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Working Group on Effects

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FURTHER DEVELOPMENT OF EFFECTS-ORIENTED ACTIVITIES

DRAFT GUIDELINES FOR REPORTING ON THE MONITORING AND MODELLING OF AIR POLLUTION EFFECTS

Report by the Bureau of the Working Group on Effects[1]

INTRODUCTION

1. At its meeting held on 5 and 6 February 2008 in Geneva, the Extended Bureau of the Working Group on Effects (the Bureau of the Working Group, the Chairs of the Task Forces and the Joint Expert Group on Dynamic Modelling, and the representatives of the programme centres

[1] The drafting of the present document was coordinated by the Coordination Centre for Effects (CCE) of the International Cooperative Programme on the Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends (ICP Modelling and Mapping) and prepared in collaboration with the secretariat.

of the International Cooperative Programmes) decided to prepare draft guidelines to harmonize the reporting of the monitoring and modelling work on the effects of air pollution under the Working Group on Effects. The Extended Bureau agreed not to address the methods that were already described in various technical manuals of the programmes. This report, presented here in accordance with item 3.1 (f) of the 2008 workplan for the implementation of the Convention (ECE/EB.AIR/91/Add.2/Amend.1), comprises the draft Guidelines for the reporting on the monitoring and modelling of air pollution effects (hereinafter, the Guidelines), which draw upon the revised long-term strategy of the effects-oriented activities (EB.AIR/WG.1/2005/15/Rev.1). The Guidelines were discussed at task force meetings of ICPs in early 2008 or brought to the attention of programme participants via mail. The Guidelines on effects are presented here in a revised format for the consideration of the Working Group, which may draft a decision to recommend that Parties implement them in their effects-oriented work. The Working Group is invited to submit the draft Guidelines and an associated draft decision to the twenty-sixth session of the Executive Body for its consideration. The Bureau wishes to note the relevance of the Guidelines with respect to possible revision of protocols.

I. OBJECTIVES

2. The Working Group on Effects contributes specifically to monitoring, research and development with regard to the effects of major air pollutants on human health and on the environment, including agricultural land, forests, materials, aquatic and other natural ecosystems. It applies and promotes these Guidelines for the reporting on the monitoring and modelling of air pollution effects (hereinafter, the Guidelines) to strengthen the work on assessing the effects of air pollution. The mandate of the Working Group on Effects (ECE/EB.AIR/68, annex III, appendix IV) is attached as annex I.

3. In line with the focus of the Working Group on Effects the objectives of these Guidelines are:

(a) To establish a scientific basis that may be used to design and assess environmental policies including cost-benefit analysis;

(b) To harmonize the reporting on effects of acidifying air pollutants, nutrient nitrogen, tropospheric ozone, volatile organic compounds (VOCs), particulate matter (PM), heavy metals and persistent organic pollutants (POPs) on human health and the environment;

(c) To assist Parties, through a common approach, in meeting their obligations on research, development, collaboration and monitoring of effects under the Convention and its protocols;

(d) To assist Parties to monitor and model air pollution effects in accordance with the methods and procedures laid down in technical manuals of the ICPs, as described in paragraph 33, and reports of the Joint Task Force on the Health Aspects of Long-range Transboundary Air

Pollution adopted by the Working Group on Effects; thus Parties facilitate the review of these data;

(e) To facilitate the harmonization of reporting with reporting of effects under the Convention under other relevant multilateral environmental agreements and relevant European Community legislation.

II. PRINCIPLES AND DEFINITIONS

4. The legal standing of the Guidelines is based on Executive Body decision 2008/[], adopted at its twenty-sixth session, and on the main obligations formulated in article 7, item (d), and article 8, item (f), of the Convention as well as in the protocols in force. However, the Executive Body may adopt subsequent decisions to alter, strengthen further or otherwise clarify the legal basis of the Guidelines.

5. The term “Parties” in the Guidelines refers to Parties to the Convention, unless otherwise specified.

6. ICP means the International Cooperative Programme of the Working Group on Effects.

7. The Working Group on Effects and its Bureau are responsible for the planning, coordination and reporting of the effects-oriented activities. The operational aspects of the effective implementation of the workplan are fulfilled by the Extended Bureau of the Working Group on Effects comprising the Bureau of the Working Group, the Chairs of the Task Forces and the Joint Expert Group on Dynamic Modelling, and the representatives of the programme centres of the ICPs.

