Emission estimation methods for particulates: the CEPMEIP emission factor database

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ABSTRACT

As a consequence of the adoption of the multi pollutant protocols (also called Gothenburg protocol) within the framework of UNECE's Convention on Long Range Transboundary Air Pollution (CLRTAP), parties to this convention have to report annual emissions of particulates as from December 2001 for the previous year.

Since emission factors are not readily available for many activities and fuels, a project called "Coordinated European program on particulate matter emission inventories, projections and guidance" CEPMEIP was initiated within the EMEP working programme and supported by the European Environment Agency. This project will also provide information and expertise as part of the technical preparation of several European Union policy activities with respect to particulate matter emissions.

The CEPMEIP project resulted in:

1) An emission inventory for the year 1995 on PM2.5, PM10 and TSP for the whole UNECE/EMEP region
2) A set of 2400 documented default emission factors, that can be used by national experts in preparing the 2000 inventory
3) An open web site (http://www.mep.tno.nl/emissions) with query functionality in this database.

This paper will present the results of this project with emphasis on approach chosen, the structure of the resulting database, the source and quality of the emission factors and the applicability in different countries. In addition PM 2.5 and PM10 emission density maps for Europe will be presented and contributions of different source sectors will be discussed. All emission factors and background information are available through the Internet.

INTRODUCTION

In 1979 the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP) was adopted. This convention aims at decreasing the adverse effects of long-range transboundary air pollutants. Under the convention a series of protocols has been negotiated and agreed:

1) The 1985 Helsinki Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30%;
2) The 1988 Sofia Protocol concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes;
3) The 1991 Geneva Protocol on the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes;
4) The 1994 Oslo Protocol on Further Reduction of Sulphur Emissions;
5) The 1998 Aarhus Protocol on Heavy Metals;
6) The 1998 Aarhus Protocol on Persistent Organic Pollutants;
7) The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone ("Multi-pollutant/Multi-effect protocol").

Work towards the next revision of the Multi-pollutant/Multi-effect CLRTAP protocol, due in 2004, will need to look at particulate matter.

In addition several activities of the European Commission need data on the emissions of particulates:

1) The European Commission is due to report to Parliament and Council by the end of 2003 on the implementation of Directive 1999/30/EC (the first daughter Directive under the Air Quality Framework Directive). The report will cover the question of future limit values for particulate matter, including the issue of whether ambient air quality limit values should be set for some measure of particulate matter other than PM10. It will have to consider the contribution to ambient concentrations of long-range transboundary formation and transport of particles as well as the contribution of local emissions.
2) The Commission plans to follow the report on Directive 1999/30/EC with a second more general report by the end of 2004 under the proposed new Clean Air for Europe Programme (CAFE). The aim of this programme will be, as far as practical, to develop integrated strategies for tackling remaining air quality problems. The scope of the programme is still under discussion.
3) In the Auto Oil 2 programme (AOP2) of the European Commission, performed in 1998-2000, information on particulate emissions and projections was used extensively. However, it was recognised that there is an urgent need for more recent and reliable PM emission data, in particular from road transport, for modelling on more detailed spatial level (regional and urban) and for integrated assessment at the urban scale

Against this background a "*Coordinated European programme on Particulate Matter Emission Inventories, Projections and guidance*" (CEPMEIP) was initiated as a joint activity by both the convention and the European Environment Agency.

This programme aimed as a first step to develop default methods and emission factors for the use of national experts when submitting particulate matter emission inventories within the CRLTAP/EMEP. This was achieved by producing an inventory for Europe for the year 1995, inbcluding full documentation of origin of activity data and emission factors and by making this information available on an open web site. This paper presents part of the methods used and shows some results.

METHODS

General

The CEPMEIP project made use of the well-established network of national emission inventory experts working closely together within the European Environment Agency's CORINAIR programme. This programme has been started in the mid eighties to collect transparent and consistent European scale emission inventories. It evolved towards a system of tools and databases that supports the European countries in fulfilling their commitments in European legislation and international conventions and protocols. The CORINAIR programme has closely worked together with the Task Force on Emission Inventories and Projections (TFEIP) within the CRLTAP/EMEP activities.

As a first step in the project the experts in European countries were approached to collect all available information within Europe. Table 1 summarizes the response. Sixteen countries provided data on measurements of individual particulate matter sources and ten countries provided a full inventory.

