

# Attacking air pollution

*Critical loads, airborne nitrogen, ozone precursors*



*Principal papers read at the  
Fourth European NGO Strategy Seminar on Air Pollution  
in Göteborg, Sweden, April 28-30, 1995*



The Swedish  
NGO Secretariat  
on Acid Rain

## **The Swedish NGO Secretariat on Acid Rain**

The Swedish NGO Secretariat on Acid Rain was formed in 1982 with a board now comprising one representative from each of the following organizations: Friends of the Earth Sweden, the Swedish Anglers' National Association, the Swedish Society for Nature Conservation, the Swedish Youth Association for Environmental Studies and Conservation, and the World Wide Fund for Nature Sweden.

The essential aim of the secretariat is to promote awareness of the problems associated with air pollution, and thus, in part as a result of public pressure, to bring about the necessary reduction of the emissions of air pollutants. The eventual aim is to have those emissions brought down to levels – the so-called critical loads – that the environment can tolerate without suffering damage.

In furtherance of these aims, the secretariat operates as follows, by

- Keeping under observation political trends and scientific developments.
- Acting as an information centre, primarily for European environmentalist organizations, but also for the media, authorities, and researchers.
- Publishing a magazine, Acid News, which is issued five times a year and is distributed free of charge to some 5000 selected recipients.
- Producing and distributing other information material.
- Supporting environmentalist bodies in other countries by various means, both financial and other, in their work towards common ends.
- Acting as coordinator of the international activities, including lobbying, of European environmentalist organizations, as for instance in connection with the meetings of the bodies responsible for international conventions, such as the Convention on Long Range Transboundary Air Pollution.
- Acting as an observer at the proceedings involving international agreements for reducing the emissions of greenhouse gases.

The work of the secretariat is largely directed on the one hand towards eastern Europe, especially Poland, the Baltic States, Russia, and the Czech Republic, and on the other towards members of the European Union. By emitting large amounts of sulphur and nitrogen oxides, all the countries here in question add significantly to the depositions of acid over Sweden.

As regards the eastern European countries, activity mostly takes the form of supporting and cooperating with the local environmentalist movements. Since 1988, for instance, financial support has been given towards maintaining information centres on energy, transport, and air pollution. All are run by local environmentalist organizations.

# Attacking air pollution

Critical loads, airborne nitrogen, ozone precursors

Report from the Fourth European NGO Strategy Seminar on Air Pollution

Göteborg, Sweden, April 28-30, 1995

**Previous reports in the series:**

No. 1 The Eastern Atmosphere (1993)

No. 2 The "Black" Triangle – a General Reader (1993)

No. 3 Sulphur emissions from large point sources in Europe (1995)

No. 4 To clear the air over Europe (1995)

No. 5 Large combustion plants. Revision of the 1988 EC directive (1995)

No. 6 Doing more than required. Plants that are showing the way (1996)

**AIR POLLUTION AND CLIMATE SERIES**

Attacking air pollution. Critical loads, airborne nitrogen, ozone precursors.

Edited by Per Elvingson and Christer Ågren.

Cover illustration: © Dan Rapp.

ISBN: 91-558-3624-0

ISSN: 1400-4909

Printed by Williamssons Offset AB, Stockholm, Sweden, 1996.

Published by The Swedish NGO Secretariat on Acid Rain, Box 7005,  
S-402 31 Göteborg, Sweden. Phone: +46-31-10 55 90. Fax: +46-31-711 46 20.

Further copies can be obtained free of charge from the publisher,  
at the above address.

# Introduction

In April 1995 representatives of European environmentalist organizations convened for the fourth time to exchange experiences and discuss common aims and strategies for bringing down emissions of air pollutants to levels that nature will be able to tolerate in the long term.

Since the last seminar of this kind in 1992, a considerable advance had been recorded at the political level with the signing in Oslo in 1994 of the revised sulphur protocol under the Convention on Long Range Transboundary Air Pollution. The knowledge that has in the meantime accumulated in the scientific field can be said, too, to have confirmed previous conclusions in regard to nature's sensitivity to air pollutants – what is called the critical loads.

Considering the gap between the scientifically determined critical limits for nature's tolerance and the actual measures that have so far been taken, it is obvious that much remains to be done. The statement that emanated from this last seminar – backed by twenty-five environmentalist organizations – calls for a reduction of the emissions of sulphur and nitrogen oxides by at least 90 per cent, and those of ammonia and volatile organic compounds by at least 75 per cent. This will involve considerable changes in several sectors of the community, as is also adumbrated in the statement.

We are reproducing here, besides the statement, the principal papers read at the seminar – which, with their updated information in regard to the critical loads and critical concentrations for air pollutants, were prominent among the items on the agenda reinforcing calls to reduce emissions.

As long as depositions of airborne pollutants exceed the critical loads, damage will occur in the environment. It is our hope that the outcome of the seminar will, with the publication of this report, help environmentalist and similar organizations, as well as individuals, to rouse opinion against air pollution.

Göteborg, July 1996

*Håkan Carlstrand*

Chairman, Swedish NGO Secretariat on Acid Rain

## *Contents*

Statement	1
International air pollution control: the critical loads approach	5
Ecological effects of airborne nitrogen pollutants	11
Critical ozone exposures and the needed reduction of emissions of ozone precursors	19
Present and expected EU directives related to acidification, eutrophication, and air quality	25
List of participants	28

## Statement

Air pollutants from power plants, land, sea and air traffic, industry and farming, all contribute to the heavy environmental stress that is affecting human health, ecosystems, and materials throughout Europe. It is estimated that sulphur for instance is being deposited in amounts that are damaging to the environment over almost a third of the area. In some of the central and northwestern parts of the continent the depositions are twenty or more times higher than the critical loads. Forests, soils, groundwaters and surface waters will inevitably be affected.

Furthermore, more than half of Europeans are exposed to concentrations of tropospheric ozone that exceed the World Health Organization's guide value.

Drastic reductions in emissions of air pollutants are urgently needed in order to protect human health, as well as the natural and man-made environment. To stop the progressive deterioration of the environment, it will be necessary to reduce the concentrations and depositions of air pollutants to below the critical loads.

Critical loads can be defined as estimates of the exposure to one or more pollutants above which adverse effects on receptors, such as plants, ecosystems or materials, may occur. Expressed more simply, critical loads are the maximum amounts of pollutant that ecosystems can tolerate without suffering change or damage.

### *Necessary reductions*

Taking as a basis up-to-date and internationally agreed scientific data on critical loads, we at this seminar reaffirm the need to achieve the following objectives concerning total European emissions of air pollutants, which were first agreed upon by environmentalist organizations in 1992:

- At least a 90-per-cent reduction in emissions of sulphur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>).
- At least a 75-per-cent reduction in emissions of volatile organic compounds (VOCs) and ammonia (NH<sub>3</sub>).
- At least a 75-per-cent reduction in concentrations of tropospheric ozone, to be achieved by meeting the objectives for NO<sub>x</sub> and VOCs as above.

The reductions refer to the emission levels of the early 1980s and apply both to western and eastern Europe, including the European part of Russia.

These are minimum demands, but they do not necessarily imply that all countries or regions must achieve equal reductions. In areas with very high emissions, greater reductions will be necessary, while in others the reductions, while still necessary, may be lower.

With improved methods of scientific research and increased knowledge, it is likely that the data on critical loads will have to be continually reviewed and revised. The degrees of reduction will, in consequence, also have to be reconsidered.

The critical-loads concept must not be taken as an excuse for allowing an increase in the concentrations and depositions of pollutants in areas now receiving pollutants below the critical loads.

### *Timeframe*

Hitherto the response of governments to the damage caused by air pollutants has been totally inadequate, although progress has been

made in some countries, especially in reducing emissions of sulphur. Together with international agreements such as the 1985 Sulphur Protocol to the Convention on Long Range Transboundary Air Pollution (CLRTAP), this has resulted in a reduction of 37 per cent in European emissions of sulphur dioxide between 1980 and 1992.

As regards nitrogen oxides, volatile organic compounds and ammonia on the other hand, only limited commitments have been made to control emissions, although evidence confirms that drastic reductions of these pollutants, too, will be required in order to safeguard human health, forests and other sensitive ecosystems over large areas of eastern and western Europe.

Since critical loads are now being widely exceeded, and have been for several decades, the need for action to curb emissions is becoming increasingly urgent. From an environmental point of view, the above reductions should be carried out without delay.

#### *For achieving reductions*

Bilateral, multilateral, and international agreements and arrangements should be used to achieve reductions as a matter of urgency. To make faster progress than international measures may require, nations could take unilateral action.

Priority must be given to the prevention of pollution at source, by establishing this as a central criterion both in energy planning and economic development.

A main aim should be to change the present energy system, based on fossil sources, to one based on renewable sources of energy.

It should be noted that the strategy here proposed for reducing emissions of sulphur dioxide, nitrogen oxides, and volatile organic compounds (including methane) has significant implications for energy use, and thus will also lower the atmospheric concentrations of greenhouse gases such as low-level ozone and carbon monoxide, as well as lowering emissions of carbon dioxide, which is the main pollutant contributing to global warming.

The urgency of meeting the reduction targets demands that a range of measures be adopted, including:

- increasing the conservation of energy;
- using renewable energy sources;
- increasing the efficiency of energy production, distribution, and use;
- switching to less polluting fuels;
- applying best available techniques in the energy, transportation, industrial, and agricultural sectors.

The price of fuel and electricity should more readily reflect the real cost to society of the social and environmental effects (so-called externalities) of air pollution and the inefficient use of energy and other resources.

The European countries and the European Union should base their transport policies primarily on environmental criteria. Priority should be given to the development of modes of transportation that have the least effect on the environment.

Measures to reduce emissions of air pollutants from the transport sector include:

- the implementation of volume control, including for example no building of new major roads, improved land-use planning to prevent urban sprawl, and increased investment in public transportation and railway freight systems;
- the adoption of plans and timetables to significantly reduce the total European volume of road and air traffic;
- in urban areas, priority should be given to cyclists, pedestrians, and public transportation;
- the adoption of standards or other mechanisms for increasing the fuel efficiency of all new motor vehicles, as well as of aircraft and ships;

- the adoption of properly regulated emission standards for all new motor vehicles, including off-road vehicles, as well as for aircraft and ships;
- the adoption of a maximum speed limit for road traffic of 100 kph. Progressive environmental standards should not be held to be trade barriers. Any harmonization that affects environmental standards should be at the most stringent current level.

Financial incentives and disincentives, such as levies on petrol, diesel, and kerosene, are useful tools in reducing air pollution. Taxing of resources and pollution could be used as a means of lowering taxes on employment – a so-called tax shift.

