Atmospheric deposition of PCB-153 on the Baltic Sea

HELCOM Baltic Sea Environment Fact Sheet (BSEFS), 2023

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Key message

Levels of annual atmospheric deposition of PCB-153 to the Baltic Sea have decreased in period from 1990 to 2021 by 70%, although the decrease was higher during the period 1990-2001 comparing to the subsequent period 2002-2021.

Results and Assessment

Relevance of the BSEFS for describing developments in the environment

This BSEFS shows the levels and trends in PCB-153 atmospheric deposition to the Baltic Sea. The deposition of PCB-153 represents the pressure of the emission sources on the Baltic Sea aquatic environment as described in the BSEFS “Atmospheric emissions of PCB-153 in the Baltic Sea region”.

Policy relevance and policy reference

The 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 PCB-153 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 PCB-153 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

To assess long-term changes of PCB-153 atmospheric input to the Baltic Sea, model simulations were carried out based on officially reported emission data complemented by expert estimates. In spite of high uncertainties in the anthropogenic and secondary emissions of PCB-153, model estimates of regional scale PCB-153 pollution levels show generally reasonable agreement with the observed pollution levels.

Airborne input of PCB-153 to the Baltic Sea has substantially decreased in the period from 1990 to 2021. Model simulations on the basis of officially reported emission data indicate that levels of annual atmospheric deposition of PCB-153 to the Baltic Sea have decreased in period from 1990 to 2021 by 70%

(Figure 1). The most substantial decrease of deposition is noted for the Western Baltic sub-basin (-81%). The lowest decrease is estimated for the Bothnian Bay sub-basin (-33%).

The decrease of PCB-153 deposition to the Baltic Sea was stronger in the period 1990-2001 comparing to the subsequent period 2002-2021. 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 2001, stronger decline is estimated with the mean annual rate of deposition decline about 8.5 kg per year with confidence factor >99%. The subsequent period of time 2003-2021 is characterised by less intensive mean annual decline rate of about 2 kg per year with confidence factor >99%. 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 PCB-153 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 PCB-153 deposition fluxes over the Baltic Sea in 2021 are estimated for the Sound and the Western Baltic sub-basins (Figures 2, 3). The lowest deposition flux is obtained for the Bothnian Sea sub-basin. Annual emissions of HELCOM countries in 2021 contributed to PCB-153 deposition over the Baltic Sea about 25% (Table 2), with the largest shares made by Finland and Sweden (Figure 4).

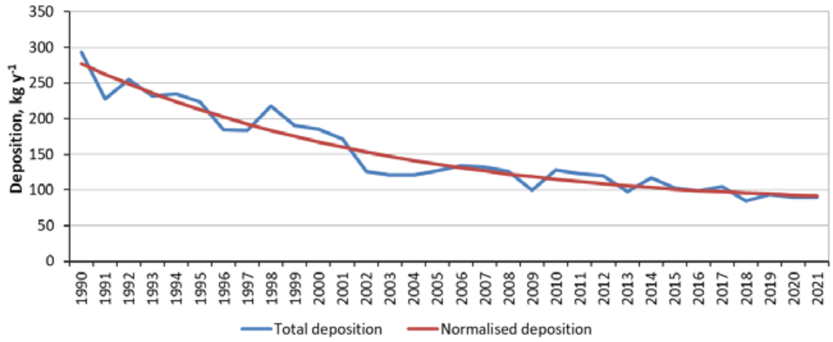

Figure 1. Changes of modelled (blue line) and normalized (red line) net annual atmospheric deposition of PCB-153 to the Baltic Sea for the period 1990-2021, (kg year^{-1}). Normalized depositions were obtained using the methodology described below in the metadata section 5.

