

5. Atmospheric Supply of Lead to the Baltic Sea in 2003

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

5.1 Lead emissions

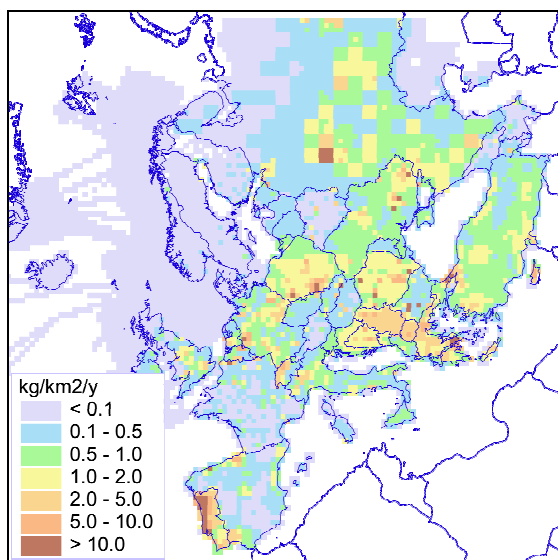
The evaluation of lead atmospheric load to the Baltic Sea was carried out using direct anthropogenic emissions, natural emissions and re-emission. As the direct anthropogenic emission of lead of HELCOM countries in 2003 the officially submitted information on lead emissions to the UN ECE Secretariat was used (EB.AIR/GE.1/2005/8). Lead 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 lead emissions in 2003 was missing. The value of total annual lead emission of Germany in 2002 was estimated using linear interpolation between submitted data for 1995 and projection for 2010 (EB.AIR/GE.1/2003/6). Total annual lead emissions of Poland and Russian Federation in 2003 were assumed the same as in previous year 2002.

The information on total annual lead emissions of HELCOM countries in 2003 and 2002 as well as total emission within the EMEP region are summarized in the Table 5.1. Total lead emission of HELCOM countries in 2003 accounts for 3271 tonnes that is lower than in 2002 by 49 tonnes (1.5%). The contribution of HELCOM countries emissions to lead anthropogenic emission within the whole EMEP region is approximately 40%. It can be seen that the most significant contributions to total anthropogenic emissions of lead within the HELCOM region belong to the Russian Federation (2118 tonnes), Poland (588 tonnes), and Germany (452 tonnes). Analysis of national emission data consistency has shown that anthropogenic emissions of lead officially submitted to the Convention cannot explain observed levels of its wet depositions in Europe (Ilyin and Travnikov, 2005). Based on the observations of lead made at the EMEP monitoring network 2-3-fold underestimation of lead emission data in Europe can be expected in official information.

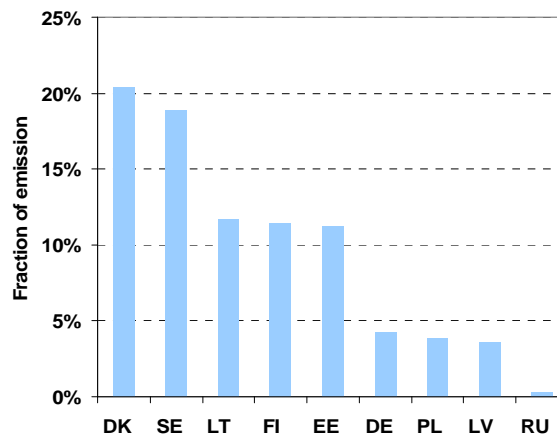
Table 5.1. Annual emissions of lead in HELCOM countries and in entire EMEP region in 2002 and 2003 following the official data and expert estimates (shaded). Units: tonnes/year

Country	2002*	2003	Change (2003-2002)
Denmark	5.25	4.66	-0.59
Estonia	36.7	39.28	2.62
Finland	39.6	33.5	-6.1
Germany	474.3	451.7	-22.6
Latvia	8.86	7.07	-1.79
Lithuania	14.9	15	0.1
Poland	610	588	-22
Russian Federation	2118	2118	0
Sweden	12.6	14.1	1.5
TOTAL – HELCOM	3320	3271	-49
TOTAL – EMEP	7998	8583	585

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



(a)



(b)

Figure 5.1. Spatial distribution of lead anthropogenic emission in Europe in 2003 (kg/km²/year) following the officially submitted data and expert estimates (a) and fractions of HELCOM countries emissions deposited to the Baltic Sea (b)

Spatial distribution of lead anthropogenic emission for 2003 is presented in Figure 5.1. It should be noted that the emission of Russian Federation in the Table 5.1 is related to its whole European territory. However only a small part of this emission is actually reaching the Baltic Sea.

The input of lead re-emission and natural emission sources of European territory for 2003 is estimated to about 0.8 ktonnes. The description of parameterization of lead natural emission and re-emission used in the MSCE-HM model can be found in (Travnikov and Ilyin, 2005).

