Atmospheric deposition of Benzo(a)pyrene on the Baltic Sea

HELCOM Baltic Sea Environment Fact Sheet (BSEFS), 2020

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Key message

Levels of annual total atmospheric deposition of benzo(a)pyrene to the Baltic Sea have decreased in period from 1990 to 2018 by 48%, although the decrease was higher during the first half of the assessment period.

Results and Assessment

Relevance of the BSEFS for describing developments in the environment

This BSEFS shows the levels and trends in benzo(a)pyrene (B(a)P) atmospheric deposition to the Baltic Sea. The deposition of B(a)P represents the pressure of the emission sources on the Baltic Sea aquatic environment as described in the BSEFS “Atmospheric emissions of Benzo(a)pyrene 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 B(a)P 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 B(a)P 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

Airborne input of B(a)P to the Baltic Sea has substantially decreased in the period from 1990 to 2018. Model simulations on the basis of officially reported emission data indicate that levels of annual total atmospheric deposition of B(a)P to the Baltic Sea have decreased in period from 1990 to 2018 by 48% (Figure 1). The most substantial decrease of deposition can be noted for the Western Baltic sub-basin (68%). The highest level of B(a)P deposition fluxes over the Baltic Sea in 2018 is noted for the Gulf of Finland and the Sound sub-basins (Figures 2). The HELCOM countries contributed to B(a)P deposition over the Baltic Sea in 2018 about 74%, with largest contributions made by Poland and Russia.

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

Presented model estimates of B(a)P deposition differ from previously published modelling results [Gauss et al., 2018]. Comparison of current and previous model estimates is discussed in the report [Guass et al., 2020].

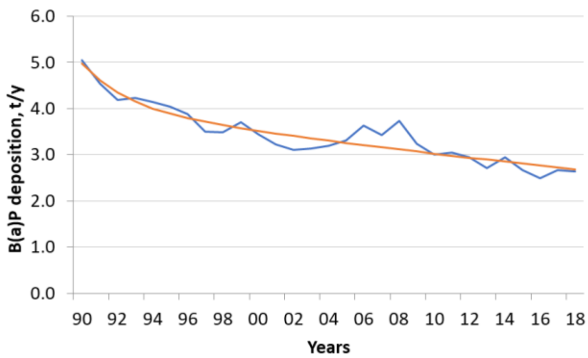

Figure 1. Changes of modelled (blue line) and normalized (red line) total annual atmospheric deposition of B(a)P to the Baltic Sea for the period 1990-2018, (tonnes/year). Normalized depositions were obtained using the methodology described below in the metadata section 5.

