7. Atmospheric Supply of Mercury to the Baltic Sea in 2001

Atmospheric depositions of mercury to the Baltic Sea sub-basins and catchments were computed for 2001 using MSC-E Eulerian Heavy Metal transport model MSCE-HM (Ilyin *et al.*, 2003). This chapter presents a short description of emission data used for computations, computed annual depositions of mercury along with their monthly variations, and contributions of HELCOM countries to the depositions to the Baltic Sea sub-basins and catchments. Obtained results were compared with available monitoring data on mercury concentrations in air and precipitation for the Baltic Sea region.

7.1 Mercury emissions

Three categories of emissions were used for the evaluation of mercury atmospheric load to the Baltic Sea: direct anthropogenic emissions, natural emissions and re-emission. Direct anthropogenic emissions of mercury in HELCOM countries were based on officially submitted data (Vestreng, 2003).

Most of the HELCOM countries officially submitted information on anthropogenic emission of mercury for 2001 to the UN ECE Secrtariat. For some of them, in particular for Germany and Russian Federation, official information on emissions in 2001 was missing. Germany submitted mercury emission data for 1995 and the forecast of emission for 2010. Lacking emission values for other years from 1995 to 2001 were estimated by linear interpolation. The emission of mercury in Russian Federation was available for years prier to 2001 therefore the value for 2000 was applied in computations for 2001.

Total annual emissions of HELCOM countries in 2001 as well as total mercury emission within the EMEP region are summarized in table 7.1. For the comparison emissions for 2000 are also presented in the table. It should be noted that some of these figures differ from those given in the previous joint report of EMEP Centres (Bartnicki *et al.*, 2002). These differences are due to updates of emission data for the previous years recently made by the countries. Total mercury emission of HELCOM countries in 2001 accounts for 66 tonnes which is slightly lower than in 2000 by 3 tonnes. The contribution of HELCOM countries emissions to mercury anthropogenic emission within the whole EMEP region accounts for approximately 35%. The highest emissions within the HELCOM region are the characteristic of Germany (28 tonnes), Poland (23 tonnes), and the Russian Federation (10 tonnes). Spatial distribution of mercury anthropogenic emission for 2001 is presented in Figure 7.1.

Table 7.1. Annual emissions of mercury in HELCOM countries and entire EMEP area used in computations for 2000 and 2001. Units: tonnes per year. The change of emissions between 2001 and 2000 is shown in the forth column as the difference between 2001 and 2000 in tonnes

Country	2000	2001	Change
Denmark	1.96	1.87	-0.09
Estonia	0.55	0.5	-0.05
Finland	0.58	0.73	+0.15
Germany	28.67	28.2	-0.47
Latvia	0.21	0.14	-0.07
Lithuania	0.25	0.52	+0.26
Poland	25.61	23.17	-2.44
Russian Federation	10	10	0
Sweden	0.81	0.69	-0.12
TOTAL – HELCOM countries	**68.6**	**65.8**	**-2.8**
TOTAL - EMEP	**200.9**	**195.4**	**-5.4**

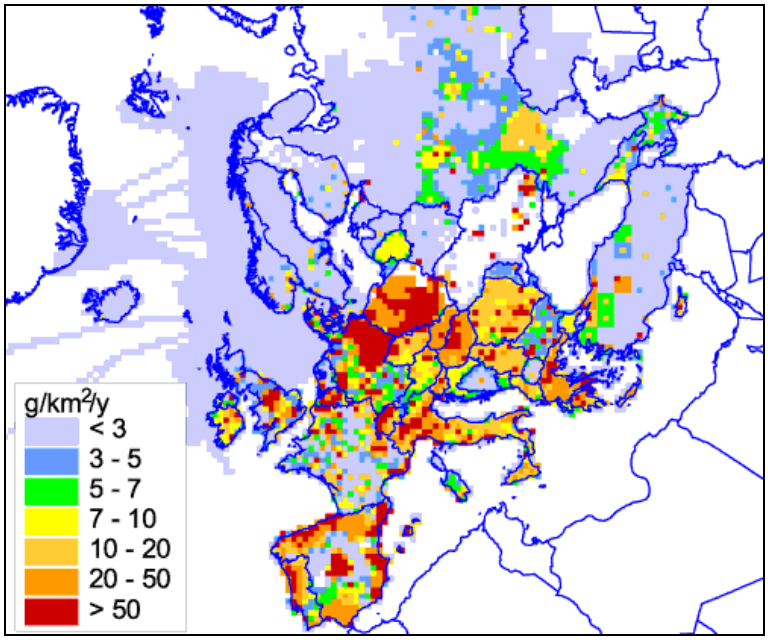


Figure 7.1. Spatial distribution of anthropogenic mercury emission within the EMEP region in 2001 with resolution 50x50 km^2. Units: g/km^2/year

