Scope and Overview of the UNECE Expert Workshop on Ammonia

Atmospheric Ammonia: Detecting emission changes and environmental impacts.

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1. INTRODUCTION

Atmospheric ammonia is emerging increasingly as the key transboundary air pollutant that will contribute to future impacts of nitrogen and acidity on terrestrial ecosystems. At the same time, ammonia is making an increasing relative contribution to particulate matter, with its associated human health risks. These features are shown clearly in Figure 1 below, from the Clean Air For Europe (CAFÉ) programme.

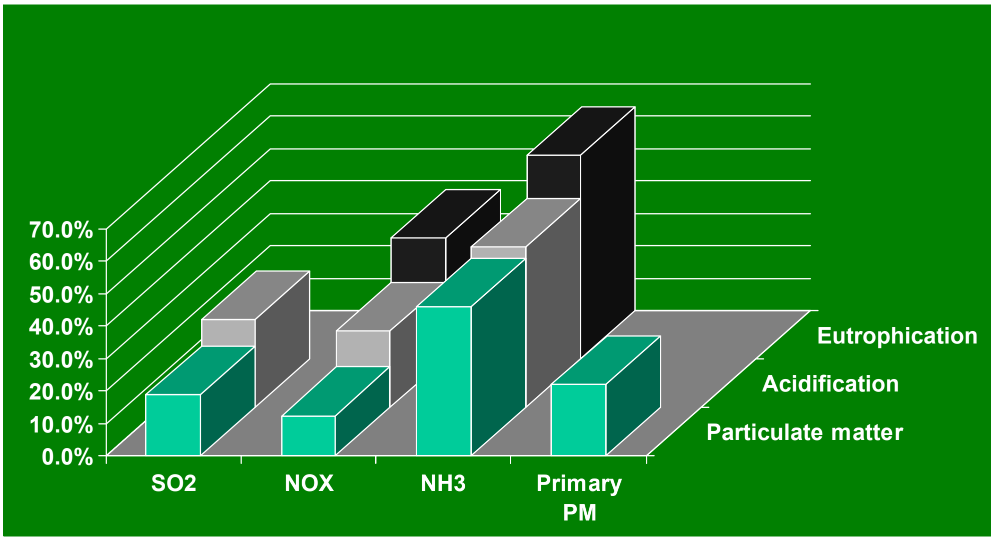

Figure 1: The estimated contribution of NH_3, SO_2, NO_x and primary PM to environmental problems in 2020. From the Clean Air For Europe (CAFÉ programme).

Thus, by 2020, it is estimated that NH_3 will be the largest single contributor to each of acidification, eutrophication and secondary particulate matter. This increase is particularly a reflection of the success of European policies to reduce SO_2 and NO_x emissions. As a result, NH_3 is increasingly dominating nitrogen and acidifying inputs, while reducing ammonia emissions and the associated environmental impacts remain major challenges for the future.

This UNECE expert workshop is focused on several key questions regarding the detection of changes and quantification of environmental impacts due to ammonia. Following the classical format of UNECE expert workshops, it aims at reaching agreement on current scientific understanding and providing draft recommendations that can be useful to the Convention on Long Range Transboundary Air Pollution.

The workshop addresses the following key questions:

1. Do existing critical thresholds for ammonia reflect current scientific understanding and, if not, what are suitable values according to current knowledge?
2. To what extent can independent atmospheric measurements verify where regional changes in NH_3 emissions have and have not occurred?

3. How can transboundary air pollution assessment be downscaled to deal with ammonia hotspots in relation to operational modelling and monitoring?
4. What are the differences between mesoscale (regional) atmospheric transport and chemistry models in relation to their formulation and results for ammonia?

These questions have been addressed previously in UNECE workshops, but in all cases the workshop conclusions can now be considered as somewhat dated, emphasizing the need for a review of the issues. Several previous UNECE Expert Workshops were particularly relevant in relation to ammonia:

- **Bad Harzburg (1988)** Critical levels workshop (origination of critical level for NH_3, Postumus, 1988)
- **Egham (1992**) Critical levels workshop (included: update review on critical level for NH_3, Ashmore and Wilson 1994, van der Eerden et al. 1994, 1991)
- **Göteborg (1992)** Workshop on the deposition of acidifying substances (included: review of reduced nitrogen dry deposition, Sutton et al. 1993)
- **Aspenaas Herrgaard (1997)** Workshop on strategies for monitoring of regional air pollution (Included: review of air monitoring for assessment of air pollution effects, Lövblad and Sutton, 1997).
- **Bern (2000)** Workshop of the UNECE Ammonia Expert Group (development of UNECE Framework advisory code of good agricultural practice for reducing ammonia emissions (Menzi and Achermann 2001) and review of the link between control of ammonia emissions and atmospheric measurements of reduced nitrogen (Sutton et al. 2001).

