5. Atmospheric Supply of Cadmium to the Baltic Sea in 2007

In this chapter the results of model evaluation of cadmium atmospheric input to the Baltic Sea and its sub-basins for 2007 is presented. Modelling of cadmium 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 cadmium emission from HELCOM countries and other European countries was used in computations. Based on these data annual and monthly levels of cadmium 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 cadmium concentrations in air and precipitation measured at monitoring sites around the Baltic Sea in 2007.

5.1 Cadmium emissions

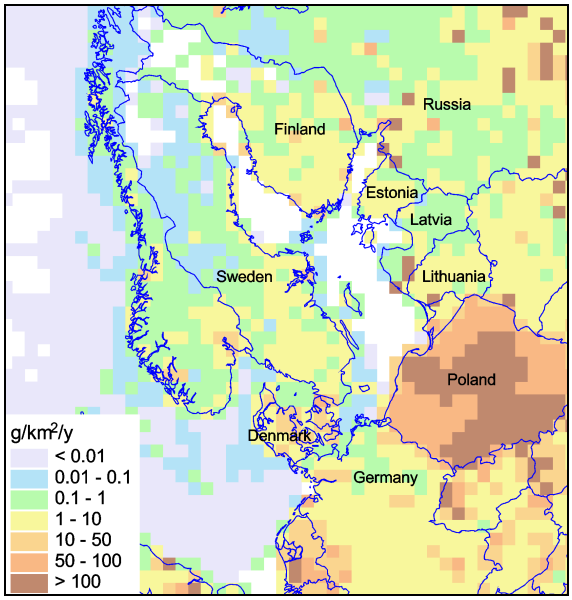


Figure 5.1. Annual total anthropogenic emissions of cadmium in the Baltic Sea region for 2007, g/km^2/y.

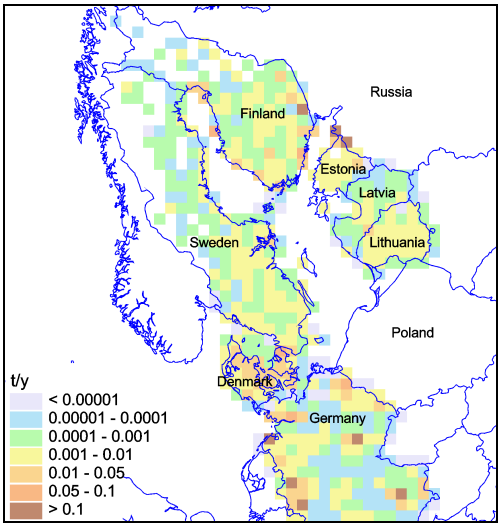


Figure 5.2. Annual cadmium emission from Combustion in Power Plants and Industry sector for 2007, t/y.

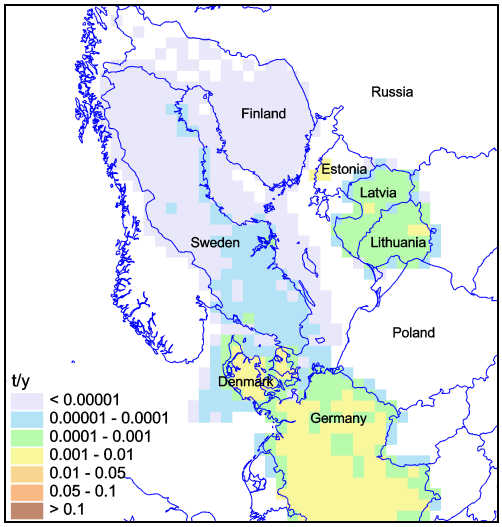


Figure 5.3. Annual cadmium emission from Transport sources below 1000 m sector for 2007, t/y.

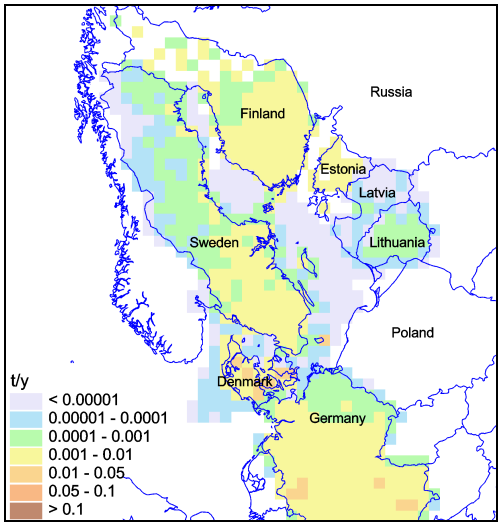


Figure 5.4. Annual cadmium emission from Commercial, Residential and Other Stationary Combustion sector for 2007, t/y.

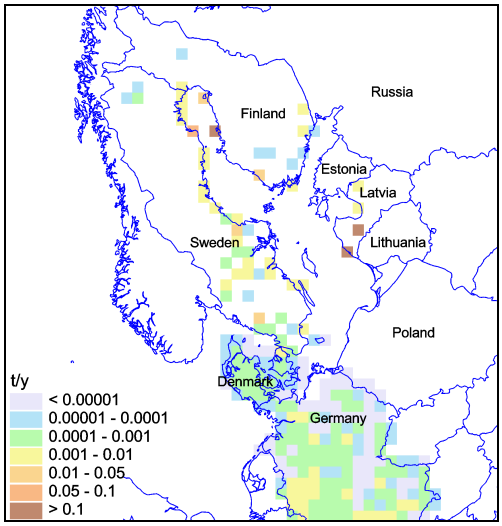


Figure 5.5. Annual cadmium emission from Industrial Processes sector for 2007, t/y.

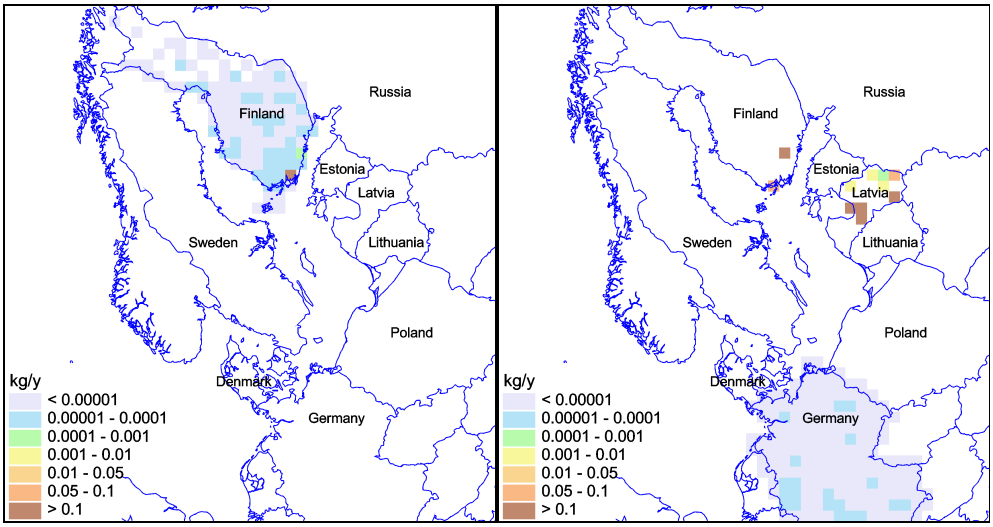


Figure 5.6. Annual cadmium emission from Solvent and Other Product Use sector for 2007, kg/y.

Figure 5.7. Annual cadmium emission from Waste sector for 2007, kg/y.

Table 5.1. Annual total anthropogenic emissions of cadmium 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	0.418	0.64	0.667	1.65	0.023	0.383	13.81	59.4	0.222
2a	Transport above 1000m	0.0002	NA	NA	NE	NA	NA	NA	NA	NE
2b	Transport below 1000m	0.045	0.01	< 0.001	0.30	0.012	0.018	0.313		0.004
3	Commercial, Residential and Other Stationary Combustion	0.279	0.03	0.249	0.5	0.001	0.003	22.54		0.176
4	Fugitive Emissions From Fuels		NA	NA				0.51		0.01
5	Industrial Processes	0.005	0	0.187	0.09	0.548		2.35		0.175
6	Solvent and Other Product Use	NA	NA	< 0.001				NA		
7	Agriculture							NA		
8	Waste		0	< 0.001	< 0.001	0.003		0.12		
9	Other									
Total		**0.75**	**0.68**	**1.1**	**2.54**	**0.59**	**0.40**	**39.65**	**59.4**	**0.58**

NA □not available
NE □not estimated

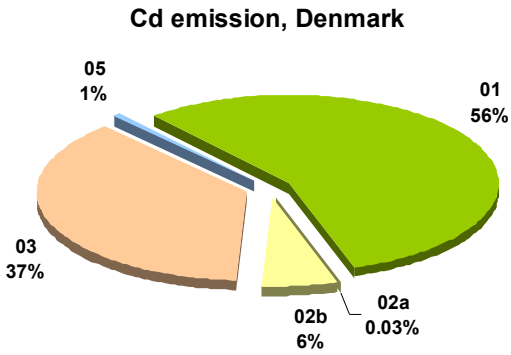


Figure 5.8. Contributions of different sector to total annual cadmium emission of Denmark in 2007.