5.2 Annual deposition of lead

Modelling of lead atmospheric transport and depositions was carried out using MSC-E Eulerian Heavy Metal transport model MSCE-HM. To obtain levels of annual and monthly lead depositions to the Baltic Sea region in 2003 modelling was performed with the official emission data submitted by countries and expert estimates. Spatial distribution of lead annual total deposition flux obtained for 2003 is given in Figure 5.3. Total annual deposition of lead to the Baltic Sea in 2003 amounts to 134 tonnes and to its catchment area 934 tonnes. Comparing to the level of depositions for the previous year 2002 the atmospheric load of lead computed for 2003 is somewhat lower (by 10%) for the Baltic Sea and nearly the same for its catchment area.

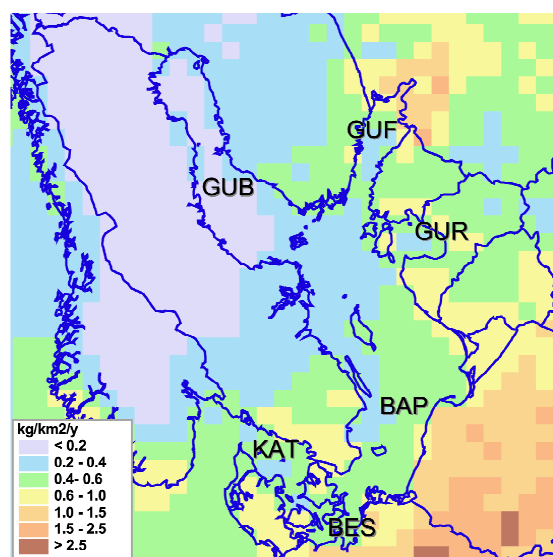


Figure 5.3. Spatial distribution of total lead deposition flux in the Baltic Sea region in 2003 with resolution 50x50 km². Units: kg/km²/year

Elevated lead deposition flux can be noted in the southern part of the Baltic Proper sub-basin (BAP) and in the Gulf of Riga (GUR) and Gulf of Finland (GUF) sub-basins. Lowest deposition rates are the characteristic of the Gulf of Bothnia sub-basin (GUB). Annual dry, wet, and total lead depositions in 2003 are presented in Table 5.2 for the sub-basins of the Baltic Sea and in Table 5.3 for its catchment area. The most significant contribution to the total depositions of lead belongs to wet deposition for most of sub-basins and catchments. The highest lead deposition fluxes to the Baltic Sea sub-basins are obtained for the Gulf of Riga sub-basin (GUR). Over the catchment area highest deposition fluxes can be noted for the catchments of the Baltic Proper (BAP).

Table 5.2. Annual dry, wet, and total depositions (tonnes/year) and total deposition fluxes (kg/km²/year) of lead to the Baltic Sea sub-basins in 2003

Deposition	GUB	GUF	GUR	BAP	BES	KAT	Baltic Sea
<i>Dry</i>	5.5	4.9	2.0	11.4	1.6	1.2	27
<i>Wet</i>	15.2	8.5	4.8	64.1	6.9	7.3	107
<i>Total</i>	20.7	13.3	6.9	75.6	8.5	8.5	134
<i>Flux</i>	0.18	0.44	0.37	0.36	0.41	0.36	0.32

Table 5.3. Annual dry, wet, and total depositions (tonnes/year) and total deposition fluxes (kg/km²/year) of lead to the Baltic Sea catchments in 2003

Deposition	GUB	GUF	GUR	BAP	BES	KAT	Catchment area
<i>Dry</i>	37	101	28	353	5	11	535
<i>Wet</i>	38	93	33	208	9	18	399
<i>Total</i>	75	194	60	561	15	29	934
<i>Flux</i>	0.15	0.46	0.44	1.01	0.59	0.34	0.54

5.3 Monthly depositions of lead

Monthly variations of total lead depositions to the Baltic Sea and its catchment area in 2003 are presented in Figure 5.4.

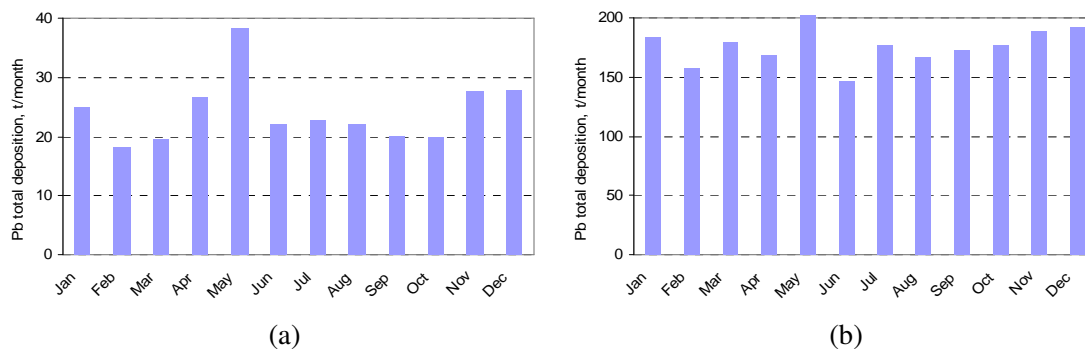


Figure 5.4. Monthly variations of lead total depositions to the Baltic Sea (a) and its catchment area (b) in 2003. Units: tonnes/month

Total monthly lead depositions to the Baltic Sea sub-basins and catchments undergo pronounced variations throughout the year with maximum in May. Over the catchment area no pronounced seasonal variation of lead depositions is obtained for 2003.

