4. Atmospheric Supply of Lead to the Baltic Sea in 2013

This chapter presents the results of model evaluation of lead atmospheric input to the Baltic Sea and its sub-basins in 2013. 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 2013 was used in model simulations. Based on these data annual and monthly levels of lead deposition to the Baltic Sea region have been obtained and contributions of HELCOM countries emissions 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 2013.

4.1 Lead emissions

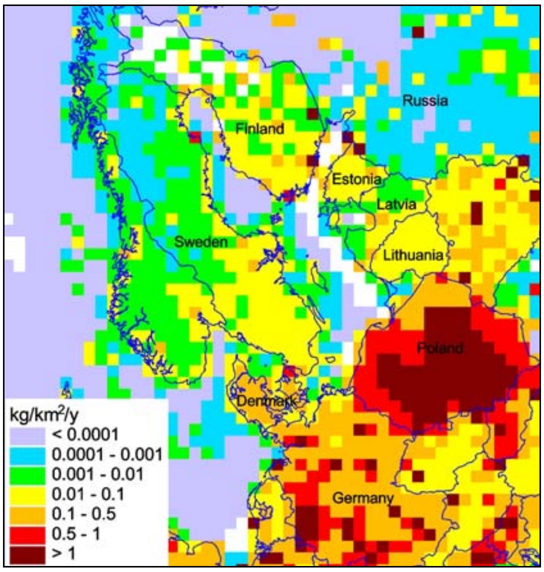


Figure 4.1. Annual total anthropogenic emissions of **lead** in the Baltic Sea region for 2013, kg/km^2/y.

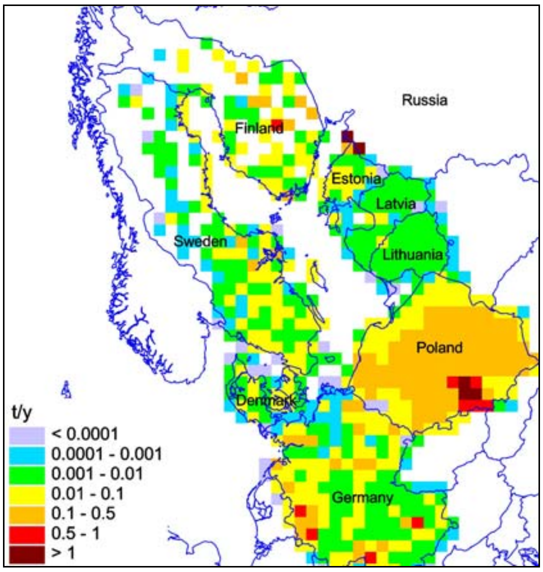


Figure 4.2. Annual lead emission from Public Power sector for 2013, t/grid cell/y (white color means no information).

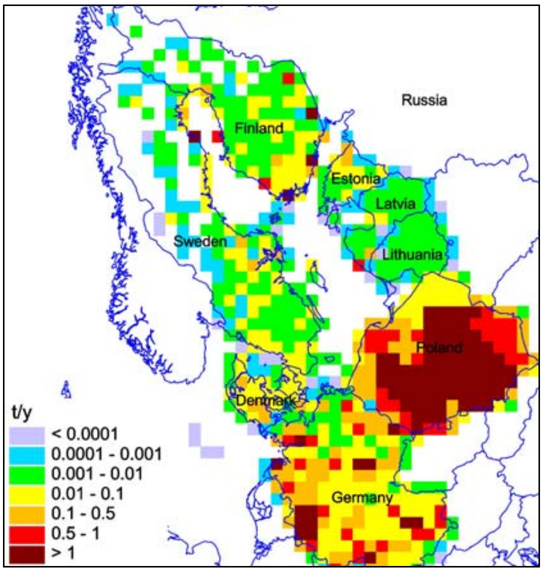


Figure 4.3. Annual lead emission from Industry sector for 2013, t/grid cell/y (white color means no information).

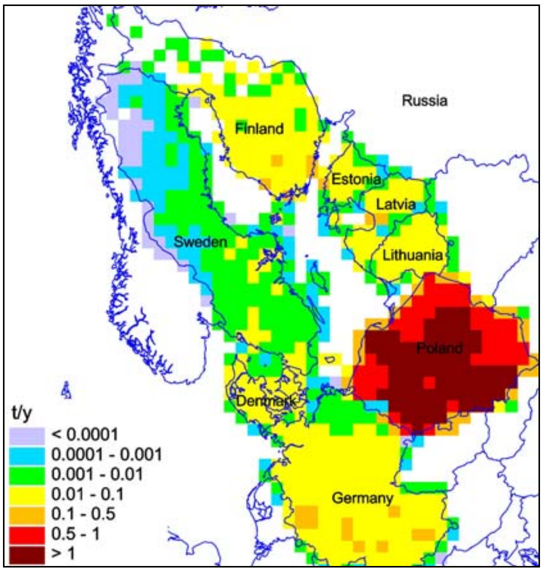


Figure 4.4. Annual lead emission from Other Stationary Combustion sector for 2013, t/grid cell/y (white color means no information).

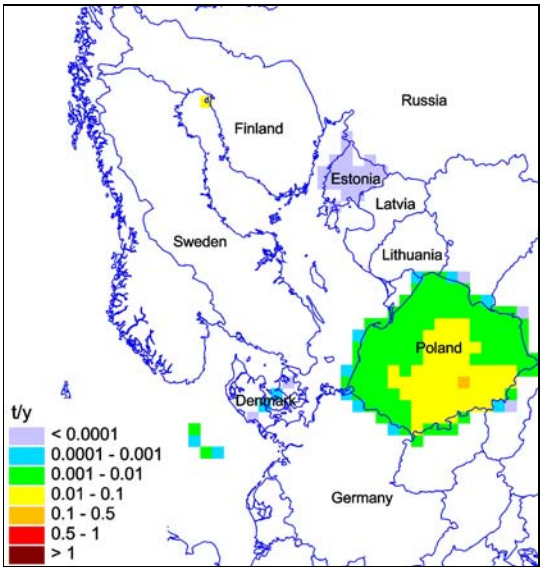


Figure 4.5. Annual lead emission from Fugitive Emissions sector for 2013, t/grid cell/y (white color means no information).

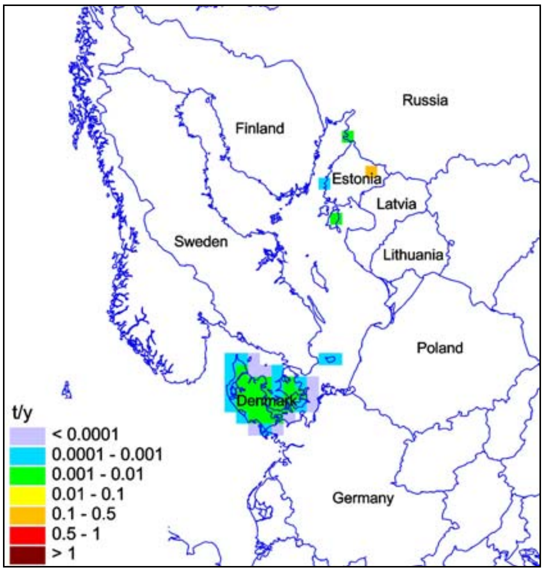


Figure 4.6. Annual lead emission from Solvents sector for 2013, t/grid cell/y (white color means no information).

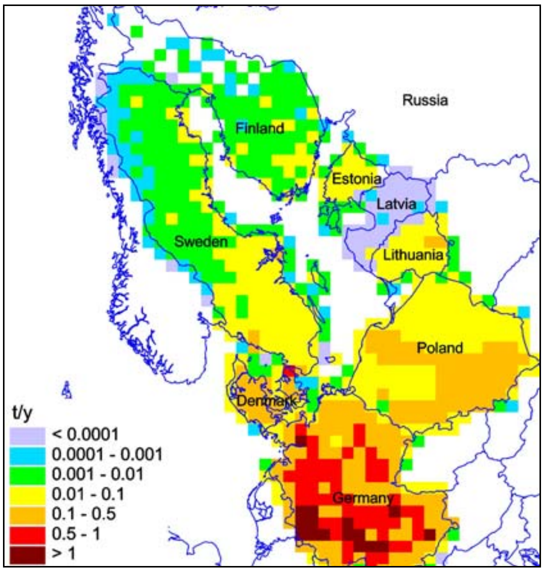


Figure 4.7. Annual lead emission from Road Transport sector for 2013, t/grid cell/y (white color means no information).

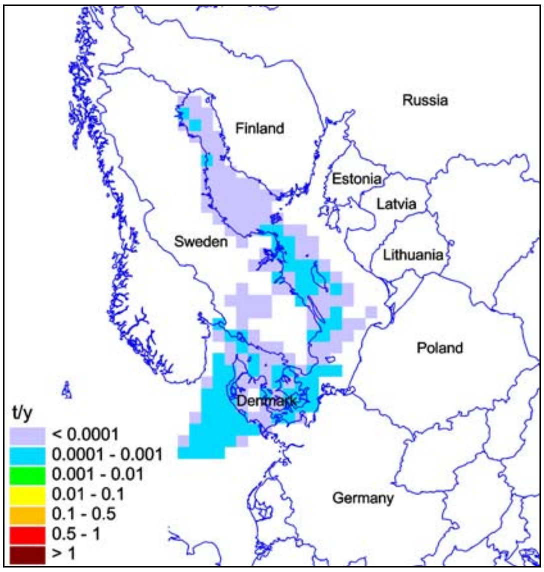


Figure 4.8. Annual lead emission from Shipping Emissions sector for 2013, t/grid cell/y (white color means no information).

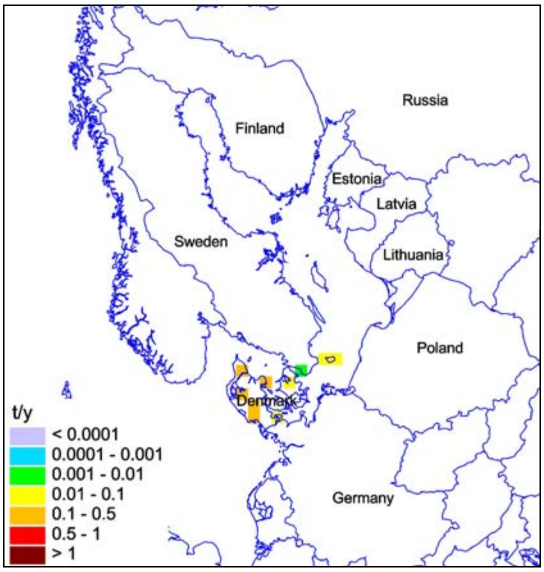


Figure 4.9. Annual lead emission from Aviation sector for 2013, t/grid cell/y (white color means no information).

