6. Atmospheric Supply of Mercury to the Baltic Sea in 2013

In this chapter the results of model evaluation of mercury atmospheric input to the Baltic Sea and its sub-basins for 2013 is presented. Modelling of mercury 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 mercury emission from HELCOM countries and other European countries was used in computations. Based on these data annual and monthly levels of mercury 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 mercury concentrations in air and precipitation measured at monitoring sites around the Baltic Sea in 2013.

6.1 Mercury emissions

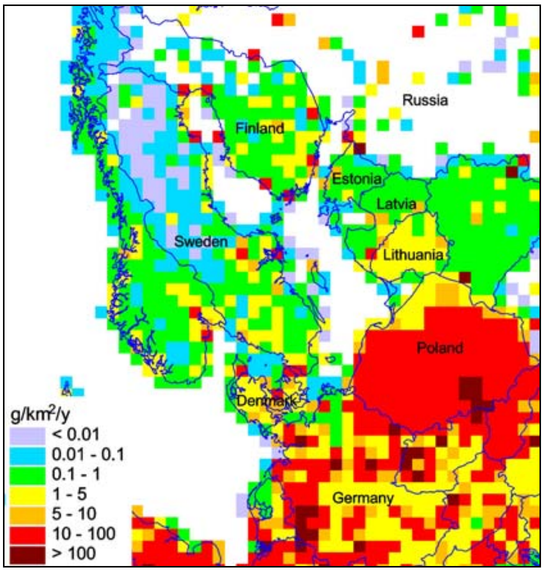


Figure 6.1. Annual total anthropogenic emissions of mercury in the Baltic Sea region for 2013, g/km^2/year.

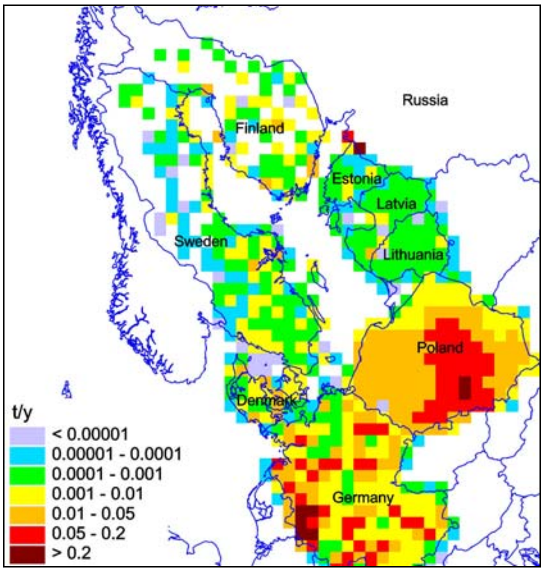


Figure 6.2. Annual mercury emission from Public Power sector for 2013, t/grid cell/y (white color means no information).

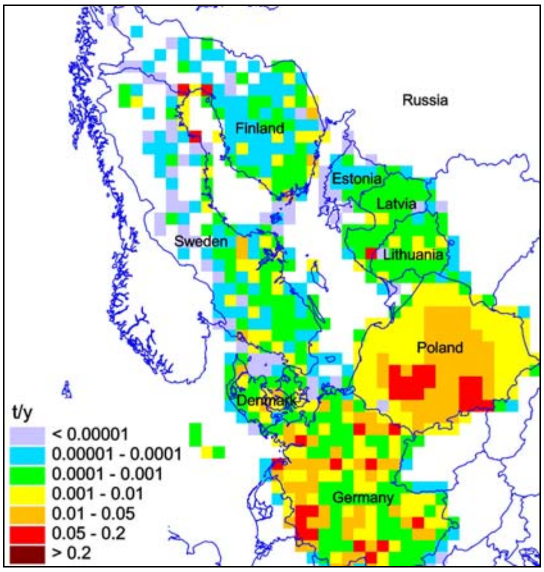


Figure 6.3. Annual mercury emission from Industry sector for 2013, t/grid cell/y (white color means no information).

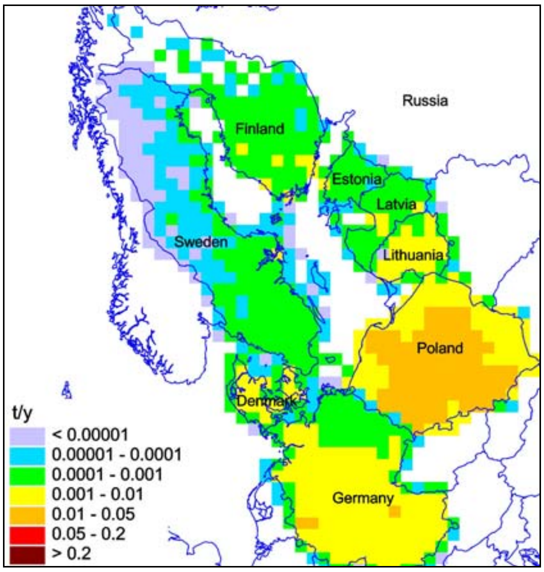


Figure 6.4. Annual mercury emission from Other Stationary Combustion sector for 2013, t/grid cell/y (white color means no information).

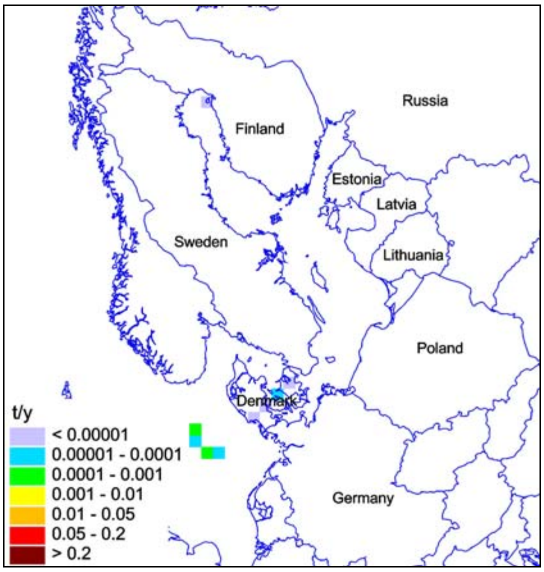


Figure 6.5. Annual mercury emission from Fugitive Emissions sector for 2013, t/grid cell/y (white color means no information).

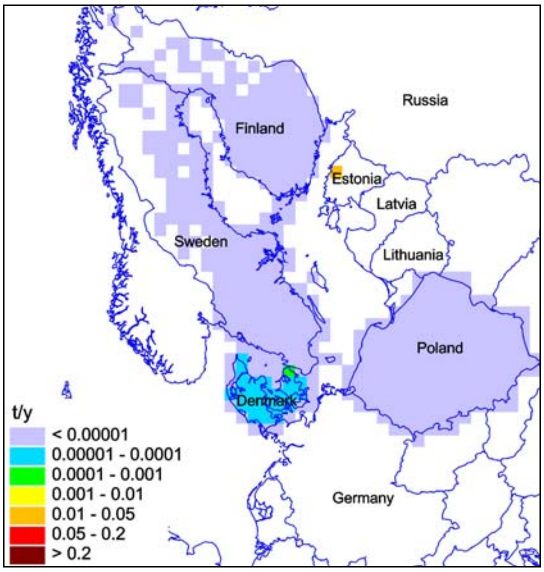


Figure 6.6. Annual mercury emission from Solvents sector for 2013, t/grid cell/y (white color means no information).

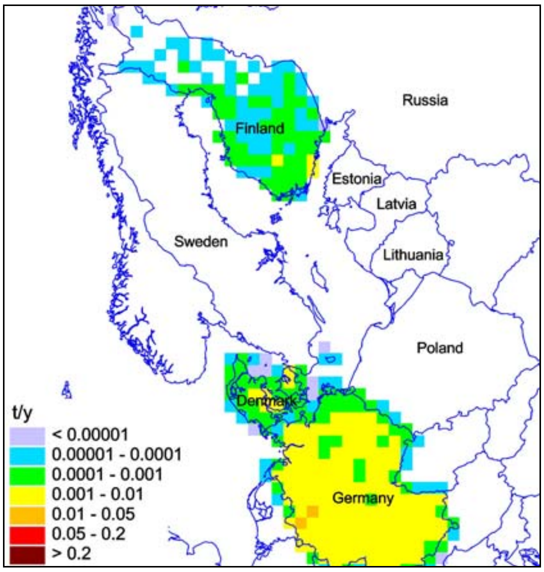


Figure 6.7. Annual mercury emission from Road Transport sector for 2013, t/grid cell/y (white color means no information).