5.4 Source allocation of lead deposition

The contributions of HELCOM countries sources to the depositions of lead to the Baltic Sea sub-basins and catchments as well as contributions of other European countries were estimated using the computations of lead transboundary fluxes over European region (Ilyin and Travnikov, 2005). The Figure 5.5 presents ten countries with highest contributions to total annual lead depositions over the Baltic Sea and its catchment area in 2003. The most significant contributions belong to Germany, Poland, and Russia. At the same time considerable input is originated from emission sources of the United Kingdom, France, the Ukraine, Czech Republic, and Belgium.

Anthropogenic sources of HELCOM countries contribute 46% to lead depositions over the Baltic Sea among which main contributions belong to Poland (17%), Germany (14%), and Russia (5%) (Figure 5.6). The sources of other HELCOM countries contribute about 10% and contribution of European countries outside the Baltic Sea region amounts to 16%. The contribution of re-emission and natural sources accounts for 37%.

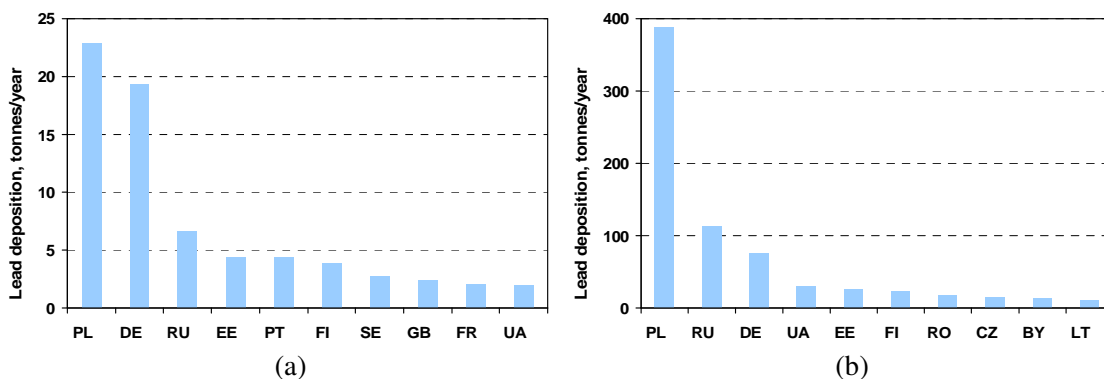


Figure 5.5. Ten countries with highest contributions to total annual lead depositions in 2003 over the Baltic Sea (a) and its catchment area (b), tonnes/year

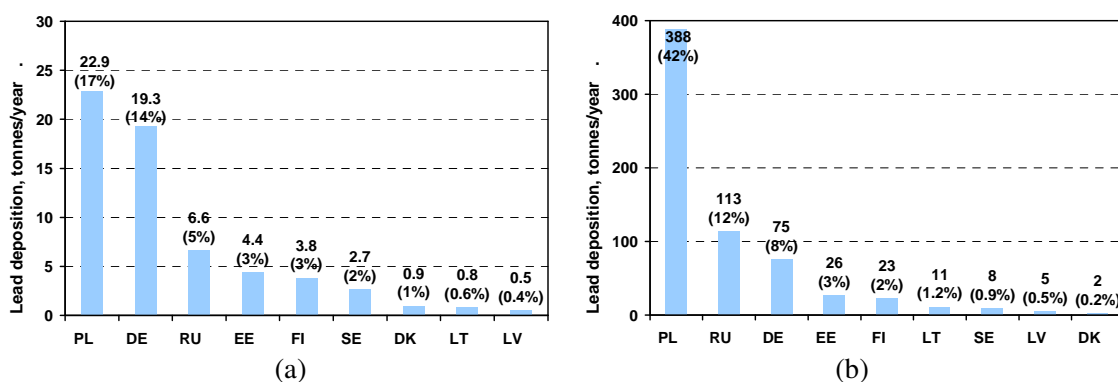


Figure 5.6. Contributions of HELCOM countries emissions from anthropogenic sources to total lead depositions to the Baltic Sea (a) and its catchment area (b) in 2003, tonnes/year

The share of lead depositions to the catchment area from anthropogenic sources of HELCOM countries is accounted for 70%. Main contributions to depositions (Figure 5.6b) among the HELCOM countries belong to Poland (42%), Russia (12%), and Germany (8%). Anthropogenic sources of other HELCOM countries contribute about 8%. Contribution of re-emission and natural sources amounts to 14% and of European countries outside the Baltic Sea region to 16%.

