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2006 JOINT REPORT OF THE INTERNATIONAL COOPERATIVE PROGRAMMES AND THE TASK FORCE ON THE HEALTH ASPECTS OF AIR POLLUTION

Report by the secretariat in collaboration with the Extended Bureau of the Working Group on Effects

INTRODUCTION

1. The Executive Body, at its twenty-third session, decided that the secretariat would prepare the annual review of the activities and results of the International Cooperative Programmes (ICPs) and the Task Force on the Health Aspects of Air Pollution, based on the information provided by the lead countries and the programme centres.

2. At its meeting in Geneva on 1–3 March 2006, the Extended Bureau of the Working Group on Effects (the Bureau of the Working Group, the Chairs of the Task Forces, and the representatives of the programme centres of the ICPs) noted the need to report recent results for the reviews of the Convention protocols. The Extended Bureau expressed its concern regarding the sustainability of funding to maintain programme activities. The Extended Bureau also agreed
that the 2006 joint report should summarize achievements reflecting the 2006 workplan according to pollutant-specific topics and have workplan items common to all programmes and reported on under cross-cutting issues.

3. This report reviews the main accomplishments of the ICPs and the Task Force on Health under seven topics that follow the 2006 workplan items of the Working Group. Details of the general activities of the programmes and the relevant literature are reported in the addendum (ECE/EB.AIR/WG.1/2006/3/Add.1) to this document.

I. ACIDIFICATION

4. ICP Forests selected from its 500 level II (intensive monitoring) plots, where deposition was monitored, between 197 and 260 plots with complete data sets for bulk and throughfall depositions of sulphate, nitrate and ammonium for the period 1998–2003. Mean annual sulphate bulk (open-field) depositions decreased from 6.2 to 4.2 kg ha$^{-1}$ year$^{-1}$ (197 plots). Mean annual sulphate throughfall decreased from 8.8 to 5.6 kg ha$^{-1}$ year$^{-1}$ (228 plots). Ammonium and nitrate bulk depositions decreased less than sulphate depositions. No clear trends were detected in throughfall depositions of the nitrogen compounds.

5. The very simple dynamic (VSD) model was applied at 37 level II plots in eight European countries by ICP Forests in cooperation with ICP Modelling and Mapping. Future soil acidification was calculated with a deposition scenario based on the emissions resulting from implementation of the 1999 Gothenburg Protocol. The majority of the plots showed a decreasing soil solution pH between 1900 and 1990 and slight recovery afterwards. However, at many plots the original acidity status would not be reached until 2050. For a subset of eight plots the layer-specific soil solution pH was calculated using the SAFE model. Reactions of the pH depended on site conditions. The BERN model was applied to a subset of three plots to relate vegetation to changing soil conditions for 1950–2050. The model predicted changes in the carbon-nitrogen (C/N) ratio and in the base saturation of the soil as a result of atmospheric depositions. These changes would lead to more unfavourable conditions for many widespread species (e.g. beech) and foster acidity-tolerating tree species (e.g. birch).

6. ICP Forests carried out international cross-comparison courses for defoliation assessment in the Czech Republic, Finland and France in 2005. For most of the assessed stands, observers agreed regarding the conclusions to be drawn. High variation in one spruce stand in the Czech Republic could be explained largely by the high stand density and exceptional defoliation. The results were used to improve the ICP Forests manual and will help in identifying systematic differences between countries for more reliable interpretation of crown conditions at level I and II plots.

7. An update of the critical loads for acidity at ICP Waters sites concluded that estimates based on 2000–2002 data were similar to those based on 1992–1995 data. The site-specific
critical loads lay close to the 5th-percentile of the 50 km × 50 km grid cell with surface water critical load data submitted to the Coordination Centre for Effects (CCE).

