the 1970s and 1980s. The fjords of eastern Jutland (Mariager, Randers, Horsens, Vejle, Åbenrå and Flensborg fjords) are characteristically long drawn out, with severely nutrient-loaded innermost parts and less affected outermost parts. That there are few species of submerged macrophytes in the innermost part of these fjords (3-9) and more in the outermost part (12-22) is also a reflection of enhanced nutrient loading.

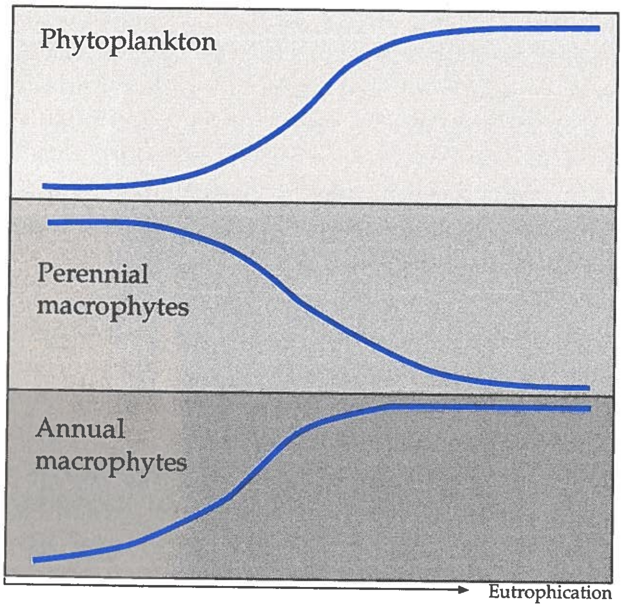


Figure 2.4.5. Schematic representation of the main principles of eutrophication of coastal waters. (Source: Borum et al., 1991).

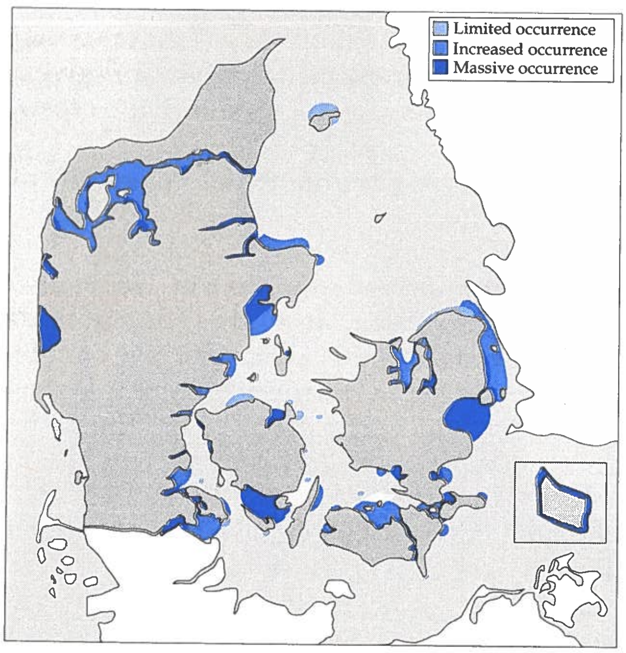


Figure 2.4.6. Areas in which eutrophication dependent occurrence of filamentous algae was recorded during the period 1989-91. (Source: Ærtebjerg et al., 1992).

In many of the more closed fjords and coastal waters, mass occurrence of eutrophication dependent filamentous algae is not uncommon (*Figure 2.4.6*).

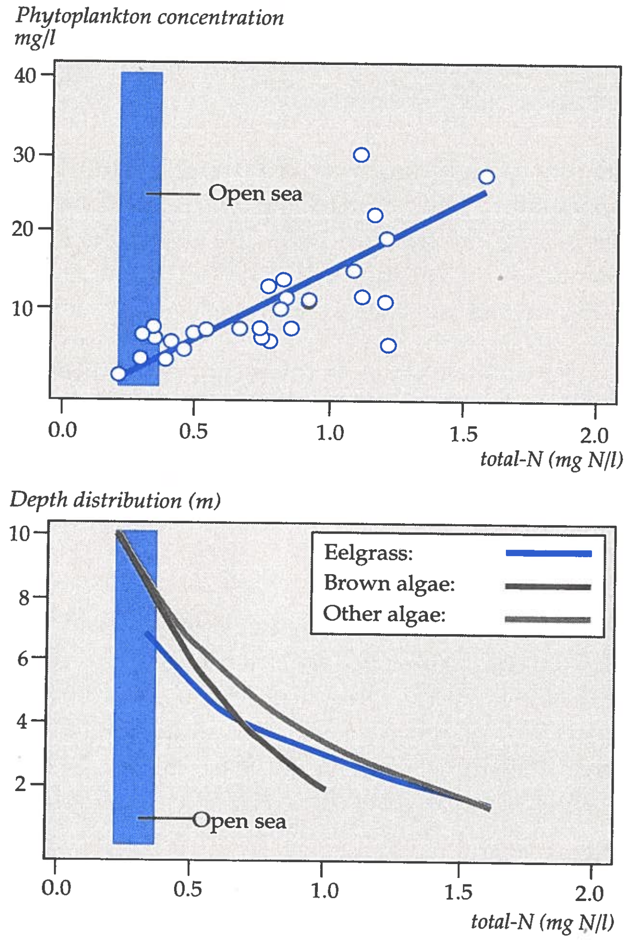


Figure 2.4.7. Relationship between nitrogen concentration, the concentration of phytoplankton and the depth distribution of submerged macrophytes. (Source: Borum et al., 1991)

In fjords and coastal areas it is especially the nitrogen level that determines phytoplankton biomass and the depth distribution of submerged macrophytes (*Figure 2.4.7*).

Within the last few years the decline in submerged macrophytes has stabilized in a number of areas, and in some areas their distribution has even increased. An example is Limfjorden, where the amount of phytoplankton and annual algae has decreased, while eelgrass has again colonized areas where it once was found (*Figure 2.4.8*). This positive development is mainly attributable to reduced nitrogen loading as a result of the less than normal runoff in recent years, as well as to reduced phosphorus discharge from point sources.

The concentration of nitrogen and phosphorus in the water flowing into the sea from rivers or point-source discharges is much greater than in sea water. The nutrient content of coastal

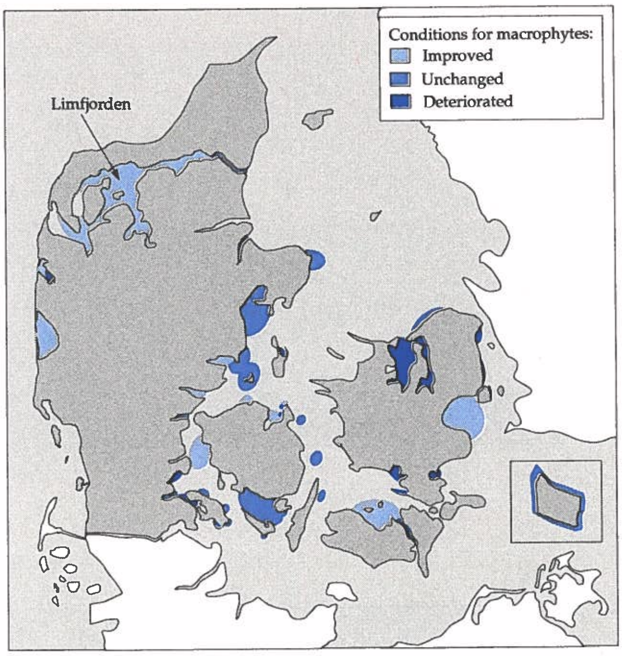


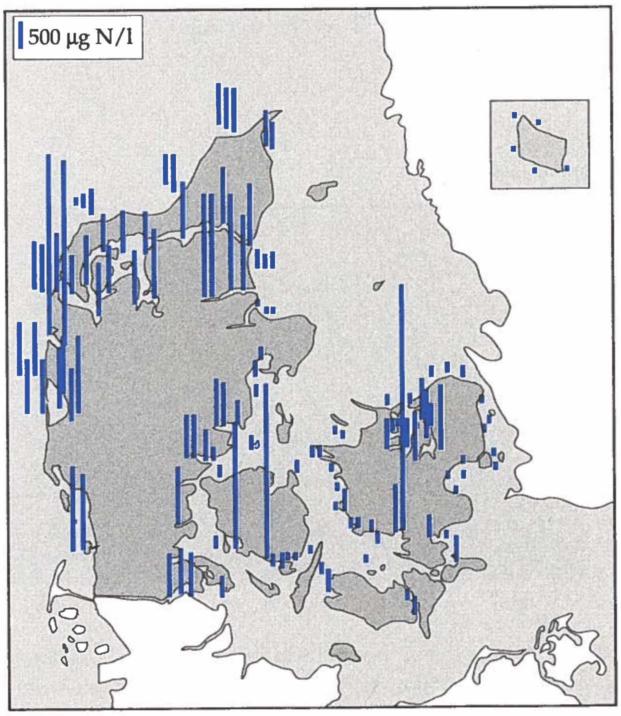
Figure 2.4.8. Summary of changes in conditions for eelgrass in Danish coastal waters over the last 5-6 years. (Source: Ærtebjerg et al., 1992).

waters is therefore increased, whereafter the concentration falls towards the open sea as a result of dilution, metabolism and sedimentation.

The extent to which the various coastal areas are affected by nutrients mainly depends on the size of the catchment area draining into the coastal area and the extent of water exchange in the area. For example, relatively closed water bodies such as Nissum Fjord, Ringkøbing Fjord, the fjords of eastern Jutland, Roskilde Fjord, Isefjorden and Limfjorden will be extremely affected by watercourses and point sources that discharge into these areas, whereas nutrient loading of the more open coastal areas such as the North Sea and Baltic coasts will depend partly on local discharge and partly on inputs from adjacent marine areas (*Figure 2.4.9*).

2.4.5 Environmental condition of Danish open marine waters

The Danish open marine waters comprise three main areas: the outer marine waters i.e. the North Sea and Skagerrak, the inner marine waters i.e. the Kattegat, the Great Belt, the Little Belt and the Belt Seas (N and S), and the Baltic. Approximately 25% of the Danish land mass drains into the North Sea and approximately 70% into the inner marine waters (including the majority of large towns), while only approximately 3% drains into the Baltic. Nutrient loading from Denmark therefore mainly affects the inner marine waters, while the nutrient concentration in the North Sea and the Baltic is mainly determined by the total input from all the surrounding countries.



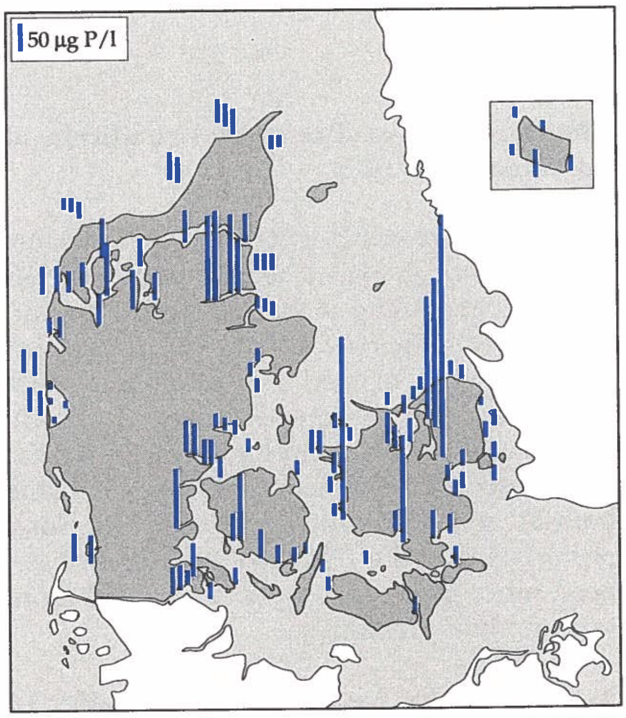


Figure 2.4.9. Spring concentration of nitrogen and phosphorus in coastal waters in 1989. (Source: Ærtebjerg et al., 1990).

In most cases the water depth in the open marine waters is so great that submerged macrophytes are absent. The biological structure in the free water masses is dominated by phytoplankton and zooplankton, and there is usually a rich community of benthic invertebrates. Part of the phytoplankton production is metabolized by the zooplankton, while the rest sinks down to the bottom, where it is metabolized by benthic invertebrates and aerobically by bacteria. In marine areas with low nutrient concentrations oxygen conditions near the bottom are usually good, and there is a rich community of benthic invertebrates with many different species. The majority of the benthic invertebrates are a food resource for a number of fish. At enhanced nutrient levels phytoplankton production increases and more sinks to the bottom to be metabolized with, as a consequence, an even greater consumption of oxygen. If this happens when the water column is stable, with little transfer of oxygen from the surface water to the bottom water, then oxygen deficit may develop. An oxygen deficient environment is hardest on the benthic invertebrates. The fish are often affected later than the benthic invertebrates since they can flee from the affected area. As the presence and composition of benthic invertebrates changes as a result of frequent periods of oxygen deficit, the food resource for fish deteriorates. With widespread oxygen deficit accompanied by hydrogen sulphide production, the fish can become "trapped", and fish kill can occur.

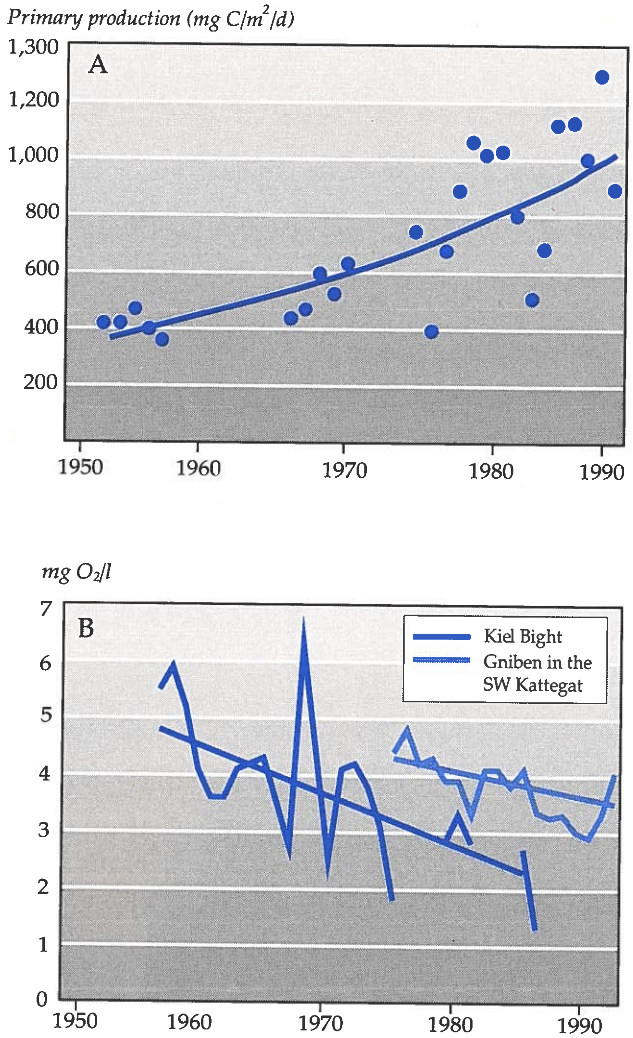


Figure 2.4.10. **A.** Trend in phytoplankton production over the period 1950-90. (Source: Richardson and Ærtebjerg, 1991): **B.** Trend in bottom water oxygen content in Kiel Bight over the period 1957-86 (September month) (Source: Hansen, 1991) and in the southwestern Kattegat (Gniben) over the period 1974-92 (yearly average).

Trends in the environmental condition of open marine waters

A marked increase in phytoplankton production in the open marine waters was observed from the beginning of the 1950s until the end of the 1980s (*Figure 2.4.10 A*). A concomitant decrease in the oxygen content of the bottom water was also observed (*Figure 2.4.10 B*). Oxygen deficit has always occurred in special "holes" in the Danish marine waters, where the bottom water is not exchanged for long periods, but in the 1980s oxygen deficits have been more frequent, longer lasting and more serious than previously.

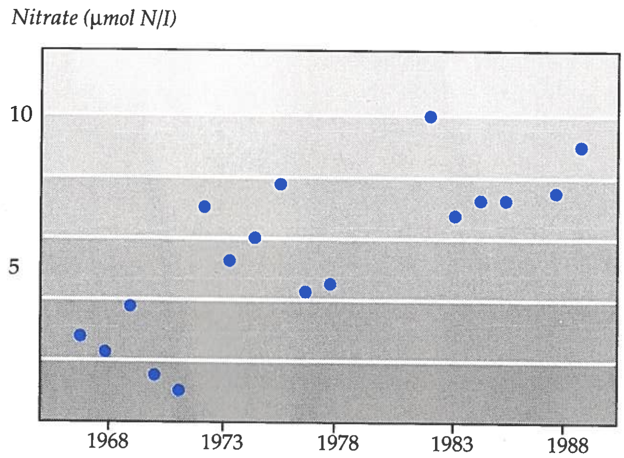


Figure 2.4.11 Trend in the winter nitrate concentration (mean value for January-February) in the surface water (0-10 m) in the eastern Kattegat (Fladen) over the period 1969-89. (Source: Kronvang et al., 1993).

In the areas that have been seriously affected by the critical oxygen conditions in the 1980s the biomass of benthic invertebrates has fallen. Fishery for edible fish has also been affected. For example, the catch of plaice and cod has fallen markedly in the inner marine waters, this seemingly being attributable to the frequent periods of oxygen deficit and the resultant change or disappearance of their food resource.

The oldest measurements of nitrogen concentration in the inner marine waters are from the end of the 1960s, the longest time-series being from Fladen in the eastern Kattegat (*Figure 2.4.11*). As with the watercourses, there was a marked increase in nitrogen concentration from the beginning of the 1970s until the end of the 1980s.

2.4.6 Sources of nutrient input to Danish inland surface waters

Phosphorus

Of total phosphorus input to inland surface waters in 1991, 50% was attributable to urban point sources, 22% to agriculture, 15% to sparsely built-up areas and 13% to natural background loading (*Figure 2.4.12 A*).

The lakes are markedly affected by phosphorus discharge in their catchment areas. Thus in most of the lakes in which input from sewage treatment plants was high, measures have been taken to reduce input from the plants, either by introducing improved treatment measures or by leading the outfalls downstream of the lakes. As a result, most Danish lakes no longer receive major input from point sources. Their poor environmental condition is mainly attributable to excessive nutrient loading from agriculture and sparsely built-up areas, as well as to previous high nutrient loading. From the average source apportionment of phosphorus input it is apparent that agriculture/sparsely built-up areas is the single most important source (*Figure 2.4.12 B*). Phosphorus input from sewage treatment plants and freshwater fish farms are also important sources, but are mainly of local significance. For example, only three of the lakes included in *Figure 2.4.12 B* receive input from freshwater fish farms. For

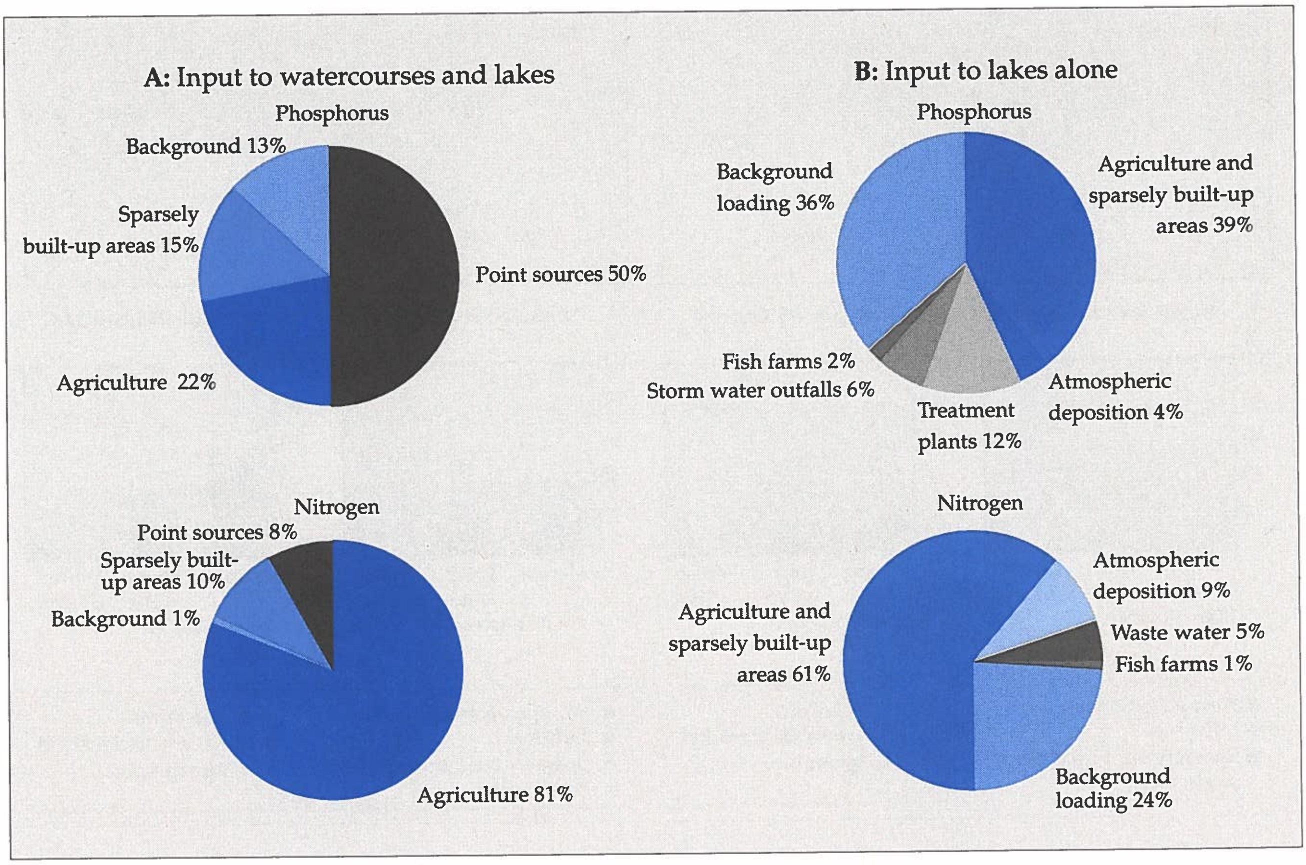


Figure 2.4.12. Source apportionment for phosphorus and nitrogen inputs in 1991. **A.** Total input to inland surface waters. **B.** Average apportionment of the 37 representative Danish lakes (i.e. those included in the Nationwide Monitoring Programme). (Source: Kronvang et al., 1992; Kristensen et al., 1992).

these three lakes, however, environmental condition is markedly affected by phosphorus loading from fish farms.

An analysis of what measures should be implemented to improve the environmental condition of Danish lakes, especially by reducing phosphorus loading, indicated that it was necessary to effectively limit point-source discharges, i.e. waste water and freshwater fish farms, but that it was also necessary to limit loading from agriculture and sparsely built-up areas.

Nitrogen

Most nitrogen loading of Danish inland surface waters - around 60-80% - is attributable to leaching from agricultural land, point-source loading being of minor importance (*Figure 2.4.12*).

2.4.7 Nutrient loading of marine areas

Danish marine waters receive nutrients from adjacent marine areas, freshwater runoff and direct point-source discharges such as municipal sewage treatment plants, individual industrial outfalls and marine fish farms, as well as via atmospheric deposition on the surface of the sea. Since the inflowing water from the adjacent marine areas generally has a lower concentration than that of Danish marine waters, the raised concentration in the latter must be attributable to loading from Denmark. This mainly affects the inner marine waters, around 75% and 80%, respectively, of the total nitrogen and phosphorus load from Denmark being input to these waters (*Figure 2.4.13*).

Nitrogen loading from the land: Diffuse loading from agriculture is the main source of the

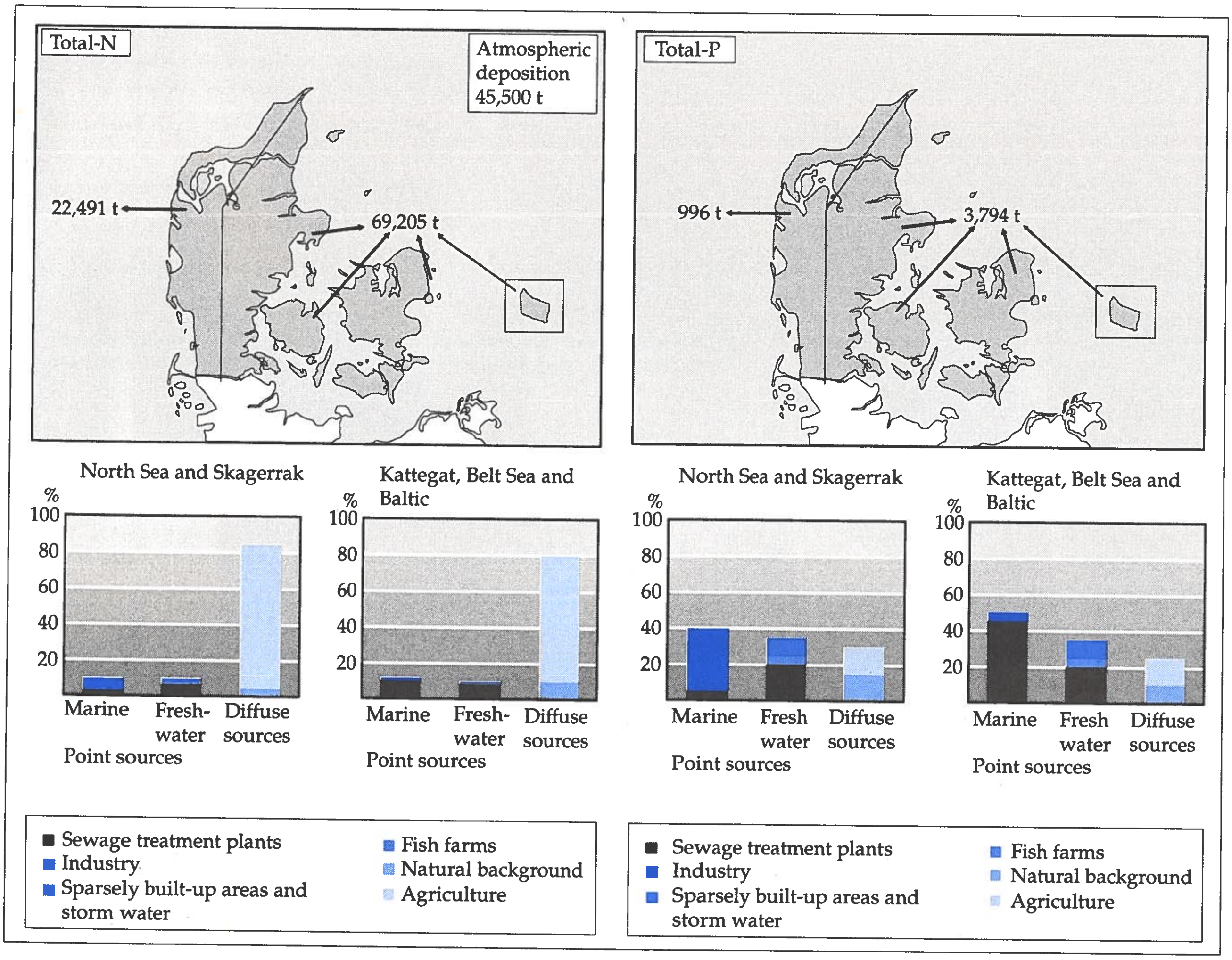


Figure 2.4.13 Nitrogen and phosphorus input to Danish marine waters. Source apportionment for point-source discharge to marine waters and inland surface waters and for diffuse loading are shown for the North Sea/Skagerrak and for the inner marine waters plus the Baltic. (Source: Kronvang et al., 1993, but updated with 1991 data).

nitrogen that is input to Danish marine waters, approximately 69% of loading from land being attributable to agriculture. Point sources account for 23%, of which 9% is discharged inland into watercourses and 14% directly discharged into coastal waters. The remaining 8% is accounted for by natural background loading.

Atmospheric deposition is also an important source of nitrogen loading (*Figure 2.4.13*). Approximately 25% is attributable to the volatilization of ammonia in agriculture, and approx. 10% is derived from national emission of nitrogen oxides in connection with the combustion of coal and oil products in the transport and energy sectors. The remaining 2/3 of the atmospheric deposition is attributable to long-range transboundary airborne transport from other countries.

Sector profile: Land-based nitrogen loading of the sea amounted to approx. 92,000 tonnes in 1991. In addition, atmospheric deposition amounted to 45,500 tonnes, giving a total input to the sea of 137,000 tonnes nitrogen. From the relative magnitude of loading from various important sectors of society (*Figure 2.4.14*) it can be seen that by far the largest contribution is made by agriculture (64%), while less than 4% is attributable to national energy consumption. Long-range transboundary airborne transport is another important item in the budget, accounting for more than 20% of the total input to the marine areas.

Phosphorus loading of marine waters

Approximately 80% of phosphorus input to the marine areas is derived from point sources and approximately 11% from agriculture. If Denmark were not inhabited, phosphorus loading would be less than 9% of what it is now (*Figure 2.4.13*). As regards the North Sea and Skagerrak, the most important sources of phosphorus are sewage treatment plants and individual industrial outfalls, although sparsely built-up areas and freshwater fish farms are also of importance. In the case of the inner marine waters sewage treatment plants are the single most important source, accounting for approx. 75% of total loading.

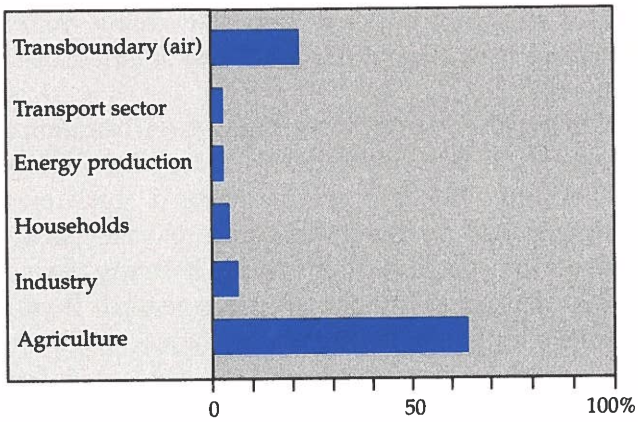


Figure 2.4.14. Sector profile for nitrogen loading of the sea from the atmosphere and land-based sources showing the relative contribution of important sectors as compared with transboundary atmospheric transport from other countries. Background loading from the land and inflow to Danish marine waters from adjacent seas is not included. (Source: National Environmental Research Institute).

2.4.8 Re-establishment of good aquatic environmental condition

The prerequisite for being able to improve the environmental condition of Danish water bodies is that nutrient loading be reduced. A number of measures implemented in connection with the Action Plan on the Aquatic Environment and county water quality targets have led and will lead to a reduction in loading. However, in many cases the reduction is insufficient and further measures may need to be taken.

Provided nutrient loading is reduced, the question is how long it will take before improved environmental quality is realized. Since the amount of nutrients accumulated in the watercourses is generally modest and residence time is short, the nutrient concentration in the watercourses will rapidly fall to a lower level determined by the magnitude of nutrient input. However, the re-establishment of better environmental condition in lakes and marine areas can take considerably longer.

In many lakes there is considerable phosphorus accumulated in the lake sediment which is slowly released to the lake water for some time after loading from the surroundings has ceased. After some time the accumulated phosphorus will have been washed out. Many of the Danish lakes in which external phosphorus loading was previously high currently suffer from this internal phosphorus loading, and in some cases it can take many years before the "sins of the past" are washed out.

During the period of poor lake environmental condition the biological structure of the lakes changed. The fish stock changed from one dominated by perch and pike to one dominated by roach and bream, and in many places submerged macrophytes disappeared. It can take a long time before the biological structure improves in response to a decreased lake water phosphorus concentration, and in some cases it can be necessary to help the lake in the right direction by measures such as the removal of planktivorous fish, the stocking of predator fish and the planting of submerged macrophytes (biomanipulation).

In coastal waters the nutrient concentration will fall fairly quickly because of the considerable water exchange. Nevertheless, biological inertia may still occur in these areas, for example eelgrass and benthic invertebrates may have difficulty in re-establishing. With respect to the open marine waters it is unclear how quickly an improvement can be expected, in part because nutrient release from the bottom will affect the environmental condition for a period.

2.4.9 Political-administrative matters relating to Danish water bodies

Assessment of water body environmental condition and the implementation of measures to improve water body environmental condition are presently undertaken collaboratively by the municipal authorities, the county councils and the Ministry of the Environment. The municipal authorities are responsible for sewage treatment plants and the supervision of farms. The county councils assess the environmental condition of the individual watercourses, lakes, fjords and coastal waters, while the environmental condition of Danish open marine waters is monitored by the Ministry of the Environment in collaboration with neighbouring countries. The county councils stipulate environmental quality targets for every single aquatic area (watercourse, lake, fjord and coastal area) in each county's Regional Plan. The environmental condition of the majority of water bodies is currently worse than the stipulated target. For example, less than 40% of watercourses and only about 30% of lakes live up to their targets, and the general goal of an unaffected or only mildly affected flora and fauna in Danish marine waters is not fulfilled in the majority of coastal areas and in much of the open marine waters.

Action Plan on the Aquatic Environment

The serious episodes of oxygen deficit that occurred in the Danish marine waters in the mid 1980s led the Danish parliament to adopt the Action Plan on the Aquatic Environment in 1987. The aim of the plan was to reduce nitrogen and phosphorus discharge to the aquatic environment by 50% and 80%, respectively, among other things by improving sewage treatment and reducing total agricultural consumption of fertilizer. In addition to the Action Plan on the Aquatic Environment, mandatory measures implemented in order to fulfil the water quality targets stipulated in each county's Regional Plan as well as the plans adopted concerning sustainable agricultural development will also help to reduce nutrient loading of water bodies.

As a consequence of the Action Plan on the Aquatic Environment, nationwide monitoring of the aquatic environment was instituted by the Ministry of the Environment and the county councils in collaboration. This effort, the Nationwide Monitoring Programme, comprises the systematic collection of information on the magnitude and sources of nutrient loading of the aquatic environment. Reviews of the state of the various aquatic environments and changes in them prepared by the responsible institutions are collated by the Danish Environmental Protection Agency as an annual overview of the state of the Danish aquatic environment. These reports are the background on which policy decisions are made concerning the need for implementing additional measures to improve the condition of the aquatic environment.

The aims of the Action Plan on the Aquatic Environment as regards reducing nutrient loading have almost been fulfilled in the case of point sources, especially sewage treatment plants and individual industrial outfalls. Thus phosphorus loading of the aquatic environment has been reduced considerably and in a number of water bodies the environmental condition has consequently improved.

However, diffuse loading from agriculture remains largely unchanged, and nitrogen loading of the water bodies is at the same level as prior to the adoption of the Action Plan on the Aquatic Environment in 1987.

In a number of water bodies, including many lakes and closed fjords, the measures implemented in the Action Plan on the Aquatic environment will not be sufficient to achieve an environmental quality corresponding to the target stipulated in the county Regional Plans. In such areas it will be necessary to implement additional measures, especially measures aimed at reducing diffuse loading from agricultural land and from sparsely built-up areas.

International conventions and agreements

In order to hinder pollution of our marine waters Denmark collaborates with the surrounding countries through a number of conventions and other joint organisations.

Under the Helsinki Commission, which covers the Baltic, the Belt Seas and the Kattegat, it has been agreed that discharges of nutrients, heavy metals and other environmental toxins shall by 1995 be halved in relation to levels in the second half of the 1980s. In the spring of 1992 an environmental investment programme was drawn up for the Baltic that aims to re-establish the ecological balance in that sea.

Under the Paris Commission, which covers the northwest Atlantic, the North Sea, Skagerrak and the Kattegat, it has been agreed that discharges of nutrients to the individual marine waters shall be reduced such as to avoid eutrophication. With respect to the North sea, it has under the North Sea Conference been agreed to halve nutrient discharge to the areas where there is a danger of pollution. Under both the Paris Commission and the North Sea Conference it has also been agreed to reduce discharges of toxic chemical substances.

It is therefore to be hoped that the Action Plan on the Aquatic Environment and the international agreements to reduce nutrient loading will result in a marked reduction in nutrient levels in Danish marine waters, and hence to an improvement in their environmental condition.

2.5 Groundwater - a vulnerable natural resource

2.5.1 Introduction

Groundwater forms the basis for the Danish water supply, approx. 99% of water consumption being derived from groundwater. This high percentage makes Denmark unique among the countries with which it is normally compared. We have previously considered our water resources as being well protected and of a good quality, and, at least at the national level, have taken it for granted that there has been plentiful water for various uses.

However, up through the 1960s and 1970s there was an explosive increase in the demand for water by households, industry and agriculture, a demand which at that time was expected to increase even further. At the same time improved analytical techniques became available, and hence the possibility to more closely examine the quality of the water.

On this background, extensive systematic investigations of groundwater quality were instigated in the 1980s. Attempts were made to identify the possible sources of pollution, and the limitations these would place on the exploitation of the groundwater resource were evaluated. Remedial and preventative measures have been initiated with regard to numerous sources of contamination that pose a threat to the groundwater: leaching from landfills, agricultural utilization of fertilizers and pesticides, industrial dumping and spillage, etc.

Even though the groundwater resource is only slowly recharged by precipitation, ample resources of sufficiently good quality remain at the national level. Nevertheless, there are many places both locally and regionally where water is in short supply. Moreover, recent investigations have shown that groundwater quality is sporadically threatened by pollutants, either directly, as a result of leaching from contaminated sites, or indirectly, as a result of the excessive exploitation of the water resource.

These problems are considered to be so serious that the Water Council, in a report from 1992, and the Danish Environmental Protection Agency, in a report from 1993, have drawn attention to the need for a new nationwide strategy for water abstraction and a concerted action against threats to the groundwater. Such a plan will necessitate significant changes in water planning and central water policy.

2.5.2 Exploitation and recharging of the groundwater resource

The existing Danish groundwater resource is estimated to be considerably greater than total annual water abstraction. Nearly all the freshwater that is used in Denmark is abstracted groundwater, surface water only being employed in special cases where it is necessary to supplement the groundwater.

Changes in the water table: The quality and size of the groundwater resource depends on climatic and geological factors in the various parts of the country. Soundings of the variation in the depth of the water table are a reflection of changes in the size of the resource and how it varies with precipitation.

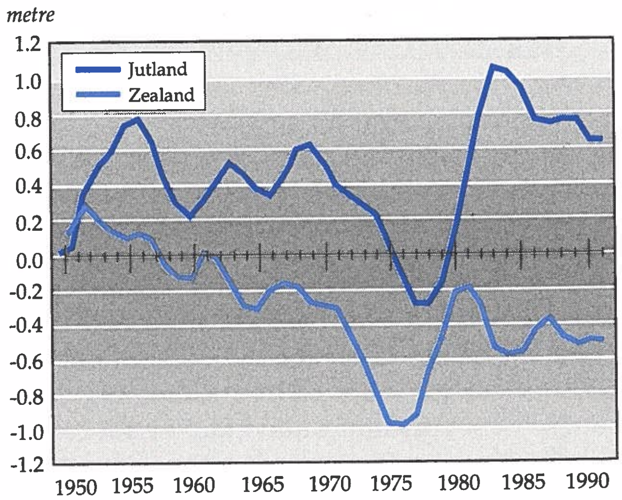


Figure 2.5.1. Change in the water table in Jutland and in Zealand over the period 1950-91. (Source: Ministry of the Environment, 1993 (after Christensen, 1992)).

Changes in the groundwater level and precipitation can also disclose areas of the country where there can be resource problems, e.g. Zealand, where the water abstraction in areas of low precipitation causes considerable lowering of the groundwater level. In Jutland, in contrast, the groundwater level is generally stable. In general, though, the groundwater level has been rising because of the increased precipitation during the last 25 years. Nevertheless, as can be seen from *Figure 2.5.1.*, there have also been dry years with less than normal precipitation (1975-79) and wet years with more than normal precipitation (1981-82). Since the end of the 1980s, the groundwater level seems to have been falling again throughout the country.

Trend in water consumption: Abstraction and consumption of freshwater increased during the 1970s, but was stagnant during the 1980s and the start of the 1990s. The trend in freshwater abstraction from 1984-91 is illustrated in *Figure 2.5.2.* Total abstraction in Denmark fluctuates around 900 million m^3 per year.

