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CO-OPERATIVE PROGRAMME FOR MONITORING AND EVALUATION
OF THE LONG-RANGE TRANSMISSION OF AIR POLLUTANTS
IN EUROPE (EMEP)

Note for further discussion:

PURPOSE, STATUS AND FUTURE DEVELOPMENT OF EMEP

Prepared by the CCC in consultation with the other EMEP centres.

Preface.

At the EMEP Bureau meeting in Geneva 26-27 April 1999 it was decided that a strategy plan for EMEP for the year 2000 and beyond, was needed. The present document has been prepared by the CCC in close consultation with the other EMEP Centres, and with substantial inputs from members of the EMEP Bureau.
Meetings were held in the beginning of July with Sonja Vidic, Anton Eliassen, Peringe Grennfelt, Arne Semb, Jan Schaug and Øystein Hov, outlining the structure which has been followed in the enclosed note. This draws on information and text from a number of sources, in particular:
"Development of EMEP: New Initiatives" by Sonja Vidic and Anton Eliassen,
"Mandate of EMEP", draft document from Martin Williams 31 May 1999,
"Operational goals for EMEP" by Roel van Aalst 28 April 1999,
"Monitoring strategy" by CCC 19 April 1999.
Further comments and improvements from the EMEP Centres have been incorporated.
The note is prepared as a background document for further discussions about the future work in EMEP.

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Summary

The main priority tasks for the Convention are *Review and extension of existing protocols and implementation of and compliance with existing agreements.* The successful implementation of the Protocols requires a dedicated system for measuring their success. The follow-up of the compliance has to be done through a well-designed integration of monitoring, modelling and emissions assessments. Without a well planned, supported and visible science based system for measuring compliance, it is likely that the Protocols will fail in their mission. At the same time exploratory work must continue on new substances that can be harmful to health and ecosystems. The tasks of EMEP are formulated in five thematic areas:

- Acid deposition/eutrophication
- Photochemical oxidants
- Heavy metals
- Persistent organic pollutants
- Small particles

Scientific support in all these five areas will require systematic collection, analysis and reporting of information from monitoring networks, from emission inventories, from modelling studies, and on various abatement measures, and integration of this information into integrated assessments.

The involvement of the participating countries in EMEP is crucial if EMEP is to meet its objectives and responsibilities. EMEP should interact with the Parties of CLRTAP in two ways: by supporting negotiations between the Parties on international emission control strategies and agreements and the implementation of such agreements, and by supporting Parties when they develop and implement particular national air pollution control measures, for example through interaction with national research and monitoring programmes.

EMEP should also interact with national and international research programmes in relevant scientific fields and utilize results of these programmes to improve the scientific quality of the work within EMEP. The total activity withing EMEP can then be described as: (1) The core activities of the EMEP Centres, which provide European-wide analysis of transboundary air pollution, and (2) Co-operation between the EMEP Centres and national and international research and monitoring activities, and interaction between these activities.

Based on an analysis of goals and requirements, and suggested improvements, the following recommendations can be made:

1. All countries will reconsider their national measurement programmes reporting to EMEP, particularly in view of the recommendation to use standardised methods (i.e. the methods specified in the EMEP manual). The location of measurement sites should also be reviewed, particularly with respect to representativeness and geographical coverage. Measurement programmes should be complete within each of the specific EMEP topics, e.g. acidification and eutrophication, photochemical oxidants, HMs, POPs and aerosol particles.
2. Countries should also, in co-operation with MSC-W and CCC, identify sites which can be used for evaluation of trends in the deposition of sulphur and nitrogen compounds, and assessment of the fulfilment of protocol obligations. Improvements with respect to the completeness in reporting of emission data are also needed for the analysis of these trends.
3. The acidification and eutrophication model is currently being improved. The spatial resolution of the model has been increased, and the mass conservation properties and the accuracy of the model results are improved. The goal with respect to accuracy of the EMEP model results has been set at ±30 % when compared with observations for all components. In order to determine if this model is satisfactory, countries should consider carefully the deposition estimates within their own borders, including the representativeness of the national measurement sites used for model verification and validation.
4. The Eulerian model for photochemical ozone formation will represent a considerable step forward in the description of surface ozone concentration fields, and the interpolation of AOT40 and AOT60 figures from measurements. Again, countries should consider

carefully if their ozone measurements are satisfactory for model validation, and the representativeness of their sampling sites.

5. Trend and compliance analyses for the reduction of ozone exposures are much more complicated than for acid deposition and eutrophication. Measurement series need to be carefully validated, and calibration of ozone instruments should follow rigorously the recommendations given in the EMEP Manual, and the instructions of the WMO Calibration centre for ozone in Switzerland. Continuation of VOC measurements are required in order to see if reductions in the concentrations of ozone precursors follow the reductions in VOC emissions specified in the Protocols. Reductions in the emissions of nitrogen oxides will be seen in the measurements of oxidized nitrogen compounds, which should be intensified.
6. Emission estimates for heavy metals (first of all for lead, cadmium and mercury) need to be verified on a national basis, in order to provide reliable source-receptor relationships from models and measurements. This work has now been taken up by the Task Force on emissions