8. The analysis of ICP Waters revealed that at many sites water chemistry had changed rapidly in the 1990s in response to the large decrease in sulphur emissions and depositions. There were year-to-year variations in both acidifying deposition and water chemistry caused by other environmental factors, generally termed “confounding factors”, such as variations in climate (including rainfall amount, drought severity, temperature and sea-salt inputs).

9. The 2006 chemical intercomparison of ICP Waters included determination of major ions and heavy metals, and results will become available in 2006. About the same numbers of laboratories participated as in 2005 – 75 laboratories in 30 countries. Based on the general target accuracy of ± 20%, 73% of the overall results for the major ions in 2005 were considered acceptable. The lowest percentage of acceptable results was observed for heavy metals, especially for lead (Pb), cadmium (Cd) and nickel, due to the very low metal concentrations used in the samples in 2005.

10. The 2006 biological intercalibration of ICP Waters included invertebrates from four countries; results will become available in 2006. Altogether 13 countries participate on a regular basis. The results for 2005 showed that most of the laboratories had identified more than 90% of the individuals in the test samples. No faults were recorded at the genus level. The quality was sufficient for stating the acidity index.

11. The workshop “Confounding Factors in Long-term Trends of Acidification” will be held in October 2006. The aim is to quantify the synergistic effects of environmental factors other than acid deposition on acidification and recovery of surface waters. Variations and long-term changes in climate are of particular interest among the confounding factors.

12. ICP Materials has developed a new model for calculating copper (Cu) runoff from surfaces on buildings and constructions, using direct laboratory and field runoff measurements and an empirical mass balance equation derived using data from the Programme sites. The rate was affected by precipitation amount, pH and dry periods between precipitation events (the first-flush effect), depending on the sulphur dioxide (SO₂) concentration. The potential capability of the model was demonstrated for 1980–2003 by runoff maps for Europe in the 50 km × 50 km grid using EMEP data. The maps showed increased runoff values in Central Europe, where SO₂ was elevated, and in areas with high precipitation, such as the Norwegian coastline.

13. During the period 1987–1997, the decreasing concentrations of acidifying air pollutants caused decreases in observed corrosion of materials at the ICP Materials sites. The corrosion of carbon steel and limestone in 1997 was on average 60% of the 1987 value, and that of zinc about 40% of the 1987 value. In 1997–2003 the corrosion rate of carbon steel decreased to 40%. However, the rates for zinc and limestone increased slightly. The relative trends in SO₂ and nitric
14. Monthly concentrations and fluxes for bulk deposition, throughfall deposition and runoff and soil water were used in a trend assessment at ICP Integrated Monitoring sites for the years 1993–2003. Statistically significant changes in several variables were observed. Sulphate concentrations in deposition and runoff and soil water were generally decreasing as a response to decreasing deposition. Nitrogen concentrations did not correlate with soil and runoff water, probably due to catchment-specific nitrogen retention processes.

15. ICP Integrated Monitoring and ICP Waters investigated the relative sensitivity of different climate-change-related processes affecting acidification recovery. The results showed that several factors were of only minor importance – for example, the increase in partial pressure of carbon dioxide in soil air and runoff. Many factors were important at only a few sites (e.g. sea salts near coastal sites), and some were important at almost all of the sites (e.g. increased concentrations of organic acids in soil solution and runoff). Changes in forest growth and decomposition of soil organic matter were important at forested sites and sites at risk of nitrogen saturation.

16. Six national focal centres (NFC) of ICP Modelling and Mapping updated their data on critical loads for acidification and dynamic modelling, including target loads, and one country provided data for the first time. CCE, in cooperation with the Centre for Integrated Assessment Modelling, developed linearized impact coefficients relating emissions to critical load exceedances for easier use of critical loads in integrated assessment models.

17. ICP Modelling and Mapping discussed various alternatives for closing the gap of critical load exceedances in integrated assessment modelling. It concluded that gap closure approaches should be anchored in sustainable endpoints for human health and the environment. They should focus on the regional distribution of the sensitivity of ecosystems rather than on the regional dispersion of depositions due to emission scenarios. Closing the gap to deposition levels derived from emission scenarios, instead of to critical loads, could be useful as an interim goal. Structural changes and future improvements in technical emission abatement techniques should also be considered in emission abatement strategies.