Tables 5.4 and 5.5 present atmospheric input of two most important contributors among the HELCOM countries to lead depositions in the six sub-basins and six catchments of the Baltic Sea in 2002 and in 2003.

Table 5.4. Comparison of main contributors to lead depositions in six 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	FI	16	PL	10	38	FI	10	PL	9	51
GUF	EE	23	RU	22	23	EE	26	RU	21	24
GUR	PL	15	DE	14	37	PL	17	DE	8	41
BAP	PL	20	DE	19	30	PL	24	DE	17	35
BES	DE	29	PL	10	28	DE	34	PL	6	33
KAT	DE	15	PL	9	39	DE	17	PT	8	44
BAS	PL	16	DE	16	31	PL	17	DE	14	37

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

Table 5.5. Comparison of main contributors to lead deposition in six 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	FI	17	RU	8	36	FI	13	PL	6	50
GUF	RU	42	EE	12	18	RU	44	EE	12	14
GUR	PL	19	RU	17	23	RU	21	PL	17	17
BAP	PL	55	DE	13	11	PL	63	DE	10	8
BES	DE	34	PL	10	26	DE	41	PL	6	29
KAT	DE	13	PL	8	39	DE	15	PL	9	42
CAT	PL	37	RU	12	16	PL	42	RU	12	14

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

5.5 Comparison of model results with measurements

Comparison of modelling results for lead was made with available measurements from HELCOM stations in 2003. Data on lead concentrations for 2003 were reported by Zingst (DE09), Keldsnor (DK5), Anholt (DK8), Pedersker (DK20), Lahemaa (EE09), Vilsandy (EE11), FI09 (Uto), Virolahti II (FI17), Hailuoto (FI53), Utö (FI9), Preila (LT15), Rucava (LV10), Zoseni (LV16), Leba (PL04), Arup (SE51), and Råö (SE14). Table 5.6 presents results of the comparison of mean annual calculated and measured lead concentrations in air and precipitation for 2003.

Table 5.6. Comparison of observed and calculated mean annual lead concentrations in air and precipitation for 2003

Station code	Station name	Observed	Calculated	Obs / Calc
<i>Pb concentrations in air (ng/m³)</i>				
DE09	Zingst	7.21	3.30	2.2
DK05	Keldsnor	7.03	2.81	2.5
DK08	Anholt	4.31	1.97	2.2
LT15	Preila	7.13	4.0	1.8
LV10	Rucava	5.10	1.96	2.6
LV16	Zoseni	2.98	1.16	2.6
SE14	Råö	3.08	1.53	2.0
<i>Pb concentrations in precipitation (µg/l)</i>				
DE09	Zingst	1.23	0.62	2.0
DK08	Anholt	1.29	0.53	2.4
DK20	Pedersker	1.75	0.59	3.0
EE09	Lahemaa	0.62	0.42	1.5
EE11	Vilsandy	0.66	0.44	1.5
FI09	Uto	2.37	0.42	5.7
FI17	Virolahti II	1.47	0.49	3.0
FI53	Hailuoto	1.60	0.39	4.1
LT15	Preila	3.59	0.68	5.3
LV10	Rucava	1.91	0.51	3.7
LV16	Zoseni	2.03	0.39	5.2
PL04	Leba	1.08	0.54	2.0
SE51	Arup	1.50	0.54	2.8

On average computed annual mean air concentrations of lead are a factor of 2 lower than measured values. For concentrations in precipitation the difference between the computed and observed levels of lead at HELCOM sites in 2003 is a factor of 3. Highest discrepancies between model results and measurements are obtained for FI9, LT15, and LV16. The most likely reason of the underestimation of observed level of concentrations can be connected with the uncertainties in spatial distribution and seasonal variations of lead emissions, the influence of local sources, and differences between precipitation amount observed at the sites and used in modelling. Comparison of monthly variations of calculated and measured lead concentrations at stations listed above is presented in Figures 5.7 – 5.26.

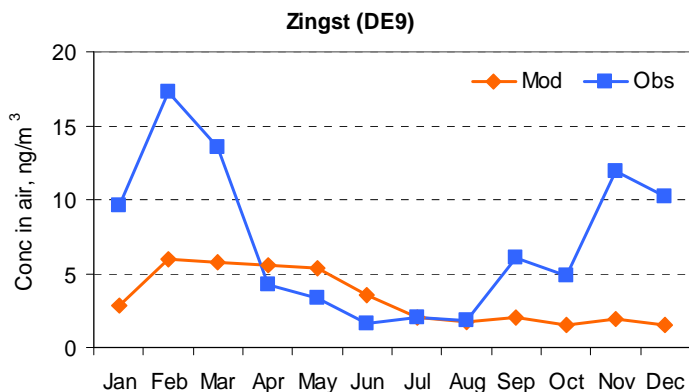


Figure 5.7. Comparison of calculated mean monthly lead concentrations in air with measured at station Zingst (DE9). Units: ng / m³.

