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

Steering Body to the Cooperative Programme for Monitoring and Evaluation
of the Long-range Transmission for Air Pollutants in Europe (EMEP)
(Twenty-eighth session, Geneva, 6-8 September 2004)
Item 4 (e) of the provisional agenda

EMEP ASSESSMENT REPORT
SUMMARY

Prepared by the Meteorological Synthesizing Centre – West (MSC-W)
in consultation with the EMEP Bureau and with the assistance of the secretariat

Introduction

1. At its first meeting, held in Vienna in October 2000, the Task Force on Measurement and Modelling came up with a proposal for an EMEP assessment report. The objective was to describe the development of long-range transboundary air pollution in Europe since the start of EMEP in 1977 up to present times. Over this period, measurement and modelling techniques have improved and, along with this, knowledge about the phenomenon of air pollution has vastly increased. Emissions have undergone significant changes, partly due to international agreements and partly due to technical, economic and political developments. The meteorological transport patterns over Europe have varied, with a tendency towards long-term changes. The concerns and priorities of national authorities in this area have changed, too. In different ways these developments are reflected in the measurement data collected within EMEP over this period. The challenge is to use this unique data set to reveal the information that it contains.

2. The planning of the assessment report was carried forward at the second meeting of the Task Force held in Portoroz (Slovenia) on 30 May - 1 June 2001. At its twenty-fifth session, held in September 2001, the Steering Body of EMEP took note, in particular, of the progress in preparing the assessment report, expressing its gratitude to all national experts contributing to the work. In December 2001, the Executive Body expressed its support for the preparation of the assessment report and called upon Parties to contribute to the work planned (ECE/EB.AIR/75, para. 57 (h)). At its meeting in Geneva on 28 February - 1 March 2002, the extended EMEP Bureau decided on the management and the responsibilities for the preparation of the report. The reviews and discussions of the work on the assessment report can be found in the reports of the Task Force on Measurements and Modelling (EB.AIR/GE.1/2002/4, EB.AIR/GE.1/2003/3).

3. The Assessment Report itself consists of two parts. Part I focuses on an overall European perspective and part II contains national assessments. The Assessment Report leader Mr. Anton Eliassen, of the EMEP Meteorological Synthesizing Centre-West (MSC-W), and a support group including Mr. Sergey Dutchak, of the EMEP Meteorological Synthesizing Centre-East (MSC-E), Mr. Øystein Hov, of the EMEP Chemical Coordinating Centre (CCC), Mr. Peringe Grennfelt (EMEP Bureau member) and Ms. Sonja Vidic (EMEP Bureau member) had the overall responsibility for the report.

4. An editorial committee, led by Ms. Gun Lövblad (Swedish Environmental Research Institute (IVL)) and including Mr. Dutchak, Ms. Leonor Tarrasón (MSC-W) and Mr. Kjetil Torseth (CCC), was responsible for part I of the report. Part I is based on the material in part II, the work carried out at the EMEP centres and the contributions from invited experts. Part II was written by national experts, in consultation with the EMEP centres. Mr. Jerzy Bartnicki (MSC-W) assisted the assessment report leader and his support group and coordinated the contributions to part II of the report.

5. Part I consists of nine chapters: introduction; sulphur pollution over Europe; nitrogen oxides pollution over Europe; ammonia pollution over Europe 1980-2000; base cations in air and precipitation; ozone; heavy metals; persistent organic components; and particles in the air. Part II includes national contributions from the following EMEP Parties: Austria, Belarus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Slovakia, Spain, Switzerland, the former Yugoslavia Republic of Macedonia and United Kingdom. National contributions are based on the checked and verified national measurement data, compatible with the corresponding data available in the EMEP/CCC database.

6. The main findings of part I are summarized below.

I. BACKGROUND

7. The discovery of the severe pollution problems associated with sulphur in the atmosphere and in precipitation, combined with its transboundary nature, provided the background for setting up EMEP in 1977. Subsequently, in 1979, the Convention on Long-range Transboundary Air Pollution was adopted with EMEP being subsumed under it. Sulphur was the primary pollutant at the start of the programme, but most other air pollution components with a transboundary character have subsequently been included. Emission control protocols have been negotiated and at present there are agreements to reduce the pollution of sulphur, nitrogen oxides, ammonia, volatile organic compounds, heavy metals and persistent organic pollutants. These compounds cause acidification, eutrophication, ozone formation, enrichment of toxic compounds in the nutrition chains, and they also contribute to damage to human health, vegetation, water and soil ecosystems. EMEP has now been in operation for more than 25 years and has been essential in providing scientific underpinning for the development of effective regional air pollution abatement policy in Europe. Significant emission decreases and considerable environmental improvements have been achieved over this period as a result of emission reductions including those agreed under the various protocols to the Convention.

