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

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Key Message

Annual atmospheric deposition fluxes of benzo(a)pyrene over the Baltic Sea have decreased by 67% during the period from 1990 to 2016.

Results and Assessment

Relevance of the BSEFS for describing developments in the environment

This indicator shows the levels and trends in benzo(a)pyrene (B(a)P) atmospheric deposition to the Baltic Sea. Levels of B(a)P deposition represent 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

Annual atmospheric deposition fluxes of benzo(a)pyrene over the Baltic Sea have decreased by 67% during the period from 1990 to 2016 (Figure 1). The figure illustrates changes of modelled annual B(a)P atmospheric deposition on to the Baltic Sea. Along with that the changes of normalized deposition are presented, which reflect the effect of emission variations without taking into account 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).

The most significant decline of B(a)P atmospheric deposition can be noted for the Western Baltic (74%) and the Kattegat (73%) sub-basins. In other sub-basins the decrease of deposition varied from almost 40% to 70% (Table 1).

According to modelling results for 2016 the highest level of B(a)P atmospheric deposition fluxes (15 $g/km^2/y$) over the Baltic Sea is estimated for the Sound sub-basin, while the lowest one (3.5 $g/km^2/y$) over the Bothnian Sea. In other sub-basins the level of deposition fluxes varied from about 5 to 14 g/km^2/y. Among the HELCOM countries the most significant contributions to deposition over the Baltic Sea was made by Poland and Russia.

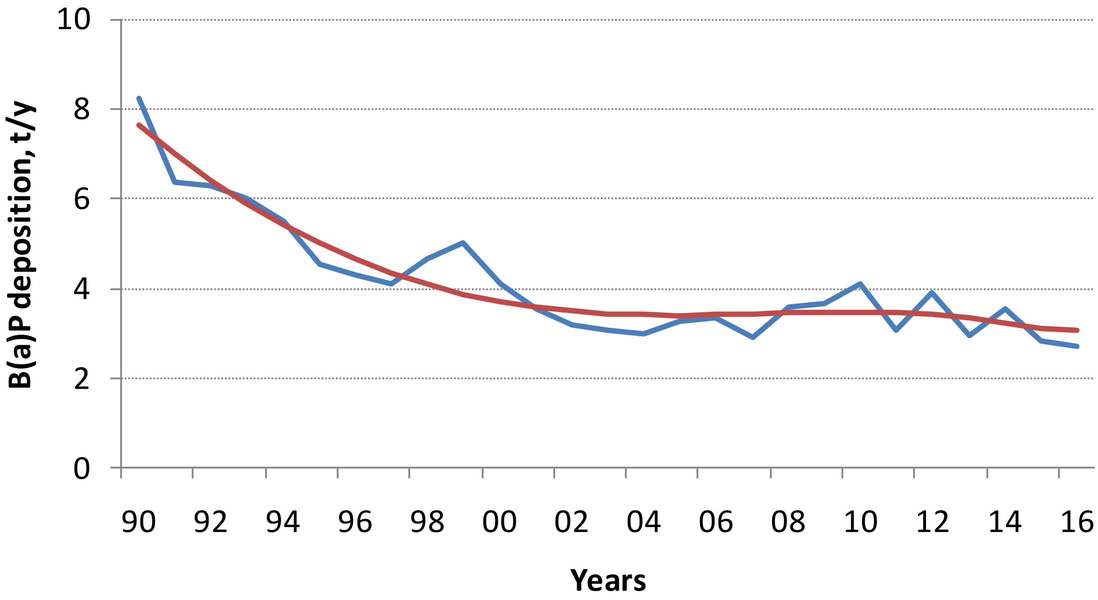

Figure 1. Changes of modeled (blue line) and normalized (red line) B(a)P atmospheric deposition to the Baltic Sea for the period 1990-2016, (t/y).