7. More exploratory work is needed for POPs. This relates to emissions, measurements, and modelling. The Task Force on Emissions have undertaken to review emission inventories for POPs, improving their consistency and compatibility. Measurements of POPs in air is to be started at five sites next year, using identical sampling methodology and with analyses at one, central laboratory for the first year. There is an apparent need for additional measurements in campaigns, with simultaneous measurements at several sites (10-20) across Europe. Samples should be analysed at one central laboratory for consistent results. At the same time, measurements of new compounds should be contemplated. For the assessment of transboundary transport, deposition and concentrations of selected POPs, development of multi-compartment models for regional, hemispheric and global scales will be continued. Special attention should be given to the understanding of the physico-chemical properties of POPs and their cycling between atmosphere, soil, water and biota.
8. In order to provide information on the long-range transport of airborne particles, measurements *of the mass concentration* of fine particles at EMEP sites are urgently required. Measurements should specify both particle size and chemical composition of particles. Information from the countries about the emissions of primary particles have been requested from the Task Force on Emissions, EMEP should specify data requirements with respect to particle sizes and chemical composition. Modelling work will consider both primary particles and secondary organic and inorganic particles. In the future, these models should be linked, providing a dynamic description of nucleation, coagulation, condensation and size-dependent deposition processes.
9. As a consequence of the commitments the Parties have made, the scientific contributions from the countries should be financed nationally, with status of voluntary in-kind contributions. In practice the contributions will often represent scientific extensions of the already existing nationally financed infrastructure for the measurement network. Plans for scientific contributions should be drafted by each country or by voluntarily formed groups of countries with similar interests in consultation with one or more EMEP centres, as appropriate. The EMEP centres may contribute to the work within their resources/priorities. The EMEP Steering Body (and its Bureau) should discuss the proposals and make recommendations for contributions to be included in the EMEP work plan and approved by the EB. Each year, the Steering Body of EMEP would review and discuss the progress in each of these tasks, and report its evaluations to the EB.

1. Mandate of EMEP

EMEP was initiated in 1977 as a special programme under the ECE. The original main objective of EMEP was to

> *"..... provide governments with information on the deposition and concentration of air pollutants as well as on the quantity and significance of long range transmission of pollutants and fluxes across boundaries. Information on the relative importance of local and distant sources resulting from such a programme will guide national authorities in setting appropriate local and regional permissible emission levels, taking into account the implications of these levels. The information on the deposition and concentration of air pollutants will be a basis of abatement strategies in the regions affected ....."*

The Convention (CLRTAP) in Article 9 stressed the importance of the Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP) and the needs for its implementation and agreed to emphasise, inter alia

- *monitoring using the framework of both national and international programmes*
- *the need to exchange data on emissions or transboundary fluxes and to make available the models used to calculate the latter*
- *the need to provide meteorological and physico-chemical data relating to atmospheric processes*
- *the need to monitor chemical components in other media, as well as a similar monitoring programme to record effects on health and the environment*
- *the desirability of extending the EMEP networks to make them operational for control and surveillance purposes.*

The Executive Body is required by Article 10 of the Convention to utilise the Steering Body of EMEP to play an integral part in the operation of the Convention, in particular with regard to data collection and scientific co-operation. The annual costs of the international centres co-operating within EMEP for the activities appearing in the work programme of the Steering Body of EMEP shall be covered by the financing of EMEP, as described in the Protocol on the Long Term Financing of EMEP. These costs may be via mandatory and voluntary contributions to the General Trust Fund, or through contributions in kind.

The Steering Body of EMEP decides on the Work Plan and on the division of work between the Centres. In general, meteorological modelling and interpretation of results have been the responsibility of the two Meteorological Synthesising Centres, while the Chemical Co-ordinating Centre has been responsible for co-ordinating the measurement activities and collecting and collation of the measurement data.

The obligations of the contracting Parties to the CLRTAP includes research and development of:

- *Instrumentation and other techniques for monitoring and measuring emission rates and ambient concentrations of air pollutants (Article 7(b))*
- *Improved models for a better understanding of the transmission of long-range transboundary air pollutants*
- *Meteorological and physico-chemical data relating to the processes during transmission (Article 8(e))*
- *The need to use comparable or standardised procedures for monitoring whenever possible is emphasised (Article 9(b),*
- *The establishment of monitoring stations and the collection of data shall be carried out under the national jurisdiction of the country in which the monitoring station is located (Article 9 (c)).*
- *The establishing of a framework for a co-operative environmental monitoring programme, based on and taking into account present and future national, sub-regional and other international programmes is emphasised (Article 9(d)),*
- *as is the desirability of extending the national EMEP networks to make them operational for control and surveillance purposes (Article 9(i)).*
- *The countries are also required to provide information on emissions for use in the model calculations performed by the Meteorological Synthesising Centres.*

As well as the more general requirements of the Convention itself, set out above, individual protocols require EMEP to carry out other tasks and to provide further information as follows:

The NOx Protocol, in Article 9, requires that EMEP utilise appropriate models and in good time before the annual meetings of the Executive Body, provide to the Executive Body calculations of nitrogen budgets and transboundary fluxes and deposition of nitrogen oxides within the geographical scope of EMEP. In areas outside the geographical scope of EMEP, models appropriate to the particular circumstances of the Parties shall be used.

