Atmospheric deposition of HCB on the Baltic Sea

HELCOM Baltic Sea Environment Fact Sheet (BSEFS), 2021

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Key message

Levels of annual total atmospheric deposition of HCB to the Baltic Sea have decreased in period from 1990 to 2019 by 95%, although the decrease was higher during the period 1990-2002 comparing to the subsequent period 2003-2019.

Results and Assessment

Relevance of the BSEFS for describing developments in the environment

This BSEFS shows the levels and trends in HCB atmospheric deposition to the Baltic Sea. The deposition of HCB represents the pressure of the emission sources on the Baltic Sea aquatic environment as described in the BSEFS “Atmospheric emissions of HCB in the Baltic Sea region”.

Policy relevance and policy reference

The updated Baltic Sea Action Plan states the ecological objectives that concentrations of hazardous substances in the environment are to be close to background values for naturally occurring substances. HELCOM Recommendation 31E/1 identifies the list of regional priority substances for the Baltic Sea.

The relevant policy to the control of emissions of HCB to the atmosphere on European scale is set in the framework of UN ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). According to the CLRTAP Protocol on Persistent Organic Pollutants (1998), the emissions of HCB must be reduced below the emission levels in 1990.

For EU member states the policy frame is set by the EU IED Directive, whereas for the Russian Federation the corresponding policy framework is embraced by the Russian Federal Act on the environmental protection and the Act on protection of atmospheric air.

Assessment

In order to assess long-term changes of HCB atmospheric input to the Baltic Sea, model simulations based on officially reported emission data were carried out. In addition, secondary sources of HCB emissions to the atmosphere (re-volatilization from the terrestrial and aquatic compartments) were taken into account. In spite of high uncertainties in the anthropogenic and secondary emissions of HCB, model estimates of regional scale HCB pollution levels show generally reasonable agreement with observed pollution levels.

Airborne input of HCB to the Baltic Sea has decreased by 95% in the period from 1990 to 2019 (Figure 1, Table 1). Slightly bigger decline is estimated for the Bothnian Sea sub-basin (-95.3%), while the lowest decline is obtained for the Gulf of Finland (-94.1%). However, variability of deposition decline among the sub-basins is low due to homogeneous spatial distribution of HCB air concentrations in the Baltic Sea region.

The decrease of HCB deposition to the Baltic Sea was higher during the period 1990-2002 comparing to subsequent period 2003-2019. Trends of deposition fluxes for both periods were analysed using Mann-Kendall test methodology [*Gilbert*, 1987; *Connor et al.*, 2012]. In the period from 1990 to 2002, stronger decline is estimated with the mean annual rate of deposition decline about 430 kg per year with confidence factor equal to 99.9%. The subsequent period of time 2003-2019 is characterised by less intensive mean annual decline rate of about 55 kg per year with confidence factor 99.9%. The values of the confidence factors indicates that the trends for the both parts of the assessment period are significant. Reduction of atmospheric input of HCB to the Baltic Sea is connected with the realization of various abatement measures, which took place in the HELCOM countries as well as other EMEP countries.

The highest total annual HCB deposition fluxes over the Baltic Sea in 2019 are estimated for the Gulf of Riga and Gulf of Finland sub-basins (Figures 2, 3). The lowest deposition flux is obtained for the Bosnian Sea sub-basin. Due to substantial reduction of contemporary HCB anthropogenic emissions and accumulation of HCB in the environmental compartments, the largest contribution to total annual deposition to the Baltic Sea in 2019 is made by secondary emission sources (re-volatilization from surface compartments) within and outside the EMEP modelling domain. Annual emissions of HELCOM countries in 2019 contributed to HCB deposition over the Baltic Sea about 3% (Table 2), with largest shares made by Finland and Denmark (Figure 4).

