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Heavy Metals:
Transboundary Pollution of the Environment

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EXECUTIVE SUMMARY

In 2009 the Meteorological Synthesizing Centre – East (MSC-E) and Chemical Co-ordinating Centre (CCC) were involved in operational and research tasks in the field of heavy metals (HMs) in accordance with the EMEP Workplan [ECE/EB.AIR/GE.1/2008/9/Rev.1]. The operational task was to provide countries of the EMEP region (including the Central Asian countries) with information on concentrations, deposition and transboundary transport of lead, cadmium and mercury for 2007. The research activity was focused on the further development of the common EMEP global modelling framework and on improvement of the regional-scale MSC-E heavy metal model. In addition to this, MSC-E cooperated with the subsidiary bodies to the Convention, the EMEP Task Forces, international organizations and national experts. This report summarizes the results achieved by CCC and MSC-E in 2009.

Data on measured concentrations of heavy metals in air and in precipitation were reported by 69 stations from 23 countries. At 25 stations concentrations of lead and cadmium were measured both in air and in precipitation, and at 22 stations in 13 countries at least one form of mercury was measured. The progress in a number of co-located measurements is noted as a result of implementation of the EMEP monitoring strategy for 2004-2009. Besides, measurement data from France, Hungary, Italy and Cyprus become available. However, spatial coverage of the measurements in the southern and the eastern parts of Europe and in Central Asia remains insufficient.

For the fist time heavy metal pollution levels over Europe and Central Asia were examined using both monitoring data and modelling results. It was shown that deposition and concentrations of lead, cadmium and mercury varied largely over Europe and Central Asia in 2007. The highest regional-scale pollution levels were obtained for Poland, north of Italy, the Benelux, the Balkan region, and the European part of Russia. In the Central Asian region elevated concentrations occurred in the northern and southern parts of Kazakhstan. Heavy metal deposition in Central Asia is not as high as deposition in Europe because of relatively low precipitation amount.

Estimated deposition of lead to the European and the Central Asian countries as a whole in 2007 is considerably higher in comparison with the results for 2006 because of essential changes in the applied emission data. The cadmium deposition remained almost the same, whereas deposition of mercury decreased slightly. Most distinct increase of deposition because of the changes in emission data took place in Russia (Pb) and Germany (Hg), and the decrease – in Bulgaria (Cd, Hg) and Romania (Cd, Hg). Inter-annual variability of meteorological parameters substantially affects pollution levels via changes of annual precipitation amounts and magnitude of input to the atmosphere caused by wind re-suspension.

Special attention is paid to the evaluation of the modelling results via comparison against the observations. The modelling results satisfactorily agree with the measurement data. At most of the stations the agreement between modelled and measured concentrations and deposition of lead and cadmium is within ±50%. The discrepancy between the simulated and observed mercury concentrations does not exceed ±20% and ±25% for air and precipitation, respectively, whereas wet deposition fluxes agree within ±50%.

To explain discrepancies between modelled and observed values joint efforts of measurement, modelling and emission communities are needed. In particular, the EMEP Task Force on Measurements and Modelling (TFMM) welcomed and supported the proposal of MSC-E to organize a case study devoted to the complex investigation of HM pollution levels on the example of a number of countries. The case study could include detailed analysis of emission data, model estimates and

monitoring data for better understanding the reasons of the discrepancies between modelled and measured values and for the evaluation of the emission data quality.

It was demonstrated that the role of transboundary transport in the pollution of the European and the Central Asian countries was substantial. Its contribution to deposition from anthropogenic sources in Europe and Central Asia exceeded 50% in 38, 36 and 26 countries for lead, cadmium and mercury, respectively. The fraction of national emissions of the European and the Central Asian countries entering transboundary transport ranged from 60% to 90% for lead and cadmium. In case of mercury, this fraction commonly varied from 70% to almost 100%.

Understanding and awareness of global-scale nature of atmospheric pollution as well as inclusion of the Central Asian region into the EMEP domain made necessary the development of global-scale models. In 2007 development of the common EMEP global modelling framework was started and in 2009 - continued by the EMEP Modelling Centres. In particular, in 2009 a pilot version of the modelling framework with the modular architecture was elaborated for heavy metals and POPs based on the newly developed global model GLEMOS (Global EMEP Multi-media Modelling System). The model was tested for lead and mercury and evaluated against measurements. Besides, the nesting procedure was implemented in the modelling framework to improve link between different scale simulations. In order to take into account specific features of mercury cycling in the environment, such as its ability to accumulate in the environment and to release back to the atmosphere after deposition (so-called re-emission), multi-media approach for mercury modelling has been developed and tested using the low resolution version of the global modelling framework (GLEMOS-LR).

The research activity of MSC-E included also the development of wet scavenging scheme depending on size distribution for heavy metals. The testing has shown that the new parameterization of below-cloud scavenging gives better spatial correlation of annual mean modelling and measured concentrations in precipitation. However, further development of the size-segregated approach for heavy metal modelling is required. Another research task was aimed at investigation of sensitivity of modelling results to refining of the vertical grid structure of the operational transport model. It has been shown that the reduction of the lowest model layer leads to some decrease of air concentrations, and to small changes of total deposition over the EMEP domain. The sensitivity of modelled concentrations and deposition at background monitoring stations is minor. Therefore, the refinement of the model vertical structure without changes in parameterization of physical properties does not lead to improvement of the model performance.

MSC-E continued cooperation with TFMM, Task Force on Hemispheric Transport of Air Pollution (TF HTAP), international organizations: AMAP, European Commission, HELCOM, OSPAR, UNEP) and the Working Group on Effects (WGE). In particular, in the framework of cooperation with WGE MSC-E together with the ICP-Vegetation carried out complex analysis of HM pollution levels across Europe using modelled deposition and measured concentrations of heavy metals in mosses. Data on HM concentrations in mosses were provided by the ICP-Vegetation. Modelled deposition of lead, cadmium and mercury demonstrated significant agreement with moss concentration data from the viewpoint of spatial distribution and long-term trends. MSC-E was actively involved in cooperation with national experts. This activity included data exchange, sharing of the model source code, participation in scientific meetings, dissemination of country-oriented reports in Russian for EECCA countries.

CONTENTS

INTRODUCTION

Adverse effects of heavy metals on the environment and human health have been studied over several decades. Heavy metals such as lead, cadmium and mercury are transported over long distances by atmospheric flows and deposit far from emission sources. Besides, these metals can be accumulated in the environmental compartments and/or tissues of living organisms increasing the risk of the harmful effects in future. In order to take control over anthropogenic emissions and to reduce transboundary pollution of heavy metals 36 Parties to the Convention on Long-Range Transboundary Air Pollution (CLRTAP, hereinafter the Convention) signed the Protocol on Heavy Metals (hereinafter Protocol). Heavy metals included in the Protocol are lead (Pb), cadmium (Cd) and mercury (Hg).

According to the Protocol, Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (EMEP) provides the Executive Body for the Convention with information on deposition, concentrations and transboundary transport of heavy metals within the geographical scope of EMEP. Monitoring of heavy metals is carried out by Parties to the Convention at the EMEP monitoring network under methodological guidance of the Chemical Coordinating Centre (CCC) of EMEP. Modelling of deposition, concentrations and source-receptor relationships is carried out by the Meteorological Synthesizing Centre East (MSC-E) of EMEP. Emission data for modelling are prepared by the new EMEP Centre for Emission Inventories and Projections (CEIP).

Information on atmospheric pollution levels can be provided by means of monitoring and modelling. Monitoring informs on actual concentrations and deposition at different points and characterizes their temporal evolution, including short-term variability and long-term trends. Besides, monitoring data present a basis for model verification. Modelling, in its turn, allows entire spatial coverage of the considered region and produces parameters which are not measured, for example, information on source-receptor relationships. Therefore, in order to provide Parties to the Convention with more detailed and more reliable information on pollution levels a combined usage and analysis of measurement data and modelling results is applied (so-called monitoring-modelling approach).

There were about 70 stations reported information on the observed concentrations in air and/or in precipitation in 2007. The measurements were available mostly in the northern and the western parts of Europe and were scarce in its eastern part and in Central Asia. Therefore, the analysis of pollution levels in these regions is based entirely on modelling results. However, complimentary monitoring data such as measurements of concentrations in mosses can also be useful for the analysis of pollution levels and for the model validation. Concentration of heavy metals in mosses in Europe is measured in more than 30 countries with periods of about 5 years. The results of pan-European moss surveys held in 1990, 1995, 2000 and 2005/2006 were provided to MSC-E by the ICP-Vegetation of Working Group on Effects (WGE) and were used in the analysis of heavy metal pollution in Europe.

It is well known that a number of pollutants (e.g., mercury and some POPs) is dispersed over the entire globe because of their long life time in the environment. It means that the EMEP region is subject to atmospheric pollution from other continents. Understanding and awareness of global-scale nature of atmospheric pollution as well as inclusion of the Central Asian region into the EMEP domain made necessary the development of global-scale models. Joint development of the common EMEP global modelling framework was started by MSC-E and MSC-W in 2007. The contribution of MSC-E to this process is reflected in the report. In particular, a pilot version of the modelling framework was elaborated and tested for heavy metals and POPs based on the newly developed global model GLEMOS (Global EMEP Multi-media Modelling System).

Specific features of mercury and POPs such as long residence time in the environment, their ability to accumulate in the environment and to release back to the atmosphere after deposition (so-called re-

emission) determine the necessity to consider cycling of these substances between different media. Therefore, the multi-media approach for mercury modelling has been developed and tested using the low resolution version of the global modelling framework (GLEMOS-LR).

Work of the EMEP Centres in 2009 with regard to evaluation of HM pollution levels was carried out according to the EMEP Workplan [ECE/EB.AIR/GE.1/2008/9/Rev.1]. This report describes the achievements of MSC-E and CCC in the field of heavy metals in 2009.

A brief overview of measurement activity concerning heavy metals is available in *Chapter 1*. The chapter describes the number of stations involved in monitoring of lead, cadmium and mercury in 2007, and characterizes spatial coverage of the EMEP region with measurements. Particular attention is paid to the progress in the EMEP monitoring network achieved as a result of implementation of the EMEP monitoring strategy for 2004-2009. Besides, measured heavy metal concentrations in air and in precipitation are shown in this chapter.

New developments regarding modelling transport and deposition of heavy metals are described in *Chapter 2*. In particular, general architecture of the EMEP global modelling framework and preliminary results of its application to simulation of heavy metals are discussed. Besides, first steps in the development of mercury multi-media approach are presented. Furthermore, dependence of wet scavenging on particle size distribution for heavy metals dispersion modelling was studied. The sensitivity analysis of modelled concentrations and deposition sensitivity with regard to the changes of vertical model grid structure is performed.

Chapter 3 is devoted to the assessment of pollution levels of HMs in 2007. The chapter includes a short description of emission data for Europe and Central Asia used in atmospheric transport modelling of heavy metals. Modelled and observed pollution levels are jointly analysed. Discrepancies between modelled and measured concentrations in air and precipitation found for some stations are examined. Furthermore, country-oriented information on transboundary transport and source-receptor relationships is presented.

Chapter 4 is focused on cooperation of MSC-E and CCC with the EMEP Task Forces (TFHTAP, TFMM), international organizations (AMAP, European Commission, HELCOM, OSPAR, UNEP) and national experts. Significant attention was paid to joint activity with the ICP-Vegetation of the Working Group on Effects (WGE) devoted to complex analysis of pollution levels and their trends using modelling results and measured data on concentration of heavy metals in mosses.

In *Chapter 5* future activities of EMEP in the field of heavy metals are outlined. Main results of the EMEP Centres work in 2007 are summarized in section *Conclusions*. Detailed source-receptor matrices of lead, cadmium and mercury for 2007 are given in *Annexes*.

1. MONITORING OF HEAVY METALS IN EMEP

Measurement network

Heavy metals were included in EMEP's monitoring program in 1999. However, earlier data has been available and collected, and the EMEP database thus also includes older data, even back to 1987 for a few sites. A number of countries have been reporting heavy metals within the EMEP area in connection with different national and international programmers such as HELCOM, AMAP and OSPAR.

Detailed information about the sites and the measurement methods are found in EMEP/CCC's data report on heavy metals and POPs [*Aas and Breivik,* 2009]. In the EMEP monitoring strategy for 2004-2009 (EB.AIR/GE.1/2004/5) it is stated that Parties should measure heavy metals in precipitation at their EMEP level 1 sites, while measurements in air is only necessary at the level 2 super sites. Mercury in both air and precipitation should also be measured at the level 2 sites. Co-located and concurrent monitoring of relevant species is highlighted as a priority, i.e. both air and precipitation measurements should be done at the same site. There should be at least one EMEP level 2 site per country. How is the status of implementing the strategy by 2007, now two years from the implementation year? In Figure 1.1 one can see there is a slight progress in number of co-located sites mainly caused by more countries starting to measure heavy metals in air. There is still a lack of sites in east part of Europe however, but positive tendency that new countries like Cyprus, France, Italy and Hungary have started monitoring heavy metals. A problem is that some countries have measurements now and then and not for long term commitment. There are only a few stations measuring mercury in Europe, and most of them are related to the OSPAR program CAMP. For mercury it is the same positive trend, but only nine sites with co-located air or aerosol measurements together with precipitation measurement are too little to give a spatial picture of Europe; all of these sites are in central or northern Europe.

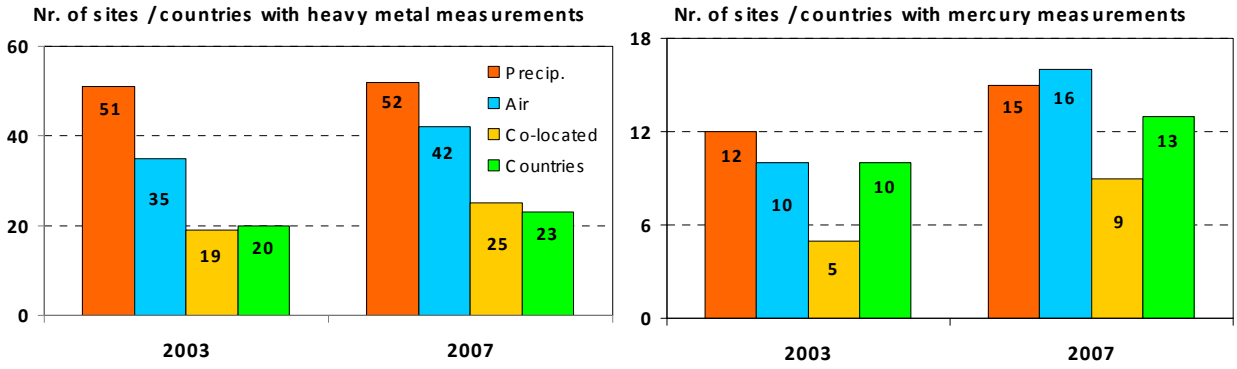


Fig. 1.1. *Development of Nr. of sites and countries measuring heavy metals in EMEP*

Observed concentration level of Pb, Cd and Hg in 2007

Annual averages of Pb, Cd and Hg concentrations in precipitation and in air in 2007 are presented in Fig. 1.2-1.7. The lowest concentrations for all elements in air as well as precipitation are generally found in northern Scandinavia. An increasing gradient can in general be seen southeast, but the concentration levels are not evenly distributed, there are some "hotspots" for some elements. I.e. an extremely high annual concentration of cadmium in precipitation (15.4 ng/L) is seen at IT01, which

most likely must be due to local influence from sources in the Rome area. Portugal has also high level of cadmium, but this is due to high detection limit, so these data are not shown in Fig 1.5. For cadmium in air the highest levels are seen in Slovakia, Belgium and the Czech Republic. For lead in precipitation, the highest levels are observed in Spain and Hungary, while in air the highest level is in Slovakia and Belgium. A somewhat unusual gradient is seen for elemental mercury in air, where the highest annual average is seen in Norway (1.86 ng/m^3), while the lowest in the Czech Republic (1.18 ng/m^3). In precipitation some of the apparent high levels in Latvia and Ireland are due to too high detection limit of the methodology used and not necessary because of high deposition level.

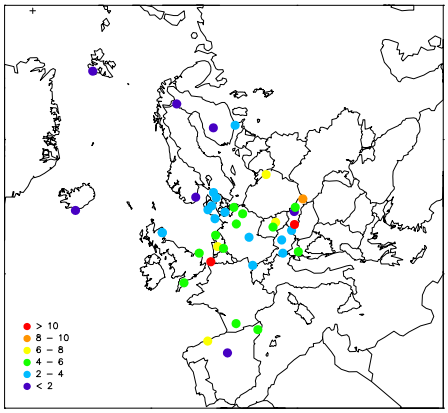


Fig. 1.2. *Pb in aerosol, ng/m^3*

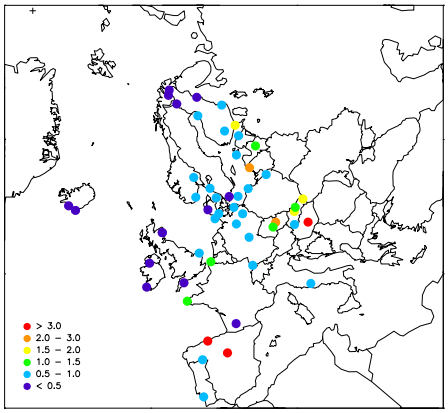


Fig. 1.3 *Pb in precipitation, µg/L*

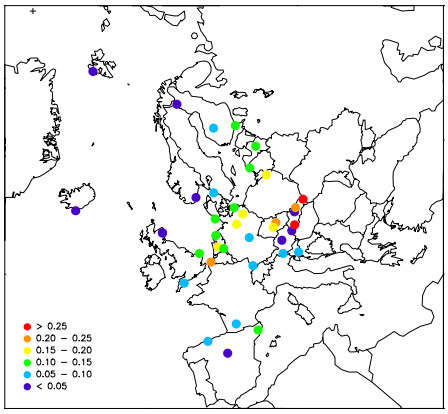


Fig. 1.4*. Cd in aerosol, ng/m^3*

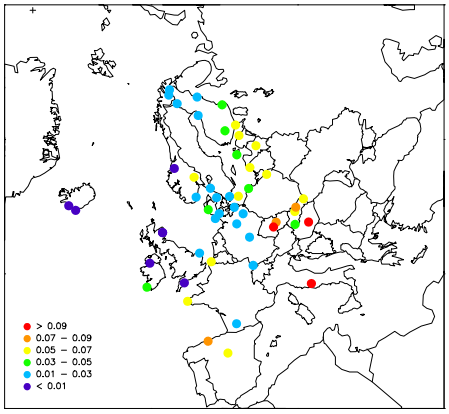


Fig. 1.5. *Cd in precipitation, µg/L*

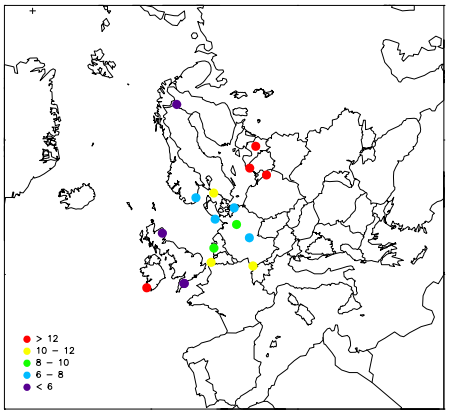


Fig. 1.6*. Hg (g) in air, ng/m^3*

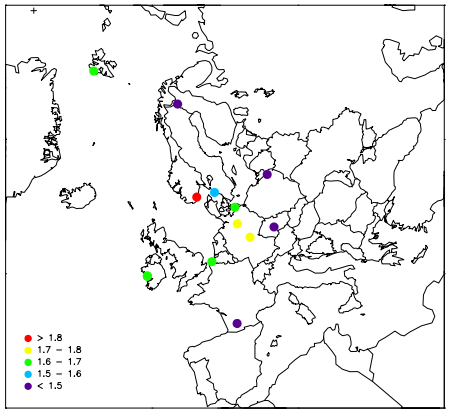


Fig. 1.7. *Hg in precipitation, ng/L*

2. HEAVY METAL MODELLING: NEW DEVELOPMENTS

This chapter is focused on the development of modelling tools used for the evaluation of transport and deposition of heavy metals. First of all, significant attention is paid to the development of the common EMEP global modelling framework. First steps in the elaboration of the multi-media global model for mercury are discussed. Besides, sensitivity of the regional-scale model results to wet scavenging schemes depending on particle size distribution is studied. Finally, the sensitivity of the model results to the depth of the lowest model layer is investigated.

2.1. Towards development of the common EMEP global modelling framework

The global modelling framework is being developed within EMEP as a flexible research tool for wide variety of tasks under the Convention. The motivation and main requirements for the modelling framework were formulated in the previous progress report [*Tarrasón and Gusev*, 2008]. They include flexibility of choice of the model domain and grid resolution, multi-pollutant and multi-media approach, essential modular structure and computational efficiency. Some of these requirements have been already implemented in the current versions of MSC-W and MSC-E global models (such as flexibility of the model domain and grid resolution). In order to evaluate the entire concept and to facilitate the framework development MSC-E has undertaken efforts to elaborate a pilot version of the framework for heavy metals and persistent organic pollutants (POPs) based on the newly developed global model GLEMOS (Global EMEP Multi-media Modelling System). The aim of this study was to develop the model architecture with essential modular structure for the multi-pollutant and multi-media modelling system. The model architecture has been successfully developed and tested as a part of new version of the GLEMOS model. Main features of this architecture are discussed below.

The GLEMOS is an Eulerian type chemical transport model with variable spatial resolution and model domain. It is driven by off-line meteorological data provided by a meteorological pre-processor (a number of modern weather forecast models are supported – GEM, WRF). Base characteristics of the model were overviewed in [*Tarrasón and Gusev*, 2008]. The atmospheric part of the model was evaluated in the TF HTAP model experiment (TP1x) along with other transport models. Current version of the model includes parameterizations for heavy metals and POPs but the general modular architecture implies possibility to extend the list of substances.

The idea of modular architecture consists of possibility to construct the suitable model configuration for particular application by means of including, removing or replacing some modules with other ones. In particular, it provides flexibility to simulate pollutants with very different properties (e.g. ozone and POPs) either all together (similar to the “one atmosphere” approach) or separately consuming smaller computer resources. It also allows considering different number of environmental media depending on a pollutant properties: only the atmosphere for pure air pollutants or also other media (soil, vegetation, the ocean etc.) for pollutants with complex environmental cycling.

The modular architecture has been realized in the GLEMOS model code. General model scheme reflecting the modular structure is presented in Fig. 2.1. Three pollutant groups have been included into the current version of the model: mercury, particle-bound heavy metals (Pb, Cd) and POPs (only two groups are shown in the figure for illustration purpose). Parameterizations of media processes for these pollutants applied in the model are largely based on the previous well developed and extensively tested hemispheric models MSCE-HM-Hem and MCSE-POP-Hem.

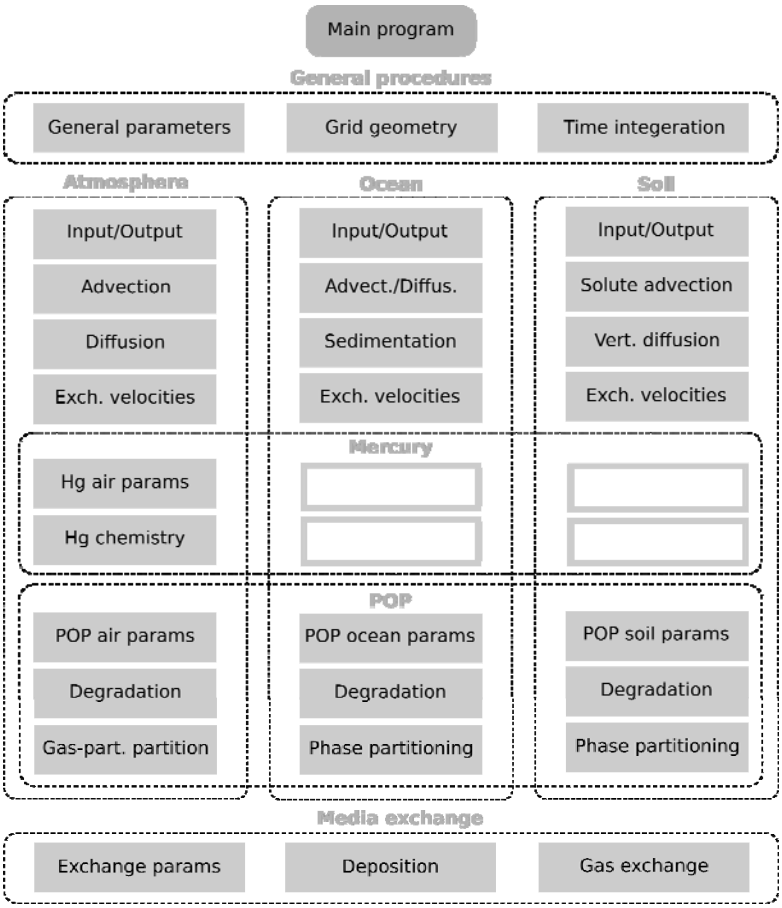


Fig. 2.1. *General scheme of the multi-media, multi-pollutant framework architecture*

As it was mentioned the modular architecture provides a flexible means to include other pollutants to the model. Simulation of heavy metals and POPs requires input information on air concentration of some other substances including ozone, OH-radical, sulphur dioxide, PM, etc. Currently, appropriate pollutant groups are presented in the model by simplistic modules reading input information generated by third parties – GEMAQ-EC (Environment Canada), MOZART (Max Plank Institute for Meteorology, Germany). But it is planned also to supply the modelling framework with full-scale modules simulating these substances, first of all, based on parameterizations available within EMEP and in close co-operation with MSC-W. These modules could be used both on-line along with heavy metals and POPs simulations or in the off-line regime pre-calculating required reactants concentrations.

The developed global modelling framework was tested for two heavy metals with diverse properties – lead and mercury. These two substances relate to different pollutant groups according to the framework classification and, therefore, functionality of the multi-pollutant modular approach was also examined. For the testing purpose we performed annual simulation run with 1×1 degrees resolution using meteorological dataset for 2001 generated with GEM (Environment Canada).

Lead can be considered as a tracer-like pollutant with relatively short life time (days to weeks) in the atmosphere with respect to dry and wet removal. Therefore, annual deposition pattern demonstrates essentially regional character of lead pollution over long periods. Nevertheless, episodic transport of lead can cover significant distances between the continents or can reach remote regions. Figure 2.2 shows simulated episode of lead transport from sources located in Central Asia, southern Ural and Siberia to the Arctic in winter (January 13-16, 2001). The plume originated in Central Asia and Southern Siberia in two days reaches northern regions of Russia, is amplified by strong source located

in Northern Siberia (Norilsk) and goes further to the Arctic. During next two days it reaches the coast of Greenland.

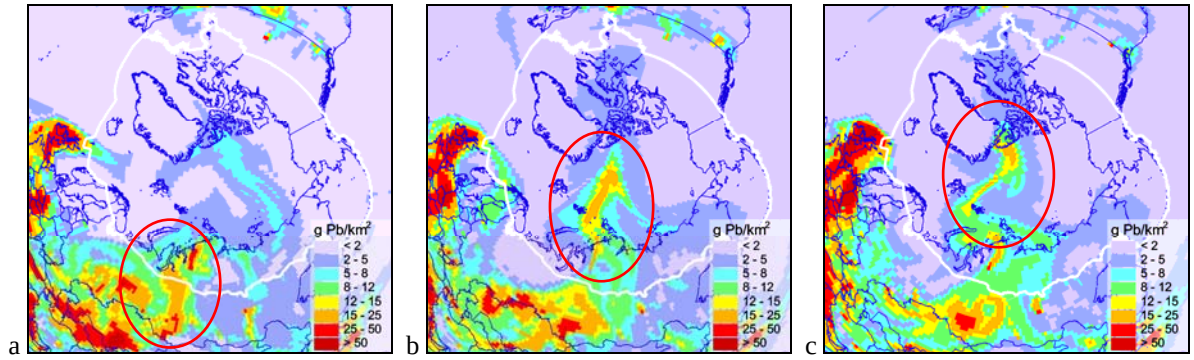


Fig. 2.2. *Daily mean mass of lead in air column showing episode of lead entrainment to the Arctic from Central Asian and Siberian sources (January 13-16, 2001): (a) – January 13; (b) – January 15; (c) – January 16*

Mercury is a more complicated pollutant characterized by intensive chemical transformations in the atmosphere. The original mercury chemical scheme from the hemispheric transport model MSCE-HM-Hem was adapted for appropriate chemical module of the GLEMOS framework. Preliminary results of the model simulation are shown in Fig. 2.3. Available observations of mercury in air and wet deposition flux from the EMEP, NADP/MDN and CAMNet monitoring networks as well as from literature are presented for comparison. As seen even these first results demonstrate satisfactory agreement with measurements. Elevated concentrations of gaseous elemental mercury (GEM) are characteristics of regions with high anthropogenic and natural emissions (Fig. 2.3a). Besides, the ambient concentration exhibits pronounced south-to-north gradient from 1.1 to 1.8 ng/m^3. Significant wet deposition mostly occur over low and temperate latitudes where major emission sources are located and most intensive precipitation takes place (Fig. 2.3b).

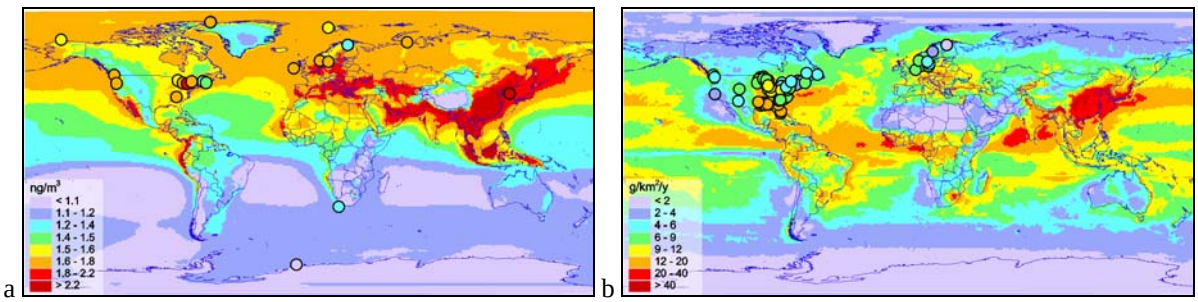


Fig. 2.3. *Annual mean concentration of elemental gaseous mercury in the ambient air (a) and mercury wet deposition flux (b). Circles present long-term measurements from the EMEP, NADP/MDN and CAMNet monitoring networks as well as from literature.*

More thorough evaluation of modelling results is required along with further improvement of the mercury chemical scheme in accordance with new findings of the scientific community. Besides, additional efforts to evaluate mercury natural emission and air-surface exchange are needed. First steps in this direction are discussed in Section 2.2.

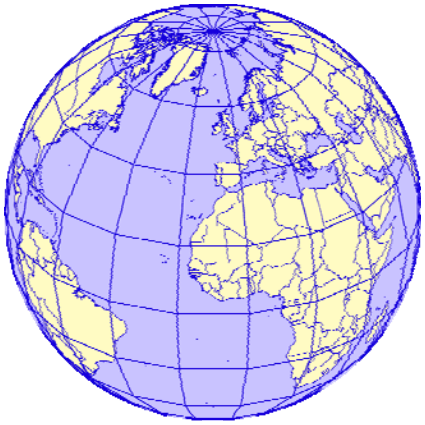
These and other aspects of the global modelling activities of two EMEP Modelling Centres are available in more detail in the Joint MSC-E and MSC-W Progress report [*Travnikov et al*., 2009]

2.2. Development of mercury multi-media modelling approach

Mercury as a relatively volatile pollutant is characterized by intensive cycling between different media. Once emitted to the atmosphere from anthropogenic or natural sources it is transported globally (mostly in elemental gaseous form) until it is transformed to one of hydrophilic oxidised forms and deposited to the ground. After entering soil or seawater, oxidized mercury can be transformed to bio-available methylmercury form or reduced back to volatile elemental form with subsequent re-emission to the atmosphere. Thus, mercury dispersion in the environment has complicated character including both atmospheric transport, chemical transformations and continuous exchange with other media. This aspect should be taken into account in the assessment of mercury contamination and, in particular, long-term dynamics of mercury pollution levels – historical trends and future scenarios.

In order to take into account mentioned above peculiarities of mercury dispersion MSC-E initiated development of a multi-media approach for mercury modelling. For development purpose, a simplified low-resolution version of the global modelling framework (GLEMOS-LR) was applied. Major distinctions of this version from the full-scale model include significantly lower spatial resolution – 20º×20º (Fig. 2.4a), simplified atmospheric and oceanic dispersion schemes and use of averaged meteorological and oceanic driving fields presenting 'climatic' conditions. All these aspects make the GLEMOS-LR model to be a very useful tool for development and testing new parameterisations and for application to very long-term simulations (scale of centuries) for evaluation of the pollutant accumulation and cycling in the environment. The model includes three environmental media – atmosphere, ocean and soil – with appropriate exchange fluxes (Fig. 2.4b).

a



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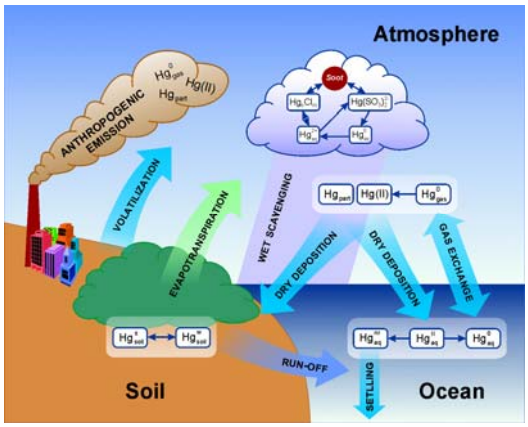


Fig.2.4. *Horizontal structure of the model domain (a) and general scheme of media and exchange processes considered in the model (b)*

An important type of input information required for estimates of mercury cycling and long-term accumulation in the environment is historical emissions. Up to date, there is no reliable estimates of mercury anthropogenic emission changes since pre-industrial period till nowadays. For the research purpose, we performed rough estimates of historical emission trend of mercury using approach suggested by *R.J.M.Hudson et al.* [1995]. Modern anthropogenic emissions were taken from the recent global mercury emission inventory for 2005 [*AMAP/UNEP*, 2008]. Since much of global mercury emission is originated from coal and other fuels combustion [*AMAP/UNEP*, 2008] we approximated historical evolution of mercury emission by scaling modern emission levels by a factor derived from historical trend of CO_2 emissions from fossil fuel combustion. Global data on fossil-fuel CO_2 emissions [*Andres et al.*, 1999] are available from the Carbon Dioxide Information Analysis Centre (http://cdiac.ornl.gov/trends/emis/overview.html).

It is clear that this trend does not reflect historical evolution of mercury emissions from other important sources including metal and cement production, waste incineration and artisanal gold mining. Therefore, in order to estimate the effect of one of the most important historical mercury emission episodes on mercury cycling in the environment we also considered emission of the pollutant from gold and silver mining in North America (Fig. 2.5). According to different estimates annual emission of mercury from this source in the second half of 19th century could be of the same order or comparable with modern global mercury emission [*Hudson et al.,* 1995, *Strode et al.*, 2009]. To evaluate contribution of this source we used recent estimates of mercury emission from North American gold rush in 1870-1880 by *S.Strode et al.* [2009] and primary mercury production in North America [*Hylander and Meili*, 2003] as a temporal scaling factor.

