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Item 4 (a) of the provisional agenda

WORKSHOP ON THE CAUSAL RELATIONS OF NITROGEN IN THE CASCADE*

Report by the organizers with the assistance of the secretariat

INTRODUCTION

1. The Workshop on the Causal Relations of Nitrogen in the Cascade took place on 21–23 November 2005 in Braunschweig, Germany. It was organized by COST Action 729 of the European Science Foundation (ESF).

* This document was submitted on the above date because of processing delays.

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2. The workshop was attended by 40 experts from the following Parties to the Convention: Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Poland, Sweden, Switzerland and the United Kingdom. The European Commission, the International Cooperative Programme (ICP) on Forests, ICP Waters, ICP Vegetation, the EMEP Meteorological Synthesizing Centre - West (MSC-W) and the UNECE secretariat were represented.

I. AIMS OF THE WORKSHOP

3. The objective of the workshop was to assess the state of knowledge of the causal relationships in the nitrogen cycle. Improved understanding and diminished uncertainty in the relationships would form the basis of enhanced and integrated policies.

4. The following main questions were addressed:

(a) What is the state of knowledge concerning cause-effect relationships?
(b) How well do we understand the different parts of the causal chain?
(c) How well can we model the chain and on what scale, and are the results suitable for integrated assessment modelling?
(d) What action is needed for research, experiments and models?

5. The workshop was opened by Mr. J. W. Erisman (Netherlands). He briefly presented the background and main aims of the workshop.

II. CONCLUSIONS

6. The workshop noted that nitrogen played an important role in many environmental issues. In most cases nitrogen was not a dominant but an important factor. Anthropogenic production of reactive nitrogen, which comprised inorganic nitrogen (e.g. ammonia (NH_3), ammonium, nitrogen oxides (NOx)) and organic nitrogen (e.g. urea, amines, proteins), in the biogeochemical cycle led to increased exposure to air pollutants (NOx, particulate matter, organic nitrogen containing toxics), water pollution (nitrates), acidification, eutrophication, changes in species composition in terrestrial and aquatic ecosystems, and changes in climate and the stratospheric ozone layer. Apart from the contribution to these effects, reactive nitrogen had the potential to cascade through the environment, contributing to different effects over time.

7. The workshop prepared an overview of current knowledge and understanding of nitrogen-related air pollution effects in Europe (see annex). In general, the evidence for the effects, based on empirical relationships between changes in the nitrogen cycle and the impacts, was adequate to good. The level of understanding and the description of processes in models were not well developed, due to the complexity of the systems and the many interactions.

8. The workshop could not propose clear indicators or thresholds for integrated assessment modelling. The exceptions were (dynamic) models for (semi-)natural vegetation in North-Western Europe and freshwater ecosystem models. The level of understanding was limited to the drivers (e.g. deposition, nitrate leaching, nitrogen cycling) in the different systems, the different roles of reduced and oxidized nitrogen, the feedback mechanisms and the link to other biogeochemical cycles.

9. The workshop agreed that emissions of major single sources of reactive nitrogen could be quantified and modelled. It considered that agriculture was the most complex emission sector with regard to understanding the processes leading to (net) production and emission of nitrogen compounds and abatement options, costs and efficiencies. Agriculture was the most important sector for NH_3 emissions equal to nitrogen oxides emissions from the energy sector. The share of agricultural sources was 10% of the greenhouse gas emissions (methane and nitrous oxide (N_2O)) and 66% of the N_2O emissions in Europe.

10. The workshop noted that abatement measures for NH_3, N_2O and nitrate included nutritional measures, animal housing and manure storage design, fertilization practices and cropping and land use planning. "Industrial and new thinking", including the optimization of the nitrogen life cycle in terms of nitrogen efficiency, was necessary for effective abatement measures as part of more integrated policies. As nitrogen cascaded through various stages in agricultural production systems before its eventual emissions, measures aiming at mitigation in an early stage would have (positive or negative) effects on emissions at later stages. These interactions were not always simple and had to be evaluated using a mass-balance model. Generalization in time and space was necessary, especially for agricultural and diffuse sources.

11. The workshop noted that nitrogen cascaded easily through different environmental compartments, where many changes in its oxidation state might occur. Nitrogen could be stored in several places. Both the storage capacity and time might vary. The stores included organic nitrogen in soils, forests (where nitrogen was cycled through tree uptake, leaves, litter and soil) and sediments in lakes, rivers and marine areas. Losses of nitrogen from the cascade eventually occurred in non-reactive gaseous form (N_2) after denitrification.

12. The workshop agreed on the need to quantify the reactive nitrogen stores, delay times and losses in the cascade. Nitrogen modelling required improved descriptions of atmospheric transport through the cascade and the atmosphere-biosphere exchange, temporal and spatial scales and other interactions (emission-concentration-deposition, chemistry). Further observations were needed to understand the different processes determining the transport of nitrogen through the system (i.e. atmoshpere, soil, water, biosphere) and to verify the models describing these transport mechanisms for quantification of the total nitrogen flows.

III. RECOMMENDATIONS

A. Effects

13. The workshop recommended that research be conducted to:

(a) Gather and make available sources of available monitoring and modelling data to develop models, indicators and impact criteria;

(b) Clarify further major effects, with harmful endpoints and intermediate indicators;

(c) Compile and make available existing dose-response relationships from case studies and extensive monitoring programmes;

(d) Compare models to observations for further validation and explore the potential for applications at large geographical scales.