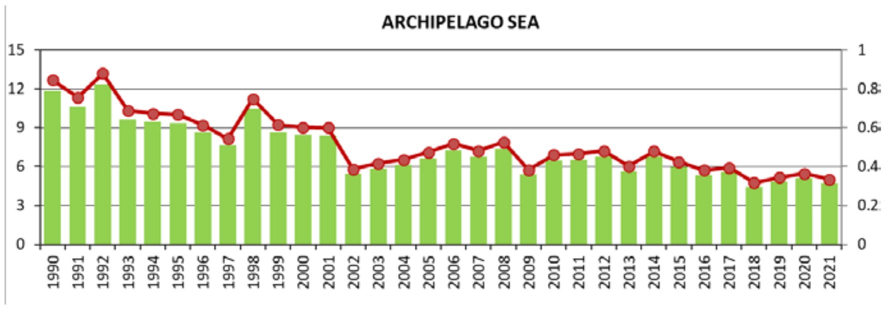

Figure 2. Time-series of computed net annual atmospheric deposition of PCB-153 to nine sub-basins of the Baltic Sea for the period 1990-2021 in kg year^{-1} as green bars (left axis) and net deposition fluxes in g km^{-2} year^{-1} as red lines (right axis).

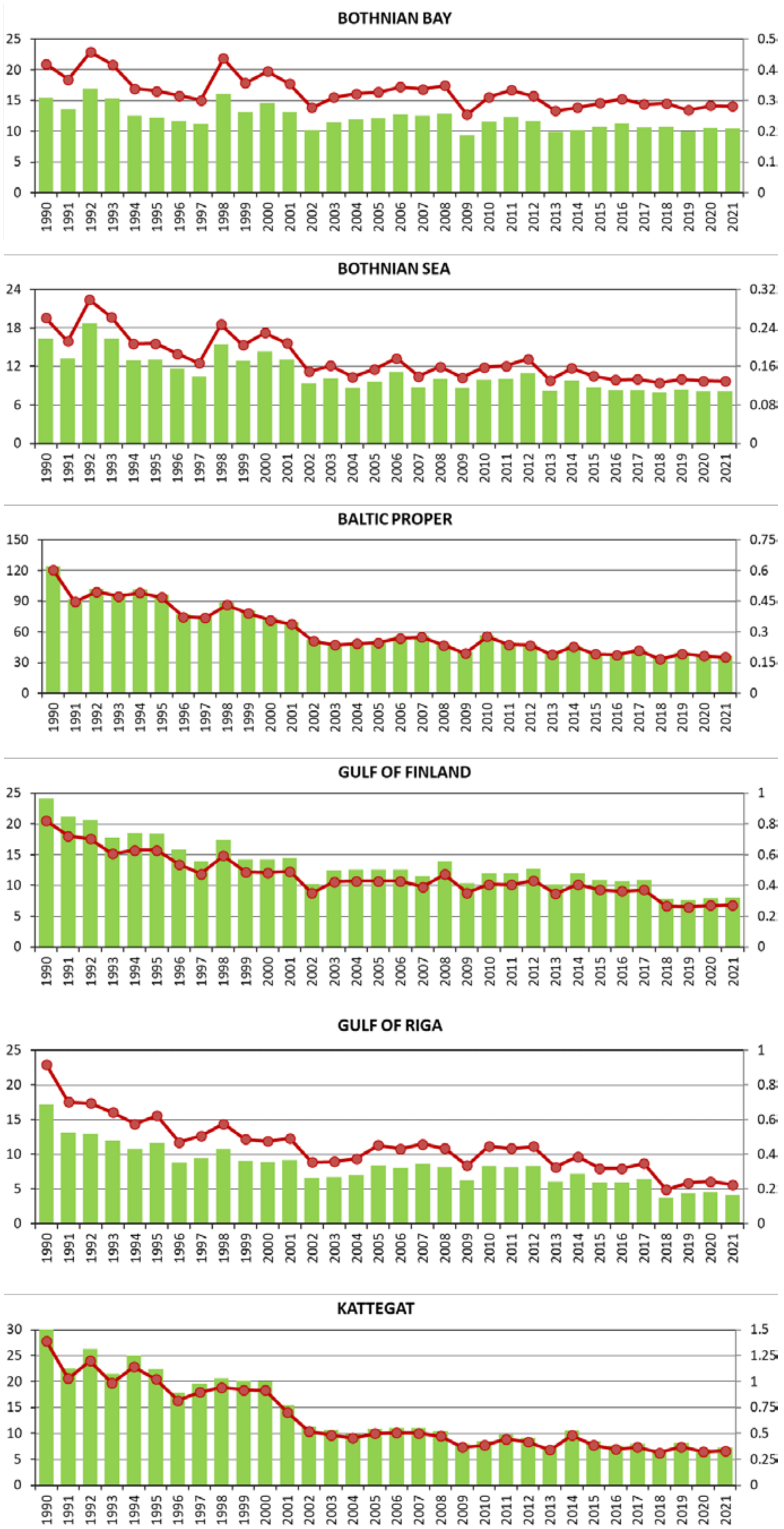

Figure 2 (continued). Time-series of computed net annual atmospheric deposition of PCB-153 to nine sub-basins of the Baltic Sea for the period 1990-2021 in kg year^{-1} as green bars (left axis) and net deposition fluxes in g km^{-2} year^{-1} as red lines (right axis).