18. The Joint Expert Group on Dynamic Modelling discussed the outcome of the 2004 call for dynamic modelling, which had been conducted by CCE. The Group considered the results a major breakthrough in assessing the effects of future air pollution, particularly in providing new insights into the predicted timescales and extent of recovery from acidification. The map of target loads of acidity derived by dynamic modelling differed significantly from the map of critical loads. The target load map suggested that in many regions deposition reductions considerably below critical loads would be required to achieve ecosystem recovery within the next 25 to 100 years. In some areas, recovery might not be possible on this timescale even if critical loads were not exceeded in the future.
19. The Joint Expert Group on Dynamic Modelling noted that dynamic model outputs could be employed in the review of the 1999 Gothenburg Protocol. Fourteen European countries were in a position to perform deposition scenario analysis with dynamic models, also using scenarios other than the two defined in the 2004 call for data.

II. NUTRIENT NITROGEN

20. ICP Forests related ground vegetation species composition on about 500 Central European and south boreal level II plots to measured soil and deposition parameters. The natural acid-base state of the organic soil layer was the main driving factor for the composition of ground vegetation in the monitoring plots studied. Plots with many nitrogen-indicating species were located in regions with high nitrogen deposition, thus indicating a highly significant relationship.

21. The analysis by ICP Vegetation of the long-term temporal trends (1829–2004) for nitrogen concentration in mosses in the Czech Republic, Finland, France and Switzerland (21–44 samples per country) showed no changes before 1960. After 1960, only for Switzerland was there a clear increase in the nitrogen concentration in mosses.

22. Several NFCs of ICP Modelling and Mapping updated their critical loads on eutrophication. The revised dataset was made available for the review of the 1999 Gothenburg Protocol as well as for other European agreements.

23. The aims of a CCE workshop on nitrogen included (a) effects indicators, critical limits and their capabilities to assess links to biodiversity and climate change, (b) modelling and empirical approaches to set critical loads, and (c) specific issues, including differences in ammonium and nitrate inputs, nitrogen losses to the atmosphere, and links to downstream ecosystems. The background document “Developments in deriving critical limits and critical nitrogen loads for terrestrial ecosystems in Europe” is to be finalized during 2007.

24. The Joint Expert Group on Dynamic Modelling noted that currently available dynamic models did, in general, contain key pathways and processes of nitrogen cycling in terrestrial ecosystems. However, several major uncertainties remained concerning nitrogen accumulation and its effects. These related to (a) nitrate immobilization and the possibility of its inhibition by ammonia, (b) rates of nitrate reduction in aerobic/anaerobic soils, and (c) abiotic nitrogen fixation. In addition, models required (a) improved quantification of the active soil carbon pool, (b) improved simulation of carbon dynamics to include the activity, and (c) stability of carbon pools and feedbacks of increased nitrogen availability on carbon accumulation.

25. The workshop “Nitrogen Dynamic Processes”, arranged in connection with the meeting of the Joint Expert Group on Dynamic Modelling, noted a range of different nitrogen models being used within the Convention. Comparative studies of predictions obtained using different
models at the same locations and against observed data were considered necessary. This would be analogous to the intercomparison studies on acidification models undertaken in the past and would help achieve consistent coverage across Europe. Linked biogeochemistry-biodiversity models for nitrogen were found to have great potential for application under the Convention in deriving biodiversity-based target loads. At their current level of development, they would primarily be used to predict the biodiversity impacts of different emission scenarios.

