4. Atmospheric Supply of Lead to the Baltic Sea in 2007

In this chapter the results of model evaluation of lead atmospheric input to the Baltic Sea and its sub-basins for 2007 is presented. Modelling of lead atmospheric transport and deposition 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 for 2007 was used in computations. Based on these data annual and monthly levels of lead deposition to the Baltic Sea region have been obtained and contributions of HELCOM countries emission sources to the deposition over the Baltic Sea are estimated. Model results were compared with observed levels of lead concentrations in air and precipitation measured at monitoring sites around the Baltic Sea in 2007.

4.1 Lead emissions

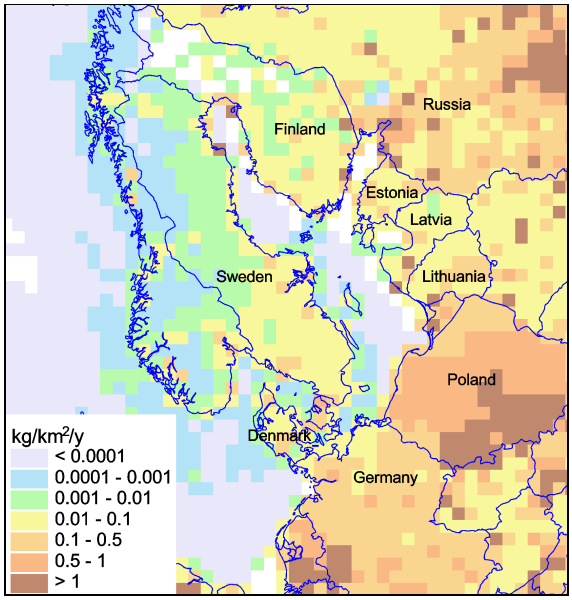


Figure 4.1. Annual total anthropogenic emissions of lead in the Baltic Sea region for 2007, kg/km^2/y.

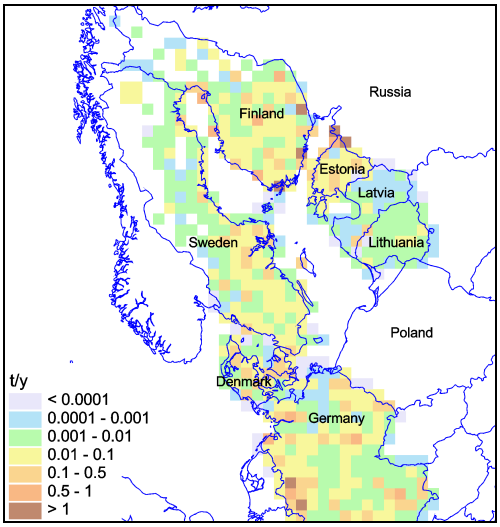


Figure 4.2. Annual lead emission from Combustion in Power Plants and Industry sector for 2007, t/y.

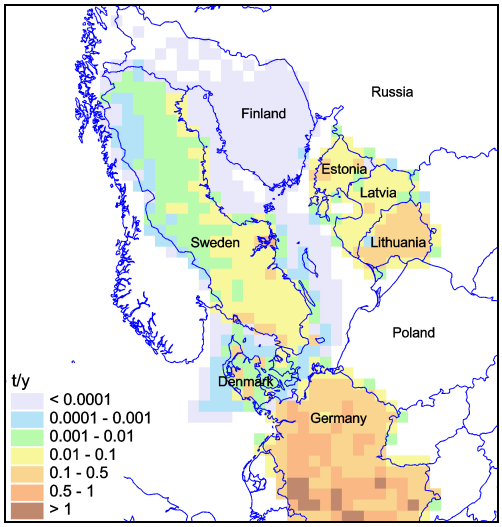


Figure 4.3. Annual lead emission from Transport sector for 2007, t/y.

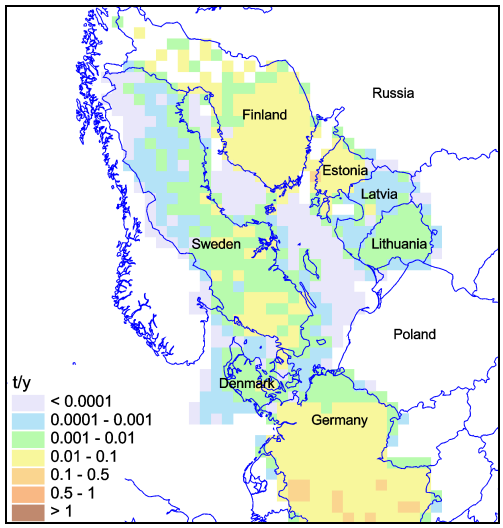


Figure 4.4. Annual lead emission from Commercial, Residential and Other Stationary Combustion sector for 2007, t/y.

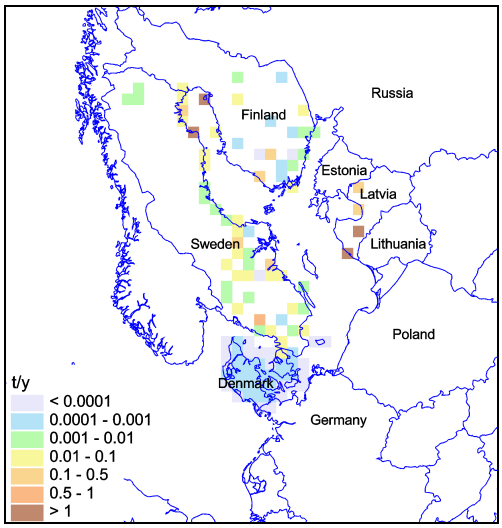


Figure 4.5. Annual lead emission from Industrial processes sector for 2007, t/y.

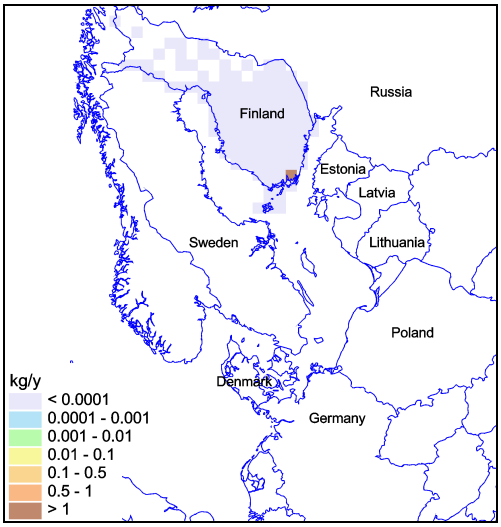


Figure 4.6. Annual lead emission from Solvent and Other Product Use sector in Finland for 2007, kg/y.

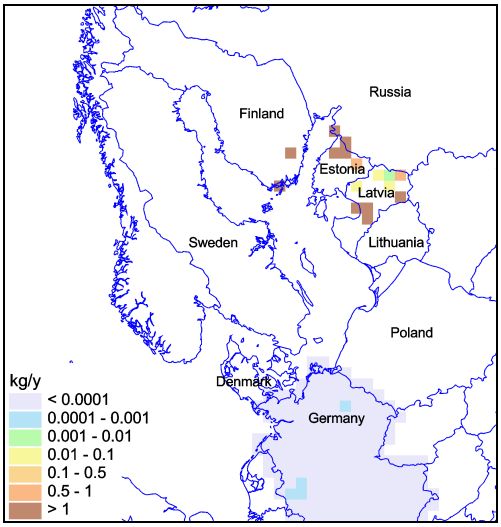


Figure 4.7. Annual lead emission from Waste sector for 2007, kg/y.