More recently the effects of ammonia as a contribution to nitrogen deposition have been reviewed in the **Bern 2002** workshop (Achermann and Bobbink, 2003, Bobbink et al., 2003). However, this focused on empirical critical loads for nitrogen, rather than explicitly on the role of ammonia. As part of that workshop, the importance of uncertainties in atmospheric N deposition, including NH_3 was addressed by Sutton et al. (2003). In addition, a more recent review of overall monitoring strategies in the EMEP programme, including regarding gas-particle distribution, was made at the **Oslo 2004** workshop (Aas 2005).

It should be noted that approaches to deal with ammonia in "hot spot" areas have received little attention in previous UNECE workshops, with the exception of sub-grid variability analysis (e.g. Sutton et al. 2001, 2003). This is presumably because this topic has previously been considered a local rather than transboundary issue. However, it is important to give due attention to these issues in the international context, since the environmental impacts even in areas of high agricultural activity are a consequence of both near-source and transboundary contributions, while inclusion allows the approaches being developed in different countries of the CLRTAP (Convention on Long Range Transboundary Air Pollution) to be compared.

In the following text some of the main issues associated with each of the four key questions are summarized, particularly bearing in mind developments since the previous expert workshops.

2. EXPLAINING THE KEY QUESTIONS OF THE WORKSHOP

To what extent can independent atmospheric measurements verify where regional changes in NH_3 emissions have and have not occurred? (Working Group 1)

This question includes the following objectives:

a. To quantify the extent to which estimated regional changes in ammonia emissions have been reflected in measurements of ammonia and ammonium in the atmosphere;

b. To distinguish cases where the estimated changes in ammonia emission are due to altered sectoral activity or the implementation of abatement policies and thereby assess the extent to which atmospheric measurements verify the effectiveness of ammonia abatement policies;
c. To make recommendations for future air monitoring and systems for assessing the national implementation of ammonia abatement policies.

The discussion on this topic was initiated in the late 1990's following the observation that expected changes in NH_3 emissions in the Netherlands and in Eastern Europe were not matched by observed reductions in NH_3 concentrations. In the Netherlands, an extensive NH_3 emissions reduction policy was implemented and it was therefore surprising that by 1997, NH_3 concentrations were no smaller than in 1993, when the policy was initiated (Erisman et al. 1998, van Jaarsveld et al. 2000). The issue became known as the "Ammonia Gap", raising questions regarding the cost effectiveness of the NH_3 abatement policy. Additionally, in eastern Europe, following the crash in agricultural livestock populations and fertilizer usage after the political changes of 1989, it was curious that available monitoring in Hungary could also not detect the expected reductions in NH_3 emissions (Horvath and Sutton 1998). Since the emissions in east Europe must have decreased, due to reduced sector activity, this raised the question of whether there were non-linearities in the link between NH_3 emissions and atmospheric concentrations and deposition. These issues were reviewed at the Bern Workshop in 2000 (Sutton et al. 2001), which noted how interactions with changing SO_2 emissions, local spatial variability, short term meteorological variability and interactions with NH_3 compensation points were among the factors explaining the difficulty to make the links.

One of the key findings of the Bern workshop described in the Working Group Report (http://www.nitroeurope.eu/ammonia_ws/documents/AEG_bern_wg2_report.pdf), was the severe lack of NH_3 monitoring data across Europe. Recommendations were therefore made regarding the need to establish robust monitoring networks, especially with the ability to speciate between NH_3 gas and NH_4^+ aerosol, a finding which was re-enforced by the Oslo Workshop (2004) on monitoring strategies (Aas 2005).

It is now 6 years since the Bern Workshop and major new datasets on European NH_3 and NH_4^+ monitoring and their relationship to estimated NH_3 emissions have become available. The focus of **Working Group 1** of the present workshop will therefore be to update the current scientific understanding based on these new datasets and assessments. In particular, the group will ask: whether there is still an "Ammonia Gap" in the Netherlands, whether such a gap exists in other countries, whether we can be confident of the effectiveness of ammonia mitigation policies and how can we best address the relationships between emission and deposition using atmospheric modelling and improved monitoring activities.