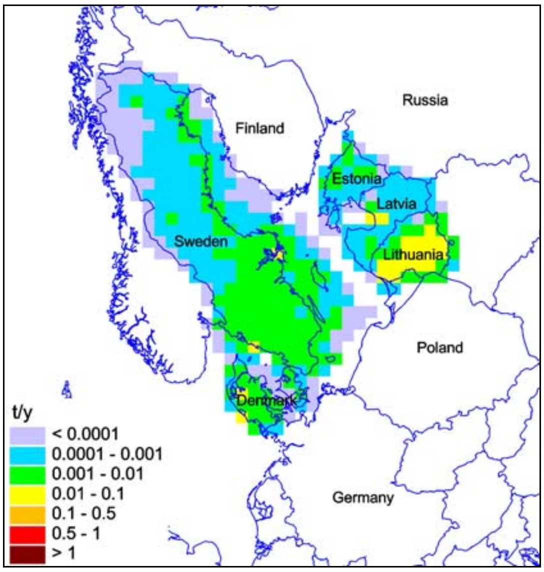


Figure 4.10. Annual lead emission from Off Road sector for 2013, t/grid cell/y (white color means no information).

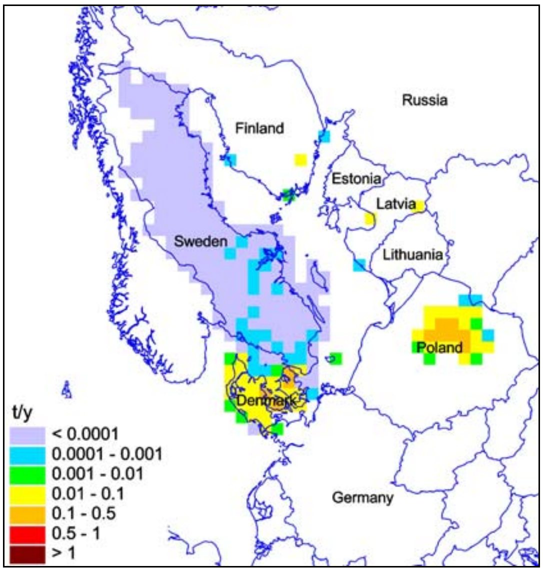


Figure 4.11. Annual lead emission from Waste sector for 2013, t/grid cell/y (white color means no information).

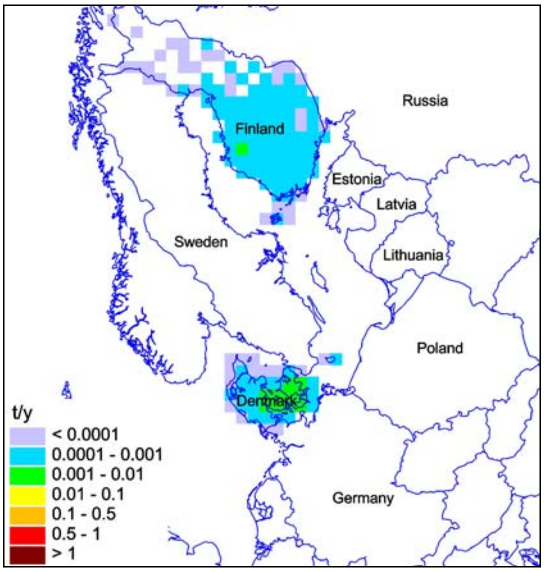


Figure 4.12. Annual lead emission from Agricultural Other sector for 2013, t/grid cell/y (white color means no information).

Table 4.1. Annual total **lead** anthropogenic emissions of HELCOM countries from different sectors for 2013, tonnes/year

GNFR emission sector	Sector name	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden
A	Public Power	0.39	37.21	3.28	10.67	0.194	0.334	29.57	0.4	2.36
B	Industry	1.52	0.539	10.8	68.25	0.63	0.281	359.91	17.91	4.22
C	Other Stationary Combustion	1.24	0.608	3.33	7.05	0.951	1.19	153.43	0.6	0.771
D	Fugitive Emissions	0.008	0.0001	0.022	NA			2.06	0.02	
E	Solvents	0.068	0.345	1.8E-07	30.51		NA	2.1E-06		2.0E-07
F	Road Transport	5.47	0.424	0.664	88.74	0.0014	1.69	14.49		4.07
G	Shipping emissions	0.018			0.066		0.0006	3.6E-07		0.011
H	Aviation	0.901	NA		4.7	NE	NE	NA		0.38
I	Off Road	0.089	0.022		0.14	0.057	0.365		0.0003	0.016
J	Waste	1.85	0.307	0.063	8.96E-06	0.03	0.034	1.75	0.13	0.008
L	Agricultural Other	0.04		0.027				NA		NA
M	Other	NO	NO	NO	NA	NA	NO	NA	13.04	NO
Total		11.6	39.45	18.19	210.14	1.86	3.9	561.21	32.11	11.82

NO – not occurring, an activity or process does not exist within a country.
NA – not applicable, the process or activity exists but emissions are considered never to occur.
NE – not estimated, emissions occur but have not been estimated or reported in this submission.

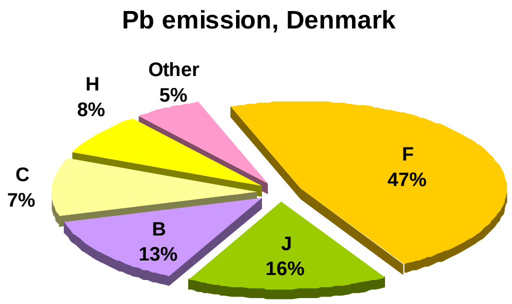


Figure 4.13. Contributions of different sector to total annual lead emission of Denmark in 2013.

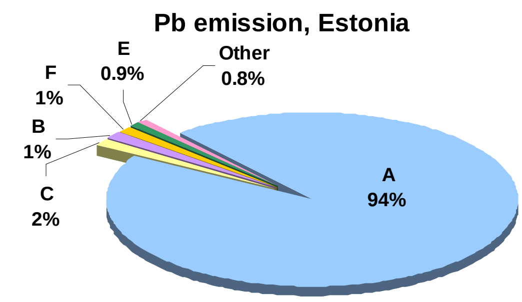


Figure 4.14. Contributions of different sector to total annual lead emission of Estonia in 2013.

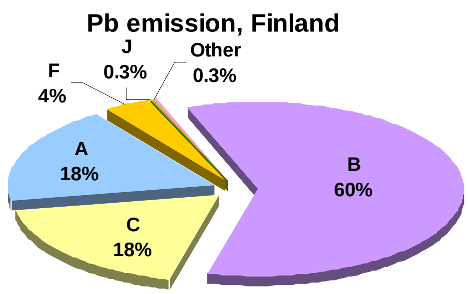


Figure 4.15. Contributions of different sector to total annual lead emission of Finland in 2013.

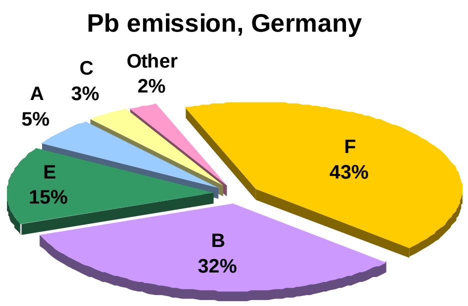


Figure 4.16. Contributions of different sector to total annual lead emission of Germany in 2013.

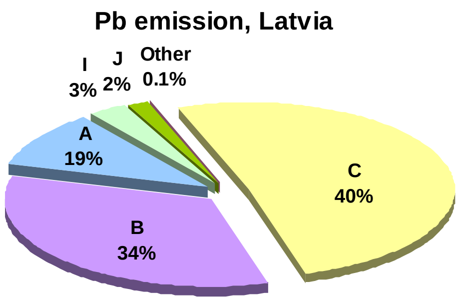


Figure 4.17. Contributions of different sector to total annual lead emission of Latvia in 2013.

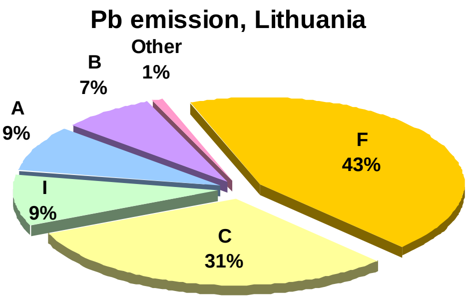


Figure 4.18. Contributions of different sector to total annual lead emission of Lithuania in 2013.

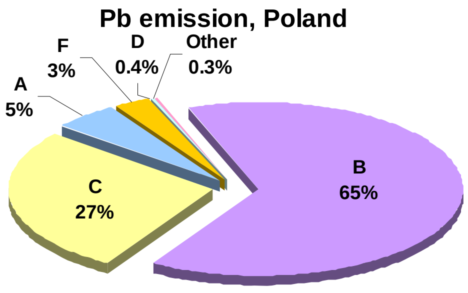


Figure 4.19. Contributions of different sector to total annual lead emission of Poland in 2013.

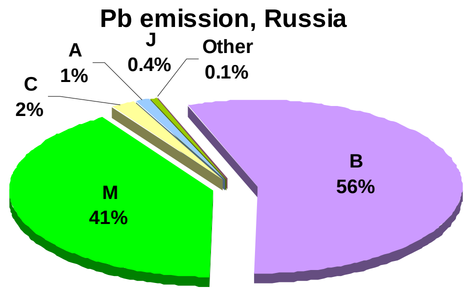


Figure 4.20. Contributions of different sector to total annual lead emission of Russia in 2013.