Table 4.1. Annual total lead anthropogenic emissions of HELCOM countries from different sectors for 2007, in tonnes per year

NFR emission sector	Sector name	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden
1	Combustion in Power Plants and Industry	4.4	37.4	15.2	14.6	0.082	0.6	325.7	355	4
2a	Transport above 1000m	0	NA	< 0.01	NE	NA	NA	NA	NA	NE
2b	Transport below 1000m	1.5	1.6	< 0.01	82.9	1.586	6.1	17.2		5.3
3	Commercial, Residential and Other Stationary Combustion	0.2	0.9	2.5	7.2	0.053	0.1	130.3		0.9
4	Fugitive Emissions From Fuels		NA					2.2		0.05
5	Industrial Processes	0.1	< 0.01	2.9	1.7	16.2		96.4		5.3
6	Solvent and Other Product Use	NA	NA	0.01				NA		
7	Agriculture							NA		
8	Waste		0.2	0.01	> 0.01	0.031		1.4		
9	Other									
Total		**6.2**	**40.2**	**20.6**	**106.4**	**17.9**	**6.8**	**573.4**	**355**	**15.7**

NA not available
NE not estimated

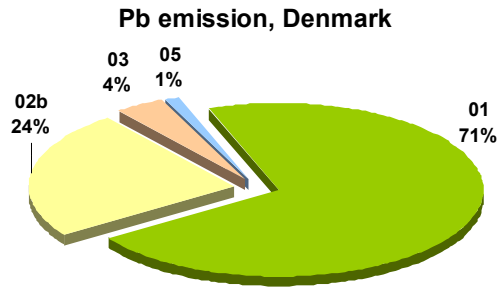


Figure 4.8. Contributions of different sector to total annual lead emission of Denmark in 2007.

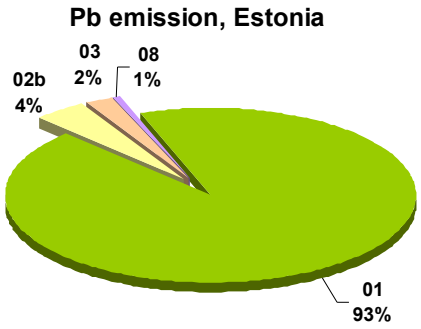


Figure 4.9. Contributions of different sector to total annual lead emission of Estonia in 2007.

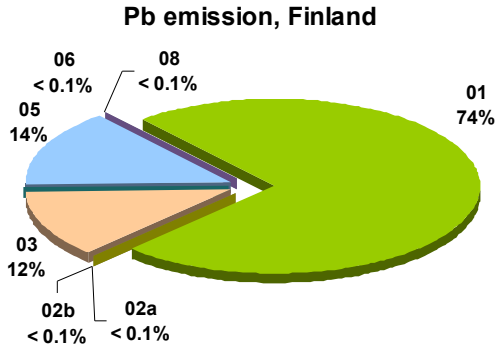


Figure 4.10. Contributions of different sector to total annual lead emission of Finland in 2007.

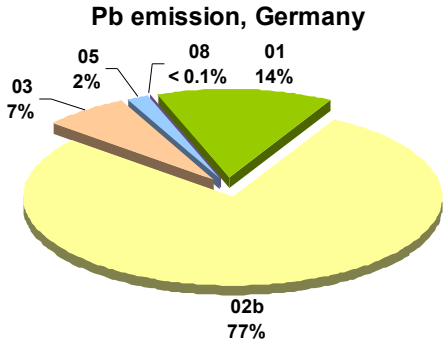


Figure 4.11. Contributions of different sector to total annual lead emission of Germany in 2007.

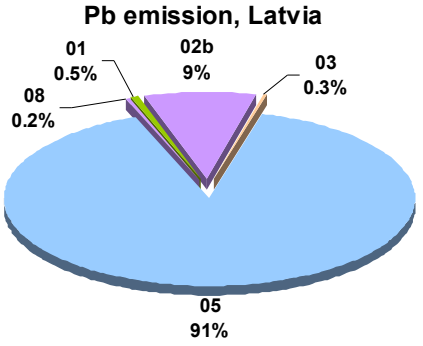


Figure 4.12. Contributions of different sector to total annual lead emission of Latvia in 2007.

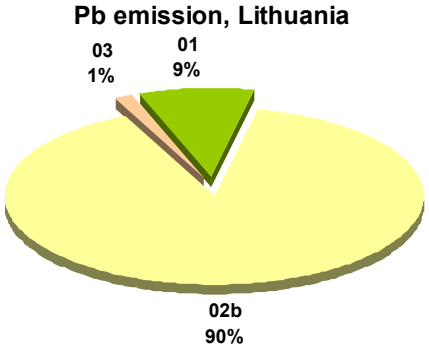


Figure 4.13. Contributions of different sector to total annual lead emission of Lithuania in 2007.

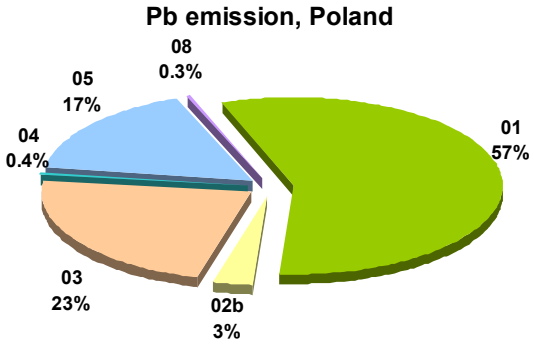


Figure 4.14. Contributions of different sector to total annual lead emission of Poland in 2007.

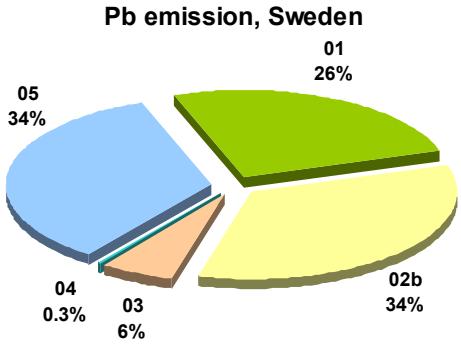
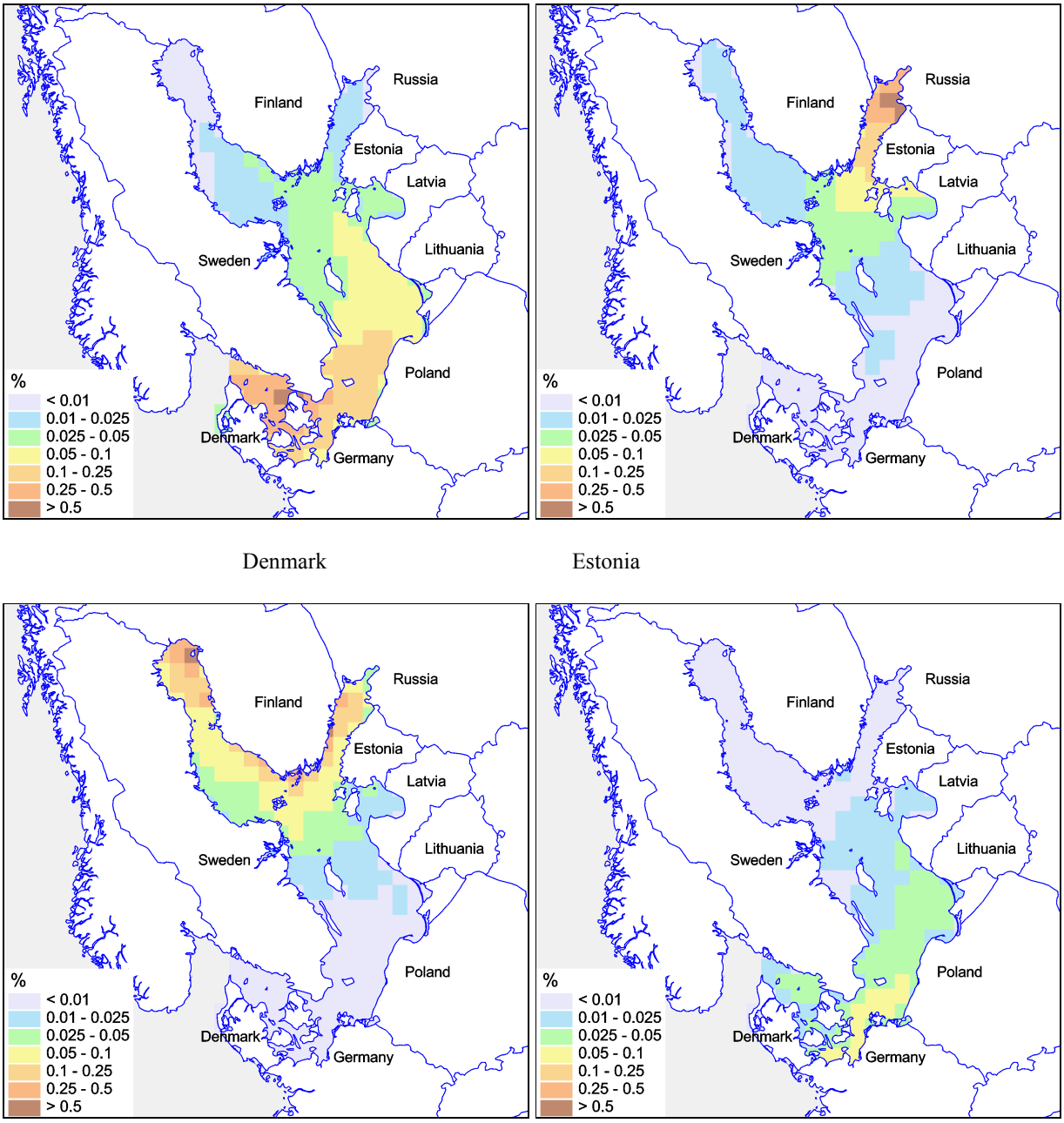


