7. Atmospheric Supply of Mercury to the Baltic Sea in 2003

This chapter presents a short description of model evaluation of mercury atmospheric input to the Baltic Sea, its sub-basins and catchment area in 2003. Modelling of mercury atmospheric transport, chemical transformations and depositions was carried out using MSC-E Eulerian Heavy Metal transport model MSCE-HM (Travnikov and Ilyin, 2005). Latest available official information on mercury emission from HELCOM countries and other European countries was used in computations. Based on these data levels of annual and monthly mercury depositions to the Baltic Sea region have been obtained and contributions of HELCOM countries emission sources to the depositions over the Baltic Sea and its catchment area are estimated. Model results were compared with observed levels of mercury concentrations in air and precipitation measured at monitoring sites around the Baltic Sea.

7.1 Mercury emissions

For the evaluation of mercury atmospheric load to the Baltic Sea emissions of the following categories were used: direct anthropogenic emissions, natural emissions and re-emission. Direct anthropogenic emission of HELCOM countries in 2003 were based on officially submitted information on mercury emissions to the UN ECE Secretariat (EB.AIR/GE.1/2005/8). Mercury emission from international shipping is not included as these data are not currently available for modelling. For Germany, Poland, and Russian Federation official information on emissions of heavy metals in 2003 was missing. Therefore the value of total annual mercury emission of Germany in 2003 was estimated by means of linear interpolation between submitted data for 1995 and the projection for 2010 (EB.AIR/GE.1/2003/6). Total annual mercury emission of Poland and Russian Federation in 2003 was assumed the same as in 2002.

The information on total annual mercury emissions of HELCOM countries in 2003 as well as total emission within the EMEP region is summarized in the Table 7.1. Along with the data for 2003 the emissions for 2002 are also given in the table for the comparison. Total mercury emission of HELCOM countries in 2003 is slightly lower than in 2002 (by 4 tonnes). The HELCOM countries contribute to total mercury anthropogenic emission within the whole EMEP region about 30%. The level of mercury emissions in 2003 outside the HELCOM region is 15 tonnes higher than in previous year 2002. It can be seen that the most significant contributions to total mercury emissions within the HELCOM region belong to the Germany (27.3 tonnes), Poland (19.8 tonnes), and Russian Federation (10.2 tonnes). Spatial distribution of mercury anthropogenic emission for 2003 is presented in Figure 7.1.

Table 7.1. Annual emissions of mercury in HELCOM countries and entire EMEP area in 2002 and 2003 following the official data and expert estimates (shaded). Units: tonnes per year

Country	2002*	2003	Change (2003-2002)
Denmark	1.24	1.19	-0.05
Estonia	0.49	0.58	0.09
Finland	0.7	0.8	0.1
Germany	27.7	27.3	-0.4
Latvia	0.14	0.15	0.01
Lithuania	0.3	0.4	0.1
Poland	23.2	19.8	-3.4
Russian Federation	10.2	10.2	0
Sweden	0.7	0.8	0.1
TOTAL – HELCOM countries	**65**	**61**	**-4**
TOTAL - EMEP	**180**	**195**	**15**

* - mercury emissions of HELCOM CPs for 2002 were used the same as in the previous Joint Report of EMEP Centre's (Bartnicki et al., 2004).