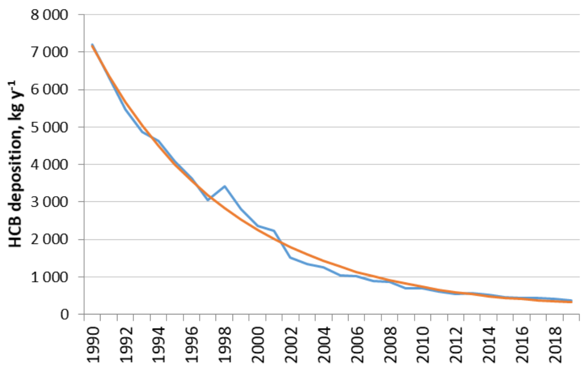

Figure 1. Long-term changes of total annual modelled atmospheric deposition (blue line) and estimates of normalized deposition (red line) of HCB to the Baltic Sea for the period 1990-2019, (kg y^{-1}). Normalized depositions were obtained using the methodology described below in the metadata section 5.

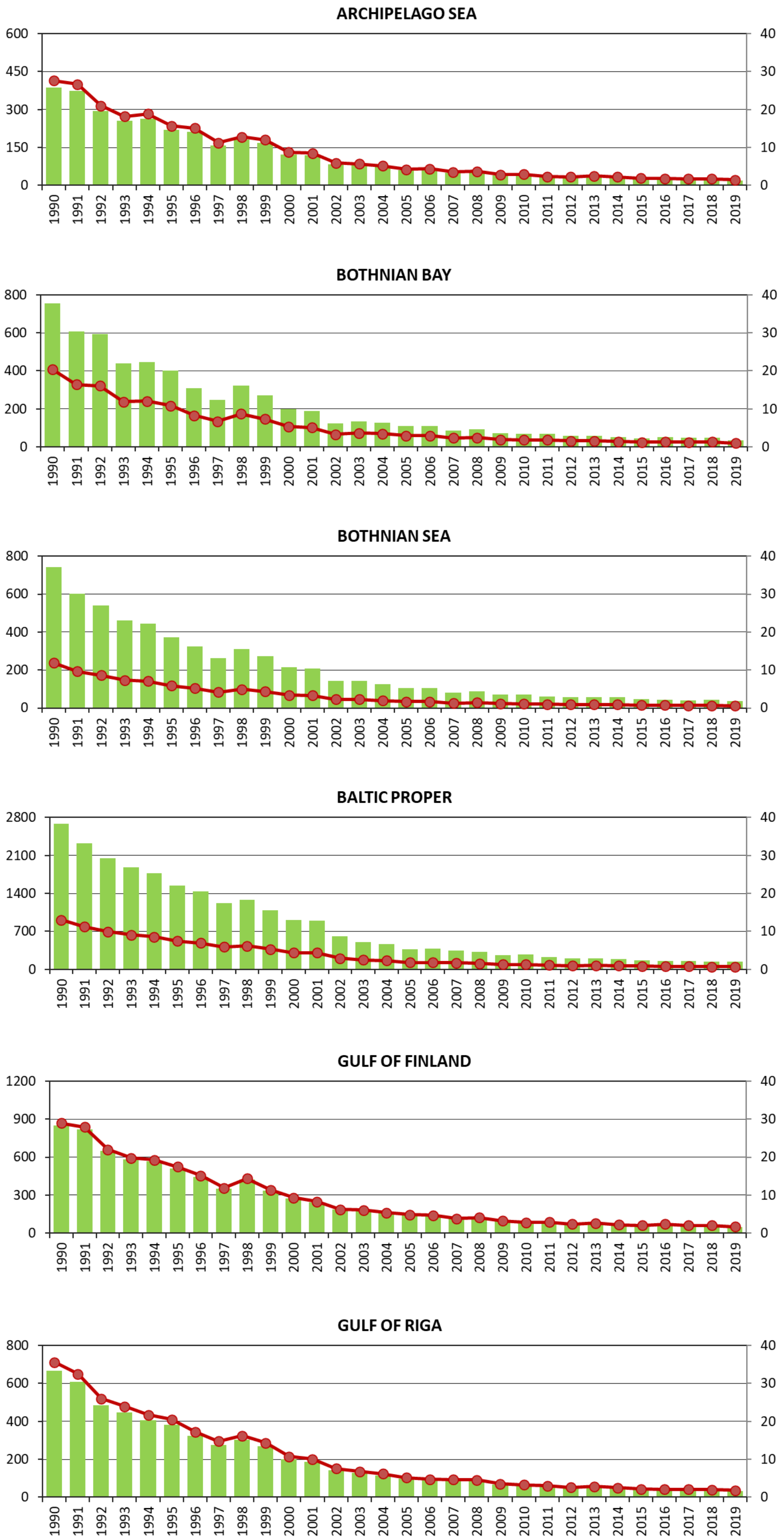

Figure 2. Time-series of computed total annual atmospheric deposition of HCB to nine