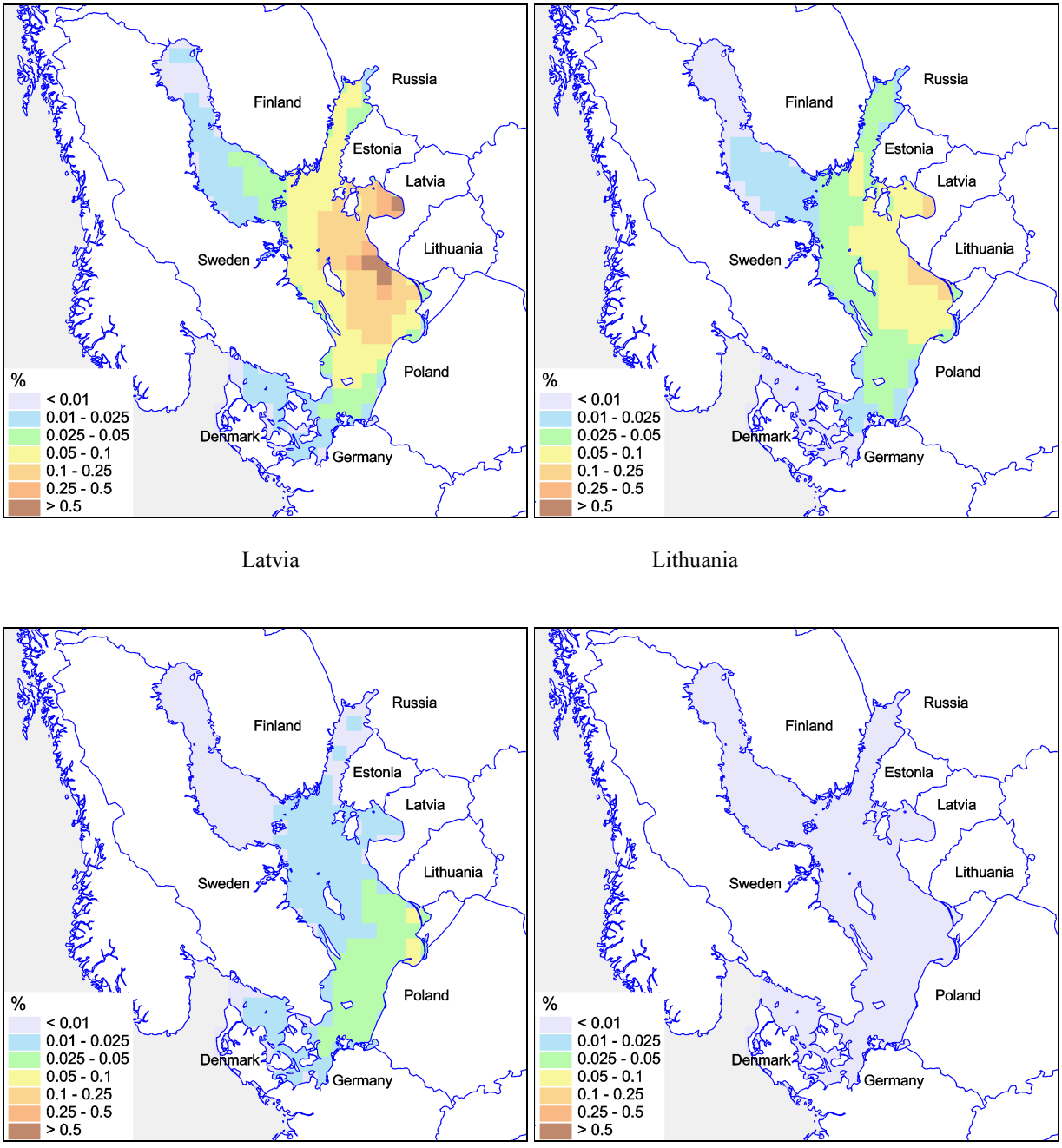
Figure 4.15. Contributions of different sector to total annual lead emission of Sweden in 2007.



Denmark Estonia

Finland Germany

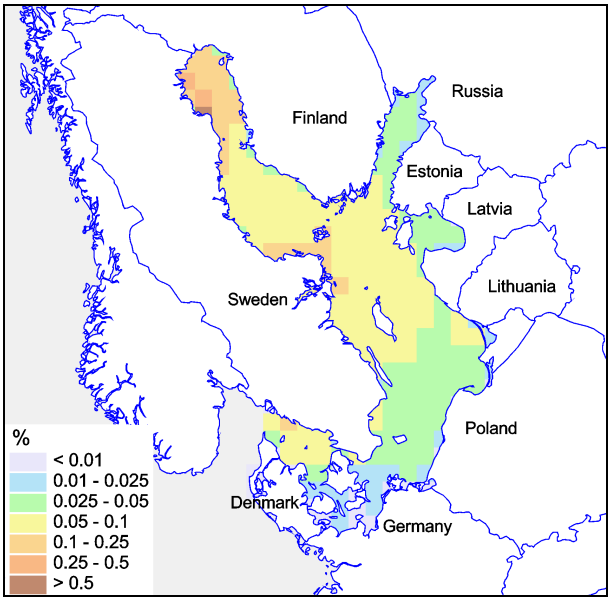
Figure 4.16. Maps with the contributions of annual total anthropogenic lead emissions from HELCOM Parties to total lead deposition over the Baltic Sea in 2007 (fraction of total deposition in % over the 50x50 km grid cell).



Latvia Lithuania

Poland Russia

Figure 4.16. **(cont.)** Maps with the contributions of annual total anthropogenic lead emissions from HELCOM Parties to total lead deposition over the Baltic Sea in 2007 (fraction of total deposition in % over the 50x50 km grid cell).



Sweden

Figure 4.16. **(cont.)** Maps with the contributions of annual total anthropogenic lead emissions from HELCOM Parties to total lead deposition over the Baltic Sea in 2007 (fraction of total deposition in % over the 50x50 km grid cell).

