Atmospheric deposition of Lead on the Baltic Sea

HELCOM Baltic Sea Environment Fact Sheet (BSEFS), 2023

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Key message

Levels of annual total atmospheric deposition of lead to the Baltic Sea have decreased in period from 1990 to 2021 by 88%, although the rate of decrease was higher in the earlier part (1990-2003) 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 lead atmospheric deposition to the Baltic Sea. The deposition of lead represents the pressure of the emission sources on the Baltic Sea aquatic environment as described in the BSEFS "Atmospheric emissions of lead 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 heavy metals to the atmosphere on European scale is set in the framework of UN ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). The CLRTAP Protocol on Heavy Metals (1998) targets three particularly harmful metals: cadmium, lead and mercury. According to one of the basic obligations emissions of these three metals must be reduced below the emission levels in 1990. The Protocol entered into force in 2003 and was signed and/or ratified by 41 countries.

Assessment

Model assessment of lead long-range transport and deposition within the Baltic Sea region in period 1990-2021 was carried out taking into account anthropogenic emissions officially reported by HELCOM and other EMEP countries. In addition, natural and secondary emissions due to wind re-suspension of particle-bound lead from terrestrial and seawater compartments were considered.

Model simulations indicate that atmospheric input of lead to the Baltic Sea declined by 88% in the period from 1990 to 2021 (Figure 1, Table 1). The decline of Pb deposition in particular sub-basins ranged from 85% to 92% for the considered period (Figure 2). The strongest decline (92%) was noted for Archipelago Sea and Gulf of Finland. The lowest deposition decrease (85%) took place in the Bothnian Sea sub-basin. The decline of lead deposition to the Baltic Sea in the period 1990-2021 was nonuniform. Two sub-periods can be selected with different deposition decline rates, namely, 1990-2002 and 2003-2021. Deposition trend in each part was analysed using Mann-Kendall test [*Gilbert*, 1987; *Connor et al*, 2012]. In the first period the mean annual decline of Pb deposition was about 30 tonnes per year, and in the second period – almost 6 tonnes per year. Mann-Kendall test reveals that the decreasing trends were significant at α = 0.05.

Temporal variations of total lead depositions are affected by changes of anthropogenic emissions of countries as well as changes of secondary emissions. It should be noted also that only a fraction of lead, emitted by the sources of particular country, deposits to the Baltic Sea. This fraction depends on the location of the country and prevailing atmospheric transport pathways. In particular, the largest fraction of total national emissions, deposited to the Baltic Sea, is estimated for Denmark (16%) while the lowest one for Russia (about 0.4%).

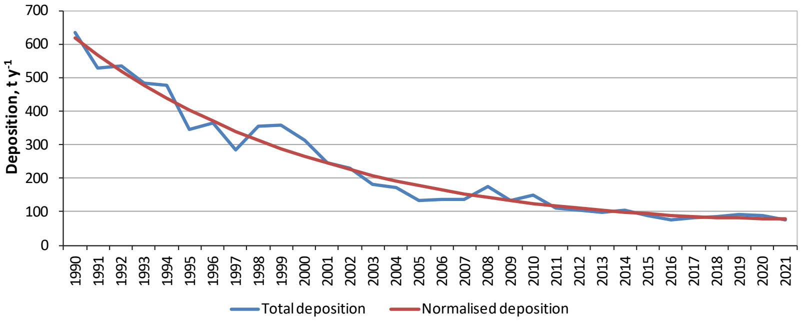
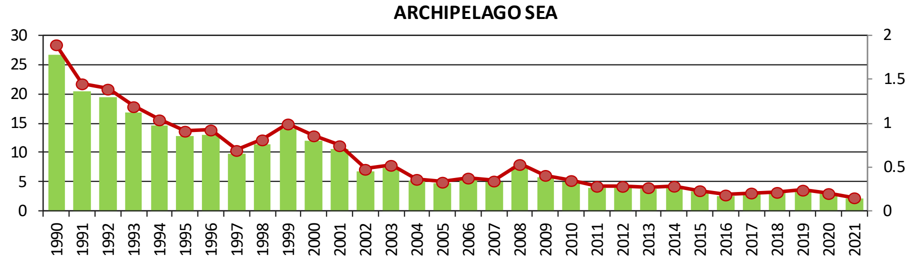


Figure 1. Changes of modelled (blue line) and normalized (red line) total annual atmospheric deposition of lead to the Baltic Sea for the period 1990-2021, (t y^{-1}). Normalized depositions were obtained using the methodology described below in the metadata section 5.