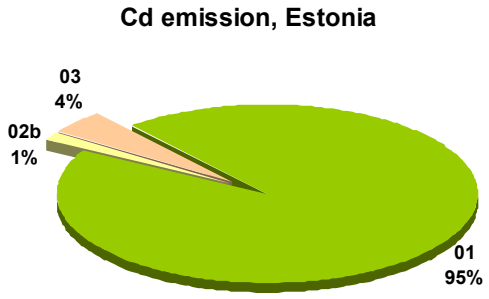


Figure 5.9. Contributions of different sector to total annual cadmium emission of Estonia in 2007.

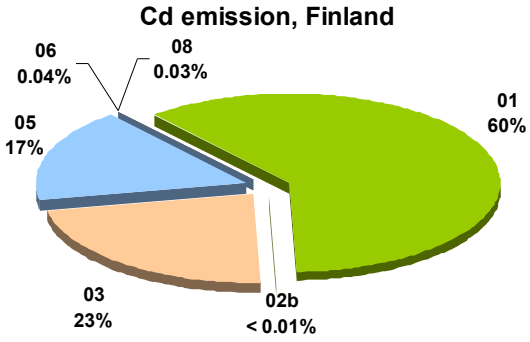


Figure 5.10. Contributions of different sector to total annual cadmium emission of Finland in 2007.

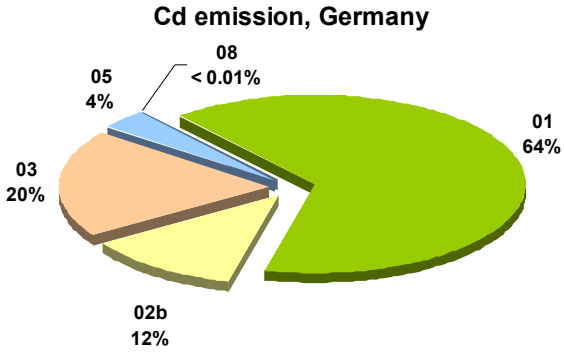


Figure 5.11. Contributions of different sector to total annual cadmium emission of Germany in 2007.

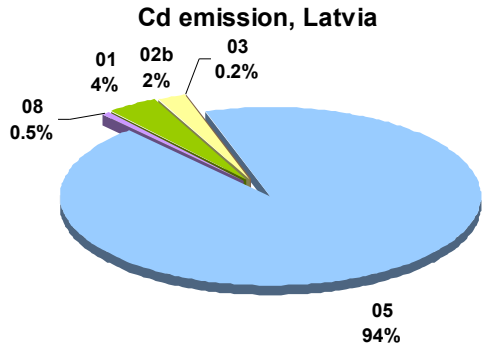


Figure 5.12. Contributions of different sector to total annual cadmium emission of Latvia in 2007.

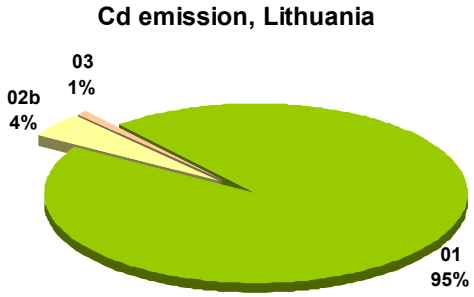


Figure 5.13. Contributions of different sector to total annual cadmium emission of Lithuania in 2007.

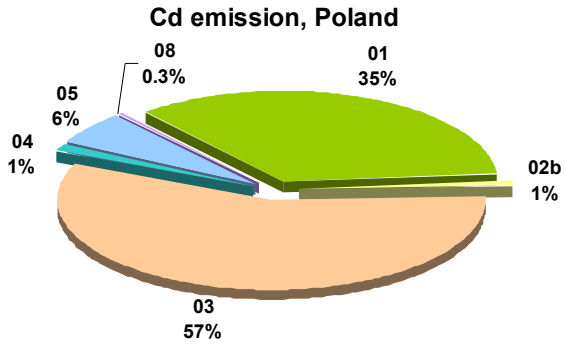


Figure 5.14. Contributions of different sector to total annual cadmium emission of Poland in 2007.

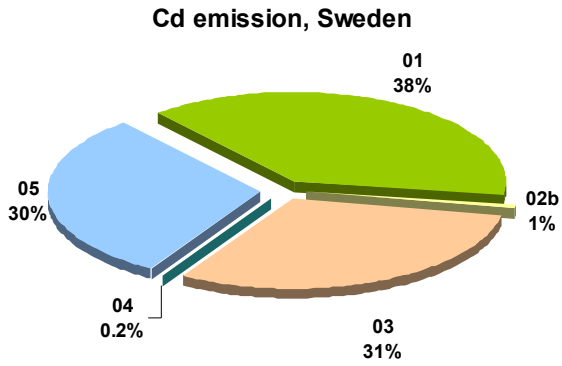
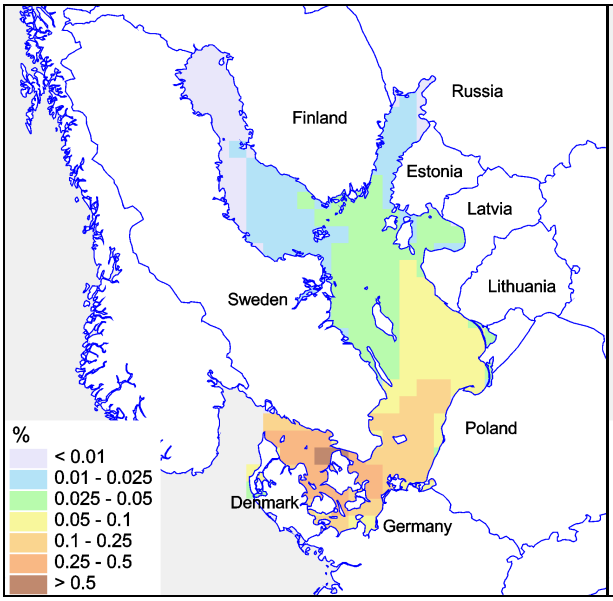
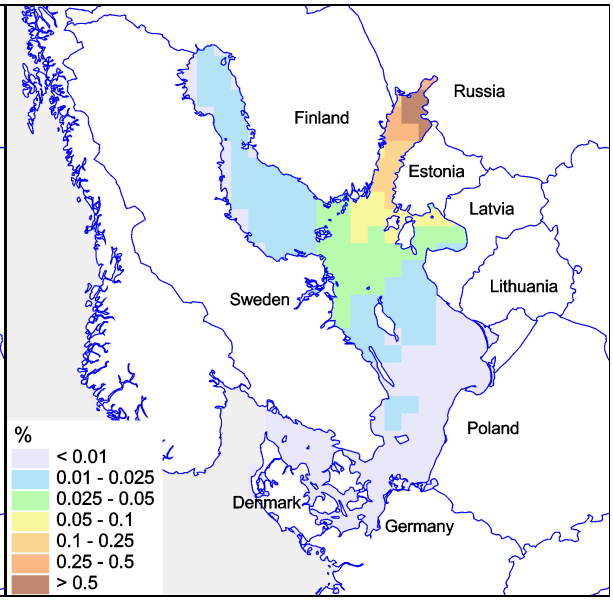


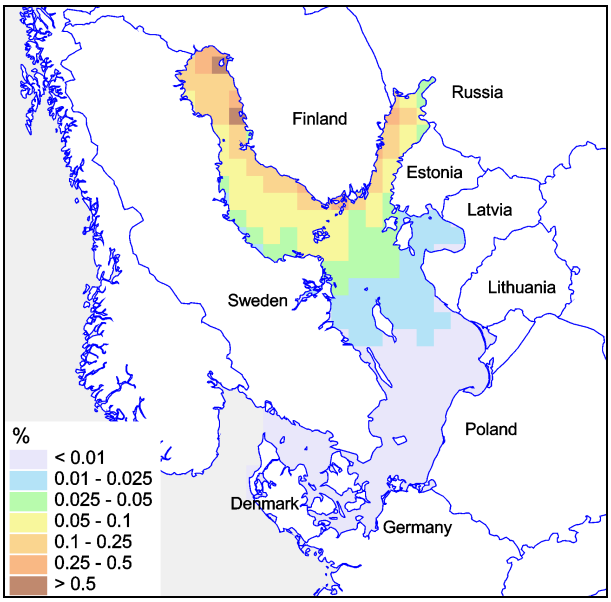
Figure 5.15. Contributions of different sector to total annual cadmium emission of Sweden in 2007.