Table 4.2. Annual total anthropogenic emissions of lead of HELCOM countries and other EMEP countries in period 1990-2007, tonnes (Expert estimates of emissions are shaded)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	120	97	88	47	12	12	10	7.7	7.0	7.1	6.8	6.1	5.3	5.0	5.3	5.7	6.1	6.2
Estonia	201	185	121	101	124	84	65	52	46	44	37	34	34	39	38	37	34	40
Finland	327	248	175	99	58	56	35	18	21	29	36	38	40	34	28	24	25	21
Germany	1801	1055	761	606	405	331	221	95	93	94	101	104	105	105	104	104	106	106
Latvia	23	19	12	9.9	12	10	12	13	15	14	13	14	14	15	15	15	17	18
Lithuania	47	49	32	28	33	30	18	20	22	19	16	15	15	15	5.2	5.7	6.0	6.8
Poland	1372	1336	986	997	966	937	960	896	736	745	647	610	588	596	600	536	524	573
Russia	3591	3553	3095	3276	2643	2426	2304	2247	2262	2339	2352	2235	2118	2207	330	355	355	355
Sweden	361	317	296	144	51	36	33	33	32	29	26	23	20	19	18	15	14	16
HELCOM	**7843**	**6858**	**5566**	**5307**	**4304**	**3922**	**3658**	**3381**	**3234**	**3321**	**3236**	**3080**	**2940**	**3035**	**1144**	**1096**	**1086**	**1142**
Albania	33	34	35	36	37	38	39	40	41	42	43	39	35	32	28	24	20	16
Armenia	11	0.820	0.610	0.790	0.340	0.334	0.009	0.009	0.010	0.005	0.005	0.503	1.0	2.5	2.5	2.5	2.5	2.5
Austria	207	172	120	86	60	16	15	14	13	13	12	12	13	13	14	14	15	15
Azerbaijan	12	12	12	12	12	12	12	12	12	12	12	13	13	13	13	14	14	14
Belarus	794	519	450	377	348	147	46	42	41	38	46	41	44	43	45	50	57	59
Belgium	437	405	386	310	249	237	238	253	174	141	104	87	81	77	86	76	71	60
Bosnia and Herzegovina	97	97	97	97	97	97	97	97	97	97	97	91	85	79	72	66	60	54
Bulgaria	436	408	381	353	325	297	279	231	251	224	213	177	105	148	143	115	124	263
Croatia	430	397	364	331	297	264	268	190	183	178	147	107	60	23	16	12	9.1	9.2
Cyprus	16	16	14	14	14	13	12	12	13	11	10	10	9	9	9.1	9.1	8.7	8.6
Czech Republic	269	240	247	232	202	180	165	180	169	157	108	47	47	39	37	47	43	40
France	4258	2852	2070	1813	1609	1434	1263	1112	995	758	239	203	197	144	127	123	115	108
Georgia	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	7.0	7.2	7.3	7.5	7.6	7.8	8.0
Greece	505	499	493	488	482	476	470	470	470	470	470	470	470	470	470	470	470	470
Hungary	658	488	208	187	155	129	100	90	82	34	35	34	35	33	36	37	37	35
Iceland	6.4	5.8	5.1	4.5	3.9	3.3	2.7	2.1	1.4	0.816	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197
Ireland	125	111	117	101	88	76	63	66	42	39	29	16	15	15	15	15	15	15
Italy	4372	3332	2460	2272	2096	1988	1874	1692	1548	1380	936	703	237	242	256	266	274	274
Luxembourg	77	71	65	59	53	30	26	18	6.8	2.3	1.8	2.0	1.9	1.9	1.9	1.9	1.9	1.9
Malta	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.8	0.8	0.8	0.8	0.8	0.8
Monaco	3.9	4.0	4.1	3.7	2.1	0.780	0.673	0.564	0.486	0.427	0.059	0.063	0.056	0.046	0.041	0.041	0.030	0.041
Netherlands	338	283	241	216	188	162	112	63	52	44	36	41	45	41	43	39	39	39
Norway	186	143	127	87	24	22	10	10	10	9	7.6	6.8	7.1	7.2	7.7	6.3	6.2	6.7
Portugal	572	589	632	612	583	561	542	521	509	342	144	160	162	166	167	158	153	149
Republic of Moldova	249	220	103	71	23	34	28	22	7.9	11	2.8	3.4	3.3	11	2.3	5.1	5.0	5.0
Romania	585	573	561	550	538	526	514	502	491	420	402	476	398	319	241	162	118	77
Serbia and Montenegro	597	567	538	508	478	448	419	389	359	329	300	275	250	225	200	176	151	126
Slovakia	150	149	148	116	84	71	73	73	70	58	67	68	69	64	70	71	73	65
Slovenia	325	290	286	305	304	193	79	69	53	46	40	24	14	14	14	13	14	14
Spain	2682	1810	1221	1116	1104	933	903	840	780	710	589	390	269	265	260	268	271	272
Switzerland	419	379	333	280	248	186	157	138	119	54	32	28	25	22	21	21	20	20
The FYR of Macedonia	210	198	185	173	161	148	136	124	112	99	87	83	79	74	70	66	62	58
Turkey	765	765	765	765	765	765	765	765	765	765	765	717	669	620	572	524	476	428
Ukraine	3878	3586	3293	3001	2709	2417	2124	1832	1540	1248	955	663	145	123	195	304	297	309
United Kingdom	2893	2639	2417	2143	1841	1531	1297	1134	832	478	150	142	131	116	118	109	82	70
EMEP	**34447**	**28720**	**23952**	**22033**	**19493**	**17367**	**15797**	**14392**	**13080**	**11539**	**9325**	**8214**	**6661**	**6495**	**4506**	**4369**	**4198**	**4235**

Expert estimates:

§ *Denier van der Gon, H.A.C., M. van het Bolscher A.J.H. Visschedijk P.Y.J. Zandveld [2006]*

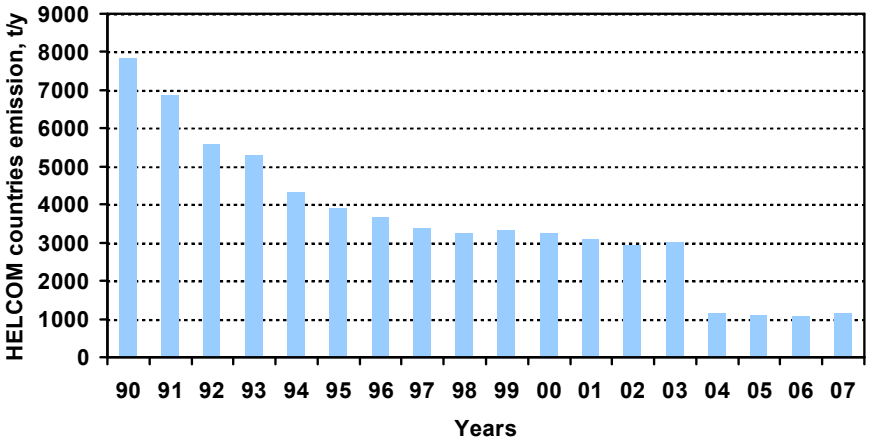


Figure 4.17. Time-series of total annual lead emissions of HELCOM countries in 1990-2007, tonnes/y.

4.2 Annual total deposition of lead

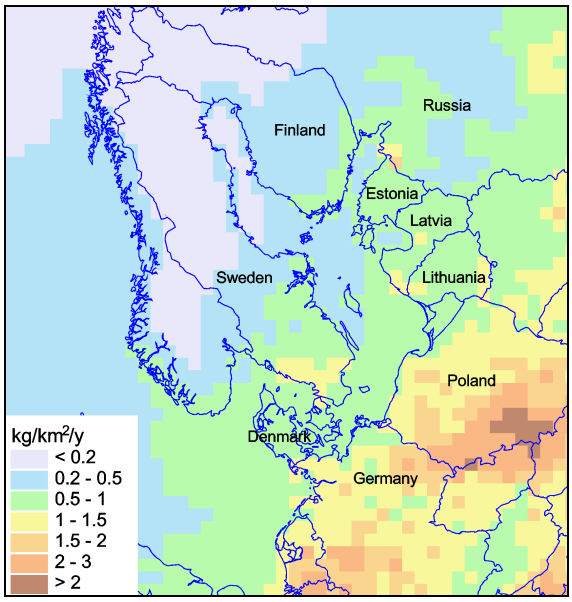


Figure 4.18. Annual total deposition fluxes of lead over the Baltic Sea region for 2007, kg/km^2/year.

4.3 Monthly total deposition of lead

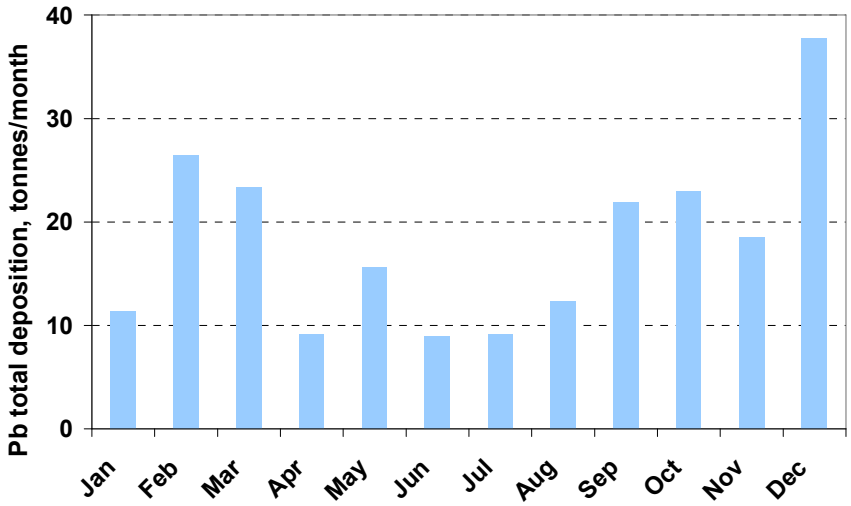


Figure 4.19. Monthly total deposition of lead to the Baltic Sea for 2007, tonnes/month.

Table 4.3. Monthly total deposition of lead to the Baltic Sea for 2007, tonnes/month.

