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# **Harmonization of Emission Inventorying in the EMEP Countries**

*Final Report*

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## CONTENTS

	Page
1 INTRODUCTION .....	4
2 DEVELOPMENT OF THE PROJECT UNTIL THE 1990 EMEP WORK- SHOP ON INTERNATIONAL EMISSION INVENTORIES .....	3
2.1 Revision of the 1988 guidelines for estimation and reporting of the SO <sub>2</sub> and NO <sub>x</sub> emissions ....	4
2.2 Technical guidelines for estimation and reporting of VOC and NH <sub>3</sub> emission in the ECE region .....	4
2.3 Source category split .....	5
2.4 The 1990 EMEP Workshop on International Emission Inventories .....	5
3 DEVELOPMENT OF THE PROJECT UNTIL THE 1991 EMEP WORKSHOP ON EMISSION INVENTORY TECHNIQUES .....	6
3.1 Preparation of the text of the guidelines .....	7
3.2 Coordination of activities of emission experts groups .....	7
3.3 The 1991 EMEP Workshop on Emission Inventory Techniques .....	9
4 CONCEPT OF EMISSION FACTOR HANDBOOK .....	10
4.1 Description of an emission factor calculation ..	11
4.2 Content of emission factor handbook chapters ...	12
5 OUTCOME OF THE PROJECT .....	16
6 ACKNOWLEDGEMENTS .....	17

## HARMONIZATION OF EMISSION INVENTORING IN THE EMEP COUNTRIES

### 1 INTRODUCTION

In order to implement existing and to plan new emission reduction strategies it is necessary to obtain a complete, accurate and uniformly structured set of emission data. The above task requires harmonization of procedures with respect to the estimation and reporting of emission data. The harmonization of these procedures ensures the comparability of the emission data and is important in order to avoid duplication of emission reporting by national authorities within substantially different formats.

With a view to obtain harmonization of emission procedures, NILU has been contracted with a project from Umweltbundesamt. Initially, there were three major objectives of the project:

- 1) improvement of the guidelines for estimation and reporting of SO<sub>2</sub> and NO<sub>x</sub> emissions, presented and discussed at the 1988 EMEP Workshop on Emission Inventories Techniques, preparation of VOC guidelines, and organization of the emission inventory workshop in 1990,
- 2) preparation of methodology for selection and determination of emission factors, and
- 3) quantification of accuracy of emission estimation.

The project started with preparation of technical guidelines for reporting and estimation of SO<sub>2</sub>, NO<sub>x</sub> and VOC emissions in Europe. Then the objectives of the project have been extended by inclusion of NH<sub>3</sub> to a list of compounds for which guidelines should be prepared, as demanded by the ECE Working Group on Abatement Strategies.

In the next step, technical guidelines for reporting and estimation of emissions have been presented and discussed at the EMEP Workshop on International Emission Inventories in Regensburg, Germany, 3-6 July, 1990. In the light of the discussions and recommendations of the 1990 Workshop, it was necessary to further revise the objectives of the project. Major focus of the project has been directed on modification of the 1990 guidelines. Preparation of a draft of the revised guidelines for estimation and reporting of emission data for  $\text{SO}_x$ ,  $\text{NO}_x$ , NMVOCs,  $\text{CH}_4$ ,  $\text{NH}_3$ , and CO in the ECE region became the most important task of the project. The above task was very time-demanding, and therefore it has been agreed to abandon in the project quantification of accuracy of emission estimation. It was then necessary to prepare a workshop in 1991 in order to discuss the draft guidelines and recommend them to the Executive Body to the Convention on Long Range Transmission of Air Pollution.

## 2 DEVELOPMENT OF THE PROJECT UNTIL THE 1990 EMEP WORKSHOP ON INTERNATIONAL EMISSION INVENTORIES

The initial task of the project was a revision of the 1988 guidelines for estimation and reporting of  $\text{SO}_2$  and  $\text{NO}_x$  emissions and preparation of the guidelines for VOC and  $\text{NH}_3$  emissions. This task included also elaboration of source category split.

A questionnaire has been prepared requesting the EMEP countries to provide information on their basic emission factors related to the emission source data, the type of fuel, the energy rate, and the economic activity rate. However, it was necessary to concentrate on other additional tasks of the project, and therefore, the distribution of questionnaire on emission factors has been abandoned. Instead, it was agreed to prepare a guidance on the structure of emission factor handbook.