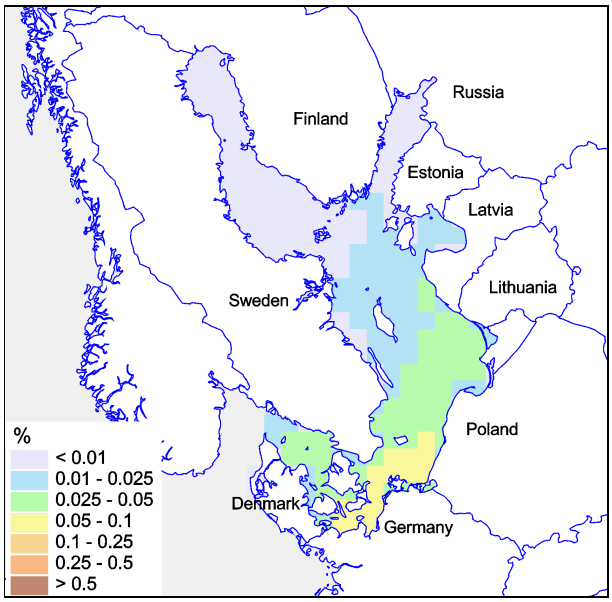
Denmark



Estonia

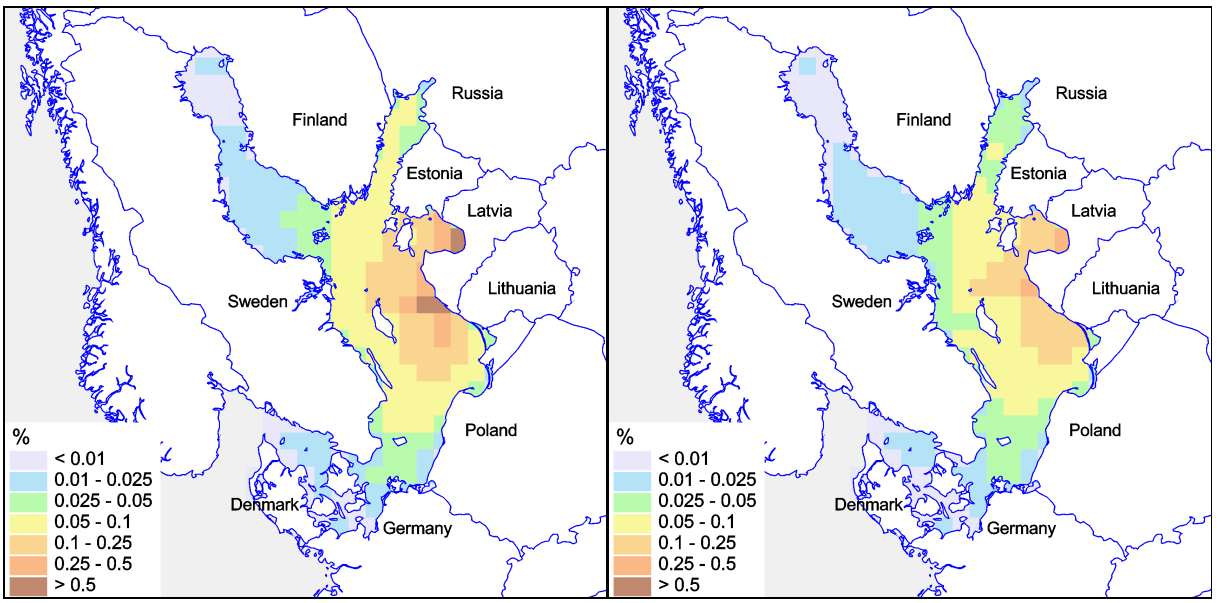


Finland

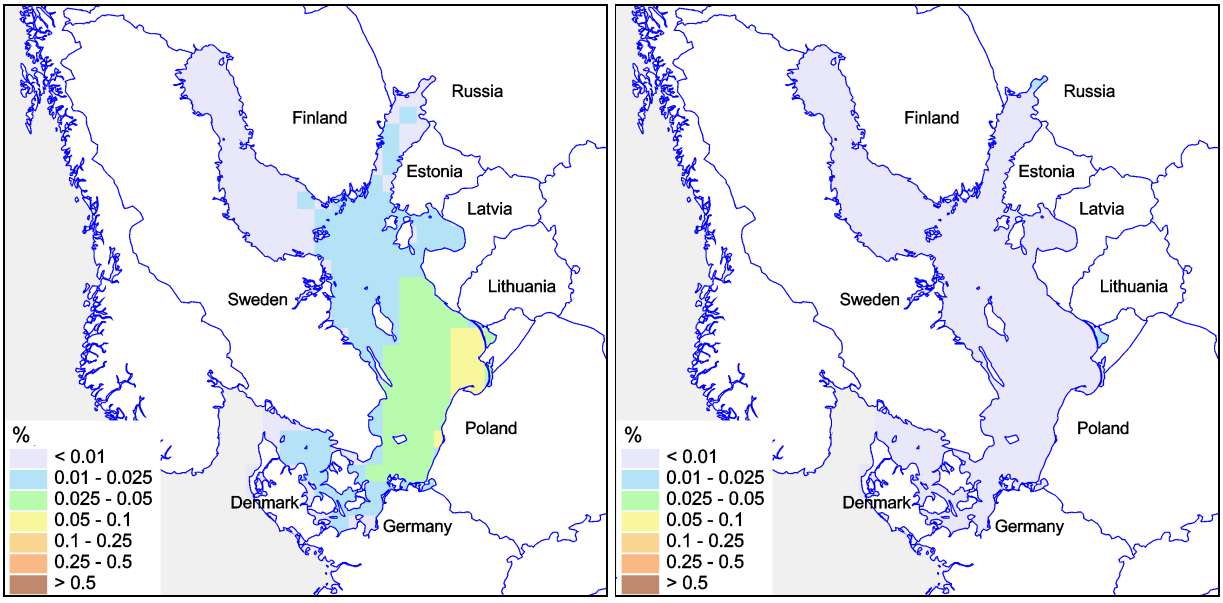


Germany

Figure 5.16. Maps with the contributions of annual total anthropogenic cadmium emissions from HELCOM Parties to total cadmium deposition over the Baltic Sea in 2007 (fraction of total deposition in % over the 50x50 km grid cell).

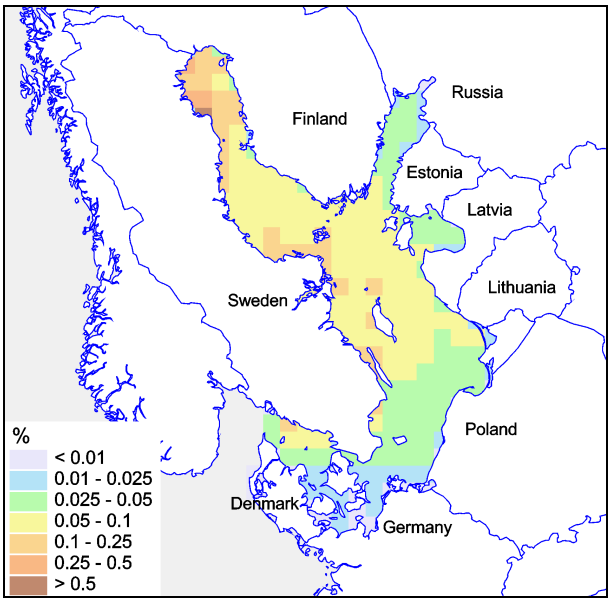


Latvia Lithuania



Poland Russia

Figure 5.16. **(cont.)** Maps with the contributions of annual total anthropogenic cadmium emissions from HELCOM Parties to total cadmium deposition over the Baltic Sea in 2007 (fraction of total deposition in % over the 50x50 km grid cell).