Month	Deposition
Jan	11
Feb	26
Mar	23
Apr	9
May	16
Jun	9
Jul	9
Aug	12
Sep	22
Oct	23
Nov	19
Dec	38

4.4 Source allocation of lead deposition

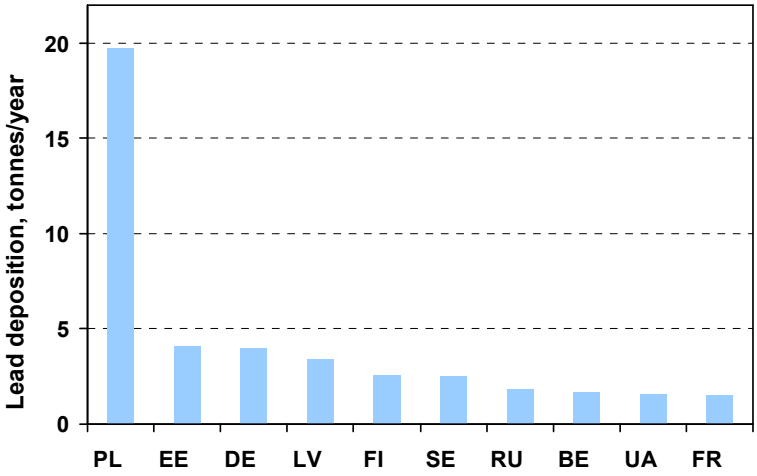


Figure 4.20. Top ten countries with the highest contribution to annual total deposition of lead into the Baltic Sea for 2007, tonnes/year.

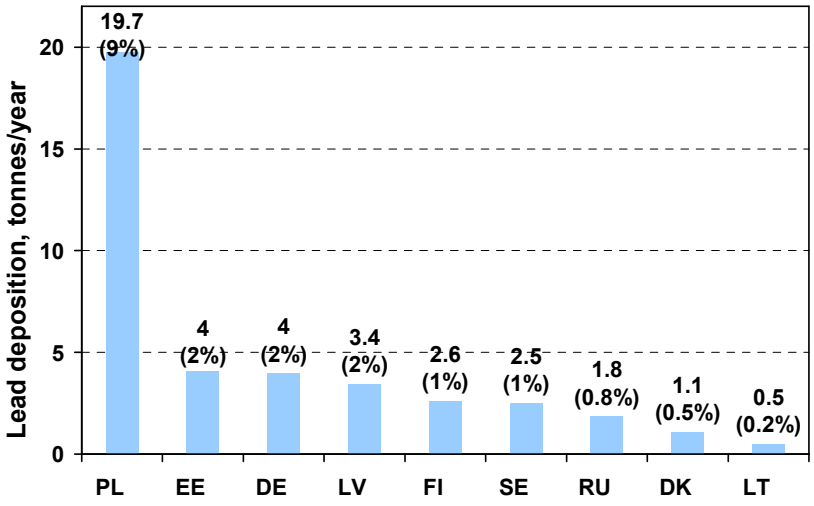


Figure 4.21. Sorted contributions (in %) of HELCOM countries to total deposition to the Baltic Sea for 2007. HELCOM countries emissions of lead contributed about 18% to the total annual lead deposition over the Baltic Sea in 2007. Contribution of other EMEP countries accounted for 8%. Significant contribution was made by other emission sources, in particular, remote emissions sources, natural emissions and re-emission of lead (74%).

Table 4.4. Two most significant contributors to the annual total deposition of lead to the six Baltic Sea sub-basins for 2007.

Sub-basin	Country	%	Country	%	*, %
GUB	Poland	6	Finland	6	72
GUF	Estonia	16	Poland	5	62
GUR	Poland	8	Latvia	5	72
BAP	Poland	11	Germany	2	73
BES	Poland	6	Germany	3	80
KAT	Poland	4	Germany	2	83
BAS	Poland	9	Germany	2	74

* - contribution of re-emission, natural and remote sources.

4.5 Comparison of model results with measurements

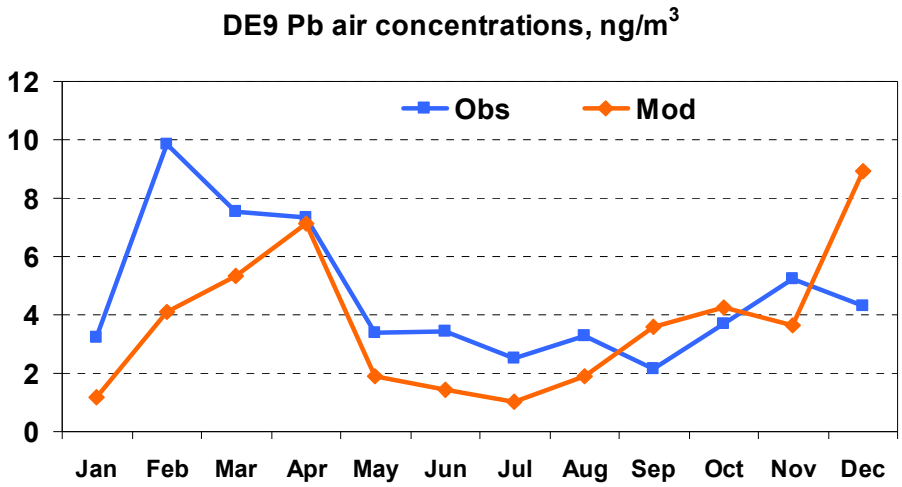


Figure 4.22. Comparison of calculated mean monthly lead concentrations in air for 2007 with measurements of the station Zingst (DE9). Units: ng / m^3.

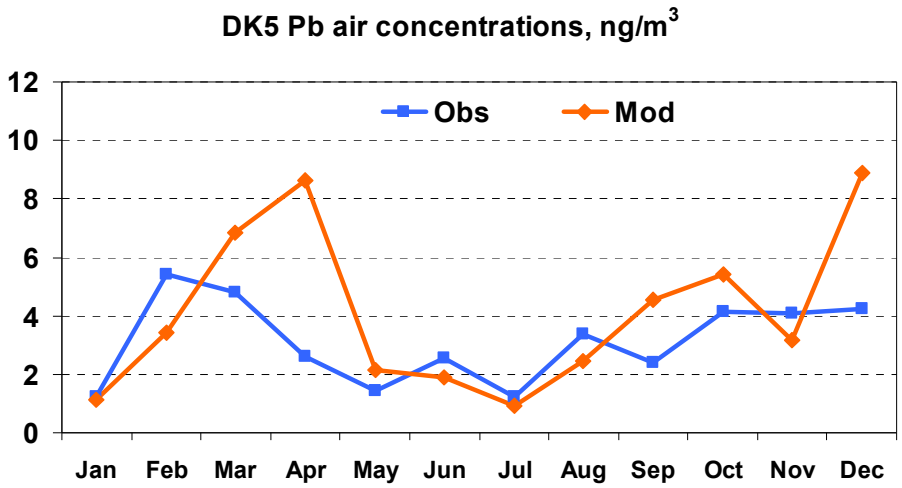


Figure 4.23. Comparison of calculated mean monthly lead concentrations in air for 2007 with measurements of the station Keldsnor (DK5). Units: ng / m^3.

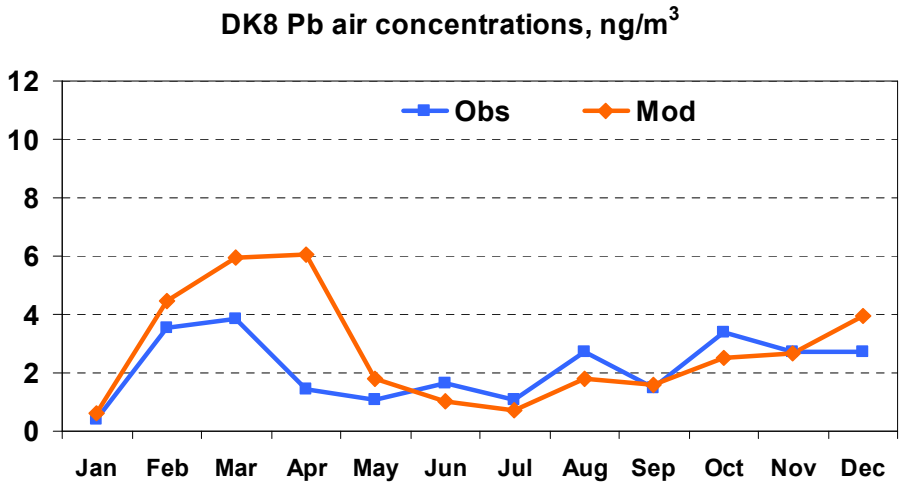


Figure 4.24. Comparison of calculated mean monthly lead concentrations in air for 2007 with measurements of the station Anholt (DK8). Units: ng / m^3.

