Atmospheric deposition of heavy metals on the Baltic Sea

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Key Message

Levels of annual total atmospheric deposition of heavy metals to the Baltic Sea have decreased in period from 1990 to 2016 by 61% for cadmium, and 34% for mercury.

Results and Assessment

Relevance of the BSEFS for describing developments in the environment

This indicator shows the levels and trends in cadmium and mercury atmospheric deposition to the Baltic Sea. The deposition of heavy metals represents the pressure of emission sources on the Baltic Sea aquatic environment.

Policy relevance and policy references

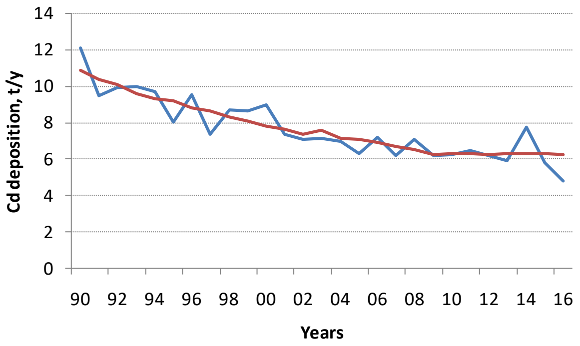
HELCOM adopted a Recommendation in May 2001 for the cessation of hazardous substance discharges/emissions by 2020, with the ultimate aim of achieving concentrations in the environment near to background values for naturally occurring substances and close to zero for man-made synthetic substances.

Assessment

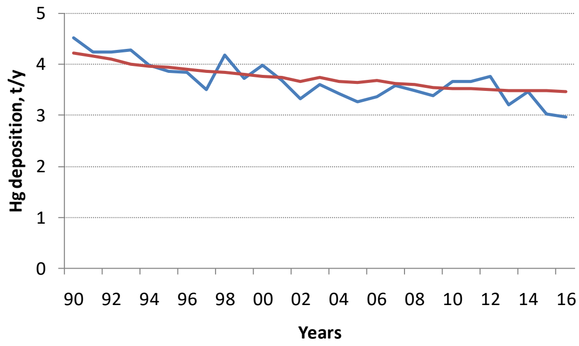
Airborne input of heavy metals to the Baltic Sea has substantially decreased in the period from 1990 to 2016 (Figure 1). The figure illustrates changes of computed total annual atmospheric deposition of cadmium and mercury to the Baltic Sea along with changes of normalized deposition, which reflect the effect of emission variations only, without the influence of inter-annual variations of meteorological conditions. Values of normalized annual depositions for the period 1990-2016 were calculated using the normalization procedure, described in the Annex D of the Joint report of the EMEP Centres (Bartnicki et al., 2017).

Levels of annual total atmospheric deposition of heavy metals to the Baltic Sea have decreased in period from 1990 to 2016 by 61% for cadmium, and 34% for mercury. The most substantial decrease can be noted for the Bothnian Bay sub-basin for cadmium (71%) and for the Sound sub-basin for mercury (61%). The highest level of cadmium and mercury deposition fluxes over the Baltic Sea in 2016 is noted for the Western Baltic and the Sound sub-basins (Figures 2 and 3). The most significant contributions among the HELCOM countries to HM deposition over the Baltic Sea in 2016 were made by Poland and Germany. HELCOM countries contributed to cadmium and mercury deposition over the Baltic Sea in 2016 about 38% and 13%, respectively, with largest contributions made by Poland and Germany.

Reduction of atmospheric input of cadmium and mercury to the Baltic Sea is a result of various activities including abatement measures as well as of economic contraction and industrial restructuring which took place in the HELCOM countries as well as other EMEP countries.



a)



b)

Figure 1. Changes of modelled (blue line) and normalized (red line) total annual atmospheric deposition of cadmium (a) and mercury (b) to the Baltic Sea for the period 1990-2016, (t/y).