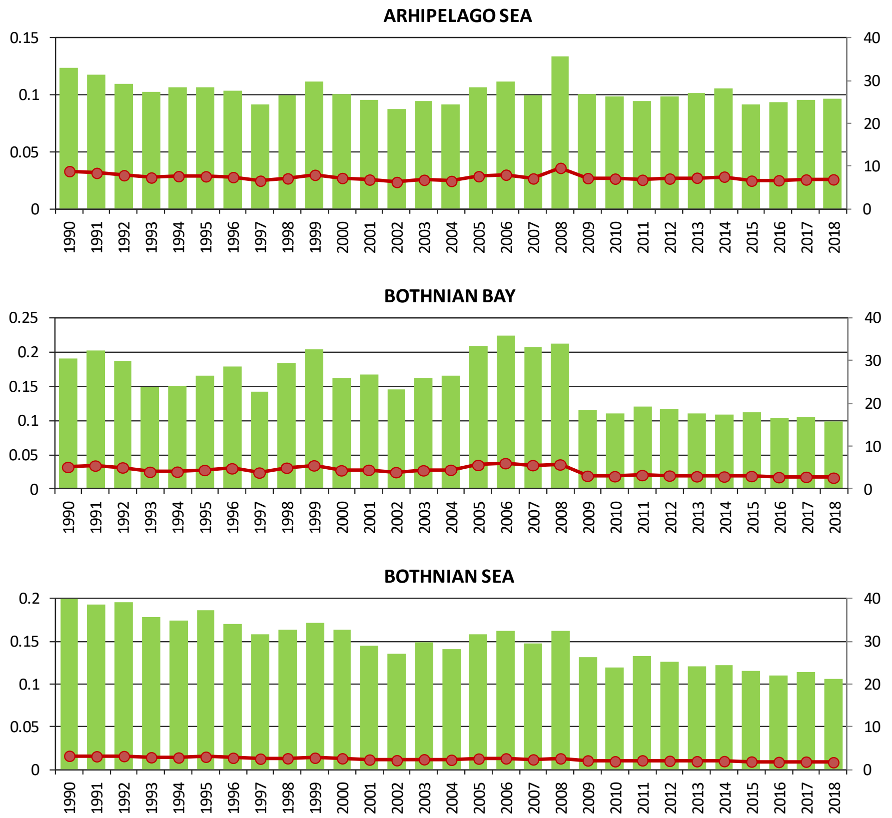

Figure 2. Time-series of computed total annual atmospheric deposition of B(a)P to nine sub-basins of the Baltic Sea for the period 1990-2018 in tonnes/year as bars (left axis) and total deposition fluxes in g/m^2/year as lines (right axis).