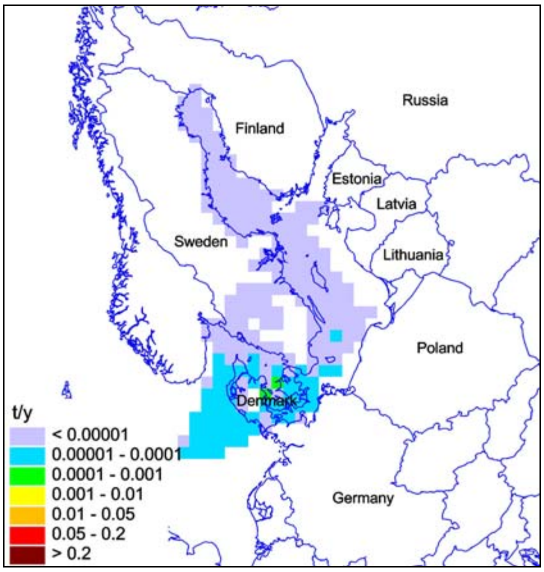


Figure 6.8. Annual mercury emission from Shipping Emissions sector for 2013, t/grid cell/y (white color means no information).

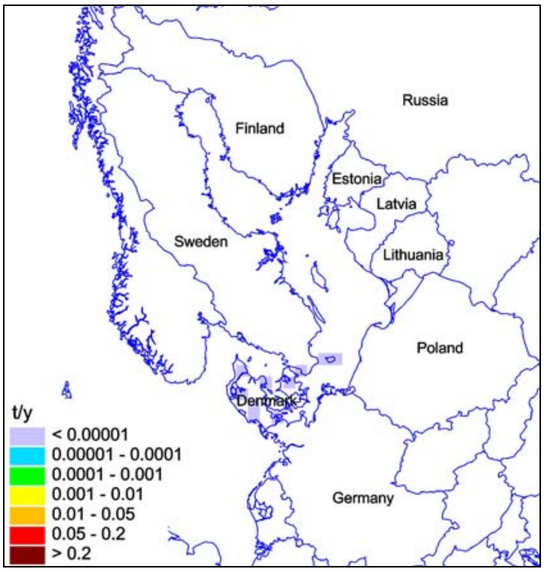


Figure 6.9. Annual mercury emission from Aviation sector for 2013, t/grid cell/y (white color means no information).

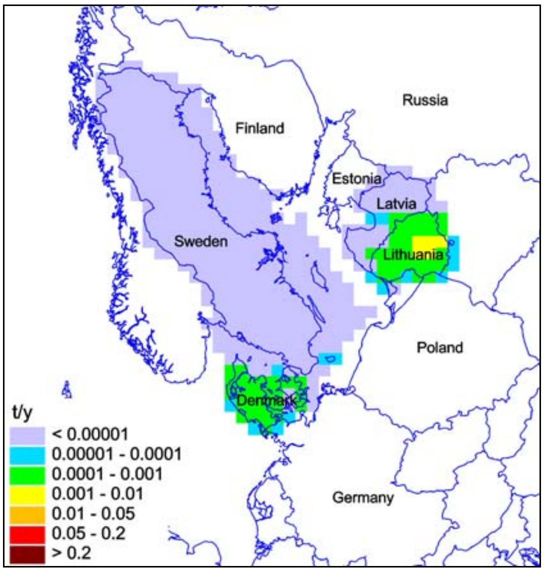


Figure 6.10. Annual mercury emission from Off Road sector for 2013, t/grid cell/y (white color means no information).

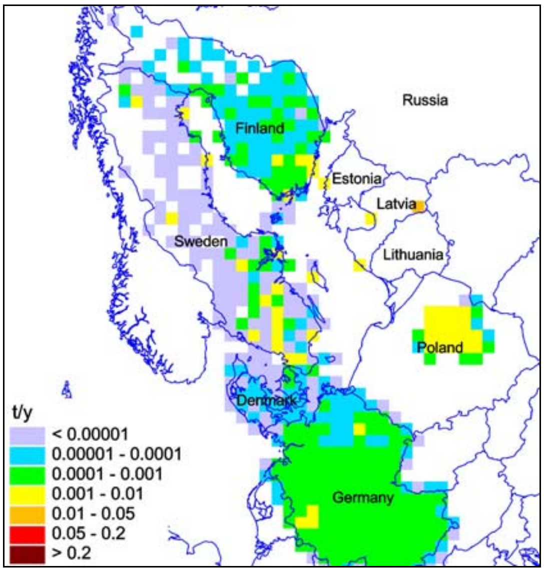


Figure 6.11. Annual mercury emission from Waste sector for 2013, t/grid cell/y (white color means no information).

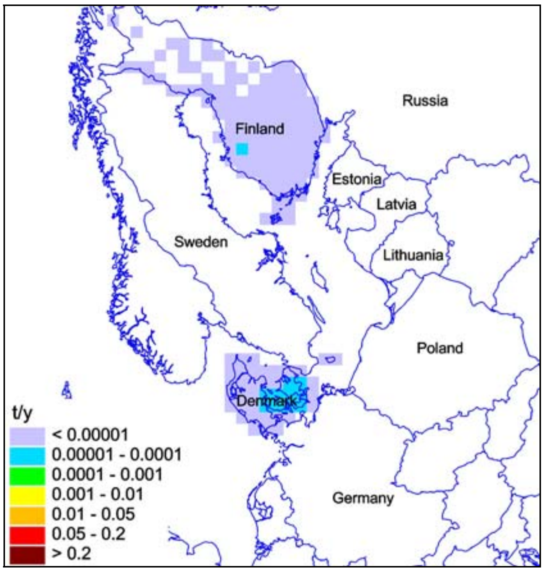


Figure 6.12. Annual mercury emission from Agricultural Other sector for 2013, t/grid cell/y (white color means no information).

Table 6.1. Annual total mercury 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	0.171	0.642	0.212	6.572	0.018	0.041	5.907		0.179
B	Industry	0.103	0.003	0.383	2.865	0.027	0.096	2.744	0.802	0.201
C	Other Stationary Combustion	0.038	0.012	0.038	0.321	0.032	0.045	1.67		0.025
D	Fugitive Emissions	0.00044		1.0E-05	NA					
E	Solvents	0.00097	0.012	3.8E-07	0.0022		NA	4.2E-06		3.99E-07
F	Road Transport	0.023		0.02	0.426	NA		NA		
G	Shipping Emissions	0.0045			0.011		0.00015	8.3E-05		0.00014
H	Aviation	1.3E-05	NA	NA	NE	NE	NE	NA		NE
I	Off Road	0.013	3.3E-05		0.016	0.00025	0.02			2.5E-06
J	Waste	0.0014	0.0088	0.02	0.044	0.024	0.026	0.055		0.047
L	Agricultural Other	0.00037		0.0002				NA		NA
M	Other	NO	NO	NO	NA	NA	NO	NA	0.178	NO
Total		0.355	0.678	0.673	10.257	0.101	0.229	10.376	0.98	0.453

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.

