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REVIEW OF AIR POLLUTION EFFECTS

EFFECTS OF AIRBORNE NITROGEN

Report by the Bureau of the Working Group on Effects

I. INTRODUCTION

1. At its meeting in September 2008, the Extended Bureau of the Working Group on Effects agreed to prepare a status report on the effects of airborne reactive nitrogen (Nr) in collaboration with the Task Force on Integrated Assessment Modelling, the Task Force on Reactive Nitrogen and the secretariat. This report was finalized in accordance with the Convention’s 2009 workplan (ECE/EB.AIR/96/Add.2, item 3.1 (d) (i)), approved by the Executive Body at its twenty-sixth session in December 2008. The Working Group is invited to discuss the report and submit it to the twenty-seventh session of the Executive Body to be held in December 2009 for its consideration.

II. BACKGROUND

2. Nr is defined as all biologically, photochemically and/or radiatively active nitrogen (N) compounds in the biosphere and atmosphere. This comprises all N except N_2 gas: for example, N oxides (NOx) and nitrate (NO_3) (summarized as NO_y), organic N compounds, nitrous oxide (N_2O), ammonia (NH_3) and ammonium (NH_4) (the latter two are summarized as NH_x).

3. Atmospheric NO_y and NH_x affect ecosystems via wet (in rain) or dry (as gas or particulates) deposition. NOx is also precursor to increased levels of tropospheric ozone (O_3). NO_y and NH_x are the main but not the only components of secondary particulate matter (PM). O_3 and PM have detrimental effects on plants, human health and building materials. N_2O also has effects on ecosystems and acts as a greenhouse gas, affecting the radiative forcing. This report will only consider the effects of Nr deposition on ecosystems, materials and health, inter alia with respect to acidification and eutrophication and consequent effects on biodiversity.

4. N is considered to be the nutrient that most often limits net primary production in terrestrial and marine ecosystems. Primary production in freshwater ecosystems can be limited by both N and phosphorus (P). In terrestrial ecosystems, N limitation occurs in particular in temperate and boreal regions.

5. Before large-scale industrial and agricultural activity, most N taken up by plants was fixed in biologically available forms by N-fixing bacteria. The production of N fertilizers for agriculture directly from atmospheric N_2 gas (Haber-Bosch process) and the burning of fossil fuels for transportation and power generation have more than doubled Nr globally. This has led, inter alia, to strongly increased N deposition to ecosystems. Forests in some parts of Northern Europe are currently receiving 10 times the natural level of atmospheric N deposition, which is causing changes to plant communities, soils and health. In marine waters, increased N inputs are often linked with nuisance algal blooms.

6. The critical load is defined as “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”. Critical loads for eutrophication will vary depending on the ecosystem type or segment under study. They have a high spatial variation.

7. Total emissions of NOx fell by 31 per cent to 18 million tons for the period 1990–2004. A further 15 per cent decrease in total emissions would be necessary to reach the overall 2010 target of the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol), reported by the Task Force on Integrated Assessment Modelling.. Half of the ratifying Parties needed further reductions to meet their NOx ceilings by 2010. Emissions of NH_3 were 7 million tons in 2004, which was 22 per cent below the 1990 levels and close to the Protocol target. All ratified Parties were expected to meet their NH_3 ceilings, some of them with additional measures. Slow progress in reducing N deposition maintained

widespread risk for detrimental impacts of eutrophication. In 2000, the forest area with N deposition exceeding the critical loads for eutrophication was four times larger than the forest area with excess acid deposition. N deposition would exceed critical loads for 53 per cent of the ecosystem area by 2020, typically by 250–750 eq ha^{-1} a^{-1}, but could peak over 1000 eq ha^{-1} a^{-1} in areas with high cattle densities.

8. The effects of the addition of N on managed lands are well known and understood and allow for the more efficient production of food for humans. The responses of natural or semi-natural systems to increases in Nr are more difficult to understand and quantify. These nutrient increases are known to change the composition of plant communities (biodiversity) and to increase the biological production of N-tolerant species. Soil microbes compete effectively with plants for Nr. Enrichment of the soil with Nr occurs through microbial assimilation of deposited Nr and through changes in plant community. Increases in soil N have repercussions on soil biota and on freshwater acidification through increased N leaching. Nr affects primary production and consequently increases carbon (C) sequestration. Microbial activity in soil also varies depending on N content and C/N ratio. In urban areas, NO_3 and NH_3 corrode and soil materials, and have harmful effects on health.

