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Atmospheric Supply of Nitrogen, Cadmium, Mercury, Benzo(a)pyrene, and PBDEs to the Baltic Sea in 2014

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Summary

The results presented in this EMEP Centres Joint Report for HELCOM are based on the modelling and monitoring data presented to Second Joint Session of the Steering Body to the EMEP and the Working Group on Effects which took place 13-16 September 2016 in Geneva. It includes measurements, as well as emissions and depositions calculated by the EMEP models of nitrogen compounds, heavy metals and POPs for the year 2014.

The measured monthly and annual 2014 concentrations in air and precipitation for nitrogen species, heavy metals (HMs), and persistent organic pollutants (POPs) are presented in the report. There is a general tendency of decreasing concentrations from south to north for all relevant species, and for many species an east west gradient. Many of the components measured in air show a winter maxima due to longer atmospheric residence time. The seasonal patterns in precipitation are not as strong as for airborne components. This is due to the presence of the precipitation effect. Though the highest deposition of reduced nitrogen is seen in summer due to enhanced agricultural activity.

Emission data and meteorology are the most important inputs for the EMEP models. For the HELCOM purpose emissions are especially interesting. Annual emissions from the HELCOM Contractig Parties and from the ship traffic on the Baltic Sea in 2014 are shown below for all pollutants considered in the report.

Country/ship	POLLUTANT				
	NO_2 kt N	NH_3 kt N	Cd tonnes	Hg tonnes	B(a)P tonnes
Denmark	34	60	0.56	0.33	2.0
Estonia	10	11	0.90	0.68	2.0
Finland	42	30	0.82	0.63	2.6
Germany	373	609	6.50	9.14	25.2
Latvia	11	14	0.62	0.08	3.5
Lithuania	16	34	0.49	0.19	3.4
Poland	220	218	13.87	9.59	43.1
Russia	945	769	58.87	15.88	22.7
Sweden	41	44	0.57	0.45	3.7
HELCOM	**1692**	**1791**	**83**	**37**	**108**
Ship-Baltic	82				

The emissions for 2014 have been derived from the 2016 official data submissions to UNECE CLRTAP as of May 2016. The gridded distributions of the 2014 emissions have been provided by the EMEP Centre on Emission Inventories and Projections (CEIP). The

emissions for the period of 2000–2013 have been derived from the data submissions to UNECE CLRTAP as of May 2015. Re-submissions of emission data in 2016 are not included since the gridded data set for 2000–2013 has not been updated by CEIP this year.

Compared to 2013, nitrogen oxides emissions in 2014 from all HELCOM CPs are 3% lower. They are lower in Poland (9%), Denmark (8%), Finland (5%), Germany (4%), and Russia (2%). The annual NO_x emissions in 2014 are higher in four HELCOM countries compared to 2013. These are: Estonia (12%), Lithuania (11%), Sweden (7%), and Latvia (3%).

Annual 2014 NO_x ship emissions are taken from the official CEIP inventory and remain on the same level in 2013 and 2014. It should be mentioned that estimations of the ship emissions from the Baltic Sea developed by the Finnish Meteorological Institute based on AIS are 19% higher in 2014 than CEIP emissions.

Annual 2014 ammonia emissions from all HELCOM countries together are 4% higher in 2014 than in 2013. They are higher in seven, out of nine, HELCOM CPs and lower only in two countries: Denmark and Finland, 1% in both countries.

Among the HELCOM Contracting Parties, the largest per cent of 2014 nitrogen emissions deposited to the Baltic Sea basin can be noticed for Denmark (14.5%) and the lowest for Russia (0.6%). However, the percent of ship emissions from the Baltic Sea deposited to the Baltic Sea basin is the highest – 15.8%.