## 2.1 REVISION OF THE 1988 GUIDELINES FOR ESTIMATION AND REPORTING OF THE SO<sub>2</sub> AND NO<sub>x</sub> EMISSIONS

Major emphasis within this task of the project has been on completion of a list of SO<sub>2</sub> and NO<sub>x</sub> emission generating activities, definition of S compounds to be included in the reported data, and collection of information on parameters affecting the emissions of the above components.

It was concluded that all anthropogenic sources of sulphur and nitrogen oxides shall be taken into account. The emissions of N<sub>2</sub>O should not be considered.

## 2.2 TECHNICAL GUIDELINES FOR ESTIMATION AND REPORTING OF VOC AND NH<sub>3</sub> EMISSION IN THE ECE REGION

The VOC guidelines consisted of two parts: introductory part and estimation procedures. The first part included definition of VOCs, description of processes generating VOC emissions, aggregation of VOCs within various emission sources and estimation practices for VOC emissions. Estimation procedure has been given in the second part of the guideline.

A request for receiving information on NH<sub>3</sub> emissions has been expressed by the EMEP modellers. The NH<sub>3</sub> guideline described emission sources of ammonia, suggested methodologies for emission estimates, and outlined procedure for determining ammonia emissions.

The VOC and NH<sub>3</sub> guidelines have then been reviewed by experts from leading institutions in the field of VOC and NH<sub>3</sub> emissions to the atmosphere, such as TNO in the Netherlands, National Center for Atmospheric Research (NCAR) in Boulder, Colorado, Brookhaven National Laboratory in Upton, New York and the International Institute for Applied Systems Analyses (IIASA) in Laxenberg, Austria.

### 2.3 SOURCE CATEGORY SPLIT

Major emphasis was placed to elaborate source category split which should be:

- complete with respect to inclusion of all source categories,
- pollutant specific,
- easy to update the emission data, e.g. directly related to international statistics, and
- applicable by all Parties to the Convention.

A hierarchical source category split (SCS) with two level structure has been proposed to report emission data within the ECE region. The first level of the proposed SCS was recommended for reporting procedures, while the second level was meant to be used when collecting and sorting out emission data.

### 2.4 THE 1990 EMEP WORKSHOP ON INTERNATIONAL EMISSION INVENTORIES

Preparation of the 1990 Workshop included elaboration of the Workshop agenda, invitation of speakers and preparation for the round-table discussions. An organizational meeting was arranged at Umweltbundesamt. Two meetings were organized by CORINAIR at CEC in Brussels in order to prepare for continuation of work within the CORINAIR project. The meeting participants were informed about the preparations for the forthcoming workshop on International Emission Inventories.

The 1990 Workshop was attended by 47 participants from 18 countries and 4 international organizations. Conclusions and recommendations of the 1990 Workshop are presented in the workshop proceedings. Concerning the two major issues discussed at the 1990 Workshop, namely source category split and guidelines for reporting and estimation of SO<sub>2</sub>, NO<sub>x</sub>, VOC, and NH<sub>3</sub> emissions, the following has been agreed:

- further work is needed in order to accept the draft CORINAIR source category split presented at the Workshop, in order to be commonly applied by all Parties to the Convention. It was concluded to develop a source category split which will be harmonized between the CORINAIR split and the one elaborated within the project, and
- more work is needed in order to obtain guidelines for emission estimation and reporting, which could be used jointly for SO<sub>2</sub>, NO<sub>x</sub>, VOC, and NH<sub>3</sub> by all Parties to the Convention. The VOC and NH<sub>3</sub> guidelines were accepted as draft annexes and their final versions still to be prepared.

The 1990 Workshop recommended that for the estimation and reporting of national emissions of SO<sub>2</sub> and NO<sub>x</sub>, where appropriate, technical guidelines from the 1988 Workshop should be applied to the extent possible, while technical guidelines presented at the 1990 Workshop should be applied for VOC and NH<sub>3</sub>.

The 1990 Workshop also recommended that a group of emission experts to be established to follow-up preparation of guidelines on emission reporting and estimation for SO<sub>2</sub>, NO<sub>x</sub>, VOC, and NH<sub>3</sub>. A follow-up workshop on emission inventory techniques should then review the guidelines and recommend further action to the Steering Body for EMEP and the Executive Body.

### **3 DEVELOPMENT OF THE PROJECT UNTIL THE 1991 EMEP WORKSHOP ON EMISSION INVENTORY TECHNIQUES**

Three major tasks of the project were to:

- prepare a draft of the guidelines for estimation and reporting of emission data for SO<sub>x</sub>, NO<sub>x</sub>, NMVOCs, CH<sub>4</sub>, NH<sub>3</sub>, and CO in the ECE region,

- discuss the guidelines with a group of emission experts, and
- organize the 1991 EMEP Workshop on Emission Inventory Techniques, held in Regensburg, Germany, 2-5 July.