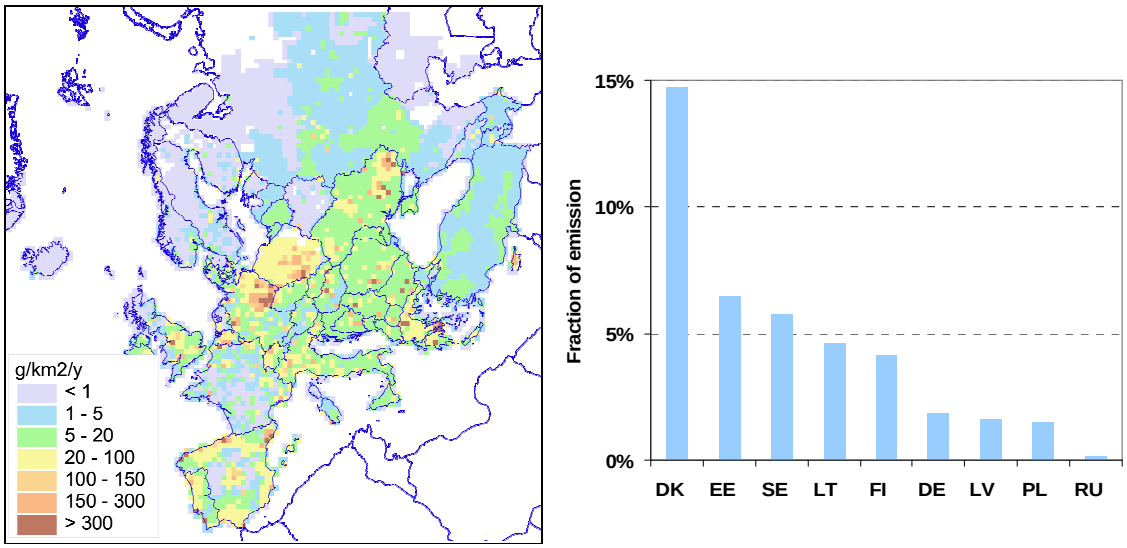


Figure 7.1. Spatial distribution of mercury anthropogenic emission within the EMEP region in 2003 (g/km^2/year) following the official data and expert estimates (a) and fractions of HELCOM countries emissions deposited to the Baltic Sea (b)

It should be noted that the emission of Russian Federation in the Table 7.1 is related to its whole European territory. However only a small part of this emission is actually reaching the

Baltic Sea. Estimated fractions of mercury anthropogenic emissions of HELCOM countries deposited to the Baltic Sea in 2002 are shown in Figure 7.1b.

Mercury re-emission from previously polluted areas and natural emission sources provide significant contribution to depositions within the EMEP region. The share of this emission in remote regions can reach 90%. The input of re-emission and natural emissions sources of mercury from the territory of Europe and marginal seas for 2003 is estimated to about 230 tonnes. The description of parameterization of mercury natural emission and re-emission used in the MSCE-HM model can be found in (Travnikov and Ilyin, 2005).

7.2 Annual deposition of mercury

Modelling of mercury atmospheric transport and depositions was carried out using MSC-E Eulerian Heavy Metal transport model MSCE-HM. To obtain levels of annual and monthly mercury depositions to the Baltic Sea region in 2003 modelling was performed with the official emission data submitted by countries and expert estimates. Total annual mercury deposition to the Baltic Sea in 2003 amounts to 4.2 tonnes and to its catchment area – about 23 tonnes. Atmospheric depositions over the Baltic Sea computed for 2003 increased by 11% and over the catchment area decreased by 5%.

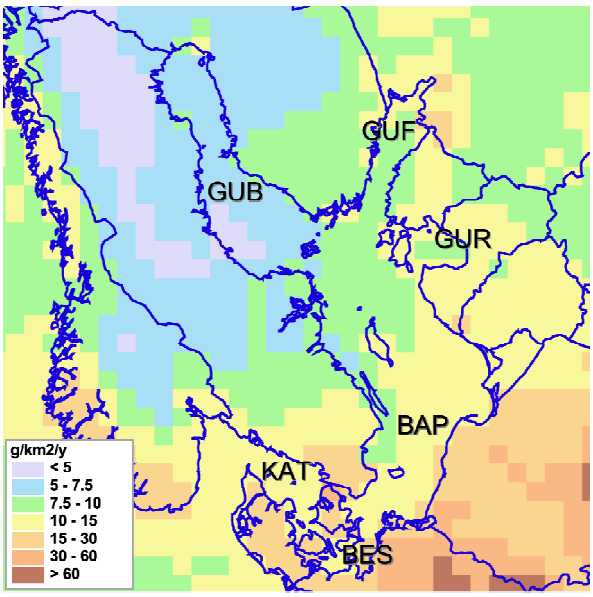


Figure 7.2. Spatial distribution of total mercury deposition flux in the Baltic Sea region for 2003 with resolution 50x50 km^2. Units: g/km^2/year

Spatial distribution of mercury total deposition flux in 2003 is given in Figure 7.2. As it can be seen mercury depositions over the Baltic Sea decrease from its southern part to northern one. Higher levels of deposition fluxes can be found in the Belt Sea sub-basin (BES) and southern part of the Baltic Proper sub-basin (BAP). Lowest values of deposition fluxes are obtained in the Gulf of Bothnia sub-basin (GUB).