Annual emissions of cadmium, mercury, and benzo(a)pyrene have declined in the period from 1990 to 2014 by 39%, 48%, and 51%, respectively. In comparison to levels of emissions in 2013, cadmium and mercury emissions in 2014 were slightly higher by 1% and 0.4%, respectively, whereas emissions of benzo(a)pyrene were lower by 9%.

Calculated annual deposition of total nitrogen to the Baltic Sea basin in 2014 is 240 kt, approximately 9% higher than in 2013. Deposition of oxidised nitrogen is 6% higher and deposition of reduced nitrogen is 12% higher in 2014 compared to 2013. Since nitrogen emissions were on the same level in 2013 and 2014, the increase of deposition is mainly caused by meteorological conditions. Deposition of oxidised nitrogen accounted for 55% of total nitrogen deposition in 2014.

In 2016 consistent meteorological input data for the EMEP/MSC-W model were available for each year of the period 1995-2014. Therefore, for the first time in 2016, the same latest and the best version of the EMEP/MSC-W model has been used for calculating historical nitrogen depositions in the period 1995-2014. These historical depositions calculated in 2016 differ, sometimes significantly, from the time series of the depositions calculated in the past. This is mainly visible in deposition of oxidised

nitrogen and in wet deposition to the Baltic Sea basin. There is a clear descending tendency in deposition of oxidised nitrogen, whereas deposition of reduced nitrogen remains on similar level. Compared to 1995 depositions, annual deposition of oxidised nitrogen declined 27% and deposition of total nitrogen 17%. Annual deposition of reduced nitrogen remains on the same level in 2014 as in 1995.

Normalised nitrogen depositions to the Baltic Sea basin have been re-calculated in 2016 for the period 1995-2014. Normalised depositions of oxidised, reduced and total nitrogen to the Baltic Sea show clear decreasing pattern in the considered period.

Germany, Poland, ship traffic on the Baltic Sea and on the North Sea are the main emission sources contributing to oxidised nitrogen deposition into the Baltic Sea basin in 2014. They contribute with 18%, 13%, 12% and 8% of the total 2014 oxidised nitrogen deposition.

Concerning reduced nitrogen deposition, Germany dominates the picture with 29% contribution to total reduced nitrogen deposition in 2014. Next on the list are: Poland (15%), Denmark (10%) and Sweden (7%). Compared to oxidised nitrogen, there is definitely more contribution from the local sources located closer to the Baltic Sea basin.

The two main sources contributing to total nitrogen deposition to the Baltic Sea basin are: Germany (23%) and Poland (14%). They are followed by sources with similar contributions: ship traffic on the Baltic Sea (6%), Denmark (6%), Sweden (5%), Russia (5%), North Sea ship traffic (4%), United Kingdom (4%), France (4%), and Finland (3%). Emissions from all HELCOM contracting Parties together contribute to 61% of total nitrogen deposition in 2014. If we add emissions from ship traffic on the Baltic Sea, contribution to total nitrogen deposition in 2014 is 67%.

It should be noticed that contribution of distant emission sources like ship traffic on the North Sea, United Kingdom and France is also significant, especially for depositions of oxidised and total nitrogen.

The results of the EMEP/MSC-W model are routinely compared with available measurements at EMEP and HELCOM stations. The comparison of calculated versus measured data indicates that the model predicts the observed air concentrations and depositions of nitrogen compounds within the accuracy of approximately 30%.

According to modelling results cadmium, mercury, and benzo(a)pyrene depositions to the entire Baltic Sea have decreased from 1990 to 2014 by 54%, 24%, and 40%, respectively. The rate of deposition decrease was higher in the early 1990-s, however after 2000 it become smaller or almost levelled off. Annual depositions in 2014 were higher comparing to 2013 by 33% for cadmium, 9% for mercury, and 23% for benzo(a)pyrene,

which can be explained by inter-annual changes of meteorological conditions, in particular, variability of atmospheric transport.