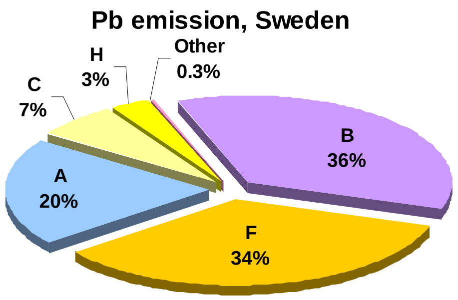
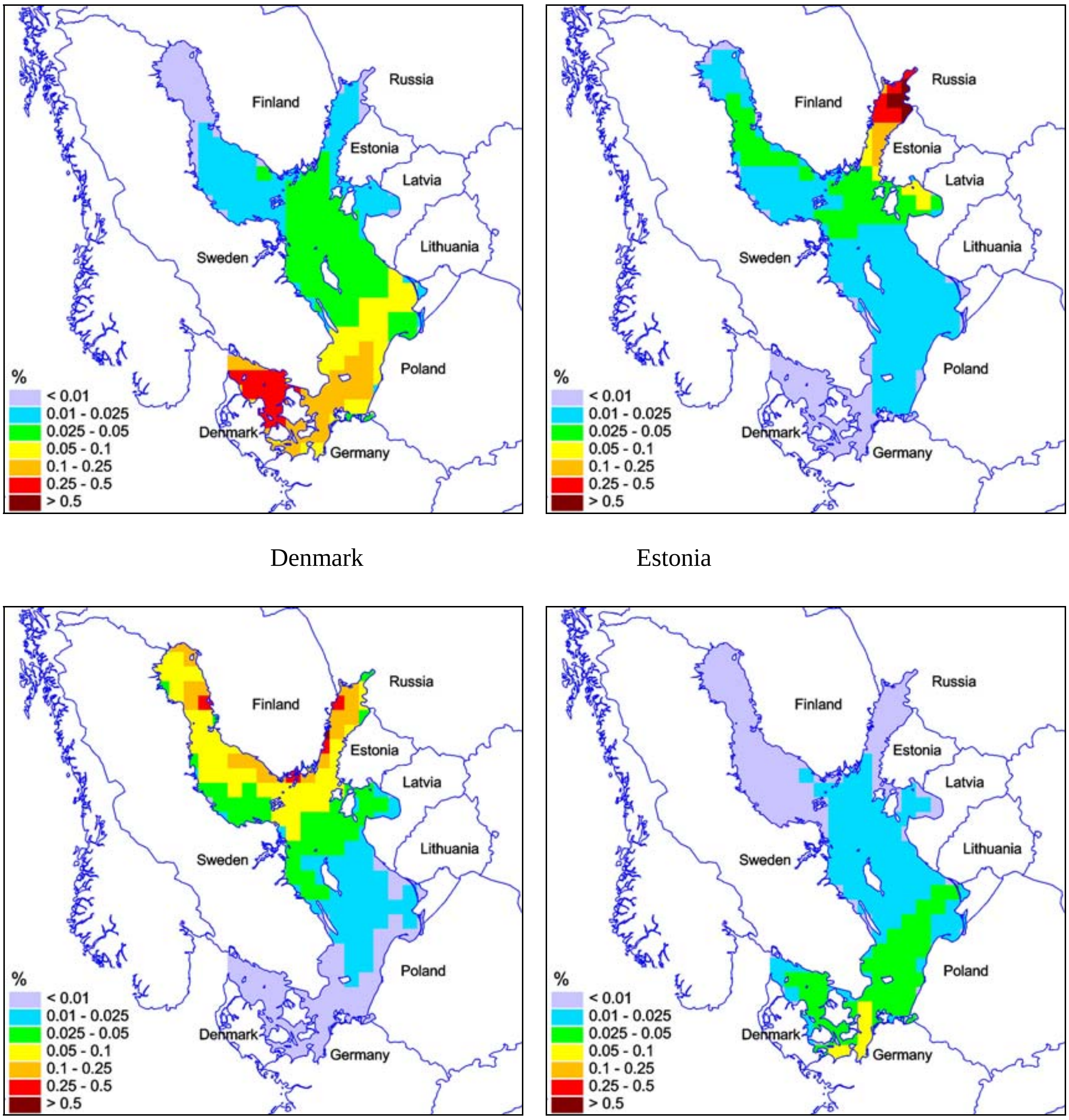


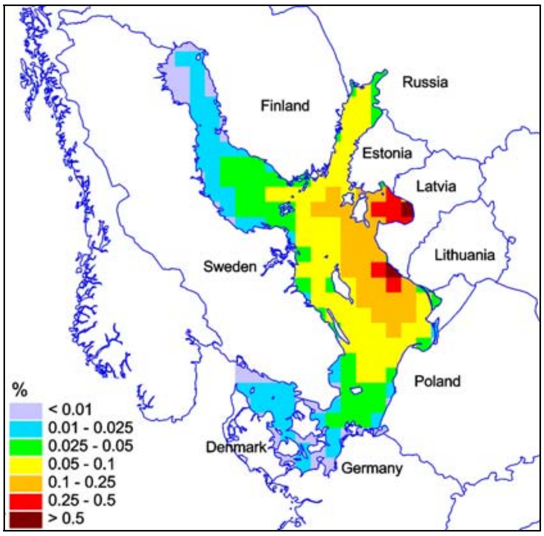
Figure 4.21. Contributions of different sector to total annual lead emission of Sweden in 2013.



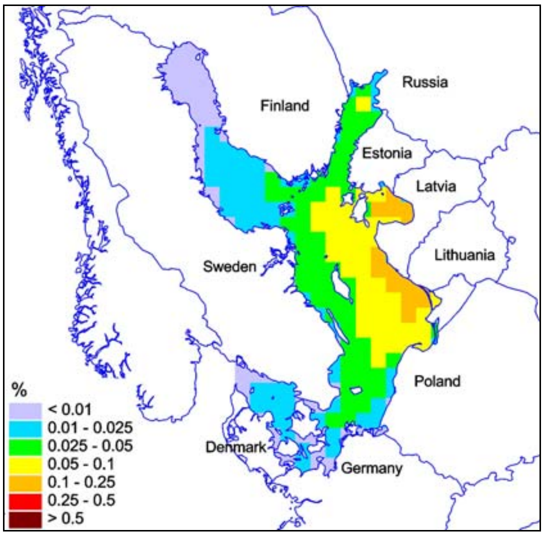
Denmark Estonia

Finland Germany

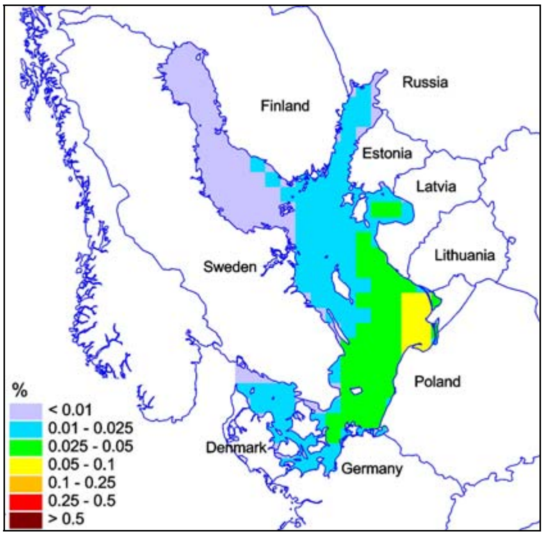
Figure 4.22. Fractions of annual anthropogenic lead emissions of HELCOM Parties deposited to the Baltic Sea in 2013 (expressed as a percent of national anthropogenic emission deposited to the particular grid cells).



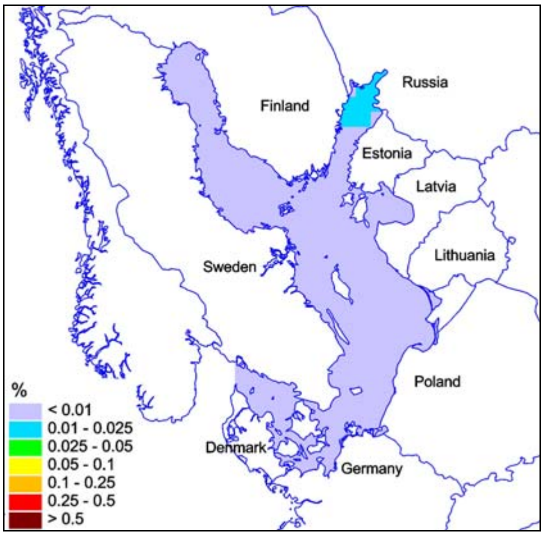
Latvia



Lithuania

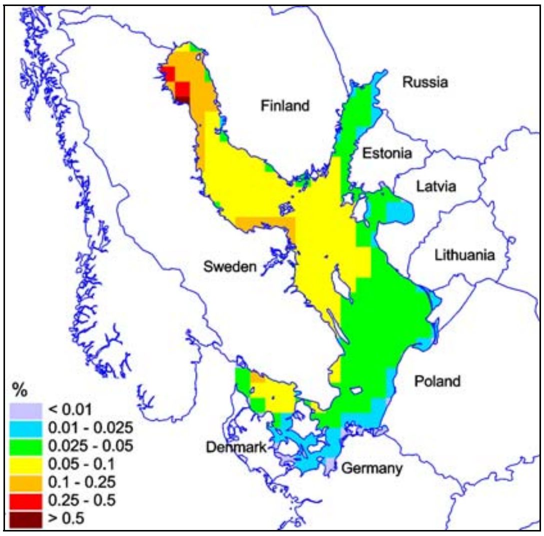


Poland



Russia

Figure 4.22. **(cont.)** Fractions of annual anthropogenic lead emissions of HELCOM Parties deposited to the Baltic Sea in 2013 (expressed as a percent of national anthropogenic emission deposited to the particular grid cells).



Sweden

Figure 4.22. **(cont.)** Fractions of annual anthropogenic lead emissions of HELCOM Parties deposited to the Baltic Sea in 2013 (expressed as a percent of national anthropogenic emission deposited to the particular grid cells).

