PRESSURE

# Pollution load on the Baltic Sea

## Summary of the HELCOM Seventh Pollution Load Compilation

# (PLC-7)

Baltic Marine Environment Protection Commission

Monitoring & assessment

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# Pollution load on the Baltic Sea

*Summary of the HELCOM Seventh Pollution Load Compilation*

## Table of Contents

## Terms used in PLC

TN – total nitrogen

TP – total phosphorus

Sub-basin division units of the Baltic Sea used for the HELCOM assessment of input of nutrients: Kattegat (KAT), Baltic Proper (BAP), Gulf of Riga (GUR), Gulf of Finland (GUF), Bothnian Sea (BOS) and Bothnian Bay (BOB). The whole Baltic Sea is abbreviated BAS.

Baltic Sea Shipping – Maritime traffic taking place in the Baltic Sea

Other countries (as referred in Figures 6 and 7) – include sources for atmospheric nitrogen deposition as the 20 EU countries not being HELCOM countries, countries outside EU including Belarus, Ukraine, etc.

Riverine input – The amount of a substance carried to the maritime area by a watercourse (natural or man-made) per unit of time

Direct input – Point sources (municipal wastewater treatment plants (MWWTP), industrial plants and aquaculture plants) discharging (defined by location of the outlet) directly to the sea

Reallocation of extra reduction – accounting for reductions below the requirements, in proportion to the effect on a neighboring basin.

EQS – environmental quality standard

# 1 PREFACE - The Seventh Pollution Load Compilation (PLC-7)

Land-based pollution remains the major source of environmental pressure on the Baltic Sea ecosystem. This pressure includes eutrophication, caused by excess supply of nutrients (nitrogen and phosphorus) to the marine environment and contamination by heavy metals, persistent organic pollutants and other synthetic hazardous substances. One of the largest Baltic Marine Environment Protection Commission or HELCOM projects, Pollution Load Compilation (PLC), is intended to supply the most up-to-date information on land-based input of nutrients and selected hazardous substances to the marine environment, their sources and pathways.

Compilation of data on the pollution load has been an integral part of the HELCOM assessment system since 1987. It includes annual and periodic reporting of national data and subsequent release of related assessment products. The assessment creates scientific background for the Contracting Parties to follow up progress towards regional and national environmental targets, undertake measures to prevent pollution of the Baltic marine environment (Article 16 of the Helsinki Convention) and evaluate their effectiveness. Most recently, the Seventh HELCOM Pollution Load Compilation (PLC-7) has delivered the following major products:

1. Annual update of HELCOM Core Pressure Indicator on nutrient inputs (Maximum Allowable Inputs (MAI) fulfilment follow-up) covering data from 1995 to 2018 (link to publication).
2. Assessment of progress towards national nutrient input ceilings (NIC assessment) covering data from 1995 to 2017 (key policy message and assessment results).
3. Assessment of sources and pathways of nutrients into the Baltic Sea environment in 2017 (link to publication).
4. Input of nutrients by the seven biggest rivers from 1995 to 2017 (link to publication).
5. Evaluation of effectiveness of measures to reduce nutrient inputs to the Baltic Sea (link to publication).
6. Assessment of input of selected hazardous substances (link to publication).

## PLC data

Scientifically sound and compatible data on pollution loads across the region is the key factor for reliable assessment results. The HELCOM PLC is based on national data on waterborne inputs from all Contracting Parties obtained mainly through national monitoring programmed. Monitored areas cover about 90% of the Baltic Sea catchment (Figure 1). Monitoring methodology is harmonized across the region utilizing regularly updated HELCOM PLC Water Guideline and HELCOM Recommendation 37-38/1. A regional intercalibration campaign carried out at the initial stage of the PLC-7 project assures data consistency. Input of nutrients from unmonitored areas (10% the Baltic Sea catchment area) is estimated by countries utilizing respective national calculating methods. Data on waterborne inputs of nutrients and selected hazardous substances are reported in the unified format using online reporting tools of the HELCOM PLC-water database. These reporting tools also perform initial data quality verification based on technical protocols and statistical analysis. Further, the data quality is verified manually by national data reporters and quality assurers. HELCOM experts fill in remaining data gaps using statistical tools and expert assessment with subsequent final approval of all data by national representatives in the PLC project. Reported data are available through the public interface of the HELCOM PLC-water database.