Mercury is characterized by significant natural emissions and re-emission in previously polluted areas. Due to long residence time in the atmosphere (about one year) it can be transported over long distances (thousands of km) . Therefore the role of re-emission, natural and global sources of mercury is more significant than that of lead and cadmium. In remote regions it can exceed 90%. 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). The input from re-emission and natural emissions within EMEP region for 2001 is estimated as much as approximately 150 tonnes.

7.2 Annual deposition of mercury

Annual and monthly depositions of mercury were computed with horizontal resolution 50x50 km^2 for six sub-basins and six catchments of the Baltic Sea. Total deposition of mercury to the Baltic Sea in 2001 amounts to 3.2 tonnes and to its catchment area – about 29 tonnes. Corresponding figures for 2000 were 3.5 tonnes and 29 tonnes indicating some decrease of mercury deposition to the Baltic Sea by 9% and practically the same level of depositions to the catchment area. Spatial distribution of mercury total deposition flux is given in Figure 7.2.

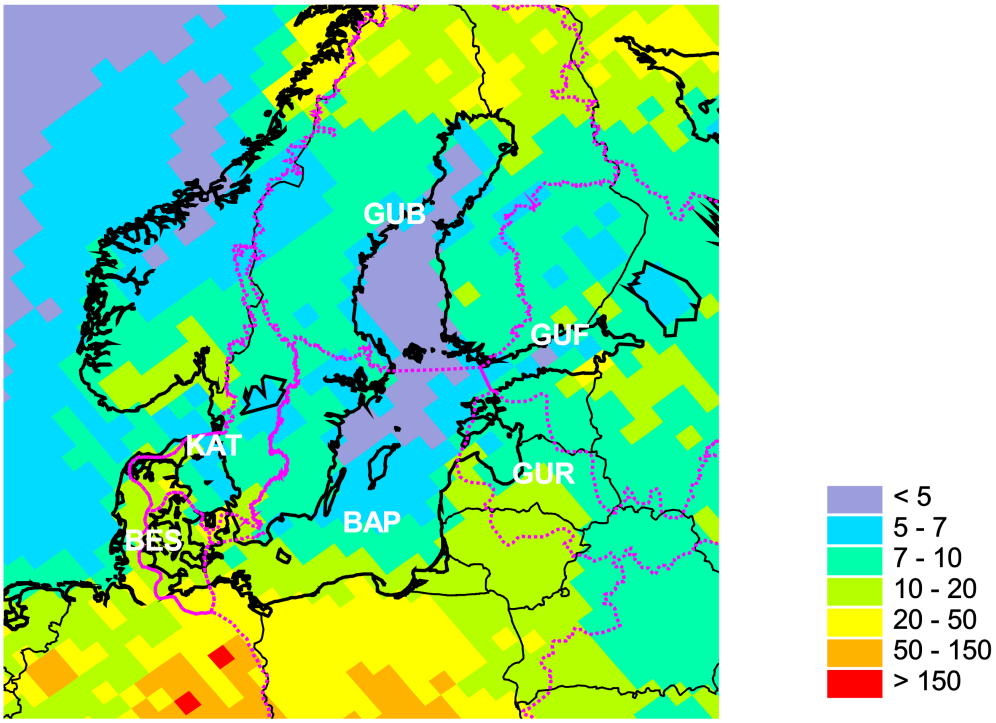


Figure 7.2. Spatial distribution of total mercury deposition flux in the Baltic Sea region for 2001 with resolution 50x50 km^2. Units: g/km^2/year

The pattern of mercury depositions to the Baltic Sea shows a clear gradient from its southern part to northern one. Elevated levels of depositions are found in the Belt Sea sub-basin (BES) and southern part of the Baltic Proper sub-basin (BAP). Lowest depositions are characteristic of Gulf of Bothnia sub-basin (GUB).

Over the Baltic Sea catchment area the highest depositions are obtained for the Baltic Proper catchment, in particular over the territory of Poland. Elevated levels of mercury depositions can also be noticed over the north of Finland and Sweden which is the effect of spring-time mercury depletion. Model parameterisation of this phenomenon can be found in (Ilyin et al., 2002; Ryaboshapko and Ilyin, 2002).