#### *Relations between West and East*

The proposed reductions and the measures to achieve them should apply equally to western and eastern Europe. In the case of eastern Europe, some specific strategies should be taken into account:

- Western European countries should undertake, bilaterally or jointly, concrete projects to assist eastern European countries in their implementation of programs for the prevention of pollution. Training and demonstration programs for clean technologies and environmental policies should be followed up by actual implementation;
- The introduction and application of environmental standards, based on the best examples of European environmental policy and legislation, should be accelerated;
- Multilateral development banks and financial assistance programs should give priority to projects that will discourage energy wastage and instead focus on improving energy efficiency within the energy and industrial sectors, and require assessments of the environmental impact, the outcome of which should be decisive for the further development of the projects.

#### *Access to information and consultation*

All data held by authorities in European states as well as by the European Commission concerning the emission, transport, concentration, and deposition of pollutants should be made publicly available.

In the development of environmental legislation, full consultation should take place both with the public and with non-governmental environmentalist organizations.

#### *Participants*

Convened by the Swedish NGO Secretariat on Acid Rain, the seminar was attended by representatives of twenty non-governmental environmentalist organizations from twelve European countries.

#### INTERNATIONAL ORGANIZATIONS:

- European Environmental Bureau
- European Federation for Transport and Environment
- International Institute for Energy Conservation Europe

#### NATIONAL ORGANIZATIONS:

- Bond Beter Leefmilieu, Belgium
- Clean Air Action Group, Hungary
- Community Atgaja, Lithuania
- Estonian Green Movement/FoE Estonia
- The Finnish Society for Nature Conservation
- The Finnish Society for Nature and Environment
- Foundation for Alternative Energy, Slovakia
- Friends of the Earth Sweden
- Greenpeace in Czech and Slovak Republics
- Hungarian Traffic Club

- Lithuanian Green Movement/FoE Lithuania
- The Norwegian Society for Nature Conservation/FoE Norway
- Polish Ecological Club/FoE Poland
- Slunicko Foundation, Czech Republic
- Sustainable Energy Information Office, Latvia
- The Swedish NGO Secretariat on Acid Rain
- Traffic League, Finland

ALSO ENDORSING THE STATEMENT:

- Friends of the Earth International
- Greenpeace International
- WWF International
- AEAEDAT, Spain
- CODA, Spain

# **International air pollution control: the critical loads approach**

*Presentation by Christer Ågren  
The Swedish NGO Secretariat on Acid Rain*

The first attempts at calculating "tolerable levels" for deposition of acidifying pollutants were made in Sweden and Canada during the late seventies. It was done by studying and comparing lakes in different areas that were exposed to varying levels of acid deposition, and so determining at what deposition levels lakes had become acidified.

The general concept gained international acceptance at the meeting of experts at the 1982 Stockholm Conference on the Acidification of the Environment. In their conclusions the experts stated that "observations from Sweden, Norway, and Canada show that in sensitive areas receiving more than 0.5 g S/m<sup>3</sup>/yr, the lakes do not experience long-term acidification." They did also say however that in some very sensitive areas, acidification could already take place at deposition levels as low as 0.3 g S/m<sup>3</sup>/yr.

In 1986 an international scientists' workshop organized by the Nordic Council of Ministers was the first to produce a definition of critical load: "The highest load that will not cause chemical changes leading to long-term harmful effects on the most sensitive systems."

## **The critical loads approach**

In 1988, the Executive Body of the Convention on Long Range Transboundary Air Pollution (CLRTAP) adopted the critical load concept, making it basic to the future development of international agreements aimed at limiting the emissions of air pollutants. In Article 2, para. 3a, of the 1988 Protocol on control of emissions of nitrogen oxides, it says that further steps should be taken to reduce emissions and that critical loads should then be taken into account.

As work within the Convention has proceeded, various alternative definitions of a critical load have been essayed, the most favoured being: "A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge." This was coined at a scientific workshop on critical loads, held in the Federal Republic of Germany in April 1988.

Almost simultaneously, also in 1988, another scientific workshop under the convention, this time dealing with gaseous forms of pollutant, produced a definition referring to critical levels: "The concentrations of pollutants in the atmosphere above which direct adverse effects on receptors such as plants, ecosystems or materials may occur, according to present knowledge."

At the meeting of the Executive Body of the Convention in November 1988, a new working group, entitled the Working Group on Abatement Strategies, was appointed to develop a common understanding of the critical loads approach and to evolve abatement strategies based on that approach. In 1989 its mandate was further

extended when the Executive Body asked it to prepare a new protocol for bringing about a further reduction of sulphur emissions after 1993, when the relevant Helsinki protocol was due to expire.

This working group presented a report on "The critical load concept and the role of the best available technology and other approaches" to the Executive Body in 1991. It contained the conclusion that the critical-loads concept provided an acceptable, effects-based scientific approach by which to devise strategies for the abatement of air pollution. The essence of the critical-loads approach is that reductions of emissions are to be negotiated on the basis of the effects of air pollutants, instead of calling for an equal percentage of reduction for every country. The goal is to reduce, in a cost-effective manner, the emissions of air pollutants to levels where, ultimately, the critical loads will not be exceeded.

It was further said in the report that because of economic, technological, and other constraints, the reductions may not be attainable everywhere, or in one step, and therefore an approach involving several steps is likely to be needed. Late in 1991 a Working Group on Strategies was formed, replacing that on Abatement Strategies and taking over its assignments.

### The practical application

Here follows a rough outline of the way the critical-loads approach is being used in working out new agreements.

Taking current and projected emissions and monitoring data as a basis, national assessments are made of current and projected loads and levels of various pollutants. This can be done by using computer models, such as RAINS (developed by IIASA, the International Institute for Applied Systems Analysis).

Each country has to make maps, depicting the critical loads and levels for various areas, receptors, and pollutants in its own territory. (It is important that the resolution size of such maps should be such as to avoid irrelevant average figures for large areas, and allow the most sensitive areas/receptors have real influence.) To provide guidance as to how the mapping should be done, the Convention's Task

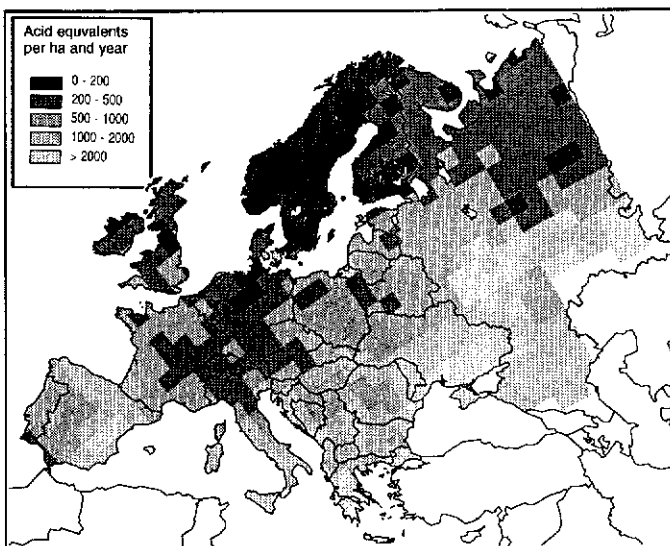


Figure 1. Critical deposition of sulphur: 5 percentile. The map shows the sensitivity of ecosystems – forest soils and surface waters – to sulphur deposition. The darker the shading, the more sensitive the area. The values are calculated to protect 95 per cent of the ecosystems in each grid cell.

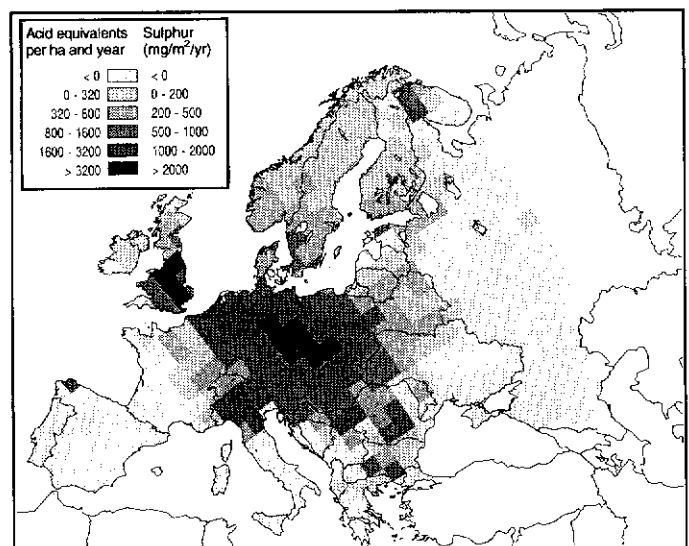


Figure 2. Degree of the exceeding of critical depositions of sulphur in 1990 (5 percentile). The darker the shading, the greater the extent to which the critical loads were being exceeded.

Force on Mapping of Critical Levels and Loads has published a "Draft manual on methodologies and criteria for mapping critical levels/loads, and geographical areas where they are exceeded."

Mapping is now steadily proceeding, after having started with maps for sulphur and/or total acidity (Figure 1). Now under production are maps for nitrogen (showing both acidifying and eutrophying effects), to be followed by maps for tropospheric ozone. The resulting data is being assembled by the Coordination Center for Effects (CCE), and used in the production of Europe-wide maps for critical loads. Taking data on the current depositions of pollutants, the CCE makes further maps showing where and by how much the critical loads are being exceeded over various parts of Europe (Figure 2).

A term that is also appearing in political negotiations aimed at the reduction of emissions is "target load." While determined essentially in accordance with the critical load concept, target loads take other aspects into consideration as well, such as national environmental objectives. They may therefore be higher or lower than the critical loads, depending on the manner in which the situation is judged in different cases (Figure 3). They may be set lower, for instance, in order to leave a margin of safety, thus following a practice that is standard in the medical field. Target loads may on the other hand be allowed to be higher, which means in effect a deliberate acceptance of a certain degree of environmental damage. When set higher, they may be regarded as interim targets, reflecting the need for a stepwise approach to the reduction of emissions – in which case they should later be progressively reduced to a level at or below the critical load.

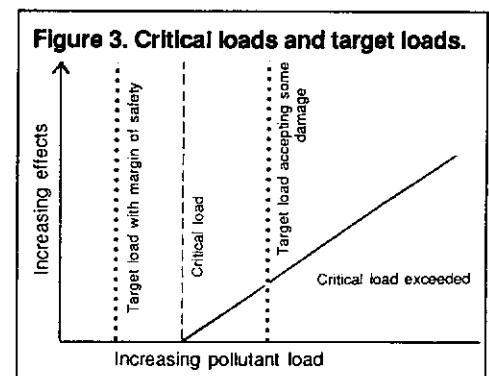
Computer models for integrated assessment, such as RAINS, will enable comparisons to be made of the cost and effectiveness of various abatement strategies for the achievement of target loads. The models can also help in finding cost-optimized strategies, in which case they can be used to calculate how, on the basis of agreed target loads, emission reductions should be distributed among the various countries in order to arrive at the least-cost solution for Europe as a whole.