All data on waterborne input of nutrients are visualized as maps in the HELCOM Map and Data Service (MADS). Data on atmospheric inputs is annually provided by the co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe, EMEP, based on national reports of nitrogen emissions and emissions from the North Sea and Baltic Sea ship traffic computed by Finnish Meteorological Institute using “STEAM” model. Atmospheric deposition of phosphorus is constant and accounted as a fixed rate of 5 kg phosphorus per $km^2$.

Overviews of the reported data on airborne and waterborne inputs of nutrients are regularly published as HELCOM Baltic Sea Environment Fact Sheets (BSEFS). The BSEFSs do not contain assessment results but provide the results of the most resent observations.

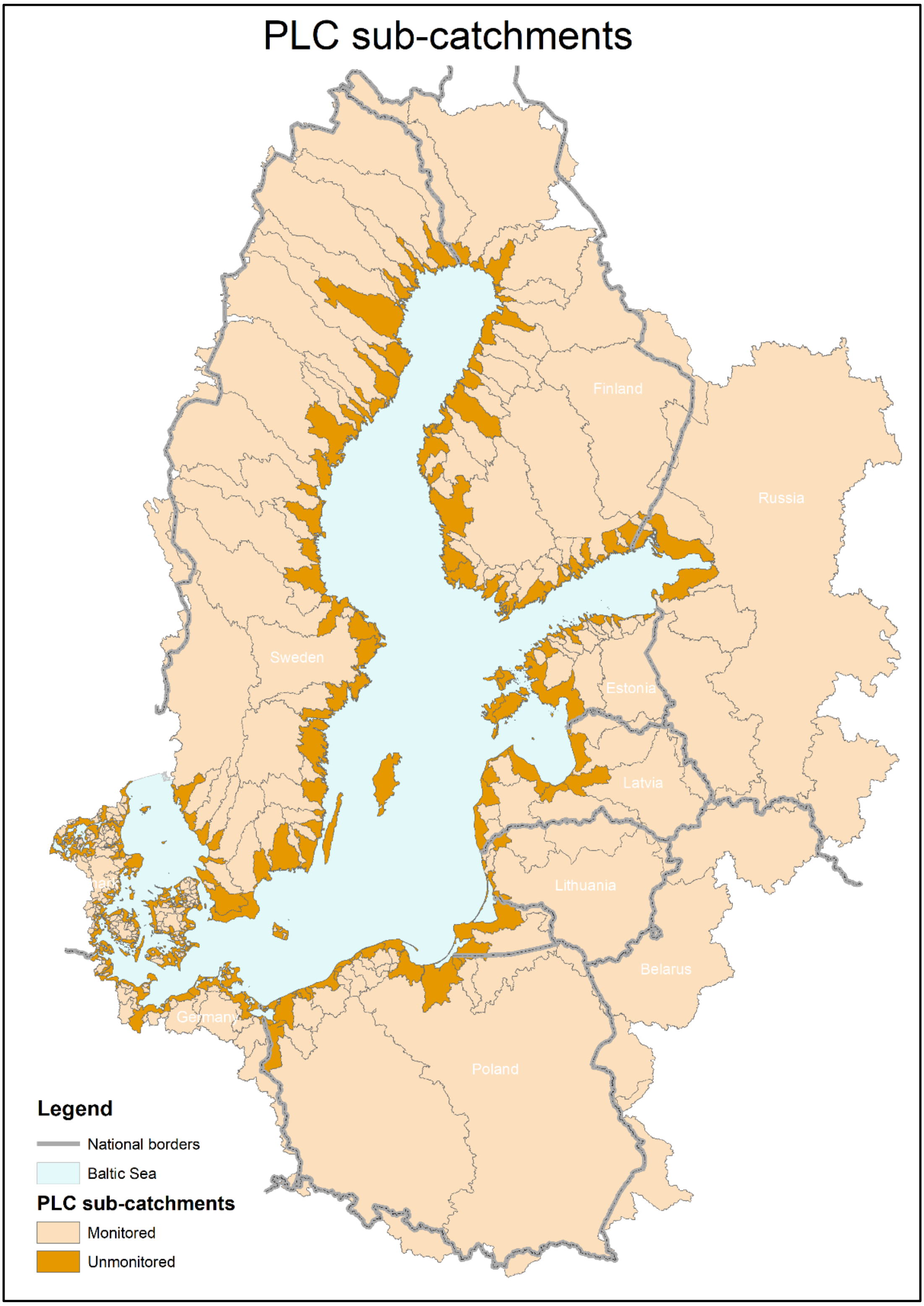



**Figure 1**. Monitored and unmonitored areas in the Baltic Sea catchment.

## MAI - Maximum Allowable Inputs

*Maximum Allowable Inputs of nutrients (MAI)* are a part of the HELCOM nutrient reduction scheme, indicating the maximum level of total (water- and airborne) input of nitrogen and phosphorus to the Baltic Sea sub-basins (map of MAI fulfilment at the HELCOM map service) that is allowed to fulfil the targets for a sea unaffected by eutrophication. The targets were first included into the Baltic Sea Action Plan in 2007 and then updated in the Copenhagen Ministerial Declaration in 2013. Brussels Ministerial Declaration 2018 confirmed that reduction requirements for nutrient inputs are based on the maximum allowable inputs which remain unchanged. Input of nutrients is one of the HELCOM core pressure indicators.

## 2 Progress towards MAI

A significant reduction of nutrient inputs has been achieved for the whole Baltic Sea by 2018. The latest assessment shows that the normalized input of nitrogen was reduced by 12% and phosphorus inputs by 26% since the reference period (1997-2003) (Figure 2). MAI of nitrogen in this period were fulfilled in the Bothnian Bay, Bothnian Sea, Danish Straits and Kattegat (Table 1a). MAI of phosphorus were fulfilled in the Bothnian Bay, Bothnian Sea, Danish Straits and Kattegat (Table 1b). The input to the Gulf of Finland is below MAI but cannot be considered as fulfilled due to statistical uncertainty.