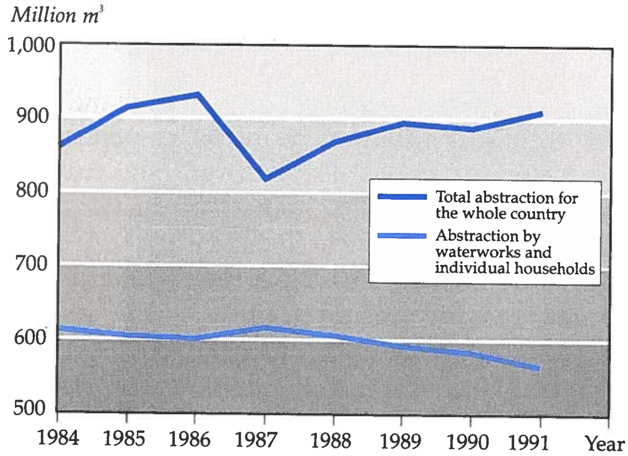


Figure 2.5.2. Trend in freshwater abstraction (both total and for drinking water) over the period 1984-91. (Source: DAVID, 1991; Geological Survey of Denmark, 1991; Danish Water Supply Association, 1991; Danish Environmental Protection Agency, 1990).

Previously, the total annual abstraction has been estimated to be about 1,200 million m^3. Because of the difficulty in estimating how much water agriculture and industry abstracted for their own purposes, abstraction by these two sectors was set at the total permitted abstraction, even though the permitted amounts were seldom utilized in full.

Abstraction by public and private joint waterworks and by individual households has tended to fall over the period 1987-91 (*Figure 2.5.2*). The water that they abstract is largely used for drinking water purposes. During the same period, there has been an increase in the abstraction of water for agricultural sprinkling and for industrial and other purposes. The low water abstraction seen in 1987 was mainly attributable to low consumption for agricultural sprinkling. The sector profile for water consumption during 1988 is shown in *Figure 2.5.3.* It should be noted, however, that considerable uncertainty is attached to the estimates for agriculture and industry.

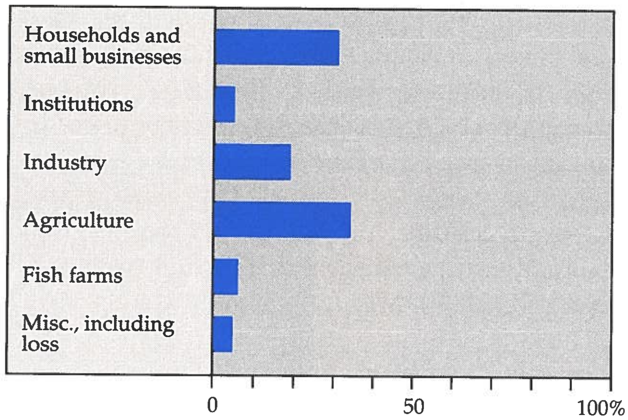


Figure 2.5.3. Sector profile for water consumption in 1988. (Source: Geological Survey of Denmark).

Climatic change: Over the last 125 years there has been considerable fluctuation in the magnitude of annual precipitation, and the importance of this for the groundwater resource has been demonstrated. For example, there was a period of extremely low precipitation just before the turn of the century, and there has been a short period of low precipitation within the last 25 years.

In a scenario for the future set out in the Ministry of the Environment's 1992 report "The greenhouse effect and climatic change", it was predicted that precipitation would increase by as much as 20% up to the year 2080, and as a consequence help to guarantee the future water supply. However, evaluation of the long time-series of precipitation data indicates that dry periods having a significant effect on the water level can occur during periods of increasing precipitation. This fact should be taken into consideration when drawing up water resource plans for the future.

While the potential for groundwater abstraction is determined by the climatic and geological conditions, the tendency to a fall in consumption of drinking water for household use is the result of water conservation measures and the increased environmental awareness of consumers.

Effects of excessive abstraction from aquifers

Although the Danish groundwater resource does not show traces of excessive abstraction at the national level, there are a number of local and regional factors that limit its exploitation. Water abstraction can also be limited by the presence of unwanted naturally occurring substances or by point-source or diffuse pollution of the groundwater.

When large amounts of groundwater are abstracted, the water table in the catchment area surrounding the water supply abstraction borehole sinks. The water table and water pressure change most in confined aquifers, e.g. sand, chalk and limestone aquifers with a clay cap (most common in eastern Denmark) and least in unconfined sand aquifers (most common in western Denmark).

The physical consequences of sinking the groundwater level can be that watercourses and aquatic areas in clay soil catchments dry out in the summer period, during which time water is not led into them from the catchment drainage, and where summer discharge is normally small and derived from groundwater. The problem is especially well known on Zealand, where water abstraction from borehole fields established alongside watercourses sink the water table by up to 10-15 m below the level of the watercourses.

Another unfortunate consequence of excessive abstraction of groundwater can be that deeper lying saline groundwater is drawn up to the boreholes. Saline groundwater occurs in Denmark under the freshwater layers at depths from sea level down to approx. 250 metres below sea level. In coastal aquifers and on smaller islands, excessive abstraction can cause sea water to penetrate into the aquifers (*Figure 2.5.4*).

Similarly, inappropriate borehole construction can enable saline groundwater to penetrate up through deep boreholes, especially where a layer of low permeability is permeated, and where saline and freshwater aquifers are therefore in contact with each other. In other areas of Denmark, water abstraction is curtailed by so-called "brown water" being drawn towards the supply boreholes by excessive abstraction. Brown water is formed by the dissolution of organic matter, e.g. from subsurface peat-containing layers.

Lowering of the water table can lead to direct changes in groundwater quality if oxic conditions are introduced to a groundwater environment where conditions were previously anoxic. For example, sulphate can be formed by the oxygenation of pyrite and other sulphur compounds. Although sulphate is not hazardous to health in the amounts normally released, oxygenation of pyrite can lead to the release of unwanted substances such as nickel and arsenic.

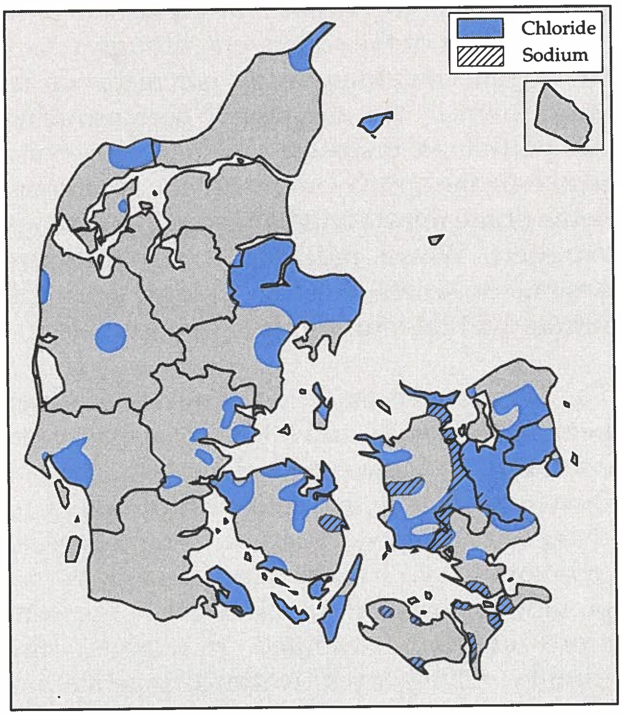


Figure 2.5.4. Areas identified by the county authorities where the salt content of the groundwater or the lowering of the water table is or might be limiting for the supply of drinking water. (Source: Geological Survey of Denmark, 1991).

Excessive abstraction in areas with low precipitation and limited regeneration of groundwater (eastern Denmark) can also draw contaminated water from nearby contaminated aquifers in towards the borehole fields. This can lead to contaminated water being spread over a large area, such as in the Greater Copenhagen area, where nearly all aquifers are affected or contaminated by organic micropollutants, etc.

2.5.3 Contamination of the groundwater

Nitrate in the groundwater

The leaching of nitrate from farmland is the primary cause of groundwater contamination with nitrate. The amount of nitrate in the groundwater is determined by the geochemical composition of the soil layers through which the nitrate-containing water percolates on its way down to the aquifers. Where reducing compounds are present, e.g. organic matter and pyrite in the soil layers under the root zone, some of the nitrate will be reduced to gaseous nitrogen. Where reducing compounds are absent, or where the flow rate is too high, nitrate will be found in the groundwater.

The average concentration of nitrate in water percolating from cultivated areas has been considerably higher during the last 30 years than previously, this being attributable to changed cultivational practice. Comprehensive crop rotation with much permanent grass was previously common, and livestock herds were more evenly distributed throughout the country. Changed cultivational practice has meant that pure crop farms have needed to use considerable amounts of commercial fertilizer, whereas farms with large livestock herds have been unable to utilize their animal manure optimally, the result being that the surface loading with nitrate has in general increased (cf. sections 2.4 and 3.4).

The data obtained with the groundwater monitoring programme set up under the Action Plan on the Aquatic Environment, and which covers the period 1989-91, is not yet sufficient to enable identification of significant increases or decreases in the nitrate content of the aquifers. In many areas the water that left the root zone in 1987 will not yet have reached the aquifers. Moreover, climatic conditions can often cause a greater variation in nitrogen leaching than that which with certainty can be ascribed to a changed agricultural practice (which would typically be reflected in time-series of at least 4-10 years).

Nevertheless, an overall evaluation of the results obtained during the whole monitoring period indicates a tendency towards a fall in the average nitrate content of the groundwater in mid and western Jutland, areas which are

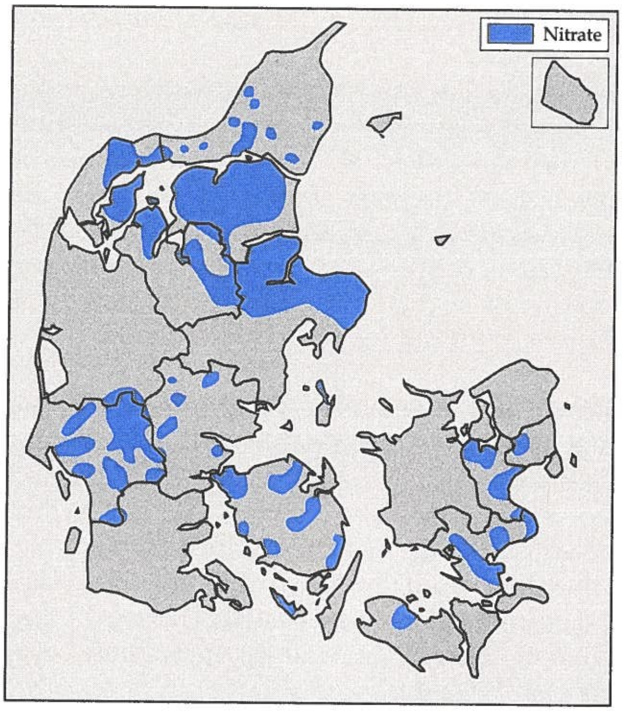


Figure 2.5.5. Localization of areas where the nitrate content of the groundwater currently or potentially can limit the drinking water supply. (Source: Geological Survey of Denmark, 1991).

dominated by vulnerable sand aquifers, and where precipitation is high and livestock herds large. In contrast, the nitrate content of newly formed groundwater in much of the rest of the country seem to be unchanged, or even to have increased slightly.

On the national level, the nitrate concentration in the groundwater is under 1 mg nitrate/l in approx. 50% of water samples from the monitoring programme stations. Approximately 22% exceed the guide level for drinking water of 25 mg NO_3/l, while approx. 13% exceed the maximum admissible concentration of 50 mg NO_3/l.

The distribution of samples with a nitrate content exceeding 50 mg/l shows that the majority of cases are from Jutland, with only very few being from Zealand. Cases of an enhanced nitrate content being found in main aquifers used for drinking water abstraction were most common in mid Jutland, in Djursland, on the northern part of the island Samsø, and at Ålborg (*Figure 2.5.5*).

The recent dry summers have reduced plant uptake of nitrogen, and the nitrate content of the root zone has therefore been high in the autumn period. As the autumns have concomitantly been mild, mineralization of the nitrogen to nitrate in the soil has been able to continue for an unusually long period of time.

The significance of this increased input of nitrate to percolating water and groundwater and of other climatic effects weighed in relation to the significance of agricultural fertilization practice cannot be determined until nitrogen analysis data is available for a longer period of years, with more usual climatic conditions.

Pesticides in the groundwater

The groundwater monitoring programme in Denmark encompasses, among other things, eight pesticides selected because they are especially mobile in the soil. The eight pesticides can be classified in three groups: phenoxy acids (4), triazines (2) and nitrophenols (2). The two nitrophenols are no longer sold and the use of the two triazines has been restricted.

Groundwater analyses undertaken by the county authorities as part of the Nationwide Monitoring Programme show that 5-7% of the boreholes included in the monitoring programme contain traces of pesticides, especially of four pesticides. The pesticides are found in unconfined sand layers lacking in clay cover, in sand layers and sand streaks under moraine clay, as well as in chalk, limestone and sandstone.

The pesticides are mainly found in the upper part of the aquifers in groundwater formed after 1953. On the national level, the pesticides are therefore mainly found in eastern Jutland and on the island part of Denmark, although triazines have been found in a few localities in western Jutland, where these compounds have been used in forestry. The number of pesticide-positive samples found in the monitoring programme and in the routine control of untreated water at water supply facilities is depicted in *Figure 2.5.6.*

Comparison of the distribution of groundwater containing pesticides and nitrate reveals that the phenoxy acids are mainly found in nitrate-free and anoxic groundwater in confined aquifers. The triazines are found both in nitrate-containing groundwater and oxic groundwater, e.g. in unconfined aquifers. This distribution is explicable by the fact that the phenoxy acids are degraded in oxic soil and groundwater environments, but are only slowly degraded in anoxic environments; in contrast, the triazines are relatively resistant to degradation in both environments. The chemical composition and surface tension of the phenoxy acids means that these compounds, at least under unfavourable climatic conditions, can be transported to the underlying aquifers in the water percolating down through the fractures found in even thick moraine clay strata.

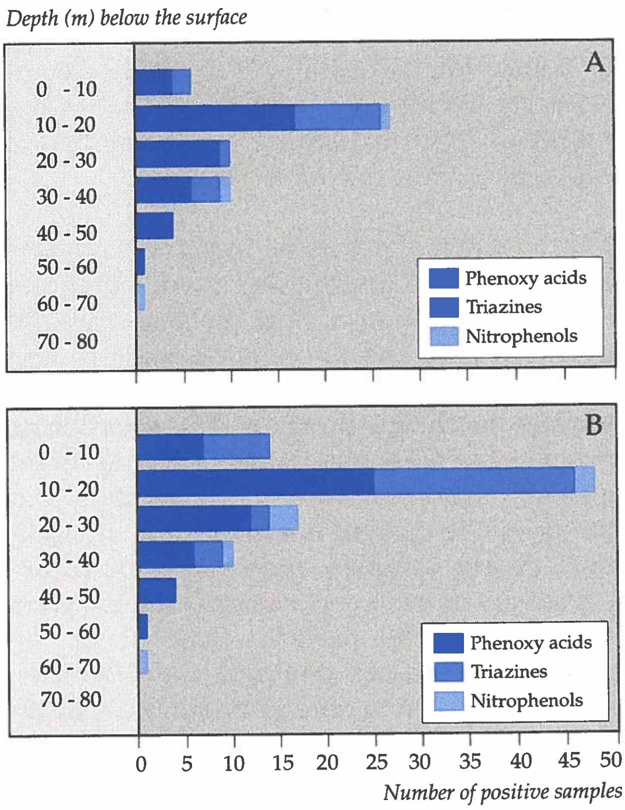


Figure 2.5.6. Number of pesticide-positive groundwater samples detected in the nationwide monitoring programme alone (A) and including those detected during routine control of untreated water at water supply facilities (B). (Source: Geological Survey of Denmark).

As a consequence of the detection of pesticides by the groundwater monitoring programme, a number of the counties have implemented analysis programmes covering untreated water from water supply boreholes.

Funen County (1993) detected pesticides at approx. 20% of the water works they investigated. By far the majority of pesticide-positive samples were under the maximum admissible concentration for drinking water of 0.1 µg/l. The boreholes were selected as having a nitrate concentration of 5 mg/l or greater, thus indicating that the water samples were derived from oxic groundwater environments. The analyses from the 14 boreholes in which pesticides were found show that phenoxy acids were only found at one borehole, while the pesticides found at the remaining boreholes were triazines.

Copenhagen County (1993) detected pesticides at 3 of 26 boreholes investigated, and possible degradation products at a further 6 boreholes. In 3 cases phenoxy acids were found in anoxic groundwater.

Storstrøm County investigated 25 boreholes in young nitrate-containing groundwater in areas of high nitrogen loading. Triazines were found at 7 water supply boreholes and a phenoxy acid at one of these seven.

The detection of pesticides in untreated water and at the monitoring programme boreholes raises the question of how the pesticides are transported to and through the aquifers, and whether the compounds are derived from point sources or diffuse loading. The monitoring programme boreholes usually only represent a small part of the water in the aquifers, and the pesticide content is usually low. In addition, repeat samples often prove pesticide-negative, a possible explanation being temporal variation in the pesticide content of the groundwater at any one particular borehole, as is also known to occur with nitrate (pulsating concentrations).

In contrast, untreated water from water works represents large water volumes that are abstracted from the whole aquifer. Repeat analyses usually confirm the presence of the pesticides and show that the concentration is constant. This indicates that both diffuse and point-source contamination such as market gardens, nurseries and buried pesticide waste can play a role in the case of boreholes that abstract large amounts of water and which affect large areas, whereas the monitoring programme findings probably usually reflect variable diffuse loading. Since two of the pesticides that are currently found in groundwater have been withdrawn from use, the groundwater content of these will probably fall in the future.

The fact that certain pesticides have now been registered in groundwater indicates that other cases can be expected in the future involving other and previously used pesticides.

Point-source contamination.

In the 1987 *Landfill Project*, it was reckoned that there were 3,000 contaminated sites in Denmark (chemically contaminated sites and old landfills). Subsequent county-wise compilation of an inventory of contaminated sites indicates that the correct figure is likely to exceed 10,000. These point sources of contamination primarily comprise organic pollutants such as chlorinated organic solvents, tar constituents, pesticides and oil/petrol, but also include inorganic pollutants such as heavy metals and cyanides, as well as microbiological/bacteriological pollutants (*Figure 2.5.7*).

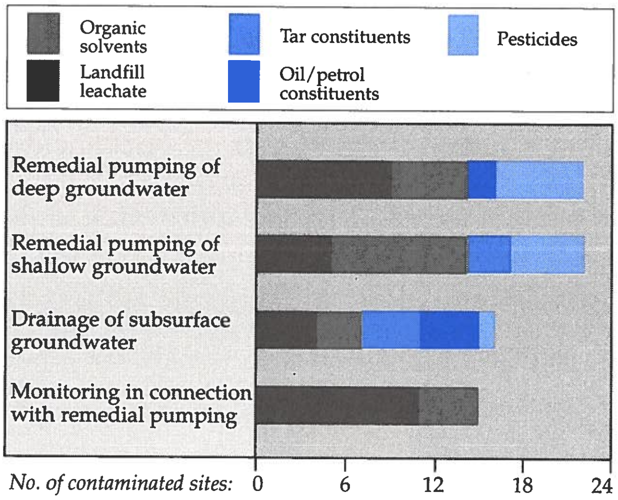


Figure 2.5.7. Number of contaminated sites where measures such as remedial groundwater pumping or draining had been or were planned to be implemented as of July 1, 1990, apportioned by type of pollutant and groundwater. (Source: DAVID, 1990).

The point sources comprise a real problem since all the above mentioned types of pollutant can lead to serious contamination of underlying aquifers, etc. Nevertheless, it is the chlorinated organic solvents that have hitherto posed the greatest problem for groundwater abstraction.

Point-source contamination in and around urban areas, especially from contaminated industrial sites, has occasionally led to such severe groundwater contamination as to preclude basing the water supply on groundwater abstracted within or in the immediate vicinity of the town. Examples are the closure of the water supply boreholes in Herlev and Esbjerg, the reason in both cases being enhanced groundwater concentrations of chlorinated organic solvents. The total number of water supply boreholes that have been shut down because of point-source contamination has not been reckoned, but the number is considerable and growing, especially in the Greater Copenhagen area.

The remedial measures currently most often used are groundwater pumping and soil removal, both of which are expensive and/or not particularly effective. Careful consideration should therefore be given to whether it is appropriate to use such measures in every single case, or whether alternative methods could be more appropriate.

In the case of landfills, it is organic compounds that pose the greatest environmental threat. In some cases the organic pollutants present are slowly degradable and can sometimes accumulate in the aquifers for years without any appreciable degradation, e.g. chlorinated organic solvents. These compounds deserve special attention because of the great risk of contamination of water supply boreholes. Nevertheless, there are also examples of considerable degradation of environmentally foreign substances taking place as a result of their being subjected to alternating anoxic/oxic conditions. In oxic aquifers, anoxic zones can sometimes form downstream of landfills as a result of the degradation of organic matter from household waste. Such zones (redox zones) promote the degradation of environmentally foreign substances. It is important to take into account this self-cleansing effect when evaluating what remedial measures should be implemented for landfills.

2.5.4 Groundwater policy and action plans

Agriculture

The government's *Action Plan for Sustainable Agricultural Development* (cf. section 3.4) stipulates that a special effort should be made to protect the groundwater in vulnerable water abstraction catchments in Nordjylland, Århus and Viborg counties that together comprise 50,000 ha. The measures planned aim to limit the nitrate concentration in the water percolating from the root zone to 50 mg/l, a level corresponding to the maximum admissible concentration in drinking water. This target is to be fulfilled by providing farmers in selected areas with compensation for undertaking the necessary measures. Selection of the areas started in summer 1992.

The setting aside of agricultural land in accordance with the set-aside scheme established under the EU agricultural reform can contribute to the protection of groundwater resources, especially if set aside is undertaken outside of normal crop rotation (i.e. permanent set-aside) in areas where the groundwater is especially vulnerable.

In accordance with the *Action Plan on Pesticides* (cf. section 2.7), the consumption of pesticide active ingredients is falling, though without a corresponding fall in the so-called treatment frequency factor (cf. section 2.7). This reflects an increased consumption of low dosage products, and probably means that a smaller amount will reach the groundwater. This does not automatically imply that the health risk reduces correspondingly, however, since the latter depends on the properties of the substances.

In accordance with the *Action Plan for Sustainable Agricultural Development*, the previously voluntary education of commercial users of pesticides will be made obligatory, as will the keeping of spraying logs.

Our knowledge of the threat of pesticides to the groundwater is still inadequate. A number of research projects have therefore been initiated to determine to what extent pesticides are able to contaminate the groundwater. In addition, groundwater monitoring is being intensified by increasing the sampling frequency in a number of areas.

Contaminated sites

The objective of the measures initiated as regards contaminated sites is to hinder detrimental effects on man and the environment. This necessitates that the sites be localized, registered and then remediated to an environmentally defensible standard. Remediation of contaminated sites is undertaken partly out of consideration for current site usage, and partly in order to protect the groundwater and, in certain cases, the recipient waters.

At present 2,600 contaminated sites are registered nationwide (old industrial sites and landfills). Of these, approximately half are landfills. In 5-10 years, when the county authorities have completed their inventory, the number of contaminated sites is expected to reach about 10,000, of which two thirds will probably be industrial sites. The majority of these contaminated sites will probably be located in or in the vicinity of urban areas, and often close to the coast.

The Danish state and counties currently expend DKK 150 million per year on remediation of contaminated sites. An important part of total expenditure is used to limit groundwater contamination. In addition, the Danish Environmental Protection Agency has entered into an agreement with the Danish Oil Industries' Environmental Clean-up Association that will ensure rapid and effective remediation of old petrol station sites which, among other things, threaten the groundwater.

Selection of groundwater resources

The assault on groundwater contamination needs to be prioritized. This should be based on the selection in each region of the groundwater resources on which the future water supply is to be based, the aim being to ensure sufficient uncontaminated water resources to cover expected future requirements. These water resources will be comprised of both existing and new groundwater abstraction catchments.

In order to aid in the selection process, the Danish Environmental Protection Agency has initiated the so-called "Contaminated Site and Groundwater Prioritization Project" costing DKK 12 million, the objective of which is to develop operational tools for use in the nationwide selection of future groundwater abstraction catchments, and for use when prioritizing remediation of contaminated sites.

This necessitates establishing guidelines for the charting of groundwater resources, the evaluation of their vulnerability and the selection of water abstraction catchments where rapid remediation is necessary, and catchments where remedial measures cannot be justified.

The Zealand Water Plan: The Zealand counties have started work on an overall plan for the management of water resources on Zealand. The plan will comprise an inventory of the resources on Zealand, a reckoning of current and future water needs, an evaluation of the risk of contamination at current borehole fields and, on the basis of the above, an evaluation of the need for new borehole fields.

Water conservation

If society improves its habits with regard to water, this will reduce the strain on the groundwater and hence on the aquatic environment as a whole. The campaigns aimed at water conservation in households, etc., are therefore of great importance.

2.6 Biodiversity

2.6.1 Introduction

Global population growth and consequent enhanced economic activity leads to the impoverishment of nature. Thousands of plant and animal species are threatened with extinction. Of these, only few are threatened because of their direct exploitation. By far the majority are threatened with extinction because the ecosystems of which they are a part are affected or disappearing as a result of man's need for space and resources.

Biodiversity is the variation of life forms in our surroundings, whether those surroundings are natural or man-made. By biodiversity is understood not only the number of different species, but also the variation in the different levels of organization of which the species are a part: 1) the variation in the genetic pool within a species or population, 2) the complex of species that define an ecosystem, 3) the ecosystems and habitats that comprise large landscape ecological units, and as the uppermost level, 4) the whole global biosphere. The lower levels depend on, and at the same time are a condition for, the stability of the latter.

It should be emphasized that the variation at all these levels is fundamental to the concept of biodiversity. While the preservation of a species' genetic variation is a precondition for being able to adapt to a changing environment, it is usually the capacity of the species to adapt and the stability of the ecosystem of which the species is a part that determine whether its potential to evolve is ever realized.

Many types of environmental change, whether anthropogenic or natural in origin, will be to the advantage of some species but the detriment of others. If the resultant shift in species composition is comprehensive, the species in decline will be threatened. Falling population size increases the risk of inbreeding and disease, and increases the species' vulnerability to environmental changes. Relatively large swings in population size caused by a variable food resource, inter-annual variation in climate, epidemics and many other factors are a concomitant natural part of population dynamics. Long-term assessment is therefore necessary in order to be able to determine whether or not a given species is on the incline or on the decline.

2.6.2 Appraisement of biodiversity

The preservation of biodiversity can be evaluated and appraised from several points of view - economic, recreative/aesthetic, ethical and ecological.

The loss of biodiversity can be related to a number of *economic factors*, including man's direct exploitation of a number of species as natural resources for the production of food products, clothes, timber, energy crops, medicine, etc., such that the decline of species increases in step with the appropriation of land for these purposes. It is estimated that for the global land mass as a whole, 40% of the total primary production derived from plant photosynthesis is appropriated for direct or indirect human consumption. Living organisms also have an indirect economic value through the provision of a number of "ecological services". For example, the hydrological cycle is maintained for the production of drinking water and the fertility of the soil is maintained through the bio-geochemical cycle.

Biodiversity can also be viewed in relation to the *recreative value* afforded by the presence of different species and landscapes. Most people need a certain amount of variety in their surroundings, especially in the nature used for various leisure activities. This aesthetic approach to biodiversity can also encompass organisms that are not immediately apparent. For example, consciousness of the presence of large whales in the oceans, elephants in Africa, and even the continued presence in Denmark of otters, etc., is of great aesthetic significance to many people. In contrast, most insects and reptiles do not enjoy the same awareness.

Biodiversity can also be appraised from a purely *ethical point of view* whereby, in contrast to both the economic and aesthetic approach, all forms of life are valued and ranked equal. Nature and all its life forms have a value in themselves that should be respected independently of mankind, and without consideration to their possible significance to humanity. All life forms are important, but their protection should be focused towards preventing the loss of species. This principle is championed by the UN Charter on Nature and the 1992 Rio Convention. Preservation of the Earth's biodiversity must be ensured through increased global, national and local monitoring/registration of threatened species and their habitats, as well as through nature conservation and the establishment of national parks and gene banks.

From the *ecological point of view*, however, the prevention of species extinction is not in itself a goal. The majority of all the species that have ever existed on the Earth are extinct, and the adaptation, extinction and development of new species through natural selection safeguard the continuance of life. The problem is rather the markedly increased rate with which extinction is currently occurring as a result of increased human activity, and that the narrowing of many species' genetic variation diminishes their potential to adapt and develop.

Biodiversity is considered not just as a precondition for human activity or an ethical goal, but is also seen as a product of man's impact on the Earth over millenniums. The objective of a preservation strategy should therefore be continuance of this co-evolution in a sustainable manner. From the ecological point of view, management of natural resources should therefore also focus on the key species that are of decisive significance for the maintenance of the structure and function of important ecosystems, as well as on those human interventions in chemical and energy cycles that can influence the ecosystem stability and capacity to regenerate.

2.6.3 Habitats in Denmark - state and trends

Habitat loss and deterioration as a result of human activity is the most important cause of the shift in species composition that has occurred in Denmark in this century. Aspects of these changes are discussed below and, where possible, trends are described with the aid of key figures. The most reliable way to determine the cause of this shift is to examine population size and growth of not just one species, but of many. An example of this is given in the section below on birds.

Arable land habitats

The presence of small habitats comprising small areas of uncultivated arable land is of decisive importance to the existence of numerous wild animals and plants in Danish arable land. The small habitats also serve as reserves for arable land flora and fauna that are threatened at their original localities, e.g. the type of vegetation that grows on meadows and commons. Moreover, the small habitats serve an important function as dispersal corridors, and therefore help to preserve genetically sound populations.

Small arable land habitats can be classified in two main groups: linear habitats such as hedgerows, borders, ditches, verges, etc., and spatial habitats such as small ponds, small mounds and small marshes. Development as regards small habitats has been subject to considerable temporal and geographic variation. The general trend in the eastern part of Denmark has been characterized by continuous loss, especially in the case of small wet habitats, which is probably attributable to vigorous structural rationalization of agriculture.

In the more meagre soil of western Jutland, in contrast, small habitats are currently making headway, both wet and dry. This probably reflects the initiation of agricultural land set-aside and marginalization, and the consequent boost that this gives to small habitats. Overall, however, there has been a considerable decline in the number of small arable land habitats (*Table 2.6.1*).

Lakes and ponds	69%
Fens	60%
Ditches and watercourses	60%
Hedges and dikes	41%
Roads, inc. field roads	28%

Table 2.6.1. Decline in small arable land habitats over the period 1884-1974. (Source: Agger & Brandt, 1992).

The game bag statistics for species associated with arable land, e.g. hare and partridge, show a continuous decline that is partly attributable to the decline in small dry habitats and possibly the changes in agricultural practice (*Figure 2.6.1*).

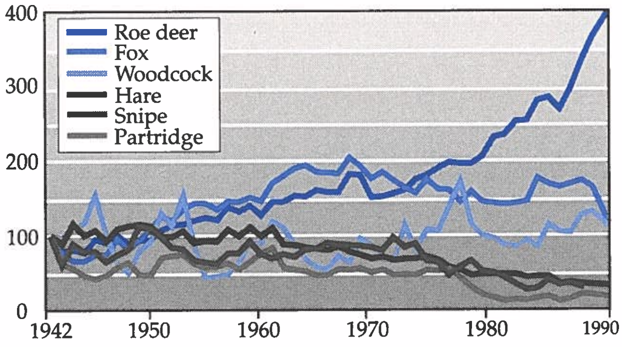


Figure 2.6.1. Game of 6 selected species bagged by hunters in Denmark over the period 1942-90. Index: 1942 bag = 100. (Source: National Environmental Research Institute).

The trend as regards small wet habitats can be seen from the trend in amphibians since the latter depend on ponds as breeding grounds. All the 14 species of amphibians that exist in Denmark are included on the list of species requiring special protection. Statistics concerning threats to amphibians show that the greatest threats are the reclamation of ponds, eutrophication caused by drainage water from fields and houses, the stocking of fish, ducks and the cessation of cattle grazing. An increasing problem is the fragmentation of the landscape because of road construction, as well as that the increasing traffic hinders amphibians in wandering back and forth between breeding ponds. The current situation for many amphibians is that they live as isolated populations that increasingly suffer the effects of inbreeding and the risk of local extinction.

Salt marshes, water meadows, commons and heaths

Salt marshes, water meadows, commons and heaths are among the most threatened ecosystem types in Denmark. Many of the animal and plant species that depend on these ecosystems are therefore threatened by extinction in Denmark. Some of the species have already disappeared from the Danish nature.

If it was not for man's intervention in the form of grazing, cutting and burning, most of these localities would radically change character by becoming overgrown with bushes and trees.

Another common feature of the above mentioned types of habitat is that the total area of each has declined considerably. In 1800, when the

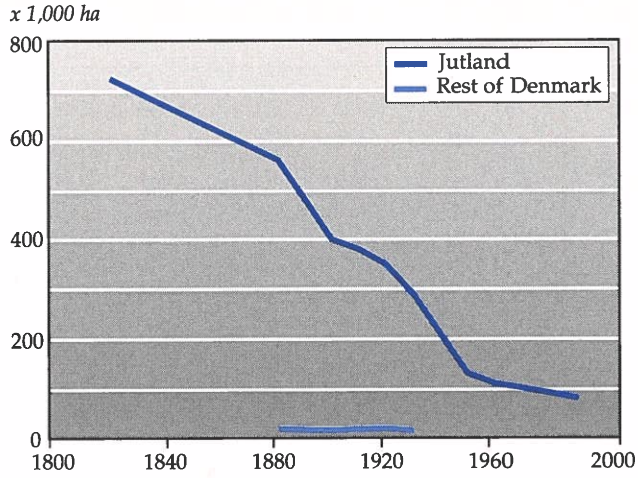


Figure 2.6.2. Trend in the area of heathland in Denmark from 1822 to 1990. (Source: National Forest and Nature Agency).

total area of heath was at its maximum, heathland accounted for 40-50% of the Jutland landscape. In 1950, this figure had fallen to approx. 2%. On the island part of Denmark, heaths have been of little significance as an ecosystem type (*Figure 2.6.2*). On Bornholm, though, heaths accounted for up to 20% of the area.

The marked decrease in the total area of each of the above mentioned habitat types has resulted in a corresponding decline in the flora and fauna associated with these areas. For example, mountain tobacco, which is a characteristic heathland species, has declined considerably in the eastern part of Jutland. On the island part of Denmark, the species has almost disappeared. Localities with mountain tobacco are only numerous in northern and western Jutland.

Heathland bird life is dominated by a small number of characteristic species. Birds that can be used as indicator species for the presence and condition of heathland localities are teal, golden plover, wood sandpiper, curlew, black grouse, crane, short-eared owl and great grey shrike. All these species are on the decline except the curlew.

Black grouse and golden plover are among the most threatened of all heathland birds (Figure 2.6.3 and 2.6.4), this being attributable to their dependence on the original open, moist heaths with a plentiful supply of berries. The survival of these species in Denmark can only be assured by a considerable effort to preserve and re-establish heathland areas.

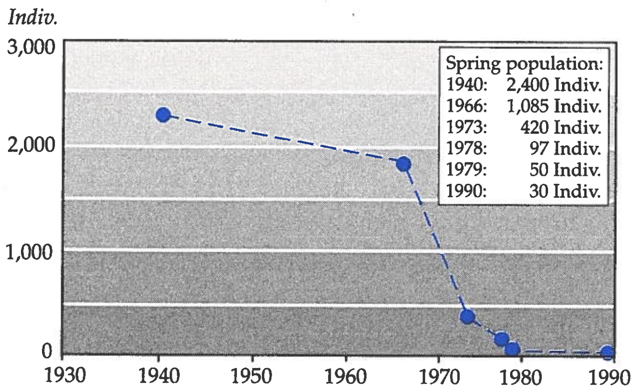


Figure 2.6.3. Trend in the black grouse population in Denmark over the period 1930-80. (Source: Larsen, 1980; National Forest and Nature Agency).

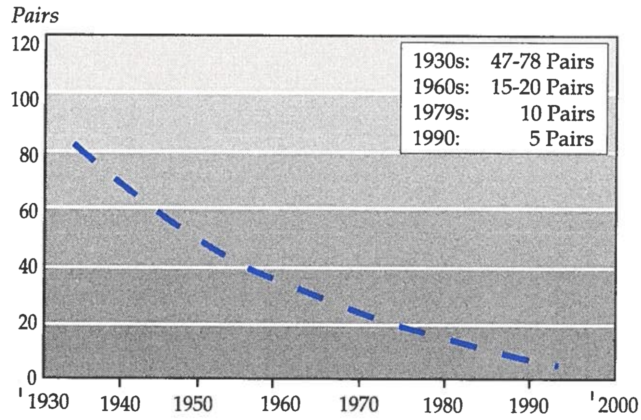


Figure 2.6.4. Trend in the golden plover population in Denmark over the period 1930-80. (Source: Larsen, 1980; National Forest and Nature Agency).

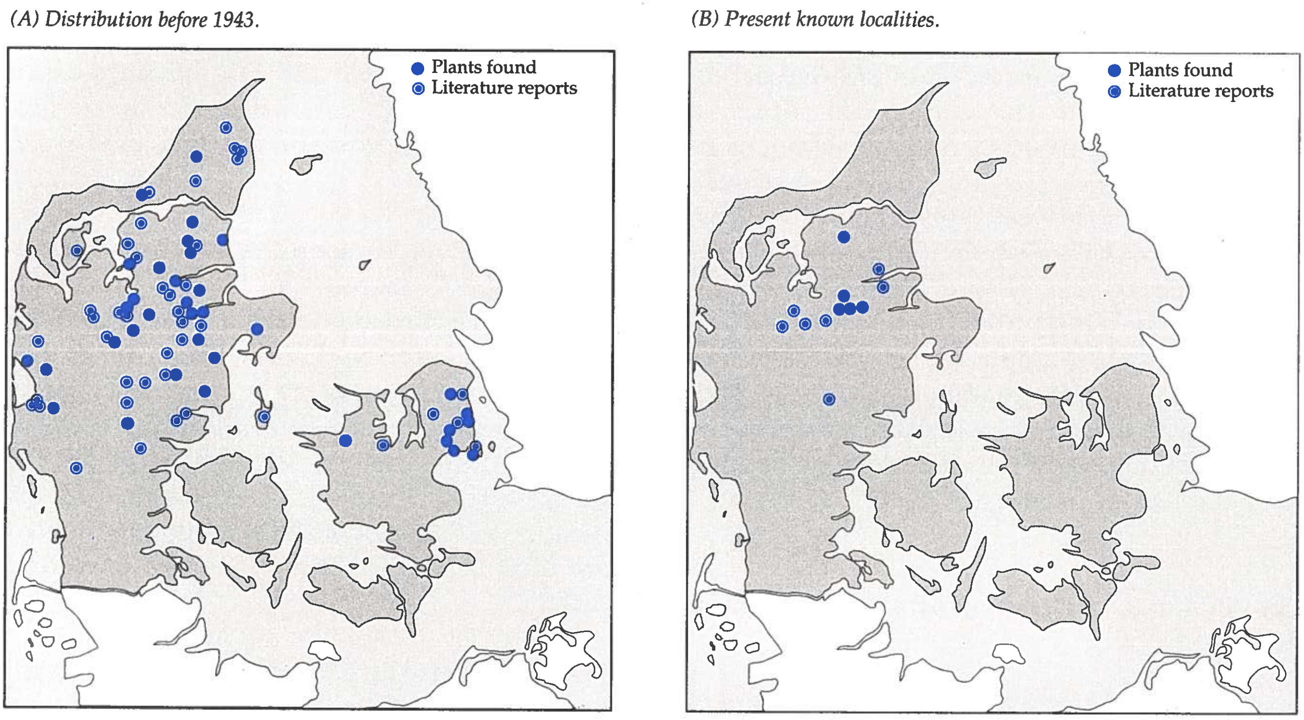


Figure 2.6.5. Distribution of the golden saxifrage prior to 1943 (**A**) and at present (**B**). (Source: Wind, 1988; Hansen et al., 1989).

Freshwater wetlands

The freshwater wetlands can be divided into bogs, springs, watercourses and lakes.

Upland bogs are defined as bogs that only receive water and nutrients from the atmosphere. The number of upland bogs has declined markedly in recent times, mainly because of peat-digging. Thus whereas there were 668 upland bogs greater than 5 ha in area in 1919, only 9 remained in 1989.