Annual dry, wet, and total mercury depositions in 2001 are presented in Table 7.2 for sub-basins of the Baltic Sea and in Table 7.3 for its catchment area. For all sub-basins and catchments wet deposition fluxes dominate over dry ones. The highest mercury deposition flux over the Baltic Sea is obtained for the Belt Sea (BES) sub-basin. Over the catchment area the highest deposition flux is characteristic of Baltic Proper catchment (BAP).

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 2001

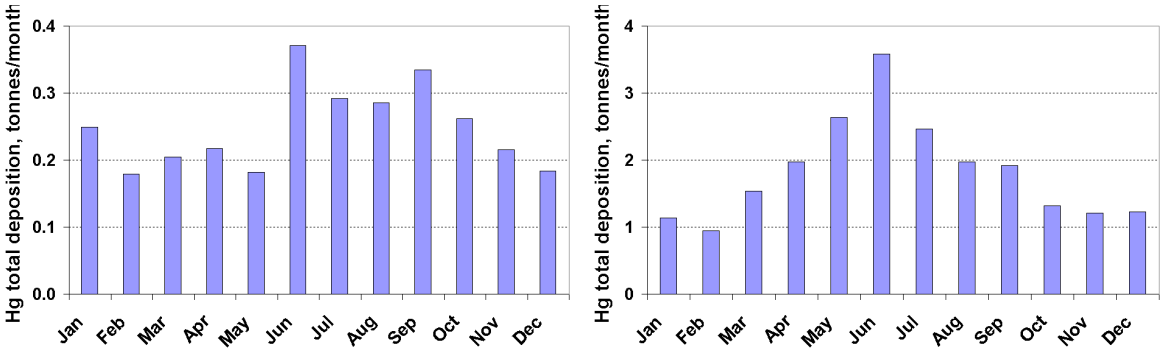
Deposition	GUB	GUF	GUR	BAP	BES	KAT	Baltic Sea
Dry	0.05	0.02	0.003	0.11	0.03	0.02	0.23
Wet	0.5	0.2	0.15	1.6	0.3	0.2	3.0
Total	0.6	0.3	0.15	1.7	0.3	0.2	3.2
Flux	4.8	8.9	8.1	8.1	15.0	8.7	7.6

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 2001

Deposition	GUB	GUF	GUR	BAP	BES	KAT	Catchment area
Dry	1.69	1.13	0.32	3.59	0.1	0.24	7.04
Wet	4.4	2.5	1.0	13.0	0.4	0.6	21.9
Total	6.1	3.7	1.4	16.6	0.5	0.8	28.9
Flux	12.3	8.7	9.8	29.7	4.5	9.3	16.8

7.3 Monthly depositions of mercury

Monthly variations of mercury total depositions to 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 2001, tonnes/month.

Mercury total depositions to the Baltic Sea and its catchment area undergo significant variations throughout the year. Maximum depositions take place in summer and early autumn and minimum in winter. These variations of depositions can be explained by elevated amount of precipitation in summer time.

7.4 Source allocation of mercury deposition

Source allocation budget of mercury depositions to the Baltic Sea, its sub-basins and catchments was estimated using the computations of mercury transboundary fluxes over European region for 2001 (Ilyin et al., 2003). This information includes the contributions of HELCOM countries to the depositions of mercury to the Baltic Sea sub-basins and catchments as well as contributions of other European countries and re-emission, natural and global sources. Figures 7.4 and 7.5 present the source allocation budgets of mercury depositions to the Baltic Sea and Figures 7.6 and 7.7 for its catchment area. It can be seen that essential contribution belongs to the input of re-emission, natural and global anthropogenic sources.

Anthropogenic sources of mercury emissions of HELCOM countries contribute to the deposition over the Baltic Sea about 36% among which main contributions belong to Germany (14%), Poland (9%), and Denmark (8%). Other HELCOM countries contribute

about 5%. Contribution of European countries outside the Baltic Sea region amounts to 5%.

For the catchment area main contribution to depositions among the HELCOM countries belong to Poland (31%) and Germany (6%). Other HELCOM countries contribute about 5%. The share of depositions from the sources of HELCOM countries is about 42%. Contribution of European countries outside the Baltic Sea region amounts to 6%.

