7. Atmospheric Supply of Mercury to the Baltic Sea in 2002

This chapter presents a short description of model evaluation of mercury atmospheric input to the Baltic Sea, its sub-basins and catchment area in 2002. Modelling of mercury atmospheric transport, chemical transformations and depositions was carried out using MSC-E Eulerian Heavy Metal transport model MSCE-HM (Ilyin et al., 2004). 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 2002 were based on officially submitted information on mercury emissions to the UN ECE Secretariat (EB.AIR/GE.1/2004/10). For Germany and Poland official information on emissions of heavy metals in 2002 was missing. Therefore the value of total annual mercury emission of Germany in 2002 was estimated by means of linear interpolation between submitted data for 1995 and projection for 2010 (EB.AIR/GE.1/2003/6). Total annual mercury emission of Poland in 2002 was assumed to be equal to the level of 2001.

The information on total annual mercury emissions of HELCOM countries in 2002 as well as total emission within the EMEP region is summarized in the Table 7.1. Along with the data for 2002 the emissions for 2001 are also given in the table for comparison. Total mercury emission of HELCOM countries in 2002 is slightly lower than in 2001 (by 1.2 tonnes). The HELCOM countries contribute to total mercury anthropogenic emission within the whole EMEP region about 36%. The changes in mercury emissions outside the HELCOM region are accounted for 16 tonnes (8%).

The highest mercury emissions within the HELCOM region were reported by the Germany (27.7 tonnes), Poland (23.2 tonnes), and Russian Federation (10.2 tonnes). Spatial distribution of mercury anthropogenic emission for 2002 is presented in Figure 7.1.

Table 7.1. Annual emissions of mercury in HELCOM countries and entire EMEP area used in computations for 2001 and 2002. Units: tonnes per year. The change of emissions between 2001 and 2002 is shown in the forth column in tonnes

Country	2001	2002	Change
Denmark	1.9	1.2	-0.7
Estonia	0.5	0.5	0
Finland	0.7	0.7	-0.1
Germany	28.2	27.7	-0.5
Latvia	0.1	0.1	0
Lithuania	0.5	0.3	-0.2
Poland	23.2	23.2	0
Russian Federation	10.0	10.2	0.2
Sweden	0.7	0.7	0
TOTAL – HELCOM countries	**65.8**	**64.6**	**-1.2**
TOTAL - EMEP	**195**	**180**	**-16**

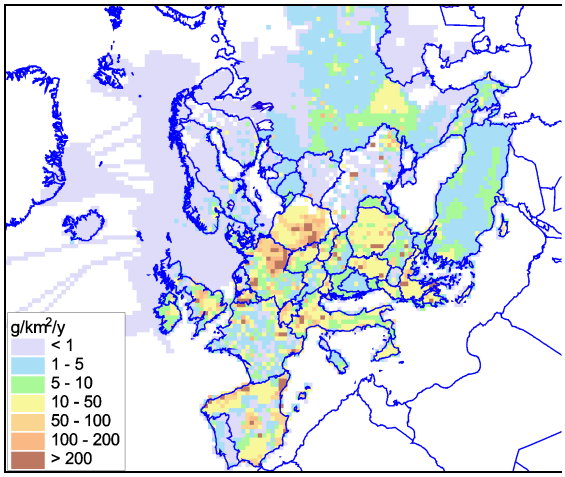


Figure 7.1. Spatial distribution of mercury anthropogenic emission within the EMEP region in 2002 with resolution 50x50 km^2. Units: g/km^2/year

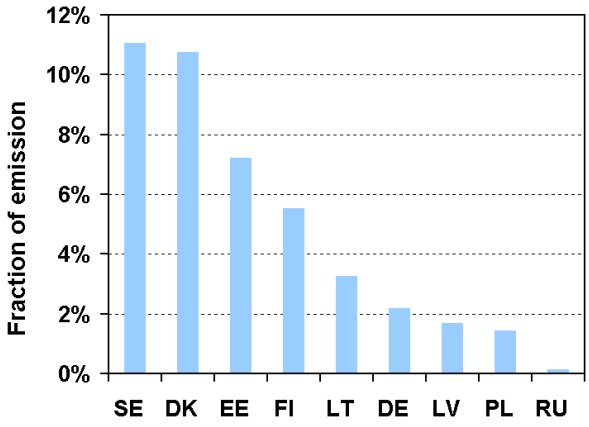


Figure 7.2. Fractions of mercury anthropogenic emissions of HELCOM countries in 2002 deposited to the Baltic Sea.