In contrast to upland bogs, fens receive water and nutrients from the surrounding groundwater. Fens are usually classified as either nutrient-rich (mesotrophic) fens or nutrient-poor (oligotrophic) fens according to the amount of nutrients available. Fens have probably followed the general decline seen with the more extensively exploited ecosystems, but no concrete data are available.

Springs are a vulnerable and threatened element of our intensively cultivated landscape, many having disappeared as a result of the falling groundwater level, land drainage and subsequent overgrowth. The golden saxifrage, the moss *Paludella squarrosa*, and several other species are characteristic plants in the vicinity of springs. These plant species, which are considered relics from the ice age, only occur in Denmark in association with summer cool springs. The golden saxifrage is a protected species, and is included on the list of threatened plants (*Figure 2.6.5*).

This century has seen the marked impoverishment of the Danish watercourse fauna, the main causes being organic pollution, harsh maintenance, channelization and ochre loading. An increasing problem is reduced discharge, especially as a result of the lowering of the groundwater table. The physical conditions in the watercourses are of especially great significance for species composition; an otherwise clean watercourse can be extremely limited in species if the physical conditions are unsuitable. The trend in species diversity for the insect families mayflies and stoneflies in a collection of representative watercourse reaches is illustrated in *Figure 2.6.6*. The majority of species in these two groups are very demanding as far as concerns watercourse quality, and are therefore well suited as indicators of a deterioration in watercourse quality.

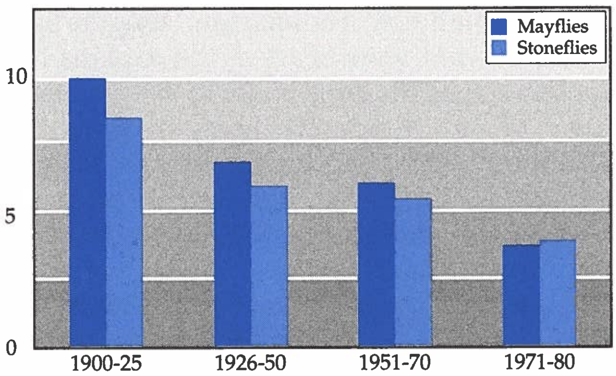


Figure 2.6.6. Trend in watercourse fauna over the period 1900-80. Units: the average number of species per locality. (Source: Jensen & Jensen, 1980).

Deciduous forest and coniferous forest

Since managed forestry became usual at the start of the last century, the total forest area has increased fivefold. However, the remnants and genetic descendants of the forest that grew at that time are few and far between. There are only approx. 1,800 ha left as state forest, and about 30,000 ha nationwide. At the last forest area census in 1990, the total area of forest in Denmark amounted to approx. 417,000 ha, which represents an increase of almost 3% since the previous forest area census in 1976.

The total area of deciduous forest was a good 4% greater in 1990 than in 1976. The area of coniferous forest remained basically unchanged during that period, although it is considerably greater than at the turn of the century (cf. *Figure 3.4.10*, section 3.4). However, within these two types of forest, there have been considerable shifts in species composition. For example, the proportion of deciduous forest accounted for by birch decreased by 4% over the period 1976-90, while the area accounted for by other deciduous species increased almost 15%.

The 1990 forest area census was undertaken prior to the implementation of various measures to promote forest area, e.g. the Protection of Nature Act and the Hardwood Support Scheme under the Forestry Act. It can therefore be expected that the total forest area will increase further in coming years, and that there will be a greater proportion of deciduous forest and natural forest (cf. section 3.4).

Landscape fragmentation

The modern anthropogenically modified landscape consists of a mosaic of small and large habitats of various types. Land usage, by which is mainly meant its use for agriculture and forestry, built-up areas and large roadways, splits the land into fragments. This has the effect that many habitat types decrease in area and become isolated. In addition, the biological quality of many habitats is adversely affected by increased fragmentation.

An obvious consequence of landscape fragmentation is enhanced genetic isolation, especially in the case of organisms with limited prospects for dispersal. Genetic isolation, especially in the case of small populations, leads to inbreeding and as a possible consequence, reduced viability and fecundity.

Marked fragmentation of habitats affects biodiversity in that organisms from the so-called natural habitats are unable to exchange genes to a sufficient extent across a strongly fragmented landscape. As a consequence, they are more liable to local extinction, while at the same time fragmentation inhibits recolonization from neighbouring populations.

2.6.4 Trends in wild plant and animal populations in Denmark

Game

For many game species, game bag statistics can serve as an indicator of the population trend. The percentage of the individual populations that the game bag comprises varies from species to species. Moreover, it will usually change over a period of years, for example because of changes in hunting seasons and hunting traditions, as well as in species abundance.

Partridge and hare are both associated with arable land, and the decrease in the game bag of these two species reflects a genuine decrease in the populations (*Figure 2.6.1*). The main cause of this decrease is undoubtedly the intensification and reorganization of agriculture that has taken place since about 1960 (cf. section 3.4), the game bag having decreased since that time.

The number of snipes (both the jack snipe and the common snipe) has also decreased, this being partly attributable to the reduced distribution of their preferred habitats, i.e. wetlands and to a lesser extent heathland.

In contrast to the above mentioned species, the roe deer, and to some extent the fox, have demonstrated greater adaptability to the changes that have taken place in the landscape.

Breeding birds

The variation in the populations of a large number of species has been monitored nationwide by the Danish Ornithological Society since 1976 (*Figure 2.6.7*).

However, it is difficult to distinguish between the long-term trend and the influence of short-term changes such as variable weather conditions, etc. Many of the smaller shore birds, and short-distance migratory birds such as the wren and the goldcrest, decline in number following a hard winter. Weather conditions during the summer can also have an effect. Nevertheless, by undertaking a so-called "Principal Component Analysis", it is possible to separate the short-term variation from the long-term trend. The overall tendencies revealed by such an analysis are given below for 21 species.

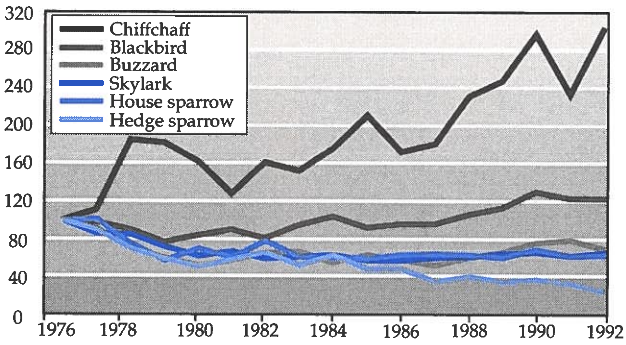


Figure 2.6.7. Trend in the populations of selected birds over the period 1976-92. Index: 1976 = 100. (Source: Danish Ornithological Society, 1992).

In the case of arable land species such as the lapwing, skylark, swallow, linnet, whitethroat, corn bunting and yellow hammer, the overall trend has been negative over the whole period.

For many of the birds associated with urban areas (gardens, parks, etc.) the overall long-term trend is positive. This applies to the magpie, chaffinch, tree sparrow, song thrush, blackbird and wren. Part of the explanation for this can be the large boom in the establishment of new residential areas between the 1950s and 1970s. The reason why the impact of this is somewhat delayed is probably because the gardens have first to grow before they are an attractive environment for birds. In contrast to the above mentioned birds, the great titmouse and the sparrow have been on the decline, however.

In the case of woodland birds, some have been on the decline, e.g. the common buzzard, hedge sparrow and goldcrest, while others have been on the incline, e.g. the garden warbler, greater spotted woodpecker and chiffchaff.

Aquatic birds

Danish marine waters are one of the most important northern European overwintering areas for waterfowl (members of the family *Anatidae*) and other aquatic birds. Denmark therefore has a special international duty to manage the birds and their habitats.

Significant threats to aquatic birds are posed by eutrophication, oil pollution and various forms of disturbances, inc. hunting and other leisure activities. Eutrophication can reduce or destroy the food resource in an area, while disturbance can lead to the birds avoiding certain areas.

Northern European waterfowl populations are generally stable or on the incline, however. While there are many reasons for this, one of the most important is that many species breed in arctic or sub-arctic areas that are as yet relatively unaffected by man. Nevertheless, the populations of the following waterfowl are either vulnerable or in need of special protection: the bean goose, pink-footed goose, brent goose and pochard.

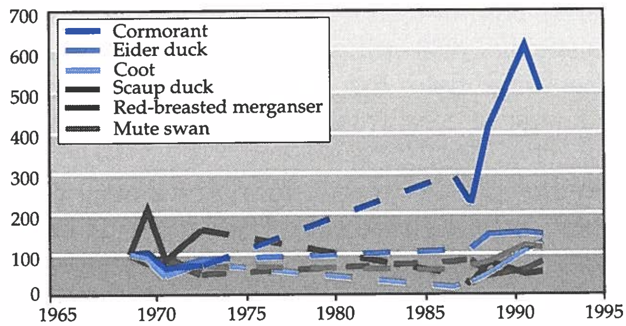


Figure 2.6.8. Trend in the populations of overwintering waterfowl for the period 1968-92. Index: 1968 = 100. (Source: National Environmental Research Institute).

The trend in the winter populations of 6 selected waterfowl species in Danish marine waters is illustrated in *Figure 2.6.8*. The cold winters in 1969/70 and in the mid 1980s had a negative effect on the populations, especially the coot population.

The decline in the scaup duck population in Danish marine waters does not reflect a general decline in the European population, but rather a change in its geographic distribution. Thus overwintering populations of scaup ducks have been increasing in recent years in Holland and in the more easterly regions of the Baltic. This underlines the importance of evaluating population trends in both a regional and global context.

Threatened plant and animal species

Lists of plant and animal groups that are threatened in Denmark - the so-called red lists - have been published regularly since 1974. Even if a species is listed as threatened in Denmark, this does not necessarily indicate that the very existence of the species is threatened. It is apparent, though, that red lists from countries that are comparable with respect to landscape, economic structure, etc., are in many ways similar, often including the same groups of species and reflecting the same types of problems. The red lists therefore give an indication as to how nature conservation should be prioritized at the international level if it is also to be effective in relation to the overall distribution of the species. Nevertheless, it is obviously a precondition that nature conservation becomes internationalized, as is the case with the conventions.

In 1986 and 1991 combined lists were published covering most existing plant and animal groups.

The 1991 red list encompasses 3,176 species in need of protection. This corresponds to 34% of the species in the plant and animal groups in question. Of these, 456 are classified as acutely threatened, 880 as vulnerable and 1,146 as seldom. The other species classified as being in need of protection are not at immediate risk of eradication, but are assessed as requiring special consideration or attention in an international context. A total of 353 species have disappeared from Denmark since 1850.

In the case of some threatened species, it has been possible to reverse the trend by, among other things, making use of the red lists when prioritizing nature conservation measures. Examples include the otter, where modification of fishing equipment and the establishment of fauna passages under roadways have considerably reduced otter mortality. The tremendous decrease in the population has been halted, and perhaps even turned into a slight increase.

By combining the maintenance and establishment of breeding ponds with rearing and stocking, it has also been possible to halt the marked decline in the fire-bellied toad population, and even reverse the trend slightly. The brent goose and the cormorant are protected from hunting, and their populations have consequently increased markedly. The population of the rare pyramidal orchid has been restored to its former size by changing the way its habitat is managed.

Despite the endeavours made in recent years, the list of threatened species is still long. Moreover, a number of more common species are in marked and permanent decline. Five species disappeared from Denmark during the period 1980/85 to 1990, and the majority of the other species on the list are on the decline or in danger of disappearing from the country.

2.6.5 Anthropogenic influences

Human impact on species abundance and distribution, as well as on habitats and the landscape, can be the result of environmental pollution or changes in land usage. The most important anthropogenic influences in this context are agriculture and forestry, traffic and the strain on nature caused by outdoor activities.

Changes in land usage: Land usage in Denmark has changed considerably during this century, as illustrated in *Figure 2.6.9*. Cultivated land (inc. market gardens and orchards) has remained constant at around 60%, whereas the percentage of less intensively exploited areas such as meadows, marshes, heaths, dunes, fens, etc., has more than halved.

This century has seen a dramatic increase in the percentage of land used for various types of built-up areas and roads, most of which had previously been agricultural land. The decrease in the latter has been compensated for by the appropriation of less intensively used areas for cultivation through the drainage of wetlands and improving soil quality in sandy-soil marginal land.

The less intensively used areas are of vital importance to a large number of plants and animals, many of which are vulnerable or directly threatened. The shift in species composition that has taken place in Danish nature is largely attributable to the change in land usage outlined above.

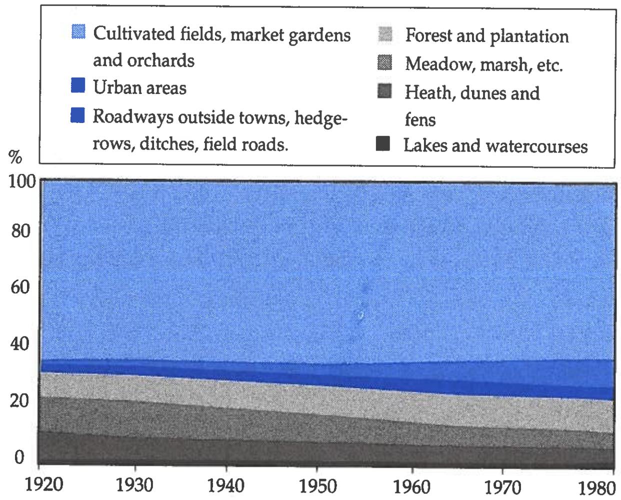


Figure 2.6.9. Trend in land usage in Denmark over the period 1920-80. (Source: Danmarks Statistik).

Intensified agriculture and forestry: Agricultural and forestal production has been considerably intensified and modified over the last century. In the case of agriculture this has meant fewer but larger farms, and at the field level, larger fields, drainage of waterlogged soil, enhanced use of commercial fertilizer, intensified use of pesticides, and cultivation of the same crop in the same field for several years in a row (change in crop rotation).

Studies of the weed flora in Danish crop rotation fields have not revealed any evidence that the total number of weed species in conventionally cultivated agricultural areas has declined since the 1960s at the national level. Nevertheless, the occurrence of these species is generally less frequent than was previously the case, and the value of the weed flora as a food resource for arable land birds and insects is probably therefore less. As revealed by studies of changes in the weed seed content of soil in Danish fields over the period 1964-89, there has been a considerable decrease in the number of species represented as viable seeds. Thus the number of fields with at least 10 species fell from 92% in 1964 to 27% in 1989.

The economic considerations that have dominated intensified forestry have led to a trend emphasizing homogeneous, intensively managed conifer stands. Given the absence of virgin forest in Denmark, and the fact that protection of ancient forests has only recently been implemented, this has probably been the reason for the impoverishment of species diversity in Danish forests.

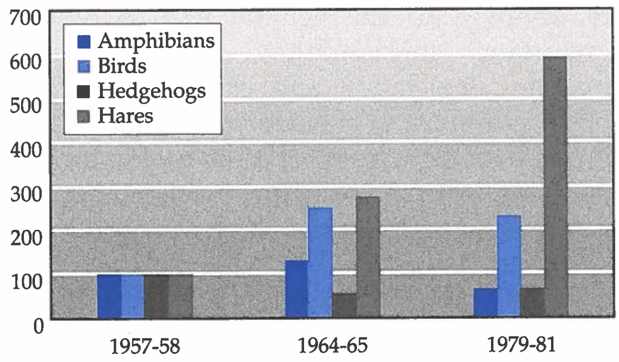


Figure 2.6.10. Trend in the number of animals killed by traffic over the period 1957-81. Index: 100 = 1957-58. (Source: Hansen, 1982).

Traffic: It is estimated that some 8-10 million mammals, birds and amphibians are killed on Danish roads each year. By far the majority are small birds and amphibians, whereas the larger animal species only account for a small percentage of total mortality. The data on which *Figure 2.6.10* is based is from a study of a relatively small geographic area, and its general applicability to the country as a whole is uncertain.

The number of birds and hares killed on the roads seems to increase in step with the increased amount of traffic: in the case of the hare, the increase has even occurred in a period during which the population has declined considerably. In addition to the direct effect in the form of increased mortality, traffic also has an equally serious but indirect effect by "fragmenting" animal habitats.

Tourism and outdoor activities: Changed patterns of leisure time and improved means of transport, as well as the increase in tourism, have led to an ongoing increase in outdoor activities. As a consequence, there is an increase in demand for areas suitable for outdoor activities, and hence in the pressure on plant and animal life caused by the resultant increase in wear on the vegetation and disturbance of the animals.

Danish forests play an important role for outdoor activities, the average Dane spending approx. 30 hours per year in the forest, a figure that corresponds to the time spent on Danish beaches. Forests in the vicinity of urban areas are of particular importance, the majority of all forest visits taking place within a 10 km radius of the visitor's residence. Numerous different and often conflicting interests are associated with forests, e.g. orienteering, bird spotting, collecting fungi, hunting and riding.

2.6.6 Nature management - national and international

International cooperation

Preservation of biodiversity is the subject of international cooperation, the distribution and occurrence of species and ecosystems often being common to several countries who acknowledge that their preservation is a joint responsibility that necessitates cooperation.

Denmark's international obligations and cooperation with respect to biodiversity emanate from a number of conventions, agreements and EU regulations. The latest and most comprehensive of these is the Biodiversity Convention that arose from the 1992 UN Conference on Environment and Development in Rio de Janeiro.

The convention, which is based on the concept of sustainability, is of wide-ranging significance for agriculture, forestry, fishery, trade, aid to other countries, etc. Each nation's right to its own natural resources, not least its genetic resources, is stipulated as a principle. Countries are obligated to draw up national strategies for the preservation and sustainable exploitation of biodiversity.

The *Ramsar Convention* on the protection of wetlands of international significance binds Denmark to designate and protect the ecological value of at least one such area. To date, 27 such areas have been designated that together cover a total of 735,000 ha.

According to the EU Protection of Birds Directive, a number of threatened or vulnerable bird species have to be protected. In Denmark this directive has been implemented through the legislation on hunting. In addition, a number of areas have to be designated as reserves whose ecological condition may not be changed in any significant way. To date, 111 reserves have been designated encompassing approx. 9,400 km^2, of which the 27 Ramsar areas are a part.

According to the *Bern Convention* - the European Convention on Nature Conservation - Denmark is bound to protect wild animals and plants and their natural habitats.

At *the EU level,* the provisions of the Bern Convention are about to be implemented in the coming Habitat Directive. In addition to ordering the specific protection of threatened species, the latter also requires the identification of special conservation areas for a number of habitats and species of community significance. This network of conservation areas - NATURA 2000 - also includes the EU bird protection areas.

The conservation areas are to be protected against deterioration of the habitats and disturbance of the species that are the reason for their selection. The proposal for Danish conservation areas has to be drawn up by June 1995.

The *Washington Convention* and subsequent supplementary EU regulations protect a number of species, mainly tropical species, but also our own birds of prey, by prohibiting all trade in them. In addition, trade in less threatened species is also limited.

According to the *Bonn Convention* on the protection of migratory species of wild animals, countries have to endeavour to enter into agreements concerning species whose conservation status would benefit from such agreements. An agreement has been entered into concerning the harbour seal in the Wadden Sea, and agreements are about to be entered into concerning the protection of European bats and the protection of small whales in the Baltic and the North sea. In addition, an agreement is about to be entered into protecting aquatic birds that migrate between Europe/Asia and Africa.

National endeavours to preserve biodiversity

As a follow-up on the Biodiversity Convention, the National Forest and Nature Agency has been given the task of drawing up a national strategy for preserving biodiversity. The existing elements that are to be incorporated in that strategy include the following.

In addition to the general and extremely important consideration taken through planning legislation and county/municipal plans, preservation of biodiversity is particularly based on general and specific habitat protection, supplemented by nature management and nature restoration, as well as species protection.

Also of considerable importance are the primary trades agriculture, forestry, fishery and raw materials retrieval, as well as the regulative control to which these trades are subject. However, it would be to go too far to discuss these matters in the present context.

The general habitat protection afforded by the Protection of Nature Act encompasses heaths, fens, salt marshes and swamps, commons and freshwater meadows larger than 2,500 m^2, lakes larger than 100 m^2, as well as larger watercourses. The Act protects these areas against intervention that would change their condition, while at the same time allowing normal operation of the areas. In addition, provisions of the Forest Act stipulate that forest shall continue to be forest, and protect oak thickets and small forest habitats.

A special endeavour to preserve the genetic resources of tree species and forest animal and plant life is made through the Natural Forest Strategy. The objective of this strategy is to ensure that by the year 2040 there is at least 40,000 ha of natural forest, untouched forest, coppice forest and grazing forest in Denmark, an area corresponding to 10% of the present forest area.

To date, 4% of the country has been declared conservation areas, and a number of areas that cannot be protected sufficiently by other means will, in accordance with current action plans for conservation at land and at sea, be declared as conservation areas in the future.

Specific protection of important breeding habitats has been achieved through the establishment of 80 game reserves in which birds and mammals are protected from disturbances during their breeding seasons. A further extension of the protection given to migrating and resting aquatic birds, for which Danish marine waters are so important, is provided by the current establishment of hunting- and disturbance-free core areas in the marine EU bird protection areas.

In principle, all mammalian and bird species are protected by the Game Act. For those species that can tolerate the depredation of hunting, the Game Act stipulates hunting seasons. Of other species that are protected can be mentioned all amphibians and all orchids.

In order to preserve anthropogenically conditioned ecosystems such as commons, salt meadows and heaths, it is necessary that such areas are utilized agriculturally or that nature management is undertaken. During the period 1989-91, county authorities have managed more than 10,000 ha of such areas, and state authorities approx. 32,000 ha.

In order to improve nature in Denmark, nature restoration and afforestation is undertaken. The afforestation target is to double the area of forest within a rotation age (80-100 years). This necessitates the planting of approx. 5,000 ha forest per year, equally shared between state and private forestry. However, the target has not yet even been half fulfilled, mainly because of the current economic recession in forestry.

Destroyed or markedly disturbed natural ecosystems have been restored to the extent of an average of DKK 130 million per year between 1989 and 1992. This has included the establishment of lakes, the excavation of ponds, first-time management of anthropogenically conditioned ecosystems, etc., and has involved more than 7,000 ha.

Finally should be mentioned the arable land set-aside scheme recently established under the EU agricultural policy reform, and which opens up the general possibility to set aside fields for 5 years. This should have a positive impact on arable land by punctuating the landscape with relatively species-rich fallow fields.

2.7 Environmentally hazardous substances

2.7.1 Introduction

About 100,000 chemical substances are currently in use in the EU, of which 20,000 are estimated to be used in Denmark. Few of these substances occur naturally in the environment, and many are environmentally hazardous. While new substances have to be investigated with respect to their impact on health and the environment prior to being marketed, the information available concerning existing substances is inadequate. Endeavours are therefore being made within the EU to improve our knowledge of existing substances, with highest priority being given to substances produced in large amounts, i.e. exceeding 1,000 tonnes per year. In future, such information will be incorporated into an overall assessment of products and materials in which the environmental impact of a product will be evaluated on the basis of a life cycle analysis encompassing production, use, disposal and the prospects for recycling.

Environmentally foreign substances are used in all sectors of society. As a consequence of their production and use, they will be spread into the atmosphere, the terrestrial environment and the aquatic environment. This section of the report therefore traverses the thematic and sectoral structure that characterizes the report as a whole.

It is impossible to systematically monitor the whole universe of environmentally foreign substances. Much of current regulative control of chemical substances is therefore based on laboratory experiments, mathematical modelling and the principle of caution. In the case of some hazardous substances, particularly those released into the environment before environmental laws came into force, or whose use is considered to be unavoidable (e.g. pesticides), monitoring and associated environmental chemistry research has been undertaken for many years. This mainly applies to heavy metals, pesticides and certain environmentally toxic organic substances.

The present section reviews a selection of these substances, focusing on their occurrence in the environment and the regulative measures implemented to limit their environmental impact. Substances designated as high priority substances for reasons unrelated to the environment, e.g. carcinogenicity or allergenic properties, are not covered here (cf. section 3.5).

2.7.2 Heavy metals

Heavy metals are environmentally toxic substances that do not degrade, but accumulate in the environment. The metals are concentrated up the food chain such that the last link in the chain, including man, is especially at risk from their noxious effects. In this section lead, cadmium and mercury have been selected to describe the trend in the impact of heavy metals on man and the environment. In man, cadmium can cause kidney and liver damage, while lead and mercury can damage the nervous system.

Atmospheric deposition

Studies of the atmospheric deposition of heavy metals in Denmark show that deposition of both lead and cadmium has decreased by roughly half over the period 1975-90 (*Figure 2.7.1*).

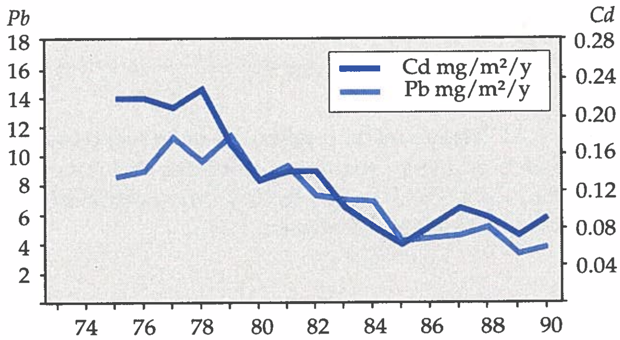


Figure 2.7.1. Atmospheric deposition of lead and cadmium in Denmark over the period 1975-90. (Source: Hovmand, 1992).

Heavy metals in the aquatic environment

In the aquatic environment, movement of heavy metals from water to sediment mainly takes place through the sedimentation of heavy metal containing organic matter. In addition, some exchange of heavy metals takes place

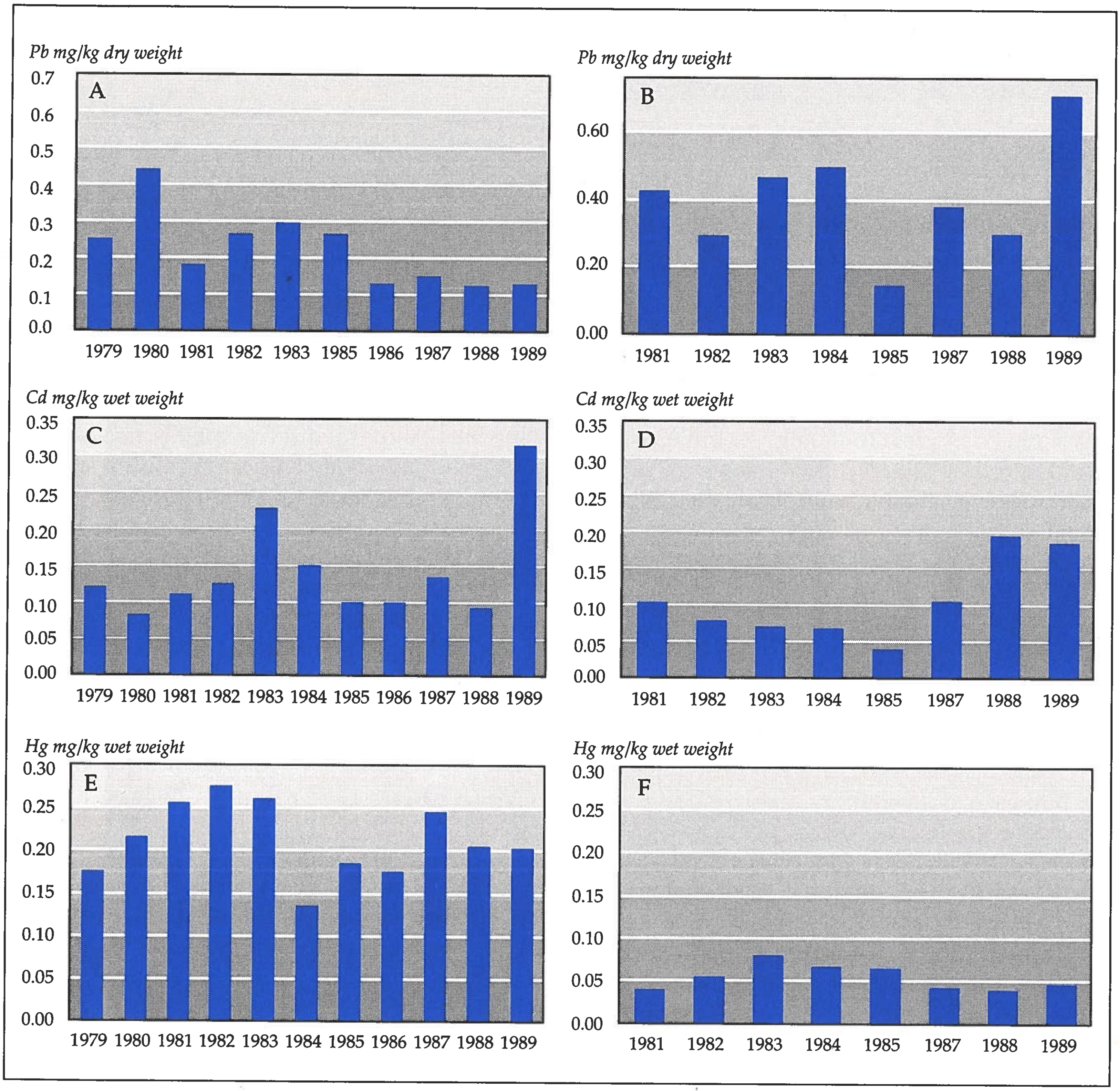


Figure 2.7.2. Heavy metal concentrations in fish tissue from Danish marine waters. **A**: Lead in flounder from the Sound (liver). **B**: Lead in plaice from the North Sea (liver). **C**: Cadmium in flounder from the Sound (liver). **D**: Cadmium in plaice from the North Sea (liver). **E**: Mercury in flounder from the Sound (muscle). **F**: Mercury in plaice from the North Sea (muscle). (Source: Jørgensen and Pedersen, 1993).

between sediment and water. The heavy metals can be directly taken up by organisms inhabiting the sediment, and from there spread to the rest of the marine food chain.

The heavy metal concentration in living sedentary fish can be used as an indicator of areas affected by human activity. *Figure 2.7.2* gives the lead, cadmium and mercury content in flounder and plaice from the Sound and the North Sea, respectively.

It can be seen that the lead concentration in fish liver fell in the Sound during the second half of the 1980s, whereas a corresponding fall does not seem to have taken place in the North Sea. The cadmium content of fish is increasing both in the Sound and in the North Sea. The great overall reduction that has taken place in the use of lead and cadmium is not reflected in the content of these heavy metals in plaice and flounder, the probable explanation being that these fish inhabit the sediment. Average sedimentation in Denmark amounts to 1 mm per year, but the activity of benthic fauna results in the mixing of the upper 3-4 cm of the sediment. As a result, the fish and other animals that inhabit the sediment are still affected by the last 30-40 years of pollution.

The mercury concentration was significantly greater in fish from the Sound than from the North Sea, even though significant discharge of mercury in Copenhagen harbour ceased in the mid 1970s.

Heavy metals in the terrestrial environment

Lead

Lead input to agricultural land is mainly attributable to atmospheric deposition, the spreading of sewage sludge and the application of fertilizers, etc. The magnitude of the various inputs is given in *Table 2.7.1.*

The amount of sewage sludge that is spread on cultivated land is expected to increase markedly in coming years as a result of the increasing amount of treatment plant waste and increasing problems with its disposal.

Source	Tonnes Pb/y*
Atmospheric deposition	300
Spreading of sludge on cultivated land	8-27**
Fertilizer, feedstuff and limestone	28-180

* All calculations are subject to considerable uncertainty.
** Lead from composted waste is not included.

Table 2.7.1. Sources and magnitude of lead input to soil in Denmark in 1985. (Source: Danish Environmental Protection Agency, 1989).

The admissible limit for how much lead may be applied to soil in sewage sludge, sewage and compost is 120 mg/kg dry matter in general, and 40 mg/kg dry matter in the case of cultivated land. The actual lead content of soil is approx. 50% of the maximum admissible concentration.

Cadmium

The dominant source of cadmium input to agricultural land is atmospheric deposition and the use of commercial fertilizer. The cadmium balance in Danish agricultural land is depicted in *Figure 2.7.3.*

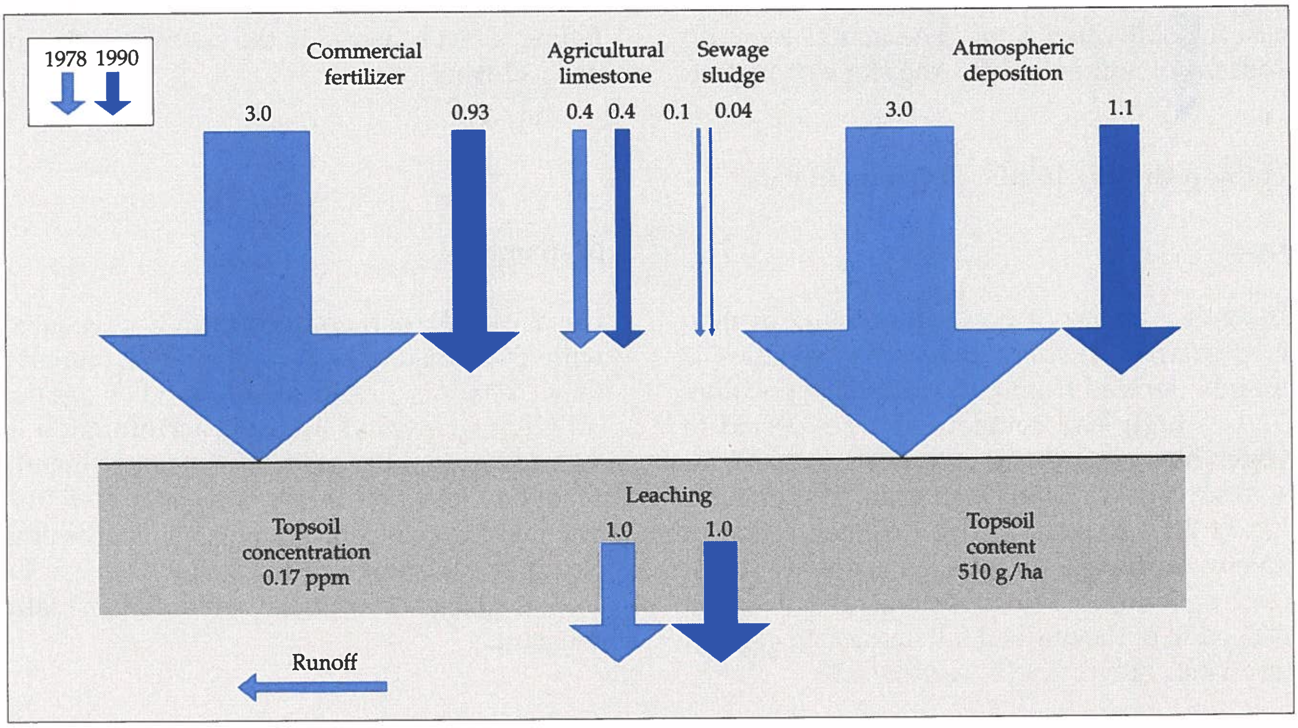


Figure 2.7.3. Average cadmium balance for Danish agricultural land (g Cd/ha/y). (Source: Danish Environmental protection Agency, 1993.)

As is apparent, the cadmium input has fallen by a factor of 2.6 during the period 1978-90, though with the exception that input with agricultural limestone has remained unchanged. Despite these reductions, the average cadmium concentration of the topsoil is still increasing by 0.3%, corresponding to a doubling in the concentration over 350 years.

The admissible limit for how much cadmium may be applied to soil in sewage sludge, sewage and compost is 1.2 mg/kg dry matter in general, and 0.5 mg/kg dry matter in the case of cultivated land. The actual cadmium content of soil is 0.11-0.32 mg/kg dry matter.

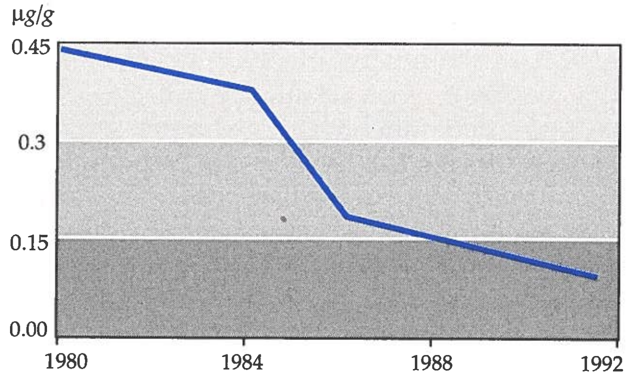


Figure 2.7.4. Trend in the lead content of kale over the period 1980-91. (Source: National Food Agency of Denmark, 1990 and 1992).

Mercury

Mercury is input to agricultural land through atmospheric deposition and the application of commercial fertilizer. Pesticides once contributed to the pollution, but the use of mercury compounds as pesticides has been prohibited by an EU Council Directive since March 31, 1992.

The admissible limit for how much mercury may be applied to soil in sewage sludge, sewage and compost is 1.2 mg/kg dry matter in general, and 0.5 mg/kg dry matter in the case of cultivated land. The actual mercury content of soil is 0.01-0.1 mg/kg dry matter.

Human dietary intake of heavy metals

Lead

As with most heavy metals, lead intake by man is primarily dietary. Lead in vegetables is mainly derived from atmospheric deposition. Thus a high lead content can be expected in vegetables with a long growth period and/or a large surface area, e.g. spinach and kale. *Figure 2.7.4* depicts the lead concentration in kale over the last decade. As is apparent, the lead content of kale is falling, this being a reflection of the marked fall in the lead content of air (cf. *Figure 2.3.11*, section 2.3).

Investigations by the National Food Agency of Denmark show that the lead content of foodstuffs in general is significantly lower after 1983 than prior to 1983.

Cadmium

The cadmium taken up by crops is mainly derived from the soil, thus rendering concentrations highest in root vegetables. The National Food Agency of Denmark has been investigating the cadmium content for a number of years, and there is no sign that the concentration is changing. For example, the concentration in carrots remained at approx. 0.04 mg/kg over the period 1980-91.

As is apparent from *Figure 2.7.3*, the concentration of cadmium in cultivated soil is not falling, a fact reflected in the cadmium content of foodstuffs.

Mercury

Dietary intake of mercury is mainly associated with the consumption of fish. The mercury they contain is almost solely found as organically bound methyl mercury accumulated in fatty tissue. In other foodstuffs mercury mainly occurs as less poisonous inorganic mercury. The mercury concentration in plaice from the North Sea is shown in *Figure 2.7.2;* as can be seen, the concentration has remained virtually constant.

Consumption of heavy metals

Approximate Danish consumption of lead, cadmium and mercury is given in *Table 2.7.2.*

Heavy metal consumption (tonnes)			
Year	Lead	Cadmium	Mercury
1977			31
1980		110	
1982-83			16-20
1985	21,000-25,000		
1990	20,800-24,600	49	10-13

Table 2.7.2. Approximate Danish consumption of lead, cadmium and mercury. Only intentional consumption is included, i.e. not the unintentional consumption that arises because heavy metals are often found as impurities in other goods and products. (Source: Danish Environmental Protection Agency).

Lead consumption in Denmark is decreasing gently, the marked fall in the consumption of lead petrol additives having been offset by an increase in consumption for other purposes. Direct emissions to the air have fallen markedly because of the reduction in the lead content of petrol (cf. *Figure 2.3.11*, section 2.3).

Cadmium consumption has more than halved since 1980, mainly because the use of cadmium in the plastics industry reduced markedly during the 1980s, and ceased almost completely in 1992. On the other hand, there has been a marked increase in the consumption of cadmium for rechargeable nickel-cadmium batteries, and even though it is expected that 75% of scrap batteries will be collected, the remaining 25% can mean an increase in the amount of cadmium in waste.

Mercury consumption has also declined during the last 10 years, mainly because of a reduction in the use of amalgam fillings and disposable batteries.

2.7.3 Pesticides

Pesticides are used in rural production (agriculture, horticulture and forestry) to combat weeds, diseases and insect pests (together denoted pests).

Approximately 100 different pesticides are in use in agriculture in Denmark. The active ingredients have quite different properties and hence different effects on the environment. The active ingredients DDT and lindane, which are only slowly degradable, are discussed in subsection 2.7.4 on environmentally toxic organic substances.

Agricultural land accounts for approx. 60% of the Danish land mass. The level of pesticide consumption in Denmark is such that on average, all the agricultural land could be sprayed with pesticides about three times yearly if using the recommended doses.

Pesticides also spread outside the areas where they are used. For example, studies from both Denmark and abroad have demonstrated pesticides in groundwater and surface water, and some studies from abroad have also demonstrated pesticides in the precipitation.