Table 4.2. Annual total anthropogenic emissions of **lead** of HELCOM countries and other EMEP countries in period 1990-2013, tonnes/year. (Expert estimates of emissions are shaded)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
DK	128	107	98	58	26	26	25	23	25	31	19	19	18	19	21	17	16	13	14	13	12	12	12	12
EE	206	189	125	103	123	86	67	47	40	40	37	37	36	38	37	36	32	40	35	28	39	38	34	39
FI	338	258	185	109	68	67	45	29	32	25	45	45	46	38	28	22	25	22	20	18	23	22	19	18
DE	2130	1359	1040	868	674	739	604	487	447	442	463	431	420	404	402	375	375	366	225	202	220	220	212	210
LV	96	81	76	73	68	60	59	52	47	6.5	6.2	6.8	6.6	6.6	6.7	4.0	4.3	4.6	4.2	3.9	3.8	3.6	3.4	1.9
LT	151	171	90	80	67	92	100	100	184	8.3	7.3	7.5	7.1	7.1	7.0	5.5	2.6	5.5	5.5	4.8	4.5	4.8	4.2	3.9
PL	642	642	642	642	642	642	660	639	571	561	524	511	545	566	572	552	582	573	562	518	573	565	554	561
RU	3591	3553	3095	3276	2643	2426	2304	2247	2262	2339	2352	2235	2118	2207	330	355	355	247	140	32	32	32	32	32
SE	358	314	294	144	53	39	35	35	34	31	28	25	21	21	19	16	15	16	14	14	14	13	12	12
AL	62	63	62	67	72	67	68	70	74	68	76	85	93	80	110	60	4	4	4	4	4	4	4	4
AM	11	0.8	0.6	0.8	0.3	0.3	0.01	0.01	0.01	0.01	0.01	0.5	1.0	3	3	3	4	9	11	9	6	7	31	12
AT	215	176	122	85	59	16	16	14	13	12	12	12	12	13	13	13	14	14	15	13	15	15	15	16
AZ	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.09	0.08	0.08	0.11	0.24	0.35	0.51	1.4	1.7	2.5	1.7	1.8	2.5	3.0	3.5	2.5
BY	794	519	450	377	348	147	46	42	41	38	46	41	44	43	45	50	57	59	63	66	70	69	68	68
BE	254	217	217	186	142	187	181	201	124	140	107	89	83	79	88	75	72	63	73	34	41	30	30	26
BA	97	97	97	97	97	97	97	97	97	97	97	91	85	79	72	66	60	54	48	42	36	30	24	18
BG	321	189	213	283	285	324	324	248	289	278	255	238	197	237	142	126	127	118	187	84	70	75	75	76
HR	538	383	304	291	319	328	275	276	281	285	276	241	151	65	58	52	8	8	8	7	7	7	6	7
CY	36	36	40	41	43	42	43	43	43	43	44	42	41	42	33	29	29	30	31	31	31	30	28	25
CZ	269	240	247	232	202	180	165	180	169	157	108	47	47	39	37	47	43	44	39	40	26	17	23	18
FR	4591	3297	2520	2275	2024	1799	1590	1405	1260	980	296	262	255	204	187	183	177	172	160	134	146	135	138	136
GE	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.26	0.31	0.38	0.40	0.42	0.45
GR	505	499	493	488	482	476	470	386	301	217	132	133	133	133	133	133	133	133	133	133	133	133	134	134
HU	60	49	32	33	30	28	28	27	24	23	23	23	23	22	21	8	8	7	10	8	7	8	8	7
IS	6.4	5.8	5.1	4.5	3.9	3.3	2.7	2.1	1.4	0.82	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IE	124	112	117	102	89	78	67	70	48	30	19	18	17	20	21	21	20	21	21	17	16	15	14	14
IT	4415	3363	2488	2305	2126	2029	1916	1740	1600	1436	946	713	252	257	272	281	290	313	302	229	260	261	260	254
KZ	4736	4323	3909	3496	3082	2669	2255	1841	1428	1014	601	609	618	627	635	644	653	661	670	679	687	696	705	713
KY	379	348	316	284	252	220	188	157	125	93	61	56	51	46	42	37	32	27	22	17	12	7	2	2
LI	0.64	0.56	0.47	0.37	0.31	0.24	0.18	0.15	0.1	0.06	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
LU	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	1.9	1.9	1.9	1.9	1.9	1.9
MT	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.74	0.73	0.79	0.76	0.8	0.81	0.83	0.73	0.73	3.4	5.8	13	7.8
MC	3.8	3.9	4.1	3.7	2.1	0.77	0.66	0.54	0.47	0.41	0.06	0.06	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
NL	337	273	230	204	175	155	98	48	43	32	28	33	37	33	34	30	31	36	31	32	38	23	16	14
NO	187	144	128	88	25	23	11	11	11	10	8	7	8	8	8	7	7	8	7	5	5	5	5	5
PT	549	603	677	718	735	754	308	311	321	325	37	35	36	35	35	36	36	36	36	34	33	33	33	33
MD	16	12	8	7	7	6	6	7	7	7	8	9	5	9	10	10	7	10	9	5	4	4	4	3
RO	585	573	561	550	538	526	514	502	491	420	402	476	377	279	180	82	81	81	70	46	51	42	67	36
RUA	1842	1723	1603	1484	1364	1245	1237	1229	1222	1214	1207	1002	797	592	387	182	149	116	83	50	16	16	16	16
ME	309	443	329	182	129	141	237	203	222	221	142	107	60	63	63	48	46	52	47	45	46	4	4	4
RS	232	245	232	124	205	209	225	242	250	202	229	242	239	235	252	254	255	240	234	173	45	44	22	22
SK	99	98	97	88	79	79	79	77	74	62	89	70	65	64	70	73	74	62	63	43	59	59	58	54
SI	352	308	300	315	314	200	84	74	58	51	47	30	18	19	17	16	17	17	18	16	17	17	16	16
ES	2657	1781	1191	1085	1071	911	888	821	755	689	547	328	206	201	194	202	200	198	196	174	181	180	182	171
CH	398	374	345	287	248	184	159	145	129	65	43	39	34	31	30	28	28	27	28	26	26	25	25	25
TJ	645	603	561	519	477	435	433	430	427	425	422	350	279	207	135	64	64	64	64	64	64	64	64	64
MK	104	90	97	100	89	98	100	103	103	100	105	104	100	93	21	23	7	6	7	7	7	8	6	4
TR	765	765	765	765	765	765	765	765	765	765	765	717	669	620	572	524	476	428	380	332	284	235	187	139
TM	394	369	343	318	292	266	265	263	262	260	258	214	171	127	83	39	39	39	39	39	39	39	39	39
UA	3878	3586	3293	3001	2709	2417	2124	1832	1540	1248	955	663	145	123	195	304	297	309	213	171	159	159	159	100
UK	2887	2633	2411	2137	1837	1529	1292	1132	829	477	149	142	132	116	116	107	88	79	73	63	63	59	61	63
UZ	1870	1748	1627	1627	1384	1263	1255	1248	1240	1232	1225	1017	809	601	393	185	185	185	185	185	185	185	185	185

Expert estimates:

- *Denier van der Gon D. H.A.C., van het Bolscher M., Visschedijk A.J.H. and Zandveld P.Y.J. [2005] Study to the effectiveness of the UNECE Heavy Metals Protocol and costs of possible additional measures. Phase I: Estimation of emission reduction resulting from the implementation of the HM Protocol. TNO-report B&O-A R 2005/193.*

- *Berdowski J.J.M., Baas J., Bloos J.P.J., Visschedijk A.J.H., Zandveld P.Y.J. [1997] The European Emission Inventory of Heavy Metals and Persistent Organic Pollutants for 1990. TNO Institute of Environmental Sciences, Energy Research and Process Innovation, UBA-FB report 104 02 672/03*

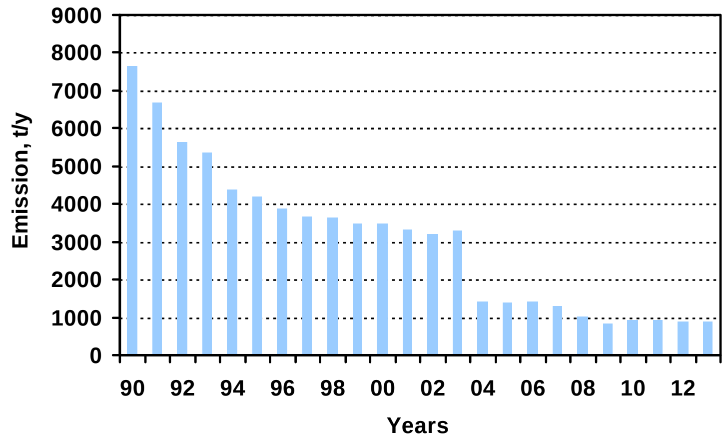


Figure 4.23. Time-series of total annual **lead** emissions of HELCOM countries in 1990-2013, tonnes/year.

4.2 Annual total deposition of lead

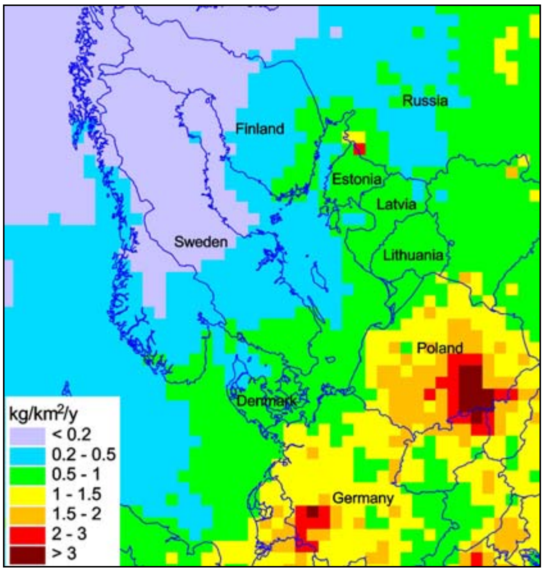


Figure 4.24. Annual total deposition fluxes of **lead** over the Baltic Sea region for 2013, kg/km^2/y.

4.3 Monthly total deposition of lead

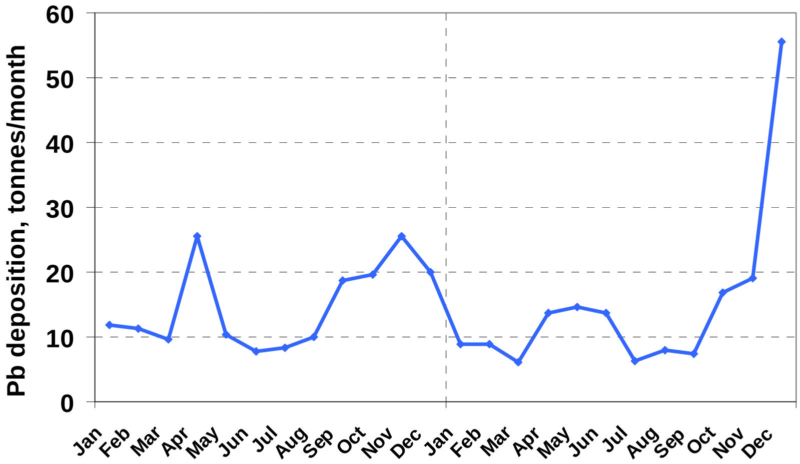


Figure 4.25. Monthly total deposition of **lead** to the Baltic Sea for 2012 and 2013, tonnes/month.

Table 4.3. Monthly total deposition of **lead** to the Baltic Sea for 2012 and 2013, tonnes/month.

Month	Pb deposition, 2012	Pb deposition, 2013
Jan	11.8	9.0
Feb	11.2	8.9
Mar	9.6	6.1
Apr	25.5	13.7
May	10.4	14.6
Jun	7.9	13.6
Jul	8.3	6.2
Aug	9.9	7.9
Sep	18.8	7.5
Oct	19.7	16.8
Nov	25.5	19.1
Dec	20.0	55.6

4.4 Source allocation of lead deposition

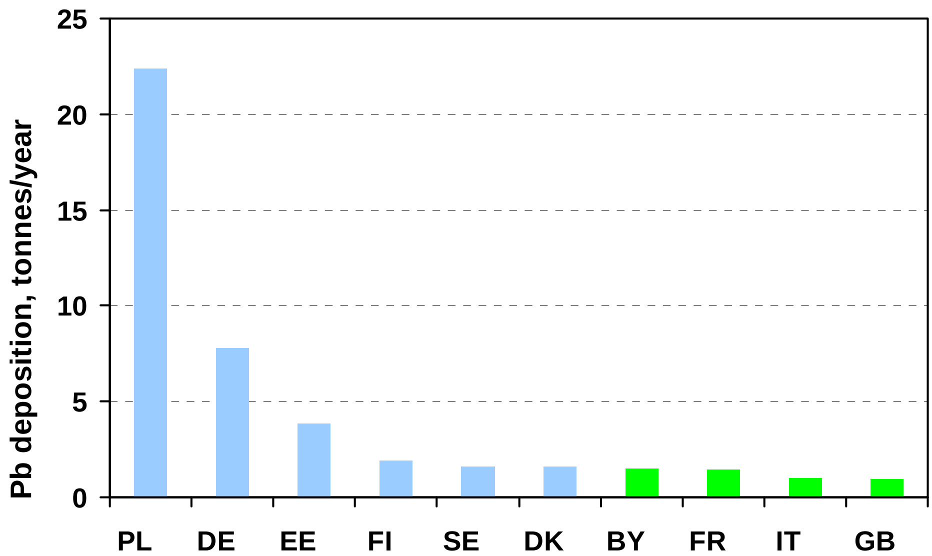


Figure 4.26. Top ten countries with the highest contribution to annual total deposition of lead into the Baltic Sea for 2013, tonnes/year. Green bars indicate non-HELCOM countries.