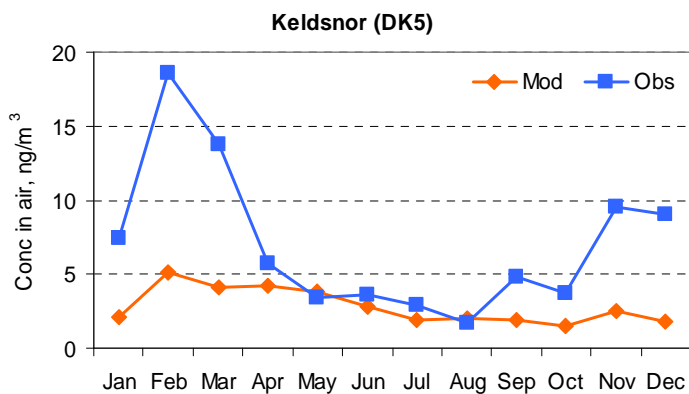


Figure 5.8. Comparison of calculated mean monthly lead concentrations in air with measured at station Keldsnor (DK5). Units: ng / m³.

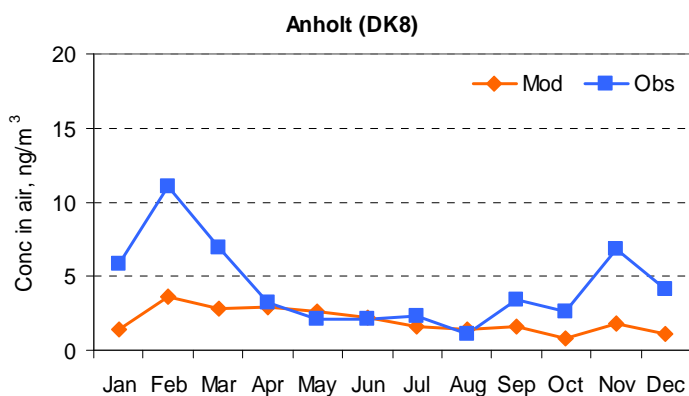


Figure 5.9. Comparison of calculated mean monthly lead concentrations in air with measured at station Anholt (DK8). Units: ng / m³.

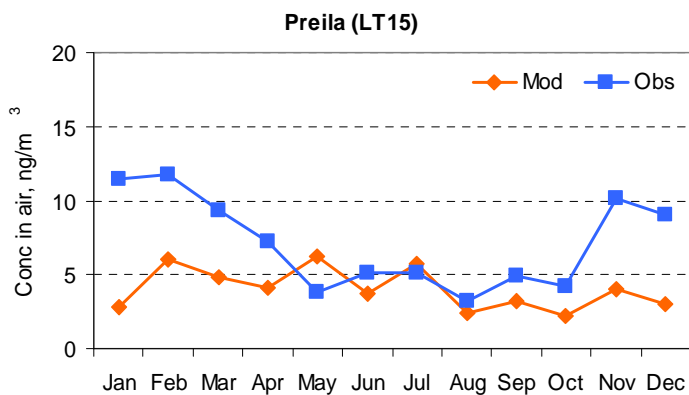


Figure 5.10. Comparison of calculated mean monthly lead concentrations in air with measured at station Preila (LT15). Units: ng / m³.

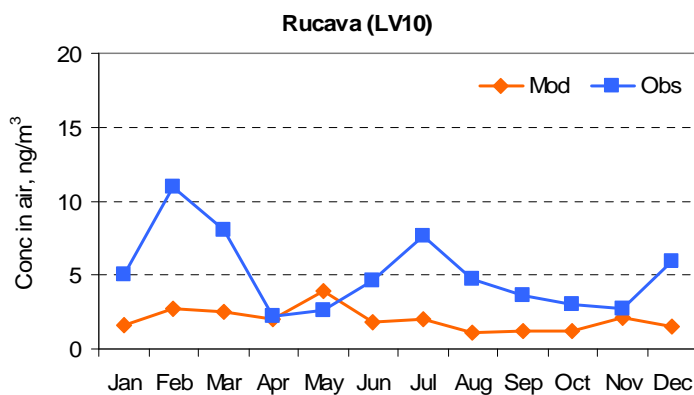


Figure 5.11. Comparison of calculated mean monthly lead concentrations in air with measured at station Rucava (LV10). Units: ng / m³.

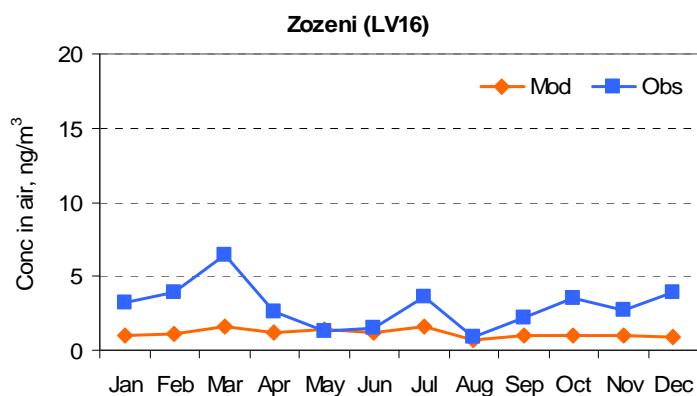


Figure 5.12. Comparison of calculated mean monthly lead concentrations in air with measured at station Zoseni (LV16). Units: ng / m^3 .