In order to arrive at further agreements for the reduction of emissions, international negotiations are to take place on target loads and strategies for abatement. Such agreements are likely to result in the setting of varying (intermediate) ceilings for each country, under which it must have brought its emissions by a specified year, as in the new sulphur protocol.

### The new sulphur protocol

A new sulphur protocol based on the critical loads concept was finalized and signed in Oslo in June 1994. After it had been accepted early in the negotiations that the new protocol should only constitute a first step, it was agreed to proceed according to a scenario under which the differences between current (1990) depositions and critical loads were to be reduced by at least 60 per cent – this being known as the 60-per-cent gap closure. Another general starting point was that different requirements should be made of the various countries, depending on the extent of the damage to which their emissions gave rise, and on the estimated costs of reducing those emissions. The intention was to bring about measures which on the European level would be as cost-effective as possible.

The scenario, which was developed by using the RAINS model, indicated the reductions required of each country for attaining the agreed target. These national reductions (or emission ceilings) then became objects for negotiation. Some countries were able to agree to their allotted targets, others were not. The latter would usually



propose higher emission ceilings for their countries or request a longer period for implementation – in some cases both. But ultimately agreement was reached on a list of country-by-country emission ceilings, with target years for their attainment (Table 1).

Besides prescribing ceilings for national emissions, the protocol contains some requirements calling for the use of best available technology (BAT) in large combustion plants, as well as a maximum sulphur content for diesel and gas oils. For new plants the emission standards are essentially similar to those introduced in the European Community in 1988, which in fact reflected the technical level of the early 1980s. While there are no mandatory standards for existing plants, there is a strong recommendation to apply the same limits as for new ones to the largest plants (500MW<sub>th</sub>), starting no later than July 1, 2004. For other existing plants (50-500 MW<sub>th</sub>) the limit values are only to be “used as guidance.”

### The new nitrogen protocol

After the signing of the new sulphur protocol, attention turned to the revision, long overdue, of the 1988 protocol on nitrogen oxides. It became clear at an early stage of the talks, which started in the autumn of 1994, that a majority of the countries were prepared to accept a protocol on the same lines as the new one for sulphur. One main question is just how comprehensive it shall be. So far most

**Table 1. Signers of the 1994 sulphur protocol, with expected reductions and new commitments. Reductions of sulphur emissions in per cent from base year 1980.**

Country	CRP <sup>1</sup>	A5 <sup>2</sup>	Commitment <sup>3</sup>		
			2000	2005	2010
Austria	80	80	80	–	–
Belgium	48	77	70	72	74
Bulgaria	50	50	33	40	45
Canada	–	–	30	–	–
Croatia	–	–	11	17	22
Czech Republic	30	72	50	60	72
Denmark	61	87	80	–	–
Finland	80	80	80	–	–
France	67	80	74	77	78
Germany	90	90	83	87	–
Greece	-49	-49	-49	-45	-43
Italy	48	73	65	73	–
Liechtenstein	–	–	75	–	–
Luxembourg	58	58	58	–	–
Netherlands	77	77	77	–	–
Norway	50	76	76	–	–
Poland	37	66	37	47	66
Russian Fed.	38	38	38	40	40
Slovakia	30	72	60	65	72
Slovenia	–	–	45	60	70
Spain	35	55	35	–	–
Sweden	81	83	80	–	–
Switzerland	52	52	52	–	–
Ukraine	56	56	40	–	–
United Kingdom	48	79	50	70	80
European Union	–	–	62	–	–

<sup>1</sup> CRP = Current Reduction Plans: reductions by 2000 as expected *before* the new sulphur protocol was signed, according to the RAINS model by IIASA.

<sup>2</sup> A5 = 60 Per Cent Gap Closure Scenario: required reductions by 2000 after international cost-optimization, according to the RAINS model.

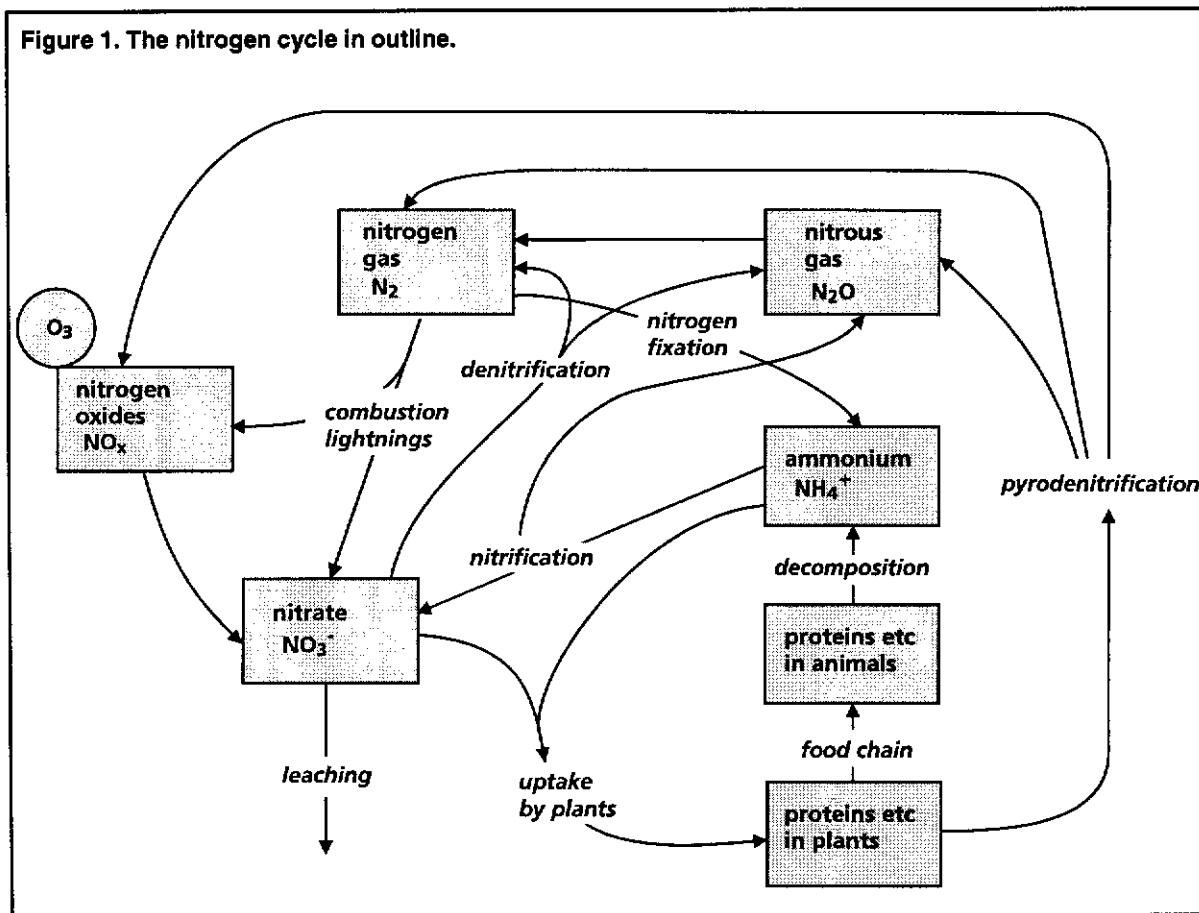
<sup>3</sup> Commitment = Committed reductions by the years 2000, 2005, and 2010 according to the 1994 CLRTAP Protocol on Further Reduction of Sulphur Emissions.

- attending the meetings also provides opportunities for direct lobbying, and may help to establish new contacts;
- supplying national environmentalist groups and the media with information on what is going on at these international meetings, in order to increase the public's interest and help form public opinion. Contacts with the media also provide good opportunities for presenting NGO standpoints;
- delivering statements presenting views and standpoints to Convention meetings;
- criticizing developments actively and publicly – both in respect of the Convention and of specific countries – for example by pointing out where commitments have been made but not fulfilled;
- presenting and distributing constructive proposals and alternatives.

It is highly important for NGOs to keep a close watch on developments, and to try and ensure, by exerting pressure both at the national and international level, that the new protocols will be really effective instruments. It was in furtherance of this end that the Swedish NGO Secretariat on Acid Rain had arranged this seminar.

### References/further reading

- Acid News** (1982-1995) Magazine published by the Swedish NGO Secretariat on Acid Rain.
- Downing, R., Hettelingh, J-P., and de Smet, P. (Eds.) (1993) **Calculation and mapping of critical loads in Europe. Status report 1993.** Coordination Center for Effects, RIVM. Bilthoven, the Netherlands.
- Elsworth, S. & Ågren, C. (Eds.) (1986) **The limits to nature's tolerance.** Report from the NGO conference on acid rain. Lida, Stockholm, Sweden. September 6-7, 1986. The Swedish NGO Secretariat on Acid Rain. Göteborg, Sweden.
- Elvingson, P. & Ågren, C. (Eds.) (1992) **Critical loads for air pollutants.** Report of the Third International NGO Strategy Seminar on Air Pollution. Göteborg, Sweden, April 10-12, 1992. The Swedish NGO Secretariat on Acid Rain. Göteborg, Sweden.
- Smit, H. (Ed.) (1989) **Nature demands stricter limits.** NGO strategy seminar on air pollution. Ede, the Netherlands. April 3-4, 1989. Stichting Natuur en Milieu. Utrecht, the Netherlands.
- Ågren C. et. al. (Eds.) (1982) **Taraxacum** No. 1, 1982. Theme issue on acid rain. International Youth Federation for Environmental Studies and Conservation (IYF). Skanderborg, Denmark.
- (1995) **Critical loads: So much and no more.** Environmental Factsheet No. 6. The Swedish NGO Secretariat on Acid Rain. Göteborg, Sweden.
  - (1982) **Ecological effects of acid deposition.** Report and background papers 1982 Stockholm Conference on the Acidification of the Environment. Expert meeting I. National Swedish Environmental Protection Board Report 1636. Solna, Sweden.
  - (1988) Protocol to the 1979 Convention on long range transboundary air pollution concerning the control of emissions of nitrogen oxides or their transboundary fluxes. United Nations Economic Commission for Europe, Geneva, Switzerland.
  - (1994) Protocol to the 1979 Convention on long range transboundary air pollution on further reduction of sulphur emissions. United Nations Economic Commission for Europe, Geneva, Switzerland.



together with some lichens and mosses. There are, too, free-living nitrogen-fixing micro-organisms. It is a riddle to biologists why *biological nitrogen fixation* has not evolved in other organisms.

Nitrogen occurs in several different states of oxidation, and different types of micro-organisms can use this in their metabolism. In a process called *nitrification*, chemical energy is obtained by certain bacteria through the conversion of ammonium ( $\text{NH}_4^+$ ) into nitrate ( $\text{NO}_3^-$ ). This process is favoured by abundant ammonium and at relatively high pH-values. It is a strongly acidifying process, since two hydrogen ions are formed for each molecule of nitrate. Compared with ammonia, nitrate is more prone to leaching to ground water and thus nitrification tends to stimulate this type of nitrogen loss from the ecosystem. In the nitrification process some nitrogen is moreover lost to the atmosphere as nitrous gas ( $\text{N}_2\text{O}$ ).