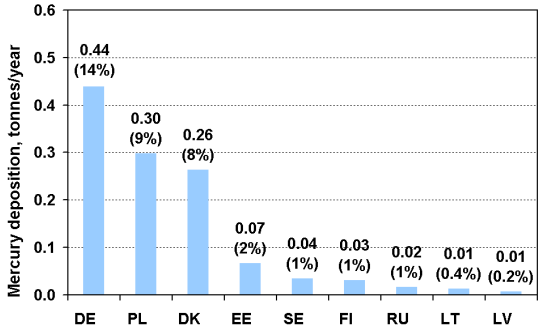


Figure 7.4. Contribution of HELCOM countries emissions to total mercury depositions to the **Baltic Sea** in 2001 from anthropogenic sources, tonnes/year

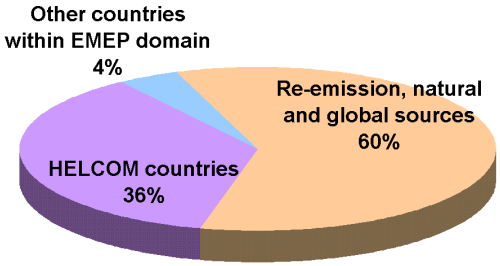


Figure 7.5. Contribution of re-emission, natural and global sources, sources of HELCOM countries and other countries within EMEP domain to total mercury deposition to the **Baltic Sea** in 2001, tonnes/year

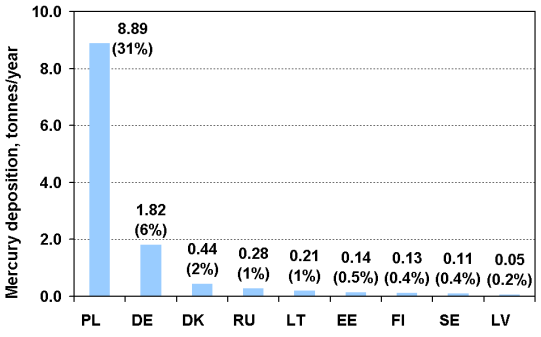


Figure 7.6. Contribution of HELCOM countries emissions to total mercury depositions to the Baltic Sea **catchment area** in 2001 from anthropogenic sources, tonnes/year

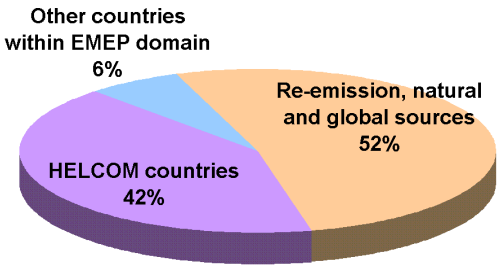


Figure 7.7. Contribution of re-emission, natural and global sources, sources of HELCOM countries and other countries within EMEP domain to total mercury deposition to the Baltic Sea **catchment area** in 2001, tonnes/year

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 2000 and 2001.

Table 7.4. Comparison of main contributors to mercury deposition in sub-basins of the Baltic Sea in 2000 and 2001. BAS means the whole Baltic Sea basin. Units: percent of total depositions

Sub-basin	2000					2001				
	Country	%	Country	%	*, %	Country	%	Country	%	*, %
GUB	PL	6	DE	4	76	FI	4	PL	2	87
GUF	EE	27	PL	3	57	EE	24	FI	3	65
GUR	PL	12	DE	7	67	PL	8	DE	4	78
BAP	DE	26	PL	20	41	DE	18	PL	15	55
BES	DE	33	DK	29	28	DK	34	DE	29	29
KAT	DK	31	DE	19	35	DK	40	DE	8	42
BAS	DE	20	PL	13	47	DE	14	PL	9	59

* - 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 2000 and 2001. CAT means the whole Baltic Sea catchment area. Units: percent of total depositions

Sub-basin	2000					2001				
	Country	%	Country	%	*, %	Country	%	Country	%	*, %
GUB	PL	2	DE	1	93	FI	1	DE	1	95
GUF	RU	5	EE	4	81	RU	5	EE	3	84
GUR	PL	9	LV	4	72	PL	5	LT	4	76
BAP	PL	54	DE	10	24	PL	52	DE	9	27
BES	DE	37	DK	28	26	DE	36	DK	31	27
KAT	DK	17	DE	12	53	DK	21	DE	7	60
CAT	PL	33	DE	8	47	PL	31	DE	6	52

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

In the northern and eastern sub-basins of the Baltic Sea (GUB, GUF, GUR) the contribution of natural input is higher and amounts to 65 - 90%. Among the HELCOM countries the most important contributors are the neighboring countries – Finland, Estonia and Poland. The central and southern sub-basins (BAP, BES, KAT) are mostly subject of the influence of Poland, Germany, and Denmark emissions. Decreasing of emissions in Poland and Germany has resulted in changing of their contributions to depositions over the Gulf of Bothnia

(GUB), the Gulf of Finland (GUF) and the Belt Sea (BES) sub-basins. For other sub-basins the contributions to mercury deposition in 2001 and 2000 are more or less the same. 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.