9. Excessive N deposition was shown to affect human well-being through ecosystem services by the Millennium Ecosystem Assessment. These included provisioning services (e.g. food and water), regulating services (e.g. climate, soil and water quality, and pest and disease regulation) and cultural services (e.g. recreation and aesthetic value).

10. The International Cooperative Programs (ICPs) under the Working Group on Effects have been active in quantifying the changes to ecosystems that have been caused by atmospheric Nr in Europe and North America. Studies have been conducted on vegetation and forests, soils, freshwaters, materials, and health. This has led to an understanding of the actual and potential problems caused by atmospheric Nr, as well as their geographical and temporal extent.

III. EFFECTS OF ATMOSPHERIC NITROGEN

A. Plant communities

11. Increasing N fertilization from the atmosphere causes changes in species composition. These included species loss, changes to inter-species competition and increased susceptibility to plant diseases, insect pests, frost, drought and wind stresses. Rare and endangered species appeared to be at particular risk, especially in regions and ecosystem types that originally received low N deposition amounts, such as heathlands and infertile grasslands. Mosses and lichens and their habitats have been identified as especially sensitive to Nr, in particular to agricultural NH_3 emissions.

12. The assessments by the effects-oriented programmes, in particular the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP

Vegetation), have identified a number of examples of plant community changes in Europe, many of which have occurred despite conservation efforts. Many undisturbed lowland heaths in Western Europe have become dominated by grass species over the past 20–50 years. The shift from dwarf shrub to grass dominance has been triggered by the opening of tree and shrub canopies by heather beetle attacks, winter injuries and droughts. These were initially affected by increased levels of N concentrations in plants. Typical lichen and moss species were negatively affected by N deposition lower than those causing a shift from dwarf shrubs to grasses.

13. Species changes were noted for example in Swedish boreal forests. The frequency of the occurrence of two dwarf shrubs was negatively associated with N deposition >6 kgN ha^{-1} a^{-1} as well as with an increased abundance of grasses and decreased abundance of mosses and other dwarf shrub species. A parasitic fungus was also positively associated with high N deposition.

14. Scottish mountain communities have changed over the past 30–40 years. The change was found to be greatest in areas with N deposition above critical loads. Across the whole range of sampled communities, NO_3 deposition was significantly correlated with changes in vegetation composition. However, this correlation was not as important as grazing intensity and climate change, which illustrated the importance of understanding all drivers of change and their interactions.

15. Significant positive correlations were detected between N deposition and the defoliation of tree crowns and the growth of trees at level I plots of the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). N deposition explained increased defoliation of European and sessile oak (*Quercus robur* and *Quercus petraea*) and common beech (*Fagus sylvatica*) as well as increased biomass growth of Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and common beech (*Fagus sylvatica*). As with lichens and mosses, forest plant growth increased especially at sites with originally low N statuses. Tree growth increased by N deposition was estimated to account for approximately 5 per cent of the C uptake by forests during the last 40 years in Europe; however, it is uncertain whether this would be sustainable in future.

B. Soils

16. Excess atmospheric N deposition was related to soil acidification and the increased availability of NH_4. Studies at the level II plots of ICP Forests indicated that increased NH_4 availability suppresses the microbial immobilization of deposited nitrate in the early stages of soil N saturation, especially in soils with low pH. If NH_4 were to become the dominant soil N compound, this would affect the growth of sensitive plant species, causing a loss of plant species with high N retention efficiency and a suppression of microbial immobilization of deposited NO_3. It would increase N leaching into soil water and consequently to streams and rivers.

17. There were large observed differences between sites in the transfer of N-originated acidity to soils at the International Cooperative Programme on Integrated Monitoring of Air

Pollution Effects on Ecosystems (ICP Integrated Monitoring) sites. These differences reflected both the amounts of N deposition and difference in plant communities and soil composition. Calculations showed a clear positive relationship between the net acidifying effect of N processes and N deposition amounts.