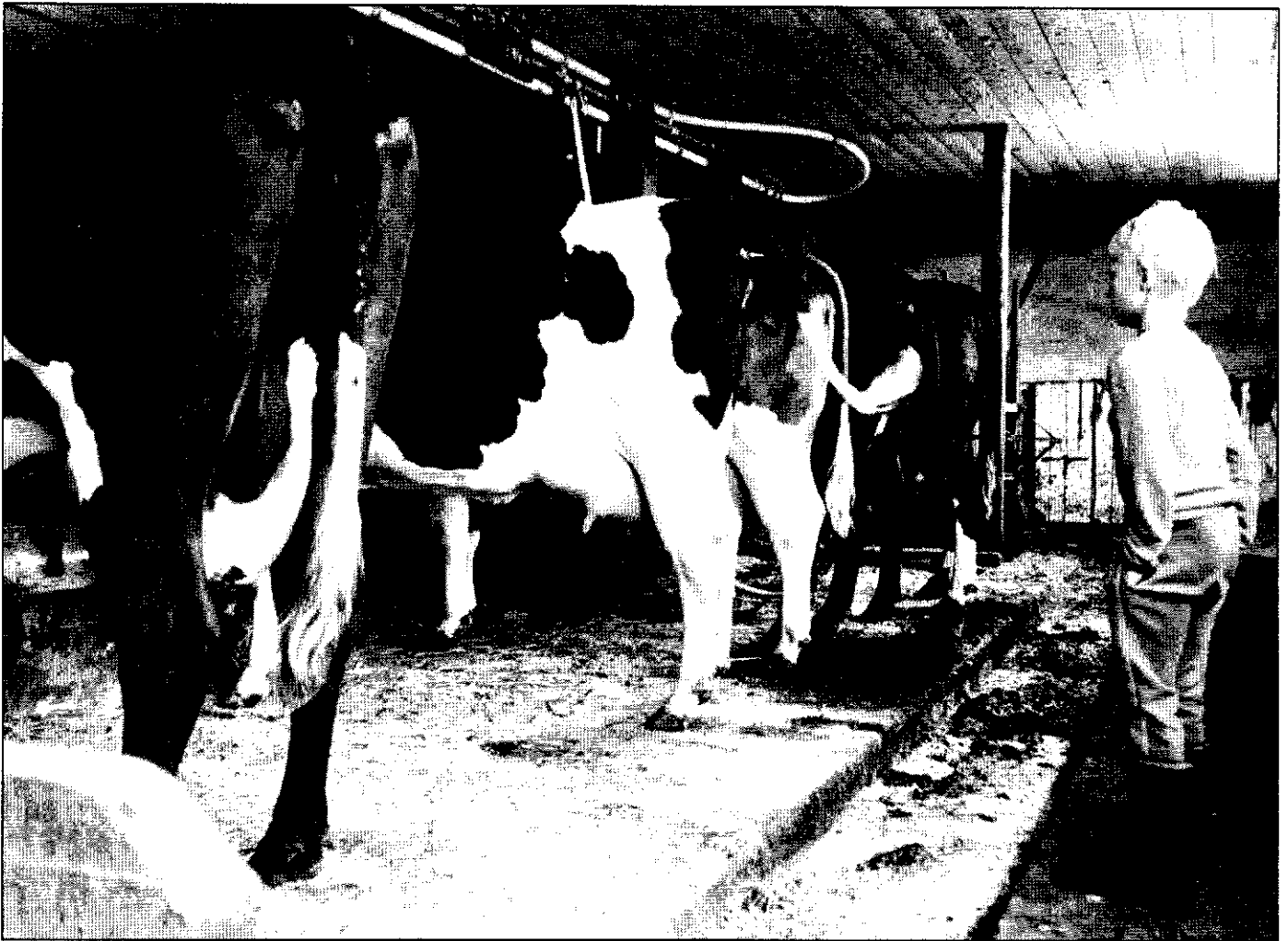
Another important microbial process is *denitrification*. Under certain soil conditions the denitrifiers use nitrate instead of oxygen in the respiration, whereby  $\text{N}_2$  and/or  $\text{N}_2\text{O}$  is formed. Since most of the rather long-lived  $\text{N}_2\text{O}$  in the atmosphere ends up as  $\text{N}_2$ , two processes of gaining plant-available nitrogen have thus been identified:

1. Electrical discharge.
2. Biological nitrogen fixation.

Two processes in which plant-available nitrogen is lost are:

1. Nitrification.
2. Denitrification, biological or through fires (=pyrodenitrification).

And so the traditional version of the natural nitrogen cycle has been outlined. It may however be worth mentioning that it has recently been found that vegetation can emit nitrogen monoxide ( $\text{NO}$ ), which can easily be converted into plant-available nitrate, but can also participate in ozone-forming reactions.



### Disturbance of the nitrogen cycle by human activities

Most of the environmental problems related to nitrogen compounds are caused by human intervention in the natural nitrogen cycle. Among the more important causes of disturbance are:

- electrical discharges from automobile engines, power plants, and some industrial processes, whereby nitrogen oxides ( $\text{NO}_x$ ) are formed, which means that plant-available and ozone-forming nitrogen compounds are created from non-plant-available nitrogen gas and oxygen gas;
- the artificial production of plant-available nitrogen for use as plant fertilizer, mainly in agriculture;
- the release of fossil nitrogen reservoirs into the atmosphere, mainly in the form of  $\text{NO}_x$  from the burning of fossil fuels;
- the stimulation of microbial processes such as nitrogen fixation, nitrification and denitrification, especially in agriculture;
- the formation of nitrous oxide in reductive processes such as the three-way catalytic cleaning of car exhausts and catalytic cleaning of the flue gas from power plants.

Thus human activities lead to an increase in the reservoirs of nitrogen in plant-available forms, which in turn stimulates nitrification and denitrification.

### Eutrophication

Most ecosystems respond strongly, through changes in their structure and function, to changes in nitrogen availability – the reason being that nitrogen is the growth-limiting nutrient in most ecosystems.

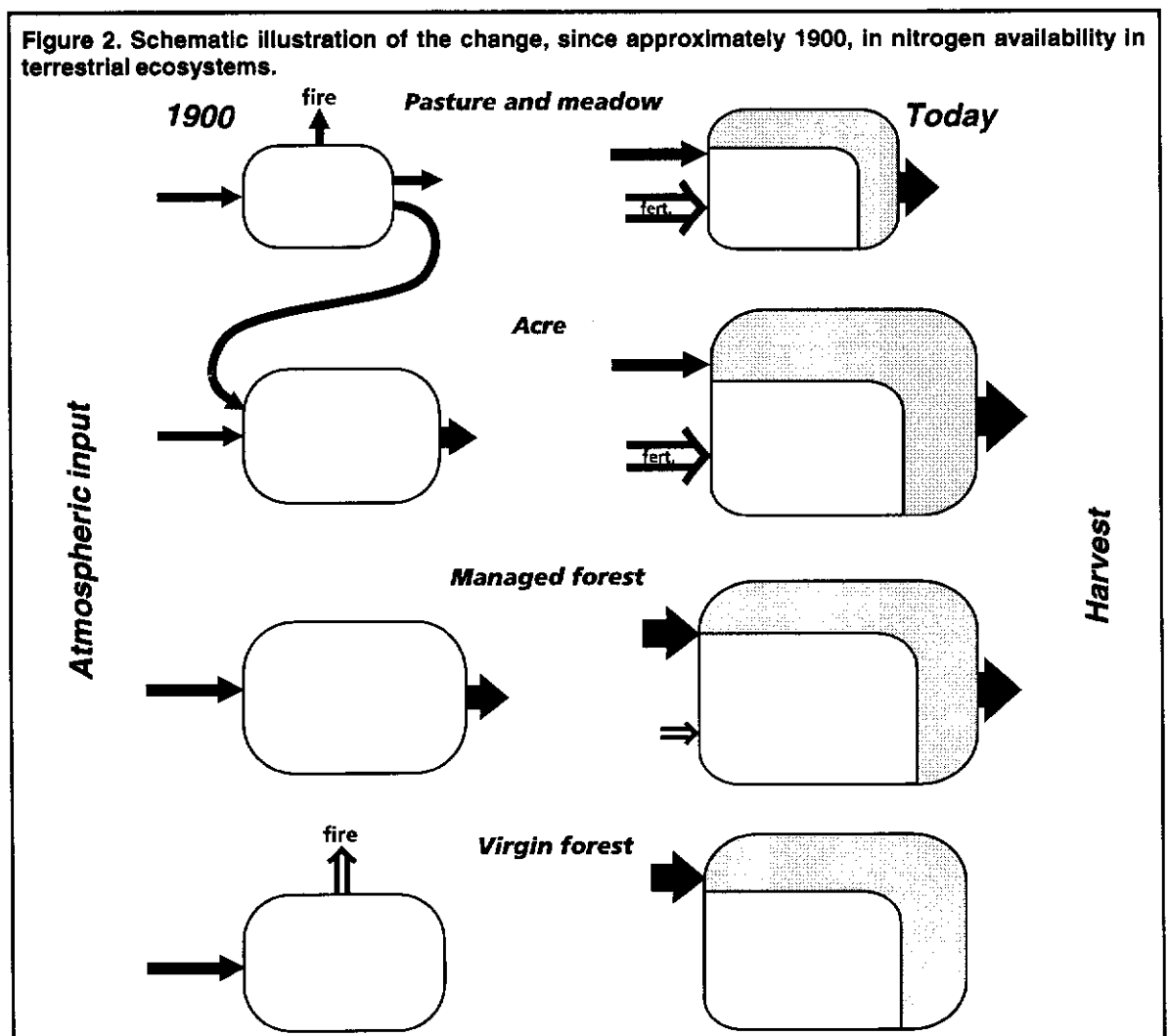
The increase in the nitrogen available to plants in various ecosystems is shown in Figure 2. Because of atmospheric deposition and fertilization, nitrogen has become more abundant in most ecosystems.

Forest fires have decreased in temperate regions (but increased strongly in the tropics), leading to a decreased loss of nitrogen from the ecosystems as a result of pyrodenitrification (see Figure 1).

The term eutrophication has usually been associated with effects in aquatic ecosystems and used mainly in connection with the local pollution of water by phosphorus and nitrogen. The local emissions are still troublesome in many areas, although measures have often been taken against them. Airborne nitrogen is of great significance for the general increase of nitrogen availability over large bodies of water such as the Baltic Sea. It may also lead to marked eutrophication effects in terrestrial ecosystems. In aquatic ecosystems anoxia (lack of oxygen) and the resulting formation of toxic sulphides in the sediments are outstanding effects of an excess supply of nutrients. In terrestrial ecosystems the effects are different.

