CONVENTION ON LONG-RANGE TRANSBOUNDARY
AIR POLLUTION

WORKING GROUP ON EFFECTS

International Cooperative Programme on
Effects of Air Pollution on Natural Vegetation and Crops

Minutes

The eighteenth meeting of the Programme Task Force was held from 1st to 4th February, 2005, Almería, Spain.

1. The meeting was attended by 59 experts from the following Parties to the Convention: Austria, Belgium, Czech Republic, Finland, France, Germany, Greece, Italy, Norway, Poland, Russian Federation, Slovenia, Spain, Sweden, Switzerland, United Kingdom and United States of America, together with the chairman and the secretary of the Convention and a representative of the ICP Forests.

2. Mrs M Fernandez (Spain) from the Ministry of Environment opened the meeting, and welcomed the participants to Spain. Mr B Gimeno (Spain) welcomed the participants to Almería and Mr F Dianez (Spain) introduced ongoing horticultural research at the University of Almería. Mr H Harmens (ICP Vegetation Coordination Centre, UK), Chairperson of the ICP Vegetation, thanked Mr B Gimeno of CIEMAT (Spain), Mr J Tello, Mrs R Blanco and their colleagues at the University of Almería (Spain) and Mrs M Fernandez of the Ministry of Environment (Spain) for organizing and supporting the meeting.

3. The Programme Task Force adopted the agenda of the meeting.

4. Mr H Gregor, chairman of the WGE, gave an overview of the organisational structure of the Convention on Long-range Transboundary Air Pollution (LRTAP), involving countries in the geographical region of the United Nations Economic Commission for Europe (UNECE), and the WGE. He emphasized the importance of (bio)monitoring, the production of dose-response functions in determining critical levels/loads for air pollutants and mapping exceedances of critical levels/loads to identify where in the UNECE region stock are at risk. He gave an overview of the results of the 23rd session of the WGE in 2004 and its new reporting structure per air pollutant. The long-term strategy of the WGE will be reviewed in 2005 and Mr Gregor acknowledged the input received so far from the ICP Vegetation. He continued with an overview of the main findings and future challenges reported in the Substantive Report of the WGE ('Review and assessment of air pollution effects and their recorded trends') and thanked the ICP Vegetation for its input into the report. In the ensuing discussion, he stated that the ICP Vegetation should continue to improve methodologies to show both increased risk and increased effects of air pollutants on vegetation.

5. Mr M Johansson, secretary of the WGE, reported on the establishment of two new groups within the Convention: 1) the Task Force on Hemispheric Transport of Air Pollution (as part of the EMEP Steering body), and 2) the Expert Group on Particulate Matter (as part of the Working Group on Strategies and Review). He emphasized the three core activities under the Convention, in which more than 1000 experts/scientists are involved: 1) measurement and modelling of atmospheric pollutants, 2) effects of atmospheric pollutants, and 3) integrated assessment. Currently the Gothenburg protocol has 14 out of 16 ratifications and is expected to come into force later during 2005. Finally, he emphasized the necessity to streamline work plans and communications within the WGE and discussed the new reporting guidelines of the United Nations.