It should be noted that the emission of Russian Federation in the Table 6.1 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 7.2.

Mercury re-emission from previously polluted areas and natural emission sources provide significant contribution to depositions within the EMEP region. Their share in remote regions can reach up to 90%. The input of re-emission and natural emissions sources of mercury from the territory of Europe and marginal seas for 2002 is estimated to about 150 tonnes. The description of parameterization of mercury natural emission and re-emission used in the MSCE-HM model can be found in (Ilyin et al., 2002).

7.2 Annual deposition of mercury

Total annual mercury deposition to the Baltic Sea in 2002 amounts to 3.1 tonnes and to its catchment area – about 19 tonnes. Atmospheric depositions over the Baltic Sea computed for 2001 were practically on the same level (3.2 tonnes). At the same time over the catchment area they were higher by 35%.

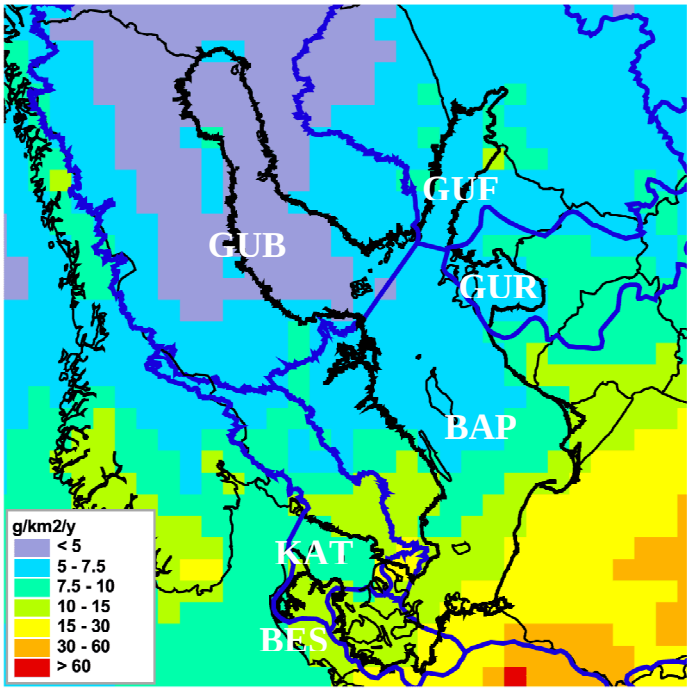


Figure 7.3. Spatial distribution of total mercury deposition flux in the Baltic Sea region for 2002 with resolution 50x50 km^2. Units: g/km^2/year

Spatial distribution of mercury total deposition flux in 2002 is given in Figure 7.3. 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 2002 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. 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 is characteristic of catchment area of the Baltic Proper sub-basin (BAP). For all 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 2002

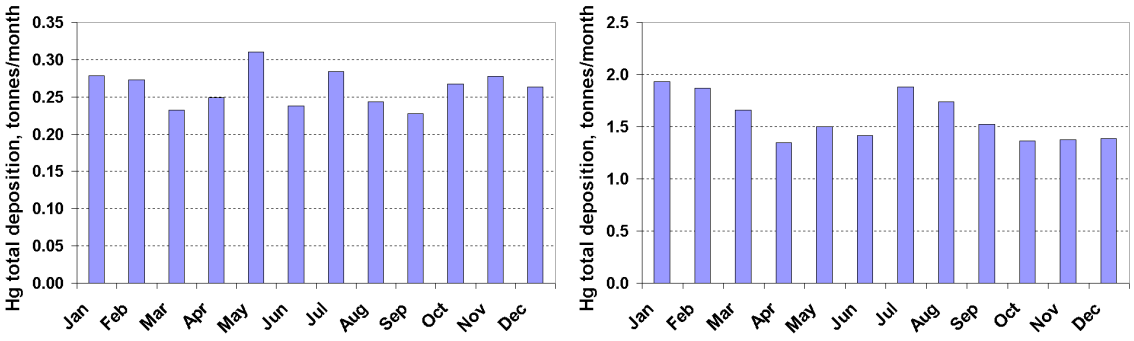
Deposition	GUB	GUF	GUR	BAP	BES	KAT	Baltic Sea
Dry	0.05	0.03	0.02	0.34	0.07	0.03	0.55
Wet	0.49	0.17	0.10	1.45	0.21	0.19	2.59
Total	0.54	0.20	0.11	1.79	0.27	0.22	3.14
Flux	5	7	6	8	13	10	7

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	0.4	0.5	0.3	4.7	0.1	0.2	6.2
Wet	2.1	1.9	0.8	7.0	0.3	0.6	12.8
Total	2.5	2.5	1.0	11.7	0.4	0.8	19.0
Flux	5	6	7	21	16	9	11

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 7.4. Monthly variations of mercury total depositions to the Baltic Sea (a) and its catchment area (b) in 2002, tonnes/month.