It has already been mentioned that terrestrial plants are strongly adapted to nitrogen shortage. This holds especially for species native to nutrient-poor habitats. It has been shown that species threatened by modern land-use, as in unfertilized hay meadows, are over-represented among nitrogen-sensitive species (Ellenberg, 1985).

There is evidence that in heathlands the composition of species has been altered by the increased supply of atmospheric nitrogen, heather for example having been replaced by grasses in the Netherlands (Bobbink et al., 1992). It has been also observed that in calcareous grasslands the grass species *Brachypodium pinnatum*



tends to increase and outcompete other species (Bobbink & Willems, 1987), and that there have been changes in the field-layer flora of oak forests in southern Sweden which are most likely to have been caused by increased nitrogen availability (Tyler, 1987). Effects on species composition are known to have taken place in many plant groups, including fungi, lichens, and mosses.

## Acidification

Acidification means that natural environments – such as soils, groundwaters, surface waters – become more acid. But the term also includes many side-effects, such as increases in toxic compounds (e.g. aluminium) and loss of nutrients (especially the so-called base cations magnesium, potassium, and calcium). The main cause is the wet and dry deposition of the strong mineral acids, sulphuric acid ( $\text{H}_2\text{SO}_4$ ) and nitric acid ( $\text{HNO}_3$ ). Historically sulphur has dominated the process because the deposition has been greater and because a large amount of the nitrate deposited with nitric acid has been taken up by plants, and this uptake neutralizes the acidification effect. A change is however now taking place. Firstly because in Europe the emissions of sulphur have substantially decreased, which is not the case with nitrogen. Secondly, as depositions have accumulated in the ecosystems over many years, nitrogen saturation has increased, resulting in a situation where less of the nitrogen is taken up by the plants and instead becomes acidifying. Nitrogen saturation also causes the leaching of nitrate from forest soils to increase. If ammonium deposited to ecosystems is not taken up by plants, it may be subject to nitrification, which is acidifying. Nitrification of forest soils is now increasing in areas where nitrogen deposition is high.

From the ecological point of view the increased acidity is not the only or even the most important consequence of acidification. A very important one is the leaching of mineral nutrients such as calcium, magnesium and potassium. A certain syndrome of needle-bleaching in Norway spruce in some mountain areas of central Europe has been shown to be due to a magnesium deficiency related to soil acidification. Adverse effects on mycorrhiza and the microbial decomposition of dead organic matter can also result from soil acidification. Acidification leads, too, to an increase in the solubility of some compounds and a decrease in that of others. Among the elements that become more soluble is aluminium, which is known to have toxic effects on plant roots. Phosphorus on the other hand, which is an important plant nutrient, may become less available in acidified soils.

## The greenhouse effect

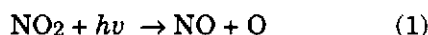
The earth is warmed by radiation from the sun, but itself emits radiation, so that there is a balance between inflow and outflow. Had it not been for the atmosphere, the average surface temperature of the earth would have been  $-28^\circ\text{C}$  and our planet had been a harsh place to inhabit. It was known a hundred years ago that the atmosphere, and in particular its content of water vapour and carbon dioxide, provides a so-called greenhouse effect because those gases absorb radiation which would otherwise have escaped directly into the universe. The greenhouse effect does not lead to a steady accumulation of heat in the atmosphere, only to a retarded emission of the radiation energy from the earth's surface and thus to a higher temperature, which permits the earth to be a green planet. A number of other gases, besides water vapour and carbon dioxide, add to this effect. Most of them are natural constituents of the atmosphere, such as methane ( $\text{CH}_4$ ), ozone ( $\text{O}_3$ ), and nitrous oxide ( $\text{N}_2\text{O}$ ), and their concentrations are increasing. But artificial compounds such as

CFCs are also very potent and long-lived greenhouse gases. The increase in the greenhouse effect resulting from man-made emissions of greenhouse gases may lead to alterations in climate and change in the sea level, with a potential for severe ecological effects all over the planet.

Nitrous oxide is a very potent greenhouse gas with a very long residence-time in the atmosphere: 170 years (Graedel & Crutzen, 1993). Its so-called Global Warming Potential per kg emitted substance is almost 300 times that of carbon dioxide in a 100-year perspective (Rodhe, 1990). Its relative contribution to the greenhouse effect within that timespace has been estimated to be 4 per cent. As mentioned, too, its concentration in the atmosphere is at present increasing.

### Photochemical oxidants

Ozone (O<sub>3</sub>) is formed in the atmosphere by photochemical reactions involving nitrogen oxides (NO<sub>x</sub>) as well as volatile organic compounds (VOCs) and carbon monoxide. Certain wavelengths of the sunlight (denoted  $h\nu$  in the formula below) are able to split NO<sub>2</sub> into NO and free oxygen atoms (O):



The free oxygen atoms react in turn with molecular oxygen to form ozone:



Ozone can then react with nitrogen monoxide, again forming nitrogen dioxide, so that we have a reaction cycle driven by light. These reactions alone do not however result in high concentrations of ozone. During their breakdown in the atmosphere VOCs and CO can nevertheless transform NO into NO<sub>2</sub> without any consumption of ozone, and the raw material for the formation of free oxygen atoms is thus recreated. In this way the nitrogen oxides can, if VOC and CO are present, be used over and over again in the formation of ozone. In very polluted areas the availability of VOCs may limit the formation of ozone, whereas in most places NO<sub>x</sub> is still the limiting factor.

The level of pre-industrial concentrations of ozone is a matter of debate. Among the sources of evidence are:

- The so-called Schönbein papers – a chemical method used to monitor ozone in the nineteenth century. Most studies indicate that the concentrations were then around 10 ppb (Volz & Kley, 1988; Anfossi et al., 1991). There are however exceptions.
- Measurements of ozone made in the former GDR from the 1950s onwards.
- Modelling (Crutzen & Zimmermann, 1991).

The overall picture that appears is that over the last hundred years the concentrations of so-called natural background ozone have increased by a factor 2 to 3. But nowadays ozone episodes, sometimes reaching 100 ppb and higher, occur in addition.

Ozone is a strong oxidative agent which is capable of reacting with and destroying biomolecules. Adverse effects of ozone on plants were first established in southern California around 1950 (Middleton, 1950). At that time there was a strong emphasis on visible injury. At present, at least four different types of ozone damage on plants can be discerned:

1. Visible injury characteristic of ozone. This is the basis for the use of ozone bio-indicators such as tobacco (*Nicotiana tabacum*, cv. Bel W3) and subterranean clover (*Trifolium subterraneum*, cv. Geraldton). After ozone episodes the leaves of these plants get typical necrotic spots. This is of economic importance in spinach. Alfalfa is another

commercially valuable plant that is liable to suffer visible injury as a result of ozone episodes.

2. Effects on biochemical and physiological systems, such as photosynthesis and stomatal behaviour, without any direct visible injury.

3. Early or premature senescence of leaves without any visible injury that would be characteristic of ozone. This effect is probably very serious, causing for instance loss of yield in cereals such as wheat – since there is strong evidence that the leaf duration in this species is becoming shortened as a result of the present levels of ozone in much of the industrialized world, and leaf duration is very important for the quantity and quality of the yield.

4. Effects on carbon partitioning. It is well established that elevated concentrations of ozone can increase the shoot-to-root ratio in several plants, for example radish. It has also been shown that the harvest index (proportion of above-ground biomass converted into grain at harvest) is decreased in wheat by higher ozone concentrations.

In the United States adverse effects of ozone have been shown in a number of tree species such as Ponderosa pine in southern California and Loblolly pine in southeastern USA. Several investigations in Europe have indicated adverse effects from present concentrations in Norway spruce, beech, and other species, and such effects have also been shown in wheat and beans. The effect on yield seems to be weaker in pasture, but there have been effects on the botanical composition. In the USA the crop loss to agriculture from ozone has been calculated to be worth approximately \$3 billion.

The effects of ozone on wild herbs and grasses are less well understood than those on crops and economically important forest trees. Effects on wild plants have sometimes been observed in the form of visible injury or lowered growth rate. It is likely, however, that, as a general rule, bred plants (such as crops) and plants that rely on high growth-rates for their competitive ability (like stand-forming trees), are more sensitive to ozone than the rich variety of stress-tolerant herbs and grasses that exist in nature.

Finally it should be mentioned that ozone is a greenhouse gas, and an increase in tropospheric ozone thus implies a contribution to the greenhouse effect.

## References

- Anfossi, D., Sandroni, S. & Viarengo, S. (1991). Tropospheric ozone in the nineteenth century: the Moncalieri series. *J. of Geophys. Res.*, 96, No. D9, 17, 349-352.
- Bobbink, R. & Willems, J. H. (1987). Increasing dominance of *Brachypodium pinnatum* (L.) Beauv. in chalk grasslands: a threat to species-rich communities. *Biol. Conserv.* 40, 301-314.
- Bobbink, R., Boxman, D., Fremstad, E., Heil, G., Houdijk, A. & Roelofs, J. (1992). Critical loads for nitrogen eutrophication of terrestrial and wetland ecosystems based upon changes in vegetation and fauna. In: Grennfelt P. & Thörnelöf, E. (eds.): *Critical loads for nitrogen – a workshop report*. Nord 1992:41, 111-159.
- Crutzen, P. J. & Zimmermann, P. H. (1991). The changing photochemistry of the troposphere. *Tellus*, 43AB, 136-151.
- Ellenberg, H. (1985). Veränderungen der Flora von Mitteleuropa unter dem Einfluss von Düngung und Immissionen. *Schweiz. Z. Forstwes.* 136, 19-39.
- Graedel, T. E. & Crutzen, P. J. 1993. *Atmospheric change. An earth system perspective*. W. H. Freeman and Company.
- Middleton, J. T., Kendrick, J. B. & Schwalm, H. W. (1950). Injury to herbaceous plants by smog or air pollution. *Plant Dis. Rep.*, 34, 245-252.

- Rodhe, H. (1990). A comparison of the contribution of various gases to the greenhouse effect. *Science*, 248, 1217-1219.
- Tyler, G. (1987). Probable effects of soil acidification and nitrogen deposition on the floristic composition of oak (*Quercus robur* L.) forest. *Flora* 179: 165-170.
- Volz, A. & Kley, D. (1988). Evaluation of the Montsouris series of ozone measurements made in the nineteenth century. *Nature*, 332, 242-242.
- Wellburn A. (1988): Air pollution and acid rain. The biological impact. Longman Scientific & Technical.

# Critical ozone exposures and the needed reduction of emissions of ozone precursors

*Presentation by Peringe Grennfelt  
The Swedish Environmental Research Institute*

The problem of tropospheric ozone may be regarded as twofold: firstly the regional episodes, and then the ozone produced in the background air and in the free troposphere.

The regional problem, which is characterized by episodic peaks in the concentrations of ozone, occurs mainly over the industrialized areas of Europe. The VOC protocol under the Convention on Long Range Transboundary Air Pollution is aimed primarily at controlling this problem (VOCs=volatile organic compounds).

