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MODELLING AND ASSESSMENT OF THE HEALTH IMPACT OF PARTICULATE MATTER AND OZONE

Summary report prepared by the joint Task Force on the Health Aspects of Air Pollution of the World Health Organization/European Centre for Environment and Health and the Executive Body

Introduction

1. At its twenty-first session the Executive Body for the Convention invited the Task Force on the Health Aspects of Air Pollution to evaluate and assess the health effects of long-range transboundary air pollution and to report to the Working Group on Effects in 2004 on health risk of particulate matter (PM) and ozone.

2. The seventh meeting of the Task Force on the Health Aspects of Air Pollution was held on 6-7 May 2004 in Bonn (Germany). It was attended by 23 experts from 11 Parties to the Convention, the World Health Organization's European Centre for Environment and Health, Bonn Office (WHO/ECEH), the European Commission (EC), the EMEP Meteorological Synthesizing Centre-West (MSC-W), the EMEP Centre for Integrated Assessment Modelling (CIAM), and the Oil Companies' European Organization for Environment, Health and Safety

(CONCAWE). The Chairman of the Working Group on Effects and the secretariat also attended the meeting.

3. Mr. Michal Krzyzanowski (WHO/ECEH) chaired the meeting. He recapitulated some of the decisions and recommendations formulated at the sixth meeting of the Task Force of Health (EB.AIR/WG.1/2003/11) which were important for the deliberations of this meeting.

4. Mr. Jürgen Schneider (WHO/ECEH) presented the recent results of the project "Systematic review of health aspects of air pollution in Europe" implemented by the WHO/ECEH Bonn Office to support the Clean Air for Europe (CAFE) programme of the EC (http://europa.eu.int/comm/environment/air/cafe/index.htm), in particular the answers to follow-up questions, which WHO had received from the CAFE secretariat. The WHO document reporting the results of the assessment was available at: http://www.euro.who.int/document/e82790.pdf. In addition, he highlighted the results from a review of evidence on the effects of air pollution on children's health.

5. The Task Force took note of the report and stressed the importance of the findings for the work under the Convention and the CAFE programme.

6. Mr. Ross Anderson (United Kingdom) summarized the findings of a meta-analysis of European time-series studies of health effects of ozone and particulate matter (PM). This analysis was performed as part of the "Systematic review of health aspects of air pollution in Europe" by a group of experts led by Mr. Anderson at St. George's Hospital in London, following a protocol established by an international task group. The meta-analysis provided summary estimates for various health outcomes. The final report was available at: http://www.euro.who.int/document/e82792.pdf.

7. The Task Force noted with appreciation the work on the meta-analysis and stressed the usefulness of this exercise for quantifying the health impacts of air pollution.

8. Mr. Leendert van Bree (Netherlands) informed the Task Force of a pilot study of the Netherlands Environment Assessment Agency at the National Institute for Public Health and the Environment (RIVM), initiated in early 2004, to establish a consistent methodology to include morbidity end points, caused by exposure to air pollution, into health impact assessments. The results of this one-year project should also provide an estimate of the health burden of morbidity in addition to that of mortality, expressed in disability-adjusted life years. The project would also include an international workshop in autumn 2004 to ensure input from various experts.

9. The Task Force took note of the work and stressed the potential importance for the work of the Convention and under CAFE. It also recognized that it was still premature to include morbidity as health outcome explicitly into the integrated assessment framework based on the RAINS (regional air pollution information and simulation) model of the International Institute for Applied Systems Analysis (IIASA). However, the Task Force recommended to make the experiences and results obtained by the project available for the cost-benefit analysis (CBA) performed within CAFE. Mr. Fintan Hurley (United Kingdom) has agreed to join the project as an adviser to ensure this link with CAFE.

10. Mr. Bertil Forsberg (Sweden) gave a brief overview of the progress in the review of the RAINS model. The review was being conducted by a team of ten experts contracted by EC. He highlighted a number of questions that the review team was discussing with experts from IIASA.

11. The Task Force took note of the review and expressed its willingness to contribute to questions of the treatment of health effects identified by the review team.