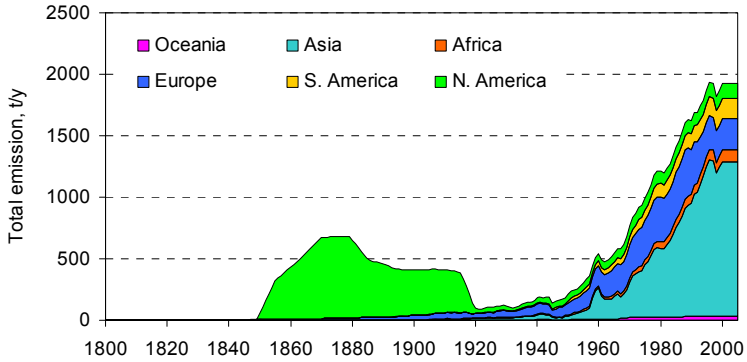


Fig.2.5. *Estimated historical emissions of mercury from fossil fuel combustion as well as gold and silver mining in North America, t/y*

Pre-industrial conditions were simulated by reaching steady-state with zero anthropogenic emissions. After that we performed 200 years simulation from the beginning of 19th century to nowadays using historical anthropogenic emissions discussed above. Figure 2.6a shows simulated changes of total mercury burden in the atmosphere, soil and the ocean as well as atmospheric deposition. The signal of mercury emission from North American gold and silver mining is clearly seen in the atmospheric mass and deposition. Response of the ocean was significantly smaller and almost no effect was obtained for the soil burden. The total mercury burden in the atmosphere has increased more then twice since the pre-industrial period till nowadays, mercury in the ocean – by about 30%, and about 10% increase was obtained for mercury in soil. It should be noted, that increase of mercury concentrations in the upper layers of soil and the ocean is more significant than in the whole media and can reach a factor of two. The largest enrichment due to anthropogenic activity was obtained for atmospheric deposition: it was enlarged by a factor 2.3. Besides, the deposition increase varies between different regions and continents (Fig. 2.6b). For example, in Asia it exceeds a factor of 3 whereas is South America it is smaller then a factor of 2.

In order to investigate long-term media response to changes of anthropogenic emissions we performed simulation of two artificial future scenarios. The first one – the '*cut-off scenario'* – simulates recovering of the global environment in case when global anthropogenic emissions are completely stopped (Fig. 2.7a). As seen from the figure, total atmospheric burden and deposition of mercury decreases quickly during the first 10 years. After that the decrease is slowing down when the atmosphere reaches equilibrium with soil, which burden changes very slowly remaining somewhat enriched with mercury in comparison with pre-industrial period. The ocean burden of mercury gradually decreases during the next hundred years. The second 'status quo' scenario considers changes of mercury levels in the environment if the current emissions are fixed in future. In this case the model predicts further growth of mercury levels in all media (Fig. 2.7b).

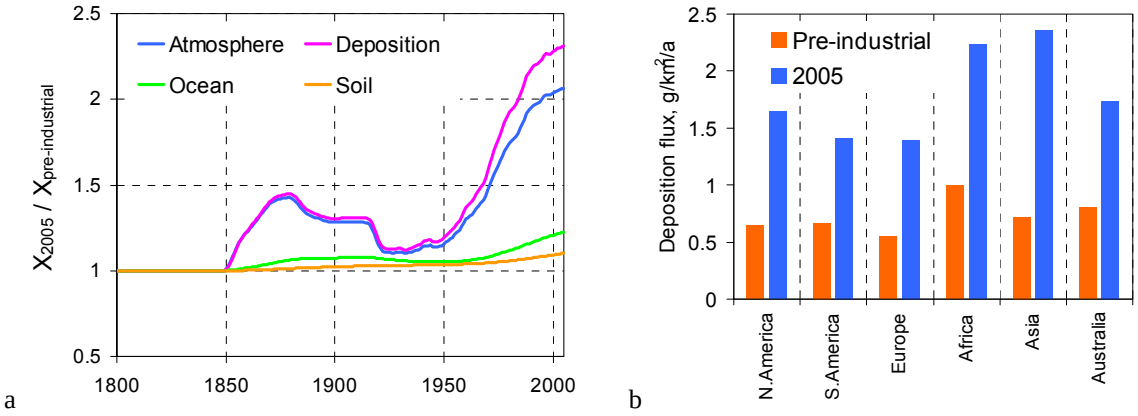


Fig.2.6. *Simulated evolution of total mercury burden in three main environmental media and atmospheric deposition since 1800 till 2005 (a) and increase of average deposition flux in different continents (b)*

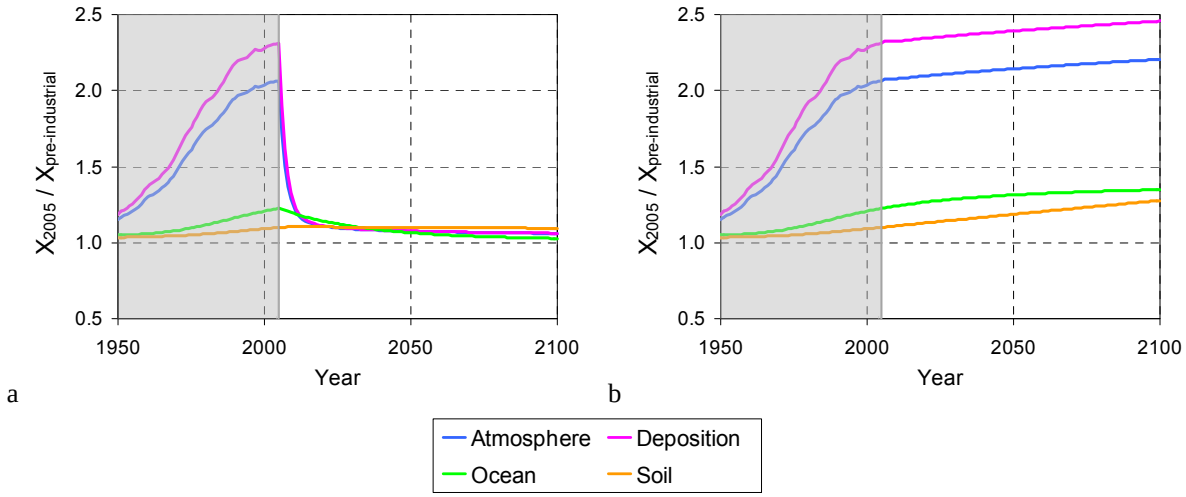


Fig.2.7. *Simulated evolution of total mercury burden in three main environmental media and atmospheric deposition for two artificial future scenarios: cut-off scenario (a) and status quo scenario (b)*

2.3. Size-segregated modelling of heavy metal dispersion and removal

The current version of the MSCE-HM regional model treats particles carrying heavy metals as mono-disperse fraction with fixed mass median diameter (MMD) [*Travnikov and Ilyin,* 2005]. The main purposes of the research described in this section is to evaluate the feasibility of operational modelling of heavy metal atmospheric transport taking into account particle size distribution and to estimate the sensitivity of calculation results to the diameter of carrier particles. This research is the first step in development of size-segregated approach for modelling of heavy metal dispersion and removal at the MSC-E.

By now dry deposition has been the only physical process dependent on a particle size in the MSCE-HM model. In this study the parameterisation of below-cloud wet scavenging has been experimentally changed to the particle size resolved one. Thus dry deposition and below-cloud scavenging schemes fully determined aerosol size dependence in the experimental version of the model used in the size-resolved simulation.

Several below-cloud scavenging schemes have been analyzed (Fig 2.8). The expression of scavenging coefficient proposed by [*Laakso et al.*, 2003] has been chosen for the experimental calculations using the MSCE-HM regional model.

Several yearly test calculations of the atmospheric transport of lead over the EMEP domain have been done. The results of these calculations have been analysed and compared with the EMEP measurements.

The testing has shown that the new parameterization of below-cloud scavenging gives better spatial correlation of annual mean modelled and measured lead concentrations in precipitation than the old one (R_{corr} = 0.54 vs. 0.51 for the base case – see Table 2.1). The temporal correlation coefficient based on monthly mean observed and modeled concentrations of lead in precipitation at most of the sites for the new below-cloud scavenging parameterization is slightly higher than for the old one.

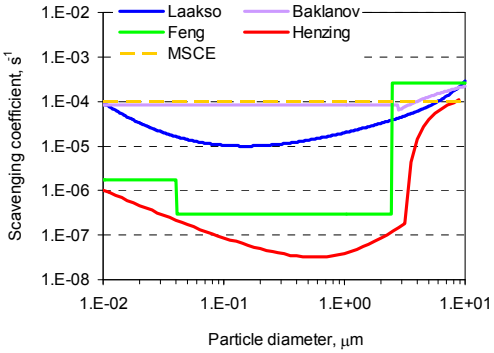


Fig. 2.8. *Below-cloud scavenging coefficient as a function of aerosol diameter for precipitation rate 1 mm/h based on different parameterizations: [Laakso et al., 2003; Baklanov and Sorensen, 2001; Feng, 2007; Henzing et.al., 2006; Travnikov and Ilyin, 2005]*

The dependence of modelling results on the carrier particle diameter (d_p) has been investigated. The increase of aerosol diameter results in the considerable growth of dry deposition of lead. Total dry deposition increases four times with changing d_p from 0.1μm and 5μm (Fig 2.9). At the same time, air concentrations and wet deposition decrease (Fig 2.9, 2.10). The mass of lead in the lowest model layer falls twice, wet deposition diminishes by ~16%.

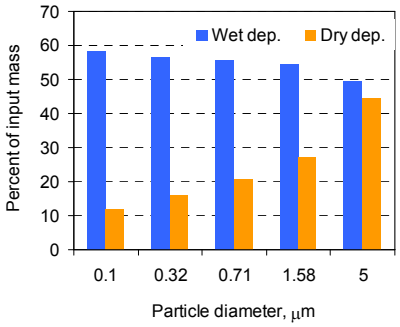


Fig. 2.9. *Annual wet and dry deposition of lead to EMEP domain in percent of input mass (initial mass + emission)*

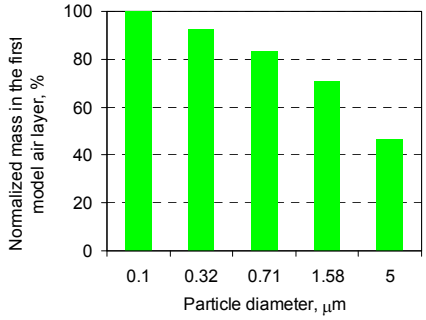


Fig 2.10. *Annual mean mass of lead in the lowest model layer in the whole EMEP domain normalized to the results of the model run with MMD=0.01mm*

A pilot size-segregated modelling has been carried out. It was supposed that concentration of particles carried lead at the moment of emission has lognormal distribution with the mass median diameter MMD = 0.55 μm (that corresponds to d_p adopted in the current monodisperse version of the MSCE-HM model for lead). The continuous lognormal function was approximated by a quasi-constant 5-bin distribution as it is shown in Fig.2.11. The modelling has been performed under the assumptions of the lack of mass exchange between the bins.

In the process of numerical simulation the particle size distribution changes as follows. The contribution of mass transported on fine particles increases while the corresponding contribution of coarse particles decreases (see example in Fig. 2.11). However, the replacement of monodisperse distribution of lead mass by the lognormal distribution with the same MMD does not lead to significant change of the statistical indicators (BIAS and coefficient of linear correlation) characterizing the level of agreement between the calculated and measured annual mean values of lead concentrations in air and precipitation (Table 2.1).

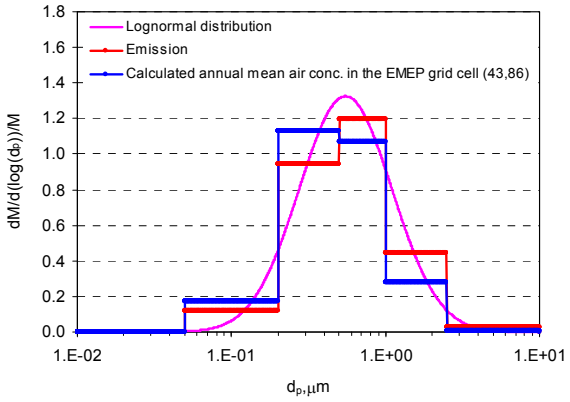


Fig. 2.11. *Particle size distributions of lead mass in the EMEP grid cell (43,86) in comparison with emission distribution*

Table 2.1. *Statistics for different model runs based on yearly mean values*

Name of model run	Concentration in air		Concentration in precipitation	
	<BIAS>, ng/m^3	R_{corr}(spatial)	<BIAS>, μg/l	R_{corr}(spatial)
Old scavenging scheme, d_p = 0.55 μm	-1.12	0.75	-0.61	0.51
New scavenging scheme, d_p = 0.55 μm	-1.01	0.74	-0.60	0.54
Size-segregated	-1.07	0.75	-0.59	0.54

Experimental numerical modelling of size-resolved HM dispersion and removal is planned to be continued. It should be pointed out that data on size-distributed emissions of heavy metals and the corresponding measurement data inside the EMEP region are highly needed for the future development of size-segregated parameterizations.

2.4. Sensitivity of modelling results to the refinement of the model vertical structure

In order to improve the MSCE-HM model performance TFMM recommended inclusion of the shallower lowest model layer [*ECE/EB.AIR/GE.1/2006/4*]. The study of the model sensitivity to the refinement of the vertical grid structure has been initiated last year [*Gusev et al.,* 2008], and this year it was finalized. This section is focused on the investigation of sensitivity of modelling results regarding to the refinement of the model vertical structure. A number of the model simulations of lead atmospheric transport and deposition with the current vertical structure (the base case) and the decreased depth of the lowest layer was performed for July and January. For the experimental runs the depth of the lowest model layer was decreased by a certain decrement, and that of the second one – increased by the same value. Thus, the total thickness of the first and the second layers was kept constant. The decrements and first layer depths are summarized in Table 2.2.

Table 2.2. *Changes in the depths of the model layers in four tests*

	Base case	Test #1	Test #2	Test #3	Test #4
Decrement, m	0	10	20	25	30
Depths of the lowest model layer*	76	66	56	51	46

* Under International Standard Atmosphere conditions (Air temperature is 15 °C, pressure is 1013.25 hPa, relative humidity is 0%).

The numerical experiments demonstrated that the decrease of depth of the lowest model layer resulted to a decline of surface concentrations in air over the European and the Central Asian countries. It is found that the larger the decrease of the depth the stronger was the decline of concentrations (Fig. 2.12). Wet deposition exhibits similar behaviour, while dry deposition increases. Relative changes in dry deposition to forests are higher than those to land cover types with lower vegetation (e.g., grasslands, croplands). Since dry deposition rises whereas the depth decreases, less mass of lead remains in the atmosphere and thus wet deposition declines. As a result, changes of total deposition in these experiments on average do not exceed 1% (Fig. 2.12).

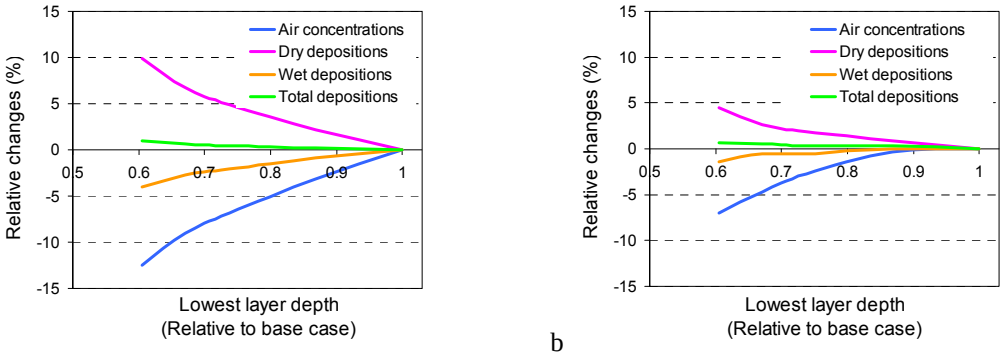


Fig. 2.12. *Changes of air concentrations, dry, wet and total deposition over Europe and Central Asia in January (a) and July (b) relative to base case simulations, %*

The idea of the increase of dry deposition over forests whereas the depth deceases is confirmed by the comparison of vertical profiles of concentrations in air over different parts of Europe. For example, over southern Poland, known for significant emissions and for considerable fraction of forested area the surface concentrations decline significantly when the layer depth deceases (Fig. 2.13a). When emission value in a grid cell is significant but forested area is negligible (e.g., east of Ukraine), the changes in the vertical profiles of air concentrations are minor (Fig. 2.13b). The final exampling profile relates to the northern part of Finland, characterized by extensive forested areas and negligible emission sources. As seen from Fig. 2.13c, concentrations in air are declining not only near surface but also along the entire vertical extent as the lowest layer depth decreases. It is explained by the fact that the decrease of the depth leads to the increase of deposition nearby sources, and hence less pollutant mass reaches remote regions.

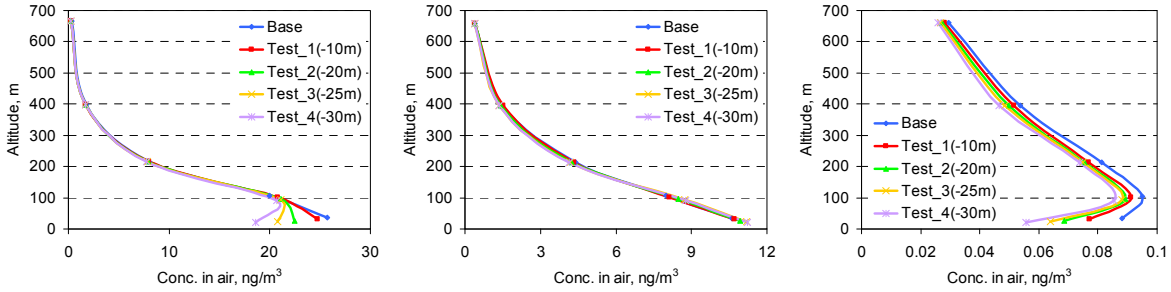


Fig. 2.13. *Vertical profiles of air concentrations of lead in January in southern Poland (a), eastern Ukraine (b) and northern Finland (c)*

Spatial distribution of relative changes of concentrations in air and deposition in Europe and Central Asia is not uniform. Figure 2.14a demonstrates the relative changes for the most extreme test when the decrease of the lowest model layer was the highest. The highest changes of concentrations occur over the central and eastern parts of Europe, northern Scandinavia and over east of Russia, which is explained mostly by relatively high areas covered by forests. Over the west of Europe and in Central

Asia the changes are mostly within 10%. Unlike the concentrations in air, total deposition in some regions increases and in other - declines as the layer depth decreases. The increase takes place in the central, southern and south-eastern parts of Europe, while in the northern and eastern parts of Europe and in Central Asia total deposition mostly decreases (Fig. 2.14b)

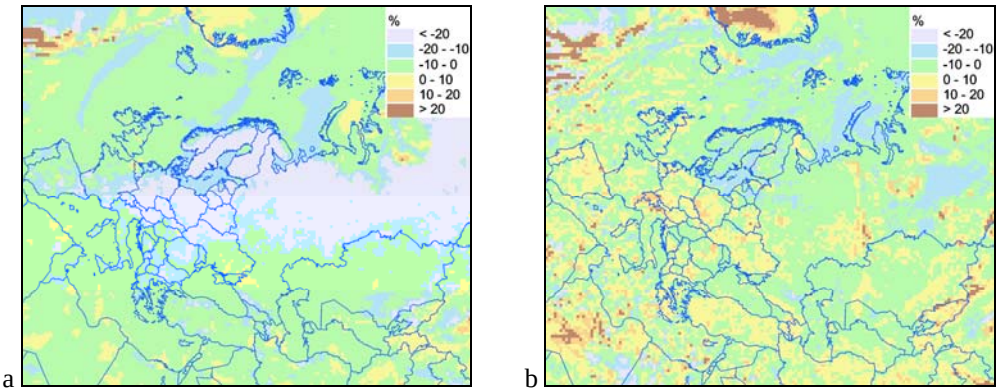


Fig. 2.14. *Relative difference between the base-case and the test #4 simulations for air concentrations (a) and total deposition (b) of lead in January, %*

The hypothesis arisen during the model review was that the decrease of the lowest model layer could lead to higher simulated concentrations and better agreement between modeled results and observations. However, the comparison of modeled concentrations in air and wet deposition fluxes, obtained in the numerical experiments, with the observed values does not demonstrate any noticeable improvement of the model performance both in July and in January (Fig. 2.15).

Numerical experiments described above showed that the sensitivity of calculated pollution levels is relatively low in regions remote from main emission sources, in particular, at the majority of monitoring stations. From the results of the experiments it is possible to conclude that the refinement of model vertical structure does not lead to improvements of model performance. More detailed information concerning this study is presented in chapter 1.1 of the MSC-E Technical report [*Gusev et al.*, 2009].

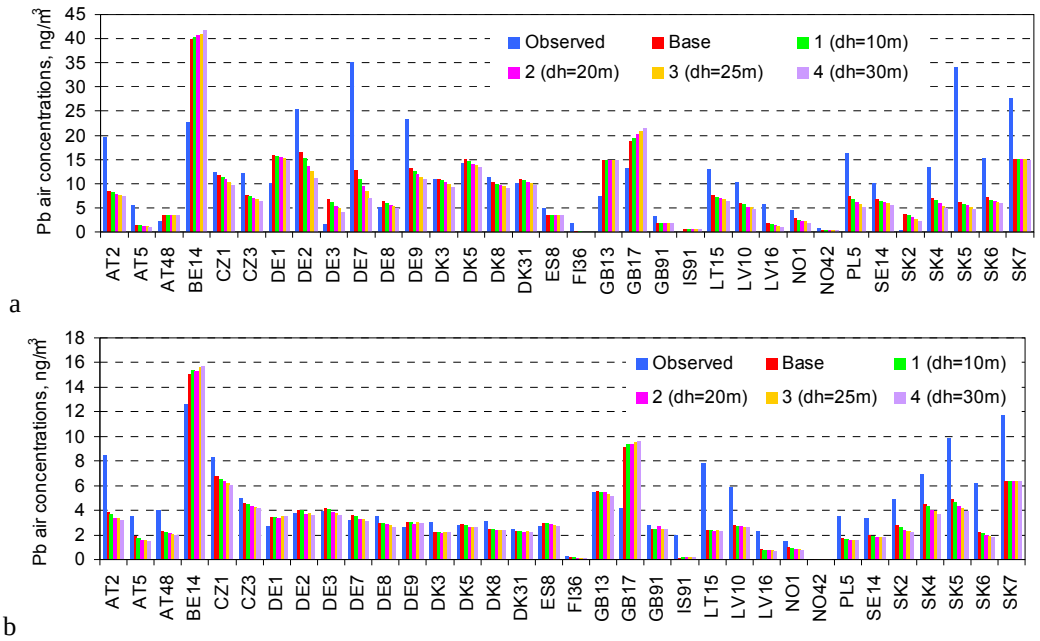


Fig. 2.15. *Monthly mean concentrations of lead in January (a) and July (b), 2006 observed at EMEP monitoring stations and calculated by the model in base case and four experimental runs, ng/m^3*

3. ASSESSMENT OF HEAVY METAL POLLUTION LEVELS

This chapter is devoted to the analysis of heavy metal pollution over Europe and Central Asia in 2007. Brief overview of the emission data used in modelling is presented. Assessment of pollution levels of lead, cadmium and mercury is based on joint use of model-based information and background monitoring data. Special attention is paid to the verification of modelling results against measurements. Source-receptor relationships are discussed.

3.1. Emissions data for model assessment

The emission data for 2007 over the traditional (used until 2008) EMEP domain destined for modelling purposes have been provided by the EMEP Centre on Emission Inventories and Projections (CEIP) [http://www.emep-emissions.at/ceip/]. The gridded distributions of the 2007 emissions have been jointly prepared by CEIP and MSC-E. The information on emissions for the Asian part of the EMEP domain was prepared by MSC-E.

The total anthropogenic emissions in the EMEP countries in 2007 are higher by more than 50% for lead and by 10% for cadmium, and lower by 7% for mercury, in comparison with the corresponding emissions for 2006. The main reason of the considerable increase of lead emissions was connected with the changes of the emission estimates for the Russian Federation used in modelling. The last reported value of the Russian emission of lead (355 tonnes) was used in the calculations for 2006 [*Ilyin et al*., 2008], whereas much higher expert estimate prepared by CEIP (about 2400 tonnes) were applied for the Russian Federation for 2007 because of absence of the official reported data. For cadmium the situation is similar: emissions for the European part of Russia were reported as 59 tonnes for 2006, and the CEIP expert estimate of 99 tonnes was used for 2007.

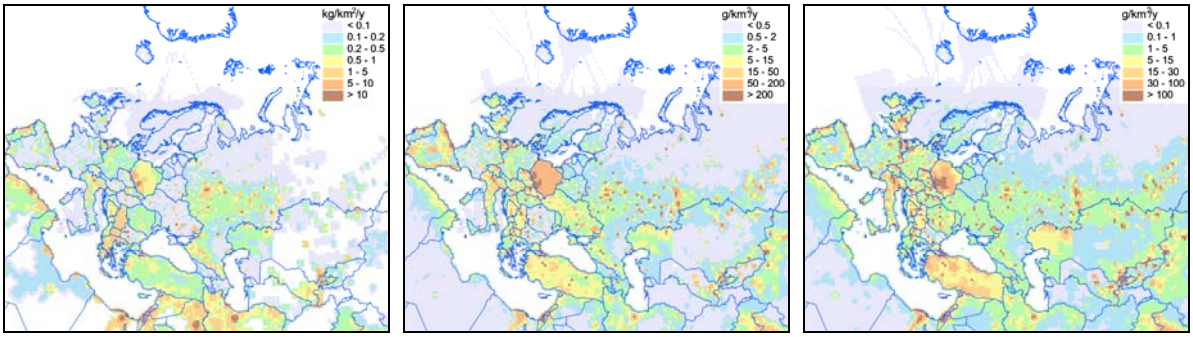
Information on emissions for the Asian part of the EMEP domain is based on non-official emission estimates. In particular, lead emission totals for Kazakhstan and Kyrgyzstan were derived from the TNO emission inventory [*Denier van der Gon et al*., 2005] using the interpolation between 2000 and 2010. Lead emissions in Turkmenistan, Tajikistan and Uzbekistan for 2007 were taken from the global inventory for 1990 [*Pacyna et al*., 1995; http://www.ortech.ca/cgeic/index.html] expecting the same emission reduction in these countries between 1990 and 2006 as in the Russian Federation according to the recent EMEP official data. Total emission of lead from the Asian part of Russia was assessed using the official emission data for the European part of the country in 2007 and keeping the ratio between the European and the Asian parts obtained from the global lead inventory. Besides, the global emission data were also used for the other Asian and African countries, falling partly or fully into the EMEP domain, assuming the same emission reduction between 1990 and 2007 as for Turkey. Turkey has been selected for this purpose because it is the only country located in Asia, for which TNO estimates of lead emissions are available. Spatial distribution of lead emissions for the Asian part of the EMEP domain was obtained by interpolation of the global gridded emissions with 1°×1° spatial resolution into the model grid.

Mercury emissions for the Asian part of the EMEP domain and for the northern African countries were derived from global mercury inventory for 2005 [*AMAP/UNEP*, 2008]. It was assumed that the emissions were not changed significantly between 2005 and 2007.

Global emission inventories for cadmium are currently not available. That is why the cadmium emission data for the Asian part of the EMEP domain and for the north of Africa were obtained on the basis of the global mercury inventory [*AMAP/UNEP*, 2008]. For this purpose, cadmium emission was assumed to be proportional to emission of mercury with a coefficient depending on a region: $E_{Cd} = \alpha \cdot E_{Hg}$. For the eastern part of Russia the proportionality coefficient (α) was taken the same as for the

European part (1.14). The coefficient for Kyrgyzstan (0.56) was applied for the other Central Asian countries (Kazakhstan, Uzbekistan, Turkmenistan, and Tajikistan). For the other Asian countries and Africa the coefficient was taken equal to that for Turkey (0.91). All coefficients were estimated on the basis of the TNO inventory [*Denier van der Gon et al*., 2005].

Spatial distributions of lead, cadmium and mercury emissions used in the modelling are shown in Fig. 3.1. Temporal and vertical distribution of the emission data and speciation of mercury emissions, employed in the MSCE-HM model, are described in [*Travnikov and Ilyin*, 2005].



a b c

Fig. 3.1. *Spatial distribution of lead (a), cadmium (b) and mercury (c) emissions over the EMEP domain in 2007*

3.2. Analysis of heavy metal pollution levels in Europe in 2007

This section is devoted to the analysis of heavy metal pollution levels over the EMEP region in 2007. For the first time, the levels of lead, cadmium and mercury are analysed using both modelling results and background monitoring data reported to EMEP/CCC. The calculated information is produced by MSCE-HM atmospheric transport model. Data from some of measurement stations were not used in the analysis because of short period of observations, doubtful quality and other reasons, described in the EMEP HM and POP Data report [*Aas and Breivik*, 2009] and EMEP/MSC-E Technical report 1/2009 [*Gusev et al.,* 2009]. Spatial distribution of heavy metal deposition and concentration, verification of the modelling results as well as description of the pollution level changes between 2006 and 2007 are considered.

LEAD

Annual mean near-surface air concentrations of lead over the most of Europe and Central Asia varied from 1 to 10 ng/m^3 (Fig. 3.2). The highest concentrations exceeding 20 ng/m^3 were found in the regions characterized by large emission fluxes (Fig. 3.1). As seen from the combined map of calculated and the observed concentrations in air, both the modelled and observed values exhibited similar spatial variability and spatial gradients. Regions with elevated air concentrations were Poland, Italy, Russia, Bulgaria, Belgium, and the Netherlands. Besides, relatively high concentrations occurred over the eastern part of Ukraine and south of Kazakhstan. The lowest concentrations were noted for the north of Scandinavia and the Arctic.

Agreement between modelled and measured air concentrations was different for different stations (Fig. 3.3). At half of the stations the relative bias between observed and measured concentrations was less than 30%, and for more than 2/3 of stations the bias was within ±50%. Satisfactory agreement between measured and modelled values was noted for stations in Germany, Denmark, the United Kingdom, the Czech Republic, Belgium, Slovenia, and France. Besides, at some stations in Finland, Slovakia and Austria calculated concentrations also matched the measured ones. However, at Polish, Norwegian and some Finnish stations (FI36 and FI37) the observed concentrations of lead were underestimated by the model with the bias exceeding 50%. On the other hand, at Dutch and Spanish (except ES8) sites the observed concentrations were overestimated. The overestimation at these sites can be partly explained by overprediction of the wind re-suspension in these regions.

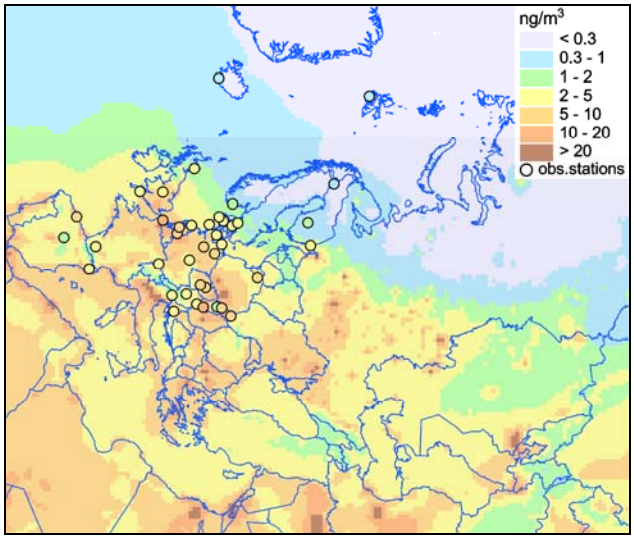


Fig. 3.2. *Calculated and measured surface concentrations of lead in air over Europe and Central Asia in 2007, ng/m^3*

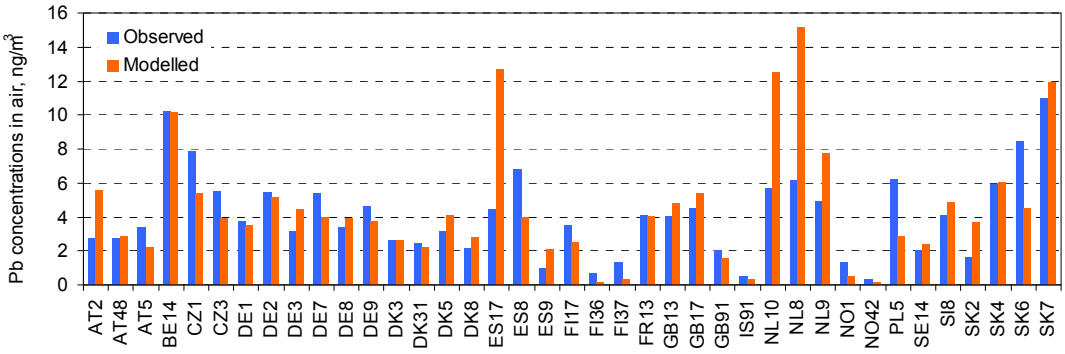


Fig. 3.3. *Comparison of modelled and measured annual mean concentrations of lead in air in 2007, ng/m^3*

In order to investigate the reasons of the discrepancies between the modelled and measured values, the modelling results were compared with observations having finer temporal resolution. The individual peaks of measured and calculated parameters were analysed by means of back trajectories. This analysis is a useful tool for evaluation of the model performance and the emission uncertainties and may indicate regions where quality of the emission data deserves special attention. For example, the emission of lead for Russia used in modelling for 2007 was more than 6 times greater than that for 2006 (see Section 3.1). The effects of changes in the emissions should be translated to behaviour of modelled values at stations located nearby Russian border. This effect could be exemplified by the Finnish station FI17 (Virolahti II): in some episodes the increased emission resulted in improved agreement between the modelled and observed concentrations (Fig. 3.4). However, in some other periods (e.g., in September) the changes in modelled levels were negligible.

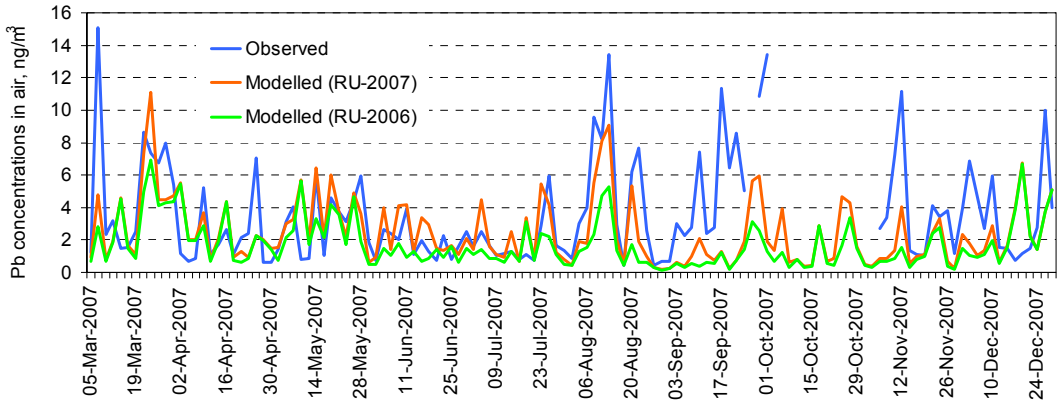


Fig. 3.4. *Daily-mean calculated and observed concentrations of lead at Finnish station FI17 (Virolahti II) in 2007. Calculated concentrations are based on emissions estimates for Russia for 2007 (orange curve) and for 2006 (green curve), ng/m^3*

Back trajectories were plotted for the period in August when the levels were reproduced well and for the period in September when the discrepancies were substantial. For example, on August 8 the modelled concentrations agreed well with measurements, when emissions of Russian data for 2007 were used. Otherwise, when the emission data for 2006 were involved, the obvious underestimation of the observed levels was obtained. The transport of air masses to the station took place on August 8 from the territory of Russia through the St. Petersburg region (Fig. 3.5a). Therefore, it is possible to suppose that the 2007 emissions data for the Russian Federation seem more realistic than the older ones. In the case of September (Fig. 3.5b) the back trajectories were passing through Sweden, Denmark and Germany. Thus, one may assume that some unaccounted emission sources in these countries or local emission sources nearby the monitoring site could lead to the underestimation. In order to facilitate the further analysis joint efforts of national experts and the EMEP Centres are needed.