In addition, ozone is formed in the free troposphere, i.e. that part of the atmosphere that comprises the volume between the so-called atmospheric boundary layer (1000-2000 m) up to the tropopause, at a height of about 10 kilometres. This free tropospheric ozone is also known as "background" ozone. Since the concentrations of free tropospheric ozone are continually increasing, they may constitute a problem of even greater importance than regional ozone.

## Ozone formation

Nitrogen oxides ( $\text{NO}_x$ ) play a key role in the atmosphere because nitrogen dioxide ( $\text{NO}_2$ ) is the only compound that forms free atomic oxygen (O) when decomposed under the influence of sunlight (a process known as photolysis). This free atomic oxygen will in turn react with atmospheric oxygen ( $\text{O}_2$ ) to form an ozone molecule ( $\text{O}_3$ ). If the atmosphere contained only oxygen and  $\text{NO}_x$ , the ozone formed would react with nitrogen monoxide (NO) and thus revert to  $\text{NO}_2$  and oxygen.

In order to get a net production of ozone there must be other compounds besides ozone to oxidize NO to  $\text{NO}_2$ , and peroxy radicals ( $\text{RO}_2^*$ ), mainly derived from the decomposition of volatile organic compounds, are the chief oxidizing compounds.

Let us take a closer look to see how the simplest VOC, methane, contributes to increasing the concentrations of tropospheric ozone. Methane is the simplest hydrocarbon, consisting of only one carbon atom and four hydrogen atoms. In the atmosphere methane molecules are oxidized to form carbon dioxide and water. During decomposition it will generate a number of peroxy radicals, which may oxidize NO to  $\text{NO}_2$  and thus increase the net production of ozone.

So instead of reacting with and decomposing ozone, as might be expected, the peroxy radical will react with NO. This results in the formation of  $\text{NO}_2$ , which is then again free for photolysis. So if the production of peroxy radicals is maintained, there will be a net production of ozone.

The oxidation of the simple molecule methane may result in the production of five peroxy radicals, and thus in the formation of five

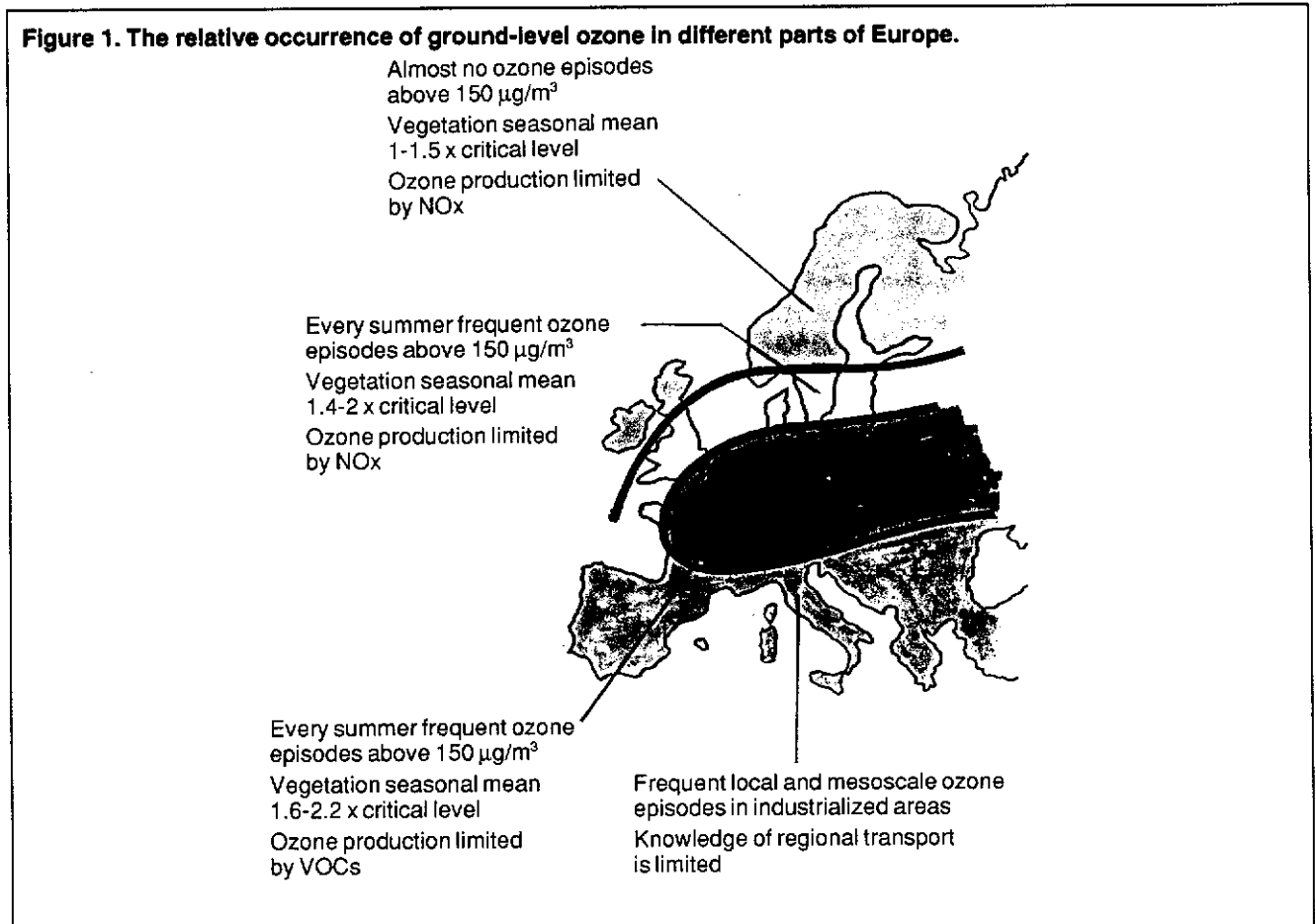
ozone molecules. When heavier hydrocarbons are decomposed, more ozone will be produced. Furthermore, when carbon monoxide (CO) is transformed to carbon dioxide (CO<sub>2</sub>), another radical will be produced (a hydroperoxy radical, HO<sub>2</sub><sup>\*</sup>).

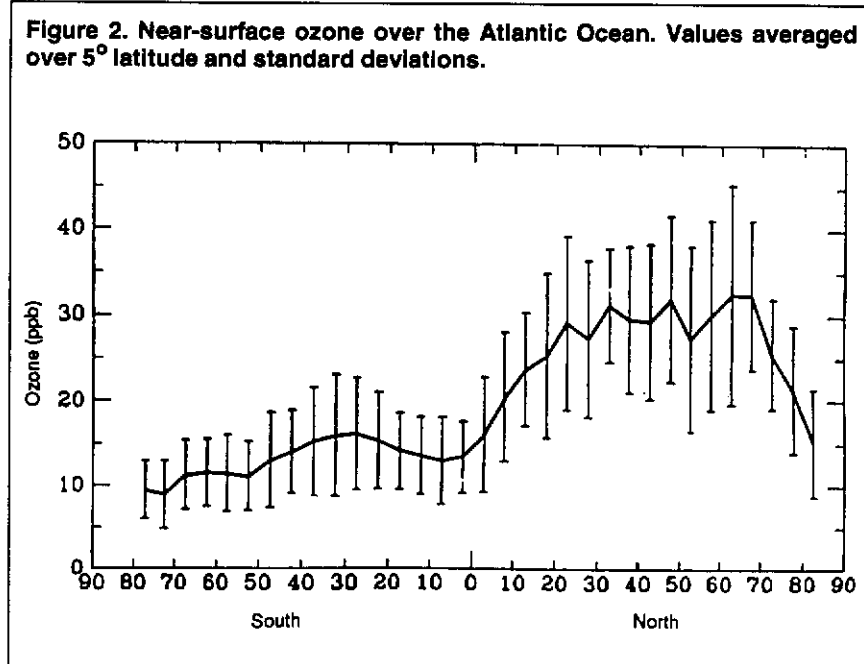
In consideration of the above, NO may be regarded as a catalyst for the process of ozone forming – since it is not consumed in the process, but becomes reconverted to NO<sub>2</sub>. The hydrocarbons may be regarded as the fuel. The more fuel we put into the process, the more ozone formation will result – or at least there will be the potential for forming more ozone. In reality however, not all of the radicals produced will eventually form ozone, since there are a number of other reactions that take place as well. But if NO is available and other conditions are favourable, most of the radicals will be likely to form ozone.

The ozone in the troposphere resulting from these reactions – to which more may be added by transport from the stratosphere – acts as a “cleaning agent” for the atmosphere. Without ozone, large amounts of chemical compounds would have gone far up into the stratosphere, where they would ultimately have been destroyed. The cleaning function of ozone comes from its ability to form radicals, especially hydroxyl radicals (OH<sup>\*</sup>), which in turn attack the various VOCs. By emitting nitrogen oxides and VOCs to the atmosphere, man has influenced the atmospheric processes, and this in turn has led to the occurrence of levels of ozone that are harmful to man and the environment.

### Regional episodes

In high pressure situations, with the air circulating and remaining in the centre for several days or even a week, all the pollutants emitted will stay in a layer between one and two kilometres high. A





cocktail of pollutants will consequently accumulate. Every day when the sun shines on this cocktail, VOCs will be decomposed, converting  $\text{NO}_x$  to nitric acid, and  $\text{SO}_2$  to particulates. Visibility will decrease, and there will be an increase in ozone levels. The high pressure cell may move on, and with it the pollution packet. Typical transport distances within a high pressure system are 1000-2000 kilometres.

Figure 1 presents a generalized picture of the extent of the regional ozone problem in Europe. The highest regional peak levels have been recorded in Germany, Switzerland and Austria. It is likely that the levels will also be high in some eastern European countries and in the Mediterranean region, although in these cases monitoring data are lacking.

The ozone episodes do not occur every week. There may be 10-15 episodes during any summer, each lasting for the most part one to three days. In many countries, and especially Germany, these summer episodes have of late attracted ever greater attention, not least because of increased awareness of the effects of ozone on health. The episodic peaks contribute surprisingly little however to the ozone dose accumulated over the year. Most of the exposure of ecosystems and human beings to ozone comes from background ozone.

At the end of the last century a large number of ozone measurements were made following a suggestion that the compound had a positive effect on lung diseases. While most of these measurements were made with methods that are impossible to reproduce with any reliability, there is one set of data from an observatory outside Paris so well monitored as to allow a reconstruction and comparison. It indicates that ozone levels today are at least twice as high as they were a hundred years ago. Long-term monitoring, too, shows a substantial increase over the last few decades.

As can be seen from Figure 2, the increase in the levels of background ozone is mainly of concern for the northern hemisphere. The data were collected on a ship travelling from 80°S to 80°N in the Atlantic. The highest levels are found between 20 and 70-80°N, in a band stretching around the entire globe.