I. OZONE

12. Mr. Dick Derwent (United Kingdom), Chairperson of the Task Force on Measurement and Modelling, presented an overview of the review of the EMEP unified Eulerian model (EB.AIR/GE.1/2004/6). This review had concluded that there was a high level of confidence in the EMEP model's representation of the broad spatial pattern of ozone exposure levels across Europe and of the model's response to emission changes. This level of confidence extended to the regional background levels, which were an essential input to the estimation of health impacts on the urban scale.

13. Ms. Leonor Tarrason (MSC-W) presented recent results from the EMEP unified eulerian model. Correlation coefficients between modelled and observed concentrations on the regional scale were high, between 0.6 and 0.8 for daily mean ozone and daily maximum values. The summer mean ozone bias was below 10%, similar to other state-of-the-art models. However, the EMEP model, as most state-of-the-art models, underestimated the occurrence of very low and high ozone values and overestimated the occurrence of medium-level ozone concentrations. In particular, the modelled winter values were lower than observations. She also stressed that meteorological variability between 1999 and 2003 was an important factor that had an influence on modelled concentrations of the same order as variations due to envisaged emission changes from 2000 to 2010 and 2020. In addition, she requested guidance on the set of indicators to be delivered, for which the model was deemed very flexible.

14. The Task Force appreciated the recent progress at MSC-W on modelling regional ozone concentrations at a European scale.

15. Mr. Markus Amann (CIAM) presented modelling results of the health effects of ozone using the RAINS model. He explained that CIAM had followed the advice given at the sixth meeting of the Task Force on Health. The attributable mortality due to exposure to ozone was calculated using the relative risk estimate produced by the WHO systematic review. Mr. Amann also explained that other side constraints had to be taken into account when selecting an appropriate metric for estimating ozone effects in integrated assessment, such as the performance of the available modelling tools for different ozone regimes. He mentioned findings of the City-Delta project model intercomparison demonstrating difficulties of state-of-the-art dispersion models to simulate low ozone levels in urban areas.

16. The Task Force noted that the WHO systematic review had confirmed that it was not possible to identify a threshold for the effects of ozone on mortality. At the same time, it acknowledged that there were increasing uncertainties concerning the shape of concentration-response function for the associations between effects and ozone levels at very low concentrations. It noted that for the integrated assessment modelling, these uncertainties should be kept in mind when selecting an indicator for ozone-related mortality.

17. Mr. Derwent pointed out that ozone was present throughout Europe on almost all days of the year because of (i) its natural background, (ii) its presence in intercontinental air masses entering Europe (with ozone levels between 20 and 40 ppb), and (iii) its photochemical production within Europe. In urban areas, chemical reactions with NOx depleted ozone so that ozone levels in some urban areas – particularly near traffic sources – were often lower than in the suburban, rural or background areas that surrounded them. Reductions in NOx emissions might lead to increased ozone levels in some urban areas and this effect confounded analyses of the impact of control policies on regional ozone levels in integrated assessment models, as it might influence the responses in areas and times of the year when ozone concentrations were close to background levels.

18. Based on these considerations, the Task Force made the following recommendations for the inclusion of ozone-related mortality:

(a) The relative risk for all-cause mortality was 1.003 for a 10 $\mu g/m^3$ increase in the daily maximum 8-hour mean. The 95% confidence interval was between 1.001 and 1.004. This summary estimate was derived by the meta-analysis within the WHO systematic review;

(b) A linear concentration-response function was assumed;

(c) The principal metric for assessing the effects of ozone on mortality should be the daily maximum 8-hour mean. This was in line with the health studies used to derive the summary estimate;

(d) Current evidence was insufficient to derive a level below which ozone had no effect on mortality. However, the use of a cut-off for integrated assessment modelling at 35 ppb, considered as a daily maximum 8-hour mean ozone concentration, was recommended. For days with ozone concentration above 35 ppb as maximum 8-hour mean, only the increment exceeding 35 ppb would be used to calculate effects. No effects of ozone on health would be calculated on days below 35 ppb as maximum 8-hour mean. Effectively, it meant that the exposure parameter was the sum of excess of daily maximum 8-h means over the cut-off of 35 ppb calculated for all days in a year. This recommendation was based on the application of a very conservative approach to integrated assessment modelling and took account of the uncertainties in the shape of concentration-response function at very low ozone concentrations. It also reflected the seasonal cycle and geographical distribution of background ozone concentrations, as well as the range of concentrations for which models provided reliable estimates;