The environmental impact of pesticides can be divided into direct effects and indirect effects. The direct effects are determined by the inherent properties of the individual active ingredients, e.g. toxicity to plants and animals. The indirect effects arise because the food resource for a number of animals is removed, e.g. when weeds, fungi and insects are eradicated. The indirect effects are therefore closely associated with the intended effect of the products.

When pesticides enter the soil they are subject to a number of influences that determine their further fate in the environment. The rate at which they degrade and their binding to soil particles are important in determining the risk that the pesticides will be transported down to the groundwater. The occurrence of pesticides in the groundwater is treated in section 2.5.

The consumption of pesticides increased sharply at the beginning of the 1980s. In order to reduce the impact of pesticides on health and the environment, the Minister of the Environment in 1986 drew up an action plan aimed at reducing pesticide consumption.

Pesticide-resistant pests in rural production

Pesticides work by inhibiting or preventing the formation of substances that are vital for the pests they are intended to combat. For example, certain fungicides prevent normal development of the cell wall or prevent cell division. When the pesticide comes in contact with the pest, the latter usually buckles under. However, mutations sometimes arise in the genetic material of the pests such that they become resistant to the pesticide. If the survival of these mutants is good, repeated treatment will lead to such strong selection that the resistant population becomes dominant. In practice, this will be manifest by the pesticide no longer having the desired effect. In the case of pesticides with a common mode of action, the development of cross resistance can have the result that all of the compounds in question lose their efficacy. The final result can be that the farmer is left unable to combat a particular pest, or may be forced to employ alternative products that are less desirable from the point of view of health or the environment.

The most widespread example of resistance in Denmark has been detected in the fungus eyespot that attacks cereals. A marked increase in the consumption of benzimidazole products for combatting eyespot at the beginning of the 1980s was followed in 1983-84 by a consider able decline in their efficacy.

The development of resistance to herbicides is more seldom. However, resistance to one of the newer types of herbicide - sulphonylurea - has developed in chickweed after annual use of the product on the same field for a period of 7 years under cultivation conditions that further promoted the risk of resistance.

While the development of resistance is not uncommon among greenhouse insects in Denmark, the only case of resistance developing on arable land concerns the widespread peach-potato aphid.

A number of examples of pesticide resistance within the three main groups of pesticides are known in Denmark (*Table 2.7.3*). Systematic monitoring of pesticide resistance in all combinations of pests/pesticides is not undertaken. However, if there are good reasons for suspecting the development of resistance, the extent of it is monitored.

In Denmark, the extent of resistant pests is relatively limited as compared with that in other countries. This is attributable to several factors related to Danish cultivational practice, crop rotation and pest control strategies. In tropical and subtropical countries, where problems with pests are greater than in Denmark, resistant insects are a great problem (*Figure 2.7.5*). In such areas the resistance problem comprises an environmental threat in that it forces the constant introduction of new types of pesticides, with possible unknown effects.

Products to which organisms have become resistant	Pests that have devoloped pesticide-resistance in Denmark
Herbicides:	
Triazines (atrazine, simazine)	Groundsel, fat hen, annual bluegrass, willow-herb
Sulphonylurea products (Glean, Ally, etc.).	Canadian fleabane, black nightshade, chickweed
Insecticides:	
Pyrethroids	Peach-potato aphid
Pirimicarb	Peach-potato aphid
Phosphorus compounds	Peach-potato aphid
Fungicides:	
Benzimidazoles (Benlate, carbendazim, etc.)	Eyespot, grey mould, apple scab, snow mould
Phenylamides (Ridomil)	Late blight
Dicarboximides (Rovral, Ronilan)	Grey mould on tomatoes
DMI- products (Bayfidan, Tilt, ect.)	Powdery mildew (reduced sensitivity)

Table 2.7.3. Occurrence of resistant species in Denmark. (Source: Danish Institute of Plant and Soil Science, 1993).

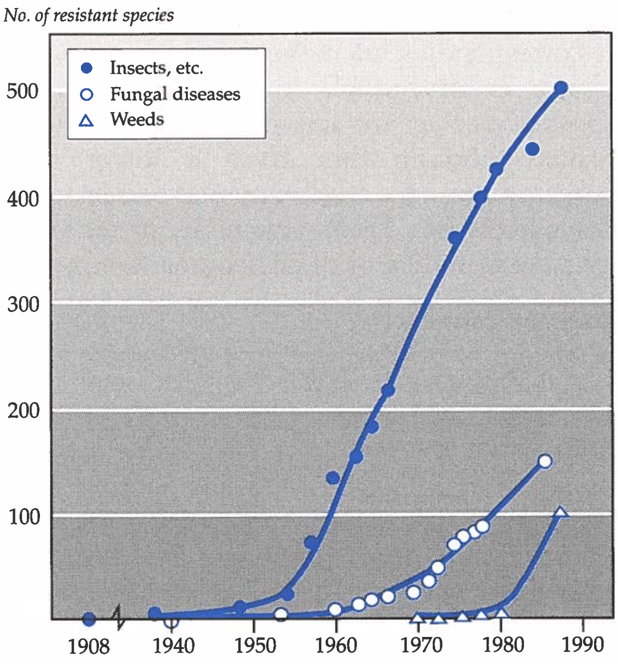


Figure 2.7.5. Global growth in the occurrence of pesticide-resistant species. (Source: Jodie & LeBaron, 1990).

Pesticide poisoning of game

Game found dead in the countryside is often forwarded to the National Veterinary Laboratory, where it is examined. If poisoning is suspected, attempts are made to identify the poison, e.g. as in the case of about 50 geese found poisoned in 1990, and where the poison was identified as a molluscicide that had been employed on a field in which the geese had been foraging.

The number of instances of parathion poisoning diagnosed by the National Veterinary Laboratory over the period 1985-92 is shown in *Figure 2.7.6.* Each instance encompasses anywhere from a single animal to a hundred or more animals. Most instances concern birds. The consumption of this pesticide in Denmark has been falling, and its sale ceased in 1993. Consumer stocks may still be used, however. As is apparent from the *Figure 2.7.6*, the number of instances of parathion poisoning is falling, and should soon cease completely.

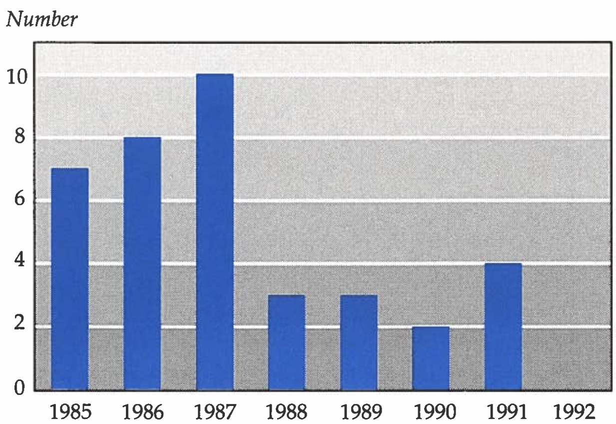


Figure 2.7.6 Number of diagnosed instances of parathion poisoning of game during the years 1985-92. (Source: National Veterinary Laboratory).

Pesticides in watercourses

Pesticides have been detected in watercourses in several countries. Pesticides sprayed on fields can be blown directly into watercourses or can leach into drains or be transported with surface runoff. Moreover, pesticides spilt during the filling or cleaning of spraying equipment can also drain to the watercourses.

In Denmark, the occurrence of 11 selected herbicides has been investigated in two watercourses. The number of herbicides is greatest in the late autumn and in the late spring, when spraying intensity is greatest. The concentrations lie between 0.02 µg/l and 7.3 µg/l. The highest concentrations are registered in the same periods as the number of herbicides in the watercourses is high. The herbicides most often found in concentrations exceeding 1 µg/l are the phenoxy acids MCPA and mechlorprop, both of which inhibit algae in concentrations of 100-200 mg/l, i.e. at much higher concentrations than those found in the watercourses. Little is known about the long-term effects of repeated exposure to low concentrations of several herbicides simultaneously.

Wood preservatives

Wood preservatives that penetrate into wood and protect it against attack by fungi and/or insects have had to be approved as pesticides since 1980. High-pressure impregnation products have accounted for a considerable portion of the wood preservatives. Although the use of high-pressure impregnated wood is particularly necessary for wood that is intended to be in contact with soil or water, high-pressure impregnated wood has often been used in places where such a high degree of protection is unnecessary. In 1980, the most used high-pressure impregnation products contained arsenic, chromium and copper.

Arsenic and chromium(VI) are considered to be carcinogenic, and the Danish Environmental Protection Agency therefore wishes to reduce the use of products containing them and eventually have them replaced with products less hazardous to health.

In addition to the hazard to health, there is also the problem of the disposal of lumber waste and old wood from the demolition of houses, telegraph poles, old fences, etc. Incineration of such wood spreads arsenic, chromium and copper into the air, and the heavy metal content of the ash residue renders it poisonous.

The trend in the sale of wood preservatives is depicted in *Figure 2.7.7*. The general decline in consumption is attributable to the use of lower doses for some of the treated wood. Substitutes have been found for arsenic, and its approval as a pesticide was withdrawn in 1992. Substitutes have not yet been found for chromium compounds, but according to an agreement entered into by the Danish Environmental Protection Agency and the relevant branch organization, the use of chromium is to be phased out before 1997.

Action Plan on Pesticides

According to the Minister for the Environment's 1986 Action Plan on Pesticides, the consumption of pesticides (relative to the average consumption in 1981-85) was to be reduced by 25% before 1990 and a further 25% before 1997. The reduction was to be both in terms of the amount of active ingredients and the so-called treatment frequency factor. The latter is a measure of how many times per year the total area of agricultural land in Denmark could be treated with pesticides if the amount sold was used at the recommended doses. The main means of achieving that goal were advice, guidance and research.

As is apparent from *Figure 2.7.8*, the reduction in pesticide consumption is approaching the target level. However, as is apparent from *Figure 2.7.9*, the treatment frequency factor is far from the target level. That consumption of active ingredients can fall without there being a corresponding fall in the treatment frequency factor is attributable to the greater use of pesticides that are active at very low doses. Thus although this gives a lower total consumption, the environmental impact is not necessarily less. The treatment frequency factor is a better indicator of environmental impact.

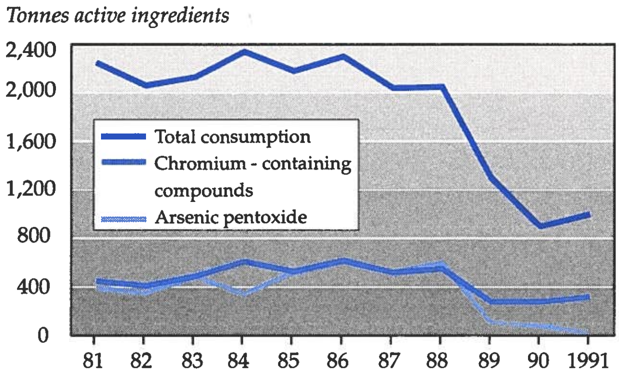


Figure 2.7.7. Trend in the sale of wood preservatives and the arsenic and chromium they contain over the period 1981-91. (Source: Miscellaneous).

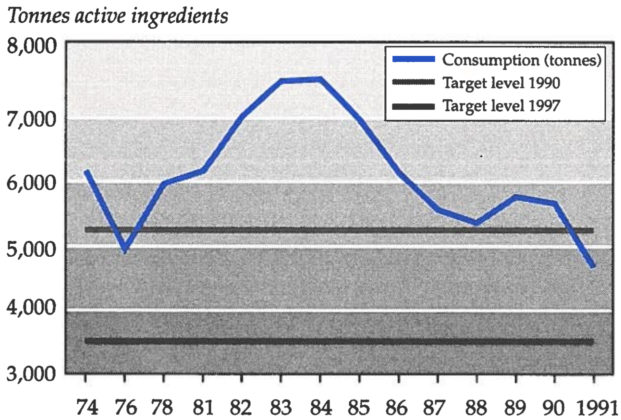


Figure 2.7.8. Trend in agricultural consumption of pesticides (amount of active ingredients) over the period 1974-91. (Source: Danish Environmental Protection Agency).

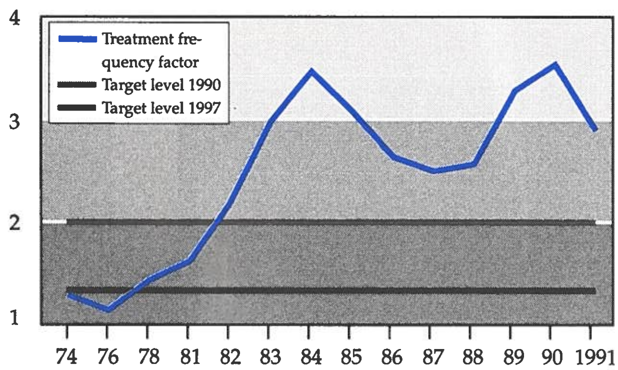


Figure 2.7.9 Trend in agricultural consumption of pesticides expressed in terms of the so-called treatment frequency factor (see text) over the period 1974-91. (Source: Danish Environmental Protection Agency).

2.7.4 Environmentally toxic organic substances (PCB, DDT, Lindane, Dioxin)

DDT and lindane are synthetic pesticides while PCB is a synthetic oil used in the electrical industry. Dioxin, in contrast, is produced as an unwanted by-product of a number of different chemical processes, e.g. during incineration or during the bleaching of paper.

These compounds are lipid soluble and chemically extremely stable, the result being that they spread through the whole environment and accumulate in the food chain. The main hazard for man seems not to be direct exposure to the compounds through the skin or by inhalation, but intake through the food. The most important route from source to man is thought to be atmospheric deposition on or discharge to marine waters, and subsequent accumulation in the food chain. Atmospheric deposition on land is of less but nevertheless some importance.

Long time-series of Danish monitoring data on PCB, DDT and dioxin do not exist. The following evaluation of the trends is therefore based on data from abroad.

PCB

The OECD countries have produced about 1.5 million tonnes PCB from the time production began in the 1930's until it ceased in the 1970s. It is estimated that one third of the total world production is currently circulating in the environment. The use of PCB has been prohibited in Denmark since 1976. "PCB" is a collective term for 209 compounds produced by the chlorination of biphenyl. Only about 120 of these PCBs have been detected in environmental samples, however. Some of the PCBs - the so-called coplanar PCBs - display dioxin-like toxicity, although they are less toxic than the so-called Seveso dioxin. However, they usually occur in the environment in higher concentrations than dioxins.

The PCB content of mussels has been measured in the North Sea in 1985 and 1990. The highest concentrations detected in 1990 were in mussels found off the western Scheldt in Holland and off the mouths of the north German rivers, but high concentrations have also been detected in Oslo Fjord, off the mouths of the Thames and the Seine, as well as at several locations on the French and Dutch coasts of the English Channel. In general, the concentrations are especially high near large cities and industrial regions, as well as at the mouths of rivers running through industrial regions. The concentrations in Danish marine waters follow the same pattern, but are generally lower (*Figure 2.7.11*). However, an old landfill at Rønne on Bornholm has led to high concentrations of PCB in offshore mussels.

The PCB content of guillemot eggs collected from the Baltic during the period 1971-89 reflects the falling load in that marine water (*Figure 2.7.10*), but is still approx. 10 times greater than in guillemot eggs from the North Atlantic.

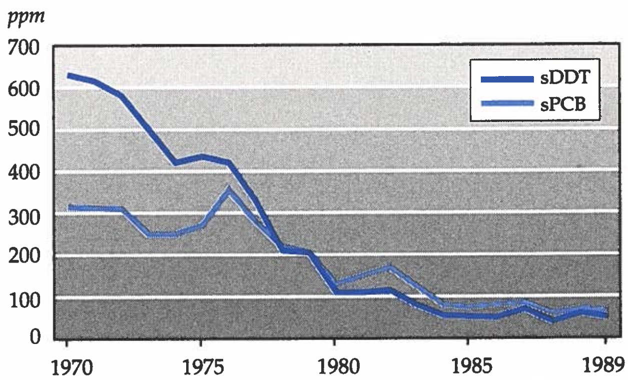


Figure 2.7.10. Trend in sPBC (sum of all PCBs) and sDDT (sum of DDT+DDE+DDD) content of guillemot eggs during the period 1971-89. (Source: Bignert et al., 1992).

The environmental PCB load declined similarly to that of DDT, although less markedly (*Figure 2.7.10*), and the PCB level appears to have stabilized after the mid 1980s. However, investigations of mussels, sediment, etc., from industrial areas indicate that numerous sources of PCB pollution still exist, e.g. old transformers and capacitors, landfills and PCB-containing sediments in rivers, lakes and marine waters.

DDT

DDT has been extensively used as an insecticide since the 1940s. Its use has been prohibited in Western countries since the mid 1970s, but is still in use in other parts of the world.

DDT's potential to spread was clearly demonstrated in Sweden in the years 1985-86. In 1983 and 1984, insect attacks in coniferous forests in southern East Germany were combated with DDT; two years later increasing concentrations of DDT were detected in fish from lake Bolmen in Småland.

DDT has a relatively low acute toxicity, but accumulates up the food chain as it is lipid soluble and slowly degradable, with a half-life of approx. 10 years. DDT interferes with reproduction, and in birds reduces the thickness of the egg shell.

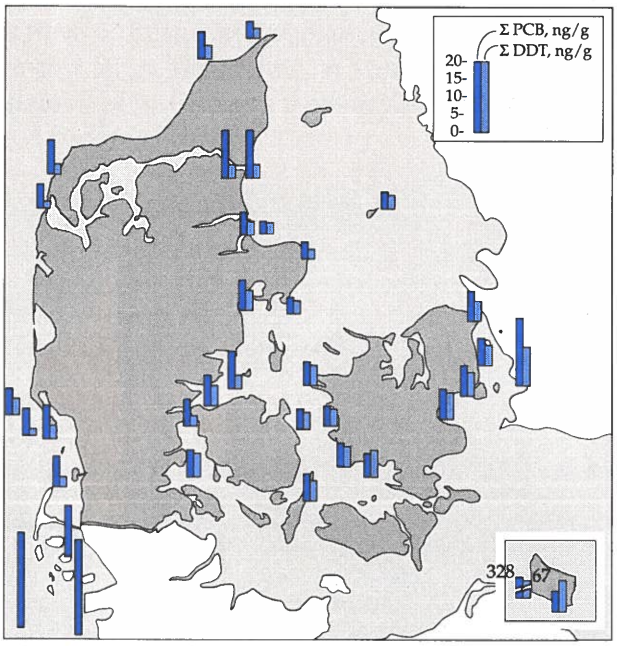


Figure 2.7.11. DDT (DDT+DDE+DDD) and PCB (sum of 7 congeners) content of mussels from Danish marine waters. Values are ng/g wet weight. (Source: National Environmental Research Institute).

As is apparent from *Figure 2.7.11*, the DDT content of mussels from Danish marine waters in 1985 and 1990 was 1-12 ng/g wet weight (excluding the high level from Rønne). Elsewhere in the North Sea that year the values ranged from 1-29 ng/g, which is similar to Danish levels, if not a little higher.

The environmental DDT load showed a clear tendency to decrease between the beginning of 1970s and the beginning of the 1980s, but has thereafter stabilized.

Lindane

Like PCB and DDT, lindane also accumulates in the environment, but is considered to be less hazardous since its half life is shorter (approx. 2 years). On the other hand, lindane is more mobile and more water soluble, and can therefore be transported over great distances, both by air and by sea. Lindane, which is prohibited in Sweden but is used to a limited extent in Denmark and in large amounts in several countries of Western Europe, thus gives rise to a transboundary environmental problem.

Atmospheric deposition of lindane: Atmospheric deposition of lindane was measured in Denmark in the years 1990-92 in precipitation samples from a varying number of monitoring stations located in 4 different parts of the country. It was found that the concentration of lindane in precipitation was clearly greatest in the spring months (*Figure 2.7.12*), this coinciding with the spring spraying season.

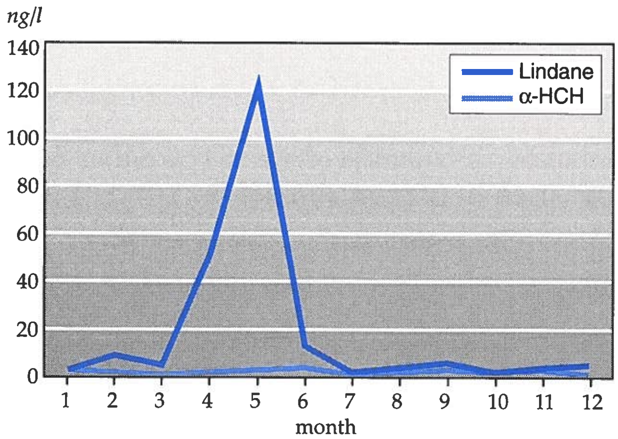


Figure 2.7.12. Concentration of lindane and α-HCH in precipitation (ng/l) from Ulborg on the west coast of Jutland in 1992. (Source: National Environmental Research Institute).

Measurements from two different years revealed that atmospheric deposition was greatest when the wind direction was southwesterly.

The average atmospheric deposition of lindane on Denmark and on the North Sea can be calculated on the basis of the measurements undertaken on precipitation; the amounts are comparable to the total annual sale in Denmark and the annual input to the North Sea via north German rivers, respectively (*Table 2.7.4*).

Even though the figures are not particularly large, they need to be taken seriously, partly because lindane is a persistent environmentally

Geographic area	Source	Lindane (tonnes)
Denmark (43,000 km²)	Atmospheric deposition Agricultural purchase (1991)	0.55 0.47 [1)]
North Sea (NSTF Subregion 5[2)]) (31,000 km²)	Atmospheric deposition Riverine input from N Germany	0.40 0.34

1) A total of 15.3 tonnes lindane was sold in Denmark in 1991, but only 0.47 tonnes was used in agriculture.
2) NSTF Subregion 5 is part of the North Sea lying off the west coast of Jutland and Germany.

Table 2.7.4. Transport of lindane to Denmark and the North Sea. (Source: National Environmental Research Institute).

Source	Year	Nordic toxicity equivalents (g)
Waste incineration - large plants	1988	34
Waste incineration - hospital plants	1987	14
Fireplaces and woodburning stoves	1992	0.4
Paper production	1990	0
Steel production - exhaust gasses	1991	13

Table 2.7.5. Total Danish atmospheric emissions of dioxins. (Source: National Environmental Research Institute).

toxic compound and partly because input is mainly attributable to long-range transboundary transport, especially from sources to the south and west of Denmark.

Dioxins

Like PCB, "dioxin" is the designation for a family of compounds having very different toxicities. The most toxic of them is 2,3,7,8-TCDD, the so-called "Seveso dioxin", which was accidentally released in Seveso near Milan in 1976. The toxicity of all other dioxins is determined relative to this compound by means of animal experiments. Each individual compound (isomer) is then assigned a "toxicity equivalent" whereby it is possible to calculate the toxicity of that mixture of dioxins that might be present in the environment. In Denmark, the toxicity of dioxins is calculated using "Nordic toxicity equivalents" (NTEQ).

Dioxins are mainly emitted as airborne pollutants. Total Danish atmospheric emissions of dioxins from various activities are given in *Table 2.7.5.*

Waste incineration is the most important source of dioxin emissions in Denmark. Waste incineration at hospitals has ceased and all hospital waste is now incinerated at large incineration plants. Moreover, flue gas purification has been implemented at the majority of large waste incineration plants. In addition, much of the PVC and related plastics previously found in household waste has now been replaced with other types of plastic. These measures may have reduced dioxin emissions, but this aspect has not been closely studied.

Dioxins can also be released to the environment by motor vehicles, in certain industrial waste water and in sludge from sewage treatment plants.

In addition, dioxins are also found as impurities in various chlorine-containing chemical products, e.g. pentachlorophenol. In contrast to the case with DDT, PCB, etc., the discharge of dioxins cannot usually be stopped by prohibition. This is because dioxin is an unwanted by-product of otherwise useful activities such as waste incineration, paper manufacturing, sewage treatment, etc., an exception being the chemical products mentioned above. Endeavours to combat dioxin are therefore directed towards reducing its formation at source, or at the purification of dioxin-containing emissions.

Occurrence in the environment: Investigations from abroad have demonstrated dioxin in the air as well as in marine sediment and harbour sludge, but there are no corresponding Danish investigations. Swedish sediment analyses indicate that the dioxins found derive from incineration, since they display a characteristic pattern of isomers. The concentration in sediment and harbour sludge varies considerably depending on the presence of point sources, especially chemical and paper plants.

There are a number of Danish studies of soil samples from various chemically contaminated sites, including a number of sites where PVC cable coatings have been burnt off. Very high dioxin concentrations are found at several of these sites, although very sporadically.

In Sweden, where the dioxin and PCB content of breast milk has been investigated for a number of years, the concentration of both substances declined up to 1984/85, and thereafter stabilized. In 1987, simultaneous investigations were undertaken in Denmark, Sweden and Norway; the dioxin level was around 17 pg NTEQ/g milk fat in Denmark, and a little higher in Sweden. Geographic variation is therefore minor, despite differences in economic structure and feeding habits.

2.7.5 Legislation and regulative measures

Endeavours to combat the environmental discharge and spread of undesirable chemical substances come under the provisions of the *Environmental Protection Act* and the *Chemical Substances and Products Act*. Regulation of the release of substances to the environment by enterprises is provided for by the Environmental Protection Act.

Much of the decrease in the emission of heavy metals and other hazardous substances is attributable to the imposition of emission standards on enterprises, power plants, etc. However, chemical substances are often spread in the environment as a result of their deliberate use within society. Heavy metals are not only released into the environment as a by-product of industrial production, but are also contained in a large number of products that circulate in society. One group of substances that is deliberately spread into the environment is pesticides. In Denmark, the Chemical Substances and Products Act can be used to counteract pollution of this type by intervening in consumption, either by directly prohibiting the use of particularly hazardous substances, or by stipulating restrictions concerning their utilization.

International conventions such as the *Helsinki, Oslo and Paris Conventions* oblige participating countries to limit pollution, for example of the North Sea and the Baltic. Specific targets for reducing the discharge of toxic substances are stipulated and monitoring programmes are implemented to follow the level of pollution.

As discussed earlier, the use and emission of a large number of substances has been curtailed over the last 20 years. This applies to PCB, a number of the most hazardous pesticides (DDT, lindane, parathion, arsenic compounds, etc.), a number of other environmentally toxic organic substances, and to a certain extent, heavy metals.

The environmental effects of well defined industrial processes and of well defined substances with limited uses are now under relatively good control. The problem with hazardous substances, though, is that the large stocks that have accumulated in the environment as a result of the "sins of the past" will have an impact for many years to come. Similarly, the use of hazardous substances in neighbouring countries and the processing of waste containing such substances will also contribute to their future occurrence in the Danish environment.

The environment is also affected by chemical substances that are not so easily defined and delimited, for example as with the diffuse loading that is a consequence of environmentally hazardous substances being necessary ingredients or impurities in many of the products that circulate in society. These substances enter the waste stream and from there will inevitably enter the environment (cf.section 3.5). Finally there are the pesticides, which are deliberately released into the environment. Although those most detrimental to the environment have been brought under control, the impact of pesticides on arable land is still so great that it is upsetting the ecological balance for the wild flora and fauna.

3. Environmental impact of society

3.1 General economic development

3.1.1 Introduction

Evolution in the state of the environment is closely linked to economic development, and hence to the nature of the economic activities. Society's production structure and utilization of technology are of decisive importance as regards the development of environmental problems. Also of importance are a number of demographic and sociological factors that affect the overall pattern of demand and consumption: population growth, changes in the age composition of the population and habitation patterns, as well as habits and behaviour.

The dynamic interaction between society and the environment, i.e. the impact that society has on the environment through pollution and the consumption of natural resources as well as the feed-back effects that this has on society, can be described at various *aggregation levels* such that the interplay, and hence the explanations for the environmental problems, is correspondingly unveiled in various levels of detail.

In the present section the general factors that have an impact on the environment are summarized at the macro level: population growth, changes in the structure of trade and industry, and growth in general economic activity. The sections that follow (3.2-3.6) describe the environmental impact of society at the *sector level* for those sectors having the greatest environmental impact, as well as the sector specific technological developments of significance for their environmental impact.

3.1.2 Demographic considerations

The population of Denmark was 5.162 million on January 1, 1992. This gives an overall population density of 120 inhabitants per square kilometre. The population has remained fairly stable since 1980, but there has been a shift in the age composition during this period: the percentage of children and youths in the age group 0-19 years fell from 29% to 24%, while the percentage in the vocationally active age group (20-64 years) increased from 56% to 60% and the percentage of elderly persons increased from 14% to 15%.

Population growth to date and Danmarks Statistik's latest forecast up to the year 2030 is illustrated by age group in *Figure 3.1.1*.

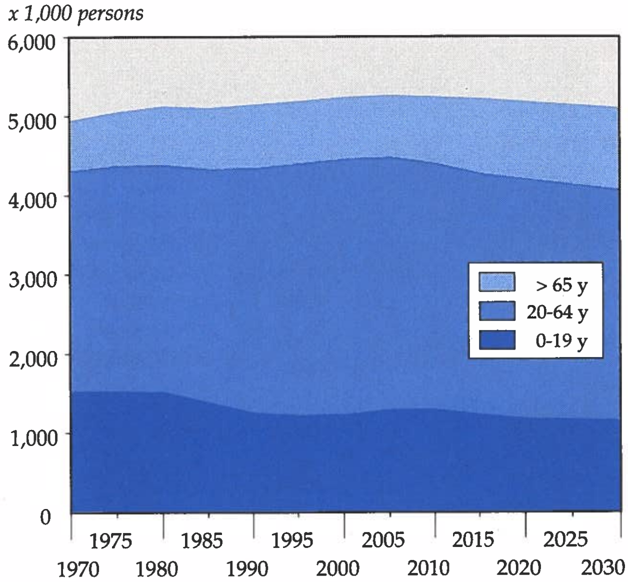


Figure 3.1.1. Population growth from 1970-2030 based on the statistics to date and Danmarks Statistik's latest forecast up to the year 2030. (Source: Danmarks Statistik, 1992).

According to this forecast the total population is expected to increase to 5.266 million in the year 2005, i.e. an increase of 2% as compared with 1992, whereafter it is expected to fall slightly up to the year 2030. After the year 2005 the percentage of the population that is vocationally active is expected to fall a little (from 60.5% to 57% in the year 2030), while the percentage of elderly persons will increase gradually from 15% to 20% during the same period.

Thus according to the latest forecast, the total population increase up to the year 2005 will be 150,000 persons more than previously predicted (1990 forecast). This difference can mean that the assumptions concerning future demand for environmentally detrimental resources and activities (e.g. energy and transport) on which earlier sector plans are based will have to be adjusted (cf. section 3.2).

3.1.3 Economic growth and the structure of trade and industry

In fixed prices the value of total Danish production (turnover) increased from DKK 498,000 million in 1970 to DKK 781,000 million in 1992, this being equivalent to real growth of 57%. The nominal value of consumption of raw materials and subsidiary substances, which reflects growth in society's total consumption of resources, increased 47% during the same period.

In connection with the launching of the government's proposition "A new course towards better times", the Ministry of Finance compiled a long term projection of the economy that takes into account the effects of the government's proposition, including a tax reform and a labour market reform. The growth in the value of production (1980 prices) during the period 1970-92 is shown for each sector in *Figure 3.1.3*, together with the projection for the period 1993-2010.

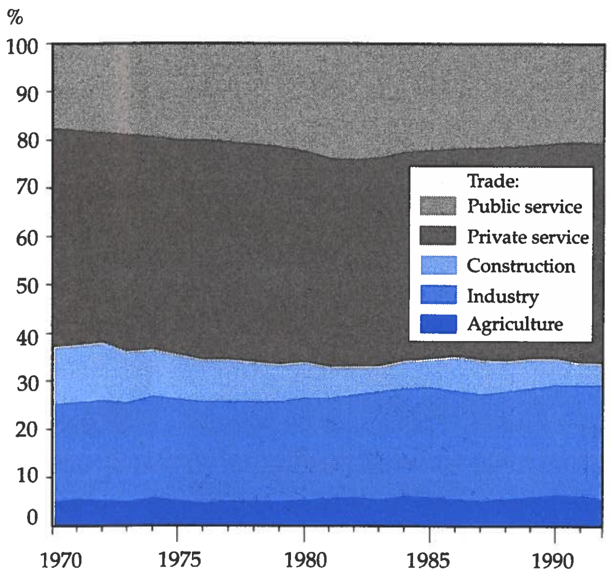


Figure 3.1.2. Trend in sectorial apportionment of GDP_f during the period 1970-92 (Source: Danmarks Statistik).

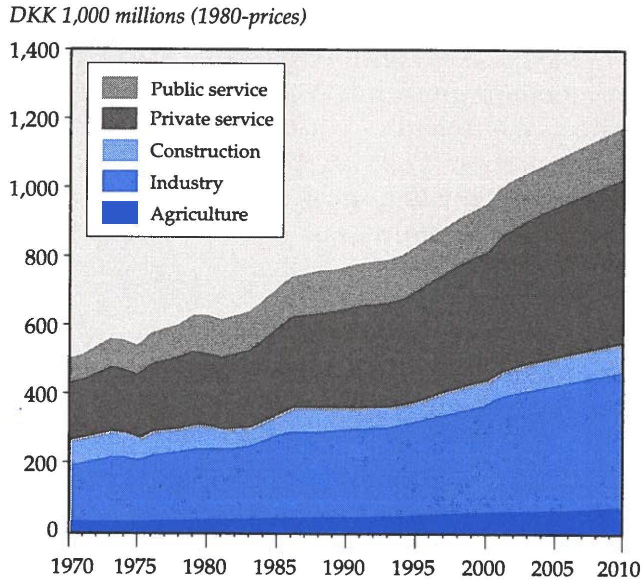


Figure 3.1.3. Growth in trade and industry production value from 1970-92 and projection from 1993-2010, expressed in 1980 prices (Source: Danmarks Statistik; Ministry of Finance, 1993).

The trend in the structure of trade and industry during the period 1970-92 is illustrated in *Figure 3.1.2*, which for each of the main sectors shows the %-share of gross domestic product at factor cost (GDP_f) measured in fixed prices. The most striking change during the period was in the building and construction sector, where the share of GDP_f fell from 11.6% in 1970 to 4.4% in 1992. Despite falling employment in the agricultural sector, its share of GDP_f has remained unchanged during this period when measured in fixed prices (although in current prices, it has fallen behind as a result of the unfavourable ratio of agricultural produce prices to prices of other goods). The industrial sector increased its share from 20.5% to 23.7% during the period. The private service sector has maintained the same share, whereas the public sector increased its share from 17.6% to 24% in 1982, whereafter it regressed to 20.5% in 1992.

Comparison of the growth in the value of production during the period 1970-90 and the expected growth during the period 1990-2010 leads to the following conclusions:

- Total growth in production in fixed prices is expected to be of the same order of magnitude during the period 1990-2010 as during the preceding two decades, namely about 55%;

- While the value of production in the building and construction sector fell by 10% during the period 1970-90, it is expected to grow by 58% in the coming two decades;

- While the value of production in the public service sector grew by a full 79% in the period 1970-90, it is only expected to increase by 20% in the coming two decades; in contrast, the private service sector is expected to grow by a full 77% in the period 1990-2010, as compared with 67% in the preceding two decades. Total growth in the service sector (public + private service) is expected to be 60% as compared with 71% in the preceding two decades.

The expected growth in the value of total production indicates an expected growth in the "physical" turnover of goods and services and hence to increased consumption of resources. However, it is not possible on the basis of these growth figures alone to draw any conclusions as to the magnitude and type of resource consumption, or to the environmental problems that will result from such growth.

That necessitates an examination of the technological perspectives within the respective sectors. The following sections therefore examine the growth and perspectives for the most environmentally relevant sectors of society: Energy, transport, agriculture, forestry, industry and housekeeping.

3.2 The energy sector

3.2.1 Introduction

As used here, the term "energy sector" shall be understood to mean Denmark's total energy consumption by both the household sector and the trade, industry and service sector, as well as Denmark's energy production.

The most important environmental problem in relation to the energy sector is air pollution from the combustion of fuels. During combustion, most of the carbon and sulphur content of the fuel is converted to carbon dioxide (CO_2) and sulphur dioxide (SO_2), respectively. Nitrogen oxides (NO_x) are formed from the nitrogen in the fuel and in the atmosphere, the amount depending primarily upon the combustion technique employed. Besides CO_2, SO_2 and NO_x, lead is emitted as a result of the combustion of leaded petrol, and quite large amounts of slag and fly ash are emitted by incinerators and power plants.

Seen from a regulatory perspective, the greenhouse gas and acid rain problems are quite different, not simply because of their different temporal and geographic dimensions, but also because of the technical possibilities for combatting them. In the case of acid rain, significant reductions can be achieved by applying various purification technologies to central units in the energy supply chain. A reduction in CO_2 emissions primarily necessitates reducing the use of fossil fuels, as can be achieved by behavioral changes, by more efficient use of energy and by converting to increased use of renewable energy. Endeavours to regulate CO_2 emissions should therefore be directed towards all links in the energy consumption and energy supply chain. While it is technically possible to collect and store CO_2, to do so is very costly.

3.2.2 The international perspective

Population growth (a doubling during the last 40 years) together with significant economic growth in the industrialized western countries has led to a major increase in world energy

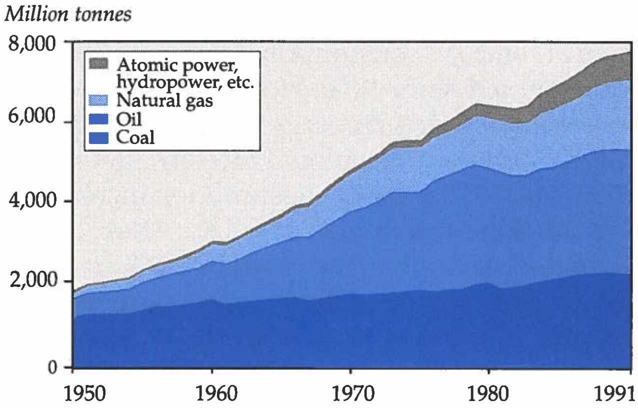


Figure 3.2.1. World energy consumption in million tonnes oil-equivalents. (Source: World Resources Institute, 1992; British Petroleum).

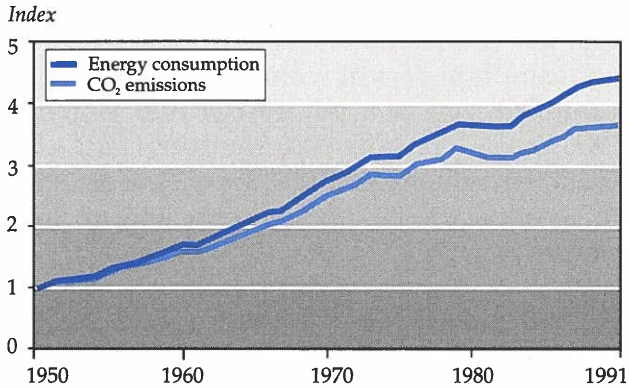


Figure 3.2.2. World energy consumption and CO_2 emissions. Index: 1950 = 1.0. (Source: World Resources Institute, 1992; British Petroleum).

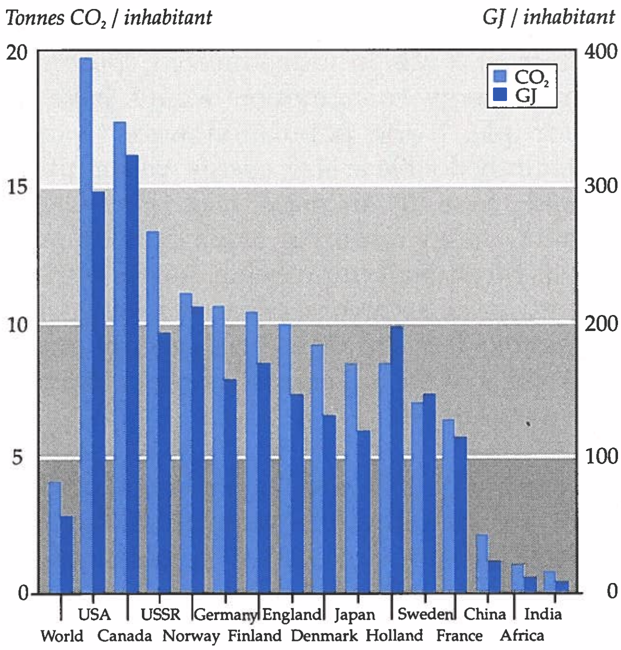


Figure 3.2.3. Energy consumption and CO_2 emissions for selected countries and regions. (Source: World Resources Institute, 1992).

consumption. As is apparent from *Figure 3.2.1*, world energy consumption has more than quadrupled since 1950. However, the energy crises and increased energy prices have significantly curtailed the annual increase. Between 1950 and 1973, energy consumption increased by an annual average of 5.1%. After 1973, energy consumption increased by 2.0% annually. In certain years energy consumption has stagnated or even fallen slightly.

