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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)
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Item 4 (e) of the provisional agenda

DRAFT EMEP MONITORING STRATEGY AND MEASUREMENT PROGRAMME 2004-2009

Prepared by the EMEP Chemical Coordinating Centre in consultation with the Bureau of the EMEP Steering Body and with the assistance of the secretariat

Introduction

1. Monitoring of atmospheric concentrations and deposition is one of the basic elements to achieve the objectives of EMEP. The Convention identifies a number of issues where close collaboration of its Parties is important to achieve its goals. These include requirements with respect to instrumentation and other techniques for monitoring ambient concentrations of air pollutants, the need to exchange meteorological and physico-chemical data relating to the processes during transmission, the need to use comparable or standardized procedures for monitoring whenever possible and the establishment of monitoring stations.

2. The EMEP Steering Body at its twenty-sixth session in 2002 requested the EMEP centres to further elaborate, in close collaboration with national experts, the EMEP monitoring strategy, which would be the basis for the measurement programme of EMEP in the coming years (2004-2009).

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3. At its twenty-seventh session, in 2003, the EMEP Steering Body discussed a proposal for a revised monitoring strategy (EB.AIR/GE.1/2003/3/Add.1). The Steering Body welcomed the strategy, acknowledged that it covered all the major issues and approved the proposed level approach. However, some Parties expressed concerns about the costs associated with implementing it. The Steering Body took note of the draft monitoring strategy and stressed that it would be an excellent basis for further discussion and requested the Task Force on Measurements and Modelling to consider the issues raised, propose revisions to the draft strategy accordingly, and report back to it at its twenty-eighth session (EB.AIR/GE.1/2003/2, para. 37 (d)-(e)). The revised strategy presented here has been developed in close collaboration between the Parties and the EMEP centres, facilitated through the Task Force on Measurements and Modelling (EB.AIR/GE.1/2004/3, chap. IV, sect. B).

4. EMEP is requested to provide Parties to the Convention with information on emissions, deposition and concentrations of air pollutants, with quantified source attribution of the concentrations, depositions and transboundary fluxes related to acidification, eutrophication, photo-oxidants, particulate matter, heavy metals and persistent organic pollutants. This information is an important basis for developing emission control strategies and implementing the Convention.

5. The EMEP observations and model calculations are important elements in establishing the regional air pollution situation in Europe and its links both to the global and to the urban scales. Transboundary transmission of air pollutants is also considered by other conventions, bodies and institutions. The EMEP strategy for 2004-2009 (http://www.unece.org/env/emep/strategy_es.html) discusses the links between EMEP observations and the information requirements of those other bodies.

I. OBJECTIVES AND GENERAL REQUIREMENTS OF EMEP MONITORING

6. The main objectives of EMEP are to:

(a) Provide observational and modelling data on pollutant concentrations, deposition, emissions and transboundary fluxes on the regional scale and identify their trends in time;

(b) Identify the sources of the pollution concentrations and depositions and to assess the effects of changes in emissions;

(c) Improve our understanding of chemical and physical processes relevant to assessing the effects of air pollutants on ecosystems and human health in order to support the development of cost-effective abatement strategies; and

(d) Explore the environmental concentrations of new chemical substances that might require the attention of the Convention in the future.

7. EMEP monitoring should be designed to fulfil its purpose. Up to now, EMEP has focused on air pollutants in rural and background areas. The EMEP network needs to be revised in order to serve the developing needs of the Convention. The main issues for the Convention during the period 2004-2009 will be related to the entry into force of the Protocols on Persistent Organic Pollutants (POPs) and on Heavy Metals and the envisaged review of the Gothenburg Protocol. The geographical scope of EMEP will have to be extended to take into account the needs of new Parties as well as the impact of intercontinental pollution transport. In addition, the Convention might further investigate the consequences of the interactions between global change and air quality issues.