III. OZONE

26. Visible ozone-caused leaf injury to the biomonitoring species white clover (Trifolium repens cv Regal) and brown knapweed (Centaurea jacea) was widespread across ICP Vegetation monitoring sites in 2005, as in previous years. This was consistent with the exceedance of the concentration-based critical level of ozone (O$_3$) for agricultural crops and (semi-)natural vegetation (dominated by annual species) at 80% of the monitoring sites.

27. ICP Vegetation, in collaboration with the EMEP Meteorological Synthesizing Centre-West (MSC-W), updated exceedance maps of critical O$_3$ levels using concentration- and flux-based methods to calculate critical O$_3$ levels for wheat and beech. The maps indicated widespread exceedances but with different spatial patterns for the two methods.

28. Results of a case study for winter wheat indicated that in a future climate the exceedance of the flux-based critical O$_3$ level might be reduced across Europe, even when taking into account an increase in tropospheric O$_3$ concentration. In contrast, the exceedance of the concentration-based critical O$_3$ level might increase due to anthropogenically induced increases in background tropospheric O$_3$ concentration and alterations to the O$_3$ mass balance.

29. In considering the responses of individual species, six classes of the EUNIS (European Nature Information System) habitats were identified by ICP Vegetation as potentially sensitive to O$_3$: dry grasslands, mesic grasslands, seasonally wet grasslands, alpine and sub-alpine grasslands, woodland fringes (E1–E5) and temperate shrub heathland (F4). Alpine and sub-alpine grasslands were identified as potentially the most sensitive to O$_3$. The sensitive communities were mapped using the harmonized Convention land cover data, which are being finalized in 2006.

30. The workshop “Critical Levels of Ozone: Further Applying and Developing the Flux-based Concept” proposed the flux-based approach as a method for assessing the risk of O$_3$-induced effects on ecosystems in integrated assessment modelling in the EMEP model domain. However, the flux-based approach could not currently be quantified for effects on (semi-)natural vegetation. Therefore, critical levels remained concentration-based for this receptor. The workshop agreed on a new critical level of an AOT40 (accumulated O$_3$ concentration over the threshold of 40 parts per billion (ppb) during daylight hours) of 5 ppm.h (parts per million × hours) over six months to prevent adverse effects on semi-natural vegetation communities dominated by perennial species.
31. The Task Force on Health acquired data on O$_3$ concentrations from some cities in countries of Eastern Europe, Caucasus and Central Asia (EECCA). No reliable assessment of health impacts based on these monitoring data in Eastern Europe was possible at this stage. However, EMEP estimates indicated that in the southern part of EECCA, O$_3$ exposure might reach levels with adverse effects on health.

IV. PARTICULATE MATTER

32. The Task Force on Health took note of the Air Quality Guidelines of the World Health Organization (WHO), which included an assessment of health hazards of particulate matter (PM). It included recommendations on guideline levels of 10 and 20 µg/m$^3$ for annual average concentrations of the fine (PM2.5) and coarse (PM10) fraction of PM, respectively. Guidance on chemical components or specific sources of PM was not given. The risk for effects has been shown to increase with exposure. There was little evidence for a threshold below which no adverse health effects would occur. Adverse health effects have been demonstrated at levels close to the background PM2.5 concentrations of 3–5 mg/m$^3$ in the United States and Western Europe.

33. The Task Force on Health obtained data on ambient PM concentrations for 2002–2004 from the Russian Federation. They were based on routine monitoring of total suspended particles in about 100 cities with a total of about 40 million inhabitants. The annual mean levels exceeded 200 µg/m$^3$ and covered more than half of the quoted population. They indicated a significant increase of serious health risks, including mortality.

V. HEAVY METALS

34. The initial analysis of ICP Vegetation showed that trends in 1990–2000 in concentrations of heavy metals in mosses in Europe were both metal- and country-specific. Most countries showed decreasing Cd and Pb concentrations in mosses, with the concentrations higher for Pb than for Cd. These data conformed to trends in modelled deposition data. For the other metals (arsenic, chromium, Cu, iron, mercury (Hg), nickel, vanadium and zinc (Zn)) no consistent trends were observed across Europe.