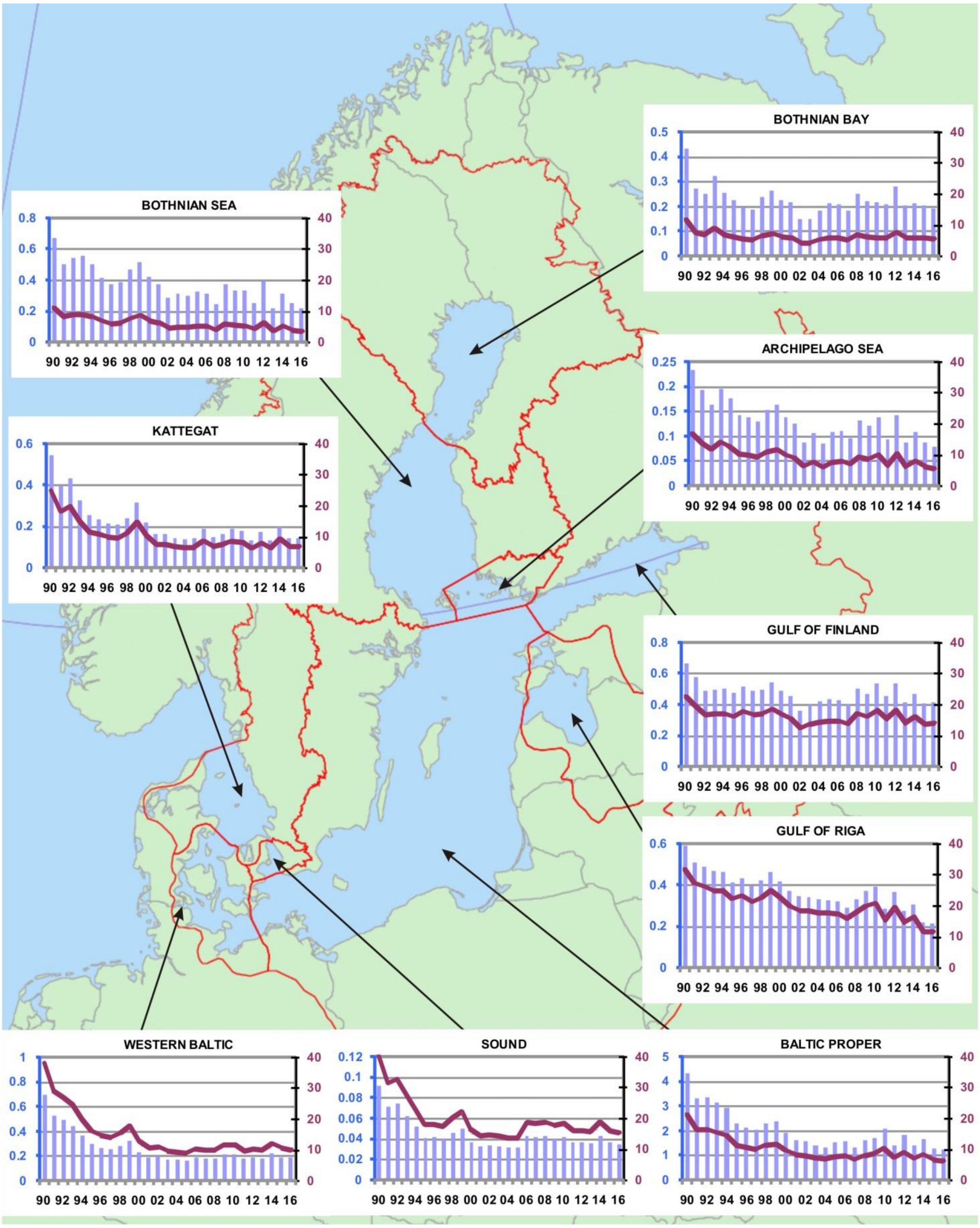

Figure 2. Time-series of computed annual atmospheric deposition of **B(a)P** over the nine sub-basins of the Baltic Sea for the period 1990-2016 in kg/year as bars (left axis) and deposition fluxes in g/km^2/year as lines (right axis). Note that different scales are used for deposition in kg/year and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