8. Particulate matter (PM) has become a priority under the Convention in relation to the envisaged review and possible revision of the Gothenburg Protocol. Although significant progress has been made over the past five years in understanding the sources, transport, transformation, air concentrations and deposition of particulate matter in the atmosphere, considerable uncertainties still remain. In particular, there is an urgent need for measurements of the chemical composition of particulate matter, and in particular carbonaceous aerosols. Speciated measurements are necessary for hydrocarbons, mercury and different POPs.

9. To address questions related to the intercontinental transport of air pollutants, the measurement programme should be extended to new regions. New stations should be established in areas not sufficiently covered, in particular in the eastern part of the EMEP region, Central Asia and the eastern Mediterranean. Sites in North Africa would also be of value. In addition, there is a need for observations of vertical profile data including air concentrations extending into the free troposphere due to their significance for the understanding of intercontinental transport processes. In the future, remote sensing from satellites might become an integral part of a network where ground-based stations and remote sensing complement each other.

10. In view of these considerations, the new EMEP monitoring strategy should:

(a) Ensure sufficient ongoing *long-term* monitoring of concentrations and deposition to test the effectiveness of the Convention's protocols;

(b) Ensure *adequate spatial coverage* in new EMEP areas as well as in areas that have been insufficiently covered up to now;

(c) Ensure *sufficient temporal resolution* that will allow investigation of atmospheric processes and model improvements as well as analysis of individual pollution events important for human health and ecosystem impacts;

(d) Ensure co-located and concurrent monitoring of *all relevant components* and adoption of standard methodologies and adequate *quality assurance* procedures;

(e) Conduct the monitoring in an *affordable* way for all Parties, particularly those with economies in transition.

11. Taking into account the complexity and costs of air quality monitoring, EMEP will, as far as possible, harmonize and make use of relevant data compiled under other networks. In addition, the EMEP monitoring network should contribute to the assessment of related environmental issues, such as urban air quality, climate, water quality and biodiversity. For example, these are covered by European Union (EU) legislation such as EU Air Quality Directives. Relevant monitoring is also carried out by the Working Group on Effects and its International Cooperative Programmes (e.g. ICP Forest, ICP Integrated Monitoring and ICP Vegetation) as well as various national and international programmes (e.g. the Arctic Monitoring and Assessment Programme (AMAP), the Commission of the Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM), the Commission for the Protection of the Marine Environment of the North-East Atlantic (OSPARCOM), the World Meteorological Organization Global Atmosphere Watch (WMO/GAW), the United Nations Framework Convention on Climate Change). EMEP will also interact with and make use of research activities performed by the scientific community particularly through the establishment of "supersites" (see below). Such an approach will ensure a sound observational basis for EMEP by combining resources and avoiding duplication of effort.

12. The strategy of EMEP is to use progress in scientific understanding represented by, for example, new methods and technologies. EMEP will make use of new approaches and methodologies as these become available.

II. GENERAL STRUCTURE OF THE NEW EMEP MONITORING PROGRAMME (2004-2009)

13. The monitoring programme will be organized to allow for monitoring stations having measurements at different levels of scope and complexity. Three levels are proposed, each targeting EMEP objectives in different ways.

14. The main objective of monitoring at level-1 sites is to provide long-term basic chemical and physical measurements of the traditional EMEP parameters. Level-1 activities would be the first priority when extending the network to areas not covered by measurements up to now (Mediterranean regions, Eastern Europe and Central Asia). By undertaking a more demanding monitoring programme, the level-1 stations should gradually be upgraded to level-2 sites.

15. Level-2 sites will provide additional parameters essential for process understanding and further chemical speciation of relevant components, and represent thus an essential supplement to the level-1 sites. The aim is to establish a total of 20-30 level-2 sites over Europe by 2009. Level-1 and level-2 sites are mandatory requirements, but with relaxations given in paragraphs 20 and 21. Level-2 sites are defined according to topic and do not have to cover all topics. A level-1 site extending its programme to include the level-2 activities for any of the specific topics will be identified as a "supersite" for this topic. Level-1 and level-2 sites will typically be operated by institutions nominated by the respective Parties for implementing their monitoring obligations.