Table 1 Information on particulates emissions obtained from national experts

Measurement data	Inventories
Belarussia	Finland
Belgium	France
Bulgaria	Germany
Czech Republic	Italy
Finland	Norway
Germany	Poland
Greece	Sweden
Hungary	Switzerland
Italy	The Netherlands
Poland	United Kingdom
Romania	
Russia	
Slovak Republic	
Spain	
The Netherlands	
United Kingdom	

Emission factors

This information was combined with an earlier European particulates emissions inventory (Berdowski et al. ref (1)) to derive a set of emission factors for a very detailed sector split. In total emission factors have been derived for 150 activities within the 10 major source sectors and a maximum of 15 fuels (see Table 2).

Table 2 Overview activities and fuels defined in the CEPMEIP particulate matter emission inventory per main source sector as defined by the Guidebook (2).

Source sector	Number of sub-sectors	Number of different fuels
01: combustion in energy and transformation industry	5	15
02: non-industrial combustion plants	2	14
03: combustion in manufacturing industry	21	14
04: production processes	45	none
05: extraction and distribution of fossil fuels a	2	none
06: solvent and other product use	6	none
07: road transport	57	3
08: other mobile sources and machinery	4	12
09: waste treatment and disposal	4	none
10: agriculture	4	None

The data as provided by country experts and as derived from the literature were used to estimate default emission factors for each relevant activity and fuel combination. Since the particulates emissions are quite dependent on the equipment and process parameters, for most sectors we decided to derive emission factors for different levels of "sophistication", resulting in different levels of emissions. These levels are given in Table 3. All in all we derived over 800 emission factors for particulates both as total suspended particles (TSP) and as the PM10 and PM2.5 fraction thereof.

Table 3 Distinction between different "levels":

Emission level	Description
Low	Modern facility, well maintained, best available technology (BAT) …
Medium	Average age, well maintained …
Medium high	Older equipment, well maintained …
High	Old facility, poor maintenance …

Since we based the emission factors on data delivered by country experts, we also have information on the sophistication level installed for each sector in most countries, enabling us to select the appropriate emission level for each activity in each country.

Activity data

This information was used together with publicly available activity data, from sources as summarized in Table 4.

Table 4 Overview of data sources for activity data used in the 1995 particulates emission inventory for Europe

Sector	Data source	Reference
Energy	IEA	(8)
Industry	UN statistics and Industrial Branch Organisations	(9)
Traffic	Samaras (2001)	(11)
Agriculture	FAO	(10)
Consumers	UN statistics	(9)
Waste	TNO data, based on Coopers&Lybrand e.o.	(14), (15), (13)

Availability of the data

Detailed data obtained in this project, together with relevant background documentation, is made available via the Internet (URL http://www.mep.tno.nl/emissions). All European national experts have been informed on this availability on time to allow them to use the default emission factors while preparing the national particulates inventories for 2000, due in January 2002.

RESULTS

Emission factors

This paper does not allow presenting all default emission factors derived within the project. This section therefore gives two examples of the emission factors as derived within the project. Table 5 shows the exhaust emission factors for road traffic and Table 6 for the use of some products by consumers.

Table 5 CEPMEIP PM2.5 default emission factors for road traffic by vehicle type, fuel and emission abatement technology (kg/million km).

Vehicle type	Driving mode	Abatement technology	Diesel	Gasoline	LPG
Passenger cars	Highway	Pre ECE	150.0	41.0	25.0
		Open Loop		3.3	
		Imp. Conv.		24.0	
		ECE 15-04		20.0	
		ECE 15-03		29.0	
		ECE 15-02		41.0	
		ECE 15-00/01		41.0	
		91/441	100.0	0.7	0.0
		2-Stroke		120.0	
	Rural	Pre ECE	70.0	44.0	30.0
		Open Loop		2.6	
		Imp. Conv.		18.0	
		ECE 15-04		20.0	
		ECE 15-03		29.0	
		ECE 15-02		44.0	
		ECE 15-00/01		44.0	
		91/441	50.0	0.7	0.0

Table 5 CEPMEIP PM2.5 default emission factors for road traffic by vehicle type, fuel and emission abatement technology (kg/million km).

