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EMEP CONTRIBUTION TO THE PREPARATORY WORK FOR THE REVIEW OF THE CLRTAP PROTOCOL ON HEAVY METALS

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Introduction

The Protocol on Heavy Metals (HMs) to the 1979 Convention on Long-Range Transboundary Air Pollution (CLRTAP) was signed in 1998 by 35 countries and the European Community. The Protocol entered into force in December 2003. As of 5 September 2005, 26 countries and the European Community (EC), i.e. 27 of 49 Parties to the CLRTAP ratified the Protocol.

The objective of the Protocol is “to control emissions of heavy metals caused by anthropogenic activities that are subject to long-range transboundary atmospheric transport and are likely to have significant adverse effects on human health or the environment” (Article 2).

The Protocol targets three metals – lead (Pb), cadmium (Cd) and mercury (Hg).

Parties to the Protocol assumed obligations (Article 3.1) to reduce their total annual emissions into the atmosphere of lead, cadmium and mercury from the level of the emission in the reference year. Parties are also obliged (Article 3.5) to develop and maintain emission inventories for these metals.

In accordance with Article 7.1, Parties within the geographical scope of EMEP annually report through the UNECE Secretariat to EMEP information on the levels of emissions of lead, cadmium and mercury. Parties in areas outside the geographical scope of EMEP make available similar information to the Executive Body (EB) if requested to do it so. In addition, many Parties voluntarily collect and report information on their emissions of several other heavy metals, taking into account the guidance on the methodologies and the temporal and spatial resolution of the Steering Body to EMEP and the Executive Body. EB decision 2002/10 on emission data reporting under the Convention and the Protocols in force [ECE/EB.AIR/77/Add.1, Annex XI] identifies 6 other metals - arsenic [As], chromium [Cr], copper [Cu], nickel [Ni], selenium [Se], zinc [Zn]) - to be included voluntarily, if a party considers this appropriate.

1. OVERVIEW OF EMISSIONS

Parties to the CLRTAP annually report to the UNECE Secretariat data on emissions of pollutants, including heavy metals, following the Guidelines for estimation and reporting emission data [EB.AIR/GE.1/2002/7], approved by the 20th session of the Executive Body [ECE.EB.AIR/87/Add1, Annex I). In 2005 and in previous years data on emissions of lead, cadmium and mercury at least for one year in the period of 1990-2003 were reported as follows: lead 39 (80%) of 49 Parties to the CLRTAP; cadmium – 36 (73%) Parties; mercury – 37 (76%) Parties. Data for each year in the period under consideration were reported by 18 countries (for lead) and 17 countries (for cadmium and mercury) (Fig. 1.1).

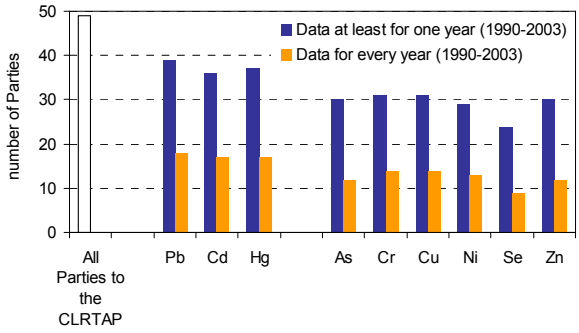


Fig. 1.1. *Official submissions of national HM emission totals*

Voluntary data on emissions of other metals at least for one year in the period of 1990-2003 were reported by the following numbers of Parties to the CLRTAP as follows: arsenic and zinc – 30 (61%), chromium and copper – 31 (63%), nickel – 29 (59%) and selenium – 24 (49%) (Fig. 1.1).

Most of the European countries and Canada reported national emissions by sectors of sources in SNAP (Selected Nomenclature for sources of Air Pollution) codes or in NFR (Nomenclature for Reporting) codes.

Data on the spatial distribution of Pb, Cd and Hg emissions over the 50x50 km cells of the EMEP grid were reported by 18 countries: Austria, Belarus, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Hungary, the Netherlands, Norway, Poland, Russian Federation, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

The officially reported emission data (total national emissions, sector emissions, and gridded emissions) are located in the EMEP database (http://webdab.emep.int/).

The review on emissions of lead, cadmium and mercury is available in the EMEP/MSC-West report [*Vestreng et al*., 2005]. Timeliness of reporting, data completeness, emission uncertainties and key emission sources are analyzed in the report.

1.1. Heavy metals included in the HMs Protocol (Pb, Cd, Hg)

Emission trends

For the EMEP region, the changes in Pb, Cd and Hg emissions for the period of 1990-2003 were estimated on the basis of the total emissions of 24 countries, which reported their national emission data for each of the metals at least for both 1990 and 2003. These countries are Austria, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Hungary, Italy, Latvia, Lithuania, Monaco, the Netherlands, Norway, Republic of Moldova, Slovakia, Slovenia, Spain,

Sweden, Switzerland and the United Kingdom (Fig. 1.2). Data for each year of the period were reported by 17 of these 24 countries. Data that were not reported by 7 countries for some years of the considered period were assessed by linear interpolation between the official data.

As shown in Figure 1.3, the total emissions from the 24 countries between 1990 and 2003 have significantly decreased for all the three metals. Emissions of lead have decreased by about 92% (or 13 times). Such significant reductions of lead emissions occurred mainly due to restrictions and bans of the usage of leaded gasoline in many countries. Emissions of cadmium have decreased by about 51% (or twice). Emissions of mercury have decreased by about 57% (or 2.3 times). A summary of major source categories where emission reductions have occurred is included in the section "Key sources of emissions" of this chapter and Annex B.

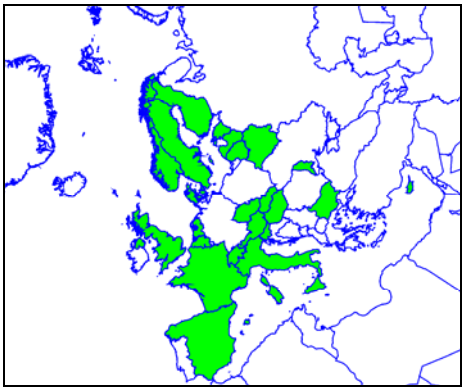


Fig. 1.2. *Countries (highlighted) that reported data on emissions of lead, cadmium and mercury at least for both 1990 and 2003*

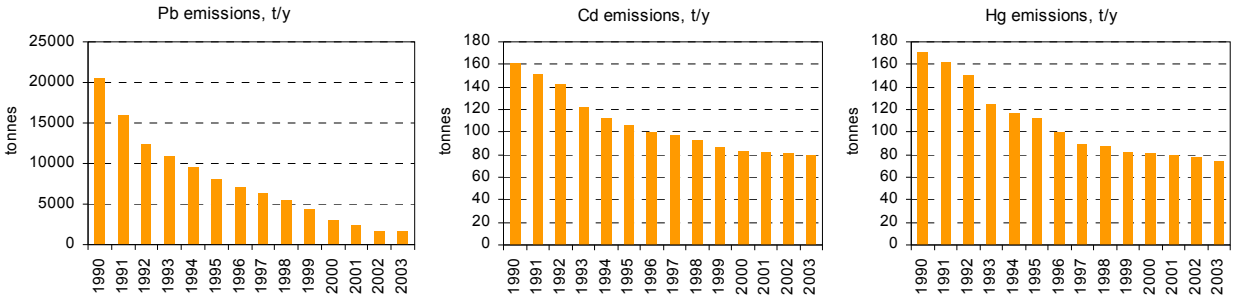


Fig. 1.3. *Reported emissions of lead, cadmium and mercury in the EMEP region (24 countries)*

Emission reductions from 1990 to 2003

The extent of emission reductions varies significantly from country to country. The relative reduction of emissions [$100*(E_{1990}-E_{2003})/E_{1990}$ (%), where E_{1990} and E_{2003} equal emissions in 1990 and 2003, respectively] was assessed for the countries that reported official data for both 1990 and 2003.

Figures 1.4-1.6 show the relative and absolute reductions of lead, cadmium and mercury emissions for the period of 1990-2003 in the 24 countries of the EMEP region and Canada based on reported data. Emissions data for 2003 are not available for the U.S.A., therefore U.S.A. is not presented in Figures 1.4-1.6. Emissions of lead have decreased in all the countries varying from about 31% (Latvia) to 99% (Monaco). The lowest reduction of cadmium is seen in Slovenia (4%), the highest – in Republic of Moldova (96%). In Spain and Cyprus emissions of cadmium have increased by 29% and 345% respectively based on reported data. The reductions of mercury emissions vary from about 17% (Slovenia) to 92% (Republic of Moldova). In Spain and Belarus, mercury emissions have increased by about 9% and 26% respectively. In Cyprus, emissions of mercury have increased almost 5 times, and in Lithuania – almost 20 times based on the reported data.

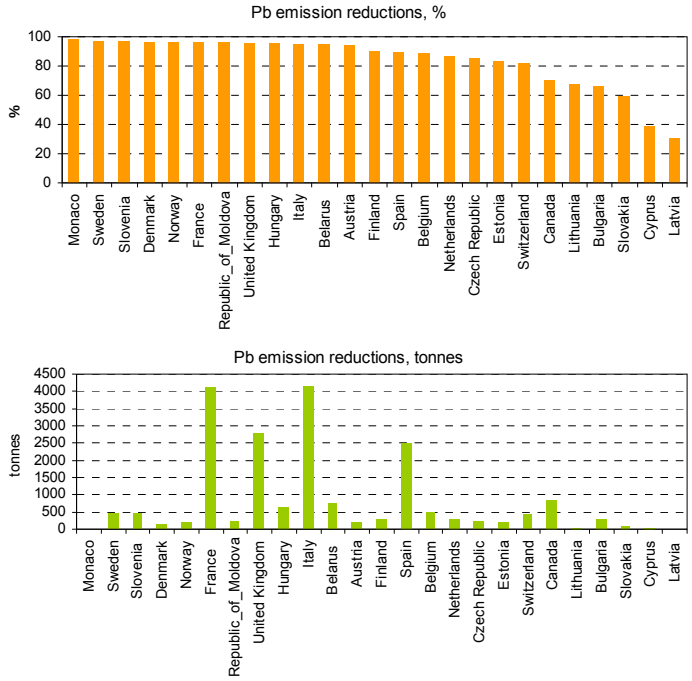


Fig. 1.4. *Reductions of lead emissions in the 24 countries of the EMEP region and Canada for the period of 1990-2003 based on official data reported for both 1990 and 2003*

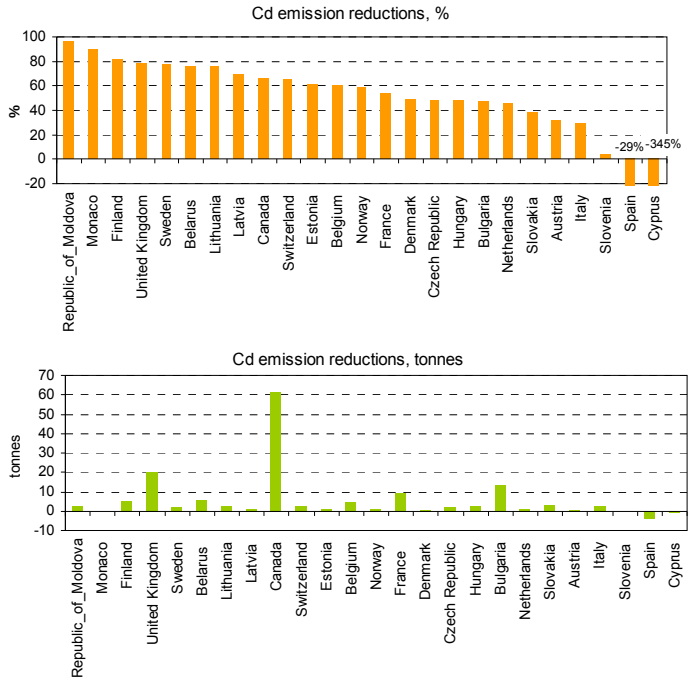


Fig. 1.5. *Reductions of cadmium emissions in the 24 countries of the EMEP region and Canada for the period of 1990-2003 based on official data reported for both 1990 and 2003*

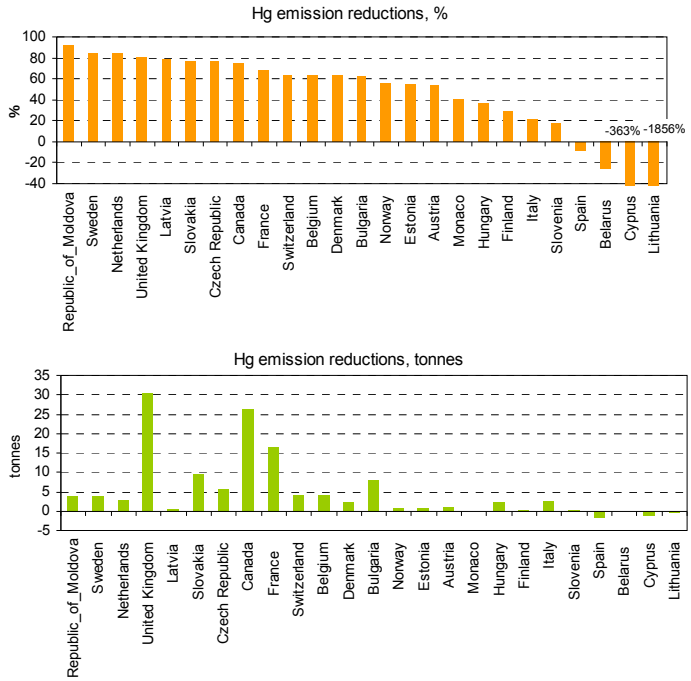


Fig. 1.6. *Reductions of mercury emissions in the 24 countries of the EMEP region and Canada for the period of 1990-2003 based on official data reported for both 1990 and 2003*

Data on the reductions on heavy metal emissions for each country that reported data for both 1990 and 2003 are given in Annex A.

Key sources of emissions

The identification of key emission sources in terms of their estimated contribution to the total current emissions is important for the development of potential future strategies to further reduce emissions both in individual countries and in the EMEP region as a whole.

The most complete data on Pb, Cd and Hg emissions by source sectors in NFR[1] codes for both 1990 and 2003 were reported by 8 European countries (Austria, Belgium, France, the Netherlands, Norway, Spain, Sweden, and the United Kingdom).

Several source sectors were included so that their contribution to the total emissions of the considered countries would be greater than 90% both in 1990 and 2003.

Figure 1.7 shows estimates of lead emissions in the nine main source sectors in 1990 as well as emission estimates in the same sectors in 2003. Their contribution to the total emission of 8 countries is about 99% in 1990 and 93% in 2003.

In 1990 the maximum contribution to the total lead emission was from the sector “Road Transportation” (about 85%). In 2003 its contribution to the total emissions dropped to about 6%. In 2003 the sector “Metal Production” became a leading source (about 28%).

1990 **2003**

[1] Nomenclature for Reporting (Guidelines for estimating and reporting emission data (EB.AIR/GE.1/2002/7))

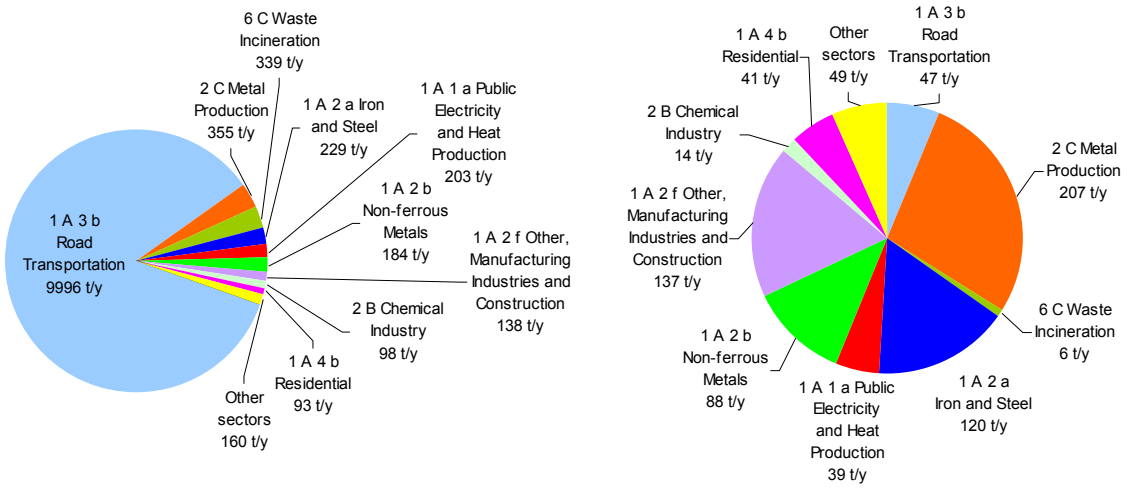


Fig. 1.7. *Changes of lead emissions in source sectors for the period of 1990-2003 (8 countries)*

Figure 1.8 shows estimates of cadmium emissions in the nine main source sectors in 1990 as well as emission estimates in the same sectors in 2003. Their contribution to the total emission of 8 countries is about 91% in 1990 and in 2003.

In 1990 the maximum contribution to the total cadmium emission was from the sector “Waste Incineration” (about 20%). In 2003 the sector “Metal Production” gained the lead (about 26%).

