7. Atmospheric Supply of PCB-153 to the Baltic Sea in 2013

In this chapter results of model evaluation of polychlorinated biphenyl-153 (PCB-153) atmospheric input to the Baltic Sea and its sub-basins for 2013 are presented. Modelling of PCB-153 atmospheric transport and deposition within the EMEP region was carried out for the period 1990-2013 using MSC-E Eulerian Persistent Organic Pollutant transport model MSCE-POP (*Gusev et al.*, 2005). Initial and boundary conditions for regional modelling were prepared using the Global EMEP Multi-media Modelling System (GLEMOS) for HMs and POPs (*Gusev et al.*, 2015).Expert estimates of PCB emissions and latest available official emission data reported by the EMEP countries were used in model assessment. In particular, emission data for modelling of PCB long-range transport and deposition were prepared on the basis of inventory of global PCB emissions (*Breivik et al.*, 2007) taking also into account official information on PCB emissions submitted by the EMEP countries. Spatial distribution of PCB-153 emissions within the EMEP region was prepared using gridded PCB emissions officially submitted by 19 EMEP countries and the emission expert estimates worked out by TNO (*Denier van der Gon et al.*, 2005). Based on results of model simulations annual and monthly levels of PCB-153 deposition to the Baltic Sea have been obtained and contributions of HELCOM countries emission sources to the deposition are estimated. Model results were compared with observed levels of PCB-153 concentrations measured at monitoring sites around the Baltic Sea in 2013.

7.1 PCB-153 emissions

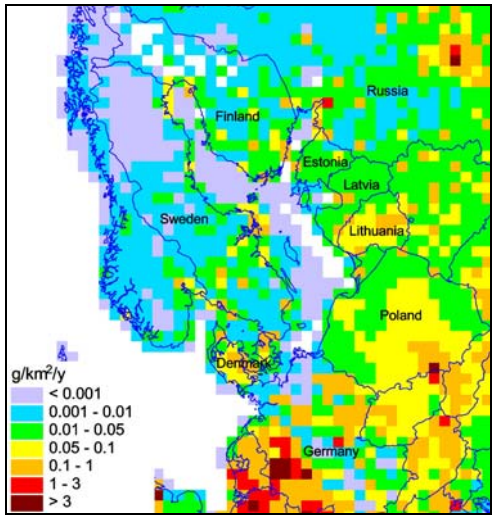


Figure 7.1. Annual total anthropogenic emissions of **PCB-153** in the Baltic Sea region for 2013 according to available expert estimates and officially reported information on emissions of the EMEP countries, $g/km^2/y$.

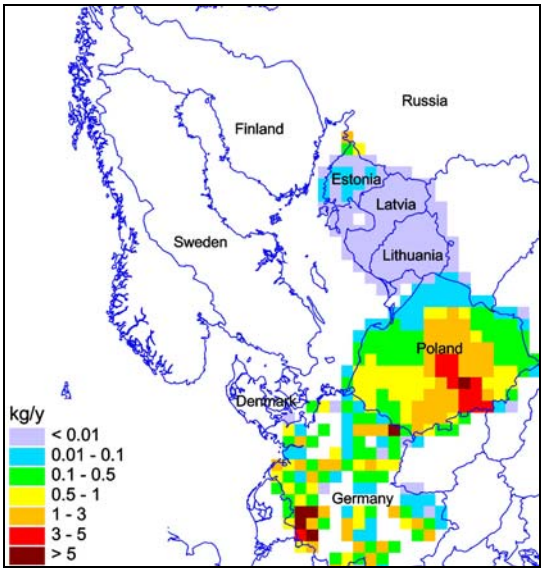


Figure 7.2. Annual PCB emission from Public Power sector for 2013, kg/grid cell/y (white color means no information).

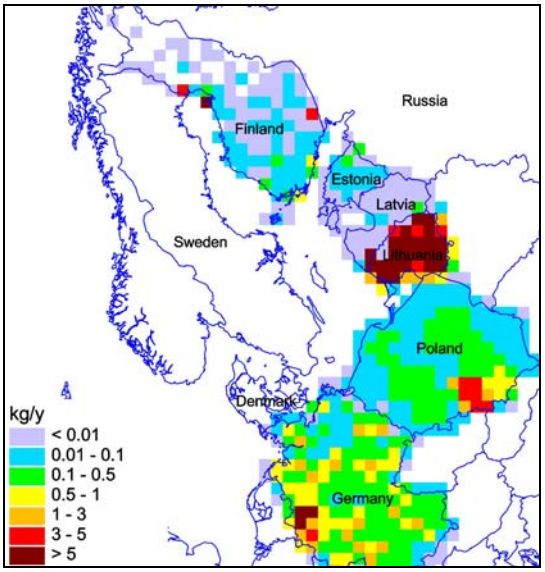


Figure 7.3. Annual PCB emission from Industry sector for 2013, kg/grid cell/y (white color means no information).

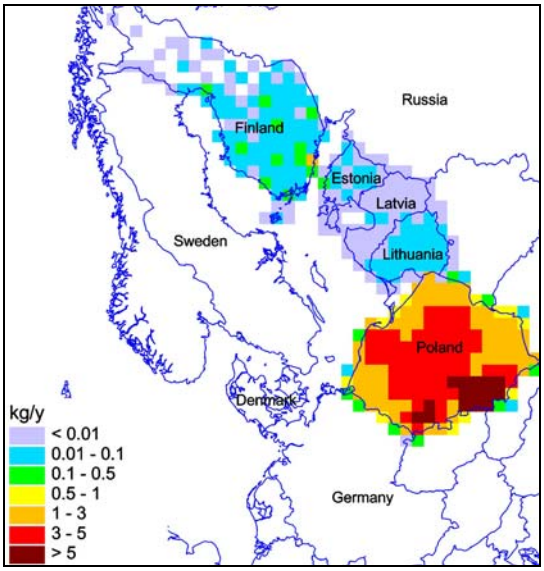


Figure 7.4. Annual PCB emission from Other Stationary Combustion sector for 2013, kg/grid cell/y (white color means no information).

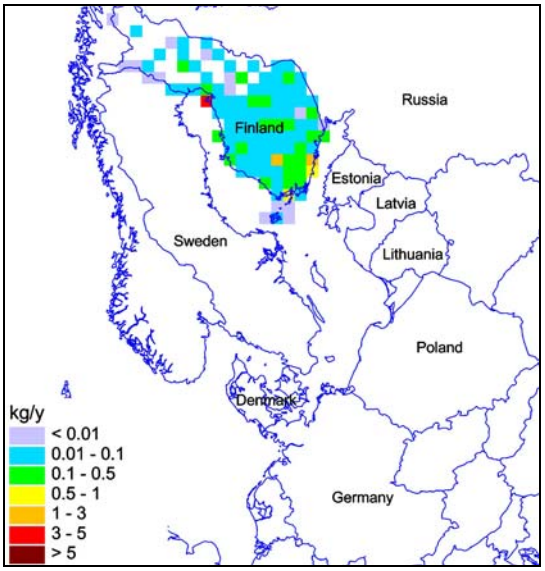


Figure 7.5. Annual PCB emission from Fugitive Emissions sector for 2013, kg/grid cell/y (white color means no information).