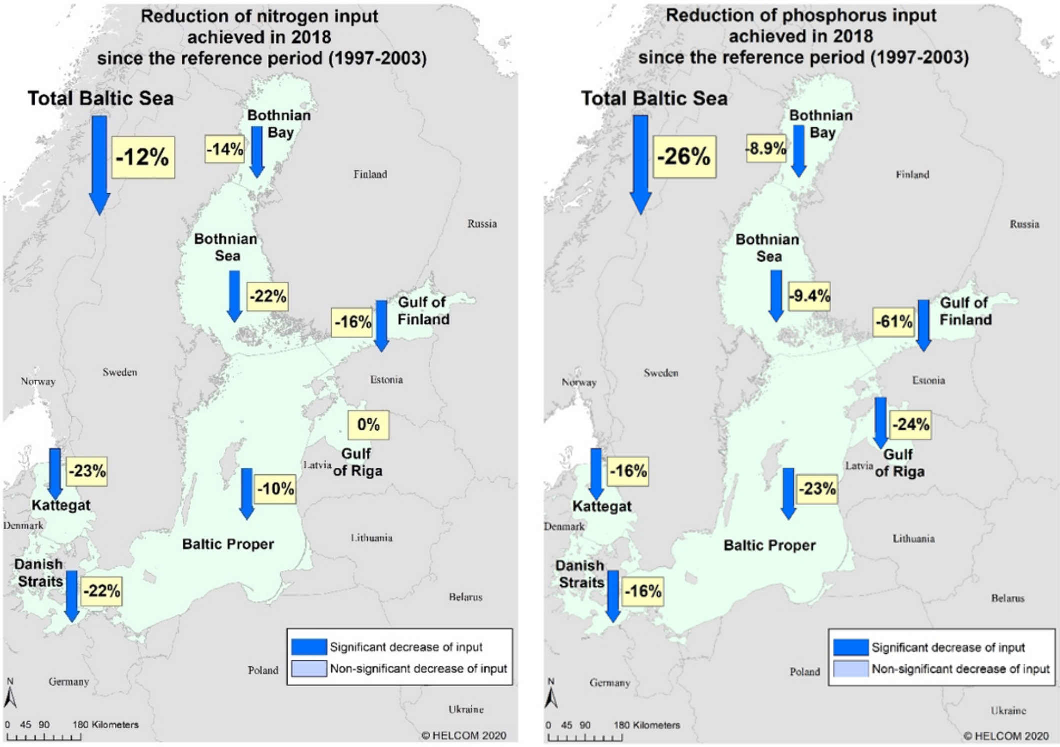



**Figure 2**. Reduction of total nitrogen and total phosphorus inputs since the reference period (1997-2003).

**Tables 1**. The trend-based estimate for normalized annual inputs of A) nitrogen (TN) and B) phosphorus (TP) in 2018. The table also contains data on statistical uncertainty, the remaining reduction needed to reach MAI and inputs in 2018 including statistical uncertainty in percentages of MAI. Classification of achieving MAI is given in colours: green=MAI fulfilled, yellow= fulfilment is not determined due to statistical uncertainty, and red=MAI not fulfilled. (Units in columns 2-5: tonnes per year). NOTE: *For consistency with MAI no rounding (to tenth, hundreds or thousands) has been performed in the indicator*.

**1A**

| Baltic Sea Sub-basin | MAI* | N input 2018 | Statistical uncertainty 2018 | N input including stat. uncert. 2018 | Exceedance of MAI in 2018 | Input 2018 including stat. uncertainty in % of MAI | Classification of achieved reduction |
|---|---|---|---|---|---|---|---|
| **Bothnian Bay (BOB)** | 57 622 | 53 628 | 1 452 | 55 080 | | 96 | green |
| **Bothnian Sea (BOS)** | 79 372 | 68 541 | 2 073 | 70 615 | | 89 | green |
| **Baltic Proper (BAP)** | 325 000 | 404 613 | 9 977 | 414 590 | 89 590 | 128 | red |
| **Gulf of Finland (GUF)** | 101 800 | 108 468 | 7 202 | 115 671 | 13 871 | 114 | red |
| **Gulf of Riga (GUR)** | 88 417 | 89 308 | 3 751 | 93 059 | 4 642 | 105 | red |
| **Danish Straits (DS)** | 65 998 | 56 719 | 1 964 | 58 683 | | 89 | green |
| **Kattegat (KAT)** | 74 000 | 66 434 | 1 472 | 67 906 | | 92 | green |
| **Baltic Sea (BAS)** | **792 209** | **864 148** | **14 515** | **878 663** | **86 454** | **111** | red |