16. Level-3 activities are research-oriented. The main objective of level-3 sites is to develop the scientific understanding of the relevant physico-chemical processes in relation to transboundary pollution and its control. Level-3 activities will typically be undertaken by research groups and may also include campaign data. Level-3 sites are a voluntary component of the new monitoring network.

17. Level-2 and level-3 sites will be nominated as "EMEP supersites"; this is intended to be an important motivation factor and to provide appropriate recognition of the data providers.

18. The specification of the different levels of monitoring is as follows:

(a) Level 1: measurements at level 1 include parameters required to describe basic aspects of particulate matter, photochemical oxidants, acidification, eutrophication and heavy metals, as well as their trends over time. Requirements also include meteorological parameters, but these may be taken from an adjacent meteorological site if representative. The financial requirements for level-1 stations are lower than for level 2. Low-cost methods are allowed for determining the partitioning between gas and particle phases and POP measurements are not required;

(b) Level 2: measurements at level-2 sites include all parameters required at level-1 sites plus a series of additional ones. For acidification, eutrophication and for

particulate matter, such additional parameters include fine time resolution (daily or by continuous methods), reliable gas/particle distribution information for semi-volatile nitrogen, and basic speciation of $PM_{2.5}$ (PM<2.5µm) mass. For photochemical oxidants, measurements are expanded to include nitrogen oxides using continuous methods and light volatile organic compounds (VOCs) and carbonyls. For heavy metals, the level-2 programme includes air concentrations of Cd and Pb (with Cu, Zn, As, Cr, Ni as a secondary priority) and Hg in air and precipitation. POPs monitoring is mandatory in level 2 and should include measurements both in air and in precipitation;

(c) Level 3: level-3 measurements are research-driven and may often be available at locations other than level-1 and level-2 sites. The research measurements at level 3 need to respond to the EMEP monitoring objectives and challenges. Interesting parameters for EMEP include: (i) dry deposition flux measurements (sulphur, nitrogen, ozone, Hg, others), (ii) hydrocarbons (C6-C12), (iii) vertical profiles of ozone and aerosols (soundings or lidar), (iv) NOy chemistry, (v) Hg speciation (total gaseous mercury (TGM), reactive gaseous mercury (RGM), total particulate mercury (TPM)), (vi) congener specific POPs (PCBs, PAHs, PCDDs and PCDFs), (vii) multi-compartment observations of POPs and Hg, (viii) particle size number distribution, (ix) aerosol optical depth, (x) chemical speciation of organic carbon (OC) in aerosols, (xi) "black carbon" and CO measurements. Other parameters may be added to this list as they become relevant for EMEP.

19. The table below summarizes the parameters to be monitored at the three levels, their relevance for the different EMEP issues as well as the minimum time resolution for measurement, the reference methodologies to be applied, and acceptable options.

20. Since the different compounds studied under EMEP are intrinsically linked, it is important that the mandatory EMEP monitoring network consists of co-located and concurrent measurements in both precipitation and air. It is recognized, however, that POPs measurements may not always be co-located with level-1 sites, since many of the POP sites are operated in support of other programmes, such as OSPARCOM, HELCOM and AMAP. It is recommended that Parties co-locate their POPs measurements with EMEP level-1/level-2 stations wherever possible.

21. The temporal resolution for the EMEP mandatory monitoring programme should be sufficient to support analysis of chemical and physical characteristics of synoptic scale transport. Thus, the temporal resolution should generally not exceed 24 hours. Finer temporal resolution is recommended where appropriate methods exist. An exception is made when the measurement activity requires significant financial resources making a continuous time integrated sampling at 24 hour resolution unrealistic. In such cases it is recommended to

continue current practice of limiting the sampling to a few short time integrated samples per week (2 hours, 24 or 48 hours per week, e.g. VOCs, carbonyls, POPs, EC/OC) or alternatively to integrate over a full week (inorganics in $PM_{2.5}$ and Hg). Another exception is where Parties provide highly spatially resolved data of level-1 components but use longer sample integration times. Sampling frequencies need continuous revision through the Task Force on Measurements and Modelling to address the requirements for the evolving needs of the Convention.