Table 7.2 presents annual dry, wet, and total mercury depositions in 2003 for six sub-basins of the Baltic Sea. The highest mercury deposition flux over the Baltic Sea is obtained for the Belt Sea (BES) sub-basin (about 16 g/km^2/y). Elevated depositions fluxes can be noted also for the Kattegat (KAT). Distribution of mercury depositions over the catchment area of the Baltic Sea sub-basins is given in the Table 7.3. As for the previous year the highest deposition flux (about 24 g/km^2/y) is characteristic of catchment area of the Baltic Proper sub-basin (BAP). For most of sub-basins and catchments wet deposition fluxes dominate over dry ones.

Table 7.2. Annual dry, wet, and total depositions (tonnes/year) and total deposition fluxes (g/km^2/year) of mercury to the Baltic Sea sub-basins in 2003

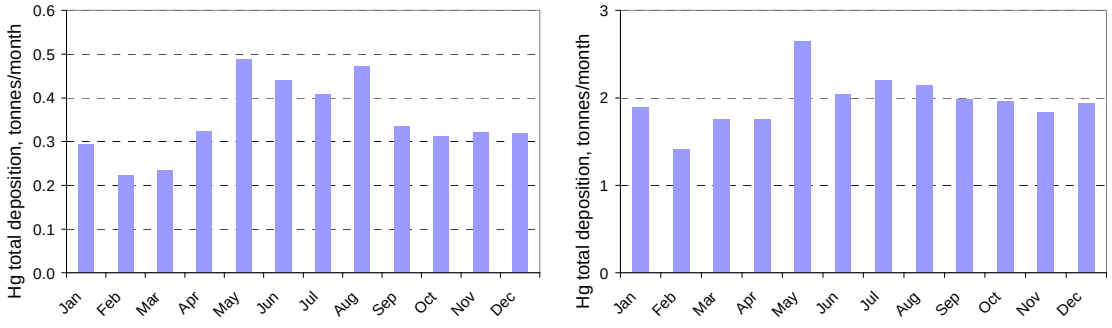
Deposition	GUB	GUF	GUR	BAP	BES	KAT	Baltic Sea
Dry	0.21	0.10	0.06	0.71	0.15	0.10	1.3
Wet	0.52	0.19	0.13	1.62	0.17	0.21	2.8
Total	0.73	0.30	0.19	2.33	0.32	0.30	4.2
Flux	6.3	9.8	10.3	11.0	15.8	13.0	9.9

Table 7.3. Annual dry, wet, and total depositions (tonnes/year) and total deposition fluxes (g/km^2/year) of mercury to the Baltic Sea catchments in 2002

Deposition	GUB	GUF	GUR	BAP	BES	KAT	Catchment area
Dry	1.0	1.3	0.5	9.1	0.3	0.4	13
Wet	1.9	2.6	0.9	4.6	0.2	0.6	11
Total	3.0	4.0	1.4	13.6	0.5	1.0	23
Flux	6.1	9.4	10.4	24.4	20.8	11.5	13.7

7.3 Monthly depositions of mercury

Variations of total monthly mercury depositions over the Baltic Sea and its catchment area are presented in Figure 7.3.



(a) (b)

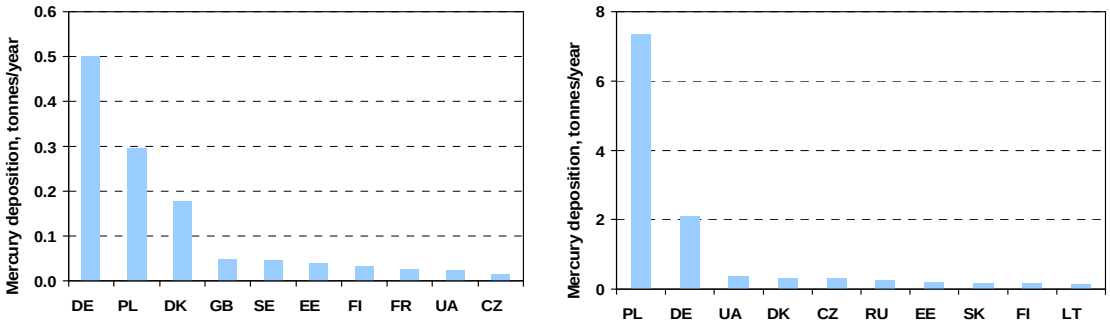
Figure 7.3. Monthly variations of mercury total depositions to the Baltic Sea (a) and its catchment area (b) in 2003, tonnes/month.