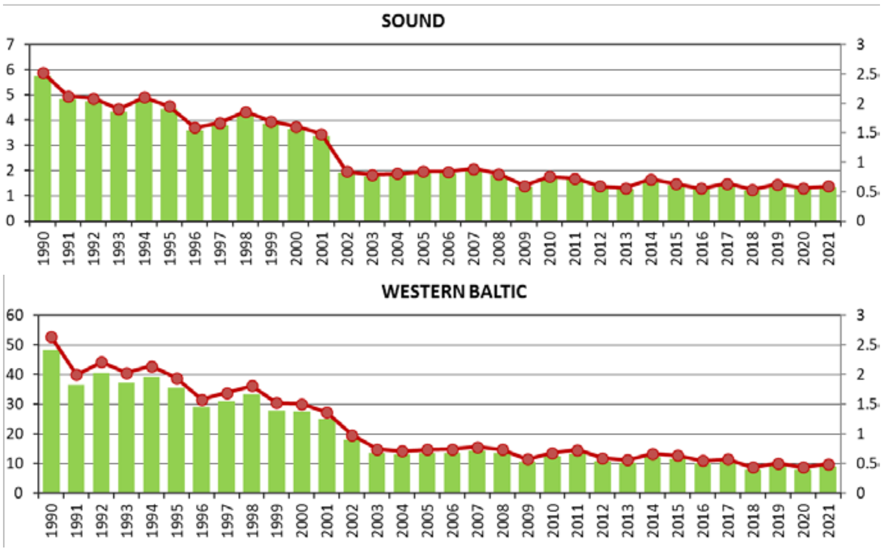

Figure 2 (continued). Time-series of computed net annual atmospheric deposition of PCB-153 to nine sub-basins of the Baltic Sea for the period 1990-2021 in kg year^{-1} as green bars (left axis) and net deposition fluxes in g km^{-2} year^{-1} as red lines (right axis).

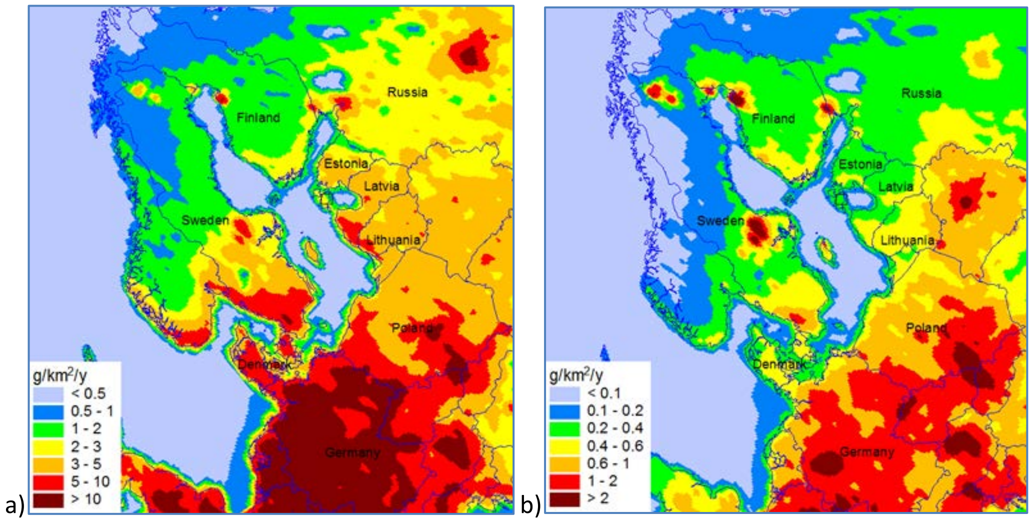

Figure 3. Spatial distribution of modelled annual net deposition fluxes of PCB-153 in the Baltic Sea region for 1990 (a) and 2021 (b), g km^{-2} year^{-1}.