**1B**

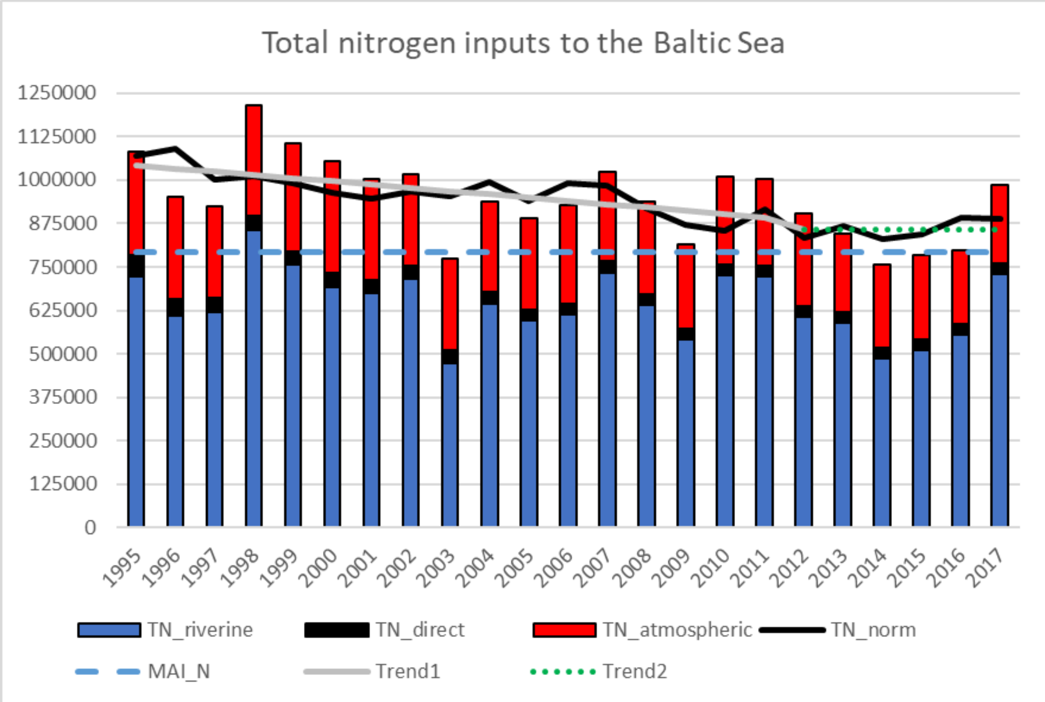
| Baltic Sea Sub-basin | MAI* | P input 2018 | Statistical uncertain-ty 2018 | P input including stat. uncert. 2018 | Exceeda n-ce of MAI in 2018 | Input 2018 incl. stat. uncertaint y in % of MAI | Classificati on of achieved reduction |
|---|---|---|---|---|---|---|---|
| **Bothnian Bay (BOB)** | 2 675 | 2 569 | 87 | 2 655 | | 99 | |
| **Bothnian Sea (BOS)** | 2 773 | 2 548 | 75 | 2 623 | | 95 | |
| **Baltic Proper (BAP)** | 7 360 | 13 585 | 606 | 14 191 | 6 831 | 193 | |
| **Gulf of Finland (GUF)** | 3 600 | 3 178 | 1 226 | 4 405 | 805** | 122 | |
| **Gulf of Riga (GUR)** | 2 020 | 2 191 | 198 | 2 389 | 369 | 118 | |
| **Danish Straits (DS)** | 1 601 | 1 235 | 52 | 1 287 | | 80 | |
| **Kattegat (KAT)** | 1 687 | 1 399 | 50 | 1 449 | | 86 | |
| **Baltic Sea (BAS)** | **21 716** | **27 518** | **998** | **28 516** | **6 800** | **131** | |

*As adopted by the 2013 HELCOM Copenhagen Ministerial Meeting (HELCOM 2013a)

**Exceedance of MAI is caused by statistical data uncertainty.

Analysis of nutrient input trends for the whole observation period starting from 1995 shows statistically significant reduction of total inputs of nitrogen and phosphorus to the Baltic Sea reaching 20 % and 33%, respectively, by 2018 (Figures 3a and 3b). A constant decreasing trend illustrating reduction of nitrogen input to the whole Baltic is observed until 2008. But no nitrogen input reduction has been observed in the last decade. Unlike nitrogen, the input of phosphorus demonstrates a steady reduction trend throughout the whole observation period. The latest published HELCOM core indicator on input of nutrients provides also illustration of long-term nutrient input trends (1995-2018) for individual sub-basins.