Monthly depositions over the Baltic Sea did not changed significantly throughout the year. Maximum of depositions take place in May. Over the catchment area elevated depositions can be noted in January, February, July, and August.

7.4 Source allocation of mercury deposition

The contributions of HELCOM countries to the depositions of mercury over 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 et al., 2004). Figures 7.5 and 7.6 present the source allocation budget of mercury depositions to the Baltic Sea and Figures 7.7 and 7.8 for its catchment area.

Anthropogenic sources of mercury emissions of HELCOM countries contribute to the deposition over the Baltic Sea about 40% with main contributions from Germany (19%) and Poland (11%). Other HELCOM countries contribute about 10%. Contribution of European countries outside the Baltic Sea region amounts to 10%.

Main contributions to deposition over the catchment area among the HELCOM countries belong to Poland (33%) and Germany (15%). Other HELCOM countries contribute about 5%. The share of depositions from the sources of HELCOM countries accounts for 53%. Contribution of European countries outside the Baltic Sea region amounts to 9%.

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 2001 and 2002.

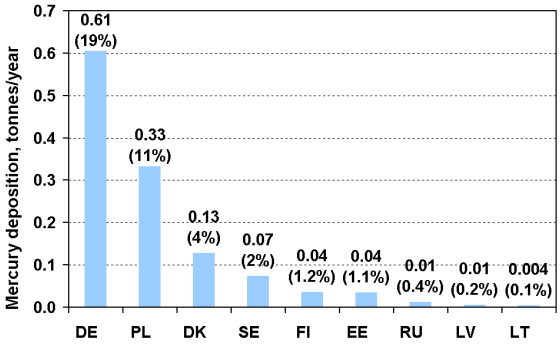


Figure 7.5. Contribution of HELCOM countries emissions from anthropogenic sources to total mercury depositions to the **Baltic Sea** in 2002, tonnes/year

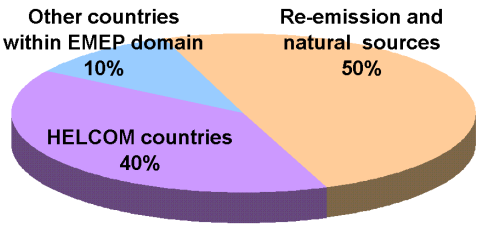


Figure 7.6. Contribution of re-emission, natural and global sources, sources of HELCOM countries and other countries within EMEP domain to total mercury deposition to the **Baltic Sea** in 2002, tonnes/year

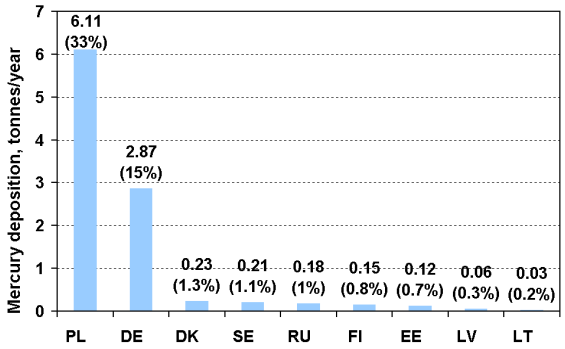


Figure 7.7. Contribution of HELCOM countries emissions from anthropogenic sources to total mercury depositions to the Baltic Sea **catchment area** in 2002, tonnes/year

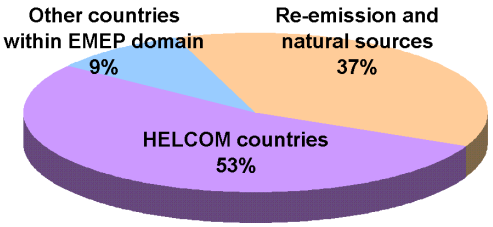


Figure 7.8. Contribution of re-emission, natural and global sources, sources of HELCOM countries and other countries within EMEP domain to total mercury deposition to the Baltic Sea **catchment area** in 2002, tonnes/year

In comparison to computations for 2001 the input to mercury depositions both over the Baltic Sea and over its catchment area from re-emission, natural and remote sources in computations for 2002 is lower. At the same time contributions of HELCOM countries in computations for 2002 are somewhat higher. The reason for these differences can be connected with interannual variability of meteorological data, in particular, transport pathways and precipitation amount.