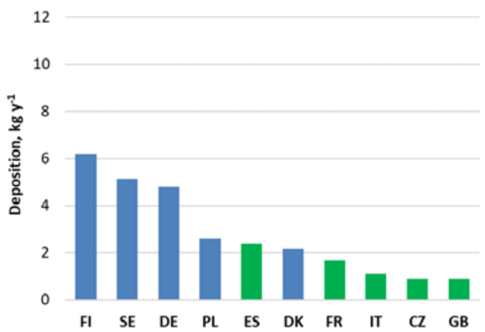

Figure 4. Ten countries with the highest contribution to annual deposition of PCB-153 to the Baltic Sea estimated for 2021, kg year^{-1}. Green bars indicate depositions from non-HELCOM countries.

Data

Numerical data on computed PCB-153 depositions to the Baltic Sea are given in the following tables.

Table 1. Computed net annual deposition of PCB-153 to nine Baltic Sea sub-basins, the whole Baltic Sea (BAS) and normalized deposition* to the Baltic Sea (Norm) for the period 1990-2021. Units: kg year^{-1}.

	ARC	BOB	BOS	BAP	GUF	GUR	KAT	SOU	WEB	BAS	Norm
1990	12	15	16	124	24	17	30	5.7	48	294	277
1991	11	14	13	92	21	13	23	4.8	37	228	263
1992	12	17	19	102	21	13	26	4.8	41	255	249
1993	10	15	16	98	18	12	22	4.3	37	232	236
1994	9	13	13	102	18	11	25	4.8	39	235	224
1995	9	12	13	97	18	12	22	4.4	36	224	213
1996	9	12	12	77	16	9	18	3.6	29	184	202
1997	8	11	10	76	14	9	20	3.8	31	183	193
1998	11	16	16	89	17	11	21	4.2	33	217	184
1999	9	13	13	81	14	9	20	3.9	28	191	175
2000	8	15	14	74	14	9	20	3.7	28	186	168
2001	8	13	13	70	14	9	15	3.4	25	172	160
2002	5	10	9	52	10	7	11	1.9	18	126	154
2003	6	11	10	49	12	7	11	1.8	14	121	147
2004	6	12	9	50	13	7	10	1.8	13	121	142
2005	7	12	10	51	13	8	11	1.9	13	127	136
2006	7	13	11	55	13	8	11	1.9	14	134	131
2007	7	12	9	56	11	9	11	2.0	14	132	127
2008	7	13	10	48	14	8	10	1.8	13	126	122
2009	5	9	9	40	10	6	8	1.4	11	100	119
2010	6	12	10	57	12	8	8	1.7	12	128	115
2011	7	12	10	49	12	8	10	1.7	13	123	112
2012	7	12	11	48	13	8	9	1.4	11	120	109
2013	6	10	8	39	10	6	8	1.3	10	98	106
2014	7	10	10	47	12	7	11	1.6	12	117	104
2015	6	11	9	39	11	6	8	1.4	12	103	101
2016	5	11	8	39	11	6	8	1.3	10	99	99
2017	6	11	8	43	11	6	8	1.4	10	105	97
2018	4	11	8	34	8	4	7	1.2	8	85	96
2019	5	10	8	40	8	4	8	1.4	9	94	94
2020	5	10	8	38	8	5	7	1.3	8	90	93
2021	5	10	8	36	8	4	7	1.3	9	90	92