Spatial distributions of annual total deposition fluxes of lead in 1990 and 2021 within the Baltic Sea region are shown in Figure 3. Total deposition fluxes of lead vary significantly among the sub-basins. The highest spatially averaged total deposition flux in 2021 among the Baltic Sea sub-basins is noted for the Sound sub-basin. This sub-basin has the lowest area and is characterized by significant land-based emission sources located nearby. The lowest flux is estimated for the Bothnian Bay sub-basin that is explained by its relatively large area and low levels of emissions in the surrounding areas.

The HELCOM Contracting Parties contributed 33% to total deposition of lead to the Baltic Sea in 2021 (Table 2). The largest contribution is made by Poland (15%) and Germany (8%) (Figure 4, Table 2). It is important to note that contributions of emissions of the Contracting Parties to deposition in particular sub-regions differ significantly. Reduction of atmospheric input of lead from anthropogenic sources 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 during the considered period.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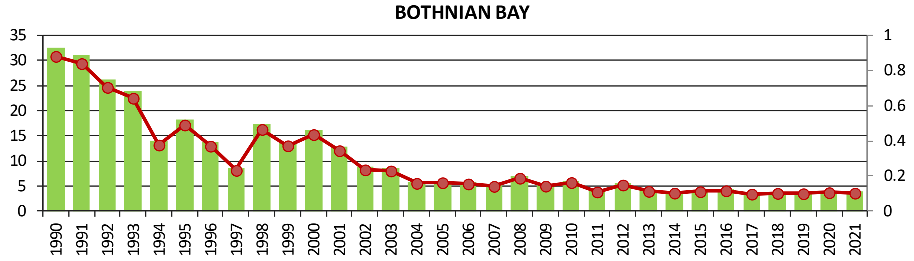
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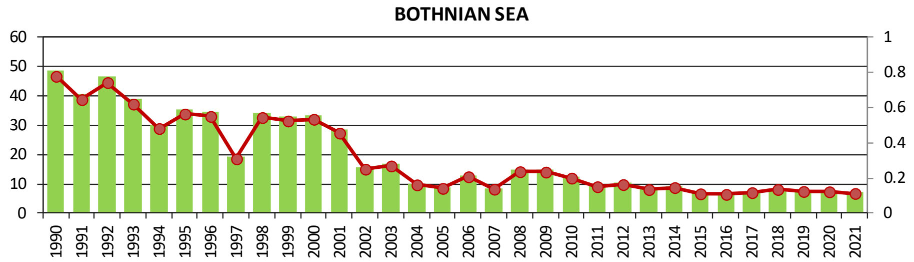
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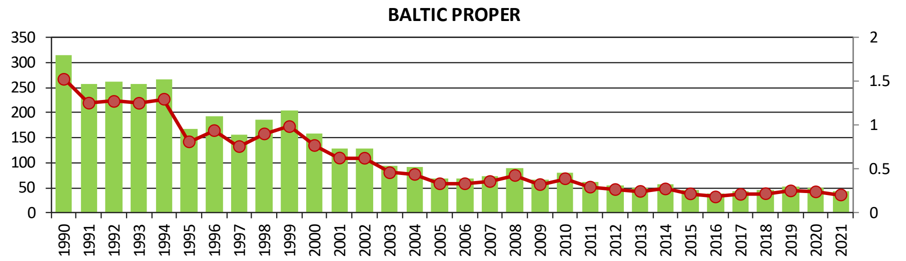
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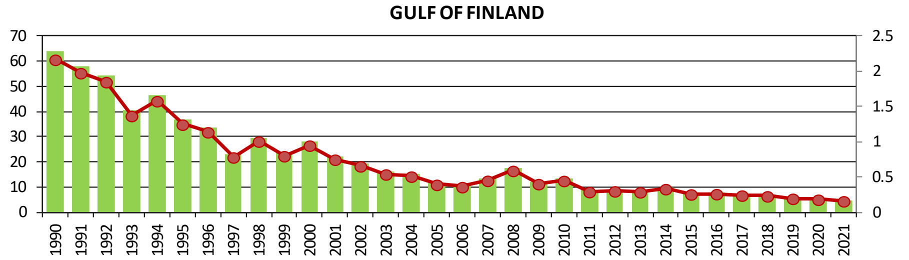
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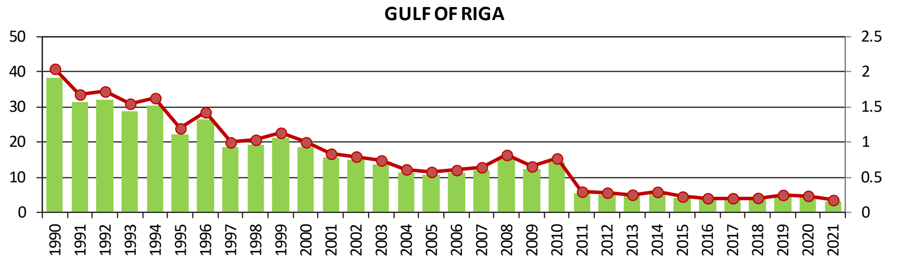
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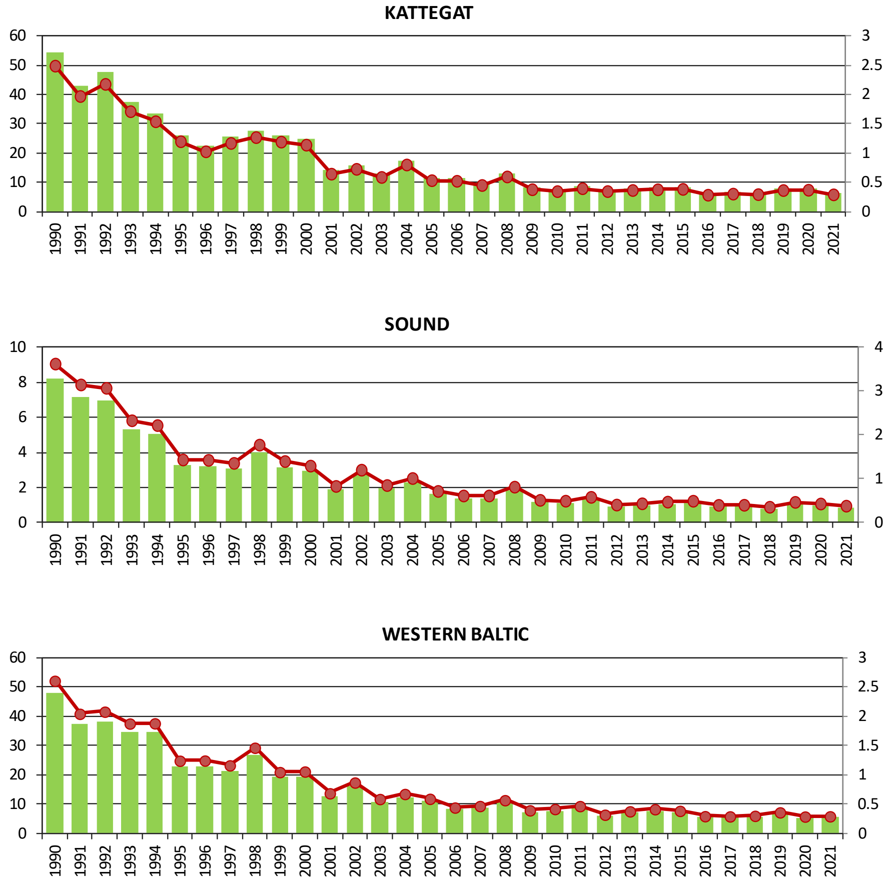

Figure 2. Time-series of computed total annual atmospheric deposition of lead to nine sub-basins of the Baltic Sea for the period 1990-2021 in t y^{-1} as green bars (left axis) and total deposition fluxes in kg km^{-2} y^{-1} as red lines (right axis).