The increase in energy consumption has led primarily to increased use of oil and natural gas. The relative consumption of coal has declined from well over 60% in 1950 to less than 30% in 1991. CO_2 emissions from energy consumption have grown at a slightly slower rate than energy consumption (*Figure 3.2.2*), this being attributable to the falling relative consumption of coal (compared to that from coal, CO_2 emission per energy unit is about 78% for oil and about 60% for natural gas), and to increased non fossil fuel dependent electricity production, i.e. hydroelectric and nuclear power.

Energy consumption and CO_2 emissions are very unequally distributed in the world's regions. Energy consumption and CO_2 emissions per inhabitant for selected countries and regions are shown in *Figure 3.2.3*.

Of the world's total energy consumption, about 80% is used by the richest 20% of humanity. If energy consumption worldwide is to increase to current levels in industrialized countries, world energy consumption would have to quadruple. If the population were to concomitantly double in size, energy consumption would have to increase eightfold. Given current energy resources, rapid development in this direction is improbable. As the world's energy resources become exhausted, and as less accessible deposits are utilized, energy prices will rise, and the increase in energy consumption will fall off.

Up to the year 2050, most international predictions operate with an annual increase in world energy consumption and CO_2 emissions of between 1% and 2%. A significant increase is expected in China, where current energy consumption is very low (*Figure 3.2.3*). China has a high economic growth and a very large coal resource, which it is planning to utilize. China's share of worldwide CO_2 emissions is expected to grow from 9.5% in 1985 to about 30% in the year 2050.

In an international context, Denmark's energy consumption is insignificant, accounting for less than 0.5% of the world's total energy consumption. Although on a per capita basis energy consumption in Denmark is high, it is nevertheless moderate compared to that in the countries to which Denmark is normally compared. This is mainly attributable to the negligible production of energy-intensive products in Denmark. In relation to energy consumption, Danish CO_2 emissions are relatively large, however, the explanation being that most electricity in Denmark is derived from coal-driven power plants.

3.2.3 Energy consumption and supply in Denmark

Since 1950, the development of energy consumption in Denmark has been characterized by significant shifts and major restructuring of the supply system. The trends in total and source-apportioned energy consumption is shown in *Figure 3.2.4*, together with the trend in the gross national product (GNP).

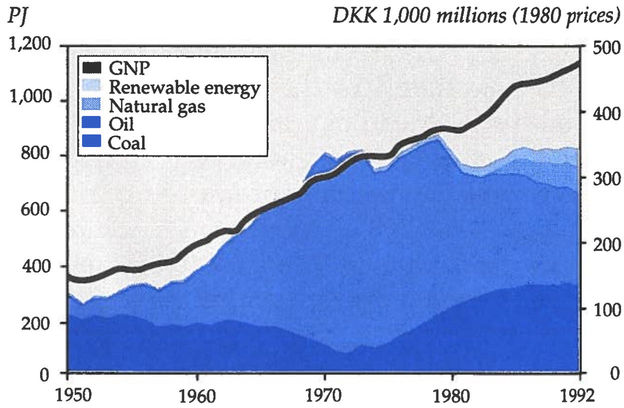


Figure 3.2.4. Trend in Denmark's gross energy consumption and gross national product (GNP) over the period 1950-92. (Source: Danish Energy Agency).

From the end of the 1950s and during the 1960s, industrial production increased significantly, and the total economy grew by around 4% per year. Energy prices were low and energy consumption grew significantly faster than the overall economy of the country. At the same time, Denmark switched over to using oil, which at the close of the 1960s comprised 90% of the country's energy consumption.

The 1970s were marked by the energy crises and by rapidly rising energy prices. Net capital outflow for imported energy increased more than fivefold in the 1970s. In general, there was a decline in energy consumption per unit produced. The period also marks a turning point in Denmark's dependence on imported oil. Oil dependence fell from over 90% in 1972 to 67% in 1980. In addition, the late 1970s and the early 1980s saw the adoption of a wide range of initiatives aimed at promoting both energy conservation and fuel source substitution, e.g. the natural gas network construction Act from 1979.

On the consumption side, the beginning of the 1980s were characterized by continued adaptation to high energy prices. Since 1986, energy consumption has largely been constant, even though there has been moderate economic growth and a significant fall in the price of imported energy. The decline in total energy intensity (total energy consumption divided by the GNP at fixed prices) which started in 1970 continued in the 1980s. By 1992, energy intensity was about 35% lower than that in 1970. An important reason for the virtually stable total energy consumption since 1986 is that the benefit of the falling price of imported energy has not been allowed to have its full impact on consumer prices, energy taxes having been raised in step with the fall in import prices. As far as concerns individual households, energy prices have therefore remained largely constant. For enterprises the situation is somewhat different as the energy taxes are refunded: their energy costs have therefore fallen.

On the supply side, the 1980s were characterized by continued conversion from oil to coal in the power plants, and an expansion of district heating and combined power production/district heating, as well as the introduction of natural gas. In 1992, natural gas covered over 10% of Denmark's total energy consumption. Consumption of renewable energy, primarily derived from waste, straw, wood and windmills, has more than doubled since 1980, and in 1992 accounted for a good 7% of Denmark's total energy consumption. Especially significant growth has occurred in the use of straw and windmills.

Production of oil and natural gas from the Danish sector of the North Sea corresponded in 1992 to 66% of Denmark's total energy consumption, while dependence on imported oil has fallen from 67% in 1980 to just 2% in 1992. Significant amounts of natural gas are exported to Sweden and Germany. Net capital outflow for energy products has thus declined from DKK 23,400 million in 1985 to DKK 3,400 million in 1992.

Household energy consumption

Households currently account for about 1/3 of Denmark's total energy consumption. Households use energy for room heating, the operation of electrical appliances (inc. lighting) and for transportation. The trend in total household energy consumption apportioned by usage is shown in *Figure 3.2.5.*

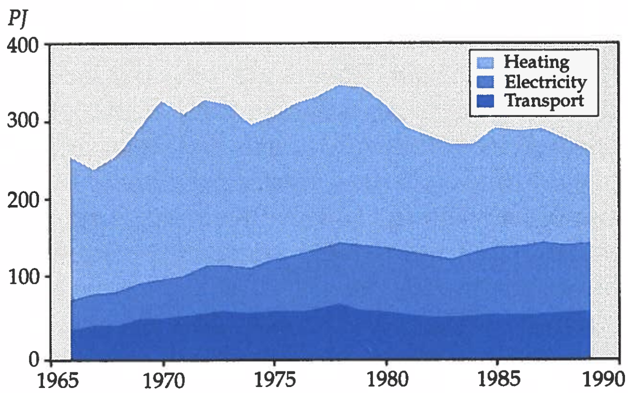


Figure 3.2.5. Trend in household energy consumption. (Source: Danmarks Statistik).

Total household energy consumption rose until the first hop in energy prices, as well as in the period between the two energy price hops. Since the second price hop, household energy consumption has tended to fall, partly because the 1986 fall in energy prices was offset by increasing energy taxes. The trend is quite different for the three uses that households make of energy.

Room heating, which accounts for the largest, but nevertheless declining, share of total household energy consumption, has varied considerably. After the first energy price hop, energy consumption for heating fell by nearly 15%, primarily due to immediate changes in behaviour, e.g. lowering room temperature and ceasing unnecessary heating. These behavioral changes were to some extent temporary, however.

The large and permanent decline in energy consumption for heating came after the second hop in energy prices, which led to significant post-construction insulation of houses, renewal of boilers and better control of energy consumption. Since 1980, energy consumption per square metre of residential area has fallen by 30%. In addition, a significant number of households have converted to district heating or natural gas.

Household electricity consumption has been characterized by significant growth in the use of various electrical appliances. Aside from reductions in connection with energy price hops, household electricity consumption has risen steadily and is currently double that of the mid-1960s. Although the immediate effect of the energy price hops on household electricity consumption was only temporary, the overall rate of increase has fallen off since 1980. New electrical appliances are typically significantly more energy-efficient than the majority of appliances currently in use, and replacement of existing appliances would therefore lead to significant saving of electrical energy. Replacement and energy savings come only gradually, however, the lifetime of electrical appliances typically being 10-15 years and the energy costs to run them usually being modest in relation to their purchase price.

Apart from in 1974 household energy consumption for transportation increased markedly each year up to 1978. The energy price hop in 1979 resulted in a shift to public transportation and a corresponding decline in household energy consumption for transportation. Since 1983, household energy consumption for transportation has risen by about 3% annually, which is about half the rate of increase prior to the energy price hops. The shift to public transportation ceased after 1983, the introduction of fuel-efficient cars is proceeding very slowly, and the number of kilometres driven is still increasing.

The trend in household energy consumption since the energy price hops has thus been characterized by declining consumption for residential heating, but continued significant increases in energy consumption for electricity and transportation.

Energy consumption in trade and industry

The various trade and industry sectors now account for approx. 2/3 of Denmark's total energy consumption; of this the primary sector accounts for 10% and industry for 40%, while the private and public service sectors account for the remaining 50%. Denmark has a very small production of energy-intensive products and, in an international context, a relatively low energy intensity. The growth in gross national product and gross energy consumption apportioned by sector is shown in *Figure 3.2.6* and that of electricity consumption in *Figure 3.2.7*. Considered as a whole, the growth in energy consumption follows the growth in production. However, energy consumption per unit produced has generally fallen since the early 1970s.

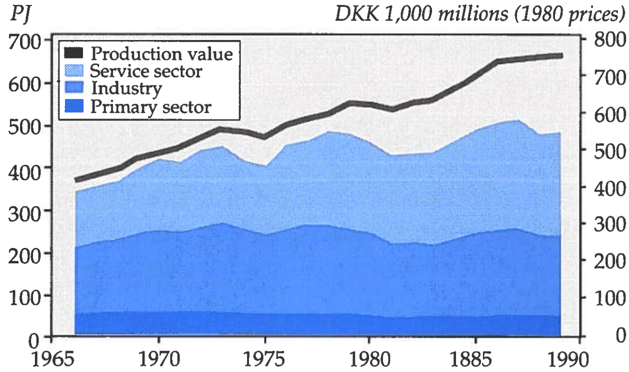


Figure 3.2.6. Trade and industry energy consumption apportioned by sector. (Source: Danmarks Statistik).

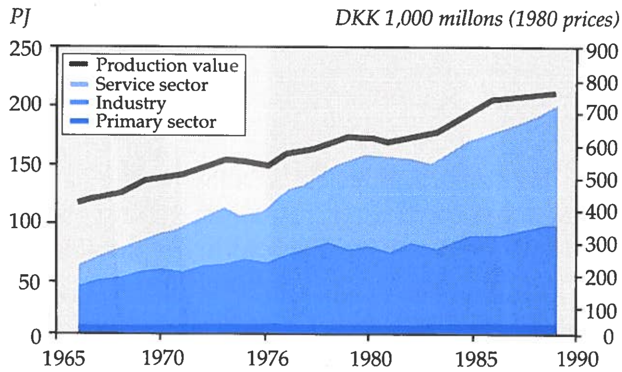


Figure 3.2.7. Trade and industry electricity consumption apportioned by sector. (Source: Danmarks Statistik).

Energy consumption per unit produced is currently 25% lower than in 1970. This decrease is partly attributable to structural shifts towards less energy-intensive branches and products, and partly to energy savings in individual production processes. Analyzing developments around the two energy price hops, it can be seen that the effect of the first and second price hops were quite different. After the first price hop, production fell, especially that of energy-intensive products, and certain energy-conserving behavioral changes took place; investment in more permanent energy savings was modest, however. The second price hop also resulted in a fall in production and a further decline in the production of energy-intensive products, but in addition led to considerable investment in energy conservation measures, and hence to a more permanent decline in the energy intensity.

While energy consumption per unit produced has been falling since 1970, electricity consumption has been increasing sharply. Trade and industry electricity consumption has more than doubled since 1970, and electricity consumption per unit produced has increased by 50%. The increase in electricity consumption in the service sector has been particularly marked.

The trend in each sector's energy and electricity intensity is shown in *Figure 3.2.8* and *Figure 3.2.9*, respectively.

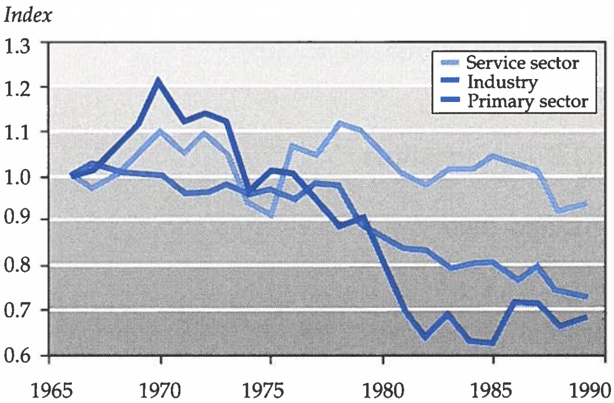


Figure 3.2.8. Trend in the energy intensity of each trade and industry sector. Index: 1966 = 1.0. (Source: Danmarks Statistik).

Primary sector comprises agriculture, horticulture and fishery. These branches have a relatively high energy intensity and this has declined by a good 40% since 1970. The savings are mainly attributable to post-construction insulation and better energy control in greenhouses and livestock housing, increased utilization by farms of their own straw for heating, and reduced tillage of the soil during the autumn.

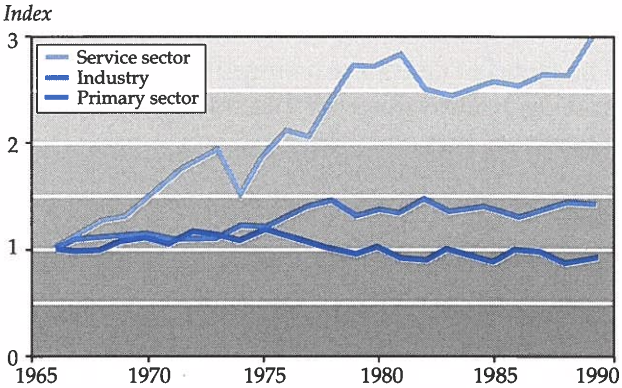


Figure 3.2.9. Trend in the electricity intensity of each trade and industry sector. Index: 1966=1.0. (Source: Danmarks Statistik)

Industry includes the building and construction industry. The energy intensity of the individual branches varies considerably, and structural shifts are therefore of significance for the overall trend in the energy intensity. Since 1970, the total energy intensity has fallen by roughly 25%, about a third of which is solely attributable to falling production among suppliers to the building industry, i.e. cement and brick works, as well as to the discontinuation of plate glass production in Denmark. In the 1980s, a number of energy-conserving investments were implemented, primarily directed towards the saving of oil. The electricity intensity has tended to increase slightly.

Service sector includes both private and public services. Energy consumption within the service sectors has increased drastically and, in contrast to the other sectors, the energy intensity has generally not declined. Some energy conserving measures have been implemented, e.g. insulation and better energy control, but these have been offset by the increased consumption of electricity for refrigeration, lighting and office-automation. The electricity intensity has roughly doubled since 1970.

3.2.4 The energy sector's environmental problems

In 1991, the energy sector emitted into the atmosphere 60,779 kilotonnes CO_2, 243,232 tonnes SO_2 and 334,094 tonnes NO_x. To this should be added 1,881 kilotonnes slag and fly ash from incinerators and power plants, as well as 93 tonnes lead from the lead-containing petrol.

The trend in energy consumption and CO_2, SO_2 and NO_x emissions by the energy sector are shown in *Figure 3.2.10*.

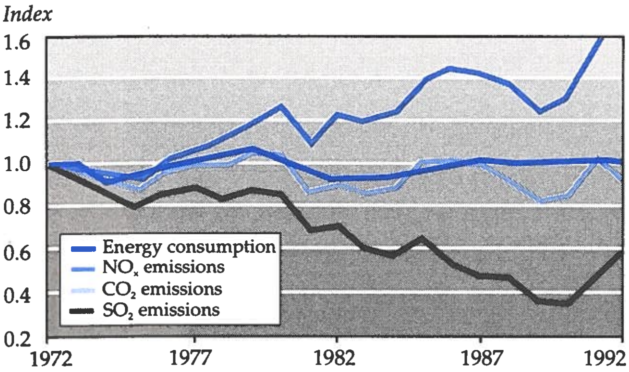


Figure 3.2.10. Trend in energy consumption and emissions in Denmark over the period 1972-92. (Source: Danish Energy Agency; Risø National Laboratory).

If correction is made for the import and export of electricity, CO_2 emissions largely follow the trend in energy consumption. The difference between the CO_2 emissions and energy consumption curves in *Figure 3.2.10* is therefore roughly equivalent to net import of electricity. In the late 1970s, Danish power plants converted from burning oil to coal, and CO_2 emissions increased slightly more than energy consumption. In the late 1980s, the introduction of natural gas and increased consumption of renewable energy had the effect that CO_2 emissions increased less than the energy consumption. The source apportionment of CO_2 emissions largely corresponds to energy consumption by the sources; however, the part accounted for by the power plants is relatively large because they mainly use coal, while that accounted for by district heating plants is relatively small because they mainly use natural gas and sustainable energy sources.

SO_2 emissions have more than halved since 1972, the decline being attributable to several factors: a considerable degree of sulphur removal from power plant flue gasses and a reduction in the legally permitted sulphur content of coal and oil, as well as the introduction of natural gas, which is largely sulphur-free. Approximately 3/4 of total sulphur emissions are derived from power plants. In relation to energy consumption, the transportation and heating sectors account for relatively little of total SO_2 emissions.

NO_x emissions have increased by a good 50% since 1972. The predominant sources of NO_x emissions are power plants and the transportation sector, each of which accounts for about 45% of total emissions. The increase in NO_x emissions is thus due to the increasing use of electricity and energy for transportation. Despite considerable NO_x removal from flue gasses, NO_x emissions from power plants have more than doubled since 1972.

In 1991, incinerators and power plants produced 592 kilotonnes slag and the power plants a further 1,289 kilotonnes fly ash. About 60% of the slag was recycled in the building and construction industry, and just under 60% of the fly ash was recycled in the cement, concrete and asphalt industries. A total of 262 kilotonnes slag and 540 kilotonnes fly ash were deposited in dumps in 1991.

The lead content of the petrol used in 1992 amounted to 960 tonnes; of this, 3/4 (720 tonnes) was emitted to the air. Since the mid-1970s, lead emissions from petrol have been reduced by a good 90%, the lead content of lead-containing petrol has been reduced by a factor of 10, and the proportion of lead-free petrol has increased to 80%.

3.2.5 Action plans

Energy 2000

Energy 2000, a Ministry of Energy action plan published in April 1990, is the government's most recent comprehensive action plan for the energy sector. The plan encompasses Denmark's total energy consumption, with the exclusion of energy used for transport. It describes a number of new initiatives aimed at fulfilling the target of a 20% reduction in CO_2 emissions by the year 2005. In relation to 1988 levels, the plan is expected to lead to an approx. 30% reduction in CO_2 emissions from energy consumption (excluding transport) by the year 2005.

The action plan also contains a baseline scenario which estimates the effects of the continuation of current trends while taking into account expected social changes and anticipated legislation (*Figures 3.2.11 and 3.2.12*).

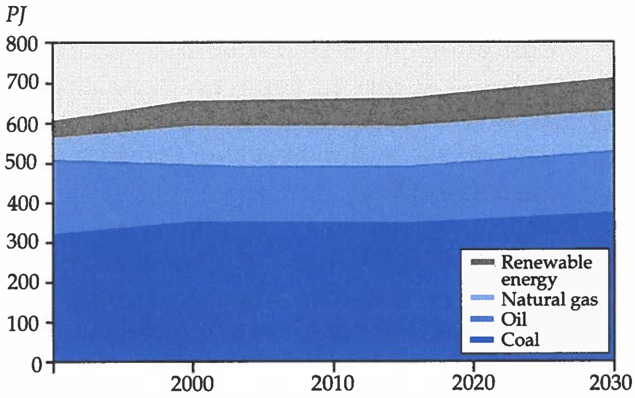


Figure 3.2.11. Projected trend in gross energy consumption to the year 2030. (Source: Ministry of Energy, 1990).

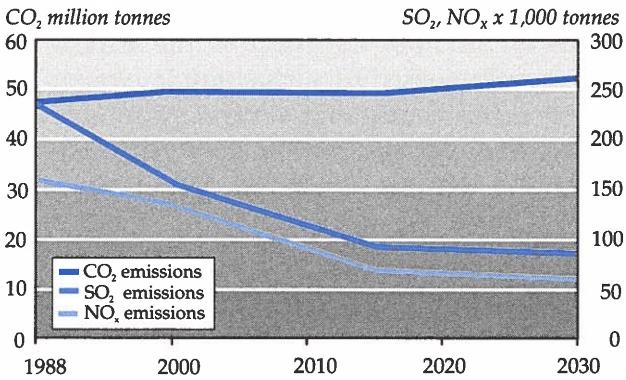


Figure 3.2.12. Projected trend in pollutant emissions to the year 2030. (Source: Ministry of Energy, 1990).

The action plan contains several initiatives relating to energy conservation and efficiency, conversion of the supply system and the use of more environmentally desirable energy sources.

In the building sector, the action plan sharpens insulation standards for new buildings and increases information and consultancy schemes for existing buildings. It is predicted that total energy consumption for room heating will be reduced by 10% in relation to the baseline scenario. As regards household electricity consumption, it is estimated that the introduction of efficiency norms for the most important household appliances in combination with labelling and information will generate a savings of 20%. Increased endeavours to save electricity in the public sector are estimated to reduce the public sector's energy consumption by 25%. In the service sector, consulting aid and the introduction of norms for and the control of larger refrigerating and freezing units will entail a 20% savings in electricity consumption.

On the supply side, expectations include further coupling to natural gas and district heating, conversion of district heating plants to decentralized combined power and district heating plants and increased use of natural gas in power plants, as well as significant expansion of windmills and consumption of biomass.

According to *Energy 2000*, CO_2 emissions from energy consumption, excluding transport, are expected to have declined by 30% by the year 2005 (in relation to 1988 levels). Taking into account transport, which is expected to increase, it is estimated that the target of a 20% reduction in CO_2 emissions resulting from energy consumption will thus be fulfilled by the year 2005. SO_2 and NO_x emissions are expected to fall by 60-70%, primarily as a result of the purification of flue gasses.

Follow-up of *Energy 2000*

Since the publication of *Energy 2000*, some of the basic economic assumptions have been revised and some of the action plan's initiatives have been implemented, while others have not. The most recent appraisal of the energy sector's evolution is published in the Danish Energy Agency's June 1993 memorandum "*Energy trends to the year 2005*". This memorandum evaluates the effect of the initiatives adopted and of some of the revised economic assumptions.

The memorandum is based on revised forecasts for fuel prices, population and building. The effect of the higher economic growth that is now expected (cf. section 3.1) is not evaluated, however. On the basis of these revised assumptions, energy consumption is expected to be generally higher than predicted in *Energy 2000.* Furthermore, fuel prices are expected to increase more slowly than predicted in *Energy 2000*, and are expected to be only partly offset by increased energy taxes. With the revised population forecast, the population in the year 2005 will be about 150,000 persons larger than predicted in *Energy 2000*. With the revised forecast for building, net growth in housing is expected to amount to only 9,000 homes per year, a level approximately half that predicted in *Energy 2000*. Higher economic growth, lower fuel prices and a larger population are factors which will increase energy consumption. The lower projected growth in housing means on one hand, less room space to heat, but on the other hand, a lower average insulation standard for housing as a whole. The net result though should be a slight reduction in energy consumption for heating purposes.

Comparison of the effects of the adopted initiatives and initiatives in the action plan reveals the need for further initiatives if the targets stipulated in *Energy 2000* are to be achieved.

In the housing sector, the current subsidy system for energy-saving home improvements is expected to generate a savings of 4 PJ by the year 2005, as compared with a savings of 14 PJ predicted in the plan. Household electricity consumption is expected to increase by 11%, whereas a decline of 16% was expected in the action plan. This difference is partly attributable to a greater number of new customers using electricity for room heating and a lower rate of conversion to other heating forms than supposed in the plan, and partly because the efficiency norms for household appliances supposed in the plan have not yet been implemented. With regard to the retail and service sectors, electricity consumption is estimated to be generally greater than in the plan. Several of the measures supposed to be implemented in the plan have not yet been implemented (e.g. more energy-efficient use of office machines, norms for refrigeration/freezing units, extended consultancy schemes, etc.). With regard to the production sector, the expected higher economic growth has not been taken into account, but the lower fuel prices and the effect of the measures recently adopted in the so-called "CO_2 package" should result in a 2% higher energy consumption in this sector. The overall evaluation is that energy consumption in the year 2005 will equal 1988 levels, whereas *Energy 2000* predicted a decline of 15% relative to 1988.

The main conclusions of the memorandum *Energy trends to the year 2005* are

- that energy consumption by the year 2005 will be significantly higher than originally projected in *Energy 2000* unless further energy-saving initiatives are implemented,

- that the fuel consumption necessary to provide for the predicted energy consumption in 2005 can be maintained at existing levels as long as there is continued expansion of decentralized and industrial combined power production/-district heating,

- that unless further energy conserving measures are implemented, a reduction in CO_2 emissions of the magnitude necessary will require significant restructuring of the energy production sector if that sector alone is to account for the reduction.

Pursuant to these conclusions, the Minister of Energy presented to parliament in November 1993 a Bill containing several proposals for following up on *Energy 2000*. The Bill is founded on an unaltered target for CO_2 emissions in the year 2005.

3.3 Transport

3.3.1 Introduction

Transport systems contribute to a broad range of environmental problems at local, regional and global levels (cf. chapter 2). Especially serious is the impact of road traffic on the local environment in urban areas. Traffic also contributes considerably to transboundary and global air pollution, and thereby to acidification, eutrophication, climatic change and substantial consumption of non-renewable resources such as oil and metals. Finally, nature and landscapes are affected by the establishment and use of transport facilities, for example by changing the ecological conditions for animal life.

Economic growth means that traffic is expected to continue to grow markedly. Comprehensive expansion and renewal of the transport systems is planned for the coming years, both in Denmark as well as in Europe as a whole. As part of this renewal, a considerable effort is being made to reduce problems such as the emission of air pollutants. These endeavours have begun to have an effect, as can be inferred from the trend in certain of the environmental problems, while the impact of others remains unchanged or is even growing. Seen as a whole, the environmental challenges in relation to transport are considerable.

This section describes some of the main trends in traffic, as well as its general environmental impact. Only total emissions and energy consumption are treated, local effects such as noise, accidents and impaired air quality in the towns being covered in section 2.3 on the urban environment. The effect of traffic on rural landscapes and ecosystems is treated in section 2.6. The focus below is on domestic traffic in Denmark, but comparisons are made to our closest neighbours.

3.3.2 Trends in traffic and transport

While the magnitude of both transport and traffic is of great environmental significance, the two phenomena express quite different factors. *Traffic*, which is measured in kilometres, has the most direct significance since there is a direct correlation between the number of kilometres travelled and, for example, the amount of pollutants emitted to the air. In contrast, total *transport* is measured in passenger-kilometres and tonne-kilometres, and reflects society's use of the transport systems to convey passengers or goods. Thus transport activity can increase without necessarily entailing more traffic and pollution, e.g. if the capacity of a given means of transport is better utilized to carry more passengers or tonnes per kilometre travelled.

Both total traffic as well as goods and passenger transport have been increasing markedly since the early 1950s. While the 1970s were partly characterized by a tendency to stagnate as a result of the oil price increases, there has been significant growth in both traffic and transport since the mid 1980s. Thus between 1980 and 1991, traffic with all (domestic) means of transport increased from approx. 30.7 to 42.8 thousand million kilometres travelled, corresponding to a growth of 40%. Road traffic, which comprises by far the majority of traffic, has grown even more, by approx. 42% (*Figure 3.3.1*).

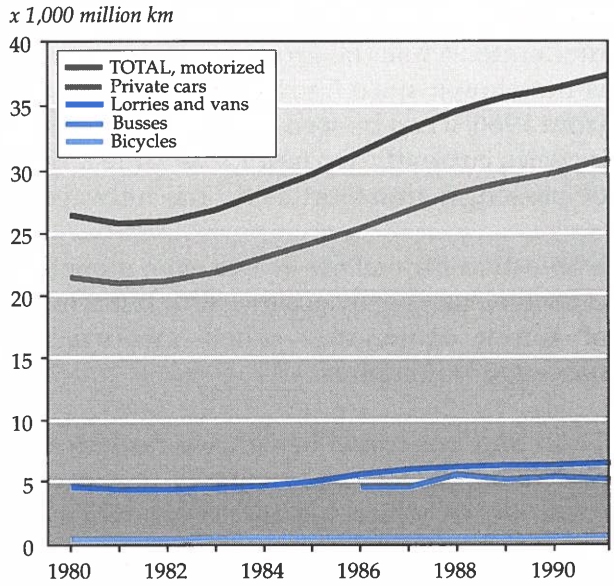


Figure 3.3.1. Growth in road traffic in Denmark over the period 1980-1991. TOTAL includes only motorized traffic as bicycle traffic has only been calculated since 1986 (Source: Road Directorate, 1992).

The reason for the growth in traffic and transport seen over the last decade is not so much that an increasing number of passengers and goods has been transported, but rather that the distance travelled during each trip has increased. In other words, trips today are longer than they were 10 years ago.

In addition, new studies also indicate that capacity utilization has been declining for both cars and lorries. Since 1981, the average number of passengers per car has declined from 1.84 to 1.68, i.e. by 9%. For lorries over 6 tonnes, average utilization rates have fallen even more, namely by 20%. From an environmental perspective, these tendencies are rather unfortunate.

Transport has evolved differently for the individual forms of transport.

Passenger transport

Growth in passenger transport over the period 1980-91 is illustrated in *Figure 3.3.2*, while apportionment of passenger transport by means of transportation is shown for 1991 in *Figure 3.3.3*.

Passenger transport is completely dominated by cars and car travel accounts for most of the increase over the last 10 years, growth in the other means of transportation having been moderate. While the growth in bicycle traffic is not shown since figures are only available from 1986, it can be seen from *Figure 3.3.3* that bicycles currently account for as large a share of passenger transport as do the railways.

Domestic air travel has grown even more than car travel, namely by approx. 30%, but remains of minor importance when measured in passenger-kilometres.

Train and bus travel has grown far less than car travel. In the case of buses it is mostly coach travel which has increased, while bus travel has only grown by approx. 10% during the last 10 years.

There could be several explanations for this trend. It has most likely played some role that public transport has become more expensive during this period, while petrol prices have become cheaper, both in direct nominal prices, as well as in relation to other consumer prices (*Figure 3.3.4*).

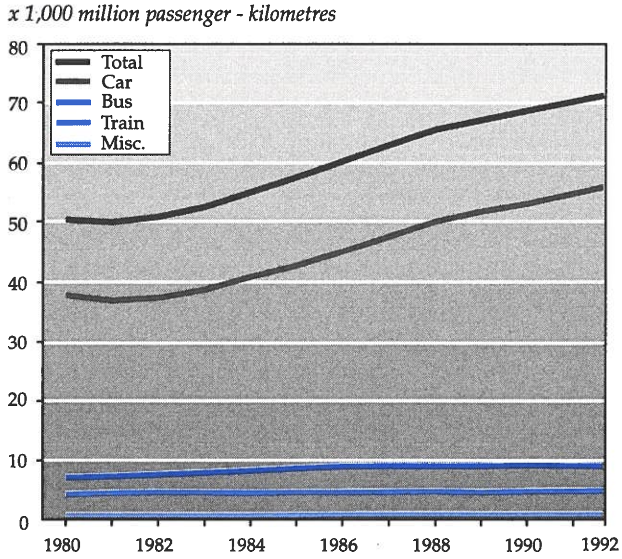


Figure 3.3.2. Growth in domestic passenger transport over the period 1980-1991. Passenger-kilometres shown both as total and apportioned by car, bus, train and misc. (air + ferry, excl. bicycles). (Source: Ministry of Transport, 1993)

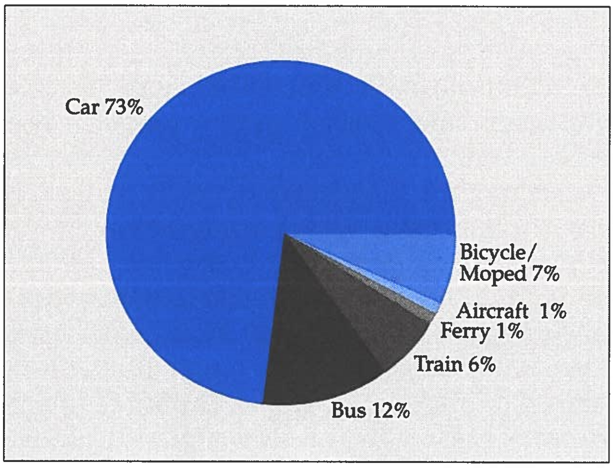


Figure 3.3.3. Apportionment of passenger transport in 1991 (Source: Road Directorate, 1992)

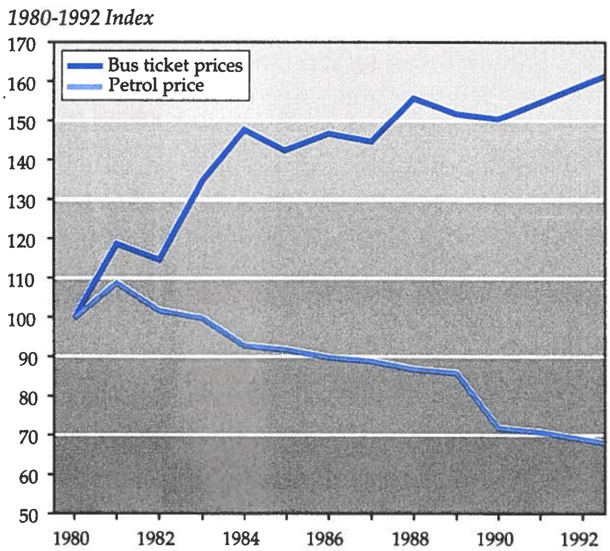


Figure 3.3.4. Trend in bus ticket and petrol prices relative to the general trend in consumer prices since 1980 (Source: Ministry of Transport, 1993).

Relative to the general trend in consumer prices since 1980, the current price of petrol has become approx. 30% lower than the average increase, whereas the price of bus tickets has become approx. 60% higher than the average increase.

Improvements in the service offered by public transport have been insufficient to offset this adverse trend in prices.

Goods transport

As regards goods transport, growth during the 1980s was mainly in road haulage by lorry, namely by approx. 22%, while the volume of both rail and ship transport has not changed much since 1980. Sea freight experienced a considerable decline in 1984, when much of the Danish North Sea oil began to be led ashore by pipeline.

Road haulage has thus grown from approx. 70% to approx. 80% (*Fig. 3.3.5*) of the total national goods transport (excluding transport by pipeline). Denmark's dependence on road haulage is average for the EU countries, while it is higher than non-EU neighbours such as Norway, Sweden and Finland. At the same time, there is a trend towards use of heavier vehicles, dual articulated lorries now accounting for about 70% of road haulage. Growth in road haulage has stagnated in recent years, however, and no growth has occurred since 1989, this being attributable to the economic recession.

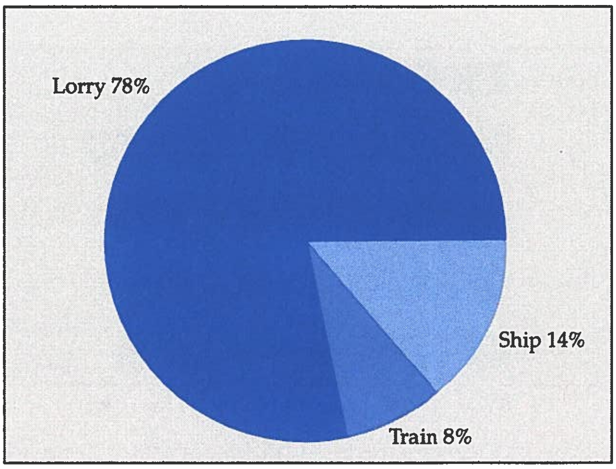


Figure 3.3.5. Apportionment of goods transport in 1991. (Source: Road Directorate, 1992).

3.3.3 The Danish car fleet

After several decades of growth, the Danish passenger car fleet appears to have stagnated at around 1.6 million cars (*Figure 3.3.6*). The trend showed a minor dip at the start of the 1980s, followed by a few years with record high car purchases such that the present level was reached by the end of the decade, approx. 15% over that in 1980. This tendency only partly coincides with the trend in road traffic. As previously shown, car travel has continued to grow into the 1990s, even though new car purchases have stagnated. Presumably, this is attributable to economic factors. While the price of petrol has in real terms fallen since the start of the 1980s, the same is not true for the purchase price of a new car. Moreover, car sales are very sensitive to variations in income.

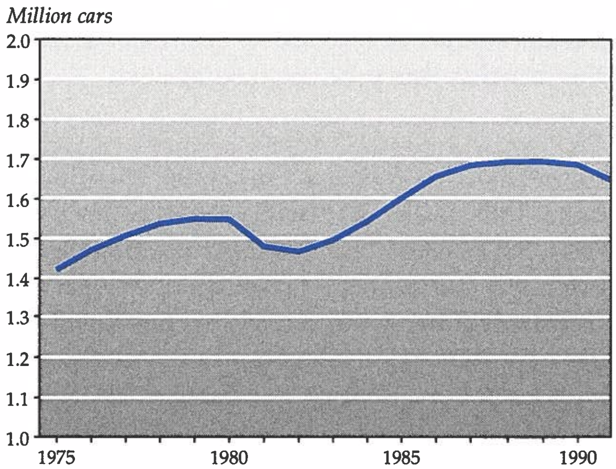


Figure 3.3.6. Trend in the Danish private car fleet from 1975-1991. Includes delivery vans under 2 tonnes, taxis, etc. (Source: Road Directorate, 1992).

At present, new car purchases are just about offset by the scrapping of older vehicles. Meanwhile, the Danish car fleet is getting older, about 34% of the cars currently being over 10 years old, versus only 26% in 1985. Extrapolation from the current level of new car purchases would seem to indicate that the size of the fleet will decrease in the future. However, current economic forecasts do not foresee such a decline. On the contrary, current economic projections envision a significant increase in the car purchases and the use of transport services. In the economic forecast on which the government's 1990 Action Plan on Transport was based, it was predicted that the Danish car fleet will grow to approx. 2.5 million vehicles by the year 2010. This implies a yearly growth of approx. 40,000 vehicles, corresponding to the growth which occurred in the mid-1980s. Whether growth in the car fleet will reach that level again is the subject of some debate.

The number of light delivery vans (under 2 tonnes) has fallen during the last 10 years, but this is more than offset by the increase in the number of larger delivery vans. The structure of Danish vehicle taxation has been a contributing factor here, in that larger delivery vans have become relatively cheaper during this period. That has now changed with the tax reform enacted in 1993.

The total number of delivery vans and lorries over 2 tonnes has grown by approx. 50% between 1980 and 1991 (*Figure 3.3.7*), most of which was accounted for by mid-sized delivery vans (2-3 tonnes) and very large lorries. The trend in sales corresponds approximately to the trend in lorry traffic (see above).

The environmental effects of these trends in the private car fleet are two-sided. On the one hand, stagnation and decline in size of the car fleet will limit the overall environmental impact resulting from the production, use and disposal of cars. On the other hand, slower replacement of the fleet could affect the rate at which new cars with catalytic converters replace older vehicles lacking such equipment. This has significance for carbon monoxide (CO), hydrocarbon (HC) and nitrogen oxide (NO_x) emissions.

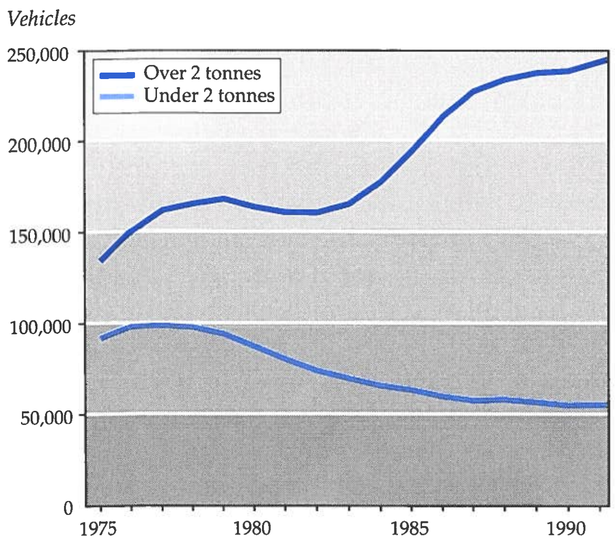


Figure 3.3.7. Trend in the number of delivery vans and lorries in Denmark over the period 1975-91. (Source: Road Directorate, 1992).