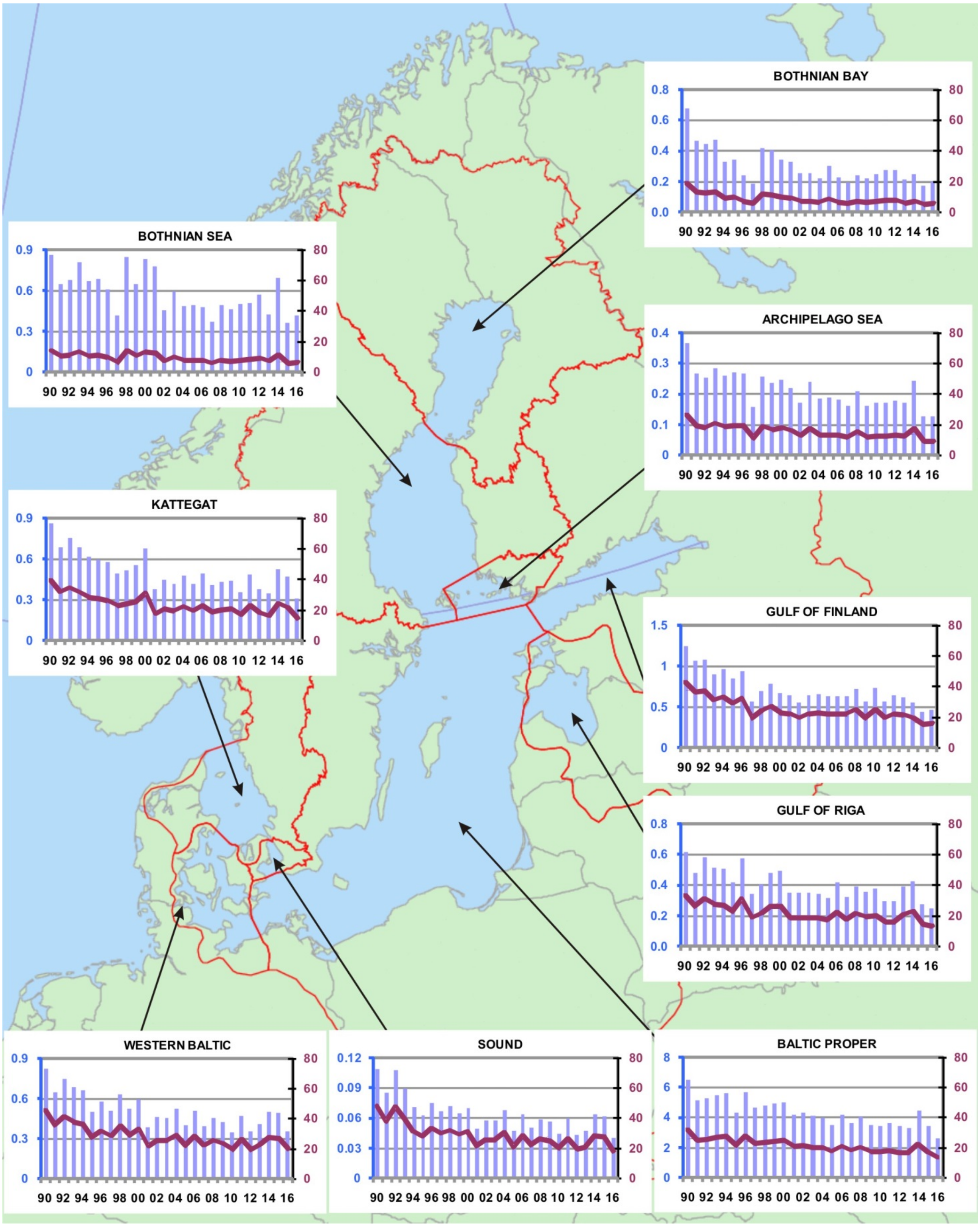


Figure 2. Time-series of computed total annual atmospheric deposition of **cadmium** to nine sub-basins of the Baltic Sea for the period 1990-2016 in tonnes/year as bars (left axis) and total deposition fluxes in g/km^2/year as lines (right axis). Note that different scales are used for total deposition in tonnes/year and the same scales for total deposition fluxes.

