# Atmospheric nitrogen depositions to the Baltic Sea in the period 1995-2014

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## Key message

Depositions of oxidised nitrogen and total nitrogen are 27% and 17% lower in 2014 than in 1995 respectively, while the reduced nitrogen deposition is 1% higher in 2014. There is a clear decreasing trend in normalised annual total deposition of nitrogen which corresponds to decreasing trend in nitrogen emissions from the HELCOM area of interest. Compared to 1995, normalised depositions of oxidised and reduced nitrogen in 2014 are lower: 36% and 12%, respectively.

## Results and Assessment

### Relevance of the indicator for describing the developments in the environment

This indicator shows the levels and trends in oxidized reduced and total atmospheric nitrogen depositions to the Baltic Sea. The deposition of nitrogen compounds represents the pressure of emission sources on the Baltic Sea basin and catchment.

### Policy relevance and policy reference

The HELCOM Ministerial Declaration of 1988 called for a 50 % reduction in discharges of nutrients to air and water by 1995 with 1987 as a base year. The 1992 Helsinki Convention and the 1998 Ministerial Declaration reaffirmed the need to further reduce discharges; leading to the adoption of several relevant Recommendations concerning measures to reduce emissions from point sources and diffuse sources. In 1990 HELCOM adopted its first Recommendation on Monitoring of Airborne Pollution Load (HELCOM Recommendation 11/1) which was later superseded by the Recommendations 14/1 and 24/1.

## Assessment

Atmospheric deposition of oxidized and reduced nitrogen was computed with the latest version of the EMEP/MSC-W model. The latest available emission data for the HELCOM countries and all other EMEP sources have been used in the model calculations presented here. Because of improvements in the model and emissions updated for previous years, deposition trends in the period 1995 – 2014 are different this year. This is mainly visible in deposition of oxidised nitrogen and in wet deposition to the Baltic Sea basin. There is a clear descending trend in deposition of oxidised nitrogen, whereas deposition of reduced nitrogen remains on similar level.

Calculated annual oxidized, reduced and total nitrogen depositions to the entire Baltic Sea basin in the period 1995 – 2014 are shown in **Figure 1**.

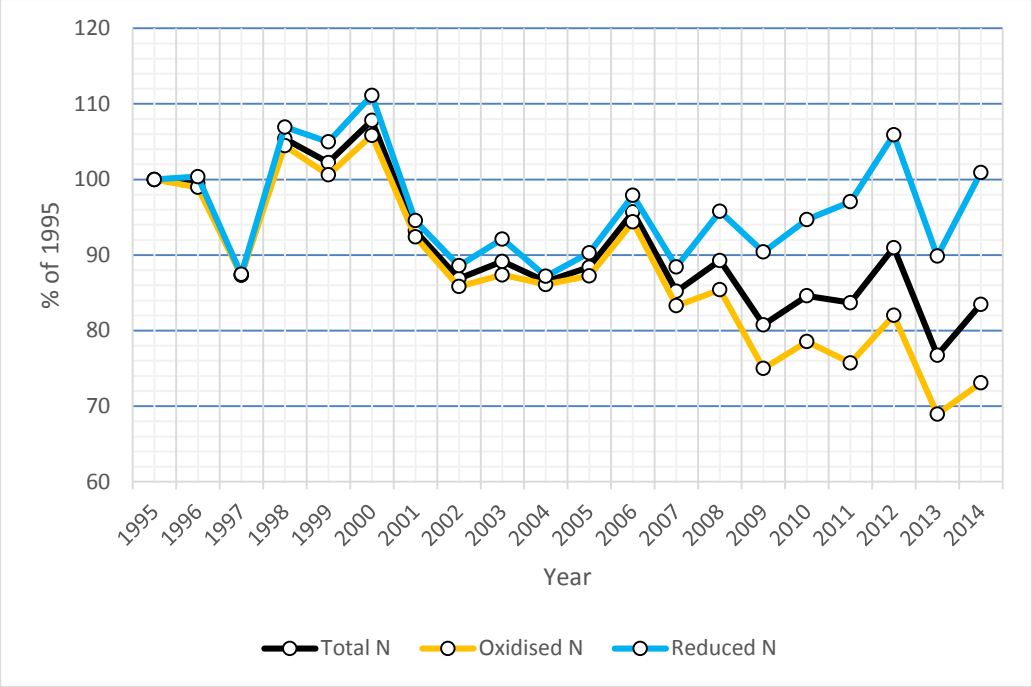


**Figure 1**. Atmospheric deposition of oxidised, reduced and total nitrogen to the entire Baltic Sea basin for the period 1995-2014, in per cent of 1995 value.

