Atmospheric emissions of Copper in the Baltic Sea region

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Key Message

Annual atmospheric copper emissions of the HELCOM Contracting Parties decreased by 12% from 1990 to 2000. At the same time, the subsequent period (2001-2019) is characterized by increasing emissions up to the level of 1990.

Results and Assessment

Relevance of the BSEFS for describing developments in the environment

This BSEFS shows the levels and trends in copper emissions from anthropogenic sources of the HELCOM Contracting Parties, and other sources in the calculations of the deposition on the Baltic Sea (cf. BSEFS "Atmospheric deposition of copper on the Baltic Sea").

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.

Copper is essential trace element for biological systems. However, excess of copper can cause harmful effects for humans [*Gautam et al.*, 2014]. Copper is also toxic for aquatic organisms even at low concentrations and for soil microorganisms [*Gautam et al.*, 2014, *Flemming and Trevor*, 1989]. European Chemical Agency classified copper as toxic to aquatic life with long lasting effects. Therefore, although this substance is not presented in the HELCOM list of priority hazardous substances, copper satisfies, at least, some of the criteria for selection and priority setting of substances.

Protocol on Heavy Metals of CLRTAP does not include copper as priority metal. Nevertheless, parties to the CLRTAP regularly report cooper emission data. Besides, copper concentrations in air and in precipitation are regularly measured at the EMEP stations. Finally, EC directive on industrial emissions 2010/75/EU sets limits on emission of copper and its compounds to air and water from industrial installations.

Assessment

Annual anthropogenic emissions of copper to the atmosphere from the HELCOM Contracting Parties decreased by 12% from 1990 to 2000. At the same time, the subsequent period (2001-2019) is characterized by increasing emissions up to the level of 1990 (Figure 1). Expert estimates of spatially distributed copper anthropogenic emission fluxes in 1990 and 2019 are shown in Figure 2. The largest emission fluxes are noted for the areas along the southern part of the Baltic Sea.

Time-series of annual total copper emissions of the HELCOM Contracting Parties are shown in Figures 3. Among the HELCOM countries the most significant drop of copper emissions is noted for Finland (74%), followed by Estonia (55%), and Sweden (39%). At the same time, emissions of Denmark, Russia, and Poland in 2019 were higher than the emissions in 1990, by 33%, 20% and 10%, respectively. In 2019 total annual copper emissions of the HELCOM Contracting Parties amounted to 1886 tonnes. The largest contributions to these emissions were made by Russia (51%) and Germany (31%).

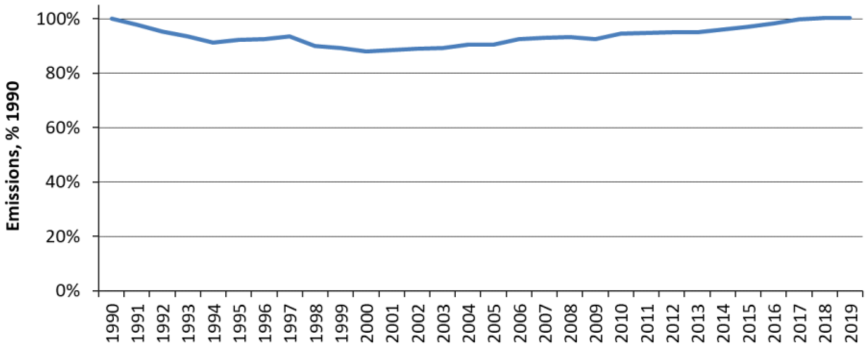

Figure 1. Relative changes of annual anthropogenic emissions of copper to the atmosphere from the HELCOM Contracting Parties in the period 1990-2019 (% of 1990).

Numerical data on Cu anthropogenic emissions from the HELCOM countries and other EMEP countries are presented in Table 1. Officially reported emission data represent the best available information on temporal variations of Cu emissions in the EMEP region. It is believed that reported inventories cover the most significant anthropogenic sources of Cu releases to the atmosphere and in general reasonably reflect temporal changes of emissions in period 1990-2019 (especially in its last decade). At the same time, for some of the countries substantial uncertainties still exist as well as incomplete information on sector distribution of emissions.

Along with the anthropogenic emission sources, Cu can be released to the atmosphere from natural (biogenic, oceanic, volcanic, and forest fires emissions) as well as secondary emission sources (re-suspension of dust particles) [*Pacyna and Pacyna*, 2001]. Relative importance of global anthropogenic and natural emissions was estimated in the studies [*Nriagu*, 1989; *Rauch and Pacyna*, 2009], which indicated their comparable contributions to total Cu emissions. In particular, anthropogenic and natural emissions in the mid-1990s were estimated to approximately 26 kt and 28 kt of Cu per year.