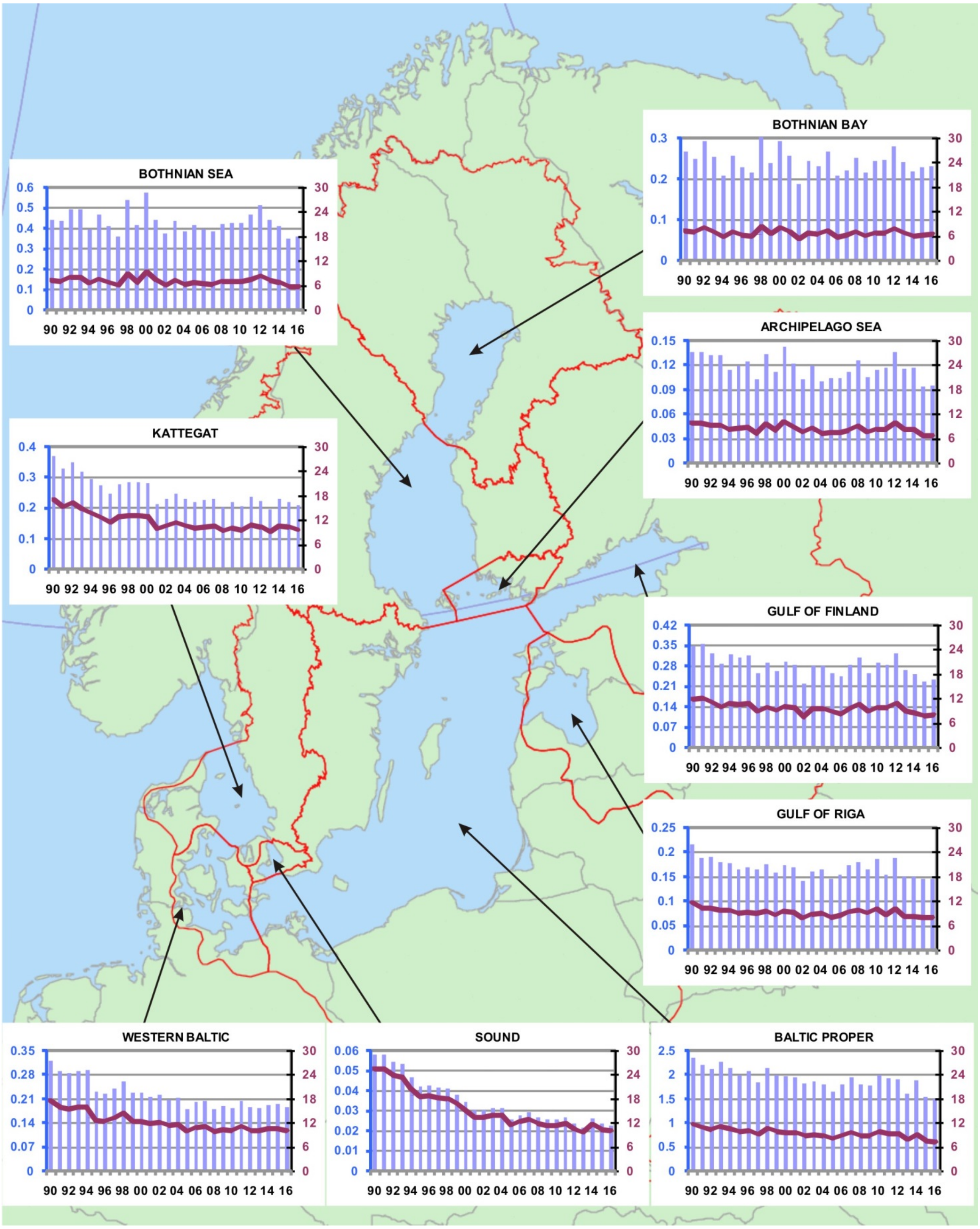


Figure 3: Time-series of computed total annual atmospheric deposition of **mercury** to nine sub-basins of the Baltic Sea for the period 1990-2016 in tonnes/year as bars (left axis) and total deposition fluxes in g/km^2/year as lines (right axis). Note that different scales are used for total deposition in tonnes/year and the same scales for total deposition fluxes.

References

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Data

Numerical data on computed HM depositions to the Baltic Sea are given in the following tables.

Table 1. Computed total annual deposition of **cadmium** to nine Baltic Sea sub-basins, the whole Baltic Sea (BAS) and normalized deposition to the Baltic Sea (Norm) for the period 1990-2016. Units: tonnes/year.

	ARC	BOB	BOS	BAP	GUF	GUR	KAT	SOU	WEB	BAS	Norm
1990	0.366	0.675	0.860	6.513	1.246	0.614	0.860	0.109	0.823	**12.07**	**10.86**
1991	0.266	0.266	0.645	5.105	1.061	0.480	0.685	0.085	0.646	**9.44**	**10.36**
1992	0.252	0.446	0.673	5.257	1.079	0.579	0.753	0.107	0.750	**9.90**	**10.09**
1993	0.285	0.475	0.810	5.486	0.896	0.514	0.687	0.089	0.682	**9.92**	**9.55**
1994	0.259	0.331	0.671	5.597	0.964	0.505	0.612	0.071	0.665	**9.67**	**9.29**
1995	0.270	0.344	0.686	4.299	0.842	0.418	0.594	0.063	0.500	**8.01**	**9.17**
1996	0.265	0.237	0.610	5.668	0.939	0.577	0.576	0.075	0.576	**9.52**	**8.80**
1997	0.158	0.186	0.415	4.623	0.563	0.340	0.491	0.067	0.507	**7.35**	**8.59**
1998	0.256	0.414	0.844	4.812	0.693	0.402	0.517	0.072	0.629	**8.64**	**8.26**
1999	0.235	0.405	0.643	4.937	0.781	0.480	0.550	0.065	0.521	**8.62**	**8.05**
2000	0.246	0.342	0.830	5.025	0.664	0.491	0.677	0.070	0.595	**8.94**	**7.79**
2001	0.220	0.329	0.777	4.180	0.637	0.352	0.377	0.049	0.387	**7.31**	**7.59**
2002	0.172	0.256	0.454	4.332	0.545	0.347	0.450	0.057	0.461	**7.07**	**7.32**
2003	0.239	0.256	0.591	4.084	0.643	0.346	0.415	0.058	0.454	**7.09**	**7.55**
2004	0.184	0.217	0.486	3.988	0.651	0.340	0.473	0.068	0.520	**6.93**	**7.09**
2005	0.187	0.298	0.493	3.480	0.626	0.314	0.417	0.047	0.401	**6.26**	**7.03**
2006	0.180	0.224	0.474	4.156	0.628	0.414	0.491	0.064	0.505	**7.14**	**6.87**
2007	0.162	0.192	0.371	3.600	0.630	0.325	0.407	0.050	0.392	**6.13**	**6.67**
2008	0.208	0.237	0.493	4.040	0.720	0.392	0.432	0.059	0.453	**7.03**	**6.49**
2009	0.162	0.221	0.458	3.457	0.561	0.355	0.440	0.056	0.423	**6.13**	**6.22**
2010	0.171	0.244	0.498	3.443	0.727	0.373	0.351	0.044	0.347	**6.20**	**6.27**
2011	0.170	0.272	0.506	3.631	0.562	0.296	0.486	0.060	0.470	**6.45**	**6.24**
2012	0.179	0.276	0.570	3.400	0.644	0.295	0.379	0.043	0.351	**6.14**	**6.24**
2013	0.172	0.210	0.424	3.277	0.609	0.386	0.345	0.047	0.406	**5.88**	**6.24**
2014	0.244	0.250	0.690	4.448	0.553	0.426	0.526	0.064	0.496	**7.70**	**6.26**
2015	0.125	0.172	0.359	3.399	0.433	0.271	0.465	0.061	0.490	**5.78**	**6.27**
2016	0.125	0.197	0.416	2.618	0.456	0.243	0.309	0.040	0.357	**4.76**	**6.21**

Table 2. Computed annual total deposition of **mercury** to nine Baltic Sea sub-basins, the whole Baltic Sea (BAS) and normalized deposition to the Baltic Sea (Norm) for the period 1990-2016. Units: tonnes/year.

