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EXECUTIVE BODY FOR THE CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

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INTEGRATED ASSESSMENT MODELLING

WORKSHOP ON COST-EFFECTIVE CONTROL OF URBAN AIR POLLUTION

Report by the Chair of the Task Force on Integrated Assessment Modelling

1. The workshop on the cost-effective control of urban air pollution took place on 16 and 17 November 2006 in Laxenburg, Austria, in accordance with the Executive Body’s 2006 workplan. It was organized by the Task Force on Integrated Assessment Modelling and the Task Force on

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Measurements and Modelling. The International Institute for Applied Systems Analysis (IIASA) hosted the meeting in accordance with the Executive Body's workplan.

2. Fifty-two experts attended the workshop. The following Parties to the Convention were represented: Austria, Croatia, Cyprus, Finland, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden and the United Kingdom of Great Britain and Northern Ireland. Also present were representatives of the Task Force on the Health Aspects of Air Pollution of the Working Group on Effects, the Centre for Integrated Assessment Modelling (CIAM) of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP), the EMEP Meteorological Synthesizing Centre-West (MSC-W), the Expert Group on Particulate Matter, the Expert Group on Techno-economic Issues, the European Commission and its Joint Research Centre (JRC), the European Environment Agency (EEA), and the Oil Companies' European Organization for Environment, Health and Safety in Refining and Distribution (CONCAWE). A member of the secretariat also attended.

3. Mr. R. Maas (Netherlands) and Mr. R. Derwent (United Kingdom) chaired the meeting.

I. AIMS OF THE WORKSHOP

4. The objectives of the workshop were:

(a) To review our current understanding of the various aspects that are relevant for the development of cost-effective strategies aimed at reducing the health risks of air pollution, and to distil the policy-relevant findings;

(b) To discuss methodological approaches for bringing this information together to help the policy process in the design of more efficient pollution control strategies.

5. The following issues were addressed:

(a) The measurement and modelling of particulate matter (PM) and ozone (O_3) exposure of the urban population;

(b) The most recent findings from health impact studies;

(c) The connections between urban air quality and regional scale pollution based on evidence derived from monitoring data in different European regions, and the findings emerging from modelling exercises;

(d) Current methodological approaches that have been developed for integrated assessment models to balance local and Europe-wide emission control measures.

6. Mr. L. Hordijk welcomed the participants on behalf of IIASA.

II. CONCLUSIONS

A. Monitored air quality and health impacts

7. The workshop noted that the understanding of the health effects of particulate matter had improved greatly in recent years. The emission reductions of the Gothenburg Protocol have had positive side effects on reducing secondary inorganic aerosols. The review of the health effects of PM, O_3, sulphur dioxide (SO_2) and nitrogen oxides (NOx) were part of the review of the Gothenburg Protocol.

8. The workshop noted the the definitions of the urban increment and the “city-delta” for the fine particulate matter ($PM_{2.5}$) were as follows:

(a) Urban increment: Incremental concentrations in a city originating from emissions of the same city (i.e., the difference between $PM_{2.5}$ concentrations in urban background air and at an upwind site);

(b) City-delta: the correction of a PM concentration value computed by a regional dispersion model in a 50 km × 50 km grid to derive the background concentration within a city in that grid cell.

9. Based on the analysis of chemical composition of PM at 34 stations in Europe the workshop noted that the same change in PM_{10} mass in Europe might result in different health responses. The share of the $PM_{2.5}$ fraction in total PM_{10} varied as well as the chemical composition of $PM_{2.5}$. The number concentration, which was dominated by particles smaller than 0.1 µm, might also contribute to harmful effects. The workshop agreed that it was important to further collect and compare data on the chemical composition of PM. A prerequisite for the synthesis of measurement data was the harmonization of the classification of rural, urban and kerbside monitoring stations.

10. The workshop noted that urban increments in coarse particulate matter (PM_{10}) and $PM_{2.5}$ ideally could be estimated using coherent sets of PM measurements at urban and upwind rural twin sites. In the comparison of observed values with EMEP model output, it should be taken take into account that the model does not include all PM fractions, such as mineral dust and

secondary organic aerosols. Also, the EMEP model calculates the 50 km × 50 km cell average, which will be higher than the rural background if such a grid cell is dominated by a large city. The workshop noted that even after harmonization of data, the estimated urban increments and spatial gradients would vary with time. The seasonal variation could be significant. The analysis of components in PM might help to reveal the relevant pollution sources. The workshop noted that at rural stations the share of ammonium nitrate could increase in winter due to more favourable thermodynamic conditions for related chemical processes. Domestic wood burning could produce a significant share of primary PM mass, and it could be long-range transported. Tracer techniques to study the origin of organic PM were available.