Sweden

Figure 5.16. **(cont.)** Maps with the contributions of annual total anthropogenic cadmium emissions from HELCOM Parties to total cadmium deposition over the Baltic Sea in 2007 (fraction of total deposition in % over the 50x50 km grid cell).

Table 5.2. Annual total anthropogenic emissions of cadmium 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	1.1	1.2	1.2	1.1	1.0	0.831	0.811	0.734	0.721	0.704	0.625	0.676	0.640	0.620	0.622	0.646	0.719	0.747
Estonia	4.4	4.2	3.0	2.2	2.9	2.0	1.0	1.1	1.0	0.945	0.605	0.560	0.560	0.620	0.586	0.576	0.548	0.680
Finland	6.3	3.5	2.9	2.8	2.2	1.6	1.5	0.9	1.3	1.3	1.3	1.6	1.3	1.2	1.5	1.3	1.3	1.1
Germany	12	8.0	5.1	3.6	2.5	2.3	2.2	2.4	2.2	2.6	2.3	2.5	2.6	2.7	2.4	2.5	2.5	2.5
Latvia	1.5	1.3	0.895	0.758	0.957	0.743	0.921	0.775	0.8	0.724	0.516	0.471	0.463	0.475	0.458	0.499	0.551	0.588
Lithuania	3.8	2.8	2.5	2.3	2.1	2.1	2.2	2.2	2.6	2.0	1.4	1.2	1.0	0.916	0.524	0.371	0.367	0.405
Poland	92	85	84	92	86	83	91	86	55	62	50	53	49	48	46	46	42	40
Russia	79	68	69	59	57	57	51	50	49	51	51	51	52	57	55	59	59	59
Sweden	2.3	1.7	1.4	1.1	0.752	0.729	0.698	0.693	0.612	0.527	0.510	0.591	0.515	0.508	0.528	0.530	0.545	0.578
HELCOM	**202**	**176**	**170**	**165**	**155**	**150**	**152**	**145**	**114**	**121**	**108**	**111**	**107**	**113**	**108**	**112**	**108**	**106**
Albania	0.647	0.602	0.557	0.513	0.468	0.423	0.378	0.333	0.289	0.244	0.199	0.199	0.198	0.198	0.198	0.197	0.197	0.197
Armenia	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.132	0.135	0.137	0.140	0.143	0.146	0.148
Austria	1.6	1.5	1.2	1.2	1.1	0.975	0.996	0.970	0.901	0.977	0.948	1.0	1.0	1.1	1.1	1.2	1.2	1.2
Azerbaijan	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.5	2.5	2.6	2.6
Belarus	2.1	2.2	2.0	1.7	1.3	1.1	1.2	1.3	1.5	1.4	1.4	1.8	1.9	1.8	1.8	2.1	2.5	2.6
Belgium	7.2	6.9	7.5	6.4	4.9	5.1	4.2	4.3	2.8	2.4	2.2	2.1	2.0	1.9	2.3	1.7	1.8	1.6
Bosnia and Herzegovina	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.6
Bulgaria	28	25	22	19	16	13	14	14	15	14	11	10	12	15	15	12	12	3
Croatia	1.3	1.2	1.1	1.1	1.0	0.950	1.0	1.0	1.1	1.1	1.0	0.874	0.929	0.948	0.877	0.826	0.836	0.790
Cyprus	0.558	0.578	0.663	0.713	0.745	0.680	0.721	0.761	0.680	0.877	0.925	0.917	1.0	1.0	1.1	1.1	1.2	1.2
Czech Republic	4.3	3.9	3.6	3.5	3.5	3.6	2.9	3.0	2.7	2.7	2.9	2.6	2.7	2.2	2.4	3.1	3.2	6.0
France	20	20	19	18	18	17	17	16	15	13	13	12	12	8.3	5.8	5.5	4.0	3.6
Georgia	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.215	0.221	0.226	0.232	0.237	0.243	0.248
Greece	4.5	4.2	4.0	3.7	3.5	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Hungary	5.5	4.7	4.0	4.1	4.1	3.9	3.4	3.3	3.1	3.3	3.2	3.2	3.0	3.0	3.0	3.5	3.4	1.5
Iceland	0.166	0.158	0.149	0.141	0.132	0.124	0.115	0.107	0.098	0.090	0.081	0.082	0.082	0.082	0.083	0.083	0.083	0.084
Ireland	0.839	0.862	0.869	0.855	0.947	0.948	0.905	0.994	1.020	1.016	1.066	0.948	0.750	0.697	0.710	0.722	0.635	0.626
Italy	10	11	10	10.0	9.6	9.6	9.3	9.1	8.9	8.8	9.1	9.0	7.3	7.5	8.2	8.5	8.6	8.6
Luxembourg	0.600	0.575	0.550	0.525	0.500	0.400	0.400	0.300	0.200	0.054	0.051	0.054	0.047	0.047	0.047	0.047	0.047	0.047
Malta	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.618	0.526	0.573	0.573	0.593	0.593	0.617
Monaco	0.056	0.058	0.063	0.069	0.006	0.006	0.007	0.008	0.007	0.007	0.008	0.008	0.007	0.006	0.005	0.005	0.004	0.005
Netherlands	2.1	1.8	1.6	1.4	1.3	1.1	1.1	1.1	1.2	1.0	1.0	1.6	2.2	2.4	1.8	1.7	1.9	1.9
Norway	1.1	1.0	1.0	1.1	1.2	0.983	1.1	1.0	1.1	1.0	0.688	0.683	0.681	0.658	0.601	0.544	0.599	0.556
Portugal	5.3	5.8	5.9	5.2	5.5	5.7	4.9	5.4	6.1	6.0	5.5	5.4	6.1	5.4	5.3	6.2	5.2	5.4
Republic of Moldova	2.4	3.5	1.7	1.4	0.819	0.594	0.659	0.364	0.328	0.148	0.173	0.114	0.226	0.122	0.114	0.145	0.158	0.158
Romania	22	20	19	18	17	15	14	13	12	12	8.7	7.4	8.1	8.7	9.4	10	6.5	2.5
Serbia and Montenegro	5.3	5.8	5.9	5.2	5.5	5.7	4.9	5.4	6.1	6.0	5.5	5.4	6.1	5.4	5.3	6.2	5.2	5.4
Slovakia	2.4	3.5	1.7	1.4	0.819	0.594	0.659	0.364	0.328	0.148	0.173	0.114	0.226	0.122	0.114	0.145	0.158	0.158
Slovenia	22	20	19	18	17	15	14	13	12	12	8.7	7.4	8.1	8.7	9.4	10	6.5	2.5
Spain	5.3	5.8	5.9	5.2	5.5	5.7	4.9	5.4	6.1	6.0	5.5	5.4	6.1	5.4	5.3	6.2	5.2	5.4
Switzerland	2.4	3.5	1.7	1.4	0.819	0.594	0.659	0.364	0.328	0.148	0.173	0.114	0.226	0.122	0.114	0.145	0.158	0.158
The FYR of Macedonia	9.1	9.2	9.3	9.3	9.4	9.4	9.5	9.6	9.6	9.7	9.8	9.8	9.7	9.7	9.7	9.7	9.7	9.7
Turkey	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	18
Ukraine	54	50	46	42	38	34	30	26	22	18	14	10	2.0	28	3.1	6.8	5.1	9.0
United Kingdom	23	23	22	14	13	11	9.4	8.6	6.3	6.0	5.9	4.6	4.5	3.2	3.4	3.5	3.5	2.9
EMEP	**477**	**441**	**422**	**391**	**368**	**354**	**343**	**330**	**287**	**287**	**262**	**257**	**245**	**273**	**240**	**250**	**239**	**230**

Expert estimates:

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

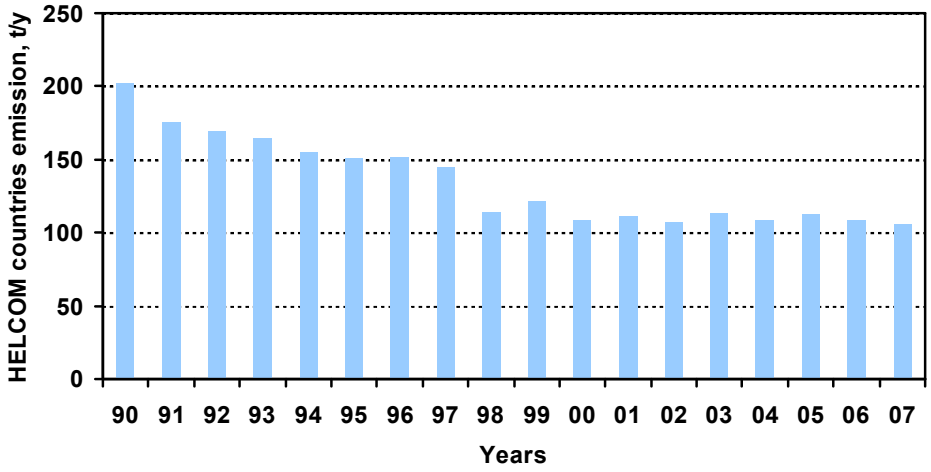


Figure 5.17. Time-series of annual cadmium emissions of HELCOM countries in 1990-2007, tonnes/y.