(e) The acronym AOT (accumulated over a threshold) should not be used for the above-mentioned indicator. SOMO35 (sum of means over 35) was proposed instead;

(f) It was highly likely that the overall effects of ozone were underestimated by this approach. Therefore, a sensitivity analysis applying no cut-off should be made. This estimate would indicate an upper estimate of the attributable effects of ozone on mortality. The same coefficient would be used;

(g) Ozone effects should be assessed over the full year;

(h) For assessing ozone exposure in urban areas, urban background concentrations should be used. To be in line with most of the evidential health studies, it was regarded as sufficient to use one average ozone concentration per city. The rural concentrations of the EMEP model results would be corrected for urban levels using correlations between rural and urban pollution levels supplied by research projects such as City-Delta;

(i) At this stage, there were insufficient data to distinguish (susceptible) sub-populations and the calculations should be applied to total population.

19. The Task Force invited MSC-W and CIAM to assess the robustness of the estimates of the proposed ozone indicator, in particular in urban areas and also in response to changes in emissions, taking into account also the results from the City-Delta project.

II. PARTICULATE MATTER

20. Mr. Derwent presented an overview of the review of the EMEP unified Eulerian model (EB.AIR/GE.1/2004/6). The review had concluded that the model in its present form significantly underestimated total PM mass concentrations (PM10 and PM2.5) due to an incomplete description of processes and emissions. For example, the formation of secondary organic aerosols and some natural aerosol sources had not been included in the EMEP model yet. However, the model was able to calculate the regional component of the main anthropogenic

PM fractions (sulphate, nitrate, ammonium, some primary components) with an accuracy sufficient for the assessment of the outcome of different control measures.

21. Ms. Tarrason presented recent results from the development of the EMEP unified Eulerian model, including progress in modelling water content of PM. Model calculations had shown on average a 28% underestimation and correlations of 0.68 for 17 stations compared to gravimetric PM2.5 measurements over Europe, which was similar to other state-of-the-art models. However, further conclusions on model performance had been hampered by the lack of measurement data on the chemical composition of PM2.5 and information on primary PM emissions for specific PM components. Ms. Tarrason stressed that the EMEP model should not be used in studies requiring the analysis of total PM mass but might be applied to analyse the effect of emission changes. It was also mentioned that inter-annual changes in meteorological conditions introduced variability in the scenario analysis that was comparable to the expected variations in PM concentrations due to emission reductions from 2000 to 2010.

22. The Task Force appreciated the recent progress at MSC-W on modelling regional PM2.5 concentrations at a European scale, but stressed the importance of developing the model further to allow a full assessment of the anthropogenic fraction of PM2.5, including the organic fraction. It also requested Parties to increase their efforts to monitor PM2.5, including its chemical composition, and to refine the primary PM emissions.

23. Mr. Amann presented the modelling results of the health effects of particulate matter using the RAINS model. He explained that CIAM had followed the advice given at the sixth meeting of the Task Force on Health (EB.AIR/WG.1/2003/11). He showed some preliminary results using estimates of reduction in life expectancy due to the exposure to fine PM.

24. The Task Force confirmed its previous advice that, for the analysis of different emission reduction scenarios, only the anthropogenic contribution to PM2.5 mass should be assessed; for this anthropogenic contribution, no no-effect level was assumed. It also reaffirmed that, due to the absence of compelling toxicological data about different PM components acting in the complex ambient PM mixture, it was not possible to precisely quantify the relative importance of the main PM components for effects on human health at this stage. The Task Force noted that this approach was fully in line with both the recent findings of the WHO systematic review and previous recommendations from a WHO working group on the "Quantification of health effects of exposure to air pollution" (http://www.euro.who.int/air/Publications/20020621_6).

25. The Task Force also stressed that the approach did not yield an overall quantification of all effects related to exposure to PM. Important effects which were currently not covered, but should be taken into account (to the extent possible and justifiable from compelling evidence) in cost benefit analyses, included infant mortality and morbidity outcomes.