### 3.1 PREPARATION OF THE TEXT OF THE GUIDELINES

Guidelines for estimation and reporting of emission data for SO<sub>x</sub>, NO<sub>x</sub>, NMVOCs, CH<sub>4</sub>, NH<sub>3</sub>, and CO in the ECE region have been prepared. They consisted of three parts:

- procedures for reporting of emission data to the EB and EMEP,
- harmonization of emission inventory, and
- general aspects of emission estimates.

The annexes to the guidelines included:

- characterization of individual pollutants,
- nomenclature of emission generating activities,
- fuel nomenclature,
- main principles of the CORINAIR emission inventory system,
- list of reference documents, and
- example of emission reporting to EMEP.

The text of the guidelines was then reviewed and discussed by a specially established group of emission experts. The role of the project was to coordinate activity of this group.

### 3.2 COORDINATION OF ACTIVITIES OF EMISSION EXPERTS GROUP

The group met twice: at CITEPA in Paris, 19-20 November, 1990 and at NILU in Lillestrøm, 29-30 April, 1991. The group included 13 experts representing major European organizations (CEC, ECE, and OECD), national institutions involved in emission inventorying (German Umweltbundesamt, NILU, CITEPA,



and Warren Spring Laboratory), European-wide programmes on air pollution (EMEP and CORINAIR), and EUROSTAT.

One of the major tasks of the EMEP expert group was to prepare jointly a common source category split. In a view of four major source sector splits available to the expert group: a two level split elaborated within this project, ISIC, ECE Statistical Office sector split and the draft CORINAIR SNAP 90, to prepare a common source category split was the first step in the process of harmonization of emission inventorying in the ECE region. A request has been made to relate source category split to economic statistics as presented within an International Standard for Industrial Classification of all Economic Activities (ISIC). However, it was pointed out, that some of the emission source categories are widely scattered through the ISIC-sectorial split and may pose problem when reporting the emission data. Then the participants were informed about source classification used to report emission data to ECE Statistical Office. The meeting agreed that an engineering approach of source category split is of first priority for the future emission inventorying. Thus, the elaboration of a common source category split was a first direct link between the ECE and CEC in the field of emission inventorying.

During the first meeting, the experts agreed as to the structure of the guidelines. The guidelines were then prepared and distributed among the experts for improvements. During the second meeting, the experts exchanged their views on the content of the guidelines and discussed the programme of the 1991 Workshop.

After the second meeting the guidelines were revised and distributed prior to the 1991 Workshop.

### 3.3 THE 1991 EMEP WORKSHOP ON EMISSION INVENTORY TECHNIQUES

The main goal of the EMEP Workshop on Emission Inventory Techniques was to discuss and finalize the guidelines for estimation and reporting of emission data for SO<sub>x</sub>, NO<sub>x</sub>, NMVOCs, CH<sub>4</sub>, NH<sub>3</sub>, and CO in the ECE region.

It has been emphasized that the guidelines exemplify the harmonization of emission inventorying. One item of this harmonization is presentation of the source category split (SCS) for use by both ECE and CEC. The SCS to be used in the guidelines is based on engineering principles and is not related to the nomenclature used in socio-economic statistics. The 1991 Workshop concluded that a transfer matrix from the source related to an economic sector-oriented nomenclature is desirable but will require more detailed reporting procedures.

The 1991 Workshop approved the guidelines for further action to the EB. Two versions of the guidelines have been worked out: short version presented in the UN ECE documents and full version presented in the Workshop proceedings. The short version included reporting procedures, information on harmonization of emission inventorying and information on definition and type of sources as well as on emission generating processes for individual pollutants. This version was prepared considering the recommendations for the maximum length of the ECE documents. The short version has become an ECE document (EB.AIR/GE.1/R.65 from 8 July, 1991). Of course the short version was included in the full version without changes.

The 1991 Workshop recommended to establish a Task Force on Emission Inventory for reviewing present emission inventories and reporting procedures in order to achieve further improvement and harmonization.

#### 4 CONCEPT OF EMISSION FACTOR HANDBOOK

The major task of the project after the 1991 EMEP Workshop on Emission Inventory Techniques was to elaborate structure for a handbook of emission factors in a view to support methodologically the ongoing activities on the CORINAIR emission factor handbook.