A new method for measuring emissions from cars based on infrared remote sensing (termed FEAT) is currently being evaluated by the National Environmental Research Institute. The principle findings of the initial studies employing this method are that a relatively small portion of the national car fleet is responsible for a large part of the emissions. Hence, the cleanest 60% of the cars account for less than 10% of total carbon monoxide emissions, while total emissions from the most polluting 10% of the fleet are of the same magnitude as total emissions from the cleanest 50%. The investigation also showed that the percentage of cars considered "completely clean" (<1% CO emission) is considerably less in Denmark (57%) than in Sweden (80%).

The size of the Danish car fleet reflects the generally high standard of living characteristic of the northwest European countries. By global standards, car density in Denmark is high, but compared to several neighbouring countries, it is relatively low. This is due to factors such as the relatively high population density, good public transport systems, significant use of bicycles and a vehicle purchase tax policy that indirectly discourages car purchase.

These differences in relation to neighbouring countries mainly affect the number of private cars, the number of delivery vans and lorries being roughly equivalent to the level in these countries. The number of private cars per 1,000 inhabitants in Denmark and four neighbouring countries in 1990 is illustrated in *Figure 3.3.8*.

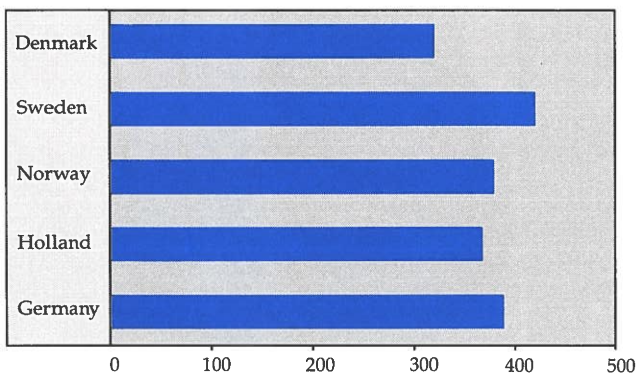


Figure 3.3.8. Private cars per 1,000 inhabitants in Denmark and 4 neighbouring countries (Figures for Sweden are from 1989; Germany after reunification). (Source: Road Directorate, 1992).

3.3.4 The road net

Denmark's road net comprises a total of 71,000 km of roads, of which 650 km are motorways. The Danish road network is of high international standard, and compared to many other countries the Danish motorway net is well developed. Expressed per inhabitant, the motorway net is of the same length as in Sweden, and a little less than in Germany and Holland. Expressed per car, however, the Danish motorway net is longer than that of Sweden and Germany, but less than that of Holland.

According to existing plans, Denmark's motorway net is to be expanded by approx. 50% by the year 2000. This includes several stretches of motorway in Jutland.

3.3.5 Trips and journeys

Daily travel is becoming increasingly longer, daily travel by adult Danes now averaging about 32.5 km per day. Studies of travel patterns indicate that daily travel has increased by about 10% since 1981.

The extent to which each individual travels depends on factors such as income, employment, gender, place of residence and whether or not the household owns a car. *Figure 3.3.9* compares daily transport in 1981 and 1992/93 for households with disparate access to a car.

It can be seen that total consumption of transport by persons in households with cars at their disposal exceeds that of persons in households without cars at their disposal by approx. 13 km, or 65%. Transport increases to approx. 47 km per day if the household has two or more cars at its disposal, consumption in this case being more than double that of persons in families without cars.

Families with large transport needs and an adequate economy will typically purchase one or more cars. However, the fact of owning a car can lead to increased transport consumption because it places within easy reach of the family a greater variety of possibilities for employment, consumption and recreation. Persons without a car at their disposal consume approximately double the amount of public transport as car owners, and they also cycle at least twice as much.

There is no doubt that time spent on daily travel to and from work is considered a burden by many people. The amount of time actually spent on transport is a much discussed issue, however. Some studies assert that significantly more time is presently spent on transport than just 10 years ago, especially by women. Other investigations indicate that time spent on this purpose is rather constant over the years. According to these studies, adult Danes spend about one hour per day travelling.

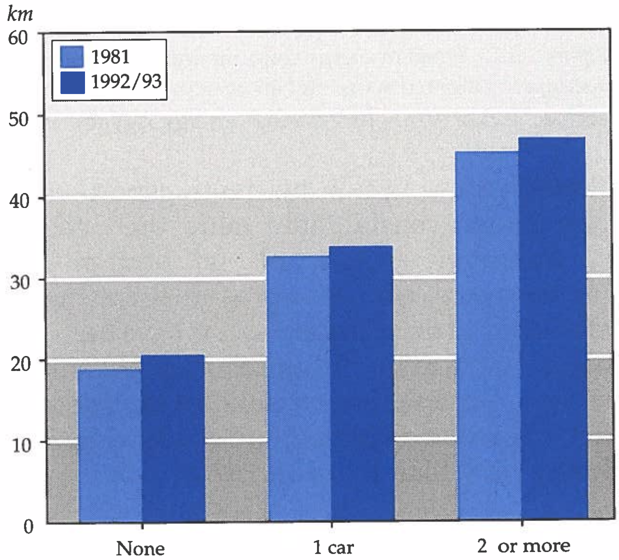


Figure 3.3.9. Daily transport in 1981 and 1992/93 (preliminary figures) for households with disparate access to a car. (Source: National Environmental Research Institute, 1994).

3.3.6 Energy consumption by the transport sector

Domestic transport accounted for around 20% of total energy consumption in 1992. This figure also includes some energy consumed by transit traffic, where fuel has been taken on in Denmark. If international traffic is also included, i.e. energy consumption for aircraft and ships engaged in non-domestic transport, total consumption by the transport sector climbs to around 27%.

The trend in energy consumption by the transport sector is shown in *Figure 3.3.10*. As can be seen, consumption has been increasing markedly since the beginning of the 1980s, consumption in 1992 being more than 25% higher than in 1981.

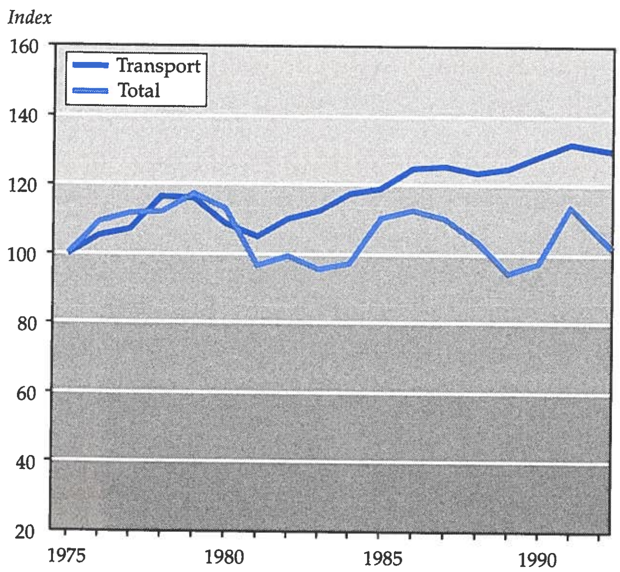


Figure 3.3.10. Trend in energy consumption by the transport sector as compared with total energy consumption by all sectors. Index 1975 = 100. (Source: Energy Agency, 1993).

Energy consumption by the transport sector has grown considerably more than energy consumption as a whole (cf. section 3.2). Furthermore, endeavours to increase energy efficiency in the transport sector have been less extensive than in the household and industry sectors. Nevertheless, consumption per passenger-kilometre or tonne-kilometre is somewhat lower now than it was in 1980.

It should be noted that the uncertainty to which the calculations of energy consumption by the transport sector are subject can lead to overestimation of consumption. However, this can hardly have any effect on the long-term trend.

Road traffic accounts for the greatest share of energy consumption by the transport sector, around 90%. This is proportionately greater than warranted by road traffic's share of both total traffic and of total transport, thus indicating that road transport is generally somewhat less energy efficient than average.

As mentioned, traffic accounts for an increasing share of total energy consumption, especially of oil consumption, on which traffic is nearly 100% dependent. Transport's dependence on oil enhances the environmental risks linked to the international distribution of oil products. Although most noticeable in connection with the large oil tanker accidents that periodically lead to large amounts of oil being spilt into marine waters, oil pollution of the seas is in fact more the result of the routine loss of oil by shipping than of actual accidents.

3.3.7 Air pollution by the transport sector

The transport sector mainly contributes to carbon monoxide (CO), hydrocarbon compounds (HC), nitrogen oxides (NO_x) and particulate emissions. These substances are all hazardous to human health, while NO_x and HC also contribute to regional air pollution problems. The contribution made by the transport sector to the emission of sulphur dioxide (SO_2), which also has a regional impact on the environment, is small, however. In addition to the above, the transport sector accounts for a large part of CO_2 emissions (see section 3.2).

The transport sector thus accounts for around 43% of NO_x emissions and 20% of CO_2 emissions, the latter being roughly equal to transport's share of total energy consumption. Oil and petrol generate a little less CO_2 per energy unit than does the coal used in power plants, however. The transport sector's share of energy consumption and pollutant emissions in 1991/92 is shown in *Figure 3.3.11*. The trend in NO_x and SO_2 emission is shown in *Figure 3.3.12*, and that of CO_2 in *Figure 3.3.13*.

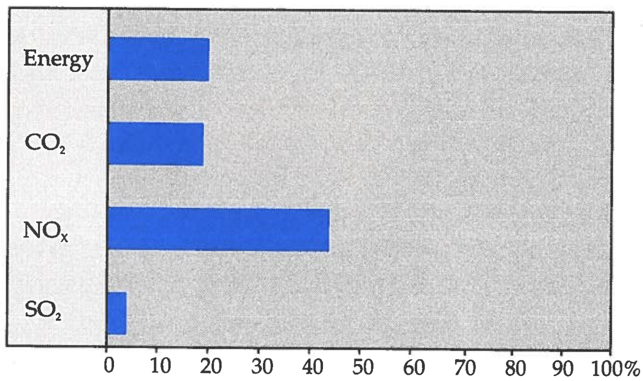


Figure 3.3.11. The transport sector's share of energy consumption and pollutant emissions in 1991/92. (Source: Risø National Laboratory).

Emissions of CO_2 and NO_x have been increasing since 1975, while those of SO_2 have concomitantly decreased slightly. However, as mentioned above, the latter is of less significance in the present context.

The size and composition of emissions is closely connected to the amount and quality of the fuel consumed. Equally important is the technological state of the means of transportation used, including engine energy efficiency and pollution-limiting equipment. Finally, of course, the trend in total emissions also depends on the extent of traffic growth.

The environmental effects of most emissions depend on where emission occurs and how they spread. A considerable part of emissions from cars and buses occur in dense urban areas where the health effects of pollution are greatest. Of the emissions associated with rail traffic, approx. 30% occur through power plant smokestacks. Emissions associated with ship and air traffic mainly take place in less vulnerable environments; in the latter case, however, some emissions occur at high altitudes, where several of the substances can have significantly greater climatic effects than emissions occurring at ground level. In the case of CO_2, in contrast, it is of no relevance where emission takes place.

Road traffic, i.e. cars, lorries, vans, buses and motorcycles, accounts for by far the greatest part of total air pollutant emissions by the transport sector (*Figure 3.3.14 and 3.3.15*), although the magnitude of road traffic's share varies depending on the substances. Thus, for example, SO_2 emissions are more closely linked to ship traffic.

In recent years, increasingly sharper vehicle emission standards have been implemented for cars and lorries. New cars must today meet emission standards for NO_x, HC and CO that necessitate catalytic converters. In addition, new diesel-driven cars must comply with particulate emission standards.

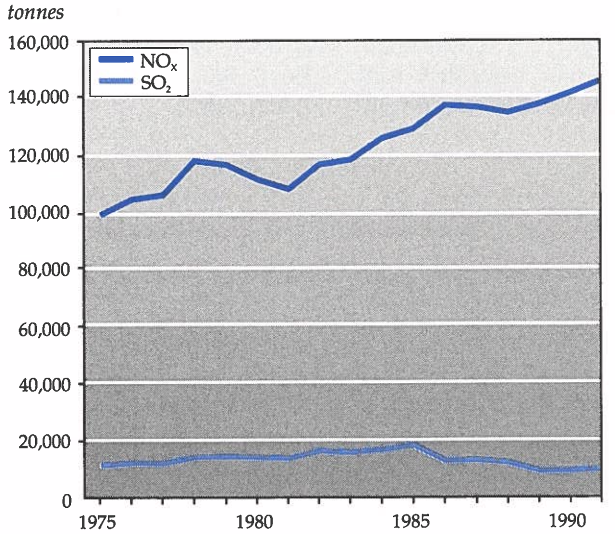


Figure 3.3.12. Trend in NO_x and SO_2 emissions by domestic transport over the period 1975-1991. (Source: Risø National Laboratory).

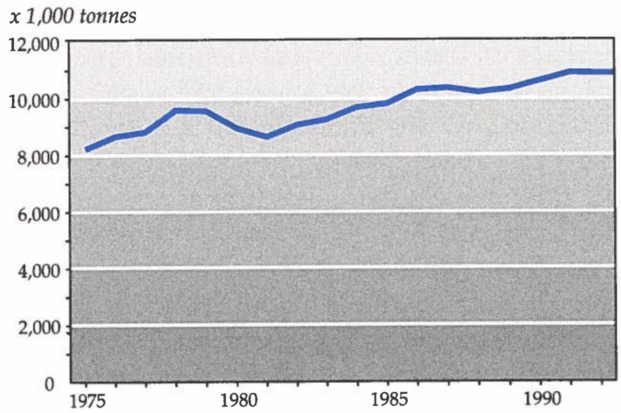


Figure 3.3.13. Trend in CO_2 emissions by domestic transport over the period 1975-1992. (Source: Risø National Laboratory)

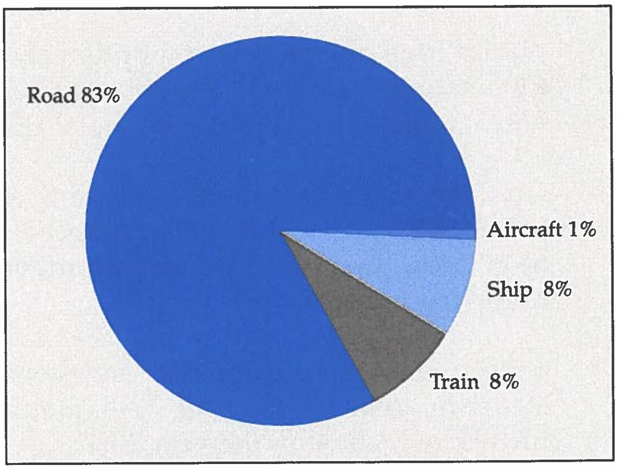


Figure 3.3.14. Apportionment of total NO_x emissions from domestic transport in 1988. (Source: Ministry of Transport, 1990)

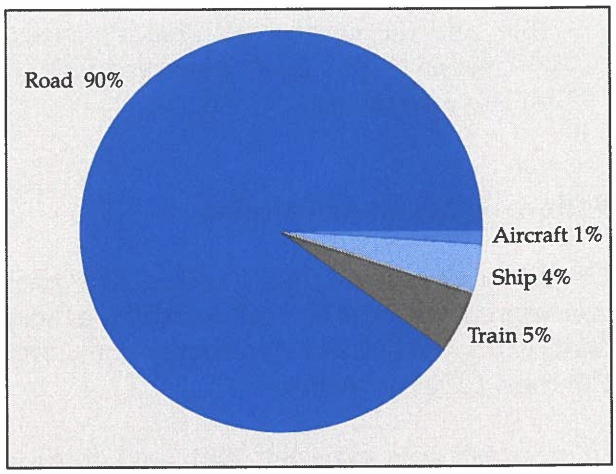


Figure 3.3.15. Apportionment of total CO_2 emissions from domestic transport in 1988. (Source: Ministry of Transport, 1990).

3.3.8 Action plans and policies

The Action Plan on Transport

In recent years there has been an increasing recognition of the unacceptable environmental impact of traffic. This has resulted in action plans for "sustainable transport" being formulated at both the national and EU level.

In 1990, the Danish government put forward the Transport Action Plan for Environment and Development (Ministry of Transport, 1990). The action plan evaluates a number of traffic-related environmental problems - global, as well as regional and local - and stipulates targets for reducing the environmental impact of the transport sector.

The targets stipulated relate to 1988 levels and are as follows:

- stabilization of energy consumption and CO_2 emissions by the year 2005, together with a reduction of 25% by the year 2030.

- a reduction of NO_x and HC emissions of at least 40% by the year 2000, a reduction of 60% by the year 2010, and a further reduction by 2030.

- a 50% reduction in particulate emissions in urban areas by the year 2010, and a further reduction by the year 2030.

- a reduction in the number of houses exposed to noise. The number of houses exposed to noise levels exceeding 55 dB(A) is to be reduced as much as possible, and the number of houses exposed to over 65 dB(A) must not exceed 100,000 in the year 2010.

Follow-up on the action plan

Of the above-mentioned targets, the ones considered the most difficult to fulfil are those concerning the reduction in energy consumption and CO_2 emissions.

In contrast, it is expected that road traffic's total emission of the so-called regulated pollutants (NO_x, HC, CO and particulates) will decrease significantly in the coming years as a result of stricter vehicle emission standards. Stricter emission standards for private cars are expected to come into force in the EU in 1997 and 2000. From 1994, new vans, lorries and buses have to comply with considerably stricter standards than previously. These emission standards will be tightened even further in the future.

The Danish Environmental Protection Agency has calculated expected road traffic emissions of regulated pollutants during the period 1980-2010. The calculations were based on the Road Directorate's most recent prediction for traffic growth between 1990-2010, while also taking into account the effect of stricter emission standards, both those already introduced and those expected to be introduced in 1997 and 2000. The results of these calculations are depicted in *Figure 3.3.16*.

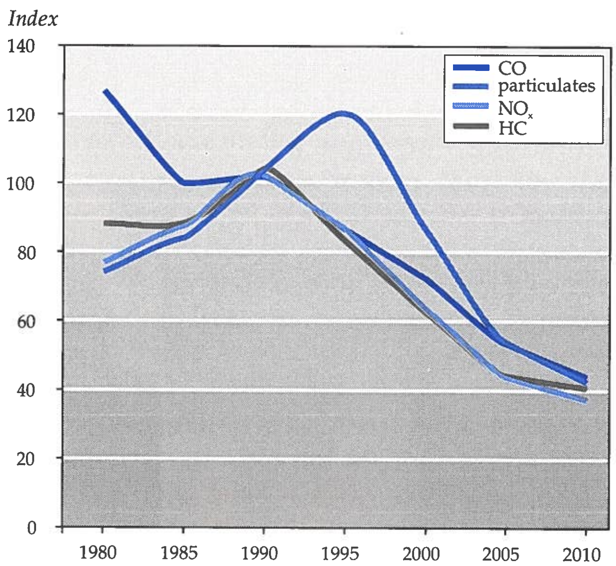


Figure 3.3.16. Calculated road traffic emissions over the period 1980-2010. Index 1988 = 100. (Source: Danish Environmental Protection Agency, 1993).

As compared with 1988 baseline levels, the calculations indicate that all vehicular emissions will have been reduced by around 60% by the year 2010.

Carbon monoxide pollution has already been on the decline for several years, partly due to advances in automotive technology. Particulate emissions lags behind the other substances since it is mainly diesel vehicles which emit particulates, and particulate emission standards were introduced later than standards for the other regulated pollutants.

The Danish Environmental Protection Agency has not made forecasts of road traffic CO_2 emissions since there are presently no emission standards for CO_2. For precisely the same reason, it must be expected that unless measures are implemented, CO_2 emissions will grow in step with the increase in energy consumption.

As part of their work with action plans, the Ministry of Transport makes projections of total transport and traffic energy consumption and air pollution for the year 2010.

The projections are based on assumptions as to expected economic growth, estimates of the growth in traffic conditions, and assumptions of energy input to and emissions from the various means of transportation. The assumptions by and large correspond to those used above for calculating vehicle emissions. The most recent forecasts are based on an expected annual growth in the gross national product of 2.25% and a growth in the gross domestic product at factor cost (plus imports) of 2.75%. The trend in these two rates is considered to determine growth in demand for passenger and goods transport services, respectively. An estimate is then made of how the increased demand will apportion among the various means of transportation (vehicle, train, ship, etc.) and what the capacity utilization will be for each means of transportation.

The prediction for traffic development thereby obtained shows that passenger traffic will increase by approx. 40% and goods traffic by approx. 60% by the year 2010.

Finally, estimates have been made of future trends in the use of different fuels and the specific energy consumption and pollutant emission per kilometre for each means of transportation. Here it is assumed that the various means of transportation will be around 10-15% more energy-efficient in the year 2010, and that the stricter pollutant emission standards for the various means of transportation will gradually have their effect. Not included here, however, are those emission standards that are planned to be introduced from the year 2000.

The Ministry of Transport's resulting forecast for air pollutant emissions is shown in *Figure 3.3.17*. According to the calculations, there will be a significant reduction in emissions of all the substances studied except CO_2; the latter is expected to increase by about 16% unless measures are implemented to hinder this. The calculations thus show that CO_2 emissions will henceforth be among the most critical air pollution problems in the transport sector.

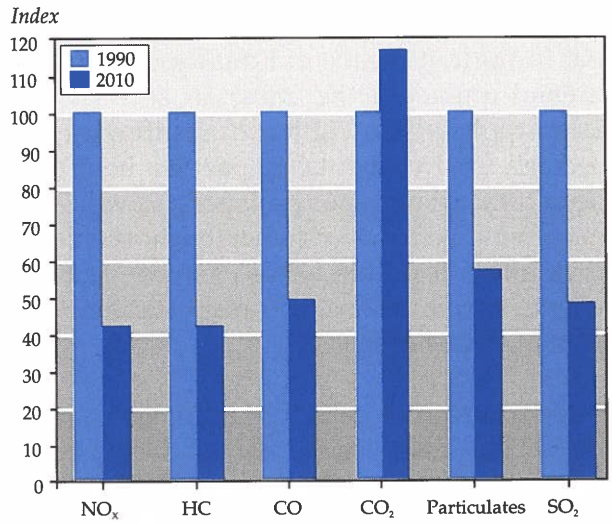


Figure 3.3.17. Total emissions from domestic transport in 1990 and in 2010 (assuming adopted vehicle emission standards). (Index 1990 = 100). (Source: Ministry of Transport)

The reduction of the other substances will be of the order of magnitude of 50-60%, though only approx. 40% for particulate emissions. These reductions are attributable to technological improvements and political measures that have already been adopted (see above).

As mentioned, the calculations are based on the assumption that technological development will *per se* mean that the various means of transportation will be more energy-efficient by the year 2010. The question is, though, whether this result can be achieved without the implementation of relevant counter initiatives. If the assumption does not hold, it could mean an even greater increase in CO_2 emissions.

International air and ship traffic are not included in the calculations, even though they account for considerable energy consumption and pollutant emissions. Furthermore, and especially in the case of ship traffic, it can be difficult to implement internationally mandatory measures to reduce emissions that are just as effective as those for road traffic.

The Danish government has just put forward a proposal for future traffic policy up to the year 2005. The proposal contains an investment plan up to the year 2005, encompassing construction activity and investments to support a "sustainable" traffic policy. The report includes a status report on the Transport Action Plan from 1990, as well as a possible strategy for fulfilling the targets concerning energy and the environment.

An important means of limiting the environmental impact of the transport sector is taxation policy. The latter can influence the sector's environmental impact by helping to limit total demand for transport, as well as by modifying demand such that the most environmentally desirable choices are selected, whether it be means of transportation, types of fuel, types of car, etc.

Road transport is subjected to several types of taxes. The most important of these are the registration tax (effectively a purchase tax of 105-180% that renders new car prices in Denmark among the highest in Europe), annual tax (based on vehicle weight), and fuel tax. The taxation pressure on the transport sector already has a limiting effect on transport-related environmental problems. Most important in this connection is the registration tax, which by drastically raising new car prices means that Denmark has a lower car density per inhabitant than most other western European countries. In addition, a tax differential between leaded and unleaded petrol in favour of the latter has helped unleaded petrol (with its lower retail price) to take over most of the market in just a few years.

In connection with the newly implemented major tax reform, the decision was made that petrol taxes should gradually increase up to 1998 by DKK 0.47 per litre (and in the case of a corresponding German petrol tax increase, by an additional DKK 0.46). In relation to current petrol prices, this will mean an increase of 8% (or 16%). In connection with the adoption of the tax reform, the environmental consequences of the fuel tax increases were evaluated. Although subject to some uncertainty, it is estimated that petrol consumption will fall by approx. 4% over a five-year period. However, as the tax reform is expected to stimulate the Danish economy, this could in turn lead to increased petrol consumption. The tax reform is therefore not expected to result in any significant net change in petrol consumption.

3.4 Rural production - agriculture and forestry

3.4.1 Introduction

Rural production encompasses exploitation of the land for the production of crops and animal products (agriculture and market gardening), as well as the production of trees and wood products (forestry).

The agriculture and forestry sector plays a central role for the development of Denmark's nature and environment. The Danish landscape reflects the exploitation of the soil for production, and in contrast to our Nordic neighbours, for example, one finds very little wilderness in Denmark. In other words, many of Denmark's valuable natural environments are the result of an interplay between nature and man, and their fate is therefore also dependent on human administration of them. Farming currently exploits approx. 65% of the country, while forest holdings cover 12% of the country. The agriculture and forestry sectors thus manage a total of 77% of the Danish land mass. Apart from having considerable impact on the landscape and arable land habitats and ecosystems, agriculture in particular affects the surrounding ecosystems through the loss of nutrients and chemical substances to the surroundings, and is therefore mainly responsible for a number of the important national environmental problems described in preceding sections: eutrophication of surface water, contamination of groundwater resources and loss of biodiversity. However, the forests simultaneously have a positive impact on the environment by binding CO_2, protecting the quality of groundwater resources and providing shade. In addition the forests accommodate a significant part of the Danish flora and fauna, and the presence of forests therefore helps to ensure biological diversity (cf. section 2.7).

History provides numerous examples of localities in which agriculture has had fatal consequences for the local or regional nature. The current situation, however, is characterized by an ecological imbalance at the *national level* in the relationship between agriculture and the surrounding environment, this trend being attributable to considerable widespread intensification and industrialization of foodstuff production.

Agricultural production and foodstuff processing have previously been the heart of Denmark's economic development, and as a consequence have been the subject of considerable political attention. However, growth of the agricultural industry depends not only on national policy, but to an increasing extent on growth in international trade in agricultural products, as well as on the terms for that growth. With Denmark's entry into the EU in 1972, common market agricultural policy became a decisive factor in the growth of the agricultural industry. Pursuit of the original goal of common market agricultural policy - self-sufficiency of the EU with respect to the most important foodstuffs - encouraged substantial growth in production. However, with the latest reform of EU agricultural policy, the so-called MacSharry reform, the stage is set for a change in policy whereby the emphasis on production is curtailed and attempts are made to integrate environmental considerations into agricultural policy. The fate of european common agricultural policy could have a decisive influence on structural development in the agricultural sector and on the environmental impact of agriculture.

Growth in agricultural and forestal production and production structure is reviewed below, together with the economic importance of these industries and the positive and negative effects that they have on the environment and nature. In addition, the most important political measures aimed at or of consequence to the environment that have been imposed upon the industries are summarized, and the likely effects of the measures are predicted.

3.4.2 Production structure

The trend in the structure of agricultural production over the last 20 years is illustrated below with the help of a number of indicators: the trend in farm size, both absolute (*Figure 3.4.1*) and relative (*Figure 3.4.2*), the degree of specialization (*Figure 3.4.3*), growth in animal and plant production (*Figure 3.4.4*), the trend

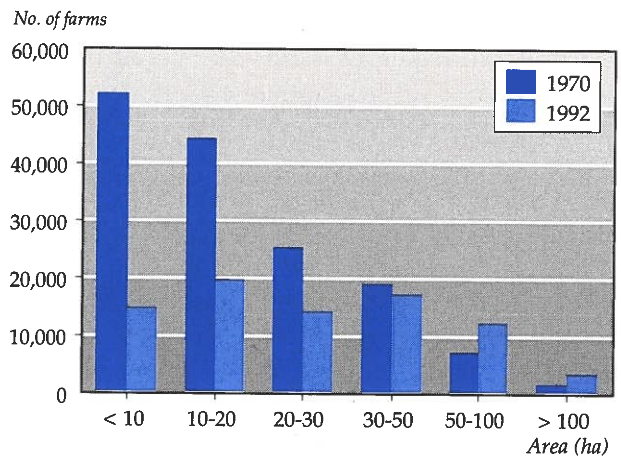


Figure 3.4.1. Trend in farm size over the period 1970-92. (Source: Danmarks Statistik, a).

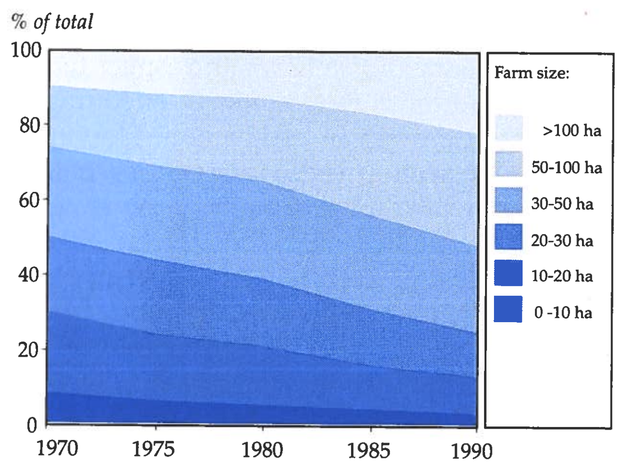


Figure 3.4.2. Trend in the percentage of total agricultural land accounted for by different sizes of farm over the period 1970-92. (Source: Danmarks Statistik, a).

in total livestock number (Figure 3.4.5) and the trend in crop acreage (Figure 3.4.6).

As is apparent from *Figure 3.4.1*, the total number of farms has fallen considerably since 1970, and there has been a shift in the relative size of the farms to larger units.

From *Figure 3.4.2*, which shows the trend in the percentage of total agricultural land accounted for by different sizes of farm, it can be seen that the tendency for agricultural land to be concentrated in large farms is continuing.

In parallel with this trend the farms are becoming more and more specialized, as is apparent from *Figure 3.4.3*, which shows the relative number of farms engaged in four categories of farming in 1968 and 1991: cattle farming, pig farming, mixed livestock farming and plant cultivation. It is primarily the production of plant products that has increased over the last 20 years, although pig production has started to accelerate in recent years (*Figure 3.4.4*). While the total number of cattle has fallen from 3.1 million head in 1950 to 2.2 million head in 1992, the number of pigs has increased from 3.2 million in 1950 to 10.5 million in 1992 (*Figure 3.4.5*). The increase in the number of pigs has led to an increase in the total amount of animal manure produced.

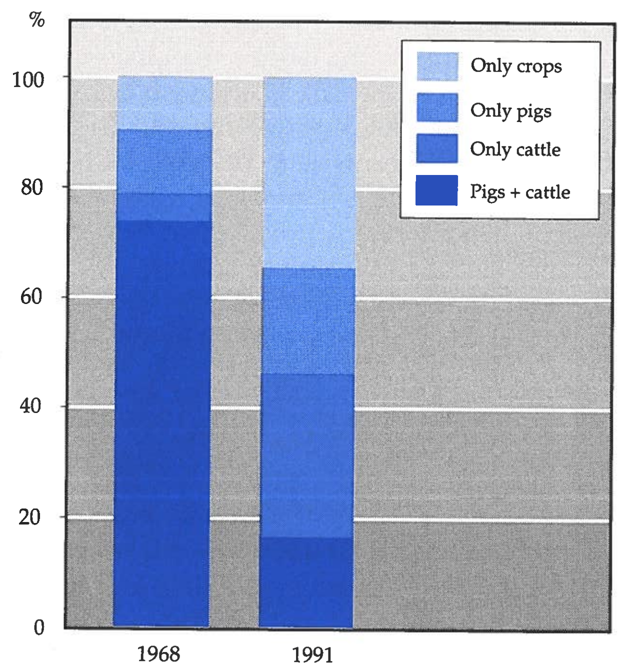


Figure 3.4.3. Degree of specialization in Danish agriculture in 1968 and 1991. (Source: Danmarks Statistik, a).

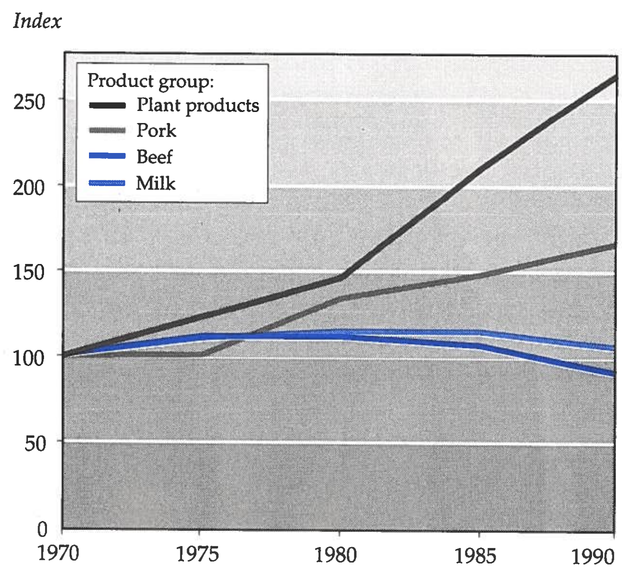


Figure 3.4.4. Growth in the production of selected agricultural products during the period 1970-90 indexed to unit production. (Source: Danmarks Statistik, a).

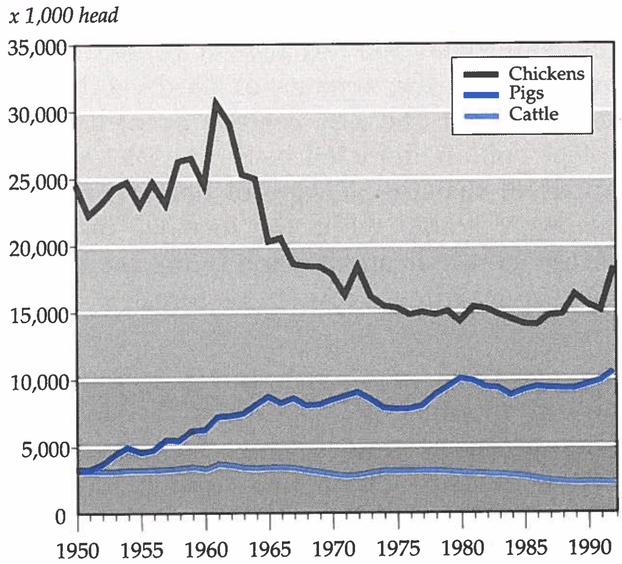


Figure 3.4.5. Trend in the total number of livestock in Denmark during the period 1950-92. (Source: Danmarks Statistik, a).

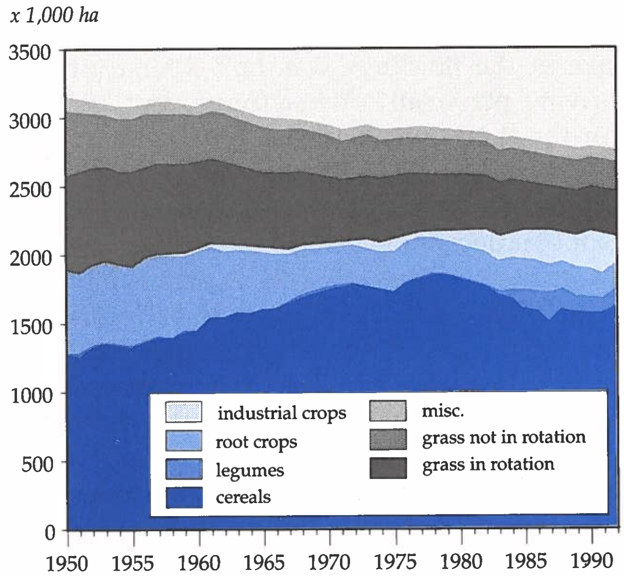


Figure 3.4.6. Trend in crop acreage during the period 1950-92. (Source: Danmarks Statistik, a).

As is apparent from the trend in crop acreage (*Figure 3.4.6*), the total amount of cultivated land fell by 12% (almost 400,000 ha) between 1950 and 1992. In addition there has been a shift in relative amount of land sown with different crops, the acreage of cereals having for example increased by 335,000 ha during the period. The increase is attributable to an increase in the acreage of spring-sown cereals at the start of the period. The total acreage of cereals was greatest at the end of the 1970s, and there has been a shift from spring-sown cereals to winter-sown cereals at the close of the period. The acreage of root crops and grass declined considerably during the period.

The decline in the acreage of these crops, which primarily serve as rough fodder, has been greatest on the island part of Denmark, where the decline in the cattle herds has been very pronounced.

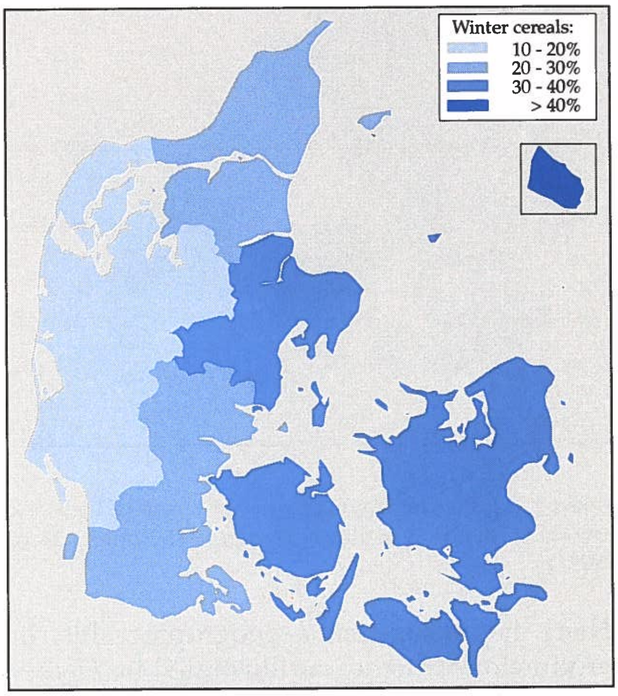


Figure 3.4.7. Acreage of winter-sown cereals expressed as a percentage of the total area of cultivated land in 1991. (Source: Skop, 1993a).

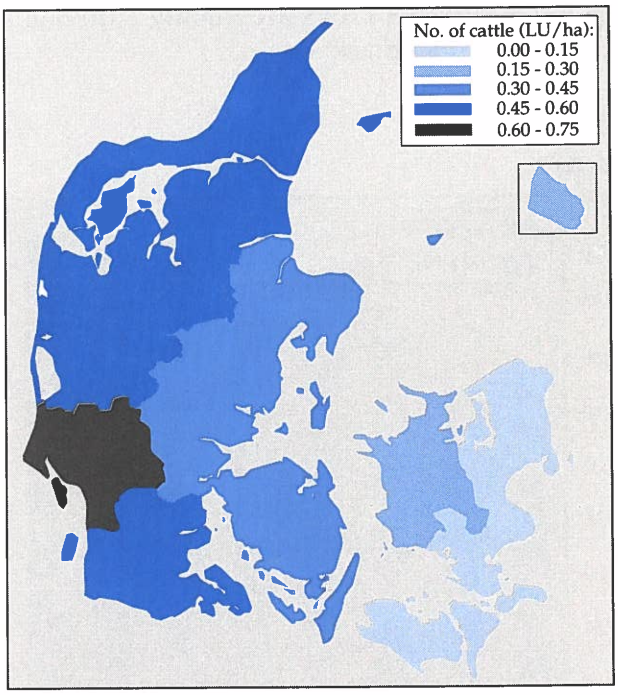


Figure 3.4.8. Cattle density expressed in terms of livestock units (LU) per ha agricultural land in 1991 (Source: Skop, 1993a).