8. Twenty-five years of measurements of concentrations and deposition as well as model calculations of emissions, transport, atmospheric-chemical conversion and deposition of air pollutants over Europe have been assessed jointly by those countries that are Party to the EMEP Protocol, the EMEP centres and the Swedish International and National Abatement Strategies for Transboundary Air Pollution (ASTA) project. The aim of this report is to summarize the main results of emission abatement over these 25 years. Taking the situation in the 1970s - 1980s as a starting point, it is essential to determine how emissions, concentrations and depositions of these pollutants have developed over time. The report aims to describe trends and to establish whether observed trends can be explained by available knowledge. The assessment also intends to answer the question of what has been achieved and what more remains to be done in terms of environmental protection in view of the forthcoming review and possible revision of protocols.

II. SULPHUR EMISSIONS

9. Sulphur emissions over Europe have decreased significantly during the past 25 years.
From 1980 to 2000 there was a considerable decrease in sulphur emissions over most of Europe. The overall reduction was nearly 70%, but there are large differences in achievements between countries and regions. The largest reductions, near 90%, were achieved in Austria, Germany, Switzerland and the Nordic countries. The smallest reductions were seen in South-Eastern Europe, where emissions on average have decreased by around 40%. In some Mediterranean countries and in Iceland, emissions have even increased.

10. The largest decrease of sulphur emissions took place from 1990 onwards. This was mainly due to the economic restructuring in Eastern Europe, fuel switches and the implementation of efficient abatement measures. For the period 1990-2000 sectoral emission data are also available. These data show that no single sector was responsible for the emission reduction, similar decreases have taken place in most of the main anthropogenic polluting sectors. A sector of growing concern is shipping in international waters, where only small emission reductions have been reported.

III. SULPHUR DIOXIDE IN AIR

11. The sulphur emission decrease has resulted in significantly reduced pollution in the atmosphere and in the environment as a whole. Long-term monitoring data for sulphur compounds are available for large parts of Europe. The data show that sulphur dioxide concentrations have declined roughly in proportion to the sulphur emissions.

12. The monitoring results also show that the frequency as well as the magnitude of episodically high concentrations – pollution episodes, mainly in winter – has decreased. The significant reduction in the number of such episodes during the 1990s is believed to be due to the decrease in emissions. However, more favourable weather with less frequent temperature inversions during winter in the 1990s may also have contributed. This is also reflected in the seasonal variation of the SO_2 levels. Winter month concentrations have decreased relatively more than summer concentrations of sulphur dioxide, resulting in a less pronounced seasonal variation towards the end of the period.

IV. SULPHATE CONCENTRATIONS IN AIR AND PRECIPITATION AND ACID DEPOSITION

13. Sulphate concentrations in air and precipitation have decreased throughout Europe. This decrease has, however, not been as large as the reduction in sulphur emissions or sulphur dioxide concentrations. Therefore, a relatively large part of the sulphur in air is now present as sulphate. This is most likely a consequence of an approximately constant oxidizing capacity of Europe's atmosphere throughout the period, in combination with a decrease of the compounds to be oxidized. Oxidation of sulphur dioxide is nowadays less oxidant-limited than in the early 1980s, and therefore takes place more efficiently.

14. The decreasing trend of sulphate in precipitation is similar to that of sulphate in the air, and has induced a general increase of pH in precipitation. Another consequence of the reduced sulphate in precipitation is decreased wet deposition of sulphur. Since the air concentrations of sulphur and therefore the dry deposition have decreased, the total deposition of sulphur has fallen all over Europe.

15. Both sulphur and nitrogen deposition contribute to acidification of terrestrial ecosystems and surface waters. This acid deposition has decreased over most of Europe and the excess deposition above the critical load for acidity has been significantly reduced. In some areas where acidification has been a problem, the deposition is now below the critical load. However, some areas of excess deposition remain. In order to protect ecosystems against acidification in all of Europe, emissions of acidifying compounds have to fall even further.

