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REPORT OF THE WORKSHOP ON THE REVIEW OF THE EMEP MSC-E MODELS ON HEAVY METALS AND PERSISTENT ORGANIC POLLUTANTS

By the Chairman of the Task Force on Measurements and Modelling

INTRODUCTION

1. The Workshop on the Review of the EMEP MSC-E Models on Heavy Metals and Persistent Organic Pollutants (POPs) took place on 13–14 October 2005 in Moscow. It was organized by the Task Force on Measurements and Modelling and supported by the Meteorological Synthesizing Centre – East (MSC-E) and the World Meteorological Organization (WMO).

2. The workshop was attended by 48 experts from Bulgaria, Croatia, the Czech Republic, Denmark, France, Germany, Hungary, Japan, Latvia, the Netherlands, Norway, Poland, the Russian Federation, the Slovak Republic, Sweden, Switzerland, the United Kingdom, the United States and the European Community. Representatives of the Chemical Coordinating Centre (CCC), the Meteorological Synthesizing Centre – West (MSC-W), MSC-E and the ESPREME

project (Estimation of willingness-to-pay to reduce risks of exposure to heavy metals and cost-benefit analysis for reducing heavy metals occurrence in Europe) also attended.

3. The workshop was preceded by an open process involving participation by and close cooperation with national experts as well as the subsidiary bodies to the Convention (Working Group on Effects, Working Group on Strategies and Review) and relevant international organizations (the Arctic Monitoring and Assessment Programme (AMAP), the European Commission (EC),the Baltic Marine Environment Protection Commission (HELCOM), the OSPAR Commission for the Protection of the Marine Environment of the Northeast Atlantic, and the United Nations Environment Programme (UNEP)). Background documentation was made available on the Internet prior to the workshop.

I. AIMS AND OBJECTIVES OF THE WORKSHOP

4. The main aim of the workshop was to establish whether the EMEP MSC-E models on heavy metals and POPs are state of the art and fit for the purpose of evaluating the contribution of long-range transport to the environmental impacts caused by heavy metals and POPs.

5. The objective of the workshop was to review the performance of MSC-E heavy metals and POPs models. The review considered the ability of the EMEP models to provide concentration and deposition data; determine trends in regional air concentration and deposition data over Europe; establish the response of regional air quality to emission changes for use in the development of emission reduction strategies (source-receptor relationship); facilitate the evaluation of the effects of air quality on ecosystems; support the assessment of health effects by providing regional concentrations of health-relevant pollutants; and support the preparatory work for the review of the Protocol on Heavy Metals and the Protocol on POPs.

6. The review and evaluation of the MSC-E heavy metals and POPs models were based on three elements: (a) examination of the model's formulation, description and parameterization of key related environmental processes, and the model's sensitivity to key parameters; (b) evaluation of the model's performance against monthly and annual measurements of air concentrations and deposition levels of heavy metals and POPs from EMEP and national monitoring networks; and (c) comparison of the MSC-E models with other numerical models simulating the fate of heavy metals and POPs in the environment.

7. The workshop was organized in plenary sessions and in two working groups (a working group on heavy metals and a working group on POPs). The presentations given at the workshop can be found on the Internet at www.msceast.org/events/review.html

II. SUMMARY OF MAIN DISCUSSION POINTS AT THE PLENARY SESSIONS

8. The workshop participants heard a presentation by CCC evaluating emission data for POPs and heavy metals and emphasizing model applications. The workshop agreed that:

(a) Official emission data were of limited value in terms of model applications because insufficient emphasis had been given to temporal and spatial resolution, speciation and environmental media coverage;

(b) Most emission data for heavy metals and POPs suffered from significant uncertainties and inaccuracy;

(c) Further improvement of official emission data through the Task Force on Emission Inventories and Projections was the most sensible way to proceed;

(d) Knowledge of the sources and emissions was likely to remain the least understood feature with respect to the overall behaviour and fate of many of these compounds. This needed to be taken into account when evaluating the MSC-E models;

(e) Great care needed to be taken in selecting, adjusting and combining emission inventories for the purpose of model application and data interpretation;

(f) Certain features of emission inventories, such as spatial patterns, temporal patterns, and congener and isomer patterns, were robust, and model evaluation exercises had to take advantage of these features.