## Critical levels

How important are the two aspects of the ozone problem with respect to the effects? For assessing this the concept of critical levels is a

1988, Bad Harzburg	Time period	Critical level (ppb)
<i>Crops</i>	1 hour	75
	8 hour	30
	Vegetation season (7 hr, 10-17 mean)	25
<hr/>		
1992, Egham	Base level, ppb	Max exceedence (ppb-hours)
<i>Crops</i>	40	3000
<hr/>		
1993, Bern	Base level, ppb	Max exceedence (ppb-hours)
<i>Crops</i>		
Three month, daylight hours	40	2,600 <sup>1</sup>
	40	5,300 <sup>2</sup>
	40	7,900 <sup>3</sup>
Three day, daylight hours <sup>4</sup>	40	700
<i>Forests</i>		
Six month, 24-hours a day <sup>4</sup>	40	10,000 <sup>2</sup>
<sup>1</sup> Yield loss 5 per cent. <sup>2</sup> Yield loss 10 per cent. <sup>3</sup> Yield loss 15 per cent. <sup>4</sup> Provisional.		

requirement. A set of such levels for ozone was internationally agreed upon for the first time in 1988 (Table 1), but the trouble with these values was that they are mainly based on experiments in the United States, not Europe.

At a UN ECE Workshop on Critical Levels in 1992, a new concept was developed for critical levels for ozone. The idea is to have one figure for the critical level. The formula is to be: [x] ppb-hours above [y] ppb baseline.

The concept was further evaluated and adopted at a workshop in Switzerland in 1993. It was then decided to use 40 ppb as a threshold value and to recommend that the critical level for crops should be set either at 5300 ppb-hours, allowing a 10-per-cent harvest reduction, or at 2600 ppbh, 5-per-cent.

A baseline figure at a high ppb value will only reflect peak levels, with consequent ignoring of the problem of increasing background levels, but the lower the [y] figure is set, the more the increasing background levels will be taken into account.

The above values are based on experiments, in which crops (mainly wheat) were exposed to various concentrations of ozone. There was found to be a connection between the accumulated ozone dose and the reduced yield. If the 40 ppb baseline is crossed for altogether 2600 ppb-hours during a period of three months (daylight hours) the harvest loss would, according to experimental data, be 5 per cent, while crossing the line for 5300 ppb-hours would mean a loss of 10 per cent. Hence, taking into account the uncertainties in the background material, the above recommendation.

### Critical versus monitored exposure

Background ozone concentrations transported into Europe are today approximately 30 ppb. Within cities and built-up areas generally ozone becomes destroyed as a result of the reaction between ozone and NO, leading to the formation of NO<sub>2</sub>. In Central Europe, the summertime formation of ozone will increase the summertime mean to 40-60 ppb over large areas. In southern Scandinavia, the increase in the summertime mean will be less (5-8 ppb) and in northern Scandinavia hardly detectable at all.

already been adopted or are under discussion, but that further substantial reductions will be needed (probably in the order of 75 per cent) to meet more stringent standards such as the 60 ppb for health and the above-mentioned critical levels for crops.

### References & further reading

- Ashmore, M.R. & R.B. Wilson (Eds.) (1994). **Critical levels of air pollutants for Europe**. Background papers from the UN ECE workshop on critical levels, held in Egham, UK, March 23-26, 1992.
- Derwent, R., Grennfelt, P. & Hov, Ö. (1991). **Photochemical oxidants in the atmosphere**. Nordic Council of Ministers. Report Nord 1991:7. Copenhagen, Denmark.
- Fuhrer, J. & B. Achermann (Eds.) (1994). **Critical levels for ozone - a UN ECE report from a workshop held in Bern, Switzerland, November 1-4, 1993**. Swiss Federal Research Station for Agricultural Chemistry and Environmental Hygiene. Liebefeld-Bern, Switzerland.
- UN ECE (1988). **Report from ECE Critical levels workshop**, held in Bad Harzburg, F.R.G., March 14-18, 1988. Umweltbundesamt. Berlin, Germany.

# Present and expected EU directives related to acidification, eutrophication, and air quality

*Presentation by Christer Ågren  
The Swedish NGO Secretariat on Acid Rain*

Total emissions of sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and ammonia (NH<sub>3</sub>) in 1990 of the present fifteen member states of the European Union were 39, 23, and 8 million tons.

## Sulphur

**a) Existing legislation:** Directives of direct relevance for emission control are that on the limitation of emissions of certain pollutants into the air from **large combustion plants** (88/609/EEC), the directive on the sulphur content of certain **liquid fuels** (93/12/EEC), and possibly the one on restricting air pollutants from **industrial plants** (84/360/EEC). The LCP directive, applying to combustion plants with a thermal input of more than 50 MW, consists of two parts, the one setting emission limit values for new (post-1987) plants, the other calling for a gradual reduction of the total national emissions from existing (pre-1987) plants. For the latter, national ceilings for emissions from existing LCPs have been set for SO<sub>2</sub> (for the years 1993, 1998 and 2003) and for NO<sub>x</sub> (for 1993 and 1998). The directive on the sulphur content of liquid fuels gives the maximum permissible limits for sulphur in gas oils and diesel oil.

There is also a directive concerning limit values for **air quality**, setting limit values and guide values for sulphur dioxide and suspended particulates (80/779/EEC amended by 89/427/EEC).

**b) Proposed or planned legislation:** The Commission was to present a proposal for revision of the LCP directive before July 1, 1995, but has still not done so. The aim of a proposal, expected by spring 1996, was to make the revised directive a daughter directive to the not yet adopted framework directive on **integrated pollution prevention and control** (IPPC). This directive is to cover emissions to air, soil, and water from all large combustion plants, as well as from industrial furnaces and production processes. The draft IPPC directive requires the setting of emission limits based on best available techniques (BAT), but taking into account geographical location and local environmental and technical considerations. Besides setting limits for new plants, it provides for an eight-year transitional period for adapting existing installations to the IPPC regime.

The Commission has been working for several years on a proposal for a directive limiting the sulphur in certain **liquid petroleum-derived fuels**. This may be regarded as an extension of directive 93/12/EEC (see above), covering a wider range of fuels. The Environment Directorate (DGXI) has several times put forward specific proposals, but so far it has failed to obtain agreement within the Commission. In an unofficial draft text, the limits proposed were 1 per cent for heavy fuel oils, 0.5 per cent for marine diesel fuels, and

0.2 per cent for aviation kerosene. No limit value was proposed for marine bunker fuels, but there was an indication that a limit for this type of fuel would be set after agreement had been reached within the International Maritime Organization (IMO). The question still remains as to whether the directive should be based on article 100A or 130S. The draft proposals have so far been blocked at a very early stage of cabinet discussions, and the future of this directive is uncertain.

There has been some thought in the Commission of preparing a directive to limit emissions from "**small**" combustion plants, i.e. with a thermal input of less than 50 MW, but no proposal has yet been presented.

A new **framework directive on ambient air quality assessment and management** is soon to be adopted. Under this directive daughter directives will be proposed for a number of substances on a pollutant-by-pollutant basis, in a first stage for SO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub>, particulates, and lead, and in a second stage for benzene, PAHs, CO, Cd, As, Ni and Hg. Proposals for limit values, alert values, and/or guide values for pollutants in the first stage, with the exception of O<sub>3</sub>, had to be put forward by the end of 1996.

## Nitrogen oxides

**a) Existing legislation:** For **stationary sources**, the LCP directive, and possibly the industrial plants directive (see above) are also of interest.

For **mobile sources** there are a number of relevant directives, such as the basic directive regulating emissions from **passenger cars** (70/220/EEC), last amended by directive 94/12/EEC, which will come into force for all new cars in 1997. Emissions from **heavy duty**

### EU Directives and proposals for directives related to emissions of acidifying and ozone-forming air pollutants.

#### Motor vehicles

70/220/EEC Air pollution from motor vehicles using ignition engines. Eight amendments: the most recent one is 91/441/EEC.

72/306/EEC Air pollution from motor vehicles using diesel engines.

77/537/EEC Air pollution from diesel-engined agricultural and forestry tractors.

91/441/EEC Air pollution from private motor cars. New value limits apply from 31/12 1992.

91/542/EEC Amendment of 88/77/EEC, on air pollution from heavy diesel-motor vehicle engines (HGVs and buses). New limit values apply from October 1996. By the end of 1996 the Commission is to propose new limit values to take effect as from October 1999.

COM(92)572 Proposal for new emission standards for air pollution from passenger cars, to apply as from 1/1 1997.

93/59/EEC Air pollution from commercial vehicles (light trucks vans, etc).

#### Fuels

75/716/EEC Sulphur content in gas oils. Newer ones: 85/377/EEC, 87/36/EEC, 93/12/EEC. The latest one prescribes a maximum of 0.2 per cent as from October 1994, and 0.05 per cent as from October 1996, for diesel oils.

78/611/EEC Lead content of petrol. Newer ones: 85/210/EEC, 85/716/EEC, 87/416/EEC, 87/33/EEC

#### Air quality

80/779/EEC Air quality limit values and guide values for sulphur dioxide and suspended particulates. Amended by 89/462/EEC.

82/884/EEC Limit value for lead in the air.

85/203/EEC Air quality standards for nitrogen dioxide.

92/72/EEC Air pollution by ozone.

COM(94)109 Proposal for a directive on assessment and management of ambient air quality.

COM(94)345 Proposal for establishing exchange of information on ambient air pollution.

#### Industrial emissions

84/360/EEC Combating air pollution from industrial plants.

86/609/EEC Limiting emissions of atmospheric pollutants from large combustion plants. Amended 17/12 1990.

COM(93)423 Proposal for a directive on integrated pollution prevention and control (IPPC).

#### VOCs

94/63/EC Control of voc emissions from the storage of petrol and its distribution from terminals to service stations.

#### Carbon dioxide

COM/92/226 Proposal for a Council directive introducing a tax on carbon dioxide emissions and energy.

#### Speed limiters

92/6/EEC Road vehicles larger than 10 tons must as from 1994/95 be equipped with speed restrictors: 85 kph for HGVs and 100 kph for buses and coaches.

#### Others

3637/92/EEC Ecopoints for HGVs in transit through Austria.

**vehicles** were first regulated by directive 88/77/EEC, last amended by directive 91/542/EEC, introducing the so-called Euro II standards as from 1996. Emissions from light-duty vehicles are regulated by directive 93/59/EEC, which came into force in 1994.

Emissions from mobile sources are also influenced to some extent by **fuel quality**. The directive regulating the sulphur content of diesel fuels has already been mentioned.

There are, further, directives on **vehicle inspection and maintenance**.

As regards **air quality**, directive 85/203/EEC sets air quality standards for nitrogen dioxide, and directive 92/72/EEC regulates ozone.

**b) Proposed or planned legislation:** As regards stationary sources, see the above descriptions of the LCP and IPPC directives.