	ARC	**BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**KAT**	**SOU**	**WEB**	**BAS**	**Norm**
1990	0.1363	0.267	0.440	2.356	0.347	0.215	0.368	0.0577	0.320	**4.51**	**4.22**
1991	0.1364	0.249	0.434	2.199	0.357	0.188	0.328	0.0578	0.290	**4.24**	**4.16**
1992	0.1320	0.292	0.493	2.117	0.324	0.191	0.349	0.0544	0.284	**4.24**	**4.09**
1993	0.1319	0.252	0.493	2.261	0.287	0.179	0.319	0.0533	0.292	**4.27**	**4.00**
1994	0.1142	0.206	0.393	2.135	0.319	0.178	0.296	0.0466	0.293	**3.98**	**3.96**
1995	0.1187	0.255	0.469	1.991	0.308	0.164	0.272	0.0419	0.230	**3.85**	**3.94**
1996	0.1239	0.229	0.413	2.074	0.315	0.169	0.247	0.0423	0.226	**3.84**	**3.90**
1997	0.1025	0.214	0.358	1.838	0.253	0.165	0.278	0.0415	0.239	**3.49**	**3.87**
1998	0.1332	0.302	0.537	2.137	0.291	0.175	0.284	0.0409	0.261	**4.16**	**3.83**
1999	0.1120	0.238	0.416	1.977	0.264	0.158	0.283	0.0381	0.228	**3.71**	**3.79**
2000	0.1417	0.292	0.574	1.965	0.293	0.174	0.280	0.0343	0.228	**3.98**	**3.77**
2001	0.1217	0.257	0.441	1.955	0.285	0.168	0.213	0.0302	0.215	**3.69**	**3.75**
2002	0.1030	0.186	0.372	1.820	0.218	0.141	0.228	0.0302	0.221	**3.32**	**3.67**
2003	0.1193	0.244	0.438	1.864	0.281	0.160	0.245	0.0311	0.208	**3.59**	**3.74**
2004	0.1004	0.230	0.384	1.790	0.281	0.165	0.230	0.0313	0.212	**3.42**	**3.66**
2005	0.1041	0.266	0.417	1.645	0.254	0.146	0.218	0.0256	0.180	**3.25**	**3.65**
2006	0.1036	0.206	0.393	1.800	0.243	0.154	0.225	0.0277	0.199	**3.35**	**3.68**
2007	0.1119	0.220	0.384	1.950	0.283	0.173	0.231	0.0291	0.204	**3.59**	**3.63**
2008	0.1255	0.251	0.422	1.790	0.307	0.179	0.202	0.0265	0.179	**3.48**	**3.61**
2009	0.1054	0.215	0.426	1.773	0.256	0.165	0.220	0.0257	0.188	**3.37**	**3.55**
2010	0.1139	0.242	0.423	1.983	0.289	0.185	0.204	0.0257	0.182	**3.65**	**3.52**
2011	0.1166	0.245	0.466	1.923	0.285	0.155	0.235	0.0264	0.204	**3.66**	**3.51**
2012	0.1363	0.279	0.511	1.893	0.322	0.187	0.222	0.0234	0.185	**3.76**	**3.51**
2013	0.1148	0.240	0.443	1.597	0.267	0.151	0.195	0.0214	0.182	**3.21**	**3.49**
2014	0.1172	0.217	0.412	1.872	0.251	0.149	0.231	0.0263	0.192	**3.47**	**3.48**
2015	0.0933	0.228	0.349	1.549	0.225	0.145	0.220	0.0234	0.195	**3.03**	**3.48**
2016	0.0946	0.230	0.357	1.492	0.232	0.144	0.208	0.0225	0.185	**2.97**	**3.46**

Table 3. Computed contributions by country to annual total deposition of **cadmium** to nine Baltic Sea sub-basins for the year 2016. Units: tonnes/year. HELCOM: contribution of anthropogenic sources of HELCOM countries; EMEP: contribution of anthropogenic sources in other EMEP countries;. NSR: contributions of sources other than primary anthropogenic emissions (natural, secondary (re-suspension), and remote sources).