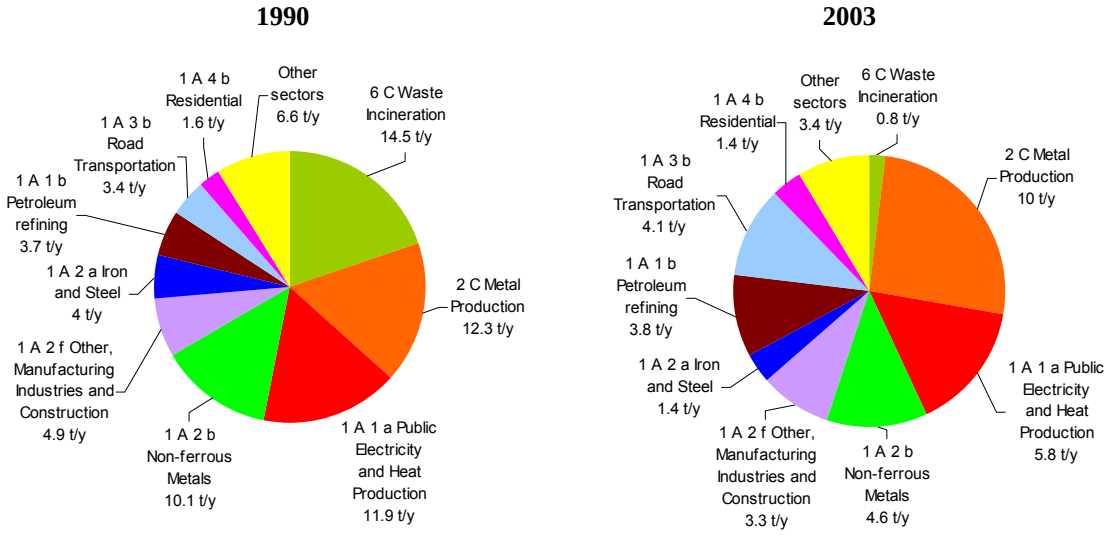


Fig. 1.8. *Changes of cadmium emissions in source sectors for the period of 1990-2003 (8 countries)*

Figure 1.9 shows estimates of mercury emissions in the nine largest source sectors in 1990 as well as emission estimates in the same sectors in 2003. Their contribution to the total emissions of 8 countries is about 92% in 1990 and 91% in 2003.

In 1990 the maximum contribution to the total mercury emissions was from the sector “Public Electricity and Heat Production” (about 29%). In 2003 the sector “Other, Manufacturing Industries and Construction” became the largest source of emissions (about 31%). The sector “Public Electricity and Heat Production” became the second largest source (about 29%).

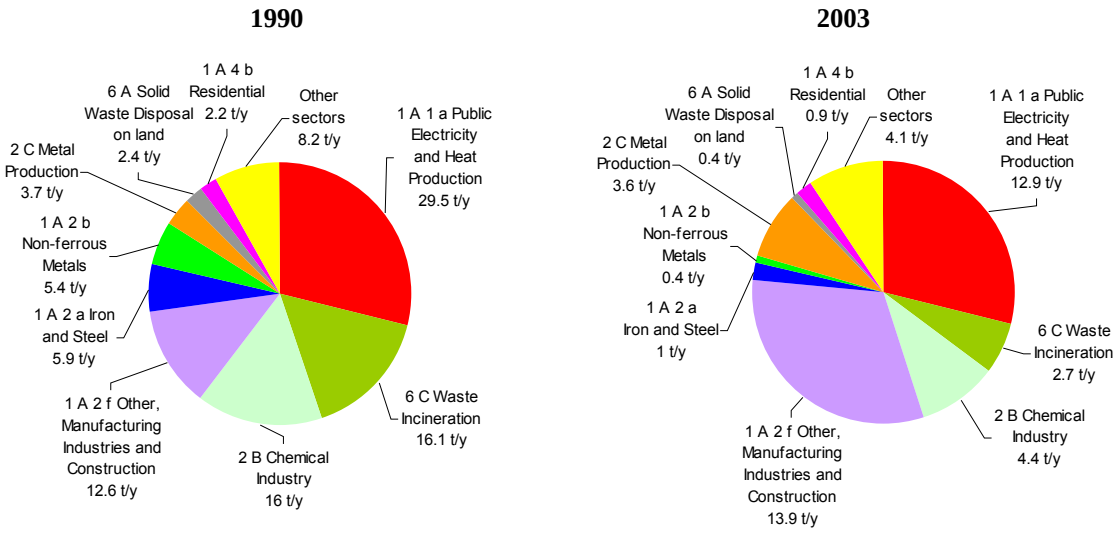


Fig. 1.9. *Changes of mercury emissions in source sectors for the period of 1990-2003 (8 countries)*

Key sources of heavy metal emissions were identified only for a small group of countries. With this in view, the outcome cannot be projected on the whole EMEP region and should be treated only as approximate.

Data on lead, cadmium and mercury emissions by source sectors are given in Annex B.

Recalculations of official emission data

Recalculations were done by various countries following the Guidelines for estimating and reporting emission data [EB.AIR/GE.1/2002/7], which states "recalculations of previously submitted estimates of emissions as a result of changes in methodologies, changes in the manner in which emission factors and activity data are obtained or used, or the inclusion of new sources which have existed since the base year but were not previously reported should be reported for the base year and all subsequent years, up to the year in which the recalculations are made and cover all inventory data" (para 28). In 2005, 15 countries recalculated previously reported data on Pb, Cd and Hg for all or for selected years in the period of 1990-2002. Tables 1-3 illustrate the changes (in percentage terms) in the total national emissions of Hg, Cd, and Pb after the recalculations [$100*(E_{current} - E_{previous})/E_{previous}$ (%), where $E_{current}$ and $E_{previous}$ are current and previous emissions in the specific year, respectively]. Negative values in the tables indicate a decrease in emissions after the recalculations, while positive values illustrate an increase in emissions.

The maximum changes in emissions of lead that resulted from the recalculation are noted in Latvia (Table 1.1). The changes in emissions of lead in Latvia for the period of 1990-2002 vary from minus 91% (1993) to plus 56% (2000). For example, the previous value of lead emission in Latvia in 1990 amounted to 108 tonnes. After recalculation, the emission value dropped down to 10 tonnes, i.e. 11 times.

The highest increase in cadmium emissions due to the recalculation is estimated to be 44% (United Kingdom, 2002). The maximum reduction after-recalculation is 31% (Switzerland, 2000).

As for mercury, the highest decrease of the emission estimate is 28% (Norway, 2002). The maximum increase after-recalculation is 13% (the Netherlands, 1990).

As shown in these tables, the recalculated value of emissions can vary significantly. In some cases the previous emission values can differ from the current recalculated values by an order of magnitude.

Table 1.1. *Changes in the official emissions of lead after the recalculations, %*

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Austria	1	2	2	2	1	<0.5	<0.5	-1	<0.5	1	1	-4	-2
Belgium											-1		-36
Canada	<0.5	<0.5	<0.5	<0.5	<0.5	-1	<0.5	-1	-1	-1	-1	-1	-1
Denmark	-1	-1	-1	-1	-17	-11	-6	-4	-2	<0.5	-1	-1	<0.5
France	1	1	1	1	2	2	2	2	3	3	12	11	8
Hungary													1
Italy	<0.5	<0.5	<0.5	<0.5	<0.5	-1	-1	-1	<0.5	<0.5	-1	-1	-2
Latvia	-90	-85	-88	-91	-89	-90	-86	-77	-74	-19	56	-20	-19
Netherlands	<0.5					<0.5					<0.5	<0.5	<0.5
Norway	1	1	1	1	5	5	13	14	14	16	19	24	20
Slovakia	-1		<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	10
Spain	-1	-1	-1	-1	-1	1	-1	-2	-2	-3	-4	-26	-7
Sweden	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-4	<0.5	<0.5	<0.5	<0.5	1	-1
Switzerland											-11		
United Kingdom	4	4	4	2	<0.5	<0.5	1	<0.5	-3	-5	-11	-13	-11

Table 1.2. *Changes in the official emissions of cadmium after the recalculations, %*

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Austria	-2	-2	-1	<0.5	<0.5	<0.5	<0.5	<0.5	-1	2	<0.5	-4	-4
Belgium											-1		26
Canada													-10
Denmark	-2	-3	-2	-2	-17	-16	-13	-14	-7	-5	-6	-4	-7
France	9	7	5	4	3	3	3	2	1	<0.5	-1	-4	-5
Hungary													1
Italy	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-1	<0.5	<0.5	<0.5	<0.5
Latvia	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Netherlands	8					8					<0.5	<0.5	<0.5
Norway	<0.5	<0.5	<0.5	<0.5	-1	-1	-1	-1	-1	-1	-2	-4	-5
Slovakia	-1					<0.5	<0.5			<0.5	<0.5	<0.5	10
Spain	-2	-2	-1	-2	-2	-2	-1	-1	-2	-4	-4	-4	-2
Sweden	<0.5	-2	-1	<0.5	-1	-1	<0.5	<0.5	-1	-1	2	<0.5	<0.5
Switzerland											-31		
United Kingdom	27	30	30	26	23	19	29	42	39	39	24	37	44

Table 1.3. *Changes in the official emissions of mercury after the recalculations, %*

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Austria	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	1	1	<0.5
Belgium											<0.5		-9
Canada	1	1	1	2	3	3	2	1	1	1	1	1	-17
Denmark	-4	-4	-4	-3	-26	-16	-13	-12	-10	-7	-2	-2	-2
France	-4	-3	-5	-4	-6	-6	-5	-8	-8	-10	-13	-15	-16
Hungary													<0.5
Italy	7	7	4	<0.5	<0.5	<0.5	-2	-7	-6	-6	-6	-5	-5
Netherlands	13					8					-9	-1	-2
Norway	-12	-12	-14	-18	-19	-21	-20	-21	-22	-22	-25	-27	-28
Slovakia	<0.5				<0.5		<0.5	<0.5	<0.5		<0.5	<0.5	15
Spain	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sweden	-1	-5	<0.5	-1	-1	-1	<0.5	<0.5	1	<0.5	1	-1	<0.5
Switzerland											-5		
United Kingdom	3	3	3	-7	-9	-8	-10	-11	-7	-9	-8	-8	-11

Uncertainties

All reported emissions estimates have some uncertainties. The degree of uncertainty varies depending on various factors, including the frequency and duration of data collection, quality of the available data, how well the available data represent a particular source and/or other sources within an industry, variability in measurement techniques, reliability of extrapolation methods and assumptions that may have been used calculate emissions estimates, and variability in control techniques, processes, and input materials for a given industry. Depending on the purpose of the emissions estimates, and what type of decisions may be made based on the estimates, it can be important to include some qualitative and/or quantitative assessment of uncertainties, to the extent feasible.

The Guidelines for estimating and reporting emissions by the EB [EB.AIR/GE.1/2002/7] encouraged Parties report quantitative information on uncertainties where this is available (para 32). The uncertainty estimates are based on emission data and on uncertainties of activity data and emission factors for each of the main emission sectors [*EMEP/CORINAIR Emission Inventory Guidebook*, 2004]. At present, however, quantitative estimates of uncertainties of national emissions are limited – currently assessed only by Denmark. The uncertainty of Pb, Cd and Hg emissions in 2003 amounted to 261%, 263% and 229% respectively [*Illerup et al*., 2005].

Considerable difference between the official data and the expert estimates [*Berdowski et al*., 1997; *Denier van der Gon et al*., 2005] points at necessity of more careful analysis of the data from viewpoint of uncertainties. For countries, where both official data and expert estimates are available, the ratio between the official data and the expert estimates is shown in Figs. 1.10-1.12. For some countries the ratio exceeds an order of magnitude.

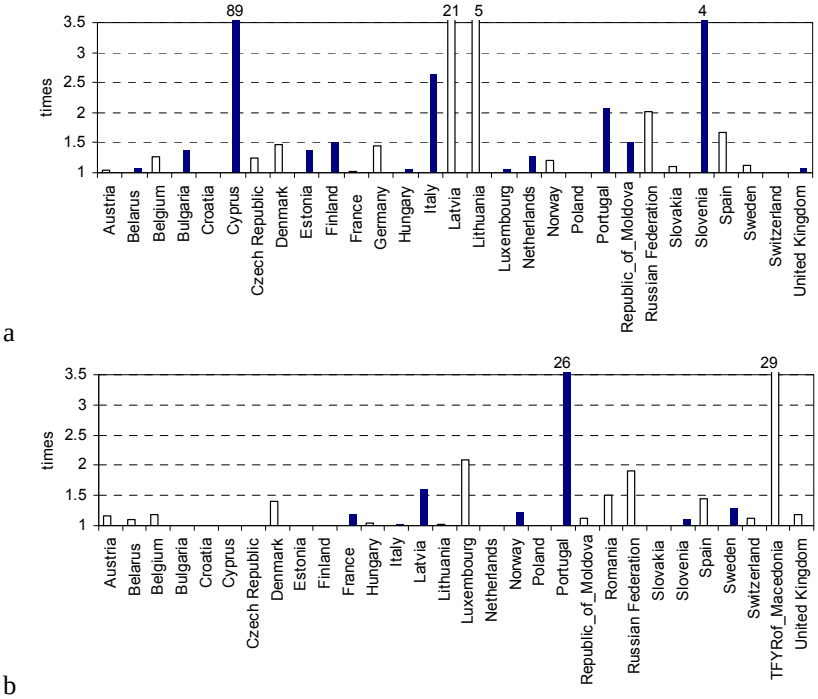


Fig. 1.10. *Differences between the official data and the expert estimates of lead emissions for 1990 (a) and 2000 (b), expressed as ratio of the larger value to the smaller one. Countries, where the official data exceed the expert estimates, are colored*

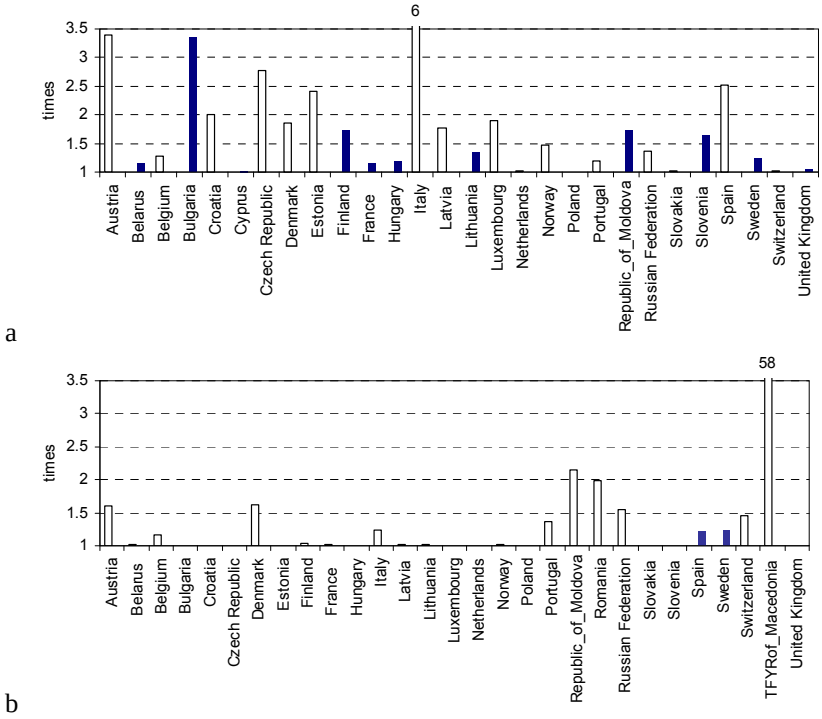


Fig. 1.11. *Differences between the official data and the expert estimates of cadmium emissions for 1990 (a) and 2000 (b), expressed as ratio of the larger value to the smaller one. Countries, where the official data exceed the expert estimates, are colored*

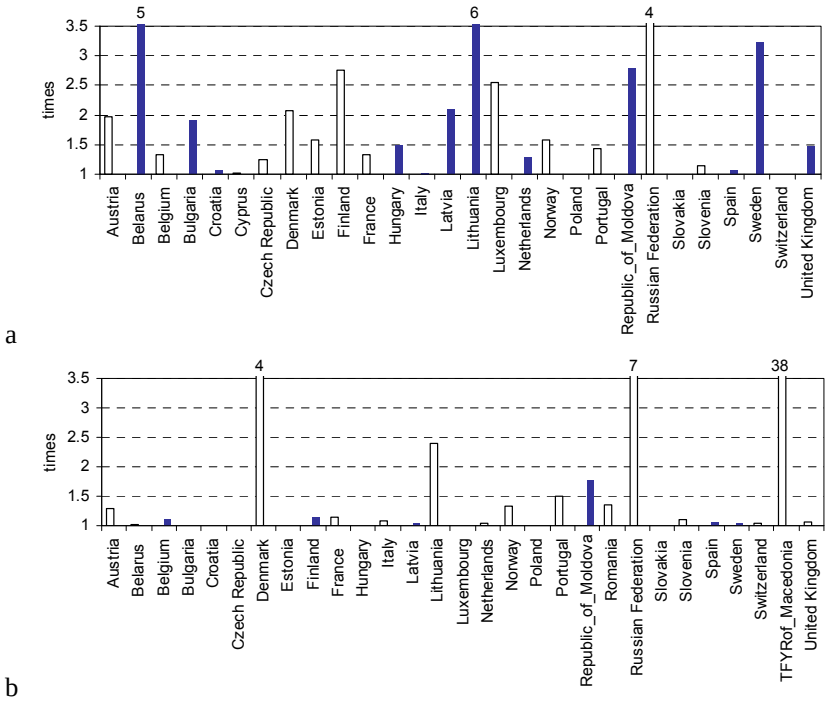


Fig. 1.12. *Differences between the official data and the expert estimates of mercury emissions for 1990 (a) and 2000 (b), expressed as ratio of the larger value to the smaller one. Countries, where the official data exceed the expert estimates, are colored*

1.2. Other Metals (As, Cr, Cu, Ni, Se, Zn)

Emission trends

The changes in As, Cr, Cu, Ni, and Zn emissions in the EMEP region for the period of 1990-2003 were estimated on the basis of total emissions of the 17 countries. For the considered period they reported their national emission data, on a voluntary basis, for each of the above metals. These countries are Belarus, Belgium, Cyprus, Denmark, Estonia, Finland, France, Hungary, Italy, Latvia, Lithuania, the Netherlands, Republic of Moldova, Slovakia, Spain, Sweden and the United Kingdom. The change in Se emissions in the EMEP region for the period of 1990-2003 was assessed on the basis of total emissions of the 13 countries (Belgium, Denmark, Estonia, France, Hungary, Italy, Latvia, the Netherlands, Republic of Moldova, Slovakia, Spain, Sweden and the United Kingdom).