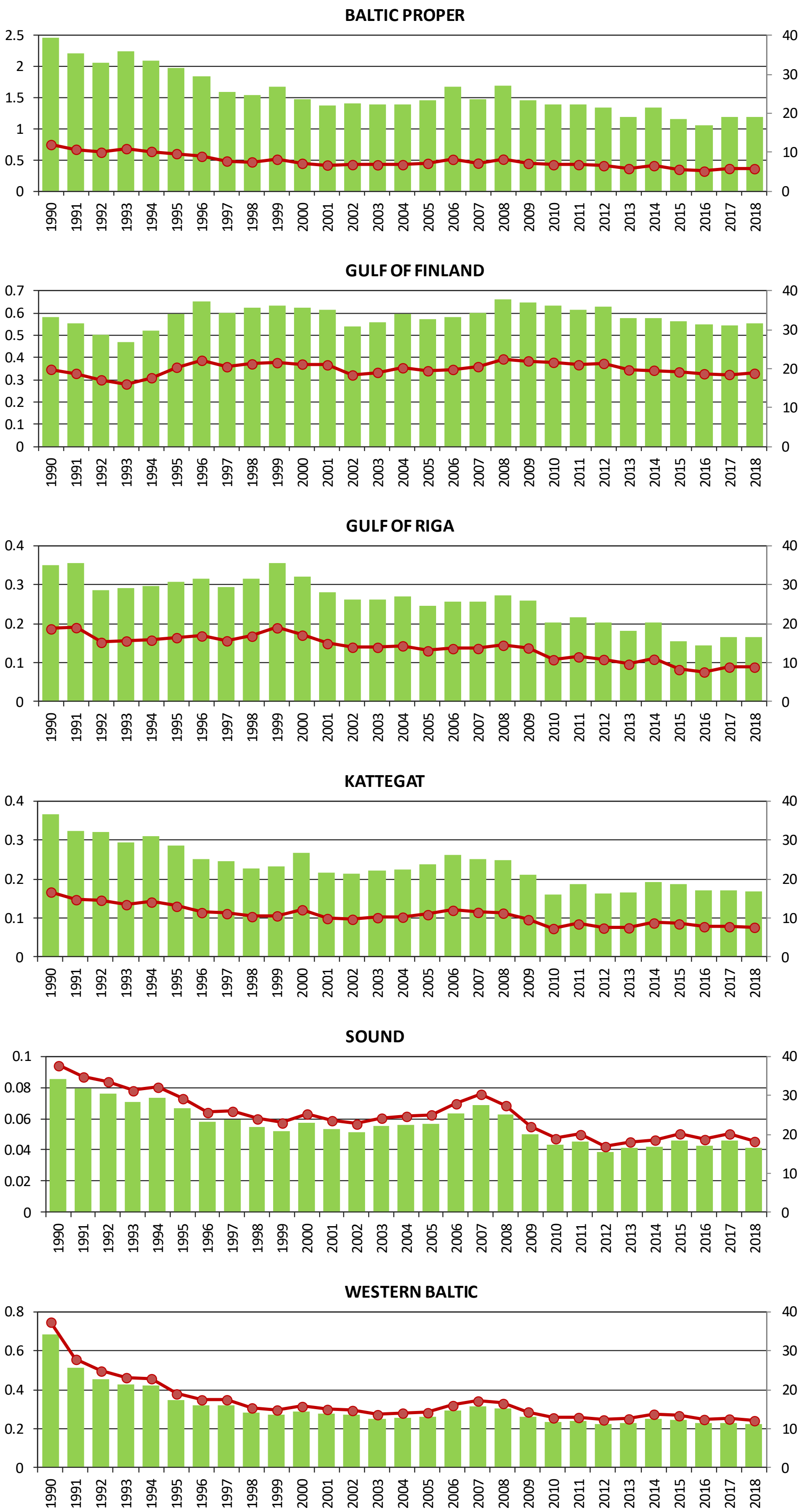

Figure 2. (continued). Time-series of computed total annual atmospheric deposition of B(a)P to nine sub-basins of the Baltic Sea for the period 1990-2018 in tonnes/year as bars (left axis) and total deposition fluxes in $g/m^2/year$ as lines (right axis).

Data

Numerical data on computed B(a)P depositions to the Baltic Sea are given in the following tables.

Table 1. Computed total annual deposition of B(a)P to nine Baltic Sea sub-basins, the whole Baltic Sea (BAS) and normalized deposition* to the Baltic Sea (Norm) for the period 1990-2018. Units: t/year.

	ARC	BOB	BOS	BAP	GUF	GUR	KAT	SOU	WEB	BAS	Norm
1990	0.123	0.191	0.200	2.460	0.582	0.350	0.366	0.086	0.686	5.04	4.98
1991	0.118	0.203	0.193	2.210	0.551	0.356	0.323	0.079	0.511	4.54	4.61
1992	0.110	0.187	0.196	2.051	0.502	0.285	0.320	0.076	0.456	4.18	4.35
1993	0.102	0.149	0.178	2.246	0.471	0.292	0.295	0.071	0.425	4.23	4.15
1994	0.107	0.150	0.175	2.097	0.518	0.296	0.309	0.073	0.420	4.14	4.00
1995	0.106	0.165	0.186	1.980	0.597	0.308	0.286	0.066	0.348	4.04	3.89
1996	0.104	0.179	0.170	1.836	0.650	0.316	0.250	0.058	0.320	3.88	3.79
1997	0.092	0.143	0.157	1.588	0.601	0.293	0.245	0.059	0.321	3.50	3.71
1998	0.099	0.185	0.163	1.541	0.623	0.315	0.228	0.055	0.282	3.49	3.64
1999	0.111	0.205	0.171	1.682	0.632	0.355	0.232	0.052	0.273	3.71	3.58