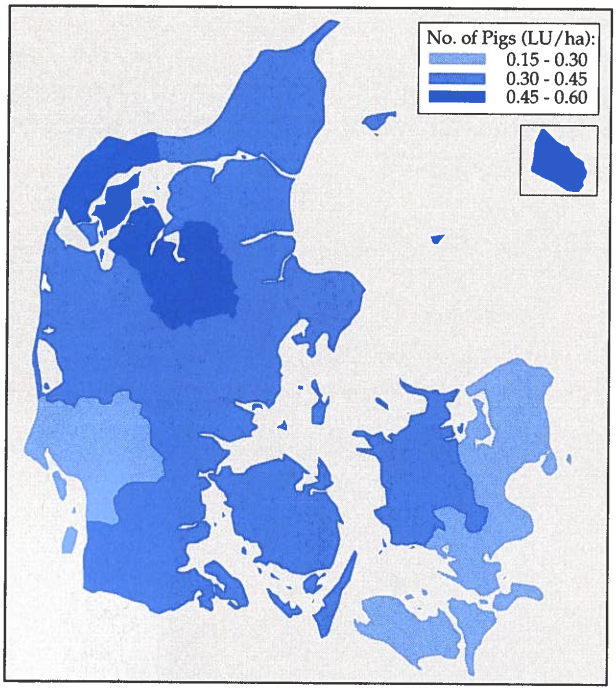


Figure 3.4.9. Pig density expressed in terms of livestock units (LU) per ha agricultural land in 1991 (Source: Skop, 1993a).

There has also been a geographic shift in production structure, as illustrated by *Figures 3.4.7 - 3.4.9.* Cattle herds have become concentrated in western Denmark, while the regional variation in pig herds is less systematic. Crop distribution also displays a geographic shift from east to west. Winter-sown cereals are mainly cultivated in eastern Denmark while grass and fodder crops are mainly cultivated in western Denmark.

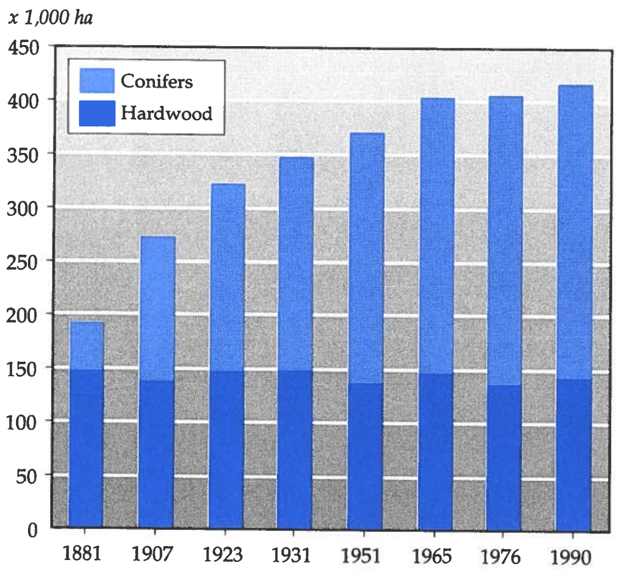


Figure 3.4.10. Trend in total area and type of Danish forest during the last century. (Source: Danmarks Statistik, a).

Total *forest acreage* has increased from 3% of the country in 1800 to 12% at present. The evolution in the acreage of hardwood and conifers over the last century according to forest polls is depicted in *Figure 3.4.10.* It is apparent that the acreage of hardwood has remained stable while the increase in total forest acreage is attributable to the establishment of additional coniferous forest.

A good 30% of Danish forest is publicly owned, of which 26% is owned by the state, while 46% is privately owned. The remaining 24% is owned by companies and funds, etc. Over the course of the last 25 years part of the forest that was previously privately owned has been transferred to company ownership of some type or other. The number of forest holdings in 1990 amounted to 20,563, by far the most part of which were privately owned (only 59 were state-owned). Thus the average size of the holdings was only 10 ha for the private, personally owned forests, but 1,831 ha for the state-owned forests.

Timber yield from Danish forests since 1980 is illustrated in *Figure 3.4.11.* The high timber yield in the years 1982-84 is attributable to windfall in 1981. The production of decorative greenery and christmas trees makes a significant contribution to turnover in many forests. However, in areas which under the law must be preserved as forest, the area that can be used for the production of christmas trees and decorative greenery is limited by the fact that it is not permitted to place more than 10% of

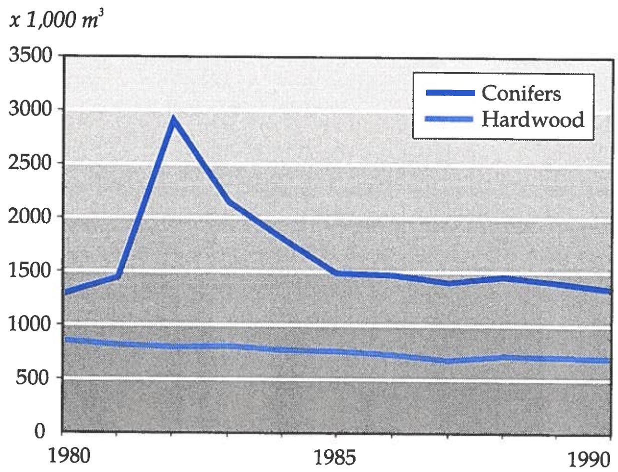


Figure 3.4.11. Timber yield in Danish forests and plantations over the period 1980-90. (Source: Danmarks Statistik, a).

the total area under short rotation. As a consequence the production of christmas trees and decorative greenery mainly takes place on agricultural land. It is estimated that christmas trees and decorative greenery are currently being produced from caucasian fir on 20,000 ha of primarily agricultural land, and that the total area is expected to increase in coming years. As regards the cultivation of silver fir, it is most suited to forest production and most of the 7,000 ha therefore lie in forests.

The nominal price of raw timber has - apart from the first half of the 1970s - been falling since 1960. The fall, which is attributable to the internationalization of the raw timber market and the recession in the building sector, has been marked in the most recent years. The price fall has reduced potential earnings in the forestry sector, although processing and rationalization of forestry have compensated for some of the loss in earnings. The poor condition of the forests, and especially of the common spruce stands, necessitates the increased felling and the sale of timber and pulp wood, even though this provides little profit. The state of health of Danish forests is discussed in more detail in section 2.2.

3.4.3 The economic significance of agriculture and forestry

The economic significance of agricultural primary production is reflected in agriculture's share of the country's total gross domestic product at factor cost (GDP_f). In 1991, GDP_f for the agricultural sector was DKK 25,000 million, corresponding to 3.5% of the total Danish GDP_f. The former includes the value of support from the EU agriculture support fund (FEOGA), which in 1991 amounted to DKK 9,800 million. The agricultural sector's share of the GDP_f has fallen from about 6% in 1970 to about 3%, as depicted in *Figure 3.4.12.*

Employment in primary agriculture has fallen considerably from approx. 170,000 employees (farmers and full-time staff) in 1970 to just about 99,000 in 1992. That the agricultural production has nevertheless increased by 2% annually is attributable to marked improvements in effectiveness and productivity, this having been made possible by the increased application of new technologies to farming -

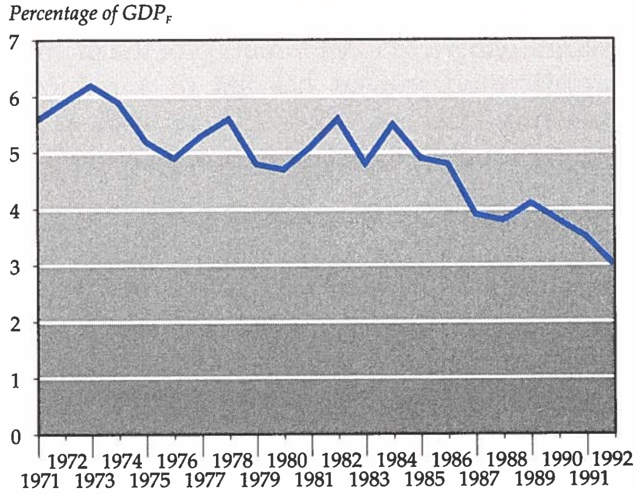


Figure 3.4.12. Trend in the agricultural sector's share of Danish gross domestic product at factor cost (GDP_f) over the period 1971-92. (Source: Danmarks Statistik, a and b).

mechanization, biotechnology and management technology. The technological development in agriculture has increased the advantages of large-scale economics and specialization, and therefore leads to a concomitant structural rationalization in agriculture.

Primary forestry is of minor economic importance, contributing less than 0.2% to the national GDP_f and employing less than 3,000 persons. Employment in the woodworking industry and enterprises processing wood is estimated to amount to 25,000.

On the other hand, forestry's role as a producer of non-material goods - namely recreative value - is of considerable significance to society. Forests are the basis for many of the population's recreative activities.

3.4.4 Environmental impact of agriculture and forestry

Because agriculture produces and consumes raw materials and occupies such a large part of the country, it contributes to the strain placed on nature and the environment. The following media are particularly affected by agricultural production:

- *Marine areas*, where the nitrogen loading from agriculture has led to enhanced primary production, increasingly frequent algal blooms, reduced depth distribution of submerged macrophytes in coastal regions, and frequent episodes of oxygen deficit in the inner Danish marine waters. The deterioration of the marine aquatic environment has led to a reduced breeding stock of edible fish, as well as to inferior quality water for leisure activities (cf. section 2.4).

- *Groundwater*, where the nitrate content has increased in recent years such that the nitrate concentration in some water supply abstraction boreholes has increased above the maximum allowable concentration of 50 mg/l. In addition, pesticides have been found in some boreholes in recent years (cf. section 2.5).

- *The countryside*, where conditions have deteriorated for the wild flora and fauna as a result of the use of pesticides, the impact of monoculture practice on the landscape and the loss of small habitats, as well as acidification and eutrophication (cf. section 2.6).

These environmental problems are attributable to the intensification of agricultural production that, among other things, has meant an increased consumption of raw materials and subsidiary substances. The trend in the consumption of commercial fertilizer nitrogen since 1950 is shown in *Figure 3.4.13*. The corollary of the high consumption of commercial fertilizer is sub-optimal use of the nitrogen produced in animal manure (approx. 340 million kg). Much of the nitrogen in animal manure is therefore lost to the environment.

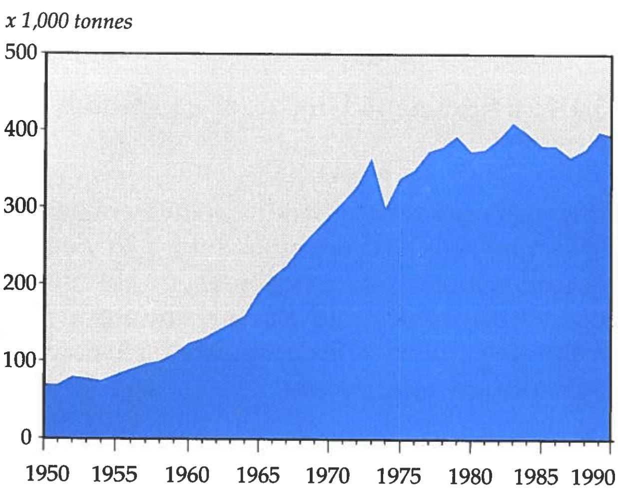


Figure 3.4.13. Trend in the total consumption of nitrogen in commercial fertilizer over the period 1950-90. (Source: Danmarks Statistik, a).

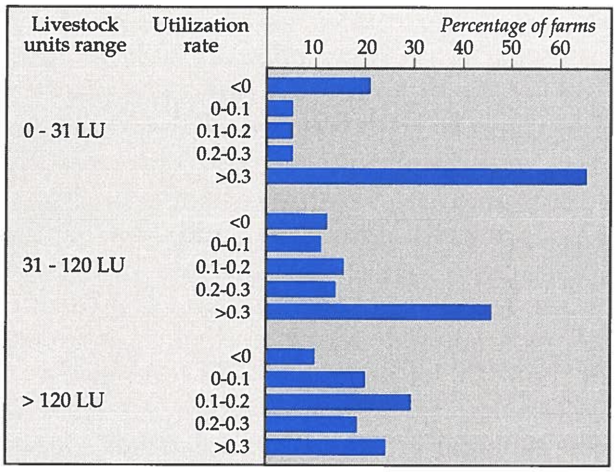


Figure 3.4.14. Percentage distribution of farms classified by utilization rate within three livestock density groupings in 1991 (expressed as livestock units LU) (Source: Skop, 1993a).

The percentage distribution of farms classified by utilization rate within three livestock density groupings (expressed as livestock units LU) is shown for 1991 in *Figure 3.4.14*. A livestock unit is a measure of manure production, manure production from a dairy cow of a large race being equivalent to 1 LU. The utilization rate is calculated as the relationship between the nitrogen requirement of the crops minus the consumption of commercial fertilizer nitrogen and the amount of nitrogen applied in animal manure. The utilization rate calculated in this way indicates what value the farmer has assigned to the animal manure and hence the actual exploitation of the animal manure. There is a clear relationship between the number of LUs on a farm and the utilization rate since the latter falls with increasing LU. In addition, there is a considerable difference between the actual utilization rate and that stipulated in the Ministry of Agriculture Standing Order on green cover, etc.

Much of the nitrogen lost to the environment from agriculture is lost by leaching from the root zone of the crops. The magnitude of leaching varies from year to year and from place to place. The geographic variation in nitrogen leaching is illustrated in *Figure 3.4.15*. The magnitude of leaching has been calculated as a function of soil type, crop selection and the consumption of commercial fertilizer and animal manure. Climatic factors are therefore not included. Leaching is generally greater in Jutland than in the rest of the country, and is

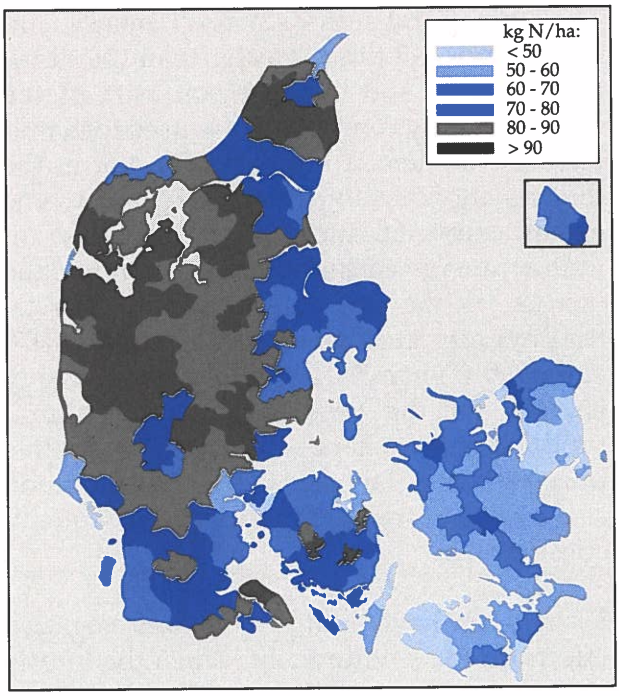


Figure 3.4.15. Magnitude of nitrogen leaching from the root zone in 1989 expressed as kg N leached per ha agricultural land. (Source: Skop, 1993b).

especially great in parts of western and northern Jutland. The regional disparity in the magnitude of leaching is mainly attributable to regional differences in soil type and livestock herds.

It is not possible to directly compare nitrogen leaching in Denmark with that in other countries since such calculation, reckoning or estimation of leaching at the national level is subject to considerable uncertainty. Instead the consumption of nitrogen in commercial fertilizer and the number of livestock units per ha agricultural land (which indicates the level of animal manure production) in EU countries are compared in *Figure 3.4.16* and *Figure 3.4.17*.

Together with Holland, former West Germany and Belgium, Denmark is one of the EU countries with the greatest consumption of commercial fertilizer nitrogen per ha, and is also one of the five EU countries with the greatest livestock density. However, Holland has both an extremely high consumption of commercial fertilizer and an average livestock density that is 2.5 times greater than that in Denmark.

The consumption of pesticide active ingredients in those EU countries for which the information is available is compared in *Figure 3.4.18*.

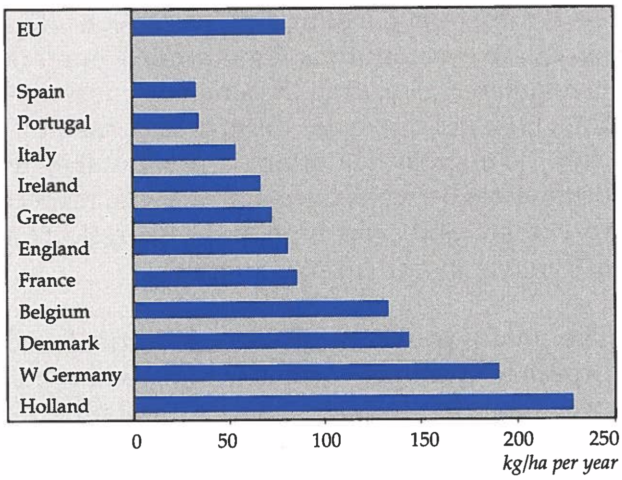


Figure 3.4.16. Annual consumption of commercial fertilizer nitrogen per ha agricultural land in EU countries in 1989. (Source: Commission of the European Communities, 1992).

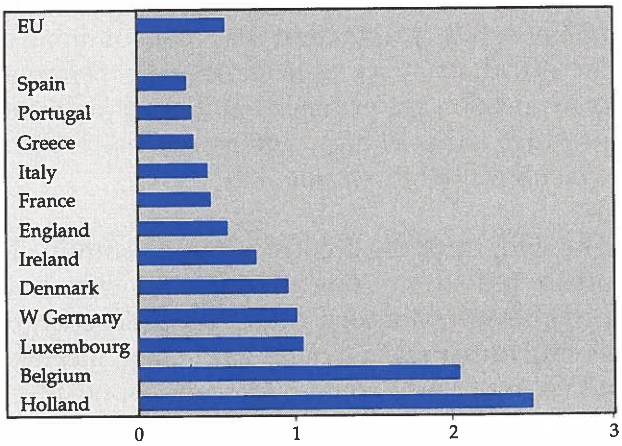


Figure 3.4.17. Number of livestock units (excluding fowl) per ha agricultural land in EU countries in 1989. (Source: National Environmental Research Institute).

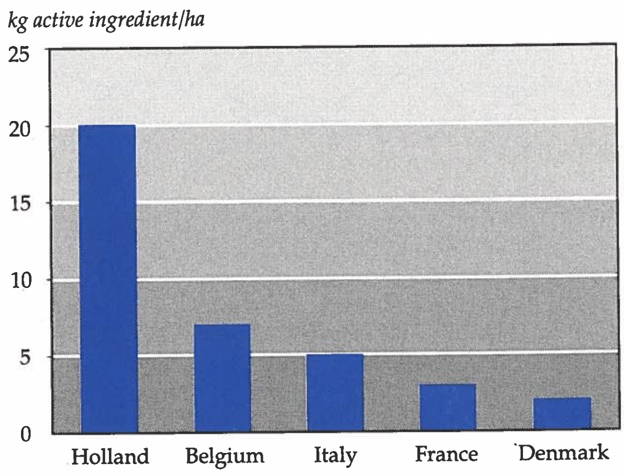


Figure 3.4.18. Pesticide consumption in kg pesticide active ingredient per ha agricultural land in those EU countries for which the information is available. (Source: Commission of the European Communities, 1992).

As is apparent, consumption varies considerably between countries. Thus while Denmark is registered as having the smallest consumption, Holland has by far the greatest consumption. The great variation is attributable to differences between the countries with respect to climate and crop type, but also reflects a difference in agricultural practice.

The main products of Danish agricultural production are primarily used for food products, while byproducts of agricultural production such as straw and animal manure are to some extent used for energy production. Approximately 1.5% of Denmark's energy consumption is derived from straw. The trend in *direct* gross energy consumption and production in the agriculture/market gardening sector since 1970 is depicted in *Figure 3.4.19*. It can be seen that the direct energy consumption has fallen while production has concomitantly increased. As a consequence, the direct energy consumption per produced unit of agricultural produce (the energy intensity) has fallen considerably (cf. section 3.2).

The fall in energy consumption cannot be attributed to any one single parameter, but possible contributory causes include energy saving measures in market gardening, increased use by farms of their own straw for heating, less soil preparation, and the replacement of elderly, petrol driven tractors with a smaller number of modern diesel driven tractors.

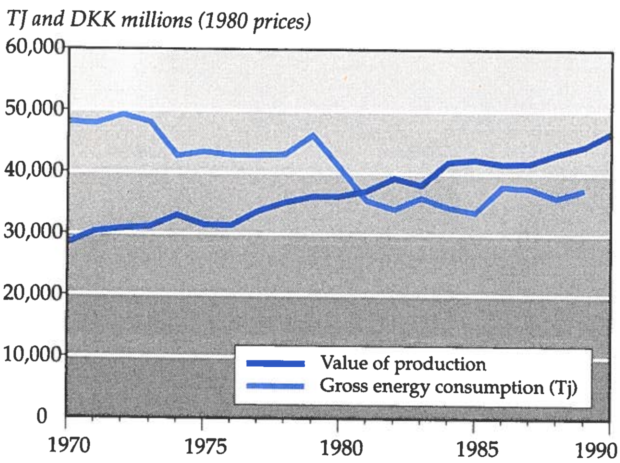


Figure 3.4.19. Trend in direct gross energy consumption and the value of agricultural production (in 1980 prices) for the agriculture/market gardening sector over the period 1970-90. (Source: Danmarks Statistik, c).

The agricultural sector's *indirect* energy consumption is 2-3 times greater than the direct consumption and a significant part of the indirect energy consumption is used to manufacture commercial fertilizer. The fall in the direct energy consumption is therefore to some extent counterbalanced by an increase in indirect energy consumption as a result of the increase in the consumption of commercial fertilizer nitrogen that occurred between 1970 and 1990 (*Figure 3.4.13*). In addition, energy is used for the processing of agricultural products, gross energy consumption for this purpose being of the same order of magnitude as the agricultural sector's direct gross energy consumption.

Forestry can have both positive and negative effects on the environment. When the forests are being built up binding of CO_2 takes place. In addition, the forests help to safeguard the quality of the groundwater resources and provide shade. Forests also play a central role in preserving the gene pool and maintaining biodiversity.

The negative impact of forestry on the environment depends on the silvicultural system in use. In this respect the production of christmas trees and decorative greenery is somewhat unique. Firstly, production occurs in short rotation and therefore does not have the same positive side effects for the environment and nature as silviculture with a rotation time of between half a century and several centuries. Secondly, the utilization of pesticides is considerably greater with christmas tree and decorative greenery stands than with real forest, where spraying is only undertaken to a limited extent and only during the first years of cultivation. The most intensively driven Nordmann pine stands are sprayed every year; nevertheless, expressed in terms of kg active ingredient per unit area the amount applied is only 0.5% of the amount applied in traditional agriculture. Furthermore, there is a trend for the use of a greater and greater number of pesticides to be prohibited, such that only pesticides having a minimal impact on the environment may be employed.

3.4.5 Action plans for agriculture and forestry

As regards the agricultural sector, several action plans and initiatives have been adopted that are especially aimed at limiting pollution of the freshwater and marine aquatic environments, but also at improving conditions for wild plant and animal life in the countryside. Several of these initiatives should be seen in relation to the restructuring of the EU common agricultural policy (e.g. the national implementation of the so-called structural measures in the latest EU agricultural reform), while others arise from national initiatives (e.g. the Action Plan on the Aquatic Environment from 1987).

In adopting the *Action Plan on the Aquatic Environment* in 1987, the Danish parliament passed a number of initiatives aimed at reducing total point-source (sewage) and diffuse (agricultural) nitrogen and phosphorus loading of the aquatic environment by 50% and 80%, respectively, before 1993 (cf. section 2.4). The action plan stipulated that the agricultural sector, through measures such as the establishment of manure storage containers, should reduce annual nitrogen loading by 127,000 tonnes. However, in the 1990 status report on the progress of the plan it was established that this target could not be achieved with the initiatives implemented. In 1991 the government therefore set forth the Action Plan on Sustainable Agricultural Development that included a number of new initiatives. In that plan the goal of halving nitrogen loading was maintained, but the time limit for achieving it was extended to the turn of the century.

The measures hitherto implemented to reduce nitrogen loading included requirements concerning the animal manure storage and application practice, the preparation of fertilizer and crop rotation plans, as well as the provision of information and advisory services to farmers. The latest reports of the results of the Action Plan on the Aquatic Environment conclude that diffuse nitrogen loading from agriculture is at the same level as in the mid 1980s. Leaching has therefore still to be halved in relation to that level in order to fulfil the targets stipulated in the Action Plan on the Aquatic Environment and the Action Plan on Sustainable Agricultural Development. On the basis of a preliminary evaluation it is estimated that the measures hitherto passed to fulfil the action plans and the EU agricultural reform will lead to a reduction of about 50,000 tonnes nitrogen. In order to fulfil current targets it is therefore necessary to implement further measures.

With respect to ammonia volatilization, the initiatives to improve the utilization of animal manure are expected to reduce ammonia volatilization from 120,000 tonnes per year to 100,000 tonnes per year.

According to the *Action Plan on Pesticides* from 1986, the use of pesticides has to be reduced by 50% before 1997. This target applies both to the amount of active ingredients sold and to the so-called treatment frequency factor. The latter is a measure of how many times per year the total area of agricultural land in Denmark could be treated with pesticides if the amount sold was used at the recommended doses. In 1991 the amount of active ingredients sold had fallen by 33% whereas the treatment frequency factor had increased 12% (cf. section 2.7.3).

In connection with the Action Plan on Sustainable Agricultural Development, consideration was therefore given to whether the stipulation that the treatment frequency factor should be halved could be revoked and supplanted by more environmentally correct and sure criteria that more accurately reflected the environmental impact of pesticides than does the treatment frequency factor. However, a status report submitted to the Parliamentary Committee on the Environment and Planning in June 1992 concluded that there was no scientific basis for such new criteria. The goal of halving the treatment frequency factor therefore still applies.

In pursuance of the latest EU agricultural reform (the MacSharry reform) from 1992 and subsequent regulations pertaining to agriculture, a number of measures have been passed that will probably be of great significance with respect to nature in agricultural areas and protection of groundwater quality. Included here are the market policy measures aimed at reducing EU agricultural production through restructuring of farm price support and regulations making set-aside a condition for obtaining support. In its first year (1993), the reform has led to approx. 200,000 ha agricultural land being set aside. Given the way that the set-aside regulations were laid down for 1993, i.e. rotational set-aside (1 year set-aside within normal crop rotation), the scheme has been of little significance to nature and the environment. However, longer term set-aside is permitted for the 1994 production year, and this could well be of greater benefit to nature and the environment.

The EU agricultural reform also includes the so-called "structural measures" with environmental and social aims. These provide member countries the possibility to implement national support schemes for environmentally friendly agricultural production, permanent set-aside, afforestation, etc. In Denmark, this part of the reform is implemented in the Ministry of Agriculture Statutory Order on support for organic farming, support for environmentally friendly agricultural measures and support for forestry measures. A number of the measures are tailored to selected areas, especially with a view to counteracting the threat to groundwater quality posed by intensive farming. The consequence of these support measures for nature and the environment depends on the sums earmarked for the purpose. Total EU funds devoted to this area amounts to only 2% of the total agricultural support budget.

In connection with the demand for reduced agricultural production, a goal is to increase the area of forest: the goal is to double the area of forest within a tree generation, i.e. 80-100 years. A doubling of forest in Denmark will mean that 25% of the country will become forest and will require the establishment of 5,000 ha forest per year, equally divided between private and state forests. However, the annual rate of afforestation to date has been under half of that target (cf. section 2.6), and the falling prices for timber do not exactly encourage private afforestation.

In view of the positive role that forests play in connection with the preservation of the gene pool and biodiversity, the National Forest and Nature Agency has drawn up strategies for preserving the gene pool of trees and bushes as well as for the preservation and designation of forest areas which under the law must be preserved as forest.

A status report on Denmark's overall forestry policy seen in the light of the Rio Conference is currently being prepared, and is expected to be completed at the end of 1993. It is anticipated that the status report will give rise to new action plans for the forestry sector.

3.5 Industry

3.5.1 Introduction

While the major questions in the environmental debate and environmental management used to involve the immediately visible, direct pollution by industry, current discussions about industry's environmental impact are now directed towards the *indirect* and *secondary* environmental problems that arise from industrial production. These include the consumption of energy and resources, direct and indirect production of waste (i.e. both industry's own waste production and the waste problems that industrially manufactured goods cause in the chain of consumption) and the risks involved in the use and marketing of new materials and products.

Even though there are still numerous individual instances of pollution, this shift in focus on industry's environmental problems reflects the fact that several types of direct industrial discharges to the soil, the atmosphere and the aquatic environment have been solved technologically by the installation of treatment measures and to a certain degree via better control over the production process.

This chapter provides a status report on industry's environmental problems. It focuses on the national and future-oriented perspective. The "sins of the past" and the accidents at giant industrial plants will not be considered here.

3.5.2 Structural development of industry

Trends in key statistics for industry's structural development over the period 1972-1992 are illustrated in *Figures 3.5.1-3.5.4*. *Figure 3.5.1* shows the growth in the total value of industrial production at fixed prices as an indicator of industry's total turnover of resources. It can be seen that the production value (in 1980 prices) has grown from DKK 170,000 million in 1972 to DKK 230,000 million in 1992, a growth rate of 35%.

Industry's share of gross domestic product at factor cost (GDP_f), which is relatively low in Denmark, has fallen slightly in this period, namely from 20.7% in 1972 to 19.0% in 1992.

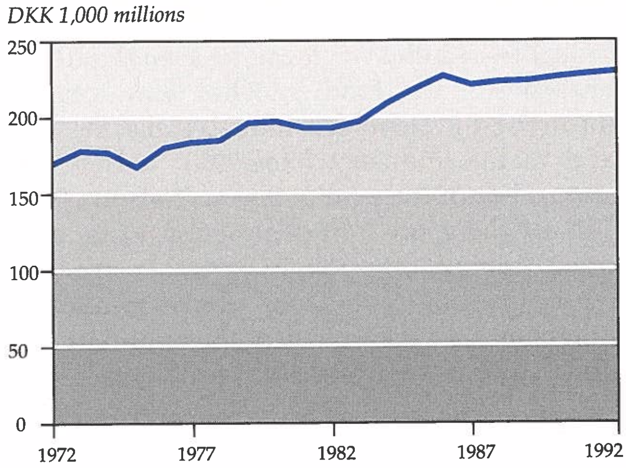


Figure 3.5.1. Growth in the value of industrial production at fixed prices (1980-prices) over the period 1972-1992. (Source: Danmarks Statistik, a).

This development, however, masks differences between branches, as depicted in *Figure 3.5.2*.

Employment in industry has fallen from 560,000 in 1972 to 500,000 in 1992, a decline of 10.5%. Industry's share of total employment has hereby fallen from about 24% to about 20%. The overall trend in employment at the branch level is depicted in *Figure 3.5.3*.

Despite declining total employment, industry has nevertheless been largely able to maintain its share of the GDP_f by increasing productivity, just as production value measured in fixed prices has risen noticeably. Despite the fact that employment trends in society indicate a movement away from industrial society towards a post-industrial information- and service-oriented society, the figures nevertheless do not indicate a movement towards a less material or less resource-consuming society.

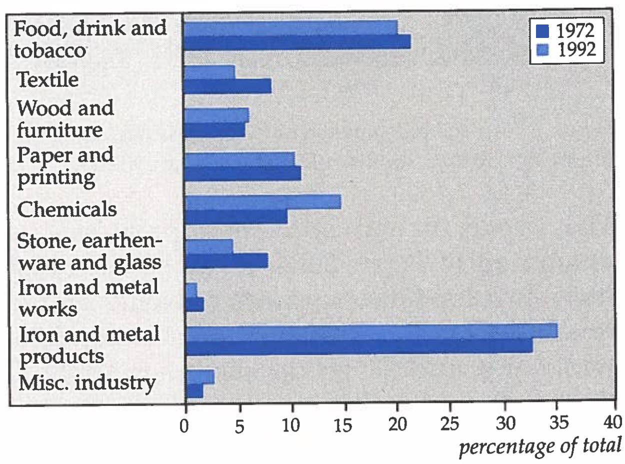


Figure 3.5.2. Industrial gross domestic product at factor cost in 1972 and 1992, apportioned by industrial branch. (Source: Danmarks Statistik, a).

As regards apportionment between the various branches of industry, it can be seen that three branches - the food, alcohol and tobacco industry, the chemicals industry and the iron and metals industry - together account for about 75% of the production value and about 70% of the growth in production value, this trend having been relatively stable over the whole period. The three above-mentioned branches are concomitantly the ones with the most serious environmental problems.

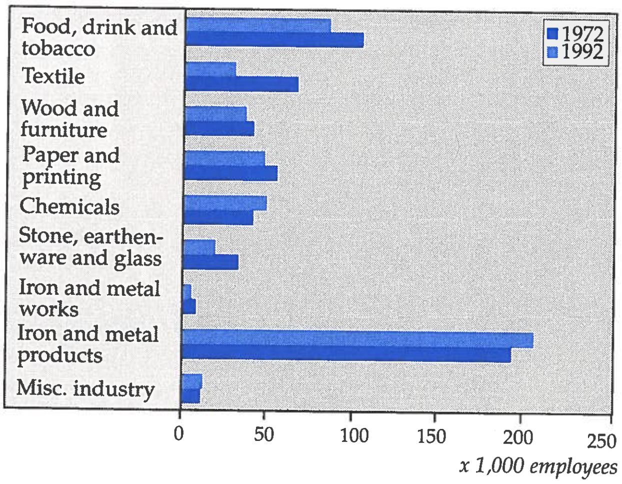


Figure 3.5.3. Industrial employment by branch in 1972 and 1992. (Source: Danmarks Statistik, a).

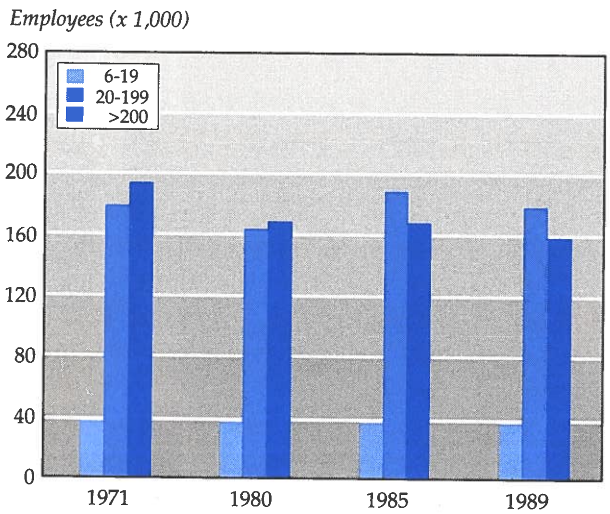


Figure 3.5.4. Total personnel in industry classified according to enterprise size. (Source: Danmarks Statistik, a).

The trends in industrial enterprise size is illustrated in *Figure 3.5.4.* It can be seen that there is a tendency towards a decline in the number of employees in the largest enterprises, while the middle group increases slightly. Denmark is characterized by a lack of giant industrial enterprises. The environmental measures must be directed towards the broad group of medium- and small-sized enterprises.

Between 1972 and the present date Danish industry has become geographically more dispersed, and its centre of gravity has shifted towards the west of Denmark. This development necessitates an even distribution of environmental expertise in the municipalities and counties.

3.5.3 Environmental impact of industry

As Denmark does not have a systematic and continuous monitoring and registration of industrial emissions, this summary builds on data and information collected from a large number of individual studies.

Industry's direct environmental impact, i.e. as a result of the generation of waste, the discharge of waste water and environmentally hazardous substances into the aquatic environment and the atmosphere, will be reviewed below.

Solid waste

Industrial generation of solid waste amounts to 2,000 million tonnes annually, or about 25% of the total amount of waste. An additional 1,500 million tonnes is generated by the building and construction industry, corresponding to about 20% of the country's total waste. Source apportionment of Denmark's waste is shown in *Figure 3.5.5.*

Of industry's total waste production, about 35% is recycled, 42% is deposited, and 23% incinerated.

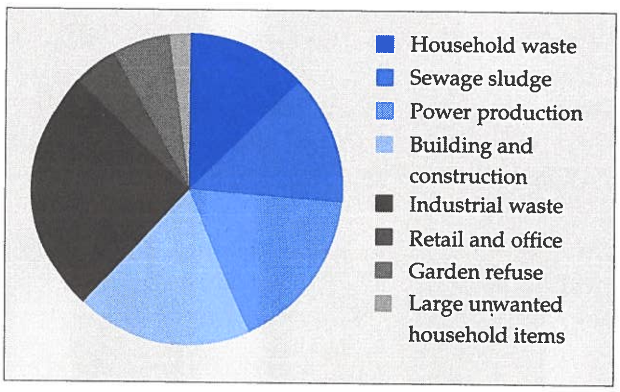


Figure 3.5.5. Source apportionment of Danish waste based on 1985 data. (Source: Danish Environmental Protection Agency, 1993b).

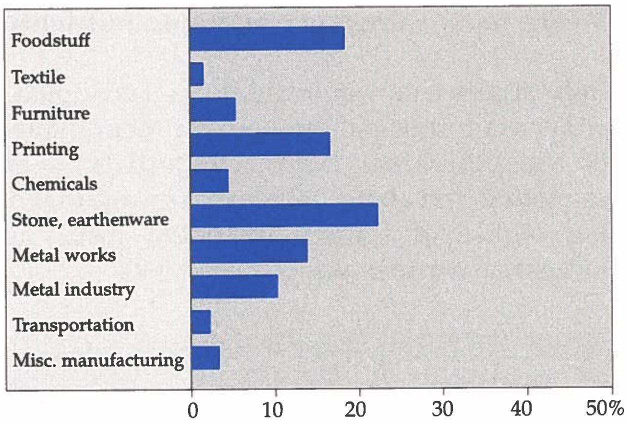


Figure 3.5.6. Industrial waste apportioned by branch in 1985. (Source: Gendan A/S, 1987).

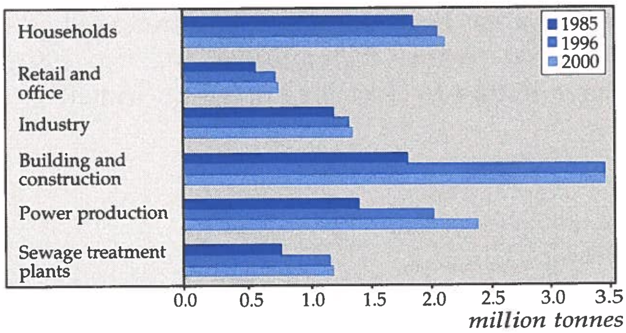


Figure 3.5.7. Actual (1985) and projected (1996 and 2000) waste production by various sectors of society. (Source: Gendan A/S, 1987).

Apportionment of industrial waste by branch is depicted in *Figure 3.5.6*. The food, drink and tobacco industry is the largest contributor, but the majority of such waste is edible and can be largely recycled as animal fodder. Other main sources are the graphics industry, the stone, earthenware and glass industry and the metals industry.

The firm Gendan A/S (now Rendan A/S) has evaluated the trend in waste production by various sectors of society up to the year 2000. As is apparent from Figure 3.5.7, the projection is for a slight increase in the amount of industrial waste, and a very marked increase in building waste.

More precise calculations are available as regards oil and chemical waste. The oil and chemical waste processing firm Kommunekemi A/S, the only firm authorized to receive chemical waste from industry and other sectors, maintains ongoing statistics about the amount and type of the waste received. As illustrated in *Figure 3.5.8*, the amount of waste that Kommunekemi A/S received increased markedly up to the end of the 1980s, an increase mainly attributable to increasing efficiency in the collection and delivery of oil and chemical waste to them. Since 1989 the

Type/Source	Production	Accidents	Clean-up	Unknown	Total
Oil products	52	3	36	9	100
Chemicals	67	2	24	7	100
Halogen - containing	89	0	8	3	100
Organic solvents	76	1	21	2	100
Organic chemicals	67	2	24	7	100
Mercury - containing	30	2	59	9	100
Pesticides	26	2	68	4	100
Inorganic chemicals	75	3	16	6	100
Misc. chemicals	33	3	51	13	100
All waste in 1992	64	2	27	7	100
All waste in 1991	64	2	27	7	100
All data are given in percent					

Table 3.5.1. Oil and chemical waste received by the waste processing firm Kommunekemi A/S apportioned by type and origin. (Source: Kommunekemi A/S).

amount has been falling gently, a trend indicating that cleaner technologies and processes have begun to have an impact on industry.