6. Mr H Harmens (ICP Vegetation Coordination Centre, UK), Chairperson of the ICP Vegetation, gave an overview of ICP Vegetation activities and achievements in 2004. After a short introduction of the ICP Vegetation he described the biomonitoring programmes for ozone damage on white clover and *Centaurea jacea* (brown knapweed) and showed that the ozone levels across much of Europe were lower in 2004 than 2003. Nevertheless, the ozone concentrations in ambient air resulted in frequent occurrences of leaf injury on the biomonitors in 2004. He continued with an overview of both the flux-based and concentration-based critical levels of ozone for vegetation as described in chapter 3 of the new Mapping Manual. Mr Harmens reported that the variation in the concentration of heavy metals in mosses across Europe in the 2000/1 survey could hardly be explained by variation in climatic and geographical parameters or by the variation in moss species and applied analytical techniques. He gave an overview of the progress with the preparations for the next European heavy metals in mosses survey (2005/6). For the heavy metals cadmium, lead and mercury, preliminary results of the relationship between the mean concentration of heavy metal in mosses per EMEP grid cell (50 by 50 km) for 2000/1 and the rate of atmospheric deposition of the heavy metals as modelled by EMEP show country specific correlations. Mr Harmens showed an example of encouraging results regarding the application of mosses as biomonitors of atmospheric nitrogen deposition in Norway and the ICP Vegetation encourages participants to include the determination of nitrogen in (selected) moss samples in the 2005/6 moss survey. Finally, he listed the reports and publications produced (partly) by the ICP Vegetation during 2004, described the work plan for 2005 and the anticipated deliverables to the WGE in 2005 and 2006. Mr Harmens thanked the UK Department for Environment, Food and Rural Affairs for their continuing financial support for the coordination of the ICP Vegetation.

7. Mr B Gimeno (Spain) gave an overview of ozone effects on Spanish plant receptors, research carried out under the framework of the ICP Vegetation. A lot of effort on ozone research is concentrated in the East of Spain, where main drivers for ozone production are present. He gave examples of ozone-induced visible leaf injury, interactions between ozone impacts and plant phenology and viral infections, and showed that leaf injury was best correlated with ozone uptake by the plants. He emphasized the importance of the regional impacts of ozone pollution in Spain and stressed the necessity for re-parameterisation of the current EMEP model with respect to Mediterranean countries.

8. Mr M Schaub (Switzerland) represented the ICP Forests and gave an overview on the work conducted by the ICP Forests in 2004/5. He reported on the relationship between passive monitoring of the atmospheric ozone concentration and visible leaf injury in trees. Whereas visible leaf injury increased with ozone exposure, the net rate of photosynthesis and stomatal conductance of leaves decreased with ozone exposure. He has developed a web site showing pictures of visible leaf injury for several plant species.

9. Mr L de Temmerman (Belgium) reported on biomonitoring atmospheric deposition of the trace elements cadmium, copper and lead using white clover. For lead and copper a strong relationship was found between the concentration of the metals in white clover and the rate of atmospheric deposition, such that the natural background concentration and the pollution thresholds for those metals in white clover could be determined. However, such a relationship and parameters could not be determined for cadmium due to variations in the cadmium concentrations in the substrate used in different years.

10. The following presentations reported on areas of research that the ICP Vegetation would like to develop further in the future: impacts of nutrient nitrogen (N) on vegetation, interactive impacts between ozone and climate change on vegetation and links with air pollution networks outside the ECE region. Mrs A Nordin (Sweden) discussed the effects of atmospheric N deposition on the process of vegetation change. N sensitive moss species showed slow recovery after reduction in atmospheric N deposition and she concluded that the current critical load for N of 10-15 kg N ha^{-1} y^{-1} might be too high and should be reduced to ca. 6 kg N ha^{-1} y^{-1}. Mr D Karnosky (USA) gave an overview of the Aspen FACE (Free Air Carbon dioxide Enrichment) research in which the interactive impacts of elevated atmospheric ozone and carbon dioxide concentrations are studied in trees. Species-specific long-term responses to ozone and carbon dioxide have been observed and both factors together offset the often contrasting response of vegetation to the single factors (e.g. elevated ozone reduces net rate of photosynthesis and leaf area index, whereas elevated CO_2 has the opposite effect). Ms L Emberson (UK) reported on the current status of the Air Pollution Crops Effect Network (APCEN), in which links are being developed in particular with air pollution networks in Asia and southern Africa. Currently, yield losses for crops in Asia due to ambient ozone concentrations are being reported and are expected to rise in the near future, which will be a severe threat to food security in the region.