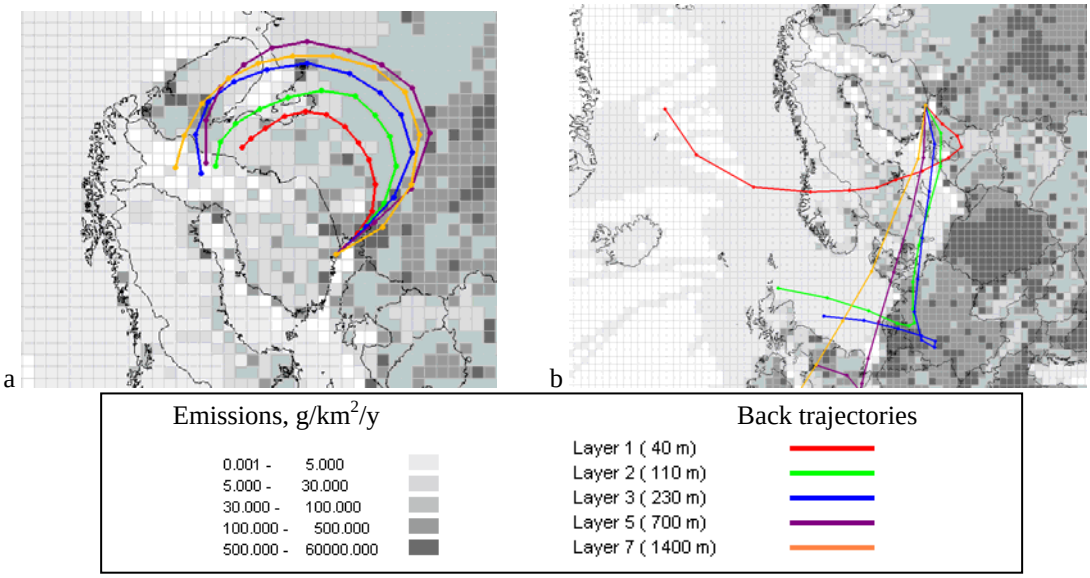


Fig. 3.5. *Back trajectories arriving at station FI17 on August 8 (a) and on September 17 (b). The background map shows lead anthropogenic emissions in 2007*

In particular, at the recent TFMM meeting held in Paris in June 2009 MSC-E proposed organizing a case study devoted to the complex research of heavy metal pollution levels on the example of a number of countries, which could include detailed analysis of the emissions data, model estimates and monitoring data. This proposal was welcomed and supported by TFMM.

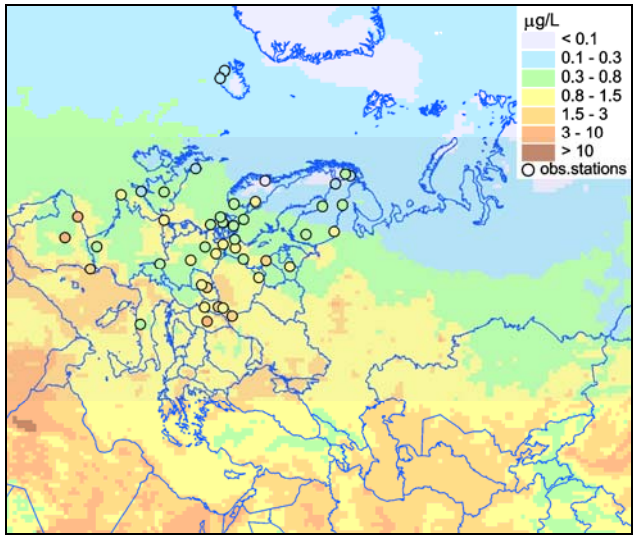


Fig. 3.6. *Calculated and measured concentrations of lead in precipitation over Europe and Central Asia in 2007, µg/L*

Concentration in precipitation is another measurable parameter characterizing pollution levels. The spatial pattern of modelled and measured concentrations in precipitation follows that of air concentrations. The exception is high concentrations over the northern part of Africa which are caused by low precipitation amounts. In general, magnitude of the modelled and observed values and their spatial variability are consistent (Fig. 3.6). In some regions there are discrepancies between the calculated and observed information. For example, the model underestimates observed concentrations in precipitation in Hungary and at some sites in Spain. More detailed analysis of the model performance with regard to measurements is given below.

Calculated concentrations in precipitation agree with the measured ones at two thirds of stations with relative bias ranging within ±50% (Fig. 3.7, 3.8). These were stations in Germany, Denmark, the United Kingdom (except GB6), Slovakia (except SK2), Iceland, Poland, Belgium, Italy and Sweden. Significant underestimation of the observed concentrations was found for Finnish, most of Norwegian, Czech, Latvian and Spanish stations. At the Norwegian, Latvian, Czech and Finnish sites the precipitation measurements were done using the bulk collector and there might be some contribution of dry deposition of dust, though this would probably not explain the whole difference. There might be additional (local) sources not included in the emission inventories or that the site was not completely representative for the EMEP grid. In Spain the observed concentration level was rather high, but it was consistent with earlier years and probably there were regional sources that were not captured in the emission inventories.

French stations present an interesting case for the analysis. The station FR13 is located in the southern part of France, while the FR90 station is situated at the westernmost part of Brittany Peninsula and is influenced mostly by atmospheric transport from the Atlantic. From the modelling point of view, higher concentrations at continental station FR13 and lower concentrations at the remote, “almost Atlantic” FR90 look logical. However, behaviour of measured values at this station is opposite to the modelled ones: concentrations and fluxes at FR90 are much higher than those at FR13. The observed relatively high deposition level at FR90 can partly be explained by monthly bulk deposition measurements that are influenced by some dry deposition while the model only includes wet deposition. More details concerning verification of the modelling results are available in technical report [*Gusev et al.,* 2009].

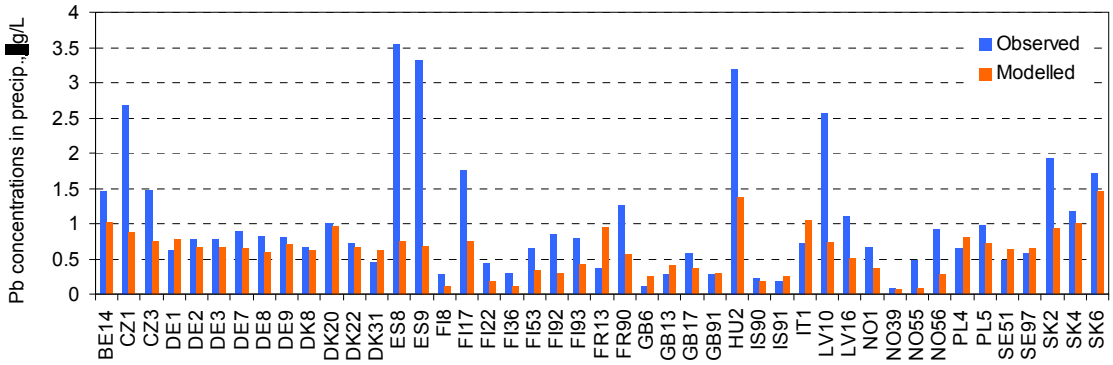


Fig. 3.7. *Modelled and measured annual mean concentrations of lead in precipitation at individual stations in 2007, µg/L*

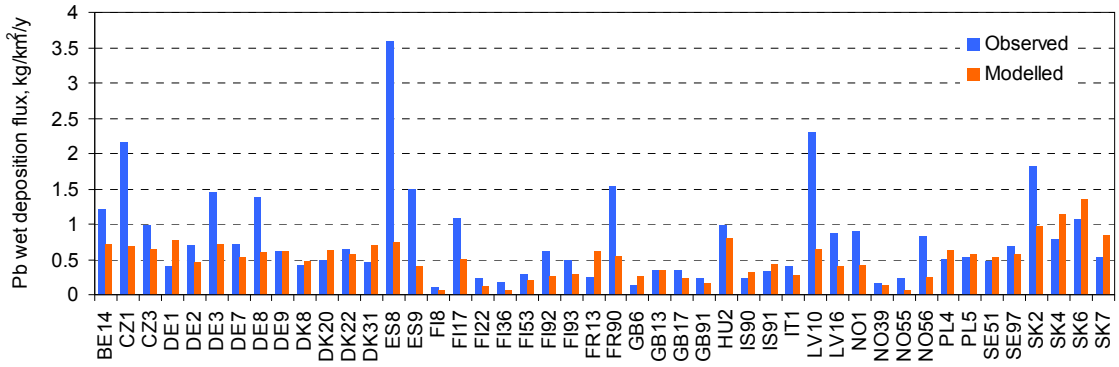


Fig. 3.8. *Modelled and measured annual wet deposition flux of lead at individual stations in 2007, kg/km^2/y*

Over the most part of Europe and Central Asia total atmospheric deposition of lead in 2007 ranged from 0.5 to 2.0 kg/km^2/y (Fig. 3.9). In regions with significant emissions annual total deposition fluxes varied from 2 to 3 kg/km^2 or even higher. Elevated deposition fluxes were noted for southern Poland, the northern part of Italy, Bulgaria and some regions in Russia. The lowest deposition took place over north of Scandinavian countries (Finland, Norway, Sweden, and Iceland) and over north-eastern regions of Russia. Low deposition over these regions was explained by minor emissions and remoteness from the areas with significant emission sources. Other areas with low lead deposition were steppe and desert parts of Central Asia. In spite of significant emissions caused by wind re-suspension of dust, deposition was not high due to low precipitation amount.

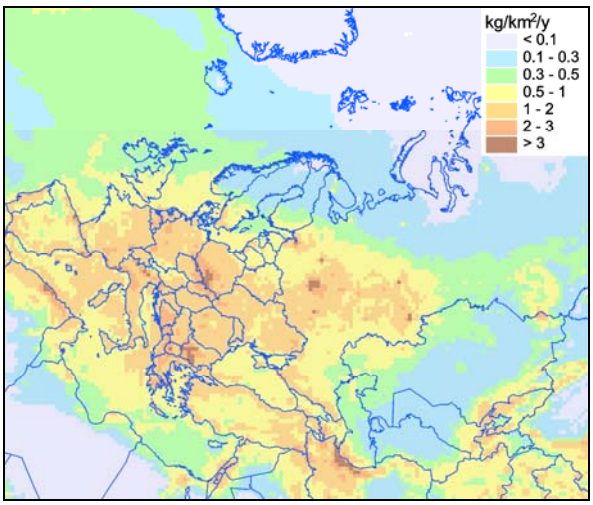


Fig. 3.9. *Total annual deposition of lead in Europe and Central Asia in 2007, kg/km^2/y*

In comparison with calculations for 2006, the most pronounced changes of pollution levels in the EMEP region took place in Russia. It is connected with the changes of emission data for the Russian Federation used in modelling (355 t/y in 2006 against 2400 t/y in 2007) (see Section 3.1). Consequently, deposition in

neighbouring countries (e.g., Finland, Ukraine) also increased because of the growth of the transboundary transport from Russia. Over the central and western parts of Europe (the United Kingdom, Germany, France, the Czech Republic, Slovakia) deposition and air concentrations declined partly due to the decrease of national emissions and also because of lower wind re-suspension fluxes in 2007 compared to 2006. Over the Mediterranean and the Black Sea basins deposition increased and concentrations in air declined mostly because of higher precipitation amounts in these regions in 2007 compared to 2006.

CADMIUM

Both measured and calculated annual mean concentrations of cadmium in the surface air in 2007 ranged mostly from 0.05 to 0.2 ng/m^3 (Fig. 3.10). Higher concentrations (more than 0.2 ng/m^3) are noted for Poland, Russia, northern Italy, east of Ukraine, Benelux and Balkan regions. Lower concentrations (below 0.01 ng/m^3) occur over the northern parts of Europe and Asia. Calculated concentrations are consistent with measured ones in the central and western parts of Europe, while over the northern part of Europe the model tends to somewhat underestimate the measurements, whereas in the middle of Spain – to overestimate the observed levels.

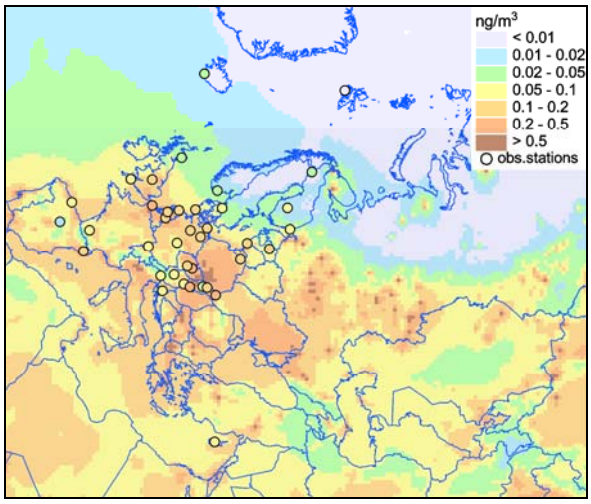


Fig. 3.10. *Calculated and measured surface concentrations of cadmium in air over Europe and Central Asia in 2007, ng/m^3*

The relative bias between observed and modelled concentrations in air falls within ±50% for more than half of the stations, and within ±30% - for 42% of the stations (Fig. 3.11). Satisfactory agreement between modelled and measured concentrations was obtained for stations in Germany, Poland, the United Kingdom, Slovenia, France, Belgium, the Czech Republic, and Slovakia (except SK2). The concentrations were underestimated at the stations in Norway, Iceland and at two Finnish sites, while for the Dutch sites the model overestimated the observed levels.

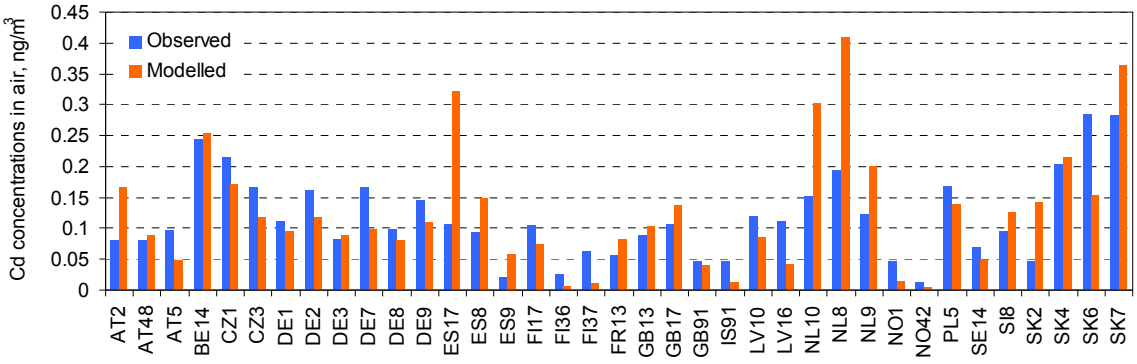


Fig. 3.11. *Comparison of modelled and measured annual mean concentrations of cadmium in air, ng/m^3*

Technical report [*Gusev et al.*, 2009] contains more details regarding evaluation of modelling results versus measurements. At some stations the model overestimates concentrations in air as it does for lead (e.g., ES17, NL8, NL9, NL19). Therefore, it is possible to suppose that the reasons of the discrepancies are similar to those for lead.

The discrepancies at some stations were analysed by means of the back trajectory approach. An example of the application of this approach to the analysis of cadmium concentrations in air was given for Spanish station ES8 (Niembro). The model overestimates measured concentrations of cadmium at this station by about 1.5 times. However, in different periods of time the agreement between modelled and measured quantities varied: in the first half of the year the agreement was quite good, while for the second half significant overestimation of the observed values was found (Fig. 3.12).

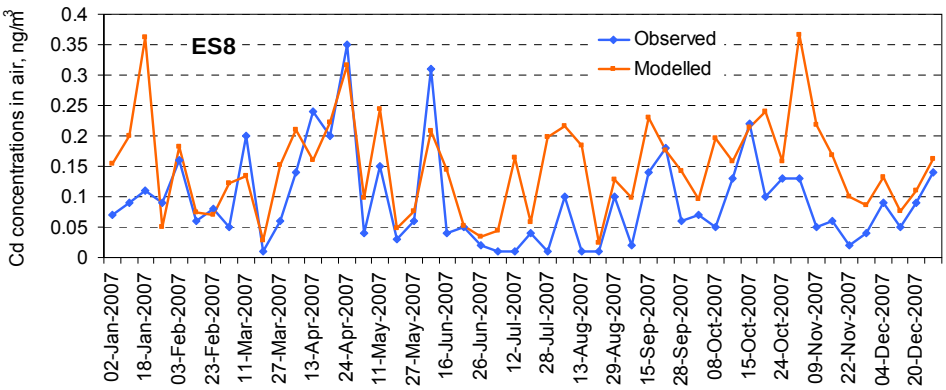


Fig. 3.12. *Modelled and observed air concentrations of cadmium at Spanish station Niembro (ES8) in 2007, ng/m^3*

Measurements at this station are carried out on weekly basis. Therefore the weekly densities of back trajectories were calculated for different periods of measurements. It was found that significant overestimation of the measured cadmium concentrations is often associated with prevailing transport from the north-east coming through France and the United Kingdom (e.g., on November 03-08; Fig. 3.13). However, if back trajectories were crossing Spain and Mediterranean basin (e.g., for April 24-May 03), the agreement between modelled and measured air concentrations was usually fine. The reason of the overestimation is probably connected with the spatial distribution uncertainties of the emission data.

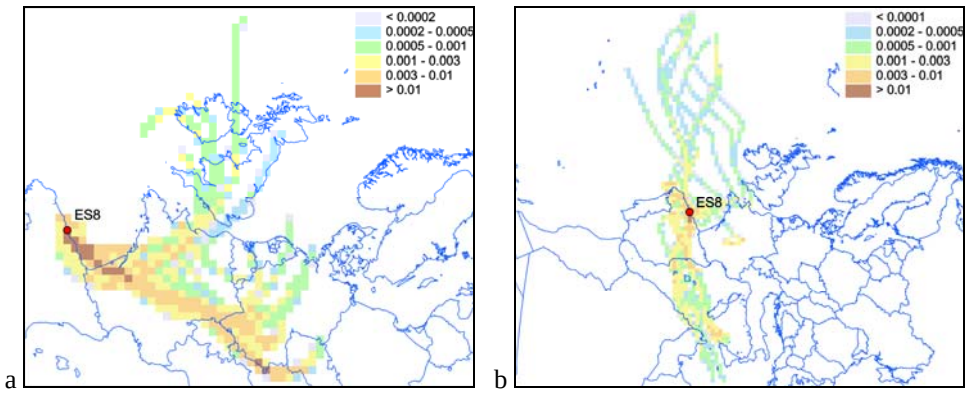


Fig. 3.13. *Density of back trajectories crossing grid cells for Spanish station ES8 for the period of November 03-08 (a) and April 24- May 01 (b)*

The spatial pattern of concentrations of cadmium in precipitation correlates with that of emission distribution. However, it is also significantly affected by meteorological conditions, in particular, by annual precipitation amount. Because of low precipitation in the northern Africa calculated concentrations in precipitation were very high compared to other regions (Fig. 3.14).

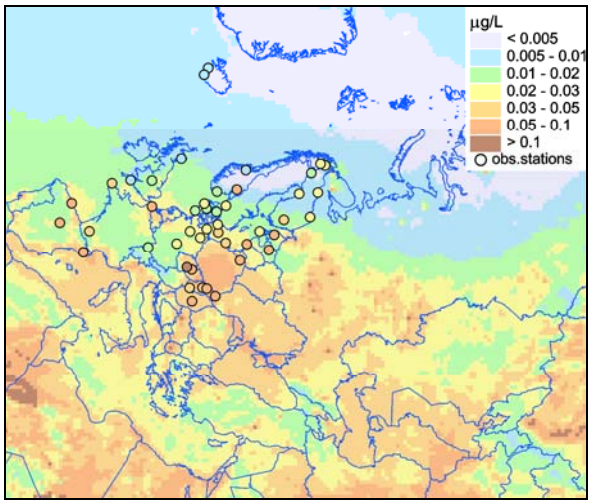


Fig. 3.14. *Calculated and measured concentrations of cadmium in precipitation over Europe and Central Asia in 2007, µg/L*

Relatively high measured and modelled concentrations of cadmium in precipitation occurred in the central part of Europe (the Czech Republic, Slovakia, Hungary, Poland). Somewhat lower levels are noted for Germany, the Netherlands, and the United Kingdom. In these regions modelled and measured values look quite consistent. Both the model and observations demonstrated distinct decline of concentrations from central Europe towards the north of Scandinavia. However, modelled concentrations in precipitation in Finland and Norway were lower than the measured ones. Underestimation of the observed levels was also seen in Spain.

Observed concentrations of cadmium in precipitation and wet deposition fluxes are generally underestimated by the model (Fig. 3.15, 3.16). The bias between modelled and measured values lay within ±50% for about a half of the stations. Good agreement between the measurements and the model was noted for stations located in Germany, Denmark, the United Kingdom, Iceland, Poland, Slovakia. Stations where the underestimation was significant were located in Norway, Sweden, Latvia, the Czech Republic, Spain and Belgium. Similar to lead, concentrations in precipitation at these sites (except the Spanish ones) were measured using the bulk collector and their results may be influenced by some dry deposition. Besides, the underestimation of the observed concentrations could be caused by other reasons including uncertainties of the emissions (both anthropogenic and wind-blown), uncertainties of measurement data and the model parameterizations. Strengthening of collaboration between national experts and the EMEP Centres can assist in assessing the main reasons.

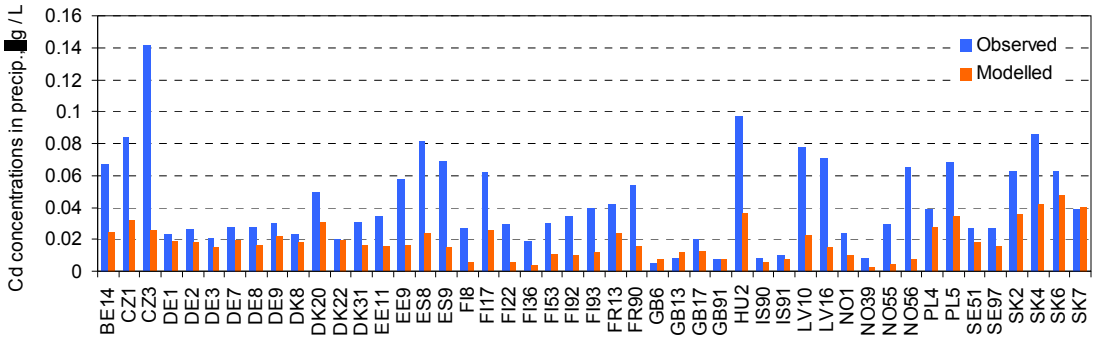


Fig. 3.15. *Modelled and measured annual mean concentrations of cadmium in precipitation at individual stations for 2007, µg/L*

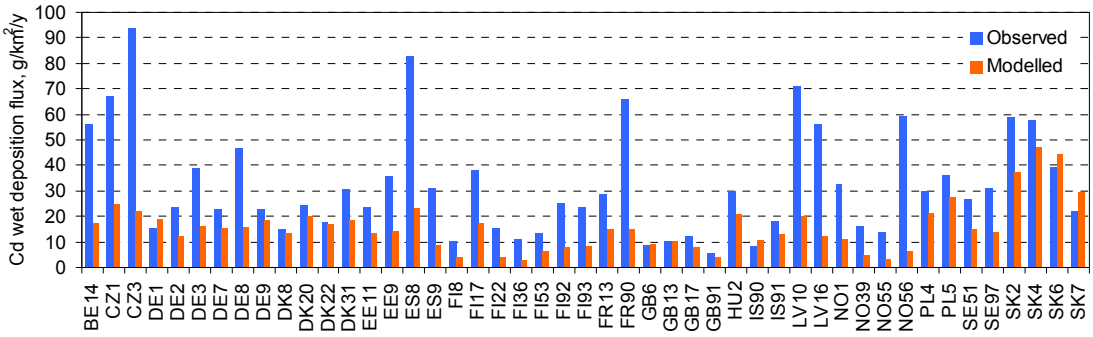


Fig. 3.16. *Modelled and measured annual wet deposition flux of cadmium at individual stations for 2007, g/km^2/y*

Total annual atmospheric deposition of cadmium in 2007 ranged between 10 and 50 g/km^2/y over most of Europe and Central Asia (Fig. 3.17). Over the Balkans, Poland, north of Italy, the Benelux region, and some regions of Russia deposition exceeded 50 g/km^2/y, and in some hot spots, in Poland, Russia and the FYR of Macedonia it even exceeded 100 g/km^2/y. The lowest deposition was noted for the northern parts of Scandinavia and Russia due to low local emissions and remoteness of these regions from main pollution sources. Besides, low deposition took place over the desert regions of Central Asia. Similar to lead deposition, it was caused by low precipitation amounts.

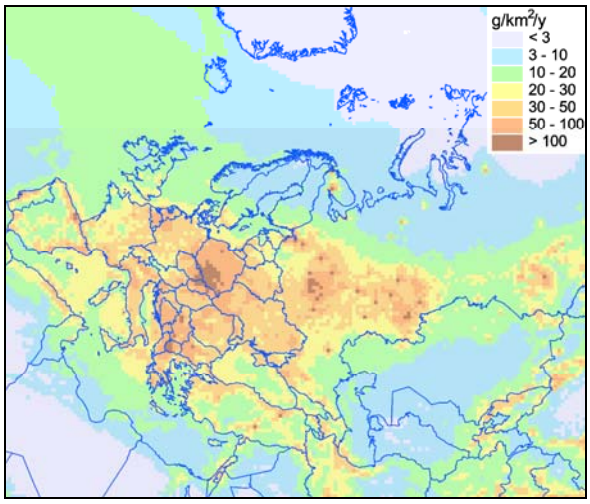


Fig. 3.17. *Total annual deposition of cadmium in Europe and Central Asia in 2007, g/km^2/y*

Compared to 2006, cadmium pollution levels in a number of regions of Europe and Central Asia changed significantly. The reasons were changes in the emission data used in modelling and natural variability of meteorological parameters, in particular, annual precipitation amounts. Deposition increased markedly over the European part of Russia and in the Mediterranean basin. Substantial decline of deposition and air concentrations occurred over Bulgaria and Romania.

MERCURY

Mercury concentrations in air are characterized by low temporal and spatial variability. It is explained by the fact that most (more than 95%) of mercury in the atmosphere is present in the elemental form, which atmospheric life time is quite long. Therefore, mercury concentration is smoothly dispersed over the globe. In Europe and Central Asia the calculated concentrations varied from 1.4 to 1.7 ng/m^3 over most part of the territory (Fig. 3.18). In the central part of Europe in the regions known for significant emissions the concentrations exceeded 1.7 ng/m^3. Low spatial variability of calculated concentrations was confirmed by measurement data. In the central part of Europe observed concentrations were within 1.6–1.8 ng/m^3 limits, and in the western part of Europe and in the north of Scandinavia they vary within 1.4–1.6 ng/m^3.

Modelled concentrations of mercury were compared with the observed ones (Fig. 3.19). As seen, the model tended to somewhat underestimate the observed levels. However, the discrepancy does not exceed 20%. The best agreement between modelled and observed concentrations was noted for stations SE14 and FI96. More detailed information concerning the model verification is available in technical report [*Gusev et al.*, 2009].

Concentrations in precipitation in Europe ranged from 5 to 12 ng/L, in Central Asia – 12-18 ng/L (Fig. 3.20). Higher concentrations in precipitation in Central Asia compared to Europe can be explained by lower precipitation amounts in this region. The same reason explains the elevated concentrations in the northern part of Africa. In Europe the lowest concentrations in precipitation occurred over Scandinavia. In central part of Europe (Germany, Belgium, the Netherlands) measured and modelled concentrations typically ranged from 8 to 12 ng/L.

Comparison of modelled and observed concentrations in precipitation and wet deposition fluxes of mercury at the EMEP stations are demonstrated in Fig. 3.21. For all the stations (except GB91) the discrepancy between the calculated and measured concentrations in precipitation does not exceed ±25%, whereas wet deposition fluxes agree within ±50%. However, it should be pointed out that some of the reported data were not included in the analysis because of insufficient data quality, for details see the EMPE/CCC Data report [*Aas and Breivik*, 2009].

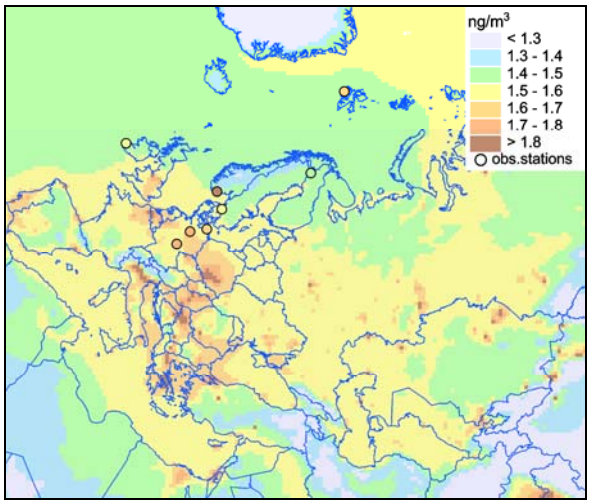


Fig. 3.18. *Calculated and measured surface concentrations of mercury in air over Europe and Central Asia in 2007, ng/m^3*

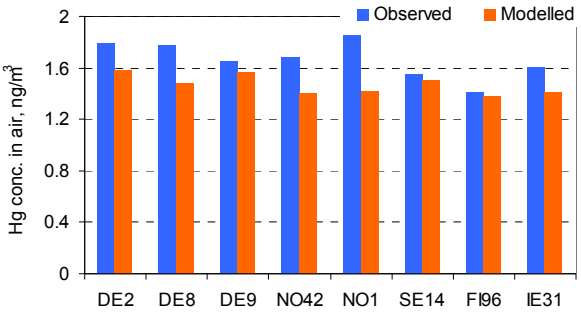


Fig. 3.19. *Calculated and measured surface concentrations of mercury in air over Europe and Central Asia in 2007, ng/m^3*

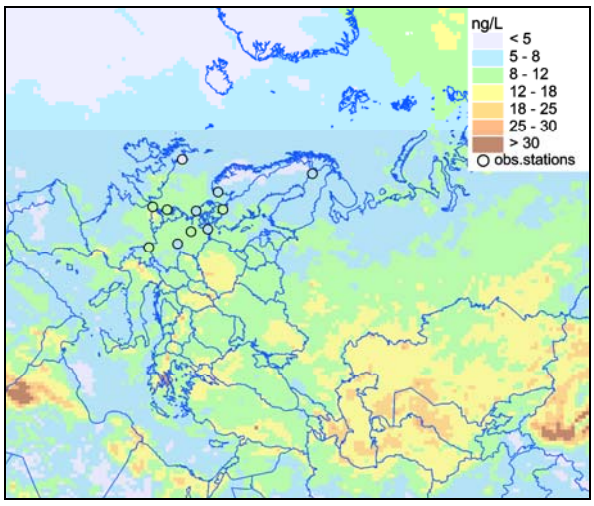


Fig. 3.20. *Calculated and measured concentrations of mercury in precipitation over Europe and Central Asia in 2007, ng/L*

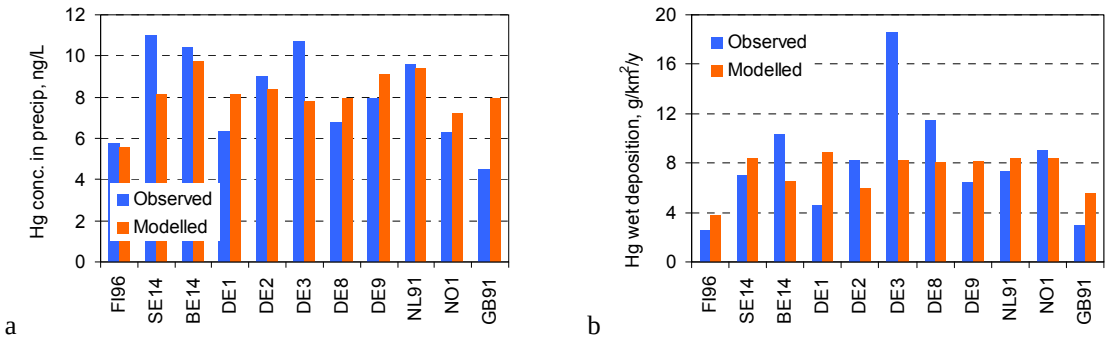


Fig. 3.21. *Modelled and measured annual mean mercury concentration in precipitation, ng/L (a) and annual wet deposition flux, g/km^2/y (b) in 2007*

Mercury total deposition varied from 7 to 20 g/km^2/y over most of Europe and Central Asia (Fig. 3.22). Countries with the highest deposition relate to the regions with high emission of mercury, e.g. Poland, Belgium, north of Italy, and the Balkan region. Total deposition fluxes in these regions exceeded 50 g/km^2/y. The lowest (less than 5 g/km^2/y) deposition levels were found over the Arctic region and over the deserted areas of Africa and Central Asia.

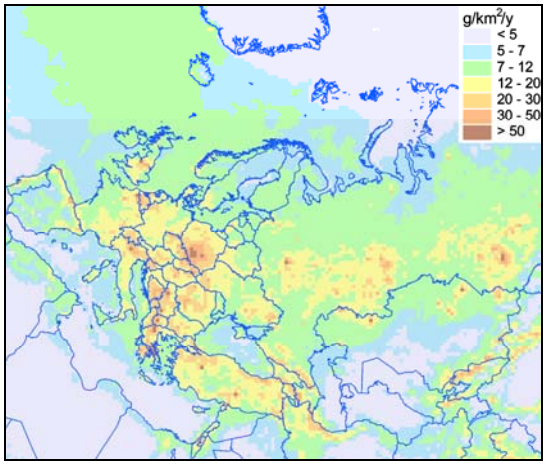


Fig. 3.22. *Total annual deposition of mercury in Europe and Central Asia in 2007, g/km^2/y*

Considerable decrease of mercury deposition in 2007 was found in Poland, Romania and Bulgaria in comparison with the levels for 2006, as a result of decrease of the reported emissions. Besides, the decline of annual precipitation caused the decrease of mercury deposition in Sweden and Spain. Substantial growth of deposition was noted for Germany and Russia because of higher emission values used for the modelling. Changes of mercury air concentrations between 2006 and 2007 were minor.

The combination of data derived by means of monitoring and model calculations of lead, cadmium and mercury allows investigating pollution levels and their spatial gradients over Europe. This analysis demonstrated that magnitudes of modelled and measured concentrations of heavy metals in air and in precipitation were similar. Both modelling and monitoring data indicated gradients of pollution levels from the south-east to the north. To explain some discrepancies between modelled and observed values joint efforts of measurement, modelling and emission communities are needed.

Spatial coverage of the EMEP region by monitoring data is still not satisfactory. Measurement data are scarce or absent over vast territories in the southern, eastern and south-eastern parts of Europe, and in Central Asia. Therefore, the modelling provides countries of these regions with the information on concentrations and deposition. Extension of the monitoring activity to the southern and eastern parts of Europe as well as to Central Asia will contribute to more detailed and reliable analysis of the heavy metal pollution levels in these regions.