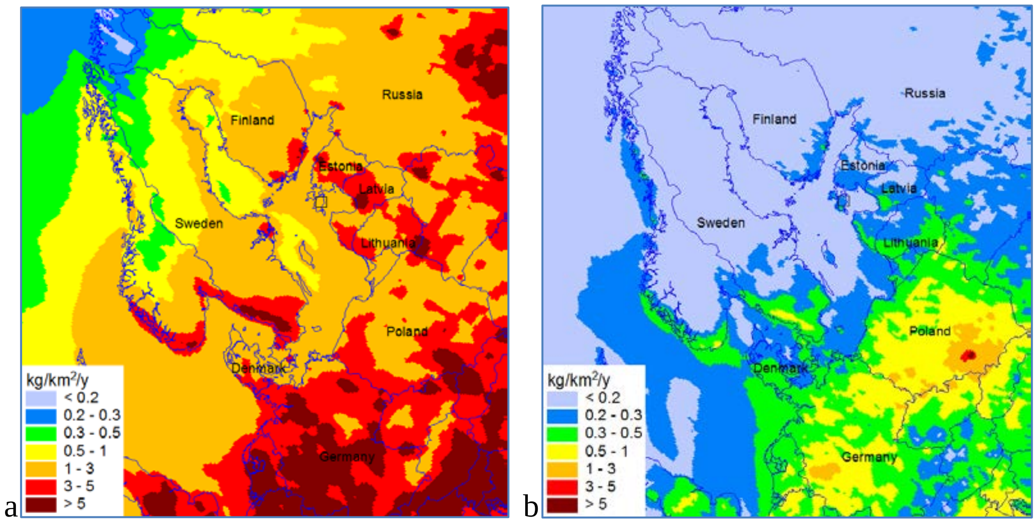

Figure 3. Spatial distribution of modelled annual total lead deposition fluxes in the Baltic Sea region for 1990 (a) and 2021 (b), kg km^{-2} y^{-1}.

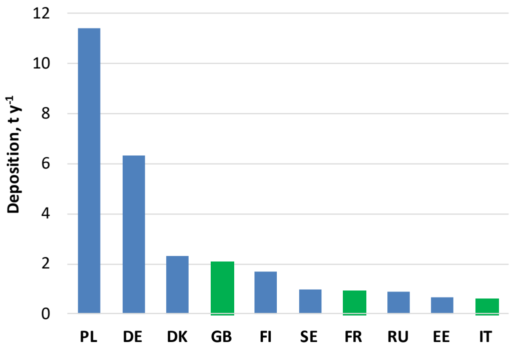

Figure 4. Ten countries with the highest contribution to annual total deposition of lead to the Baltic Sea estimated for 2021, t y^{-1}. Green bars indicate non-HELCOM countries.

Data

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

Table 1. Computed total annual deposition of lead 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: t y^{-1}.