**3A**




**3B**

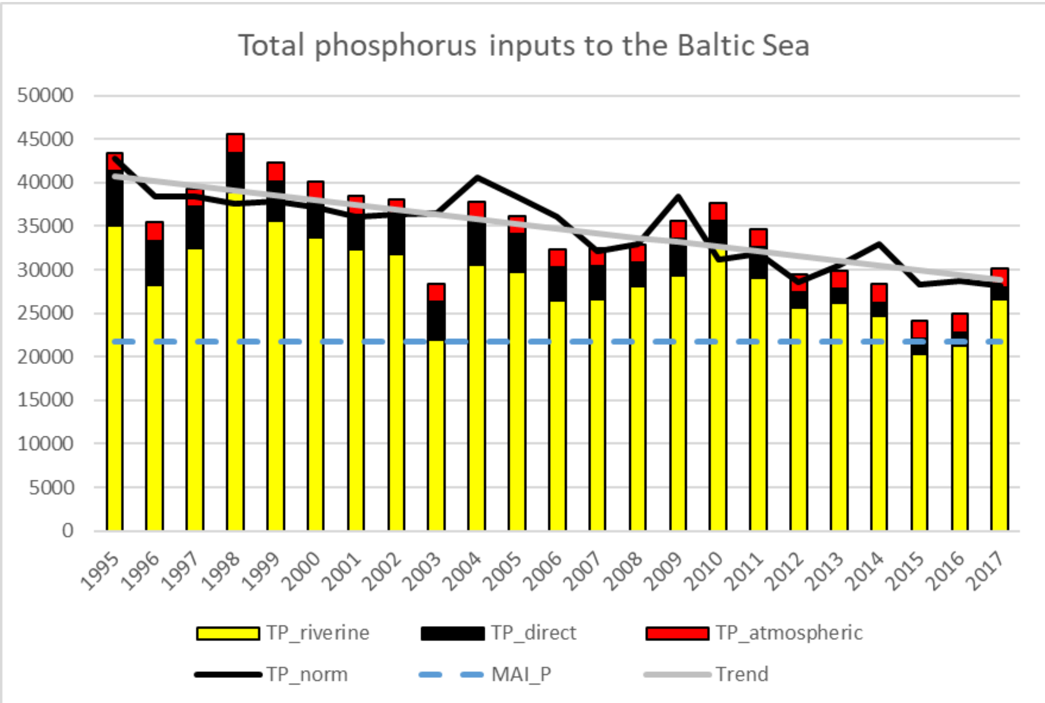



**Figure 3**. Actual total air- and waterborne annual input of A) nitrogen (TN) and B) phosphorus (TP) to the Baltic Sea and sub-basins from 1995 to 2018 (tonnes). The normalized annual inputs of TN and TP are given as a black line. Trend lines for normalized TN and TP input are given as a line with markers.

NIC - National ceilings for net input of nutrients

*Net input of nutrients* is an estimation of the amount of nutrients which ends up in the Baltic Sea sub-basins integrating waterborne (direct coastal point sources and discharges from rivers), airborne (atmospheric deposition from a particular country or a group of countries) and transboundary inputs (input via rivers through another country).

*National ceilings for net input of nutrient input* define maximum inputs via water and air released from a country to achieve good status with respect to eutrophication for Baltic Sea sub-basins. The sum of input ceilings set for all countries to a specific sub-basin is equal to the MAI for that sub-basin.

# 3 Progress towards NIC

Net inputs of nitrogen and phosphorus from each country to each sub-basin in 2017 were computed by statistical estimation of trends, based on complete time series of normalized net inputs for the period 1995–2017. The method also takes into account uncertainty of the estimation. Achievement of the net input ceilings for total nitrogen and total phosphorus in 2017 are illustrated in figures 4 and 5. Since the assessment had been produced before the adoption of the Baltic Sea Action plan 2030 in October 2021, non-revised values for NICs of nutrients were applied in the assessment.

**A) Including reallocation of extra reduction.**

| Country/basin | BOB | BOS | BAP | GUF | GUR | DS | KAT |
|---|---|---|---|---|---|---|---|
| Denmark | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Estonia | ↓ | ↓ | ↓ | | | ↓ | ↓ |
| Finland | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Germany | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Latvia | ↓ | | ↑ | | | ↓ | ↓ |
| Lithuania | | | ↑ | | ↑ | | |
| Poland | ↓ | ↓ | | ↓ | ↓ | ↓ | ↓ |
| Russia | | | | ↓ | ↓ | | |
| Sweden | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Belarus | | | | | ↓ | | |
| Czech Republic | | | ↓ | | | | |
| Ukraine | | | ↑ | | | | |
| Baltic Sea shipping | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Other countries | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |

B) Without reallocation of extra reduction.

| Country/basin | BOB | BOS | BAP | GUF | GUR | DS | KAT |
|---|---|---|---|---|---|---|---|
| Denmark | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Estonia | ↓ | ↓ | ↓ | | | ↓ | ↓ |
| Finland | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Germany | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Latvia | ↓ | | ↑ | | | ↓ | ↓ |
| Lithuania | | | ↑ | | ↑ | | |
| Poland | ↓ | ↓ | | ↓ | ↓ | ↓ | ↓ |
| Russia | | | | ↓ | ↓ | | |
| Sweden | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Belarus | | | | | ↓ | | |
| Czech Republic | | | ↓ | | | | |
| Ukraine | | | ↑ | | | | |
| Baltic Sea shipping | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Other countries | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |

**Figure 4**. Total Nitrogen – achievement of input ceilings (NIC) for the Baltic Sea sub-basins A) including reallocation of extra reduction and B) without reallocation of extra reduction.