3.3. Heavy metal transboundary pollution in 2007

This section presents the results of modelling transboundary pollution in Europe and Central Asia, including information on country-averaged deposition fluxes, contribution of national and external sources to country deposition and contribution of the countries to the transboundary transport. Besides, evaluation of the atmospheric load to the regional seas is presented.

LEAD

In 2007 total anthropogenic emission of lead from the EMEP domain made up 7458 tonnes. This value consists of emissions from the European part (6585 tonnes) and those from the Asian part of the EMEP domain (873 tonnes) including the Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan) and the Asian part of Russia. Compared to 2006, emission total value increased from 4860 tonnes to 7458 tonnes. This change is mostly caused by much higher emission value for the European part of Russia according to the estimates of CEIP (2422 tonnes in 2007 versus officially reported 355 tonnes used in modelling for 2006).

Total deposition of lead to the European and the Central Asian countries from anthropogenic sources amounted to 5691 tonnes, whereas deposition to the European part were 5059 tonnes, and to the Asian part – 632 tonnes. Compared to the results obtained for 2006, the deposition to the European countries was higher by 77% [*Ilyin et al.,* 2008]. This significant increase is mostly explained by essential change of emission data for Russia as well as for some other countries. Total deposition to the EMEP domain from all sources (anthropogenic, wind re-suspension and non-EMEP sources) made up 13789 tonnes. This value includes deposition to European countries (12106 tonnes) and to the Asian part of the EMEP region (1683 tonnes). The deposition values caused by wind re-suspension should be taken with caution because the parameterization of this process is under development.

The highest country-averaged fluxes of lead total deposition are calculated for Monaco, the FYR of Macedonia, Bulgaria and Montenegro (Fig. 3.23). The lowest deposition fluxes are found for Iceland and Norway. As seen from the figure, the contributions of wind re-suspension and anthropogenic sources to total deposition are comparable in the majority of countries. It is important to note that wind re-suspension flux includes both purely natural component and pollution caused by previous long-term (historic) anthropogenic emissions. It is also important to stress that current estimates of natural and historical emissions are subject of significant uncertainty. The contribution of non-EMEP sources (both natural and anthropogenic) is less than 20% over most of countries. It is the lowest (2-3%) in the central European countries (Poland, the Czech Republic, Slovakia, Belgium) and the highest (35 – 50%) in countries close to the EMEP domain borders, such as Armenia, Tajikistan, Turkmenistan, etc. The contribution of non-EMEP sources includes the influence of inflow of lead through the EMEP domain boundaries. Besides, lead emissions from African and Asian countries were also taken into account.

Relative contribution of the transboundary transport to anthropogenic deposition ranges from almost 100% in Monaco and 93% in Republic of Moldova to 15% in Portugal (Fig. 3.24). In 38 countries this contribution exceeds 50%, and in 19 countries – 80%. Contribution of the transboundary transport to deposition is controlled by a number of factors including size of a country's territory, magnitude of national emissions, peculiarities of typical meteorological conditions (wind transport patterns, precipitation amounts etc.) In countries with significant emissions the contribution of national sources to deposition is relatively high, and thus the contribution of external anthropogenic sources is typically low. For example, in Poland the contribution is around 20%, in Bulgaria - 34%. Relatively low

contribution of the external sources is also typical for the remote countries, especially if they are situated in the “upwind” direction relative to major emission sources (e.g., the United Kingdom, Spain, Ireland). Among the countries of Central Asia the highest contribution of the transboundary transport from EMEP and Central Asian anthropogenic sources was estimated for Kyrgyzstan (82%), the lowest – for Kazakhstan (50%).

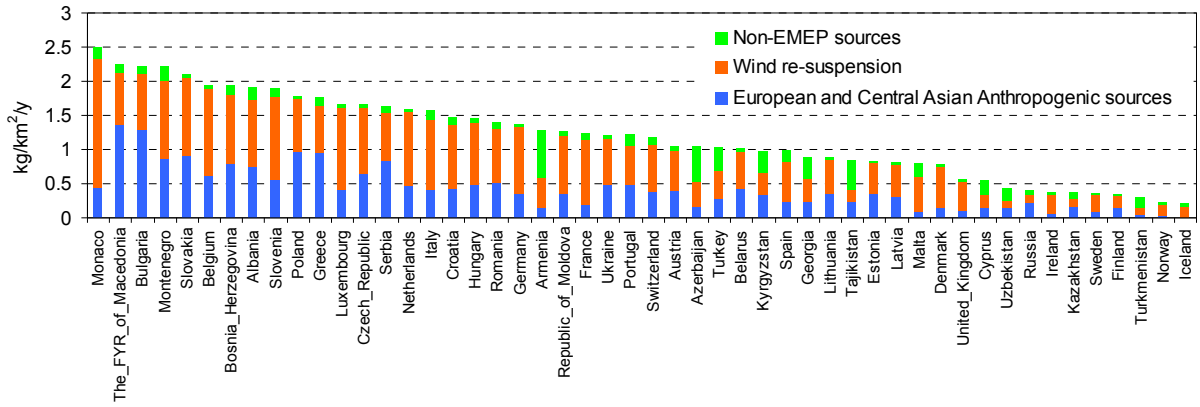


Fig. 3.23. *Country-averaged deposition fluxes of lead from the European and Central Asian anthropogenic, natural/historical and non-EMEP sources in 2007*

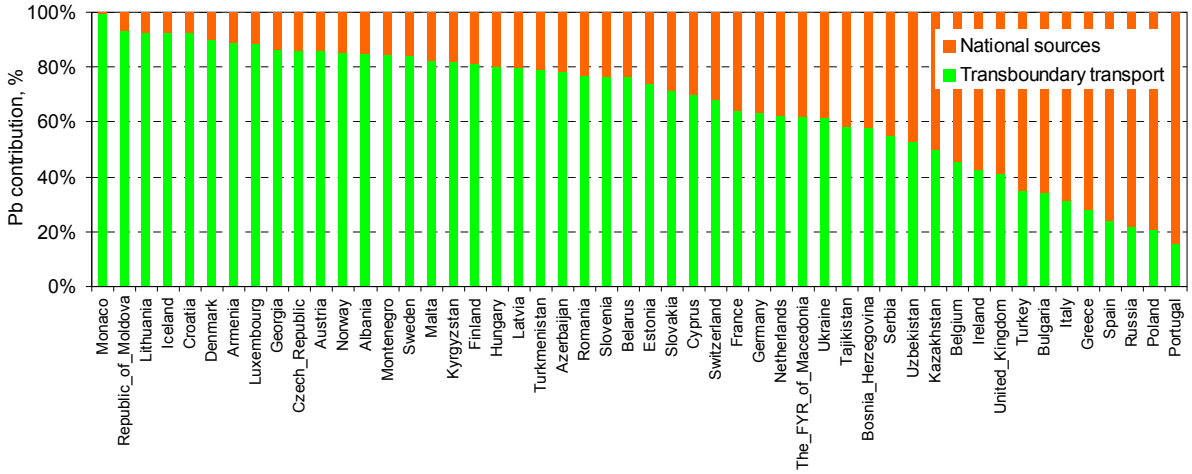


Fig. 3.24. *Relative contribution of the transboundary transport and national sources to anthropogenic lead deposition in the European and Central Asian countries in 2007*

Contribution of countries to transboundary pollution was evaluated as the mass of the pollutant, emitted by national sources and transported outside country’s territory. The largest contribution to the transboundary transport in 2007 was made by Russia (585 tonnes) followed by Kazakhstan (430 tonnes) and Greece (around 380 tonnes) (Fig. 3.25). Fraction of emitted mass of lead entering the transboundary transport ranges from 60 to 90% for the majority of countries. The exception is Russia where this fraction is 22%. The reason for this is a large territory of the country, and location of most sources relatively far from the state borders.

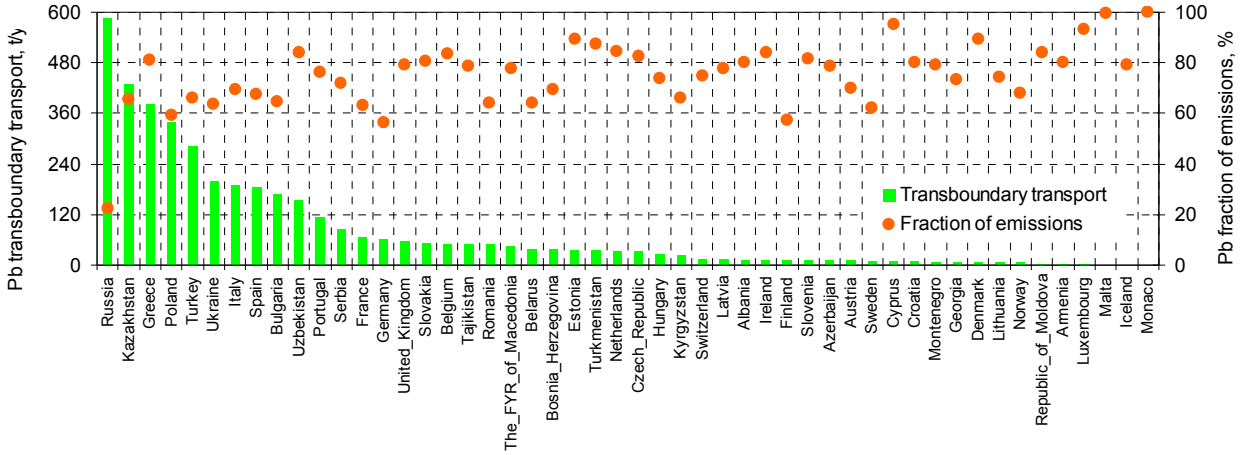


Fig. 3.25. *Absolute contribution of the European and Central Asian countries to lead transboundary transport in Europe and Central Asia in 2007 and relative fraction of national emissions involved into the transboundary pollution*

CADMIUM

Total emission of cadmium within the EMEP domain in 2007 was about 318 tonnes, including 277 tonnes emitted from sources in the European part of the EMEP domain and 41 tonnes – from the Central Asian sources and the Asian part of Russia. In comparison with 2006, emission values for Europe increased, and for Central Asia – decreased. The increase in Europe is cased by two reasons. First of all, expert estimates prepared by CEIP for Russia are 60% higher than the officially reported value used in calculations for 2006. Besides, reported emission totals in some countries (e.g., Slovakia, Ukraine) for 2007 were much higher than the values for 2006. Emissions of cadmium for Central Asia were estimated via assumption of proportionality to mercury emissions (see chapter 3.1). Changes in the mercury global data for 2005 led to the lower estimate of cadmium emissions in Central Asia.

Total deposition from anthropogenic sources to the European and the Central Asian countries in 2007 was 227 tonnes, including 179 tonnes deposited to the European part, and 48 tonnes – to the Asian part of the EMEP domain. In comparison with the estimates for 2006 [*Ilyin et al*., 2008], total deposition to the European countries changed insignificantly (less than by 1%). The deposition from all sources (anthropogenic, wind re-suspension, and non-EMEP sources) in 2007 amounted to 440 tonnes. This value consists of deposition to the European countries (330 tonnes) and to the Asian part of the EMEP domain (110 tonnes). Similar to lead, estimates of contribution of wind re-suspension should be taken with certain caution because of pilot character of this process parameterization used in the study.

Levels of country-averaged deposition of cadmium in the European and the Central Asian countries in 2007 varied from 150 g/km^2/y in The FYR of Macedonia to 6.5 g/km^2/y in Turkmenistan (Fig. 3.26). The deposition fluxes consist of three components: input from anthropogenic sources of the European and the Central Asian countries, from wind re-suspension and from non-EMEP sources. In 28 countries (of 50) deposition from the anthropogenic sources dominates over that caused by wind re-suspension. The contribution of non-EMEP sources varies from 1% in Poland to about 50% in Tajikistan and Turkmenistan. Similar to lead, this contribution is the lowest in regions with significant national emissions and located far from the EMEP boundaries. High contribution of non-EMEP sources is estimated for the Central Asian countries and Transcaucasia because of the influence of Asian emission sources.

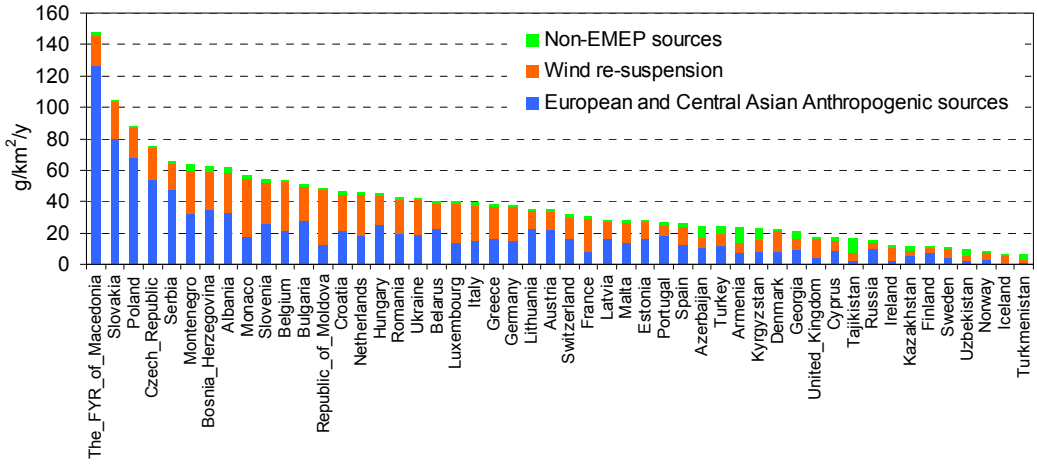


Fig 3.26. *Country-averaged deposition fluxes of cadmium from the European and Central Asian anthropogenic, natural/historical and non-EMEP sources in 2007*

Contribution of transboundary transport of cadmium to deposition from anthropogenic sources varies from 98% in Monaco to 12% in the FYR of Macedonia (Fig. 3.27). In 36 countries of Europe and Central Asia the contribution exceeds 50%, in 16 countries – 80%. Among the Central Asian countries the highest contribution of transboundary transport takes place in Turkmenistan (97%), the lowest – in Uzbekistan (51%).

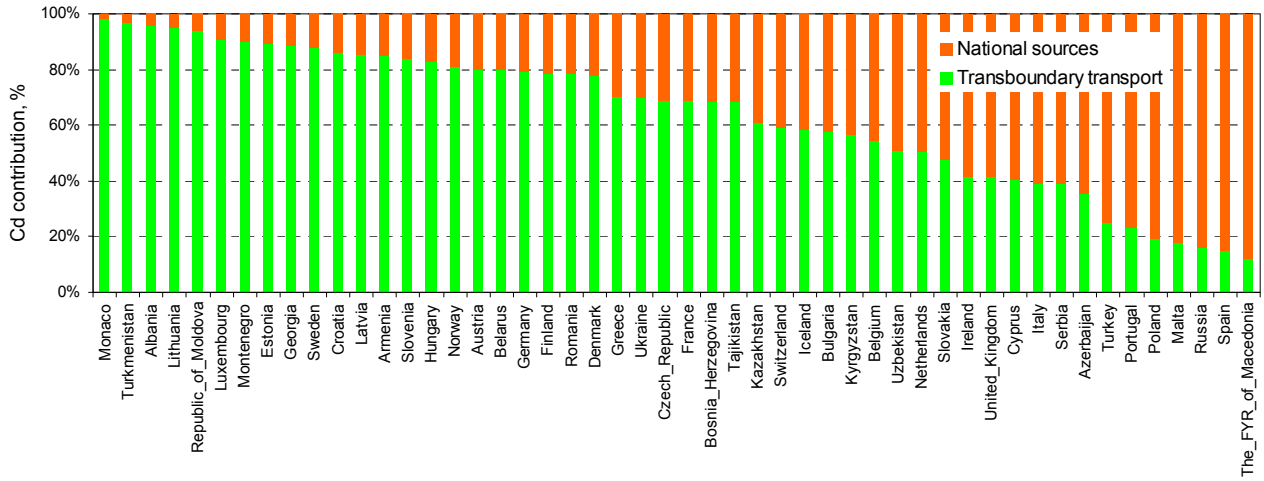


Fig. 3.27. *Relative contribution of the transboundary transport and national sources to anthropogenic cadmium deposition in the European and Central Asian countries in 2007*

Contribution of the European and the Central Asian countries to transboundary transport of cadmium ranges from almost 27 tonnes (Russia) to some few kilograms (Monaco) (Fig. 3.28). Other important contributors are countries with high national emissions of cadmium: Poland, Turkey, Spain and Kazakhstan. The fraction of national emissions of cadmium entering the transboundary transport typically varies from 60 to 90%. Similar to lead, Russia is an exception, which supplies only around 20% of national emissions to the transboundary pollution. As a rule, this fraction is higher either in small countries irrespective their national emissions (Belgium, Republic of Moldova), or countries with dry climate (Turkmenistan, Uzbekistan). When a country is small, emitted mass of cadmium (or other heavy metal) rapidly quits the country's territory and deposits elsewhere. If a country is known for arid climatic conditions, the emitted cadmium is not removed by precipitation and freely transported outside the country.

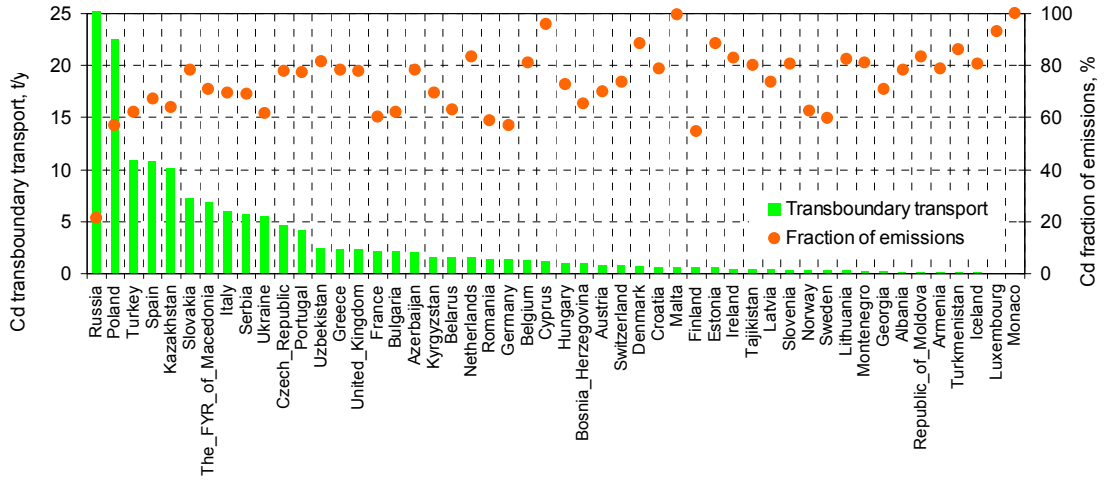


Fig. 3.28. *Absolute contribution of the European and Central Asian countries to cadmium transboundary transport in Europe and Central Asia in 2007 and relative fraction of national emissions involved into the transboundary pollution*

MERCURY

Total anthropogenic emission of mercury from the European and the Central Asian countries in 2007 was almost 225 tonnes. It includes 174 tonnes from European part and 51 tonnes from the Central Asian region and the Asian part of Russia. Unlike lead and cadmium, mercury emissions in Europe went down from 2006 to 2007 by about 10 tonnes. Total deposition of mercury to the European and the Central Asian countries from anthropogenic sources made up 74 tonnes, including 65 tonnes deposited to the European countries and 9 tonnes to the Central Asian countries. Deposition of mercury to the European and the Central Asian countries from all sources (anthropogenic, natural, re-emission, and non-EMEP) amounted to 231 tonnes. Among them 201 tonnes were deposited to Europe (including the Asian part of Russia) and 30 tonnes – to Central Asia.

Country-averaged deposition of mercury in the European and the Central Asian countries in 2007 varied from 4 g/km^2/y in Turkmenistan to 27 g/km^2/y in Belgium (Fig. 3.29). In addition to Belgium, other countries with highest country-averaged deposition flux were the FYR of Macedonia, Slovakia and Bosnia and Herzegovina. The lowest deposition was found in countries with low national emissions (e.g., Finland, Sweden). Besides, low deposition of mercury in some countries of Central Asia (e.g., Uzbekistan, Turkmenistan) were connected with low precipitation amounts. Two major types of sources are responsible for deposition of mercury: anthropogenic emissions in Europe and Central Asia and non-EMEP emission sources. Contribution of natural and re-emission sources located in the EMEP domain was minor. It is expected that mercury is emitted from natural sources and re-emitted in the elemental gaseous form. This mercury form is characterized by very long residence time in the atmosphere. As a result the most part of these emissions was transported beyond the boundaries of the model domain. In 15 countries (of 50) contribution of EMEP anthropogenic sources was higher than that of non-EMEP sources. In 35 countries the deposition from non-EMEP sources exceeded 50%. These figures indicate that sources located outside the EMEP region significantly affect mercury pollution levels in Europe. Therefore, global-scale modelling is needed in order to evaluate the contributions of these sources more accurately.

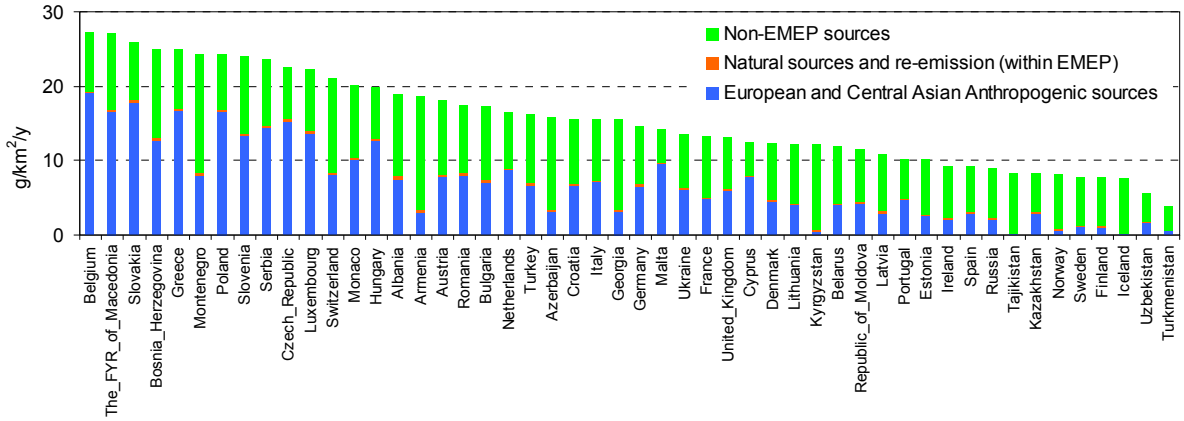


Fig. 3.29. *Country-averaged deposition fluxes of mercury from the European and Central Asian anthropogenic, natural/historical and non-EMEP sources in 2007*

Contribution of the transboundary transport to anthropogenic deposition of mercury in Europe varied essentially from country to country (Fig. 3.30). The highest contribution of the transboundary transport was estimated for Iceland (98%) and Latvia (97%). In Malta the contribution was the lowest (7.5%). In 26 countries this contribution exceeded 50%, and in 10 countries – 80%. Among the Central Asian countries the highest contribution was obtained for Tajikistan and Turkmenistan (more than 90%) and the lowest – for Kazakhstan (22%).

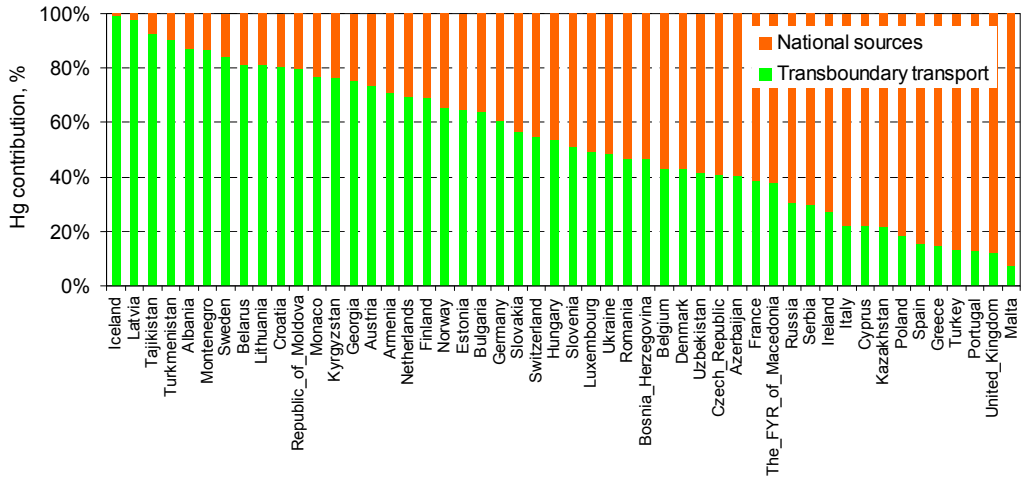


Fig. 3.30. *Relative contribution of the transboundary transport and national sources to anthropogenic mercury deposition in the European and Central Asian countries in 2007*

Russia was characterized by the largest amount of mercury (28.5 tonnes) emitted by national sources and transported outside country's territory (Fig. 3.31). Other substantial sources of mercury transboundary pollution were Kazakhstan, Turkey, Poland and Greece. The fraction of national mercury emissions involved into the transboundary transport ranged from 63% for Russia to more than 95% for Monaco, Iceland, Tajikistan, Malta, Kyrgyzstan and Cyprus. This fraction of mercury emissions was higher than that of other heavy metals (lead or cadmium). The reason for this is in considerable part of mercury emitted in elemental gaseous form. This form of mercury is slowly scavenged from the atmosphere and readily enters the transboundary and global transport.

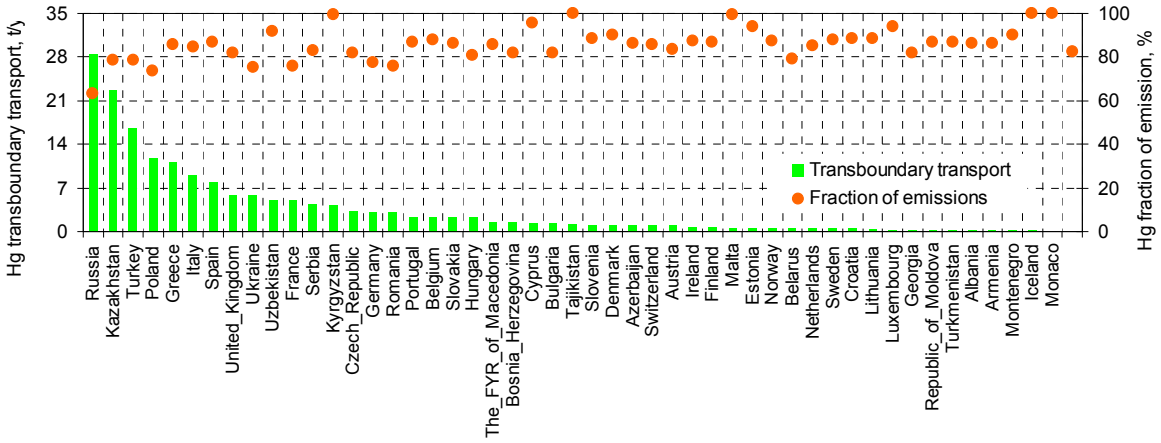


Fig. 3.31. *Absolute contribution of the European and Central Asian countries to mercury transboundary transport in Europe and Central Asia in 2007 and relative fraction of national emissions involved into the transboundary pollution*

Deposition to regional seas

Following the workplan MSC-E carried out calculations of lead, cadmium and mercury deposition to the seas surrounding Europe: the Black (with Azov), the North, the Mediterranean, the Baltic and the Caspian. The highest deposition of lead was calculated for the Mediterranean and the Black Seas (Fig. 3.32) and amounted to about 0.8 kg/km^2/y. The Black Sea is characterized also by the highest deposition of cadmium (around 24 g/km^2/y). The highest mercury deposition took place to the North Sea followed by the Baltic Sea.

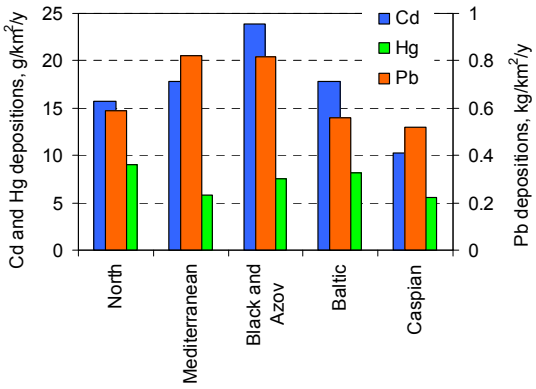


Fig. 3.32. *Averaged deposition fluxes of lead, cadmium and mercury to regional seas in 2006*

Compared to the results for 2006, deposition of lead to the Black and Mediterranean Seas increased by 27% and around 20%, respectively. For cadmium the increase made up about 20% over both seas. Besides, deposition of lead to the Caspian Sea increased by 30%, and deposition of cadmium – by 10%. The increase in deposition over the Mediterranean Sea is connected with changes in annual precipitation. Growth of the deposition of lead and cadmium to the Black Sea is caused by both increase of precipitation and by increase of emission values used in modelling, for example, in Russia (Pb, Cd), Bulgaria (Pb), and Ukraine (Cd). Deposition to the Caspian Sea increased because of the increase of emission values used in modelling in some neighbouring countries, e.g., Russia (Pb, Cd) and Kazakhstan (Pb). It is interesting to note that deposition of mercury to the Black and the Mediterranean Seas decreased. The decrease of deposition to the Black Sea is explained by significant reduction of emissions in Romania, Bulgaria and Ukraine compared to values used in modelling for 2006. As for the Mediterranean Sea, the decrease is caused mostly by the decline of deposition from non-EMEP anthropogenic sources and also some reduction of emissions in countries of the Mediterranean basin, e.g. Spain and France.

Contribution of different countries to deposition of heavy metals to each of the mentioned above seas was also evaluated (Annex B). Examples demonstrating contributions of the European and the Central

Asian countries to deposition of lead, cadmium and mercury to the Black Sea in 2007 are shown in Fig. 3.33. The highest contribution to deposition of lead and cadmium is made by Russia (about 1/3 of deposition from EMEP anthropogenic sources). About 1/5 of deposition is caused by the sources of Turkey. In case of mercury Turkey is a primary contributor: Almost one half of deposition from EMEP anthropogenic sources comes from this country. Ukraine is responsible for 13 – 15% of deposition. Other important contributors to deposition are Poland, Bulgaria (Pb), Greece (Pb, Hg), Serbia (Cd) and the FYR of Macedonia (Cd).

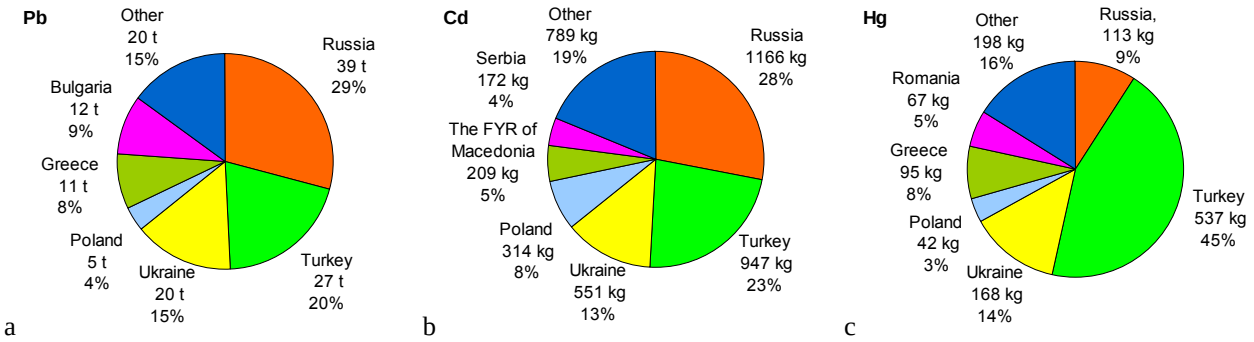


Fig. 3.33. *Contribution of different countries to anthropogenic deposition of lead(a), cadmium(b) and mercury (c) to the Black Sea in 2007*

4. CO-OPERATION

4.1. Working Group on Effects

According to the recommendation of the EMEP Steering Body MSC-E continued collaboration with the Working Group on Effects (WGE) in the field of assessment of heavy metal pollution levels across Europe and Central Asia and evaluation of modelling results against observations, including the heavy metals in mosses. Moreover, this year MSC-E together with the ICP-Vegetation of WGE worked on comparison of calculated heavy metal deposition and concentrations in mosses. The results of the common activity could be useful for complex analysis of temporal and spatial variability of heavy metals pollution over the EMEP domain. The ICP-Vegetation provided MSC-E with data on concentrations of lead, cadmium and mercury in mosses sampled during four moss surveys: 1990, 1995, 2000 and 2005/2006. These surveys involved more than 30 European countries.

The joint analysis of calculated heavy metal deposition and measured concentrations in mosses was focused on comparison of spatial distribution of modelled and measured levels and their long-term trends. For a number of countries significant spatial correlation between deposition and concentrations in mosses was found (Fig. 4.1). The highest correlation was found for Scandinavian countries (Finland, Sweden, Norway). For example, for lead the correlation coefficient in these countries was 0.7 - 0.9 (Fig. 4.1a). Satisfactory agreement between spatial distributions of modelled deposition and concentrations in mosses was also noted for some countries in central and western Europe (Fig. 4.1b.c).

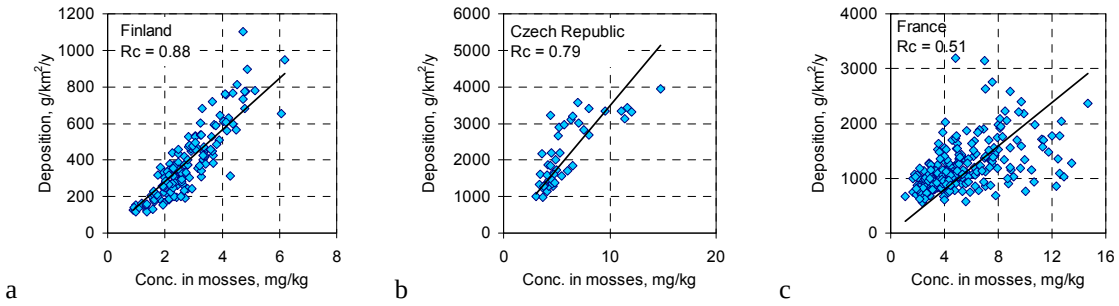


Fig. 4.1. *Comparison of calculated total deposition fluxes of lead and concentrations in mosses in Finland (a), Czech Republic (b) and France (c). Rc is correlation coefficient*

Long-term trends of deposition and moss concentrations are favourably comparable in different parts of Europe. For example, long-term decrease of cadmium deposition following the decrease of emission agrees well with the decrease of country-averaged cadmium concentrations in mosses in the northern and central parts of Europe (Fig 4.2a, b). In Bulgaria (south-eastern Europe) calculated trend of deposition follows that of national emissions (Fig. 4.2c), but not consistent with the trend of cadmium concentrations in mosses. In order to explain this inconsistency, further joint efforts of emission, modelling and measurement communities together with national experts are needed. Analysis of modelled deposition and concentrations in mosses can give additional information not only on pollution levels, but also on model performance and on the quality of emission data.