11. The workshop noted that the regional background dominated urban levels according to ozone and PM data in the Europe-wide database “Airbase”. Within-city variations could be up to 30%. $PM_{2.5}$ and PM_{10} were found to be highly correlated. The share of $PM_{2.5}$ in total PM_{10} was about 70-80% in rural areas, but generally lower in cities (60%). The share of elemental (EC) and organic carbon (OC) in $PM_{2.5}$ in cities was higher than in rural areas (30–40%). The share of secondary inorganic aerosols in $PM_{2.5}$ was 30–40%; in cities; this share was higher than in rural areas. No clear trends were detected for PM_{10}, probably due to meteorological conditions, although emissions have decreased. For ozone, there were increasing trends at urban and (less) at rural level for ozone. The ozone indicator SOMO35 ((the sum of daily 8-hour means over 35 parts per billion (ppb)) was relatively constant between 1995 and 2005. The differences in ozone concentration between urban and rural areas had become smaller, as the urban decrements had slowly disappeared.

12. The workshop took note of the new *Air Quality Guidelines* of the World Health Organization (WHO), which provide challenging targets for air pollution control. They promote attention to long-term exposure of even low $PM_{2.5}$ levels. However, short-term (24-hour) exposures and exposure to coarse fraction of PM_{10} was also associated with health effects, though the magnitude of risk associated with these exposures was smaller. There was increasing evidence on cardiovascular effects of fine PM. Evidence from updated six-city study in the United States of America confirmed that health risks were reduced with reductions in exposures. European cohort studies had become available and were consistent with cohorts in the United States. Health risks of PM might be higher if exposure assessment were more precise. Differences in health risks due to the heterogeneity of $PM_{2.5}$ mass needed to be studied further as new epidemiological studies in the United States showed the importance of differences in the composition of PM. WHO would convene a workshop on “Health relevance of particulate matter from various sources” to be held on 26 and 27 March 2007 in Bonn, Germany (in connection with the meeting of the Task Force on Health) to evaluate progress in the research concerning this important issue.

B. Air quality modelling

13. The workshop took note of the three phases of the City-Delta project of European Union (EU) that aimed to evaluate urban decrements of ozone and increments of PM using several high-resolution models at selected European cities. All models reasonably simulated ozone, but better in rural than in urban areas. They captured relative daily and seasonal variations. For PM_{10} the simulations were rather poor, although observed large scale models underestimated mass concentrations even more. No systematic $PM_{2.5}$ validation was possible due to lacking measurements. The average of the model results (ensemble) performed better than any individual model. The project had helped to understand model performances, and improving urban emission inventories could enhance the results.

14. The workshop noted that modelling was necessary at all spatial levels of air quality management. Currently measurements were available at selected locations only and models would complement areas where measurements were not available. Models could also be used to predict future air quality levels and the effects of control measures. Models could be used in linking spatial scales, in particularly for health impact assessments and the assessment of the effects of control strategies. The health risks were probably underestimated with the current 50 km × 50 km resolution. More detailed models could help to find out which sectors and geographical locations should have priority.

15. The workshop noted that within the EU, the common legislation had harmonized the air quality management practices. However, differences existed in measurements and modelling at local levels. Hence there were large differences in identification of current and future exceedances of air quality limit values. Assessment requirements had changed the emphasis from monitoring station values to development of air quality maps. There was, however, no clear standard method. Data quality control and modelling review were needed both at the national EU levels. An EU-wide facility for consistent data to be used in scenario analysis was desirable, in particular, on traffic emission factors and regional background concentrations. In summary, standards and review procedures were needed for harmonizing and improving model comparability.

16. The workshop took note of the work in the United Kingdom on fine scale modelling of ozone exposure. All modelled ozone indicators tended to worsen from 2003 to 2010. A model with high spatial resolution proved to reproduce the measurements better than the EMEP model. However, its performance depended greatly on the availability of reliable emission inventory data for ozone precursors at a scale of 1 km × 1 km.

C. Urban air quality in integrated assessment models

17. The workshop noted the work done on deriving functional relationships for modelling urban pollution in the integrated assessment model, RAINS. The aim was to quantify the influence of regional and local emission to urban background, to estimate health impacts of $PM_{2.5}$ and O_3 and to develop functional relations for use in cost-effectiveness analysis, noting that no results were yet available for O_3. The analysis covered all larger European cities (473 cities with more than 100,000 people, covering 60% of the European population). The ensemble response of the fine-scale models used in the City-Delta project was used to assess the effect of switching off low-level primary emissions in a city. The computed urban increments were dependent on, inter alia, the size of the city, the number of low wind-speed days, and emission densities, which were estimated with a top-down method for wood burning and industrial processes as no urban inventories were available. There appeared to be a considerable improvement in the agreement between modelled urban background levels and the monitored data. In summary, the methodology resulted in $PM_{2.5}$ increments up to 15 $\mu g/m^3$, but it was sensitive to target domain definition and the emission data quality. In particular, the assumption that wood burning was attributed to the grid cells proportionally to the population could indicate an overestimation of PM emissions in cities. Low urban increments were found in some countries, possibly due to national domestic $PM_{2.5}$ emissions per capita being lower than in the majority of countries. Meteorological data used might be another reason for low increments. Uncertainties in available monitoring data and missing information of the monitoring site classification were considered to hamper an extended validation.