Vehicle type	Driving mode	Abatement technology	Diesel	Gasoline	LPG
		2-Stroke		120.0	
	Urban	Pre ECE	100.0	63.0	40.0
		Open Loop		4.4	
		Imp. Conv.		30.0	
		ECE 15-04		30.0	
		ECE 15-03		42.0	
		ECE 15-02		63.0	
		ECE 15-00/01		63.0	
		91/441	80.0	1.1	0.0
		2-Stroke		120.0	
Light duty vehicles	Highway	Conventional	400.0	40.0	
		91/542/EEC Stage I	150.0	0.7	
	Rural	Conventional	200.0	40.0	
		91/542/EEC Stage I	60.0	0.7	
	Urban	Conventional	300.0	40.0	
		91/542/EEC Stage I	100.0	0.9	
Heavy duty vehicles	Highway	Conventional	500.0	400.0	
		91/542/EEC Stage I	300.0	400.0	
	Rural	Conventional	400.0	400.0	
		91/542/EEC Stage I	300.0	400.0	
	Urban	Conventional	750.0	400.0	
		91/542/EEC Stage I	500.0	400.0	
Motorcycles 2-stroke	Urban	Conventional		120.0	
	Rural	Conventional		120.0	
	Highway	Conventional		120.0	
Motorcycles 4-stroke	Urban	Conventional		40.0	
	Rural	Conventional		40.0	
	Highway	Conventional		40.0	

Table 6 CEPMEIP default emission factors for PM10: product use

Source name	Unit	Low	Medium	Medium high	High
Construction-related activities, dwellings	kg/1000 m2	107.6	107.6	107.6	107.6
Construction-related activities, utilities	kg/1000 m2	61.3	61.3	61.3	61.3
Commercial and residential meat frying	kg/ton meat consumed	1.3	1.3	1.3	1.3
Commercial and residential barbecue's, emission from food heating	kg/ton meat consumed	40.0	40.0		
Tobacco smoking	kg/ton tobacco	40.0	40.0	40.0	40.0
Use of fire works	g/inhabitant	35.0	35.0	35.0	35.0

Within the CEPMEIP project it is assumed that all exhaust related particulates emissions form road traffic are emitted as particles smaller then 2.5 ìm (PM2.5). In addition to that also default emission factors for brake and tyre wear have been derived.

Emissions Inventory for 1995

European particulate emissions in 1995

Using the default emission factors of CEPMEIP and the activity data for 1995 as derived form the information sources listed in Table 4 an emission inventory for all of Europe for the year 1995 was produced. The 44 countries, included in this study are listed in Table 7. These countries include the present 15 member states of the European Union, the 13 countries that are at present in the process of accession to EU membership and 16 other countries. This latter group includes three Western European countries (Norway, Switzerland, Iceland) that are not members of the European Union and a number of countries in Eastern Europe, mainly in the former Soviet Union and in the former Yugoslavia. This group therefore is rather inhomogeneous.

Table 7 Countries included and country grouping in the CEPMEIP 1995 inventory for particulate matter.

Group	Countries
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
Accession	Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovak Republic, Slovenia, Turkey
Other	Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Croatia, Federal Republic of Yugoslavia, Former Yugoslav Republic of Macedonia, Georgia, Gibraltar, Iceland, Norway, Republic of Moldova, Russia, Switzerland, Ukraine