Table 7.4. Comparison of main contributors to mercury deposition in sub-basins of the Baltic Sea in 2001 and 2002. BAS means the whole Baltic Sea basin. Units: percent of total depositions

Sub-basin	2001					2002				
	Country	%	Country	%	*, %	Country	%	Country	%	*, %
GUB	FI	4	PL	2	87	SE	8	DE	6	65
GUF	EE	24	FI	3	65	EE	15	DE	8	55
GUR	PL	8	DE	4	78	DE	16	PL	9	58
BAP	DE	18	PL	15	55	DE	25	PL	14	45
BES	DK	34	DE	29	29	DE	29	DK	11	40
KAT	DK	40	DE	8	42	DK	15	DE	10	54
BAS	DE	14	PL	9	59	DE	19	PL	11	50

* - 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 2001 and 2002. CAT means the whole Baltic Sea catchment area. Units: percent of total depositions

Sub-basin	2001					2002				
	Country	%	Country	%	*, %	Country	%	Country	%	*, %
GUB	FI	1	DE	1	95	DE	5	PL	4	77
GUF	RU	5	EE	3	84	DE	7	PL	7	64
GUR	PL	5	LT	4	76	PL	14	DE	13	55
BAP	PL	52	DE	9	27	PL	49	DE	19	21
BES	DE	36	DK	31	27	DE	34	DK	10	36
KAT	DK	21	DE	7	60	DE	10	DK	9	58
CAT	PL	31	DE	6	52	PL	33	DE	15	37

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

For the Gulf of Bothnia (GUB), the Gulf of Finland (GUF), and the Gulf of Riga (GUR) sub-basins the most important contributors from HELCOM countries are Sweden, Estonia, Germany, and Poland. The central and southern sub-basins (BAP, BES, KAT) are mostly influenced by emission sources of Germany, Denmark, andPoland. Contribution of anthropogenic emission sources of Germany has increased for most of the sub-basins comparing to the results for 2001. At the same time the input of Denmark to mercury depositions becomes lower which is caused by the decrease of mercury emission from Denmark by 37%.

For most of sub-basins and catchments of the Baltic Sea the input of mercury due to re-emission and from natural and global sources is the most significant contributor. Thus in the northern part where the influence of the anthropogenic emission sources is lower the contribution of natural input amounts to 55 - 65%. In southwestern sub-basins it is somewhat lower accounting for 40 - 45%.

Over the catchment area contrary to computations for 2001 in all of the sub-basins two most important contributors are Germany, Poland, and Denmark. Decreasing of emissions in Denmark in comparison to 2001 has resulted in decreasing of its contributions to depositions.

7.5 Comparison of model results with measurements

Model results for mercury were compared with available measurements made on HELCOM stations for 2002. Measurements of mercury concentrations were reported by Zingst (DE9), Bredkälen (SE5), Rörvik (SE2), Vavihill (SE11), and Råö (SE14). In Table 7.6 results of the comparison of mean annual calculated and measured mercury concentrations for 2002 are presented.

Model results for listed in table stations are in a good agreement with observed concentrations of mercury. For all of the mean annual computed and observed concentrations of mercury the differences are less than factor of two. Comparison of monthly variations of calculated and measured mercury concentrations at stations listed above is presented in Figures 7.9 – 7.14.

Table 7.6. Comparison of calculated and measured mean annual mercury concentrations in air and precipitation for 2002

Station code	Station name	Observed	Calculated	Obs / Calc
Hg concentrations in air (ng/m^3)				
DE09	Zingst	1.63	2.03	0.8
SE14	Råö	1.67	1.69	1.0
Hg concentrations in precipitation (ng/l)				
DE09	Zingst	8.7	14.0	0.6
SE05	Bredkälen	7.2	7.0	1.0
SE11	Vavihill	9.9	8.8	1.1
SE14	Råö	12.3	7.7	1.6