sub-basins of the Baltic Sea for the period 1990-2019 in kg y^{-1} as green bars (left axis) and total deposition fluxes in g km^{-2} y^{-1} as red lines (right axis).

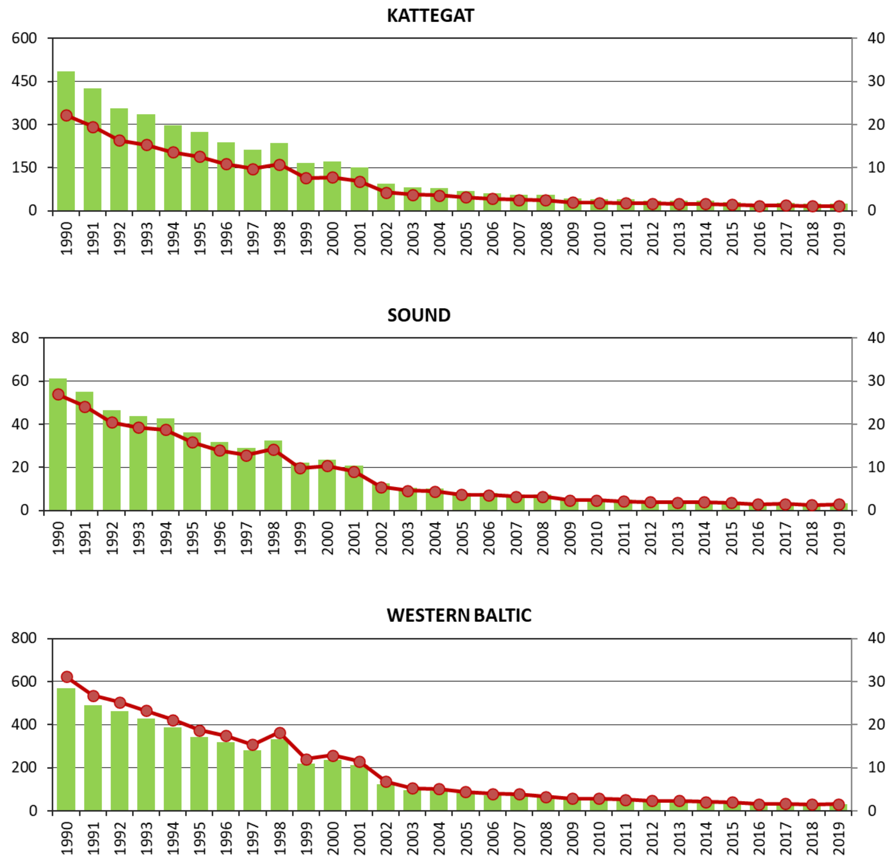

Figure 2. (continued). Time-series of computed total annual atmospheric deposition of HCB to nine sub-basins of the Baltic Sea for the period 1990-2019 in kg y^{-1} as green bars (left axis) and total deposition fluxes in g km^{-2} y^{-1} as red lines (right axis).