V. NITROGEN OXIDES EMISSIONS

16. In parallel to the serious sulphur pollution, increasing emissions of nitrogen oxides from traffic throughout the 1980s was observed as a growing threat. The efforts to cut these emissions started in the mid-1980s, but were not always successful before the mid-1990s. The emission reduction reported so far is smaller than for sulphur. The total decrease in nitrogen oxides emissions is around 25% in the officially reported emission data and around 30% when experts´ estimates for mobile sources are considered. The differences throughout Europe are, however, far more significant than for sulphur.

17. Some countries and regions have succeeded in reducing their NO_x emissions by 40-50%. The largest decrease has taken place in Eastern Europe, and is a result of economic restructuring. Germany and Switzerland have also achieved a nearly 50% reduction in NO_x emissions. The decrease in Western Europe is mostly around 30%. In Southern Europe, the emissions have generally not changed. In several Mediterranean countries the NO_x emissions have actually increased.

18. The reductions between 1990 and 2000 are due to significantly decreased emissions from stationary combustion in power plants, from industry and from residential heating. These sectors'emissions have fallen by almost 40%. The decrease from the transport sector is similar to the total NOx emission reduction, around 25%. A growing concern is the emissions from shipping in international waters. These emissions increase in importance (20% of the total emission in 2000) when other emissions fall.

VI. CONCENTRATIONS OF NITROGEN DIOXIDE AND NITRATE, DEPOSITION OF OXIDIZED NITROGEN

19. Since the emission reductions in nitrogen oxides vary considerably from country to country, so do the trends for nitrogen oxides in air and for nitrate deposition. The trend evaluation is further complicated by the fact that there are fewer long-term monitoring data available than for sulphur. In several countries, the NO_2 trends observed are in line with the national emission reduction. The largest NO_2 decreases are seen at EMEP sites in Central European countries such as the Czech Republic, Slovakia and Germany, mostly due to restructuring of the energy and industrial sectors.

Large decreases are also seen in Switzerland and the United Kingdom. Around a 30% reduction has taken place in many countries including the Nordic countries, Italy and the Netherlands. Tight emission standards for vehicles, which led for example to the introduction of catalytic converters on cars, has been a major cause of decreasing NO_x emissions even if part of the effect has been counteracted by increasing traffic.

20. Just as for sulphur, the most oxidized nitrogen compound - nitrate - shows a less pronounced decreasing trend. This has a similar explanation as for sulphur; reduced emissions together with a relatively stable oxidizing capacity give less oxidant limitation and therefore a more efficient oxidation process. Long-term monitoring data to support this hypothesis are, however, largely lacking. The few data available show decreases of 20-30% for total nitrate in air at sites in the Nordic countries and the United Kingdom. Nitrate in precipitation has decreased in a similar way at most sites, even though inter-annual variations are large.

21. Deposition of oxidized nitrogen has decreased due to lower concentrations in air and precipitation. Together with decreasing deposition of ammonium, the total nitrogen deposition has decreased. The nitrogen deposition is now in many areas approaching the critical loads for euthrophication. Areas of exceedance, as well as the magnitude of exceedance above the critical load, are decreasing. But, as for sulphur, the efforts to cut emissions must be continued in order to protect terrestrial and marine ecosystems.

VII. AMMONIA EMISSIONS AND DEPOSITIONS OF AMMONIUM

22. Ammonia is mainly emitted from agricultural activities. These emissions introduce - as a total over Europe - amounts of nitrogen into the atmosphere similar to the nitrogen emitted via nitrogen oxides. When deposited, the nitrogen from ammonia will contribute to the acidification and euthophication of ecosystems in the same way as nitrogen oxides. The emissions of ammonia have decreased by approximately 20% in Europe overall, but there are large differences between regions. The largest reductions are reported in Central and East European countries such as the Baltic States, the Czech Republic, Hungary, Poland, the Russian Federation and Slovakia. In most other parts of Europe the decrease has been around 10%. In Southern Europe the emissions have been more or less constant for the past 10 years.