In order to properly fulfil its function as a supportive tool to estimate emissions, the handbook of emission factors shall be:

- complete with respect to providing information on basic emission factors for all sources considered in a given emission inventory;
- homogeneous with source category split used in a given emission inventory,
- transparent with respect to explaining conditions or circumstances at which the factors have been obtained, and
- easy to update.

Basic emission factors mentioned above are the emission factors obtained for sources defined at the lowest source category split level or much more detailed (e.g. emission factors for various types of boilers). In contrary, the aggregate emission factors are at a given level of source category split, which are determined as a weighted average across the sub-level categories.

A handbook of emission factors can be organized as a set of chapters representing major source categories. Therefore, individual chapters shall closely follow a source category split used in a given emission inventory. As a result, a handbook of emission factors is to be ascribed to certain type of emission inventorying. A European handbook of emission factors shall be prepared for the European emission inventorying as outlined in the guidelines. Thus, the European handbook shall consist of 11 chapters representing 11 major source categories, as agreed at the 1991 Workshop. Of course, handbook of emission factors

shall be flexible with respect to inclusion of new chapters, in the same manner as the SCS to inclusions of new sources.

#### 4.1 DESCRIPTION OF AN EMISSION FACTOR CALCULATION

Emission factor provides information on a quantity of emission of a given air compound generated during consumption of a certain amount of raw materials, e.g. fuels or during production of a certain amount of industrial goods. Thus, the emission factor determines a quantity of emission related to a certain economic activity rate.

The factors presented in the European handbook shall be "basic" emission factors, which can then be used to calculate "aggregate" emission factors, if necessary.

The factors are given as "uncontrolled" emission factors, which can then be used to calculate emissions from sources with control equipment of different efficiency. If "controlled" emission factors are in use, an uncontrolled emission factor and a control efficiency must be given together with information whether primary or secondary, or both measures of control are in use. Information on control efficiency shall be given for secondary measures. For example, in the case of  $\text{NO}_x$  emissions from stationary sources employing secondary control measures (e.g. selective catalytic reactors), or in the case of  $\text{NO}_x$  emissions from mobile sources equipped with catalyzers (e.g. 3-way catalyzer), uncontrolled  $\text{NO}_2$  emission factors are to be provided with information on control efficiency.

Generally, any readily available information on the effects of different abatement measures has to be reported.

There are two major methods to estimate emission factors:

- on the basis of measurements of concentrations of a given pollutant in exhaust gases, or

- on the basis of chemical mass balances of a given pollutant during an emission generating process of concern.

Emission factors on the basis of measurements are intended to characterize a collective of sources.

Emission factors for mobile sources are often based on measurements carried out during special tests rather than during ordinary traffic.

As the measurements are often very expensive, emission factors for small point and area sources are often based on calculations of what amounts might be emitted.

In the case of emission factors based on measurements, it is of vital importance to assure that measurements are representative for a given emission source. It shall also be assured that the best available method of sampling and analytical analysis is used to minimize potential losses of a pollutant and to obtain required accuracy.

#### 4.2 CONTENT OF EMISSION FACTOR HANDBOOK CHAPTERS

Chapter of emission factor handbook should contain information presented in a homogeneous and complete manner. The information within a given chapter describing emission factors for a given source category shall include the following:

- 1) Short introduction outlining the scope of a given chapter and defining the source category to be considered.  
Description of a given source category should be included in each chapter. For example, the following information could be given when describing the source category "Public power, cogeneration, and district heating plants":

- definition of public power, cogeneration and district heating plants,
- type of power plants existing in the ECE region (e.g. single-fired, double-fired, and triple-fired), and
- type of fuels burnt in the ECE region to produce electricity and heat.

2) Description of processes generating emissions of air pollutants.

Within a given source category, there may be several processes generating emissions of air pollutants. These processes shall be defined and presented in a respective chapter.

3) Presentation of a range of basic emission factors of pollutants of concern for a given emission source with description of technological (process) conditions at which the factors were obtained.

In the case of emission factors obtained on the basis of measurements, e.g. in large electric power plants; a range of values for these factors should be presented together with information on process temperature and pressure.

Recently, the COPERT programme has proposed a range of emission factors for road traffic with data for hot start emission factors for gasoline passenger cars <3.5 tonnes, and separately for other vehicle categories, as well as for cold start emission factors.

4) Indication of an emission factor which can be regarded as a mean emission factor for a given emission source at defined conditions.