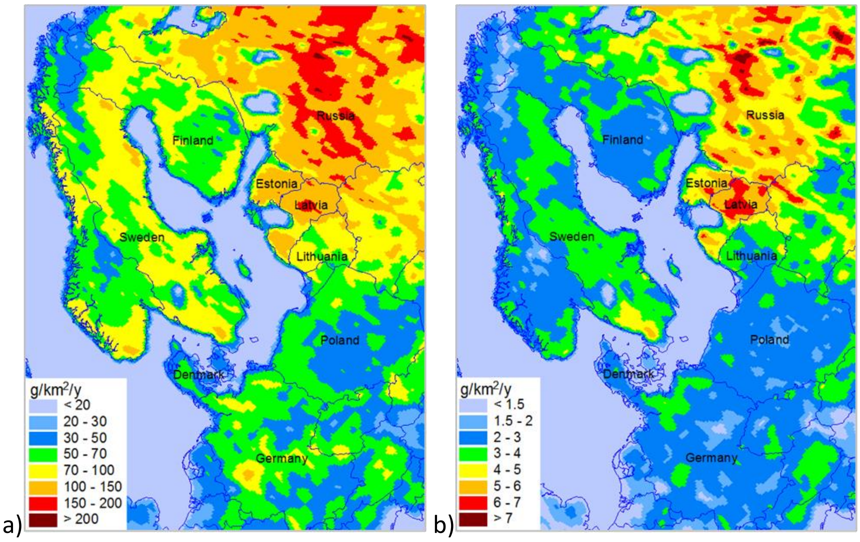

Figure 3. Spatial distribution of modelled annual total deposition fluxes of HCB in the Baltic Sea region for 1990 (a) and 2019 (b), g km^{-2} y^{-1}.

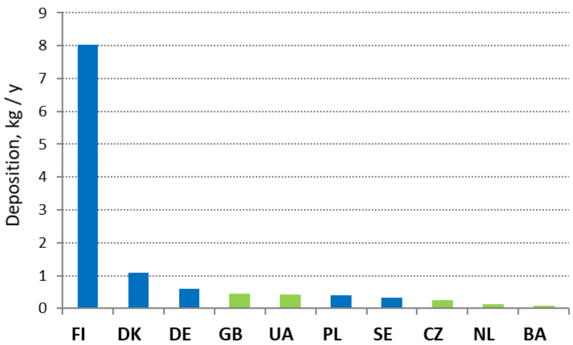

Figure 4. Ten countries with the highest contribution to annual total deposition of HCB to the Baltic Sea estimated for 2019, kg y^{-1}. Green bars indicate non-HELCOM countries.

Data

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

Table 1. Computed total annual deposition of HCB to nine Baltic Sea sub-basins, the whole Baltic Sea (BAS) and normalized deposition* to the Baltic Sea (Norm) for the period 1990-2019. Units: kg y^{-1}.

	ARC	BOB	BOS	BAP	GUF	GUR	KAT	SOU	WEB	BAS	Norm
1990	387	753	743	2690	852	665	485	61	570	7208	7152
1991	375	608	604	2320	821	608	426	55	491	6308	6369
1992	295	595	539	2053	648	486	357	46	462	5481	5672
1993	255	438	461	1877	582	447	335	44	426	4866	5052
1994	264	445	446	1770	567	406	298	43	387	4627	4499
1995	221	403	371	1542	513	383	274	36	343	4086	4007
1996	212	308	325	1437	445	322	238	32	320	3639	3570
1997	158	249	264	1225	349	276	213	29	281	3045	3180
1998	180	322	309	1278	424	303	235	32	333	3418	2833
1999	169	271	271	1089	335	268	166	22	220	2811	2525
2000	123	200	215	910	276	201	171	24	236	2355	2250
2001	120	190	208	896	245	187	150	21	212	2229	2006
2002	83.8	124	143	605	184.5	142	93.2	12.5	124	1512	1789
2003	80.3	134	141	505	178.3	127	82.5	10.4	95.4	1354	1596
2004	72.2	128	125	471	159.5	115	77.6	10.1	92.4	1251	1424
2005	59.6	111	105	372	142.6	96.0	68.0	8.24	80.7	1043	1272
2006	62.3	110	106	377	139.1	89.0	61.3	8.14	73.1	1026	1137
2007	49.9	87.6	80.5	347	112.7	86.7	55.0	7.40	70.3	897	1017
2008	51.6	91.2	88.1	320	121.8	85.8	54.7	7.33	59.9	880	910
2009	39.6	72.5	71.6	259	97.0	66.4	41.8	5.37	51.7	705	816
2010	40.9	68.5	70.0	269	82.8	61.3	40.4	5.40	51.5	690	733
2011	33.3	68.7	61.6	223	84.9	57.2	39.0	4.83	46.9	619	659
2012	31.3	59.7	55.5	198	70.5	49.2	36.1	4.42	42.1	547	595
2013	35.5	59.3	57.3	207	78.2	53.6	34.5	4.30	43.3	573	538
2014	32.1	52.3	57.6	194	66.0	47.5	35.0	4.37	37.5	526	488
2015	26.6	46.2	45.1	170	61.7	40.8	30.9	3.97	36.9	462	445
2016	25.6	51.1	44.3	153	70.7	39.3	25.4	3.17	28.4	441	407
2017	24.0	47.3	41.1	156	61.0	38.7	27.8	3.48	30.4	430	375
2018	25.0	49.3	43.4	139	59.9	37.3	24.1	2.95	27.1	408	348
2019	20.4	35.9	34.7	142	49.9	33.4	24.0	3.29	29.3	373	325