The VOC Protocol, also in Article 9, requires EMEP to utilise appropriate models and measurements to provide to the annual meetings of the Executive Body relevant information on the long-range transport of ozone in Europe. In areas outside the geographical scope of EMEP, models appropriate to the particular circumstances of the Parties shall be used.

The Second Sulphur Protocol, in Article 5, requires EMEP to receive data on emissions of sulphur, reported by Parties to the Executive Secretary of the Commission with frequency and a temporal and spatial resolution specified by the Steering Body of EMEP. The Protocol, in Article 5, further requires EMEP to provide information to the Executive Body on ambient concentrations and depositions of oxidised sulphur compounds, and calculations of sulphur budgets.Parties in areas outside the geographical scope of EMEP are required to make similar information available if requested to do so by the Executive Body.
The HM Protocol, in Article 7, requires EMEP to specify methodologies for HM emission inventories and their temporal and spatial resolution, to receive emission data on HMs, reported by Parties through the Executive Secretary of the Commission to EMEP. The Protocol, in Article 8, also requires EMEP to provide the Executive

Body with calculations of transboundary fluxes and depositions of heavy metals within the geographical scope of EMEP. In areas outside the geographical scope of EMEP, models appropriate to the particular circumstances of Parties to the Convention shall be used.
The POP Protocol, in Article 9, requires EMEP to receive information on the levels of emissions of POPs, with in the geographical scope of EMEP, reported by Parties through the Executive Secretary of the Commission, using methodologies and the temporal and spatial resolution specified by the Steering Body of EMEP. Parties in areas outside the geographical scope of EMEP shall make available similar information to the Executive Body if requested to do so. EMEP also in good time before each annual sessions of the Executive Body shall provide information on the long-range transport and deposition of persistent organic pollutants.

2. Strategic issues for EMEP

The main priority tasks for the Convention are identified in EB.AIR/1998/5:

- *Review and extension of existing protocols*
- *Implementation of and compliance with existing agreements*

For EMEP the tasks are to provide sound scientific support for atmospheric monitoring and modelling, emissions and emissions projections, and integrated assessment modelling. EMEP's results on physical and chemical air pollution aspects, together with results of effect studies from the Working Group on Effects, should satisfy the information needs of the new Working Group on Strategies and Review, and support the work of the Implementation Committee

The successful implementation of the Protocols requires a dedicated system for measuring their success. The follow-up of the compliance has to be done through a well-designed integration of monitoring, modelling and emissions assessments. Without a well planned, supported and visible science based system for measuring compliance, it is likely that the Protocols will fail in their mission. Tools need to be developed and applied to assess and verify that the implementation process is taking place and that it is cost-effective.

At the same time exploratory work must continue on new substances that can be harmful to health and ecosystems. In parallel with the follow-up of compliance, the *scientific* findings *of* EMEP can make protocol revisions or replacements necessary in order to enhance the cost-effectiveness of the abatement strategies advocated.

Following the note “Visions for the EMEP work by 2005/2010, Seventh phase programme” (EB.AIR/GE.1/1998.3), the tasks of EMEP are to be formulated in five thematic areas:

- Acid deposition/eutrophication
- Photochemical oxidants
- Heavy metals

- Persistent organic pollutants
- Small particles

Scientific support in all these five areas will require systematic collection, analysis and reporting of information from monitoring networks, from emission inventories, from modelling studies, and on various abatement measures, and integration of this information into integrated assessments. In this context, assessment may be defined as quantification, analysis and evaluation of air quality and deposition in relation to its causes and impacts. In particular, the tasks of EMEP in its seventh phase are to:

- Determine the state and trends of air pollution in Europe for assessment of effects.
- Quantify transboundary fluxes and allocate the sources of the estimated depostion.
- Survey the compliance of the Parties with protocol commitments by analysing the progress towards reduction of deposition fluxes, in particular as they concern exceedances to critical loads.
- Provide guidance for the development of cost-effective abatement strategies at national and international level.

EMEP should interact with the Parties of CLRTAP in two ways. EMEP should:

- Support negotiations between the Parties on international emission control strategies and agreements, and the implementation of such agreements.
- Support Parties when they develop and implement particular national air pollution control measures, for example through interaction with national research and monitoring programmes.

In addition, EMEP should interact with international research programmes in relevant scientific fields, and utilize results of these programmes to improve the scientific quality of the work within EMEP. The total activity within EMEP can then be described as:

- the core activities of the EMEP centres, which provide overall, European-wide analysis of transboundary air pollution, and
- co-operation between the EMEP centres and national and international research and monitoring activities, and interaction between these activities.

In this way the Parties of CLRTAP will improve the basis for their efforts in assessing the state of the environment and its dependence on transboundary air pollution, pinpointing problem areas, prioritizing efforts, for example by requiring cost-efficient measures, suggesting new initiatives, and forecasting the development in the state of the environment both for measures already decided and for new initiatives. It will finally lead to more robust emission control protocols (or amendments to protocols) and a better basis for evaluating the compliance with the protocols.

Very considerable research activities in fields relevant to EMEP is carried out within different international cooperative research programmes and projects. Interaction with

and utilization of results from this research is essential for developing EMEP along with our improved understanding of the physics and the chemistry of the atmosphere.