22. It is proposed that the site density should be defined through target densities for each level, whilst providing for some flexibility. In general, the site density should depend on the residence time of the pollutants in the atmosphere and should be highest in areas with strong gradients in air concentrations and deposition. For the compounds of interest for EMEP, the target site density varies typically between one and two sites per 100,000 km^2. All Parties with an area larger than 10,000 km^2 are requested to operate at least one level-1 site.

23. Level-2 activities represent the core additional requirement of the new EMEP monitoring network. However, due to the additional expense of observations at level 2, it is for the short term (until 2009) proposed to aim for a target of 20-30 level-2 sites across Europe, and all Parties with an area larger than 50,000 km^2 are expected to operate at least one level-2 site. Possibilities for regional collaboration on the operation of sites should be explored.

24. Level-3 measurements are voluntary in EMEP, but at the same time important for further progress. A guiding site density at level 3 is 20-25 sites with fair spatial distribution across Europe. The level-3 sites can to some extent be expected to reflect the priority pollution issues relevant for different regions.

25. EMEP will maintain and further improve its quality assurance programme to make sure that observation data are of known quality and adequate for their intended use. Field inter-comparisons and laboratory ring tests are important, as well as the maintenance of good links between national data providers and the EMEP centres. These activities can be strengthened through collaboration with the central quality assurance facilities in the EU and in the WMO-GAW system. Measurements should also satisfy the requirements in terms of quality assurance and quality control (www.nilu.no/projects/ccc/qa/index.htm). The EMEP Manual for Sampling and Chemical Analysis gives the criteria that need to be satisfied for instrumentation and analytical methods. Other methods such as automatic monitors can replace manual methods when the data quality can be proven to be equivalent or better.

IV. COMPLIANCE, IMPLEMENTATION AND FURTHER EVOLUTION OF THE STRATEGY

26. Due to the large number of parameters to be measured, and the proposed site density, some Parties might for various reasons have different priorities or have difficulties in conducting all activities defined at mandatory level 1 and level 2. EMEP will thus, on a provisional basis, acknowledge information not fully satisfying the requirements given for level 1. Such a relaxation of the mandatory requirements would, for example, be acceptable in cases where it was necessary to allow for extension into level 2 or for higher spatial resolution of measurements made in areas of large regional gradients, even if that implied a relaxation in the temporal resolution.

27. Parties with economies in transition that have not been able to operate an adequate EMEP monitoring site in the past are encouraged to enter the programme as soon as possible, but if necessary at a lower level of ambition, e.g. by implementing only parts of the programme at the beginning. The EMEP Chemical Coordinating Centre (CCC) is committed to providing guidance to the Parties on which parameters to monitor pending their abilities, location, etc.

28. All Parties are requested to ensure the full implementation of the monitoring strategy.

29. It is essential to extend the programme over Mediterranean regions, Eastern Europe and Central Asia, starting with level 1.

30. There is a need for regional cooperation to provide a sufficient number of level-2 sites. Parties are urged to coordinate their efforts in order to share and reduce costs. At present, only very few sites fulfil the requirements of level 2, although in some areas a number of sites are currently being upgraded. The Parties, in close consultation with the EMEP centres, should do the selection of level-2 sites. Full advantage should be taken of other monitoring frameworks in Europe, such as GAW, the national monitoring networks reporting to the European Commission under the European Union's Air Quality Directives and the Exchange of Information Decision and national and local monitoring efforts.

31. As EMEP monitoring should involve all Parties, there is a need for an ongoing operational activity linking all Parties and EMEP centres. It is the responsibility of both the Parties and the EMEP centres to develop and maintain these connections. Level-3 activities are research-driven and CCC should, in collaboration with the scientific community, facilitate the access of such data for EMEP use. These activities are not mandatory and are dependent on research funding priorities.