11. Twenty-three posters were presented at the meeting. These showed the results of a variety of ozone themes, e.g. comparison of modified AOT40 and flux maps at a local scale, stomatal and non-stomatal fluxes into crops, ozone sensitivity of upland vegetation at the species and plant community level, visible leaf injury in crops and young trees, interactive impacts of ozone and nitrogen on Mediterranean grasses. Regarding heavy metals, results were presented on the influence of digestion procedures on the determination of elements by ICP-MS and spatial and temporal variation of heavy metals in mosses.

12. The meeting split into parallel sessions considering the ozone and heavy metals sub-programmes.

13. The ozone session on flux modelling was opened by Mr D Simpson (EMEP MSC-W), reviewing recent progress with mapping exceedance of AOTX and stomatal flux ($AF_{st}Y$) in Europe. He described how the uncertainty of these indicators increases with increasing threshold (X in AOTX, Y in $AF_{st}Y$). He also had estimated the uncertainty due to the variations and biases from modelling of ozone concentrations. He pointed out that from a mapping perspective, there seemed to be an optimal choice for the threshold that would minimize the overall uncertainty of the exceedance maps. Mr Simpson also pointed out that gradients across Europe of AOTX were approximately five times larger than those for $AF_{st}Y$ (e.g. from central to northern Europe).

14. Mr P Büker (UK) provided a comparison of photosynthesis (Pn) and multiplicative algorithm (MA)-based stomatal flux modelling methods and concluded that the high data input requirement of the Pn-based models might be problematic for their application on a European scale. Gas exchange data for wheat collected during 2004 was used by Mr H Pleijel and colleagues (Sweden) to review parameterisation of the EMEP model and to compare Pn and MA-based methods. When optimally parameterised, both Pn and MA methods were of similar competence in predicting stomatal conductance. The importance of the F_{phen} function and appropriate choice of g_{max} were also discussed. Open-top chamber experiments conducted in the USA on the responses of soya bean to O_3 and CO_2 were described by Mr F Booker (USA). A good relationship was found between mean midday O_3 flux and yield for the O_3 +/- CO_2 treatments. The ensuing discussion covered outstanding issues in need of resolution for flux-based methods including consideration of irrigation and dealing with uncertainty.

15. Two papers described impacts of ozone on (semi-)natural vegetation. Firstly, Mr J Fuhrer (Switzerland) indicated the importance of considering ozone profiles within canopies. This showed that in pasture, some of the most sensitive plants are often found low in the canopy where ozone concentrations can be less than half of the above-canopy concentrations. Next, Mrs G Mills (ICP Vegetation Coordination Centre, UK) described how a database containing response functions for over 80 species of (semi-)natural vegetation is being used to identify ozone sensitive plant communities within the EUNIS (European Nature Information System) classification. Developments with land-cover mapping procedures that would allow the ozone-sensitive communities to be mapped in Europe were also described.

16. Ms L Emberson (UK) described recent progress with modelling flux to forest trees. The outcome of discussions at a recent informal meeting of forest flux modellers in which data and modelling requirements for the forthcoming Workshop 'Critical levels of ozone: further applying and developing the flux-based concept' (Obergurgl, Austria 14-18 November, 2005) was described. Mr G Wieser (Austria), one of the local hosts for the meeting, outlined plans for the workshop, including the objectives and registration procedure. The scientific steering committee for the Obergurgl Workshop met later to consider working groups, plenary papers, discussion themes and chairs and rapporteurs.

17. Mrs G Mills (ICP Vegetation Coordination Centre, UK) described the results from the white clover biomonitoring experiments in the summer of 2004. Temperatures and AOT40s were lower than in 2003, and yet ozone injury was still detected at almost every site. Mrs Mills showed how some Mediterranean countries detected ozone injury over a long time period from May to October. Efforts to develop a canopy flux model for clover were described by Ms L Emberson (UK); a call for more data for leaf area index at harvest was made.