Figure 1.13 shows that the total reported emissions of other metals in the considered countries have decreased between 1990 and 2003. Chromium ranks first (emission decreased by about 70%). It is followed by arsenic (64%), nickel (54%), zinc (31%) and copper (24%). Emissions of selenium have decreased only by 7%.

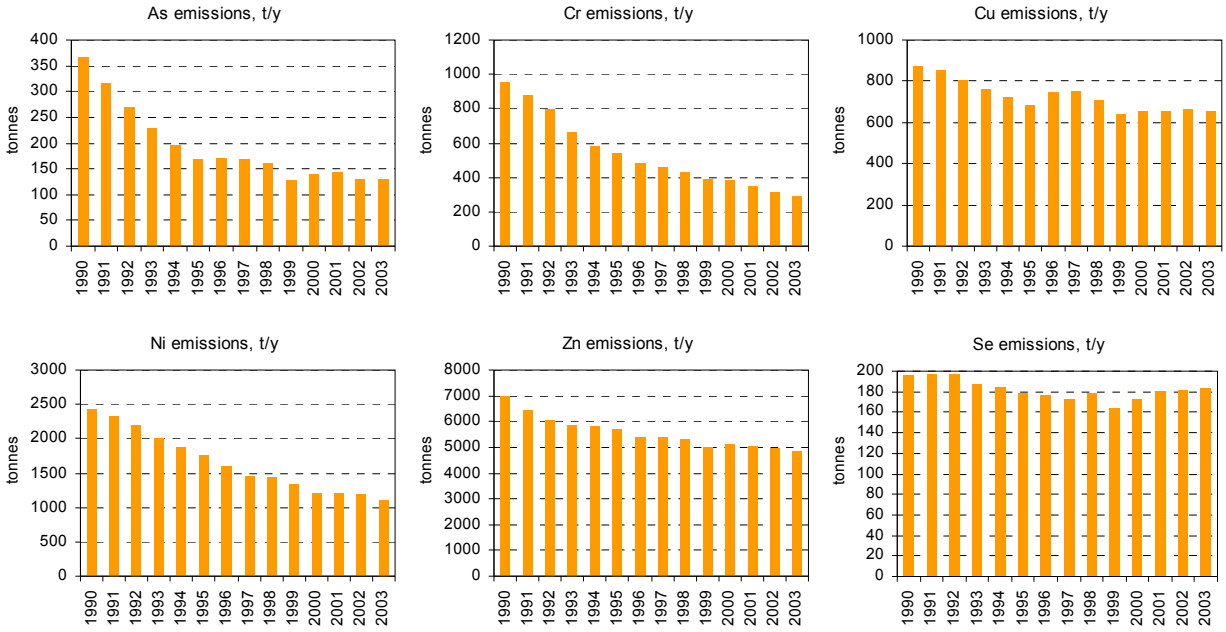


Fig. 1.13. *Reported emissions of arsenic, chromium, copper, nickel, zinc (17 countries) and selenium (13 countries) in the EMEP region*

Emission reductions

Figures 1.14-1.19 show the reductions of emissions of other heavy metals in the countries that submitted emission data for both 1990 and 2003.

The reductions of arsenic emissions (Fig. 1.14) vary from 13% (the Netherlands) to 92% (Slovakia). In Italy, Estonia and Spain the reported emissions of arsenic have increased by 14%, 25% and 33% respectively.

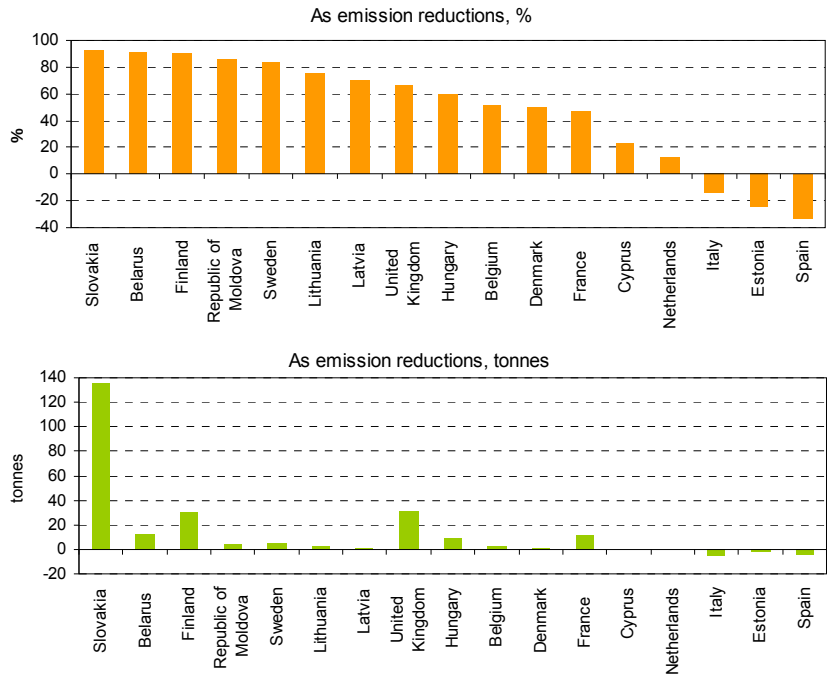


Fig. 1.14. *Reductions of arsenic emissions in the 17 countries of the EMEP region for the period of 1990-2003 based on official data reported for both 1990 and 2003*

The reductions of chromium emissions (Fig. 1.15) vary from 13% (Finland) to 91% (Slovakia). In Estonia, Spain and Cyprus emissions of chromium have increased by 15%, 32% and 51% respectively.

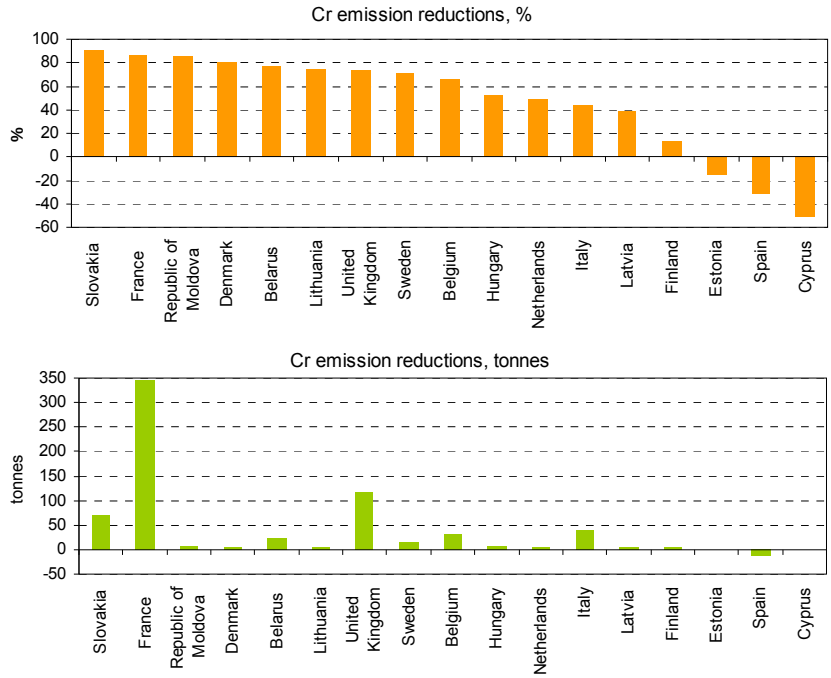


Fig. 1.15. *Reductions of chromium emissions in the 17 countries of the EMEP region for the period of 1990-2003 based on official data reported for both 1990 and 2003*

The reductions of copper emissions (Fig. 1.16) vary from 12% (Italy) to 79% (Republic of Moldova). In France, the Netherlands, Cyprus, Spain and Estonia emissions of chromium have increased by 3%, 11%, 54%, 67 and 101% respectively.

The reductions of nickel emissions (Fig. 1.17) vary from 17% (Sweden) to 98% (Republic of Moldova). In Italy, Spain and Estonia emissions of nickel have increased by 2%, 5%, and 54% respectively. In Cyprus emission of nickel has grown 18 times.

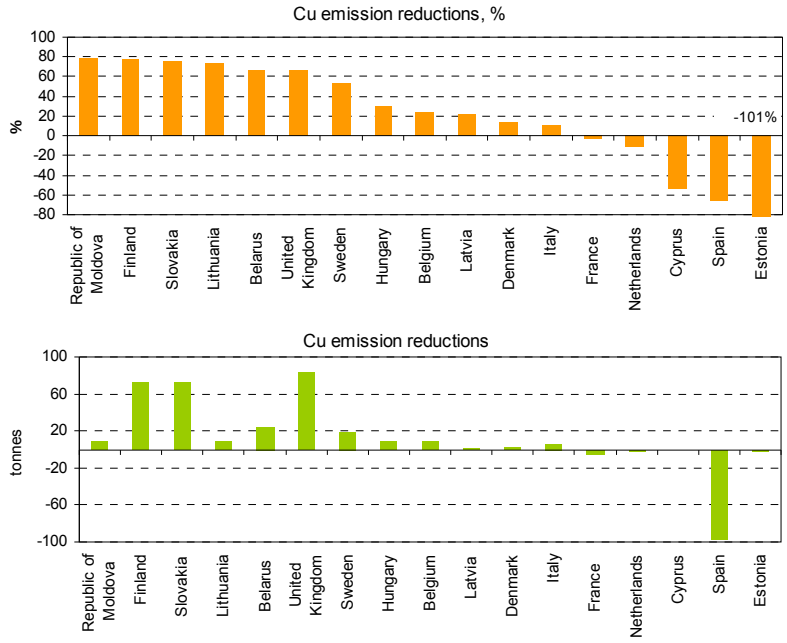


Fig. 1.16. *Reductions of copper emissions in the 17 countries of the EMEP region for the period of 1990-2003 based on official data reported for both 1990 and 2003*

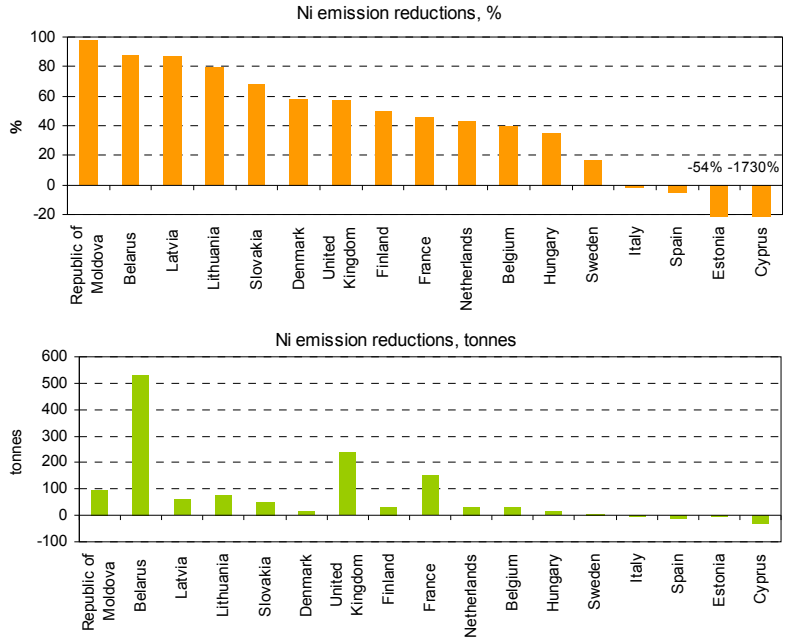


Fig. 1.17. *Reductions of nickel emissions in the 17 countries of the EMEP region for the period of 1990-2003 based on official data reported for both 1990 and 2003*

The reductions of zinc emissions (Fig. 1.18) vary from 6% (Italy) to 89% (Finland). In Belarus, Cyprus, Spain and Estonia emissions of nickel have increased by 2%, 11%, 62 and 73% respectively.

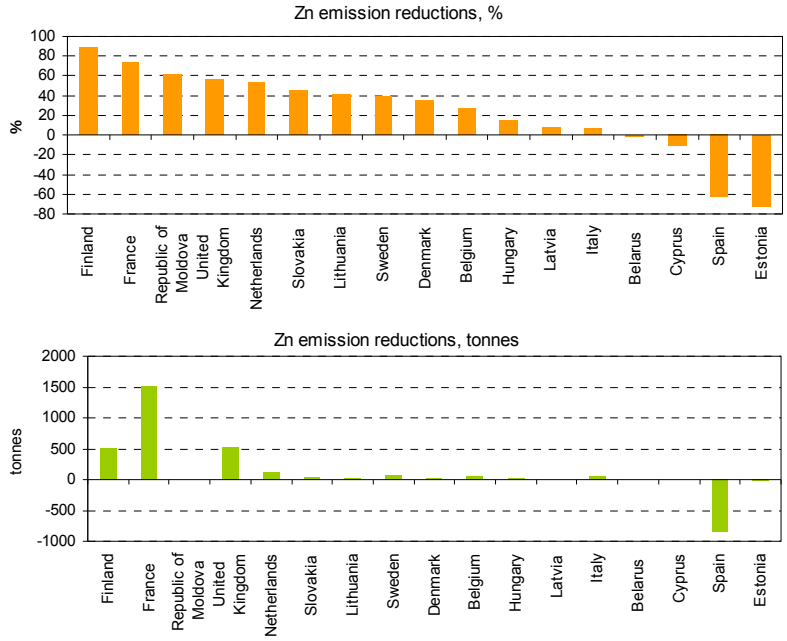


Fig. 1.18. *Reductions of zinc emissions in the 17 countries of the EMEP region for the period of 1990-2003 based on official data reported for both 1990 and 2003*

The reductions of selenium emissions (Fig. 1.19) vary from 4% (Italy) to 95% (Estonia). In Belgium, Sweden, Italy and Spain emissions of selenium have increased by 6%, 19%, 22 and 68% respectively.

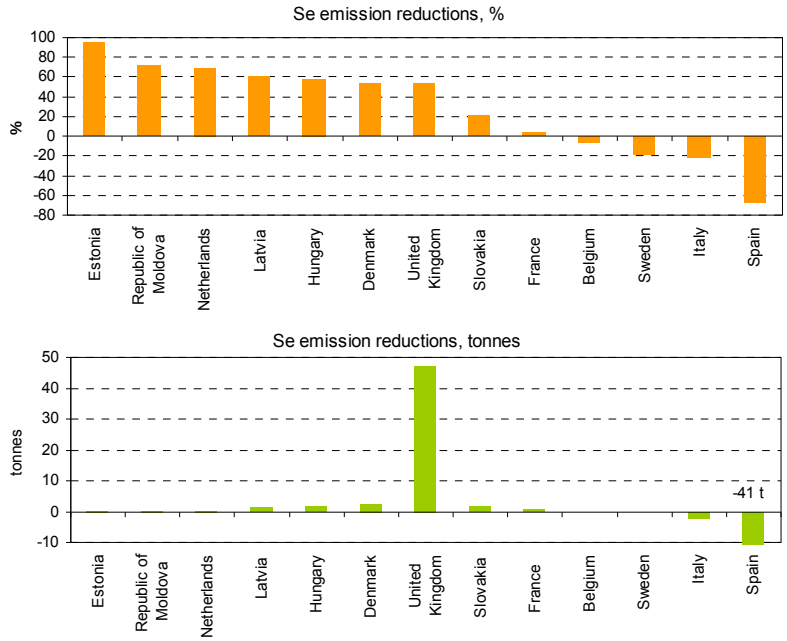


Fig. 1.19. *Reductions of selenium emissions in the 13 countries of the EMEP region for the period of 1990-2003 based on official data reported for both 1990 and 2003*

Data on the reductions of heavy metal emissions for each country that reported data for both 1990 and 2003 are given in Annex A.

Key sources of emissions

Key emission sources of other heavy metals (As, Cr, Cu, Ni, Zn) were assessed for 2003 on the basis of data reported by 9 countries (Belgium, Finland, France, Hungary, the Netherlands, Slovakia, Spain, Sweden, the United Kingdom). Sources of selenium emissions were assessed for the same countries with the exception of Finland. Several key sources were included so that their contribution to the total emission of the considered countries would be at least 90%.

Figure 1.20 shows seven largest sources of arsenic emissions in 2003. Their contribution to the total emission of the 9 countries is 90%. Almost 51% of arsenic emission is caused by two sectors: “Other, Manufacturing Industries and Construction” (29%) and “Non-ferrous Metals” (22%).

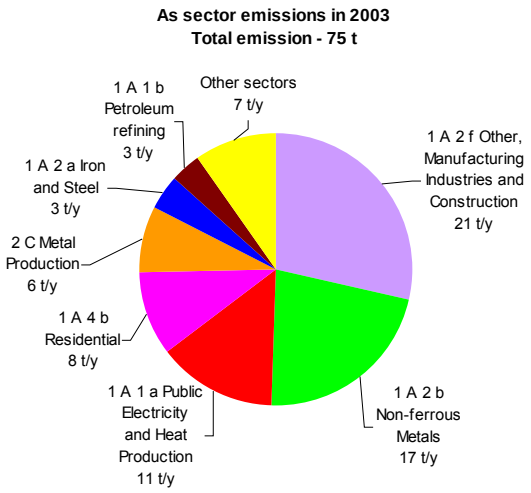


Fig. 1.20. *Sources of arsenic emissions in 2003 (9 countries)*

Figure 1.21 shows eight largest source sectors of chromium emissions in 2003. Their contribution to the total emission of the 9 countries is 91%. About 45% of chromium emission is accounted for by two sectors with almost similar contributions to total emission, namely: “Metal Production” (23%) and “Other, Manufacturing Industries and Construction” (22%).