32. The EMEP monitoring network must be dynamic and ready to adapt to new needs and requirements identified by EMEP and the Convention. At the same time, consistent long-term time series should be maintained to monitor emission reductions. This requires the strategy and its implementation to be regularly reviewed and, as appropriate, revised. The Task Force on Measurements and Modelling will coordinate reviews and facilitate the involvement of the EMEP centres and experts from the Parties in this process. The results of reviews and recommendations for revisions will be presented to the EMEP Steering Body.

Table Monitoring requirements for the various levels specified by the EMEP monitoring strategy. (Mandatory level 1 and level 2, with compliance according to paras. 20 and 21)

Programme	Parameters	Minimum time resolution	Reference methodology [1]	Notes
Level-1 sites				
Inorganic compounds in precipitation	SO_4^{--}, NO_3^-, NH_4^+, H^+ (pH), Na^+, K^+, Ca^{++}, Mg^{++}, Cl^- (cond)	24h=Daily	Wet-only/bulk IC/AES/AAS	
Heavy metals in precipitation	Cd, Pb (1st priority), Cu, Zn, As, Cr, Ni (2nd priority)	Daily/weekly	Wet-only/bulk ICP MS or GF-AAS	
Inorganic compounds in air	SO_2, SO_4^{--}, NO_3^-, HNO_3, NH_4^+, NH_3, (sNO_3, sNH_4), HCl,Na^+, K^+, Ca^{++}, Mg^{++}	24h=Daily	FP-filter pack IC/AES/AAS	Needs to be complemented with low-cost denuders
NO_2 in air	NO_2	24h=Daily	NaI method	Continuous NOx monitors with photolytic converter may be used
Ozone in air	O_3	Hourly	UV-abs	
PM mass in air	$PM_{2.5}$, PM_{10}	Hourly/Daily	LVS-PM_{10}, HVS-PM_{10} or equivalent	Gravimetric methods preferred, but monitors can be used where equivalence can be demonstrated.
Gas particle ratios	NH_3, NH_4^+,HCl HNO_3, NO_3^- (in combination with filter pack sampling)	Monthly	Low cost Denuder	Low-cost alternative to basic PM speciation that provides necessary gas-particle ratios for level-1 sites.
Meteorology	Precipitation amount (RR), temperature (T), wind direction (dd), wind speed (ff), relative humidity (rh), atmospheric pressure (pr)	Hourly	AWS	Can be taken from a representative meteorological site
Level-2 sites (additional parameters)		***Level-2 sites should also measure all parameters required at level 1***		
Acidification and eutrophication				
Gas particle ratio	NH_3/NH_4^+, HNO_3/NO_3^- (artifact-free methods, contribute also to PM)	Hourly/Daily	Manual denuders	Continuous denuders/steam-jet may also be used. Replace low cost denuders from level 1. See also PM speciation.
Ammonia in emission areas (optional)	NH_3	Monthly	Low cost denuders	Optional low-cost alternative to provide high spatial resolution information in emission areas, where desired.
Photochemical oxidants				
NOx	NO, NO_2	Hourly	Monitor	NOx monitors with photolytic converter
Light hydrocarbons	C_2-C_7	Hourly	Monitor or canister/GC	Monitoring 10-15 min twice a week may also be used
Carbonyls	Aldehydes and ketones	8hourly twice a week	2,4 DNFH silica cartridges/ HPLC	
Heavy metals				
Mercury in precipitation	Hg	Weekly	Wet-only/bulk CV-AFS	Spec. sampling of borosilicate or halocarbon
Mercury in air	Hg (total gaseous mercury)	Hourly/Daily	Monitor or gold traps CV-AFS	Sampling 1 day per week (or weekly)
Heavy metals in air	Cd, Pb (1st priority), Cu, Zn, As, Cr, Ni (2nd priority)	Daily/Weekly	HVS or LVS/ICP MS or GF-AAS	Analytical method is determined by the concentration level
Persistent organic pollutants				
POPs in precipitation	PAHs, PCBs, HCB, chlordane, HCHs, DDT/DDE	Weekly	Wet-only/bulk GC-MS/HPLC	
POPs in air	PAHs, PCBs, HCB, chlordane, HCHs, DDT/DDE	Daily/Weekly	HVS, PUR foam GC-MS/HPLC	Sampling 1 day per week (or weekly)
Particulate matter				
Major inorganics in both $PM_{2.5}$ and PM_{10}	SO_4^{--}, NO_3^-, NH_4^+, Na^+, K^+, Ca^{++}, Mg^+ (Cl^-)	Hourly/Daily	Manual denuders or continuous monitors	Continuous denuder/steam-jet and other instruments may also be used
Mineral dust in PM_{10}	Si	Daily/Weekly	XRF, INAA, PIXE	Reference methodology is under development
Elemental carbon (EC) Organic carbon (OC)	EC, OC	Daily/Weekly	Thermooptical	