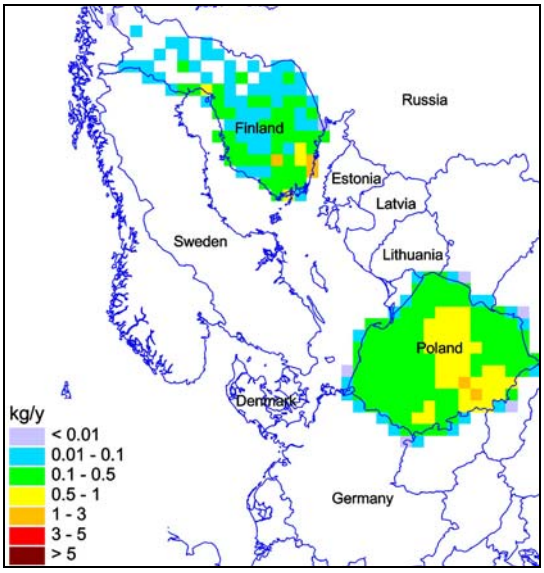


Figure 7.6. Annual PCB emission from Road Transport sector for 2013, kg/grid cell/y (white color means no information).

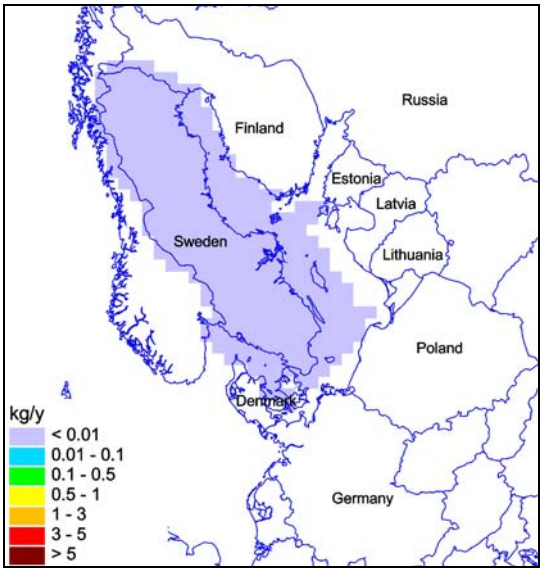


Figure 7.7. Annual PCB emission from Shipping Emissions sector for 2013, kg/grid cell/y (white color means no information).

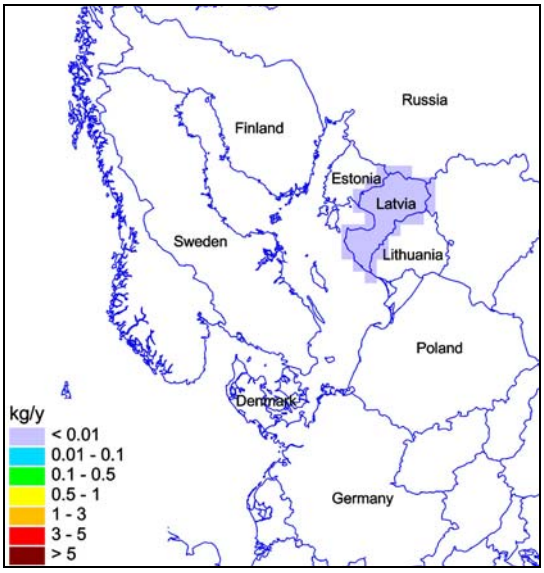


Figure 7.8. Annual PCB emission from Off Road sector for 2013, kg/grid cell/y (white color means no information).

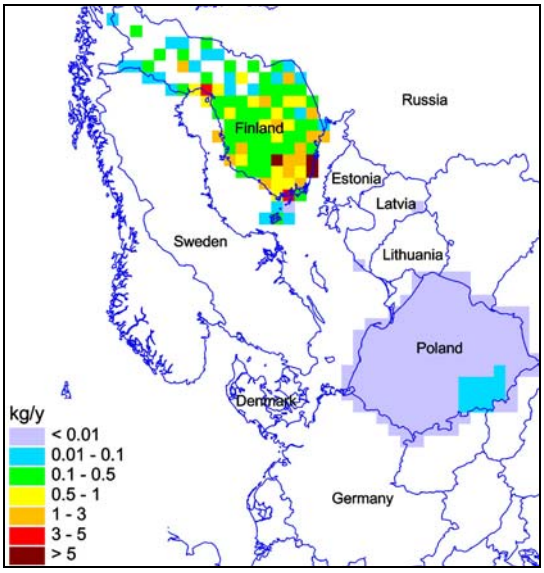


Figure 7.9. Annual PCB emission from Waste sector for 2013, kg/grid cell/y (white color means no information).

Table 7.1. Annual total **PCB** anthropogenic emissions of HELCOM countries from different sectors for 2013 based on the officially reported data on emissions, in kg/y

GNFR emission sector	Sector name	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Sweden
A	Public Power	0.283	2.69	NA	99.88	0.032	0.022	136.93	NE
B	Industry	0.131	0.893	19.17	103.98	0.253	295.92	45.84	
C	Other Stationary Combustion	0.116	0.34	5.56	28.59	0.185	0.745	511.44	
D	Fugitive Emissions			16.83	NA			NA	
E	Solvents	0.002	NA				NA	NA	
F	Road Transport	22.27	NE	19.17		NA	NE	60.04	
G	Shipping emissions	0.057		0.092	0.244	NA		NA	0.037
I	Off Road	17.14	4.2E-05	0.023	0.007	0.00032		NA	0.022
J	Waste	0.025	0.016	91.2	0.197	0.00082	0.00037	0.962	
L	Agricultural Other	1.8E-05						NA	NA
Total		40.02	3.94	152.05	232.89	0.471	296.69	755.2	0.059

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.