9. The workshop also heard a presentation by CCC evaluating monitoring data for heavy metals and POPs, again with an emphasis on model applications. Participants' attention was drawn to the work of the Stockholm Convention on POPs, as its activities complemented those of EMEP. It was stressed that monitoring data from different laboratories should be used with care in model evaluation because of different quality assurance (QA)/quality control (QC) procedures. A campaign using passive samplers for POPs planned for the EMEP network during the summer of 2006 was highlighted.

10. The workshop agreed that:

(a) EMEP monitoring data were particularly suited for model evaluation purposes because of their QA/QC procedures and their coverage of seasonal and long-term trends and congener and isomer patterns;

(b) EMEP monitoring data, however, suffered from limited spatial and temporal coverage, lack of speciation for mercury, limited coverage of environmental media and the presence of significant uncertainties.

11. Attention was drawn to the processing of meteorological data for use in the modelling of heavy metals and POPs by the National Environmental Research Institute of Denmark. Comparisons were made between the use of the MM5 and MSC-E models for generating meteorological fields for the DEHM.[1] It was recommended that MSC-E:

(a) Provide some validation of the meteorological fields generated;

(b) Consider increasing the number of vertical layers and the time resolution of the meteorological fields employed.

12. The workshop was informed about the results of applying the CMAQ[2] model to benzo[a]pyrene and to lead and cadmium. It was concluded, on the basis of these results, that the CMAQ model could be a valuable tool for MSC-E to stand alongside the MSC-E heavy metals and POPs models. CMAQ could provide self-consistent O_3 and OH concentrations for the MSC-E mercury and POPs models.

III. RECOMMENDATIONS FOR FUTURE WORK

13. The workshop noted that a number of long-term strategic issues might need to be taken into account in the future development of the MSC-E modeling. Some of the issues had been raised at the seventh meeting of the Task Force on Measurement and Modelling (in April 2005 in Zagreb, Croatia). These included (a) extending the scale of the mercury and POPs modelling to the global scale and involvement of MSC-E with the Task Force on the Hemispheric Transport of Air Pollution; (b) the description of those emission processes that were driven by meteorology, such as re-suspension and volatilization from soils; (c) the potential advantages of moving to meteorological data from the European Centre for Medium Range Weather Forecasting (ECMWF), particularly for the global scale; and (d) the advantages resulting from closer cooperation between MSC-E and MSC-W and harmonizing their activities on the hemispheric and global scales.

14. It was recommended that MSC-E consider the following issues for scientific investigation in the long term in their future workplan:

(a) Extension of the MSC-E heavy metals model to the consideration of other elements and heavy metals, including nickel, copper, chromium, arsenic, zinc and selenium;

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[1] Danish Eulerian Hemispheric Model.

[2] Community Multiscale Air Quality.

(b) Application of the MSC-E POPs model to screening a wider range of POPs for their potential environmental significance;

(c) Development of emission algorithms and models for the representation of emissions driven by meteorological processes, such as re-suspension and volatilization from soils;

(d) Inverse modelling using passive sampling campaign data;

(e) Extension of the MSC-E models to the global scale;

(f) The potential influence of climate change on the fate and behaviour of mercury and POPs.

IV. CONCLUSIONS OF THE MODEL REVIEW AND EVALUATION

15. Based on an evaluation of the model formulations and an examination of comparisons between monitored data and with other models, the workshop drew the following conclusions regarding the performance of the MSC-E models with respect to policy applications.

A. The MSC-E Heavy Metals model

16. The model parameterizations of atmospheric transport were appropriate for the operational modelling of heavy metals at the regional scale. However, the inclusion of a shallow lowest layer was recommended in order to better represent the heights of heavy metals emissions from road traffic.

17. The descriptions of wet and dry deposition processes in the model were relevant for the reliable evaluation of heavy metal deposition on the regional scale. The wet scavenging approach, used by many other models, was deemed appropriate for simulating cloud physics and chemistry, even though some models used a more elaborate approach. There appeared to be significant measurement and modelling uncertainties in quantifying dry deposition of mercury to forests. Further scientific progress is needed to quantify the magnitude of dry deposition to forests, to evaluate the ability of the models to simulate it, and to improve the models if necessary.

18. The model's chemistry scheme was appropriate for the description of the principal mercury transformations in the atmosphere. However, analytical solutions needed to be flexible as new chemical kinetics data became available and as new species were introduced into mechanisms. There were major uncertainties concerning the completeness of the description of the chemical kinetics of the reactions of atmospheric mercury.

19. The heavy metals air concentrations and deposition levels estimated with the MSC-E Heavy Metals model were found to agree with those estimated with other transport models in the various intercomparison exercises.