18. Good progress was made in 2004 with the development of a biomonitoring method for (semi-)natural vegetation using brown knapweed (*Centaurea jacea*). Mrs G Mills (ICP Vegetation Coordination Centre, UK) reported that no participants had problems with growing the plants and that progress was being made with the collection of stomatal conductance measurements. During the year, participants from Switzerland had cloned ozone-sensitive and –resistant biotypes of *Centaurea* and successfully transferred the plantlets to soil, grown them on to full size and exposed them to ozone. Ms F Keller (Switzerland) reported that it was hoped that a Europe-wide pilot study with cloned material would be conducted in 2006. In the ensuing discussion, improvements in the method of assessment of ozone injury were agreed for the *Centaurea* system. It was also agreed that the nitrogen interaction study with this species should be stopped because of inconclusive results.

19. The heavy metal session was opened by Mr E Steinnes (Norway), describing three decades of moss surveys in Norway and how to interpret the data. Southern Norway receives long-range transboundary air pollution from other parts of Europe and over the years lead pollution has decreased by a factor 10 and pollution from metals such as vanadium, cadmium and arsenic by a factor 4. Calibration of the concentration of heavy metals in mosses against bulk atmospheric deposition proved to be successful for some metals and confounding factors were discussed. Mrs C Rausch de Traubenberg (France) presented temporal trends in the heavy metal concentrations in mosses between 1996 and 2000 in France and discussed the improved protocol used in 2000. Decreases in lead and cadmium in mosses were in agreement with decreases in emissions. For mercury no change in the concentration in mosses was observed in contrast to decreased emissions and for zinc an increase in the concentration in mosses was observed despite no changes in emissions. Ms L Shotbolt (UK) reported on the reconstruction of past heavy metal deposition in the UK using herbarium moss samples. She concluded that for some metals the concentration in herbarium material reflects past deposition rates, which could be estimated for lead, cadmium and arsenic, but not for copper and zinc. For most heavy metals the concentration was higher in herbarium material than in the 2000 moss survey. Mr I Suchara (Czech Republic) discussed the main factors that could explain the variability in the heavy metals concentration in mosses in the 2000 moss survey; these factors were altitude, precipitation, forest landscape and urbanisation.

20. In the next session, the use of mosses as biomonitors for atmospheric nitrogen deposition was discussed. Mr H Zechmeister (Austria) showed examples of good correlations between the N concentration in mosses and the rate of atmospheric N deposition. The correlations are better for ammonium than nitrate, better for some

than other moss species and can be confounded by direct impacts of N on the growth rate of mosses. He also showed how applying the ^{15}N technique can be used to identify the source of N pollution. Mr E Kubin (Finland) also reported on good correlations between the total N concentration in mosses and the rate of atmospheric N deposition. The decrease (20-40%) in N deposition in Finland between 1985 and 2000 was in agreement with a similar decrease in the N concentration in mosses. Mr W Schröder (Germany) applied unique multivariate statistical analysis on the German heavy metals in mosses metadata (1990, 1995, and 2000) and reported on significant correlations with the distances from trees, roads, and industries, moss species and certain topographical features. In addition, he presented results on mapping the nitrogen concentration in mosses in Germany (Bavaria, North Rhine-Westphalia, Lower Saxony). The highest correlation between the N concentration in mosses and the bulk deposition of N was observed near factory farming in Lower Saxony. Whereas the N concentration in mosses did not very much between 1983 and 1991 in Bavaria, in some ecoregions a decrease in the N concentration in mosses was observed since 1992. Regarding the N concentration in mosses for selected European countries, Mr H Harmens (ICP Vegetation Coordination Centre, UK) reported that country specific differences were observed (e.g. higher concentrations in Germany than Scandinavian countries), but that no temporal trends were found between 1980 and 2000. For Norway good correlations were found between the N concentration in mosses and the annual deposition rates of reduced, oxidised and total N. The ICP Vegetation recommends to participants to include the determination of the N concentration in (selected) moss samples in the 2005/6 moss survey in order to investigate the feasibility of using mosses as biomonitors of atmospheric N pollution at the European scale.