5.2 Annual total deposition of cadmium

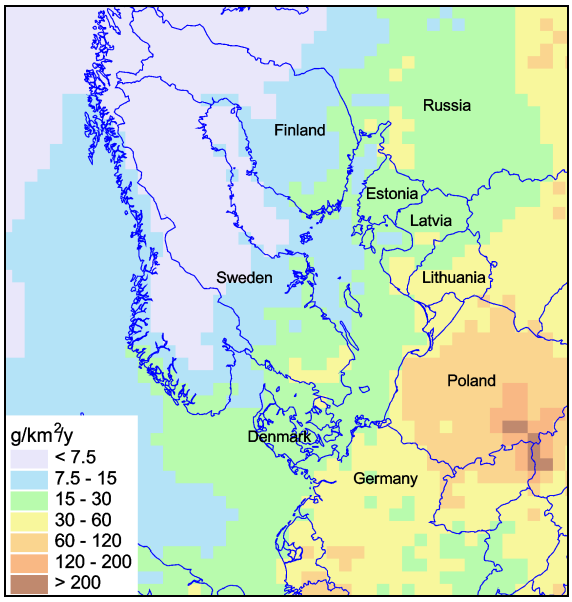


Figure 5.18. Annual total deposition fluxes of cadmium over the Baltic Sea region for 2007, g/km^2/year.

5.3 Monthly total deposition of cadmium

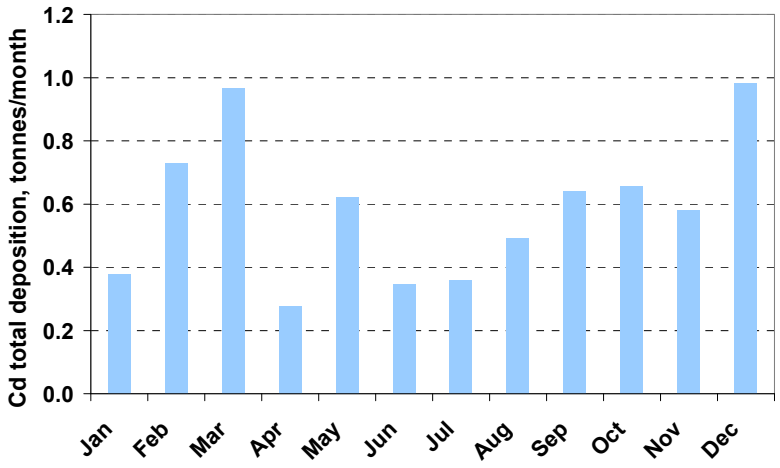


Figure 5.19. Monthly total deposition of cadmium to the Baltic Sea for 2007, tonnes/month.

Table 5.2. Monthly total deposition of cadmium to the Baltic Sea for 2007, tonnes/month.

Month	Cd
Jan	0.38
Feb	0.73
Mar	0.97
Apr	0.28
May	0.62
Jun	0.35
Jul	0.36
Aug	0.49
Sep	0.64
Oct	0.66
Nov	0.58
Dec	0.98

5.4 Source allocation of cadmium deposition

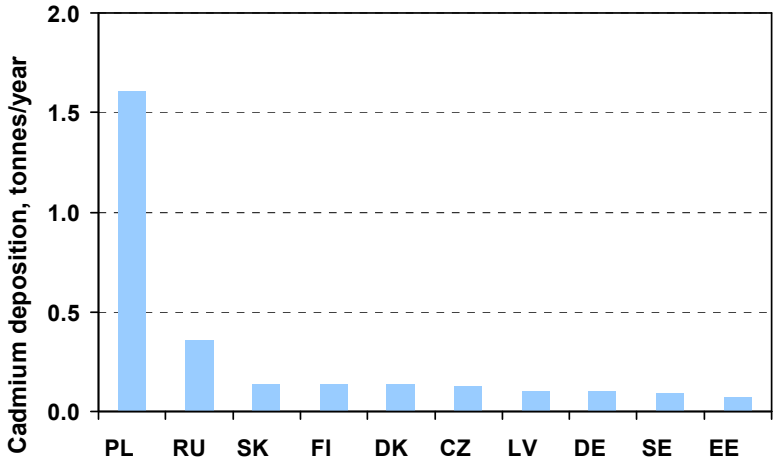


Figure 5.20. Top ten countries with the highest contribution to annual total deposition of cadmium over the Baltic Sea for 2007, tonnes/year.

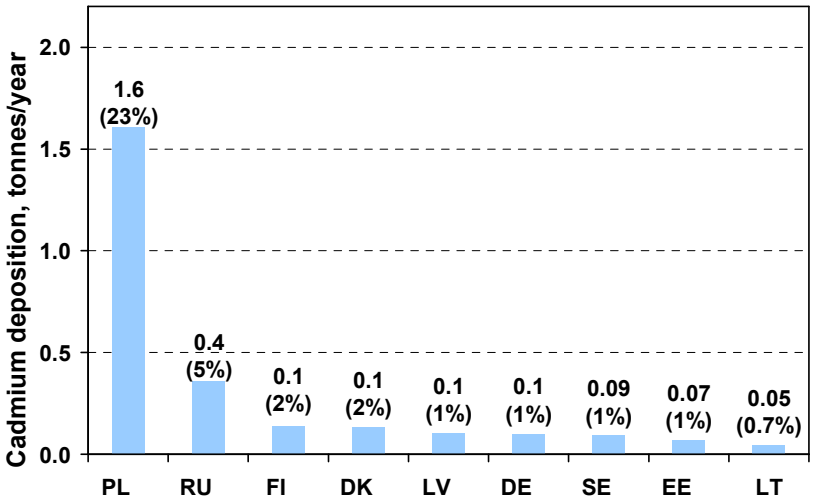


Figure 5.21. Sorted contributions (in %) of HELCOM countries to total deposition over the Baltic Sea for 2007. HELCOM countries emissions of cadmium contributed about 38% to the total annual cadmium deposition over the Baltic Sea in 2007. Contribution of other EMEP countries accounted for 11%. Significant contribution was made by other emission sources, in particular, remote emissions sources, natural emissions and re-emission of cadmium (51%).

Table 5.3. Two most significant contributors to the annual total deposition of cadmium to the six Baltic Sea sub-basins for 2007.

Sub-basin	Country	%	Country	%	*, %
GUB	Poland	15	Finland	11	51
GUF	Russia	17	Poland	12	46
GUR	Poland	20	Russia	6	50
BAP	Poland	28	Russia	4	49
BES	Poland	14	Denmark	6	62
KAT	Poland	11	Denmark	7	65
BAS	Poland	23	Russia	5	51

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

5.5 Comparison of model results with measurements

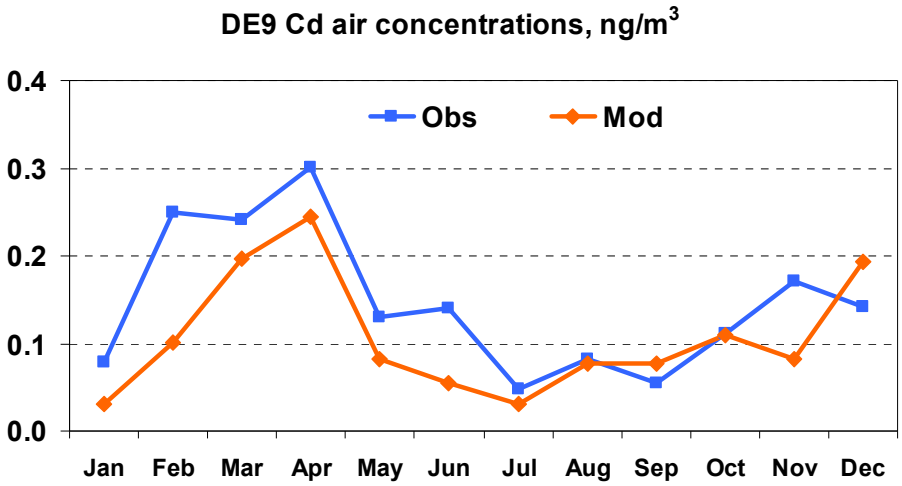


Figure 5.22. Comparison of calculated mean monthly cadmium concentrations in air for 2007 with measurements of the station Zingst (DE9). Units: ng / m^3.