- The WMO/GAW programme, with its mission to make reliable, comprehensive observations of the chemical composition and selected physical characteristics of the atmosphere, to further our understanding of the chemistry and physics and the cycles of atmospheric constituents, is an important programme that should contribute considerably to EMEP. The European regional components of GAW and EMEP have nearly identical goals and should supplement and support each other.

- Monitoring assessment and research on air pollution is also carried out in connection with international requirements or agreements outside CLRTAP (EC DG-XI Framework Directive for Air Pollution, European Environment Agency, and EU Topic Centers for Air Quality and for Air Emissions, HELCOM, OSPAR and the Barcelona Convention). EMEP should benefit from, as well as contribute to these activities.

- European Environment Agency (EEA) develops EUROAIRNET air quality monitoring network, which is mainly urban. This network will consist of monitoring stations that are in operation in the European countries today, and in general the establishment of EUROAIRNET will not imply the recommendation to establish new stations. The strategy for the design and operation of EUROAIRNET is determined by the objectives of the monitoring activities: (1) Compliance monitoring, (2) representative air quality surveillance monitoring, (3) exposure/damage assessment monitoring, (4) on-line monitoring (for forecasting pollution episodes, to inform and warn the population and to carry out short-term abatement actions to reduce episodic high concentrations), (5) operational monitoring near specific sources to avoid unacceptable pollution burden in their neighbourhood, and (6) monitoring programmes to support research. The national EMEP sites are needed as an important component in EUROAIRNET, in addition monitoring in industrial and populated and urban areas will be needed. Furthermore an on-line capability will be required, and a forecasting capability is to be developed. The monitoring and dataflow in EMEP are developing in this direction, as improved technology and data communications allow on-line measurements and near real time transmission of information to the public, provided that adequate quality control procedures are implemented. EUROAIRNET has an important urban air quality component. Also in EMEP it is likely that urban air quality problems including exposure to air pollution of humans, will become an important issue. Often the transboundary component of the pollution load makes an important contribution to the total urban pollution level.

- There is a clear need to co-ordinate common efforts between EMEP, AMAP and UNEP in the field of emission inventories, measurements and modelling of long-range transport at hemispherical and global levels.

- In view of common goals of these international organizations, and in the interest of the Parties to the same, EMEP should share its scientific findings as well as its data

and infrastructure with them (monitoring and modelled data, emission data, software, QA/QC procedures, etc.).

- EUROTRAC-2 studies the transport and the chemical transformation of pollutants in the troposphere over Europe. EMEP should benefit from this major effort by actively participating within selected issues of particular importance. Research funded by the European Commission-DG XII and North American research activities under NARSTO is relevant for EMEP in a similar way.

- Strengthening the overall cooperation within EMEP, and in particular cooperation involving better and broader use of EMEP products at a national level, might facilitate a wider acceptance of the protocols of CLRTAP, and further legislative action towards their ratification. Presently there are 43 Parties to CLRTAP, typically half of these have ratified emission control protocols.

- Having thus shown that national research and monitoring activities constitute an indispensable part of a well-functioning EMEP and CLRTAP, it is important to ensure that such activities in fact are carried out and that they contribute to EMEP. Here the representatives of the Parties to the Executive Body of CLRTAP should take a responsibility for facilitating such activities in their country. The Steering Body of EMEP, its Bureau and the centres should all actively contribute towards establishing scientific cooperation with the national activities.

The EMEP programme is based on the integration of monitoring, emission inventorying and modelling studies to address the environmental goals and needs that are stated in the Protocols or will come up in the future on the international or national level. A concrete definition a strategy for this programme requires the formulation of operational, quantitative goals, or information products. These product specifications are important for communication with the Working Group for Strategies, the International Co-operative Programmes, and the Working Group on Effects. These groups should be made fully aware of the information to be expected from EMEP, and should have the opportunity to amend the specifications. The operational goals are also important for scientific contributions from the countries, as they can serve to retain coherence in the EMEP programme while extending the number of scientific contributions.

In the following, strategic elements are outlined for each of the five thematic areas of EMEP. Goals are related to the effects of the pollutants and to the Convention. This further defines the products that are needed by the participating countries, as well as by the other Bodies of the Convention. A discussion of the present status of EMEP is also needed to identify shortcomings of the programme with respect to its goals and needs, forming a basis for the suggestion of necessary improvements.

2.1 Acidification and eutrophication

The main goals are:

- Determine the state and trend of deposition fluxes for effect assessment

- Calculate transboundary fluxes and provide source attribution of estimated or measured deposition fluxes in the form of contributions from emissions in one country to the deposition in a particular country or region.
- Verification of the reductions of emissions under the sulphur and nitrogen protocols to the CLRTAP, and the effectiveness of these measures with respect to reduction of the deposition fluxes, particularly in relation to exceedances of Critical loads.

Requirements for fulfilling these goals:

Measurements and derived data are required on the European scale, with source allocation. The spatial resolution in model predictions should be 50 km or better.

The accuracy requirements are related to the use of the data in connection with effect assessments requiring that the difference between measurements and model results should generally be less than +/- 30 %, with a minimum of systematic differences in error between different geographical regions. These accuracy requirements apply equally to the determination of deposition fluxes and their source attribution, and put a combined demand on the quality both of measurements (station network (representativeness, geographical coverage, analytical methods, component spectrum, time resolution, QA/QC procedures), and on modelling (emissions, meteorological data, land use information, physical and chemical parameterisations).