8. ICP Forests means ICP on Assessment and Monitoring of Air Pollution Effects on Forests, led by Germany. The mandate of ICP Forests is to monitor effects of air pollution as well as other anthropogenic and natural stress factors on the condition and development of forests in Europe and to contribute to a better understanding of cause-effect relationships in forest ecosystem functioning in various parts of Europe. Its Programme Centre is with the Federal Research Centre for Forestry and Forest Products, in Hamburg, Germany.

9. ICP Waters means ICP on Assessment and Monitoring of Acidification of Rivers and Lakes, led by Norway. The objectives for ICP Waters are to assess, on a regional basis, the degree and geographical extent of the effects of atmospheric pollution, in particular acidification of surface waters. The data collected should provide information on dose-response relationships under different conditions and describe and evaluate long-term trends and variation in aquatic chemistry and biota attributable to atmospheric pollution. Its Programme Centre is the Norwegian Institute for Water Research, Oslo.

10. ICP Materials means ICP on Effects of Air Pollution on Materials, including Historic and Cultural Monuments, led by Italy and Sweden. The objective of ICP Materials is to perform a quantitative evaluation of the effect of sulphur and nitrogen compounds and other major pollutants on the atmospheric corrosion of important materials. The quantitative evaluation aims at determining dose-response relationships as a basis for assessing critical and/or target levels and calculating costs due to material damage. Its Programme Centre is with the Corrosion and Metals Research Institute, Stockholm.

11. ICP Vegetation means ICP on Effects of Air Pollution on Natural Vegetation and Crops. The objectives of the ICP Vegetation are to evaluate the effects of air pollutants, identify realistic dose-response functions, validate and substantiate critical levels of ozone for crops and non-wood plants, facilitate the production of European ozone exceedance maps. Its Programme Centre is with the Centre for Ecology and Hydrology, Bangor, United Kingdom.

12. ICP Integrated Monitoring means ICP on Integrated Monitoring of Air Pollution Effects on Ecosystems led by Sweden. The objective of the ICP Integrated Monitoring is to determine and predict of the state of ecosystems (or catchments) and their changes from a long-term perspective with respect to the regional variation and effect of air pollutants, especially nitrogen, sulphur, ozone, and metals, and including effects on biota. Investigations of air pollutants acting on particular receptors have shown that an integrated approach is needed to understand the mechanisms of damage and the resulting effects. Its Programme Centre is with the Finnish Environment Institute, Helsinki.

13. ICP Modelling and Mapping means ICP on Modelling and Mapping of Critical Loads and Critical Levels and their Air Pollution Effects, Risks and Trends led by Germany. The objectives of the ICP Modelling and Mapping includes the assessment of damage to forests, crops, natural vegetation, soils, surface and ground waters, and materials by determining critical thresholds, critical loads and critical levels for the response of these systems and to map geographical areas to determine the scope and extent of pollutant depositions/ concentrations which exceed critical levels/loads. Its Coordination Centre for Effects, in Bilthoven, the Netherlands, develops modelling and mapping methodologies, including calls for data for the assessment of critical loads and exceedance on a European scale.

14. Task Force on Health means the Joint Task Force on the Health Aspects of Long-range Transboundary Air Pollution of the Executive Body and the World Health Organization (WHO), led by WHO European Centre for Environment and Health (ECEH), in Bonn, Germany. The objective of the Task Force on Health is to assess the health effects of long-range transboundary air pollution and provide supporting documentation. Assessments aim to quantify the contribution of transboundary air pollution to human health risks and help define priorities for guiding future monitoring and abatement strategies. The Task Force brings together experts delegated by countries that are Parties to the Convention, and its work is based on estimates of air pollution concentrations, in particular those derived by the Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (EMEP),

and on the results of hazard assessment performed by WHO (e.g. in the scope of the revision of the WHO *Air Quality Guidelines*).