* - normalized depositions were obtained using the methodology described below in the metadata section 5.

Table 2. Computed contributions by country to annual total deposition of HCB to nine Baltic Sea sub-basins for the year 2019. Units: kg y^{-1}. (*HELCOM*: contribution of anthropogenic sources of HELCOM countries; *EMEP*: contribution of anthropogenic sources in other EMEP countries; *Other*: contributions of secondary and remote non-EMEP emission sources).

Country	ARC	BOB	BOS	BAP	GUF	GUR	KAT	SOU	WEB	BAS
DK	8.81E-03	3.41E-03	9.97E-03	3.00E-01	9.83E-03	1.66E-02	3.29E-01	9.19E-02	3.29E-01	1.10E+00
EE	1.80E-03	5.16E-04	1.34E-03	5.84E-03	2.07E-02	1.12E-02	1.21E-04	1.80E-05	1.43E-04	4.16E-02
FI	6.74E-01	2.46E+00	3.89E-01	4.37E-01	3.84E+00	2.07E-01	1.36E-02	1.87E-03	1.46E-02	8.04E+00
DE	9.16E-03	2.84E-03	8.04E-03	3.06E-01	8.67E-03	1.47E-02	3.69E-02	9.13E-03	2.02E-01	5.98E-01
LV	1.09E-03	2.67E-04	9.41E-04	8.32E-03	1.90E-03	1.61E-02	1.13E-04	2.07E-05	1.65E-04	2.89E-02
LT	1.33E-03	4.10E-04	1.36E-03	1.45E-02	1.79E-03	6.19E-03	3.21E-04	5.95E-05	3.99E-04	2.63E-02
PL	1.02E-02	2.73E-03	8.39E-03	3.15E-01	8.86E-03	1.71E-02	8.78E-03	2.12E-03	1.55E-02	3.89E-01
RU	1.12E-03	1.06E-03	1.38E-03	1.03E-02	3.22E-02	1.40E-03	3.85E-04	6.18E-05	4.43E-04	4.84E-02
SE	1.93E-02	3.76E-02	6.12E-02	1.44E-01	1.48E-02	1.57E-02	2.01E-02	3.44E-03	5.95E-03	3.22E-01
AL	8.31E-07	6.24E-07	1.28E-06	8.69E-06	1.22E-06	1.32E-06	1.09E-06	1.55E-07	1.31E-06	1.65E-05
AM	2.72E-07	3.27E-07	4.91E-07	1.80E-06	5.98E-07	3.69E-07	1.48E-07	2.36E-08	1.45E-07	4.17E-06
AT	2.36E-03	1.00E-03	2.30E-03	3.24E-02	2.94E-03	3.88E-03	2.89E-03	5.39E-04	4.60E-03	5.29E-02
AZ	6.71E-07	9.38E-07	1.25E-06	4.40E-06	1.50E-06	8.95E-07	4.07E-07	5.78E-08	3.96E-07	1.05E-05
BA	4.09E-03	3.00E-03	6.30E-03	5.08E-02	6.50E-03	7.29E-03	4.96E-03	7.67E-04	6.32E-03	9.00E-02