18. A by-product of increasing N accumulation in plants and soils was the concurrent C increase in soil pools. C/N ratios in the soil organic horizon at European forested sites receiving elevated throughfall N deposition seemed to give reasonable estimates of the risk for elevated N leaching and risk for detrimental effects in waters and soils. According to a study on European sites, including those of ICP Integrated Monitoring, important parameters to determine N leaching were N deposition, organic layer C/N ratio and annual temperature. N input determined N leaching at C/N ratios below 23 and N input and temperature for higher ones. Such empirical relationships were used to predict the regional response of NO_3 leaching to elevated N deposition in forests across Europe.

C. Water

19. According to studies by the International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes (ICP Waters), N deposition was related to N leaching from forest soils into surface and ground waters, especially for forest soils that were already N enriched. NO_3 leaching in acid-sensitive ecosystems led to surface water acidification, as it was accompanied by acidity and inorganic aluminium cations. Both were toxic to aquatic biota at high concentrations and main causes for salmon and trout population extinctions. They also damaged other acid-sensitive aquatic biota such as snails and clams, which needed to maintain their calcium carbonate shells. Fish exposure to inorganic aluminium led to clogging of the gill and subsequently reduced respiratory function.

20. Acidification led to loss of biodiversity in freshwaters. Key species (salmon and trout) were lost and species richness in a more general sense was reduced (e.g. for insects and snails), while ecosystem structure (i.e. the food web structure) becomes altered.

21. N deposition and associated enhanced N leaching to surface waters could increase primary productivity in freshwaters. Co-limitation of phytoplankton by N and P was common and enrichment of freshwaters with both nutrients gave usually stronger effects on production than enrichment with single nutrients. There were strong indications that growth of nuisance aquatic plants, such as the N tolerant rushes (*Juncus bulbosus*), was stimulated by atmospheric Nr. Nuisance species changed the recreational use of the water (e.g. for fishing and bathing), as well as affected ecosystem biodiversity. Nr effects on the function and structure of low nutrient ecosystems, very common in north temperate regions in Northern Europe and Canada, were not well understood.

22. Several studies showed that N input to coastal areas contributed to eutrophication and nuisance algal growth. Examples were found all over the world and were particularly well

documented in the Baltic Sea. The relative contribution of atmospheric input and riverine input to eutrophication of coastal seas was not yet well known.

D. Human health

23. The update of the World Health Organization’s *Air Quality Guidelines* in 2005 resulted in recommendations on numerical guidelines on different air pollutants. It retained the value for NO_2 as an annual average of 40 µg m^{-3}. The Guidelines defined the air quality targets to be achieved everywhere in order to significantly reduce the adverse health effects of the pollution. According to the Joint Task Force on the Health Aspects of Air Pollution of the World Health Organization (WHO)/European Centre for Environment and Health (ECEH) and the Convention’s Executive Body, they provided an important input to the Convention’s work.

E. Materials

24. High Nr levels, especially in the form of the highly acidic nitric acid (HNO_3), are harmful to some materials, especially in urban areas with high traffic. They contribute to economic loss and the degradation of cultural heritage. NO_2 can act as an oxidant. Laboratory experiments showed a synergistic effect of sulphur dioxide (SO_2) and NO_2 on several materials. NO_2 can also be important for the degradation of certain polymer materials.

IV. SPATIAL ASSESSMENT OF THE SEVERITY OF NITROGEN EFFECTS

25. Nr effects are variable across ecosystems. It was thus important to use tools with objective criteria that can integrate detrimental effects across large areas. Such tools can provide both policymakers and citizens with information on the spatial extent and severity of the problem.