35. Heavy metal budgets and critical loads of Pb, Cd and Hg were calculated at ICP Integrated Monitoring sites. The input of heavy metal deposition, calculated by EMEP, was in many cases underestimated. The sums of throughfall and litterfall gave higher and probably more appropriate values. Deposition was often higher than leaching, indicating accumulation in the catchment. Elevated heavy metal concentrations influence biological activities and hamper decomposition. Critical loads were exceeded for Pb and Hg, when input was estimated with throughfall and litterfall, but not for Cd.
36. Five NFCs of ICP Modelling and Mapping updated their critical loads of heavy metals. The revised European data set was made available for the review of the Protocol on Heavy Metals and for other European agreements. The update did not change the areas at risk as much as the update of depositions computed by the EMEP Meteorological Synthesizing Centre - East (MSC-E). The critical load update explained about one third of the change in exceeded area for Pb, while for Cd and Hg there was no change. The areas at risk of ecosystem effects, using updated data on critical loads and new deposition in 2000, were about 0.1%, 53% and 85% for Cd, Pb and Hg, respectively. For health effects the areas were about 1%, 17% and 2.4%, respectively.

37. The European critical load database of CCE was made available to calculate areas at risk from the deposition of Cd, Pb and Hg. MSC-E provided data on emissions and deposition of the heavy metals to assess the impacts of different scenarios.

38. The Task Force on Health reassessed the health risks of heavy metals. It concluded that in spite of the decreasing Cd emissions, ambient air concentrations and deposition, the recently published data did not show decreases of Cd body burdens in non-smokers during the last decade. Cd is accumulating in soils and catchments under certain environmental conditions, thus increasing the risk of future exposure through food. Therefore, considering the narrow margin of safety, every effort should be made to further reduce Cd emissions to the atmosphere and other inputs to the soil. The Task Force noted that long-range transboundary air pollution might contribute to the Pb contents of crops significantly through direct deposition. Though uptake via roots is relatively small, in the long term the rise of Pb level in soils is a matter of concern and should be avoided due to the possible health risk of low-level Pb exposure. The Task Force also noted that reducing emissions of Hg to the atmosphere is important for decreasing methylmercury concentrations in fish. In some populations that consume large amounts of fish, or contaminated fish, the intake of methylmercury may reach hazardous levels. Since fish consumption has important health benefits, decreasing Hg content in fish should be treated as a high priority.

39. The Joint Expert Group on Dynamic Modelling agreed that soil organic matter dynamics and acidity were key to modelling heavy metals. It further concluded that the models and databases were available for preliminary trials of dynamic modelling of selected heavy metals (Cd, Pb, Zn and Hg).

VI. PERSISTENT ORGANIC POLLUTANTS

40. The Task Force on Health received no requests from the Working Group on Strategies and Review for revising the health risk assessment of persistent organic pollutants (POP). Therefore, no work on health hazard evaluation was initiated. However, the Task Force recognized that, according to the overall objectives of the Protocol on POPs and its text, demonstrating actual observed health effects was not necessary for inclusion of a pollutant. The
likelihood of such effects due to the potential of build-up in the environment and bioaccumulation of the levels was deemed sufficient reason for inclusion.

VII. CROSS-CUTTING ISSUES

41. The European Commission is constructing a joint forest health database to be shared with ICP Forests and authorized third parties. The database will comprise level I and level II data and will be accessible through a Web interface that allows online data submission by the NFCs. It will be operational in 2008, with a regularly updated copy at the ICP Forests programme centre. The responsibility for database management will be shared between ICP Forests and the European Commission.

42. ICP Materials mapped the potential corrosion of materials used on cultural heritage objects (carbon steel, Zn, bronze, Cu and limestone) for Germany and the Czech Republic. The maps were based on multi-pollutant dose-response functions and derived on a 1 km × 1 km grid for 1990 and 2000. The corrosion maps were combined with tolerable corrosion rates to identify areas of exceedance. It was not possible to directly link the exceedance maps to individual pollutants because the dose-response functions depended on several pollutants.