15. The Joint Expert Group on Dynamic Modelling is led by the United Kingdom and Sweden. An objective of the Joint Expert Group on Dynamic Modelling is to facilitate collaboration with ICPs by bringing together experts in the field of dynamic modelling of biogeochemical processes in terrestrial and aquatic ecosystems to share knowledge, produce joint reports on all aspects of dynamic modelling, and provide advisory support on the use of these models in individual programmes.

16. NFC means a national focal centre of an ICP or task force. An NFC represents the research, monitoring, modelling or mapping expertise of a Party in the area of activities covered by the respective ICP.

17. Selected key parameters mean a category of effects-oriented indicators that are considered most representative, but not exhaustive, for monitoring the effectiveness and sufficiency of emission reductions with respect to adverse effects over the UNECE geographic area (see annex II). Selected key parameters also refer to indicators developed for integrated assessment modelling carried out by the Task Force on Integrated Assessment Modelling in collaboration with the centres of EMEP.

18. Call for data means the request for data expressed by the Working Group via its individual programme to the contacts or NFCs of Parties. The requested data allow reporting of the monitoring and modelling of air pollution effects, including selected key parameters.

19. Workplan items common to all programmes as specified under paragraph 28 mean work of the Working Group on Effects that strengthens the coherence of the reporting and collaboration of ICPs, including the use of observations for model verification.

20. Critical threshold is the quantitative estimate of an exposure, by means for example of deposition, concentration or flux, to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. This definition includes the commonly used terms of critical loads and critical levels.

21. Exposure-response relationships mean the observed relationships between exposure to pollution as a cause and specific outcomes as an effect, normally based on a commonly accepted hypothesis of cause-effect or exposure-response relationship. They often refer to damage and production loss incurred in the ongoing year, regardless of when the pollution has occurred.

22. Monitoring under the Working Group’s workplan is the regular observation and recording of effects of air pollution to human health or the environment.

23. Modelling under the Working Group's workplan is the development and application of symbolic mathematical descriptions of air pollution related processes in the atmosphere, in terrestrial or in aquatic ecosystems that cause adverse effects to human health or the environment.

24. Robustness in the reporting of monitored and modelled effects of air pollution means that reports under the workplan of the Working Group on Effects are likely not to be affected by systematic errors.

III. SCOPE

25. The Guidelines offer guidance for estimating and reporting monitoring and modelling data on effects of air pollution to human health and the environment. Technical details for monitoring are specified in the technical manuals of the ICPs. The manuals also describe the selected key parameters (see list in annex II), which are all monitored by the programmes.

26. Parties are required to report only on monitored and modelled effects set forth in protocols that they have ratified and that have entered into force.

27. The Guidelines apply to Parties within the EMEP modelling domain, including those Parties whose respective national territories have a part that overlaps with the EMEP grid and another part lying outside the EMEP modelling domain. Parties outside the EMEP modelling domain are encouraged to follow the Guidelines when preparing, submitting and reporting their data.

28. The reporting of monitored and modelled effects required under the Convention and its protocols is set out in subparagraphs (a) to (h) below:

(a) Each Party should, in accordance with article 7, item (d) and article 8, item (f) of the Convention, conduct research into effects of major air pollutants on human health and the environment with a view to establishing a scientific basis for dose-effect relationships, and exchange available information on data relating to effects of air pollution and the extent of damage;

(b) The workplan items common to all programmes are particularly important and they include updated information on:

(i) Exposure-response relationships and stock at risk;

(ii) Links between observations and critical thresholds, loads and levels;

(iii) Robustness of monitored and modelled air pollution effects;

(iv) Parameters, applied methodologies and spatial extent and temporal frequency of the monitoring and modelling;

(c) Each Party to the 1988 Sofia Protocol concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes should, in accordance with that Protocol's article 6, item (a) and article 8, item (f), identify and quantify effects of emissions of nitrogen oxides and report annually on progress in establishing critical loads;

(d) Each Party to the 1991 Geneva Protocol on the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes should, in accordance with article 5 of the Protocol, report on the development and application of methods to achieve national or international tropospheric ozone standards and other goals to protect human health and the environment, in particular, to identify and quantify effects of emissions of VOCs and photochemical oxidants and to determine the geographical distribution of sensitive areas;