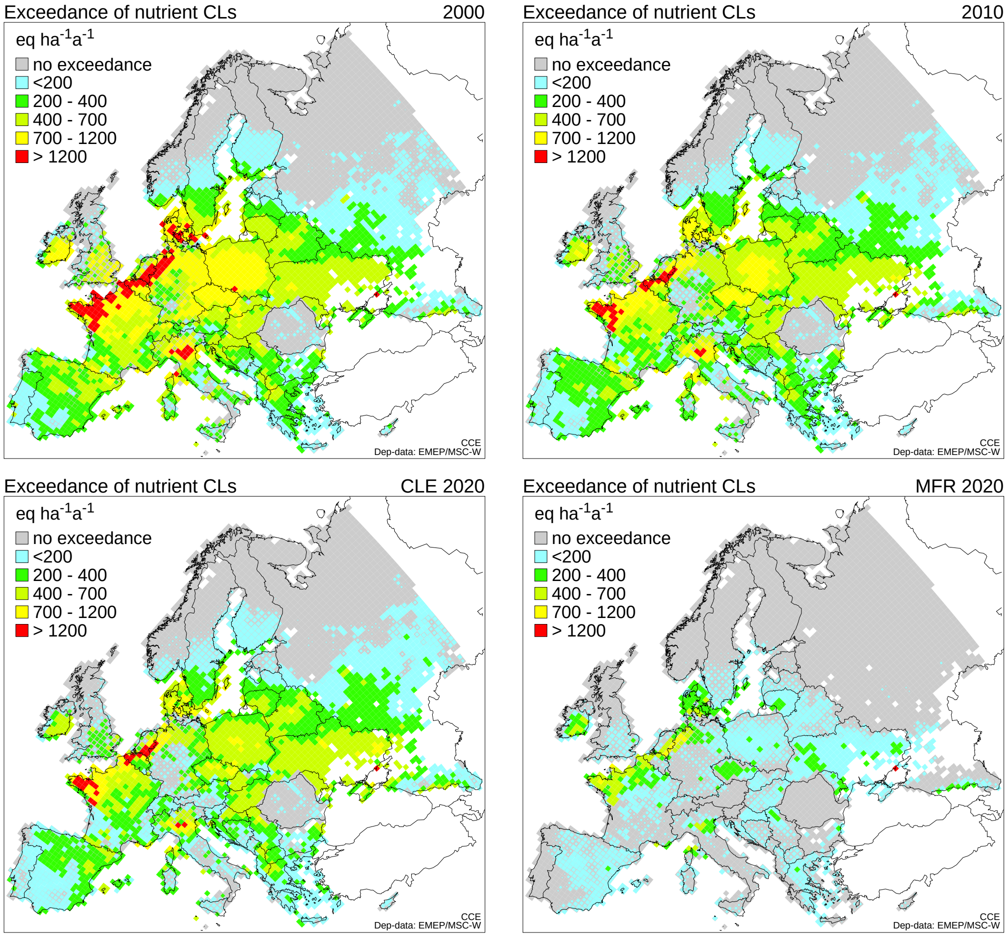
26. When Nr deposition rates were lower than critical loads calculated for a particular receptor (e.g. a sensitive aquatic ecosystem), these maintained their ecological functions and long-term integrity against stress. When deposition was higher than the critical load, the latter being exceeded and the receptor at risk of detrimental effects at some point in time. The exceedance of critical loads for eutrophication by nutrient N is a key indicator of risk to adverse effects on ecosystem structure and functioning, including biodiversity.

27. Critical loads for eutrophication were exceeded in two thirds of soils at the level II plots of ICP Forests, showing that N deposition and the resulting N enrichment in the soils is a widespread risk. Risks of eutrophying N deposition were mapped for Europe by the International Cooperative Programme on Modelling and Mapping of Critical Loads and Levels and Air Pollution Effects, Risks and Trends (ICP Modelling and Mapping) calculated from critical load data submitted by its national focal centres and modelled deposition using data from Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP). The exceedance of critical loads was calculated for different years and

deposition scenarios. The total European area at risk from eutrophication is modelled to decrease from 49 per cent in 2000 to 47 and 17 per cent in 2020, when deposition was calculated from emissions assuming current legislation (CLE) and maximum technically feasible reductions (MFR) in 2020, respectively.

28. In addition to the area of ecosystems at risk, the average accumulated exceedance (AAE) was also important for assessing air pollution abatement needs. The areas with high critical load exceedance were found in particular in areas with intensive agriculture and significant NH_3 emissions, e.g. in parts of North-Western Europe and Northern Italy.

Figure 1. Exceedance of critical loads for eutrophication by modelled total N depositions in 2000 (top left) and in 2010 (top right), and for two emission scenarios in 2020 assuming CLE (bottom left) and MFR (bottom right)



Source: Coordination Centre for Effects (CCE) and EMEP Meteorological Synthesizing Centre-West (MSC-W).