43. HNO$_3$ and PM trends are needed in order to evaluate observed corrosion trends for Zn and limestone. A technical manual was prepared on the procedures and network of new exposure sites. The description covers labelling, marking and handling of test specimens, specific instructions for individual materials, and procedures for characterizing pollution conditions at the test sites with passive samplers.

44. The workshop “Economic Impacts of Air Pollution on Cultural Heritage”, organized by the Network of Experts on Benefits and Economic Instruments and ICP Materials, noted the importance of improved estimates of stock at risk in Europe. It was important to include all the potential costs of cleaning in the cost-benefit assessments. Cleaning, if done incorrectly, might cause damage to buildings that was equivalent to many years of corrosion. The estimation of social benefits was interpreted as valuing impacts on a large stock of cultural heritage objects rather than individual sites only.

45. ICP Vegetation made a literature review on the interactive impacts of O$_3$ and nitrogen. It showed that nitrogen could in many ways affect both the sensitivity and the exposure of plant species to O$_3$. The two pollutants could interact both synergistically and antagonistically, depending on species and community type. Nitrogen-poor communities of (semi-)natural vegetation were predicted to be at greatest risk from the combination of high O$_3$ concentration and high nitrogen deposition.

46. The CCE workshop on nitrogen discussed a background document that reviewed critical limits of nitrogen and terrestrial dynamic modelling methodologies, which include vegetation
changes and biodiversity. The document will provide information for NFCs to revisit their results related to critical loads of nitrogen.

A. **Recent information on effects-based approaches for the Protocol reviews**

47. ICP Forests will update the trends with regard to sulphur and nitrogen deposition in open-field and beneath the canopy. In addition, nitrogen depositions measured at level II sites will be compared with values modelled by EMEP. The exceedances of critical loads of acidity and nitrogen in forest soils will be addressed.

48. ICP Waters data showed that the reduced deposition not only of sulphur but also nitrogen has continued to improve the acidification status of surface waters in large regions of Europe and North America. Furthermore, biological recovery (fish and invertebrates) was reported at some localities at which the chemical recovery has been sufficient.

49. The new multi-pollutant dose-response functions and definitions for tolerable corrosion rates made it possible to identify areas where climate and air pollution contribute to intolerable corrosion levels. A SO$_2$ level of 10 µg/m$^3$ was proposed to protect 80% of the European area, assuming present HNO$_3$ levels, based on functions and tolerable levels for indicator materials (carbon steel, Zn and limestone). PM was included in the dose-response functions for the corrosion of carbon steel, cast bronze and Portland limestone; however, the effect was found to be relatively small. The main effect of PM is soiling, for which dose-response functions were developed for painted steel, white plastic and limestone. Based on an acceptable soiling level and a time between cleaning, an acceptable PM10 level of 15 µg/m$^3$ was proposed.

50. Concentration-based O$_3$ critical levels for crops, (semi-)natural vegetation and forest trees and flux-based O$_3$ critical levels for crops and forest trees have been described in detail in the *Manual on methodologies and criteria for modelling and mapping critical loads and levels and air pollution effects, risks and trends*. The workshop “Critical Levels of Ozone: Further Applying and Developing the Flux-based Concept” agreed on a new concentration-based critical level to prevent adverse effects of O$_3$ for communities of (semi-)natural vegetation dominated by perennial species. The workshop proposed the flux-based approach for assessing the risk of effects of O$_3$ on crops and forest trees in integrated assessment modelling within the EMEP model’s domain.

51. ICP Integrated Monitoring analysed trends in deposition and soil and surface water data. Heavy metal budgets, processes and critical loads were calculated. Recovery and confounding effects of climate change were studied with site-specific dynamic models.