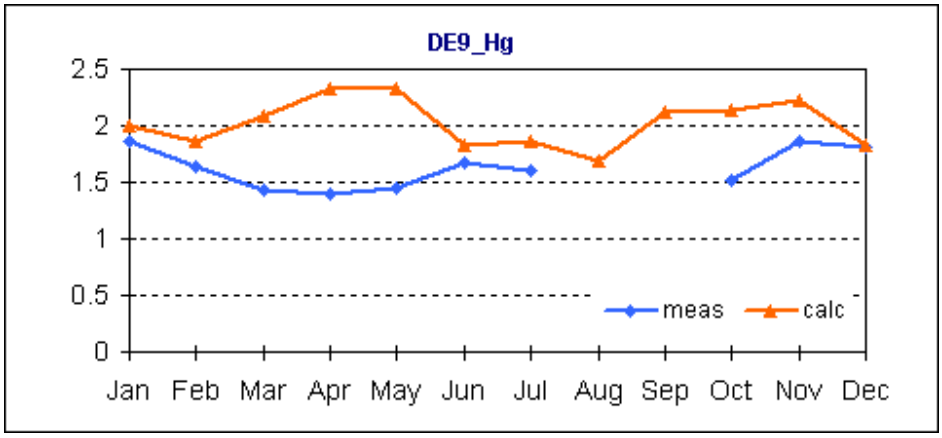


Figure 7.9. Comparison of calculated mean monthly mercury concentrations in air with measured at station Zingst (DE9). Units: ng / m^3.

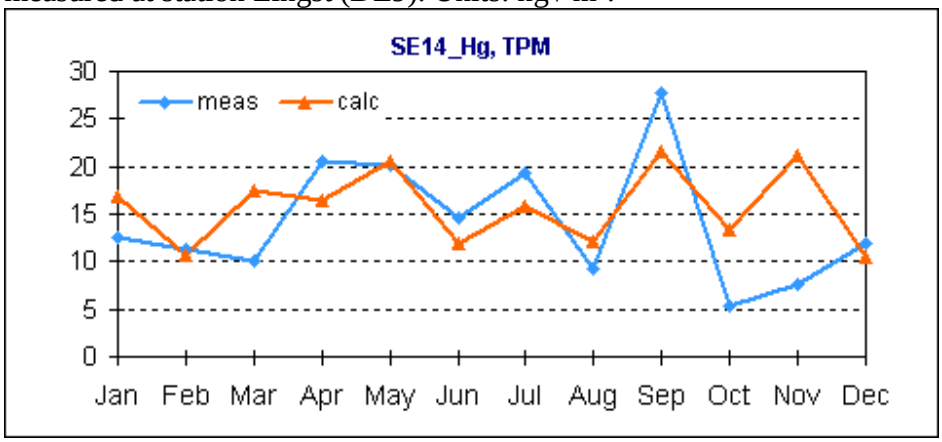


Figure 7.10. Comparison of calculated mean monthly mercury concentrations in precipitation with measured at station Raö (SE14). Units: ng / m^3.

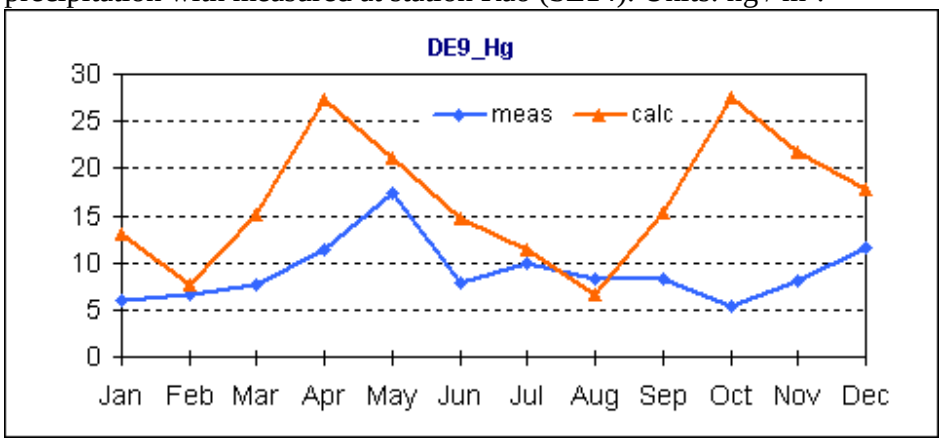


Figure 7.11. Comparison of calculated mean monthly mercury concentrations in precipitation with measured at station Zingst (DE9). Units: ng / l.