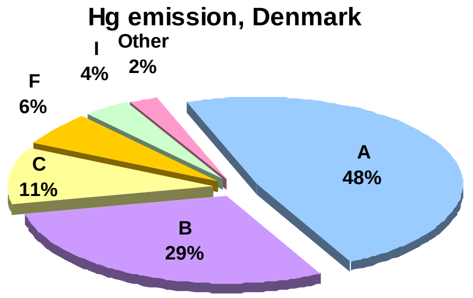


Figure 6.13. Contributions of different sectors to total annual mercury emission of Denmark in 2013

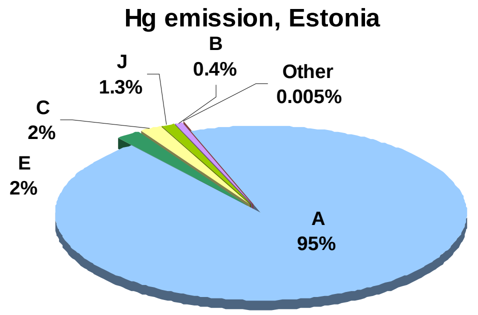


Figure 6.14. Contributions of different sectors to total annual mercury emission of Estonia in 2013

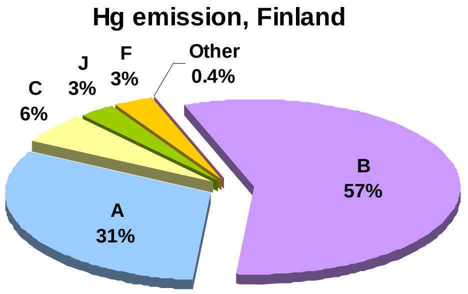


Figure 6.15. Contributions of different sectors to total annual mercury emission of Finland in 2013

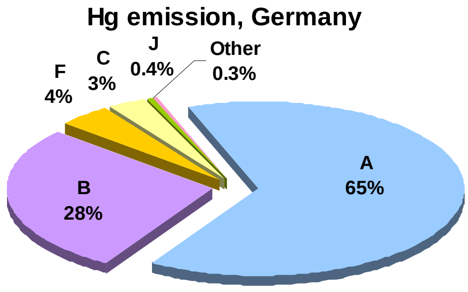


Figure 6.16. Contributions of different sectors to total annual mercury emission of Germany in 2013

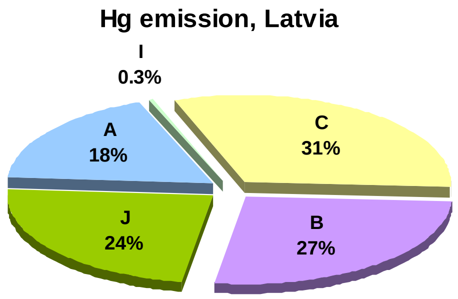


Figure 6.17. Contributions of different sectors to total annual mercury emission of Latvia in 2013

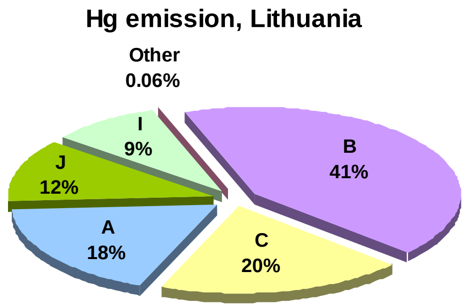


Figure 6.18. Contributions of different sectors to total annual mercury emission of Lithuania in 2013

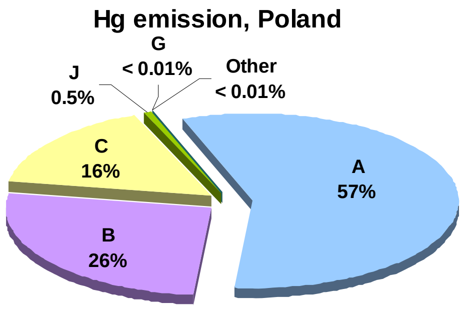


Figure 6.19. Contributions of different sectors to total annual mercury emission of Poland in 2013

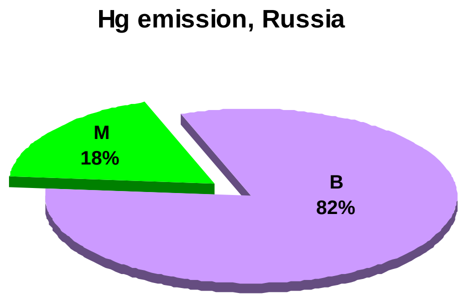


Figure 6.20. Contributions of different sectors to total annual mercury emission of Russia in 2013

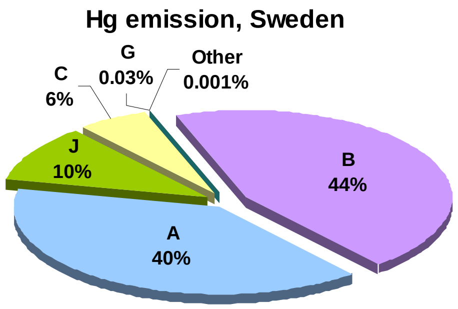
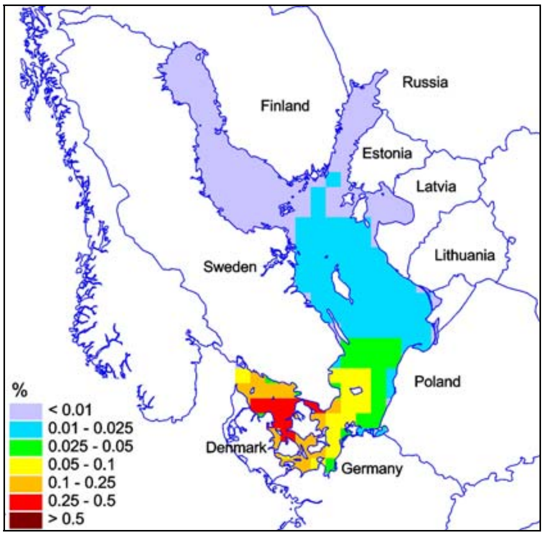
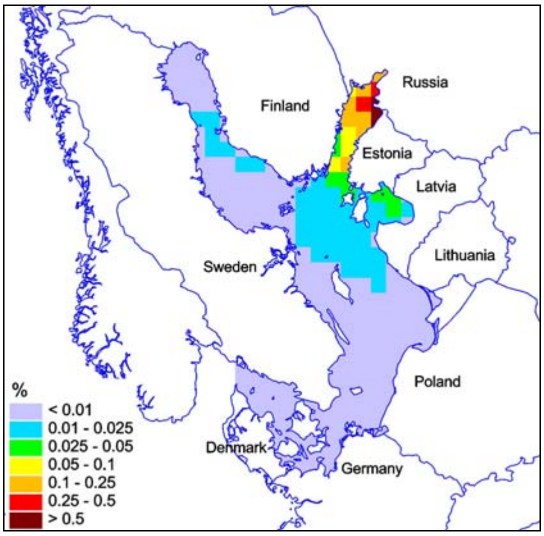


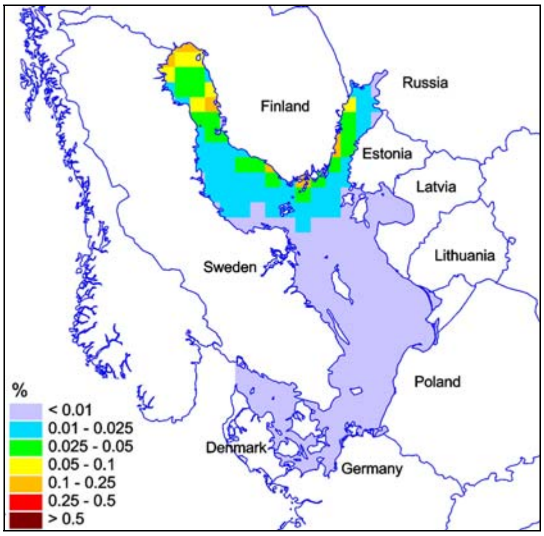
Figure 6.21. Contributions of different sectors to total annual mercury emission of Sweden in 2013



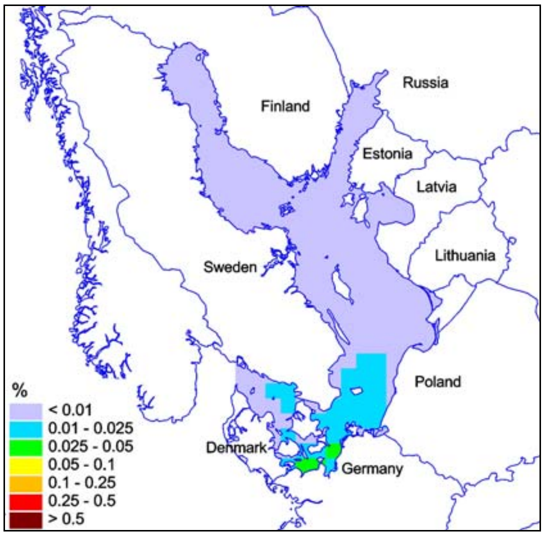
Denmark



Estonia



Finland



Germany

Figure 6.22. Fractions of annual anthropogenic mercury 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).