Do existing critical thresholds for ammonia reflect current scientific understanding and if not what are suitable values according to current knowledge? (Working Group 2)

This question includes the following objectives:

a. To examine the case for setting new ammonia critical threshold(s) based on current evidence of direct impacts of ammonia on different receptors;
b. To discuss the extent to which vegetation and sensitive ecosystems appear to be differentially sensitive to ammonia versus other forms of reactive N;
c. To debate the case for establishing indicative air concentration limits for indirect effects of ammonia, which would be consistent with current critical loads for nitrogen.

The critical level for NH_3 has stood for nearly 15 years since its last revision at the Egham Workshop (1992) (Ashmore and Wilson 1994). This lack of activity has perhaps been because critical loads of nitrogen tend to be exceeded at much lower NH_3 concentrations than required to exceed the NH_3 critical levels values set at that workshop. The values set were 3300, 270, 23 and 8 μg m^{-3} for hourly, daily, monthly and annual values, based on the work of van der Eerden et al. (1991, 1994). This has resulted in NH_3 receiving a lower level of attention, since its contribution is in some way hidden in the calculation of total nitrogen deposition, despite the fact that gaseous NH_3 is often the largest single component of nitrogen inputs.

Among the limitations of the data available at Egham (1992) was the fact that these only referred to very short-term studies. As a result, no attention was given to what are the long-term effects of high ammonia concentrations. Thus the annual critical level refers to the exceedance for a particular year, rather than being a long-term annual value which should not be exceeded, as is the case for the empirical critical loads. Recent evidence from the UK shows that the effects of NH_3 concentrations interact over longer periods than a year, pointing to the need to set a long-term annual mean critical level.

One of the questions is how to name a NH_3 concentration threshold that equates to indicative exceedance of the critical load values, such as may be used in setting air quality target values. If such long-term effects of NH_3 are considered "indirect", then there is a difficulty with the critical level nomenclature, since this strictly refers only to "direct" effects. On the other hand, it appears that the original meaning of "indirect" in this context was that effects are mediated via the soil. Hence, it might be argued that even long-term effects of NH_3 are direct, since most of the uptake occurs directly to the plants. In some cases, the mechanism of damage also demonstrates to direct effects, such as damage to sensitive lichens, which is partly mediated through changes in substrate pH rather than just nitrogen supply.

Studies have also shown that for a given N input, NH_3 can show larger effects than other nitrogen forms. This is obviously a difficulty for the critical loads approach, where all forms of N are considered to have an equal effect simply through N dose. Is there a practical way that such differences might be included in the critical loads estimation, or is the simpler approach of incorporating the NH_3-specific effects in the critical level more achievable?

These issues are considered further in a discussion document (http://www.nitroeurope.eu/ammonia_ws/documents/NH3_critical_level_initial_discussion.pdf) that was originally drafted in 2003 and has been brought up-to-date with current questions. The full background document for **Working Group 2** will be available in November 2006 and will take on board the findings of other international experiments and observations of NH_3 effects.

How can transboundary air pollution assessment be downscaled to deal with ammonia hotspots in relation to operational modelling and monitoring? (Working Group 3)

This question includes the following objectives:

a. Review current emission and atmospheric dispersion modelling methods for downscaling NH_3 dispersion and deposition in hot spots;
b. Examine the status of methods for effect assessment and air monitoring in NH_3 hot spots;
c. Recommend broad principles for assessment approaches in ammonia hot spots, including spatial approaches and the interactions between transboundary ammonia emission reduction targets and other policy measures.

To date, most attention in modelling NH_3 dispersion and deposition has focused on the regional and European scale. Certainly, within the UNECE Convention on Long-Range Transboundary Air Pollution, little attention has been given to dealing with NH_3 in hot-spot areas. In the past, it was considered that this was a local problem and not relevant for the transboundary interest of the Convention. However, the role of hot-spots is increasingly recognized by the Task Force on Measurement and Modelling, for example, when modelling the so called city-delta, which is the urban enhancement of particulate matter concentrations above background.

In the case of NH_3, developing assessment approaches in hot-spot areas is similarly important: there are the areas of acutest environmental impact and regulatory focus, for example in protecting designated nature conservation areas near farm sources. In addition, assessments in hot-spot areas need to consider the fraction that derives from local sources versus that which is of more distant national or transboundary origin.