	ARC	BOB	BOS	BAP	GUF	GUR	KAT	SOU	WEB	BAS	Norm
1990	26.6	32.6	48.7	314.5	63.8	38.2	54.4	8.2	47.9	634.8	618.1
1991	20.4	31.1	40.4	258.4	58.2	31.3	43.1	7.1	37.6	527.6	567.2
1992	19.5	26.1	46.5	262.5	54.5	32.2	47.6	7.0	38.2	534.0	520.7
1993	16.7	23.8	38.8	258.1	40.4	28.9	37.4	5.3	34.5	483.9	478.0
1994	14.6	14.0	30.1	267.6	46.5	30.4	33.6	5.0	34.6	476.5	438.9
1995	12.8	18.2	35.3	167.5	36.8	22.3	26.2	3.3	22.9	345.2	403.2
1996	13.0	13.7	34.5	193.9	33.6	26.6	22.4	3.2	23.0	363.8	370.5
1997	9.7	8.6	19.4	156.4	23.1	18.6	25.5	3.1	21.5	285.9	340.5
1998	11.4	17.2	34.1	186.1	29.7	19.3	27.7	4.0	27.0	356.5	313.2
1999	14.0	13.8	32.8	203.3	23.6	21.2	26.0	3.2	19.3	357.3	288.2
2000	12.1	16.2	33.4	158.9	28.0	18.6	24.9	2.9	19.5	314.6	265.3
2001	10.5	12.8	28.5	129.3	22.2	15.6	14.0	1.9	12.7	247.5	244.5
2002	6.7	8.7	15.7	128.9	19.4	14.8	15.8	2.7	16.1	229.0	225.5
2003	7.4	8.5	16.8	94.8	16.0	13.8	12.8	1.9	10.9	183.0	208.1
2004	5.1	5.9	10.1	90.9	15.1	11.4	17.5	2.3	12.5	170.9	192.4
2005	4.7	6.0	8.9	68.9	11.7	10.8	11.6	1.6	11.0	135.2	178.0
2006	5.3	5.8	13.0	69.0	10.8	11.2	11.4	1.4	8.3	136.1	165.0
2007	4.9	5.3	8.6	74.2	13.4	12.0	9.8	1.4	8.7	138.2	153.2
2008	7.5	7.0	14.8	88.4	17.5	15.3	13.0	1.9	10.6	175.9	142.5
2009	5.8	5.3	14.7	67.0	12.0	12.2	8.2	1.2	7.4	133.8	132.9
2010	4.9	6.1	12.5	80.7	13.3	14.3	7.5	1.1	7.8	148.4	124.3
2011	4.0	4.1	9.5	61.0	8.7	5.5	8.6	1.3	8.7	111.5	116.6
2012	4.0	5.6	10.2	55.3	9.0	5.2	7.5	0.9	6.0	103.9	109.7
2013	3.8	4.2	8.5	50.9	8.6	4.7	7.9	1.0	7.1	96.7	103.6
2014	4.0	3.9	9.2	56.7	9.9	5.5	8.2	1.1	7.8	106.2	98.2
2015	3.3	4.2	6.9	45.2	7.7	4.2	8.3	1.1	7.2	88.2	93.6
2016	2.6	4.4	6.7	37.9	7.8	3.8	6.2	0.9	5.6	75.9	89.6
2017	3.0	3.6	7.4	43.9	7.2	3.8	6.6	0.9	5.5	81.9	86.2
2018	3.1	3.8	8.5	45.6	6.9	3.8	6.4	0.8	5.7	84.6	83.4
2019	3.4	3.7	7.8	52.1	5.9	4.6	7.9	1.1	6.8	93.3	81.2
2020	2.9	4.0	7.7	49.9	5.5	4.4	8.0	1.0	5.5	88.7	79.6
2021	2.2	3.9	7.1	42.6	4.9	3.3	6.3	0.9	5.5	76.6	78.5

* - 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 lead to nine Baltic Sea sub-basins for the year 2021. Units: t y^{-1}. HELCOM: contribution of anthropogenic sources of HELCOM countries; EMEP: contribution of anthropogenic sources in other EMEP countries; Other: contributions of sources other than primary anthropogenic emissions (natural, secondary (re-suspension), and non-EMEP sources).