Country	**ARC**	**BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**KAT**	**SOU**	**WEB**	**BAS**
DK	1.3E-03	9.9E-04	3.1E-03	4.7E-02	1.8E-03	1.9E-03	2.6E-02	4.0E-03	2.2E-02	1.1E-01
EE	2.3E-03	1.9E-03	6.9E-03	1.6E-02	5.8E-02	6.3E-03	3.6E-04	3.4E-05	2.6E-04	9.2E-02
FI	8.6E-03	2.3E-02	2.6E-02	1.6E-02	2.4E-02	2.9E-03	4.2E-04	3.4E-05	2.7E-04	1.0E-01
DE	6.8E-03	7.1E-03	1.9E-02	2.7E-01	1.1E-02	1.0E-02	4.8E-02	6.7E-03	7.5E-02	4.5E-01
LV	1.9E-03	9.8E-04	4.2E-03	4.5E-02	4.2E-03	2.1E-02	6.5E-04	7.3E-05	4.5E-04	7.8E-02
LT	7.7E-04	4.8E-04	1.8E-03	1.9E-02	1.5E-03	3.9E-03	4.0E-04	4.4E-05	2.8E-04	2.9E-02
PL	1.2E-02	9.5E-03	3.2E-02	3.6E-01	2.2E-02	2.1E-02	1.9E-02	2.8E-03	2.1E-02	5.0E-01
RU	1.0E-02	2.8E-02	4.1E-02	1.3E-01	1.2E-01	2.6E-02	4.5E-03	4.9E-04	4.2E-03	3.6E-01
SE	3.4E-03	1.6E-02	1.6E-02	2.9E-02	2.8E-03	2.2E-03	4.1E-03	6.4E-04	9.9E-04	7.4E-02
AL	1.2E-05	1.3E-05	2.5E-05	1.3E-04	3.4E-05	1.9E-05	5.9E-06	6.5E-07	4.7E-06	2.4E-04
AT	3.4E-04	3.1E-04	1.0E-03	8.1E-03	7.2E-04	5.5E-04	7.5E-04	1.0E-04	8.5E-04	1.3E-02
BE	9.3E-04	1.3E-03	3.1E-03	3.7E-02	1.7E-03	1.6E-03	9.7E-03	1.1E-03	1.1E-02	6.8E-02
BG	1.0E-04	1.1E-04	1.7E-04	9.9E-04	3.8E-04	1.7E-04	4.1E-05	3.3E-06	2.2E-05	2.0E-03
BA	1.3E-04	1.1E-04	2.8E-04	2.1E-03	4.3E-04	2.7E-04	9.5E-05	1.3E-05	1.3E-04	3.5E-03
BY	4.7E-04	3.5E-04	1.3E-03	7.4E-03	1.6E-03	1.3E-03	3.6E-04	3.6E-05	2.0E-04	1.3E-02
CH	1.9E-04	2.3E-04	5.6E-04	4.4E-03	3.8E-04	2.8E-04	9.0E-04	9.9E-05	8.9E-04	7.9E-03
CY	1.3E-07	3.4E-07	3.4E-07	2.5E-06	7.6E-07	2.7E-07	8.9E-08	1.2E-08	7.6E-08	4.5E-06
CZ	5.8E-04	5.0E-04	1.7E-03	1.5E-02	1.0E-03	8.5E-04	1.5E-03	2.0E-04	1.6E-03	2.3E-02
ES	3.1E-04	5.8E-04	1.1E-03	5.4E-03	5.9E-04	4.4E-04	1.1E-03	1.0E-04	1.0E-03	1.1E-02
FR	5.3E-04	7.5E-04	1.8E-03	1.5E-02	9.3E-04	8.1E-04	4.3E-03	4.2E-04	3.9E-03	2.8E-02
GB	9.5E-04	9.5E-04	2.9E-03	3.2E-02	1.9E-03	1.9E-03	1.0E-02	9.1E-04	7.6E-03	5.9E-02
GR	8.1E-05	1.2E-04	1.9E-04	7.9E-04	3.2E-04	1.5E-04	2.8E-05	2.7E-06	2.0E-05	1.7E-03
HR	1.0E-04	8.5E-05	2.7E-04	2.0E-03	2.8E-04	2.0E-04	1.1E-04	1.4E-05	1.2E-04	3.2E-03
HU	3.8E-04	2.7E-04	1.0E-03	8.2E-03	8.8E-04	7.1E-04	4.8E-04	6.1E-05	5.2E-04	1.3E-02
IE	4.9E-05	5.5E-05	1.5E-04	1.5E-03	1.0E-04	1.0E-04	4.4E-04	4.0E-05	3.2E-04	2.7E-03
IS	1.1E-06	5.6E-06	6.8E-06	2.4E-05	2.7E-06	1.6E-06	4.9E-06	4.8E-07	3.3E-06	5.1E-05
IT	4.7E-04	7.2E-04	1.6E-03	9.6E-03	1.4E-03	9.4E-04	1.0E-03	1.4E-04	1.3E-03	1.7E-02
MD	2.2E-05	1.9E-05	5.5E-05	5.1E-04	9.8E-05	6.8E-05	2.7E-05	2.8E-06	1.4E-05	8.1E-04
MK	8.1E-06	8.8E-06	1.7E-05	8.7E-05	2.7E-05	1.4E-05	3.2E-06	3.1E-07	2.2E-06	1.7E-04
NL	2.8E-04	3.3E-04	9.0E-04	1.1E-02	5.2E-04	5.3E-04	3.0E-03	3.3E-04	3.3E-03	2.0E-02
NO	3.9E-04	1.0E-03	2.0E-03	4.6E-03	6.2E-04	4.9E-04	7.7E-04	5.0E-05	3.5E-04	1.0E-02
PT	5.3E-05	9.2E-05	1.8E-04	1.2E-03	9.3E-05	1.0E-04	1.9E-04	1.7E-05	1.9E-04	2.1E-03
RO	3.1E-04	2.8E-04	7.6E-04	5.9E-03	1.2E-03	7.7E-04	3.1E-04	3.5E-05	2.4E-04	9.7E-03
SK	5.3E-04	3.7E-04	1.5E-03	1.1E-02	1.1E-03	9.5E-04	6.1E-04	8.2E-05	7.6E-04	1.7E-02
SI	8.9E-05	9.0E-05	3.1E-04	2.4E-03	2.6E-04	2.0E-04	1.7E-04	2.5E-05	1.6E-04	3.7E-03
UA	1.6E-03	1.6E-03	4.7E-03	2.9E-02	6.1E-03	4.4E-03	1.2E-03	9.9E-05	7.0E-04	4.9E-02
RS	2.7E-04	2.3E-04	5.9E-04	3.8E-03	7.7E-04	4.7E-04	1.2E-04	1.7E-05	1.5E-04	6.4E-03
AM	1.8E-06	6.8E-06	7.7E-06	3.3E-05	1.2E-05	4.3E-06	9.9E-07	1.4E-07	1.3E-06	6.7E-05
AZ	1.2E-06	5.2E-06	5.1E-06	4.0E-05	9.1E-06	3.1E-06	1.1E-06	1.6E-07	1.5E-06	6.7E-05
KZ	5.5E-05	1.9E-04	2.4E-04	9.3E-04	2.6E-04	1.4E-04	3.8E-05	4.3E-06	4.2E-05	1.9E-03
GE	3.6E-06	1.4E-05	1.4E-05	6.2E-05	2.4E-05	9.0E-06	1.6E-06	2.4E-07	2.0E-06	1.3E-04
TR	2.5E-04	6.4E-04	4.9E-04	2.5E-03	1.6E-03	6.6E-04	8.4E-05	1.1E-05	9.5E-05	6.4E-03
LU	2.4E-05	3.3E-05	7.8E-05	7.6E-04	3.9E-05	3.6E-05	1.5E-04	1.6E-05	1.5E-04	1.3E-03
MC	8.5E-08	1.6E-07	3.1E-07	1.9E-06	2.4E-07	1.6E-07	2.7E-07	3.9E-08	4.0E-07	3.6E-06
KY	2.2E-07	1.2E-06	1.6E-06	3.7E-06	7.5E-07	2.6E-07	1.8E-07	2.3E-08	2.0E-07	8.1E-06
UZ	6.3E-06	2.5E-05	2.5E-05	3.3E-04	4.3E-05	1.7E-05	9.6E-06	1.3E-06	1.4E-05	4.7E-04
TM	5.9E-07	2.3E-06	2.3E-06	3.6E-05	4.3E-06	1.6E-06	9.6E-07	1.4E-07	1.5E-06	5.0E-05
TJ	1.4E-07	6.9E-07	1.0E-06	1.7E-06	4.3E-07	1.6E-07	8.7E-08	8.6E-09	5.3E-08	4.2E-06
MT	2.0E-07	3.3E-07	6.9E-07	2.1E-06	5.2E-07	3.1E-07	2.2E-07	1.8E-08	1.9E-07	4.6E-06
ME	5.7E-06	5.2E-06	1.1E-05	6.8E-05	1.7E-05	9.9E-06	3.1E-06	4.1E-07	3.4E-06	1.2E-04
AF	1.4E-04	2.4E-04	4.4E-04	1.7E-03	3.9E-04	2.0E-04	1.8E-04	1.6E-05	1.5E-04	3.4E-03
AS	4.3E-05	1.4E-04	1.8E-04	8.2E-04	2.4E-04	8.8E-05	3.4E-05	4.2E-06	3.8E-05	1.6E-03
NSR	0.068	0.097	0.235	1.458	0.184	0.128	0.168	0.022	0.197	2.556
EMEP	0.010	0.012	0.030	0.225	0.026	0.019	0.038	0.004	0.036	0.400
HELCOM	0.047	0.088	0.150	0.928	0.247	0.096	0.104	0.015	0.125	1.799
Total	0.125	0.197	0.415	2.612	0.457	0.243	0.309	0.040	0.358	4.755