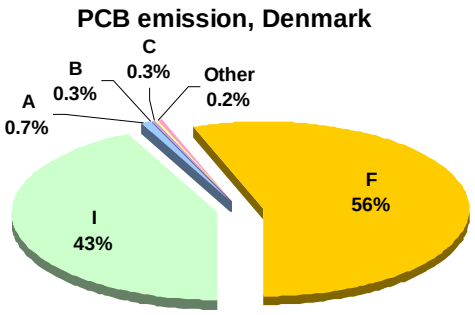


Figure 7.10. Contributions of different sectors to total annual PCB emission of Denmark in 2013

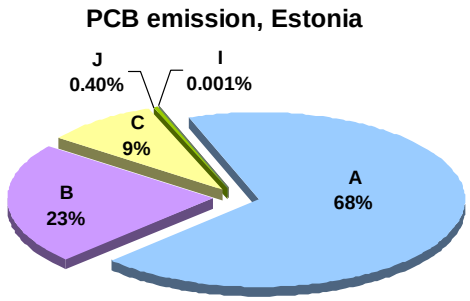


Figure 7.11. Contributions of different sectors to total annual PCB emission of Estonia in 2013

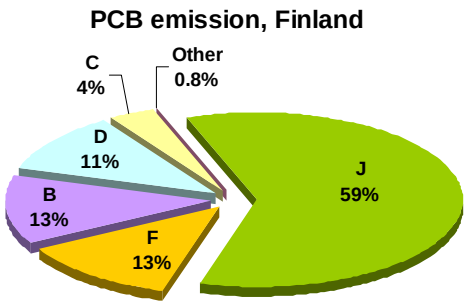


Figure 7.12. Contributions of different sectors to total annual PCB emission of Finland in 2013

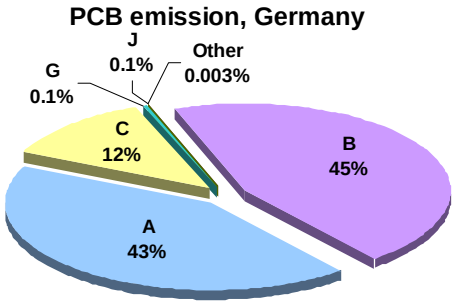


Figure 7.13. Contributions of different sectors to total annual PCB emission of Germany in 2013

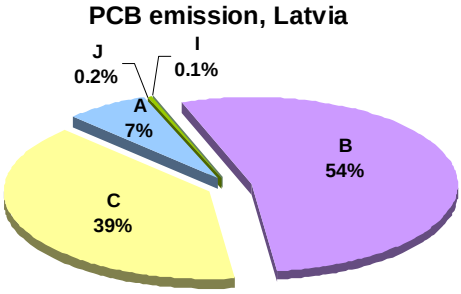


Figure 7.14. Contributions of different sectors to total annual PCB emission of Latvia in 2013

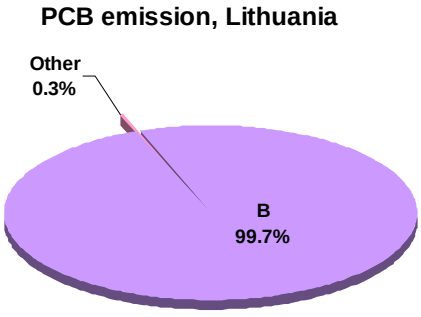


Figure 7.15. Contributions of different sectors to total annual PCB emission of Lithuania in 2013

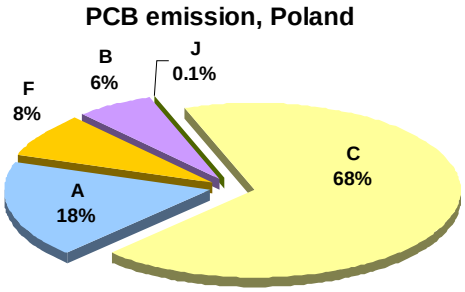


Figure 7.16. Contributions of different sectors to total annual PCB emission of Poland in 2013

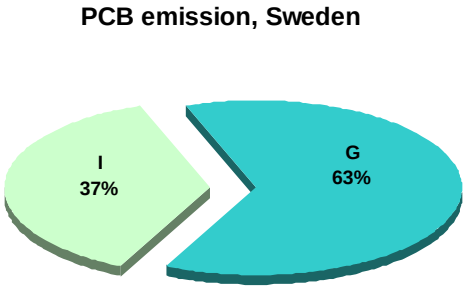
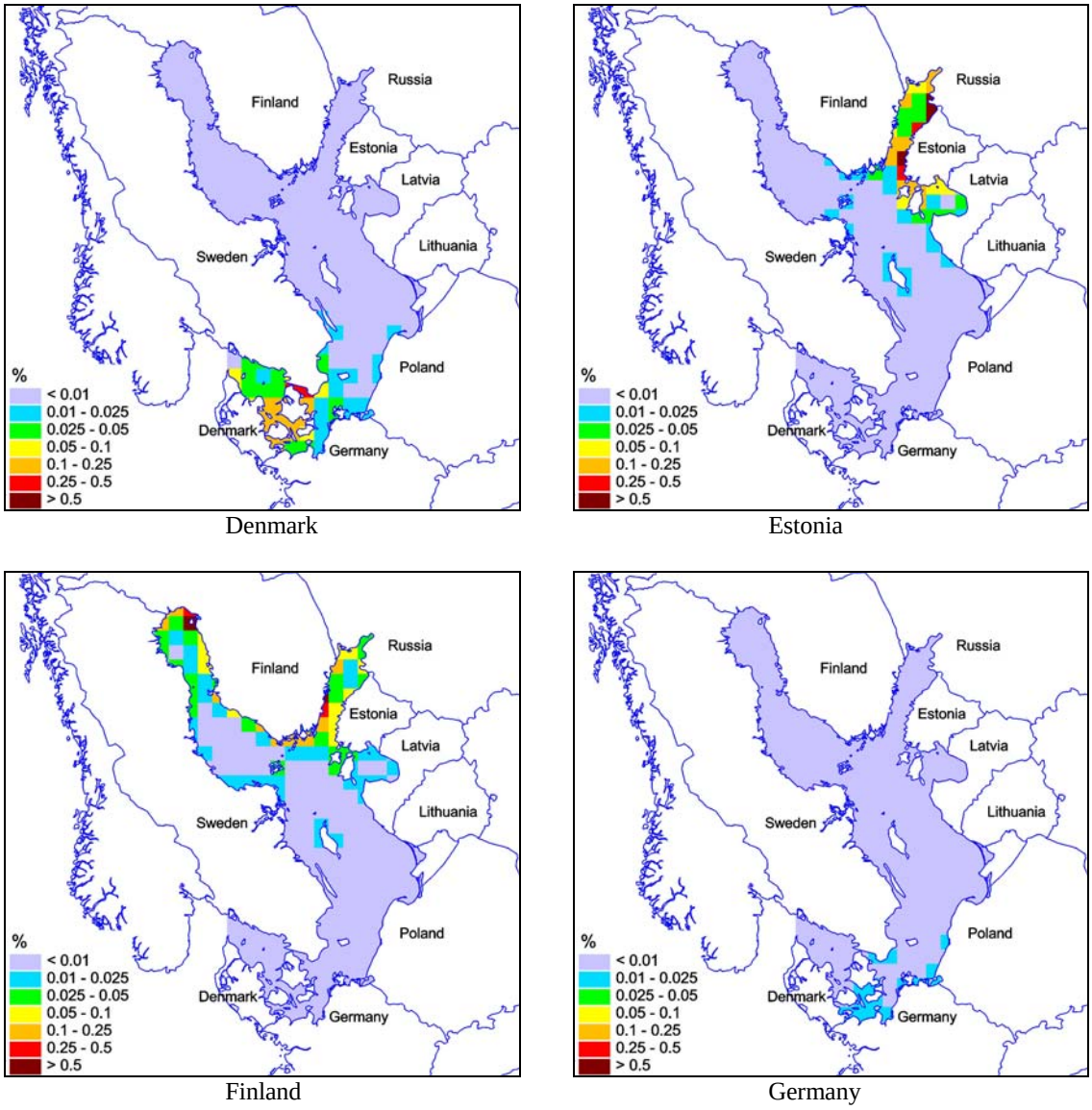