Compliance monitoring based on trends in measured concentration and deposition require long and consistent time series of well-documented measurements at sites which are representative of regions where critical loads have been exceeded. Alternatively, the compliance may be determined on the basis of the general agreement between the model and the measurements. Time series analyses require that long-term average values should be accurate or consistent to at least within 5-10%.

Present status:

The present status of the EMEP programme for acidification and eutrophication is reviewed in EMEP Report 1/99, in terms of emission reporting, measurement data and model results.

The EMEP system of combining measurements and modelling based on emissions and meteorology has been substantially improved over the last few years and is now well advanced with respect to describing average concentration fields and deposition fluxes over the region.

The trajectory model used previously as a basis for the protocol negotiations had a large fraction of inattributable S and large variation in the regional differences between measured and calculated concentrations/depositions. This has been considerably improved by the development of the 3-dimensional Eulerian model. For some components, particularly SO_2 and SO_4^{--}, however, the difference between measured concentrations and model estimates is still too high to be satisfactory.

Primary gas emissions of acidifying components are reported for at least one year by 2/3 of the Parties. The completeness of the reported emission data is not satisfactory, only 40% of the Parties have reported national totals for all years, and only 4% have reported sectoral data for all requested years.

The quality of the EMEP precipitation measurements is largely satisfactory. The measurements of airborne concentrations of sulphur compounds in air need further harmonisation and standardisation. There is insufficient measurement data for gaseous nitric acid and nitrate in aerosol particles, and for ammonia/ammonium. In 1997 only 60% of the EMEP sites reported concentrations of all requested nitrogen compounds.

Only few monitoring stations have data suitable for historical trend analysis, but some sites have long data series suitable for determining trends in deposition fluxes and concentrations of both sulphur and nitrogen compounds. Convincing trends are indicated for sulphur compounds, reflecting the large reductions of the sulphur dioxide emissions. For N the emission reductions have occurred more recently and are too small to result in readily quantifiable changes in long-term concentration and deposition. Trend evaluation of measurement series requires expert advice and involvement of the national laboratories with respect to assessments of changes in methods, procedures, staff and equipment.

Historical emission data are needed for long-term analyses, particularly in relation to effects in aquatic and terrestrial ecosystems. While the methods of preparing emission inventories have been improved substantially over the last few years, emissions data from the period 1950-1985 are only estimated on the basis of available statistical data and relatively simple assumptions about emission factors.

Improvements needed:

- The modelling capability needs to be further developed, using the data provided by the measurement programme as well as other information, in order to reach the accuracy required, and to provide a representative and sufficiently detailed overview of the deposition fluxes of sulphur and nitrogen compounds over Europe.
- The completeness of reported emission data should be improved, particularly concerning sectoral emission data and trends.
- The monitoring system should be strengthened by using the recommended techniques for sampling and analysis in all countries. This is particularly important for future trend analyses and for determination of compliance. Monitoring efforts need to be increased in Eastern Europe and in the Mediterranean area, and for nitrogen compounds in particular. Data quality objectives must be adopted at all working levels.
- The national participation in interpretation and assessment should be enhanced. This refers to the question of site representativeness in relation to a larger area, and to the use of data provided by EMEP in relation to national networks and assessments of concentration and deposition fields at the national level. The involvement of the countries is essential to interprete time trends and reconstruct historical emissions. In relation to inputs of nitrogen to marine environments,

interaction with the international commissions of the Helsinki and the Oslo and Paris Conventions should be strengthened.
- Enhanced cross-organisational interaction with institutions such as the EEA, and the WMO is important in order to obtain the benefit of co-operation with respect to monitoring of air and precipitation in Europe. The monitoring activities should be harmonized in order to obtain a better overview of the relationships between urban and regional pollution, and between the regional and the global scale.

2.2 Photochemical ozone formation

The main goals are:

- Assessment of ozone exposure to man, crops and forests.
- Verification of emission reductions under the VOC and the multi-effect Protocols.
- Source attribution of precursors contributing to ozone formation.
- Trend establishment of ozone over Europe.

Requirements for fulfilling these goals:

The complexity of emission, transformation and removal processes requires mapping of precursors, intermediates and end products, and an evaluation methodology that includes all driving forces (emissions, chemistry, meteorology, land-use or surface properties). Determination of the source-exposure causal relationship requires a quantitative understanding of the chemical mechanisms, and the interaction between the emissions and the dispersion and reaction of the precursors resulting in enhanced ozone concentrations. This can only be achieved by a model which describes the concentration of precursor chemical compounds and reaction products with appropriate spatial and temporal resolution.

The assessment needs both measurements and models which can be used to generalize the measurement results, and an understanding of the exposure and the effect mechanisms. Presently, mapping of AOT40 and AOT60 doses are required in a 50*50 km grid network. More sophisticated plant uptake mechanisms may be required for accurate exposure or damage estimates.

Emission inventories should have the necessary detail, particularly with respect to chemical species and temporal variations, and national totals should be accurate within 10%. Emissions from natural sources, particularly emissions of VOC from plants, are also needed.

Improved methodology for source attribution for ozone is needed.