2000	0.101	0.162	0.163	1.467	0.621	0.320	0.266	0.058	0.289	3.45	3.52
2001	0.096	0.166	0.144	1.376	0.616	0.279	0.217	0.054	0.275	3.22	3.46
2002	0.088	0.146	0.135	1.399	0.539	0.262	0.213	0.052	0.270	3.10	3.41
2003	0.095	0.162	0.149	1.387	0.559	0.261	0.222	0.055	0.251	3.14	3.36
2004	0.091	0.166	0.141	1.396	0.593	0.268	0.225	0.056	0.258	3.19	3.31
2005	0.107	0.208	0.159	1.464	0.571	0.245	0.239	0.057	0.260	3.31	3.26
2006	0.112	0.224	0.162	1.677	0.581	0.255	0.263	0.063	0.294	3.63	3.21
2007	0.099	0.207	0.147	1.475	0.602	0.256	0.251	0.069	0.315	3.42	3.16
2008	0.134	0.213	0.162	1.686	0.660	0.271	0.247	0.062	0.303	3.74	3.12
2009	0.100	0.115	0.132	1.462	0.645	0.258	0.210	0.050	0.263	3.24	3.07
2010	0.099	0.111	0.120	1.393	0.634	0.202	0.161	0.043	0.235	3.00	3.03
2011	0.095	0.121	0.133	1.398	0.616	0.215	0.186	0.045	0.237	3.05	2.98
2012	0.099	0.116	0.126	1.342	0.626	0.203	0.163	0.039	0.226	2.94	2.94
2013	0.102	0.110	0.120	1.188	0.577	0.180	0.164	0.041	0.231	2.71	2.90
2014	0.105	0.108	0.122	1.344	0.575	0.204	0.192	0.042	0.253	2.94	2.85
2015	0.092	0.112	0.116	1.147	0.562	0.154	0.187	0.046	0.246	2.66	2.81
2016	0.093	0.103	0.109	1.052	0.548	0.143	0.171	0.043	0.228	2.49	2.77
2017	0.096	0.106	0.114	1.191	0.543	0.166	0.171	0.046	0.230	2.66	2.73
2018	0.096	0.098	0.106	1.183	0.552	0.166	0.168	0.041	0.222	2.63	2.69