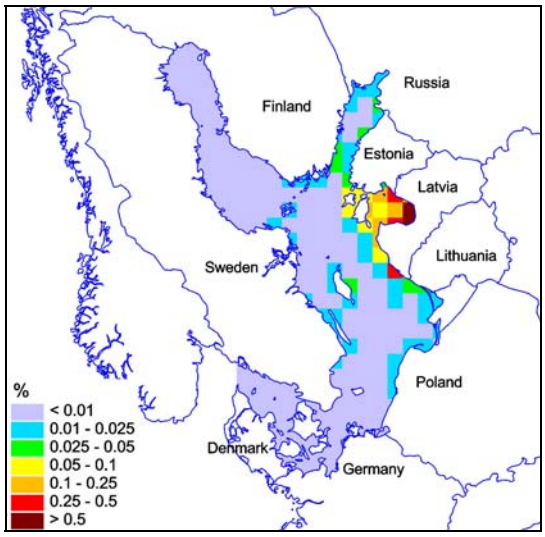
Figure 7.17. Contributions of different sectors to total annual PCB emission of Sweden in 2013



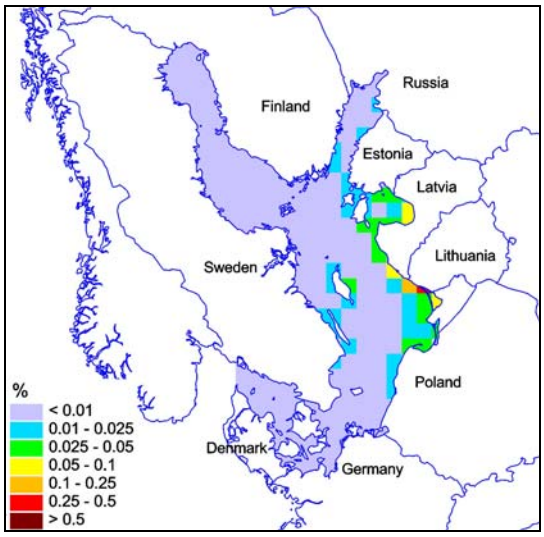
Denmark Estonia

Finland Germany

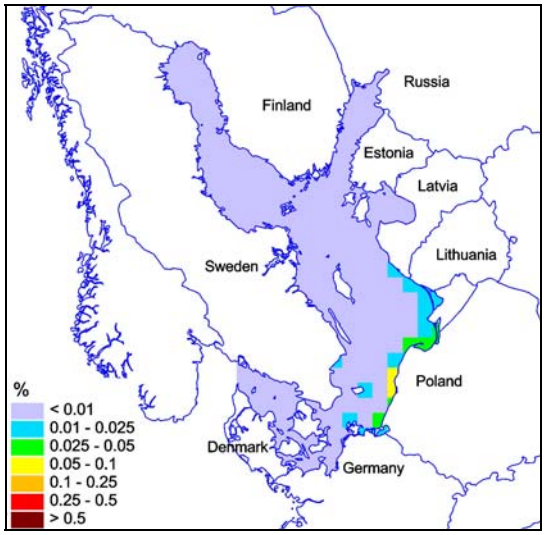
Figure 7.18. Fractions of annual anthropogenic PCB-153 emissions of HELCOM Parties deposited to the Baltic Sea in 2013 (expressed as a percent of national anthropogenic emission deposited to the particular grid cells).



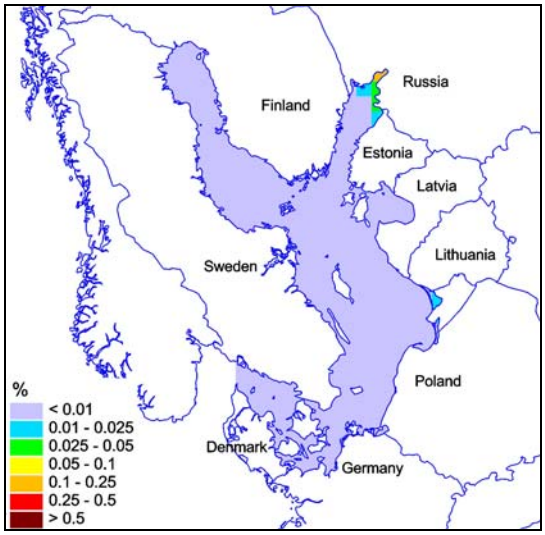
Latvia



Lithuania

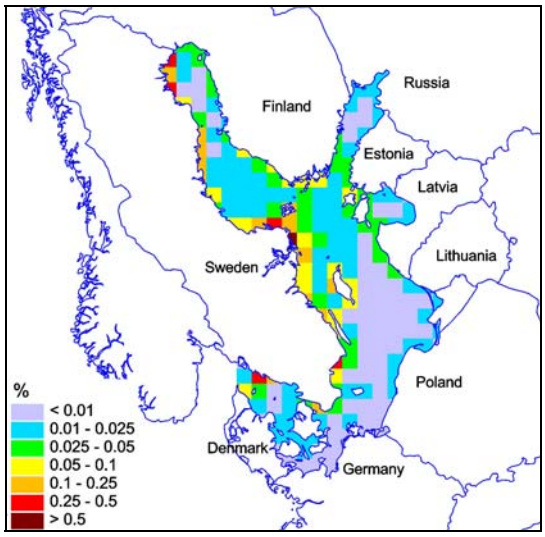


Poland



Russia

Figure 7.18. (cont.) Fractions of annual anthropogenic PCB-153 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 7.18. (cont.) Fractions of annual anthropogenic PCB-153 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 7.2. Annual total anthropogenic emissions of **PCB-153** of HELCOM countries and other EMEP countries in period 1990-2013 based on the inventory of *Breivik et al.*, (2007), kg/y