BE	2.11E-03	9.60E-04	2.51E-03	3.10E-02	2.65E-03	3.21E-03	9.46E-03	1.28E-03	1.46E-02	6.78E-02
BG	1.37E-04	9.75E-05	1.96E-04	1.28E-03	2.07E-04	2.01E-04	1.53E-04	2.10E-05	1.74E-04	2.46E-03
BY	5.24E-04	2.78E-04	7.01E-04	4.46E-03	1.15E-03	1.44E-03	2.18E-04	3.73E-05	2.28E-04	9.04E-03
CH	5.31E-05	2.20E-05	5.73E-05	7.22E-04	6.63E-05	8.35E-05	9.77E-05	1.89E-05	1.64E-04	1.28E-03
CY	1.14E-07	1.04E-07	1.95E-07	7.66E-07	1.82E-07	1.57E-07	7.81E-08	1.04E-08	8.27E-08	1.69E-06
CZ	1.02E-02	3.18E-03	9.16E-03	1.72E-01	1.03E-02	1.53E-02	1.30E-02	2.60E-03	2.18E-02	2.57E-01
ES	7.29E-04	6.38E-04	1.07E-03	6.98E-03	1.00E-03	1.05E-03	1.39E-03	1.80E-04	1.71E-03	1.48E-02
FR	3.12E-03	1.53E-03	3.59E-03	3.98E-02	3.57E-03	4.52E-03	1.04E-02	1.43E-03	1.52E-02	8.31E-02
GB	1.45E-02	8.70E-03	2.05E-02	1.87E-01	1.90E-02	2.18E-02	7.98E-02	7.99E-03	8.18E-02	4.41E-01
GE	1.21E-04	1.35E-04	2.07E-04	8.32E-04	2.68E-04	1.74E-04	6.21E-05	9.83E-06	5.88E-05	1.87E-03
GR	7.79E-05	6.30E-05	1.22E-04	7.11E-04	1.29E-04	1.24E-04	8.24E-05	1.15E-05	9.18E-05	1.41E-03
HR	4.01E-05	2.59E-05	5.12E-05	5.23E-04	6.45E-05	7.65E-05	4.61E-05	7.39E-06	6.02E-05	8.95E-04
HU	5.39E-04	2.89E-04	5.83E-04	7.70E-03	8.53E-04	1.05E-03	6.58E-04	1.16E-04	9.38E-04	1.27E-02
IE	9.05E-04	5.84E-04	1.28E-03	1.01E-02	1.17E-03	1.32E-03	3.91E-03	3.83E-04	3.93E-03	2.35E-02
IS	1.38E-05	2.21E-05	2.67E-05	1.21E-04	2.08E-05	1.89E-05	3.59E-05	4.14E-06	3.69E-05	3.00E-04
IT	5.65E-04	4.03E-04	7.74E-04	6.64E-03	9.07E-04	1.02E-03	7.24E-04	1.17E-04	1.05E-03	1.22E-02
KY	1.85E-06	3.12E-06	3.51E-06	9.69E-06	3.34E-06	2.04E-06	9.41E-07	1.27E-07	1.01E-06	2.56E-05
KZ	9.51E-05	1.32E-04	1.77E-04	6.17E-04	1.84E-04	1.18E-04	6.87E-05	9.05E-06	7.32E-05	1.47E-03
LI	1.19E-07	4.24E-08	1.19E-07	1.89E-06	1.61E-07	2.15E-07	2.55E-07	5.34E-08	4.47E-07	3.30E-06
LU	2.60E-04	1.11E-04	2.89E-04	3.90E-03	3.26E-04	4.41E-04	9.40E-04	1.45E-04	1.57E-03	7.98E-03