Total monthly mercury depositions to the Baltic Sea sub-basins undergo pronounced seasonal variations with maximum in warm period (May – August). Over the catchment area no pronounced seasonal variation of mercury depositions is obtained for 2003. Maximum of depositions take place in May. Elevated deposition fluxes can be noted for June, July, and August.

7.4 Source allocation of mercury deposition

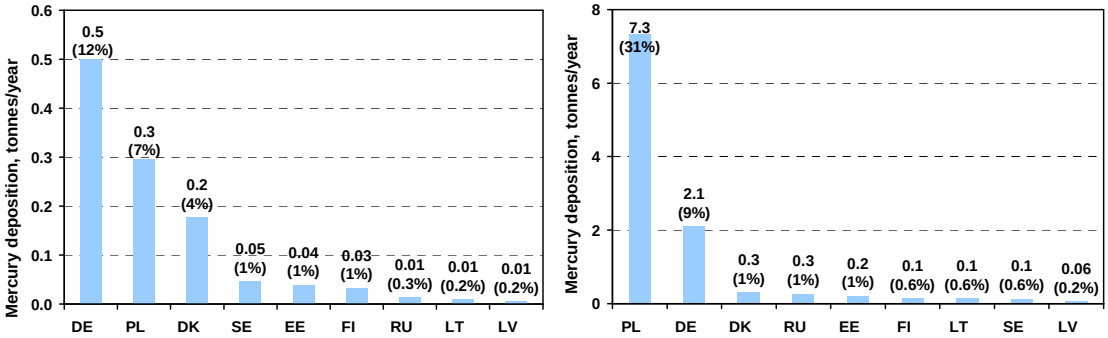
The contributions of HELCOM countries sources to the depositions of mercury to the Baltic Sea sub-basins and catchments as well as contributions of other European countries were estimated using the computations of mercury transboundary fluxes over European region (Ilyin and Travnikov, 2005). The Figure 7.4 presents ten countries with highest contributions to total annual mercury depositions over the Baltic Sea and its catchment area in 2003. The most significant contributions belong to Germany, Poland, and Denmark. Considerable input is originated also from emission sources of the United Kingdom, France, the Ukraine, and Czech Republic.

Figure 7.5 present the source allocation budget of mercury depositions to the Baltic Sea and its catchment area.



(a) (b)

Figure 7.4. Ten countries with highest contributions to total annual mercury depositions in 2003 over the Baltic Sea (a) and its catchment area (b), tonnes/year



(a) (b)

Figure 7.5. Contributions of HELCOM countries emissions from anthropogenic sources to total mercury depositions to the Baltic Sea (a) and its catchment area (b) in 2003, tonnes/year

Anthropogenic sources of mercury emissions of HELCOM countries contribute to the deposition over the Baltic Sea about 30% with main contributions from Germany (12%) and Poland (7%). Other HELCOM countries contribute about 10%. Contribution of European countries outside the Baltic Sea region amounts to 5%. Major part of mercury depositions is due to re-emission, natural and remote sources (68%).

Main contributions to deposition over the catchment area among the HELCOM countries belong to Poland (31%) and Germany (9%). Other HELCOM countries contribute about 5%. The share of depositions from the sources of HELCOM countries accounts for 46%. Contribution of European countries outside the Baltic Sea region amounts to 7%.

Tables 7.4 and 7.5 demonstrate the input of two most important contributors to mercury depositions in the six sub-basins and six catchments of the Baltic Sea in 2002 and 2003.