In the case that a range of emission factors can be presented for a given source, it is often necessary to indicate an emission factor which could best describe an average amount of pollutants generated by a unit of

production of industrial goods or of consumption of raw materials. In many of such cases, an average (arithmetic or geometric) over the range can be calculated.

- 5) Attempts to describe the accuracy of presented emission factors.

The limitations and applicability of emission factors must be understood. To give some notion of the accuracy of the factors for a specific process, each process can be ranked as "A", "B", "C", "D", or "E". For a process with an "A" ranking, the emission factor should be considered excellent, i.e., based on field measurements of a large number of sources. A process ranked "B" should be considered above average, i.e. based on a limited number of field measurements. A ranking of "C" is considered average; "D", below average; and "E", poor. These rankings are to be presented throughout the handbook chapters.

- 6) Presentation of methods allowing to find out appropriate emission factors with respect to varying conditions, e.g. models or equations allowing for calculation of emission factors, as well as diagrams, tables, etc., showing dependence of emission factors on temperature, pressure, volume of exhaust gases and some surrogate parameters, such as boiler load.

Various parameters can influence a value of emission factor for a given source. Major parameters have been presented in the full version of the guidelines for estimation and reporting of emission data for  $\text{SO}_x$ ,  $\text{NO}_x$ , NMVOCs,  $\text{CH}_4$ ,  $\text{NH}_3$ , and CO in the ECE region, included in the proceedings of the 1991 EMEP Workshop on Emission Inventory Techniques. There are models allowing to recalculate on emission factor with respect to changing ambient air and technological conditions. For example, starting a cold engine and driving for some distance with an engine not in thermal equilibrium have a profound effect on emissions. Correction factors for this and other phenomena have been developed (e.g. the

COPERT programme) and need to be included to the emission factor handbook. A set of equations has been prepared for estimation of natural VOC emissions from forests in Europe. The influence of the load factor has been investigated by several experts and the load correction factors as a function of load have been prepared. Models allowing for elaboration of emission factors for actual traffic conditions have been developed, and the results of their applications should be summarized in the chapter of the handbook describing mobile emissions.

Investigations to assess influence of various parameters on emission factor values have resulted in elaboration of several diagrams and tables, showing for example impact of ambient temperature on evaporative emissions from mobile sources, or impact of fuel composition burned in selective vehicle types on emission factors for mobile sources, mowing with various speeds. There are also data which are indirectly relevant to the value of emission factors, such as a diagram showing a mileage against vehicle age in various countries. All the above diagrams and tables should be included either directly in the respective chapter or as an annex to the handbook.

- 7) Information on practical means to verify to some extent the suggested emission factors.  
There are some methods to verify emission factors suggested for a given source category. Plausibility checks should be approached with comparison of emission factors proposed in Europe.
- 8) Information on most frequently used methods for air pollution abatement with indication of control efficiency, which can be obtained.



Each chapter should be accompanied by a short survey of techniques applied to control emission. Both primary and secondary measures to control emissions shall be briefly described with emphasis on efficiency of reduction, cost, and benefits.

- 9) List of reference documents to be examined for a given source category/ chapter of the handbook.

The reader must be cautioned not to use the emission factors indiscriminately.

## 5 OUTCOME OF THE PROJECT

The final product of the project, the guidelines for estimation and reporting of emission data for  $\text{SO}_x$ ,  $\text{NO}_x$ , NMVOCs,  $\text{CH}_4$ ,  $\text{NH}_3$ , and CO in the ECE region have been accepted by EB at the meeting in Geneva during 18 through 22 November 1991 (ECE/EB. AIR/29 from 18 December 1991).

Major achievements of the project are presented in two documents:

- proceedings of the EMEP Workshop on Emission Inventory Techniques, Regensburg, Germany, 2-5 July, 1991 (EMEP/CCC-Report 1/91, edited at the Norwegian Institute for Air Research, Lillestrøm, Norway), and
- proceedings of the EMEP Workshop on International Emission Inventories, Regensburg, Federal Republic of Germany, 3-6 July, 1990 (EMEP/CCC-Report 7/90, edited at the Norwegian Institute for Air Research, Lillestrøm, Norway).

The above two documents contain information illustrating development of the project and its role in the process of harmonization of emission inventorying in the ECE region. It

should be underlined that the major results of the project are presented in the proceedings of the 1991 EMEP Workshop on Emission Inventory Techniques.

The third document of the project is this final report informing not only about the progress of the project but also focusing on the structure of European handbook of emission factors, as the present CORINAIR handbook needs to be restructured, completed, and subsequently updated.

## 6 ACKNOWLEDGEMENTS

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