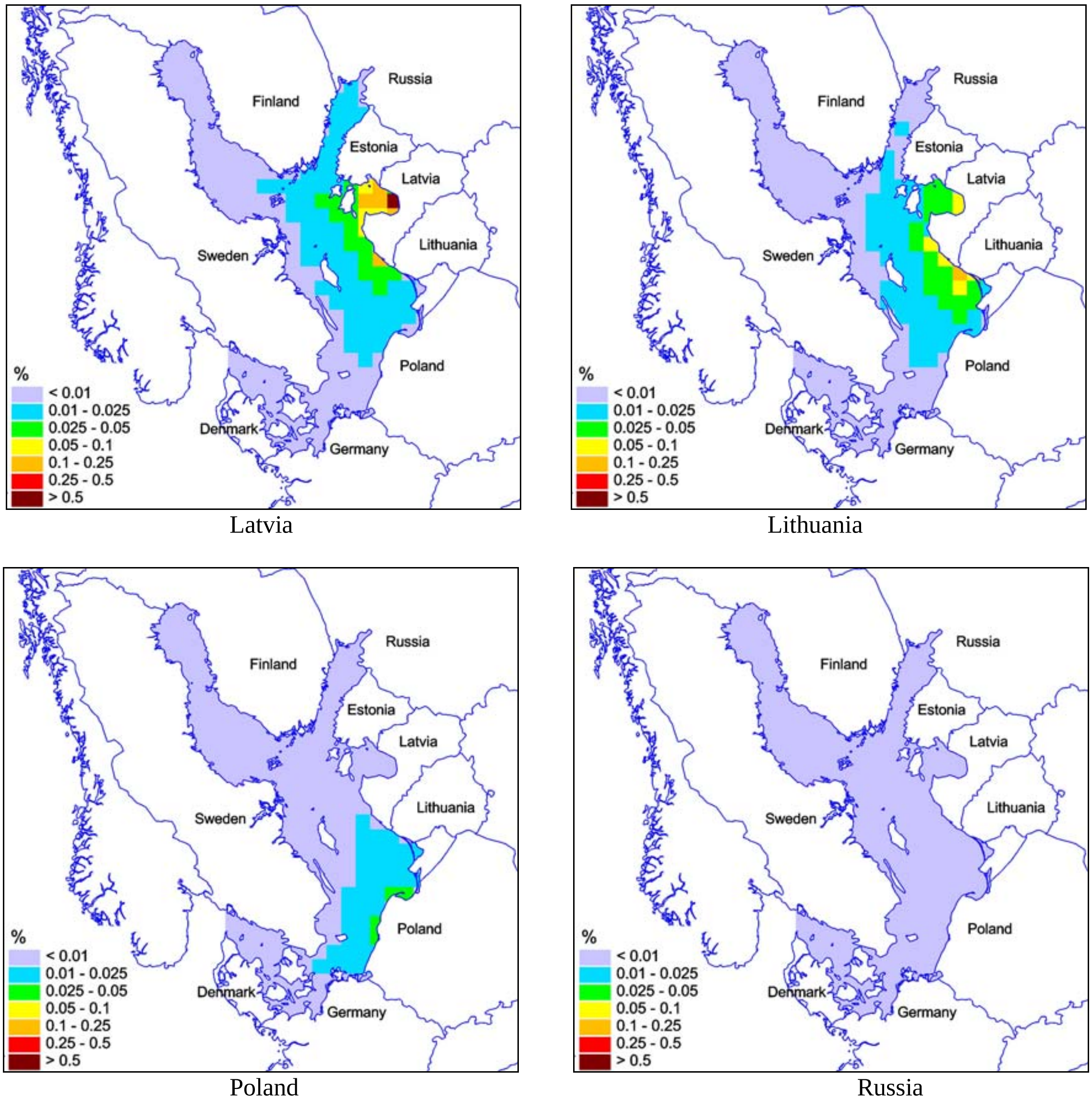
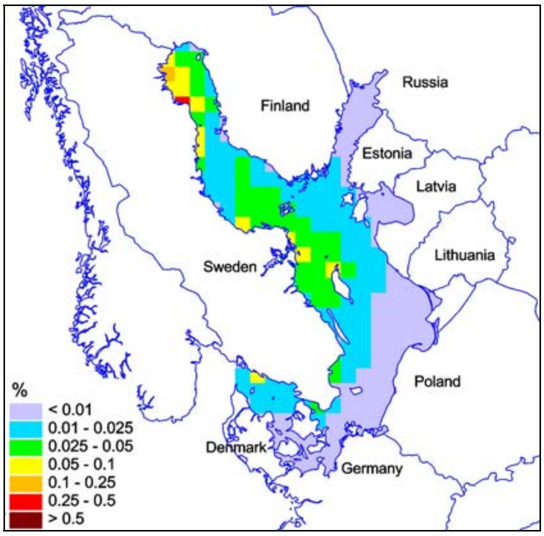


Figure 6.22. (cont.) Fractions of annual anthropogenic mercury emissions of HELCOM Parties deposited to the Baltic Sea in 2013 (expressed as a percent of national anthropogenic emission deposited to the particular grid cells).



