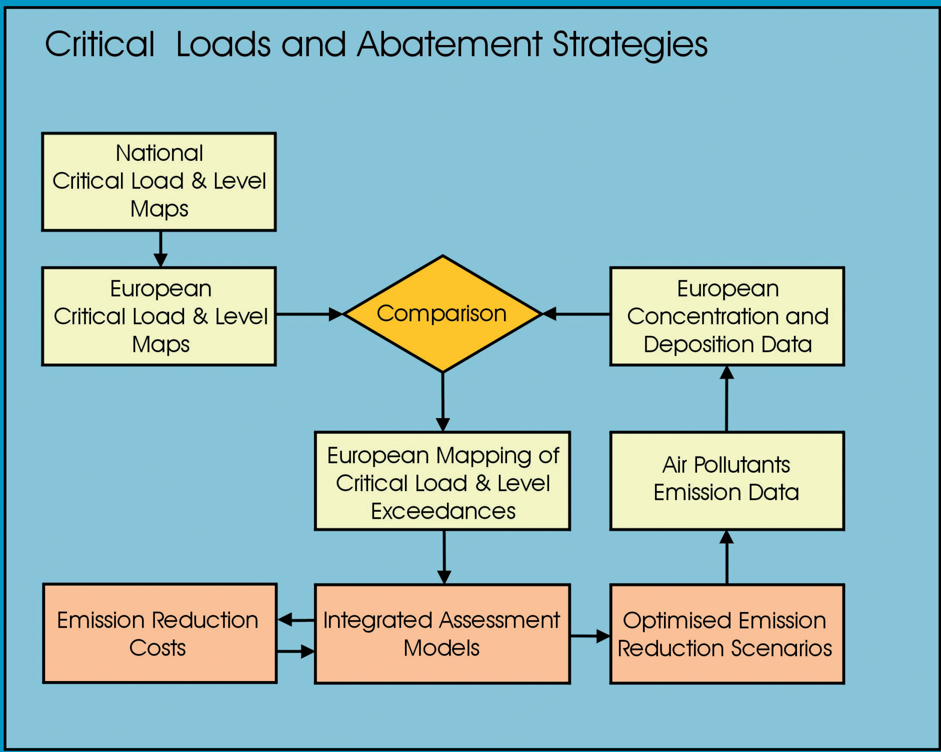
Mapping Manual 2004



Chapter 1 has been edited by Till Spranger (Germany), Chairman of the Task Force on Modelling and Mapping.

1 Introduction

The critical loads and levels concept is an effect-based approach that has been used for defining emission reductions aimed protecting ecosystems and other receptors. Sustainability indicators are defined for specific combinations of pollutants, effects, and receptors (see definitions of critical levels in chapter 3, of critical loads in chapter 5.1, and of indicators and criteria used in dynamic models in chapter 6). Critical loads and levels provide a sustainable reference point against which pollution levels can be compared. They can further be used for calculating emission ceilings for individual countries with respect to acceptable air pollution levels (e.g., defined reductions of critical load/level exceedances).

The development of critical loads/levels and their application in an emission reduction policy framework can be seen as an environmental design process, using the same models and methods as causal research but in a reverse sequence (Figure 1).

1.1 The critical load and level concept in the UNECE Convention on Long-range Transboundary Air Pollution

During the 1970s it was recognised that transboundary air pollution has ecological and economic consequences (e.g. for the forest and fish industries) caused by acidifying air pollutants. In response to this, the countries of the UN Economic Commission for Europe (UNECE) developed a legal, organisational and scientific framework to deal with this problem. The UNECE Convention on Long-range Transboundary Air Pollution (LRTAP)) was the first international legally binding instrument to deal with problems of air pollution on a broad regional basis (see www.unece.org/env/lrtap). Signed in 1979, it entered into force in 1983.

The LRTAP Convention requires that its Parties cooperate in research into the effects of sulphur compounds and other major air pollutants on the environment, including agriculture, forestry, natural vegetation, aquatic ecosystems and materials (Article 7(d) of the Convention). The Convention also calls for the exchange of information on the physico-chemical and biological data relating to the effects of LRTAP and the extent of damage which these data indicate can be attributed to LRTAP (Article 8(f) of the Convention). To this end the Executive Body for the Convention established a Working Group on Effects (WGE) that is supported by a number of International Cooperative Programmes (ICPs).