Emission inventories for VOC and NOx with an uncertainty in total national emissions better than 10 per cent. Accuracy and temporal consistency of data series are essential for trend assessment. In order to detect a 30 per cent reduction in the emissions, the accuracy in the measurements should be better than 10 per cent, and a 10 per cent trend would require measurements with an accuracy in the order of 1 per cent, which may not be possible.

High quality exposure and dose data (i.e. integrated concentration exceeding some limit value over a given time period) are required for the assessment of effects on man and environment. Trends in exceedance of critical loads for ozone (AOT60, AOT40) probably require ozone data qualities comparable to those above.

Regional sites for ozone show small spatial variability and the network density could be 50 - 200 km, but local conditions and surroundings of the sites may influence measurements. Sites located specifically for the purposes of emission verification and compliance monitoring are located closer to the emission areas and have larger variability. Site representativeness of both existing and new sites needs to be carefully evaluated
Because of the relatively small variations in ozone concentrations levels at regional sites , measurements of other primary and secondary components are needed for evaluations of model performance, particularly with respect to parameterisation of chemical transformation processes. These measurements are also needed for trend studies and compliance monitoring, e.g. with respect to VOC emission reductions.
There are important interactions between the concentrations of ozone and precursors on the hemispheric or global scale, with the photochemical ozone formation on the European scale. A full description of these phenomena requires a linking of models of different scales. Understanding of the interactions between ozone formation on the regional scale with emissions and activities within the respective participating countries may also benefit from a linking of the EMEP models with models describing the dispersion and photochemistry on a finer grid scale.

Present status:

The understanding of the processes involved in the formation and dispersion of photochemical ozone is good. *However, the* quality of the emission survey needs to be assessed in all parts of Europe, and in particular the biogenic emissions in southern Europe are still poorly known.

The Langrangian ozone model seems to perform well over a series of years and in many regions, there is nevertheless a need for continued model evaluation, in particular for the Mediterranean region. Estimated AOT40 and AOT60 levels from the model are still very uncertain, however, and there is a need for corrections on a statistical basis by comparison with measurements.

Measurement techniques for O_3, NO_2 and VOC exist and are well documented, and the EMEP network is operational for ozone and nitrogen dioxide. More regional sites are required, however, and there is an additional need for sites aiming at compliance monitoring.

A small network for VOC exists with 11 - 12 sites. These are now run by the countries, while part of the analyses are still carried out by the CCC at a reasonable cost. These VOC measurements have proven to be very useful in the model validation, and should be further used in connection with estimating compliance with the VOC Protocol.

QA/QC programmes for all these components exist, partly in co-operation with WMO-GAW. A quality assessment is feasible, involving site audits, but have not been carried out.

Improvements needed:

- The quality of the emission survey, and. the measurement data, needs to be assessed in all parts of the network and for all components. This result will call for a better data quality to meet the requirements, and the implementation of QA/QC procedures for ozone, nitrogen dioxide, and VOC will need to be reviewed and further improved.
- In particular the demand for very high quality data for trend studies could be met by a limited number of carefully selected and dedicated sites ("supersites" or "trend sites"). Depending upon the representativeness of the site, which should be carefully assessed, the measurements could be combined with high quality measurements of other components.
- The photochemical models should be further developed with improved process implementation, and continued evaluation in order to reach a sufficiently good performance in all regions. Improvements in estimates of exposure doses are needed.

2.3 Heavy metals

The main goals are:

- Quantification and harmonisation of national emissions, quantifying and minimising emission uncertainty, in a first step of cadmium, lead, and mercury, and in a second step of copper, zinc, arsenic, chromium, and nickel.
- Assessment of emission reductions of the same substances for compliance.
- Quantification of transboundary fluxes and deposition and source attribution.
- Contribute to research on effects on the human health and the environment.

Requirements for fulfilling these goals:

The Protocol on heavy metals specifies limit values for emissions from stationary sources but does not set specific national goals for emission reductions. In order to detect reductions of emissions less than 30 per cent, measurements of both air and precipitation need to be accurate or consistent within at least 5-10%. Likewise, a 10 per cent accuracy in national total emissions is needed.
In order to improve model estimates, national experts are requested to provide more detailed emission inventories, including particle size distributions, characteristics of large point source emissions, and chemical speciation of mercury in the emissions.
Serious attention should be given to the natural emissions and re-emissions of mercury, as well as to the hemispheric and global cycling of atmospheric mercury, including mercury from non-European anthropogenic sources.

The sites to be used for trend analysis and compliance monitoring will have to be carefully selected, taking into account representativeness, source regions, meteorology and statistics for meteorological parameters**.** Corrections for meteorological variability should be considered.

Development and evaluation of heavy metal models should be continued. A cluster of models of different scales should be used to reveal local and regional effects, as well as hemispheric effects in the case of mercury. Besides, the rates of chemical reactions involved into mercury chemical module, physical transformations and exchange processes between various media should be defined more accurately.

Research on the effects on the environment and man involves co-operation with WGE and ICPs as well as other organisations.

Present status:

In 1996 an emission survey accuracy of 25 per cent was expected for lead, and 50 per cent for cadmium and mercury for Europe as whole [EB.AIR/GE.1/1997/6]. For a specific country the emission uncertainty can be as high as factor of 3. Natural emissions, re-emission, particle size distribution in the emissions, background concentrations outside the region are known in the first approximation.