As for mobile sources, the Commission has recently finished a two-year program, carried out jointly with the European oil and automobile industries, called the **auto-oil program**. In it studies were made for the development of cost-effective packages of measures, with the aim of further reducing emissions of air pollutants. It focussed primarily on a few selected air pollutants with direct effects on human health. It is expected that the Commission will use this as a base for proposals for new directives on such matters as **emission standards** (to be introduced after 2000), **vehicle fuel quality**, and **inspection and maintenance**.

There is also a proposal (COM/95/350) for a new directive, to set emission limits for NO<sub>x</sub> and other pollutants from the engines of **non-road mobile machinery**.

For air quality, see above.

## Ammonia

There is at present no EU legislation aimed at reducing emissions of ammonia. The proposed IPPC-directive will however cover emissions of ammonia from some of the major livestock industries.

## Volatile organic compounds (VOCs)

According to some data, the total man-made emissions of VOCs in the twelve member states comprising the EC amounted in 1990 to about 10 million tons, of which 35-40 per cent came from vehicle exhausts, about 35 per cent from solvents, and 15 per cent from petrol vapours. About two-thirds of the last consisted of evaporative losses from cars, one-fifth from storage terminals and distribution operations, and the rest from refuelling of vehicles.

**a) Existing legislation:** Emissions of VOCs are primarily covered by the directives for the control of emissions from **mobile sources** (see above under nitrogen oxides).

There is also a directive on the control of VOC emissions resulting from the **storage of petrol and its distribution** from terminals to service stations (94/63/EEC), so-called Stage I, coming into force on December 31, 1995.

**b) Proposed or planned legislation:** A second directive, called VOC stage II, is being prepared by the Commission. This will call for the establishment of controls on **petrol refuelling**, through the fitting of equipment to capture petrol vapours displaced from vehicles' fuel tanks during refuelling and return them to the service station's storage tanks.

Also discussed for some years has been a directive for controlling the emissions of solvents, applying in a first stage to **solvent use in industry**. A proposal is expected in 1996.

## Participants and speakers

**Karola Taschner, European Environmental Bureau**  
26 Rue de la Victoire, B-1060 Brussels, Belgium  
Phone work: +32-2-539 00 37. Fax: +32-2-539 09 21

**Gijs Kuneman, European Federation for Transport and Environment**  
26 Rue de la Victoire, B-1060 Brussels, Belgium  
Phone: +32-2-537 66 39. Fax: +32-2-537 73 94

**Bart Martens, Bond Beter Leefmilieu**  
Home address: Klapeistr. 99, B-2060 Antwerpen, Belgium. Phone work: +32-3-272 56 46

**Karel Murtinger, Nadace Slunicko**  
U Cihelny 5, 37006 C. Budejovice, Czech Republic  
Phone work: +42-38-313 49

**Petr Hlobil, Greenpeace Czech and Slovak Republics**  
U Prasne Brany 3, 116 29 Praha 1, Czech Republic  
Phone work: +42-2-24 23 05 04. Fax: +42-2-24 21 12 55

**Tõnu Lausmaa, Renewable Energy Center Taasen**  
23A Akadeemia tee, EE-0026 Tallinn, Estonia  
Phone work: +372-6-392 047. Fax: +372-6-397 901

**Harri Ajomaa, Finlands Naturskyddsförening**  
Kotkankatu 9, 00510 Helsingfors, Finland  
Phone work: +358-0-22 80 82 23. Fax: +358-0-22 80 82 00

**Ulrika Cronström, Natur & Miljö**  
Bulevarden 30, 00120 Helsingfors, Finland  
Phone work: +358-0-64 47 31. Fax: +358-0-60 58 50

**James Rojas, Hungarian Traffic Club**  
pf. 102, H-2041 Budaörs, Hungary  
Phone work: +36-1-206 55 98. Fax: +36-1-206 55 76

**Paul Barons, Sustainable Energy Information Office**  
Turgeneva 19-447, LV-1018 Riga, Latvia  
Phone work: +371-2-21 35 66. Fax: +371-2-212 917

**Baiba Zasa, Sustainable Energy Information Office**  
Turgeneva 19-447, LV-1018 Riga, Latvia  
Phone work: +371-2-21 35 66. Fax: +371-2-212 917

**Linus Vainius, Energy and Air Pollution Information Centre**  
Central Post, Box 156, 3000 Kaunas, Lithuania  
Phone work: +370-7-20 72 50. Fax: +370-7-20 92 74

**Saulus Piksrys, Energy and Air Pollution Information Centre**  
Norvegu 7-4, 3002 Kaunas, Lithuania  
Phone work: +370-7-207 250. Fax: +370-7-209 274

**Knut Smedsvig, Norges Naturvernforbund**  
Postboks 2113, Grünerløkka, N-0505 Oslo 5, Norway  
Phone work: +47-22-71 55 20. Fax: +47-22-71 56 40

**Arne Otto Iversen, Norges Naturvernforbund**  
Pb 718, N-4601 Kristiansand, Norway  
Phone work: +47-38 02 57 66. Fax work: +47-38 02 57 66

**Dag Arne Höystad, Norges Naturvernforbund and Swedish NGO Secretariat on Acid Rain**  
Daasgatan 16, N-0259 Oslo, Norway  
Phone work: +47-22 56 24 00

**Katarzyna Klich, Information Centre on Air Pollution (ICAP), PKE**  
Pl. Grunwaldzki 8-10, 40950 Katowice, Poland  
Phone & fax work: +48-32-59 43 15

**Emil Bedi, Foundation for Alternative Energy/SZOPK**  
Gorkeho 6, 81101 Bratislava, Slovakia  
Phone work: +42-7-36 46 65. Fax: +42-7-31 39 68

**Mikael Johannesson, Friends of the Earth Sweden**  
Torsten Alms gata 57, 126 51 Hägersten, Sweden  
Phone work: +46-8-16 12 90. Fax work: +46-8-15 59 87

**Reinhold Pape, Christer Ågren, Per Elvingson, Swedish NGO Secretariat on Acid Rain**  
Box 7005, S-402 31 Göteborg, Sweden  
Phone: +46-31-10 55 90. Fax: +46-31-711 46 20

**Helen Moss, International Institute for Energy Conservation**  
1-2 Purley Place, London, England N1 1QA  
Phone work: +44-171-704 67 37. Fax: +44-171-704 87 57

### Speakers

**Peringe Grennfelt**  
IVL, Box 47086, S-402 58 Göteborg, Sweden  
Phone: +46-31-46 00 80. Fax: +46-31-48 21 80

**Håkan Plejfel**  
IVL, Box 47086, S-402 58 Göteborg, Sweden  
Phone: +46-31-46 00 80. Fax: +46-31-48 21 80

## Sweden's lakes and forests

BECAUSE OF AIR POLLUTION, close on 14,000 lakes are now distinctly acidified in Sweden – and about 4000 of them very badly so. And rapid further deterioration will ensue if acid deposition continues at the same rate as today – it being estimated that after only a few decades the number of acidified lakes will have risen to 34,000. In total, the country has something like 85,000 lakes with a surface area of more than one hectare.

Acidification has extensive biological effects in lakes. For one thing the diversity and number of aquatic species diminishes, resulting in a greatly changed ecosystem. Such effects occur already when the pH-level of the water drops below 6. Among the sensitive animal species are snails, mussels, crustaceans, and certain species of insects and fish.

As regards the effects on forest soils, the pH value of the soil on some 650,000 hectares of forest land in South Sweden is now under 4.4, which is thought to be a critical level at which release of potentially toxic metals to the soil water will start. On a further 700,000 hectares in that part of the country the pH values range between 4.4 and 4.7, and unless there is a dramatic reduction of the acid deposition, the acidification of these soils too will go over the critical level within a couple of decades.

One effect of acidification is the greatly increased leaching of plant nutrients from the soil.

Since 1950, in some areas more than half of the available magnesium, potassium, and calcium has become lost in this way.

National inventories of the scale and distribution of forest damage have been carried out since the mid 1980s. In 1993 eleven per cent of the trees were classed as moderately to severely damaged, i.e. they had lost more than a quarter of their foliage.

Other negative effects caused by the sulphur and nitrogen pollution are changes in the flora and fauna, acidification of the groundwater, reduced crop yields, damage to materials and cultural monuments, and direct effects on human health.

The cause of acidification is to be found in man-made emissions to the atmosphere, primarily of sulphur dioxide and nitrogen compounds.

As shown by data from the European monitoring program, between 80 and 90 per cent of the sulphur and oxidized nitrogen compounds that are deposited over Sweden comes from abroad, the countries contributing the most being Germany, Britain, and Poland.

The discovery of the acidification problem in Sweden, in the mid-1960s, led to the adoption of measures to reduce the emissions of sulphur dioxide, starting in 1969. In 1970 Swedish emissions of sulphur dioxide amounted to about 900,000 tons. By 1980 they had been nearly halved, and by 1994

they had fallen to 97,000 tons – a reduction of 80 per cent as compared to the level of 1980. Parliament had decided that the aim should be to reduce emissions by 80 per cent between 1980 and 2000.

Swedish emissions of nitrogen oxides amounted in 1980 to 453,000 tons, and by 1994 they had been reduced by 13 per cent, to 393,000 tons. The target for reductions as decided by the Swedish parliament was to have been a 30-per-cent reduction by 1995, but according to estimates by the Swedish Environment Protection Agency, this target is not likely to be attained until around 2000.

The amount of acid deposition that various types of soil will manage to neutralize in the long run – the so-called critical load – will depend primarily on the rate of mineral weathering. The critical load may be defined as the greatest

superaddition of a certain pollutant that ecosystems can support without suffering damage in the long term. The additions of acid substances should therefore not take place at a rate exceeding that at which they can be neutralized through the weathering of the soil.

In Scandinavia, the critical loads for acid deposition are being exceeded on 80 per cent of the forest area. According to calculations made by the Swedish Environmental Protection Agency, for Sweden the deposition will have to be reduced by at least 70 per cent between 1990 and 2010 if the acidification of the soil is not to go on increasing. To reverse acidification will naturally require still greater reductions. And the quicker the desired rate of recovery, the faster and greater they must be.



*Areas where the forest soils are so acidified that there is a risk of extensive damage to trees and other vegetation.*

How much will the emissions of acidifying air pollutants have to be reduced in order to avert damage to the environment? And how it is to be done? Attention again centred on these questions at the Fourth European NGO Strategy Seminar on Air Pollution, attended by representatives from some twenty European environmentalist organizations, in Göteborg.

Here are presented some of the principal papers read at the seminar, reporting on the latest scientific knowledge concerning the loads and concentrations of pollutants that the environment should safely be able to withstand, together with an account of the political situation in regard to these matters. The conclusions drawn by the representatives of the environmentalist organizations participating in the seminar appear in the statement issuing from it.

This report is published by the Swedish NGO Secretariat on Acid Rain, the organizer of the seminar.