Anthropogenic emission sources of HELCOM countries contributed to annual deposition over the Baltic Sea in 2014 about 27% for cadmium, 14% for mercury, and 59% for benzo(a)pyrene. Among the HELCOM countries the most significant contribution to cadmium, mercury, and benzo(a)pyrene deposition to the Baltic Sea in 2014 was made by Poland, Russia, and Germany. Along with anthropogenic emission sources significant contribution to cadmium and mercury deposition (more than 50%) was made natural emissions, re-suspension with dust, distant emissions, and re-emission.

Modelling results for cadmium, mercury, and benzo(a)pyrene were generally in reasonable agreement with measured concentrations for 2014. In particular, model predictions for cadmium concentrations were lower then measurements with relative bias equal to -15% for concentrations in air, and -37% for concentrations in precipitation. For mercury, modelling results slightly overestimated observed concentrations in air by 11%, and concentrations in precipitation by 18%. For benzo(a)pyrene, the model tended to underestimate observed air concentrations with relative bias -28%, and overestimate measured B(a)P deposition fluxes by 48%.

Comparison of modelling results with measurements indicated that about 60% of modelled cadmium concentrations in air and in precipitation were within an agreement of a factor of 2 with measurements. In case of mercury, more than 90% of modelled concentrations in air and 70% of concentrations in precipitation were within a factor of 2 with measurements. For benzo(a)pyrene, it was shown that about 80% of modelled air concentrations and 70% of deposition fluxes were within a factor of 2 with measured concentrations and deposition fluxes.

Pilot model evaluation of PBDE atmospheric input to the Baltic Sea from the emission sources of EMEP countries has been carried out. Results of model simulations and measurements for selected indicator congener BDE-99 were used to describe spatial variations of pollution levels in the Baltic Sea region for 2014. Model predictions indicated significant contribution of emissions from HELCOM countries to BDE-99 deposition over the Baltic Sea as well as transboundary transport from other EMEP countries.

Annual 2014 depositions of all considered pollutants to individual sub-basins and to the entire Baltic Sea basin are shown in the Table below.

Basin	POLLUTANT				
	Ox-N kt N	Red-N kt N	Cd tonnes	Hg tonnes	B(a)P tonnes
ARC	3.5	2.2	0.24	0.12	0.10
BAP	73.5	60.1	4.35	1.84	1.69
BOB	5.3	3.4	0.25	0.21	0.19
BOS	12.7	7.5	0.68	0.41	0.28
GUF	8.2	5.2	0.55	0.25	0.35
GUR	5.5	4.1	0.42	0.15	0.29
KAT	11.8	11.7	0.49	0.23	0.21
SOU	1.3	1.2	0.06	0.03	0.04
WEB	9.7	13.0	0.45	0.19	0.24
BAS	**131.3**	**108.3**	**7.5**	**3.4**	**3.4**

Preface

The Co-operative Program for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP) and the Baltic Marine Environment Protection Commission (HELCOM) are both conducting work on air monitoring modelling and compilation of emission inventories. In 1995, HELCOM decided to rationalise its current programs by avoiding duplication of efforts with specialised international organizations. At the request of HELCOM, the steering Body of EMEP at its nineteenth session agreed to assume the management of atmospheric monitoring data, the preparation of air emission inventories and the modelling of air pollution in the Baltic region.

Following the coordination meeting held in Potsdam in Germany and the Pollution Load Input meeting held in Klaipeda-Joudkrante in Lithuania, both 1996. It was agreed that EMEP Centres should be responsible for regular evaluation of the state of the atmosphere in the Baltic Sea region and should produce an annual joint summary report which includes updated emissions of selected air pollution, modelled deposition fields, allocation budgets and measurement data.

This report was prepared for HELCOM, based on model estimates and monitoring results presented to the Second Joint Session of the Steering Body to the EMEP and the Working Group on Effects which took place 13-16 September 2016 in Geneva. Following decision of the HELCOM /MONAS-10 Meeting, it presents the results for the year 2014.

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