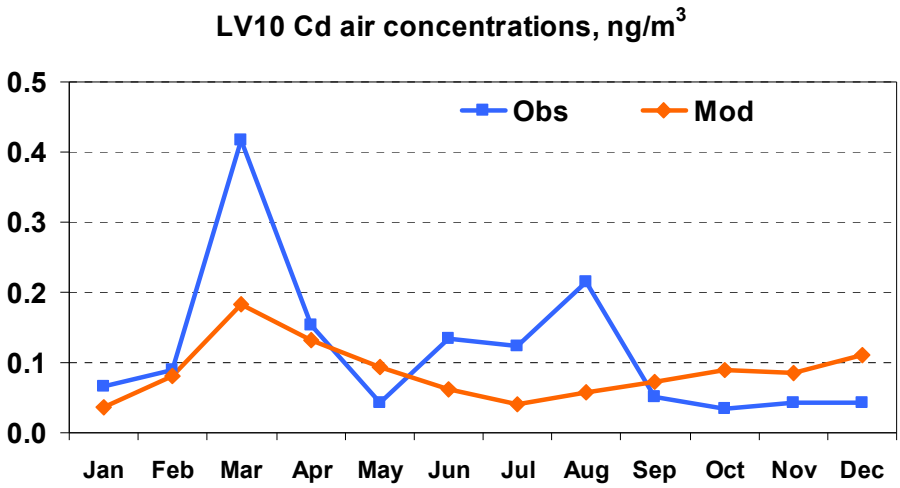


Figure 5.23. Comparison of calculated mean monthly cadmium concentrations in air for 2007 with measurements of the station Rucava (LV10). Units: ng / m^3.

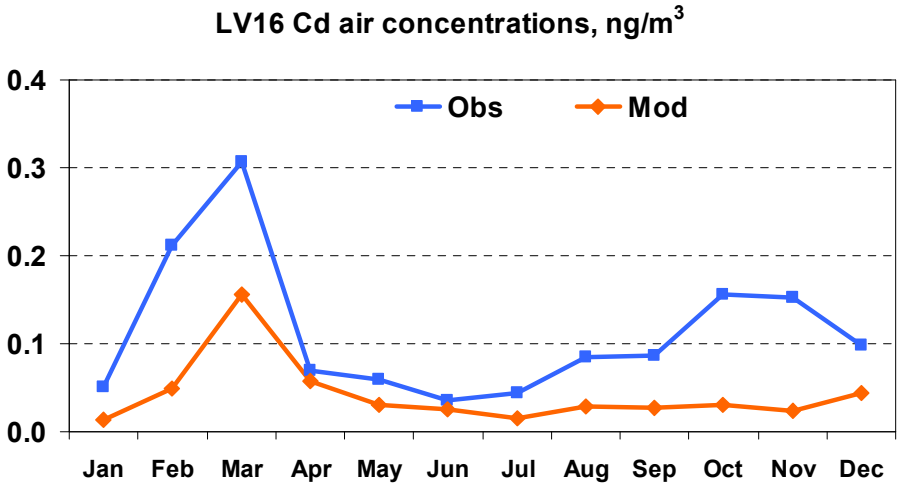


Figure 5.24. Comparison of calculated mean monthly cadmium concentrations in air for 2007 with measurements of the station Zoseni (LV16). Units: ng / m^3.

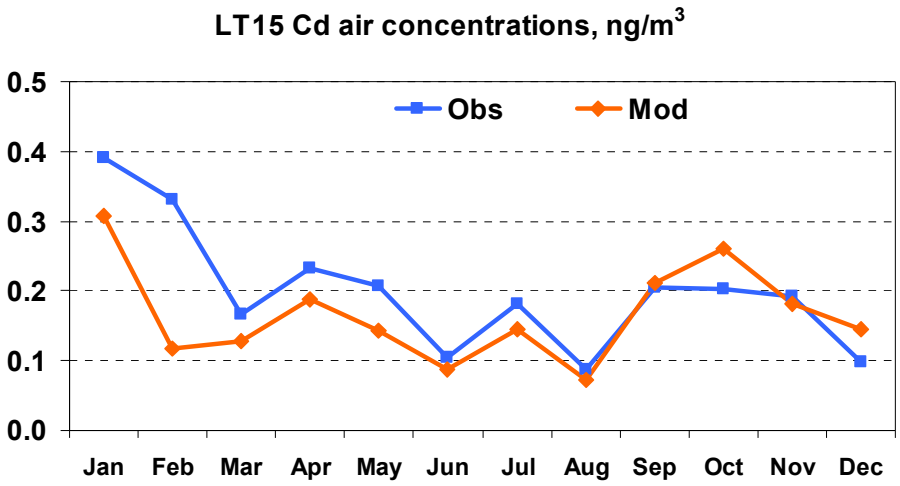


Figure 5.25. Comparison of calculated mean monthly cadmium concentrations in air for 2007 with measurements of the station Preila (LT15). Units: ng / m^3.

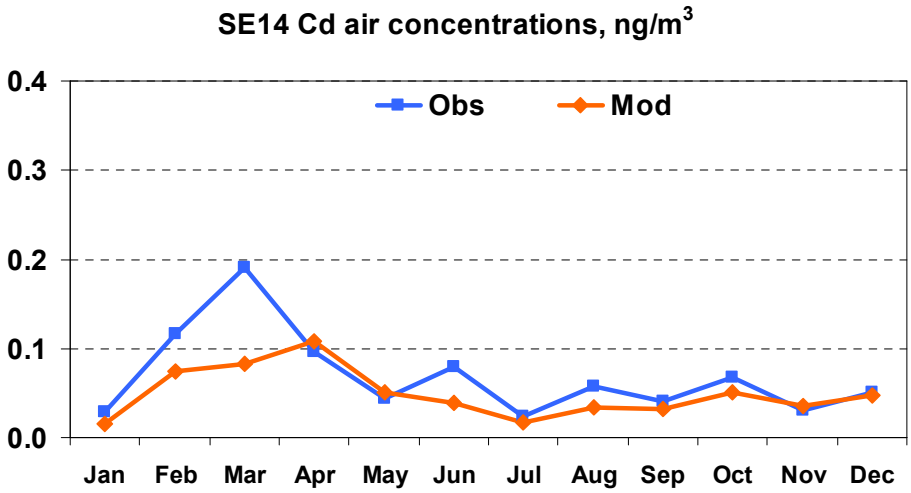


Figure 5.26. Comparison of calculated mean monthly cadmium concentrations in air for 2007 with measurements of the station Räö (SE14). Units: ng / m^3.

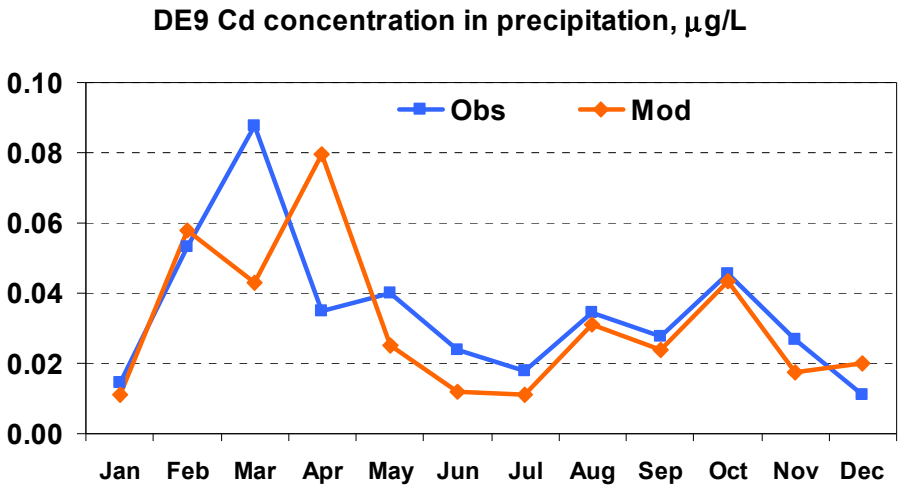


Figure 5.27. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Zingst (DE09). Units: µg / L.