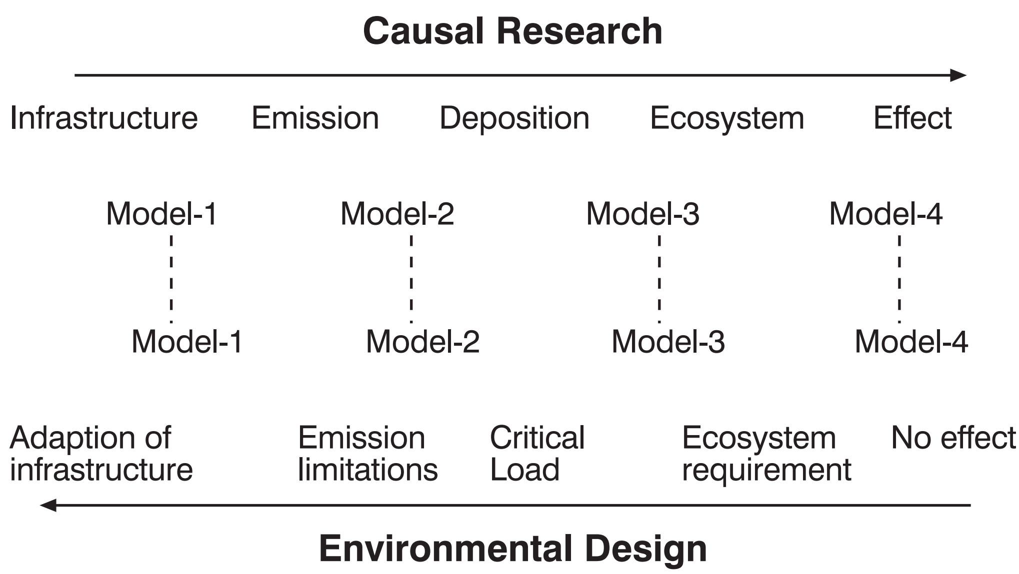


Figure 1: Environmental research vs. environmental design (adapted from Harald Sverdrup)

1 Introduction

In 1986 a work programme under the Nordic Council of Ministers (Nilsson 1986) agreed scientific definitions of critical loads for sulphur and nitrogen. This provided the necessary stimulus to work under the Convention and in March 1988 two Convention workshops were held to further evaluate the critical levels and loads concept and to provide up-to-date figures. The Bad Harzburg (Germany) workshop dealt with critical levels for direct effects of air pollutants on forests, crops, materials and natural vegetation, and the Skokloster (Sweden) workshop (Nilsson and Grennfelt 1988) on critical loads for sulphur and nitrogen compounds. Furthermore, at the Bad Harzburg workshop the first discussions took place on the possible use of critical level/loads maps for defining areas at risk. It was foreseen that these could play an important role in the development of policy.

As a result of these workshops, in 1988 the Executive Body for the Convention approved the establishment of a programme for mapping critical loads and levels (Task Force on Mapping) under the Working Group for Effects (WGE) with Germany as the lead country (www.icpmapping.org). In 1989 the Executive Body welcomed the offer of the Netherlands to host a Coordination Center for Effects (CCE) that was established at the RIVM in Bilthoven, The Netherlands (www.rivm.nl/cce).

The mandates of the Task Force of the International Cooperative Programme on Modelling and Mapping of Critical Loads and Levels and their Air Pollution Effects, Risks and Trends (ICP M&M)[1] , the CCE and the National Focal Centres[2] are described below.

The structure of the Programme within the Convention is shown in Figure 2.

[1] established by the Executive Body in 1999 to replace the Task Force on Mapping, see chapter. 1.3