MC	1.05E-06	6.80E-07	1.37E-06	1.08E-05	1.53E-06	1.65E-06	1.39E-06	2.22E-07	2.02E-06	2.07E-05
MD	9.24E-05	4.96E-05	1.23E-04	9.18E-04	1.49E-04	1.86E-04	7.54E-05	1.17E-05	7.64E-05	1.68E-03
ME	1.17E-05	8.55E-06	1.82E-05	1.33E-04	1.80E-05	2.02E-05	1.34E-05	2.02E-06	1.79E-05	2.43E-04
MK	2.82E-04	1.98E-04	4.17E-04	2.80E-03	4.01E-04	4.42E-04	3.08E-04	4.52E-05	3.75E-04	5.27E-03
MT	1.96E-06	1.66E-06	3.10E-06	1.97E-05	3.49E-06	3.57E-06	2.58E-06	3.65E-07	3.11E-06	3.95E-05
NL	3.68E-03	1.67E-03	4.33E-03	5.98E-02	4.38E-03	5.58E-03	1.83E-02	2.64E-03	3.22E-02	1.33E-01
NO	1.83E-03	1.39E-03	3.87E-03	1.26E-02	1.97E-03	1.97E-03	7.82E-03	4.34E-04	2.46E-03	3.44E-02
PT	8.85E-05	9.41E-05	1.40E-04	8.26E-04	1.35E-04	1.32E-04	1.63E-04	2.10E-05	1.92E-04	1.79E-03
RO	5.20E-04	3.22E-04	6.94E-04	5.17E-03	8.17E-04	9.10E-04	5.25E-04	7.87E-05	6.06E-04	9.65E-03
RS	3.24E-04	2.13E-04	4.58E-04	3.89E-03	4.78E-04	5.52E-04	3.43E-04	5.65E-05	4.70E-04	6.79E-03
SI	7.32E-05	4.56E-05	9.26E-05	9.25E-04	1.12E-04	1.29E-04	8.23E-05	1.40E-05	1.13E-04	1.59E-03
SK	1.13E-03	4.45E-04	1.10E-03	1.58E-02	1.35E-03	1.88E-03	1.19E-03	2.18E-04	1.72E-03	2.48E-02
TJ	1.80E-06	3.89E-06	3.70E-06	7.94E-06	3.55E-06	1.83E-06	9.17E-07	1.10E-07	9.48E-07	2.47E-05
TM	5.85E-06	9.36E-06	1.18E-05	3.30E-05	1.24E-05	6.73E-06	3.71E-06	5.00E-07	3.79E-06	8.71E-05
TR	1.35E-04	1.13E-04	2.23E-04	9.99E-04	2.43E-04	2.07E-04	8.42E-05	1.19E-05	8.02E-05	2.10E-03
UA	2.56E-02	1.89E-02	4.06E-02	2.12E-01	5.23E-02	4.49E-02	1.59E-02	2.46E-03	1.55E-02	4.28E-01
UZ	4.29E-06	8.67E-06	9.11E-06	1.97E-05	8.98E-06	4.44E-06	2.07E-06	2.65E-07	2.05E-06	5.95E-05
Other	19.5	35.1	35.7	139.0	47.2	32.2	21.9	3.0	26.6	360.19
EMEP	0.07	0.04	0.10	0.87	0.11	0.12	0.17	0.02	0.21	1.73
HELCOM	0.73	2.50	0.48	1.54	3.94	0.31	0.41	0.11	0.57	10.59
Total	20.32	37.64	36.30	141.39	51.29	32.58	22.49	3.14	27.36	372.51