23. The levels of ammonium in Europe vary between regions with a deposition maximum in North-Western Europe. The ammonium concentrations in air and precipitation by and large show trends similar to those for nitrate in air and precipitation. This is reasonable, since the decreases in ammonia and nitrogen oxide emissions are similar on the European scale. Looking at trends of ammonia and nitrate concentrations in individual countries, these are more similar to what the corresponding national emission trends would suggest. The explanation of this phenomenon is not straightforward.

VIII. BASE CATIONS

24. Base cations influence the acidification of ecosystems. A large deposition of base cations counteracts acidification. Similarly, the acidification process causes leaching of base cations from the soil. Base cations are emitted to the atmosphere as particles from several different types of anthropogenic sources. Many base cations in the environment have, however, a natural origin such as wind-blown dust.

25. The deposition of base cations has decreased over the past 25-30 years. In Western Europe there was a significant decrease in anthropogenic base cation emissions already during the 1970s. In the early 1990s, with the closing of many lignite-fired power stations and many other significant emitters such as iron and steel works and other industrial plants and the implementation of effective abatement technologies, a second reduction in particulate base cation emissions took place.

26. It is important to improve the quantification of base cation deposition and its trends over Europe. This would lead to more accurate estimates of critical loads and support studies of ecosystem recovery from acidification. Wet deposition data from EMEP measurements have been crucial to obtain the crude estimates available at present However, more measurements as well as novel modelling efforts could improve these estimates.

IX. PARTICLES IN AIR

27. "Particles in air" is a parameter of growing concern over Europe. Atmospheric particulate matter (PM) was for a long time considered to be a local pollution problem, but growing awareness of its transboundary nature led to its inclusion in EMEP monitoring in the late 1990s. Since then, PM_{10} (particulate matter <10µm) measurements have been reported to EMEP from an increasing number of sites. The available monitoring data indicate that the present levels in rural areas can be around 20 $\mu g/m^3$ or even higher. Such levels can cause serious health effects.

28. PM is complex. Particles exist over a wide size range, from a few nanometres to several micrometres, can have quite different physical and chemical characteristics, and originate from a number of different anthropogenic and natural sources. Particles are emitted directly, as well as indirectly, i.e. formed in the air from reactions between gaseous compounds. Primary PM emission data are so far not sufficiently reported by countries. Data are available only for recent years.

29. National and international studies suggest that there have been substantial reductions in particle emissions. Although PM monitoring from sites in different countries is not always comparable, the data on PM mass (including total suspended particles and PM_{10}) and soot/black

smoke show that concentrations decreased considerably in the past decade. The partial particle mass due to sulphate, nitrate and ammonium has also decreased, but not in proportion to the emissions reductions of SO_2, NOx and ammonia. Furthermore, the origin of the particle mass consisting of organic compounds is not completely known. This makes it difficult to assess the response of particle concentrations to changes in emissions. Clearly, improved knowledge of the origin and processes involved in the generation of particles will be necessary to refine the development of effective international control strategies. Improving PM emission inventories, monitoring and modelling will be an important issue for EMEP in the years to come.

X. SURFACE OZONE

30. Threshold values for the protection of vegetation and human health from ozone damage are currently exceeded over large parts of the continent. The ozone levels and exceedances are generally highest in Central and Southern Europe. Based on the AOT40 concept (accumulated ozone exposure over the threshold of 40 parts per billion by volume (ppbv)), the critical level for crops and semi-natural vegetation is exceeded over most of Europe except to the far North and North-West, while the exceedance of the critical level for forests is confined to the European mainland. The highest values represent a six-fold exceedance of the critical level for crops and semi-natural vegetation and a three-fold exceedance of the critical level for forests. However, these exceedances cannot be directly translated into economic losses. In addition, new flux-based approaches are being established, and they may provide a different picture.

31. Long-term trends in ozone and the causes of these trends are difficult to assess for many reasons. Firstly, ozone in air is a pollutant formed by photochemical reactions between nitrogen oxides and volatile organic compounds and thus closely linked to the regional weather conditions from year to year. Secondly, the hemispheric background concentration of ozone, determined by emissions and physical processes outside Europe, is an important contributor to the European ozone problem. Finally, only in certain areas of Europe are the monitoring time series of ozone and its main precursor substances long enough to detect long-term trends and their possible underlying causes with sufficient significance.