References

Bartnicki J., Gusev A., Aas W., Gauss M., and J. E. Jonson (2017) Atmospheric supply of nitrogen, cadmium, mercury, lead, and PCDD/Fs to the Baltic Sea in 2015. EMEP Centres Joint Report for HELCOM. EMEP/MSC-W Technical Report 1/2017. Norwegian Meteorological Institute. Oslo, Norway. Available in the web: http://www.emep.int/publ/helcom/2017/index.html

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Data

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

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

	ARC	**BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**KAT**	**SOU**	**WEB**	**BAS**	**Norm**
1990	0.234	0.431	0.671	4.313	0.662	0.591	0.542	0.092	0.695	**8.23**	**7.62**
1991	0.193	0.273	0.502	3.308	0.576	0.508	0.396	0.071	0.529	**6.36**	**6.99**
1992	0.163	0.249	0.539	3.347	0.491	0.490	0.430	0.074	0.488	**6.27**	**6.41**
1993	0.195	0.323	0.554	3.135	0.495	0.466	0.325	0.062	0.445	**6.00**	**5.88**
1994	0.176	0.254	0.503	2.910	0.501	0.464	0.254	0.052	0.362	**5.48**	**5.42**
1995	0.142	0.224	0.416	2.286	0.473	0.413	0.232	0.041	0.294	**4.52**	**5.00**
1996	0.138	0.196	0.370	2.105	0.518	0.433	0.215	0.041	0.264	**4.28**	**4.64**
1997	0.130	0.188	0.389	2.022	0.487	0.394	0.206	0.040	0.254	**4.11**	**4.33**
1998	0.152	0.238	0.468	2.306	0.495	0.422	0.241	0.045	0.282	**4.65**	**4.08**
1999	0.163	0.263	0.518	2.376	0.542	0.462	0.314	0.050	0.326	**5.01**	**3.86**
2000	0.138	0.223	0.421	1.913	0.488	0.417	0.221	0.037	0.231	**4.09**	**3.70**
2001	0.125	0.217	0.374	1.618	0.451	0.369	0.164	0.033	0.191	**3.54**	**3.57**
2002	0.087	0.147	0.283	1.565	0.359	0.345	0.163	0.033	0.196	**3.18**	**3.48**
2003	0.106	0.147	0.310	1.419	0.401	0.342	0.142	0.032	0.172	**3.07**	**3.43**
2004	0.084	0.183	0.300	1.334	0.422	0.328	0.140	0.031	0.170	**2.99**	**3.40**
2005	0.108	0.212	0.323	1.525	0.434	0.327	0.141	0.031	0.161	**3.26**	**3.39**
2006	0.111	0.209	0.311	1.549	0.428	0.321	0.186	0.043	0.189	**3.35**	**3.40**
2007	0.095	0.184	0.243	1.310	0.401	0.290	0.148	0.042	0.182	**2.89**	**3.42**
2008	0.132	0.249	0.372	1.606	0.501	0.329	0.163	0.043	0.181	**3.58**	**3.44**
2009	0.120	0.220	0.334	1.696	0.466	0.370	0.186	0.040	0.213	**3.65**	**3.46**
2010	0.138	0.215	0.331	2.073	0.534	0.390	0.177	0.042	0.213	**4.11**	**3.47**
2011	0.094	0.209	0.251	1.409	0.455	0.286	0.135	0.036	0.174	**3.05**	**3.45**
2012	0.142	0.281	0.392	1.807	0.534	0.364	0.171	0.037	0.187	**3.91**	**3.41**
2013	0.088	0.205	0.219	1.386	0.414	0.274	0.131	0.036	0.178	**2.93**	**3.33**
2014	0.109	0.212	0.312	1.658	0.469	0.306	0.198	0.043	0.220	**3.53**	**3.20**
2015	0.087	0.205	0.248	1.280	0.404	0.217	0.144	0.036	0.189	**2.81**	**3.11**
2016	0.078	0.193	0.218	1.228	0.412	0.215	0.145	0.035	0.183	**2.71**	**3.06**

Table 2. Computed contributions by country to annual total deposition of B(a)P 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; Other: contributions of remote emission sources (outside the EMEP model domain).