Table 4. Computed contributions by country to annual total deposition of **mercury** to nine Baltic Sea sub-basins for the year 2016. Units: tonnes/year. HELCOM: contribution of anthropogenic sources of HELCOM countries; EMEP: contribution of anthropogenic sources in other EMEP countries;. NSR: contributions of sources other than primary anthropogenic emissions (natural, secondary (re-suspension), and remote sources).

Country	**ARC**	**BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**KAT**	**SOU**	**WEB**	**BAS**
DK	2.0E-04	1.5E-04	5.6E-04	9.3E-03	2.7E-04	2.7E-04	7.9E-03	1.9E-03	7.8E-03	2.8E-02
EE	7.3E-04	5.0E-04	1.9E-03	5.1E-03	2.9E-02	2.1E-03	9.7E-05	9.9E-06	6.9E-05	3.9E-02
FI	1.4E-03	9.3E-03	3.8E-03	1.9E-03	3.9E-03	3.3E-04	5.0E-05	4.1E-06	3.0E-05	2.1E-02
DE	1.6E-03	1.6E-03	4.5E-03	6.4E-02	2.5E-03	2.2E-03	9.7E-03	1.6E-03	2.3E-02	1.1E-01
LV	9.1E-05	3.3E-05	1.7E-04	1.5E-03	2.0E-04	2.0E-03	2.0E-05	2.6E-06	1.5E-05	4.1E-03
LT	5.4E-05	2.8E-05	1.2E-04	1.7E-03	1.1E-04	3.5E-04	2.4E-05	3.2E-06	1.8E-05	2.4E-03
PL	2.6E-03	2.0E-03	7.2E-03	1.0E-01	5.1E-03	5.0E-03	4.0E-03	7.6E-04	6.0E-03	1.4E-01
RU	6.9E-04	2.2E-03	2.9E-03	7.8E-03	4.2E-03	1.6E-03	3.3E-04	3.5E-05	2.7E-04	2.0E-02
SE	7.7E-04	5.1E-03	3.1E-03	7.1E-03	4.8E-04	3.7E-04	1.0E-03	2.4E-04	2.0E-04	1.8E-02
AL	1.9E-06	3.1E-06	5.4E-06	2.7E-05	6.5E-06	4.0E-06	1.6E-06	1.7E-07	1.2E-06	5.1E-05
AT	5.7E-05	5.9E-05	1.8E-04	1.3E-03	1.3E-04	9.8E-05	1.0E-04	1.5E-05	1.3E-04	2.1E-03
BE	1.1E-04	1.5E-04	3.8E-04	3.5E-03	1.9E-04	1.6E-04	8.5E-04	1.0E-04	1.1E-03	6.6E-03
BG	7.5E-06	1.7E-05	2.4E-05	1.2E-04	3.6E-05	1.8E-05	7.6E-06	7.6E-07	6.0E-06	2.4E-04
BA	4.7E-05	4.6E-05	1.1E-04	8.0E-04	1.6E-04	1.1E-04	4.1E-05	5.3E-06	5.3E-05	1.4E-03
BY	2.4E-05	1.8E-05	6.2E-05	4.3E-04	7.2E-05	6.2E-05	1.5E-05	1.7E-06	1.1E-05	7.0E-04
CH	3.5E-05	4.3E-05	1.1E-04	6.7E-04	6.6E-05	4.7E-05	9.9E-05	1.2E-05	1.1E-04	1.2E-03
CY	9.8E-08	2.1E-07	3.8E-07	1.3E-06	3.4E-07	1.8E-07	1.0E-07	1.0E-08	6.4E-08	2.7E-06
CZ	4.4E-04	3.9E-04	1.3E-03	1.1E-02	7.9E-04	6.9E-04	8.1E-04	1.4E-04	1.1E-03	1.7E-02
ES	5.4E-05	1.0E-04	2.1E-04	9.4E-04	1.0E-04	7.3E-05	1.8E-04	1.6E-05	1.5E-04	1.8E-03
FR	1.4E-04	2.0E-04	4.8E-04	3.2E-03	2.5E-04	1.9E-04	7.5E-04	7.9E-05	7.6E-04	6.1E-03
GB	3.2E-04	3.9E-04	1.1E-03	9.6E-03	6.1E-04	5.5E-04	2.8E-03	2.8E-04	2.6E-03	1.8E-02
GR	2.4E-05	4.9E-05	7.1E-05	2.9E-04	9.8E-05	5.3E-05	1.4E-05	1.4E-06	1.0E-05	6.1E-04
HR	1.2E-05	1.3E-05	3.5E-05	2.4E-04	3.6E-05	2.7E-05	1.5E-05	1.8E-06	1.6E-05	3.9E-04
HU	7.2E-05	5.6E-05	2.0E-04	1.5E-03	1.7E-04	1.4E-04	7.6E-05	1.0E-05	1.0E-04	2.3E-03