The inclusion of ammonia hot spots for **Working Group 3** is thus the first time that this issue has been treated specifically in a UNECE Expert Workshop. As a result, a large part of the work will be to compare the different approaches that are being implemented in different countries. This needs to consider both: whether similar framework approaches are being taken, as well as the comparability and reliability of the detailed models and methods being implemented. The focus on atmospheric dispersion modelling is in the rural environment rather than the urban environment, so the uncertainty in agricultural NH_3 emissions estimates for specific sites, needs to be considered alongside modelling issues which are relevant in the rural context. The tools to be considered range from detailed models for assessment of the effects of landscape structure, such as the effect of tree belts round farms, to general dispersion models at the landscape scale, as well as the development and application of screening tools. Most focus at these scales to date has been on the fluxes and impacts of NH_3 dry deposition: guidelines also need to be considered regarding the contribution of locally enhanced wet and aerosol NH_4^+ deposition. Overall, Working Group 3 will seek to address whether common lessons can be learned from the experience in different countries. This will consider the broad principles of modelling approaches and the interaction with other policy issues (e.g., Habitats Directive, other forms of N pollution).

While modelling is a major focus, the advances in measurement approaches in hot-spot areas also need to be discussed. This may include developing principles for practical monitoring of NH_3 concentrations in hot-spots, as well as the bioindication of nitrogen responses near NH_3 sources.

What are the differences between mesoscale (regional) atmospheric transport and chemistry models in relation to their formulation and results for ammonia? (Working Group 4)

This question includes the following objectives:

a. Review emission parameterizations used in the models, establishing comparability, spatial and temporal resolution and uncertainties;
b. Review dispersion, air chemistry and deposition formulations identifying key differences and uncertainties;
c. Assess the overall performance of the models against measurements and against a common reference, leading to recommendations for improving mesoscale models of ammonia transport and deposition.

Atmospheric transport and chemistry models are key tools for the assessment of air pollution fluxes and their impacts. Such models typically include NH_3 as one of a suite of pollutants being simulated and as such the degree of attention given to NH_3 is very variable. In many cases models have been originally developed for other pollutants and thus may not be well suited or developed for ammonia. For example, models originally developed to simulate the dispersion of high stack emissions, may include significant uncertainty or simplification in the estimation of ground level NH_3 concentrations (1–2 m), as measured in monitoring networks. The focus of **Working Group 4** is on the formulation, input and performance of mesoscale (regional or country scale) atmospheric transport models and how these relate to European scale assessments.

The primary input to all atmospheric dispersion models are the emission data. The first question is therefore, what is the quality and comparability of the NH_3 emission data used between different models. The unit NH_3 emission estimates used for mapping may derive from emission factors or a mass flow approach and these differ between countries. But are these differences fully justified by differences in agricultural management practices?

There are a wide range of models from Lagrangian to Eulerian, as well as combination approaches. To what extent to these differences affect the outcomes for modelling of NH_3 dispersion and deposition? What are the differences in chemical formulations between NH_3 and other pollutants in the models and how does this affect the modelled atmospheric transport distance of NH_3 and NH_4^+? What are the uncertainties in parameterization of wet deposition and how well is orographic enhancement of wet deposition treated? Finally, it is recognized that modelling dry deposition (or bidirectional exchange) of NH_3 is a major uncertainty at the regional scale: what is the current evidence regarding the effect of SO_2 interactions on NH_3 uptake resistances and deposition velocities and to what extent have NH_3 compensation point formulations been incorporated in the regional models?

This working group will focus initially on validation of the modelled NH_3 emission data and then summarize the existing differences between models and how this may relate in principle to differences in their performance for NH_3 and NH_4^+. A complete model inter-comparison is not feasible at this stage, (due in part to the fact that different regional models run over different domains with varying input data requirements). However, it is planned to see how the performance of each of the regional models compares with results of the European scale EMEP model, which is used in the calculations under the Convention.