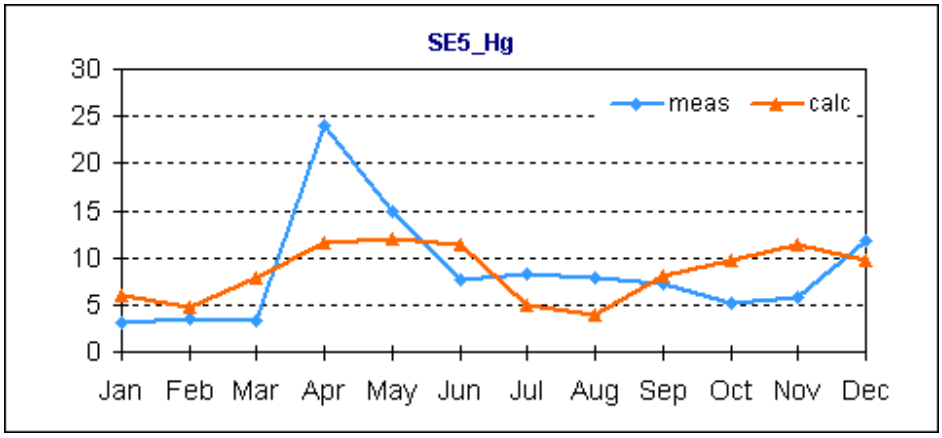


Figure 7.12. Comparison of calculated mean monthly mercury concentrations in precipitation with measured at station Bredkälen (SE5). Units: ng / l.

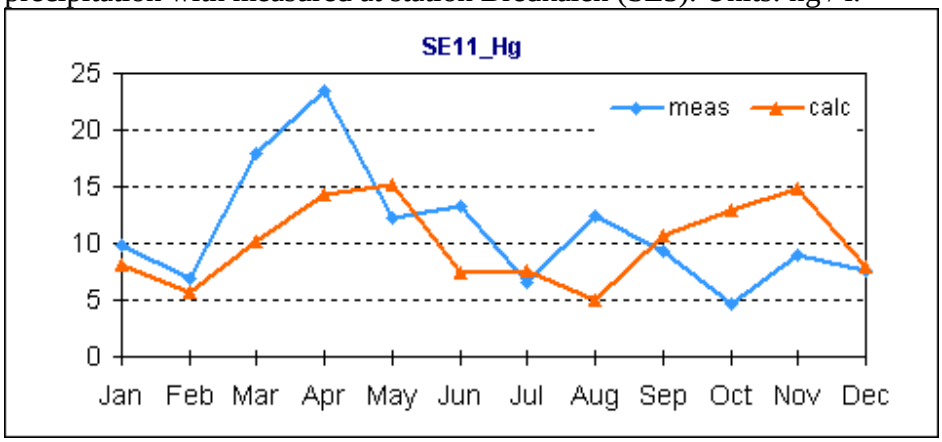


Figure 7.13. Comparison of calculated mean monthly mercury concentrations in precipitation with measured at station Vavihill (SE11). Units: ng / l.

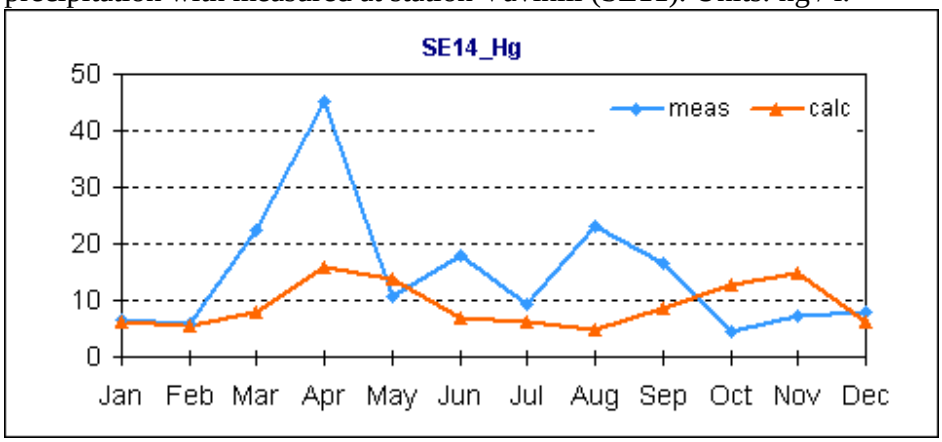


Figure 7.14. Comparison of calculated mean monthly mercury concentrations in precipitation with measured at station Råö (SE14). Units: ng / l.