However, regional-scale ratios between the natural and anthropogenic Cu emissions may differ substantially. For example, *Wu et al* [2020] estimated that natural Cu emissions in China made up about 10% of its total release to the atmosphere. Cu releases due to re-suspension of dust particles and sea-spray aerosols were estimated using modelling approach described in the BSEFS "*Atmospheric deposition of Copper on the Baltic Sea*". Modelling results indicate more significant contribution of anthropogenic emissions to air pollution levels comparing to the natural and secondary emissions.

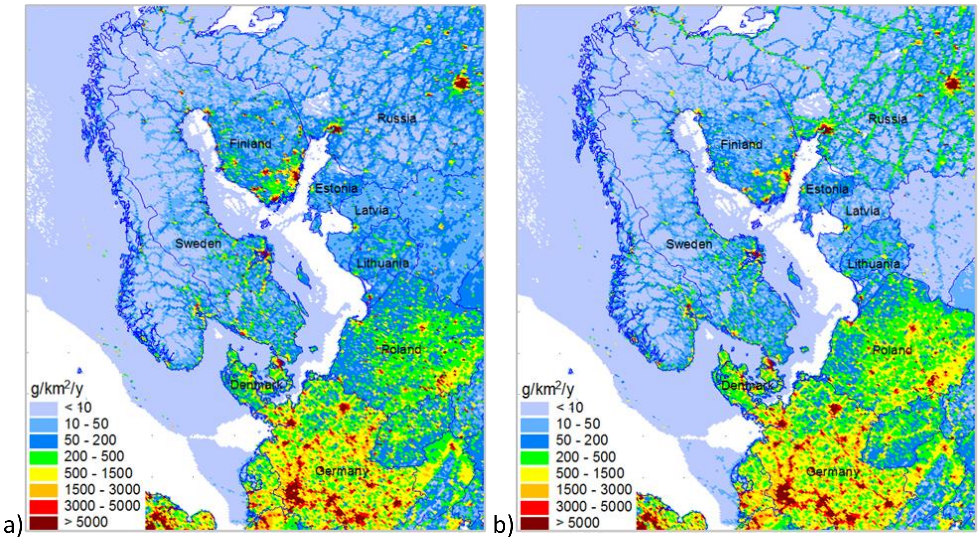

Figure 2. Spatial distribution of annual anthropogenic emissions of copper to the atmosphere in the Baltic Sea region in 1990 (a) and in 2019 (b), in g km^{-2} y^{-1}.

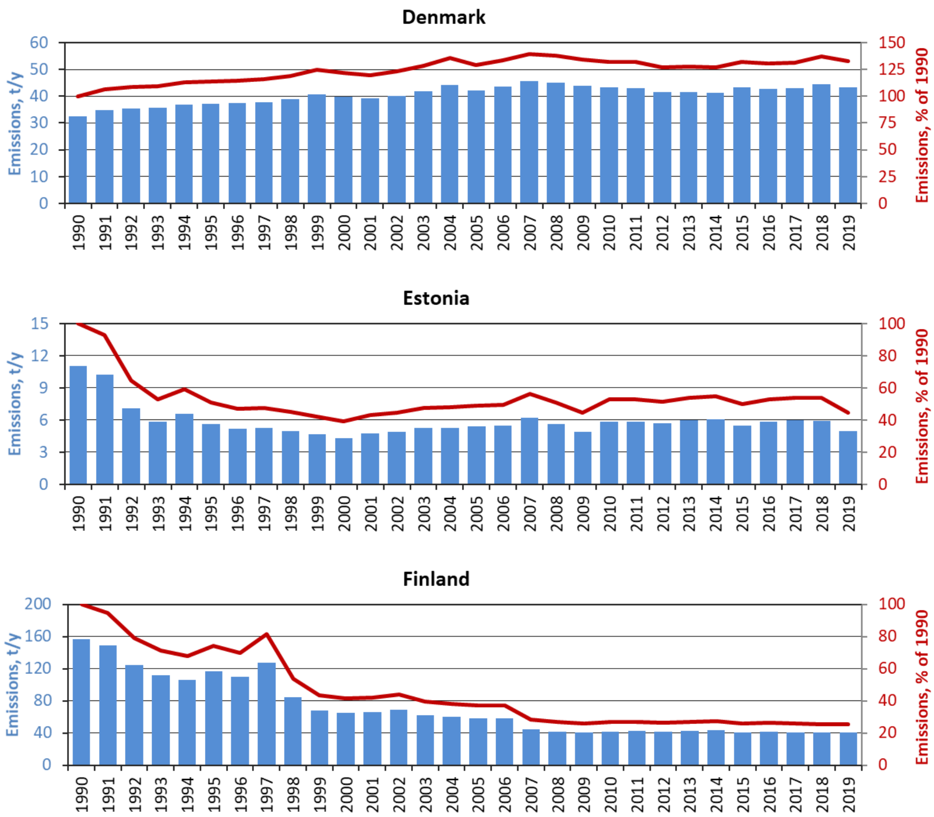

Figure 3. Copper emissions of the HELCOM Contracting Parties (CP) to the atmosphere for the period 1990-2019 in t y^{-1} (blue bars) and in % of 1990 (red line). The emission data of the CP refer to the total area of the CP except for Russia, where emissions from the territory of Russia within the EMEP domain is used.