III. UNCERTAINTY TREATMENT

26. Mr. Amann reported on work at IIASA on the treatment of uncertainties within integrated assessment modelling. He gave an overview of previous work of CIAM on such treatment, including a recent workshop (http://www.iiasa.ac.at/rains/meetings/Uncertainty-Jan2002/announcement.html). This workshop had concluded that policy makers, in contrast to scientists, might have difficulties in understanding the nature of mathematical uncertainties for decision-making. A more constructive approach would make use of the robustness of the results from scenario analyses of future strategies. Robustness implied that strategies (control needs and priorities between countries, sectors, pollutants) did not significantly change due to changes in the uncertain model elements. The integrated assessment modelling dealing mainly with scenario analyses focused on calculating relative changes between strategy options, whereas some applications, such as the development of air quality standards, might consider absolute pollutant levels. He also urged other bodies providing data relevant for integrated assessment modelling, such as other effect-oriented work, to provide CIAM with estimates on the biases of air pollution effects on ecosystems and materials, including the presumed magnitude and direction of such biases.

27. The Task Force took note of the report and stressed that the analysis of uncertainties was an important and integral part of the integrated assessment modelling. Therefore, the Task Force invited CIAM to:

(a) Make an inventory of all possible biases in its approach assessing emission reduction strategies and their effects on health, in close collaboration with other relevant groups, and to assess the possible implications of these biases;

(b) Conduct on sensitivity analysis to identify critical assumptions in the model construction;

(c) Assess to the extent possible the statistical uncertainties of the model, using information on the uncertainties of the different input parameters and/or performance of the models.

IV. COST-BENEFIT ANALYSIS

28. Mr. Hurley reported on plans for CBA, which were currently being developed for CAFE. He explained that CBA needed to be more comprehensive than the integrated assessment modelling in terms of the health outcomes investigated. Benefits would be systematically underestimated if only those effects which were currently included in RAINS were considered. He stressed that some seldom studied health end points, like chronic bronchitis or restricted activity days, might represent a major public health burden compared with better-studied end

points like respiratory hospital admissions. Because of limited data on background rates, it might be necessary to use impact functions (number of events annually per $\mu g/m^3$ per 100,000 population) rather than conventional concentration-response functions (% change in relative risk per $\mu g/m^3$). He also mentioned work currently being developed using life table analyses of the cohort studies. The aim was to provide output in terms of deaths as well as life years, because some economists thought that the value of a statistical life was more reliable than the value of a life-year. A methodology note on CBA in CAFE was available at http://europa.eu.int/comm/environment/air/pdf/cba_methodology.pdf and would be updated. The proposals would be reviewed formally. A stakeholder consultation day was planned for 5 July 2004 in Brussels.

29. The Task Force took note of the report on CBA and stressed that the methodologies applied for the health impact assessment within RAINS and the cost-benefits analysis should be coherent, and that both exercises were complementary. However, specific differences were also mentioned. The main purpose of the integrated assessment modelling was to identify robust cost-effective policies to meet environmental and health-related objectives. For this purpose, it was not necessary to yield an overall quantification of all effects related to exposure to air pollution. Only the main pollutant/health outcome pairs were included, and it was recommended to apply a conservative approach. In contrast, CBA should yield a complete assessment of all benefits expected to occur when applying abatement measures. The Task Force stressed that if certain effects (and subsequent benefits) were not included, this would imply zero benefits. Therefore, it was necessary also to include in CBA to the extent possible those effects which were currently not part of the RAINS modelling framework, like effects on infant mortality and on morbidity.

V. EXAMPLES FROM COUNTRIES ON SMOG AND HEATWAVE DEATHS

30. Mr. Peter Straehl (Switzerland) reported on work to assess the mortality attributed to ozone during the heatwave in summer 2003 in Switzerland. Exposure was assessed using data from the Swiss national monitoring network. Effects were calculated using concentration-response functions from the WHO systematic review. It was estimated that up to 300 excess deaths could be attributed to the exposure to ozone during the summer of 2003 in Switzerland.