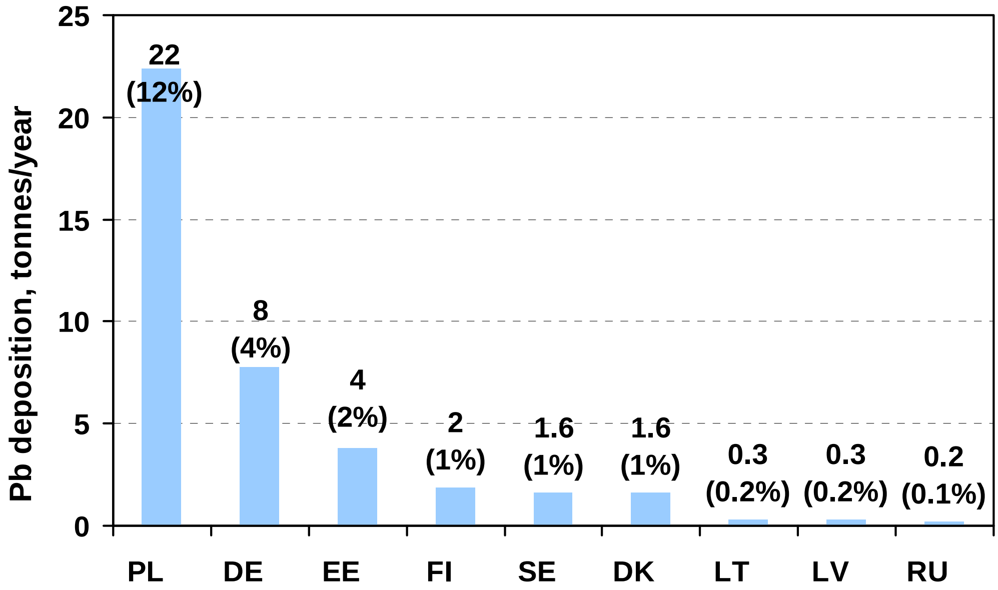


Figure 4.27. Sorted contributions (in tones/year and in %) of HELCOM countries to total deposition to the Baltic Sea for 2013. HELCOM countries emissions of lead contributed about 22% to the total annual lead deposition over the Baltic Sea. Contribution of other EMEP countries accounted for 6%. Significant contribution was made by other emission sources, in particular, remote emissions sources, natural emissions and wind re-suspension of **lead** (72%).

Table 4.4. Two most significant contributors to annual total deposition of **lead** to the nine Baltic Sea sub-basins for 2013.

Sub-basin	Country(1)	%	Country(2)	%	*, %
ARC	Poland	11	Finland	4	73
BOB	Sweden	9	Finland	8	68
BOS	Poland	7	Finland	3	75
BAP	Poland	16	Germany	5	71
GUF	Estonia	15	Poland	7	67
GUR	Poland	12	Germany	2	75
KAT	Poland	8	Germany	6	74
SOU	Poland	9	Germany	7	71
WEB	Germany	9	Poland	8	73
BAS	Poland	12	Germany	4	72

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

4.5 Comparison of model results with measurements

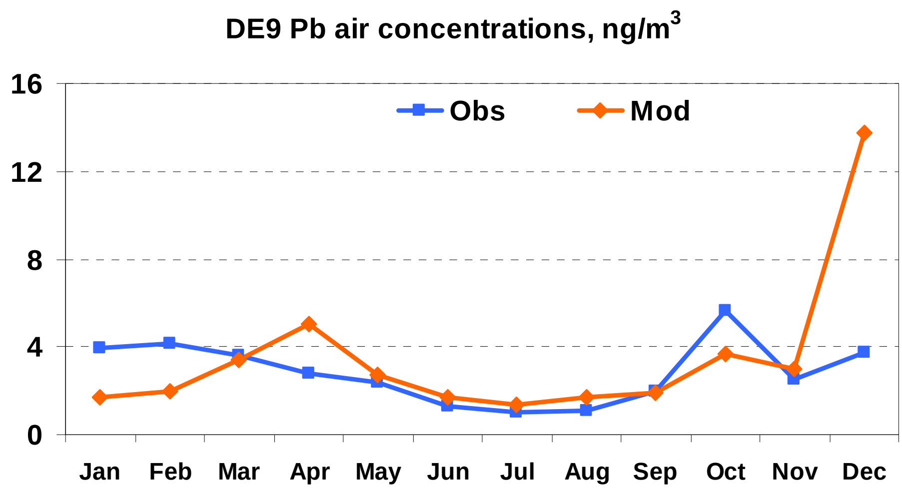


Figure 4.28. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Zingst (DE9). Units: ng / m^3.

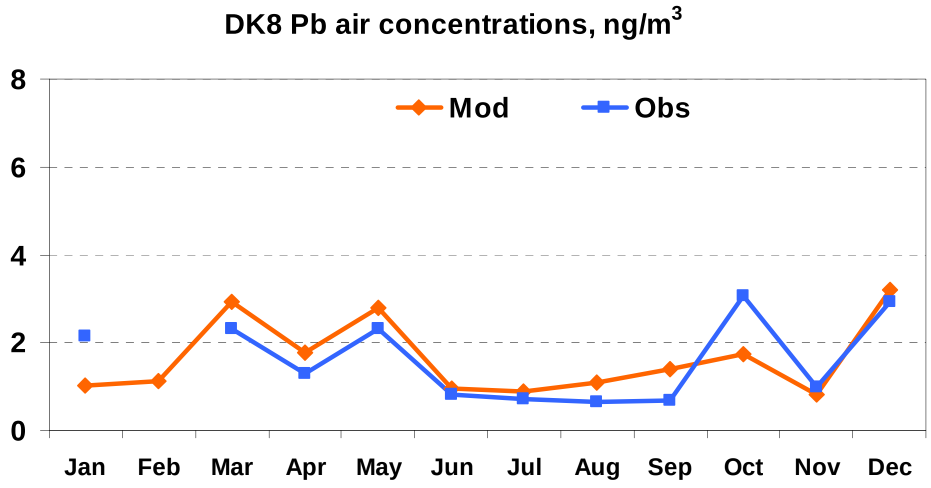


Figure 4.29. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Anholt (DK8). Units: ng / m^3.

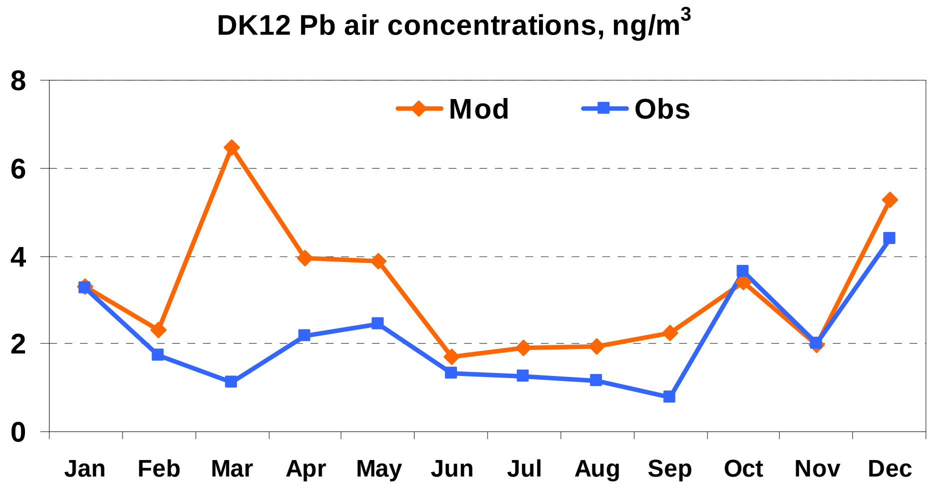


Figure 4.30. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Risoe (DK12). Units: ng / m^3.

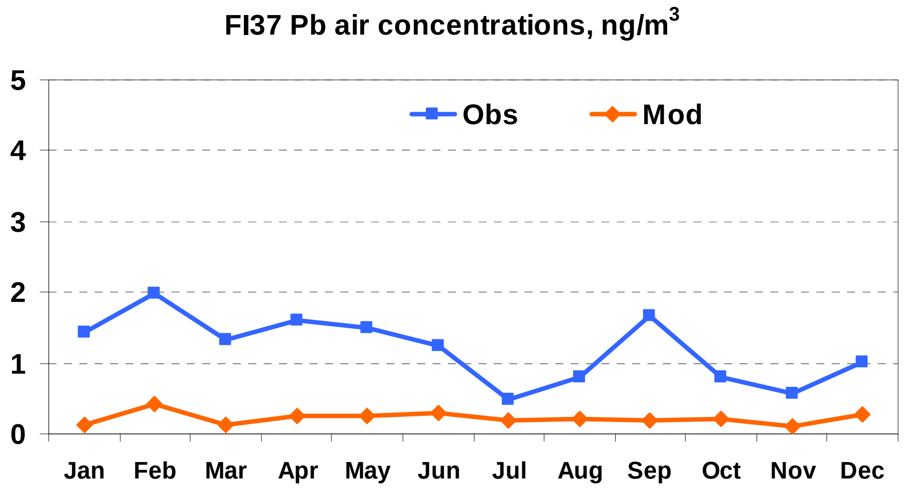


Figure 4.31. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Ähtäri II (FI37). Units: ng / m^3.

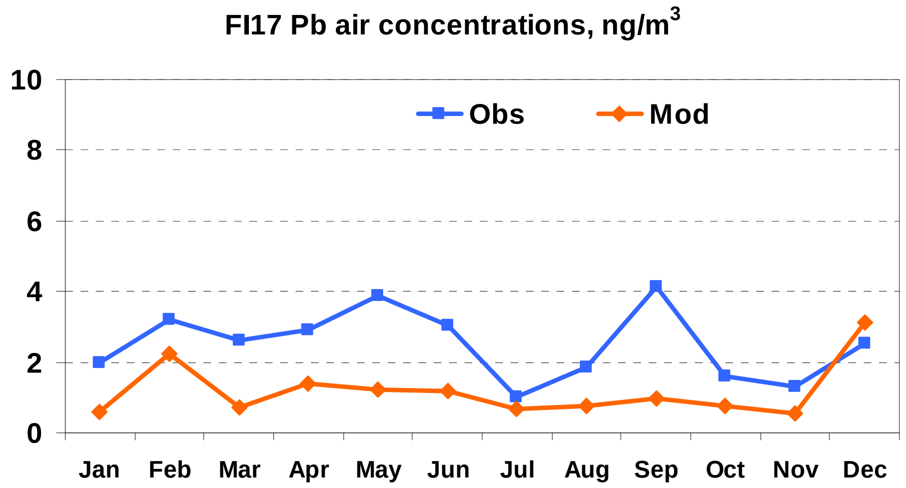


Figure 4.32. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Virolahti II (FI17). Units: ng / m^3.