29. Exceedance of Nr as an acidifying, as opposed to eutrophying, substance has also been calculated. Currently, the regions most severely being affected by acidification from N range

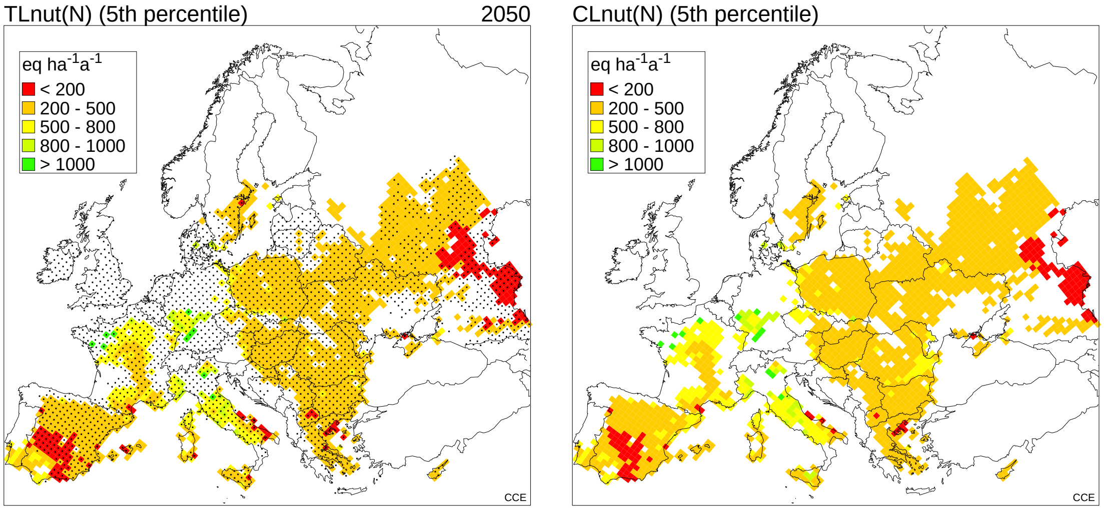
from southern Scandinavia to the British Isles and to Eastern Europe. The affected region was expected to be considerably reduced in 2020. Modelling suggested that applying maximum technically feasible emission reductions would reduce critical load exceedance to a few hot spots.

V. PREDICTING THE FUTURE WITH MODELS

A. Dynamic modelling of ecosystem effects

30. Critical loads relate to a sustainable state of a given ecosystem. They exclude time-dependent changes in ecosystem functions, such as the reduction of soil cation exchange capacity with continuous acid deposition. In order to predict time dependent changes in ecosystem conditions, models should include dynamic soil, plant or chemical processes. Modelling reveals time-dependent responses of ecosystems to deposition scenarios. Dynamic models can also be used to define the deposition rates, which are necessary to reach the critical load of an ecosystem by a given year and not to exceed it thereafter. By definition, these target loads are lower than critical loads. Figure 2 illustrates target loads computed with the very simple dynamic (VSD) model by ICP Modelling and Mapping.

Figure 2. The target loads for 2050 (left panel) and critical loads (right panel) for eutrophication due to nutrient N



Note: A black dot in a grid cell indicates that there are also ecosystems with target loads that cannot be attained by 2050.
Source: Coordination Centre for Effects (CCE).

31. The VSD model was also tentatively used by ICP Modelling and Mapping to simulate the development of the C/N ratio in 2100. Two alternative scenarios were tested for the period 1980–2100: (a) constant 1980 deposition and (b) deposition assuming maximum feasible emission reductions. Results indicate that protected areas with C/N>25 increased from 30 to 40

per cent and from 40 to 50 per cent, respectively. The uncertainty of such dynamic model results at a European scale could be managed within integrated assessment, i.e. by the Task Force on Integrated Assessment Modelling, provided that a sufficient number of scenarios were used.

32. More complex dynamic plant, soil and water models offer the ability to assess the changes that could be expected in response to future N emission reductions. The models contain mathematical representations of the biotic and abiotic processes that control N cycling in the environment. Their applicability to Convention work has been discussed e.g. in the Joint Expert Group on Dynamic Modelling. These models can also be used to determine the long-term effects of air pollution together with climatic and land management changes, because many processes inducing changes in plant population and chemical conditions are climate-dependent.

33. A number of dynamic vegetation models were used to assess changes that could be expected in plant communities with changes in N deposition. These coupled models, or model chains or systems, consisted of a combination of biogeochemical models of N behaviour in the soil, connected with vegetation models, which predicted N impacts on plant species and biodiversity. All model systems had advantages and disadvantages, but were deemed suitable to predict changes in plant species assemblages and habitat suitability in relation to atmospheric deposition and climate change.