(e) Each Party to the 1994 Oslo Protocol on Further Reduction of Sulphur Emissions should, in accordance with article 4, paragraph 2, item (b) and article 6, items (d) and (f), of the Protocol, collect and maintain information on effects of depositions of oxidized sulphur and other acidifying compounds. Each Party should also encourage research on effects of sulphur emissions on human health, the environment (in particular acidification) and materials taking into account the relationships between air pollutants, and the economic evaluation of benefits;

(f) Each Party to the 1998 Aarhus Protocol on Heavy Metals should, as appropriate and in accordance with the Protocol's article 6, items (a), (b), (c) and (g), encourage research related, but not limited, to existing levels in the biotic and abiotic environment; to pollutant pathways and inventories in representative ecosystems; to relevant effects on human health and the environment including quantification of those effects, to an integrated effects-based approach on measured or modelled environmental levels, pathways, and effects on human health and the environment;

(g) Each Party to the 1998 Aarhus Protocol on Persistent Organic Pollutants should, in accordance with article 8, items (c) and (f), of the Protocol, promote research on, but not limited, to relevant quantified effects on human health and the environment to an integrated effects-based approach on measured or modelled environmental levels, pathways, and effects on human health and the environment;

(h) Each Party to the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone that is within the geographical scope of EMEP should, in accordance with the Protocol's article 6, paragraph 2, item (b), article 7, paragraphs 4 and 5, and article 8 items (a), (e), (g) and (k):

(i) Collect and maintain information on the effects of ambient concentrations and of the deposition of sulphur, nitrogen compounds, VOCs and ozone on human health, terrestrial and aquatic ecosystems and materials;

(ii) Prepare information with a view to reducing further the difference between actual depositions of sulphur and nitrogen compounds and critical load values as well as the difference between actual ozone concentrations and the critical levels of ozone, or alternative assessment methods;

(iii) Pursue research and cooperation related to the international harmonization of methods for the calculation and assessment of the adverse effects for use in establishing critical loads and levels;

(iv) Encourage research and monitoring on the identification of trends over time and the scientific understanding of effects of sulphur, nitrogen and VOCs and photochemical pollution on human health and the environment, including their contribution to concentration of PM, the environment and materials taking into account the relationships between the pollutants;

(v) Quantify and, where possible evaluate economically the benefits for the environment and human health resulting from emission reductions.

IV. METHODS AND ORGANIZATION OF WORK

29. The scientific basis of work to assess effects on ecosystems and materials is largely provided by large-scale transnational monitoring and evaluation networks, which observe and document the present situation with respect to chemical and biological parameters, generate and collect data, and collate the best available information and scientific knowledge (on a regional basis) on the effects of major air pollutants and their recorded trends. This information is used for the creation and validation of models to reflect environmental processes and assess the risks of air pollution. The work includes comprehensive case studies, modelling and mapping of effects and assessment of damage and recovery in a broad context.

30. The work on the effects on human health of air pollutants is based on the comprehensive knowledge gathered and synthesized from inputs from research organizations and EMEP as well as from WHO and its collaborating networks, such as those on exposure assessment and health effects studies.

31. Parties should use the latest versions of the technical manuals of the ICPs and of the Task Force on Health as well as the data templates provided with calls for data by the programme centres. The manuals are available through the webpage of the Working Group on Effects at the respective programme websites.

32. Parties should quantify the robustness of their estimates of indicators on effects of air pollution using the most appropriate methodologies available.

33. Procedures for quality assurance and quality control (QA/QC) should be implemented by the Parties according to the manuals and reports of ICPs.

V. REPORTING GUIDANCE

34. Reporting guidance is provided in calls for data by the programme centres under the Working Group on Effects and covers deadlines for submission of data, initiation of the annual reporting and preparation of templates and electronic submissions of data.

35. In accordance with the workplan of the Working Group on Effects, each Party should report to ICPs through their programme centres as requested or in response to calls for data on:

(a) Indicators for effects of air pollution to human health and the environment;

(b) Results for the workplan items common to all programmes, as specified in paragraph 28 (b);

(c) Selected key parameters (see annex II);

(d) Critical thresholds, loads and levels;

(e) Submission of results from specific effects-oriented research conducted at national level.