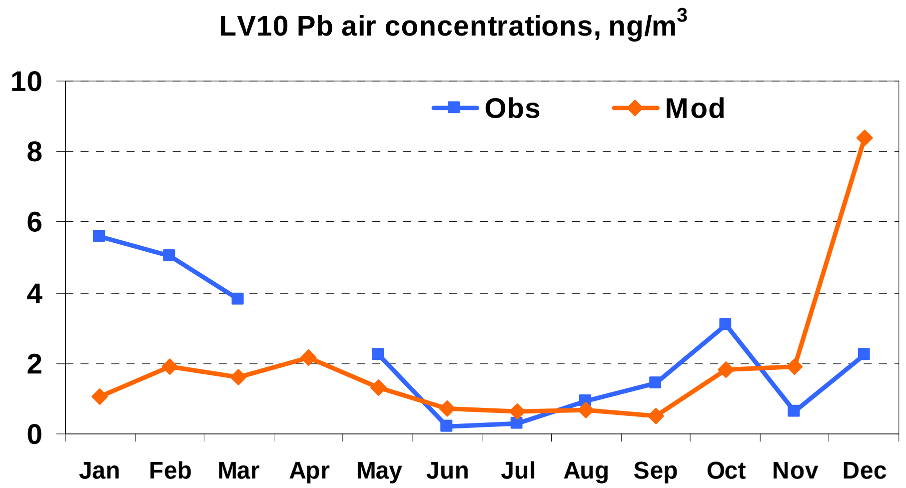


Figure 4.33. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Rucava (LV10). Units: ng / m^3.

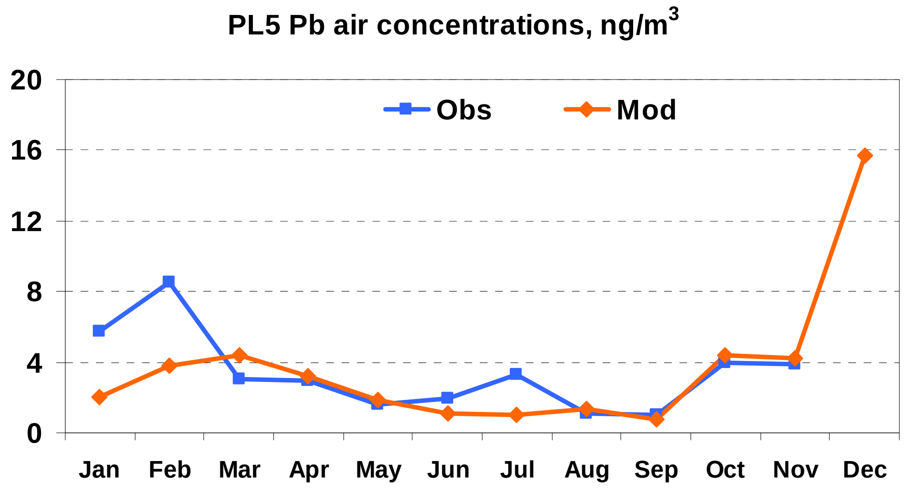


Figure 4.34. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Diabla Gora (PL5). Units: ng / m^3.

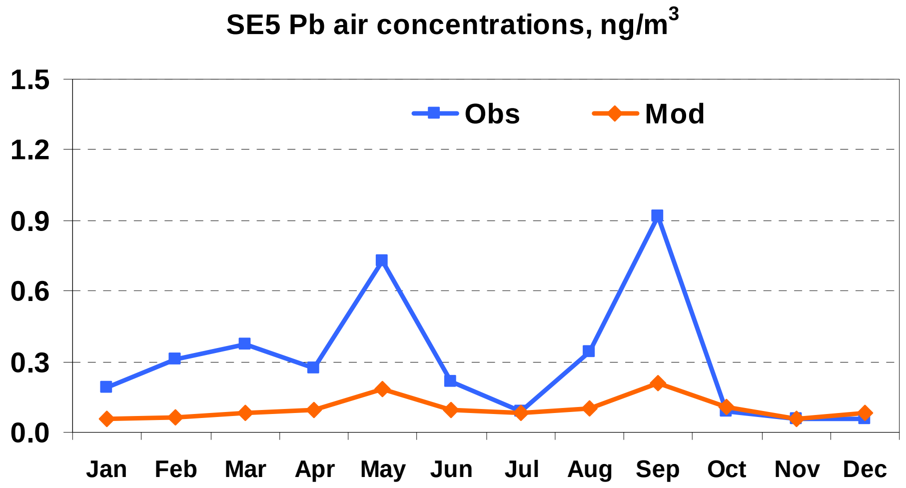


Figure 4.35. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Bredkälen (SE5). Units: ng / m^3.

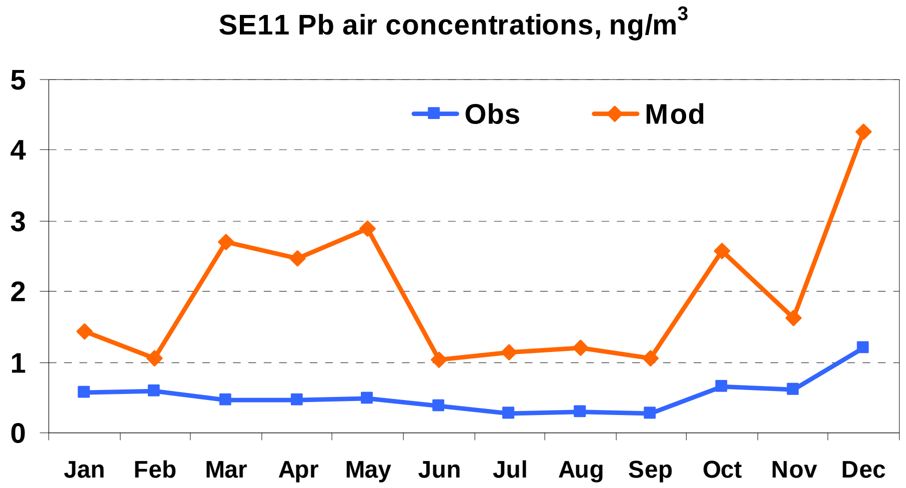


Figure 4.36. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Vavihill (SE11). Units: ng / m^3.

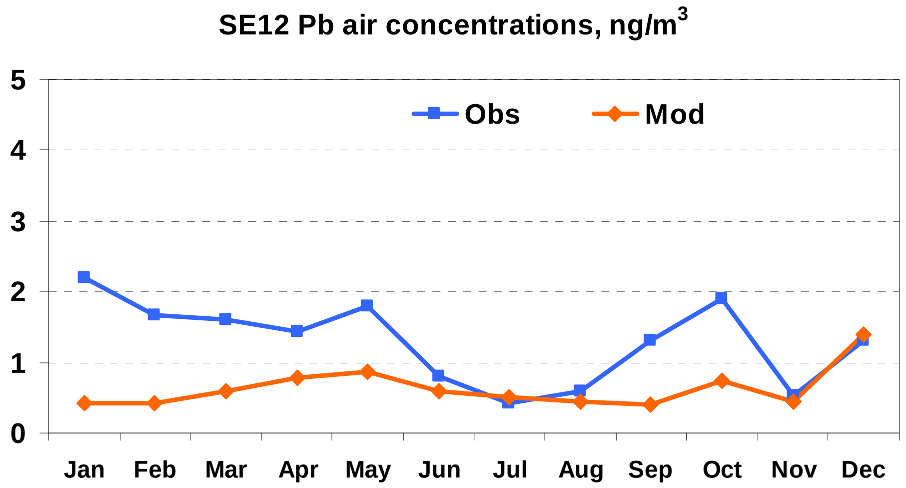


Figure 4.37. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Aspvreten (SE12). Units: ng / m^3.

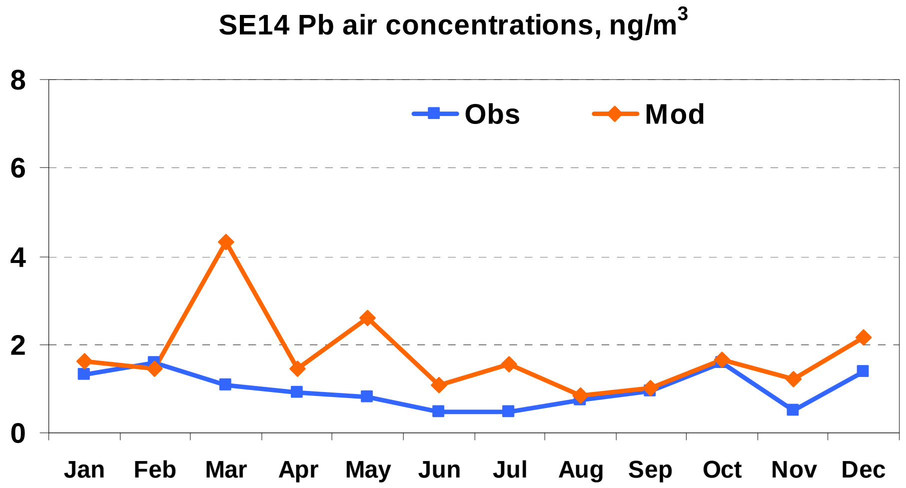


Figure 4.38. Comparison of calculated mean monthly lead concentrations in air for 2013 with measurements of the station Räo (SE14). Units: ng / m^3.

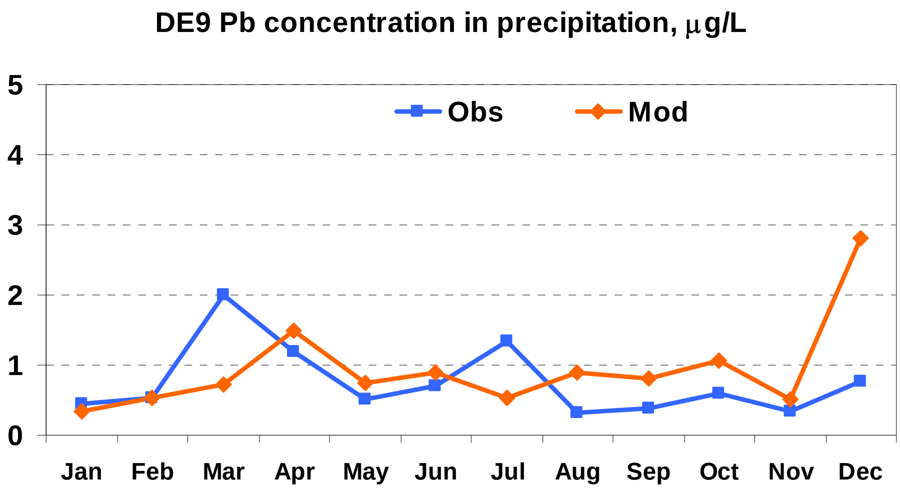


Figure 4.39. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Zingst (DE9). Units: µg / L.