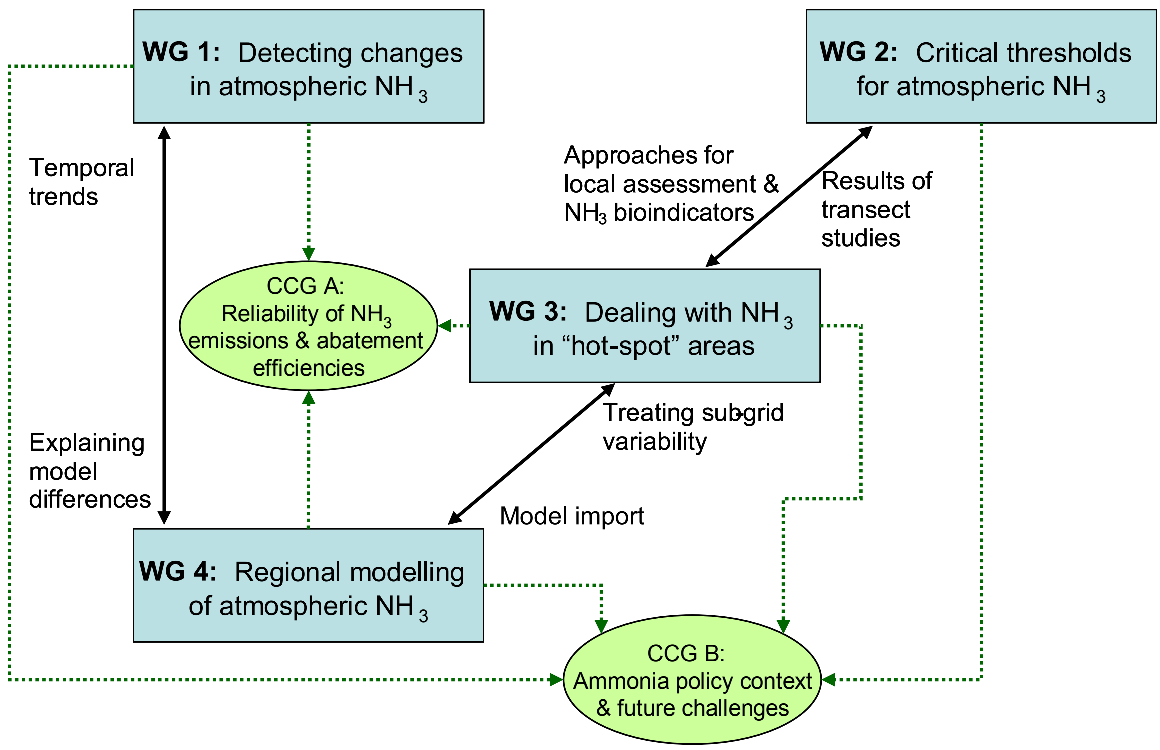

Figure 2: Summary of major interactions and expert exchange between the different Working Groups and Cross Cutting Groups.

INTEGRATION AND SYNERGIES IN THE WORKSHOP

The workshop will be conducted first by plenary presentation and discussion of background documents for each of the topics. The four Working Groups will then run in parallel allowing for discussion of the key issues, selected presentations of new results and debate leading to conclusions and draft recommendations. Each of the working groups is to some extent interrelated with one or more of the others. The major points of interaction between groups are illustrated in Figure 2. To deal with these interactions, the Working Groups will encourage exchange of relevant experts between groups during their main sessions on the afternoon of Tuesday 5 December. In addition, two Cross Cutting Groups will meet during this period to encourage the links to be made between topics:

What are the reliability of ammonia emissions data and abatement efficiencies? (Cross Cutting Group A).

This group will draw together information considered in each of Working Groups 1, 3 and 4 regarding the reliability of ammonia emissions data, both for national totals and spatially distributed estimates for input into atmospheric models at farm, landscape and regional scales. It will consider the known uncertainties in emission inventories regarding abatement efficiencies and the implications of the atmospheric verification results (WGs 1,3 and 4) regarding the need to improve the inventory calculations of emissions the effectiveness of mitigation techniques.

What is the agricultural and environmental policy context and how can scientific understanding help address the future challenges to reduce the negative effects of ammonia? (Cross Cutting Group B).

This group will consider the policy context of the ammonia problem, including socio-economic, environmental, institutional and technological aspects. It will address the links between the different Working Group themes to summarize the current challenges faced in relation to the different environment and health effects of ammonia emissions. Based on the scientific findings from the different groups, the CCG will address the potential role of different policy options to help mitigate these impacts.

Workshop Conclusions and Draft Recommendations

The findings of the different Working Groups and the Cross Cutting Groups will be presented and discussed in plenary on Wednesday 6 December. This will provide the basis to summarize the conclusions and draft recommendations of the expert workshop These will be presented to the relevant components groups of the Convention, including, the Ammonia Expert Group, the ICP on Mapping and Modelling, the Task Force on Measurement and Modelling, for subsequent consideration by the EMEP Steering Body, the Working Group on Effects and the Working Group on Strategies and Review.

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