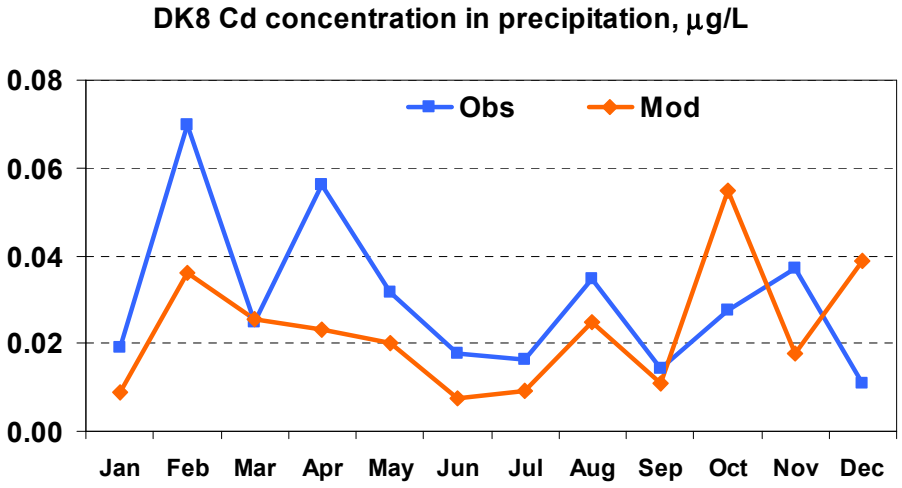


Figure 5.28. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Anholt (DK8). Units: µg / L.

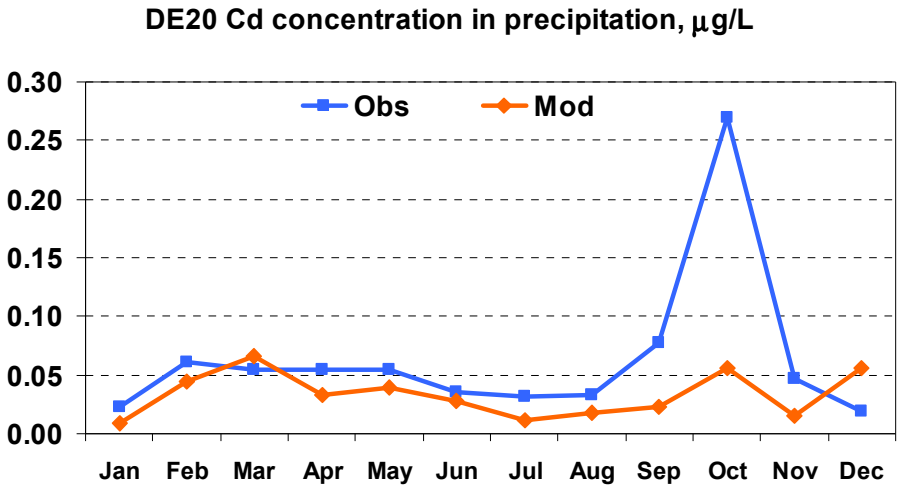


Figure 5.29. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Pedersker (DK20). Units: µg / L.

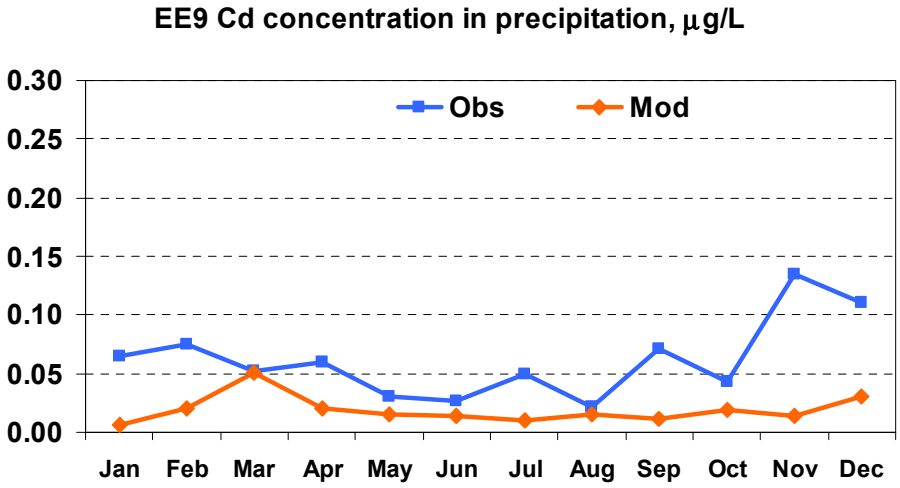


Figure 5.30. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Lahemaa (EE9). Units: µg / L.

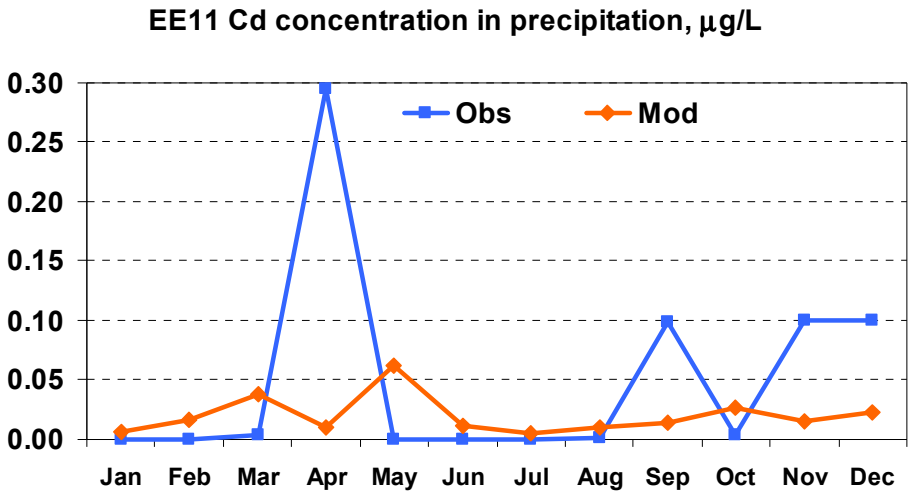


Figure 5.31. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Vilsandi (EE11). Units: µg / L.

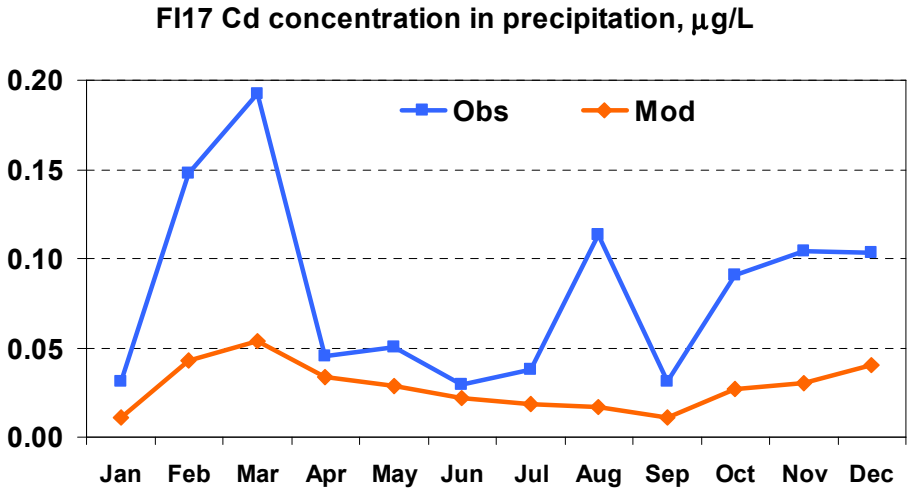


Figure 5.32. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Virolahty II (FI17). Units: µg / L.