	ARC	BOB	BOS	BAP	GUF	GUR	KAT	SOU	WEB	BAS
DK	2.53E-02	2.77E-02	6.41E-02	9.01E-01	4.06E-02	4.54E-02	6.20E-01	1.51E-01	4.47E-01	2.32E+00
EE	2.27E-02	2.04E-02	4.30E-02	1.60E-01	3.21E-01	8.39E-02	3.61E-03	2.91E-04	2.53E-03	6.57E-01
FI	1.26E-01	3.44E-01	2.90E-01	2.64E-01	5.93E-01	4.75E-02	9.01E-03	6.58E-04	5.94E-03	1.68E+00
DE	1.14E-01	1.00E-01	2.87E-01	3.67E+00	1.84E-01	1.89E-01	6.80E-01	9.54E-02	9.96E-01	6.32E+00
LV	1.33E-02	9.53E-03	2.76E-02	1.63E-01	4.36E-02	1.84E-01	2.99E-03	3.52E-04	2.51E-03	4.46E-01
LT	1.04E-02	8.30E-03	2.49E-02	2.16E-01	2.50E-02	4.68E-02	4.22E-03	5.47E-04	3.53E-03	3.40E-01
PL	3.01E-01	2.89E-01	8.72E-01	7.78E+00	4.99E-01	5.68E-01	5.27E-01	6.22E-02	5.43E-01	1.14E+01
RU	3.12E-02	1.25E-01	1.18E-01	3.22E-01	2.29E-01	4.57E-02	1.20E-02	1.10E-03	8.21E-03	8.92E-01
SE	3.68E-02	2.79E-01	1.80E-01	3.45E-01	3.91E-02	2.69E-02	4.42E-02	5.62E-03	1.54E-02	9.72E-01
AL	4.86E-04	6.44E-04	1.55E-03	1.05E-02	7.77E-04	4.95E-04	3.09E-04	5.33E-05	2.66E-04	1.50E-02
AM	2.19E-05	8.31E-05	1.22E-04	3.34E-04	1.19E-04	5.37E-05	9.85E-06	1.38E-06	7.03E-06	7.52E-04
AT	6.19E-03	8.21E-03	2.02E-02	1.08E-01	9.68E-03	6.92E-03	1.82E-02	1.78E-03	1.76E-02	1.97E-01
AZ	4.97E-05	2.25E-04	3.38E-04	6.23E-04	3.79E-04	1.01E-04	1.91E-05	2.20E-06	1.20E-05	1.75E-03
BA	8.04E-03	1.38E-02	3.10E-02	1.40E-01	1.14E-02	6.27E-03	1.17E-02	1.53E-03	6.95E-03	2.31E-01
BE	7.90E-03	5.87E-03	1.71E-02	2.00E-01	1.24E-02	1.22E-02	4.93E-02	7.26E-03	5.69E-02	3.69E-01
BG	1.79E-03	2.48E-03	5.12E-03	2.46E-02	3.90E-03	1.97E-03	1.43E-03	1.83E-04	7.57E-04	4.23E-02
BY	7.64E-03	7.26E-03	2.29E-02	1.12E-01	2.32E-02	2.03E-02	3.23E-03	3.79E-04	2.36E-03	2.00E-01
CH	4.35E-03	7.34E-03	1.65E-02	9.04E-02	8.05E-03	5.69E-03	1.88E-02	1.66E-03	2.06E-02	1.73E-01
CY	6.97E-06	3.70E-05	3.14E-05	7.70E-05	1.00E-04	1.86E-05	3.06E-06	5.42E-07	2.08E-06	2.77E-04
CZ	1.16E-02	1.20E-02	3.28E-02	2.68E-01	1.71E-02	1.78E-02	3.53E-02	3.60E-03	3.69E-02	4.35E-01
ES	1.21E-02	2.04E-02	4.32E-02	1.56E-01	1.96E-02	1.32E-02	4.32E-02	4.49E-03	4.06E-02	3.53E-01
FR	2.04E-02	2.45E-02	5.83E-02	4.69E-01	3.71E-02	3.19E-02	1.29E-01	1.57E-02	1.39E-01	9.25E-01
GB	6.19E-02	5.16E-02	1.74E-01	1.10E+00	7.62E-02	7.01E-02	2.98E-01	3.56E-02	2.21E-01	2.09E+00
GE	1.19E-04	3.98E-04	6.10E-04	1.99E-03	4.62E-04	2.62E-04	5.95E-05	9.73E-06	4.38E-05	3.96E-03
GR	4.69E-04	7.07E-04	1.47E-03	7.36E-03	1.31E-03	6.42E-04	2.66E-04	4.20E-05	2.14E-04	1.25E-02
HR	1.63E-03	2.66E-03	6.23E-03	2.65E-02	2.49E-03	1.42E-03	3.57E-03	4.34E-04	2.71E-03	4.76E-02