31. Mr. van Bree gave an overview of work performed at RIVM to calculate the effect of air pollution (ozone and PM10) on the mortality during the summer of 2003. He concluded that in the Netherlands a significant part (30–60%) of the deaths now being attributed to the hot summer weather in 2003 (1000–14000 additional deaths) could reasonably be expected to have been caused by ambient ozone and, to some extent, particles.

32. Mr. John Stedman (United Kingdom) provided a summary of his work to estimate the effects of air pollution on mortality during the heatwave in summer 2003 in the United Kingdom. He estimated that between 225 and 593 additional deaths were brought forward due to the exposure to high ozone concentrations. Around 200 additional deaths might have been brought forward due to exposure to PM10. This represented 21–38% of reported excess deaths in England and Wales.

33. The Task Force took note of the reports and stressed the importance of such assessments on a national scale. It acknowledged that the estimated effects were of high concern and considerable public health relevance. At the same time, the Task Force agreed that it was not easy to disentangle the effect of heat versus air pollution on health and stressed that there was a need to understand better the interactions between air pollutants and temperature exposures during events like the heat wave in summer 2003. More detailed investigations of the impact of the heatwave could be expected from research groups throughout Europe in the coming months, in particular from the project "Assessment and Prevention of Acute Health Effects of Weather Conditions in Europe" (http://www.epiroma.it/phewe/), which was funded by the European Commission.

VI. COLLABORATIONS

34. Mr. André Zuber (EC) reported on the development of a set of indicators to be used within CAFE. He mentioned that different sets of indicators would be suitable for different purposes. The selection of indicators was not ready yet. He invited WHO and the Task Force on Health to collaborate in agreeing on a final set of indicators. Mr. van Bree agreed to find ways to include a programme session on indicators at the next conference of the thematic network on air pollution and health (AIRNET).

35. Mr. van Bree provided an overview of recent developments within AIRNET (http://airnet.iras.uu.nl/). He highlighted that two working groups – on health impact assessment and on the science-policy interface – were currently finalizing two reports, which were also of high relevance for the work under the Convention. He also drew attention to the coming AIRNET conference in Prague, 21–23 October 2004.

VII. WORK-PLAN

36. Mr. Matti Johansson (UNECE secretariat) provided an overview of the work on heavy metals and persistent organic pollutants (POPs) under the Convention. Protocols on both groups of substances had entered into force recently. The Task Force on POPs was already operational and a task force on heavy metals was to be prepared both under the Working Group on Strategies and Review.

37. Mr. Krzyzanowski presented the work-plan of the Task Force for 2004/2005. He explained that the Task Force on Health was expected to provide a health risk assessment of heavy metals from long-range transboundary air pollution as part of the coming review of the 1998 Protocol on Heavy Metals. It was stressed that such an assessment should ideally take several exposure routes into account. A final report on the assessment should be completed in 2006. Mr. Krzyzanowski also invited delegates to indicate possible future candidate heavy metals in addition to those currently covered by the Protocol on Heavy Metals (lead, mercury and cadmium). Parties to the Convention were invited to designate experts to contribute to the assessment.

38. Mr. Krzyzanowski reported that the Task Force on Health was invited to produce a report on the health risk of PM from long-range transboundary air pollution by the end of 2004. The outline of the report would be as follows:

(a) Introduction (history, information sources, methods);
(b) Sources (including primary PM and gases for secondary PM relevant for long-range air pollution;
(c) Modelling of long-range transport;
(d) Contribution of long-range air pollution to population exposure;
(e) Hazard assessment of PM;
(f) Estimation of risk including assumptions, caveats, uncertainties;
(g) Risk estimates;
(h) Conclusions.

39. A similar report on ozone would be drafted in 2004 and was expected to be finalized in 2005.

40. The Task Force accepted these initiatives of the work-plan. It stressed that especially the planned PM report should bring together existing activities and material (provided by MSC-W, CIAM, WHO and CAFE) and would be important for the policy discussions as part of the expected review of the 1999 Gothenburg Protocol. Experts from the EMEP centres and Parties were invited to contribute to drafting the report and/or participate at an editorial meeting planned for autumn 2004.