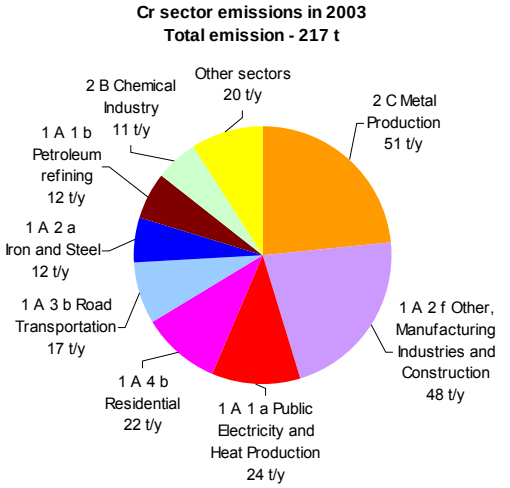


Fig. 1.21. *Sources of chromium emissions in 2003 (9 countries)*

Figure 1.22 shows eight largest source sectors of copper emissions in 2003. Their contribution to the total emission of the 9 countries is 92%. The maximum contribution to the total copper emission is caused by the sector “Road Transportation” (45%).

Figure 1.23 shows ten largest source sectors of nickel emissions in 2003. Their contribution to the total emission of the 9 countries is 92%. Almost 70% of nickel emission is made by 3 sectors: “Petroleum refining” (33%), “Public Electricity and Heat Production” (22%) and “Other, Manufacturing Industries and Construction” (14%).

Figure 1.24 shows six largest source sectors of zinc emissions in 2003. Their contribution to the total emission of the 9 countries is 94%. The maximum contribution to zinc emission is made by the sector “Road Transportation” (42%). The second largest source is the sector “Metal Production” (21%).

Figure 1.25 shows five largest source sectors of selenium emissions in 2003. Their contribution to the total emission of the 8 countries is 93%. The greatest contribution to the total selenium emission is made by the sector “Other, Manufacturing Industries and Construction” (67%).

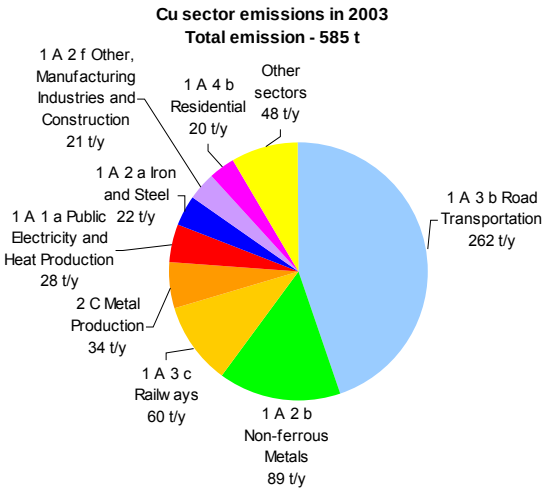


Fig. 1.22. *Sources of copper emissions in 2003 (9 countries)*

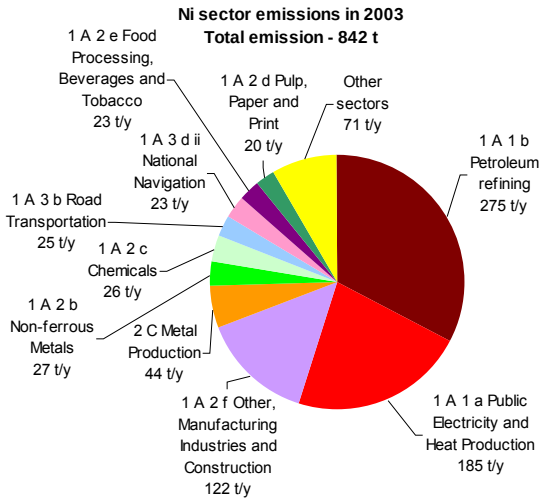


Fig. 1.23. *Sources of nickel emissions in 2003 (9 countries)*

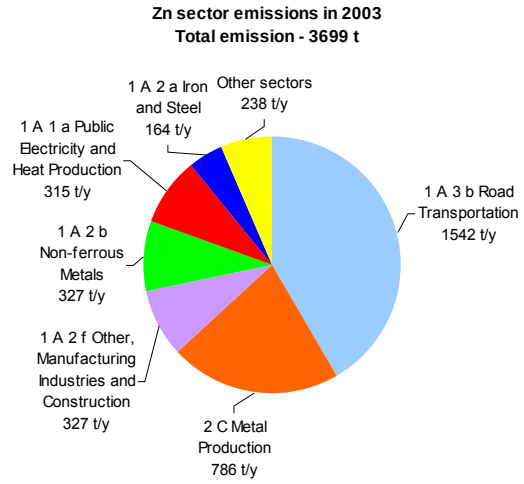


Fig. 1.24. *Sources of zinc emissions in 2003 (9 countries)*

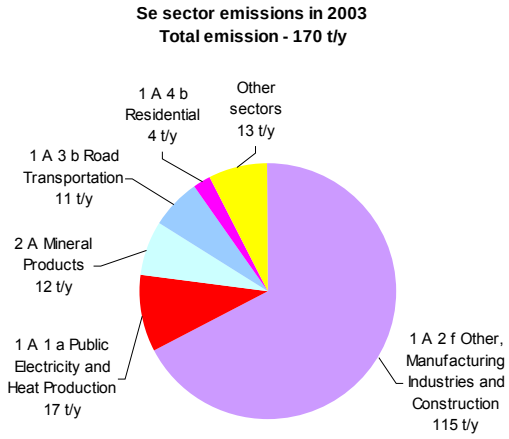


Fig. 1.25. *Sources of selenium emissions in 2003 (8 countries)*

2. ATMOSPHERIC TRANSPORT

2.1. Lead

Measured data

In 1990 measurement data on background atmospheric concentrations of lead were available from 30 stations in Europe, located in 9 countries. In 2003 measurement data were carried out at 63 stations in Europe, situated in 20 countries. However, there are still large areas where measurement data are not available, e. g. southern, south–eastern and eastern parts of Europe.

In 1990 the concentrations of lead in air were measured at stations located in the central part of Europe and along the coast of the North Sea. Measured background concentrations were mainly within 10 - 30 ng/m^3 range. In 2003 the concentrations mainly ranged between 5 and 15 ng/m^3. Concentrations in precipitation in central Europe in 1990 were around 2 – 5 μg/L. In 2003 these concentrations typically ranged from 1 to 3 μg/L.

In order to estimate long-term trends for different parts of Europe measurement data were averaged over different countries. The long-term changes of air concentrations and concentrations in precipitation vary considerably across Europe. In central and north-western Europe the decrease was about 2 – 3 times from 1990 to 2003 based on these data (Fig. 2.1a,b). In northern Europe the decrease of concentrations in precipitation was 1.5 – 3 times.

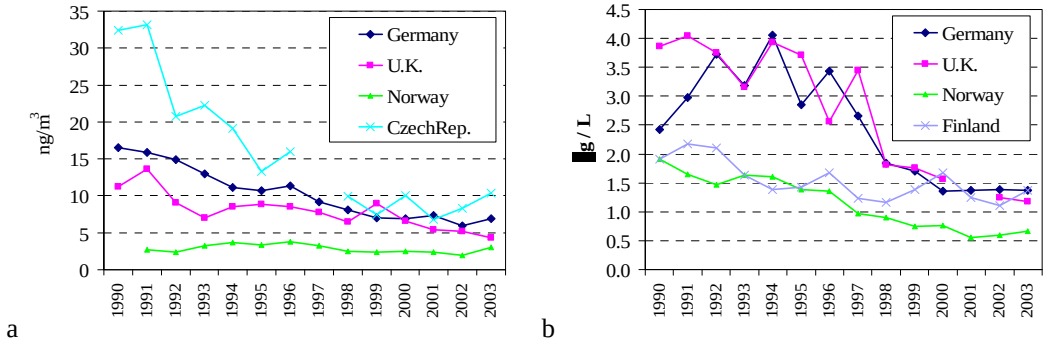
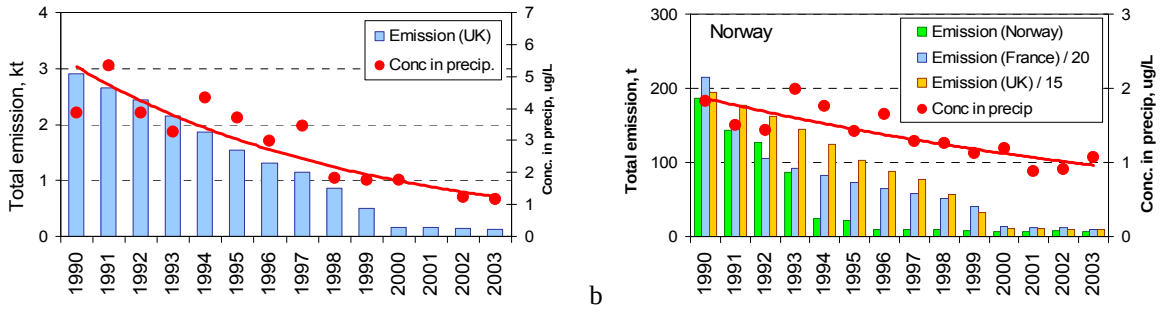


Fig. 2.1. *Long-term variations of concentrations of lead in air (a) and in precipitation (b) in different parts of Europe*

Long-term changes of European emissions of lead are likely reflected in monitoring trends. In order to evaluate consistency between official European emissions and monitoring data, emission and measurement trends were compared [*Ilyin and Tranvikov*, 2005]. These trends differ significantly over individual countries. In some countries the reduction of emissions for 1990 – 2003 was more than 10 times, but the decline of observed lead levels in air and in precipitation is much lower (2-3 times). This fact is confirmed by examples of the United Kingdom and Norway, shown in Fig. 2.2a,b. Lead pollution levels in the United Kingdom are mainly conditioned by national emission sources. Lead pollution in Norway is considerably influenced by long-range transport. That is why trend of official emissions in Norway is accompanied by official emission trends of France and the United Kingdom (Fig. 2.2.b). These countries are main contributors to lead transboundary pollution in Norway.



a b

Fig. 2.2*. Long-term trends of lead total anthropogenic emissions in some countries and mean concentration in precipitation in the United Kingdom (a) and Norway (b). Red circles show annual measurements, red line – exponential approximation*

The inconsistency between measured levels of lead and its official European emissions is revealed not only for individual countries, but also for Europe as a whole. Comparison of lead total official anthropogenic emissions in Europe with total wet deposition to EMEP countries based on measurement data only demonstrates that observed depositions are higher than the emissions in 1995 – 2003 (Fig. 2.3). The exception is 1990, when measured depositions were available only from Scandinavian stations, and, hence, were probably too low compared to European-mean depositions.

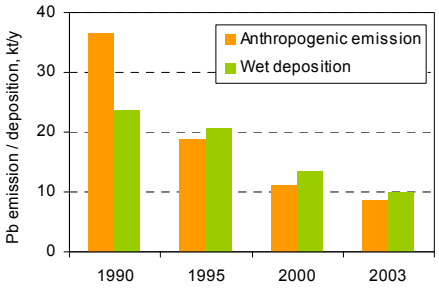


Fig. 2.3. *Comparison of lead total official anthropogenic emissions with total wet deposition to EMEP countries based on measurement data*

The inconsistencies between official emissions and observed lead concentrations and depositions could be explained by either underestimation of official data, or significant unaccounted influence of natural emissions and re-emissions of historic depositions, or by both reasons. These inconsistencies should be further investigated.

Modelled lead pollution levels

The use of official emissions in modelling in the EMEP region resulted in significant (2-3 times) underestimation compared to measurements. The Executive Body of the Convention raised the concern about quality of the official emission data and called upon Parties to improve it [EB.AIR/WG.5/8]. Evaluation of transboundary transport of lead for the period 1990 - 2003 was performed on the base of emission expert estimates, prepared by MSC-E [*Ilyin and Tranvikov*, 2005]. These expert estimates include anthropogenic emissions, and preliminary estimates of natural emission and re-emission.

Fig. 2.4a shows spatial distribution of estimated annual mean concentrations of lead in air in 1990 and 2003. In 1990 over significant parts of Europe concentrations varied between 15 and 40 ng/m^3, and in some areas exceeded 40 ng/m^3. By 2003 the concentrations in air markedly decreased and were within 2 - 15 ng/m^3 over most of Europe (Fig. 2.4b). Spatial distribution of depositions is similar to that of concentrations. In 1990 over most parts of Europe modelled depositions ranged within 2 - 8 kg/km^2/y (Fig. 2.5a). By 2003 depositions decreased and their values were mainly within 0.5 - 4 kg/km^2/y range (Fig. 2.5b).

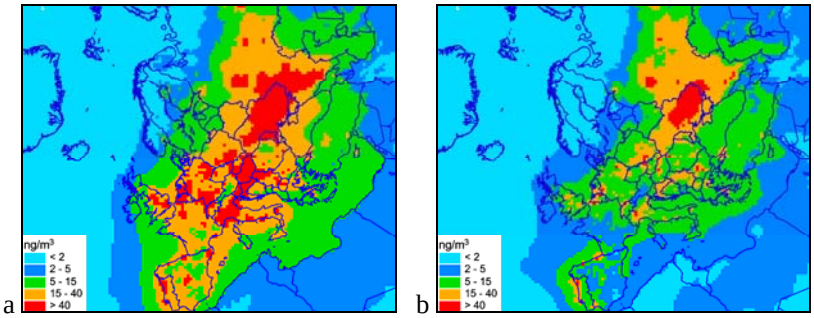


Fig. 2.4. *Spatial distributions of modelled air concentrations of lead in EMEP region in 1990 (a) and 2003 (b)*

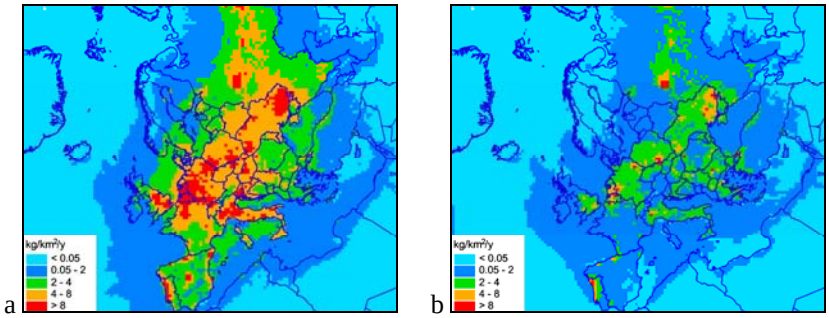


Fig. 2.5. *Spatial distributions of modelled total depositions of lead in EMEP region in 1990 (a) and 2003(b)*

The largest decrease of air concentrations, averaged over country's territory, (Fig. 2.6) took place in Slovenia (7 times). In 18 countries the concentrations decreased at least 3 times, and in 16 countries – between 2 and 3 times.

Similar decreases took place for air depositions: from 6 times in Slovenia to minor changes (within 10%) in Iceland and Greece. In 16 countries the decrease exceeded 3 times. In 17 countries the decrease ranges from 2 to 3 times. For the considered period depositions of lead to Europe as a whole reduced from about 40000 to 17500 tonnes (2.3 times).

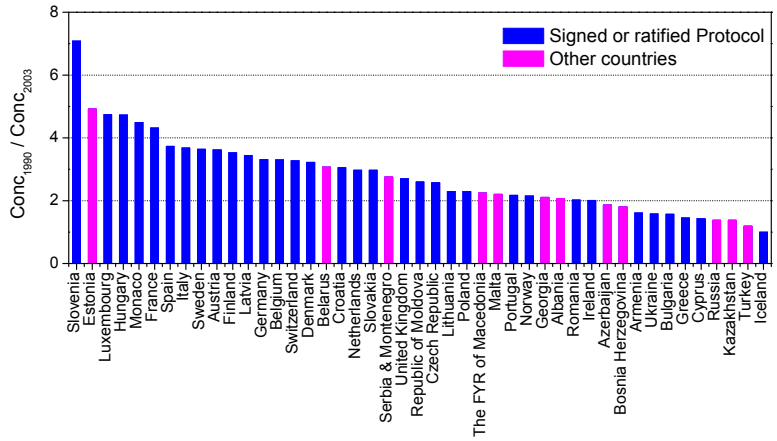


Fig. 2.6. *Ratio of the modelled country-averaged air concentrations of lead in 1990 to those in 2003 in countries of Europe*

The contribution of lead depositions to country's territory caused by transboundary transport varies significantly (10 – 90%) between countries (Fig. 2.7). The highest contribution took place for Republic of Moldova, Luxembourg, Monaco and Belarus. In 20 countries the contribution exceeds 50%, in 36 countries exceeds 30%.

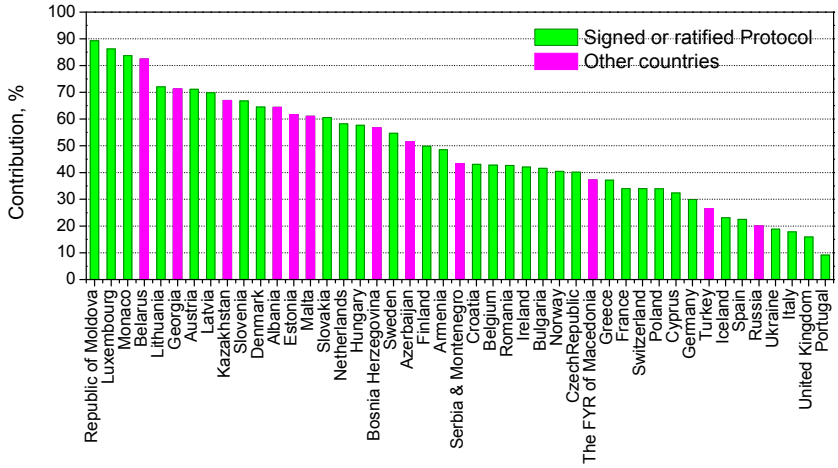


Fig. 2.7. *Contribution of external European anthropogenic sources to depositions of lead in Europe in 2003.*

The contribution of external sources to depositions is distributed nonhomogeneously over countries territories. For example, this contribution for entire Germany is about 30% (Fig. 2.8a). However, in regions close to national borders this contribution can exceed 50%, whereas in the central part it can be less than 15% (Fig. 2.8b).