[2] in 2003, 24 National Focal Centres are actively participating in the ICP M&M

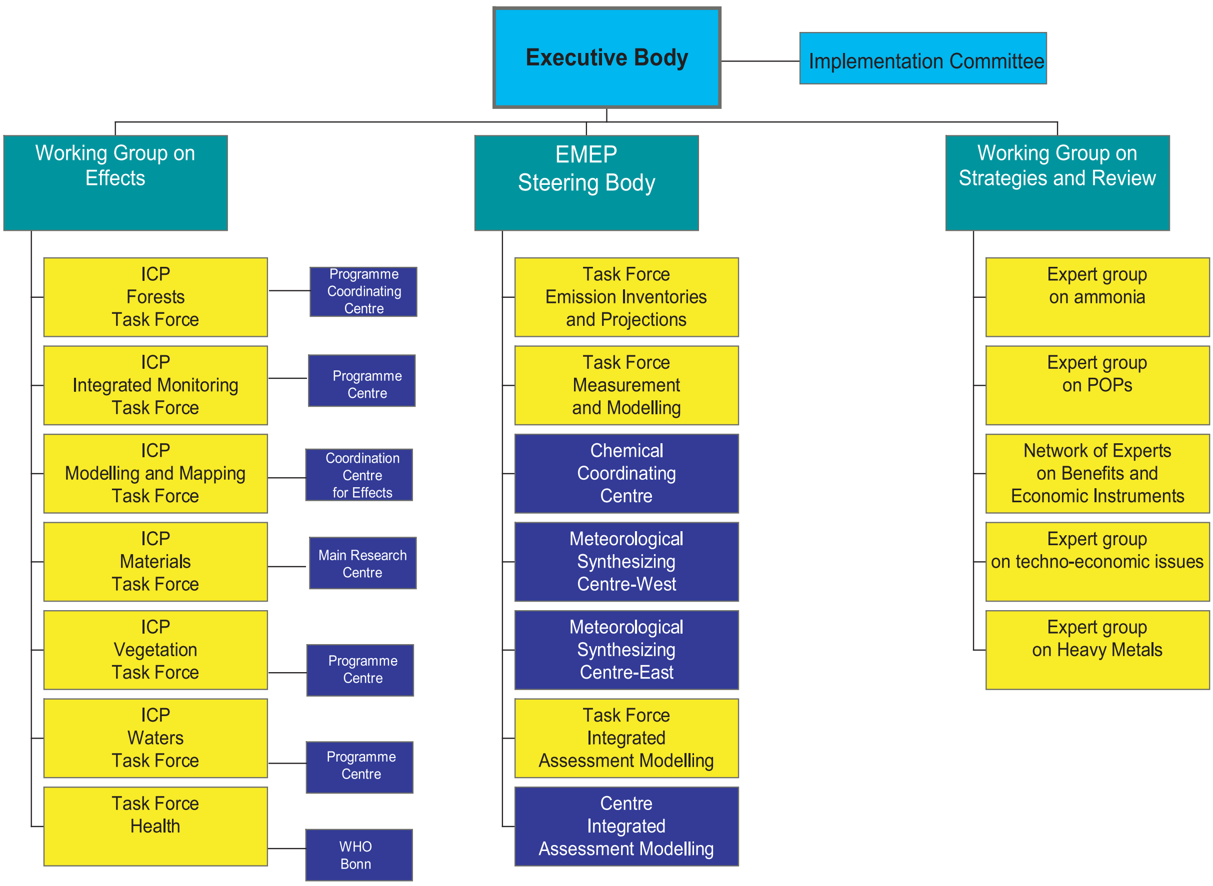


Figure 2: LRTAP Organogram

The Convention has been extended by eight protocols, which identify specific obligations or measures to be taken by Parties. The first substance-specific protocols were negotiated on the basis of economic and technological information (e.g. best available technologies). They set the same emission targets for all Parties, either in terms of a percentage reduction, or as a decrease to an emission level of a former year. They took no direct account of the effects of the emissions.

A second generation of protocols came into being when, in June 1994, a second protocol for reducing sulphur emissions (the 'Oslo protocol') was signed by 30 countries. This identified effects-based, cost-effective abatement measures based on the analysis of impacts using critical loads. The long-term objective for negotiating national emission reductions was to eliminate the excess sulphur deposition over critical loads for sulphur, i.e. avoid future exceedances. However, cutting sulphur dioxide emissions to achieve deposition levels below critical loads was not feasible for all ecosystems in Europe. Even so, the negotiations were based on the assessment of environmental effects and the protection of ecosystems as well as technical and economic considerations.

The role of critical levels/loads maps for the development and implementation of air pollution control strategies is shown in Figure 3.