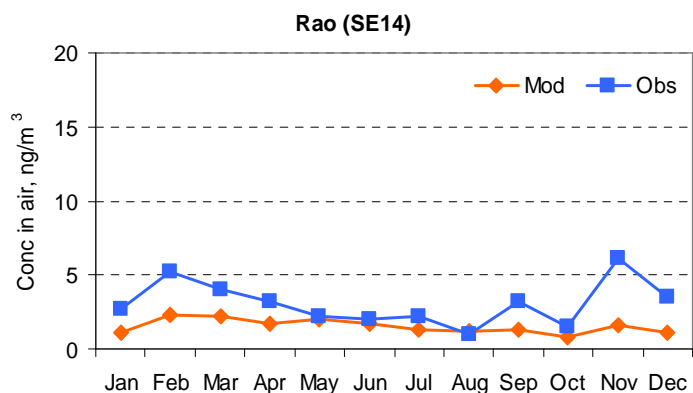


Figure 5.13. Comparison of calculated mean monthly lead concentrations in air with measured at station Rão (SE14). Units: ng / m^3 .

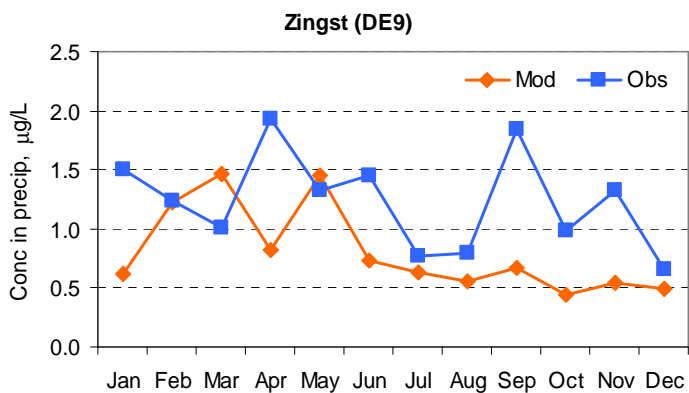


Figure 5.14. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Zingst (DE09). Units: $\mu\text{g} / \text{L}$.

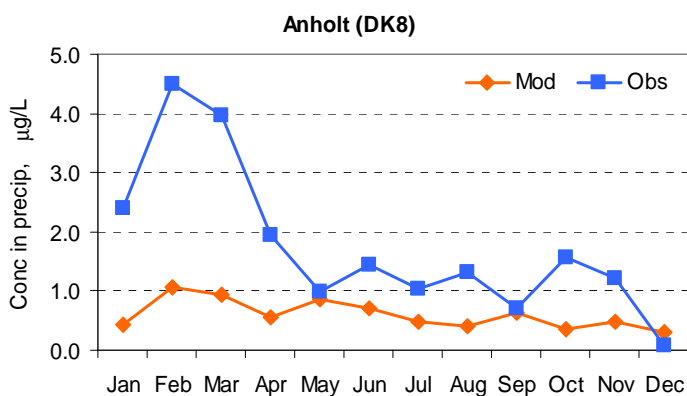


Figure 5.15. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Anholt (DK08). Units: $\mu\text{g} / \text{L}$.

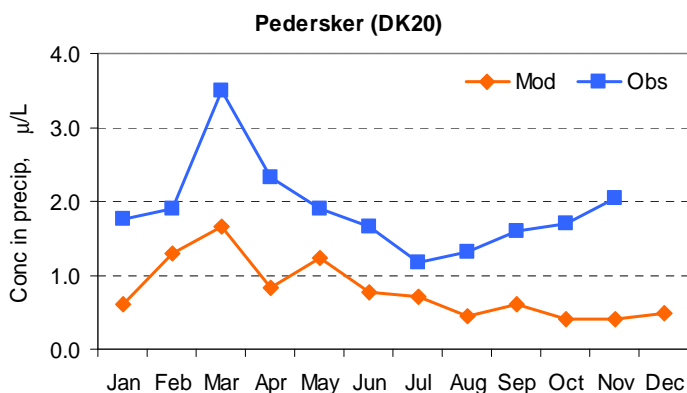


Figure 5.16. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Pedersker (DK20). Units: $\mu\text{g} / \text{L}$.