18. The workshop noted the study on the relationships between local scale increments of PM and emissions in 50 km × 50 km grid in the United Kingdom. A site-specific source attribution model was employed at 132 sites in the United Kingdom by examining the impact of switching off all local primary $PM_{2.5}$ sources and estimating the urban increments for a 1 km × 1 km grid cells. As expected, this resulted in higher increments than calculated by the approach with the RAINS model, where only low level primary emission sources were switched off and where the average increment was calculated for a 10 km × 10 km grid cell. Further analysis for low-level emission sources only and at a more aggregated grid size could explain differences to other increment estimates.

D. The potential for controlling emission in urban areas

19. The workshop noted the study on the effectiveness of national and urban policies and programs in Europe, which summarized the reported management plans and programmes in response to the EU Air Quality Framework Directive. Exceedance had been reported for PM_{10}, SO_2 and nitrogen dioxides (NO_2). Of this, 60% cover areas of more than 10 km × 10 km. Traffic

was considered the main source for exceedance of NO_2 and PM. Residential sources were considered the second most important source for PM. Current programmes and plans did not appear to be sufficient to ensure compliance with air quality limit values. In many cases, the effectiveness of measures was not assessed; however, several examples of good practice existed. Speed limits, parking policies, clean public transport, clean roads, low emission zones, congestion charges, and regulation for construction equipment could prove to be cost-effective local measures.

20. The workshop took note of the experience from the road tax for driving in the inner Stockholm city area. The time-restricted trial had resulted in large traffic and emission reductions, but had only a small effect on concentrations. The calculated effects on health were notable. The trial was considered as a cost-effective measure compared to other possibilities in reducing air pollution levels.

E. Integrated assessment of urban air quality

21. The workshop noted the results from a multi-objective optimization to select effective PM_{10} control policies in Northern Italy. The calculation system comprised SO_2, NOx, NH_3, volatile organic compounds and PM_{10}. A case study in the Milan area had identified options to significantly improve air quality in hot-spot areas with relatively low reduction costs and the priority sectors in a cost-effective abatement strategy.

22. The workshop noted the study on the cost-effectiveness optimization with the RAINS and GAINS models for local and Europe-wide emission control measures, where the GAINS model additionally included greenhouse gases and selected non-technical measures compared to the RAINS model. The GAINS approach could represent multi-pollutant technologies, energy efficiency improvement measures and fuel substitutions, while the RAINS model relied on add-on technological controls for individual pollutants. The GAINS model had extended the range of possible emission reductions by having greenhouse gas mitigation embedded in the maximum feasible reductions concept. When the possibilities of energy efficiency measures and fuel substitutions in GAINS were “switched off” the model runs in the “RAINS mode”, which produces results comparable with the original RAINS model. The formulation of “city-deltas” of $PM_{2.5}$ concentrations employed a simple linear relation to national emissions. Analysis of the cost-effectiveness of local measures would require additional EMEP transfer matrices for urban emissions. Urban measures could be integrated in the analysis when the resulting emission reductions were allocated simultaneously to all cities in a country.

III. RECOMMENDATIONS

23. The workshop recommended that research be done on the following priority issues:

(a) There was a need for an improved link between urban and regional concentration levels. Several approaches, including the “city-delta”, the comparison of measurements from twin-sites at rural and urban areas, and detailed national modelling, could provide the necessary parameters to be used in integrated assessment models;

(b) Further scrutinization by national experts was needed on the assumptions and data used in the “city-delta” approach, calling for relevant Convention bodies to establish a mechanism;

(c) The results from the City-Delta project were dependent on the grid cell size used to define the target domain. Urban increments were larger when a higher spatial resolution was used. High-resolution emission data could ensure substantial improvements when high-resolution dispersion models were used. The population-weighted mean exposure for urban area should be calculated using high-resolution model estimates covering all grid cells in the city as the indicator the best linked with the health impact of pollution;

(d) Improved national information was needed on emissions relevant for the urban scale exposure, in particular on the biomass burning in rural areas and the domestic use of wood and other solid fuels;

(e) Harmonization of classification of measurement stations was required, in particular for urban and traffic classes. Additional information was needed to assure the comparability and quality of measurement data. Countries were to be encouraged to submit data on the methods used, the assessment of measurement uncertainties, and the characteristics of measurement stations to the air-quality database, “Airbase”;

(f) Further epidemiological and toxicological studies were required to analyse the importance of the composition of PM in the health impact of pollution;

(g) Progress made should be continued regarding investigation of the cost-effectiveness of local measures and the sharing of information on the experiences;

(h) Countries should be encouraged to integrate urban inventories in their national emission databases to complement their gridded emission data submissions to EMEP;

(i) Ways should be sought to ensure the continuity in the exchange of urban air quality modelling expertise, as initiated by the researchers within the City-Delta project.