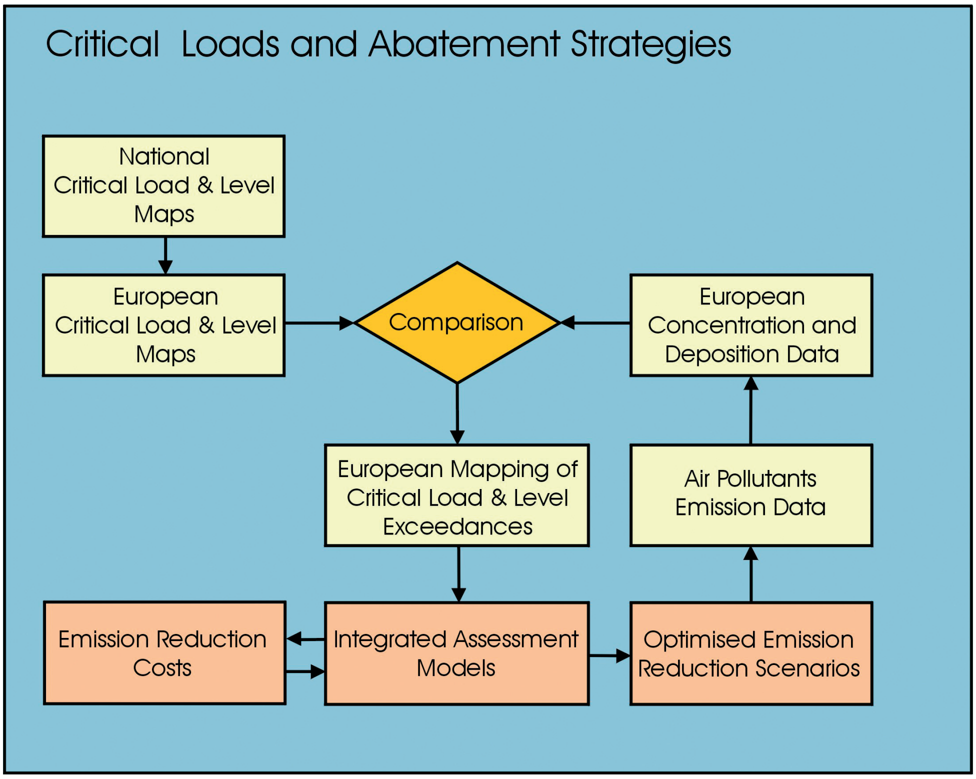


Figure 3: Critical Loads and Abatement strategies

Summarising this figure, the following "crucial steps" are involved:

- Define methods and criteria to determine and map critical loads and levels (Convention workshops);
- Obtain international approval (Working Group on Effects and Executive Body);
- Perform a mapping exercise (based on this Manual and on the proceedings of critical levels/loads and mapping workshops);
- Define excess deposition/concentration per unit area;
- Use the results for developing strategies and negotiating agreements.

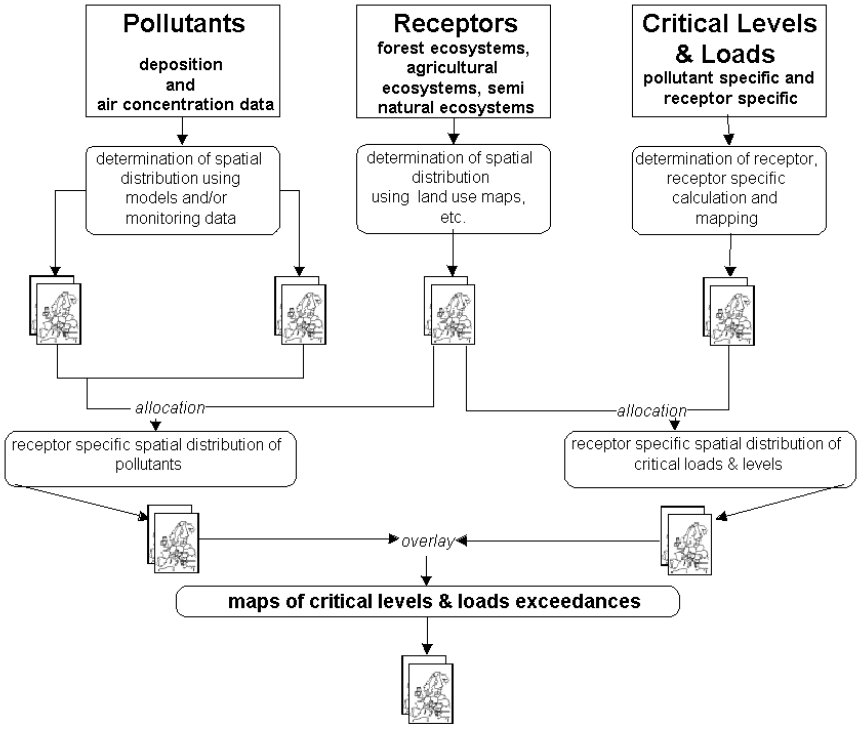


Figure 4: Production of critical levels/loads exceedance maps (adapted from GAUGER et al. 2002)