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

Table 2. Computed contributions by country to annual deposition of PCB-153 to nine Baltic Sea sub-basins for the year 2021. Units: kg $year^{-1}$. 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	8.86E-03	5.65E-03	1.40E-02	4.59E-01	1.01E-02	1.30E-02	6.12E-01	2.81E-01	7.67E-01	2.17E+00
EE	3.28E-03	1.97E-03	2.83E-03	1.56E-02	3.59E-01	2.13E-02	3.86E-04	4.57E-05	3.19E-04	4.05E-01
FI	4.78E-01	4.00E+00	8.44E-01	1.85E-01	6.31E-01	4.20E-02	6.57E-03	6.71E-04	5.37E-03	6.19E+00
DE	6.23E-02	5.58E-02	1.26E-01	2.74E+00	8.06E-02	9.18E-02	3.18E-01	6.50E-02	1.27E+00	4.81E+00
LV	1.80E-03	5.06E-04	1.49E-03	2.68E-02	3.33E-03	4.73E-02	2.91E-04	5.06E-05	3.14E-04	8.19E-02
LT	5.48E-03	2.28E-03	6.88E-03	1.23E-01	8.61E-03	2.45E-02	1.80E-03	3.61E-04	2.09E-03	1.75E-01
PL	6.59E-02	4.67E-02	1.34E-01	1.96E+00	7.90E-02	1.11E-01	8.13E-02	1.45E-02	1.03E-01	2.60E+00
RU	5.85E-03	7.80E-03	1.07E-02	9.32E-02	2.50E-01	1.06E-02	2.54E-03	3.41E-04	2.17E-03	3.83E-01
SE	2.10E-01	2.57E-01	7.10E-01	2.53E+00	1.07E-01	1.39E-01	8.70E-01	2.03E-01	1.01E-01	5.12E+00
AL	1.22E-04	2.06E-04	3.47E-04	2.47E-03	2.57E-04	1.97E-04	8.26E-05	1.56E-05	8.24E-05	3.78E-03
AM	2.89E-04	9.21E-04	8.59E-04	3.42E-03	9.51E-04	6.22E-04	1.60E-04	2.78E-05	1.04E-04	7.35E-03
AT	1.16E-02	1.77E-02	3.15E-02	2.36E-01	1.63E-02	1.68E-02	2.87E-02	3.75E-03	3.51E-02	3.97E-01
AZ	1.81E-02	6.40E-02	6.43E-02	1.62E-01	6.56E-02	3.06E-02	7.62E-03	1.02E-03	4.89E-03	4.18E-01
BA	4.48E-05	6.95E-05	1.26E-04	7.54E-04	8.48E-05	6.37E-05	3.59E-05	6.32E-06	3.81E-05	1.22E-03
BE	3.37E-03	3.23E-03	6.96E-03	5.97E-02	4.57E-03	4.06E-03	1.80E-02	2.33E-03	2.56E-02	1.28E-01
BG	2.18E-04	3.16E-04	5.82E-04	2.48E-03	6.55E-04	3.75E-04	1.11E-04	1.57E-05	1.01E-04	4.85E-03
BY	3.91E-02	3.02E-02	7.16E-02	3.76E-01	1.15E-01	9.36E-02	1.44E-02	2.68E-03	1.48E-02	7.58E-01
CH	2.03E-03	3.70E-03	6.74E-03	4.50E-02	2.98E-03	2.54E-03	7.44E-03	8.59E-04	1.11E-02	8.24E-02
CY	1.09E-04	2.89E-04	3.10E-04	7.22E-04	4.94E-04	2.19E-04	2.74E-05	3.63E-06	1.86E-05	2.19E-03
CZ	2.37E-02	2.46E-02	5.89E-02	5.74E-01	3.09E-02	4.13E-02	5.50E-02	8.01E-03	7.23E-02	8.88E-01
ES	7.68E-02	1.70E-01	3.11E-01	1.05E+00	1.23E-01	8.60E-02	2.75E-01	2.97E-02	2.73E-01	2.40E+00
FR	4.32E-02	6.13E-02	1.12E-01	7.89E-01	6.55E-02	5.55E-02	2.25E-01	2.60E-02	2.93E-01	1.67E+00
GB	2.68E-02	2.33E-02	5.76E-02	3.97E-01	3.40E-02	2.97E-02	1.41E-01	1.56E-02	1.47E-01	8.72E-01
GE	7.38E-04	1.92E-03	2.30E-03	1.18E-02	2.14E-03	1.57E-03	6.32E-04	1.32E-04	4.34E-04	2.17E-02
GR	3.86E-03	8.72E-03	1.31E-02	5.16E-02	1.39E-02	7.78E-03	2.42E-03	4.02E-04	2.37E-03	1.04E-01