	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	53	50	48	46	44	40	37	33	30	27	23	18	14	11	9.2	8.7	8.2	7.8	7.4	7.1	6.7	6.4	6.1	5.7
EE	12	11	10	9.7	9.0	8.3	7.6	6.7	6.4	6.1	5.8	5.6	5.3	5.0	4.7	4.5	4.2	3.9	3.7	3.4	3.2	3.0	2.7	2.5
FI	42	40	38	36	35	32	30	27	25	23	20	17	14	13	12	11	11	10	9.6	9.2	8.8	8.4	8.1	7.7
DE	1471	1396	1326	1264	1210	1118	1027	939	851	766	630	484	303	288	271	252	238	225	214	203	193	183	173	163
LV	18	17	16	15	14	13	12	10	9.8	9.3	8.9	8.6	8.1	7.7	7.3	6.9	6.4	6.1	5.7	5.3	4.9	4.6	4.2	3.8
LT	25	23	22	20	19	17	16	14	13	13	12	12	11	10	9.9	9.3	8.8	8.3	7.7	7.2	6.7	6.2	5.7	5.2
PL	159	152	146	141	136	134	132	125	113	91	64	59	53	47	42	37	33	29	26	24	22	21	20	19
RU	682	636	595	556	516	475	432	382	365	349	333	319	302	286	270	255	240	225	211	197	183	170	156	143
SE	56	53	51	49	47	43	40	36	32	29	24	19	18	17	16	15	14	13	12	12	11	11	10	9.6
AL	5.5	5.3	5.0	4.7	4.5	4.2	4.0	3.7	3.5	3.2	3.0	2.8	2.5	2.4	1.9	1.4	1.1	0.95	0.84	0.76	0.72	0.68	0.65	0.61
AM	6.0	5.6	5.2	4.9	4.6	4.2	3.8	3.4	3.2	3.1	3.0	2.8	2.7	2.5	2.4	2.2	2.1	2.0	1.9	1.7	1.6	1.5	1.4	1.3
AT	120	114	109	105	101	95	89	84	79	74	69	64	59	59	48	32	27	22	20	17	16	16	15	14
AZ	2.0	1.9	1.8	1.7	1.7	1.6	1.4	1.3	1.3	1.2	1.1	1.1	0.99	0.9	0.78	0.7	0.62	0.57	0.51	0.47	0.44	0.41	0.38	0.36
BY	60	56	53	49	46	42	38	34	32	31	29	28	27	25	24	23	21	20	19	17	16	15	14	13
BE	179	172	165	158	153	144	135	126	117	109	96	83	69	67	64	61	59	57	55	53	51	49	47	45
BA	10	9.9	9.3	8.8	8.3	7.7	7.2	6.7	6.2	5.7	5.2	4.7	4.1	3.6	3.1	2.6	2.3	1.9	1.7	1.5	1.4	1.4	1.3	1.2
BG	22	21	20	19	18	17	16	14	13	12	11	10	9.1	8.1	6.9	5.7	4.8	4.1	3.6	3.2	3.0	2.9	2.7	2.6
HR	14	14	13	12	11	11	10	9.3	8.6	7.9	7.2	6.4	5.6	4.9	4.2	3.6	3.1	2.7	2.3	2.1	2.0	1.9	1.8	1.7
CY	7.8	7.6	7.4	7.2	7.0	6.7	6.4	6.1	5.8	5.5	5.1	4.6	4.2	3.7	2.9	2.4	1.9	1.7	1.4	1.2	1.2	1.1	1.1	1.0
CZ	178	169	160	151	142	134	125	117	108	98	88	79	69	61	52	44	38	33	28	25	24	23	22	21
FR	1865	1777	1696	1623	1558	1465	1375	1288	1208	1136	995	848	673	554	521	490	469	447	421	394	372	354	336	318
GE	28	26	24	23	21	19	18	16	15	14	14	13	12	12	11	10	9.8	9.2	8.6	8.0	7.5	6.9	6.4	5.8
GR	39	37	36	35	34	32	30	29	27	27	25	25	26	27	20	9.0	5.6	5.1	4.9	4.6	4.4	4.2	4.0	3.8
HU	43	41	38	36	34	32	30	28	26	24	21	19	17	15	13	11	9.6	8.3	7.3	6.5	6.2	5.9	5.5	5.2
IS	3.4	3.3	3.1	3.0	2.9	2.8	2.7	2.5	2.4	2.4	2.3	2.3	2.3	2.4	1.9	1.1	0.84	0.64	0.58	0.48	0.46	0.44	0.42	0.4
IE	44	43	41	40	39	37	34	32	30	28	26	24	23	22	18	11	9.6	6.5	6.0	5.2	5.0	4.7	4.5	4.3
IT	763	732	707	687	673	635	600	567	538	512	463	415	362	320	291	267	247	207	183	173	167	160	154	147
KZ	84	78	73	68	63	58	53	47	45	43	41	39	37	35	33	31	30	28	26	24	23	21	19	18
KY	14	13	12	11	11	9.8	8.9	7.8	7.5	7.2	6.8	6.6	6.2	5.9	5.6	5.2	4.9	4.6	4.3	4.0	3.8	3.5	3.2	2.9
LU	11	10	9.7	9.2	8.8	8.2	7.5	6.9	6.3	5.7	4.8	3.7	2.5	2.3	2.2	1.9	1.8	1.7	1.6	1.5	1.5	1.4	1.3	1.2
MT	4.3	4.1	4.0	3.9	3.8	3.6	3.4	3.3	3.1	2.9	2.7	2.4	2.2	1.9	1.6	1.4	1.2	1.0	0.90	0.83	0.80	0.76	0.73	0.70
MC	0.018	0.018	0.017	0.016	0.016	0.015	0.014	0.014	0.013	0.012	0.011	0.010	0.009	0.007	0.007	0.006	0.006	0.005	0.004	0.004	0.004	0.004	0.004	0.004
NL	197	187	177	169	162	149	136	123	111	99	79	59	41	39	37	35	33	32	30	29	28	26	25	24
NO	32	30	29	27	26	24	22	19	17	15	12	9.7	6.8	5.5	4.9	4.5	3.9	3.2	3.0	2.9	2.7	2.5	2.4	2.2
PT	138	134	130	127	126	120	115	110	107	105	96	86	76	65	51	40	33	27	23	20	19	18	17	17
MD	15	14	13	13	12	11	10	9.1	8.6	8.1	7.5	7.0	6.4	5.9	5.4	4.9	4.5	4.1	3.8	3.5	3.3	3.0	2.8	2.6
RO	60	56	53	50	47	44	41	38	35	32	30	27	23	21	18	15	13	12	10	9.1	8.6	8.2	7.7	7.3
RUA	171	159	149	139	129	119	108	95	91	87	83	80	76	72	68	64	60	56	53	49	46	43	39	36
ME	2.8	2.7	2.5	2.4	2.2	2.1	1.9	1.8	1.7	1.5	1.4	1.3	1.1	0.96	0.83	0.71	0.61	0.52	0.45	0.41	0.39	0.37	0.35	0.33
RS	27	25	24	22	21	20	18	17	16	15	13	12	10	9.1	7.8	6.7	5.8	4.9	4.3	3.8	3.6	3.4	3.3	3.1
SK	52	49	46	43	41	38	36	33	31	28	26	23	20	18	15	13	12	10	8.8	7.9	7.4	7.0	6.6	6.3
SI	5.0	4.8	4.5	4.3	4.1	3.8	3.6	3.4	3.1	2.9	2.7	2.5	2.3	2.1	1.8	1.3	1.1	0.94	0.83	0.73	0.69	0.65	0.62	0.59
ES	1221	1186	1156	1135	1128	1075	1029	988	959	946	852	756	651	558	471	366	292	243	207	185	176	167	159	151
CH	101	96	92	88	84	78	72	67	61	56	48	39	29	28	25	22	20	18	17	16	15	14	14	14
TJ	9.6	9.0	8.4	7.9	7.3	6.7	6.1	5.4	5.2	4.9	4.7	4.5	4.3	4.0	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0
MK	5.7	5.4	5.1	4.9	4.6	4.3	4.1	3.8	3.5	3.3	3.0	2.8	2.5	2.3	1.9	1.4	1.1	0.99	0.87	0.79	0.75	0.71	0.68	0.64
TR	103	99	95	92	88	84	79	75	72	69	66	65	65	66	53	33	27	22	20	17	16	15	15	14
TM	20	18	17	16	15	14	13	11	11	10	9.9	9.4	8.9	8.4	7.7	7.2	6.7	6.2	5.8	5.4	5.0	4.7	4.3	3.9
UA	286	267	249	233	216	199	181	160	153	146	140	134	127	120	113	107	100	94	88	82	77	71	65	60
UK	1128	1083	1045	1017	1004	928	854	780	709	636	556	476	386	324	260	225	211	119	113	107	102	97	92	87
UZ	47	44	41	38	36	33	30	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	9.9