Country	**ARC**	**BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**KAT**	**SOU**	**WEB**	**BAS**
DK	1.4E-03	1.7E-03	4.2E-03	4.7E-02	2.4E-03	2.5E-03	3.0E-02	1.1E-02	4.2E-02	1.4E-01
EE	3.6E-03	3.3E-03	7.5E-03	1.5E-02	8.3E-02	1.3E-02	4.0E-04	5.0E-05	2.3E-04	1.3E-01
FI	1.3E-02	4.8E-02	3.0E-02	1.3E-02	3.6E-02	3.9E-03	5.3E-04	5.8E-05	2.8E-04	1.4E-01
DE	5.2E-03	8.3E-03	1.5E-02	1.8E-01	1.1E-02	1.0E-02	2.6E-02	5.3E-03	6.1E-02	3.2E-01
LV	3.1E-03	2.6E-03	6.0E-03	4.3E-02	1.1E-02	6.5E-02	9.3E-04	1.0E-04	4.6E-04	1.3E-01
LT	1.2E-03	1.7E-03	2.9E-03	4.6E-02	4.5E-03	8.6E-03	1.2E-03	1.2E-04	5.2E-04	6.7E-02
PL	6.7E-03	1.0E-02	1.5E-02	3.3E-01	2.2E-02	2.2E-02	2.1E-02	3.6E-03	2.1E-02	4.5E-01
RU	1.3E-02	2.7E-02	4.0E-02	9.5E-02	1.6E-01	2.3E-02	3.4E-03	4.0E-04	2.1E-03	3.6E-01
SE	9.5E-03	5.4E-02	3.9E-02	7.8E-02	8.4E-03	6.2E-03	1.4E-02	5.3E-03	2.9E-03	2.2E-01
AL	2.5E-05	4.3E-05	5.7E-05	3.0E-04	1.2E-04	8.1E-05	1.8E-05	2.8E-06	1.8E-05	6.6E-04
AT	1.6E-04	2.2E-04	3.5E-04	4.3E-03	4.9E-04	3.4E-04	5.0E-04	7.5E-05	5.3E-04	7.0E-03
BE	4.9E-04	7.5E-04	1.5E-03	1.3E-02	9.7E-04	8.5E-04	3.1E-03	4.7E-04	4.0E-03	2.5E-02
BG	9.1E-05	1.8E-04	2.4E-04	8.9E-04	5.0E-04	3.2E-04	4.9E-05	6.8E-06	5.3E-05	2.3E-03
BA	4.3E-05	6.1E-05	8.3E-05	7.8E-04	1.8E-04	1.0E-04	6.8E-05	1.0E-05	5.8E-05	1.4E-03
BY	2.6E-03	3.0E-03	6.2E-03	3.9E-02	8.7E-03	9.7E-03	2.3E-03	2.3E-04	1.1E-03	7.3E-02
CH	5.0E-05	8.3E-05	1.3E-04	1.3E-03	1.3E-04	9.9E-05	2.1E-04	3.2E-05	2.7E-04	2.3E-03
CY	5.4E-05	1.7E-04	2.2E-04	9.7E-04	4.4E-05	5.5E-05	4.8E-05	5.5E-06	3.1E-05	1.6E-03
CZ	1.8E-03	2.7E-03	4.1E-03	5.6E-02	5.6E-03	4.9E-03	6.0E-03	9.7E-04	7.6E-03	9.0E-02
ES	7.1E-04	1.7E-03	2.4E-03	1.3E-02	1.4E-03	1.0E-03	2.2E-03	3.6E-04	3.0E-03	2.5E-02
FR	3.8E-04	6.4E-04	1.1E-03	7.4E-03	8.2E-04	6.4E-04	1.6E-03	2.1E-04	1.9E-03	1.5E-02
GB	1.1E-03	2.2E-03	4.0E-03	2.1E-02	2.5E-03	2.0E-03	5.5E-03	7.7E-04	5.4E-03	4.5E-02
GR	5.0E-05	1.4E-04	1.7E-04	4.8E-04	2.9E-04	1.7E-04	3.4E-05	5.2E-06	4.8E-05	1.4E-03
HR	8.8E-05	1.2E-04	1.9E-04	1.6E-03	3.0E-04	1.7E-04	1.7E-04	2.2E-05	1.2E-04	2.8E-03
HU	4.9E-04	6.4E-04	9.7E-04	1.4E-02	1.9E-03	1.1E-03	1.3E-03	1.8E-04	1.1E-03	2.2E-02
IE	4.5E-04	9.7E-04	1.6E-03	7.1E-03	9.7E-04	7.6E-04	1.7E-03	2.3E-04	1.5E-03	1.5E-02
IS	1.6E-06	4.8E-06	8.0E-06	4.5E-05	3.4E-06	2.0E-06	3.7E-06	7.1E-07	4.7E-06	7.3E-05