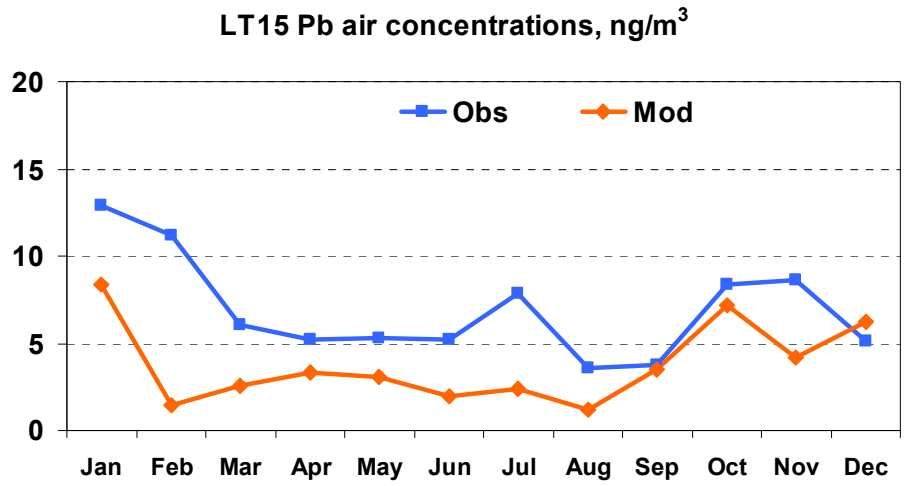


Figure 4.25. Comparison of calculated mean monthly lead concentrations in air for 2007 with measurements of the station Preila (LT15). Units: ng / m^3.

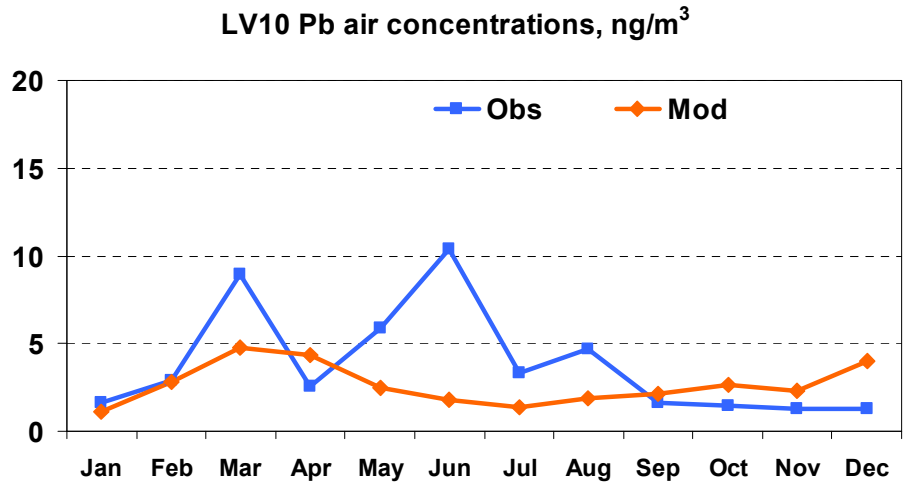


Figure 4.26. Comparison of calculated mean monthly lead concentrations in air for 2007 with measurements of the station Rucava (LV10). Units: ng / m^3.

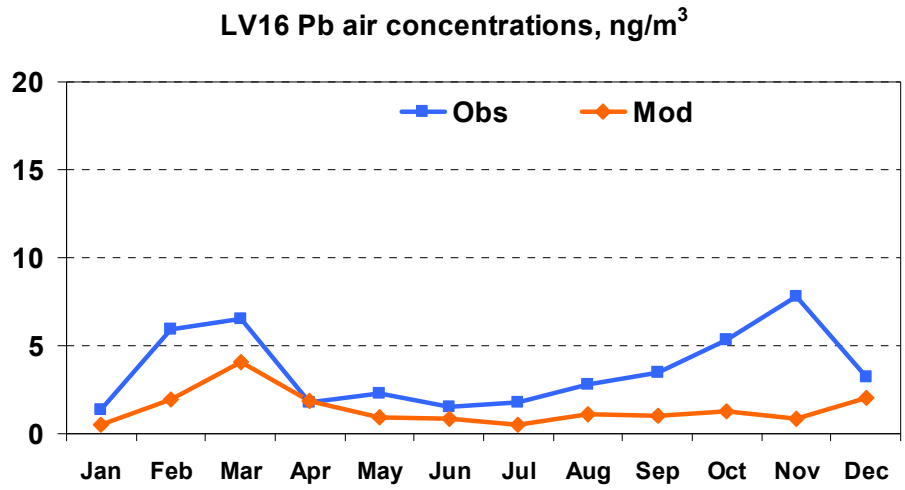


Figure 4.27. Comparison of calculated mean monthly lead concentrations in air for 2007 with measurements of the station Zoseni (LV16). Units: ng / m^3.

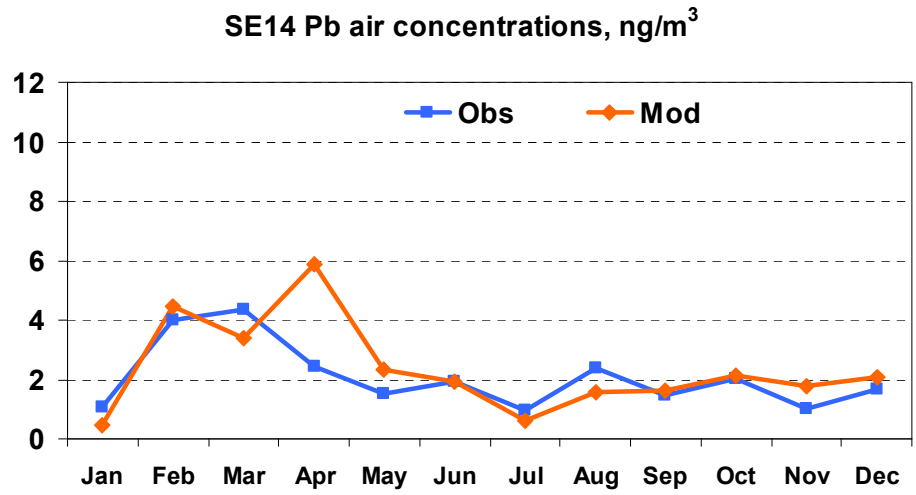


Figure 4.28. Comparison of calculated mean monthly lead concentrations in air for 2007 with measurements of the station Räo (SE14). Units: ng / m^3.

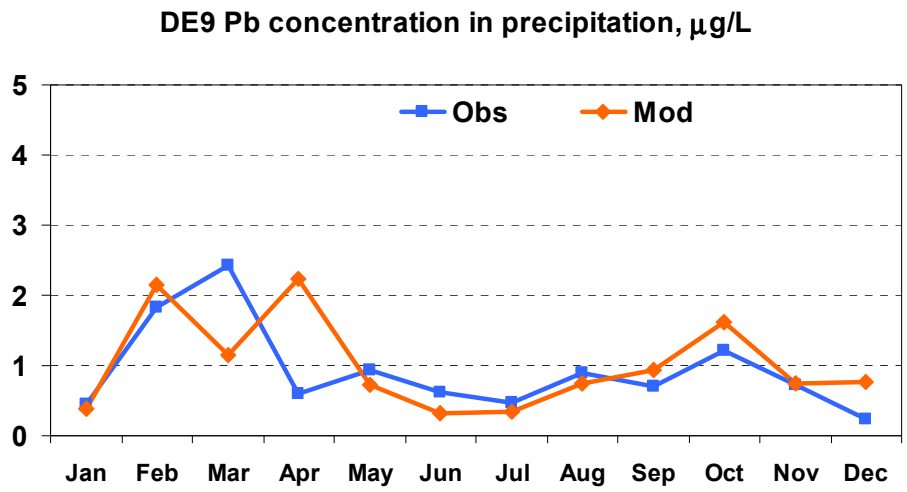


Figure 4.29. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Zingst (DE9). Units: µg / L.