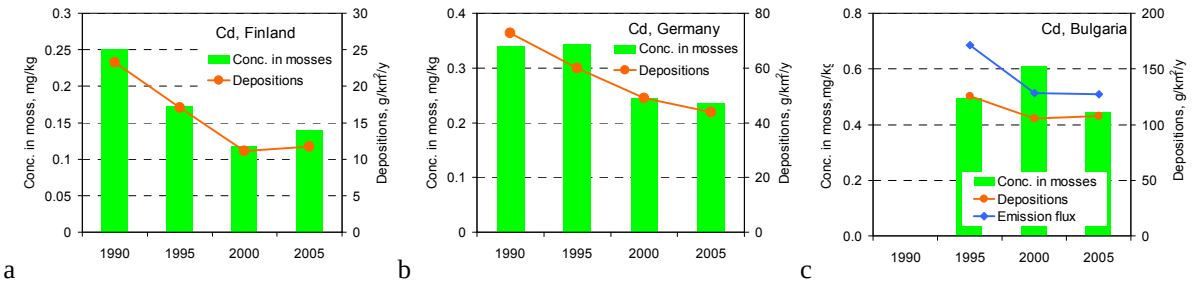


Fig. 4.2. *Long-term trends of deposition and concentrations in mosses of cadmium in Finland (a), Germany (b) and Bulgaria (c)*

Results of the joint work of MSC-E and the ICP-vegetation were presented and discussed at the 22nd Task Force Meeting of the ICP Vegetation (Braunschweig, Germany, February 2009) and at the 10th TFMM annual meeting (Paris, France, June 2009). It was agreed to continue this joint activity in future. Detailed description of modelled EMEP heavy metal deposition against moss measurements is available in section 1.4 of EMEP/MSC-E Technical report [*Gusev et al.*, 2009].

4.2. Task Force on Hemispheric Transport of Air Pollution

MSC-E continued cooperation with the EMEP Task Force on Hemispheric Transport of Air Pollution (TF HTAP). Particularly, the Centre participates in the intercomparison study of hemispheric and global models organised in the framework of TF HTAP. The aim of the study is assessment of intercontinental source-receptor relationships for different pollutants including mercury and selected POPs, evaluation of current models variability and uncertainties, and guidance of future model developments.

The Centre co-ordinates activity on collection and processing of the modelling results for the TF HTAP mercury multi-model comparison. The results of the model intercomparison were presented at the TF HTAP Workshop in St.Petersburg, Russia in April 2009 and plans for the extension of the multi-model experiment were discussed. Besides, the multi-model assessment of the mercury dispersion on a global scale along with estimates of the intercontinental transport will be included into the HTAP 2010 assessment.

MSC-E participated in the joint TFHTAP/ TFMM workshop on Regional-Global and Air Quality-Climate Linkages held in Paris, France in June 2009. The workshop included several sessions devoted to the discussion of methodological issues in linking of regional and global scale air quality modelling and impacts of climate change. The session on linking of regional and global scale models considered recent progress and challenges for the work in this direction. MSC-E contributed to the work of this session and presented the information on the on-going development of the EMEP global multi-scale modelling framework. In particular, basic features of the modelling framework including nesting capabilities were described. Preliminary results on modelling of mercury on global and regional levels including application of one-way nesting were reported.

It was stressed that further progress in the multi-scale HM modelling significantly depended on the availability of fine resolution emission data and global HM emission inventories. The workshop participants recognized that linking EMEP regional modelling with global and local scale modelling was an important direction for further refinement of evaluation of HM pollution levels.

4.3. Task Force on Measurements and Modelling

MSC-E continued to be actively involved in the TFMM work. In particular, special attention was paid to the development of common EMEP global modelling framework, verification of modelling results via comparison with measurements, and usage of complimentary measurement data for pollution levels assessment.

MSC-E participated in the TFMM Modelling Workshop held in Oslo, Norway in October 2008. The workshop participants were informed about the progress in the development of common EMEP global modelling framework. In particular, performance of GEM, IFS and WRF meteorological drivers was evaluated via comparison of processed meteorological fields (air temperature, precipitation, wind velocity) with observations. Besides, comparison of atmospheric modules of global models EMEPGLOB (MSC-W) and GLEMOS (MSC-E) was demonstrated. It was concluded that GEM and IFS drives demonstrated similar performance when compared with observations. Testing of the atmospheric modules in the framework of TH HTAP tracer experiment demonstrated that the results of EMEPGLOB and GLEMOS modelling systems are comparable.

MSC-E contributed to the tenth annual meeting of the TFMM held in Paris, France in June. The Centre presented information on application of monitoring-modelling approach to characterize the pollution levels of HMs in Europe and linked discrepancies between modelled and measured values with the uncertainties of HM emission data by means of back trajectories. It was stressed that measurements with high temporal resolution were particularly helpful for the back trajectory approach.

TFMM welcomed and supported a proposal of MSC-E to organize a case study devoted to the complex investigation of HM pollution levels on the example of a particular country. One of the main aims of the study is to better understand reasons of the discrepancies between modelled and measured values and to analyze quality of emission data.

Besides, usage of complimentary monitoring data, received from the ICP-Vegetation for validation of modelling results and complex analysis of pollution levels over Europe was discussed. It was shown that EMEP modelled HM levels significantly correlated with concentrations in mosses. Long-term trends of modelled HM deposition agreed well with the trends of the concentrations in mosses in most of countries.

4.4. International programmes (UNEP, AMAP)

MSC-E contributed to the UNEP report “Global Atmospheric Mercury Assessment: Sources, Emissions and Transport” co-ordinated by the Arctic Monitoring and Assessment Programme (AMAP). This work was partly funded by UNEP and AMAP. In particular, MSC-E took part in drafting the overview of contemporary modelling approaches applied for assessment of mercury pollution levels on a global scale. It also performed comparative analysis of the results of mercury atmospheric modelling. The report was presented to the 25th session of the UNEP Governing Council in Nairobi in February 2009. The AMAP/UNEP report was actively cited while elaborating the decision on the development of a legally binding instrument for the reducing of Hg in environment. In particular, the UNEP Governing Council agreed “*… to further international action consisting of the elaboration of a legally binding instrument on mercury, which could include both binding and voluntary approaches, together with interim activities, to reduce risks to human health and the environment …*” [UNEP/GC.25/17].

4.5. Marine Conventions (HELCOM, OSPAR)

Helsinki Commission

In accordance with the Memorandum of Understanding between the Baltic Marine Environment Protection Commission (HELCOM) and the United Nations Economic Commission for Europe on cooperation in the field of monitoring of air pollutants EMEP Centres (CCC, MSC-E and MSC-W) annually prepared a joint report on the evaluation of airborne pollution load to the Baltic Sea. MSC-E had the main responsibility for the evaluation of atmospheric transport and deposition of lead, cadmium, and mercury to the Baltic Sea. The deposition and atmospheric transport were assessed on the base of EMEP officially submitted emission data. Besides, this report provided detailed information about emissions of heavy metals in HELCOM countries and comparison of modelling results against measurement data collected in the HECLOM region in 2006.

In addition to the joint annual report, MSC-E prepared environmental indicator reports with the updated information on atmospheric emissions of heavy metals and their deposition to the Baltic Sea for 1990 – 2006 period. These reports are available in the Internet at the web site of the Helsinki Commission [www.helcom.fi].

According to the officially reported emission data, cadmium emissions in HELCOM countries declined by 47%, mercury – by 45% and lead by 86% for the period from 1990 to 2006 (Fig. 4.3). Generally, the reduction of heavy metal emissions in this area is caused by extensive use of unleaded gasoline and application of cleaner production technologies. Besides, it is partly connected with economic re-structuring which has taken place in Poland, Estonia, Latvia, Lithuania, and Russia since early 1990s. The highest decrease of cadmium emissions took place in Lithuania (90%) and Estonia (88%). In case of lead emission, the most significant decrease can be seen for Denmark and Sweden where the emissions in 2006 were more than 20 times lower than in 1990. Mercury emission most significantly decreased in Latvia (92%) and Germany (85%). Essential reduction of annual lead emission of HELCOM countries from 2003 to 2004 is mostly caused by the change of emission in Russia.

Following the reduction of atmospheric emissions, deposition of heavy metals decreased for the period 1990 – 2006 as shown in Fig. 4.4. Deposition of lead is characterized by the most significant decline (66%). The decrease of cadmium deposition made up 43%, and mercury – 33%. When considering individual sub-basins of the Baltic Sea the highest decrease of cadmium and lead deposition was revealed for the Gulf of Finland (67% and 74%, respectively). For mercury, the most significant decline in deposition was obtained for the Belt Sea (37%).

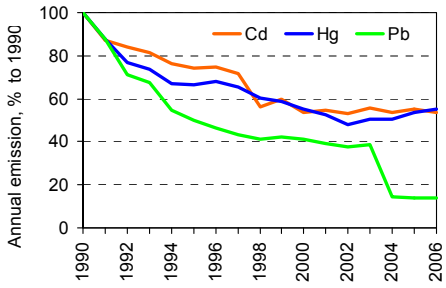


Fig. 4.3. *Trend of anthropogenic emissions of cadmium, mercury, and lead from HELCOM countries in 1990-2006 according to official emissions data*

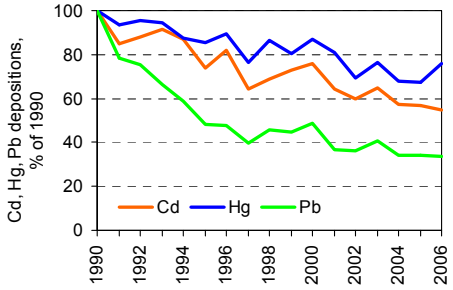


Fig. 4.4. *Temporal variations of cadmium, mercury, and lead deposition to the Baltic Sea in 1990-2006*

In 2006 the highest modelled deposition of heavy metals were indicated for the southern-western part of the Baltic Sea (the Belt Sea and the Kattegat). Poland, Germany and Russia are the major contributors to atmospheric deposition of heavy metals to the Baltic Sea in 2006 among HELCOM countries.

OSPAR Commission

In the framework of cooperation programme between EMEP and the OSPAR Commission (Convention for the Protection of Marine Environment of the North-East Atlantic) MSC-E continued the work on the evaluation of atmospheric input of lead, cadmium, and mercury to the OSPAR maritime area. This year following the request of the OSPAR Commission MSC-E updated the time-series of emission and deposition levels in period 1990-2005 adding the information for 2006 and included estimates of the contributions of the OSPAR countries emissions to deposition over the OSPAR Convention Waters.

Total annual emissions of selected HMs from the OSPAR countries did not change significantly from 2005 to 2006. In particular, total emissions of lead, cadmium, and mercury in OSPAR countries in 2006 were 6-8% lower in comparison to the emissions in 2005. Following the declining of emissions the values of total deposition of heavy metals in most of the OSPAR regions are lower in 2006 than that in 2005. At the same time levels of lead and cadmium deposition in the Bay of Biscay and the Wider Atlantic in 2006 are higher comparing to the deposition for 2005. Mercury total deposition in 2006 is lower in all the OSPAR regions but the Bay of Biscay. In Figure 4.5 updated long-term trends of total deposition and net deposition fluxes of cadmium over five main OSPAR maritime regions is demonstrated.

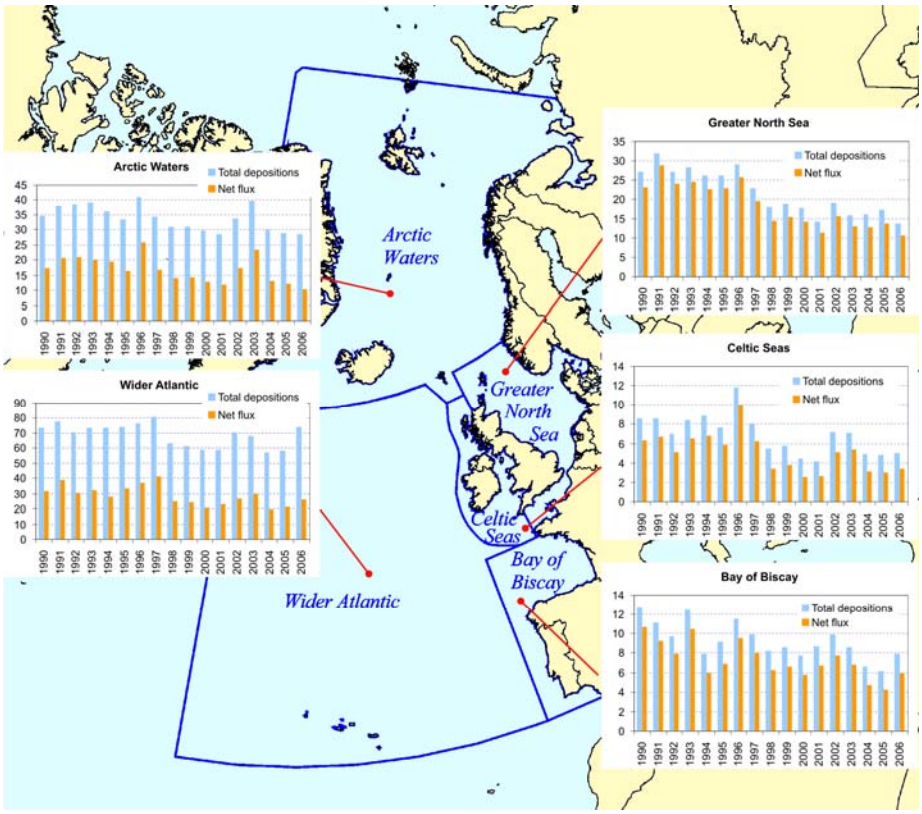


Fig. 4.5. *Time series of modelled total annual deposition and net atmospheric input of cadmium to the five main OSPAR regions for the period 1990-2006*

The information on contribution of individual countries to the annual HM deposition in 2006 over the OSPAR maritime area was prepared for the 5 OSPAR regions. The most significant contribution to the anthropogenic deposition of lead in 2006 over the Regions I, II, and III was made by the United Kingdom (Fig. 4.6). In case of the Regions IV and V these were Spain and Portugal, respectively. In case of cadmium deposition from the anthropogenic emission sources the most significant contribution was made by Poland for the Region I, the United Kingdom for the Regions II and III, and Spain for the Regions IV and V. Similar to lead the contribution of the United Kingdom to the mercury anthropogenic deposition in 2006 was dominating in the Regions I, II, and III. Spain was the major contributor to the mercury deposition over the Regions IV and V.

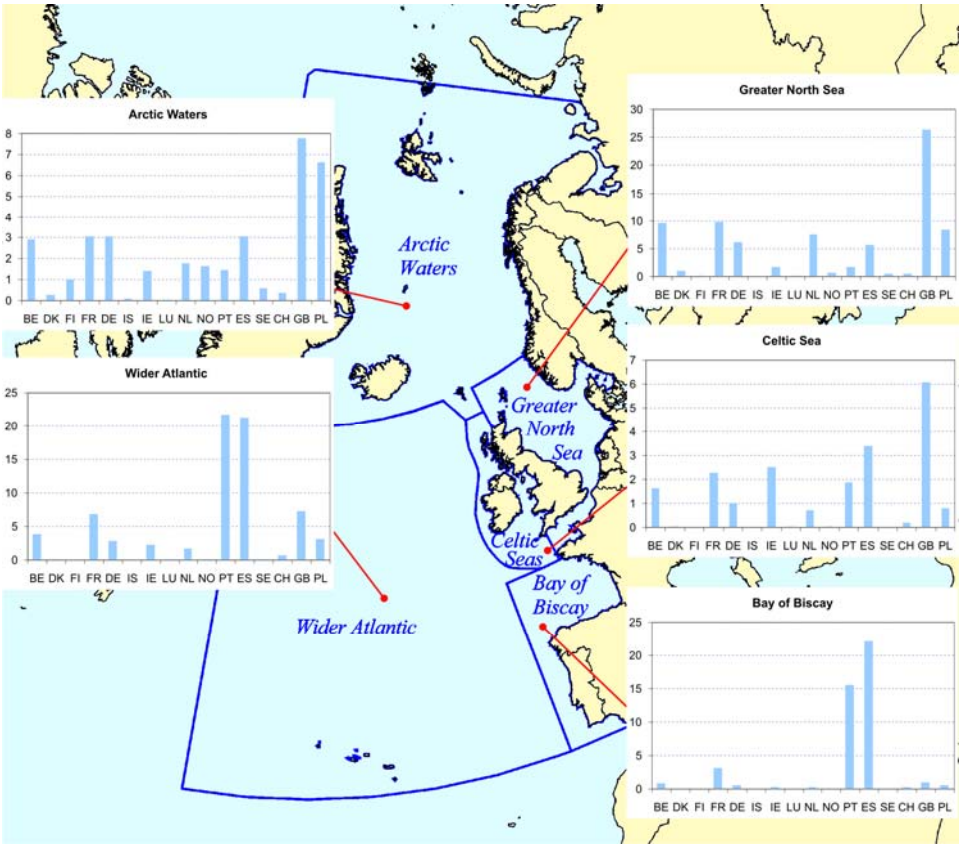


Fig. 4.6. *Contribution of individual countries to the annual deposition of lead to the 5 OSPAR regions for 2006*

Updated information on atmospheric input of lead, cadmium, and mercury to the OSPAR maritime area was used in course of preparation of 2009 CAMP data assessment report.

4.6. European Commission (HEIMTSA)

MSC-E takes part in the EU HEIMTSA project launched in 2007 under the 6th Framework Programme of the European Commission (EC). The project aims to support the Environment and Health Action Plan (EHAP) by extending health impact assessment (HIA) and cost benefit analysis (CBA) methods and tools so that environment and health impacts of policy scenarios in key sectors can be evaluated reliably at the European level. The responsibility of MSC-E in the project is to assess by means of its chemical transport models the atmospheric dispersion of selected heavy metals and POPs and their concentration in different environmental media.

The main activities carried out by MSC-E during this year were connected with review of methods and models for assessment of concentrations of heavy metals in the environment as well as modelling activity within the HEIMTSA case study on complex pollutants with multi-pathway exposure. Particularly, MSC-E took part in review of available data and models to be used in the full chain assessment of the case study on complex pollutants, discussions of the assessment procedure and development of the case study work plan. It also contributed to the report on review of methods for modelling environmental concentrations, describing model adjustments, developments and applications. Besides, it collected and submitted required modelling data on the considered pollutants (As and Pb) atmospheric deposition and concentration in ambient air. The Centre also contributed to the report of the case study on complex pollutants covering the field of atmospheric dispersion modelling.

An example of the simulation results of country-averaged deposition fluxes of arsenic to terrestrial ecosystems is presented in Fig. 4.7. The most significant deposition fluxes were predicted for the Benelux countries, and also some other countries such as Germany, France and Greece. The highest deposition reduction by 2010 and 2020 is characteristic of countries with large deposition and also in some other countries. In general, somewhat more significant reduction is predicted for the Central and the East European countries (Slovenia, Romania, Slovakia, Hungary etc.)

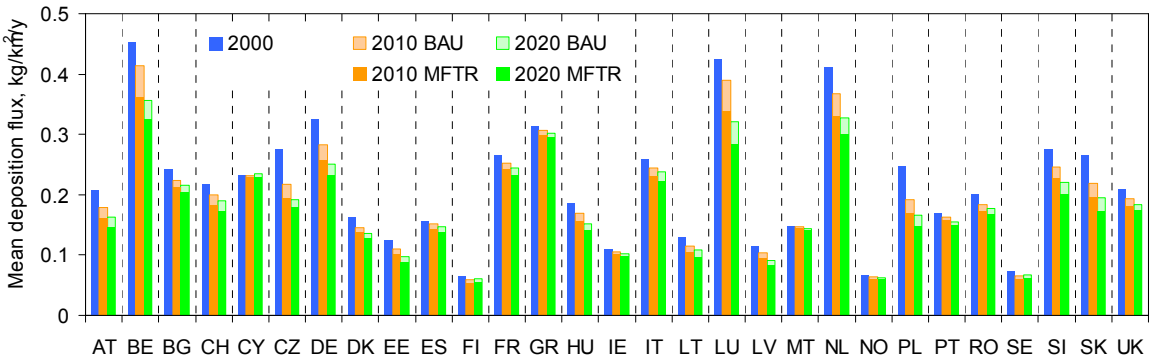


Fig. 4.7. *Simulated country-averaged total deposition flux (dry+wet) of arsenic to terrestrial compartments*

4.7. Co-operation with countries and national experts

Close collaboration with national scientific experts is considered as highly important activity under EMEP. This year MSC-E took part in a variety of co-operative activities:

- At the request of Spanish colleagues the source code and input data of the MSCE-HM model were delivered to the Group of air quality modelling of CIEMAT (National Research Centre for Energy, Environment and Technology) as the EMEP contribution to the development of national air quality model for heavy metals.

- Calculated deposition data of lead, cadmium and mercury for various years were transferred to the experts from Switzerland (FUB-Research Group for Environmental Monitoring), Bulgaria (Institute of Botany BAS), Germany (University of Vechta) and Austria (University of Vienna) involved in the heavy metal measurements in mosses. These data were used for detailed analysis of heavy metal deposition based both on modelling results and measured concentrations in mosses. The results of the analysis are planned to be published in a peer-reviewed journals.

- In order to support national-scale modelling of mercury atmospheric transport over Italy the experts from CESI RICERCA SpA were provided with data on three-dimensional concentrations of mercury for setting up initial and boundary conditions. Besides, general aspects of the parameterization of mercury natural emission and re-emission were discussed with the experts and the required input information was provided for generation of spatially distributed natural emission dataset.

- Representatives of MSC-E took part in 9th International Conference on Mercury as a Global Pollutant, held in Guiyang, China in June, 2009. The conference considers a wide variety of aspects concerning mercury pollution worldwide. They include anthropogenic sources and emissions, environmental monitoring and modelling, analytical chemistry, health effects, socioeconomic aspects etc. The conference demonstrated increasing interest of the scientific community to mercury pollution problems. MSC-E presented new EMEP results obtained in the field of mercury modelling. In particular, the newly developed multi-media approach for mercury modelling was demonstrated along with first simulation results of mercury cycling in the environment.

- Taking into account that increasing cooperation with EECCA countries is one of the main EMEP priorities, MSC-E prepared country oriented reports including source-receptor calculations for all 12 EECCA countries in Russian language. The country reports are available on MSC-E website (www.msceast.org).

5. FUTURE ACTIVITIES

In order to further improve the quality of modelling results of lead, cadmium and mercury pollution over the EMEP region, the following activities are proposed for 2010:

I. CCC activities

1. Annual activities:

    1.1. Publish 2008 data, including a quality assessment.

    1.2. Review, store and make available 2009 monitoring data for the modelling centres and Parties.

    1.3. Coordinate and carry out the intensive advanced measurements on the topics to be defined by TFMM.

    1.4. Provide training/guidance to Parties to establish monitoring activities in compliance with the EMEP monitoring strategy, with a special focus on countries in EECCA.

    1.5. Arrange laboratory intercomparisons for main components, heavy metals, EC/OC and POPs, and carry out field intercomparisons at selected sites.

    1.6. Address integration of quality assessment/quality control (QA/QC) activities of regional monitoring programmes on the global scale, including standards for metadata provision, intercomparisons, etc.

    1.7. Contribute to preparation, review and assessments of observations data presented in the series of EMEP reports.

    1.8. Maintain close interaction with relevant organizations and bodies in relation to integration of observations. This includes monitoring efforts under other bodies under the Convention (e.g. the International Cooperative Programmes (ICPs)), national monitoring obligations to European Commission Directives, as well as activities undertaken by EEA, WMO, the OSPAR Commission, the Baltic Marine Environment Protection Commsision (HELCOM), UNEP, AMAP, NinE (Nitrogen in Europe), Global Monitoring for the Environment and Security (GMES)/Global Earth Observation System of Systems (GEOSS) and others.

2. New developments

    2.1. Start implementing the new monitoring strategy for 2010–2019.

    2.2. Improve the Web interface of the database to include more statistical opportunities for aggregated data, further develop the plotting routines, and develop improved export routines for data downloading for modellers.

    2.3. Contribute to the development of standard methods and QA/QC procedures in relation to the new parameters included in the monitoring requirements of the 2010–2019 strategy.

II. MSC-E activities

1. Annual activities

1.1. Preparation of meteorological data for operational modelling based on the European Centre for Medium-Range Weather Forecasts (ECMWF) analysis and meteorological driver update/development (global Weather Research and Forecasting Model (WRF)).

1.2. Processing of HM emissions data as input for operational modelling.

1.3. Calculations of lead, cadmium and mercury air concentration and deposition fields and country-to-country deposition matrix for 2008 and evaluation of modelling results against monitoring data.

1.4. Estimates of lead, cadmium and mercury deposition to regional seas (the Baltic, Black, Caspian, Mediterranean and North Seas).

1.5. Cooperation with the subsidiary bodies to the Convention and the EMEP Task Forces, international bodies: AMAP, EU, HELCOM, OSPAR, UNEP and national experts

1.6. Preparation of individual country status reports in English and Russian for the EECCA countries.

1.7. Dissemination of results (e.g. via status reports, technical notes, the website, publication in peer-reviewed journals).

2. Research and development activities

2.1. Update the operational regional heavy metal model based on new developments of the mercury scheme (e.g. implementation of halogen chemistry, improvement of natural emission and media exchange).

2.2. Analyse discrepancies between modelling results and monitoring data for lead and cadmium (including back trajectory analysis, uncertainty of anthropogenic emissions, wind resuspension, measurement data quality, etc.).

2.3. Study the sensitivity of heavy metal pollution levels in Europe to the major meteorological parameters associated with climate change.

2.4. Further development and testing of the common EMEP global modelling framework and its architecture.

2.5. Review, collection and evaluation of global datasets on soil properties (soil texture, OC content, etc.).

2.6. Development of the EMEP global modelling framework:

- Evaluation of the effect of using different geophysical and emission data in the existing global models used at the two Meteorological Synthesizing Centres.

- Evaluation of means for the flexible introduction of different meteorological drivers to be used in the common EMEP global model.

- Identification of the changes in existing model routines that are necessary to facilitate common modules for global modelling in EMEP.

2.7. Contribute to the TFHTAP 2010 assessment report on intercontinental transport of air pollution.

2.8. Joint analysis with ICP Vegetation of the Working Group on Effects (WGE) of heavy metal pollution levels in Europe using modelling results and measurements in mosses, assessment of ecosystem-dependent deposition of heavy metals in Europe for the effects community.

CONCLUSIONS

The main activities of the EMEP Centres CCC and MSC-E in the field of monitoring and modelling of heavy metals in 2009 were focused on the evaluation of pollution levels in countries of Europe and Central Asia for 2007. Progress in the EMEP monitoring for 2004 – 2007 is overviewed. Pollution levels were examined on the base of modelling and measurement data. Furthermore, the status of development of the common EMEP global model is described and the improvements of regional-scale MSCE-HM model are discussed. Special attention was paid to cooperation with the subsidiary bodies to the Convention, EMEP Task Forces, international organizations and programmes and national experts. The main conclusions of the activities of MSC-E and CCC in 2009 are formulated below.

Monitoring of heavy metals

1. The progress in the field of heavy metal monitoring was noted as a result of the implementation of the EMEP monitoring strategy for 2004-2009. In particular, the number of stations performing the co-located measurements (in air an in precipitation, simultaneously) was increased. Along with this, measurement data from France, Hungary, Italy and Cyprus become available. However, spatial coverage of the measurements in the southern and eastern parts of Europe and in Central Asia remains insufficient.

2. Monitoring information on lead and cadmium concentration in air and precipitation in 2007 was reported by 69 stations from 23 countries. Among them at 25 stations the concentrations were measured in air and in precipitation. Measurement data on at least one mercury form were reported from 22 stations.

Heavy metal modelling: new developments

1. MSC-E continued the work on the development of the common EMEP global modelling framework in close co-operation with MSC-W. In particular, a pilot version of the modelling framework with the modular architecture has been elaborated for heavy metals and POPs based on the newly developed global model GLEMOS. The model was tested for lead and mercury and evaluated against measurements. Besides, the nesting procedure was implemented in the modelling framework to improve link between different scale simulations.

2. The multi-media approach is being developed for mercury modelling. First simulations of mercury cycling in the environment demonstrate that mercury atmospheric deposition has increased by 2.3 times since the pre-industrial period. The enrichment of mercury content in the environmental media amounts to 2.1 times for the atmosphere, 25% for the ocean, and 10% for soil. The future scenario simulation predicts recovering of the media during 50 years for the ‘cut-off’ scenario and continuous increase of mercury levels for the ‘status quo’ scenario.

3. Development of the size-segregated wet scavenging scheme for the HM atmospheric transport model has been initiated. A series of the model experiments have been performed to test different parameterizations. The testing has shown that the new parameterization of below-cloud scavenging provides better spatial correlation of annual mean modelled and measured concentrations in precipitation. However, further development of the size-segregated approach for heavy metal modelling is required.

4. Investigation of sensitivity of the modelling results to refining of the vertical grid structure of the operational transport model was finalized. It was showed that the refinement of lowest model layer leads to some decrease of air concentrations, and to minor changes of total deposition over the EMEP domain. The sensitivity of modelled air concentration and deposition at background monitoring stations is minor. Therefore, the refinement of the model vertical structure without changes in parameterization of physical properties does not lead to improvement of the model performance.

Assessment of heavy metal pollution levels

1. For the first time, heavy metal pollution levels in Europe were examined with the combined application of the modelling and measurement information. Deposition and concentrations of lead, cadmium and mercury varied largely over Europe and Central Asia in 2007. The highest regional-scale pollution levels were obtained for Poland, north of Italy, the Benelux, the Balkan region, and the European part of Russia. In the Central Asian region elevated concentrations occurred in the northern and southern parts of Kazakhstan. Heavy metal deposition in Central Asia is not as high as deposition in Europe because of relatively low precipitation amount.

2. Estimated deposition of lead to the European and the Central Asian countries as a whole in 2007 is considerably higher in comparison with the results for 2006 because of essential changes in applied emissions data. The cadmium deposition remained almost the same, whereas deposition of mercury decreased slightly. Most distinct increase of deposition because of the changes in emission data took place in Russia (Pb) and Germany (Hg), and the decrease – in Bulgaria (Cd, Hg) and Romania (Cd, Hg). Inter-annual variably of meteorological parameters substantially affects pollution levels via the changes of annual precipitation amounts and magnitude of input to the atmosphere caused by wind re-suspension.

3. The modelling results satisfactorily agree with the measurement data. At the most of stations agreement between modelled and measured concentration and deposition of lead and cadmium is within ±50%. The discrepancy between the simulated and observed mercury concentrations does not exceed ±20% and ±25% for air and precipitation, respectively, whereas wet deposition fluxes agree within ±50%.

4. The transboundary atmospheric transport affects considerably heavy metal pollution levels in the European and the Central Asia countries. Contribution of the transboundary transport to deposition from anthropogenic sources in Europe and Central Asia exceeds 50% in 38, 36 and 26 countries for lead, cadmium and mercury, respectively. The fraction of national emissions of the European and the Central Asian countries entering transboundary transport ranges from 60% to 90% for lead and cadmium. In case of mercury, this fraction is commonly varies from 70% to almost 100%.

Co-operation

1. In the framework of cooperation with the EMEP Task Force on Measurements and Modelling (TFMM, June 2009, Paris, France) MSC-E reported about application of the monitoring-modelling approach to characterize the pollution levels of HMs in Europe. Besides, it demonstrated the application of back trajectory approach for the analysis of discrepancies between the modelled and measured values as well as evaluation of emission data

uncertainties. It was stressed that measurements with high temporal resolution were particularly helpful for the analysis of the discrepancies between modelled and measured values.

2. TFMM (June, 2009, Paris, France) welcomed and supported the proposal of MSC-E to organize a case study devoted to the complex investigation of HM pollution levels on the example of a number of countries. The case study could include detailed analysis of emission data, model estimates and monitoring data for better understanding the reasons of the discrepancies between modelled and measured values and for the evaluation of emission data quality.

3. Data on concentrations of heavy metals in mosses sampled in pan-European moss surveys provided by the ICP-Vegetation of the Working Group on Effects (WGE) were used for the complex analysis of pollution levels across Europe and for the model verification. Modelled deposition of lead, cadmium and mercury demonstrated significant agreement with the moss concentration data from the viewpoint of spatial distribution and long-term trends. The results of this activity were presented at the 22nd Task Force Meeting of the ICP-Vegetation (February 2009, Braunschweig, Germany).

4. MSC-E also contributes to the EMEP Task Force on Hemispheric Transport of Air Pollution (TF HTAP). The Centre participates in the intercomparison study of hemispheric models organised within the framework of TF HTAP. In particular, it co-ordinates activity on collection and processing of the modelling results for the TF HTAP mercury multi-model experiment. The results of the model intercomparison were presented at the TF HTAP Workshop (April 2009, St. Petersburg, Russia). In addition, MSC-E reported on the on-going development of the EMEP global multi-scale modelling framework, pilot modelling results and implementation of the nesting procedure (June 2009, Paris, France).

5. In the framework of cooperation between EMEP and the OSPAR Commission MSC-E updated model assessment of atmospheric input of lead, cadmium, and mercury to the OSPAR maritime area. In particular, time-series of emissions and deposition levels for the period 1990-2006 were prepared. Contributions of the emission sources in OSPAR countries to the deposition over the OSPAR Convention Waters for 2006 were evaluated.

6. MSC-E contributed to the preparation of the EMEP Centres joint report on the evaluation of airborne pollution loads to the Baltic Sea for Helsinki Commission. The information on the assessment of lead, cadmium, and mercury deposition to the Baltic Sea for 2006 was provided and environmental indicator reports with regard to temporal variations of HM emissions of HELCOM countries and HM deposition over the Baltic Sea in the period from 1990 to 2006 were updated.

7. MSC-E was also actively involved in cooperation with national experts. In particular, the source code of the MSCE-HM model was shared for the development of national atmospheric transport model for heavy metals in Spain. Besides, scientific experts from Italy, Germany, Bulgaria, Switzerland and Austria were provided with necessary model output information. Along with this, the achievements of MSC-E in the field of mercury modelling were also presented at the 9th International Conference on Mercury as Global Pollutant (June 2009, Guiyang, China).

8. To support EECCA countries country-oriented reports were prepared in Russian language.

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ANNEX A

EMEP work-plan for HMs in 2009

2.1. Emissions

Description/objectives:

To further develop emission inventories; improve the quality, transparency, consistency, completeness and comparability of reported emission and projection data; support the review of compliance; and assist Parties with their emission reporting. TFEIP, led by Norway and co-chaired by Sweden and EEA, provides a technical forum for sharing information, harmonizing emission factors, establishing methodologies for the evaluation of emission data and projections, and identifying and resolving reporting problems, with a view to harmonizing as far as possible reporting requirements with UNFCCC and the European Union's National Emission Ceilings (NEC) directive.

Main activities by the EMEP Centres:

(d) Elaborate a data set of validated and complete emission data submitted during the 2009 reporting round by 15 April 2009 for use in the EMEP 2007 assessments. Increase the transparency in use of non-Party estimates for modelling (CEIP, MSC-W, MSC-E);

(e) Review sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOCs), ammonia (NH3) and particulate matter (PM) emissions (MSC-W) and heavy metals and persistent organic pollutant (POP) emissions for modelling purposes (MSC-E);

Main activities by TFEIP

(b) Consider and propose further actions to close the gap between official emission data for heavy metals and POPs and modelling results in close collaboration with the modelling community (TFEIP, TFMM, MSC-E);

2.2. Atmospheric measurements and modelling

Description/objectives

To support the implementation of protocols to the Convention; provide the measurement and modelling tools necessary for further abatement policies; compile and evaluate information on transboundary air pollution; and implement the EMEP monitoring strategy adopted in 2004. The Task Force on Measurements and Modelling, led by France and co-chaired by WMO, reviews and assesses the scientific and operational activities of EMEP related to monitoring and modelling, evaluates their contribution to the effective implementation and further development of the protocols, and reviews national activities related to measurement, modelling and data validation.