Sweden

Figure 6.22. (cont.) Fractions of annual anthropogenic mercury 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 6.2. Annual total anthropogenic emissions of **mercury** 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	3.2	3.3	3.0	2.9	2.6	2.3	2.5	2.0	1.7	1.5	1.0	0.88	0.85	0.89	0.75	0.71	0.64	0.61	0.62	0.47	0.45	0.40	0.32	0.35
EE	1.2	1.0	0.86	0.67	0.68	0.64	0.63	0.64	0.57	0.54	0.55	0.53	0.53	0.61	0.56	0.54	0.54	0.67	0.59	0.46	0.64	0.65	0.57	0.68
FI	1.0	0.83	0.82	0.61	0.65	0.72	0.78	0.57	0.55	1.20	0.58	0.76	0.68	0.81	0.76	0.86	1.0	0.84	0.80	0.74	0.87	0.62	0.73	0.67
DE	32	26	22	19	17	17	17	17	17	16	16	16	15	15	14	13	13	12	11	9.9	10.2	10.2	10.3	10.3
LV	0.27	0.24	0.21	0.18	0.14	0.11	0.11	0.10	0.10	0.09	0.08	0.09	0.08	0.08	0.08	0.08	0.09	0.10	0.08	0.08	0.08	0.10	0.10	0.10
LT	1.3	1.2	0.62	0.40	0.44	0.47	0.35	0.45	0.41	0.23	0.24	0.29	0.31	0.24	0.34	0.42	0.34	0.37	0.24	0.20	0.21	0.41	0.23	0.23
PL	13	13	13	13	13	13	13	13	12	12	11	11	10	11	11	10	11	10	10	9.8	10	10	10	10
RU	16	13	11	12	10	10	10	9.6	9.4	9.9	10	10	10	11	12	14	14	9.7	5.3	1.0	1.0	1.0	1.0	1.0
SE	1.5	1.2	1.1	0.98	1.0	0.92	0.98	0.83	0.84	0.84	0.72	0.56	0.59	0.68	0.69	0.64	0.49	0.52	0.47	0.52	0.48	0.47	0.44	0.45
AL	0.27	0.14	0.07	0.05	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.06	0.06	0.10	0.12	0.12	0.12	0.12	0.12	0.12
AM	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
AT	2.1	2.0	1.6	1.4	1.2	1.2	1.2	1.1	0.95	0.93	0.89	0.96	0.92	0.96	0.94	0.99	1.0	1.01	1.02	0.91	1.01	1.00	1.01	1.02
AZ	0.04	0.04	0.04	0.04	0.04	0.10	0.10	0.10	0.12	0.12	0.12	0.14	0.14	0.15	0.15	0.21	0.27	0.43	0.44	0.47	0.49	0.48	0.48	0.46
BY	1.07	1.1	0.88	0.72	0.60	0.51	0.30	0.31	0.39	0.38	0.36	0.52	0.57	0.60	0.63	0.65	0.72	0.74	0.81	0.91	0.85	0.86	0.92	0.92
BE	5.7	5.5	5.5	2.7	4.1	3.0	3.3	3.6	2.6	3.1	3.0	2.9	4.0	3.8	3.7	2.2	2.3	3.4	3.9	2.0	1.9	1.9	1.5	1.7
BA	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	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8
BG	2.4	2.0	1.8	1.8	1.9	1.9	1.9	2.0	1.8	1.6	1.5	1.4	1.3	2.2	2.1	1.6	1.7	1.5	1.4	1.0	0.87	0.94	0.78	0.74
HR	1.15	1.10	1.12	0.32	0.30	0.29	0.28	0.33	0.35	0.38	0.48	0.49	0.54	0.56	0.57	0.59	0.56	0.60	0.57	0.51	0.53	0.51	0.48	0.48
CY	0.11	0.10	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.11	0.09	0.07	0.08	0.08	0.09
CZ	7.5	7.4	7.3	7.5	7.2	7.4	5.9	5.5	5.2	3.7	3.8	3.3	2.8	1.8	2.1	3.8	3.8	3.9	4.1	4.3	3.5	3.2	3.0	2.7
FR	25	25	24	22	22	20	19	15	14	12	12	10.2	9.3	6.8	6.4	6.4	6.3	4.8	4.6	4.2	4.5	4.6	4.0	3.8
GE	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.27	0.27	0.28	0.28	0.29	0.29	0.30	0.31	0.31	0.32	0.32
GR	13	13	13	13	13	13	13	11	9.8	8.2	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.6	7.7	7.8	7.9	8.0	8.1
HU	3.1	3.1	2.8	2.8	2.7	2.4	2.3	2.2	2.2	2.1	2.1	2.1	2.0	1.9	1.8	1.5	1.4	1.2	1.3	1.1	1.3	1.2	1.1	0.87
IS	0.05	0.05	0.06	0.07	0.07	0.08	0.08	0.09	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10
IE	0.90	0.92	0.84	0.85	0.80	0.80	0.84	0.80	0.62	0.59	0.65	0.65	0.62	0.64	0.67	0.69	0.66	0.63	0.64	0.58	0.60	0.55	0.57	0.56
IT	12	11	11	10	10	10	9.8	10.0	9.5	8.8	9.3	9.4	9.3	9.1	9.9	10.0	10	11	10	8.5	8.7	8.6	8.3	8.1
KZ	21	22	22	22	22	23	22	21	21	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
KY	4.6	4.6	4.6	4.6	4.6	4.6	4.7	4.8	4.9	5.0	5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
LI	1E-4	1E-4	1E-4	1E-4	1E-4	1E-4	1E-4	1E-4	2E-4	2E-4	2E-4	1E-4	2E-4	2E-4	2E-4	2E-4	2E-4	2E-4	2E-4	2E-4	2E-4	2E-4	2E-4	2E-4
LU	0.30	0.28	0.25	0.23	0.20	0.10	0.10	0.10	0.10	0.29	0.27	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
MT	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.69	0.54	0.58	0.58	0.60	0.61	0.63	0.56	0.56	0.01	5E-4	8E-4	0.01
MC	0.11	0.11	0.12	0.13	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.08	0.06	0.06	0.06	0.04	0.06	0.05	0.05	0.05	0.05	0.05	0.05
NL	3.5	2.9	2.5	2.0	1.6	1.4	1.2	1.0	0.80	0.90	1.02	0.84	0.72	0.68	0.85	0.87	0.80	0.75	0.63	0.59	0.53	0.63	0.56	0.52
NO	1.5	1.4	1.2	0.92	1.0	0.82	0.85	0.86	0.81	0.85	0.70	0.65	0.61	0.61	0.63	0.62	0.57	0.56	0.53	0.41	0.47	0.41	0.39	0.39
PT	3.2	3.3	3.8	3.3	3.1	3.4	3.0	3.3	3.4	3.5	3.1	2.9	3.1	2.4	2.4	2.6	2.2	2.1	1.9	1.9	1.7	1.6	1.6	1.5
MD	0.67	0.51	0.35	0.26	0.24	0.21	0.22	0.23	0.22	0.22	0.23	0.25	0.17	0.25	0.27	0.28	0.22	0.26	0.27	0.18	0.15	0.16	0.16	0.06
RO	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.2	6.3	6.7	7.3	6.8	6.3	5.9	5.4	5.1	5.1	4.5	2.6	2.2	2.4	2.2	1.9
RUA	65	59	53	48	42	36	32	29	26	22	19	19	19	19	19	19	19	19	19	19	19	19	19	19
ME	0.07	0.08	0.06	0.06	0.05	0.02	0.07	0.06	0.08	0.08	0.07	0.06	0.09	0.08	0.08	0.06	0.08	0.06	0.09	0.05	0.09	0.09	0.09	0.09
RS	1.9	1.7	2.1	1.8	1.6	1.7	1.9	2.0	1.9	1.5	1.6	1.6	1.7	1.7	1.9	1.6	1.8	1.8	1.8	1.5	1.6	1.7	1.4	1.4
SK	13	9.5	6.2	5.0	3.9	4.3	3.4	3.6	3.9	3.6	6.1	4.0	3.2	2.9	3.2	3.0	3.5	2.6	2.8	1.1	1.4	1.2	1.3	1.3
SI	0.61	0.53	0.52	0.45	0.44	0.45	0.44	0.50	0.52	0.50	0.54	0.50	0.49	0.49	0.50	0.48	0.51	0.52	0.53	0.44	0.47	0.44	0.38	0.39
ES	13	14	15	14	14	15	14	12	12	13	11	10	11	9.5	9.3	9.5	8.5	7.8	7.0	5.7	5.4	5.3	5.1	4.2
CH	6.6	6.0	5.7	5.3	4.8	4.0	3.7	3.4	3.2	2.3	2.0	1.7	1.3	0.93	0.96	0.94	0.99	0.97	0.97	0.83	0.91	0.92	0.89	0.86
TJ	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
MK	0.95	0.57	0.53	0.47	0.42	0.55	0.63	0.54	0.54	0.51	0.55	0.32	0.30	0.27	0.24	0.28	0.28	0.24	0.39	0.30	0.39	0.41	0.30	0.27
TR	18	18	18	18	18	18	18	18	18	18	18	19	19	19	20	20	21	21	22	22	22	23	23	24
TM	0.52	0.60	0.68	0.76	0.84	0.92	0.88	0.83	0.79	0.75	0.71	0.63	0.54	0.46	0.37	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
UA	36	35	34	33	32	31	30	29	28	27	26	25	5.9	30	6.6	6.0	16	7.6	6.8	5.6	6.8	6.8	6.8	6.8
UK	37	38	36	22	21	20	15	12	11	8.3	8.2	8.0	7.2	7.7	6.7	7.4	7.5	7.0	6.9	6.5	6.5	5.9	5.7	6.1
UZ	6.0	6.2	6.3	6.5	6.7	6.9	6.9	6.9	7.0	7.0	7.0	6.8	6.5	6.3	6.1	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9

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*

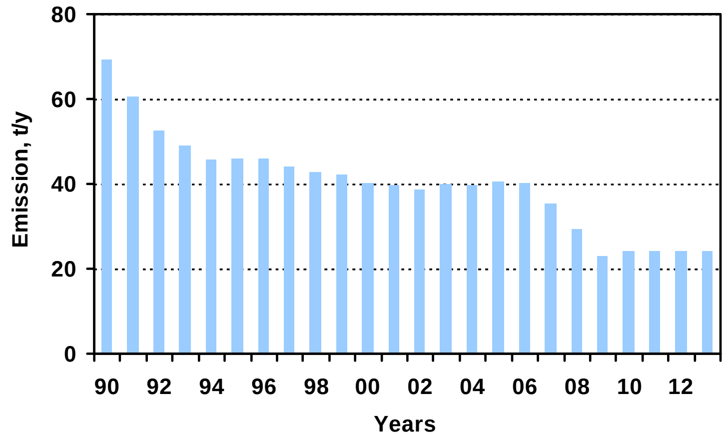


Figure 6.23. Time-series of total annual **mercury** emissions of HELCOM countries in 1990-2013, tonnes/year.

6.2 Annual total deposition of mercury

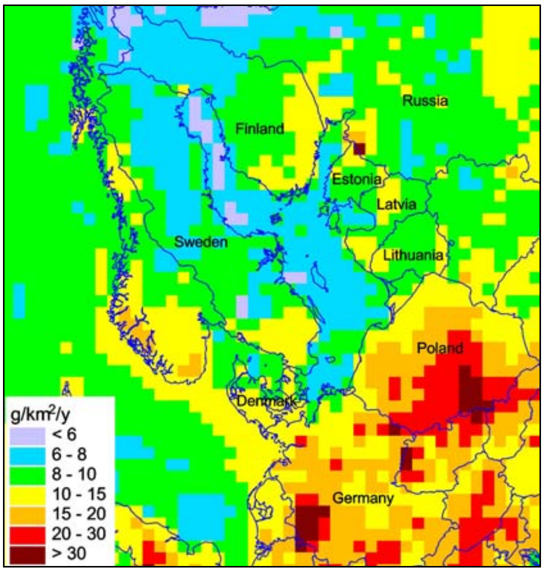


Figure 6.24. Annual total deposition fluxes of **mercury** over the Baltic Sea region for 2013, g/km^2/year.