VI. RECORD-KEEPING

36. Parties should archive all relevant information on indicators of effects of air pollution to human health and the environment.

VII. LANGUAGES

37. The reports should be submitted in one of the working languages of the United Nations Economic Commission for Europe (i.e. English, French, or Russian). Where possible, Parties submitting reports in French and Russian are encouraged to provide an English translation.

VIII. UPDATING OF GUIDELINES

38. The Guidelines are subject to review and revision as decided by the Executive Body. The Task Forces of the ICPs may, if necessary, propose amendments through the Working Group on Effects to achieve harmonization with other reporting obligations, as well as to meet needs for

increased transparency or other needs for further revision. The Task Forces should inform to the Working Group of any problems or discrepancies encountered by experts in the application of the Guidelines.

Annex I

Mandate of the Working Group on Effects

(ECE/EB.AIR/68, annex III, appendix IV)

1. At the request of the Executive Body and as required for the effective implementation of the Convention, the Working Group on Effects collects, assesses and further develops knowledge and information on:

(a) The present status and long-term trends in the degree and geographical extent of the impact of air pollution, in particular its long-range transboundary impact;

(b) Dose-response relationships for agreed air pollutants;

(c) Critical loads, levels and limits for agreed air pollutants;

(d) Damage and benefits, as a basis for the further development of air pollution abatement strategies.

2. The Working Group on Effects carries out work to:

(a) Assess the results and effectiveness of the implementation of the existing protocols to the Convention;

(b) Identify the most endangered areas, ecosystems and receptors and the extent of the effects of air pollution on human health and terrestrial and aquatic ecosystems and materials;

(c) Provide scientific substantiation for the review and further development of protocols.

3. The Working Group works in close collaboration with the Executive Body's other subsidiary bodies and with other relevant organizations. The Working Group on Effects provides information for related scientific activities outside the Convention and/or for joint efforts with other bodies/organizations.

4. The Bureau of the Working Group on Effects undertakes the detailed planning, coordination, assessment and reporting of activities as defined in the workplan for the implementation of the Convention and carried out by its subsidiary units.

Annex II

Selected key parameters on air pollution effects

1. Networks for monitoring and modelling air pollution effects on terrestrial and aquatic ecosystems and corrosion of materials have been operated by the Working Group on Effects since early 1980s. These networks are vital in terms of showing the widespread damage from air pollution and trends in effects in Europe and North America. They provide indications for past and future emission control policies by gathering monitoring data and studying cause-effect relationships. This evidence is important for the verification of modelled effects and interpretation of exceedance of critical loads. Effects studies contribute to the understanding of the effectiveness of emission abatement, and they are the only means to address the sufficiency of emission reductions.

2. This annex describes key parameters to monitor the effectiveness of emission reductions and related responses to human health and the environment (tables 1–7). All selected parameters are already being monitored by the Convention's effects-oriented activities. The concentration and deposition data are compiled in collaboration with activities outside the Working Group (table 8).These parameters are supported by other observational parameters which further clarify air pollution mechanisms. In addition, the monitoring programmes monitor and collect other relevant data that extend our understanding of effects.

Table 1. Acidification effects on ecosystems

Receptors	Main processes	Related effects	Monitoring or evaluation coverage and frequency	Suggested key parameters for reporting
Aquatic eco-systems.	Increase of sulphate and nitrate concentrations ($[SO_4]$, $[NO_3]$) in water.	Biological damage, including sensitive diatoms, micro- and macrophytes, loss of fish stock or invertebrates.	Representative acid-sensitive streams and lakes (in km^2). Sampling yearly (in autumn turnover) or monthly (streams).	Acid neutralizing capacity (ANC), pH, alkalinity, aluminium concentration ([Al]), total organic carbon (TOC), and others.
Aquatic ecosystems (critical thresholds).	Increase of $[SO_4]$ and $[NO_3]$ in water. Criteria based on ANC limits.	*idem.*	Sensitive small headwater lakes or streams. Evaluation every 1–5 years.	Critical loads, exceedance, and threshold criteria.
Terrestrial eco-systems.	Loss of soil nutrients through leaching.	Increase of aluminium toxic for tree roots, nutrient imbalances, growth reduction, susceptibility to other stress factors.	Representative forest and (semi-)natural ecosystem soil types (in km^2). Sampling every 1–5 years.	Soil base saturation (BS), ANC leaching, pH, $[SO_4]$, $[NO_3]$, total [Al], ratio of base cations to aluminium (BC/Al), and others.