Figure 1 Emissions of particulates in Europe in 1995

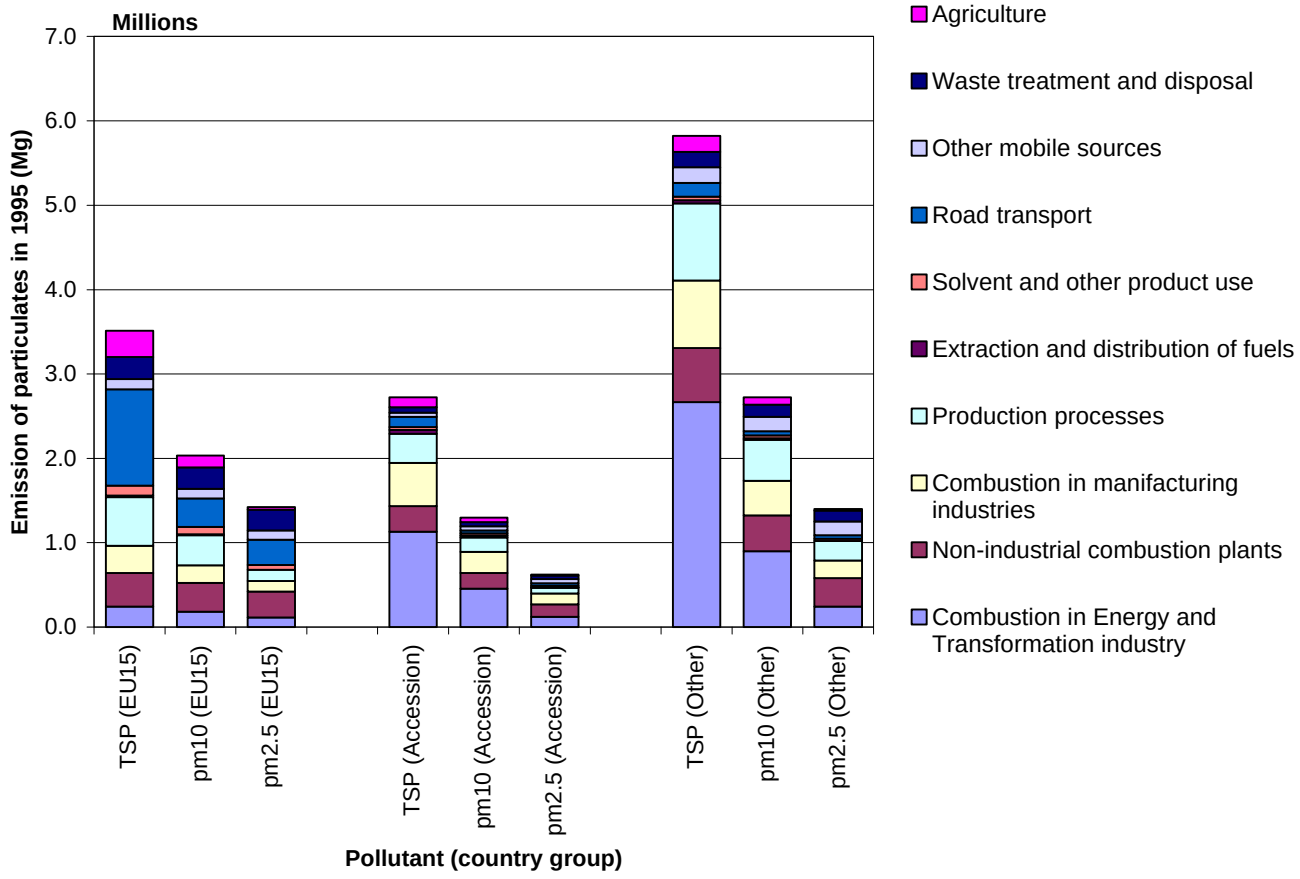

Figure 1 presents the total emissions by source sector of total suspended particulates, PM10 and PM2.5 for the three country groups of Table 7 respectively. Western European countries, as represented by the EU15, show a remarkable difference from the accession countries and the other countries

1. In the EU15 the size distribution of particulates shows a larger contribution of the smaller particles. In the EU15 PM10 contains about 60% and PM2.5 about 40% of the total mass in the emission of suspended particulates. In the accession these are about 50% and 25% respectively.

   Bearing the fact that, the smaller the particles are, the more dangerous they will be for human health, we have to conclude that the particulates emitted in Western Europe are more harmful than the ones emitted in Central and Eastern Europe.

2. The EU15 have a relatively low contribution of stationary combustion to the emissions of particulates as compared to the accession countries and the other countries. Stationary combustion causes about 27 % of TSP emission in the EU15, whereas the same source sectors contribute about 70 % of the TSP emissions in the rest of Europe.

3. Emissions form mobile sources show a different picture: the contribution in Western Europe is about 36 % and in Eastern Europe about 6 % of total suspended particulates emissions.

Table 8 shows that the per capita emissions of particulates also differ quite substantially between the three groups of countries. For both total suspended particulates and for PM10 the emissions per inhabitant in Western Europe are about half of those in Eastern Europe. The difference for PM2.5 appears to be much smaller.

Table 8 Per capita emissions of particulates in European countries in 1995 (kg/inhabitant).

	TSP	PM10	PM2.5
European Union Member states (EU15)	9.4	5.5	3.8
Accession countries	16.3	7.8	3.7
Other countries	22.9	10.7	5.5

DISCUSSION AND CONCLUSIONS

The project results in a complete set of emission factors for particulate matter that can be and is used by European countries while preparing their national particulates emissions in response to the requirements of the UNECE Convention on Long Range Transboundary Air Pollution. All emission factors and background information are available through the Internet (http://www.mep.tno.nl/emissions).

This project thus contributes to

1) A better understanding of the extent of the air pollution by particulates in Europe;
2) The development of comparable national emission inventories for particulates throughout Europe.

Within the CEPMEIP programme a complete emission inventory for particulates (TSP, PM10 and PM2.5) for Europe in 1995 has been compiled. In Central and Eastern Europe stationary combustion sources constitute a larger part of the emissions as compared to Western Europe. Mobile sources (diesel cars) are relatively more important in Western Europe.

This difference results in a relatively higher share of the smallest particles in Western Europe, where PM2.5 amounts to more then one third of the total particulate mass emitted. In Central and Eastern Europe this is about one fourth.

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