6.3 Monthly total deposition of mercury

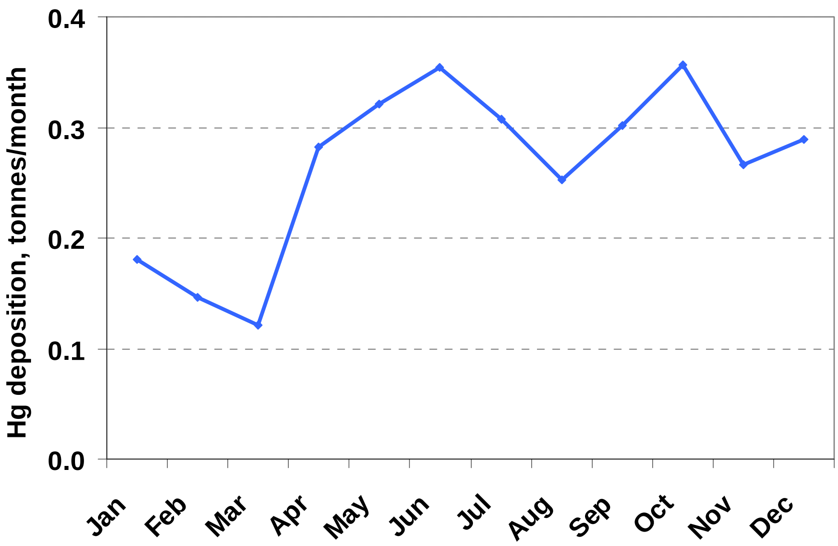


Figure 6.25. Monthly total deposition of **mercury** to the Baltic Sea for 2013, tonnes/month.

Table 6.3. Monthly total deposition of **mercury** to the Baltic Sea for 2013, tonnes/month.

Month	Hg deposition
Jan	0.18
Feb	0.15
Mar	0.12
Apr	0.28
May	0.32
Jun	0.35
Jul	0.31
Aug	0.25
Sep	0.30
Oct	0.36
Nov	0.27
Dec	0.29

6.4 Source allocation of mercury deposition

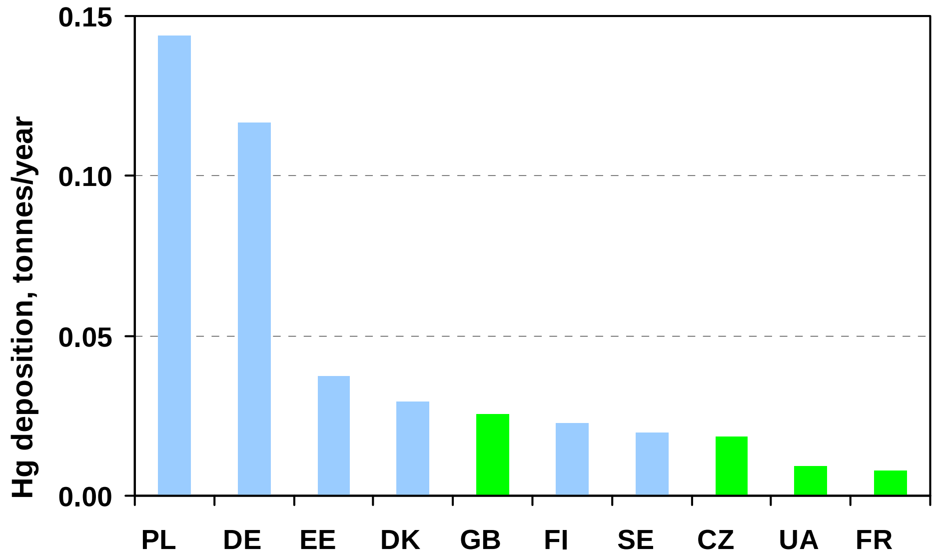


Figure 6.26. Top ten countries with the highest contribution to annual deposition of **mercury** over the Baltic Sea for 2013, tonnes/year.

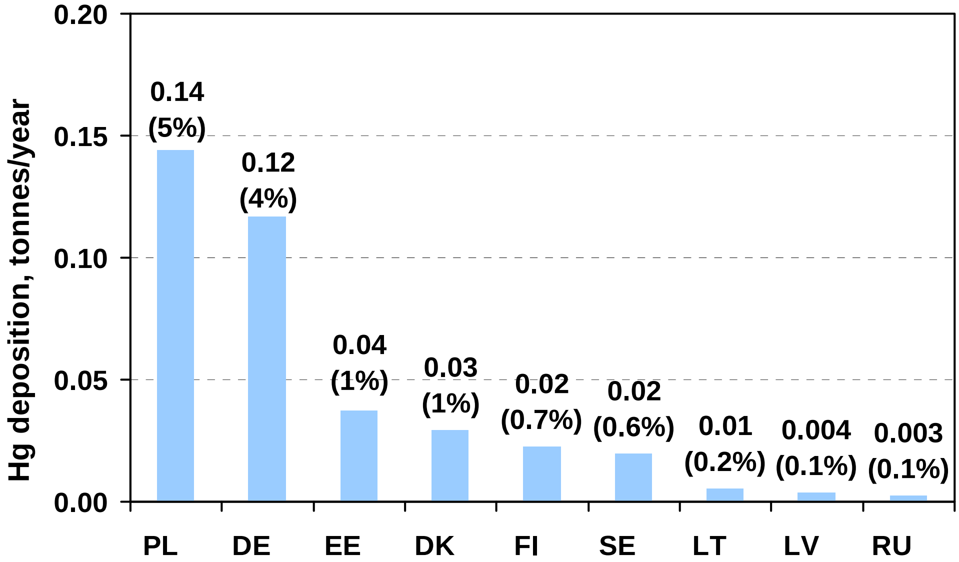


Figure 6.27. Sorted contributions (in %) of HELCOM countries to total deposition of **mercury** over the Baltic Sea for 2013. HELCOM countries emissions of mercury contributed 12% to the total annual **mercury** deposition over the Baltic Sea. Contribution of other EMEP countries accounted for 4%. Significant contribution was made by other emission sources, in particular, remote emissions sources, natural emissions and re-emission of **mercury** (84%).

Table 6.4. Two most significant contributors to the annual total deposition of **mercury** to the nine Baltic Sea sub-basins for 2013.

Sub-basin	Country(1)	%	Country(2)	%	*, %
ARC	Poland	3	Germany	2	90
BOB	Finland	4	Sweden	2	90
BOS	Germany	1	Poland	1	93
BAP	Poland	7	Germany	4	82
GUF	Estonia	10	Poland	2	81
GUR	Poland	4	Germany	2	86
KAT	Germany	5	Denmark	4	83
SOU	Denmark	9	Germany	8	72
WEB	Germany	12	Denmark	4	74
BAS	Poland	5	Germany	4	84

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

6.5 Comparison of model results with measurements

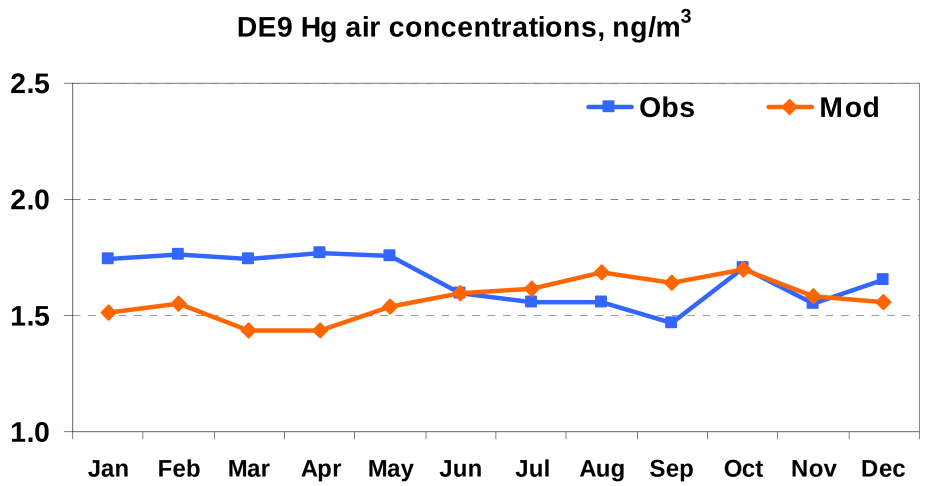


Figure 6.28. Comparison of calculated monthly mean Hg concentrations in air for 2013 with measurements of the station Zingst (DE9). Units: ng / m^3.