Receptors	Main processes	Related effects	Monitoring or evaluation coverage and frequency	Suggested key parameters for reporting
Terrestrial ecosystems (calculated critical loads).	Loss of soil nutrients through leaching. Criteria based on BC/Al, BS, [Al].	Increased level of aluminium toxicity for tree roots. No net loss of nutrients. [Al] levels toxic for biota.	Forest soils (in km^2). Evaluation every 1–5 years.	Calculated critical loads, exceedance and threshold criteria.

Table 2. Eutrophication effects on terrestrial ecosystems

Receptors	Main processes	Related effects	Monitoring or evaluation coverage and frequency	Suggested key parameters for reporting
Terrestrial eco-systems.	Enrichment of available nutrient nitrogen (N).	N saturation, nutrient imbalances, changes in vegetation structure, loss of biodiversity, links to climate change.	Representative soil types of forests and (semi-)natural ecosystems (in km^2). Sampling every 1–5 years.	Total N content in soil (N_{total}), NO_3 leaching ($NO_{3,leach}$), carbon-nitrogen ratio (C/N), and others.
	Enrichment of available nutrient N.	N saturation, nutrient imbalances, changes in vegetation structure, loss of biodiversity.	Representative forest trees and (semi-)natural ecosystem species (in km^2). Sampling every 1–5 years.	Ratios of nutrients (N, phosphorous (P), potassium (K) and magnesium (Mg)) in foliage for dominant and key species (N/P, N/K, N/Mg), and others.
Terrestrial ecosystems (calculated critical loads).	Enrichment of available nutrient N. Criteria based on $NO_{3,leach}$, C/N and nutrient ratios.	N accumulation, unfavourable change in species composition.	Representative soil types of forests and (semi-)natural ecosystems and their vegetation (in km^2). Evaluation every 1–5 years.	Calculated critical loads, exceedance. and threshold criteria.
Terrestrial ecosystems (empirical critical loads).	Enrichment of available nutrient N. Criteria based on empirical evidence and observations.	*idem.*	Representative soil types of forests and (semi-)natural ecosystems and their vegetation (in km^2). Evaluation every 1–5 years.	Empirical critical loads, exceedance, and threshold criteria.

Table 3. Ground-level ozone effects on vegetation and health

Receptors	Main processes	Related effects	Monitoring or evaluation coverage and frequency	Suggested key parameters for reporting
Agricultural and horticultural crops, forest trees and (semi-)natural vegetation.	Ozone (O_3) concentration or flux damaging the plant.	Premature senescence, reduced growth/ yield, reduced photo-synthetic capacity, changes in vegetation structure.	Representative (semi-)natural ecosystem species (in km^2). Frequent sampling (minimum every year).	Growth reduction, leaf and foliar damage, climatic factors, and others.
Agricultural crops, forest trees and (semi-)natural vegetation (critical levels, fluxes and accumulated doses).	O_3 concentration or flux damaging the plant.	Reduction of growth, biomass, quality of product.	Representative selected species (in km^2). Evaluation every 1–5 years.	Exceedance of selected AOT values (accumulated ozone concentrations above the selected threshold in parts per billion (ppb)), accumulated flux exceedance, and others.
Materials, including cultural heritage.	Corrosion.	Mass loss of materials.	Test sites for materials. Evaluation annually or every 1–5 years.	Degree of soiling, acceptable and/or tolerable levels of soiling, and others.
Humans.	Increased number of illness.	Morbidity.	Sites relevant for population exposure in Europe. Annual average concentration levels. Evaluation annually or every 1–5 years.	SOMO35 (sum of mean 8-hour ozone concentrations above 35 ppb), its exceedance, and others.