Figure 4: describes in more detail and on a national level how spatial information on receptors, pollutants and critical levels/loads are combined in the mapping process.

In practice, maps of critical loads have been used as yardsticks to assess the need for reducing depositions in each grid cell of the Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP). An emission scenario may be viewed by comparing a computed European deposition map with the European critical loads map. In support of the Oslo protocol the negotiators started to consider the use of computer models to assess the costs and effectiveness of emission reduction scenarios. One of these "integrated assessment models" is the Regional Acidification INformation and Simulation (RAINS) model. Figure 5 illustrates the modules of the RAINS model. The first module addresses energy use, agricultural and other productive activities, while related emissions and control costs are reflected in the following two modules. The fourth module handles atmospheric dispersion, while the last module addresses environmental effects. The RAINS model can be operated in two distinct modes. In the scenario analysis mode, the model is run forward: it can predict the regional pattern of concentrations/depositions that will result from the particular combinations of economic activities, along with the costs and environmental benefits of alternative emission control strategies. In optimisation mode, RAINS can determine the least expensive way to arrive at a predetermined deposition level.

The model user can specify environmental targets in various ways: a certain percentage reduction of excess over critical loads, a deposition pattern of a past year, etc. This mode of RAINS has been used extensively in political negotiations in Europe. Please note that this is a specification and extension of the general concept as shown in Figure 1.

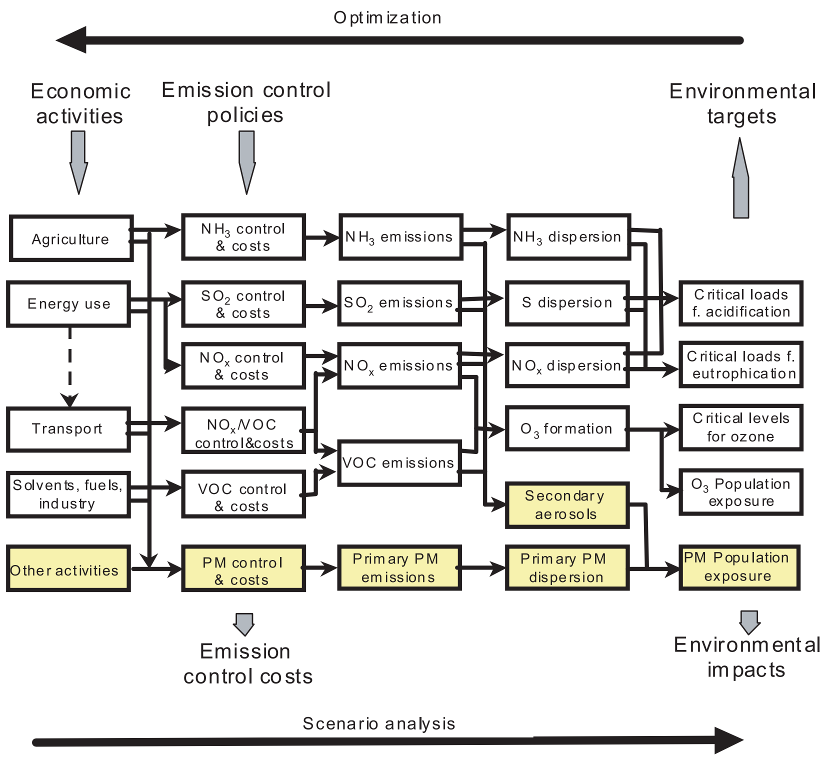


Figure 5: Scheme of the RAINS model (adapted from Amann et al.)

Since the Oslo Protocol negotiations, the complexity of the work under the ICP M&M has increased.