No significant trends could be detected in annual deposition of reduced nitrogen to the Baltic Sea basin in the considered period. However, a decreasing tendency is clearly visible in both depositions of oxidised and total nitrogen. Depositions of oxidised nitrogen and total nitrogen are 27% and 17% lower in 2014 than in 1995 respectively, while the reduced nitrogen deposition is 1% higher in 2014.

Mainly because of inter-annual changes in meteorological conditions, annual nitrogen deposition to the Baltic Sea and its sub-basins varies significantly from one year to another in the entire period 1995 – 2014. Maximum annual deposition of oxidized nitrogen (190 kt N), reduced nitrogen (119 kt N) and total nitrogen (309) to the Baltic Sea takes place in the same year 2000. Minimum of annual deposition can be noticed in the years 2013 and 2004 for oxidised nitrogen (124 kt N) and reduced nitrogen (94 kt N), respectively. Minimum of total nitrogen deposition (220 kt N) is in the same year as minimum of oxidized nitrogen deposition – 2013.

To avoid a strong influence of inter-annual meteorological variability on annual nitrogen deposition, the so called “normalised” nitrogen deposition was calculated in the way described in Appendix D of the EMEP report for HELCOM. The calculated normalised annual deposition of total nitrogen in the period 1995-2014 is shown in **Figure 2**.