A variety of heavy metal measurements are currently carried out in Europe, in precipitation and air at regional sites, as contributions to HELCOM, OSPARCOM and AMAP, or as a part of national surveillance programmes. These data are in general available for EMEP. Most sites measure cadmium and lead , only 3-4 sites reported data for mercury in air and (or) in precipitation during 1994-1996. The laboratory comparison in 1994 revealed that more than 60 per cent of the laboratories had an analytical accuracy better than 10 per cent for lead, while nearly 40 per cent obtained that accuracy for cadmium. Mercury was not included in thiscomparison.

3-D Eulerian atmospheric transport model ASIMD was adopted for calculations of long-range transport and country-to-country depositions for lead and cadmium. The lead and cadmium model was compared with some advanced models developed by different scientific groups, and satisfactory results were obtained. In 1999 the first attempt was made to use the model in operational regime. The differences between annually mean measured and calculated values (for selected most reliable monitoring stations) are around 30%. However, for many monitoring stations the differences are too high to be satisfactory. A chemical module to describe physical-chemical transformations of mercury compounds in the atmosphere was created and incorporated into the transport model. Tentative results for EMEP-scale mercury transport showed the agreement with measurements within factor of 2.

Improvements needed:

- The Atmospheric Emission Inventory Guidebook may need to be updated to include techniques for assessment and verification of heavy metal emissions.

- The demand for very high quality data for trend studies could be met by a limited number of carefully selected and dedicated sites ("supersites" or "trend sites"). Depending upon the representativeness of the site, which should be carefully assessed, the measurements could be combined with high quality measurements of other components specified by the Protocols. Recommendations on site locations have been made at workshops in Moscow and at Gothenburg (EMEP/MSCE-Report 1/97, EMEP/CCC-Report 10/97).
- Existing methods and QA/QC protocols should be reviewed and strengthened considering the data targets. Any method which cannot be expected to provide data with sufficient quality, must be replaced by a recommended method. Recommended methods/SOPs need to be included in the Manual for sampling and chemical analysis.

- Detailed meteorological information on clouds is planned for inclusion in mercury models. Heavy metal models of different scales will be linked to provide reliable assessment of concentrations and deposition in different parts of Europe. In the case of mercury a multi-compartment model (air, clouds, soils, fresh waters, see water) will be created.
- Research on the effects on the environment and man in co-operation with WGE could include e.g study of the physical, chemical and biological behaviour in various compartments, measurements in different compartments (probably by ICPs), and model estimates of response times for metal concentration indifferent compartments in response to reduced emissions.

2.4 Persistent organic pollutants

The main goals are:

- Quantification of the spatial distribution, transboundary fluxes, deposition, and accumulation in various environmental compartments as well as source attribution.
- Mapping of the occurrence of POPs and their possible harmful effects on ecosystems and human health.
- Establish causal chain; emissions-dispersion-transformation-deposition cycling-exposure-effects in biota .
- Trend establishment for compliance.

Requirements for fulfilling these goals:

Development of harmonized emission inventory methodologies and application of emission inventories and verification procedures at national level. Compilation of emission data for substances scheduled for elimination or restricted use and in particular for substances included in model calculations with estimates of emission quality. Emission expert estimates are also needed for hemispherical and global inventories.

Requirements as to measurement quality: Trend analysis and compliance monitoring will require an accuracy in the order of 10 per cent for a 30 per cent emission reduction.

Improved process understanding; including emission and re-emission, transformation, cycling between atmosphere, soil, water, and ocean, and biota, deposition and final removal.

Evaluate the POPs contamination in different media. The evaluation of POPs transport on regional, hemispheric and global levels depending on different POPs groups under consideration is needed. Establishment of the magnitude of the POP-problem for different regions for different groups of POPs should be made.

Strengthen the collaboration with national and international organizations such as EUROTRAC, HELCOM, OSPAR, AMAP, UNEP, WMO and others.

Present status:

The POP Protocol may not focus on an adequate compound spectrum. Few data series are available and only from northern and central parts of Europe. Data from HELCOM and OSPARCOM are made available for EMEP. Emission data are becoming available for some groups of POPs. There is only little systematic knowledge on concentrations, cycles and trends. There is an extensive documentation in the literature on POP concentrations in biota including trends, but distribution in space with time is to a large extent missing.

A sampling technique for airborne components exists. The separation of particles and gas in the sampling of substances with high vapour pressure may be biased, and the sampling of the most volatile compounds is incomplete. Deposition measurements may be unreliable due to re-emission and adhesion of substance to surfaces.

Analytical methods exist or can be worked out for most components, chemical treatment of samples and analytical techniques are time-consuming and expensive. Chemical analysis need to be carried out in chemical research laboratories rather than in laboratories for routine analyses. The laboratory analysis uncertainty is about 20 per cent for many POPs. Parallel measurements of PAH can have a precision as low as 6-12 per cent (expressed as the SD of the ratio) when outliers are removed.