In comparison to computations for 2002 contribution of re-emission, natural and remote sources to mercury depositions both over the Baltic Sea and its catchment area from in computations for 2003 is higher. At the same time contributions of HELCOM countries in computations for 2002 are somewhat lower.

Table 7.4. Comparison of main contributors to mercury deposition in sub-basins of the Baltic Sea in 2002 and 2003. BAS means the whole Baltic Sea basin. Units: percent of total depositions

Sub-basin	2002					2003				
	Country	%	Country	%	*, %	Country	%	Country	%	*, %
GUB	SE	8	DE	6	65	SE	4	FI	3	84
GUF	EE	15	DE	8	55	EE	12	FI	3	72
GUR	DE	16	PL	9	58	PL	6	DE	5	78
BAP	DE	25	PL	14	45	DE	15	PL	11	65
BES	DE	29	DK	11	40	DE	27	DK	17	47
KAT	DK	15	DE	10	54	DK	18	DE	10	62
BAS	DE	19	PL	11	50	DE	12	PL	7	68

* - contribution in percent of re-emission, natural and global sources.

Table 7.5. Comparison of main contributors to mercury deposition in sub-catchments of the Baltic Sea in 2002 and 2003. CAT means the whole Baltic Sea catchment area. Units: percent of total depositions

Sub-basin	2002					2003				
	Country	%	Country	%	*, %	Country	%	Country	%	*, %
GUB	DE	5	PL	4	77	FI	2	SE	2	89
GUF	DE	7	PL	7	64	RU	5	EE	5	77
GUR	PL	14	DE	13	55	PL	8	DE	3	71
BAP	PL	49	DE	19	21	PL	52	DE	12	26
BES	DE	34	DK	10	36	DE	35	DK	16	41
KAT	DE	10	DK	9	58	DK	12	DE	7	69
CAT	PL	33	DE	15	37	PL	31	DE	9	47

* - contribution in percent of re-emission, natural and global sources.

7.5 Comparison of model results with measurements

Model results for mercury were compared with available measurements made on HELCOM stations for 2003. Measurements of mercury concentrations were reported by Zingst (DE9), Bredkälen (SE5), Vavihill (SE11), and Råö (SE14). In Table 7.6 results of the comparison of mean annual calculated and measured mercury concentrations for 2003 are presented.

Model results for listed in table stations are in a good agreement with observed concentrations of mercury. Comparison of monthly variations of calculated and measured mercury concentrations at stations listed above is presented in Figures 7.6 – 7.10.

Annual and monthly computed air concentrations of mercury are in a good agreement with measured ones at the site Råö (SE14). For concentrations in precipitations the discrepancies are somewhat higher. Model results for mercury in precipitation are 40% higher than measured values on average.

Table 7.6. Comparison of calculated and measured mean annual mercury concentrations in air and precipitation for 2003

Station code	Station name	Observed	Calculated	Obs / Calc
Hg concentrations in air (ng/m^3)				
SE14	Råö	1.8	1.6	1.1
Hg concentrations in precipitation (ng/l)				
DE09	Zingst	9.4	14.2	0.7
SE05	Bredkälen	4.8	7.4	0.6
SE11	Vavihill	11.2	13.2	0.8
SE14	Råö	7.2	10.0	0.7

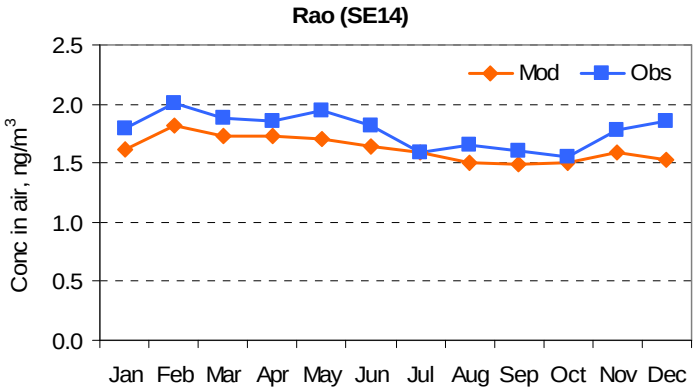


Figure 7.6. Comparison of calculated monthly mean Hg concentrations in air with measured at station the Råö (SE14). Units: ng / m^3.