IT	4.7E-04	7.7E-04	1.1E-03	8.4E-03	1.4E-03	9.4E-04	9.7E-04	1.4E-04	9.5E-04	1.5E-02
LI	2.5E-06	6.0E-06	1.3E-05	1.5E-05	6.2E-06	2.4E-06	1.4E-06	1.6E-07	1.1E-06	4.7E-05
MD	8.4E-05	1.6E-04	2.3E-04	2.5E-03	4.8E-04	4.2E-04	1.7E-04	2.4E-05	1.4E-04	4.2E-03
MK	4.8E-05	8.7E-05	1.3E-04	4.5E-04	2.1E-04	1.4E-04	2.2E-05	3.3E-06	2.3E-05	1.1E-03
NL	4.1E-04	6.7E-04	1.4E-03	9.9E-03	8.0E-04	6.7E-04	2.7E-03	4.0E-04	3.7E-03	2.1E-02
NO	5.0E-04	8.8E-04	1.8E-03	6.0E-03	8.7E-04	6.9E-04	2.1E-03	2.1E-04	7.7E-04	1.4E-02
PT	1.0E-04	2.1E-04	3.0E-04	1.7E-03	1.8E-04	1.6E-04	3.0E-04	5.1E-05	4.6E-04	3.5E-03
RO	7.8E-04	1.4E-03	1.8E-03	1.5E-02	3.6E-03	2.8E-03	1.0E-03	1.5E-04	1.1E-03	2.8E-02
SK	3.2E-04	4.6E-04	7.0E-04	1.1E-02	1.3E-03	8.9E-04	9.9E-04	1.5E-04	9.5E-04	1.6E-02
SI	9.5E-05	1.3E-04	2.0E-04	2.1E-03	3.1E-04	1.9E-04	2.3E-04	3.0E-05	1.7E-04	3.4E-03
UA	3.3E-03	6.2E-03	8.9E-03	7.1E-02	1.7E-02	1.2E-02	5.1E-03	6.3E-04	3.7E-03	1.3E-01
RS	2.0E-04	2.8E-04	3.6E-04	3.4E-03	8.3E-04	5.1E-04	2.6E-04	3.9E-05	2.7E-04	6.1E-03
AM	8.9E-06	4.4E-05	5.5E-05	4.9E-05	4.0E-05	1.2E-05	3.8E-06	3.9E-07	2.1E-06	2.1E-04
AZ	2.3E-04	8.4E-04	1.4E-03	4.3E-03	1.9E-04	1.2E-04	1.9E-04	2.6E-05	8.6E-05	7.4E-03
KZ	2.3E-04	6.4E-04	1.1E-03	1.1E-03	6.1E-04	2.3E-04	7.1E-05	8.6E-06	3.8E-05	4.0E-03
GE	2.3E-05	9.4E-05	1.4E-04	4.1E-04	9.5E-05	2.9E-05	3.4E-05	5.5E-06	4.7E-05	8.8E-04
TR	1.4E-04	7.2E-04	8.5E-04	7.5E-04	1.3E-03	5.5E-04	5.2E-05	6.0E-06	4.3E-05	4.4E-03
LU	6.5E-04	1.1E-03	2.2E-03	9.0E-03	1.6E-03	1.4E-03	5.5E-04	6.7E-05	5.0E-04	1.7E-02
MC	9.9E-06	3.7E-05	6.5E-05	7.5E-05	2.1E-05	1.2E-05	8.2E-06	1.2E-06	4.0E-06	2.3E-04
KY	1.8E-05	4.9E-05	1.2E-04	4.7E-04	2.6E-05	1.1E-05	3.1E-05	5.1E-06	2.5E-05	7.5E-04
UZ	1.9E-05	4.3E-05	9.6E-05	1.3E-04	3.9E-05	1.9E-05	1.2E-05	1.3E-06	7.5E-06	3.7E-04
TM	2.6E-06	7.0E-06	1.2E-05	1.2E-05	7.8E-06	2.8E-06	7.5E-07	7.9E-08	3.7E-07	4.5E-05
TJ	8.4E-06	2.1E-05	4.5E-05	3.2E-05	1.9E-05	6.6E-06	2.3E-06	2.0E-07	8.6E-07	1.4E-04
MT	1.2E-06	2.6E-06	7.3E-06	6.2E-05	2.2E-06	1.1E-06	4.5E-06	9.7E-07	5.1E-06	8.7E-05
ME	1.3E-04	2.6E-04	4.6E-04	1.3E-03	4.1E-04	2.3E-04	9.7E-05	1.3E-05	8.7E-05	2.9E-03
Other	0.004	0.008	0.009	0.053	0.018	0.012	0.008	0.003	0.012	0.127
EMEP	0.016	0.029	0.047	0.330	0.057	0.045	0.040	0.006	0.040	0.608
HELCOM	0.057	0.155	0.160	0.848	0.337	0.154	0.098	0.026	0.131	1.965
Total	0.077	0.193	0.216	1.230	0.411	0.211	0.145	0.035	0.183	2.700