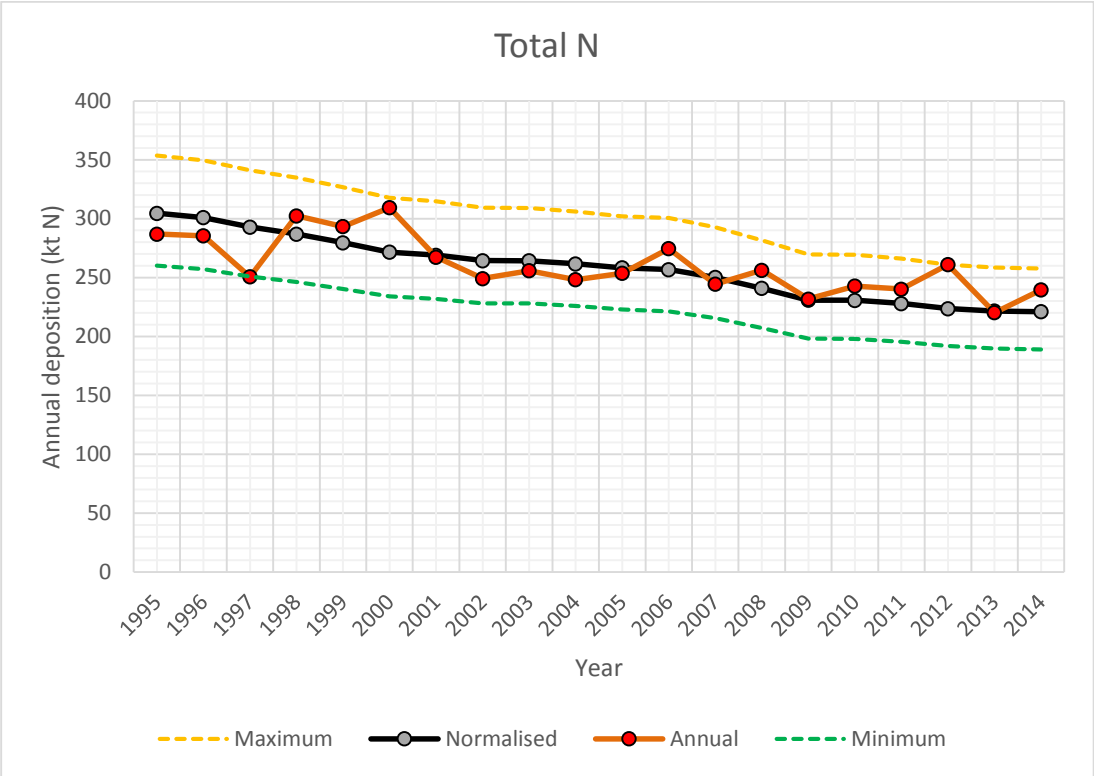


**Figure 2.** Normalised deposition of total nitrogen for the period 1995-2014. Minimum, maximum and actual annual values of the deposition are also shown. The minimum and maximum annual values are determined by the meteorological conditions for each particular year.

A quick inspection of Figure 2 indicates clearly decreasing trend in normalised annual total deposition of nitrogen which corresponds to decreasing trend in nitrogen emissions from the HELCOM area of interest. Compared to 1995, normalised depositions of oxidised and reduced nitrogen in 2014 are lower: 36% and 12%, respectively.

Calculated annual total nitrogen depositions to new nine sub-basins of the Baltic Sea in the period 1995 – 2014 are presented in **Figure 3**.