First, a more complex formulation of critical loads was developed and used in support of the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (the Gothenburg Protocol). It recognizes that:

a) sulphur as well as oxidized and reduced nitrogen contribute to acidification. Therefore, two critical loads for acidity had to be distinguished, the critical load of sulphur-based acidity and the critical load of nitrogen-based acidity (see chapter 5.1 - 5.4).

b) both oxidized nitrogen and volatile organic compounds contribute to the formation of tropospheric ozone, for which critical levels are identified for forests, crops and natural vegetation (see chapter 3.2.4).

c) a small deposition rate of nitrogen which can be taken up by vegetation or immobilized is essential for ecosystems (see chapter 5.3).

d) deposition of both oxidized and reduced nitrogen exceeding the critical load for nutrient nitrogen contribute to eutrophication (see chapter 5.1 to 5.3).

Second, there have been major activities to develop an effects-based approach also for heavy metals for the preparation of the review and possible revision of the 1998 Århus Protocol on Heavy Metals. Critical limits, transfer functions and methods to determine and apply critical loads of heavy metals are being developed and are listed in chapter 5.5.

1.2 Aims of the ICP on Modelling and Mapping

The aims and objectives of the ICP on Modelling and Mapping were approved by the WGE at its nineteenth session in 2000 (Annex VII of document EB.AIR/WG. 1/2000/4):

"To provide the Working Group on Effects and the Executive Body for the Convention and its subsidiary bodies with comprehensive information on critical loads and levels and their exceedances for selected pollutants, on the development and application of other methods for effect-based approaches, and on the modelling and mapping of the present status and trends in impacts of air pollution."

Short-term and specific aims are agreed annually at sessions of the Working Group and approved by the Executive Body. The reader is invited to view the documents relating to long- and medium-term strategies, and relating to the work-plan of the Executive Body, through the web pages of the Convention (www.unece.org/env/wge/documents and www.unece.org/env/ebrespectively).

1.3 Division of Tasks within the Programme

A network of National Focal Centres (NFCs) under the ICP M&M is responsible for the generation of national data sets. NFCs cooperate with the Coordination Center for Effects to develop modelling methodologies and European databases for critical loads. CCE reports on this work to the Task Force of the ICP M&M.

The Programme´s organization and division of tasks between its subsidiary bodies, as approved by the WGE (EB.AIR/WG.1/2000/4) are as follows:

"The International Cooperative Programme on Modelling and Mapping was established in 1999 (ECE/EB.AIR/68, para. 52 (f)) to further develop and expand activities so far carried out by the Task Force on Mapping of Critical Levels and Loads and their Exceedances (led by Germany) and by the Coordination Center for Effects (at the National Institute of Public Health and the Environment at Bilthoven, Netherlands), pursuant to their original mandates (EB.AIR/WG.1/18), amended to reflect the present structure of the Executive Body and the new requirements:

1.3.1 Mandate for the Task Force of the ICP on Modelling and Mapping

(a) The Programme Task Force supports the Working Group on Effects, the Working Group on Strategies and Review and other subsidiary bodies under the Convention by modelling, mapping, reviewing and assessing the critical loads and levels and their exceedances and by making recom mendations on the further develop ment of effect-based approaches, and on future modelling and mapping requirements;

(b) The Task Force plans, coordinates and evaluates the Programme's activities, it is responsible for updating the Programme Manual, as well as for quality assurance;

(c) The Task Force prepares regular reports, presenting, and, where appropriate, interpreting Programme data.

1.3.2 Mandate for the Coordination Center for Effects

(a) The Coordination Center for Effects (CCE) assists the Task Force of the ICP on Modelling and Mapping, and gives scientific and technical support, in collaboration with the Programme Centres under the Convention, to the Working Group on Effects and, as required, to the Working Group on Strategies and Review, as well as to other relevant subsidiary bodies under the Convention, in their work related to the effects of air pollution, including the practical development of methods and models for calculating critical loads and levels and the application of other effect-based approaches;

(b) In support of the critical loads/levels mapping and modelling exercise, CCE:

(i) Provides guidance and documentation on the methodologies and data used in developing critical loads and critical levels of relevant pollutants, and their exceedances;

(ii) Collects and assesses national and European data used in the modelling and mapping of critical loads and levels of relevant pollutants. The Center circulates draft maps and modelling methodologies for review and comment by National Focal Centres, and updates modelling methodologies and maps as appropriate;