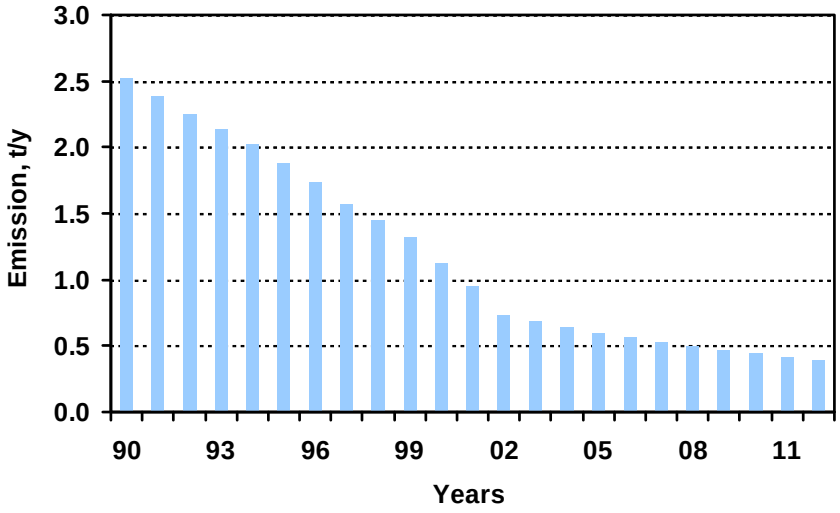


Figure 7.19. Time-series of total annual **PCB-153** emissions of HELCOM countries for 1990-2013, kg/year.

7.2 Annual total deposition of PCB-153

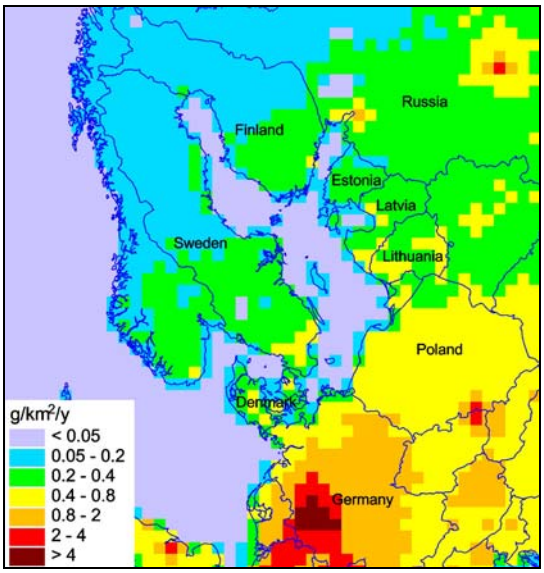


Figure 7.20. Annual total deposition fluxes of **PCB-153** over the Baltic Sea region for 2013 , g/km^2/y.

7.3 Monthly total deposition of PCB-153

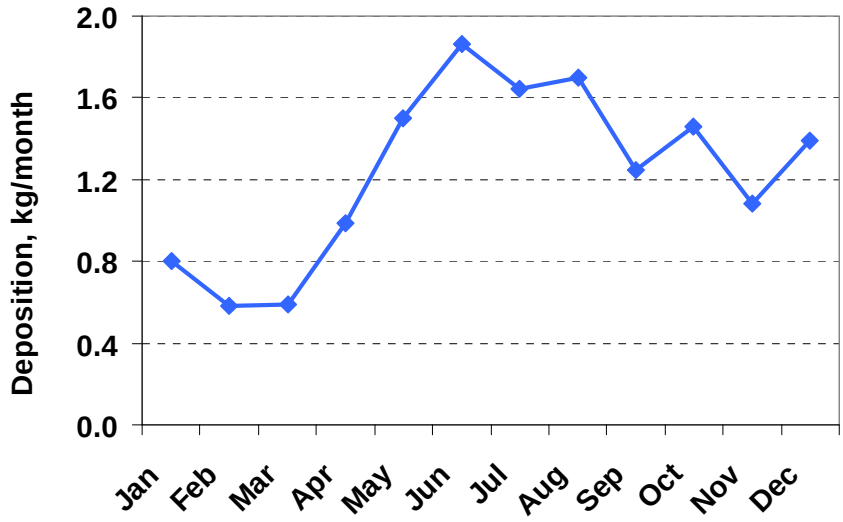


Figure 7.21. Monthly total deposition of PCB-153 over the Baltic Sea for 2013, kg/month.

Table 7.3. Monthly total deposition of PCB-153 over the Baltic Sea for 2013, kg/month.