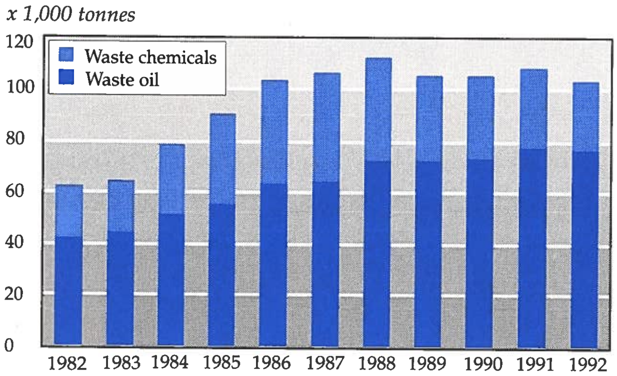


Figure 3.5.8. Trend in the amount of oil and chemical waste received by the waste processing firm Kommunekemi A/S over the period 1982-92 (Source: Kommunekemi A/S).

From *Table 3.5.1* it can be seen that waste from industrial processes constitutes the major part of the waste received by Kommunekemi A/S. The second main component is waste from clean-up operations, most of which derives from the remediation of contaminated sites.

In general, it can be concluded that the total amount of waste generated by the manufacturing sector is still tending to increase, while there seems to be a tendency for the amount of hazardous waste to be reduced at source. As regards the normal waste from industry, this will often contain considerable potential for recycling inasmuch as, in contrast to household waste, industrial waste is usually relatively pure.

Waste water - organic matter and nutrients

Industrial waste water discharge takes place either via municipal sewage treatment plants or via individual industrial outfalls. It is estimated that about half of the sewage entering municipal sewage treatment plants is industrial waste water (*Figure 3.5.9*).

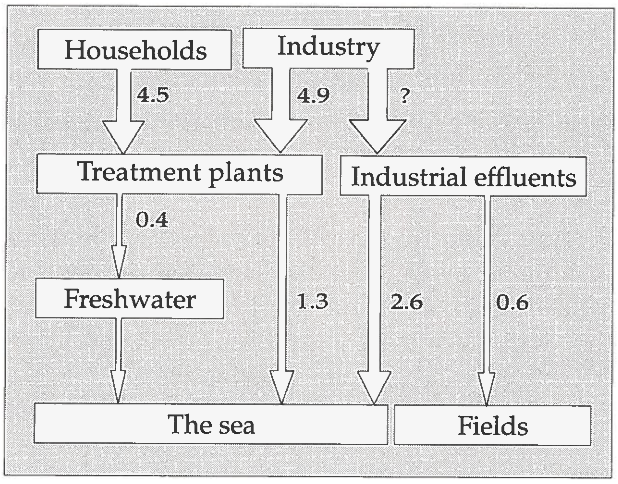


Figure 3.5.9. Sewage flow in Denmark, in million of person equivalents. (Source: Danish Environmental Protection Agency, 1990a and 1990b).

The trend in discharge from the municipal sewage treatment plants and from individual industrial outfalls from the mid-1980s and until full implementation of the Action Plan on the Aquatic Environment in 1995 is shown in *Figure 3.5.10* and *Figure 3.5.11*, respectively.

It can be seen that there is a generally declining tendency towards the targets stipulated in the plan, but that there continues to be a gap which needs to be closed, especially for nitro-

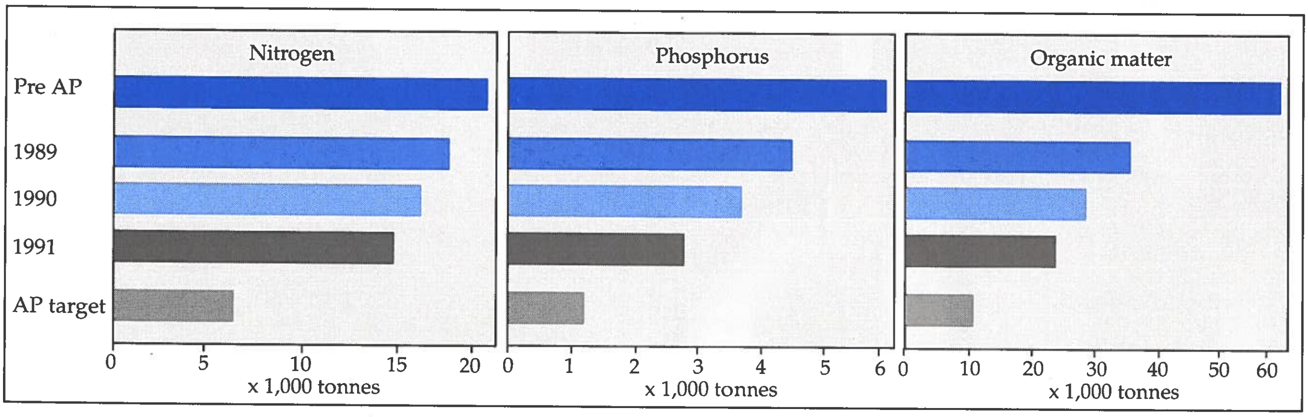


Figure 3.5.10. Nutrient and organic matter discharge from sewage treatment plants prior to the Action Plan on the Aquatic Environment (Pre AP), for the years 1989-91, and the levels expected upon full implementation of the plan in 1995 (AP target). (Source: Danish Environmental Protection Agency, 1992).

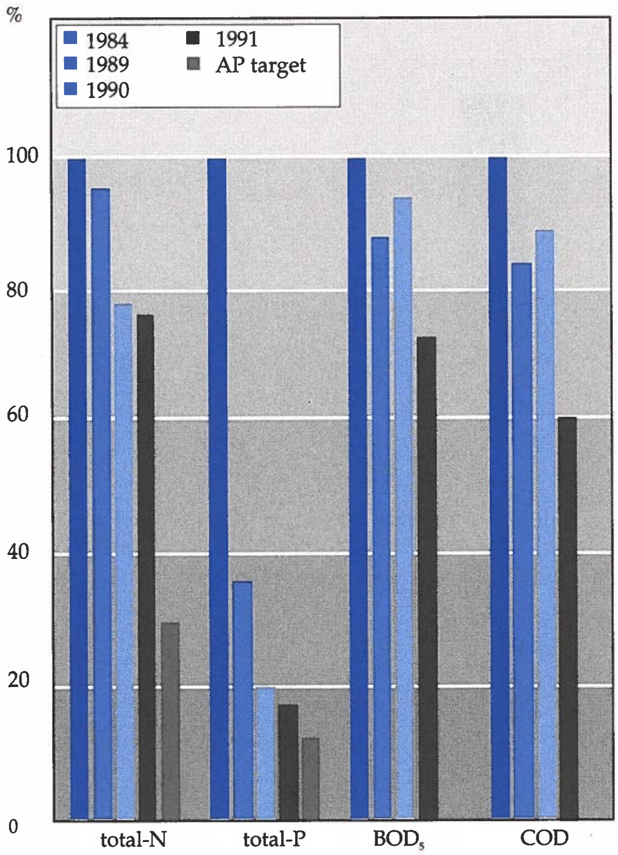


Figure 3.5.11. Trend in nutrient and organic matter discharge from individual industrial outfalls relative to levels prior to the Action Plan on the Aquatic Environment (1984), for the years 1989-91, and the levels expected upon full implementation of the plan in 1995 (AP target). (Source: Danish Environmental Protection Agency, 1992).

gen. With the initiatives so far implemented, however, there is nothing to indicate that the targets will not be reached on schedule.

Hence there is nothing which speaks for a general tightening of the stipulations concerning nitrogen discharge from municipal and industrial outfalls, in that agriculture is currently the predominant source of nitrogen loading. With regard to organic matter, the trends in water quality in freshwater and coastal areas do not indicate a need for further restrictions. In the case of phosphorus, there remains a problem with the phosphorus concentration in many lakes (cf. section 2.4). However, the main sources of phosphorus loading are sparsely built-up areas and diffuse loading from agricultural land.

From a social economic point of view, the measures implemented to reduce nitrogen loading from municipal and industrial sources have been very expensive in relation to what a corresponding reduction from agriculture would have cost. Moreover, it can be debated whether the sewage treatment structure chosen in Denmark, in which major emphasis is placed on municipal plants, is the most optimal, or whether it could have been more advantageous to have placed more emphasis on a greater degree of on-site treatment at the enterprises themselves. The question continues to be current, in that the dimensions of sewage treatment plants are still being adjusted in the private and public sectors. There is ongoing discussion of this issue, not least when determining how the measures are to be financed at the local level.

Emissions hazardous to health and the environment

Industry emits to the atmosphere and aquatic environment a large number of substances hazardous to health and the environment. These include heavy metals and numerous organic and inorganic compounds. Many of these substances are directly toxic to man, animals or plants, while others have more long-term effects because they accumulate in the environment and in living organisms. At present there is no integrated monitoring program for such emissions in Denmark, and an evaluation of the developmental tendencies has therefore to be collated from a number of different investigations.

Industrial waste water discharge has been investigated in a research project initiated by the Danish Environmental Protection Agency (Danish Environmental Protection Agency, 1990b). The study included the majority of industrial discharges containing environmentally foreign substances, special focus having been placed on large enterprises with individual outfalls.

Figure 3.5.12 illustrates some of the main results of this project. The projected figures for 1995 are based on a conservative estimate of the impact on industry of developments in environmental technology. It can be seen that all the groups of substances illustrated exhibit a marked decline from the mid to the late 1980s, as well as that this decline will continue through to 1995.

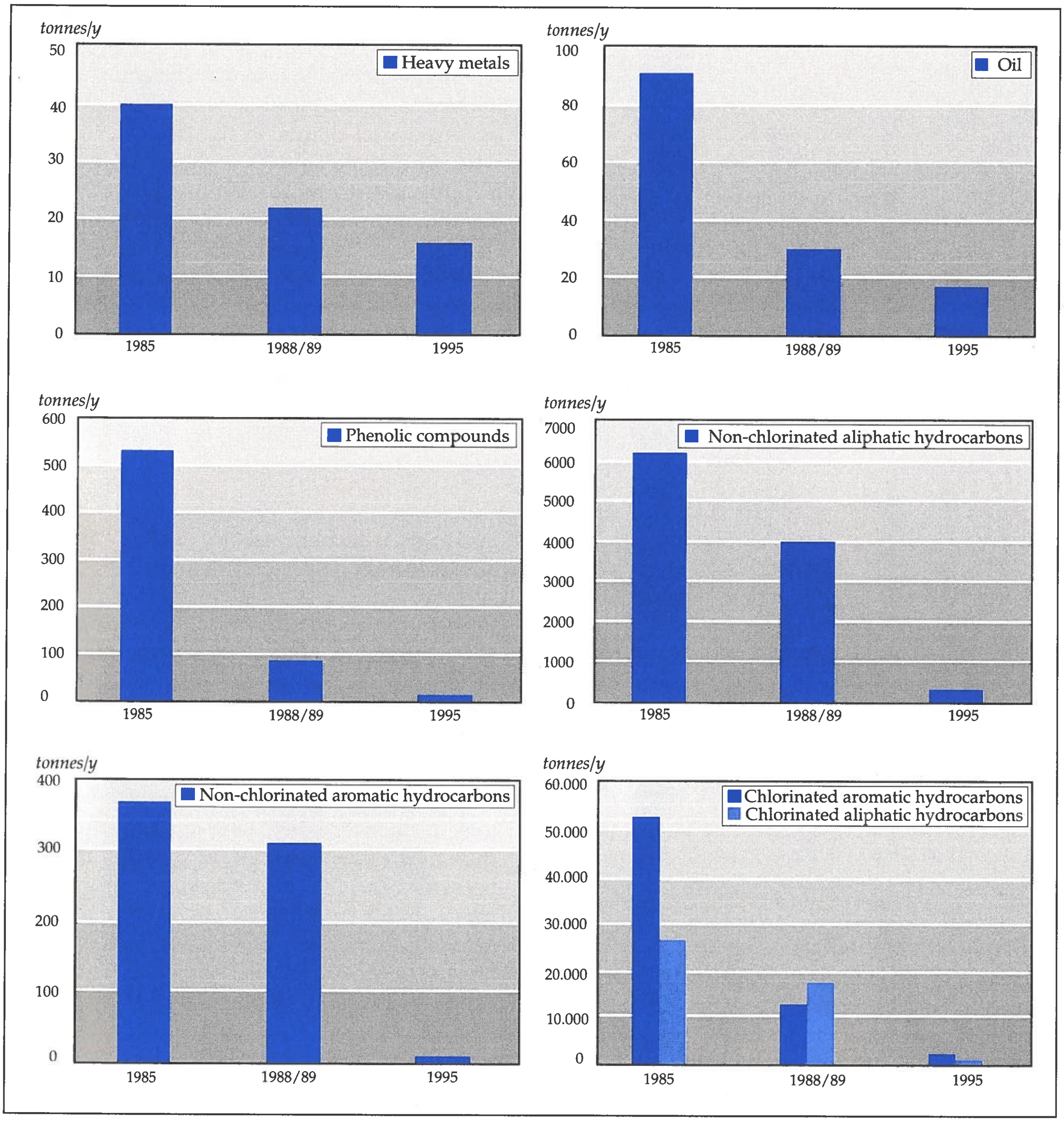


Figure 3.5.12. Direct industrial discharge of environmentally foreign substances in waste water. (Source: Danish Environmental Protection Agency, 1990b).

Denmark has entered into international agreements (e.g. within the Baltic and North Sea Conventions) to reduce marine discharge of environmentally foreign substances from all sources by 50% over the period 1985-95. The figures show that as a general rule, industry's share of the reduction will be achieved as planned. However, there may be individual substances where this does not apply. As corresponding information about the magnitude of other sources (municipal sewage treatment plants and diffuse sources) is not available, it is not possible to draw any general conclusion. Nevertheless, it is estimated that industry accounts for a large part of the total discharge of these substances.

Fulfilment of international agreements does not *per se* mean that all problems are solved, however, partly because it is not possible to be sure that the agreed international targets will prove adequate in the long run, and partly because local problems may still arise. As far as concerns industry, the latter will have to be solved via county and municipal environmental certification procedures and by routine environmental controls.

An overall survey of atmospheric emissions of substances hazardous to health and the environment by industry is not available.

The regulation of atmospheric emissions is undertaken locally, on the basis of centrally issued guidelines. Exceptions to this include those substances for which there exist international agreements. These include ozone-degrading compounds (CFCs and halons), as well as CO_2, CO, SO_2, NO_x and VOCs (Volatile Organic Compounds); the former are discussed in sections 2.1-2.3, while the latter, which are almost exclusively related to energy consumption, are discussed in section 3.2. A major investigation of VOC emissions has recently been undertaken by the Danish Environmental Protection Agency in cooperation with industry. Although not yet published, some of the main conclusions are nevertheless shown in *Table 3.5.2.*

VOC emissions in tonnes	1988	1990
Food, drink and tobacco industry	3,100	2,550
Wood and furniture industry	3,800	3,100
Iron and metals industry	4,600	4,300
Car trade	7,575	5,150
Plastics industry	1,525	1,300
Printing trade	1,500	1,550
Chemicals industry	1,900	1,250
Total industry studied	24,000	19,200

Table 3.5.2. Industrial VOC emissions, excluding methane, VOCs from aerosol propellants and chlorinated organic solvents (inc. CFCs). (Source: Danish Environmental Protection Agency, 1993a).

The Danish Environmental Protection Agency is currently concluding negotiations with industry regarding a reduction of industrial VOC emissions. This agreement is a means of fulfilling our obligation with respect to an international treaty under the Geneva Convention to reduce VOC emissions from all sources by 30%.

Industry's consumption of resources

Industry accounts for 26% of the total energy consumption (cf. section 3.2) and uses approx. 170 million m^3 water, or 19% of the total water consumption (cf. section 2.5). To this should also be added the consumption of numerous raw materials, many of which are imported.

Environmental problems linked to the life cycle of industrial products

A wide range of industrial products can generate environmental problems during their subsequent use, whether this is as private consumption or as input to other branches. This is especially so in the case of chemical compounds and products, which are consequently also regulated by special legislation (cf. section 2.7).

In their further life-cycle, industrial products ultimately end up in the societal waste stream. Two types of problems arise in this connection. The first is the size of this waste stream, which has been growing exponentially over the last 30 years, and which continues to grow, though more slowly. Part of this growth is linked to new integrated production concepts which, combined with high wage costs for repair and maintenance compared with the purchase price, mean that many industrial products have a relatively short life-span. Attempts are being made to combat the resultant waste problem using various forms of return-to-manufacturer schemes, e.g. the recent agreement concerning the return of used car tyres.

The second problem in connection with the waste stream is attributable to the fact that industrial products have embedded within them numerous environmentally hazardous substances which can be released during subsequent waste processing. *Table 3.5.3* lists a number of substances that occur in significant concentrations in leachate from waste dumps, as well as in flue gasses and cinders from waste incineration plants.

Finally, it must be mentioned that the growth in industrial production, especially the increasing international division of labour, generates an increasingly growing amount of freight transport (cf. section 3.3).

Aluminium	7429-90-5	Dichloromethane	75-09-2
Antimony	7440-36-0	Di(2-ethylhexyl) Phthalate	117-81-7
Arsenic	7440-38-2	Diethyl Phthalate	84-66-2
Benzene	71-43-2	Fluoride	7664-39-3
Benz(a)anthracene	56-55-3	Hexachlorobutadiene	87-68-3
Benzo(a)fluoranthene	203-33-8	Lead	7439-92-1
Benzo(a)pyrene	50-32-8	Mercury	7439-97-6
Benzo(h)fluoranthene	205-99-2	N-Nitrosodiethylamine	55-18-5
Benzo(e)pyrene	192-97-2	Nickel	7440-02-0
Beryllium	7440-41-7	4-Nonyl Phenol	104-40-5
Copper	7440-50-8	Nonylphenolethoxylates	9016-45-9
Bromoethylene	593-60-2	Pentachlorophenol	87-86-5
Cadmium	7440-43-9	Phenol	108-95-2
4-Chloroaniline	106-47-8	Polybrominated biphenyls	59536-65-1
Chlorinated paraffins		Polybrominated diphenylethers	
4-Chloro-3-methylphenol	59-50-7	Polychlorinated biphenyls	1336-36-3
Chromium	7440-47-3	Polychlorinated terphenyls	61788-33-8
Chrysotile-(asbestos)	12001-29-5	Silver	7440-22-4
Cobalt	7440-48-4	Tetrachloroethene	127-18-4
Creosote	8001-58-9	Tributyltinoxide	56-35-9
Cyanide	57-12-5	1,2,4-Trichlorobenzene	120-82-1
Dibenz(a,h)anthracene	53-70-3	1,1,1-Trichloroethane	71-55-6
1,2-Dibromomethane	106-93-4	Trichloroethene	79-01-6
Dibutyl Phthalate	84-74-2	Triphenyl Phosphate	115-86-6
1,4-Dichlorobenzene	106-46-7	Vanadium	7440-62-2
3,3-Dichlorobenzidine	91-94-1	Zinc	7440-66-6
1,1-Dichloroethene	75-35-4		
1,2-Dichloroethane	107-06-2		

Table 3.5.3. Environmentally hazardous substances detected in connection with waste processing. The chemical identification numbers (CAS-numbers) are given. (Source: I. Krüger A/S, 1993).

The general conclusion concerning the environmental impact of industry is that there has been marked progress towards reducing direct and process-related problems. Future challenges therefore lie to a great extent with the indirect environmental impact of industry: resource consumption, the waste stream and transport.

3.5.4 Regulative control of the environmental impact of industry

Regulative control of the environmental impact of industry is accomplished through several different laws and ministerial Statutory Orders.

The Environmental Protection Act is the most important general legislation in so far as industry is concerned. The Act was revised in 1992, the main emphasis being placed on preventative measures and cleaner technology. One of the key provisions of the Environmental Protection Act is mandatory authorization of certain specific categories of enterprise. The authorization procedure was tightened and simplified in 1992. Authorization and control are now largely decentralized, being undertaken by the municipal and county authorities. In order to promote the application of cleaner technology and facilitate administration, the enactment of the new Act was accompanied by the introduction of several new control measures: environmental agreements, environmental auditing, the eco-labelling scheme and the consulting aid scheme, as well as the possibility to use financial control instruments.

The Environmental Protection Act, in keeping with current Danish legislative practice, is a so-called "framework law", i.e. it provides only the overall framework of the legislation with the legislative details subsequently being stipulated by means of ministerial Statutory Orders or by regulations stipulated at the regional or local level. As such the Act is characterized by a great degree of decentralized administration and decentralized stipulation of supplementary regulations, except for those aspects for which the "framework" is filled out with nationally applicable regulations. This applies to those aspects for which Denmark has entered into international agreements, e.g. those concerning transboundary atmospheric pollution, discharges into the marine environment, etc., as well as to those of a national character, e.g. fulfilment of the goals stipulated in the Action Plan on the Aquatic Environment or Action Plan on Waste and Recycling.

Another Act of importance from the environmental point of view is the Chemical Substances and Products Act, which is also a so-called "framework law". Its administration and the stipulation of supplementary detailed regulations are undertaken centrally by the Danish Environmental Protection Agency. The Act provides the powers to prohibit or limit the use of especially dangerous chemical substances. Other relevant legislation includes the Planning Act and the Environmental Impact Assessment Procedure Statutory Order, which regulate the placement and environmental impact of larger industrial plants.

A general action plan aimed at reducing industry's environmental impact does not exist at present.

3.6 Households

3.6.1 Introduction

Households affect the environment directly and indirectly via their consumption of goods and services. Their environmental impact depends on the range of goods and services available to and selected by consumers, as well as the behaviour displayed by consumers in connection with consumption. Finally, their environmental impact to a very great extent depends on how the waste products derived from household consumption, waste and sewage are dealt with.

A large part of society's total consumption of energy and water - over a third - is accounted for by households. Consumption of energy for heating, lighting and transport generates direct or indirect atmospheric pollution of CO_2, NO_x, SO_2, etc. Water consumption creates pressure on scarce groundwater resources and leads to the discharge of waste water containing nutrients and, to a certain degree, environmentally foreign substances. The use of environmentally hazardous substances sometimes entails a health risk for the consumer himself. Household production of normal and dangerous waste is quite significant, and its disposal causes environmental problems, the most important of which is the risk of contaminating the soil and groundwater.

This section describes the trends in these aspects. Household energy consumption and the importance of this for air pollution is described in section 3.2, to where the reader is referred.

3.6.2 Trends in total household consumption

The trend in household consumption (inc. consumption by tourists) over the period 1981-91 is shown in *Figure 3.6.1*. It can be seen that total consumption at fixed prices has increased by DKK 42,000 million in the period 1981-91, or by about 20%. However, this trend masks considerable fluctuations, e.g. the considerable increase in consumption in the period 1981-86, following which consumption fell until 1989.

The Ministry of Finance's long-term projections (cf. section 3.1) estimated total real growth in private consumption for the period 1992-2010 to be 92%, but this masks reduced growth in the period 1992-1994, considerable growth in the period 1995-98, and a more moderate rate of growth during the remainder of the period.

Growth in the consumption of various goods and services in the period 1981-91 is shown in *Table 3.6.1*. The consumer categories "Foreign travel" and "Leisure and entertainment" have

DKK 1,000 millons	1981	1991	%-increase 1981-91
Food	36.3	40.3	11.0
Drink and tobacco	16.7	16.3	-2.4
Clothing	11.5	13.6	18.3
Housing costs	39.9	44.2	10.8
Energy	14.9	15.0	0.7
Household items, housekeeping	14.2	15.0	5.6
Medicine and medical fees	3.7	5.4	45.9
Transport and communication	29.3	39.1	33.4
Leisure and entertainment	19.6	27.5	40.3
Foreing travel	7.5	12.3	64.0
Other items and services	18.2	25.3	39.0
Household consumption, total	211.8	254.0	19.9

Table 3.6.1. Trend in total household (inc. tourist) consumption of goods and services apportioned by category. (Source: Danmarks Statistik, 1993).

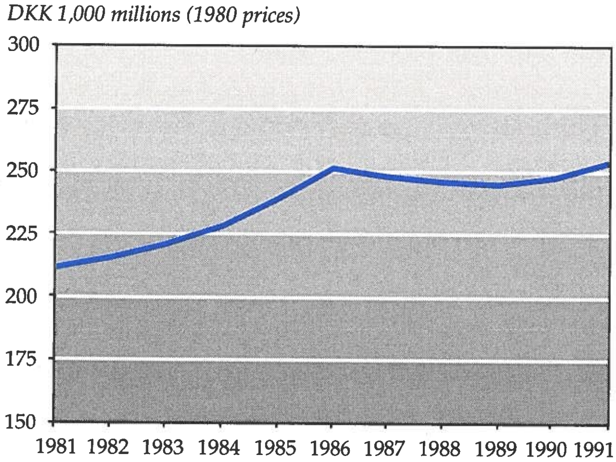


Figure 3.6.1. Growth in total household (inc. tourist) consumption over the period 1981-91. (Source: Danmarks Statistik).

increased considerably, as has "Transport and communication". It is noteworthy that there has been almost no growth in household total energy consumption (excl. energy consumption for transport), just as consumption of food products has risen only moderately.

3.6.3 Household water consumption and sewage production

Water consumption in Denmark is nearly entirely based on the abstraction of groundwater, which does not need to be subjected to costly treatment and purification before it can be utilized as drinking water. Denmark thus occupies a unique position in relation to nearly all other countries, most of which rely to a greater or lesser extent on surface water for their water supply. Only 2% of the water consumed in Denmark is derived from surface water.

Out of a total annual water consumption of 900 million m^3, households and institutions accounted for 380 million m^3, of which 330 million m^3 were accounted for by households. According to water supply statistics, annual household water consumption per inhabitant fell from approx. 63 m^3 in 1989 to approx. 58 m^3 in 1992, or 159 litres per day. However, it is difficult to establish the precise magnitude of the household water consumption, as not all households have water meters.

The amount of *sewage* generated by households is normally expressed in "person equivalents"(PE), i.e. the amount of sewage produced by one person. One PE is equivalent to 21.6

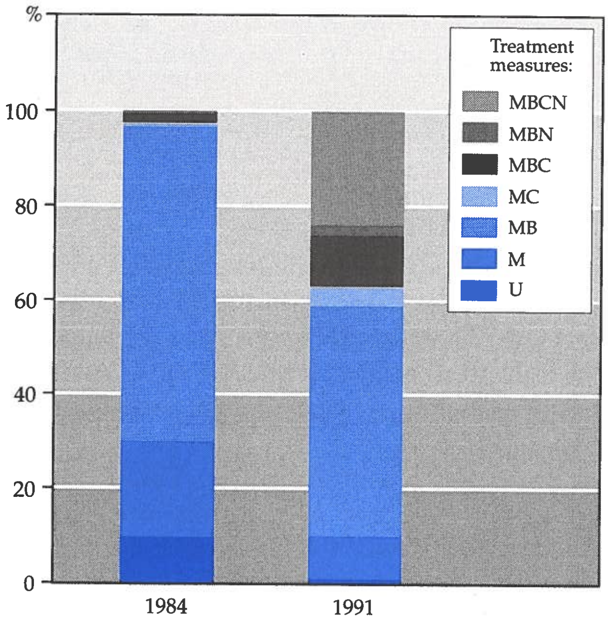


Figure 3.6.2. Treatment procedures employed in 1984 and 1991 apportioned according to the percentage of sewage treated using each procedure. Treatment measures: U = untreated, M = mechanical, B = biological, C = chemical, N = Nitrogen removal. (Source: Danish Environmental Protection Agency, 1992).

kg organic matter per year measured as BOD_5 (the biochemical oxygen demand after five days), 4.4 kg total-N per year or 1.5 kg total-P per year.

The vast majority of the households, about 93%, are linked to the sewerage system and associated treatment plants. Most of the plants (1,499 in 1991) are municipal, and these treat virtually all household sewage together with much of the waste water discharged by industry (cf. section 3.5). However, there are also several smaller, private plants (378 with a capacity of over 30 PE in 1991), but these treat less than 1% of the total amount of sewage. The sewage undergoes various types of treatment processes in the plants where, depending on the type of plant, the nutrient and organic matter content of the sewage is reduced before it is discharged to freshwater or marine environments. Municipal sewage treatment is undergoing major changes in recent years (fewer and larger plants, a greater degree of treatment) as a result of the implementation of the Action Plan on the Aquatic Environment. Treatment procedures employed at municipal and private plants both prior to the implementation of the plan and in 1991 are shown in *Figure 3.6.2*, apportioned according to the percentage of sewage treated using each procedure.

3.6.4 Household waste production

The amount and composition of household waste reflects developments in production, production methods and the kind of goods consumed.

The existing data on waste is from 1985 and is calculated mainly on the basis of statistical information and spot checks of waste from various enterprises and households. The amounts given here are therefore subject to some uncertainty. Moreover, time-series showing the trend in the amount of waste do not exist.

Registration of waste will in future be considerably improved as a result of the implementation of a new registration system in which a number of waste disposal enterprises must register and declare to the Danish Environmental Protection Agency information concerning the waste that they process.

Despite the inadequacy of the available data, there is no doubt that the last 30 years of growth in consumption have led to a major increase in the amount of waste. Of a total waste production by society of 9.3 million tonnes in 1985, household waste, large discarded household items and garden waste together comprised 1.9 million tonnes. In the year 2000, it is expected that this amount will have increased by 5-20%.

Total annual production of waste by households, commerce and business comprised approx. 470 kg per inhabitant. In an international context, this is about average for the OECD countries. In the United States, the figure according to the OECD is 744 kg per inhabitant. However, differences in the registered amounts can to some extent be due to differences between the classification and definition of various categories of waste in the various countries.

In 1985, 51% of household waste was incinerated in waste incineration plants and 33% deposited at dumping grounds, while 16% (mainly newspaper and glass) was recycled.

Recent years have seen several experiments in recycling of household waste, including the testing of various systems for sorting at source, as well as the so-called "ecological waste systems" (composting of the wet, organic fraction of household waste combined with sorting of the dry fraction). Annual collection of newspapers and magazines from private households increased by 45,000 tonnes during the period 1985-90, while annual glass collection rose by about 25,000 tonnes during the period 1985-91. In the period 1987-92, separate collection of compostable and non-compostable waste was implemented in 220,000 households. As a result, an additional 50,000 tonnes of waste is being converted to compost annually.

Recycling arrangements, where the substances or products circulate outside the waste collection system, can save society the expense of processing significant amounts of waste. The established return-system for drink containers, especially that for beer and soft-drink bottles, thus saves society from having to handle and process very large amounts of discarded packaging.

Handling of waste is itself resource demanding, requiring the selection of dumping grounds and entailing environmental nuisance and the risk of contaminating soil and groundwater. The number of dumping grounds (waste tips and landfills) has decreased in recent years, and the capacity remaining at existing grounds is diminishing. However, the amount of waste added to the dumping grounds has fallen in recent years. The number of environmentally approved dumping grounds was 129 in 1991. The capacity remaining at waste tips has been calculated to be 31 million tonnes, and that of landfills to be 14.3 million tonnes. The waste tips and landfills receive about 700,000 tonnes of household waste annually.

Even though technical measures (membranes) at the waste tips limit leaching of pollutants into the soil and groundwater, seepage remains a risk, and it is therefore usually attempted to locate new waste tips in areas lacking in useful groundwater resources. In addition, since the waste tips are usually considered an aesthetic nuisance, the finding of locations for new waste tips is not usually without problems.

There were 39 waste incineration plants in 1992, and they together treated approx. 2.2 million tonnes of waste, of which about 55% was estimated to be household waste. The incineration of waste results in the emission to the air of several harmful substances, as well as the annual production of approx. 50,000 tonnes of substances removed from smoke during purification processes and approx. 400,000 tonnes slag. Part of the slag (approx. 50%) is used as filler material for roads, paths, and noise-deflection ramparts, while the rest must be dumped. Sharpened environmental standards regarding the emission of HCl (hydrochloric acids) and particulates were imposed on waste incineration plants in 1992. Current figures for air pollution from waste incineration plants do not exist. The latest measurements are from 1989, before the sharpening of emission standards. The results of these measurements are shown in *Table 3.6.2*. The figure for dioxin is expressed in "Seveso equivalents", i.e. corresponding to the toxicity of the most toxic dioxin (the Seveso dioxin). The measurements showed a considerably lower dioxin content than originally feared. Installation of de-acidification plants, now well under way, will reduce dioxin emissions considerably. There is no official Danish limit value for dioxin emissions, but a new EU directive on waste incineration plants that is expected to appear in 1994 will stipulate a dioxin limit value.

Compound group	Measured levels 1989
SO_2	1,679 tonnes
HCl	3,771 tonnes
Particulates	1,292 tonnes
Dioxins and furans expressed in Nordic toxicity equivalents	34 g

Table 3.6.2. Atmospheric emissions from waste incineration plants estimated on the basis of measurements undertaken in 1989. (Source: Recalculated from Danish Environmental Protection Agency, 1989).

Total public expenses for waste handling in 1990 ran to an estimated DKK 2,600 million, and there are thus both economic and environmental interests in limiting the amount of waste.

The magnitude of household *oil and chemical waste* has not been determined. The best estimate lies in the range of 20,000-25,000 tonnes annually (including containers), of which 5,000 tonnes is delivered to Kommunekemi A/S, the only authorized chemical waste disposal firm.

The establishment of collection arrangements for oil and chemical waste from the general public with the intention of their disposal in an environmentally defensible manner has been obligatory for the municipalities since January 1, 1991. It is expected that direct household collection of oil and chemical waste will only be offered to part of the country's households. Oil and chemical waste not disposed of via the municipal receiving system, will either end up in the normal waste collection, which can create working environment problems for the employees involved as well as have a negative impact on the external environment.

3.6.5 Household consumption and emission of environmentally foreign substances

By their consumption of household chemicals, households contribute to the discharge of numerous environmentally foreign and environmentally hazardous substances in waste or sewage. As used here, household chemicals shall be understood to mean chemical compounds and products used within the households for various purposes, except for fuels for transport and heating (petrol, oil, etc.), as well as building materials (mortar, plaster, cement, etc.).

Retail sales of chemicals have most recently been reckoned up in 1989 by the Danish Environmental Protection Agency based on data for the years 1985/86 (*Table 3.6.3*). As is apparent from the table, annual consumption of cleaning fluids, textile treatment products and car care products is rather considerable (70,000, 50,000 and 100,000 tonnes, respectively), as is that of surface treatment products.

Detergents constituted 80% of the total textile treatment products, household consumption of detergents thus being approx. 40,000 tonnes per year. This amount flows with the sewage to the municipal sewage treatment plants. Since 1985, phosphate consumption in detergents has fallen by between 30 and 50%, the phosphate having been replaced by zeolites and other alkaline compounds. This reflects the desire to reduce phosphate discharge to the aquatic

Product type	1,000 tonnes/y
Cleaning compounds	70.0
Metal polish	<0.1
Decalcifiers	2.0
Textile treatment products	50.0
Impregnation and leather treatment products	0.3
Surface treatment products	22.0
Glue, sealants, etc	4.4
Furniture and floor polish, etc.	0.2
Car care products, inc. motor oil	100.0
Photographic chemicals	<0.1
Swimming pool chemicals	0.3
Pesticides	<0.1
Fertilizers	17.5
Artists paint	<0.1

Table 3.6.3. Retail sales of chemicals in 1985/86. (Source: Danish Environmental Protection Agency, 1989b).

environment.

Surface treatment products, largely comprising paints, varnish and wood protection products, account for much of the private consumption of and exposure to organic solvents. On this background the Danish Union of Paint and Varnish Manufacturers in 1989 entered into an agreement with the Danish Environmental Protection Agency to over a three year period markedly reduce the volatile organic solvent content of floor varnish, paint, and paint and varnish remover designed for consumer use. The agreement will soon be evaluated, but on first sight it does not seem that the expected results have been achieved.

At present there is no existing total overview over trends in the potential environmental impact of household chemicals or of the actual impact on health and the environment caused by their use by the general public. While examples exist of the marketing of more environmentally friendly household chemicals, it is not known whether this is a general tendency. Besides general classification and labelling regulations, the authorities have not taken initiatives towards specific product groups with regard to minimizing their impact on man and the environment.

3.6.6 Action plans directed at the environmental impact of household consumption

Current initiatives to deal with the impact household consumption has on the environment are directed towards establishing systems to counteract the growing amounts of waste, and towards water consumption and sewage.

As regards waste, the primary objective is to reduce the amount and environmental impact of all types of waste. A secondary objective is to utilize the resources in the waste in the best possible way, first and foremost the materials in the waste, secondarily the energy content of the waste. The hierarchy of measures for reducing and handling the waste is therefore: promotion of cleaner product technology, recycling of materials in waste (inc. composting), incineration of waste combined with utilization of the energy thereby released, and environmentally defensible dumping.

The initiatives which aim at limiting the amounts of solid waste - the waste prevention measures - include promoting less polluting and waste-intensive products, as well as promoting and ensuring a return cycle for products and substances outside the municipal waste collection system. The control instruments for implementing these measures include legislation, subsidies, charges and branch agreements.

As regards recycling, the government Action Plan on Waste and Recycling from 1992 has as its goal to increase the recycling of household waste from the existing level of approx. 16% to 50% before the year 2000. This goal is expected to be achieved if 2/3 of the country's households are included in a waste scheme comprising at source sorting of household waste into four fractions: organic waste for composting; dry recyclable waste, including newspaper, paper and cardboard; glass; and other waste.

Furthermore, it is planned that all waste which is not intended to be recycled, or whose incineration does not give any special environmental problems, should be redirected to incineration during the course of the 1990s.

Of the large discarded household items that have to be disposed of, the majority are electrical and electronic appliances, e.g. refrigerators, freezers, and other kitchen appliances, as well as audio, video and computer equipment. In total, this type of waste is estimated to amount to 100,000 tonnes annually. It is estimated that if a return scheme for these products could be established, it would account for 30,000-35,000 tonnes waste per year. The goal for 1994 is to establish branch agreements for voluntary return-to-manufacturer schemes for unwanted appliances and electronic products.

As regards the aquatic environment, it is the goal of the Danish Environmental Protection Agency's groundwater strategy to ensure groundwater resources of sufficient magnitude and quality to meet the needs of future generations. If effective protection of the groundwater resources is not implemented in combination with an active effort towards reducing water consumption, it will have wide-ranging consequences for our future drinking water supply.

Efforts are therefore being directed towards limiting unnecessary water consumption. As far as concerns household consumption, this means that fraction of consumption attributable to the poor habits that have arisen as a result of water having been an easily accessible and cheap consumer commodity, as well as the water lost from the supply network by leakage.

Household consumption can be influenced by registering abnormal deviation from consumption norms, by minimizing consumer demand, by placing restrictions on garden watering, by installing water meters and by diffusing consumer information. Experience shows that more widespread installation of water meters can help limit water consumption. Charging on the basis of actual consumption will also insure that there is a direct relationship between water consumption and costs.

Most large water supply facilities charge according to measured water consumption, either by measuring consumption in the individual household or by measuring the combined water consumption of several households, whereas many smaller waterworks charge on the basis of estimated consumption. At present an estimated 820,000 water meters are in use for measuring household consumption.

Of these, approx. 670,000 are in single-family homes, while approx. 150,000 are in apartments or two-family homes, where consumption is measured collectively for the building as a whole. It is further estimated that there are an additional 415,000 households where consumption is not measured.

The savings potential in household consumption is estimated at 5-10% in the short term. Savings can be achieved through increasing awareness of water consumption, through maintenance of the existing installations, through utilization of simple water-saving installations, and through increasing consumer charges and thereby providing an incentive to save.

It is estimated that the possibilities for economizing on household water consumption could in the long term amount to 25% of current water consumption. However, such a saving would necessitate the replacement of household fixtures such as taps and toilets, a measure that would be costly for many consumers. It must therefore be estimated that most consumers will delay purchasing major fixtures until the existing ones are no longer serviceable. Hence, several years will pass before the reduction in household water consumption will reach its full extent.

As regards household *sewage*, comprehensive expansion of sewage treatment measures at the municipal treatment plants is currently under way as a result of the 1987 Action Plan on the Aquatic Environment (cf. sections 2.4 and 3.5).

In order to limit the damage caused by *environmentally hazardous and environmentally foreign substances* derived from household consumption, the Danish Environmental Protection Agency is working to replace products within those product groups which have especially harmful effects. Initiatives are thus under way aimed at reducing the environmental impact of detergents. The tightening of requirements for biodegradability is being considered at both the national and EU levels, and a project has been initiated to develop easily degradable tensides. Two voluntary agreements have been entered into with SPT (the soap, perfume and toiletries branch association) to limit the use of certain undesirable tensides. In order to reduce the use of environmentally harmful detergents, criteria for EU eco-labelling of detergents and cleaning compounds are being elaborated, and consideration is being given to tightening the provisions of the Chemical Substances and Products Act governing the conditions under which products may be marketed as environmentally safe.

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