Metadata

Technical information

1. Source:

Meteorological Synthesizing Centre East (MSC-E) of EMEP

2. Description of data:

Atmospheric depositions of HCB to the Baltic Sea for the period from 1990 to 2019 were estimated using the GLEMOS model developed at EMEP/MSC-E (http://en.msceast.org/index.php/j-stuff/glemos). The latest available official HCB emission data for the HELCOM and other EMEP countries have been used in the model computations. Emissions of HCB for each year of this period were officially reported by most of the HELCOM countries. These data are available from the web site of the EMEP Centre on Emission Inventories and Projections (CEIP) (http://www.ceip.at/). The information on HCB emission data used in model simulations is presented in the BSEFS "Atmospheric emissions of HCB in the Baltic Sea region".

3. Geographical coverage:

Model predictions of HCB atmospheric deposition were obtained for the European region and surrounding areas covered by the EMEP modelling domain.

4. Temporal coverage:

Time-series of annual atmospheric deposition of HCB were estimated for the period 1990 – 2019.

5. Methodology and frequency of data collection:

Atmospheric input and source allocation budget of HCB deposition to the Baltic Sea were computed using the latest version of GLEMOS model using the EMEP domain (https://www.ceip.at/ms/ceip_home1/ceip_home/new_emep-grid/). Model estimates describe regional scale distribution of pollution levels and source-receptor relationships.

Global modelling framework GLEMOS is a multi-scale multi-pollutant simulation platform developed for operational and research applications within the EMEP programme [*Tarrason and Gusev,* 2008; *Travnikov et al.,* 2009; *Jonson and Travnikov*, 2010; *Travnikov and Jonson*, 2011]. The framework allows simulations of dispersion and cycling of different classes of pollutants (e.g. heavy metals and persistent organic pollutants) in the environment with a flexible choice of the simulation domain (from global to local scale) and spatial resolution. The vertical structure consists of 20 irregular terrain-following sigma layers covering the height up to 10 hPa (ca. 30 km). Among these layers 10 lowest layers cover the first 5 km of the troposphere and height of the lowest model layer is about 75 m.

Anthropogenic emission data for modelling of HCB have been prepared based on the gridded emissions fields provided by CEIP for the EMEP longitude-latitude grid system with spatial resolution 0.1x0.1 degree. Gridded emissions are complemented by additional emission parameters required for model runs (e. g. intra-annual variations and vertical distribution). Atmospheric concentrations of chemical reactants and particulate matter, which are required for the description of HCB gas-particle partitioning and degradation, were imported from the MOZART model [*Emmons et al*., 2010]. Boundary conditions for model simulations over EMEP domain were estimated using the global scale GLEMOS model simulations [*Ilyin et al.*, 2021]. To evaluate accumulation of HCB in the terrestrial and aquatic compartments and subsequent re-volatilization, spinup global scale model simulations were carried out for period 1945-2019 based on the updated MSC-E expert estimates of global historical HCB emissions [*Shatalov et al.*, 2010].

Meteorological data used in model simulations for 1990-2019 were obtained using WRF meteorological data pre-processor [*Skamarock et al*., 2008] on the basis of meteorological re-analyses data (ERA-Interim) of European Centre for Medium-Range Weather Forecasts (ECMWF).

Model assessment of atmospheric transport and deposition of HCB is carried out on regular basis annually two years in arrears on the basis of emission data officially submitted by the Parties to LRTAP Convention.

Normalized values of HCB deposition for the period 1990-2019 were obtained on the basis of results of model simulations using bi-exponential approximation [*Colette et al*., 2016].

Quality information

6. Strength and weakness:

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

Weakness: uncertainties of officially submitted inventories of HCB emissions, and of model estimates of secondary emissions from terrestrial and aquatic compartments.

7. Uncertainty:

Modelling approach, developed by the MSC-E for POPs, has been verified using regular comparisons of modelling results with measurements of the EMEP monitoring network [*Gusev et al*., 2005, 2006; *Shatalov et al.,* 2005; *Ilyin et al.*, 2021] and 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 POPs in Europe" [ECE/EB.AIR/GE.1/2006/4].

8. Further work required:

Further work is required to reduce uncertainties of HCB pollution model assessment including uncertainties of monitoring data, emission inventories, and modelling approach applied in the EMEP GLEMOS model.

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