Month	PCB-153 deposition
Jan	0.8
Feb	0.6
Mar	0.6
Apr	1.0
May	1.5
Jun	1.9
Jul	1.6
Aug	1.7
Sep	1.2
Oct	1.5
Nov	1.1
Dec	1.4

7.4 Source allocation of PCB-153 deposition

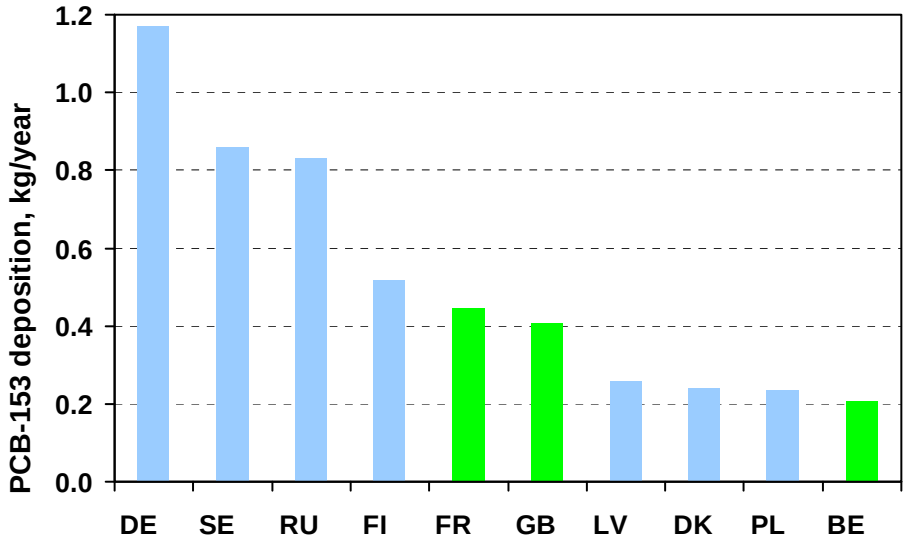


Figure 7.22. Top ten countries with the highest contribution to annual total deposition of PCB-153 over the Baltic Sea for 2013, kg/y. Green bars indicate non-HELCOM countries.

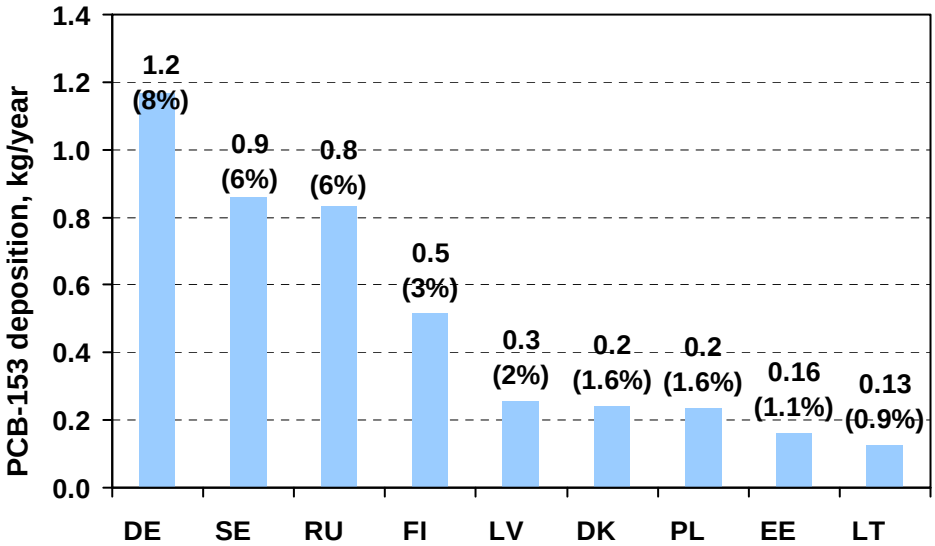


Figure 7.23. Contributions of HELCOM countries to annual total PCB-153 deposition to the Baltic Sea for 2013 (in kg/y and in %). HELCOM countries emissions of PCB-153 contributed 30% to total PCB-153 deposition over the Baltic Sea in 2013. Contribution of other EMEP countries accounted for 12%. Significant contribution was made by other emission sources, in particular, global emissions sources and re-emission of PCB-153 (58%).

Table 7.4. Two most significant contributors to annual total deposition of PCB-153 to the nine Baltic Sea sub-basins for 2013.

Sub-basin	Country (1)	%	Country (2)	%	*, %
ARC	Sweden	15	Finland	10	56
BOB	Finland	17	Sweden	15	57
BOS	Sweden	14	Finland	5	64
BAP	Germany	10	Sweden	6	60
GUF	Russia	28	Finland	10	46
GUR	Latvia	14	Germany	4	60
KAT	Germany	8	Sweden	6	63
SOU	Denmark	14	Germany	9	60
WEB	Germany	14	Denmark	5	64
BAS	Germany	8	Sweden	6	59

* - contribution of re-emission and remote sources.

7.5 Comparison of model results with measurements

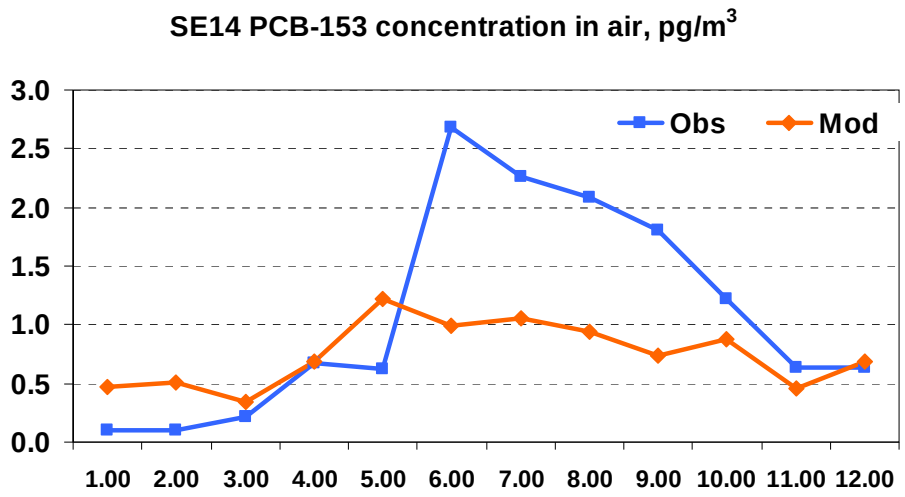


Figure 7.24. Comparison of calculated monthly mean PCB-153 concentrations in air for 2013 with measurements of the station Råö (SE14). Units: pg / m^3.

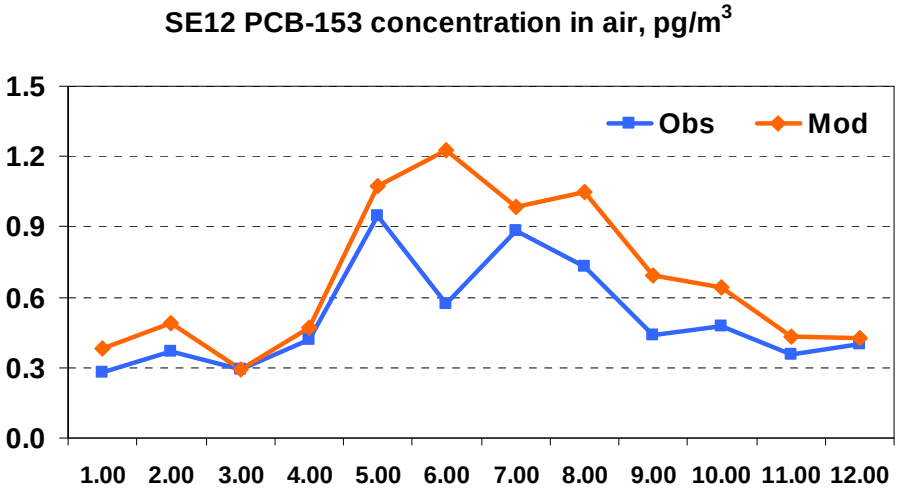


Figure 7.25. Comparison of calculated monthly mean PCB-153 concentrations in air for 2013 with measurements of the station Aspvreten (SE12). Units: pg / m^3.