Main activities by the EMEP Centres:

(c) Provide validated data on concentrations, deposition and transboundary fluxes of heavy metals (mercury (Hg), lead (Pb) and cadmium (Cd)) and POPs for 2007 over the extended (eastward) EMEP domain, and update source-allocation calculation, including EECCA countries (MSC-E, CCC);

(d) Prepare individual country status reports; update web access to electronic source-allocation information with validated data for the main pollutants and PM and for heavy metals and POPs (MSC-W, MSC-E);

(e) Review, store and make available the 2008 monitoring data; assess uncertainties in, and the representativeness of, monitoring data required by the EMEP monitoring strategy (CCC, MSC-E and MSC-W);

(f) Provide access to validated databases with EMEP measurement data in 2008 by 31 December 2009 (CCC), after joint revision with MSC-E and MSC-W and bilateral discussions with Parties experts;

(j) Continue support and training in EECCA countries (CCC, MSC-East and MSC-W).

Main activities and time schedule for atmospheric modelling for HMs:

(a) New developments in mercury deposition: Consider nationally available measurements on dry deposition of Hg to forests to evaluate measurement uncertainties and improve model parameterization (CCC, MSC-E, Parties);

(b) New developments in ecosystem dependent deposition: Evaluate ecosystem-dependent depositions of heavy metals and contribute to the development of the effect-based approach (MSC-E, CCE);

(c) New developments in heavy metal dispersion modelling: Continue to develop the heavy metal model parameterization including improvement of the wind re-suspension scheme and implementation of aerosol size-segregated description and removal processes (MSC-E);

(d) New developments in Hg chemistry: Update the Hg chemical scheme in the regional and global models based on new findings of the research community (MSC-E);

(e) New developments in meteorological data preparation: Investigate the possibility to update meteorological drivers by application of WRF (Weather Research and Forecasting Model).

2.4. Hemispheric transport of air pollution

Description/objectives:

To develop a fuller scientific understanding of the hemispheric transport of air pollution and estimate the hemispheric transport of specific air pollutants, the Task Force on the Hemispheric Transport of Air Pollution, led by the United States and the European ECE/EB.AIR/2008/8 ECE/EB.AIR/GE.1/2008/9/Rev.1 Page 12

Community, coordinates activities, including collaboration with other international bodies, programmes and networks, both within and outside the UNECE region, with related interests.

Main activities by the EMEP Centres:

(a) Participate in the TFHTAP model inter-comparison for O3, PM compounds POPs and heavy metals with the two EMEP global models (MSC-W, MSC-East);

(b) Contribute to the TFHTAP 2010 assessment report on intercontinental transport of air pollution (MSC-E, MSC-W, CIAM, CCC);

(c) New development - integrated EMEP global system: Evaluate the effect of using different geophysical and emission data in the existing global models used at the two meteorological synthesizing centres (MSC-E, MSC-W);

(d) New development - integrated EMEP global system: Evaluate means for the flexible introduction of different meteorological drivers to be used in the common EMEP global model (MSC-E, MSC-W);

(e) New development - integrated EMEP global system: Identify the changes in existing model routines that are necessary to facilitate common modules for global modelling in EMEP (MSC-W, MSC-E);

(f) New developments for global emission data: Evaluate the new EDGAR THTAP global emission data in comparison with other available expert estimates (CEIP, MSC-W, MSC-E).

ANNEX B

COUNTRY-TO-COUNTRY DEPOSITION MATRICES FOR 2007

Table B.1. *Codes of countries, regions and seas*

Country/Region/Sea	Code	Country/Region/Sea	Code
Albania	AL	Monaco	MC
Armenia	AM	Montenegro	ME
Austria	AT	Netherlands	NL
Azerbaijan	AZ	Norway	NO
Belarus	BY	Poland	PL
Belgium	BE	Portugal	PT
Bosnia and Herzegovina	BA	Republic of Moldova	MD
Bulgaria	BG	Romania	RO
Croatia	HR	Russian Federation (European part)	RU
Cyprus	CY	Russian Federation (Asian part)	RUA
Czech Republic	CZ	Serbia	RS
Denmark	DK	Slovakia	SK
Estonia	EE	Slovenia	SI
Finland	FI	Spain	ES
France	FR	Sweden	SE
Georgia	GE	Switzerland	CH
Germany	DE	The Former Yugoslav Republic of Macedonia	MK
Greece	GR	Tajikistan	TJ
Hungary	HU	Turkey	TR
Iceland	IS	Turkmenistan	TM
Ireland	IE	Ukraine	UA
Italy	IT	United Kingdom	GB
Kazakhstan	KZ	Uzbekistan	UZ
Kyrgyzstan	KY	Baltic Sea	BAS
Latvia	LV	Black Sea	BLS
Lithuania	LT	Caspian Sea	CAS
Luxembourg	LU	North Sea	NOS
Malta	MT	Mediterranean Sea	MDT

***Table B.2**. Matrix of lead country-to-country deposition from anthropogenic sources in 2007, kg/y*

Receptors ↓ Emitters →

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	
AL	**3233**	0.2	19.3	1.2	290.7	13.9	1904	12.8	18.4	1.1	33.5	43.8	1.5	**AL**
AM	2.7	**500.1**	1.2	502.7	5.5	1.4	56.2	6.9	0.9	16.4	2.7	4.2	0.3	**AM**
AT	25.5	0.4	**4643**	2.0	395.5	371.3	546.7	83.6	802.9	0.3	1055	2874	19.9	**AT**
AZ	4.7	124.6	3.0	**3017**	11.3	3.5	124.0	26.0	2.5	24.2	7.2	11.0	0.8	**AZ**
BA	361.2	0.4	191.2	1.9	**16615**	57.7	1621.8	32.9	62.9	1.1	302.8	281.2	9.1	**BA**
BE	1.0	0.0	21.9	0.2	9.7	**10066**	30.7	9.9	55.8	0.0	41.6	1075	12.2	**BE**
BG	377.1	3.8	71.7	15.4	611.2	40.3	**93510**	160.2	33.5	17.0	198.1	165.5	8.2	**BG**
BY	60.5	4.6	193.6	24.6	411.7	289.3	1418	**21074**	130.1	5.1	1013	1014	102.4	**BY**
CH	8.2	0.1	86.3	0.4	80.1	247.6	138.7	8.2	**4974**	0.1	59.5	767.8	3.8	**CH**
CY	2.6	0.3	0.5	0.5	3.5	0.4	30.8	1.5	0.4	**415.1**	1.0	1.2	0.1	**CY**
CZ	15.8	0.5	909.0	1.9	200.3	429.5	376.4	157.7	327.2	0.4	**6971**	3091	43.0	**CZ**
DE	26.6	0.8	1236	3.5	215.6	10150	540.8	298.1	3358	0.9	2477	**46492**	349.0	**DE**
DK	1.6	0.1	21.5	0.6	12.7	475.2	39.4	51.5	33.5	0.3	88.9	748.0	**655.5**	**DK**
EE	5.9	0.5	17.9	3.4	31.5	123.0	100.9	313.0	20.9	0.9	81.0	269.7	41.0	**EE**
ES	65.8	0.1	80.1	0.9	323.6	567.4	453.8	29.4	280.7	3.2	123.8	589.1	9.1	**ES**
FI	10.6	2.0	52.7	11.5	87.2	315.2	155.1	621.4	54.0	2.5	212.6	645.7	120.4	**FI**
FR	89.6	0.3	341.3	1.8	628.5	7596	819.9	80.6	2541	0.9	523.3	5491	67.7	**FR**
GB	3.7	0.2	35.3	1.2	23.5	1131	90.7	49.2	58.9	0.4	98.5	767.8	45.8	**GB**
GE	9.3	177.9	6.3	685	22.6	6.6	316.9	43.4	3.9	25.8	16.8	21.6	1.7	**GE**
GR	730.0	1.8	42.1	8.2	430.9	31.7	10977	75.0	30.9	25.5	99.7	103.3	4.9	**GR**
HR	173.4	0.3	292.5	1.6	3309	53.0	1031	34.9	83.8	0.7	312.2	279.5	5.7	**HR**
HU	101.7	0.9	549.9	4.1	1774	105.0	2324	98.4	128.2	1.1	734.9	577.4	13.7	**HU**
IE	0.8	0.02	7.0	0.1	5.7	117.1	15.9	5.5	10.4	0.0	14.6	105.8	5.6	**IE**
IS	0.5	0.01	2.9	0.1	2.6	20.9	10.5	1.9	5.6	0.0	6.3	37.7	2.8	**IS**
IT	521.8	0.8	555.8	4.1	2685	222.0	2753	79.7	1039	6.4	483.5	902.5	12.8	**IT**
KY	4.8	9.4	4.1	47.2	16.1	4.9	90.5	21.0	4.6	9.9	9.4	16.2	0.8	**KY**
KZ	67.0	158.8	58.2	1081	228.4	97.6	1696	692.7	55.0	77.7	166.0	264.6	20.0	**KZ**
LT	12.5	0.6	63.8	3.5	80.0	198.1	258.0	1250	53.0	0.8	308.6	602.6	82.1	**LT**
LU	0.1	0.0	3.9	0.01	1.5	217.5	4.0	0.8	9.7	0.0	5.5	133.6	0.8	**LU**
LV	10.0	0.6	39.5	4.1	59.0	213.9	205.7	742.3	41.4	1.0	180.6	545.8	75.8	**LV**
MC	0.01	0.0	0.03	0.0	0.1	0.01	0.1	0.0	0.1	0.0	0.03	0.1	0.0	**MC**
MD	27.5	2.4	16.7	10.9	86.6	15.0	1166	121.5	8.9	4.3	57.1	59.0	3.7	**MD**
ME	566.2	0.1	19.5	0.5	839.4	10.1	821.0	8.3	13.9	0.5	31.6	38.4	1.2	**ME**
MK	661.2	0.4	15.2	1.7	190.9	9.0	5239	15.2	9.1	1.3	37.4	34.6	1.5	**MK**
MT	0.2	0.001	0.1	0.002	0.6	0.1	1.1	0.0	0.1	0.03	0.1	0.2	0.0	**MT**
NL	0.7	0.0	15.7	0.2	6.4	4503	16.8	12.8	36.5	0.1	39.6	1263	18.5	**NL**
NO	4.0	0.6	22.8	3.2	24.3	701.3	83.1	130.9	44.0	1.6	95.2	785.4	174.9	**NO**
PL	69.2	3.5	810.0	15.2	716.2	1400	1811	2652	493.3	3.5	9252	6750	458.2	**PL**
PT	3.8	0.0	4.2	0.0	16.0	43.2	25.3	2.1	19.0	0.0	6.7	39.1	0.6	**PT**
RO	417.2	9.0	346.2	38.6	2339	169.0	20506	570.6	136.2	20.1	880.4	757.6	33.1	**RO**
RS	610.3	1.2	163.6	5.0	3120	59.0	10660	70.1	54.7	2.7	345.8	290.6	10.8	**RS**
RU	456.1	288.8	564.3	2585	1856	1332	12400	17769	470.7	144.2	2092	3498	401.9	**RU**
RUA	123.8	129.8	124.7	684.9	429.8	225.8	2344	1205	127.9	74.3	351.7	616.1	55.9	**RUA**
SE	10.3	1.3	82.7	7.4	79.0	1113	295.2	479.0	107.1	3.4	343.9	1876	857.9	**SE**
SI	19.4	0.1	334.9	0.6	372.8	28.2	278.8	19.2	61.6	0.1	161.6	181.5	1.9	**SI**
SK	42.3	0.5	387.6	2.2	545.1	108.0	1019	109.9	98.5	0.5	2865	530.4	18.8	**SK**
TJ	1.8	4.1	1.3	19.9	5.5	1.7	31.3	7.9	1.4	3.8	3.1	5.4	0.3	**TJ**
TM	3.0	21.1	2.9	167.3	9.3	3.6	69.0	21.0	3.0	10.1	6.4	11.0	0.6	**TM**
TR	316.3	339.4	87.2	417.3	487.1	71.0	7611	422.9	48.5	987.5	212.3	241.9	15.7	**TR**
UA	343.3	45.2	430.1	260.2	1669	406.1	12109	4528	227.6	40.2	1945	1579	109.5	**UA**
UZ	3.4	21.6	3.0	133.6	10.1	4.5	80.4	28.1	3.2	10.7	7.0	12.7	0.8	**UZ**
BAS	29.9	2.0	176.4	11.3	187.9	1634	707.2	1005	204.9	3.1	861.9	3956	1088	**BAS**
BLS	244.5	59.2	105.5	218.3	639.9	80.5	11500	802.1	49.4	95.9	300.7	319.4	27.8	**BLS**
CAS	6.9	83.9	5.6	1552	18.2	10.1	210.9	99.4	4.2	28.4	17.6	26.8	2.2	**CAS**
MDT	3298	12.8	724.5	35.8	6260	646.9	18554	312.8	970.4	1845	914.3	1569	40.9	**MDT**
NOS	14.7	1.0	135.7	4.5	100.8	6512	310.3	278.6	305.3	1.8	459.6	4933	652.0	**NOS**
	AL	**AM**	**AT**	**AZ**	**BA**	**BE**	**BG**	**BY**	**CH**	**CY**	**CZ**	**DE**	**DK**	

***Table B.2**. Matrix of lead country-to-country deposition from anthropogenic sources in 2007, kg/y (continued)*

Receptors ↓ Emitters →

	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KY	KZ	
AL	2.5	238.9	0.9	83.7	14.8	1.3	6519	31.3	74.9	2.2	0.01	2489	0.2	22.4	**AL**
AM	1.7	11.4	0.6	3.1	1.2	197.5	134.0	0.8	4.0	0.2	0.0	26.0	1.3	378.5	**AM**
AT	9.8	530.5	7.4	696.5	190.8	1.8	350.1	203.0	636.0	22.9	0.05	6030	0.2	41.4	**AT**
AZ	5.5	20.6	1.9	7.2	3.0	294.0	216.9	1.8	9.4	0.5	0.0	50.1	14.0	1999	**AZ**
BA	7.0	404.3	3.3	184.3	43.6	1.7	2288	645.4	1008	5.9	0.02	3656	0.2	33.6	**BA**
BE	5.7	352.8	2.3	3404	782.3	0.1	15.3	2.8	18.1	73.6	0.1	121.7	0.0	6.9	**BE**
BG	27.5	230.4	8.4	100.2	38.8	21.2	14547	69.8	446.0	6.0	0.02	1491	1.4	319.7	**BG**
BY	639.2	351.3	170.8	363.6	260.7	22.3	1033	90.9	528.3	36.3	0.1	1314	0.5	955.0	**BY**
CH	2.0	706.4	1.1	1444	184.4	0.2	151.9	32.8	50.5	26.8	0.03	5401	0.01	9.7	**CH**
CY	0.2	7.4	0.1	1.9	0.5	0.7	251.8	0.5	1.8	0.1	0.0	25.7	0.01	2.3	**CY**
CZ	17.4	276.9	12.1	549.4	246.3	2.2	211.1	76.5	710.4	28.4	0.1	1362	0.04	59.3	**CZ**
DE	97.4	2384	43.5	9458	3940	3.4	328.7	61.4	404.8	415.4	0.6	3543	0.1	144.9	**DE**
DK	20.9	155.2	9.1	428.7	563.5	0.6	25.7	3.6	21.3	59.7	0.1	118.7	0.01	23.1	**DK**
EE	**4224**	56.8	279.9	126.1	111.3	2.6	110.0	6.6	35.8	13.5	0.04	116.5	0.03	175.1	**EE**
ES	7.2	**87801**	3.5	2961	523.8	0.6	1257	74.8	176.2	92.2	0.1	3476	0.1	19.4	**ES**
FI	3511	179.0	**8812**	331.5	407.0	7.7	131.0	19.0	112.2	58.2	0.4	316.6	0.6	461.9	**FI**
FR	35.4	22450	16.3	**40032**	3494	1.3	1028	177.6	364.5	573.7	0.5	10120	0.1	55.8	**FR**
GB	27.8	1040	8.7	1405	**14792**	0.9	50.1	5.1	43.7	1678	0.8	172.4	0.04	57.3	**GB**
GE	7.4	28.3	2.5	11.3	6.7	**2120**	415.2	3.6	23.4	1.1	0.01	82.5	2.4	586.3	**GE**
GR	10.3	394.2	3.8	138.3	37.2	9.7	**88916**	49.8	195.9	5.7	0.02	2268	0.9	184.9	**GR**
HR	5.7	459.9	2.9	247.0	38.5	1.3	1365	**1835**	1205	5.3	0.02	4762	0.2	32.8	**HR**
HU	13.2	333.1	5.5	256.7	71.0	4.5	1280	592.8	**9006**	8.8	0.03	3384	0.3	53.1	**HU**
IE	3.2	180.2	1.3	161.9	547.7	0.1	12.4	1.4	7.5	**2360**	0.3	48.0	0.01	4.3	**IE**
IS	5.2	33.1	4.5	35.3	64.7	0.0	10.1	0.7	3.0	23.5	**40.6**	26.2	0.04	2.8	**IS**
IT	15.8	3291	8.3	1940	166.8	3.5	7074	781.9	880.4	26.6	0.1	**83566**	0.8	93.6	**IT**
KY	8.7	36.3	2.7	12.3	4.0	15.4	127.7	2.7	11.3	0.6	0.01	69.9	**12390**	21842	**KY**
KZ	269.7	312.7	92.7	164.5	95.5	410.2	1946	34.5	161.2	14.5	0.1	824.4	6202	**223066**	**KZ**
LT	208.4	131.2	66.4	215.3	177.2	2.8	186.9	19.9	117.9	22.6	0.1	334.7	0.04	174.8	**LT**
LU	0.4	37.6	0.2	326.0	35.0	0.0	1.9	0.5	2.7	4.0	0.0	21.4	0.0	0.6	**LU**
LV	653.7	101.9	136.8	220.5	177.4	3.2	173.7	12.4	69.0	22.1	0.1	224.9	0.04	205.6	**LV**
MC	0.0	0.2	0.0	0.5	0.0	0.0	0.1	0.04	0.1	0.0	0.0	3.4	0.0	0.0	**MC**
MD	20.7	44.3	5.4	24.0	14.9	14.0	672.1	11.2	69.1	2.4	0.01	208.7	0.5	233.5	**MD**
ME	2.0	119.1	0.7	47.8	9.0	0.6	1582	39.0	82.0	1.3	0.0	1405	0.1	10.1	**ME**
MK	2.9	79.5	1.0	31.5	8.9	1.8	8926	19.6	86.1	1.2	0.0	670.8	0.1	31.7	**MK**
MT	0.0	3.0	0.0	0.8	0.1	0.0	5.9	0.1	0.2	0.0	0.0	7.3	0.0	0.05	**MT**
NL	5.6	289.3	2.5	1829	1075	0.2	10.7	1.7	12.1	92.3	0.1	83.8	0.01	9.2	**NL**
NO	211.4	314.8	184.4	695.9	1485	2.6	69.9	5.9	34.6	201.7	1.6	192.6	0.2	130.5	**NO**
PL	204.3	907.8	95.2	1452	1166	16.0	985.3	224.4	1730	148.5	0.3	3099	0.2	495.6	**PL**
PT	0.5	5617	0.2	168.3	49.7	0.0	66.4	3.5	9.2	8.3	0.02	166.8	0.01	1.1	**PT**
RO	127.7	597.6	32.6	334.2	142.3	49.5	8028	301.2	2415	21.4	0.1	4019	1.9	680.1	**RO**
RS	17.4	277.0	5.0	140.1	51.2	5.3	4993	243.8	1418	7.1	0.02	2377	0.4	77.4	**RS**
RU	21295	1866	4873	1726	1433	1779	10595	304.4	1526	197.8	1.4	5597	199.3	103229	**RU**
RUA	827.0	682.7	378.4	388.3	267.7	310.8	2508	65.8	286.8	41.4	0.6	1595	1867	126587	**RUA**
SE	1039	415.8	1334	1012	1299	6.4	200.2	20.0	131.1	158.1	0.7	475.7	0.4	304.6	**SE**
SI	2.6	191.3	1.3	128.4	19.0	0.5	205.8	399.5	277.1	2.3	0.01	3390	0.1	16.6	**SI**
SK	15.6	166.8	6.6	179.6	76.9	2.4	560.5	175.7	2353	9.3	0.03	1520	0.1	31.6	**SK**
TJ	3.3	12.7	1.0	4.1	1.5	6.6	46.8	0.9	3.8	0.2	0.0	23.5	1262.4	5188	**TJ**
TM	8.5	17.3	2.8	7.2	3.5	51.1	107.3	1.7	7.3	0.6	0.01	45.9	156.0	5221	**TM**
TR	51.1	726.0	19.2	195.2	75.6	549.0	26826	67.7	379.6	12.7	0.1	2207	5.0	1811	**TR**
UA	449.3	716.7	137.9	571.5	416.6	234.4	7703	292.6	2234	62.7	0.2	4114	9.1	5702	**UA**
UZ	11.0	19.7	3.6	8.5	4.4	48.3	112.3	1.7	7.6	0.7	0.01	47.4	1370	15994	**UZ**
BAS	4093	622.9	2570	1478	1343	9.2	495.7	44.4	311.7	162.7	0.4	889.6	0.3	548.0	**BAS**
BLS	109.8	285.7	37.9	138.4	94.5	564.0	10796	81.8	458.0	15.2	0.1	1688	12.2	2929	**BLS**
CAS	25.0	27.9	9.1	14.6	11.1	255.2	296.7	2.8	17.3	1.7	0.02	77.5	64.6	12227	**CAS**
MDT	50.6	23417	24.8	6138	620.7	42.6	123834	1184	1619	110.4	0.2	62749	4.7	636.3	**MDT**
NOS	181.8	2797	76.1	6793	16211	4.5	196.3	24.2	151.3	1544	3.4	995.5	0.2	244.6	**NOS**
	EE	**ES**	**FI**	**FR**	**GB**	**GE**	**GR**	**HR**	**HU**	**IE**	**IS**	**IT**	**KY**	**KZ**	

***Table B.2**. Matrix of lead country-to-country deposition from anthropogenic sources in 2007, kg/y (continued)*

Receptors ↓ Emitters →

	LT	LU	LV	MC	MD	ME	MK	MT	NL	NO	PL	PT	
AL	1.2	0.5	2.5	0.1	6.0	241.5	2588	4.5	8.5	0.7	334.5	44.5	**AL**
AM	0.5	0.1	1.0	0.0	1.2	1.0	11.1	0.2	0.9	0.2	41.1	3.5	**AM**
AT	11.4	22.8	28.2	0.5	6.4	25.4	100.5	1.1	243.5	6.9	6492	113.6	**AT**
AZ	1.7	0.1	3.9	0.01	3.4	2.0	21.2	0.3	2.5	0.6	115.7	5.8	**AZ**
BA	4.3	2.3	9.6	0.3	9.0	650.5	573.8	2.9	44.1	3.0	2570	71.7	**BA**
BE	3.0	98.4	10.4	0.04	0.7	0.9	5.0	0.1	1443	3.7	522.0	79.7	**BE**
BG	9.5	1.5	18.7	0.1	114.0	149.2	3968	3.7	30.1	3.5	2200	58.3	**BG**
BY	780.5	9.0	737.2	0.1	130.9	48.7	250.6	1.0	243.4	43.5	23715	77.6	**BY**
CH	1.6	16.0	3.8	0.9	1.0	6.1	30.7	0.8	108.9	1.7	543.6	138.7	**CH**
CY	0.1	0.0	0.2	0.0	0.4	0.8	10.2	0.2	0.3	0.0	12.0	1.4	**CY**
CZ	24.2	19.2	56.2	0.2	8.1	16.1	74.1	0.5	329.7	11.9	28429	53.7	**CZ**
DE	75.2	505.5	216.4	0.9	12.8	23.0	109.7	1.6	9101	67.5	24107	481.3	**DE**
DK	13.5	6.8	52.3	0.03	1.3	1.5	6.2	0.1	462.6	26.1	1718	25.4	**DK**
EE	115.6	3.0	632.7	0.02	4.8	4.0	24.4	0.1	93.9	24.5	1876	14.7	**EE**
ES	5.5	20.1	14.1	1.0	3.5	36.3	163.5	9.5	286.9	6.0	1195	13344	**ES**
FI	161.3	7.3	639.8	0.1	10.8	9.2	38.9	0.2	246.9	212.8	4445	51.5	**FI**
FR	19.7	420.5	61.1	10.7	7.1	65.7	249.1	8.7	2575	26.0	5284	3311	**FR**
GB	10.5	15.1	38.5	0.04	2.9	2.8	14.7	0.1	704.3	31.4	1323	334.2	**GB**
GE	2.9	0.2	5.8	0.01	9.1	3.8	46.4	0.4	4.9	1.0	282.7	7.3	**GE**
GR	4.9	1.1	9.8	0.2	40.9	118.1	3901	12.6	21.0	2.3	1127	86.9	**GR**
HR	4.1	2.6	8.9	0.5	6.8	138.2	318.2	2.9	37.8	1.9	2429	76.8	**HR**
HU	9.1	5.6	18.4	0.4	17.6	122.9	462.9	1.6	80.3	4.4	6123	65.1	**HU**
IE	1.2	2.4	4.7	0.01	0.4	0.6	2.8	0.02	69.4	3.3	164.9	80.6	**IE**
IS	0.4	0.6	2.2	0.0	0.1	0.3	1.8	0.01	15.6	6.6	74.1	13.1	**IS**
IT	10.7	11.6	25.3	7.0	18.6	289.1	1005	35.5	130.8	5.3	4010	574.8	**IT**
KY	1.6	0.2	3.5	0.01	2.5	2.4	17.8	0.3	3.4	0.8	133.9	10.3	**KY**
KZ	45.9	3.3	108.6	0.1	63.6	37.1	287.9	1.9	71.0	20.7	2790	83.6	**KZ**
LT	**1733**	5.5	1276.0	0.1	12.3	9.5	49.8	0.3	165.2	28.9	8798	27.4	**LT**
LU	0.2	**124.7**	0.6	0.01	0.1	0.1	0.7	0.01	40.5	0.2	59.6	6.8	**LU**
LV	645.4	5.6	**4036**	0.04	10.0	7.6	41.6	0.1	170.1	31.9	4520	20.8	**LV**
MC	0.0	0.0	0.0	**0.03**	0.0	0.01	0.03	0.0	0.0	0.0	0.3	0.0	**MC**
MD	6.2	0.5	11.3	0.02	**792.5**	15.9	136.5	0.4	12.8	1.6	974.0	9.8	**MD**
ME	0.8	0.4	1.8	0.1	3.0	**1713.2**	565.8	1.7	6.9	0.5	304.0	20.9	**ME**
MK	1.4	0.3	2.9	0.04	7.7	74.0	**12788**	1.6	6.4	0.6	396.9	18.2	**MK**
MT	0.0	0.0	0.01	0.0	0.0	0.1	0.4	**5.5**	0.03	0.0	0.9	0.4	**MT**
NL	3.3	15.4	12.3	0.03	0.9	0.6	3.1	0.0	**6203**	4.7	512.7	67.8	**NL**
NO	40.7	11.7	158.8	0.1	3.2	2.9	14.8	0.2	521.0	**2173**	1943	73.2	**NO**
PL	325.8	41.9	562.2	0.4	63.3	64.4	326.4	1.6	1253	93.0	**234975**	193.3	**PL**
PT	0.5	1.7	1.3	0.1	0.3	1.9	9.4	0.4	20.5	0.5	68.8	**35439**	**PT**
RO	33.6	7.1	62.4	0.4	608.8	326.5	2380	4.7	131.9	13.0	10240	128.8	**RO**
RS	6.6	2.4	14.4	0.2	35.7	934.2	3865	2.3	47.7	3.7	3263	54.9	**RS**
RU	1222	38.8	2904	0.6	614.3	273.0	1991	8.3	1012	425.9	40430	456.9	**RU**
RUA	102.3	7.5	271.2	0.2	75.7	66.0	449.8	3.8	166.5	97.8	5613	170.3	**RUA**
SE	171.8	19.9	822.0	0.1	13.2	8.6	47.4	0.4	959.1	896.4	7482	90.9	**SE**
SI	2.1	1.6	4.3	0.3	2.1	18.7	59.6	0.8	20.1	0.7	1171	36.3	**SI**
SK	12.8	4.9	27.3	0.1	10.6	43.5	202.1	0.7	79.9	5.2	16768	35.9	**SK**
TJ	0.6	0.1	1.2	0.0	0.9	0.9	6.3	0.1	1.2	0.3	45.0	3.6	**TJ**
TM	1.5	0.1	3.4	0.01	1.9	1.4	12.0	0.2	2.6	0.7	96.7	4.6	**TM**
TR	24.3	2.5	46.2	0.2	128.4	106.6	1617	12.3	51.1	8.5	2971	150.8	**TR**
UA	219.3	13.7	372.4	0.4	1193	228.2	1720	4.5	350.6	44.8	36861	157.9	**UA**
UZ	2.0	0.2	4.7	0.01	2.2	1.6	13.6	0.2	3.3	0.9	111.2	5.2	**UZ**
BAS	487.8	33.3	3432	0.2	23.8	22.5	135.3	0.6	1421	245.3	19763	127.7	**BAS**
BLS	44.3	2.7	87.2	0.1	364.1	116.4	1334	4.0	67.9	15.4	4799	69.3	**BLS**
CAS	6.0	0.3	13.6	0.01	9.5	3.2	31.9	0.3	7.6	2.2	319.0	6.7	**CAS**
MDT	29.6	27.5	70.2	8.1	127.3	1118	6654	391.2	369.4	20.5	8651	3427	**MDT**
NOS	66.2	79.5	238.7	0.3	9.2	11.7	55.9	0.8	5317	545.7	7404	721.1	**NOS**
	LT	**LU**	**LV**	**MC**	**MD**	**ME**	**MK**	**MT**	**NL**	**NO**	**PL**	**PT**	

***Table B.2**. Matrix of lead country-to-country deposition from anthropogenic sources in 2007, kg/y (continued)*

Receptors ↓ Emitters →

	RO	RS	RU	RUA	SE	SI	SK	TJ	TM	TR	UA	UZ	Total, t/y	
AL	175.6	1934	284.8	0.9	1.5	24.7	102.9	0.1	1.0	542.7	187.6	1.7	**21.5**	**AL**
AM	16.4	17.5	783.6	14.5	0.5	1.2	6.6	1.6	107.8	1434	94.6	67.0	**4.5**	**AM**
AT	237.0	711.1	619.0	1.7	17.7	2226	1793	0.1	1.8	109.9	385.0	2.7	**32.7**	**AT**
AZ	41.4	37.3	4676	46.2	1.7	2.7	16.5	22.2	502.0	1747	352.7	352.3	**13.9**	**AZ**
BA	521.4	4869	425.1	1.2	6.4	216.9	916.3	0.1	1.6	340.3	442.2	2.2	**39.5**	**BA**
BE	14.7	23.6	106.4	0.3	7.1	8.4	34.2	0.0	0.3	7.7	40.2	0.4	**18.5**	**BE**
BG	3961	5316	4024	11.5	9.4	70.5	608.5	1.1	13.7	5383	3400	20.4	**141.9**	**BG**
BY	1064	924.8	18795	39.1	188.1	149.5	1472	0.8	27.0	766.2	8349	39.0	**89.4**	**BY**
CH	36.4	100.1	71.8	0.7	2.7	77.1	79.9	0.01	0.6	33.4	41.7	0.8	**15.7**	**CH**
CY	5.8	11.0	38.4	0.1	0.1	0.6	2.4	0.01	0.3	531.6	16.8	0.3	**1.4**	**CY**
CZ	222.3	486.8	852.6	1.2	32.6	245.4	2246	0.1	2.5	88.1	536.8	3.7	**49.8**	**CZ**
DE	294.4	496.3	2268	5.0	165.1	213.4	1022	0.1	5.3	151.2	803.3	7.6	**126.1**	**DE**
DK	22.6	29.2	365.5	1.1	93.3	10.2	58.4	0.01	1.0	27.3	80.7	1.4	**6.6**	**DK**
EE	57.9	72.1	6206	10.0	148.4	10.8	91.4	0.04	5.8	90.7	450.0	7.8	**16.2**	**EE**
ES	135.7	407.2	220.3	1.6	7.9	117.6	254.7	0.1	1.4	196.6	141.9	2.0	**115.5**	**ES**
FI	139.8	180.6	21536	39.8	1603	33.7	245.4	0.7	15.2	215.6	1012	22.0	**47.5**	**FI**
FR	240.0	756.8	727.8	3.5	45.6	335.2	597.0	0.1	2.9	185.8	303.8	4.0	**111.8**	**FR**
GB	58.2	59.0	626.1	3.1	31.9	12.6	106.4	0.05	2.3	35.2	215.5	3.3	**25.2**	**GB**
GE	116.5	84.8	5500	19.9	3.1	5.1	41.4	2.6	131.0	3928	734.6	94.2	**15.7**	**GE**
GR	869.3	1947	2109	7.5	5.3	45.9	288.8	0.7	7.4	6765	1410	12.0	**123.6**	**GR**
HR	380.0	2467	377.6	1.1	4.7	555.9	1030	0.1	1.4	192.9	376.9	2.1	**24.0**	**HR**
HU	1630	4930	829.3	2.0	9.7	559.8	7363	0.2	2.9	327.6	1002	3.7	**45.0**	**HU**
IE	7.7	11.4	72.6	0.4	4.2	3.2	16.0	0.01	0.2	5.2	21.6	0.3	**4.1**	**IE**
IS	3.5	6.7	51.4	2.0	5.1	1.5	6.0	0.04	0.1	3.0	5.5	0.3	**0.5**	**IS**
IT	601.7	2593	997.9	3.6	12.5	1487	1135	0.6	4.8	1456	673.0	7.9	**122.2**	**IT**
KY	33.4	39.5	2534	159.4	1.8	3.9	20.0	8499	598.9	533.4	222.1	20839	**68.4**	**KY**
KZ	672.4	598.7	126390	12234	58.4	53.2	339.2	7277	4961	7070	9889	34576	**445.9**	**KZ**
LT	147.4	187.8	5216	11.0	147.9	39.7	319.9	0.1	5.7	120.2	784.4	7.5	**23.7**	**LT**
LU	1.7	3.6	7.8	0.0	0.6	1.5	4.3	0.0	0.0	0.9	3.3	0.0	**1.1**	**LU**
LV	115.8	135.1	4847	11.9	193.3	22.6	190.1	0.1	6.9	127.4	771.4	8.9	**20.0**	**LV**
MC	0.0	0.1	0.03	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	**0.01**	**MC**
MD	1405	308.6	2053	7.9	5.2	14.1	155.8	0.5	13.3	673.8	2624	18.4	**12.1**	**MD**
ME	120.7	2030	156.9	0.4	1.1	23.0	100.3	0.0	0.5	220.0	122.6	0.7	**11.0**	**ME**
MK	244.0	2360	379.4	1.3	1.5	16.3	118.7	0.1	1.2	819.2	267.4	1.7	**33.6**	**MK**
MT	0.2	0.6	0.4	0.0	0.0	0.1	0.2	0.0	0.0	1.8	0.2	0.0	**0.03**	**MT**
NL	13.5	12.4	144.6	0.4	8.9	4.3	30.1	0.01	0.4	6.7	55.0	0.6	**16.4**	**NL**
NO	46.8	54.6	3356	27.3	443.0	12.9	81.7	0.3	4.9	115.1	222.6	6.9	**14.9**	**NO**
PL	1244	1732	8342	19.5	330.8	505.6	6152	0.3	19.3	600.8	4946	27.1	**296.8**	**PL**
PT	10.5	22.9	13.4	0.1	0.7	5.7	14.8	0.01	0.1	15.9	10.1	0.1	**41.9**	**PT**
RO	**27731**	10179	7915	30.0	33.9	320.5	3508	1.5	37.9	4695	8956	47.8	**120.4**	**RO**
RS	2144	**32870**	978.2	2.8	8.7	149.3	1300	0.3	4.0	967.2	1082	5.7	**72.7**	**RS**
RU	5861	4605	**1640220**	8869	1695	467.8	3585	206.4	2719	24794	80986	3969	**2025.8**	**RU**
RUA	895.3	965.3	229424	**138888**	224.5	107.1	612.6	2349	2287	6782	8065	9442	**549.4**	**RUA**
SE	179.7	205.8	7180	28.8	**5920**	48.4	299.2	0.5	11.1	271.3	819.5	14.8	**37.1**	**SE**
SI	102.0	432.4	185.4	0.6	1.9	**2675**	436.0	0.1	0.6	43.8	123.9	1.1	**11.4**	**SI**
SK	648.5	1395	623.6	1.2	13.4	310.2	**12733**	0.1	1.7	138.1	662.6	2.1	**44.5**	**SK**
TJ	11.3	13.4	891.0	47.0	0.6	1.3	6.8	**13470**	569.0	209.6	80.9	10269	**32.3**	**TJ**
TM	22.9	24.6	3235	112.2	1.8	2.7	13.4	1147.7	**4946**	780.3	270.6	7249	**23.9**	**TM**
TR	1830	1992	17044	65.9	23.5	83.4	550.1	5.0	242.6	**144772**	6841	193.9	**222.9**	**TR**
UA	8934	4715	60531	167.5	158.5	397.6	6173	10.6	314.8	8776	**112028**	438.4	**290.1**	**UA**
UZ	26.3	27.3	3991	155.7	2.3	2.8	14.5	6678	2299	832.0	355.6	**29397**	**61.9**	**UZ**
BAS	362.0	476.9	17632	35.0	2481	94.1	758.9	0.3	19.6	401.1	1565	26.6	**72.0**	**BAS**
BLS	3987	2584	38976	76.1	44.8	104.9	828.7	11.5	168.1	27479	19526	246.5	**132.6**	**BLS**
CAS	87.3	59.1	16271	131.9	6.6	4.6	37.1	130.3	1964	2361.9	1671	1859	**40.1**	**CAS**
MDT	2788	8565	6528	22.6	40.3	1316	2235	3.7	29.8	40417	4057	50.4	**342.6**	**MDT**
NOS	181.5	233.4	2906	12.4	390.5	58.1	374.8	0.2	9.4	176.6	674.9	14.3	**62.4**	**NOS**
	RO	**RS**	**RU**	**RUA**	**SE**	**SI**	**SK**	**TJ**	**TM**	**TR**	**UA**	**UZ**	**Total, t/y**	