HU	6.45E-03	9.31E-03	2.36E-02	9.82E-02	8.85E-03	6.53E-03	1.01E-02	1.24E-03	1.06E-02	1.75E-01
IE	1.88E-03	2.02E-03	6.14E-03	3.58E-02	2.34E-03	2.16E-03	1.05E-02	1.11E-03	6.34E-03	6.84E-02
IS	2.43E-05	7.22E-05	8.13E-05	4.45E-04	7.17E-05	4.23E-05	6.42E-05	8.04E-06	4.85E-05	8.58E-04
IT	1.98E-02	4.49E-02	8.97E-02	3.06E-01	4.34E-02	2.02E-02	5.74E-02	5.55E-03	4.71E-02	6.34E-01
KY	2.89E-05	1.24E-04	1.52E-04	4.15E-04	6.28E-05	5.63E-05	9.73E-06	1.12E-06	1.12E-05	8.62E-04
KZ	6.11E-03	2.86E-02	3.09E-02	6.41E-02	2.98E-02	1.01E-02	2.99E-03	2.68E-04	1.72E-03	1.75E-01
LI	1.71E-05	2.79E-05	6.08E-05	3.38E-04	3.00E-05	1.99E-05	6.57E-05	5.63E-06	7.24E-05	6.38E-04
LU	3.88E-04	4.43E-04	1.08E-03	1.09E-02	7.42E-04	6.80E-04	2.99E-03	3.25E-04	3.36E-03	2.09E-02
MC	7.95E-07	1.96E-06	3.82E-06	1.07E-05	1.86E-06	1.10E-06	2.73E-06	2.30E-07	2.33E-06	2.56E-05
MD	7.57E-04	9.23E-04	2.07E-03	8.33E-03	1.41E-03	1.26E-03	1.84E-04	2.40E-05	1.25E-04	1.51E-02
ME	7.63E-05	1.24E-04	2.60E-04	1.38E-03	1.10E-04	6.74E-05	7.25E-05	1.02E-05	4.17E-05	2.14E-03
MK	3.42E-04	4.37E-04	9.81E-04	6.38E-03	5.11E-04	3.55E-04	2.75E-04	3.93E-05	1.60E-04	9.48E-03
MT	1.67E-05	4.80E-05	6.55E-05	2.86E-04	6.57E-05	2.78E-05	2.49E-05	2.31E-06	2.38E-05	5.61E-04
NL	3.35E-03	2.45E-03	7.84E-03	9.25E-02	5.44E-03	5.33E-03	2.19E-02	3.21E-03	2.53E-02	1.67E-01
NO	5.43E-03	1.31E-02	2.24E-02	5.80E-02	9.64E-03	6.96E-03	1.86E-02	1.15E-03	7.16E-03	1.43E-01
PT	9.40E-04	1.63E-03	3.84E-03	1.42E-02	1.39E-03	1.17E-03	3.63E-03	4.24E-04	4.08E-03	3.13E-02
RO	1.33E-02	1.82E-02	3.87E-02	1.48E-01	2.20E-02	1.39E-02	5.88E-03	7.53E-04	3.49E-03	2.64E-01
RS	1.06E-02	1.71E-02	4.06E-02	1.49E-01	1.27E-02	7.74E-03	1.44E-02	1.69E-03	7.53E-03	2.61E-01
SI	1.81E-03	2.74E-03	6.45E-03	2.83E-02	2.88E-03	1.69E-03	4.63E-03	5.50E-04	3.70E-03	5.28E-02
SK	3.74E-03	5.57E-03	1.38E-02	7.46E-02	6.06E-03	5.72E-03	4.87E-03	6.00E-04	5.57E-03	1.21E-01
TJ	1.67E-04	8.06E-04	8.69E-04	3.23E-03	3.30E-04	3.50E-04	8.67E-05	1.12E-05	1.01E-04	5.95E-03
TM	4.54E-04	2.32E-03	2.64E-03	6.14E-03	3.91E-03	9.64E-04	1.97E-04	2.32E-05	1.51E-04	1.68E-02
TR	2.28E-03	8.72E-03	1.23E-02	4.51E-02	1.45E-02	5.13E-03	1.64E-03	2.55E-04	1.15E-03	9.11E-02
UA	1.31E-02	2.16E-02	4.48E-02	1.48E-01	2.84E-02	1.95E-02	3.89E-03	5.26E-04	3.01E-03	2.83E-01
UZ	7.96E-04	3.82E-03	4.07E-03	1.43E-02	3.77E-03	1.79E-03	4.23E-04	5.13E-05	4.06E-04	2.94E-02
HELCOM	0.7	1.2	1.9	13.8	2.0	1.2	1.9	0.3	2.0	25.1
EMEP	0.2	0.3	0.8	4.0	0.4	0.3	0.8	0.1	0.7	7.7
Other	1.3	2.3	4.4	24.7	2.5	1.7	3.6	0.5	2.8	43.8
Total	2.2	3.9	7.1	42.6	4.9	3.3	6.3	0.9	5.5	76.6