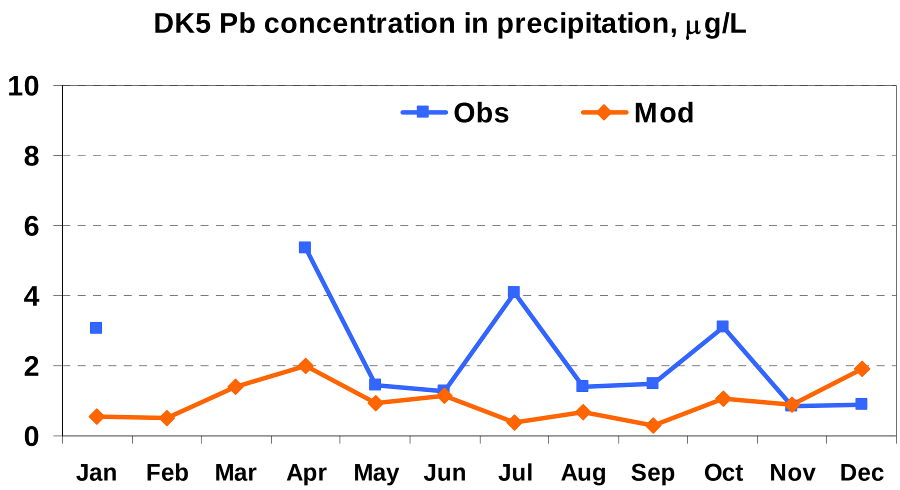


Figure 4.40. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Keldsnor (DK5). Units: µg / L.

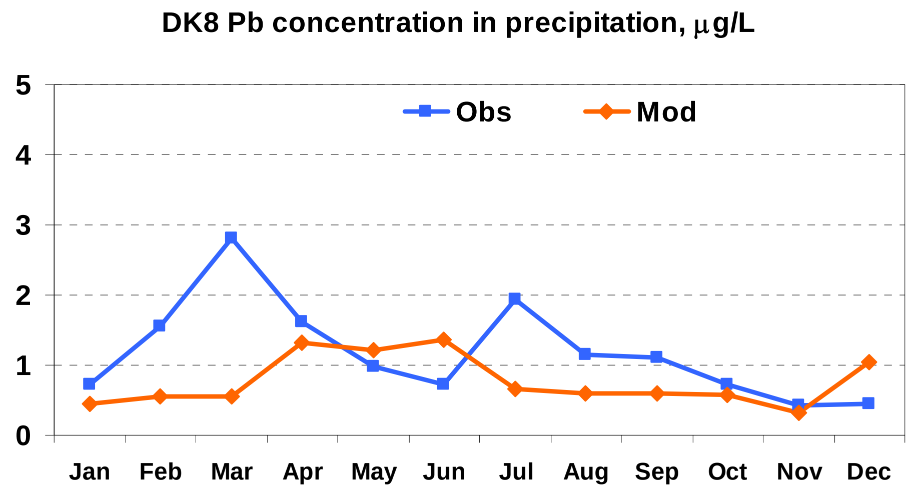


Figure 4.41. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Anholt (DK8). Units: µg / L.

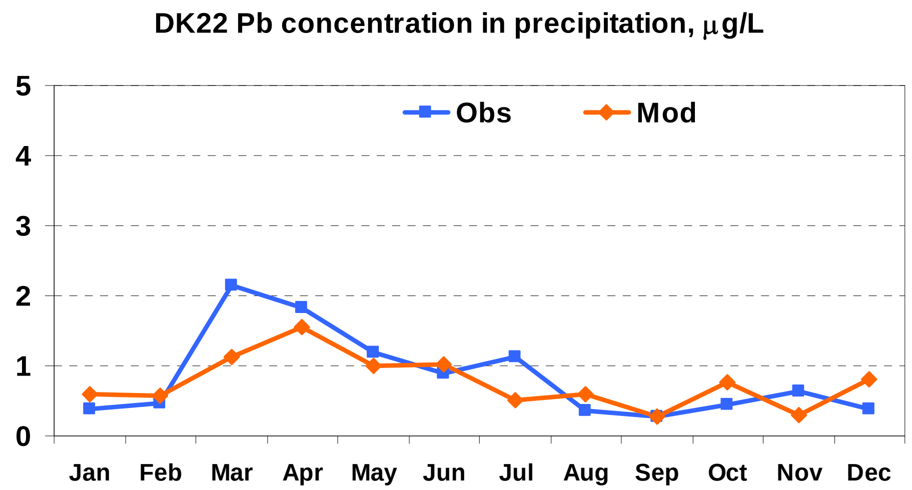


Figure 4.42. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Storebaelt (DK22). Units: µg / L.

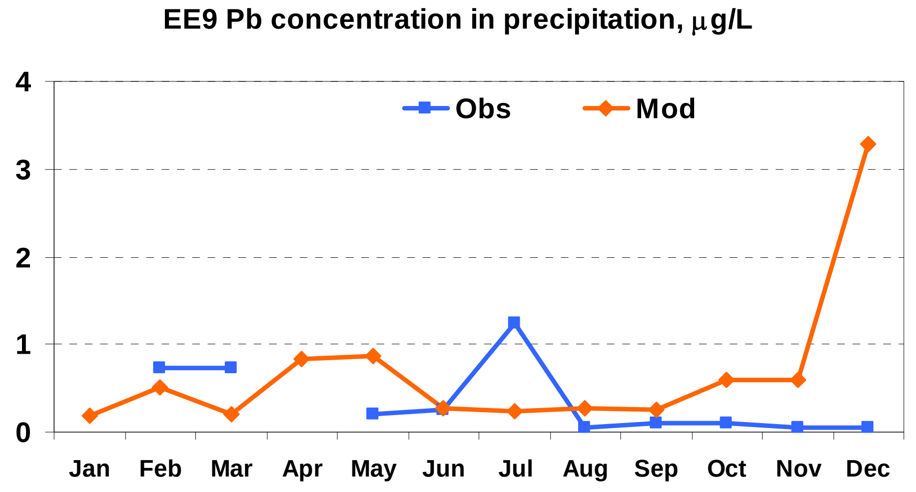


Figure 4.43. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Lahemaa (EE9). Units: µg / L.

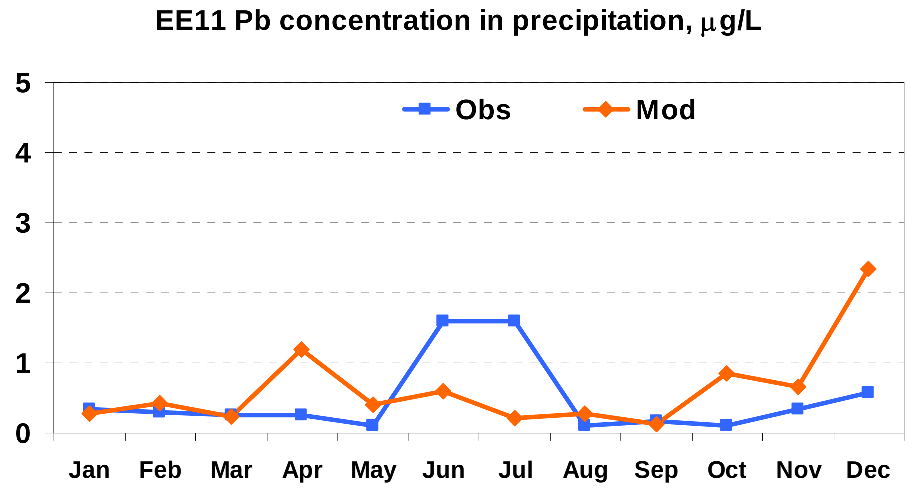


Figure 4.44. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Vilsandi (EE11). Units: µg / L.

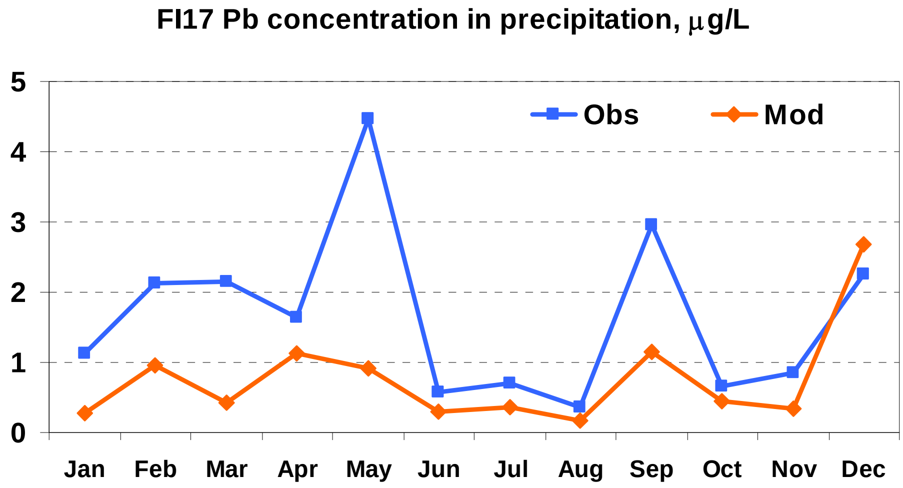


Figure 4.45. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Virolahty II (FI17). Units: μg / L.

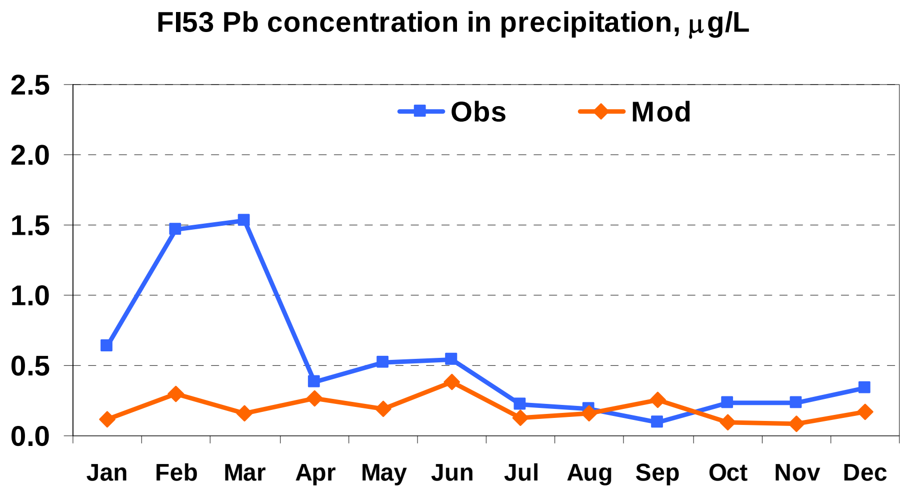


Figure 4.46. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Hailuoto (FI53). Units: μg / L.