20. The transboundary fluxes of heavy metals calculated with the MSC-E Heavy Metals model corresponded well with, and were within the range of, those obtained with other transport models.

21. Other models, such as the MSC-E Heavy Metals model, underestimated air and precipitation concentrations of lead and cadmium when using official emission data. For the 1990s the model underestimations for lead were ± 40%, whereas for more recent years they were much larger and in some cases possibly by a factor of 3 to 7. The origins of these discrepancies need to be investigated and may involve the omission of key source categories in official statistics, neglect of the emission heights of some sources, neglect of re-suspension from soils and inadequate treatment of particle size distributions in the treatment of deposition processes. In one model, it has been possible to eliminate underestimation for lead in the 1990 case.

22. The monitoring data and adjusted emission scenarios used to evaluate model performance were largely appropriate. However, some concerns were expressed about the adjustment of emissions data for lead and cadmium. Because of the difficulties associated with the official emission estimates, it has been difficult to test the performance of the MSC-E heavy metals and other models against observations in an objective manner. Subject to these limitations, the MSC-E model satisfactorily reflected the observed spatial distribution of heavy metals in air and precipitation in Europe. It also adequately reproduced the temporal variations characterized by the observations.

23. Model performance would be improved by using meteorological fields with a $1^{o} \times 1^{o}$ spatial resolution rather than the $2.5^{o} \times 2.5^{o}$ currently used.

24. The MSC-E Heavy Metals model was suitable for evaluating the long-range transboundary transport and deposition of heavy metals in Europe. However, significant difficulties remained with official emissions data for lead and cadmium. Furthermore, significant uncertainties were associated with the chemistry of elemental mercury in all models and with the representation of heavy metal dry deposition.

B. The MSC-E POPs model

25. Results from the MSC-E POPs model demonstrated its ability to provide spatially resolved air concentrations and depositions of POPs across Europe. Similarities between

measurements and model predictions were encouraging, given the constraints with emission and measurement data.

26. Future emission data would need to provide improved spatial, temporal and speciation information to allow better comparisons between model predictions and measurements. Further measurement studies of long-term and seasonal air concentration data across the whole EMEP region were also essential.

27. Although the model provided reasonable agreement with long-term temporal trends of air pollution at most EMEP monitoring sites, some aspects of the measurement data remained unclear concerning the importance of location and local sources.

28. There was limited confidence in the model's ability to represent the observed seasonal variations of air concentrations and depositions of PCB-153, benzo[a]pyrene (B[a]P) and dioxins/furans (PCDD/Fs). The main reason for this discrepancy was that the emissions data employed did not adequately represent the seasonal variations caused by domestic heating. Possible additional reasons included the degradation of gas-phase and particle-bound POPs, scavenging by snow and the seasonal dependence of soil volatilization.

29. The currently existing POPs monitoring network was not sufficient for model development and validation purposes. Full implementation of the EMEP monitoring strategy would give up to 50 monitoring sites for POPs across Europe, and this would allow a better understanding of model performance.

30. Strong support should be given to the organization of a pilot study using passive and active air samplers to monitor POPs across the EMEP domain to provide spatially and temporally resolved air concentration data. The participation of South European countries would be of particular importance.

31. Boundary conditions of the MSC-E model, as determined by the EMEP grid, needed further improvement. This could be achieved using the hemispheric model, which provided information on air concentrations beyond the EMEP domain.

32. The parameterizations in the MSC-E POPs model were based on up-to-date information and conformed with those employed in most of the other models used to simulate the behaviour of POPs in the environment. Remaining differences in process descriptions were caused by several specific assumptions underlying the set-up of each particular model. A main goal of the POPs model intercomparison exercise was to make these assumptions transparent.

33. The general level of agreement found between the different POPs models in the model intercomparison exercise was encouraging given the wide range of model approaches and structures employed. Nevertheless, a number of significant discrepancies were identified that require further investigation.

34. The MSC-E POPs model's predictions of concentrations at the interfaces between the main environmental media were in reasonable agreement with the results of other models. There were some discrepancies in the mass fluxes between environmental compartments calculated by different models. It was an objective of the POPs model intercomparison exercise to analyse the causes of such discrepancies.

35. Within the limitations of current understanding of the sources and emissions of POPs and of their fate and behaviour in the environment, the MSC-E POPs model represents the state of the science. It was also considered fit for the purpose of evaluating the contribution of long-range transport to the environmental impacts caused by POPs.