HR	1.17E-03	1.93E-03	3.39E-03	1.86E-02	2.17E-03	1.62E-03	1.43E-03	2.15E-04	1.50E-03	3.20E-02
HU	1.54E-03	2.06E-03	4.11E-03	2.49E-02	2.51E-03	2.27E-03	1.51E-03	3.05E-04	2.35E-03	4.16E-02
IE	1.45E-04	1.57E-04	3.38E-04	1.82E-03	1.84E-04	1.54E-04	6.07E-04	6.35E-05	5.45E-04	4.01E-03
IS	3.08E-04	6.29E-04	8.43E-04	3.03E-03	5.30E-04	3.36E-04	6.01E-04	6.93E-05	5.96E-04	6.95E-03
IT	3.55E-02	7.46E-02	1.24E-01	6.01E-01	6.67E-02	4.66E-02	6.45E-02	8.70E-03	7.40E-02	1.10E+00
KY	7.96E-05	1.58E-04	2.86E-04	7.19E-04	7.40E-05	5.95E-05	3.83E-05	3.83E-06	3.15E-05	1.45E-03
KZ	1.06E-03	3.00E-03	3.17E-03	7.94E-03	2.67E-03	1.29E-03	4.23E-04	4.55E-05	3.13E-04	1.99E-02
LI	8.37E-06	1.50E-05	2.61E-05	1.80E-04	1.16E-05	9.53E-06	2.72E-05	3.42E-06	4.25E-05	3.24E-04
LU	1.00E-04	1.49E-04	2.71E-04	2.32E-03	1.52E-04	1.47E-04	5.02E-04	6.48E-05	7.60E-04	4.47E-03
MC	5.64E-05	1.11E-04	2.00E-04	7.62E-04	1.00E-04	7.18E-05	1.20E-04	1.35E-05	1.39E-04	1.57E-03
MD	5.31E-04	5.12E-04	1.08E-03	4.42E-03	1.16E-03	9.84E-04	1.58E-04	2.58E-05	1.55E-04	9.02E-03
ME	8.32E-05	1.23E-04	2.20E-04	1.47E-03	1.54E-04	1.24E-04	4.68E-05	9.11E-06	5.34E-05	2.29E-03
MK	1.98E-04	2.53E-04	4.72E-04	3.26E-03	4.40E-04	3.22E-04	1.14E-04	1.74E-05	1.07E-04	5.18E-03
MT	3.02E-06	7.70E-06	1.22E-05	5.45E-05	7.15E-06	5.42E-06	3.87E-06	5.98E-07	3.59E-06	9.80E-05
NL	3.44E-04	2.75E-04	7.10E-04	7.34E-03	4.53E-04	4.42E-04	2.25E-03	3.01E-04	3.57E-03	1.57E-02
NO	2.78E-03	3.44E-03	6.98E-03	1.87E-02	2.84E-03	2.22E-03	9.64E-03	5.77E-04	4.37E-03	5.15E-02
PT	3.84E-04	7.84E-04	1.54E-03	5.16E-03	5.79E-04	4.27E-04	1.86E-03	1.80E-04	1.55E-03	1.25E-02
RO	2.15E-03	2.57E-03	5.32E-03	1.94E-02	4.94E-03	3.45E-03	7.13E-04	1.10E-04	7.00E-04	3.93E-02
RS	2.04E-03	2.94E-03	5.55E-03	3.13E-02	3.76E-03	2.99E-03	1.45E-03	2.37E-04	1.45E-03	5.18E-02
SI	4.61E-05	7.45E-05	1.28E-04	7.56E-04	8.91E-05	6.52E-05	7.33E-05	1.09E-05	8.04E-05	1.32E-03
SK	7.37E-03	8.91E-03	1.91E-02	1.40E-01	1.17E-02	1.27E-02	1.03E-02	1.67E-03	1.32E-02	2.25E-01
TJ	1.81E-06	4.30E-06	6.42E-06	1.44E-05	1.82E-06	1.30E-06	7.96E-07	8.03E-08	6.58E-07	3.16E-05
TM	5.95E-06	2.75E-05	1.95E-05	4.78E-05	2.83E-05	8.95E-06	2.49E-06	2.79E-07	1.76E-06	1.43E-04
TR	1.57E-04	4.20E-04	5.31E-04	1.95E-03	6.50E-04	3.52E-04	8.80E-05	1.57E-05	6.96E-05	4.23E-03
UA	3.00E-03	2.88E-03	6.42E-03	3.12E-02	7.22E-03	5.95E-03	1.32E-03	2.28E-04	1.34E-03	5.95E-02
UZ	9.89E-06	3.27E-05	3.31E-05	8.12E-05	2.41E-05	1.06E-05	4.23E-06	4.40E-07	3.25E-06	1.99E-04
Other	0.84	4.38	1.85	8.13	1.53	0.50	1.89	0.56	2.25	21.94
EMEP	0.31	0.52	0.92	4.69	0.59	0.45	0.87	0.10	0.99	9.44
HELCOM	3.35	5.46	5.12	23.78	5.77	3.06	4.76	0.76	6.13	58.19
Total	4.50	10.35	7.89	36.60	7.88	4.02	7.53	1.43	9.37	89.57