34. For example, a dynamic vegetation model HEATHSOL-UK was used to assess long-term impacts of N deposition on lowland heaths from the years 1850 to 2050 under different land management regimes. The results suggested that land use management was as important as recent N deposition in controlling lowland heath community composition. The model predicted that deposition prior to 1950 did not lead to significant increases in N availability, except in regions with very high deposition. In contrast, the long-term impacts of grazing, cutting and burning on the N budget of a site were predicted to be more significant in terms of sensitivity of heathland status to increased N deposition. However, unmanaged plant communities could be highly sensitive to N deposition exceeding the critical loads. It should be noted that dynamic models contain uncertainties due to incomplete understanding of some N processes in soils and waters.

35. The model of acidification of groundwater in catchments (MAGIC) was used extensively in Europe and North America to assess the chemistry and transformation of sulphur (S) and N in soils, streams and lakes. Field studies showed that N leaching from soils to freshwaters was unlikely to occur at deposition less than 8 kgN ha^{-1} a^{-1}. At values above this threshold, catchment soil composition, (e.g. C/N ratio) and other characteristics determined the severity of the leaching problem on aquatic eutrophication and acidification. These observations provide the basis for dynamic models.

B. Modelling of effects on materials

36. The effects of different air pollutants on corrosion have been derived as dose-response relationships, where temperature and relative humidity, among others, were also influential. These relationships could be used to evaluate the risk of different corrosion rates caused by pollutants to various materials. Although N effects could not be isolated from an exposure to multiple pollutants, its relative importance could be calculated by the International Cooperative Programme on Effects of Air Pollution on Materials, including Historic and Cultural Monuments (ICP Materials). In particular, HNO_3 was included in dose-response functions for the indicator materials zinc and limestone, but not for carbon steel. HNO_3 was one of the contributors to corrosion in the multi-pollutant situation, together with other acidifying pollutants. The functions for zinc and limestone could be used to calculate its relative importance.

C. Modelling human health effects

37. The knowledge of effects of air pollutants on health was gathered from various epidemiological, toxicology and other studies. The exposure-response relationships were combined with current and future modelled levels of air pollutants concentration and deposition as well as geographical data on population. The assessment of health effects was mainly based on pollutants for which N is a precursor gas. The effects of O_3 were evaluated with the annual sum of daily maximum eight-hour means of concentration levels above 35 parts per billion (SOMO35). The effects of PM were quantified with the mass of fine PM ($PM_{2.5}$).

VI. KEY DRIVERS AND LINKS TO OTHER POLICIES

38. Effects of Nr in ecosystems, built environments and human populations are linked to other pollutants that affect the interaction with receptors. In addition, land use, climate change and other anthropogenic activities influence the determination of its effects. An improved understanding would require a comprehensive view of the whole Nr cycle, which is one of the aims of the Task Force on Reactive Nitrogen.

39. Airborne anthropogenic Nr mainly originates from food production and energy combustion activities. These activities change in response to changes in demography, prosperity, markets, technology and policy. There is increased awareness that the diets chosen by humans have direct effects on food production and hence on Nr production. Increases in prosperity and mobility, globalization and individualization all affect energy use directly or indirectly, and hence Nr production. Understanding the intimate but complex relationships between societal behaviour and airborne Nr production is key to developing more effective and efficient policies.

40. The Convention has played a key role in the development of Nr emission abatement policy, notably through the 1988 Sofia Protocol Concerning the Control of Emissions of Nitrogen Oxides or Their Transboundary Fluxes (NOx Protocol) and the Gothenburg Protocol. While significant progress has been made with the abatement of NOx emissions from

combustion sources, relatively little progress has been made with respect to the abatement of NH_3 emissions from agricultural sources. The slow responses to NH_3 emission abatement policies in agriculture have been ascribed to: (a) the significant differences in farming systems and environmental conditions, combined with the complexity of the N cycle; (b) a variable interpretation by Parties of the targets and provisions in protocols and regulations; (c) a hesitation to implement measures, due to the perceived high costs to farmers and limited effectiveness; (d) a hesitation to introduce mechanisms to monitor compliance by farmers, due to the perceived high costs; (e) legislative delays; (f) the failure by farmers to implement measures, due to within-system constraints, perceived and actual costs and the needed learning time; and (g) potential antagonisms between measures, especially the lack of integration of measures aimed at decreasing NO_3 leaching and those aimed at abating NH_3 emissions. Evidently, these considerations would require a reconsideration and integration of agricultural and Nr emission abatement policy.