52. ICP Modelling and Mapping provided necessary input for the review of the Convention protocols as part of its normal workplan.
53. The Task Force on Health took note of the WHO Air Quality Guidelines on PM, O₃, nitrogen dioxide (NO₂) and SO₂. The new guideline levels were recommended for PM2.5 and PM10 (annual average 10 and 20 µg/m³, respectively), O₃ (daily maximum 8-hour mean 100 µg/m³) and SO₂ (24-hour mean 20 µg/m³). The guideline for NO₂ remained unchanged (annual average 40 µg/m³). Interim targets were proposed for PM, O₃ and SO₂, thus encouraging reduction of air pollution in more polluted areas. The new guideline values provided an important benchmark for efforts to reduce pollution and its health impacts to the minimum.

B. Dose-response functions and stock at risk

54. The ICP Forests report on cause-effect relationships, to be finalized later in 2006, will summarize the effects of air pollution on forests, in particular from nitrogen. It will also address the impact of acidity and nitrogen deposition to the species composition of ground vegetation, and effects of O₃ on the leaves of ground vegetation and trees.

55. ICP Waters has identified two steps in the dose-response relationships for the acidification of surface waters. The first step is the response of water chemistry to a given dose of acid deposition. Acid-neutralizing capacity (ANC) is the most commonly used water chemistry response criterion. The empirical data from ICP Waters and other national and international monitoring and research clearly confirm this dose-response function. The dose-response function relating acid deposition to water ANC is used in most critical load models. The second step is the biological response to changes in water chemistry. ANC is the most common water chemistry parameter related to changes in fish and invertebrate populations. This relationship establishes the critical limit in critical load calculations. Solid experimental and empirical data confirm these dose-response functions. The stocks at risk receiving most attention are fish populations, in particular trout populations in inland lakes and streams and salmon populations in coastal rivers. Quantitative assessment of these stocks is available for the countries in Fennoscandia.

56. ICP Materials has developed dose-response functions for carbon steel, Zn, Cu, bronze, limestone and glass which is representative of medieval stained-glass windows, considering the effects of climate, sulphur, nitrogen and PM. Climate and SO₂ are important for all materials, while the effects of HNO₃ and PM are material dependent. These functions are suitable for mapping areas of increased risk of corrosion and for calculating damage costs. A number of techniques for estimating stock at risk have been developed comprising different policy and management requirements.

57. ICP Vegetation has described the dose-response functions for vegetation and the underlying literature in the Mapping manual. The O₃ dose-response functions for vegetation are primarily based on experiments in open-top chambers describing impacts on above-ground growth. The Mapping manual provides an indication of the relative sensitivity of crop and tree species and communities of (semi-)natural vegetation to O₃, based on the literature. For (semi-)natural vegetation ICP Vegetation has developed a new database (OZOVEG) describing dose-
response functions for 83 species. The data were collated from the literature from experiments in open-top chambers, field release systems and solar domes to determine O$_3$ impacts on above-ground biomass. This database was used to identify plant traits associated with sensitivity to O$_3$ and to predict the sensitivity of plant communities to O$_3$. Information on stock at risk for crops has been compiled in an assessment of the economic impact of O$_3$ on 23 arable crops in 47 European countries. This assessment quantified ozone-induced yield losses as 2% of the arable agricultural production in Europe in 2000.

58. ICP Integrated Monitoring has derived empirical thresholds for nitrogen deposition based on mass budget calculations and relations to soil chemistry indicators (e.g. the carbon-nitrogen ratio).

59. The critical load of acidification employs as a critical threshold the ratio of base cations to aluminium, which is also an important indicator in dynamic modelling. The ratio is used to evaluate deposition-dependent time delays to reach it. Dynamic models enable the identification of deposition values (target loads) that lead to recovery in a given time period. ICP Modelling and Mapping has described the methods in the *Mapping manual*. Critical loads for acidification and eutrophication cover about 6 and 5.5 million km$^2$ of ecosystem area, respectively, in Europe.