IE	1.6E-05	2.1E-05	5.4E-05	4.1E-04	3.4E-05	2.9E-05	1.1E-04	1.1E-05	9.0E-05	7.7E-04
IS	7.3E-07	2.3E-06	3.5E-06	1.1E-05	1.7E-06	1.0E-06	1.7E-06	1.7E-07	1.3E-06	2.4E-05
IT	1.7E-04	2.7E-04	6.0E-04	3.2E-03	4.6E-04	3.2E-04	3.3E-04	4.2E-05	4.2E-04	5.8E-03
MD	2.9E-06	3.8E-06	9.3E-06	6.7E-05	1.2E-05	8.6E-06	4.1E-06	4.1E-07	2.7E-06	1.1E-04
MK	3.2E-06	5.9E-06	8.4E-06	4.3E-05	1.3E-05	7.1E-06	2.1E-06	2.1E-07	1.5E-06	8.4E-05
NL	7.2E-05	8.3E-05	2.4E-04	2.5E-03	1.2E-04	1.1E-04	6.9E-04	7.5E-05	8.9E-04	4.8E-03
NO	6.1E-05	1.1E-04	2.8E-04	7.3E-04	8.0E-05	6.4E-05	1.4E-04	7.8E-06	5.3E-05	1.5E-03
PT	1.1E-05	2.2E-05	4.4E-05	2.0E-04	2.0E-05	1.6E-05	3.3E-05	2.8E-06	2.9E-05	3.8E-04
RO	3.8E-05	4.5E-05	1.1E-04	8.0E-04	1.5E-04	1.0E-04	4.8E-05	5.6E-06	5.0E-05	1.3E-03
SK	1.5E-04	1.1E-04	4.3E-04	3.3E-03	3.7E-04	3.1E-04	1.8E-04	2.7E-05	2.6E-04	5.1E-03
SI	7.9E-06	8.7E-06	2.8E-05	2.0E-04	2.3E-05	1.8E-05	1.5E-05	2.1E-06	1.4E-05	3.2E-04
UA	8.9E-04	1.2E-03	2.7E-03	1.4E-02	3.0E-03	2.7E-03	6.6E-04	6.9E-05	5.1E-04	2.5E-02
RS	5.6E-05	5.8E-05	1.4E-04	8.6E-04	1.8E-04	1.2E-04	3.6E-05	4.5E-06	4.4E-05	1.5E-03
AM	1.0E-06	3.4E-06	4.6E-06	1.5E-05	4.4E-06	2.2E-06	7.8E-07	8.9E-08	6.8E-07	3.2E-05
AZ	8.9E-07	3.2E-06	3.9E-06	1.8E-05	3.8E-06	2.0E-06	8.2E-07	9.8E-08	7.5E-07	3.3E-05
KZ	5.5E-05	1.3E-04	2.7E-04	6.6E-04	1.5E-04	9.6E-05	4.1E-05	3.9E-06	3.0E-05	1.4E-03
GE	1.0E-06	3.9E-06	4.3E-06	1.5E-05	4.3E-06	2.3E-06	6.9E-07	7.8E-08	5.8E-07	3.2E-05
TR	6.2E-05	2.1E-04	2.0E-04	7.2E-04	3.3E-04	1.8E-04	4.0E-05	4.5E-06	3.2E-05	1.8E-03
LU	9.1E-06	1.1E-05	2.8E-05	2.2E-04	1.4E-05	1.1E-05	4.1E-05	4.5E-06	4.2E-05	3.8E-04
MC	2.8E-08	5.2E-08	1.1E-07	5.4E-07	7.3E-08	4.8E-08	7.3E-08	9.7E-09	1.0E-07	1.0E-06
KY	3.8E-07	9.5E-07	2.1E-06	4.1E-06	8.0E-07	4.0E-07	4.1E-07	2.9E-08	2.3E-07	9.4E-06
UZ	4.9E-06	1.4E-05	2.5E-05	8.2E-05	1.5E-05	7.4E-06	5.3E-06	4.9E-07	4.1E-06	1.6E-04
TM	5.0E-07	1.5E-06	2.3E-06	1.1E-05	2.0E-06	9.0E-07	5.7E-07	6.2E-08	5.4E-07	2.0E-05
TJ	1.8E-07	4.7E-07	1.0E-06	1.9E-06	3.8E-07	1.9E-07	1.9E-07	1.3E-08	1.0E-07	4.4E-06
MT	2.4E-08	4.2E-08	8.3E-08	3.0E-07	6.7E-08	4.4E-08	2.7E-08	2.7E-09	2.5E-08	6.1E-07
ME	1.9E-06	2.2E-06	4.2E-06	2.8E-05	6.6E-06	4.3E-06	1.3E-06	1.6E-07	1.3E-06	5.0E-05
AF	3.1E-05	5.3E-05	1.0E-04	3.9E-04	8.8E-05	5.2E-05	4.0E-05	3.9E-06	3.3E-05	7.9E-04
AS	2.0E-05	5.2E-05	9.4E-05	2.6E-04	6.5E-05	3.4E-05	1.9E-05	1.8E-06	1.4E-05	5.6E-04
NSR	0.083	0.205	0.323	1.227	0.179	0.124	0.177	0.017	0.139	2.474
EMEP	0.003	0.004	0.010	0.062	0.008	0.006	0.008	0.001	0.009	0.111
HELCOM	0.008	0.021	0.024	0.202	0.046	0.014	0.023	0.005	0.037	0.380
Total	0.095	0.230	0.357	1.492	0.232	0.144	0.208	0.022	0.185	2.965