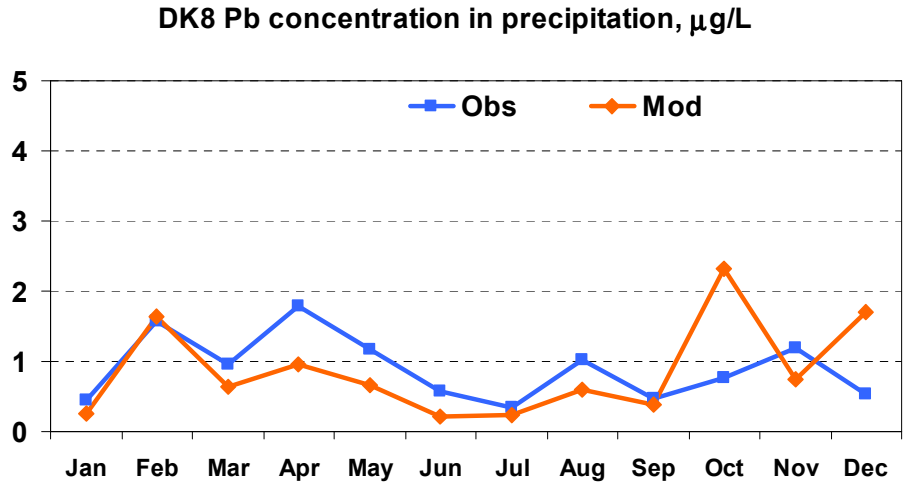


Figure 4.30. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Anholt (DK8). Units: µg / L.

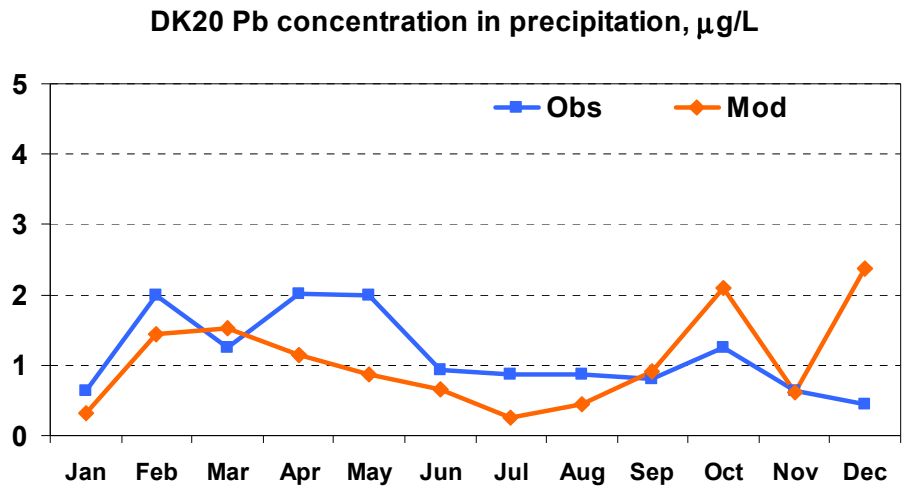


Figure 4.31. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Pedersker (DK20). Units: µg / L.

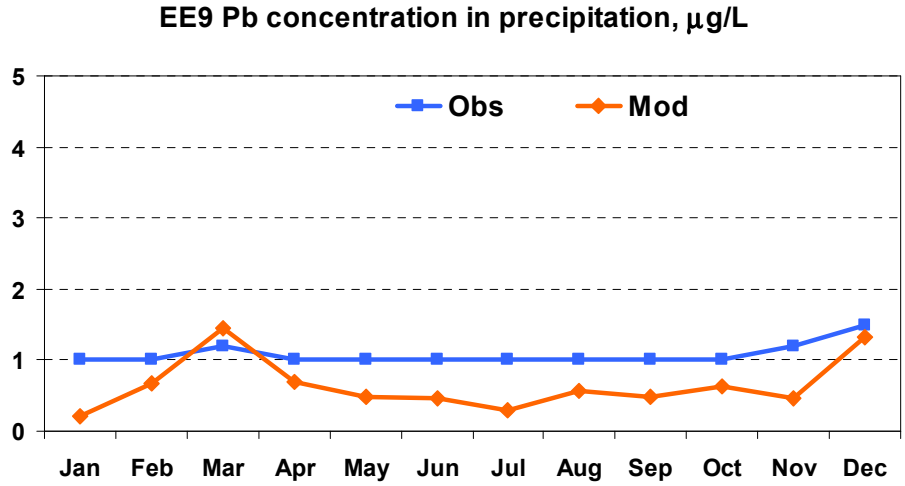


Figure 4.32. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Lahemaa (EE9). Units: µg / L.

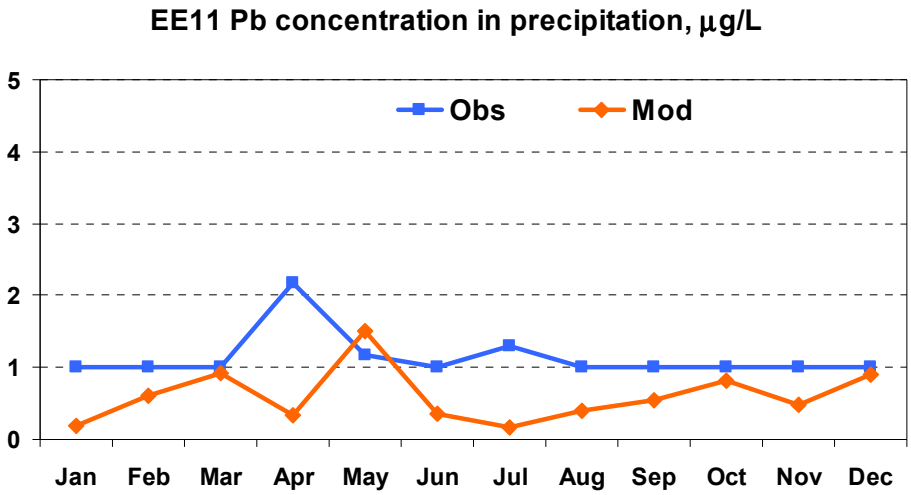


Figure 4.33. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Vilsandi (EE11). Units: µg / L.

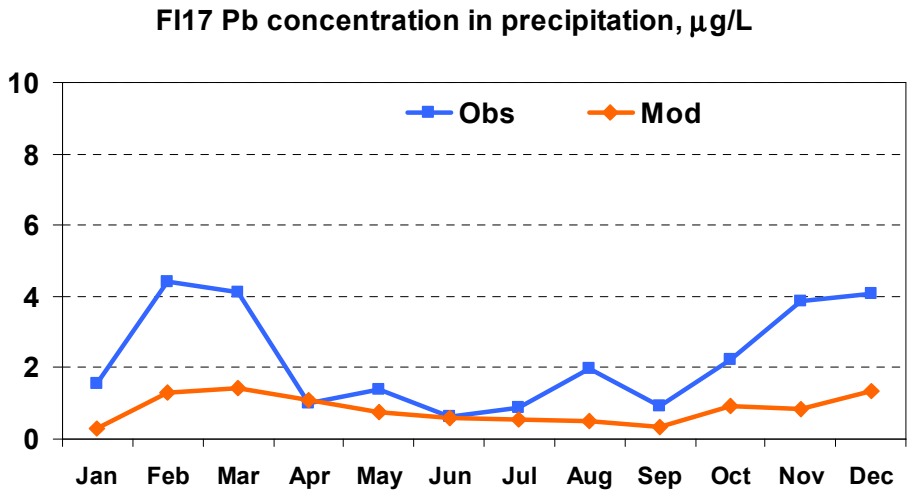


Figure 4.34. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Virolahty II (FI17). Units: µg / L.