21. In the final heavy metal session Mr S Leblond (France) presented results of an experimental study to optimise the conversion of heavy metal concentrations in mosses into absolute deposition rates, using *Scleropodium purum* and iron as an example. Iron concentrations in the apical meristem were higher in the spring and summer than in the autumn and winter and the iron concentration in mosses would drop down to background levels 7 months after finishing experimental spraying. Mrs M Frontasyeva (Russian Federation) applied the moss survey for assessing hot points of heavy metal contamination in the Bor region (Serbia) with copper mining and processing industries. Factor analysis showed a strong component associated with the copper smelter complex in Bor, with very high loadings for Cu, Zn, As, Se, Mo, Ag, Cd, In, Sb, and Pb. Mr W Purvis (UK) gave an overview of the history of the air pollution problem and observed changes in the lichen and bryophyte distribution in London in relation to air pollution levels and other environmental factors.

22. Mr H Harmens (ICP Vegetation Coordination Centre, United Kingdom) led a general discussion on the European heavy metals in mosses survey 2005/6. He gave an overview of the countries potentially participating in the survey and which countries have secured funding so far. The distribution and inclusion of moss standards as part of the analytical process was discussed. For quality assurance and control purposes, the moss standards M2 and M3, used in the 1995 moss survey, will be distributed to participants by Mr E Kubin (Finland) at a reduced cost. Finally, the draft version of the monitoring manual was discussed

and accepted by the Task Force Meeting. Mr H Harmens will prepare the final version of the monitoring manual. The manual can be downloaded from the ICP Vegetation web site (http://icpvegetation.ceh.ac.uk).

23. In the final plenary session the meeting reviewed the work plan for 2005 as indicated in Annex I, revised the objectives for the programme as indicated in Annex II and reviewed the medium-term work plan and deliverables to the WGE as indicated in Annex III. Mr P E Karlsson (Sweden) suggested to study the impacts of ozone on leaf injury in commercially important crops in the future in a standardised biomonitoring experiment in addition to the white clover and *Centaurea jacea* biomonitoring system. Mr M Johansson, secretary of the WGE, emphasized again the need to streamline work plans and deliverables within the WGE and the Convention. This issue will be discussed in more detail at the next WGE Extended Bureau meeting on 22-25 February 2005 in Geneva, where all Programme and Centre Heads are present. As the streamlining process might affect the timing of the deliverables to the WGE (see Annex III), the deliverables for 2007 were not discussed in detail at the meeting. Mr Harmens informed the meeting that WGE Bureau is preparing a revision of its long-term strategy, which will be discussed in more detail at the WGE Extended Bureau meeting. Mrs G Mills (ICP Vegetation Coordination Centre, UK) informed the meeting about the outcome of the meeting of the scientific steering committee for the Obergurgl Workshop on critical levels of ozone. There will be three working groups covering the following themes: 1) forest trees; 2) (semi-)natural vegetation, and 3) applications of the flux-based concept (e.g. crops, land cover mapping, scaling issues, uncertainty analysis). Chairs and rapporteurs for the working groups were announced.

24. The venue of the next ICP Vegetation Task Force Meeting has to be decided yet. Mr H Harmens (ICP Vegetation Coordination Centre, United Kingdom) closed the meeting by thanking the local organisers, CIEMAT, Ministry of Environment and the University of Almería for their hospitality and support, colleagues at CEH Bangor for their contributions, the participants for their continuing support of the programme and the UK Department for Environment, Food and Rural Affairs for continued financial support for the coordination of the ICP Vegetation.