Metadata

Technical information

1. Source:

EMEP/MSC-E

2. Description of data:

Levels of atmospheric deposition of heavy metals over the Baltic Sea were obtained using the latest version of MSCE-HM model developed at EMEP/MSC-E (Travnikov and Ilyin, 2005). The latest available official emission data for the HELCOM countries have been used in the model computations. Emissions of Cd and Hg for each year of this period were officially reported by most of HELCOM countries. These data are available from the EMEP Centre on Emission Inventories and Projections (CEIP) (http://www.ceip.at/). The information on the HM emission data used for modelling is presented in the indicator on the HM emission to the air.

3. Geographical coverage:

Atmospheric deposition of cadmium and mercury were obtained for the European region and surrounding areas covered by the EMEP modelling domain.

4. Temporal coverage:

Time-series of annual atmospheric deposition are available for the period 1990 – 2016.

5. Methodology and frequency of data collection:

Atmospheric input and source allocation budgets of heavy metals (cadmium and mercury) to the Baltic Sea and its catchment area were computed using the latest version of MSCE-HM model. MSCE-HM is the regional-scale model operating within the EMEP region. This is a three-dimensional Eulerian model which includes processes of emission, advection, turbulent diffusion, chemical transformations of mercury, wet and dry deposition, and inflow of pollutant into the model domain. Horizontal grid of the model is defined using stereographic projection with spatial resolution 50 km at 60º latitude. The description of EMEP grid system can be found in the internet (http://www.emep.int/grid/index.html). Vertical structure of the model consists of 15 non-uniform layers defined in the terrain-following -coordinates and covers almost the whole troposphere. Detailed description of the model can be found in EMEP reports (Travnikov and Ilyin, 2005) and in the Internet on EMEP web page http://www.emep.int under the link to information on Heavy Metals. Meteorological data used in the calculations for 1990-2016 were obtained using MM5 meteorological data pre-processor on the basis of meteorological analysis of European Centre for Medium-Range Weather Forecasts (ECMWF).

Calculations of atmospheric transport and deposition of cadmium and mercury are provided on the regular basis annually two years in arrears on the basis of emission data officially submitted by Parties to LRTAP Convention.

Quality information

6. Strength and weakness:

Strength: annually updated information on atmospheric input of cadmium and mercury to the Baltic Sea and its sub-basins.

Weakness: uncertainties in officially submitted data on emissions of heavy metals.

7. Uncertainty:

The MSCE-HM model has been verified in a number of intercomparison campaigns with other regional HM transport models (Gusev et al., 2000; Ryaboshapko et al., 2001,2005) and has been qualified by means of sensitivity and uncertainty studies (Travnikov, 2000). It was concluded in these publications that the results of heavy metal airborne transport modelling were in satisfactory agreement with the available measurements and the discrepancies did not exceed on average a factor of two. The comparison of calculated versus measured data indicates that the model predicts the observed air concentrations of cadmium within the accuracy of 30%. For concentrations in precipitation the difference between calculated and measured values may reach two times. Computed mercury concentrations deviate from measured values within a factor of two.

The model was thoroughly reviewed at the workshop held in October, 2005 under supervision of the EMEP Task Force of Measurements and Modelling (TFMM). It was concluded that “MSC-E model is suitable for the evaluation of long-range transboundary transport and deposition of HMs in Europe” [*ECE/EB.AIR/GE.1/2006/4*].

8. Further work required:

Further work is required to reduce uncertainties in HM modelling approaches applied in the EMEP MSCE-HM model.