Figure 3. (continued) Copper emissions of the HELCOM Contracting Parties (CP) to the atmosphere for the period 1990-2019 in t y^{-1} (blue bars) and in % of 1990 (red line). Green bars indicate expert estimates. The emission data of the CP refer to the total area of the CP except for Russia, where emissions from the territory of Russia within the EMEP domain is used.

Data

Numerical data on anthropogenic copper emissions of the HELCOM Contracting Parties are given in the following table.

Table 1. Copper emissions from anthropogenic sources of the HELCOM Contracting Parties, and other EMEP countries from 1990 to 2019.
Units: t y^{-1}.

	DK	EE	FI	DE	LV	LT	PL	RU	SE	HELCOM	Other
1990	32.6	11.0	157	620	4.6	7.8	185	800	64.8	1883	1926
1991	34.8	10.3	149	576	4.5	8.2	198	800	62.7	1843	2010
1992	35.4	7.1	124	548	3.7	5.1	199	800	71.4	1794	1870
1993	35.8	5.9	112	531	3.6	4.2	208	800	60.3	1760	1837
1994	36.9	6.6	106	516	3.1	3.6	196	800	51.4	1720	1859
1995	37.1	5.6	117	522	2.7	3.8	196	800	51.2	1735	1880
1996	37.4	5.2	110	521	2.8	3.8	208	800	52.3	1740	1928
1997	37.8	5.2	128	532	2.7	4.0	196	800	53.1	1760	1953
1998	38.9	5.0	84.5	532	2.7	4.2	177	800	51.5	1696	1966
1999	40.7	4.6	68.1	541	2.7	3.7	173	800	47.9	1682	1973
2000	39.7	4.3	65.3	544	2.9	3.3	153	800	45.2	1658	1937
2001	39.1	4.8	66.2	545	3.4	3.4	152	810	43.0	1666	1927
2002	40.2	4.9	69.3	545	3.4	3.6	150	819	41.3	1677	1976
2003	41.9	5.3	61.9	541	3.6	3.6	155	829	40.1	1681	2001
2004	44.2	5.3	60.0	549	3.7	4.0	162	838	38.7	1705	2010
2005	42.0	5.4	58.1	540	3.9	4.2	166	847	36.8	1704	2023
2006	43.5	5.4	58.6	553	4.3	4.5	177	857	37.1	1740	2044
2007	45.5	6.2	44.1	561	4.9	5.2	177	866	40.5	1751	2017
2008	45.0	5.6	42.0	559	4.4	5.3	182	876	38.2	1758	1938
2009	43.8	4.9	40.4	541	3.9	4.3	182	885	37.0	1742	1869
2010	43.2	5.8	42.0	549	4.1	4.4	199	894	37.6	1779	1835
2011	43.0	5.9	42.4	553	3.5	4.4	194	901	38.1	1785	1821
2012	41.5	5.7	41.2	555	3.5	4.5	193	908	37.5	1790	1783
2013	41.7	6.0	42.4	552	3.6	4.3	184	915	37.5	1787	1754
2014	41.4	6.0	43.1	567	3.8	4.7	182	922	37.9	1808	1774
2015	43.2	5.5	40.7	579	3.9	4.9	184	929	38.4	1828	1779
2016	42.7	5.8	41.6	584	4.0	5.0	193	936	39.2	1852	1784
2017	42.9	5.9	40.6	587	4.2	5.3	209	943	40.3	1878	1837
2018	44.6	5.9	40.2	585	4.3	5.7	210	950	40.7	1887	1838
2019	43.3	4.9	40.2	587	4.4	5.9	204	957	39.9	1886	1815

Meta data

Technical information:

1. Source:

Meteorological Synthesizing Centre East (MSC-E) of EMEP, Centre on Emission Inventories and Projections (CEIP) of EMEP.

2. Description of data:

Annual total emissions of copper were officially reported to the UN ECE Secretariat by the HELCOM Contracting Parties. These data are available from the EMEP Centre on Emission Inventories and Projections (CEIP) (http://www.ceip.at/). Expert estimates of spatial distribution of copper anthropogenic emissions within the EMEP region were prepared by MSC-E using officially reported gridded PM2.5 emissions.