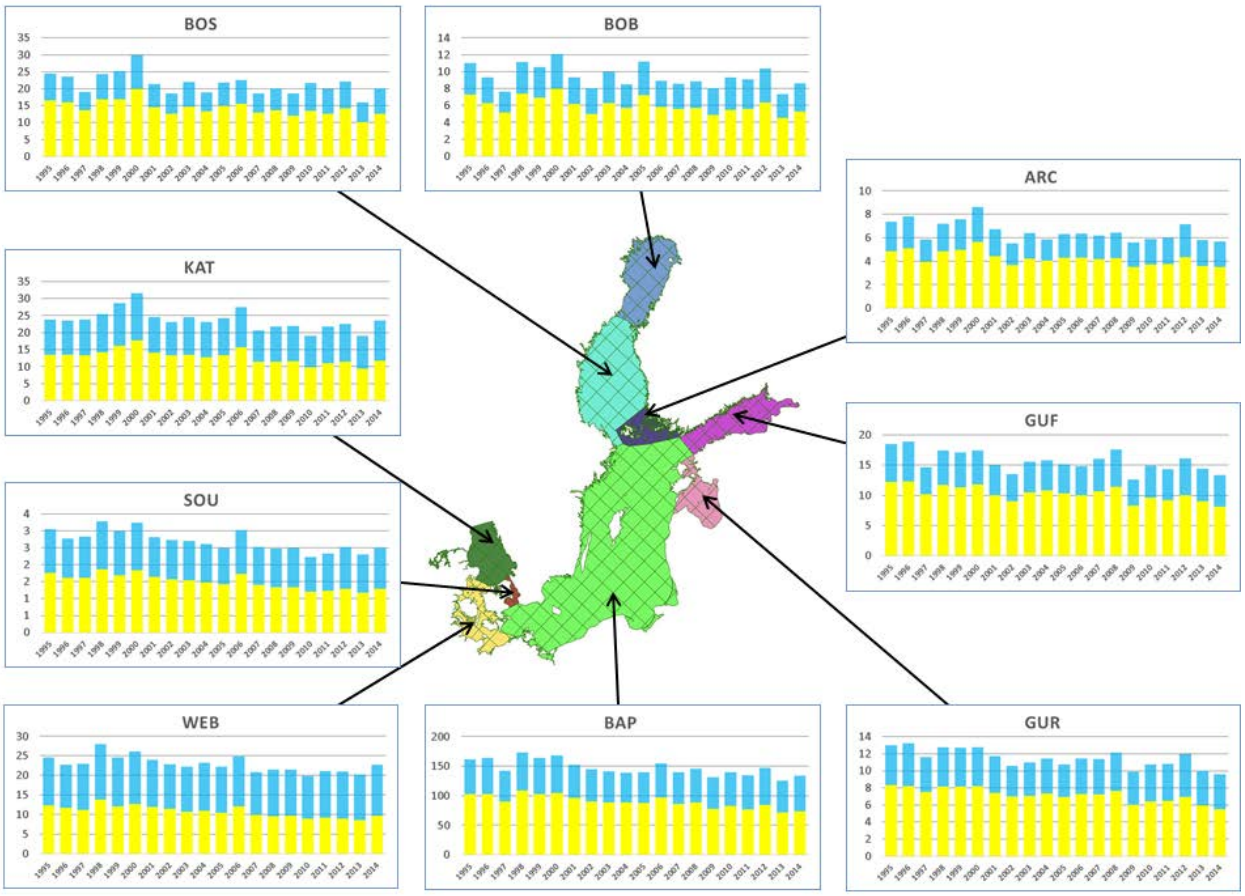


**Figure 3**. Atmospheric deposition of oxidised, reduced and total nitrogen to nine sub-basins of the Baltic Sea for the period 1995 - 2014. Units: ktonnes N/year. **Note**: the scales for the sea regions are different! Sub-basins: ARC=Archipelago Sea; BAP=Baltic Proper; BOB=Bothnian Bay; BOS=Bothnian Sea; GUB=Gulf of Bothnia; GUF=Gulf of Finland; GUR=Gulf of Riga; KAT=Kattegat; SOU=The Sound; WEB=Western Baltic.

Annual depositions of oxidised nitrogen are clearly lower (13-34%) in 2014 than in 1995 in all sub-basins. Also depositions of total nitrogen are lower in 2014 compared to 1995 in the range of 2-28%. Annual depositions of reduced nitrogen are higher in 2014 than in 1995 in three out of nine sub-basins only: KAT (13%), WEB (6%) and BAP (3%). They are lower (5-16%) in remaining six sub-basins. There is a significant inter-annual variability in annual nitrogen depositions to individual sub-basins, but for most of them maximum of the deposition can be noticed in the year 2000.

## Data

**Table 1**. Annual depositions of oxidised nitrogen to the sub-basins and the entire basin of the Baltic Sea in the period 1995-2014. Units: kt N per year and basin.

| YEAR | Sub-basin | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ARC | BAP | BOB | BOS | GUF | GUR | KAT | SOU | WEB | BAS |
| 1995 | 4.8 | 102.8 | 7.3 | 16.5 | 12.3 | 8.3 | 13.5 | 1.8 | 12.3 | 179.6 |
| 1996 | 5.1 | 103.0 | 6.3 | 16.1 | 12.3 | 8.2 | 13.4 | 1.6 | 11.7 | 177.8 |
| 1997 | 4.0 | 90.3 | 5.2 | 13.7 | 10.2 | 7.5 | 13.4 | 1.6 | 11.2 | 156.9 |
| 1998 | 4.9 | 108.7 | 7.4 | 16.9 | 11.7 | 8.2 | 14.3 | 1.9 | 13.8 | 187.7 |
| 1999 | 5.0 | 102.7 | 6.9 | 16.8 | 11.4 | 8.2 | 16.1 | 1.7 | 12.1 | 180.7 |
| 2000 | 5.6 | 104.2 | 8.0 | 19.9 | 11.9 | 8.2 | 17.7 | 1.8 | 12.8 | 190.1 |
| 2001 | 4.4 | 95.8 | 6.2 | 14.5 | 10.1 | 7.4 | 14.0 | 1.6 | 11.9 | 166.0 |
| 2002 | 3.7 | 90.5 | 5.0 | 12.6 | 9.1 | 7.0 | 13.3 | 1.6 | 11.5 | 154.2 |
| 2003 | 4.2 | 88.4 | 6.3 | 14.7 | 10.5 | 7.1 | 13.5 | 1.5 | 10.7 | 157.0 |
| 2004 | 4.0 | 88.1 | 5.7 | 13.4 | 10.8 | 7.4 | 12.8 | 1.5 | 11.0 | 154.7 |
| 2005 | 4.3 | 87.7 | 7.2 | 14.9 | 10.3 | 6.9 | 13.4 | 1.4 | 10.5 | 156.7 |
| 2006 | 4.3 | 97.1 | 5.8 | 15.5 | 10.0 | 7.3 | 15.6 | 1.7 | 12.1 | 169.5 |
| 2007 | 4.2 | 86.3 | 5.6 | 12.9 | 10.7 | 7.3 | 11.4 | 1.4 | 10.0 | 149.6 |
| 2008 | 4.3 | 88.2 | 5.7 | 13.7 | 11.4 | 7.6 | 11.5 | 1.3 | 9.6 | 153.4 |
| 2009 | 3.5 | 77.3 | 4.9 | 12.1 | 8.3 | 6.0 | 11.6 | 1.3 | 9.6 | 134.7 |
| 2010 | 3.7 | 82.4 | 5.5 | 13.5 | 9.6 | 6.4 | 9.9 | 1.2 | 8.9 | 141.1 |
| 2011 | 3.7 | 76.9 | 5.6 | 12.7 | 9.2 | 6.5 | 11.0 | 1.2 | 9.2 | 136.0 |
| 2012 | 4.3 | 83.9 | 6.3 | 14.2 | 10.0 | 6.9 | 11.5 | 1.3 | 8.9 | 147.4 |
| 2013 | 3.6 | 71.4 | 4.5 | 10.2 | 9.0 | 6.0 | 9.4 | 1.2 | 8.5 | 123.8 |
| 2014 | 3.5 | 73.5 | 5.3 | 12.7 | 8.2 | 5.5 | 11.8 | 1.3 | 9.7 | 131.3 |