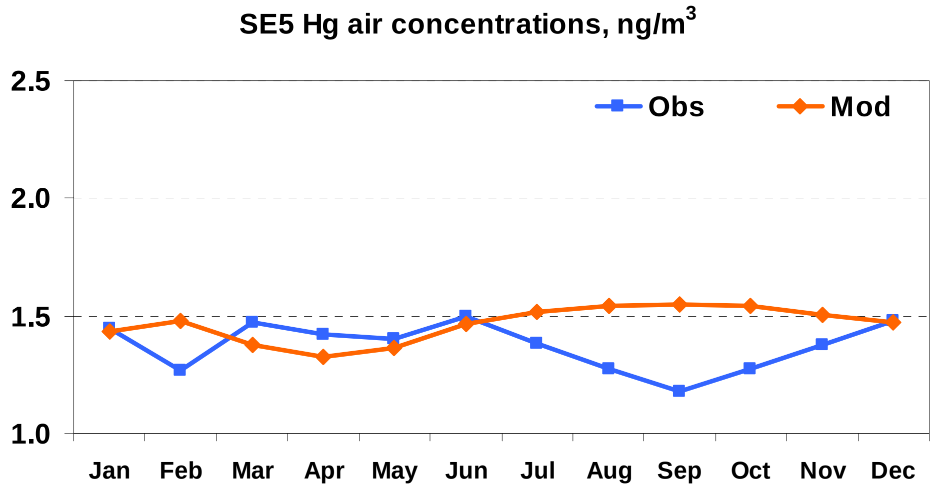


Figure 6.29. Comparison of calculated monthly mean Hg concentrations in air for 2013 with measurements of the station Bredkälen (SE5). Units: ng / m^3.

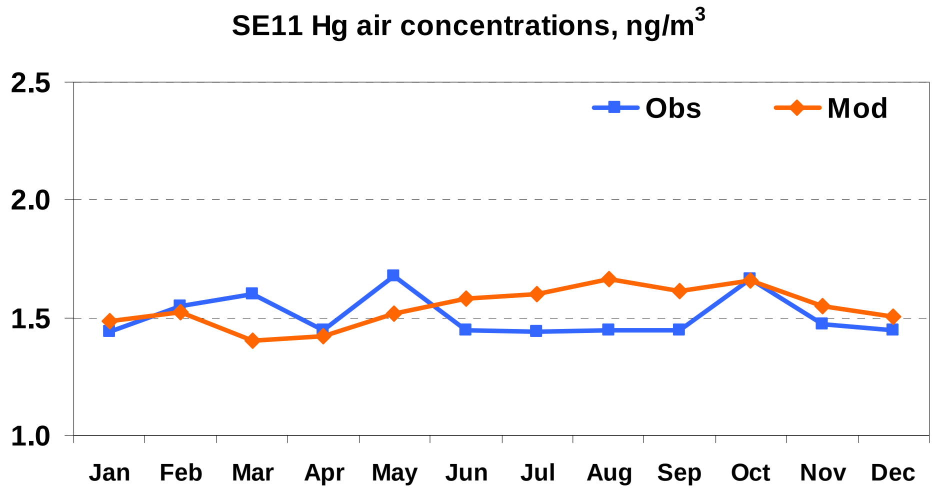


Figure 6.30. Comparison of calculated monthly mean Hg concentrations in air for 2013 with measurements of the station Vavihill (SE11). Units: ng / m^3.

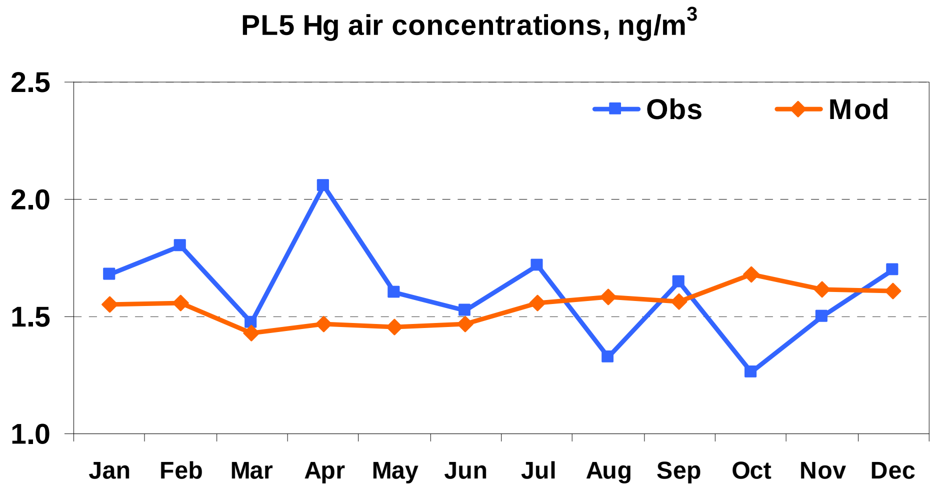


Figure 6.31. Comparison of calculated monthly mean Hg concentrations in air for 2013 with measurements of the station Diabla Gora (PL5). Units: ng / m^3.

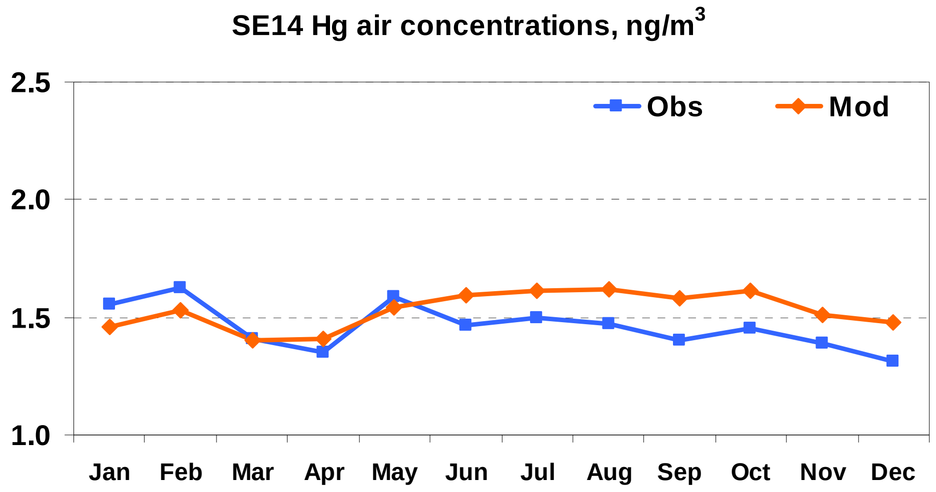


Figure 6.32. Comparison of calculated monthly mean Hg concentrations in air for 2013 with measurements of the station Råö (SE14). Units: ng / m^3.

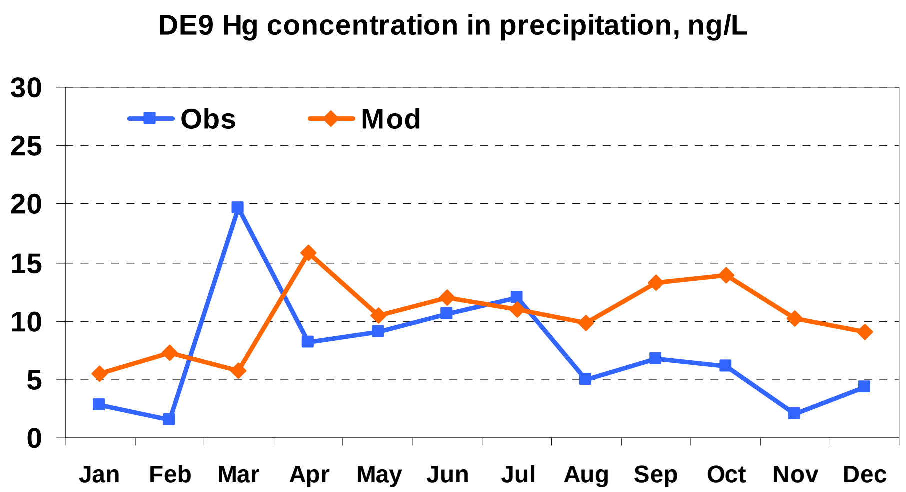


Figure 6.33. Comparison of calculated monthly mean Hg concentrations in precipitation for 2013 with measurements of the station Zingst (DE9). Units: ng/L.