For northern and eastern catchments of the Baltic Sea (GUB, GUF, GUR) the largest contribution belongs to re-emission, natural and global sources. The catchments of BAP, BES, and KAT sub-basins are mostly subject of influence of Poland, Germany, and Denmark emissions. Decreasing of emissions in Poland and Germany in comparison to 2000 has resulted in decreasing of their contributions to depositions whereas contribution of Denmark mercury emission sources has somewhat increased.

7.5 Comparison of model results with measurements

Modelling results for mercury were compared with available measurements made on HELCOM stations for 2001. The following four stations have reported concentrations of mercury in precipitation: Zingst (DE9), Rörvik (SE2), Bredkälen (SE5), and Vavihill (SE11). Air concentration of mercury were reported for Rörvik (SE2). Table 7.6 presents results of the comparison of mean annual calculated and measured mercury concentrations for 2001.

Table 7.6. Comparison of calculated and measured mean annual mercury concentrations in air and precipitation for 2001

Station code	Station name	Observed	Calculated	Obs / Calc
Hg concentrations in air (ng/m^3)				
SE2	Rörvik	1.7	1.9	0.9
Hg concentrations in precipitation (ng/l)				
DE9	Zingst	9.3	35.1	0.3
SE2	Rörvik	9.3	10.2	0.9
SE5	Bredkälen	6.5	6.6	1.0
SE11	Vavihill	9.4	21.4	0.4

Modelled values for Rörvik (SE2) and Bredkälen (SE5) stations are in a good agreement with observed concentrations of mercury. An appreciable overestimation of mercury concentrations in precipitation is noted for Zingst (DE9) and Vavihill (SE11). The reason for it can be incomplete set of data on the distribution of mercury physical-chemical forms in emissions, uncertainties of model parameterizations and difficulties in mercury monitoring. Comparison of monthly variations of calculated and measured mercury concentrations at stations listed above is presented in Figures 7.8 – 7.12.

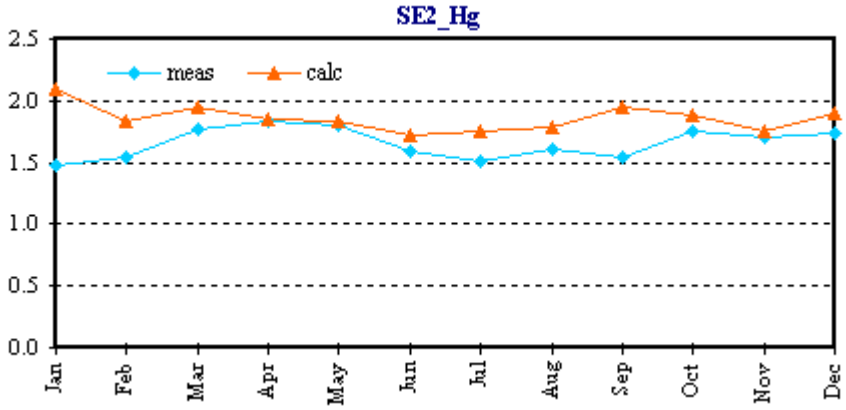


Figure 7.8. Comparison of calculated mean monthly mercury concentrations in air with measured at station Rörvik (SE2). Units: ng / m^3.

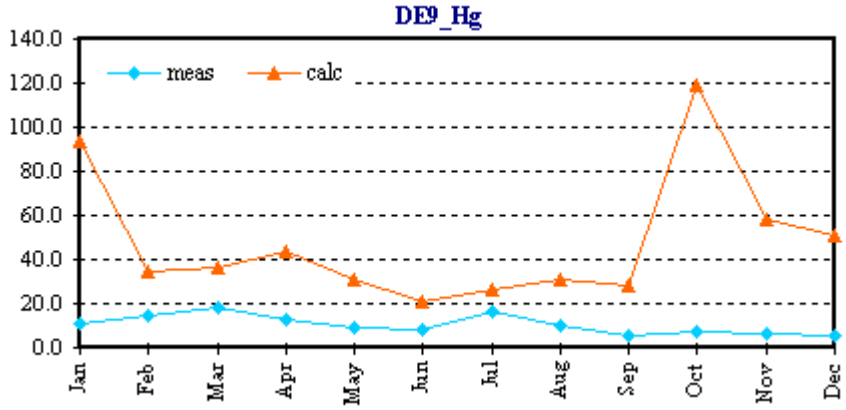


Figure 7.9. Comparison of calculated mean monthly mercury concentrations in precipitation with measured at station Zingst (DE9). Units: ng / l.