Potential of lead to intercontinental transport is lower compared to e.g., mercury or some POPs. However, the role of intercontinental transport of lead in pollution of Europe and North America needs further investigation.

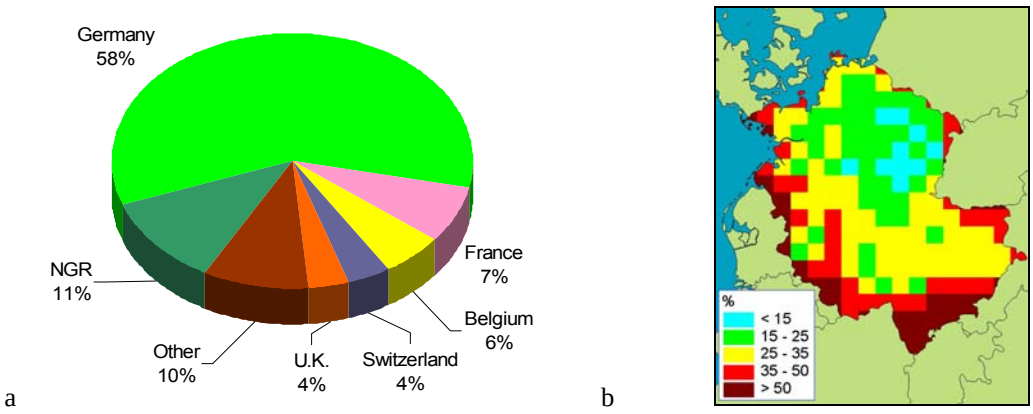


Fig. 2.8. *Main contributors to deposition of lead in Germany. NGR: Natural, Global sources and Re-emission (a). Spatial distribution of contribution of external anthropogenic sources to depositions of lead in Germany(b)*

Evaluation of modelling results

Model evaluation included analysis of model uncertainties, and comparison of modelled results with observations and with results computed by other models. Analysis of the model uncertainties demonstrates that intrinsic model uncertainty (uncertainty of model without emission data) varies across Europe from 20 to 60% for concentrations in air, in precipitation and for total depositions [*Travnikov and Ilyin,* 2005]. Intercomparison of atmospheric transport models of lead shows that air concentrations and depositions estimated by MSCE-HM model are in good agreement with other transport models [*TFMM Workshop Minutes*, 2005].

Comparison of modelling results based on official emission data, against measurements results to essential (2-3 times) underprediction of observed values by the model. Modelling results, based on emission expert estimates, for 1990 - 2003 [*Ilyin and Travnikov*, 2005] demonstrates that the modelled concentrations of lead in air and in precipitation well agree with the measurements. The correlation coefficient for annual lead concentrations in air is almost 0.9, and for concentrations in precipitation – 0.7. About 90% of modelled lead concentrations in air and 70% of concentrations in precipitation agree with measurements with accuracy better than ±50% of measured value. Discrepancies between model output, based on official emissions, and measurements could be mainly connected with uncertainties of official emission data, natural emissions and re-emission of historic deposition of lead.

Concluding remarks

- From 1990 to 2003 the number of countries involved in monitoring of lead in Europe increased from 9 to 20. However, there are still large areas, with insufficient lead monitoring networks, in particular, southern, eastern and south-eastern Europe. In the USA there were a total of 454 monitoring stations for lead in 1990 and 196 stations in 2003.

- Both monitoring and modelling data indicate a 2-3 fold decrease of lead levels for Europe as a whole. In some individual countries the magnitude of lead pollution decrease is as much as 6 – 7 times. In the U.S., lead air concentrations decreased greatly in the 1980s, and continued to decline through the 1990s, although at a slower rate, with concentrations decreasing about 57% between 1993 and 2002.

- Transboundary transport is an important factor of atmospheric lead pollution in European countries. Its contribution to depositions to countries varies from about 10 to 90%.

- Calculated pollution levels of lead, obtained both for Europe on the base of official emission data, are significantly lower (2 – 4 times) compare to observations. This discrepancy is most likely caused by underestimation of official emission data and re-emission of historic deposition of lead.

2.2. Cadmium

Measured data

Observed background values of cadmium concentrations in the atmosphere in 1990 were available from 40 stations, located in 11 countries in Europe. In 2003 there were 61 stations (in 18 countries of Europe) provided measurement data.

In 1990 concentrations of cadmium in air were measured at stations located in central Europe and along the North Sea coast. The concentrations ranged between 0.2 and 1 ng/m^3. In 2003 typical ranges of concentrations in air were 0.05 – 0.2 ng/m^3 (northern Europe), 0.2 – 0.5 ng/m^3 (central Europe) and 0.06 – 0.12 ng/m^3 (southern Europe).

Measurements of concentrations in precipitation in the early 1990s took place in Scandinavian countries and along the North Sea coast. Annual mean concentrations ranged between 0.03 and 0.35 μg/L. By 2003 data on measured levels became available from central Europe and from stations of the Baltic Sea region. In northern Europe the concentrations typically range from 0.02 to 0.07 μg/L, and the central Europe – from 0.04 to 0.2 μg/L.

From the early 1990s to 2003, the country-averaged concentrations of cadmium in air decreased around 2 times in central and north-western Europe (Fig. 2.9a). Measured concentrations in precipitation decreased 3 - 4 times in central and north-western Europe (Fig. 2.9b). In the northern part of Europe trends of concentrations in precipitation are not evident during this time period (1990 to 2003).

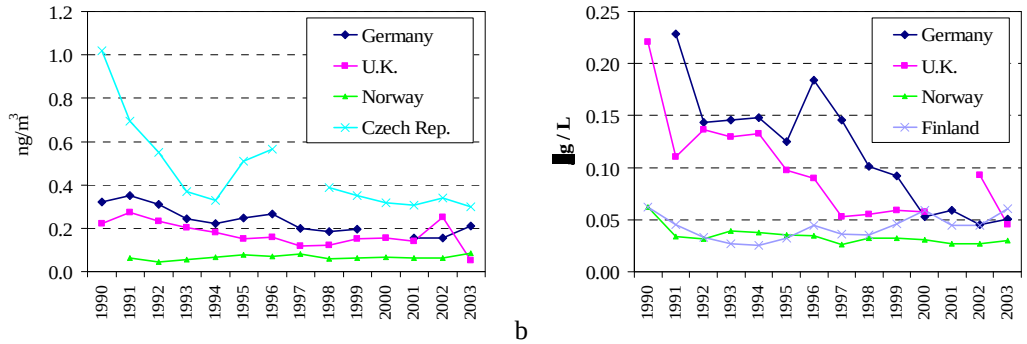


Fig. 2.9. *Long-term variations of measured concentrations of cadmium in air (a) and in precipitation (b) in different parts of Europe*

Analysis of observed cadmium wet depositions revealed that total wet depositions of cadmium in Europe are about twice exceed total official emissions from European countries (Fig. 2.10) [*Ilyin and Travnikov*, 2005]. Since this comparison did not account for dry depositions of emitted cadmium, the discrepancy between measurements and emissions could be significantly higher.

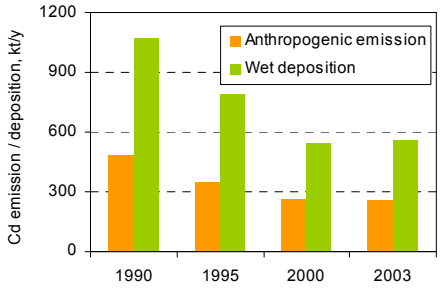


Fig. 2.10 *Comparison of and cadmium total official anthropogenic emissions with total wet deposition to EMEP countries based on measurement data*

The inconsistencies between the official emissions and observed cadmium wet depositions could be explained by either underestimation of official data, or significant contribution of natural emissions and re-emissions of historical depositions to total European emissions, or by both reasons. These inconsistencies should be further investigated.

Modelled cadmium levels

As in case of lead, the use of official emissions of cadmium leads to significant (around 3 times) underestimation of modelled concentrations and depositions compared to measured ones. The Executive Body of the Convention raised the concern about quality of the official emission data and called upon Parties to improve it [EB.AIR/WG.5/8]. The modelling of cadmium pollution levels for 1990 -2003 was based on the emission expert estimates, developed by MSC-E. These estimates include anthropogenic emissions, natural emission and re-emission of historic depositions. Detailed description of the approach used to derive these emissions is described in [*Ilyin and Travnikov*, 2005].

In 1990 over most of Europe modelled concentrations exceeded 0.3 ng/m^3 (Fig. 2.11a). By the end of the considered period concentrations over western and central parts of Europe declined and ranged from 0.1 to 0.3 ng/m^3 (Fig. 2.11b). Total modelled depositions of cadmium in 1990 typically ranged from 50 to 300 g/km^2/y (Fig. 2.12a). By 2003 the depositions reduced in most regions of Europe. Typical range of depositions was 15 – 150 g/km^2/y (Fig. 2.12b).

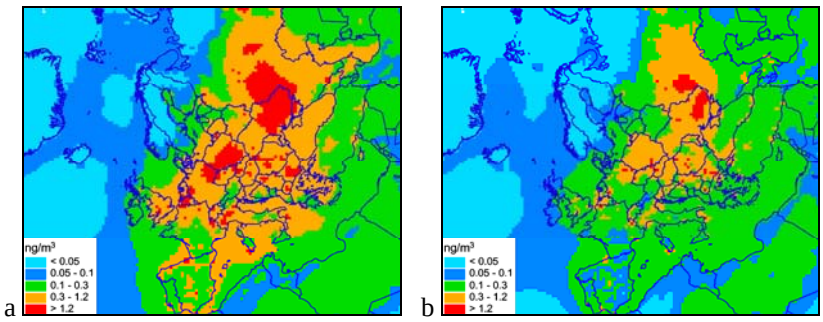


Fig. 2.11. *Spatial distributions of modelled air concentrations of cadmium over EMEP region in 1990 (a) and 2003 (b)*

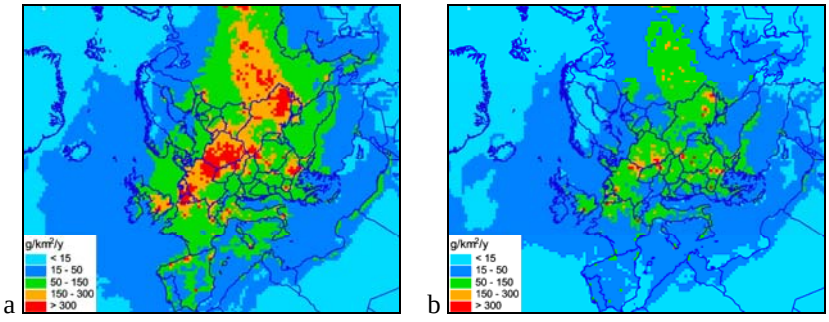


Fig. 2.12. *Spatial distributions of modelled total depositions of cadmium over EMEP region in 1990 (a) and 2003(b)*

For Europe as a whole atmospheric concentrations of cadmium are characterized by about a two-fold decrease. In individual countries the highest estimated decline of concentrations took place in Monaco (3.4 times) and the Netherlands (3.3 times) (Fig. 2.13). As much as 13 countries are

characterized by the decrease more than 2.5 times. In 16 countries the decrease was between 2 – 2.5 times.

Similar magnitudes of estimated decrease were obtained for depositions to countries. For Europe as a whole the decrease was 2.3 times, and in individual countries (Monaco, the Netherlands) it reaches 3.3 times. As many as 27 countries are characterized by at least a 2-fold deposition decrease.

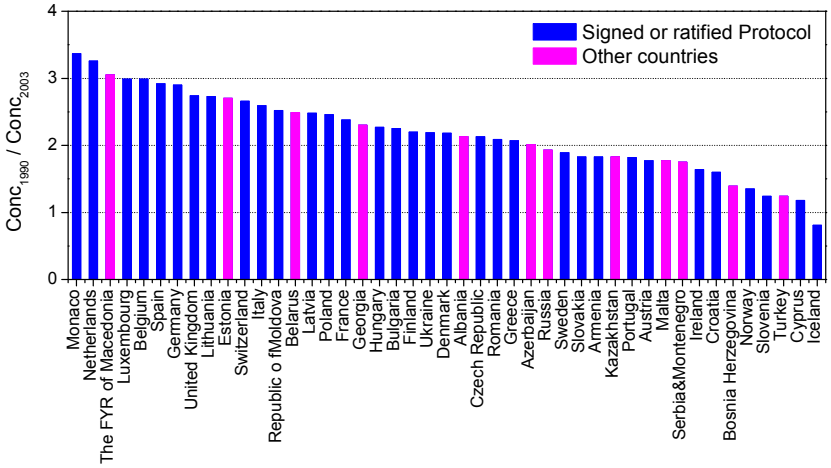


Fig. 2.13. *Ratio of the modelled country-averaged air concentrations of cadmium in 1990 to those in 2003 in countries of Europe*

Contribution of transboundary transport from anthropogenic sources in Europe to depositions of cadmium in European countries varies from about 83% in Republic of Moldova to around 7% in Spain (Fig. 2.14). In sixteen countries this estimated contribution exceeds 50%, and in 27 countries – 30%.

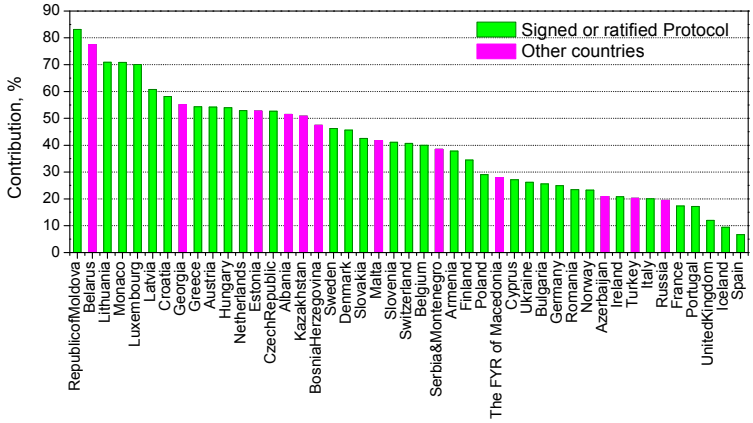


Fig. 2.14. *Contribution of external European anthropogenic sources to depositions of cadmium in Europe in 2003*

For each country of Europe the main contributors of cadmium transboundary pollution were evaluated by the model. The example of these estimates is presented for Hungary (Fig. 2.15a). External European anthropogenic sources contribute 54% of depositions to the country as a whole. National sources make up 25%, and natural, global sources and re-emission – 22%.

Contribution of external European sources to Hungary is uneven across the country (Fig. 2.15b). In the central part it amounts to about 40%, while near state borders it exceeds 70%.

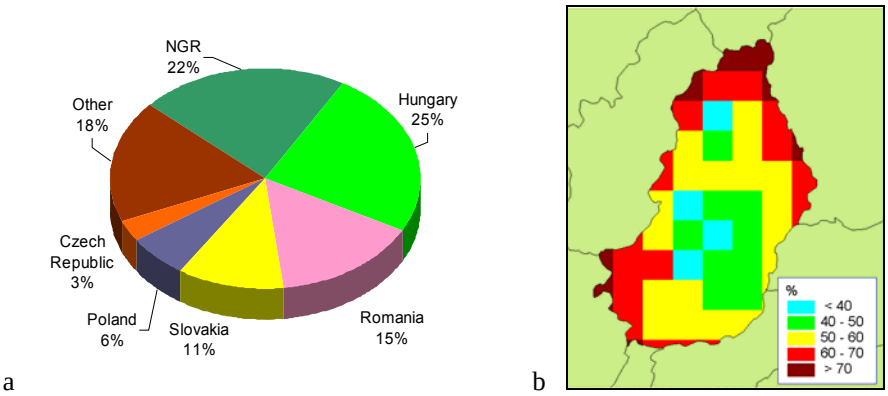


Fig. 2.15. *Main contributors to deposition of lead in Hungary. NGR: Natural, Global sources and Re-emission (a). Spatial distribution of contribution of external anthropogenic sources to depositions of lead in Hungary(b)*

Unlike long-living atmospheric pollutants, such as mercury or some POPs, cadmium lifetime in the atmosphere is relatively short and its potential to intercontinental transport is lower. However, the contribution of intercontinental transport of cadmium to pollution in Europe and North America requires more research.

Evaluation of modelling results

Analysis of the model uncertainties shows that the intrinsic model uncertainty (uncertainty of model without emission data) varies across Europe from 20 to 60% for concentrations in air, in precipitation and for total depositions [*Travnikov and Ilyin,* 2005]. Intercomparison of atmospheric transport models of cadmium demonstrated that air concentrations and depositions computed by MSCE-HM model well agree with other transport models [*TFMM Workshop Minutes*, 2005].

Comparison of modelling results based on official emission data, against measurement results to essential (about 3 times) underprediction of observed values by the model. Cadmium concentrations in air predicted by the model for 1990 – 2003 on the base of emission expert estimates are in good agreement with available monitoring data in aggregate [*Ilyin and Travnikov*, 2005]. The correlation is high (the coefficient is 0.8) and for more than 70% of compared values the difference between modelled and measured concentrations does not exceed ±50%. The observed cadmium concentrations in precipitation are commonly underestimated by the model. However, correlation between the modelled and measured values is high (almost 0.8) and almost 80% of model/measurement pairs of concentrations in precipitation agree within the range ±50% of measured value. Discrepancies between modelling results, based on official emissions, and observed levels of cadmium could be mainly caused by uncertainties of official emission data, natural emissions and re-emission of historic deposition of cadmium.