(iii) Produces reports and maps on critical loads/levels documenting mapping and modelling methodologies, with the assistance of the National Focal Centres and in cooperation with the Task Force on ICP on Modelling and Mapping;

(iv) Provides, upon request, the Working Group on Effects and the Task Force on ICP on Modelling and Mapping, the Working Group on Strategies and Review and the Task Force on Integrated Assessment Modelling, with scientific advice regarding the use and interpretation of data and modelling methodologies for critical loads and levels;

(v) Maintains and updates relevant databases and methodologies, and serves as a clearing house for data collection and exchange regarding critical loads and levels among Parties to the Convention, in consultation with the International Cooperative Programmes and EMEP;

(vi) Conducts periodic training sessions and workshops to assist National Focal Centres in their work, and to review activities and develop and refine methodologies used in conjunction with the critical load and critical level mapping exercise;

(c) While the Coordination Center for Effects reports to the Working Group on Effects and the Task Force of ICP on Modelling and Mapping, and receives guidance and instruction from them concerning tasks, priorities and timetables, it also assists the Working Group on Strategies and Review, the Task Force on Integrated Assessment Modelling, and other bodies under the Convention, when appropriate.

1.3.3 Responsibilities of the National Focal Centres

The tasks of the National Focal Centres have been defined previously in the preceding version of the Mapping Manual:

The National Focal Centres are responsible for:

(a) the collection and archiving of data needed to obtain maps in accordance with the Manual guidelines and in collaboration with the Coordination Center for Effects,

(b) the communication of national mapping procedures (data, formats, models, maps) to the Coordination Center for Effects,

(c) the provision of written reports on the methods and models used to obtain national maps,

(d) organising training facilities for national experts in collaboration with the Coordination Center for Effects

(e) making the necessary provisions to obtain national maps in accordance with the resolution and standards (measurement units, periodicity, etc.) described in the Manual,

(f) collaborating with the Coordination Center for Effects to permit assessment of the methods applied in order to perform multinational mapping exercises (e.g. using GIS) and model comparisons,

(g) updating the Mapping Manual as appropriate, in collaboration with the Task Force on Mapping and the Coordination Center for Effects.

1.4. Objectives of the Manual

The principal objectives of this Manual are to describe the recommended methods to be used by the Parties to the Convention, represented by their National Focal Centres, to:

(a) Model and map critical levels and loads in the ECE region;

(b) Model and map areas with air pollution values exceeding critical levels or loads;

(c) Develop, harmonize and apply methods and procedures (including dynamic modelling) to assess recovery and risk of future damage;

(d) Determine and identify sensitive receptors and locations.

Thus it provides a scientific basis for the application of critical levels and loads, their interrelationships, and the consequences for abatement strategies, e.g. for the assessment of optimized allocation of emission reductions.

This Manual includes methodologies used by ICP Materials (chapter 4) and (concerning ozone) ICP Vegetation (chapter 3.2.4). In contrast to manuals (or comparable methodological documents) of other ICPs and EMEP CCC this manual does not contain information on methods of measurement and specific details on data generation. This reflects the aims and tasks of the ICP Modelling and Mapping within the Convention.

Specific technical information as well as detailed results and other information by National Focal Centres can be found in the biannual Status Reports of the CCE (see also chapter 1.6).

1.5. Structure and scope of the Manual

Chapter 2 describes methods to map pollutant concentrations and depositions. These may be used to generate exceedance maps by subtracting critical levels/loads with them. At the European scale, EMEP model results are used to construct such maps. The modelled pollutant concentrations and depositions are derived from national emissions which provide the link to negotiations on emission controls. In addition, NFCs are encouraged to produce high resolution maps which can be used for effects assessments in specific ecosystems at the national and local level. This chapter was produced by experts including those from EMEP.

Chapter 3 describes the methods developed for the quantification and mapping of critical levels / fluxes of gaseous pollutants for vegetation. It is largely based on conclusions and recommendations of Convention workshops and, for ozone, on intensive work coordinated by ICP Vegetation in cooperation with EMEP.

Chapter 4 describes derivation and application of acceptable levels for effects on materials. It constitutes an informal Manual of the ICP on Materials (www.corr-institute.se/ICP-Materials).