**Table 2**. Annual depositions of reduced nitrogen to the sub-basins and the entire basin of the Baltic Sea in the period 1995-2014. Units: kt N per year and basin.

| YEAR | Sub-basin | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ARC | BAP | BOB | BOS | GUF | GUR | KAT | SOU | WEB | BAS |
| 1995 | 2.5 | 58.3 | 3.7 | 8.0 | 6.2 | 4.7 | 10.3 | 1.3 | 12.3 | 107.3 |
| 1996 | 2.7 | 60.6 | 3.0 | 7.6 | 6.6 | 5.0 | 10.0 | 1.2 | 11.0 | 107.7 |
| 1997 | 1.9 | 52.0 | 2.5 | 5.4 | 4.5 | 4.1 | 10.5 | 1.2 | 11.7 | 93.8 |
| 1998 | 2.3 | 64.2 | 3.7 | 7.5 | 5.7 | 4.6 | 11.1 | 1.4 | 14.2 | 114.7 |
| 1999 | 2.6 | 61.2 | 3.7 | 8.4 | 5.8 | 4.6 | 12.6 | 1.3 | 12.6 | 112.6 |
| 2000 | 3.0 | 63.4 | 4.1 | 10.0 | 5.6 | 4.6 | 13.9 | 1.4 | 13.4 | 119.3 |
| 2001 | 2.3 | 56.1 | 3.2 | 6.9 | 4.9 | 4.3 | 10.5 | 1.2 | 12.1 | 101.5 |
| 2002 | 1.8 | 53.9 | 3.0 | 6.0 | 4.4 | 3.6 | 9.9 | 1.2 | 11.3 | 95.1 |
| 2003 | 2.2 | 53.1 | 3.7 | 7.3 | 5.0 | 3.9 | 11.0 | 1.2 | 11.5 | 98.8 |
| 2004 | 1.8 | 50.7 | 2.8 | 5.5 | 5.0 | 4.1 | 10.3 | 1.1 | 12.2 | 93.6 |
| 2005 | 2.0 | 51.8 | 4.0 | 6.9 | 4.8 | 3.8 | 10.8 | 1.1 | 11.7 | 96.9 |
| 2006 | 2.0 | 57.9 | 3.1 | 7.1 | 4.8 | 4.2 | 11.9 | 1.3 | 12.7 | 105.0 |
| 2007 | 2.0 | 53.4 | 3.0 | 5.8 | 5.4 | 4.1 | 9.2 | 1.1 | 10.9 | 94.9 |
| 2008 | 2.2 | 57.1 | 3.1 | 6.4 | 6.2 | 4.5 | 10.3 | 1.2 | 11.9 | 102.8 |
| 2009 | 2.1 | 53.9 | 3.2 | 6.5 | 4.3 | 3.9 | 10.3 | 1.2 | 11.8 | 97.0 |
| 2010 | 2.2 | 56.7 | 3.9 | 8.1 | 5.3 | 4.3 | 9.1 | 1.0 | 10.9 | 101.6 |
| 2011 | 2.2 | 57.9 | 3.5 | 7.3 | 5.2 | 4.3 | 10.7 | 1.1 | 11.9 | 104.1 |
| 2012 | 2.8 | 63.3 | 4.1 | 7.9 | 6.2 | 5.0 | 11.1 | 1.2 | 12.1 | 113.7 |
| 2013 | 2.2 | 53.8 | 2.8 | 5.8 | 5.4 | 4.0 | 9.6 | 1.1 | 11.6 | 96.4 |
| 2014 | 2.2 | 60.1 | 3.4 | 7.5 | 5.2 | 4.1 | 11.7 | 1.2 | 13.0 | 108.3 |