Concluding remarks

- The number of European countries providing measurement data on cadmium in the atmosphere increased from 11 to 18 from 1990 to 2003. However, there are still large areas, not covered by cadmium monitoring network, in particular, southern, eastern and south-eastern Europe.
- Both monitoring and modelling demonstrate decrease of cadmium levels in Europe. Cadmium pollution levels are characterized by about a two-fold decrease for Europe as a whole in the

period 1990-2003. In some individual countries the estimated magnitude of cadmium pollution decrease is as much as 3 - 4 times.

- Transboundary transport within Europe is an important factor of atmospheric pollution by cadmium in European countries. Its contribution to depositions to countries varies from around 10 to 80%.
- Calculated pollution levels of cadmium, obtained both for Europe on the base of official emission data are significantly (3 – 5 times) underpredicted compared to measurement data. The difference between modelled and measured data is most likely connected with underestimation of anthropogenic emissions and re-emission of historic depositions.

2.3. Mercury

Measured data

In 1990 the information on measured concentrations of mercury in Europe was available from 7 stations, located in five countries. By 2003 the number of mercury monitoring stations increased to 15 in Europe, located in 8 countries.

Mercury is a global pollutant. Spatial and temporal variability of its air concentrations at regional scale is not high. According to measurement data from EMEP stations, collected for the period 1990-2003, measured air concentrations of mercury mainly ranged from 1.3 to 2 ng/m^3.

In 1990 measurement data on concentrations in precipitation were too scarce to draw any conclusions about spatial pattern. The concentration averaged over few stations was around 15 ng/L. In 2003 the concentrations typically were 5 – 10 ng/L in northern and 6 – 10 ng/L in central part of Europe.

There are only few stations in Europe providing long-term measurements of mercury. Concentrations of mercury in air do not demonstrate any noticeable long-term trend. Concentrations in precipitation based on these limited data have reduced about twice in central and northern Europe (Fig. 2.16a, b)

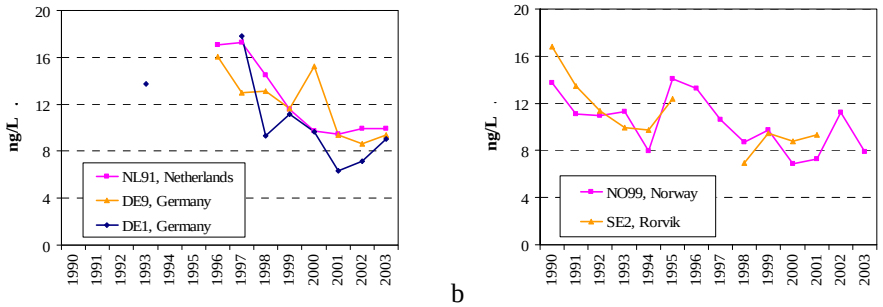


Fig. 2.16. *Observed concentrations of mercury in precipitation at stations in central (a) and northern (b) parts of Europe*

Modelled mercury concentrations and depositions

Modelling of mercury concentrations, depositions and transboundary fluxes over Europe for 1990 – 2003 was performed on the base of official emissions and expert estimates [*Berdowski et al*., 1997], using MSCE-HM model.

Modelled concentrations of mercury in precipitation in 1990 are mainly within the range of 12 – 40 ng/L over central and eastern parts and within 6 – 12 ng/L in the northern and south-western parts of Europe (Fig. 2.17a). In 2003 the concentrations are lower compared to those in 1990 (Fig. 2.17b). They ranged from 6 to 12 ng/L over most of Europe, and from 12 to 20 ng/L in the eastern part of Europe.

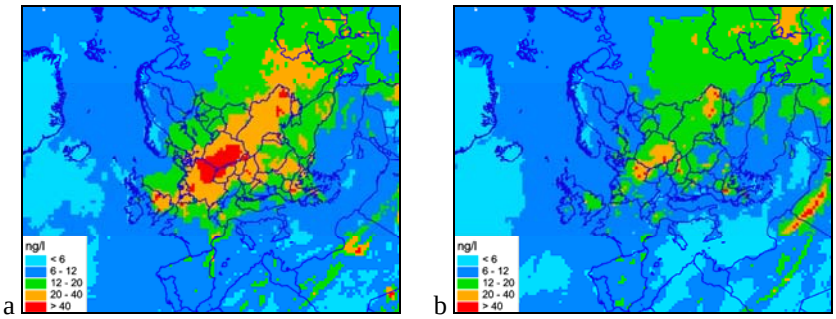


Fig. 2.17*. Modelled concentrations of mercury in precipitation over EMEP region in 1990 (a) and 2003 (b)*

For Europe as a whole the decrease of depositions for 1990 – 2003 was an estimated 1.6 times. The decrease of depositions in individual countries is different reaching about three times in Germany, Czech Republic, Republic of Moldova and Slovakia (Fig. 2.18). In 11 countries an estimated two-fold decrease took place. In 12 countries the depositions decreased by about 1.5 - 2 times.

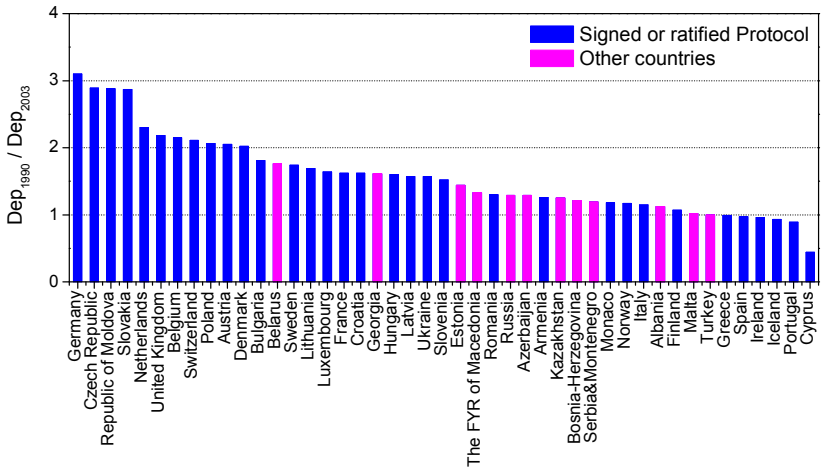


Fig. 2.18*. Ratio of modelled total depositions of mercury in 1990 to those in 2003 in countries of Europe*

Contributions to mercury depositions to countries from external anthropogenic European sources vary from 2 to 55% (Fig. 2.19). In 11 countries this contribution made up more than 30%. The contribution of natural, global sources and re-emissions to mercury pollution is higher compared to that of lead or cadmium: it ranges from 20% in Poland to 98% in Iceland. This high contribution is explained mainly by the global character of mercury atmospheric pollution.

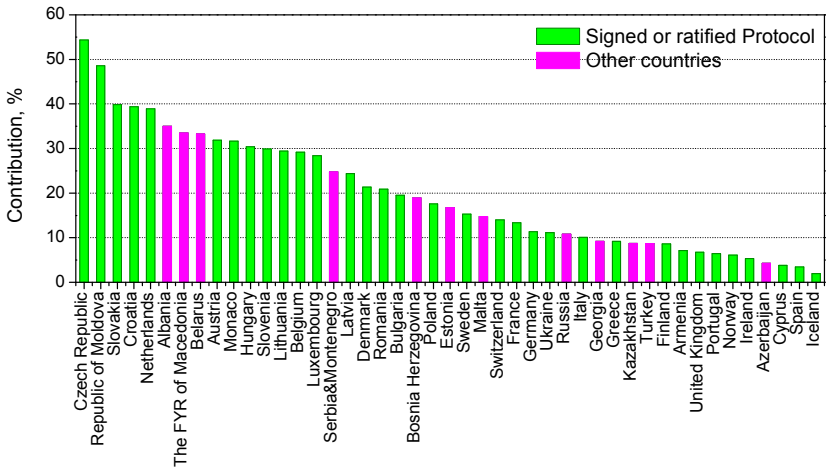


Fig. 2.19. *Contribution of external European anthropogenic sources to depositions of mercury in Europe in 2003*

Intercontinental transport of mercury

Evaluation of contribution of intercontinental transport of mercury to deposition levels over Europe and North America was estimated by hemispheric version of EMEP/MSC-E model (MSCE-Hg-Hem). Figure 2.20 shows the modelled contributions of different continents to depositions of mercury to Europe. As one can see, emissions from Asia contribute 15% to depositions in Europe, and emissions from North America contributed about 5% to deposition in Europe. Contribution from own European sources is about 60%.

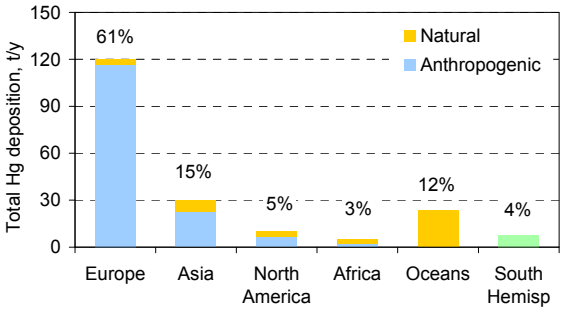


Fig 2.20. *Contributions of global sources to mercury depositions in Europe in 1996*

Depositions of mercury to Europe caused by intercontinental transport vary from 2.5 to 10 g/km^2/y (Fig. 2.21). Relative contribution of mercury emission sources outside Europe to depositions in Europe is spatially inhomogeneous (Fig. 2.22). In the central part of Europe the contribution is about 25% while on the periphery of the region it exceeds 60%.

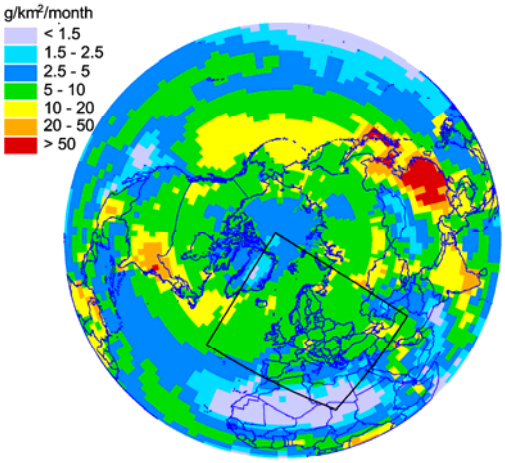


Fig. 2.21. *Spatial distribution of modelled annual deposition of mercury in the Northern Hemisphere (except for the deposition from European emission sources). Black line delineates the EMEP region*

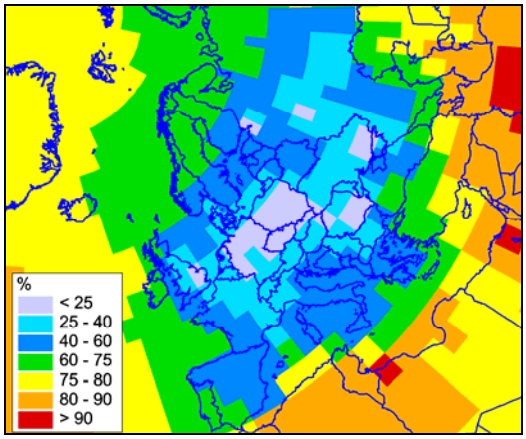


Fig. 2.22. *Relative contribution of non-European sources to mercury deposition in Europe in 1996*

Mercury is capable of transporting over thousands of kilometres and deposits in remote regions like the Arctic. According to calculations of EMEP/MSC-E [*Dutchak et al*., 2003], more than 30% of depositions to the Arctic are caused by sources located in Asia, and more than 20% are from Europe (Fig. 2.23). The contribution of the North American sources is estimated to be about 10%.

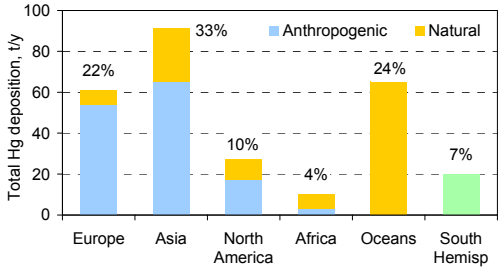


Fig. 2.23. *Contribution of different regions to the total annual deposition of mercury to the Arctic in 1996*

Modelled depositions over continental parts of the Artic range from 4 to 20 g/km^2/y (Fig. 2.24). Over marine parts the depositions vary from 2 to 8 g/km^2/y.

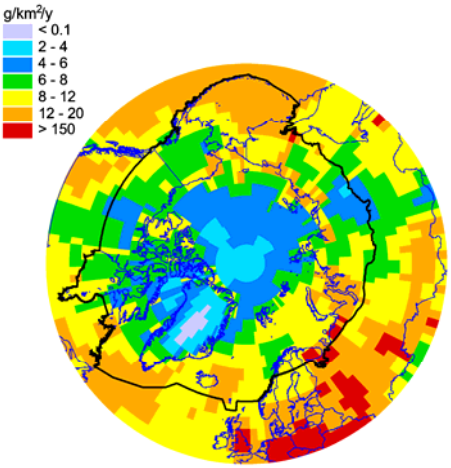


Fig. 2.24. *Spatial distribution of annual mercury deposition fluxes in the Arctic. Black line delineates the Arctic boundary as specified by AMAP*

Evaluation of modelling results

Evaluation of the MSCE-HM model uncertainties demonstrates that the intrinsic model uncertainty (uncertainty of model without emission data) varies over Europe from 15 to 20% for concentrations in air, from 30 to 70% for concentrations in precipitation and from 20 to 60% for total depositions [*Ilyin and Travnikov*, 2005].

Multi-stage mercury intercomparison study has shown that the participated models could predict the observed concentrations of elemental mercury with accuracy within ±20%. The accuracy for wet deposition is within a factor of two, whereas discrepancy between the models did not exceed 40%. Detailed description of the mercury intercomparison results is available in the scientific paper [*Ryaboshapko et al.,* 2002] and MSC-E reports [*Ryaboshapko et al*., 2003, 2005].

Concentration levels of mercury in air and in precipitation are well reproduced by the MSCE-HM based on available official emission data and expert estimates. Only few mean annual values of modelled total gaseous mercury (TGM) concentrations differ from the observed ones more than by 30%. As much as 80% of modelled values agree with measurements within the range ±50% of measured value. However, the model tends to somewhat overestimate mercury concentrations in precipitation.

Concluding remarks

- In 1990 there were five, and in 2003 - eight countries providing measurement data on mercury in Europe. Number of monitoring stations also significantly increased. However, only northern and central Europe is covered by mercury monitoring network. In North America, there were a few stations in the early 1990s measuring wet deposition, 13 stations in 1995, and over 85 stations by 2005.

- Both monitoring and modeling results indicate decreases of mercury levels in Europe. Mercury levels decreased by about 1.5 – 2 times for Europe as whole. In individual countries the magnitude of decrease is estimated to be as high as 3 times.

- Transboundary transport is an important factor of atmospheric deposition of mercury in European countries. Its contribution to depositions to countries can reach about 50%.

- Intercontinental transport plays an important role in mercury pollution in Europe and in North America. Contribution of global sources (both natural and anthropogenic) to depositions in different regions of Europe varies from 25 to 60%.