Metadata

Technical information

1. Source:

EMEP/MSC-E

2. Description of data:

The latest available official emission data for the HELCOM countries have been used in the model computations. Emissions of benzo(a)pyrene 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 calculated for the European region and surrounding areas covered by the EMEP modelling domain.

4. Temporal coverage:

Timeseries of annual atmospheric B(a)P deposition are available for the period 1990 – 2016.

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 MSCE-POP model. MSCE-POP 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, wet and dry deposition, degradation, gaseous exchange with underlying surface, 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 horizontal 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 s-coordinates and covers almost the whole troposphere. Detailed description of the model can be found in EMEP reports (Gusev et al., 2005) and in the Internet on EMEP web page (http://www.emep.int/) under the link to information on Persistent Organic Pollutants. Meteorological data used in the calculations for 1990-2016 were obtained using MM5 meteorological data preprocessor on the basis of meteorological analysis of European Centre for Medium-Range Weather Forecasts (ECMWF).

Results of model simulation of atmospheric transport and annual 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 and available expert estimates of emission.

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 emissions of B(a)P.

7. Uncertainty:

The MSCE-POP model results were compared with measurements of EMEP monitoring network [Gusev et al., 2006, Shatalov et al., 2005]. The model was evaluated through the comparison with available measurements during EMEP TFMM meetings held in 2005. It was concluded that the MSCE-POP model is suitable for the evaluation of the long range transboundary transport and deposition of POPs in Europe.

8. Further work required:

Further work is required on reducing uncertainties in emission data and modeling approaches used in MSCE-POP model.