41. Dietary changes for dairy cows and cattle may decrease methane emissions from ruminants by 5–10 per cent. However, as the ingredients in the diet for methane production decrease, the protein content tends to increase and thereby also the N excretion by the ruminants and the potential for NH_3 emissions. This antagonistic effect occurs especially when drastic changes are made. As long as the changes in the diet are modest, the antagonistic effects are much smaller or even absent. For example, dietary changes to lower the protein content can be made without much change in the amounts of ingredients (e.g. celluloses) for methane production. Research on measures to decrease methane emissions from ruminants is still in its infancy. It is complex and there are many other trade-offs, including animal health and welfare.

42. Dynamic model simulations indicated that N emission controls were important in enabling the maximum recovery from S emission reductions. Increased N leaching had the potential to offset the recovery predicted in response to S emission reductions and further decrease pH in freshwaters. Large decreases in S deposition that occurred between 1980 and 2000 would in most cases stop the decrease in soil base saturation, but there would be little or no recovery of the soil acidity status in future due to the continuing high N deposition. Studies at ICP Integrated Monitoring sites have indicated that climate change would almost certainly drive ecosystem changes, which would occur regardless of atmospheric N deposition. Thus, pre-industrial status of ecosystems would almost certainly not be achievable in all locations.

43. Interactions between C and N influence C sequestration in soils and plants. In the past, increased N deposition has increased the storage of C in forests while decreasing it in some other natural ecosystems, such as bogs. In the long run, increased storage of Nr will increase the risk of increased leaching of Nr, with detrimental consequences for aquatic conditions and major impacts in the consecutive transport to the sea.

44. Recent data indicated a total C sequestration range of 20–75 kgC/kgN, but the impact was counteracted by increasing N_2O emissions. Terrestrial ecosystems would only respond to elevated N inputs if they were N limited. In areas with high N deposition, N fertilization might

not be beneficial anymore, because it could lead to adverse growth effects due to impacts of N-induced eutrophication and acidification of forests. For example, a growth improvement in a highly N-saturated Dutch Scots pine stand was observed when the N input to the forest floor was reduced by means of a roof. The impact of N on C sequestration might be negative for peatlands. N-induced eutrophication led to vegetation change, most notably to the loss of peat-forming species such as *Sphagnum*, with a replacement by grasses and mosses. This might reduce or even reverse the positive effect of N deposition on C sequestration, placing existing peatland C stocks at risk. It would seem risky to rely on maintaining high N deposition levels as a measure to mitigate climate change.

45. Land use was not considered in most current assessments of the impacts of N deposition. Vegetation modelling indicated that caution was needed in the interpretation of studies, which related current N deposition to recent ecological change and to biological indicators of possible change. Variation in historical land use management might make the N deposition signal difficult to detect. Results in the United Kingdom suggested climate extremes could increase sensitivity to N deposition in terrestrial systems, while at the same time, warming would increase pathogen attacks on plant ecosystems.

46. Though most of the work done in the ICPs has been based in Europe, there have also been related activities in North America. Work has covered the secondary effects of N, especially O_3 damage of vegetation. Recent work in isolated lakes in the Rocky Mountains in the United States of America and in arctic areas in Canada has shown shifts in lake algal species under very low N deposition. Studies in Canada using indicators derived in Europe have suggested a number of agricultural and industrial regions where critical loads for eutrophication have been exceeded.

VII. CONCLUDING REMARKS

47. The effects of Nr on human environments include acidification and eutrophication of soils and waters, soiling and corrosion of materials and, in particular by secondary PM, increased human health risks. Enhanced deposition of Nr has contributed considerably to a reduced plant biodiversity in some habitats.

48. The Convention has played a key role in developing N emission abatement policies. These policies have resulted in significant NOx emission reductions, in particular from combustion sources. However, relatively little has been achieved in terms of abating NH_3 emissions from agriculture.

49. In spite of current legislation, current N emissions and deposition continue to have adverse effects on the environment and health. In the work to revise the Gothenburg Protocol, further N abatement measures are required, in particular measures for reducing NH_3 emissions.

50. Climate change will almost certainly influence the future effects of N as an air pollutant. It is therefore important to enhance monitoring and research activities related to N effects.