Multi-compartment models are available on a conceptual or qualitative basis**.** In particular, preliminary versions of quantitative multicompartment models for selected POPs (PCBs, PAHs, PCDD/Fs, and lindane) are developed. These models comprise the rough description of exchange processes between atmosphere and underlying surface (soil, sea, vegetation). The description is based on investigations of individual physical-chemical properties of the above listed POPs. The model description of POP

transport by sea currents and hemispheric transport POP model are under development. Tentative calculations were performed for some groups of pollutants.

Improvements needed:

- Establish 5 sites in a first step, and only with air sampling to start with. Deposition measurements to be started in a second step. QA/QC procedures and SOPs to be included in the Manual. One central laboratory should be responsible for the analyses in the start phase, at the same time as laboratory comparisons and training of personnel in other laboratories take place.
- Compilation of emission data and estimates of their uncertainties.
- Refine physical-chemical properties of selected POPs (selected PCBs, PAHs, PCDD/Fs, lindane, and HCB). Improve the multicompartment models of POPs transport: revise the input meteorological and geophysical data including data on vegetation and sea currents, refine air/sea module integrating sedimentation process and transport with sea currents, further improve the air/vegetation exchange module in particular with refinement of degradation parameters, continue development of hemispheric models, validate developed models by comparison with measurement data and other models.
- Exploratory work on components not yet included in the EMEP Programme, in the form of measurement campaigns and collection of preliminary information.

2.5 Airborne particles

The main goals are:

- Establish concentrations and population exposures of long-range transported aerosol particles.
- Calculate transboundary fluxes of aerosol particles and their source attribution.
- Quantify the visibility impairments caused by airborne small particles in Europe
- Determine the effects of airborne particles on radiation forcing and climate change.

Requirements for fulfilling these goals:

The present requirement is to provide yearly averaged concentrations of total aerosol mass, and of aerosols with diameters less than 10 μm or 2.5 μm, respectively. These should be related to emissions, both of primary particles and of precursors for secondary particles, on a country to country, or a country to grid basis.

Further characterisation may be necessary, with respect to chemical composition as well as size distribution and other physical parameters.

Present status:

For the moment, EMEP is only able to provide concentrations and source apportionment for the secondary inorganic fraction of the aerosol mass. Ammonium

sulphate and ammonium nitrate constitute typically 10-50% of the measured PM10 concentrations, the rest is either primary particles, which may be either organic or inorganic, or secondary organic particles.

A European-wide emission estimate has been made for primary particles, and emission data for particles has been requested from the countries through the Task Force on Emissions. Further work needs to be done on the characterization of these emissions for modelling purposes, particularly with respect to size distribution and chemical composition

Once emission data are available, they can be used with excisting models to provide first estimates of concentration levels due to emissions of primary particles. However, it is expected that first emission estimates will be relatively uncertain on the European level, and will need to be verified against measured ambient levels and chemical composition data.

Only few (4) countries report measured aerosol concentrations, using different methods.

Work is also in progress concerning the concentrations of secondary organic aerosols, using available photochemical models and emission inventories for VOCs. Again, however, verification against measurements will be required.

Improvements needed:

- All participating countries should measure and report concentrations of aerosols at representative EMEP sites. The measurements should be compatible with the measurements carried out in urban areas, as outlined in recent recommendations from the European Union. This will form a useful data base for defining the rural background concentration levels across Europe.
- Countries should provide national emission estimates for particles, particularly particles with aerodynamic diameter <2.5 μm and <10 μm. The reporting should follow the methodology of the common EMEP/CORINAIR Guidebook.
- Both measurements and emissions are further required to be speciated with respect to particle size distributions and chemical composition, distinguishing between inorganic and organic, and between organic carbon and elementary carbon (soot). This will be necessary in order to verify source attribution.
- Models should include aerosol dynamics, in the sense that they should be able to describe the changes in aerosol size distributions resulting from formation and condensation of secondary aerosols, and the depletion by deposition processes.

3. Long-term financing, geographical coverage and monitoring costs

Long-term financing of EMEP Centres must be secured.

In addition, examination of the implementation of the EMEP monitoring programme in the respective participating countries show that there are large differences with respect to the levels of commitments. In general, small countries are more committed than large countries to providing measurement data, but the costs of measurements relative to the GDPs of the different countries also show large variations related to national priorities. Lack of resources clearly prevents high-quality measurements in

many countries, although these measurements may clearly be needed to resolve uncertainties in present model estimates or emission inventories.

While the measurements should continue to be under national jurisdiction, there are several possibilities to improve the measurement network and provide needed information about ambient concentration levels and deposition rates. To obtain a set of measurement data of uniform data quality for components such as POPs and mercury, it appears most relevant to carry out a common pilot measurement programme of limited duration with collection of samples at previously identified sites, and analyse these samples in one laboratory only.

However, attention has repeatedly been drawn to the poor geographical coverage of the EMEP measurement network in Eastern Europe and in the Mediterranean area. Since this is clearly linked with the lack of resources in some countries, it is necessary to address this problem. The following solutions are suggested:

- Bilateral, or multi-lateral co-operation between several countries.
- Involvement of co-operating organisations or networks, such as WMO and EURONET, to the extent that these have common goals with EMEP.
- The CCC could provide sampling equipment and chemical analyses for a limited time period at sites to be identified by the Steering Body,
- In connection with the adoption of EMEP reference measurement methods in all participating countries, standardized sampling equipment (e.g. filter holders) should be made available for the use at selected sampling sites.