32. Nevertheless, a reduction in peak ozone values during the 1990s is reported from several regions in Europe, while there is no clear trend in the exceedances of the critical level (expressed as AOT40). Stations in the North and West report increasing hemispheric background concentrations of 0.3-0.5 ppbv $year^{-1}$. The declining trend of the peak values is to some extent counterbalanced by the gradual rise in background ozone and may also be counteracted by climatic change giving higher risks of hot and ozone-rich summers.

33. The reduction in peak ozone values is in line with model predictions based on the decreased precursor emissions in Europe and is a very likely result of this emission abatement. On

the other hand, the fact that long-term exposure indexes such as AOT40 are not significantly changed reflects that intermediate ozone concentrations are much more difficult to reduce. The counteracting influence from an increasing background may also counteract the effect of European emission reductions.

34. Further policies to reduce the emission of all ozone precursors including the cross-continental, hemispherical perspective will be necessary to reduce the harmful effects from ozone on the environment, crops and human health.

XI. HEAVY METALS

35. Human activities have drastically changed the biogeochemical cycles and balance of most heavy metals. The main anthropogenic sources of heavy metals are various industrial processes, mining, foundries, smelters, combustion and petrol. The heavy metals of most concern to the Convention and covered by its Protocol on Heavy Metals are mercury (Hg), cadmium (Cd) and lead (Pb). The emissions and concentrations of lead in air and deposition decreased by 60-70% between 1990 and 2000. The decrease is due to the phasing-out of leaded petrol all over Europe. The emissions and concentrations of cadmium in air and deposition decreased by 30-40% between 1990 and 2000. This decrease in Cd emissions is mostly related to the use of highly efficient emission control in Europe to reduce the emissions of particles. For the period from 1990 to 2000 anthropogenic emissions of mercury in Europe were cut by 50%. Over the same period depositions decreased roughly by one third. The main reason for this was the introduction of flue gas desulphurization in European power plants which removed not only sulphur dioxide but also gaseous Hg.

36. Pollution levels of lead, cadmium and mercury are assessed on the basis of modelling supported by monitoring. The number of monitoring sites has increased steadily to 69 in 2001. Among those, 22 sites provided data on heavy metals both in air and precipitation; Hg was measured at 15 sites.

37. Reductions in emissions and depositions from 1990 – 2000 differ significantly between countries. In some countries emissions and depositions even increased, while emissions of lead have been reduced more than 10-fold in some countries. Despite the overall reductions, the contribution of transboundary transport remains considerable in most European countries. In many countries, transboundary emissions account for the bulk of the depositions.

38. As mercury is a hemispheric or even global pollutant, its transport is evaluated not only for Europe, but for the Northern hemisphere. The contribution from non-European sources to mercury depositions varies from less than 25% to 60% in different parts of Europe. Further work on heavy metal pollution will be carried out in close collaboration with the effects community (Working

Group on Effects) to establish an effect-based approach (e.g. critical loads) to support the review of the Protocol on Heavy Metals.

XII. PERSISTENT ORGANIC POLLUTANTS

39. Environmental levels of the persistent organic pollutants (POPs) included in the Protocol on POPs show a clear decreasing trend due to restrictions on their production, use and release. Emissions as well as concentrations in air and deposition have decreased between 1990 and 2000 by 20-30% for PAHs, about 50% for dioxins and furans and PCBs, 20% for HCB and over 90% for gamma-HCH.

40. Some POPs (such as PCBs or gamma-HCH) can be accumulated in environmental compartments such as soil and sea water and may also be subject to re-emissions into air. Due to their high stability in the atmosphere, some POPs (such as HCB or PCBs) can be transported over long distances. Considerable levels of these substances are therefore detected even in very remote areas such as the Arctic. For a comprehensive evaluation of the environmental distribution of these POPs, the application of hemispheric or even global approaches seems warranted.

41. The assessment of environmental contamination by POPs is performed on the basis of both modelling and monitoring. The number of monitoring sites has increased steadily; in 2001, data from 13 sites were obtained. However, the spatial distribution of the sites is still not satisfactory. The cycling of POPs between air, biota, soil and water presents challenges both for the monitoring and the modelling of the atmospheric transport of these substances, which include a number of compounds with different chemical and physical properties. Further POP assessment activities will be carried out in close collaboration with the effects community to establish effect-based approaches (risk assessment) and to support the review of the Protocol on POPs.