**Table 3**. Annual depositions of total nitrogen to the sub-basins and the entire basin of the Baltic Sea in the period 1995-2014. Units: kt N per year and basin.

| YEAR | Sub-basin | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ARC | BAP | BOB | BOS | GUF | GUR | KAT | SOU | WEB | BAS |
| 1995 | 7.4 | 161.1 | 11.0 | 24.5 | 18.5 | 13.0 | 23.9 | 3.1 | 24.6 | 286.9 |
| 1996 | 7.8 | 163.6 | 9.3 | 23.6 | 18.9 | 13.3 | 23.5 | 2.8 | 22.7 | 285.4 |
| 1997 | 5.8 | 142.3 | 7.6 | 19.1 | 14.7 | 11.6 | 23.9 | 2.8 | 22.9 | 250.7 |
| 1998 | 7.2 | 172.9 | 11.1 | 24.4 | 17.4 | 12.8 | 25.4 | 3.3 | 28.0 | 302.4 |
| 1999 | 7.5 | 163.9 | 10.6 | 25.2 | 17.1 | 12.7 | 28.7 | 3.0 | 24.6 | 293.4 |
| 2000 | 8.6 | 167.7 | 12.1 | 29.8 | 17.4 | 12.8 | 31.6 | 3.2 | 26.1 | 309.3 |
| 2001 | 6.7 | 151.9 | 9.3 | 21.5 | 15.0 | 11.7 | 24.5 | 2.8 | 24.0 | 267.4 |
| 2002 | 5.5 | 144.4 | 8.0 | 18.6 | 13.5 | 10.6 | 23.1 | 2.7 | 22.8 | 249.2 |
| 2003 | 6.4 | 141.5 | 10.0 | 22.0 | 15.6 | 11.0 | 24.5 | 2.7 | 22.2 | 255.8 |
| 2004 | 5.9 | 138.8 | 8.5 | 18.9 | 15.8 | 11.4 | 23.1 | 2.6 | 23.2 | 248.2 |
| 2005 | 6.3 | 139.5 | 11.2 | 21.8 | 15.2 | 10.8 | 24.2 | 2.5 | 22.2 | 253.6 |
| 2006 | 6.3 | 155.0 | 8.9 | 22.6 | 14.9 | 11.5 | 27.5 | 3.0 | 24.9 | 274.6 |
| 2007 | 6.2 | 139.6 | 8.5 | 18.7 | 16.1 | 11.4 | 20.7 | 2.5 | 20.9 | 244.5 |
| 2008 | 6.5 | 145.3 | 8.8 | 20.1 | 17.6 | 12.2 | 21.8 | 2.5 | 21.5 | 256.2 |
| 2009 | 5.6 | 131.2 | 8.1 | 18.6 | 12.6 | 9.9 | 21.9 | 2.5 | 21.5 | 231.7 |
| 2010 | 5.9 | 139.1 | 9.3 | 21.7 | 14.9 | 10.7 | 19.0 | 2.2 | 19.8 | 242.7 |
| 2011 | 6.0 | 134.9 | 9.1 | 20.0 | 14.4 | 10.8 | 21.7 | 2.3 | 21.1 | 240.2 |
| 2012 | 7.2 | 147.2 | 10.4 | 22.1 | 16.2 | 11.9 | 22.6 | 2.5 | 21.0 | 261.0 |
| 2013 | 5.8 | 125.2 | 7.3 | 16.0 | 14.4 | 10.0 | 19.0 | 2.3 | 20.2 | 220.2 |
| 2014 | 5.7 | 133.5 | 8.6 | 20.1 | 13.4 | 9.6 | 23.5 | 2.5 | 22.7 | 239.6 |