3. Geographical coverage:

EMEP region

4. Temporal coverage:

Data on annual anthropogenic copper emissions are available for the period 1990 – 2019 for all HELCOM Contracting Parties with the exception of Russia. Copper emissions from Russian sources were based on expert estimates, worked out by TNO [*Denier van der Gon et al.*, 2005].

5. Methodology and frequency of data collection:

National data on copper emissions are annually submitted by countries Parties to LRTAP Convention to the UN ECE Secretariat. The methodology is based on the combination of measurements of releases to the atmosphere and estimation of emission based on activity data and emission factors. Submitted emission data are processed using quality assurance and quality control procedure and stored in the UN ECE/EMEP emission database at EMEP/CEIP Centre.

Quality information:

6. Strength and weakness:

Strength: data on emissions are annually submitted, checked and stored in the EMEP database

Weakness: gaps in sector distribution of national emissions, uncertainties in the emission factors and activity data, and lack of gridded emissions.

7. Uncertainty:

Officially reported emission data represent the best available information on temporal variations of Cu emissions in the EMEP region. It is believed that reported inventories cover the most significant anthropogenic sources of Cu emissions to the atmosphere. At the same time, for some of the countries significant uncertainties and incomplete information on sector distribution still exist.

Evaluation of emission uncertainties is made by the HELCOM contracting parties on the base of methodology presented in EMEP/EEA guidebook [*EEA*, 2019]. The methodology considers uncertainties of both the activity data and the emission factors applied for each emission sector. It is important to note that the uncertainties of emission factors are much higher than those for the activity data. For heavy metals the default value of emission factor uncertainty suggested by the guidebook exceeds 100%.

Among the HELCOM countries the level of uncertainty of official data on Cu emission was reported by Denmark, Finland, and Sweden. From other EMEP countries the information on uncertainties of Cu official emissions is available for Belarus, Belgium, Croatia, France, Monaco, Republic of Moldova, and the United Kingdom. The uncertainty of reported data on Cu emissions expressed as percentage relative to mean value of emission is as follows:

Denmark:	938%
Finland:	76%
Sweden:	62%
Belarus:	64%
Belgium:	207%
Croatia:	162%
France:	226%
Monaco:	28%
Republic of Moldova:	158%
UK:	±>50%

8. Further work required:

Further work to refine national inventories of copper emissions is required to reduce their uncertainties, to fill the gaps in sector distribution of emissions, and to generate gridded emission data. Besides, further studies to evaluate copper releases to the atmosphere from natural and secondary sources are of importance for the assessment of pollution levels.

References

Denier van der Gon D. H.A.C., van het Bolscher M., Visschedijk A.J.H. and P.Y.J.Zandveld [2005] Study to the effectiveness of the UNECE Heavy Metals Protocol and costs of possible additional measures. Phase I: Estimation of emission reduction resulting from the implementation of the HM Protocol. TNO-report B&O-A R 2005/193.

EEA [2019]. EMEP/EEA air pollutant emission inventory guidebook 2019. Technical guidance to prepare national emission inventories. EEA Report No 13/2019. 21 p.

Gautam R.K., Sharma S.K., Mahiya S. and Chattopadhyaya M.C. [2014]. CHAPTER 1: Contamination of Heavy Metals in Aquatic Media: Transport, Toxicity and Technologies for Remediation, in Heavy Metals In Water: Presence, Removal and Safety, 2014, ed. by Sharma S. pp. 1-24 DOI: 10.1039/9781782620174-00001

Flemming C.A. and Trevor J.T. [1989]. Copper toxicity and chemistry in the environment: a review. Water, Air, and Soil Pollution 44: 143-158.

Nriagu, J.O. 1989. A global assessment of natural sources of atmospheric trace metals. Nature, 338: 47-49.

Pacyna J.M. and Pacyna E.G [2001]. An assessment of global and regional emissions of trace metals to the atmosphere from anthropogenic sources worldwide. Environ. Rev. 9: 269–298.

Rauch J.N. and Pacyna J.M. [2009]. Earth's global Ag, Al, Cr, Cu, Fe, Ni, Pb, and Zn cycles. GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 23, GB2001, doi:10.1029/2008GB003376, 2009

Wu Y., Lin S., Tian H., Zhang K., Wang Y., Sun B., Liu X., Liu K., Xue Y., Hao J., Liu H., Liu S., Shao P., Luo L., Bai X., Liu W., Wu B., Zhao S. [2020]. A quantitative assessment of atmospheric emissions and spatial distribution of trace elements from natural sources in China. Environmental Pollution 259 (2020) 113918.