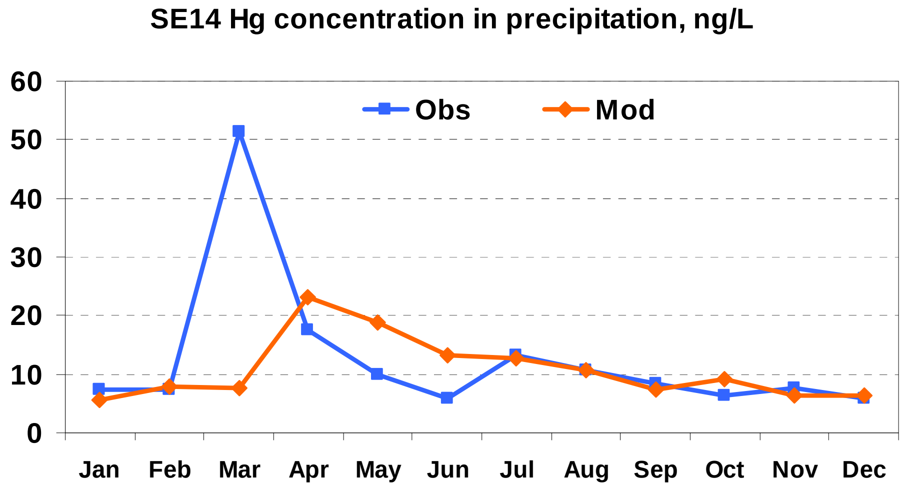


Figure 6.34. Comparison of calculated monthly mean Hg concentrations in precipitation for 2013 with measurements of the station Råö (SE14). Units: ng/L.

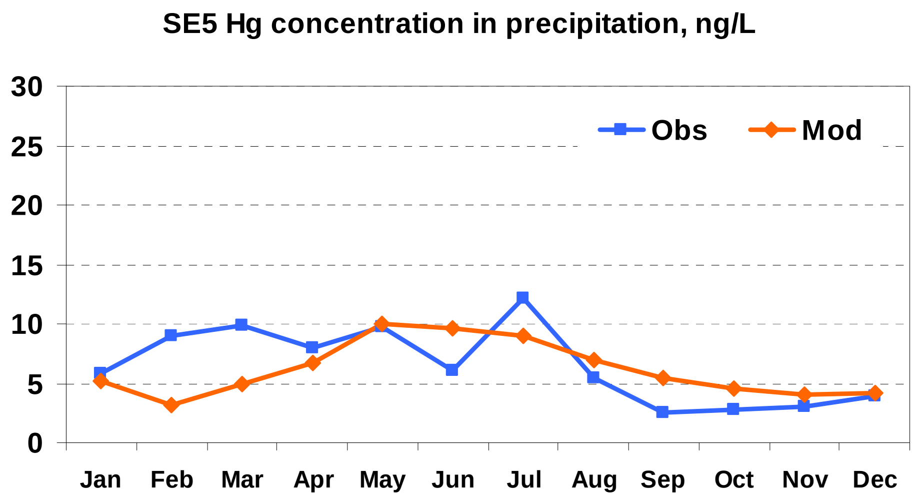


Figure 6.35. Comparison of calculated monthly mean Hg concentrations in precipitation for 2013 with measurements of the station Bredkälen (SE5). Units: ng/L.

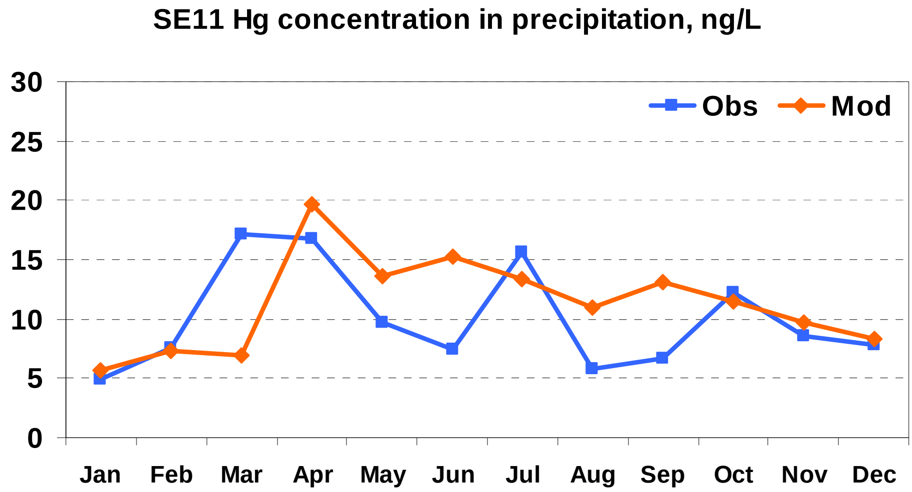


Figure 6.36. Comparison of calculated monthly mean Hg concentrations in precipitation for 2013 with measurements of the station Vavihill (SE11). Units: ng/L.

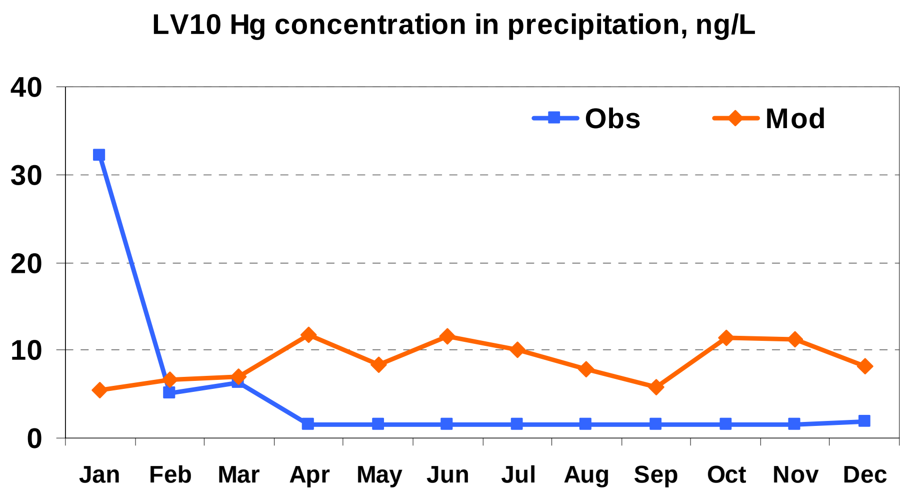


Figure 6.37. Comparison of calculated monthly mean Hg concentrations in precipitation for 2013 with measurements of the station Rucava (LV10). Units: ng/L.

Modelled concentrations of mercury in air and in precipitation were compared with the measurement data of 6 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 mercury can be explained by the uncertainties in seasonal variation of mercury emission used in modeling (anthropogenic and natural), differences between measured precipitation amount and the one used in the model, and difficulties in measurements of mercury.

6.6 Concluding remarks

- Mercury emissions from HELCOM countries have decreased from 1990 to 2013 by 65%, whereas from 2012 to 2013 emissions have slightly increased by 0.2%.
- Annual deposition of mercury to the Baltic Sea has decreased from 1990 to 2013 by 29%. Mercury deposition in 2013 was higher comparing to 2012 by 15%.
- The contribution of anthropogenic sources of HELCOM countries to total mercury deposition over the Baltic Sea was estimated to 12%. Essential contribution belongs to the global and natural sources and re-emission (84%) and anthropogenic sources of other EMEP countries (4%).
- The most significant contribution to mercury deposition over the Baltic Sea was made by Poland (5%) and Germany (4%).
- Modelling results for mercury were generally within an accuracy of 25% in comparison to measured concentrations obtained around the Baltic Sea in 2013.