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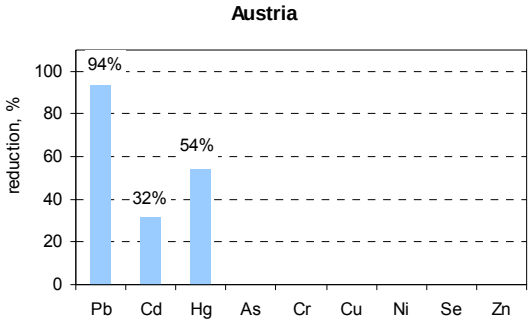
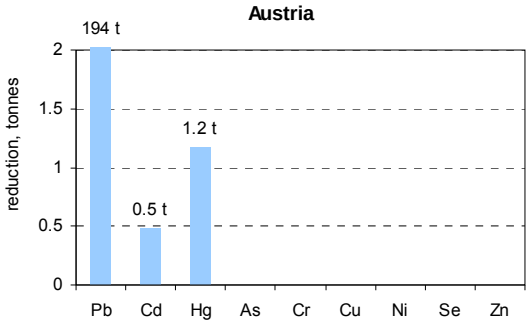
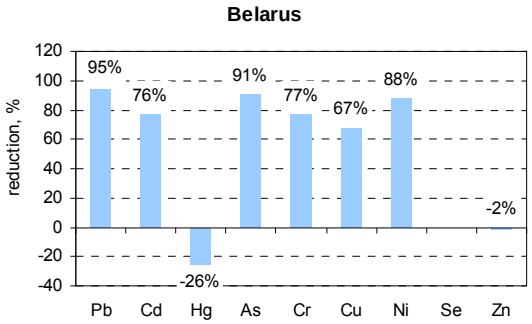
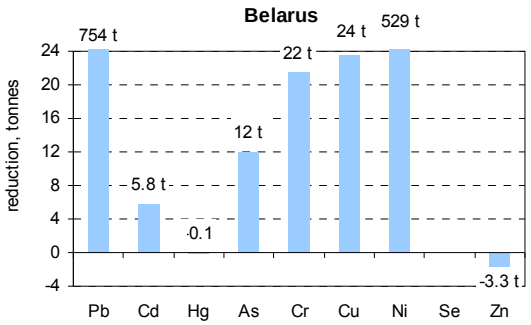
Annex A

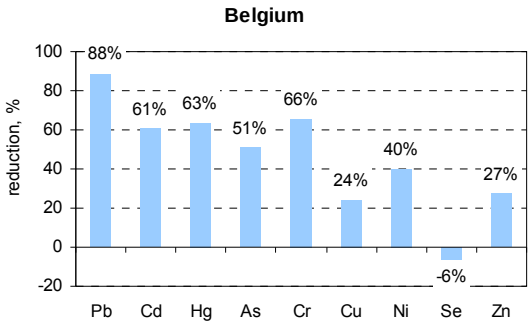
REDUCTIONS OF HEAVY METAL EMISSIONS IN COUNTRIES FOR THE PERIOD OF 1990-2003 BASED ON OFFICIAL DATA

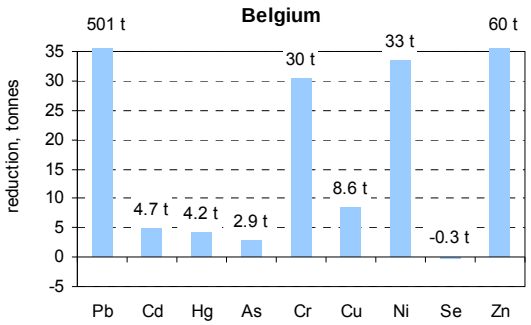


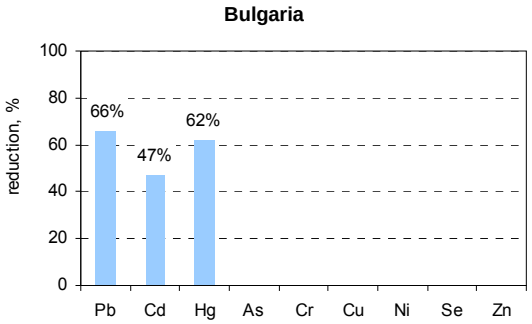


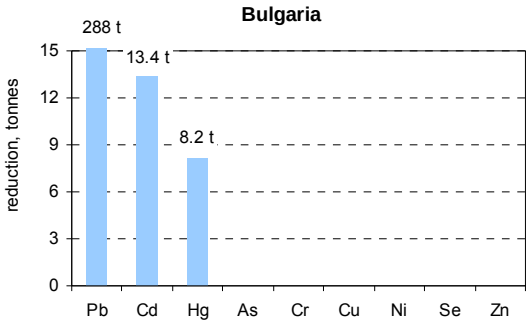


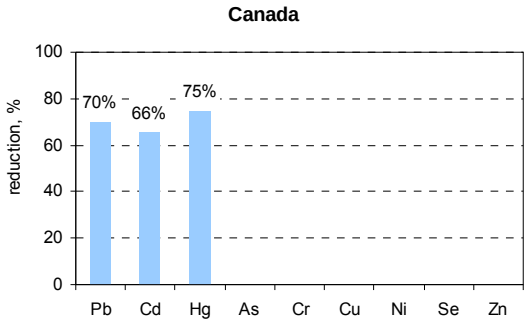


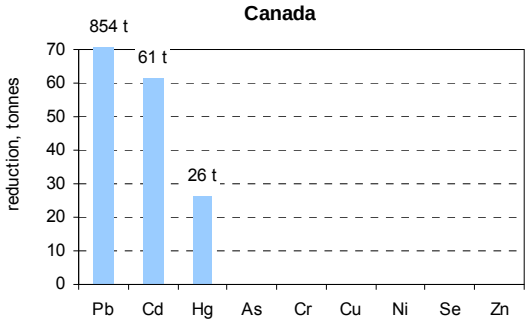


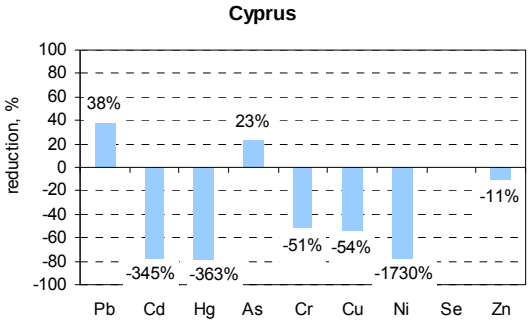


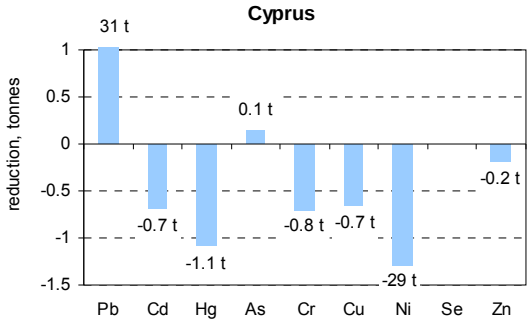


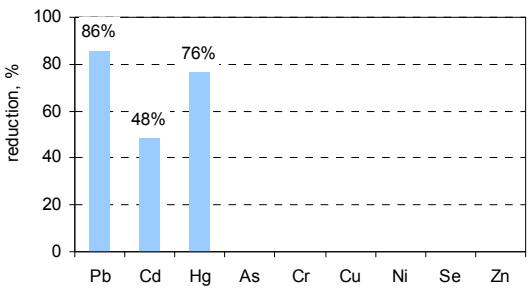


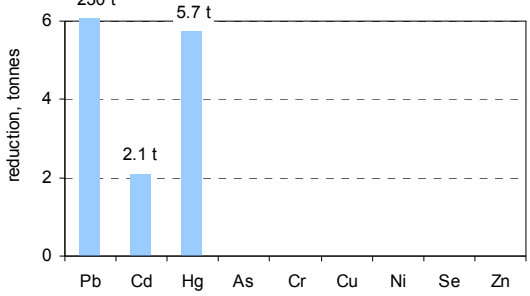

Canada
reduction, %
100
80
60
40
20
0
70%
66%
75%
Pb Cd Hg As Cr Cu Ni Se Zn

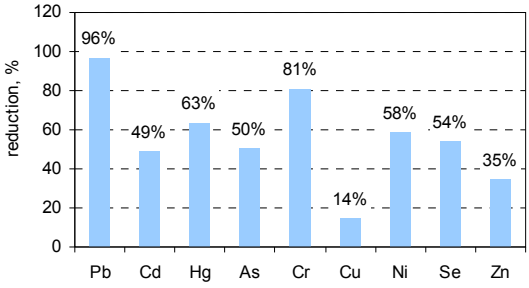

Canada
reduction, tonnes
70
60
50
40
30
20
10
0
854 t
61 t
26 t
Pb Cd Hg As Cr Cu Ni Se Zn

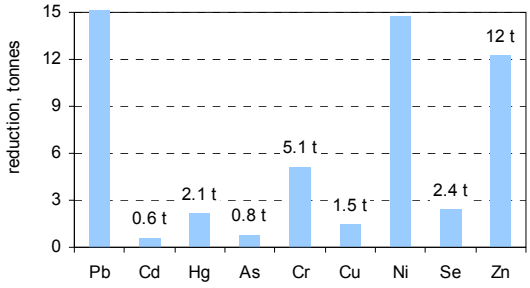

Cyprus
reduction, %
100
80
60
40
20
0
-20
-40
-60
-80
-100
38%
-345%
-363%
23%
-51%
-54%
-1730%
-11%
Pb Cd Hg As Cr Cu Ni Se Zn

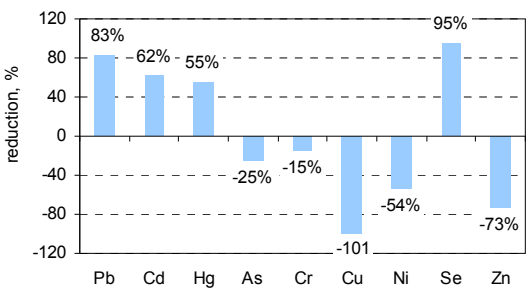

Cyprus
reduction, tonnes
1
0.5
0
-0.5
-1
-1.5
31 t
-0.7 t
-1.1 t
0.1 t
-0.8 t
-0.7 t
-29 t
-0.2 t
Pb Cd Hg As Cr Cu Ni Se Zn

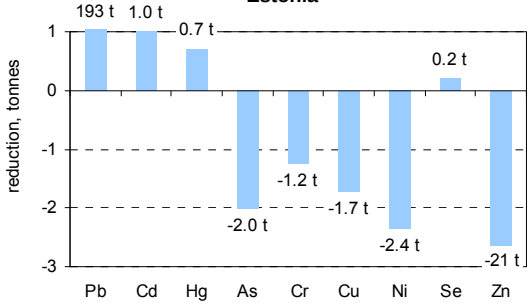

Czech Republic
reduction, %
100
80
60
40
20
0
86%
48%
76%
Pb Cd Hg As Cr Cu Ni Se Zn

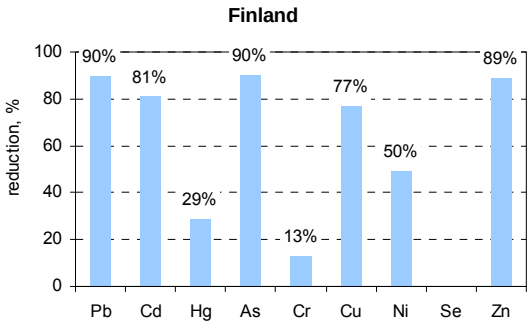

Czech Republic
reduction, tonnes
6
4
2
0
230 t
2.1 t
5.7 t
Pb Cd Hg As Cr Cu Ni Se Zn

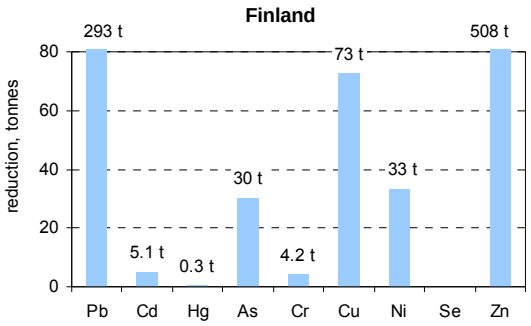

Denmark
reduction, %
120
100
80
60
40
20
0
96%
49%
63%
50%
81%
14%
58%
54%
35%
Pb Cd Hg As Cr Cu Ni Se Zn

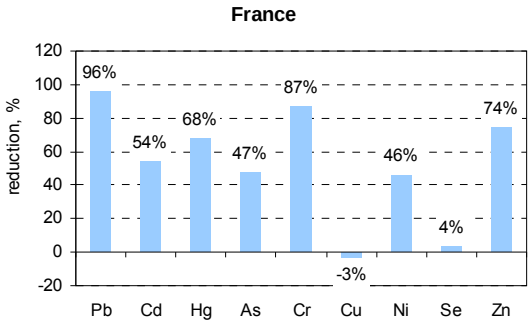

Denmark
reduction, tonnes
15
12
9
6
3
0
118 t
0.6 t
2.1 t
0.8 t
5.1 t
1.5 t
15 t
2.4 t
12 t
Pb Cd Hg As Cr Cu Ni Se Zn

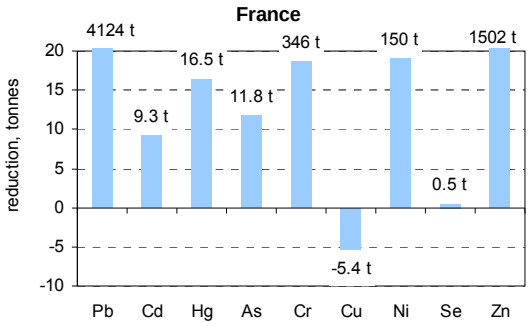

Estonia
reduction, %
120
80
40
0
-40
-80
-120
83%
62%
55%
-25%
-15%
-101
-54%
95%
-73%
Pb Cd Hg As Cr Cu Ni Se Zn

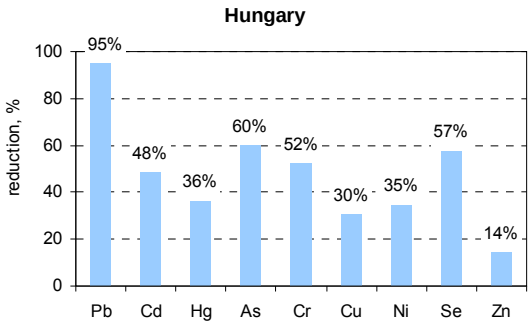

Estonia
reduction, tonnes
1
0
-1
-2
-3
193 t
1.0 t
0.7 t
-2.0 t
-1.2 t
-1.7 t
-2.4 t
0.2 t
-21 t
Pb Cd Hg As Cr Cu Ni Se Zn

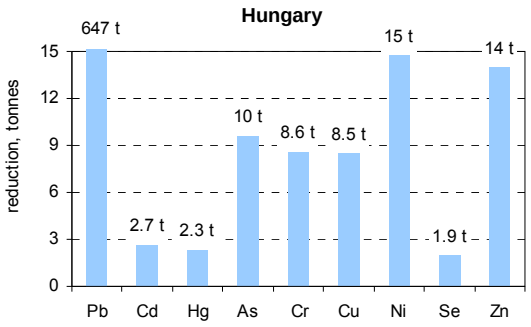

Finland
reduction, %
100
80
60
40
20
0
90%
81%
29%
90%
13%
77%
50%
89%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

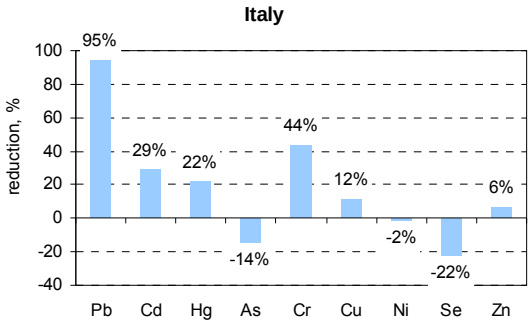

Finland
reduction, tonnes
80
60
40
20
0
293 t
5.1 t
0.3 t
30 t
4.2 t
73 t
33 t
508 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

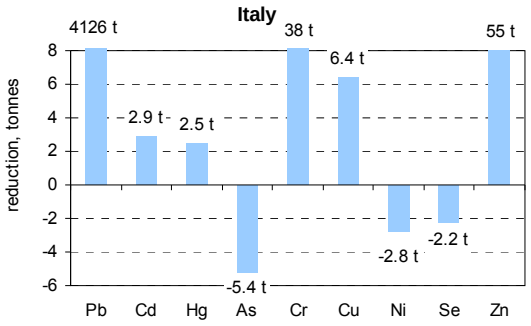

France
reduction, %
120
100
80
60
40
20
0
-20
96%
54%
68%
47%
87%
-3%
46%
4%
74%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

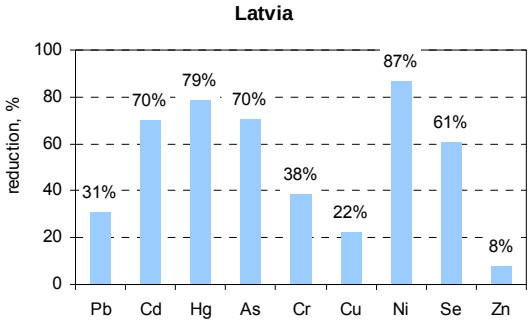

France
reduction, tonnes
20
15
10
5
0
-5
-10
4124 t
9.3 t
16.5 t
11.8 t
346 t
-5.4 t
150 t
0.5 t
1502 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

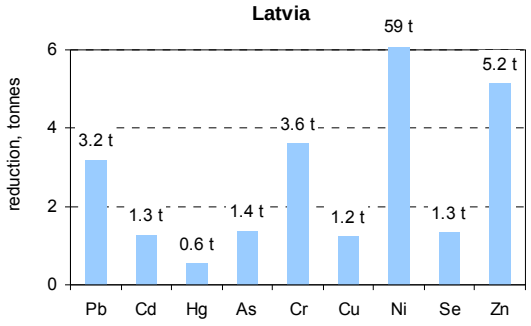

Hungary
reduction, %
100
80
60
40
20
0
95%
48%
36%
60%
52%
30%
35%
57%
14%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

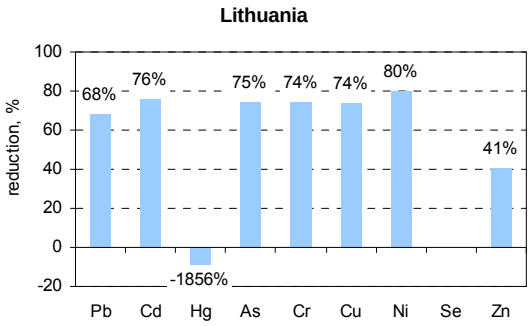

Hungary
reduction, tonnes
15
12
9
6
3
0
647 t
2.7 t
2.3 t
10 t
8.6 t
8.5 t
15 t
1.9 t
14 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

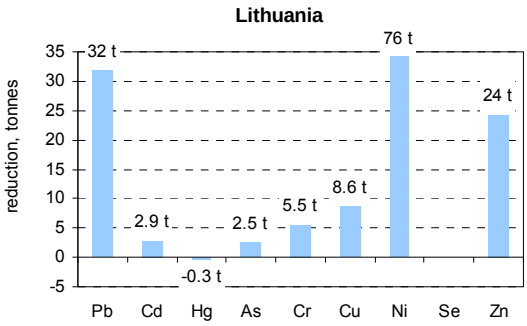

Italy
reduction, %
100
80
60
40
20
0
-20
-40
95%
29%
22%
-14%
44%
12%
-2%
-22%
6%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

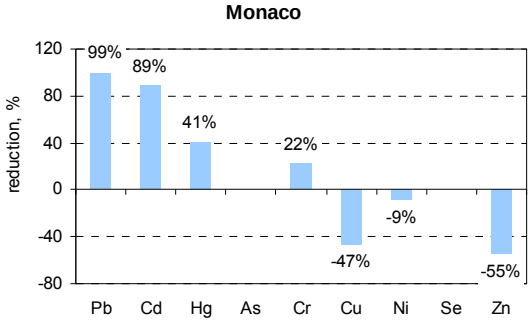

Italy
reduction, tonnes
8
6
4
2
0
-2
-4
-6
4126 t
2.9 t
2.5 t
-5.4 t
38 t
6.4 t
-2.8 t
-2.2 t
55 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