Table 4. Particulate matter effects on materials and health

Receptors	Main processes	Related effects	Monitoring or evaluation coverage and frequency	Suggested key parameters for reporting
Materials, including cultural heritage.	Deposition of coarse particulate matter (PM_{10}) on material surfaces.	Soiling of materials.	Relative changes at representative test sites for materials. Evaluation annually or every 1–5 years.	Degree of soiling, acceptable and/or tolerable levels of soiling, and others.
Humans.	Increased number of deaths.	Mortality.	Sites relevant for population exposure in Europe. Evaluation annually or every 1–5 years.	Annual average fine PM ($PM_{2.5}$) concentration, epidemiological studies, and others.

Table 5. Heavy metals effects on ecosystems and health

Receptors	Main processes	Related effects	Monitoring and evaluation coverage and frequency	Suggested key parameters for reporting
Aquatic ecosystems.	Toxicity of heavy metal concentrations.	Detrimental effects on representative organisms.	Representative acid-sensitive streams and lakes (in km^2). Sampling every 1–5 years.	Concentrations of heavy metals in water and lake sediments, and others.
Terrestrial ecosystems (forest soils, mosses).	Accumulation of heavy metals.	*idem.*	Representative ecosystems (in km^2) or selected sites. Sampling every 1–5 years.	Concentrations of heavy metals, and others.
Terrestrial ecosystems (forest soils and agricultural crops) (critical loads).	Accumulation of heavy metals.	Bio-accumulation.	Representative ecosystems (in km^2).	Critical loads, exceedance, and threshold criteria.
Humans (critical loads)	Toxicity of heavy metals.	Detrimental health effects.	Number of people affected or at risk.	Critical loads, exceedance, and threshold criteria.

Table 6. Persistent organic pollutants effects on the environment and health

Receptors	Main processes	Related effects	Monitoring or evaluation coverage and frequency	Suggested key parameters for reporting
Aquatic ecosystem.	Bioaccumulation.	Toxicity.	Representative species.	Concentration levels in vital organs, concentration levels in lake sediments.
Humans.	Accumulation to organisms high in food chain.	Detrimental health effects.		Biomarkers of human exposure.

Table 7. Multiple pollutant effects on materials

Receptors	Main processes	Related effects	Monitoring or evaluation coverage and frequency	Suggested key parameters for reporting
Materials, including cultural heritage.	Soiling and corrosion due to SO_2, nitric acid (HNO_3) and O_3.	Mass loss of materials.	Test sites for materials. Sampling every year with up to several years of continuous exposure.	Mass loss of materials (carbon steel, zinc), acceptable and/or tolerable levels of corrosion, and others.

Table 8. Concentrations and depositions of air pollutants

Pollutant	**Suggested key parameters for evaluation**	**Evaluation method, coverage and frequency**	**Existing monitoring networks and deposition modelling**
Acidifying compounds.	Total sulphur and N deposition.	Measured and/or modelled at the site for best linkage with the effects indicator. Annual average may be obtained from more frequent sampling. Comparison with measured and modelled depositions of EMEP is ongoing.	ICP Forests, ICP Integrated Monitoring, ICP Modelling and Mapping; EMEP/CCC (Chemical Coordinating Centre), EMEP/MSC-W (Meteorological Synthesizing Centre-West); national networks.
Eutrophying compounds.	Total N deposition (oxidized and reduced N separately).		
O_3.	O_3 concentration, AOT values, fluxes.	Modelled annual averages for selected years (EMEP Eulerian model in 50 km × 50 km grid).	ICP Forests, ICP Vegetation, EMEP/CCC, EMEP/MSC-W; national networks.
PM.	Concentration of $PM_{2.5}$, PM_{10}, total suspended particles (TSP).	*idem.*	EMEP/CCC, EMEP/MSC-W; national networks.
Heavy metals.	Deposition of cadmium, lead and mercury.	*idem.*	EMEP/MSC-E (Meteorological Synthesizing Centre-East).
POPs.	Deposition of selected POPs.	*idem.*	*idem.*