* - 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 **B(a)P** to nine Baltic Sea sub-basins for the year 2018. Units: t/year. 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	1.78E-04	1.07E-04	3.00E-04	3.11E-02	1.44E-04	1.84E-04	8.58E-02	2.24E-02	9.68E-02	2.37E-01
EE	2.86E-03	3.68E-04	1.42E-03	8.47E-03	5.11E-02	1.65E-02	3.36E-05	3.53E-06	2.02E-05	8.09E-02
FI	3.26E-02	4.11E-02	2.42E-02	3.91E-03	8.14E-02	1.53E-03	2.73E-05	1.93E-06	1.44E-05	1.85E-01
DE	5.09E-04	3.97E-04	7.34E-04	6.46E-02	8.20E-04	9.74E-04	1.07E-02	2.33E-03	6.18E-02	1.43E-01
LV	2.92E-03	2.65E-04	1.72E-03	5.14E-02	4.30E-03	7.39E-02	1.07E-04	2.10E-05	9.59E-05	1.35E-01
LT	1.52E-03	1.48E-04	1.13E-03	3.62E-02	1.33E-03	1.06E-02	1.23E-04	3.28E-05	1.52E-04	5.12E-02
PL	6.71E-03	1.72E-03	8.83E-03	6.60E-01	4.15E-03	1.09E-02	1.16E-02	2.75E-03	1.18E-02	7.19E-01
RU	2.02E-03	7.94E-04	1.94E-03	7.09E-02	1.91E-01	2.62E-03	2.95E-04	6.14E-05	3.69E-04	2.70E-01
SE	2.91E-03	1.48E-02	2.62E-02	6.56E-02	5.75E-04	6.61E-04	1.71E-02	2.77E-03	1.44E-03	1.32E-01
AL	4.41E-06	6.89E-06	2.45E-05	8.07E-05	1.15E-05	2.80E-05	1.14E-05	4.92E-06	1.06E-05	1.83E-04
AM	1.46E-08	8.22E-08	4.71E-08	4.84E-07	8.02E-07	6.58E-08	1.71E-09	4.99E-10	7.89E-10	1.50E-06
AT	8.78E-06	1.40E-05	2.23E-05	6.72E-04	4.43E-05	2.21E-05	6.70E-05	1.57E-05	8.06E-05	9.47E-04
AZ	2.31E-08	3.07E-06	1.34E-07	6.69E-07	6.89E-07	5.83E-08	4.26E-09	6.22E-10	1.50E-09	4.65E-06
BA	1.48E-06	2.58E-06	5.11E-06	3.52E-05	8.46E-06	5.83E-06	3.97E-06	1.12E-06	4.35E-06	6.81E-05
BE	4.57E-05	4.98E-05	1.02E-04	1.55E-03	7.03E-05	5.79E-05	5.33E-04	7.25E-05	9.91E-04	3.48E-03
BG	6.89E-06	3.08E-05	4.99E-05	6.78E-05	2.56E-05	5.90E-05	5.86E-06	3.38E-06	9.06E-06	2.58E-04
BY	5.77E-04	8.72E-05	4.82E-04	4.88E-03	1.14E-03	2.23E-03	3.95E-05	5.91E-06	3.74E-05	9.47E-03
CH	9.06E-06	3.38E-05	4.12E-05	2.55E-04	4.31E-05	1.73E-05	2.89E-05	6.20E-06	7.60E-05	5.11E-04
CY	1.63E-08	7.47E-08	1.79E-08	8.43E-08	1.34E-08	1.56E-08	5.05E-10	9.20E-11	5.28E-10	2.23E-07
CZ	1.96E-04	8.82E-05	3.24E-04	1.92E-02	3.14E-04	5.12E-04	2.26E-03	4.51E-04	1.99E-03	2.53E-02
ES	9.80E-05	2.42E-04	2.87E-04	3.13E-03	5.72E-04	3.48E-04	3.80E-04	5.82E-05	3.80E-04	5.49E-03
FR	5.30E-05	1.37E-04	2.00E-04	1.03E-03	2.05E-04	9.97E-05	2.57E-04	3.35E-05	3.64E-04	2.38E-03
GB	1.26E-04	3.72E-04	4.83E-04	4.62E-03	4.18E-04	1.38E-04	1.64E-03	1.58E-04	1.90E-03	9.86E-03
GE	4.51E-07	3.03E-06	1.38E-06	5.67E-06	3.59E-06	1.13E-06	1.22E-07	2.59E-08	2.55E-07	1.57E-05
GR	2.40E-05	3.44E-05	8.06E-05	1.92E-04	1.90E-04	7.87E-05	1.57E-05	8.86E-06	2.08E-05	6.46E-04
HR	5.42E-06	1.78E-05	1.90E-05	2.88E-04	2.85E-05	1.28E-05	3.35E-05	5.64E-06	2.11E-05	4.32E-04
HU	3.05E-05	1.37E-05	6.04E-05	1.61E-03	5.03E-05	6.45E-05	7.88E-05	1.53E-05	3.74E-05	1.97E-03
IE	7.51E-05	1.77E-04	3.04E-04	2.48E-03	2.58E-04	1.21E-04	4.54E-04	7.34E-05	5.08E-04	4.45E-03
IS	4.22E-07	3.46E-06	8.83E-07	1.26E-05	2.41E-05	3.89E-06	6.47E-07	1.07E-07	8.91E-07	4.71E-05
IT	2.71E-04	7.84E-04	1.17E-03	3.66E-03	1.09E-03	3.68E-04	2.33E-04	5.31E-05	3.96E-04	8.03E-03
KY	6.26E-06	1.14E-05	2.02E-05	6.90E-05	3.81E-05	2.94E-05	1.94E-06	5.13E-07	2.81E-07	1.77E-04
KZ	9.03E-06	1.44E-05	2.15E-05	1.38E-04	9.13E-05	3.32E-05	8.27E-06	1.25E-06	7.28E-07	3.18E-04
LI	2.65E-08	2.32E-07	1.21E-07	1.11E-06	1.48E-07	5.69E-08	1.30E-07	2.55E-08	3.15E-07	2.17E-06
LU	1.79E-06	1.82E-06	3.25E-06	6.79E-05	3.06E-06	2.85E-06	1.71E-05	2.92E-06	3.88E-05	1.39E-04
MC	5.04E-09	1.01E-08	1.40E-08	6.15E-08	2.44E-08	9.06E-09	3.37E-09	4.42E-10	4.98E-09	1.33E-07