Metadata

Technical information

1. Source:

Meteorological Synthesizing Centre East (MSC-E) of EMEP.

2. Description of data:

Atmospheric deposition of lead to the Baltic Sea for the period from 1990 to 2021 were estimated using the latest version of GLEMOS model developed at EMEP/MSC-E (http://msceast.org/index.php/j-stuff/glemos). Annual Pb emissions, officially reported by EMEP countries in 2020, were used in model computations for the years 1990-2018. Pollution levels of Pb in 2019 were evaluated using emission data, reported for the previous year 2021, the results for 2020 are based on emissions submitted in 2022 and emissions reported in 2023 were used to calculate Pb levels for 2021. These data are available from the EMEP Centre on Emission Inventories and Projections (CEIP) (http://www.ceip.at/). Detailed description of reported emission data, gap-filling methods, and expert estimates can be found in the CEIP Technical report [*Poupa*, 2022].

3. Geographical coverage:

Atmospheric depositions of lead were estimated for the European region and surrounding areas covered by the EMEP modelling domain.

4. Temporal coverage:

Time-series of annual Pb atmospheric deposition were estimated for the period 1990 – 2021.

5. Methodology and frequency of data collection:

Atmospheric input and source allocation budget of lead deposition to the Baltic Sea were computed using the latest version of GLEMOS model over the new 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.

GLEMOS modelling framework 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 Pb emission data for modelling 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). Boundary conditions for model simulations over EMEP domain were estimated using the global scale GLEMOS model simulations [*Ilyin et al.*, 2022].

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 data of European Centre for Medium-Range Weather Forecasts (ECMWF).

Lead presents in the atmosphere being bound to aerosol particles. Therefore, atmospheric properties of lead, such as wet scavenging, dry deposition velocity or potential to travel over long distances is governed by properties of the particles-carriers.

Lead is naturally occurring element with mean content in the Earth's crust 14 ppm [*CRC*, 2008]. Therefore, lead can enter the atmosphere due to suspension of wind-blown dust. Parameterization of wind re-suspension of lead from soil and seawater is described in [*Gusev et al.*, 2006*; Ilyin et al*., 2007]. Information on spatial distribution of background Pb concentrations in topsoil is based on the results of FOREGS project [*Salminen*, 2005]. Besides, enrichment of soil by anthropogenic inputs of Pb was assumed in order to take into account long-term accumulation of Pb from anthropogenic sources and to reach a better fit of the modelled concentrations and wet deposition with the EMEP measurement data. In the current work secondary emissions of Pb from the territories of the HELCOM countries (except for Russia) and the Baltic Sea area were estimated at the level of about 515 t in 1990 and about 230 t in 2021.

Normalized deposition values 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 reported data on lead emissions to the atmosphere.

Weakness: uncertainties in the officially submitted lead emission data and estimates of secondary emissions.

7. Uncertainty:

Discrepancies between the modelled and observed values can be caused by a number of reasons. One of them is uncertainties of officially reported emission data. In addition to this, uncertainties of spatial distribution as well as distribution along the vertical also contributes to the emission-related uncertainties.

Another source of the discrepancies is uncertainties of the model parameterizations and input data. Most of parameterizations of physical processes used in GLEMOS were transferred from previous model MSCE-HM used in operational modelling under EMEP [*Travnikov and Ilyin*, 2005]. The MSCE-HM model has been verified in a number of intercomparison campaigns with other regional HM transport models [*Gusev et al*., 2006; *Ryaboshapko et al.,* 2001, 2005] and has been qualified by means of sensitivity and uncertainty studies [*Travnikov*, 2000]. It was concluded 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 [*UNEP*, 2010a,b]. 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*].

Finally, the discrepancies can be contributed by the uncertainties of measurements. Regular laboratory intercomparisons are carried out annually by the supervision of CCC. In the majority of laboratories analyses of Pb satisfy data quality objectives [*CCC*, 2023]. However, it is important to mention that laboratory intercomparison provides only analytical component of the uncertainties of measurement data. Other sources of the uncertainties (sampling, storing, shipping etc.) remain unaccounted.

8. Further work required:

Further work is required to reduce uncertainties in Pb modelling approaches applied in the GLEMOS model. It can be reached through joint efforts of measurement, emission and modelling communities.

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