Table (cont.) Monitoring requirements for the various levels specified by the EMEP monitoring strategy. (Monitoring at level 3 is research-based and voluntary)

Programme	Parameters	Minimum time resolution	Reference methods[1]	Notes
Level-3 sites (monitoring at these sites does not require all level 1 and level-2 parameters)				
Dry deposition flux of sulphur and nitrogen species	SO_2, NH_3, HNO_3 (SO_4^{--}, NH_4^+, NO_3^-)	Hourly/Daily	-	Contributes to acidification and eutrophication EMEP programme for evaluation of effects on ecosystems and health
Dry deposition flux of O_3	O_3	Hourly/Daily	-	Contributes to photo-oxidant EMEP programme for evaluation of effects on ecosystems and health.
Hydrocarbons	C_6-C_{12}	Hourly/Daily	-	Contributes to photo-oxidant EMEP programme for evaluation of effects on ecosystems and health.
NOy chemistry	NO, NO_2, PAN, organic nitrates	Hourly/Daily	-	Contributes to photo-oxidant and particulate matter EMEP programmes for evaluation of effects on ecosystems and health.
OC speciation	Both water soluble and water insoluble OC	Hourly/Daily	-	Contributes to EMEP programme for PM evaluation of effects on health and analysis of synergies with global change
"Black carbon"	BC	Hourly/Daily	-	Contributes to EMEP programme for PM evaluation of effects on health and analysis of synergies with global change
Size/number distribution	dN/dlogDp	Hourly/Daily	-	Contributes to EMEP programme for PM evaluation of effects on health and analysis of synergies with global change
Light scattering	Aerosol optical depth	Hourly/Daily	-	Contributes to EMEP programme for PM evaluation of effects on health and analysis of synergies with global change
Vertical profiles	O_3 soundings, PM lidar	Hourly/Daily	-	Contributes to EMEP modelling of intercontinental pollution transport
Mercury speciation	TGM, RGM and TPM	Daily/Weekly	-	Contributes to EMEP programme on heavy metals for evaluation of effects on ecosystems and health.
Congener-specific	POPs: PCBs, PAHs, PCDDs and PCDFs	Daily/Weekly	-	Contributes to EMEP programme on POPs for evaluation of effects on ecosystems and health.
Multi-compartment (air, soil, water)	POPs and Hg	Daily/Weekly	-	Contributes to EMEP programme on heavy metal and POPs for evaluation of effects on ecosystems and health.

1) Reference methods can change in time as new methods become available. AAS: Atomic Absorption Spectroscopy; CV-AFS: Cold Vapour Atomic Fluorescence Spectroscopy, GF-AAS: Graphite Furnace Atomic Absorption Spectroscopy; DNFH: Dinitrophenylhydrazin; FP: Filter Pack; PUR: Polyurethane, GC: Gas Chromatography; HPLC: High Performance Liquid Chromatography; HVS: High Volume Sampler; LVS: Low Volume Sampler; ICP-MS: Inductively Coupled Plasma Mass Spectrometry; PIXE: Proton Induced X-ray Emission; INAA: Neutron Activation Analysis; XRF: X-ray Fluorescence; IC: Ion Chromatography; AES: Atomic Emission Spectroscopy, GC-MS: Gas Chromatography- Mass Spectroscopy. AWS: Automatic Weather Station.