**Table 4**. Normalized depositions of oxidised, reduced and total nitrogen to the Baltic Sea basin in the period 1995-2014. Units: kt N per year.

| Year | Oxidised | Reduced | Total |
|---|---|---|---|
| 1995 | 191.5 | 113.1 | 304.6 |
| 1996 | 189.7 | 111.3 | 300.9 |
| 1997 | 182.5 | 110.5 | 292.9 |
| 1998 | 177.7 | 109.6 | 286.9 |
| 1999 | 172.8 | 107.4 | 279.6 |
| 2000 | 168.1 | 104.2 | 271.6 |
| 2001 | 166.1 | 103.5 | 268.9 |
| 2002 | 162.8 | 102.1 | 264.3 |
| 2003 | 163.2 | 101.6 | 264.3 |
| 2004 | 161.3 | 100.7 | 261.7 |
| 2005 | 159.1 | 99.5 | 258.2 |
| 2006 | 157.3 | 99.9 | 256.8 |
| 2007 | 151.1 | 99.5 | 250.2 |
| 2008 | 142.8 | 98.7 | 240.8 |
| 2009 | 134.1 | 97.5 | 230.9 |
| 2010 | 135.2 | 96.3 | 230.7 |
| 2011 | 131.9 | 97.0 | 228.0 |
| 2012 | 128.9 | 95.6 | 223.6 |
| 2013 | 126.4 | 96.0 | 221.5 |
| 2014 | 122.3 | 99.7 | 221.1 |

## Metadata

### Technical information

1. Source: EMEP/MSC-W.

2. Description of data: The atmospheric depositions of oxidized and reduced nitrogen were calculated with the latest version of EMEP/MSC-W model in Oslo. The latest available official emission data for the HELCOM countries have been used in the model computations. Emissions of two nitrogen compounds for each year of this period were officially reported to the UN ECE Secretariat by the HELCOM Contracting Parties. Missing information was estimated by experts. Both official data and expert estimates were used for modeling atmospheric transport and deposition of nitrogen compounds to the Baltic Sea - http://www.ceip.at/ .

3. Geographical coverage: Atmospheric depositions of oxidized and reduced nitrogen were computed for the entire EMEP domain, which includes Baltic Sea basin and catchment.

4. Temporal coverage: Time series of annual atmospheric depositions are available for the period 1995 – 2014.

5. Methodology and frequency of data collection:

Atmospheric input and source allocation budgets of nitrogen (oxidised, reduced and total) to the Baltic Sea basins and catchments were computed using the latest version of EMEP/MSC-W model. EMEP/MSC-W model is a multi pollutant, three-dimensional Eulerian model which takes into account processes of emission, advection, turbulent diffusion, chemical transformations, wet and dry depositions and inflow of pollutants into the model domain. Complete description of the model and its applications is available on the web http://www.emep.int.

Calculations of atmospheric transport and depositions of nitrogen compounds are performed annually two years in arrears on the basis of emission data officially submitted by Parties to CLRTAP Convention and expert estimates.

### Quality information

6. Strength and weakness:

Strength: annually updated information on atmospheric input of oxidized and reduced nitrogen to the Baltic Sea and its sub-basins.

Weakness: gaps and uncertainties in officially submitted by countries time series of nitrogen emissions to air increase the uncertainty of computed depositions.

7. Uncertainty:

The results of the EMEP Unified 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 of nitrogen within the accuracy of approximately 30%.

8. Further work required:

Further work is required on reducing uncertainties in emission data and better parameterization of physical processes in the EMEP Unified model.

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