Chapter 5 describes how to quantify critical loads of nutrient nitrogen, potential acidity and heavy metals. Since this is still the central task of ICP Modelling and Mapping, this is the most detailed chapter. The structure has been changed from the 1996 Manual in that the main distinction is by method (empirical vs. modelled), and not by effect (eutrophication vs. acidity). The chapter starts with an overview including definitions (5.1), followed by a subchapter on empirical critical loads (5.2) with sections on nutrient N (results of a workshop in Berne in 2002) and acidity. Chapter 5.3 describes methods to model critical loads for terrestrial ecosystems (SMB model), again divided into subchapters on nutrient N (eutrophication) and acidity. Compared to the previous Manual, it has been updated taking into account a.o. the results of workshops in Copenhagen (1999) and York (2000), as well as various CCE workshops. Chapter 5.4 deals with critical loads for surface waters (developed in close cooperation with ICP Waters). Finally, chapter 5.5 describes methods to model and map critical loads of heavy metals[5].

Chapter 6 describes dynamic models and the use of their results. The authors developed it in cooperation with the Joint Expert Group on dynamic modelling.

Chapter 7 describes how to identify critical load exceedance and parameters derived from exceedance (protection isolines, [average] accumulated exceedances).

Chapter 8 describes procedures needed to produce maps, including map geometry / projections, spatial generalisation and repre-

[5] to be finalised by 2004 with assistance from the ad hoc WG on critical loads of heavy metals

sentativity, and the estimation of uncertainty and bias.

Annex I lists definitions and descriptions of the most important parameters, processes, indicators and criteria.

Annex II describes land use data and ecosystem classification systems used within the Modelling and Mapping programme.

Annex III gives an overview on unit conversions.

In addition, the ICP M&M website (www.icpmapping.org) lists "related documents" (e.g. on deposition methods, on empirical critical loads for nutrient nitrogen) describing certain methodological aspects in more detail.

References

For historical details on the establishment of the Task Force on Mapping and the mandates of the cooperating partners in the mapping exercise see EB AIR/R.18/Annex IV, Section 3.6 and EB AIR/WG.1/R.18/Annex I.

The historical development of the programme and the approaches used for calculating critical loads and levels can be followed by consulting the following background material:

(a) Report of the Initial ECE Mapping Workshop, Bad Harzburg 1989, Draft Manual on Methodologies and Criteria for Mapping Critical Loads/Levels 1990 with scientific Annexes I to IV, both available at the Federal Environmental Agency, Berlin, Germany

(b) Mapping Vademecum 1992, available at the Coordination Center for Effects, Bilthoven, The Netherlands, RIVM Report No. 259101002.

(c) Manual on Methodologies and Criteria for Mapping Critical Loads/Levels (First Edition); Texte Umweltbundesamt 25/93, Federal Environmental Agency (UBA)(ed.), Berlin, Germany

(d) Manual on Methodologies and Criteria for Mapping Critical Loads/Levels and Geographical Areas Where They Are Exceeded (fully revised in 1995/1996); Texte Umweltbundesamt 71/96, Federal Environmental Agency (UBA)(ed.), Berlin, Germany

(e) various interim revisions to (d), e.g. for the mapping of critical levels for ozone

(f) numerous scientific articles referenced in the following chapters.

Status, results and agenda of the ICP Modelling and Mapping are described in various documents to be found on the Convention's web site (www.unece.org/env/wge/documents). Various aspects concerning technical and scientific background and detailed results also of National Focal Centres can be found in CCE publications,

especially the biannual CCE Status Reports (www.rivm.nl/cce).

Amann et al. IIASA, The RAINS model, www.iiasa.ac.at/rains

Gauger T, Anshelm F, Schuster H, Erisman JW, Vermeulen AT, Draaijers GPJ, Bleeker A, Nagel HD (2002) Mapping of ecosystem specific long-term trends in deposition loads and concentrations of air pollutants in Germany and their comparison with Critical Loads and Critical Levels, Final Report 299 42 210 Umweltbundesamt Berlin

Nilsson J (ed) (1986) Critical Loads of Nitrogen and Sulphur. Enviromental Report 1986:11, Nordic Council of Ministers, Copenhagen, 232 pp.

Nilsson J, Grennfelt P (eds.) (1988) Critical loads for sulphur and nitrogen. Report from a workshop held at Skokloster, Sweden 19-24 March 1988. Miljorapport 15, 1-418.