ANNEX I: **Workplan of the ICP Vegetation for 2005**
(Updated 3-2-05)

Ozone	**Heavy Metals**	**Nutrient N**
• Clover biomonitoring as in 2004 • *Centaurea jacea* biomonitoring with improved method • Economic impact assessment (flux vs AOT40) • Further development of methods for mapping impacts on (semi-) natural vegetation • Review on interactive impacts of ozone and climate change on vegetation • Review of flux-modelling including critical level workshop in Obergurgl (Austria)	• Start moss 2005/6 survey • Distribution of moss standards • Finalising monitoring manual for moss survey • Analysing temporal trends in mosses • Compare 2000/1 moss data with EMEP deposition data for Pb, Hg and Cd	• Determining N content of mosses from herbaria samples and mosses collected in the 2005 HM moss survey

ANNEX II: **Objectives of the ICP Vegetation**
(Updated 3-2-05)

Long-term objectives

1. To meet the requirements of the UNECE Convention on Long-range Transboundary Air Pollution for information on the responses of (semi-) natural vegetation and crops to atmospheric pollutants.

2. To evaluate experimental data on the responses of (semi-)natural vegetation and crops to air pollutants to validate the critical levels defined in the mapping manual and to show the effects of exceedance.

3. To provide information for the further development of effects-driven protocols with respect to (semi-)natural vegetation and crops.

Short- and medium- term objectives

1. To monitor the impacts of ambient ozone on various crops and (semi-)natural vegetation.

2. To further develop and apply the concept of concentration-based and flux-based critical levels of ozone for crops, (semi-)natural vegetation and trees.

3. To produce maps of exceedance of the revised ozone critical levels (in collaboration with ICP Forests, EMEP MSC-W and the ICP on Modelling and Mapping).

4. To provide further information on response functions and land cover for use in an economic assessment of crop losses due to ozone.

5. To conduct literature reviews and specific experiments to provide further information on the critical levels of air pollutants for selected plants, plant communities and biodiversity.

6. To conduct literature reviews and experiments on the accumulation of atmospheric deposition of heavy metals by vegetation and the transfer of heavy metals into the human food chain (in collaboration with TF Health).

7. To prepare for and conduct the 2005/6 survey of heavy metal concentrations in mosses in Europe.

8. To investigate methods for estimating and mapping heavy metal deposition from the heavy metal concentration in mosses data (in collaboration with EMEP MSC-E).

9. To study the spatial and temporal trends in the atmospheric deposition of nitrogen by determining the nitrogen concentration in mosses.

10. To review the literature on, and conduct studies of, the interactions between ozone and nitrogen.

11. To review the literature on the effects of ozone in a changing climate (including rising CO_2 concentration) and to consider the possibility of including experimental and modelling work within the programme.

12. To consider the feasibility of including nutrient nitrogen effects on (semi-) natural vegetation within the programme of work.

13. To consider the feasibility of collaborating on air pollution effects outside the UNECE region (e.g. Asia and southern Africa).

ANNEX III: **Medium-term work-plan: intended deliverables to the WGE**
(Updated 3-2-05)

	2005	2006	2007
Ozone (O_3)	• Flux-effect model for clover • Comparison of economic impacts on crops using concentration-based and flux-based approaches • Identification of communities of (semi-) natural vegetation at risk • Maps of revised critical levels of O_3 for TFIAM	• Report on interactive impacts of ozone and nitrogen on crops and (semi-)natural vegetation (see nutrient N) • Flux-effect models for additional crop species • Flux-effect maps for agricultural species • Risk assessment for (semi-)natural vegetation that includes the influence of modifying factors and improved mapping procedures	
Heavy metals (HM)	• Material for possible review of the Protocol • Report on HM deposition and potential contamination of food crops	• Temporal trends in HM in mosses • Update on progress with the 2005 moss survey	
Nutrient N	• Temporal trends in N content of mosses in Europe	• Report on interactive impacts of ozone and nitrogen on crops and (semi-)natural vegetation (see ozone)	