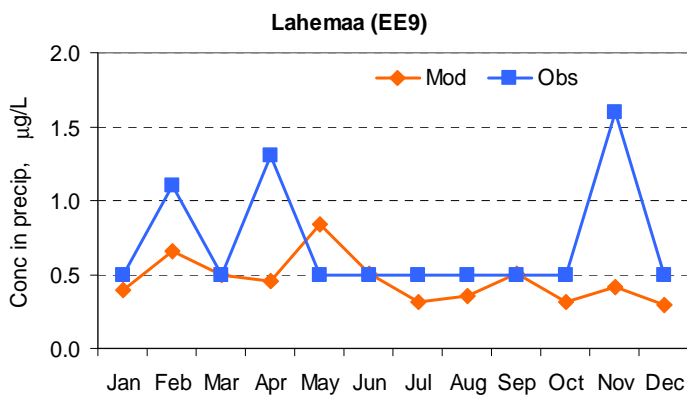


Figure 5.17. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Lahemaa (EE9). Units: $\mu\text{g} / \text{L}$.

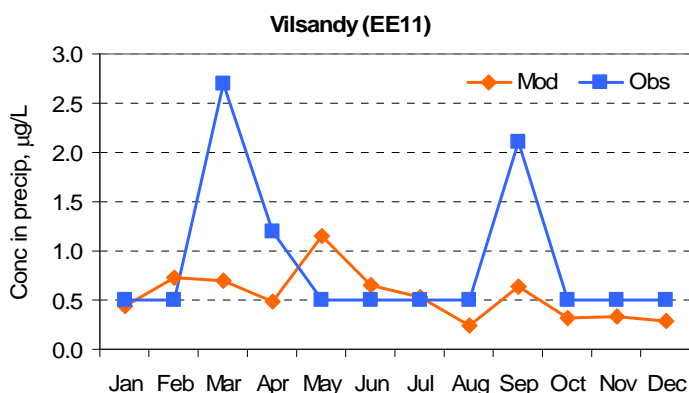


Figure 5.18. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Vilsandy (EE11). Units: $\mu\text{g} / \text{L}$.

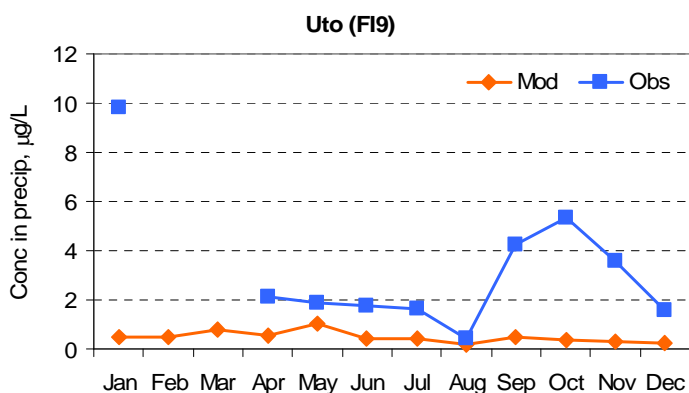


Figure 5.19. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Uto (FI9). Units: $\mu\text{g} / \text{L}$.

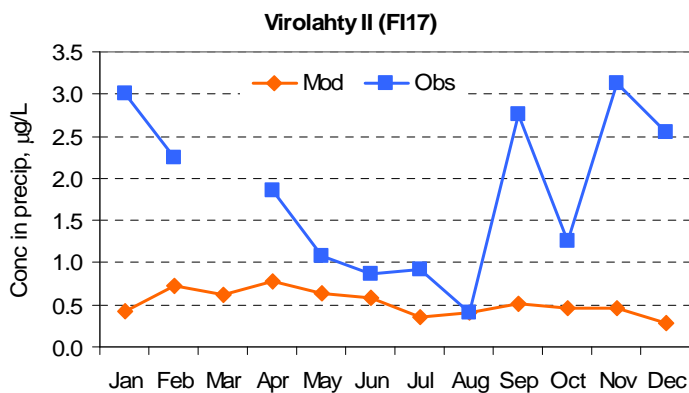


Figure 5.20. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Vilsandy (FI17). Units: $\mu\text{g} / \text{L}$.

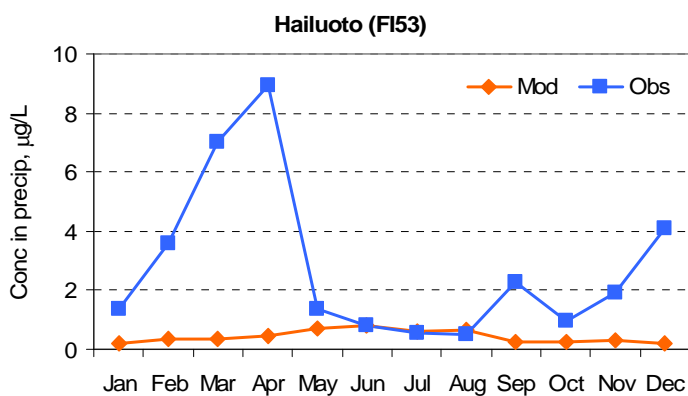


Figure 5.21. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Vilsandy (FI53). Units: $\mu\text{g} / \text{L}$.