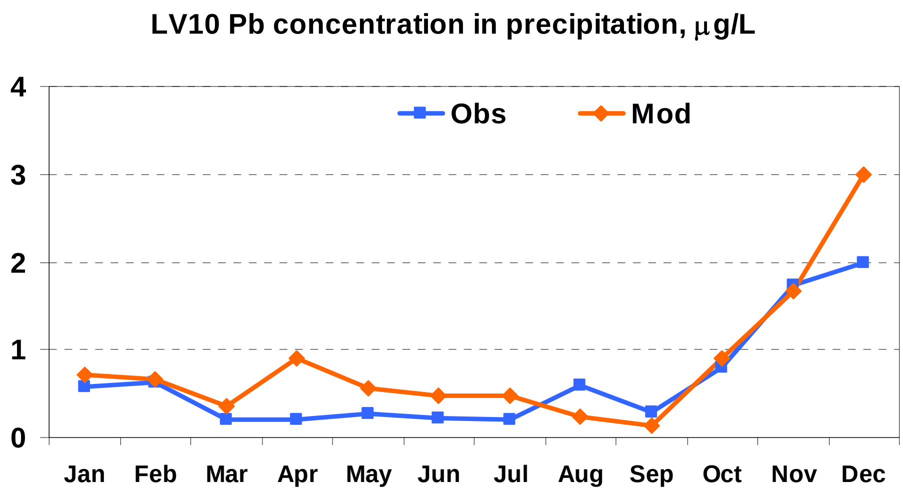


Figure 4.47. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Rucava (LV10). Units: µg / L.

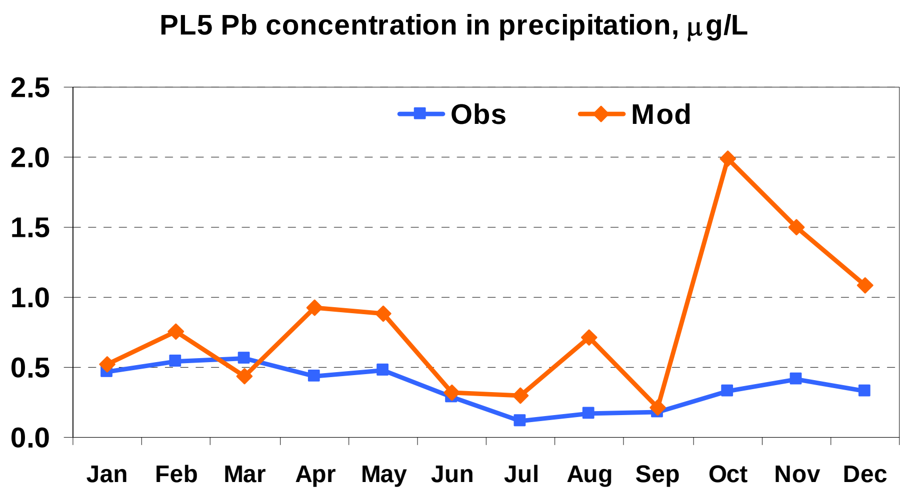


Figure 4.48. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Diable Gora (PL5). Units: µg / L.

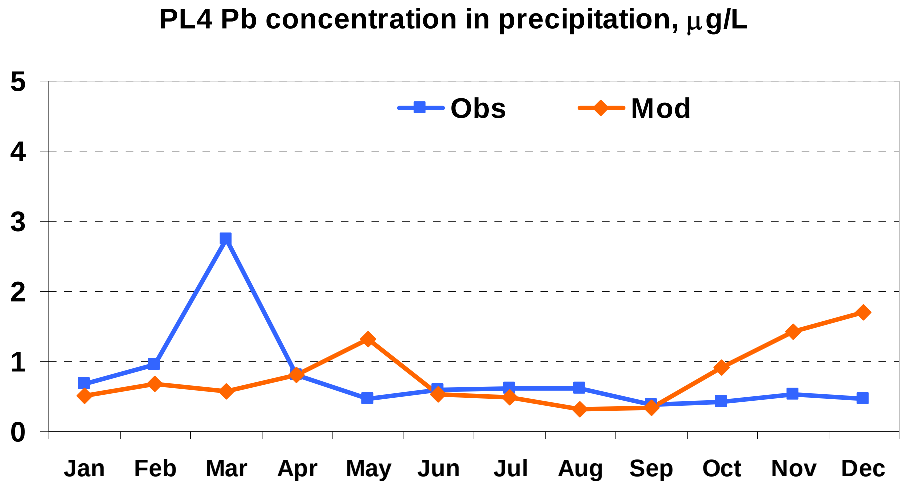


Figure 4.49. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Leba (PL4). Units: µg / L.

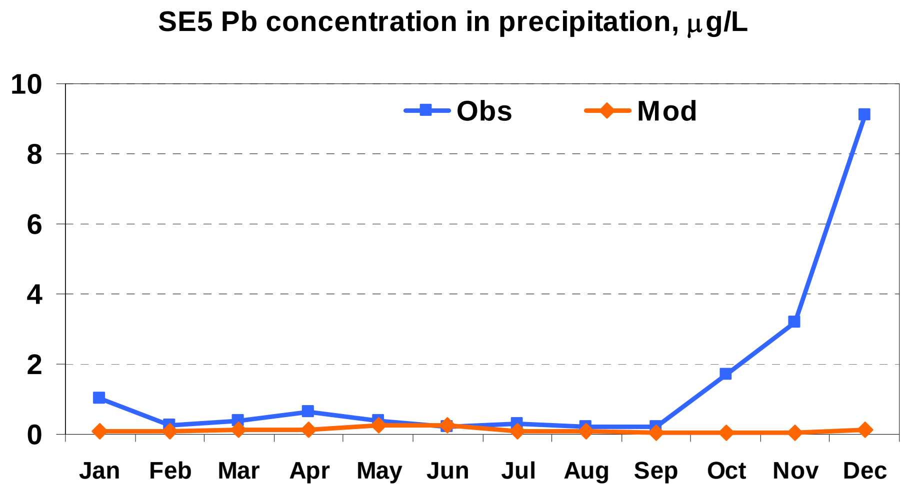


Figure 4.50. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Bredkälen (SE5). Units: µg / L.

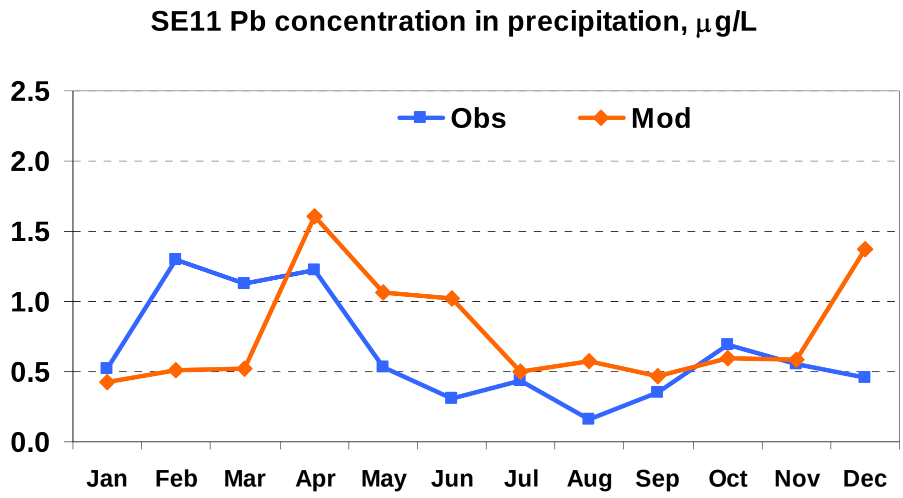


Figure 4.51. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Vavihill (SE11). Units: µg / L.

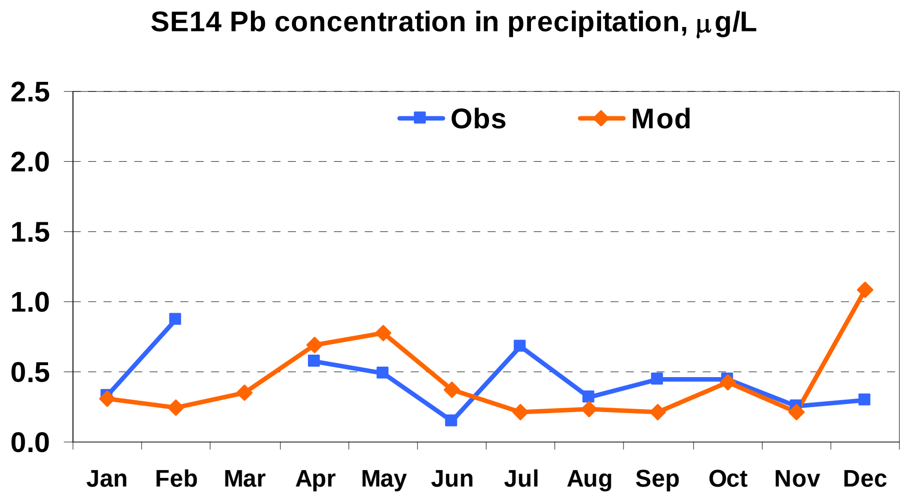


Figure 4.52. Comparison of calculated mean monthly lead concentrations in precipitation for 2013 with measurements of the station Räo (SE14). Units: µg / L.

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 the simulated and observed monthly mean concentrations of lead can likely be explained by the uncertainties in seasonal variation of lead emission used in modeling (underestimation of winter time emissions), differences between measured precipitation amount and the one used in the model, and difficulties in measurements of heavy metals.

4.6 Concluding remarks

- Emissions of lead from HELCOM countries have decreased from 1990 to 2013 by 88%. Lead emission in HELCOM countries have slightly increased from 2012 to 2013 by 1%.

- Annual deposition of lead to the Baltic Sea has dropped from 1990 to 2013 by 81%. From 2012 to 2013 the deposition of lead has decreased by 1.2%.

- The contribution of anthropogenic sources of HELCOM countries to total lead deposition over the Baltic Sea was estimated to 22%. Essential contribution belongs also to the anthropogenic sources of other EMEP countries (6%), natural sources and wind re-suspension (72%).

- The most significant contribution among the HELCOM countries to lead deposition over the Baltic Sea was made by Poland (12%) followed by Germany (4%).

- Modelling results for lead were generally within an accuracy of a factor of two in comparison with annual mean measured concentrations around the Baltic Sea in 2013.