MD	4.79E-06	2.48E-06	5.66E-06	1.02E-04	1.12E-05	1.17E-05	2.83E-07	5.68E-08	3.99E-07	1.39E-04
ME	2.45E-09	2.58E-09	9.82E-09	4.75E-08	6.96E-09	2.61E-08	6.90E-09	3.19E-09	6.20E-09	1.12E-07
MK	2.36E-06	6.60E-06	1.32E-05	3.47E-05	1.60E-05	1.10E-05	2.10E-06	8.78E-07	4.65E-06	9.15E-05
MT	1.67E-08	1.61E-07	8.88E-08	1.13E-07	4.98E-08	1.19E-08	1.32E-08	2.32E-09	2.11E-08	4.78E-07
NL	3.71E-05	5.04E-05	8.72E-05	1.68E-03	5.68E-05	4.65E-05	6.63E-04	9.24E-05	1.52E-03	4.23E-03
NO	5.44E-05	3.28E-04	2.40E-04	7.57E-04	2.11E-04	5.78E-05	5.96E-04	2.32E-05	1.32E-04	2.40E-03
PT	5.08E-05	7.83E-05	1.66E-04	1.92E-03	1.45E-04	7.46E-05	1.48E-04	2.32E-05	2.83E-04	2.89E-03
RO	1.43E-05	2.23E-05	3.69E-05	6.08E-04	5.54E-05	4.24E-05	1.09E-05	2.74E-06	1.21E-05	8.05E-04
RS	8.63E-06	2.19E-05	4.52E-05	1.49E-04	4.03E-05	3.41E-05	1.04E-05	3.51E-06	1.47E-05	3.27E-04
SI	2.87E-06	9.16E-06	1.24E-05	1.29E-04	1.78E-05	5.13E-06	8.96E-06	1.63E-06	6.13E-06	1.93E-04
SK	7.44E-05	2.76E-05	1.43E-04	3.41E-03	8.75E-05	1.35E-04	1.49E-04	2.48E-05	6.44E-05	4.12E-03
TJ	2.97E-06	4.47E-06	9.02E-06	2.95E-05	1.20E-05	1.54E-05	8.67E-07	3.49E-07	9.79E-08	7.47E-05
TM	5.41E-08	2.83E-07	7.50E-08	1.06E-06	5.89E-07	6.16E-08	9.39E-10	3.15E-10	1.48E-09	2.12E-06
TR	2.77E-05	1.58E-04	1.02E-04	2.63E-04	2.15E-04	5.17E-05	1.04E-05	1.88E-06	1.63E-05	8.46E-04
UA	4.04E-04	8.98E-05	4.13E-04	6.53E-03	6.28E-04	1.18E-03	7.79E-05	6.52E-06	3.23E-05	9.36E-03
UZ	1.20E-06	1.70E-06	3.17E-06	1.02E-05	7.37E-06	5.06E-06	1.73E-07	6.53E-08	5.57E-08	2.89E-05
Other	0.021	0.023	0.022	0.275	0.099	0.030	0.044	0.009	0.057	0.581
EMEP	0.002	0.003	0.005	0.060	0.006	0.006	0.008	0.001	0.009	0.100
HELCOM	0.052	0.060	0.066	0.993	0.334	0.118	0.126	0.030	0.172	1.95
Total	0.076	0.085	0.094	1.327	0.440	0.154	0.177	0.041	0.238	2.63

Metadata

Technical information

1. Source:

    Meteorological Synthesizing Centre East (MSC-E) of EMEP

2. Description of data:

    Levels of atmospheric deposition of B(a)P on the Baltic Sea for the period from 1990 to 2018 were obtained using the latest version of GLEMOS model developed at EMEP/MSC-E (http://en.msceast.org/index.php/j-stuff/glemos). The latest available official emission data for the HELCOM and other EMEP countries have been used in the model computations. Emissions of B(a)P 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 B(a)P emission data used for modelling is presented in the indicator on the B(a)P emission to the air.

3. Geographical coverage:

    Atmospheric deposition of B(a)P 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 B(a)P are available for the period 1990 – 2018.

5. Methodology and frequency of data collection:

    Atmospheric input and source allocation budgets of B(a)P 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 B(a)P 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 B(a)P 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 1990-2018 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 B(a)P 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 B(a)P deposition for the period 1990-2018 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 B(a)P to the Baltic Sea and its sub-basins.

Weakness: uncertainties in officially submitted data on emissions of B(a)P.

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 POP modelling approaches applied in the EMEP GLEMOS model.

References

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