14. The workshop identified the following research priorities to fulfil future policy needs:

(a) Continue to develop models linking soil status to biodiversity to assess past and future trends in species change at the regional level under different deposition scenarios. This requires an expansion of monitoring and experimental work to provide the data needed to understand processes and develop and test models;

(b) Quantify and develop models which allow interactions with other drivers (e.g. ozone, greenhouse gas emissions, climate change including elevated carbon dioxide (CO_2), management of nitrogen, for example, at farms and forests) to interpret and predict spatial and temporal trends in ecosystem compartments;

(c) Quantify feedbacks between ecosystem components, including changes in plant diversity (focusing on mosses and lichens due to their sensitivity), fauna (macro and micro), soil microbes, and implications for biogeochemical functioning and ecosystem resilience to stresses;

(d) Separate oxidized and reduced nitrogen effects in all ecosystem compartments;

(e) Develop, in a stepwise approach, an integrated assessment model on emission reduction requirements, including methods for spatial and temporal upscaling;

(f) Identify major paths in the causal chain of emissions, atmospheric transport and effects on specified receptors.

B. Emissions

15. The workshop recommended that research on emissions be done to:

(a) Gather high-quality experimental observations for statistical analyses and model validation;

(b) Connect models with clear boundary definitions and upscale models from micro-scale to regional scale;

(c) Compile agricultural management data (e.g. farm management) and information on emission abatement options;

(d) Develop an integrated assessment model on different environmental issues and socioeconomic aspects across various spatial and temporal scales;

(e) Cultivate innovative thinking on agricultural production and regional mitigation options.

C. Transport and surface exchange

16. The workshop noted the following needs for research:

(a) More insight into missing and/or poorly quantified diffuse emission sources (e.g. NH_3 emissions from waters, N_2O emissions from wetlands);

(b) Expansion of nitrogen budget studies to catchment scale;

(c) Better understanding of the status and trends of relations between emissions and concentrations;

(d) Study of the consequences of spatial and temporal upscaling and downscaling of the nitrogen cycle;

(e) Incorporation into regional models of recently identified mechanisms, including effects of the nitrogen monoxide–nitrogen dioxide–ozone triad in the canopy, effects of gas-particle interconversion in the canopy, the ammonia compensation point and meteorology as a driving force on nitrogen emissions, in particular NH_3.

Annex

Summary of current knowledge and understanding of effects related to nitrogen air pollution in Europe (excluding agricultural systems). The scale ranges from not known (– –) to well known (++); "Manual" denotes the Convention's *Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risks and Trends*.

Effects	Evidence for effect	Level of processes	Status of modelling	Impact indicator	Critical value and indicator	Spatial and temporal scales	Gaps in knowledge	Remarks
Terrestrial ecosystems and species diversity								
(Semi-) natural vegetation (semi-temperate vegetation, non-productive natural forest)	++	+	+ empirical critical loads, +/– dynamic	– empirical and simple mass balance critical loads in Manual; qualitative indicators (directives, red lists, etc.)	Empirical and simple mass balance critical loads; – no quantitative level for habitat protection	Mostly North-Western Europe and North America; temporal effect determined by acute or chronic input	Regional application; Eastern Europe, Caucasus and Central Asia missing	Modelling in progress, applications pending, validation needed
Soil microbes	+	–	– –	– –	– –	– –	Changes in diversity on ecosystem functioning, resistance and resilience	
Faunal (micro and macro)	+	+/– (– for processes)	–	Quantification missing	– –	– –	Identify direct and indirect effects (e.g. food chain)	
Soil quality								
Nutritional balance	++	+	+	+ critical loads for forests in Manual	+ see Manual	Depends on load		Known only for forests, perhaps crops; expand for other species

Effects	Evidence for effect	Level of processes	Status of modelling	Impact indicator	Critical value and indicator	Spatial and temporal scales	Gaps in knowledge	Remarks
Acidification of soils	++	++	++	+ base cation to aluminium (Al) ratio, pH and [Al]	Abundant	Slow (from decades to century); large spatial impact		
Production of forests	+ for growth	+	+	+ yield	Effect is positive	Spatially complex, temporally quick		Interaction with other drivers
Production of (semi-)natural vegetation	+/–	+/–	+/–	Yes, qualitatively	–	Temporally quick		Many systems used for low-intensity production; relevant to quantify carbon sequestration
Sensitivity to events (frost, drought, diseases, management)	+	+	+/–	Case studies	–	Takes years to build up susceptibility		Trees and vegetation; case studies on harmful effects (risk) on trees
Waters								
Surface waters	++	++	Many for acidification; links to biology exist	pH and ANC for acidity; also for eutrophication	Yes for acidification; for eutrophication varies among countries linked to Water Framework Directive	Timing slow; more data available for North-Western Europe	Regional application; data mainly from North-Western Europe	Also biological

Effects	Evidence for effect	Level of processes	Status of modelling	Impact indicator	Critical value and indicator	Spatial and temporal scales	Gaps in knowledge	Remarks
Marine	++	+						Insufficient expertise in group
Climate								
Nitrous oxide	++	+	++	CO_2-equivalents	Does not exist			
Methane	+/–	+/–	+/–	CO_2-equivalents	Does not exist		Data from more regions, soils and habitats	
Carbon dioxide flux from soil organic matter	+/–	+/–	–	CO_2	–	Quick direct effects; slow indirect effects (change in litter quality)	Reported effects on decomposition need to be fully tested	
Fine particles	+	+	+	–	–			Linked to other secondary aerosols

Note: Human health issues, including nitrate in drinking water, air pollution, ozone and nitrogen oxides, fine particles and pollen production, were all issues beyond the expertise of the group and were not discussed.