Table B.3*. Matrix of cadmium country-to-country deposition from anthropogenic sources in 2007, kg/y*

Receptors ↓ Emitters →

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	
AL	**43.1**	0.02	1.6	0.2	8.4	0.3	23.2	0.5	1.0	0.1	4.9	1.0	0.2	**AL**
AM	0.03	**31.3**	0.1	68.9	0.1	0.03	0.7	0.3	0.05	2.2	0.3	0.1	0.03	**AM**
AT	0.3	0.02	**368.4**	0.4	11.0	9.8	6.8	3.3	45.2	0.03	163.9	75.2	2.4	**AT**
AZ	0.05	8.0	0.2	**576.3**	0.3	0.1	1.6	1.1	0.1	3.3	1.0	0.2	0.1	**AZ**
BA	4.6	0.02	16.4	0.3	**555.8**	1.4	19.7	1.3	3.4	0.1	44.7	6.4	1.1	**BA**
BE	0.01	0.002	1.5	0.03	0.3	**302.1**	0.4	0.4	3.0	0.01	7.1	29.0	1.5	**BE**
BG	5.0	0.2	6.1	2.6	18.8	1.0	**1319**	6.6	1.8	2.1	27.7	3.8	1.0	**BG**
BY	0.7	0.3	14.5	4.8	11.3	7.2	17.3	**953.6**	6.5	0.6	130.3	23.8	12.3	**BY**
CH	0.1	0.003	9.0	0.1	2.0	6.8	1.7	0.3	**285.0**	0.01	9.0	15.8	0.4	**CH**
CY	0.03	0.02	0.0	0.1	0.1	0.0	0.4	0.1	0.0	**48.1**	0.1	0.0	0.0	**CY**
CZ	0.2	0.03	70.1	0.3	5.9	11.1	4.8	6.5	17.2	0.05	**1323**	69.2	5.4	**CZ**
DE	0.3	0.04	89.2	0.7	5.9	281.6	6.7	12.7	186.9	0.1	504.4	**1094**	46.2	**DE**
DK	0.02	0.01	1.5	0.1	0.3	11.2	0.5	2.1	1.7	0.03	14.7	21.2	**84.8**	**DK**
EE	0.1	0.03	1.3	0.6	0.8	3.0	1.2	12.6	1.1	0.1	11.7	6.5	4.7	**EE**
ES	0.8	0.01	6.3	0.2	8.7	14.6	5.6	1.1	14.9	0.4	17.5	13.1	1.0	**ES**
FI	0.1	0.1	3.9	2.1	2.3	7.5	1.9	24.3	2.8	0.3	30.7	15.6	13.8	**FI**
FR	1.1	0.02	25.8	0.3	16.4	223.2	9.9	3.2	144.8	0.1	83.7	127.8	8.2	**FR**
GB	0.04	0.01	2.5	0.2	0.6	28.6	1.1	2.0	3.2	0.05	16.1	19.9	5.8	**GB**
GE	0.1	11.7	0.5	143.1	0.6	0.2	4.2	1.8	0.2	3.4	2.2	0.5	0.2	**GE**
GR	9.6	0.1	3.3	1.4	12.6	0.8	168.4	3.1	1.6	3.4	13.3	2.2	0.5	**GR**
HR	2.3	0.02	26.3	0.3	81.6	1.4	13.0	1.4	4.5	0.1	46.2	6.6	0.7	**HR**
HU	1.3	0.1	52.1	0.7	51.3	2.6	29.1	4.0	6.7	0.1	111.5	13.6	1.7	**HU**
IE	0.01	0.001	0.5	0.02	0.2	3.0	0.2	0.2	0.6	0.01	2.4	2.5	0.7	**IE**
IS	0.01	0.0	0.2	0.01	0.1	0.5	0.1	0.1	0.3	0.005	1.0	0.9	0.3	**IS**
IT	6.4	0.05	53.4	0.7	73.6	5.7	34.0	3.1	58.7	0.9	69.8	20.8	1.5	**IT**
KY	0.05	0.5	0.3	7.2	0.4	0.1	1.1	0.8	0.2	1.4	1.2	0.3	0.1	**KY**
KZ	0.7	8.9	4.3	192.4	6.3	2.3	21.6	28.7	2.8	10.4	21.8	5.8	2.2	**KZ**
LT	0.1	0.03	4.8	0.7	2.2	5.0	3.0	53.8	2.8	0.1	44.7	14.6	9.4	**LT**
LU	0.0	0.0	0.3	0.0	0.0	7.9	0.05	0.0	0.5	0.0	0.9	3.0	0.1	**LU**
LV	0.1	0.04	2.8	0.8	1.6	5.3	2.5	29.9	2.1	0.1	26.5	13.1	8.7	**LV**
MC	0.0	0.0	0.002	0.0	0.003	0.0	0.001	0.0	0.004	0.0	0.004	0.001	0.0	**MC**
MD	0.3	0.14	1.2	2.1	2.4	0.4	14.3	5.3	0.5	0.5	7.5	1.3	0.4	**MD**
ME	6.9	0.01	1.6	0.1	24.3	0.2	9.3	0.3	0.7	0.1	4.6	0.9	0.1	**ME**
MK	8.9	0.02	1.3	0.3	5.6	0.2	56.2	0.6	0.5	0.2	5.4	0.8	0.2	**MK**
MT	0.003	0.0	0.01	0.0	0.02	0.002	0.02	0.001	0.01	0.01	0.01	0.0	0.0	**MT**
NL	0.01	0.0	1.1	0.03	0.2	100.7	0.2	0.6	1.9	0.01	6.9	36.9	2.4	**NL**
NO	0.04	0.03	1.6	0.6	0.6	16.8	1.0	5.0	2.2	0.2	15.2	19.7	21.0	**NO**
PL	0.8	0.2	64.0	2.8	20.7	34.9	22.1	124.7	25.8	0.5	1232	170.4	59.8	**PL**
PT	0.04	0.0	0.3	0.01	0.4	1.1	0.3	0.1	1.0	0.01	1.0	0.9	0.1	**PT**
RO	5.4	0.5	27.1	6.9	71.0	4.1	259.3	23.6	7.1	2.4	123.2	16.9	4.0	**RO**
RS	8.4	0.1	14.2	0.8	99.8	1.5	127.4	2.9	2.9	0.3	51.0	6.8	1.3	**RS**
RU	5.1	17.4	40.4	528.9	49.7	31.3	157.0	778.6	23.1	18.3	273.5	77.6	44.0	**RU**
RUA	1.2	7.0	8.7	115.2	11.3	5.2	29.1	47.4	6.3	9.6	45.0	13.1	6.0	**RUA**
SE	0.1	0.1	5.8	1.3	2.1	26.7	3.4	19.1	5.4	0.4	52.5	48.8	99.7	**SE**
SI	0.3	0.01	34.3	0.1	10.3	0.7	3.6	0.7	3.3	0.01	23.1	4.5	0.2	**SI**
SK	0.5	0.03	36.3	0.4	15.9	2.9	12.5	4.8	5.4	0.1	384.6	13.2	2.5	**SK**
TJ	0.02	0.2	0.1	3.0	0.1	0.04	0.4	0.3	0.1	0.5	0.4	0.1	0.0	**TJ**
TM	0.03	1.3	0.2	31.4	0.3	0.1	0.9	0.9	0.2	1.4	0.9	0.3	0.1	**TM**
TR	3.9	21.1	6.8	59.8	14.2	1.7	104.8	17.8	2.5	135.6	28.5	5.3	1.8	**TR**
UA	4.1	2.6	33.2	53.1	46.9	9.7	149.9	205.0	11.7	4.8	251.3	35.4	13.1	**UA**
UZ	0.03	1.3	0.2	22.9	0.3	0.1	1.0	1.2	0.2	1.5	1.0	0.3	0.1	**UZ**
BAS	0.3	0.1	12.9	2.0	5.1	39.3	8.2	40.7	10.5	0.4	129.1	100.7	134.6	**BAS**
BLS	2.9	3.6	8.0	42.8	18.2	1.8	149.8	32.4	2.5	12.0	38.4	6.9	3.0	**BLS**
CAS	0.1	5.4	0.4	351.0	0.5	0.2	2.7	4.0	0.2	3.8	2.4	0.6	0.2	**CAS**
MDT	38.2	0.8	58.4	6.1	172.5	15.8	243.6	12.1	50.6	273.9	123.6	33.3	4.5	**MDT**
NOS	0.2	0.1	9.2	0.7	2.6	149.7	3.6	11.0	15.5	0.2	71.6	138.0	80.1	**NOS**
	AL	**AM**	**AT**	**AZ**	**BA**	**BE**	**BG**	**BY**	**CH**	**CY**	**CZ**	**DE**	**DK**	

Table B.3*. Matrix of cadmium country-to-country deposition from anthropogenic sources in 2007, kg/y (continued)*

Receptors ↓ Emitters →

	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	
AL	0.04	13.5	0.04	2.5	0.6	0.04	51.5	2.9	3.3	0.1	0.003	86.9	**AL**
AM	0.02	0.6	0.02	0.1	0.04	7.0	0.7	0.1	0.1	0.01	0.001	0.7	**AM**
AT	0.1	30.1	0.4	23.1	7.9	0.1	2.1	17.3	26.3	0.9	0.02	173.1	**AT**
AZ	0.1	1.2	0.1	0.2	0.1	12.0	1.2	0.1	0.4	0.02	0.002	1.5	**AZ**
BA	0.1	23.5	0.1	5.5	1.7	0.05	14.7	62.6	38.5	0.2	0.01	114.6	**BA**
BE	0.1	18.2	0.1	128.9	35.5	0.004	0.1	0.2	0.7	3.1	0.03	3.7	**BE**
BG	0.4	13.1	0.4	3.0	1.5	0.6	77.9	6.3	18.9	0.2	0.01	46.9	**BG**
BY	10.7	19.1	8.1	11.4	10.5	0.7	6.5	7.3	22.5	1.5	0.05	37.3	**BY**
CH	0.03	39.1	0.1	54.9	7.8	0.01	0.9	2.5	1.9	1.1	0.01	188.5	**CH**
CY	0.003	0.4	0.003	0.1	0.0	0.02	1.7	0.0	0.1	0.003	0.0	0.9	**CY**
CZ	0.3	15.1	0.6	17.9	10.3	0.1	1.4	6.6	29.4	1.2	0.02	40.1	**CZ**
DE	1.5	125.6	2.1	313.1	165.0	0.1	2.1	4.8	17.0	17.2	0.2	109.6	**DE**
DK	0.3	8.1	0.5	13.9	23.5	0.02	0.2	0.3	0.8	2.5	0.05	3.4	**DK**
EE	**78.1**	3.0	12.6	4.0	4.4	0.1	0.7	0.5	1.5	0.5	0.01	3.4	**EE**
ES	0.1	**5250**	0.2	88.2	22.0	0.02	8.0	6.0	6.7	4.1	0.1	109.8	**ES**
FI	58.5	9.5	**504.0**	10.4	15.9	0.2	0.8	1.5	4.4	2.3	0.1	9.1	**FI**
FR	0.5	1216.0	0.8	**1424**	160.9	0.04	6.6	14.0	14.0	24.8	0.2	323.7	**FR**
GB	0.4	58.2	0.4	48.0	**641.6**	0.03	0.3	0.4	1.8	71.5	0.3	5.2	**GB**
GE	0.1	1.6	0.1	0.3	0.3	**72.0**	2.5	0.3	0.9	0.04	0.003	2.4	**GE**
GR	0.1	22.5	0.2	4.0	1.4	0.3	**648.2**	4.3	7.8	0.2	0.01	75.7	**GR**
HR	0.1	26.2	0.1	7.3	1.5	0.04	8.8	**166.6**	48.3	0.2	0.01	149.7	**HR**
HU	0.2	18.4	0.3	7.8	2.8	0.1	8.0	53.9	**402.9**	0.4	0.01	98.6	**HU**
IE	0.05	11.1	0.1	5.5	23.4	0.002	0.1	0.1	0.3	**106.4**	0.1	1.4	**IE**
IS	0.1	1.8	0.2	1.1	2.7	0.001	0.1	0.1	0.1	1.0	**16.3**	0.8	**IS**
IT	0.2	194.4	0.4	60.8	6.8	0.1	45.5	65.4	34.6	1.1	0.02	**2661**	**IT**
KY	0.1	2.0	0.1	0.4	0.1	0.5	0.8	0.2	0.4	0.02	0.002	1.9	**KY**
KZ	4.1	17.8	4.3	5.1	3.7	13.0	12.0	2.7	6.8	0.6	0.1	23.8	**KZ**
LT	3.5	7.0	3.3	6.9	7.1	0.1	1.2	1.6	5.0	0.9	0.02	9.8	**LT**
LU	0.01	2.0	0.01	8.2	1.6	0.0	0.01	0.0	0.1	0.2	0.002	0.6	**LU**
LV	11.5	5.4	6.6	7.1	7.1	0.1	1.1	1.0	2.9	0.9	0.02	6.4	**LV**
MC	0.0	0.01	0.0	0.02	0.0	0.0	0.0	0.003	0.002	0.0	0.0	0.1	**MC**
MD	0.3	2.4	0.2	0.7	0.6	0.4	4.2	0.9	3.2	0.1	0.003	6.1	**MD**
ME	0.03	6.8	0.03	1.4	0.4	0.02	10.6	3.7	3.5	0.1	0.002	46.8	**ME**
MK	0.04	4.6	0.04	0.9	0.3	0.05	72.1	1.8	3.8	0.05	0.002	22.1	**MK**
MT	0.0	0.2	0.0	0.03	0.004	0.0	0.04	0.01	0.01	0.001	0.0	0.3	**MT**
NL	0.1	14.8	0.1	61.5	46.3	0.01	0.1	0.1	0.5	3.9	0.03	2.5	**NL**
NO	3.3	16.3	9.8	22.6	60.0	0.1	0.4	0.4	1.4	8.2	0.6	5.5	**NO**
PL	3.4	49.2	4.9	46.5	47.4	0.5	6.2	18.9	76.3	6.0	0.1	90.4	**PL**
PT	0.0	341.5	0.01	5.1	2.1	0.001	0.4	0.3	0.4	0.4	0.01	5.2	**PT**
RO	1.9	33.2	1.4	10.0	5.5	1.4	49.3	26.3	113.6	0.8	0.03	120.7	**RO**
RS	0.3	16.0	0.2	4.3	2.1	0.1	35.2	23.3	57.1	0.3	0.01	75.2	**RS**
RU	361.0	99.7	239.6	52.7	54.1	55.1	65.1	23.5	63.3	7.6	0.5	157.1	**RU**
RUA	12.2	36.9	17.6	11.7	10.0	9.6	15.5	5.0	11.4	1.6	0.2	44.1	**RUA**
SE	16.9	22.1	74.9	32.5	53.0	0.2	1.2	1.5	4.9	6.5	0.3	13.6	**SE**
SI	0.0	10.9	0.1	3.9	0.8	0.0	1.3	33.9	11.6	0.1	0.003	108.3	**SI**
SK	0.2	9.3	0.3	5.9	3.3	0.1	3.5	15.0	108.3	0.4	0.01	43.6	**SK**
TJ	0.0	0.7	0.04	0.1	0.1	0.2	0.3	0.1	0.1	0.01	0.0	0.7	**TJ**
TM	0.1	1.1	0.1	0.2	0.1	1.8	0.7	0.1	0.3	0.02	0.002	1.4	**TM**
TR	0.8	40.5	0.9	5.7	2.9	13.3	167.1	5.7	14.8	0.5	0.02	69.0	**TR**
UA	7.2	39.1	6.4	17.5	16.1	6.7	46.8	24.1	116.0	2.5	0.1	118.6	**UA**
UZ	0.2	1.2	0.2	0.3	0.2	1.6	0.7	0.1	0.3	0.03	0.003	1.4	**UZ**
BAS	71.9	32.3	135.6	46.9	54.0	0.3	2.9	3.6	12.3	6.5	0.1	25.6	**BAS**
BLS	1.6	15.5	1.7	4.0	3.5	14.6	65.6	6.7	18.7	0.6	0.0	49.5	**BLS**
CAS	0.4	1.6	0.4	0.4	0.4	9.0	1.7	0.2	0.8	0.1	0.0	2.3	**CAS**
MDT	0.7	1481.6	1.0	182.1	24.2	1.2	764.5	99.4	61.4	4.4	0.1	2086	**MDT**
NOS	2.7	148.7	3.6	220.1	681.4	0.1	1.1	1.8	5.9	63.5	1.3	28.4	**NOS**
	EE	**ES**	**FI**	**FR**	**GB**	**GE**	**GR**	**HR**	**HU**	**IE**	**IS**	**IT**	

***Table B.3**. Matrix of cadmium country-to-country deposition from anthropogenic sources in 2007, kg/y (continued)*

Receptors ↓ Emitters →

	KY	KZ	LT	LU	LV	MC	MD	ME	MK	MT	NL	NO	PL	
AL	0.01	0.5	0.1	0.01	0.1	0.01	0.2	4.2	481.4	3.3	0.4	0.1	19.0	**AL**
AM	0.1	9.4	0.02	0.001	0.03	0.0	0.04	0.02	1.6	0.1	0.04	0.01	2.5	**AM**
AT	0.01	0.8	0.6	0.6	0.8	0.1	0.2	0.9	13.4	0.8	11.3	0.6	333.1	**AT**
AZ	0.8	51.3	0.1	0.003	0.1	0.001	0.1	0.1	3.1	0.2	0.1	0.05	7.9	**AZ**
BA	0.01	0.6	0.2	0.1	0.3	0.04	0.3	25.1	87.8	2.0	2.0	0.3	138.1	**BA**
BE	0.0	0.1	0.2	2.8	0.3	0.005	0.02	0.03	0.7	0.05	75.9	0.3	30.9	**BE**
BG	0.1	6.9	0.4	0.04	0.6	0.01	3.7	4.0	461.1	2.6	1.4	0.3	133.8	**BG**
BY	0.03	21.3	25.5	0.2	24.5	0.02	3.9	1.4	38.3	0.7	11.6	3.8	2037	**BY**
CH	0.0	0.2	0.1	0.4	0.1	0.1	0.03	0.2	4.6	0.6	5.2	0.2	28.7	**CH**
CY	0.0	0.1	0.005	0.0	0.01	0.0	0.01	0.02	1.8	0.1	0.0	0.004	0.8	**CY**
CZ	0.002	1.2	1.3	0.5	1.7	0.03	0.2	0.6	10.9	0.3	16.2	1.1	1304	**CZ**
DE	0.005	3.1	4.5	13.4	6.7	0.1	0.4	0.7	16.2	1.0	462.3	6.3	1419	**DE**
DK	0.0	0.5	1.0	0.2	1.6	0.004	0.04	0.04	0.8	0.1	22.7	2.5	121.3	**DK**
EE	0.002	3.6	10.7	0.1	21.0	0.002	0.1	0.1	3.7	0.04	4.5	2.1	151.5	**EE**
ES	0.01	0.4	0.3	0.5	0.4	0.1	0.1	1.0	28.3	6.8	13.5	0.6	63.4	**ES**
FI	0.04	9.6	11.5	0.2	20.0	0.01	0.3	0.3	5.9	0.1	11.4	14.2	350.5	**FI**
FR	0.01	1.2	1.2	11.0	1.8	1.4	0.2	1.8	39.3	5.9	129.5	2.5	279.8	**FR**
GB	0.002	1.2	0.7	0.4	1.2	0.005	0.1	0.1	2.0	0.1	36.0	3.1	84.0	**GB**
GE	0.2	15.7	0.1	0.005	0.2	0.001	0.3	0.1	7.2	0.3	0.2	0.1	18.9	**GE**
GR	0.1	4.2	0.2	0.03	0.3	0.02	1.3	2.9	628.3	9.0	0.9	0.2	65.2	**GR**
HR	0.01	0.6	0.2	0.1	0.3	0.1	0.2	4.2	49.5	2.0	1.8	0.2	132.6	**HR**
HU	0.02	1.1	0.4	0.1	0.6	0.05	0.5	4.5	68.6	1.1	3.7	0.4	358.5	**HU**
IE	0.0	0.1	0.1	0.1	0.1	0.001	0.01	0.02	0.4	0.01	3.4	0.3	10.1	**IE**
IS	0.002	0.1	0.03	0.01	0.1	0.001	0.004	0.01	0.3	0.01	0.7	0.5	3.9	**IS**
IT	0.05	1.9	0.5	0.3	0.7	0.9	0.6	8.0	166.6	26.4	6.0	0.5	217.6	**IT**
KY	**713.9**	302.1	0.1	0.005	0.1	0.001	0.1	0.1	2.7	0.2	0.1	0.1	7.8	**KY**
KZ	414.1	**5811**	2.3	0.1	3.2	0.01	2.0	1.0	45.1	1.3	3.2	1.6	189.2	**KZ**
LT	0.002	3.8	**70.3**	0.1	45.1	0.01	0.4	0.3	7.3	0.2	7.9	2.6	806.7	**LT**
LU	0.0	0.01	0.01	**3.4**	0.0	0.001	0.002	0.004	0.1	0.004	2.2	0.02	3.2	**LU**
LV	0.003	4.4	91.2	0.1	**154.9**	0.004	0.3	0.2	6.1	0.1	8.1	2.8	384.0	**LV**
MC	0.0	0.0	0.0	0.0	0.0	**0.004**	0.0	0.0	0.004	0.0	0.0	0.0	0.01	**MC**
MD	0.03	5.2	0.3	0.01	0.3	0.002	**26.4**	0.4	19.9	0.2	0.6	0.1	69.9	**MD**
ME	0.003	0.2	0.04	0.01	0.1	0.01	0.1	**44.3**	94.9	1.1	0.3	0.04	17.0	**ME**
MK	0.01	0.6	0.1	0.01	0.1	0.01	0.2	1.6	**2813.3**	1.1	0.3	0.1	22.9	**MK**
MT	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.003	0.1	**4.2**	0.002	0.0	0.1	**MT**
NL	0.0	0.2	0.2	0.4	0.4	0.004	0.03	0.02	0.5	0.03	**324.5**	0.5	32.2	**NL**
NO	0.01	2.7	3.0	0.3	4.8	0.01	0.1	0.1	2.1	0.1	24.9	**209.0**	145.1	**NO**
PL	0.01	10.8	15.0	1.0	18.4	0.05	1.9	2.2	47.6	1.1	59.8	9.0	**17135**	**PL**
PT	0.0	0.0	0.03	0.04	0.04	0.01	0.01	0.1	1.6	0.3	1.0	0.05	3.9	**PT**
RO	0.1	14.6	1.5	0.2	1.9	0.05	18.4	10.6	347.5	3.2	6.0	1.1	644.4	**RO**
RS	0.03	1.6	0.3	0.1	0.4	0.02	1.1	36.5	550.7	1.7	2.3	0.4	182.0	**RS**
RU	12.8	2254	61.4	0.9	89.5	0.07	18.8	7.6	309.7	5.5	45.3	30.5	2945	**RU**
RUA	125.0	3931	5.2	0.2	7.8	0.02	2.2	1.8	70.1	2.4	7.2	6.9	358.2	**RUA**
SE	0.02	6.6	14.2	0.5	25.2	0.01	0.4	0.3	6.3	0.3	46.3	70.5	585.6	**SE**
SI	0.01	0.3	0.1	0.04	0.1	0.04	0.1	0.7	8.4	0.5	0.9	0.1	62.5	**SI**
SK	0.01	0.7	0.7	0.1	0.9	0.02	0.3	1.5	29.6	0.5	4.0	0.5	976.6	**SK**
TJ	20.5	44.7	0.02	0.002	0.03	0.0	0.02	0.02	0.9	0.1	0.05	0.02	2.6	**TJ**
TM	7.4	97.0	0.1	0.003	0.1	0.001	0.1	0.04	1.9	0.1	0.1	0.1	6.9	**TM**
TR	0.3	43.4	1.1	0.1	1.4	0.02	4.3	2.8	263.9	8.5	2.3	0.7	194.1	**TR**
UA	0.6	130.5	9.6	0.3	12.0	0.05	39.9	6.7	261.7	3.0	16.0	4.0	2826	**UA**
UZ	45.4	187.1	0.1	0.004	0.1	0.0	0.1	0.04	2.1	0.1	0.2	0.1	7.8	**UZ**
BAS	0.0	11.3	46.4	0.8	103.9	0.0	0.7	0.7	18.8	0.4	67.3	21.1	1611.3	**BAS**
BLS	0.8	67.4	1.9	0.1	2.5	0.0	12.2	3.2	208.5	2.7	2.9	1.2	314.0	**BLS**
CAS	3.4	324.6	0.3	0.0	0.4	0.0	0.3	0.1	4.7	0.2	0.3	0.2	22.4	**CAS**
MDT	0.3	14.5	1.4	0.6	1.9	1.0	3.9	26.9	1044	296.6	16.3	1.7	450.5	**MDT**
NOS	0.0	4.8	4.3	2.0	6.9	0.0	0.3	0.3	7.4	0.5	261.8	53.0	469.9	**NOS**
	KY	**KZ**	**LT**	**LU**	**LV**	**MC**	**MD**	**ME**	**MK**	**MT**	**NL**	**NO**	**PL**	

***Table B.3**. Matrix of cadmium country-to-country deposition from anthropogenic sources in 2007, kg/y (continued)*

Receptors ↓ Emitters →

	PT	RO	RS	RU	RUA	SE	SI	SK	TJ	TM	TR	UA	UZ	Total	
AL	1.3	5.5	136.1	8.8	0.1	0.05	0.7	13.2	0.002	0.003	16.5	5.4	0.02	**942.8**	**AL**
AM	0.1	0.4	1.0	22.3	1.4	0.02	0.03	0.7	0.02	0.4	53.2	2.4	1.4	**211.0**	**AM**
AT	3.1	9.7	53.8	19.8	0.1	0.6	78.6	322.2	0.002	0.01	3.7	11.5	0.03	**1834**	**AT**
AZ	0.2	1.1	2.3	118.3	4.9	0.1	0.1	1.8	0.3	1.8	72.0	9.4	8.7	**893.9**	**AZ**
BA	2.1	19.7	397.5	12.7	0.1	0.2	6.6	123.5	0.002	0.005	10.4	12.8	0.03	**1759**	**BA**
BE	2.1	0.6	1.5	3.7	0.03	0.2	0.2	5.4	0.0	0.0	0.3	1.2	0.004	**662.7**	**BE**
BG	1.9	101.6	378.1	126.5	1.1	0.3	2.2	71.8	0.02	0.04	163.5	98.4	0.3	**3125**	**BG**
BY	1.9	30.5	62.2	640.6	3.9	7.1	4.3	181.9	0.01	0.1	27.6	284.8	0.4	**4733**	**BY**
CH	3.8	1.2	7.0	2.2	0.1	0.1	2.3	11.6	0.0	0.002	0.9	1.2	0.01	**697.8**	**CH**
CY	0.0	0.2	0.7	1.3	0.01	0.004	0.0	0.3	0.0	0.001	22.8	0.5	0.004	**80.9**	**CY**
CZ	1.5	10.4	36.0	28.4	0.1	1.1	7.9	1186	0.001	0.01	3.3	16.7	0.03	**4266**	**CZ**
DE	12.5	12.8	33.4	80.5	0.5	5.6	6.6	192.7	0.001	0.02	5.4	25.5	0.1	**5297**	**DE**
DK	0.6	0.9	1.9	13.3	0.1	3.0	0.3	10.5	0.0	0.003	1.0	2.5	0.01	**376.5**	**DK**
EE	0.4	2.0	4.6	353.8	1.0	5.8	0.3	12.8	0.0	0.02	3.6	12.8	0.1	**747.3**	**EE**
ES	372.8	5.3	28.4	7.0	0.1	0.3	3.4	32.2	0.001	0.004	5.8	4.2	0.03	**6154**	**ES**
FI	1.5	5.1	12.0	1054	6.4	57.7	1.0	38.0	0.01	0.05	9.3	27.5	0.2	**2359**	**FI**
FR	80.3	8.8	51.3	24.4	0.3	1.5	10.0	91.8	0.001	0.01	5.3	9.0	0.04	**4588**	**FR**
GB	7.5	2.3	3.7	22.7	0.3	1.1	0.4	16.5	0.001	0.01	1.3	6.3	0.03	**1100**	**GB**
GE	0.2	3.1	5.6	116.8	2.1	0.1	0.1	4.5	0.04	0.5	176.3	19.6	1.9	**623.3**	**GE**
GR	2.7	22.7	115.4	65.6	0.8	0.2	1.3	32.6	0.01	0.02	205.1	39.5	0.2	**2184**	**GR**
HR	2.2	15.5	213.7	12.0	0.1	0.2	16.5	138.3	0.001	0.004	6.1	11.5	0.02	**1201**	**HR**
HU	1.8	76.9	356.4	26.0	0.2	0.3	17.0	533.5	0.002	0.01	11.1	34.0	0.04	**2365**	**HU**
IE	1.7	0.3	0.8	2.8	0.04	0.1	0.1	2.4	0.0	0.0	0.2	0.7	0.00	**182.5**	**IE**
IS	0.3	0.1	0.4	3.1	0.3	0.2	0.04	0.8	0.0	0.0	0.1	0.2	0.00	**39.0**	**IS**
IT	17.4	20.2	191.3	31.1	0.3	0.4	44.1	166.5	0.01	0.01	46.8	20.1	0.1	**4367**	**IT**
KY	0.3	0.9	2.4	91.2	14.2	0.1	0.1	2.1	101.0	1.4	23.6	5.5	346.0	**1636**	**KY**
KZ	2.6	17.9	38.4	5494	1299	2.0	1.5	37.8	84.8	15.2	300.7	250.4	539.4	**14960**	**KZ**
LT	0.7	5.3	12.5	271.2	1.1	5.7	1.2	49.3	0.0	0.02	4.4	25.3	0.1	**1509**	**LT**
LU	0.2	0.1	0.2	0.3	0.002	0.02	0.04	0.7	0.0	0.0	0.0	0.1	0.0	**36.1**	**LU**
LV	0.5	4.0	8.5	192.2	1.2	7.5	0.6	28.4	0.0	0.02	4.9	23.0	0.1	**1067**	**LV**
MC	0.001	0.001	0.01	0.001	0.0	0.0	0.002	0.01	0.0	0.0	0.0	0.0	0.0	**0.2**	**MC**
MD	0.2	21.1	19.6	66.9	0.8	0.2	0.4	15.1	0.01	0.05	23.6	91.8	0.2	**419.1**	**MD**
ME	0.6	3.9	128.1	4.6	0.04	0.04	0.7	12.5	0.0	0.001	6.5	3.3	0.01	**440.9**	**ME**
MK	0.6	7.1	113.1	11.2	0.1	0.1	0.5	14.4	0.001	0.004	24.3	7.3	0.02	**3205**	**MK**
MT	0.01	0.01	0.05	0.01	0.0	0.0	0.004	0.03	0.0	0.0	0.1	0.01	0.0	**5.1**	**MT**
NL	1.7	0.6	0.8	5.2	0.05	0.3	0.1	4.8	0.0	0.001	0.3	1.7	0.01	**655.3**	**NL**
NO	1.7	1.5	3.3	453.5	3.9	16.5	0.4	12.9	0.003	0.01	4.7	6.2	0.1	**1109**	**NO**
PL	5.1	54.8	124.9	280.0	2.0	12.5	15.6	1092	0.004	0.1	22.1	172.6	0.2	**21193**	**PL**
PT	**1227**	0.4	1.5	0.4	0.01	0.02	0.2	1.7	0.0	0.0	0.5	0.3	0.002	**1600**	**PT**
RO	3.5	**1021**	687.3	252.3	2.9	1.2	9.7	349.5	0.02	0.1	152.9	290.3	0.6	**4737**	**RO**
RS	1.6	71.6	**2554**	30.7	0.3	0.3	4.6	150.9	0.004	0.01	31.8	32.0	0.1	**4187**	**RS**
RU	12.2	152.9	290.6	**67351**	1018	57.5	13.0	405.1	2.6	9.3	1013	2176	59.1	**81566**	**RU**
RUA	4.9	25.4	59.9	9885	**20029**	7.3	2.9	70.7	25.9	6.9	294.9	204.5	154.8	**35770**	**RUA**
SE	2.3	6.0	13.4	320.1	3.9	**232.3**	1.3	50.5	0.01	0.03	11.0	23.5	0.1	**1914**	**SE**
SI	1.0	4.1	36.0	6.0	0.0	0.1	**86.4**	69.3	0.0	0.002	1.5	3.9	0.01	**534.2**	**SI**
SK	1.0	34.0	100.4	20.7	0.1	0.5	9.5	**2035**	0.0	0.01	4.7	23.7	0.02	**3914**	**SK**
TJ	0.1	0.3	0.8	30.2	4.1	0.02	0.03	0.7	**122.7**	1.1	9.4	2.0	139.6	**387.6**	**TJ**
TM	0.1	0.7	1.7	120.5	12.5	0.1	0.1	1.6	8.2	**16.0**	35.5	7.4	128.9	**491.4**	**TM**
TR	4.1	48.2	131.6	522.4	6.5	0.8	2.4	65.4	0.1	0.8	**6655**	197.4	3.1	**8886**	**TR**
UA	4.1	250.3	306.0	2012	15.4	5.9	11.6	510.4	0.1	1.1	304.2	**3449**	5.1	**11408**	**UA**
UZ	0.2	0.8	1.8	151.6	16.8	0.1	0.1	1.7	72.1	6.8	38.0	9.3	**555.3**	**1134**	**UZ**
BAS	3.4	13.1	31.5	780.7	3.7	92.5	2.8	137.5	0.0	0.1	14.8	46.1	0.3	**3885**	**BAS**
BLS	2.0	87.1	171.6	1166	7.0	1.5	3.0	84.9	0.1	0.6	946.5	551.5	3.3	**4147**	**BLS**
CAS	0.2	2.2	3.8	456.5	12.4	0.2	0.1	4.2	1.4	6.8	102.7	41.5	31.9	**1410**	**CAS**
MDT	113.7	77.5	553.4	202.6	2.3	1.3	38.6	285.9	0.0	0.1	1427	116.4	0.7	**10418**	**MDT**
NOS	16.1	6.7	14.2	103.5	1.3	12.4	1.6	60.3	0.0	0.0	6.7	19.4	0.1	**2695**	**NOS**
	PT	**RO**	**RS**	**RU**	**RUA**	**SE**	**SI**	**SK**	**TJ**	**TM**	**TR**	**UA**	**UZ**	**Total**	