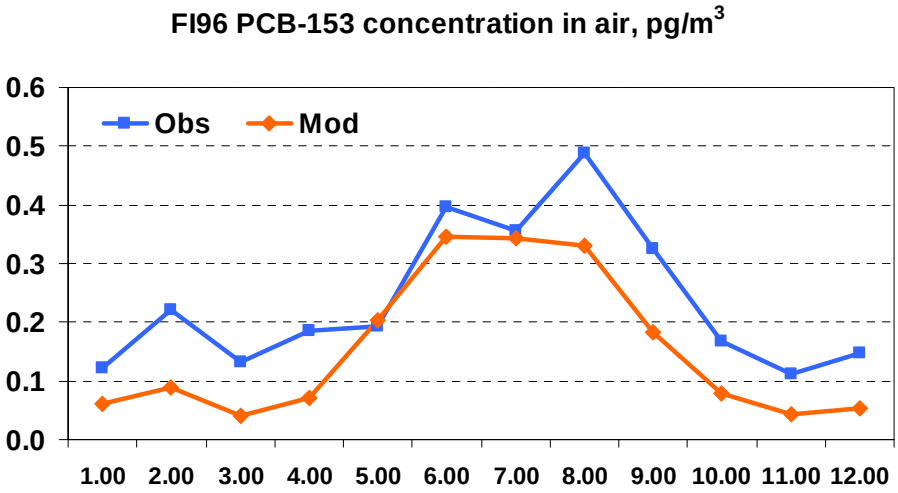


Figure 7.26. Comparison of calculated monthly mean PCB-153 concentrations in air for 2013 with measurements of the station Pallas (FI96). Units: pg / m^3.

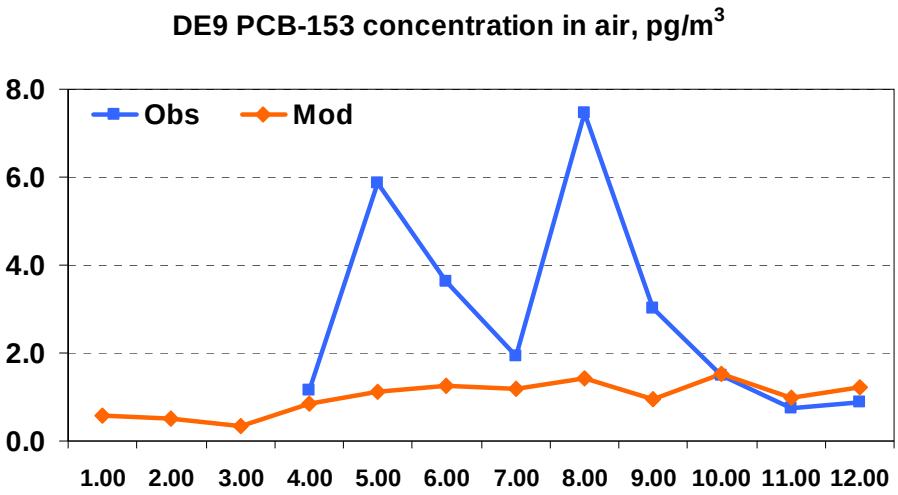


Figure 7.27. Comparison of calculated monthly mean PCB-153 concentrations in air for 2013 with measurements of the station Zingst (DE9). Units: pg / m^3.

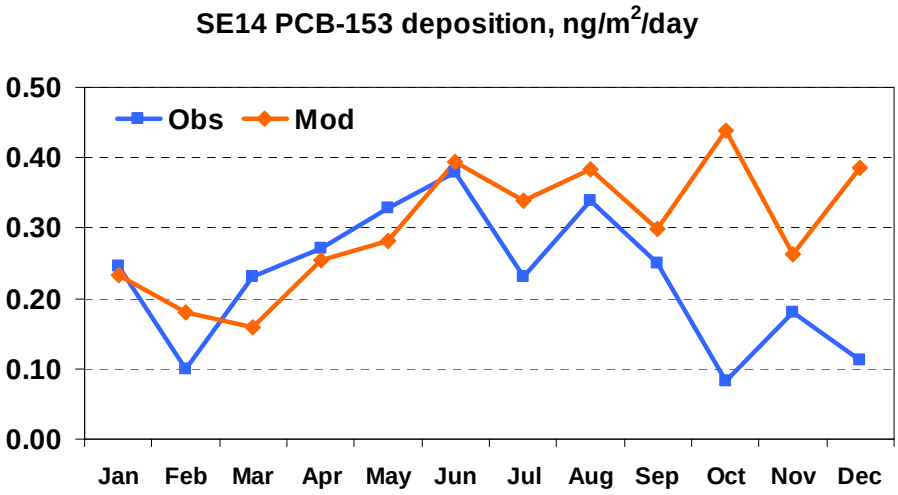


Figure 7.28. Comparison of calculated monthly mean PCB-153 deposition fluxes for 2013 with measurements of the station Råö (SE14). Units: ng / m^2 / day.

Modelled concentrations of PCB-153 in air and deposition fluxes were compared with the measurement data of 4 monitoring sites around the Baltic Sea. It can be seen that that the model values generally agree with the measured concentrations. Some deviations between simulated and observed monthly mean concentrations of PCB-153 can be explained by the uncertainties in PCB-153 emission used in modeling, uncertainties in model parameterization of POP exchange with underlying surface, and difficulties in measurements of PCBs.

7.6 Concluding remarks

- PCB-153 emission from HELCOM countries have decreased from 1990 to 2013 by 47%. PCB-153 emission in HELCOM countries have slightly decreased from 2012 to 2013 by 1.1%.
- Annual PCB-153 deposition to the Baltic Sea has decreased from 1990 to 2013 by 71%. Level of PCB-153 deposition in 2013 has decreased comparing to 2012 by about 7%.
- The contribution of anthropogenic sources of HELCOM countries to total PCB-153 deposition over the Baltic Sea was estimated to approximately 30%. Essential contribution belongs to the anthropogenic sources of other EMEP countries (12%) and other sources of emission including re-emission and global sources (58%).
- The most significant contribution to PCB-153 deposition over the Baltic Sea in 2013 was made by Germany (8%) and Sweden (6%).
- Modelling results for PCB-153 were in general within a factor of two in comparison to measured concentrations obtained around the Baltic Sea in 2013.

References

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