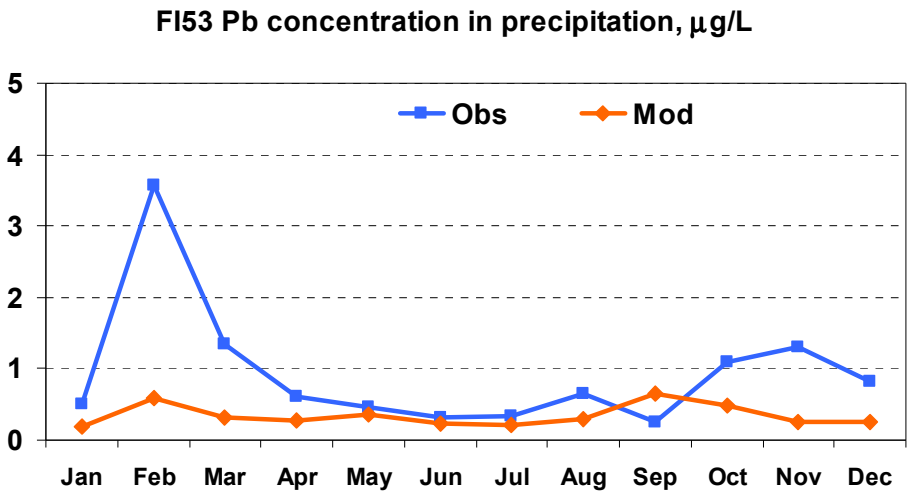


Figure 4.35. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Hailuoto (FI53). Units: µg / L.

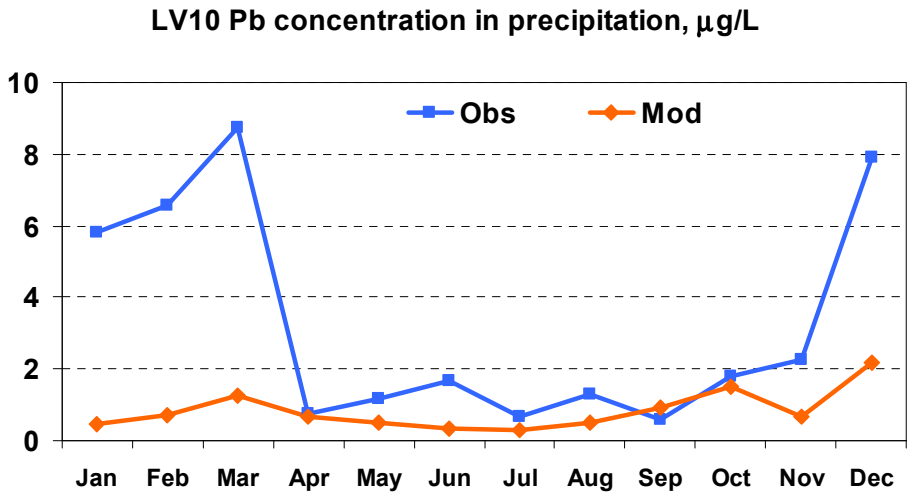


Figure 4.36. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Rucava (LV10). Units: µg / L.

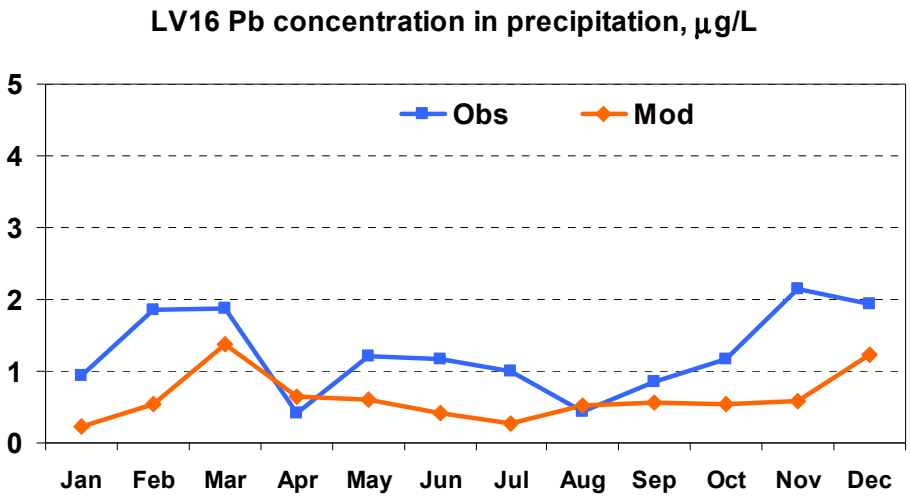


Figure 4.37. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Zoseni (LV16). Units: µg / L.

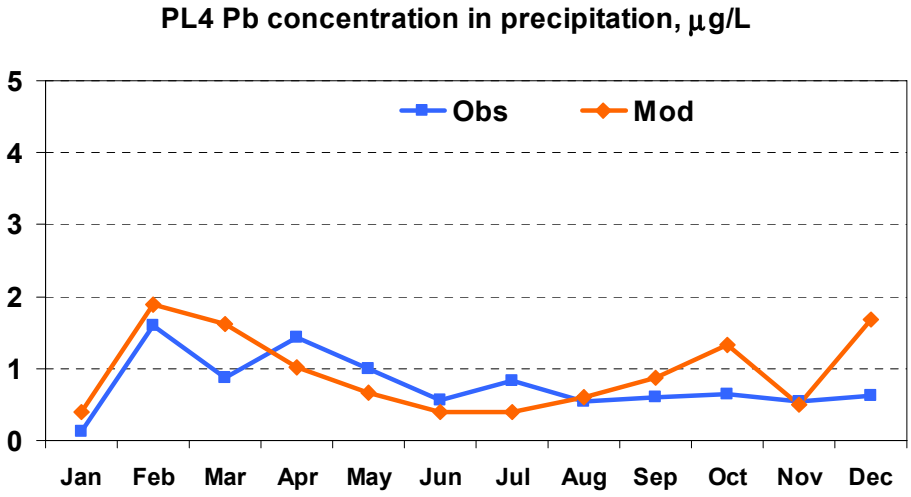


Figure 4.38. Comparison of calculated mean monthly lead concentrations in precipitation for 2007 with measurements of the station Leba (PL4). Units: µg / L.

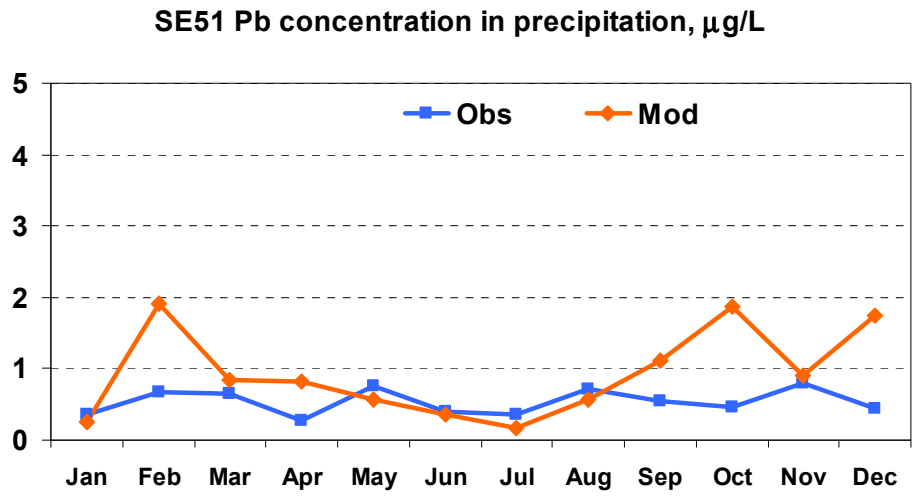


Figure 4.39. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Arup (SE51). Units: µg / L.

It can be seen that in general, computed concentrations of lead in air and in precipitation obtained for the selected monitoring sites around the Baltic Sea reasonably agree with the measured concentrations. Some deviations between simulated and observed monthly mean concentrations of lead can be connected with the uncertainties in seasonal variation of lead emission used in modeling, differences between measured precipitation amount and the one used in the model, and difficulties in measurements of heavy metals.

4.6 Conclusions for Chapter 4

- Emissions of lead from HELCOM countries have decreased from 1990 to 2007 by 85%. There is a slight increase of lead emission in HELCOM countries from 2006 to 2007 by 5%.

- Annual deposition of lead to the Baltic Sea has decreased from 1990 to 2007 by 69%. Level of lead deposition in 2007 was lower by 9% comparing to 2006.

- The contribution of anthropogenic sources of HELCOM countries to total lead deposition over the Baltic Sea was estimated to approximately 20%. Essential contribution belongs also to the anthropogenic sources of other EMEP countries, natural sources and resuspension.

- The most significant contribution to lead deposition over the Baltic Sea was made by Poland followed by Estonia.

- Modelling results for lead were within an accuracy of 60% in comparison with measurements made around the Baltic Sea in 2007.