60. The Task Force on Health has compiled various relationships between ambient concentrations of PM and O$_3$ and a range of health effects. They are based on the analysis of data from available epidemiological studies, which compare the incidence of effects in populations exposed to various pollution levels. At current PM levels most of the total European population of over 800 million in the EMEP model domain is at risk of adverse health effects. The quantification of health impacts is based on the association between pollution concentrations and total mortality. The risks differ between population groups. Children are most vulnerable due to the effects of the pollution on the development of the respiratory system. Air pollution also increases the risk of cardiovascular and respiratory diseases in older people.

61. The target load maps produced from dynamic model applications suggested that in many regions deposition reductions considerably below critical loads will be required to achieve ecosystem recovery within the next 25 to 100 years. The Joint Expert Group on Dynamic Modelling considered these target load maps to be a more realistic and relevant picture of future ecosystem response than the critical load and exceedance maps.

C. **Links between observations and critical thresholds, loads and levels**

62. ICP Forests has noted that the exceedance of critical loads for acidification and eutrophication may cause harmful effects in forests, depending on the amount and duration of deposition and ecosystem properties. Results from the United States have shown that at sites where the critical loads were exceeded, the crown transparency and the dieback of tree crowns were more pronounced than at sites with no exceedance. The severity of the symptoms increased
with exceedance. The nitrate output from the catchments also increased, indicating that excess acidifying and eutrophying deposition reduces the ability of forests to filter water.

63. There is generally close agreement between exceedance (and non-exceedance) of critical loads for acidity and field observations of adverse chemical and biological effects which have been reported by ICP Waters and national and international monitoring and research. Acidified surface waters with ANC below the limit value lay in areas where the critical load of sulphur is being or has been exceeded. Similarly, acidified surface waters are not found in areas where the critical load has never been exceeded. The lack of agreement between acidification status and field observations is to a large extent due to damage and recovery delay times. At most sites the delay time is particularly long in the case of acidifying nitrogen.

64. ICP Materials has concluded that although the corrosion rates have decreased substantially, exceedances of tolerable corrosion levels for cultural heritage materials (carbon steel, Zn and limestone) are still frequent. The highest exceedances can be found in industrial areas with high pollution levels, in urban areas with high traffic impact and in areas affected by sea-salt aerosols.

65. ICP Vegetation will collate evidence of the effects of current ambient O$_3$ concentrations on crops and (semi-)natural vegetation in 2006–2007.

66. The application of models at ICP Integrated Monitoring sites allows comparisons using critical loads. Heavy metal budgets at the sites generally indicate ongoing accumulation.

67. ICPs with monitoring activities have been encouraged to collaborate with ICP Modelling and Mapping to validate maps of critical loads and their exceedances for acidification and eutrophication. NFCs of ICP Modelling and Mapping have been encouraged to provide empirical critical loads for ecosystems covered in the harmonized European land cover map, made available by CCE in collaboration with other institutes.

68. The Task Force on Health has noted, based on the review of the existing evidence, that the risk of death increases by 6% with an increase in long-term exposure to PM$_{2.5}$ of 10 µg/m$^3$ (confidence interval 2–11%). Epidemiological studies have been unable to identify a threshold concentration below which ambient PM has no effect on health. The Task Force has noted that the WHO systematic review has confirmed the impossibility of identifying a threshold for O$_3$ effects on mortality. The relative risk for all-cause mortality is 1.003 for a 10 µg/m$^3$ increase in the daily maximum 8-hour mean (95% confidence interval 1.001–1.004). There are uncertainties regarding the shape of the concentration-response function associating effects with very low O$_3$ concentration levels. The cut-off level of 35 parts per billion as a daily maximum 8-hour mean is recommended for integrated assessment modelling. The SOMO35 (sum of means over 35) indicator has been proposed for an exposure proportional to impacts on mortality.