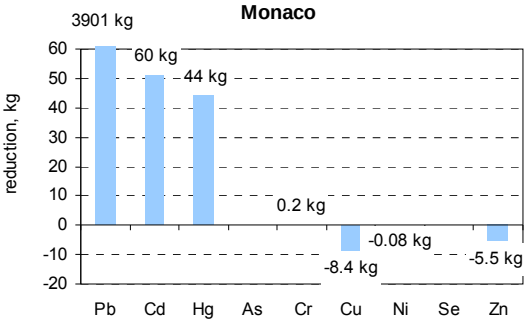

Latvia
reduction, %
100
80
60
40
20
0
31%
70%
79%
70%
38%
22%
87%
61%
8%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

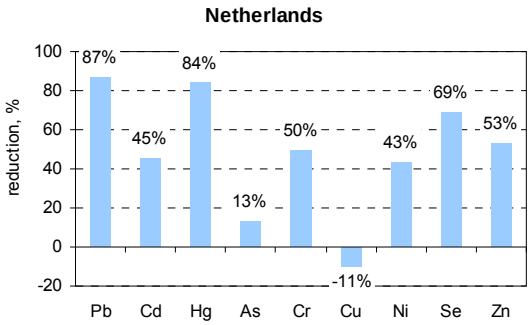

Latvia
reduction, tonnes
6
4
2
0
3.2 t
1.3 t
0.6 t
1.4 t
3.6 t
1.2 t
59 t
1.3 t
5.2 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

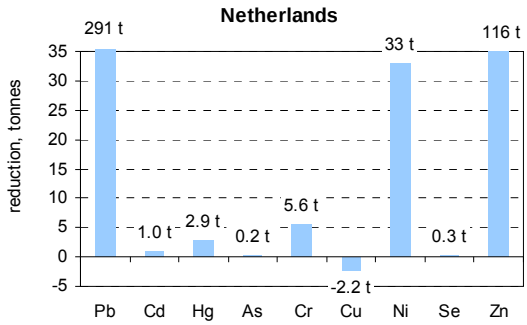

Lithuania
reduction, %
100
80
60
40
20
0
-20
68%
76%
-1856%
75%
74%
74%
80%
41%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

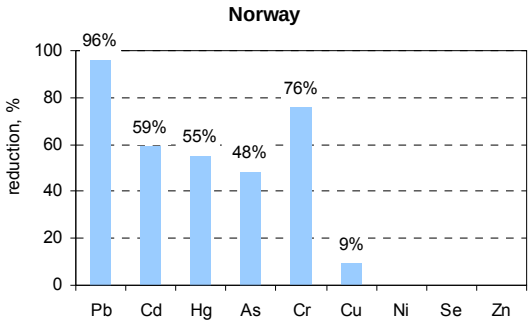

Lithuania
reduction, tonnes
35
30
25
20
15
10
5
0
-5
32 t
2.9 t
-0.3 t
2.5 t
5.5 t
8.6 t
76 t
24 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

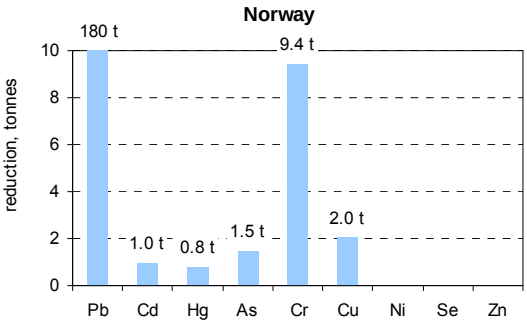

Monaco
reduction, %
120
80
40
0
-40
-80
99%
89%
41%
22%
-47%
-9%
-55%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

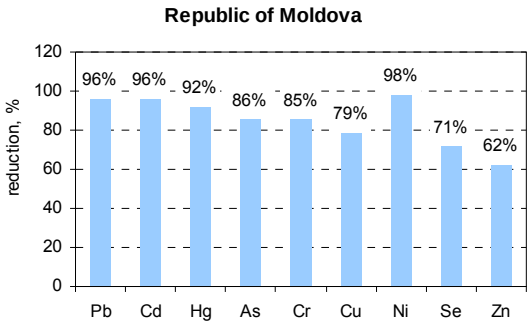

Monaco
reduction, kg
60
50
40
30
20
10
0
-10
-20
3901 kg
60 kg
44 kg
0.2 kg
-8.4 kg
-0.08 kg
-5.5 kg
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

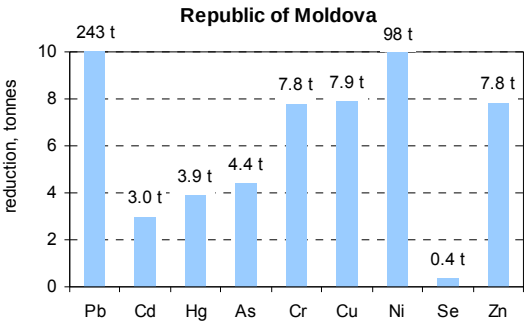

Netherlands
reduction, %
100
80
60
40
20
0
-20
87%
45%
84%
13%
50%
-11%
43%
69%
53%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

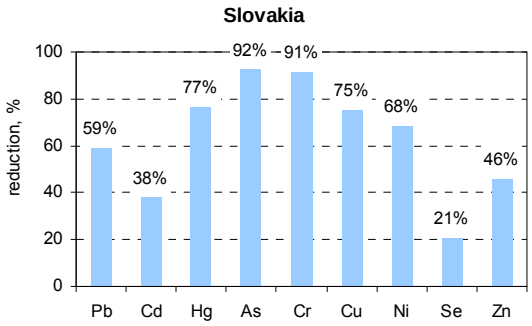

Netherlands
reduction, tonnes
35
30
25
20
15
10
5
0
-5
291 t
1.0 t
2.9 t
0.2 t
5.6 t
-2.2 t
33 t
0.3 t
116 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

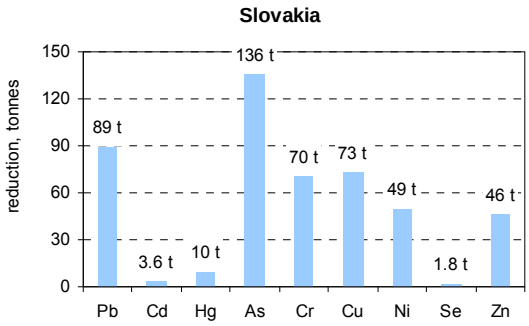

Norway
reduction, %
100
80
60
40
20
0
96%
59%
55%
48%
76%
9%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

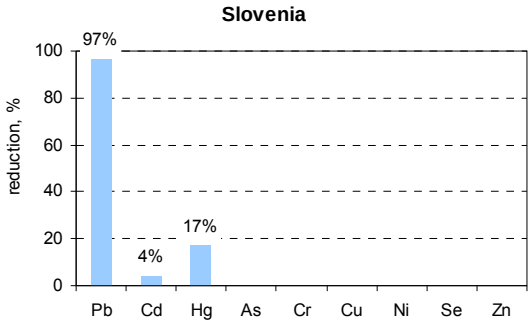

Norway
reduction, tonnes
10
8
6
4
2
0
180 t
1.0 t
0.8 t
1.5 t
9.4 t
2.0 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

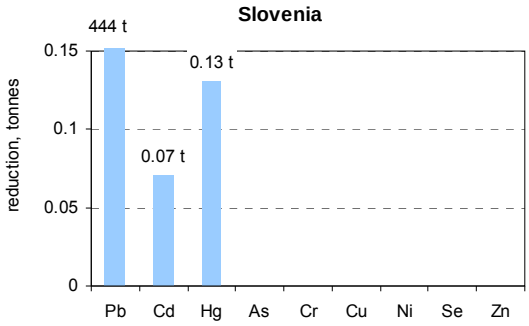

Republic of Moldova
reduction, %
120
100
80
60
40
20
0
96%
96%
92%
86%
85%
79%
98%
71%
62%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

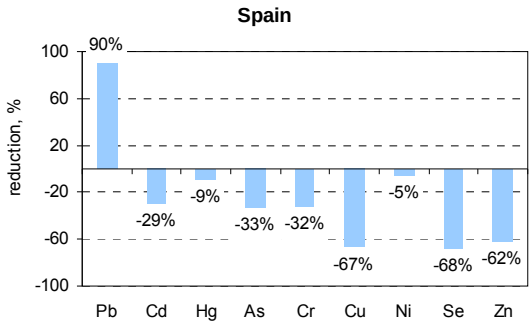

Republic of Moldova
reduction, tonnes
10
8
6
4
2
0
243 t
3.0 t
3.9 t
4.4 t
7.8 t
7.9 t
98 t
0.4 t
7.8 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

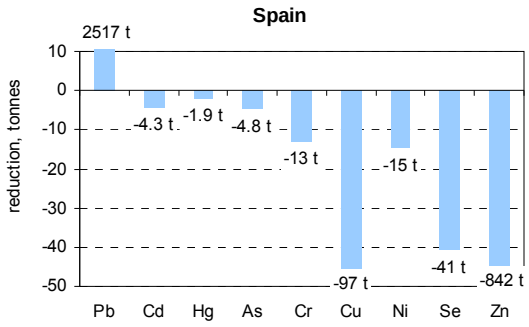

Slovakia
reduction, %
100
80
60
40
20
0
59%
38%
77%
92%
91%
75%
68%
21%
46%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

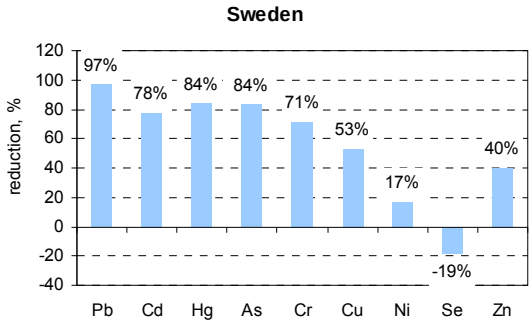

Slovakia
reduction, tonnes
150
120
90
60
30
0
89 t
3.6 t
10 t
136 t
70 t
73 t
49 t
1.8 t
46 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

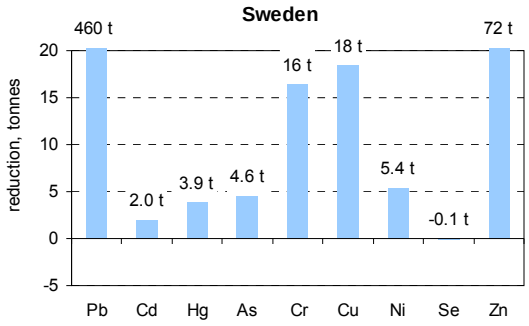

Slovenia
reduction, %
100
80
60
40
20
0
97%
4%
17%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

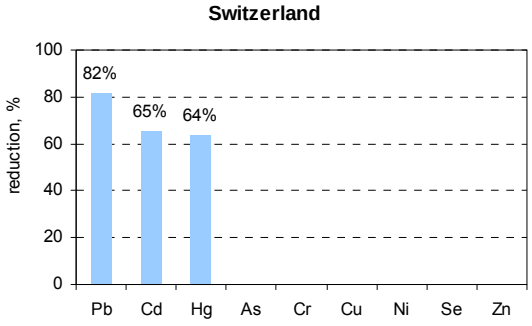

Slovenia
reduction, tonnes
0.15
0.1
0.05
0
444 t
0.07 t
0.13 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

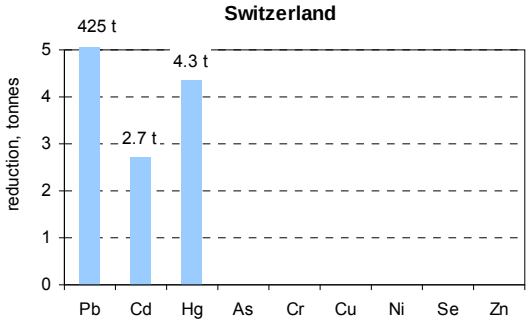

Spain
reduction, %
100
60
20
-20
-60
-100
90%
-29%
-9%
-33%
-32%
-67%
-5%
-68%
-62%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

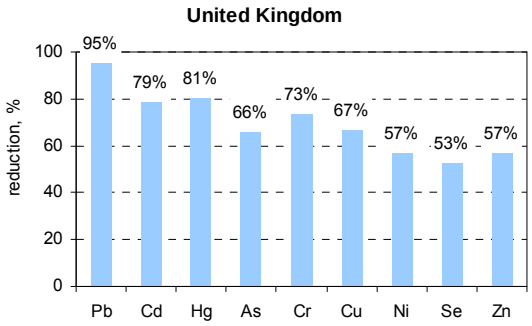

Spain
reduction, tonnes
10
0
-10
-20
-30
-40
-50
2517 t
-4.3 t
-1.9 t
-4.8 t
-13 t
-97 t
-15 t
-41 t
-842 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

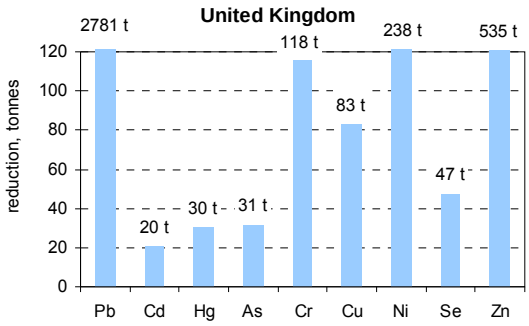

Sweden
reduction, %
120
100
80
60
40
20
0
-20
-40
97%
78%
84%
84%
71%
53%
17%
-19%
40%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn


Sweden
reduction, tonnes
20
15
10
5
0
-5
460 t
2.0 t
3.9 t
4.6 t
16 t
18 t
5.4 t
-0.1 t
72 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn


Switzerland
reduction, %
100
80
60
40
20
0
82%
65%
64%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn


Switzerland
reduction, tonnes
5
4
3
2
1
0
425 t
2.7 t
4.3 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn


United Kingdom
reduction, %
100
80
60
40
20
0
95%
79%
81%
66%
73%
67%
57%
53%
57%
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn


United Kingdom
reduction, tonnes
120
100
80
60
40
20
0
2781 t
20 t
30 t
31 t
118 t
83 t
238 t
47 t
535 t
Pb
Cd
Hg
As
Cr
Cu
Ni
Se
Zn

Annex B

HEAVY METALS SECTOR EMISSIONS

***Table B1**. Pb sector emissions*

NFR sectors	1990		2003		Reduction	
	tonnes	%	tonnes	%	tonnes	%
1 A 3 b Road Transportation	9996.172	84.7	47.005	6.3	9949.168	99.5
2 C Metal Production	355.198	3.0	207.240	27.7	147.958	41.7
6 C Waste Incineration	338.775	2.9	5.680	0.8	333.095	98.3
1 A 2 a Iron and Steel	228.964	1.9	120.253	16.1	108.711	47.5
1 A 1 a Public Electricity and Heat Production	203.490	1.7	39.466	5.3	164.025	80.6
1 A 2 b Non-ferrous Metals	184.347	1.6	88.353	11.8	95.995	52.1
1 A 2 f Other, Manufacturing Industries and Construction	137.517	1.2	137.128	18.3	0.388	0.3
2 B Chemical Industry	98.461	0.8	13.688	1.8	84.774	86.1
1 A 4 b Residential	92.652	0.8	41.403	5.5	51.249	55.3
Other sectors	160.397	1.4	48.967	6.5	111.430	69.5
Total emission (8 countries*)	11796	100	749	100	11047	94

***Table B2.** Cd sector emissions*

NFR sectors	1990		2003		Reduction	
	tonnes	%	tonnes	%	tonnes	%
6 C Waste Incineration	14.501	19.9	0.775	2.0	13.726	94.7
2 C Metal Production	12.277	16.8	9.999	25.9	2.278	18.6
1 A 1 a Public Electricity and Heat Production	11.894	16.3	5.847	15.1	6.047	50.8
1 A 2 b Non-ferrous Metals	10.103	13.8	4.595	11.9	5.508	54.5
1 A 2 f Other, Manufacturing Industries and Construction	4.906	6.7	3.348	8.7	1.558	31.8
1 A 2 a Iron and Steel	4.028	5.5	1.435	3.7	2.593	64.4
1 A 1 b Petroleum refining	3.748	5.1	3.801	9.8	-0.053	-1.4
1 A 3 b Road Transportation	3.351	4.6	4.106	10.6	-0.755	-22.5
1 A 4 b Residential	1.646	2.3	1.396	3.6	0.249	15.2
Other sectors	6.584	9.0	3.361	8.7	3.223	49.0
Total emission (8 countries*)	73	100	39	100	34	47

***Table B3.** Hg sector emissions*

NFR sectors	1990		2003		Reduction	
	tonnes	%	tonnes	%	tonnes	%
1 A 1 a Public Electricity and Heat Production	29.502	28.9	12.858	29.0	16.645	56.4
6 C Waste Incineration	16.137	15.8	2.729	6.2	13.409	83.1
2 B Chemical Industry	15.981	15.7	4.364	9.8	11.618	72.7
1 A 2 f Other, Manufacturing Industries and Construction	12.635	12.4	13.923	31.4	-1.288	-10.2
1 A 2 a Iron and Steel	5.866	5.8	1.017	2.3	4.849	82.7
1 A 2 b Non-ferrous Metals	5.443	5.3	0.375	0.8	5.068	93.1
2 C Metal Production	3.684	3.6	3.608	8.1	0.077	2.1
6 A Solid Waste Disposal on land	2.386	2.3	0.412	0.9	1.974	82.7
1 A 4 b Residential	2.202	2.2	0.910	2.1	1.293	58.7
Other sectors	8.161	8.0	4.147	9.4	4.014	49.2
Total emission (8 countries*)	102	100	44	100	58	57

* Austria, Belgium, France, the Netherlands, Norway, Spain, Sweden, the United Kingdom