Metadata

Technical information

1. Source:

Meteorological Synthesizing Centre East (MSC-E) of EMEP

2. Description of data:

Assessment of transport and fate of PCBs in the EMEP region was made on the basis of the inventory of global PCB emissions [*Breivik et al.*, 2007] and emissions officially reported by the EMEP countries. Officially reported inventories of PCB emissions do not provide congener composition of emissions. Therefore, expert estimates of PCB emissions with information on particular congeners were applied [*Breivik et al.*, 2007]. The inventory provides consistent set of historical and future emissions of 22 individual PCB congeners from 1930 up to 2100. It included three scenarios of emissions, namely, minimum, average, and maximum, which represented the range of emission variations. For the evaluation of pollution levels maximum scenario of emissions was chosen since it permitted to obtain modelling results with more reasonable agreement with measurements comparing to average and minimum scenarios. Model simulations were carried out for the indicator congener PCB-153.

Temporal variations of PCB-153 emissions in period 1990-2021 were derived from officially reported PCB emissions. For countries not reporting their PCB emissions temporal changes were taken from expert estimates of [*Breivik et al.*, 2007]. Annual PCB-153 emissions for the years 1990-2018 were prepared using officially reported emissions in 2020. For 2019-2020 PCB-153 emissions were based on national inventories, reported in 2022. For 2021 similar level of emissions as in 2020 was assumed in model simulations.

The spatial distribution of PCB-153 emissions within the EMEP region was prepared using gridded PCB emissions officially submitted by 24 EMEP countries, including some HELCOM Contracting Parties, namely Denmark, Finland, Latvia, Lithuania, Poland, and Sweden. For other countries spatial distribution of PCB-153 emission was made on the basis of gridded population density.

3. Geographical coverage:

Atmospheric deposition of PCB-153 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 PCB-153 are available for the period 1990 – 2021.

5. Methodology and frequency of data collection:

Atmospheric input and source allocation budgets of PCB-153 to the Baltic Sea and its catchment area were computed using the latest version of GLEMOS model using the new EMEP domain (https://www.ceip.at/ms/ceip_home1/ceip_home/new_emep-grid/).

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. In the vertical the model domain covers the height up to 10 hPa (ca. 30 km). The current vertical structure consists of 20 irregular terrain-following sigma layers. Among them 10 layers cover the lowest 5 km of the troposphere and height of the lowest layer is about 75 m.

Anthropogenic emission data for modelling of PCB-153 have been prepared based on the gridded emissions fields provided by CEIP with spatial resolution 0.1x0.1 degree and complemented by additional emission parameters required for model runs. Atmospheric concentrations of chemical reactants and particulate matter, which are required for description of PCB-153 gas-particle partitioning and degradation, were imported from the MOZART model [*Emmons et al.*, 2010]. Boundary conditions for the regional scale simulations of all considered pollutants have been obtained from the GLEMOS model runs on a global scale.

Meteorological data used in the calculations for 1990-2021 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).

Calculations of atmospheric transport and deposition of PCB-153 are provided on the regular basis annually two years in arrears on the basis of emission data officially submitted by Parties to LRTAP Convention.

Normalized values of PCB-153 deposition for the period 1990-2021 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 PCB-153 to the Baltic Sea and its sub-basins.

Weakness: uncertainties in officially submitted data on emissions of PCB-153.

7. Uncertainty:

Most of parameterizations of physical processes used in the GLEMOS model were transferred from the previous model MSCE-POP used in operational modelling under EMEP [*Gusev et al.,* 2005].

The MSCE-POP model was evaluated against the measurements of the EMEP monitoring network [*Gusev et al.*, 2006; *Shatalov et al.,* 2005] 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 in modelling approach for PCB-153 applied in the EMEP GLEMOS model.

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