***Table B.4**. Matrix of mercury country-to-country deposition from anthropogenic sources in 2007, kg/y*

Receptors ↓ Emitters →

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	
AL	**27.66**	0.01	0.42	0.03	3.04	0.21	2.61	0.04	0.31	0.05	0.98	0.42	**AL**
AM	0.01	**25.22**	0.05	14.73	0.10	0.06	0.14	0.04	0.04	0.76	0.15	0.10	**AM**
AT	0.14	0.01	**172.4**	0.06	4.78	6.36	0.79	0.37	18.39	0.02	68.74	28.98	**AT**
AZ	0.03	5.48	0.12	**155.3**	0.22	0.15	0.30	0.12	0.10	1.16	0.40	0.27	**AZ**
BA	1.92	0.01	4.79	0.04	**345.9**	0.86	1.81	0.14	1.09	0.05	10.39	2.64	**BA**
BE	0.01	0.001	0.46	0.01	0.11	**331.2**	0.05	0.06	1.07	0.00	2.11	25.58	**BE**
BG	1.75	0.08	1.81	0.29	7.82	0.72	**280.5**	0.52	0.69	0.73	6.24	1.80	**BG**
BY	0.24	0.09	4.01	0.56	4.15	3.95	2.46	**156.3**	2.16	0.21	25.80	10.85	**BY**
CH	0.05	0.002	2.38	0.02	0.91	4.65	0.28	0.04	**152.1**	0.00	2.87	7.52	**CH**
CY	0.01	0.01	0.01	0.01	0.03	0.01	0.05	0.01	0.01	**56.22**	0.03	0.02	**CY**
CZ	0.08	0.01	25.83	0.06	2.18	6.47	0.49	0.69	6.27	0.02	**707.3**	38.30	**CZ**
DE	0.16	0.02	32.88	0.13	2.97	160.3	0.91	1.60	80.72	0.05	208.0	**904.1**	**DE**
DK	0.01	0.004	0.42	0.02	0.16	5.75	0.08	0.28	0.70	0.01	4.29	10.35	**DK**
EE	0.02	0.01	0.37	0.08	0.31	1.37	0.17	1.42	0.38	0.03	2.53	2.52	**EE**
ES	0.22	0.01	1.20	0.04	2.43	5.66	0.72	0.13	3.81	0.13	3.19	4.75	**ES**
FI	0.06	0.05	1.05	0.33	0.88	3.86	0.35	2.40	0.98	0.11	6.53	6.64	**FI**
FR	0.38	0.01	6.63	0.08	5.68	160.7	1.32	0.45	62.15	0.06	20.95	79.89	**FR**
GB	0.02	0.01	0.75	0.04	0.31	17.65	0.17	0.25	1.24	0.02	4.53	10.63	**GB**
GE	0.05	6.30	0.18	26.65	0.34	0.18	0.76	0.17	0.12	1.28	0.65	0.36	**GE**
GR	3.91	0.04	0.92	0.17	4.44	0.55	41.90	0.24	0.57	0.92	2.76	1.18	**GR**
HR	0.86	0.01	7.84	0.04	37.50	0.81	1.11	0.14	1.33	0.03	10.80	2.69	**HR**
HU	0.46	0.02	17.17	0.09	22.05	1.65	2.40	0.44	2.15	0.05	30.69	6.24	**HU**
IE	0.00	0.001	0.14	0.005	0.07	1.62	0.03	0.03	0.22	0.00	0.66	1.27	**IE**
IS	0.00	0.001	0.07	0.01	0.05	0.30	0.03	0.02	0.10	0.00	0.30	0.41	**IS**
IT	2.58	0.02	13.79	0.11	27.16	3.37	3.71	0.33	22.12	0.28	15.53	7.99	**IT**
KY	0.02	0.11	0.09	0.49	0.17	0.12	0.13	0.07	0.10	0.26	0.31	0.22	**KY**
KZ	0.40	4.19	2.32	33.21	3.85	3.29	4.31	3.56	2.01	4.10	8.50	5.90	**KZ**
LT	0.04	0.01	1.27	0.08	0.86	2.41	0.39	8.46	0.87	0.03	9.46	6.28	**LT**
LU	0.001	0.00	0.07	0.001	0.01	4.64	0.01	0.01	0.17	0.00	0.26	2.33	**LU**
LV	0.04	0.01	0.75	0.10	0.60	2.31	0.33	3.68	0.68	0.04	5.48	5.07	**LV**
MC	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**MC**
MD	0.09	0.05	0.37	0.22	0.84	0.24	2.35	0.61	0.18	0.19	1.65	0.67	**MD**
ME	3.26	0.003	0.46	0.01	10.72	0.15	1.06	0.03	0.23	0.02	1.00	0.37	**ME**
MK	4.22	0.01	0.37	0.03	2.26	0.16	7.34	0.05	0.18	0.06	1.15	0.38	**MK**
MT	0.001	0.00	0.002	0.00	0.01	0.001	0.002	0.00	0.002	0.001	0.003	0.001	**MT**
NL	0.00	0.001	0.32	0.01	0.08	77.63	0.04	0.07	0.65	0.00	2.14	34.14	**NL**
NO	0.03	0.02	0.62	0.14	0.46	8.06	0.29	0.70	0.92	0.08	4.38	8.65	**NO**
PL	0.30	0.09	18.22	0.44	7.82	17.51	2.36	20.71	8.71	0.17	274.2	104.9	**PL**
PT	0.02	0.00	0.07	0.003	0.15	0.44	0.05	0.01	0.25	0.00	0.21	0.35	**PT**
RO	1.76	0.19	8.33	0.81	30.55	2.54	33.56	2.34	2.55	0.97	28.19	7.90	**RO**
RS	3.52	0.03	4.13	0.10	46.95	0.95	10.40	0.26	1.01	0.11	12.05	2.92	**RS**
RU	1.94	7.93	13.34	80.86	20.02	21.02	23.05	96.57	9.99	6.64	64.18	41.20	**RU**
RUA	0.80	3.47	5.33	19.54	8.24	9.02	6.69	7.23	4.85	4.43	20.31	15.68	**RUA**
SE	0.06	0.05	1.85	0.29	0.98	12.18	0.64	2.36	2.08	0.14	14.26	20.28	**SE**
SI	0.09	0.003	12.13	0.02	3.97	0.44	0.32	0.07	0.95	0.01	5.97	1.61	**SI**
SK	0.18	0.01	11.79	0.06	5.95	1.61	0.96	0.54	1.88	0.03	64.19	5.81	**SK**
TJ	0.01	0.04	0.03	0.20	0.06	0.04	0.05	0.02	0.03	0.11	0.10	0.08	**TJ**
TM	0.03	0.78	0.17	7.63	0.28	0.24	0.28	0.18	0.16	0.63	0.60	0.43	**TM**
TR	1.33	12.50	2.33	9.70	5.70	1.68	26.62	1.49	1.35	58.72	7.33	3.51	**TR**
UA	1.28	0.97	9.59	6.41	16.64	5.80	22.37	26.76	4.26	1.76	49.12	16.66	**UA**
UZ	0.03	0.68	0.18	4.74	0.29	0.26	0.30	0.23	0.17	0.66	0.66	0.48	**UZ**
BAS	0.13	0.06	3.72	0.35	1.99	19.10	1.14	5.47	4.04	0.15	31.53	46.97	**BAS**
BLS	0.90	1.21	2.12	4.05	6.35	1.19	32.43	2.44	0.92	3.78	7.61	3.13	**BLS**
CAS	0.05	2.57	0.23	88.52	0.37	0.31	0.54	0.42	0.18	1.35	0.89	0.58	**CAS**
MDT	16.54	0.27	14.05	0.81	58.51	7.31	40.82	1.03	12.94	180.50	25.11	12.39	**MDT**
NOS	0.08	0.03	2.78	0.17	1.41	90.23	0.63	1.41	5.61	0.09	19.80	66.28	**NOS**
	AL	**AM**	**AT**	**AZ**	**BA**	**BE**	**BG**	**BY**	**CH**	**CY**	**CZ**	**DE**	

***Table B.4**. Matrix of mercury country-to-country deposition from anthropogenic sources in 2007, kg/y (continued)*

Receptors ↓ Emitters →

	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	
AL	0.09	0.01	1.63	0.01	1.49	0.47	0.01	62.66	0.75	1.75	0.05	0.002	**AL**
AM	0.03	0.02	0.20	0.01	0.16	0.12	3.77	1.18	0.03	0.15	0.01	0.001	**AM**
AT	1.76	0.06	5.40	0.07	18.43	7.89	0.02	2.96	4.92	21.90	0.63	0.01	**AT**
AZ	0.09	0.05	0.46	0.05	0.39	0.33	7.22	2.12	0.07	0.37	0.04	0.004	**AZ**
BA	0.61	0.04	2.91	0.03	3.86	1.60	0.02	17.47	21.45	31.97	0.15	0.005	**BA**
BE	1.01	0.03	2.94	0.02	129.9	32.99	0.002	0.14	0.06	0.48	1.69	0.00	**BE**
BG	0.54	0.13	2.14	0.07	2.37	1.59	0.17	96.24	1.60	11.51	0.16	0.01	**BG**
BY	7.62	4.16	3.56	1.15	8.13	8.70	0.22	8.75	1.68	12.31	0.81	0.02	**BY**
CH	0.30	0.02	6.41	0.02	42.64	7.95	0.004	1.25	0.74	1.41	0.75	0.004	**CH**
CY	0.01	0.001	0.05	0.001	0.04	0.02	0.01	1.93	0.01	0.04	0.003	0.00	**CY**
CZ	3.48	0.09	2.43	0.10	13.26	8.83	0.03	1.68	1.50	21.65	0.68	0.01	**CZ**
DE	36.08	0.50	20.24	0.35	247.6	138.7	0.05	3.41	1.52	13.40	9.19	0.04	**DE**
DK	**112.8**	0.15	1.41	0.07	8.96	20.48	0.01	0.28	0.07	0.56	1.37	0.01	**DK**
EE	2.94	**40.77**	0.58	2.03	2.47	3.55	0.03	0.95	0.14	0.99	0.29	0.005	**EE**
ES	0.51	0.06	**1212**	0.07	46.56	16.03	0.01	9.15	1.12	3.11	1.98	0.02	**ES**
FI	8.40	23.19	2.14	**106.7**	6.94	13.33	0.10	1.52	0.37	2.65	1.30	0.04	**FI**
FR	4.63	0.23	188.9	0.20	**1609**	153.6	0.02	8.53	3.44	8.60	13.56	0.05	**FR**
GB	3.81	0.15	10.99	0.09	41.26	**1307**	0.01	0.66	0.13	1.29	48.77	0.03	**GB**
GE	0.14	0.05	0.50	0.04	0.46	0.41	**52.58**	3.94	0.10	0.72	0.05	0.004	**GE**
GR	0.32	0.06	2.98	0.05	2.62	1.36	0.09	**1874**	1.12	4.64	0.14	0.01	**GR**
HR	0.44	0.03	3.01	0.03	4.77	1.41	0.01	9.16	**73.42**	47.43	0.13	0.004	**HR**
HU	1.31	0.08	2.62	0.05	5.62	2.80	0.04	9.19	18.70	**541.3**	0.24	0.01	**HU**
IE	0.38	0.02	2.45	0.02	4.14	24.46	0.002	0.17	0.03	0.21	**108.0**	0.01	**IE**
IS	0.18	0.06	0.41	0.07	0.77	2.08	0.002	0.17	0.02	0.11	0.49	**0.06**	**IS**
IT	0.88	0.10	24.01	0.10	39.89	5.83	0.04	53.96	18.04	21.61	0.60	0.02	**IT**
KY	0.05	0.04	0.44	0.04	0.36	0.28	0.11	0.84	0.06	0.27	0.03	0.003	**KY**
KZ	2.32	2.11	6.98	1.51	8.06	8.16	6.23	21.93	1.23	6.75	0.89	0.10	**KZ**
LT	6.35	1.53	1.33	0.48	4.35	5.53	0.03	1.44	0.40	3.09	0.48	0.01	**LT**
LU	0.07	0.003	0.30	0.002	5.90	1.51	0.00	0.02	0.01	0.06	0.10	0.00	**LU**
LV	5.39	4.68	0.99	0.95	4.05	5.44	0.03	1.45	0.24	1.70	0.46	0.007	**LV**
MC	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**MC**
MD	0.30	0.11	0.43	0.04	0.60	0.56	0.12	5.29	0.23	1.92	0.06	0.002	**MD**
ME	0.08	0.01	0.93	0.01	0.93	0.33	0.01	13.04	1.04	2.24	0.03	0.001	**ME**
MK	0.10	0.02	0.70	0.01	0.74	0.37	0.02	80.09	0.49	2.28	0.04	0.002	**MK**
MT	0.00	0.00	0.01	0.00	0.01	0.002	0.00	0.04	0.002	0.003	0.00	0.00	**MT**
NL	1.92	0.03	2.41	0.02	45.24	38.68	0.003	0.14	0.04	0.43	1.96	0.004	**NL**
NO	13.49	1.36	3.39	2.14	15.00	42.36	0.05	1.17	0.19	1.21	4.27	0.05	**NO**
PL	39.70	1.21	8.22	0.70	30.87	37.57	0.19	7.81	4.28	45.87	3.08	0.03	**PL**
PT	0.04	0.01	44.38	0.01	2.42	1.37	0.001	0.53	0.06	0.18	0.19	0.004	**PT**
RO	2.58	0.58	5.20	0.23	7.63	5.35	0.45	59.48	7.72	84.49	0.52	0.02	**RO**
RS	0.74	0.08	2.25	0.04	3.17	1.88	0.05	33.47	8.00	45.97	0.18	0.01	**RS**
RU	28.29	178.3	25.82	35.69	45.40	55.34	23.87	89.97	6.53	39.27	5.42	0.34	**RU**
RUA	6.93	7.09	17.12	6.56	21.08	24.99	5.03	34.25	2.65	13.66	2.75	0.37	**RUA**
SE	80.10	5.70	4.46	22.34	19.88	42.36	0.10	2.42	0.45	3.47	3.47	0.05	**SE**
SI	0.16	0.01	1.35	0.01	2.50	0.68	0.01	1.23	12.56	8.89	0.06	0.002	**SI**
SK	1.56	0.08	1.37	0.05	4.03	2.68	0.03	3.61	4.03	119.0	0.23	0.004	**SK**
TJ	0.02	0.02	0.16	0.01	0.13	0.10	0.04	0.33	0.02	0.09	0.01	0.001	**TJ**
TM	0.13	0.11	0.60	0.09	0.60	0.54	1.08	1.60	0.09	0.49	0.06	0.01	**TM**
TR	1.17	0.30	7.11	0.26	5.52	4.02	6.18	264.3	1.69	10.39	0.45	0.03	**TR**
UA	8.34	2.81	7.55	1.10	13.39	14.05	2.36	59.22	5.65	63.91	1.40	0.04	**UA**
UZ	0.16	0.13	0.62	0.10	0.65	0.63	0.91	1.66	0.10	0.50	0.07	0.01	**UZ**
BAS	142.99	35.84	6.17	28.27	29.44	47.97	0.13	4.41	0.92	7.69	3.74	0.03	**BAS**
BLS	1.62	0.46	2.91	0.27	3.19	3.03	6.25	95.14	1.50	10.20	0.32	0.02	**BLS**
CAS	0.24	0.17	0.68	0.12	0.73	0.75	4.28	3.12	0.12	0.69	0.08	0.01	**CAS**
MDT	2.39	0.31	262.09	0.32	130.66	17.39	0.43	1494.48	30.10	32.46	1.99	0.05	**MDT**
NOS	64.02	0.98	26.17	0.67	178.08	671.97	0.06	2.39	0.60	4.52	36.51	0.09	**NOS**
	DK	**EE**	**ES**	**FI**	**FR**	**GB**	**GE**	**GR**	**HR**	**HU**	**IE**	**IS**	

Table B.4*. Matrix of mercury country-to-country deposition from anthropogenic sources in 2007, kg/y (continued)*

Receptors ↓ Emitters →

	IT	KY	KZ	LT	LU	LV	MC	MD	ME	MK	MT	NL	NO	
AL	20.28	0.002	0.23	0.02	0.03	0.00	0.04	0.07	1.05	37.38	0.79	0.06	0.02	**AL**
AM	0.42	0.02	4.51	0.01	0.01	0.001	0.002	0.02	0.01	0.14	0.03	0.01	0.01	**AM**
AT	81.16	0.01	0.59	0.24	1.60	0.01	0.21	0.10	0.21	0.91	0.23	2.22	0.21	**AT**
AZ	0.96	0.15	26.80	0.04	0.02	0.003	0.00	0.06	0.02	0.30	0.06	0.04	0.04	**AZ**
BA	34.43	0.003	0.34	0.08	0.14	0.004	0.10	0.11	6.77	4.90	0.48	0.32	0.09	**BA**
BE	1.22	0.001	0.11	0.07	9.67	0.004	0.01	0.01	0.01	0.05	0.01	35.24	0.10	**BE**
BG	13.73	0.01	2.77	0.14	0.11	0.01	0.04	1.64	0.86	33.45	0.74	0.24	0.12	**BG**
BY	12.89	0.02	10.10	13.36	0.50	0.57	0.06	1.51	0.30	2.35	0.16	1.77	1.12	**BY**
CH	88.38	0.001	0.18	0.04	1.11	0.002	0.36	0.02	0.05	0.33	0.12	1.10	0.05	**CH**
CY	0.18	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.08	0.02	0.00	0.00	**CY**
CZ	13.35	0.003	0.64	0.47	1.18	0.02	0.07	0.12	0.11	0.61	0.08	2.67	0.31	**CZ**
DE	38.58	0.01	2.04	1.54	36.23	0.06	0.29	0.21	0.20	1.26	0.26	93.90	1.78	**DE**
DK	1.20	0.001	0.33	0.41	0.34	0.02	0.01	0.02	0.01	0.07	0.01	3.88	1.04	**DK**
EE	1.31	0.003	1.58	4.83	0.13	0.64	0.01	0.06	0.02	0.23	0.01	0.61	0.59	**EE**
ES	26.17	0.01	0.48	0.11	0.84	0.00	0.26	0.05	0.16	1.31	0.98	1.51	0.16	**ES**
FI	3.49	0.02	5.93	4.34	0.37	0.36	0.02	0.15	0.06	0.46	0.05	1.65	4.67	**FI**
FR	122.7	0.01	1.10	0.45	39.63	0.02	7.43	0.12	0.35	2.26	1.25	23.54	0.68	**FR**
GB	2.14	0.01	0.63	0.25	0.98	0.01	0.02	0.05	0.02	0.19	0.03	7.21	0.86	**GB**
GE	1.26	0.03	7.27	0.05	0.02	0.003	0.01	0.16	0.04	0.58	0.08	0.05	0.04	**GE**
GR	19.95	0.01	1.72	0.07	0.08	0.004	0.05	0.47	0.55	65.62	2.13	0.17	0.08	**GR**
HR	48.17	0.004	0.31	0.07	0.16	0.003	0.16	0.08	0.86	2.37	0.41	0.29	0.06	**HR**
HU	34.93	0.01	0.59	0.18	0.35	0.01	0.12	0.23	0.86	3.77	0.28	0.64	0.15	**HU**
IE	0.55	0.002	0.08	0.03	0.15	0.001	0.004	0.01	0.00	0.04	0.01	0.57	0.08	**IE**
IS	0.39	0.01	0.19	0.02	0.04	0.002	0.002	0.00	0.00	0.03	0.01	0.10	0.16	**IS**
IT	**1651**	0.02	1.07	0.19	0.73	0.01	3.91	0.22	1.56	9.02	7.40	1.07	0.18	**IT**
KY	0.76	**21.58**	29.54	0.03	0.02	0.002	0.004	0.03	0.01	0.17	0.03	0.03	0.03	**KY**
KZ	16.33	146.8	**6136**	1.32	0.41	0.08	0.09	1.17	0.35	4.28	0.54	0.99	1.13	**KZ**
LT	3.40	0.003	1.70	**49.35**	0.26	0.84	0.02	0.16	0.06	0.40	0.04	1.17	0.74	**LT**
LU	0.21	0.00	0.01	0.01	**18.00**	0.00	0.002	0.00	0.00	0.01	0.00	0.74	0.01	**LU**
LV	2.34	0.003	1.99	54.69	0.23	**4.38**	0.01	0.12	0.04	0.36	0.03	1.11	0.79	**LV**
MC	0.06	0.00	0.00	0.00	0.00	0.00	**0.03**	0.00	0.00	0.00	0.00	0.00	0.00	**MC**
MD	1.89	0.01	1.99	0.13	0.04	0.01	0.01	**28.91**	0.09	1.06	0.06	0.10	0.06	**MD**
ME	11.48	0.001	0.12	0.01	0.02	0.001	0.02	0.04	**14.97**	5.79	0.30	0.05	0.02	**ME**
MK	6.56	0.002	0.29	0.02	0.03	0.001	0.02	0.09	0.36	**260.0**	0.38	0.06	0.02	**MK**
MT	0.12	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.004	**3.29**	0.00	0.00	**MT**
NL	0.86	0.001	0.15	0.09	0.99	0.004	0.01	0.01	0.01	0.04	0.01	**95.97**	0.14	**NL**
NO	3.05	0.02	2.65	1.29	0.61	0.07	0.02	0.08	0.03	0.28	0.05	3.56	**88.36**	**NO**
PL	29.96	0.02	5.50	6.65	2.21	0.24	0.15	0.91	0.45	2.67	0.27	9.11	2.57	**PL**
PT	1.22	0.001	0.05	0.01	0.06	0.001	0.01	0.00	0.01	0.09	0.04	0.11	0.02	**PT**
RO	37.65	0.03	6.17	0.63	0.43	0.03	0.13	8.95	2.30	20.47	0.73	0.99	0.42	**RO**
RS	23.25	0.01	0.75	0.11	0.15	0.01	0.07	0.42	10.85	44.30	0.47	0.35	0.11	**RS**
RU	67.38	2.66	1611	26.20	2.46	1.96	0.33	8.23	1.79	20.40	1.70	7.74	10.67	**RU**
RUA	35.36	22.18	2197	3.54	1.05	0.23	0.19	1.66	0.73	7.89	1.13	2.48	4.60	**RUA**
SE	5.84	0.02	5.12	5.68	0.94	0.33	0.04	0.23	0.07	0.58	0.08	6.41	27.62	**SE**
SI	55.48	0.003	0.17	0.03	0.10	0.00	0.10	0.03	0.14	0.43	0.13	0.15	0.02	**SI**
SK	14.37	0.004	0.42	0.25	0.29	0.01	0.05	0.14	0.28	1.46	0.12	0.62	0.16	**SK**
TJ	0.27	0.86	5.45	0.01	0.01	0.00	0.002	0.01	0.01	0.06	0.01	0.01	0.01	**TJ**
TM	1.39	3.40	93.38	0.07	0.03	0.00	0.01	0.06	0.02	0.31	0.05	0.07	0.07	**TM**
TR	22.36	0.09	17.99	0.41	0.22	0.02	0.09	2.11	0.66	16.60	1.94	0.53	0.34	**TR**
UA	37.38	0.13	62.48	4.47	0.80	0.21	0.15	26.69	1.37	14.65	0.80	2.49	1.36	**UA**
UZ	1.44	24.38	190.9	0.09	0.03	0.01	0.01	0.07	0.03	0.32	0.06	0.08	0.08	**UZ**
BAS	9.95	0.02	6.56	22.13	1.53	1.77	0.06	0.35	0.14	1.23	0.11	10.60	7.55	**BAS**
BLS	14.00	0.09	22.40	0.62	0.16	0.03	0.05	7.15	0.65	12.26	0.69	0.47	0.35	**BLS**
CAS	1.70	0.76	328.67	0.13	0.04	0.01	0.01	0.16	0.04	0.48	0.10	0.10	0.10	**CAS**
MDT	772.83	0.08	6.39	0.48	1.18	0.02	3.44	1.33	4.98	54.62	105.50	2.28	0.59	**MDT**
NOS	10.98	0.03	3.32	1.70	4.16	0.08	0.09	0.17	0.10	0.66	0.16	58.14	19.72	**NOS**
	IT	**KY**	**KZ**	**LT**	**LU**	**LV**	**MC**	**MD**	**ME**	**MK**	**MT**	**NL**	**NO**	

Table B.4*. Matrix of mercury country-to-country deposition from anthropogenic sources in 2007, kg/y (continued)*

Receptors ↓ Emitters →

	PL	PT	RO	RS	RU	RUA	SE	SI	SK	TJ	TM	TR	UA	UZ	Total	
AL	2.29	0.14	2.73	34.87	0.61	0.05	0.02	0.60	1.20	0.00	0.001	6.81	1.09	0.01	**215.1**	**AL**
AM	0.60	0.03	0.37	0.31	2.47	0.36	0.01	0.06	0.13	0.003	0.11	28.33	0.82	0.26	**86.1**	**AM**
AT	55.26	0.53	5.18	11.86	1.90	0.13	0.16	87.39	29.49	0.001	0.003	1.97	3.18	0.02	**649.9**	**AT**
AZ	1.69	0.07	0.90	0.70	15.71	1.24	0.04	0.13	0.35	0.02	0.68	30.44	2.92	1.57	**259.8**	**AZ**
BA	19.73	0.25	8.79	95.07	1.01	0.08	0.06	5.72	12.39	0.001	0.002	4.39	2.72	0.01	**647.7**	**BA**
BE	4.12	0.31	0.32	0.34	0.36	0.04	0.06	0.21	0.48	0.00	0.001	0.15	0.39	0.00	**583.1**	**BE**
BG	19.22	0.27	90.88	74.31	8.92	0.38	0.10	1.87	8.72	0.002	0.01	80.86	22.34	0.06	**781.3**	**BG**
BY	305.3	0.44	16.44	12.06	70.08	1.11	1.60	3.50	19.03	0.004	0.03	11.09	77.66	0.11	**831.0**	**BY**
CH	4.67	0.51	0.89	1.73	0.31	0.06	0.03	2.44	1.13	0.00	0.001	0.56	0.39	0.01	**336.8**	**CH**
CY	0.12	0.01	0.10	0.11	0.13	0.01	0.00	0.02	0.03	0.00	0.00	12.54	0.14	0.00	**72.1**	**CY**
CZ	268.4	0.24	4.52	6.97	2.59	0.11	0.26	5.90	39.27	0.001	0.003	1.71	4.48	0.01	**1195**	**CZ**
DE	208.7	1.95	7.12	8.78	7.45	0.50	1.36	6.01	15.95	0.003	0.01	3.01	8.08	0.04	**2308**	**DE**
DK	16.82	0.12	0.50	0.48	1.26	0.08	1.14	0.21	0.73	0.00	0.001	0.50	0.87	0.01	**198.3**	**DK**
EE	18.08	0.08	0.97	0.91	13.95	0.26	1.35	0.29	1.25	0.001	0.01	1.36	3.36	0.02	**115.9**	**EE**
ES	7.28	59.91	1.98	4.25	0.97	0.24	0.10	2.05	2.25	0.003	0.003	2.38	1.04	0.03	**1427.2**	**ES**
FI	40.60	0.30	2.50	2.30	54.72	2.72	13.41	0.80	3.00	0.005	0.02	4.16	7.85	0.09	**344.0**	**FI**
FR	36.77	9.51	4.61	9.95	3.05	0.49	0.42	8.40	6.97	0.003	0.01	3.07	3.06	0.04	**2615**	**FR**
GB	13.23	1.33	1.32	0.89	1.92	0.24	0.29	0.36	1.56	0.001	0.003	0.76	1.98	0.02	**1486**	**GB**
GE	3.27	0.07	2.24	1.26	16.86	0.57	0.04	0.19	0.69	0.005	0.15	76.12	5.69	0.36	**213.2**	**GE**
GR	8.92	0.32	13.33	22.27	4.49	0.28	0.06	1.14	3.46	0.002	0.01	103.16	8.08	0.04	**2201**	**GR**
HR	19.43	0.24	7.09	52.20	0.91	0.07	0.05	17.72	15.15	0.001	0.002	2.32	2.43	0.01	**373.6**	**HR**
HU	69.58	0.26	39.37	84.46	2.24	0.12	0.11	17.06	237.2	0.001	0.003	4.73	8.90	0.02	**1172**	**HU**
IE	1.70	0.33	0.19	0.18	0.27	0.05	0.04	0.08	0.23	0.00	0.00	0.14	0.25	0.00	**148.9**	**IE**
IS	0.71	0.07	0.11	0.15	0.41	0.25	0.06	0.05	0.10	0.001	0.001	0.12	0.11	0.01	**8.8**	**IS**
IT	30.46	1.73	9.64	34.56	2.54	0.28	0.14	65.72	13.81	0.003	0.01	15.93	4.37	0.04	**2117**	**IT**
KY	1.20	0.06	0.45	0.48	3.80	1.50	0.03	0.11	0.25	2.06	0.12	4.50	1.08	19.11	**91.6**	**KY**
KZ	40.49	1.09	15.02	11.31	506.9	415.7	1.14	2.47	7.22	8.85	5.94	120.35	85.63	176.8	**7850**	**KZ**
LT	98.04	0.14	2.55	2.54	27.10	0.31	1.31	0.97	4.21	0.001	0.01	1.80	6.58	0.02	**258.9**	**LT**
LU	0.45	0.03	0.03	0.04	0.03	0.00	0.01	0.03	0.06	0.00	0.00	0.02	0.03	0.00	**35.2**	**LU**
LV	44.80	0.11	1.88	1.65	15.45	0.34	1.70	0.54	2.39	0.001	0.01	1.84	5.89	0.03	**187.2**	**LV**
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.1**	**MC**
MD	13.21	0.05	24.78	3.33	5.62	0.18	0.06	0.39	2.53	0.001	0.01	9.92	30.10	0.04	**141.7**	**MD**
ME	2.33	0.08	2.14	30.24	0.35	0.03	0.01	0.65	1.35	0.00	0.00	3.00	0.75	0.00	**109.8**	**ME**
MK	3.14	0.08	4.06	28.63	0.77	0.05	0.02	0.45	1.61	0.00	0.001	9.99	1.50	0.01	**419.2**	**MK**
MT	0.01	0.001	0.002	0.01	0.00	0.00	0.00	0.003	0.002	0.00	0.00	0.02	0.001	0.00	**3.6**	**MT**
NL	4.84	0.24	0.34	0.24	0.49	0.04	0.09	0.12	0.50	0.00	0.001	0.15	0.55	0.00	**311.8**	**NL**
NO	19.01	0.43	1.38	1.27	10.08	1.98	4.24	0.47	1.42	0.005	0.01	2.93	2.93	0.06	**255.3**	**NO**
PL	**4191**	0.95	24.01	24.15	27.98	0.79	2.83	11.96	97.70	0.004	0.02	10.29	50.86	0.08	**5138**	**PL**
PT	0.56	**357.9**	0.18	0.29	0.10	0.03	0.01	0.10	0.15	0.00	0.00	0.24	0.10	0.00	**412.0**	**PT**
RO	113.1	0.56	**1007**	155.4	20.53	0.90	0.35	9.38	66.18	0.005	0.03	64.15	78.38	0.14	**1889**	**RO**
RS	27.02	0.23	45.76	**893.0**	2.27	0.14	0.08	4.16	19.60	0.001	0.004	12.69	6.81	0.02	**1271**	**RS**
RU	404.5	3.54	93.03	57.90	**8055**	340.8	14.43	13.16	48.89	0.31	2.75	397.8	686.0	11.47	**12813**	**RU**
RUA	89.42	2.54	24.64	21.80	867.3	**7287**	4.36	5.46	14.57	2.48	2.21	131.4	82.92	35.53	**11098**	**RUA**
SE	75.16	0.53	3.87	3.18	21.55	2.11	**77.84**	1.24	4.30	0.005	0.02	5.73	8.14	0.08	**496.7**	**SE**
SI	9.87	0.12	2.04	7.22	0.46	0.03	0.02	**131.8**	6.32	0.00	0.001	0.61	0.90	0.01	**269.3**	**SI**
SK	190.5	0.16	14.49	19.43	2.00	0.09	0.12	8.37	**381.3**	0.001	0.002	2.12	6.46	0.01	**872.9**	**SK**
TJ	0.41	0.02	0.16	0.17	1.36	0.46	0.01	0.04	0.09	**1.59**	0.08	1.86	0.39	6.65	**21.7**	**TJ**
TM	2.48	0.09	0.93	0.81	18.31	5.71	0.07	0.19	0.48	1.23	**26.49**	15.85	3.63	78.79	**270.7**	**TM**
TR	31.97	0.82	36.19	24.62	47.14	2.16	0.31	2.75	8.63	0.02	0.24	**4514**	51.34	0.72	**5218**	**TR**
UA	496.0	0.90	150.02	55.30	305.8	4.02	1.55	10.21	104.5	0.02	0.28	129.4	**1869**	0.99	**3623**	**UA**
UZ	2.88	0.09	0.97	0.83	22.70	8.36	0.08	0.19	0.52	13.73	5.58	15.61	4.53	**434.3**	**742.1**	**UZ**
BAS	219.6	0.70	6.82	6.21	53.76	1.64	32.03	2.37	10.05	0.00	7.12	0.02	13.69	0.10	**838.4**	**BAS**
BLS	42.13	0.38	67.41	28.07	112.6	1.78	0.35	2.43	10.08	0.01	537.4	0.11	168.1	0.47	**1221**	**BLS**
CAS	4.48	0.10	1.75	1.11	68.09	3.81	0.10	0.25	0.76	0.12	35.14	4.26	13.95	6.49	**579.7**	**CAS**
MDT	54.48	9.51	37.86	86.25	15.21	1.25	0.42	32.94	22.25	0.02	773.5	0.03	23.07	0.24	**4354**	**MDT**
NOS	67.01	2.92	4.24	3.90	9.29	1.22	3.83	1.55	5.60	0.01	3.95	0.01	6.78	0.09	**1384**	**NOS**
	PL	**PT**	**RO**	**RS**	**RU**	**RUA**	**SE**	**SI**	**SK**	**TJ**	**TM**	**TR**	**UA**	**UZ**	**Total**	