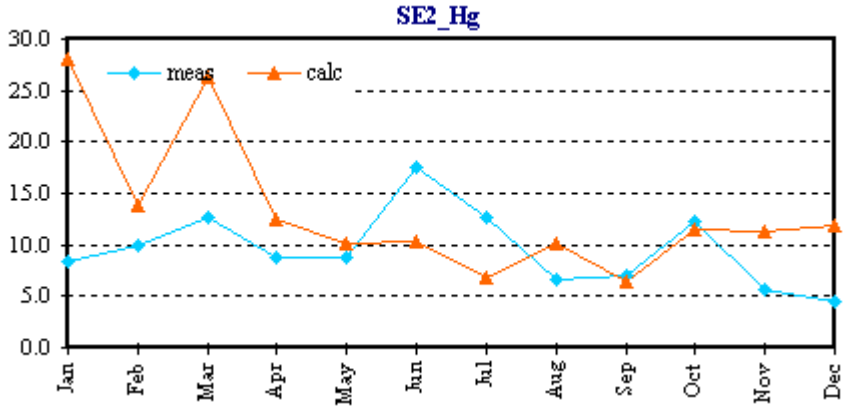


Figure 7.10. Comparison of calculated mean monthly mercury concentrations in precipitation with measured at station Rörvik (SE2). Units: ng / l.

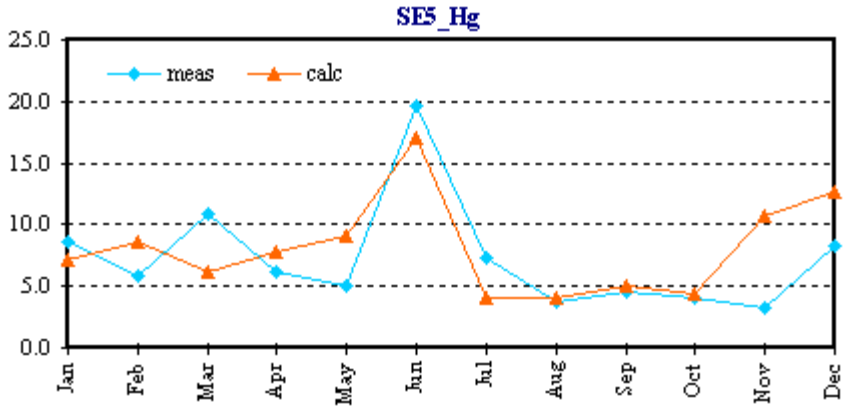


Figure 7.11. Comparison of calculated mean monthly mercury concentrations in precipitation with measured at station Bredkälen (SE5). Units: ng / l.

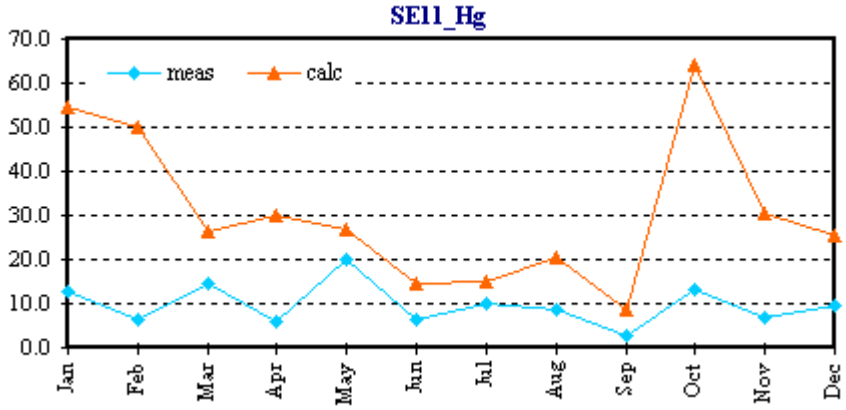


Figure 7.12. Comparison of calculated mean monthly mercury concentrations in precipitation with measured at station Vavihill (SE11). Units: ng / l.