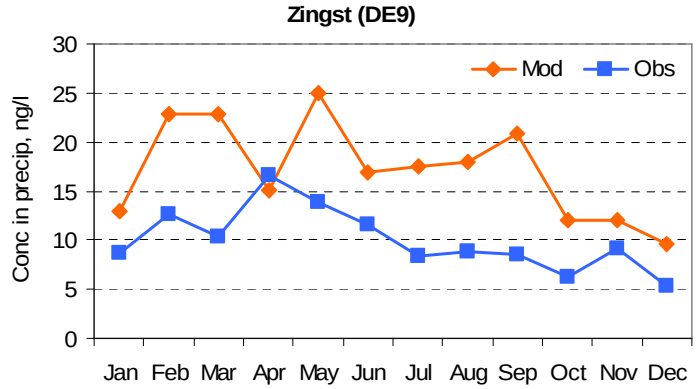


Figure 7.7. Comparison of calculated monthly mean Hg concentrations in precipitation with measured at station Zingst (DE9). Units: ng/L.

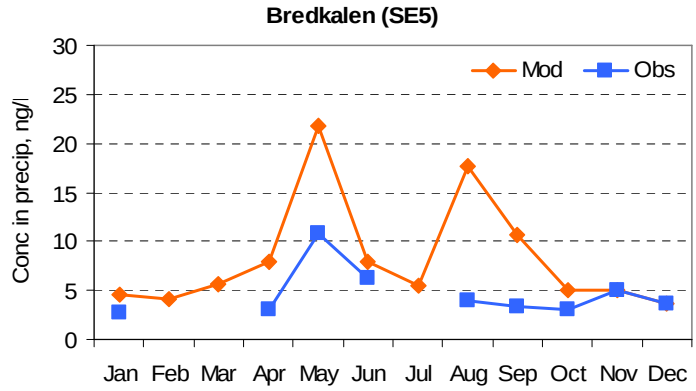


Figure 7.8. Comparison of calculated monthly mean Hg concentrations in precipitation with measured at station Bredkälen (SE5). Units: ng/L.

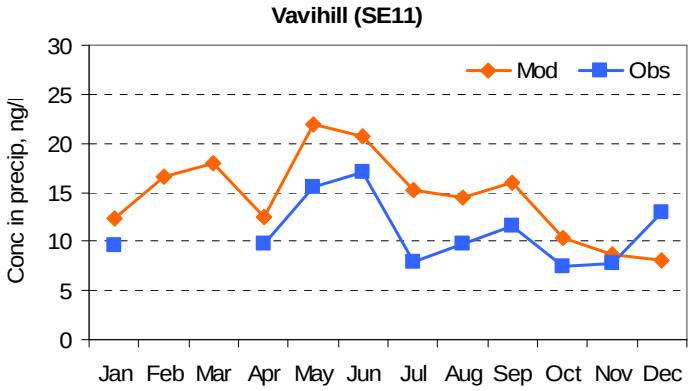


Figure 7.9. Comparison of calculated monthly mean Hg concentrations in precipitation with measured at station Vavihill (SE11). Units: ng/L.

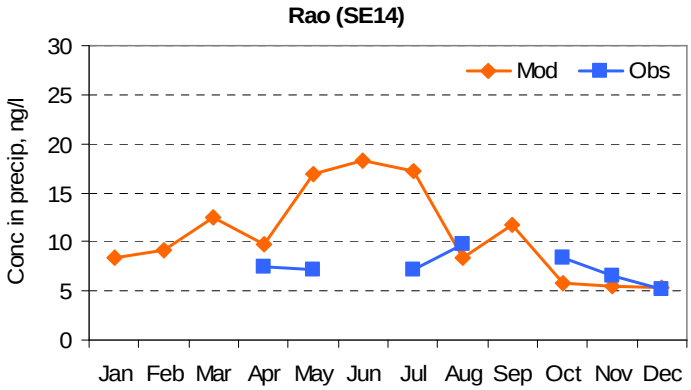


Figure 7.10. Comparison of calculated monthly mean Hg concentrations in precipitation with measured at the station Råö (SE14). Units: ng/L.