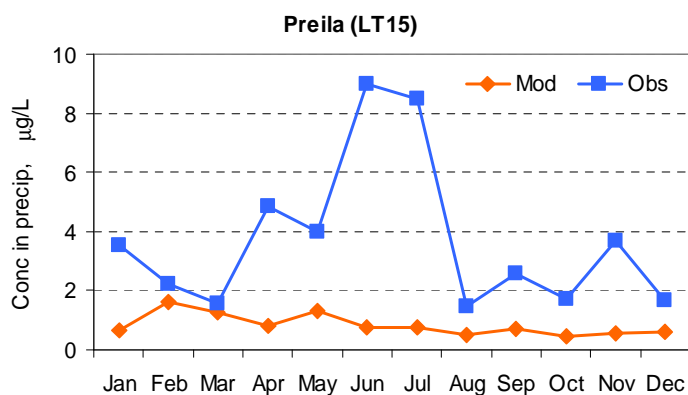


Figure 5.22. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Preila (LT15). Units: $\mu\text{g} / \text{L}$.

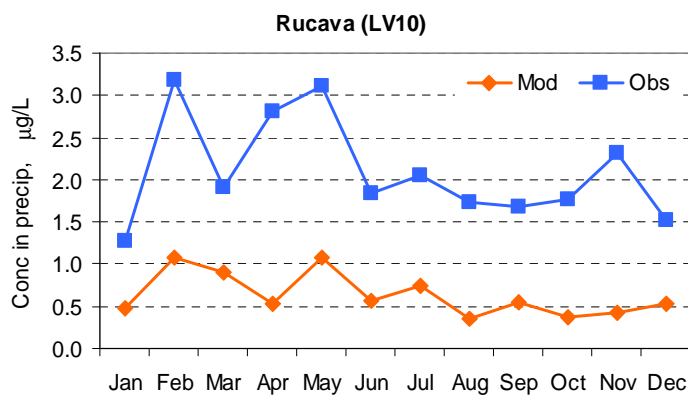


Figure 5.23. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Rucava (LV10). Units: $\mu\text{g} / \text{L}$.

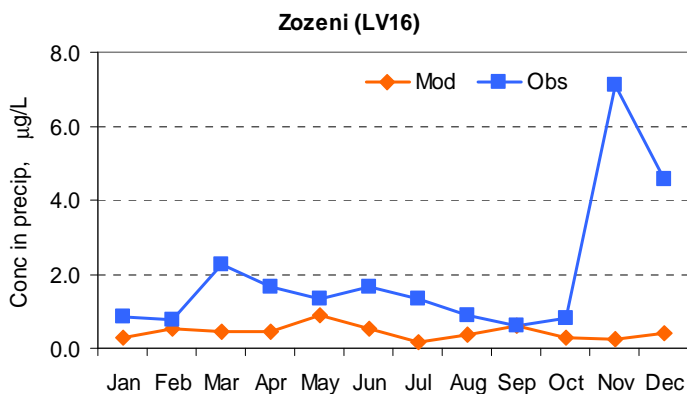


Figure 5.24. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Zozeni (LV16). Units: $\mu\text{g} / \text{L}$.

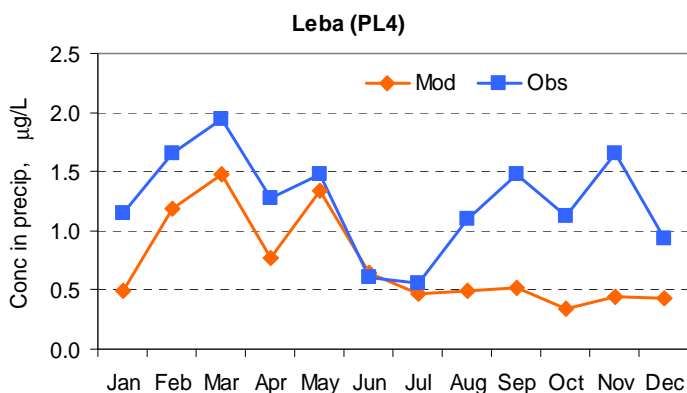


Figure 5.25. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Leba (PL04). Units: $\mu\text{g} / \text{L}$.

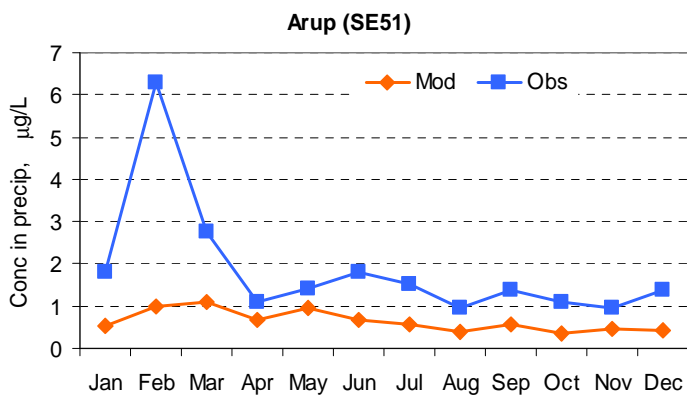


Figure 5.26. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Arup (SE51). Units: $\mu\text{g} / \text{L}$.