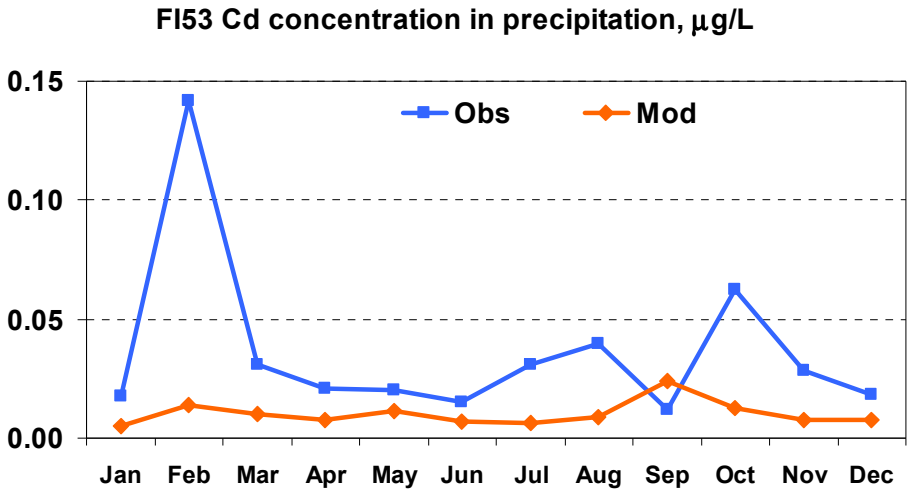


Figure 5.33. Comparison of calculated mean monthly cadmium concentrations in precipitation 2007 with measurements of the station Hailuoto (FI53). Units: µg / L.

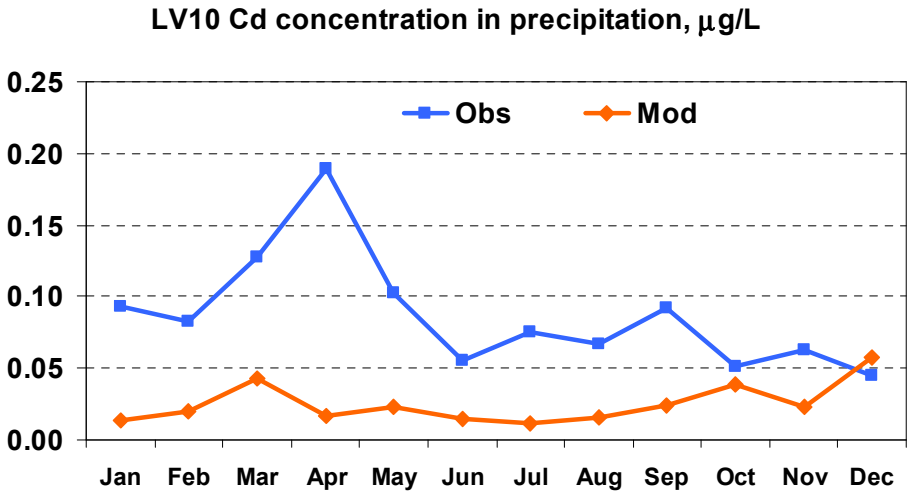


Figure 5.34. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Rucava (LV10). Units: µg / L.

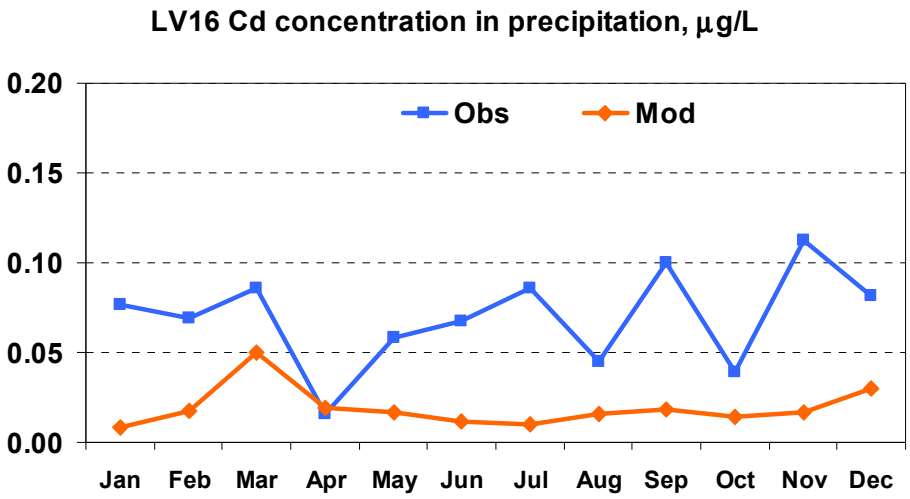


Figure 5.35. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Zoseni (LV16). Units: µg / L.

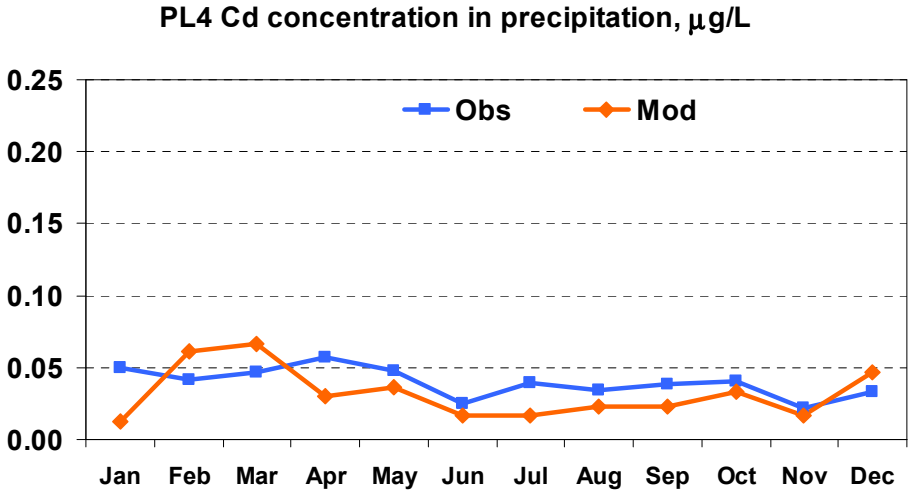


Figure 5.36. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Leba (PL4). Units: µg / L.

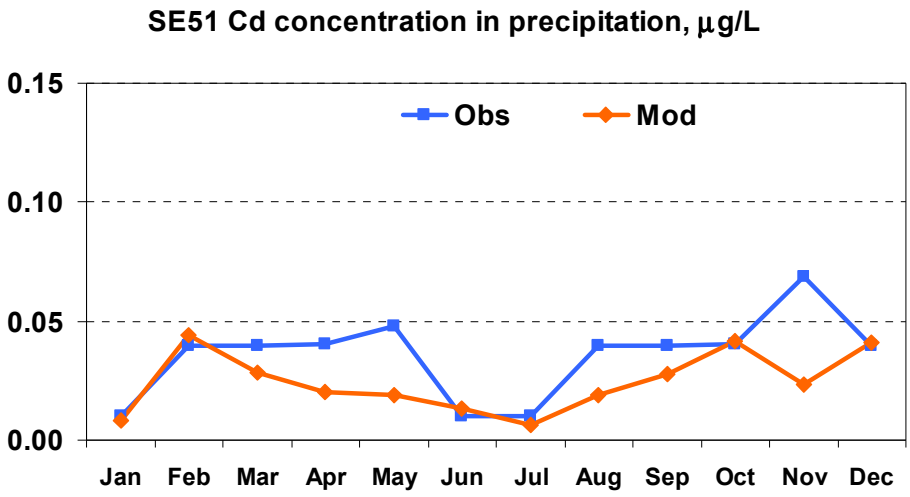


Figure 5.37. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2007 with measurements of the station Arup (SE51). Units: µg / L.

In general, reasonable level of agreement between the computed concentrations of cadmium in air and in precipitation is obtained for the selected monitoring sites around the Baltic Sea. Comparing to lead more significant deviations between simulated and observed monthly mean concentrations of cadmium can be mentioned. The reason of deviations is connected with the uncertainties in seasonal variation of cadmium emission, differences between measured precipitation amount and the one used in the model, and difficulties in measurements of heavy metals.

5.6 Conclusions for Chapter 5

- Emissions of cadmium from HELCOM countries have decreased from 1990 to 2007 by 48%. Decrease of cadmium emission from 2006 to 2007 is accounted for 2%.

- Annual deposition of cadmium to the Baltic Sea has decreased from 1990 to 2007 by 46%. Level of cadmium deposition in 2007 was lower 6% comparing to 2006.

- The contribution of anthropogenic sources of HELCOM countries to total cadmium deposition over the Baltic Sea was estimated to approximately 40%. Essential contribution belongs to the anthropogenic sources of other EMEP countries, natural sources and resuspension.

- The most significant contribution to cadmium deposition over the Baltic Sea was made by Poland and Russia.

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