**A) Including reallocation of extra reduction.**

| Country/basin | BOB | BOS | BAP | GUF | GUR | DS | KAT |
|---|---|---|---|---|---|---|---|
| Denmark | | | ↓ | | | ↓ | ↓ |
| Estonia | | | | ↓ | ↓ | | |
| Finland | ↓ | | | ↓ | | | |
| Germany | | | | | | ↓ | |
| Latvia | | | ↓ | | | | |
| Lithuania | | | ↓ | | ↓ | | |
| Poland | | | ↓ | | | | |
| Russia | | | | ↓ | | | |
| Sweden | | ↓ | ↓ | | | ↓ | |
| Belarus | | | ↓ | | | | |
| Czech Republic | | | | | | | |
| Ukraine | | | | | | | |
| Baltic Sea shipping | | | | | | | |
| Other countries | | | | | | | |

B) Without reallocation of extra reduction.

| Country/basin | BOB | BOS | BAP | GUF | GUR | DS | KAT |
|---|---|---|---|---|---|---|---|
| Denmark | | | ↓ | | | ↓ | ↓ |
| Estonia | | | | ↓ | ↓ | | |
| Finland | ↓ | | | ↓ | | | |
| Germany | | | | | | ↓ | |
| Latvia | | | ↓ | | | | |
| Lithuania | | | ↓ | | ↓ | | |
| Poland | | | ↓ | | | | |
| Russia | | | | ↓ | | | |
| Sweden | | ↓ | ↓ | | | ↓ | |
| Belarus | | | ↓ | | | | |
| Czech Republic | | | | | | | |
| Ukraine | | | | | | | |
| Baltic Sea shipping | | | | | | | |
| Other countries | | | | | | | |

**Figure 5**. Total Phosphorus - achievement of input ceilings (NIC) for the Baltic Sea sub-basins A) including reallocation of extra reduction and B) without reallocation of extra reduction.

Legend for figures 4 and 5.

Remaining reduction to reach ceilings is
less than 10%
between 10 and 30%
between 30% and 50%
50% or more
Within statistical certainty, the fulfilment of NIC cannot be justified
NIC is with 95 % statistical certainty fulfilled; inputs ceiling not exceeded
Classification is not relevant

only airborne inputs to the sub-basin
only transboundary waterborne inputs to the sub-basin
application of extra reduction achieved in neighbouring basins changed status

**Arrows**: statistically significant changes of nutrient inputs since the reference period (1997-2003), taking into account 95% confidence interval for both latest inputs and reference values.

↓ significant decrease

↑ significant increase

## Net nitrogen input ceilings

All HELCOM countries achieved remarkable progress in reducing input of nutrients to the Baltic Sea sub-basins but Denmark is the only country that has fulfilled nitrogen ceilings to all Baltic Sea sub-basins. Finland, Germany and Sweden meet input requirements for most of the sub-basins but still not for all. Other HELCOM countries achieved substantial progress but their inputs in 2017 still exceeded ceilings for most of the sub-basins, though, in many cases the remaining reduction was within a few percent or within statistical uncertainty. Atmospheric nitrogen inputs from Baltic Sea shipping and non-HELCOM countries exceeded their target values to all sub-basins. It is important to note that the total nitrogen inputs to the Bothnian Sea, Bothnian Bay, Danish Straits and Kattegat were below the respective MAIs and the countries which exceeded national input ceilings for these sub-basins have only minor airborne contribution. The mechanism of reallocation of extra reduction has been applied for the first time in the assessment. It helped Denmark and Latvia to demonstrate achievement of reduction requirements for Baltic Proper and Germany for Kattegat.

## Net phosphorus input ceilings

No countries achieved phosphorus input ceilings for all Baltic Sea sub-basins in 2017 without reallocation of extra reduction. Application of this mechanism helped Denmark to demonstrate compliance with the input ceiling for Baltic Proper and thus to achieve required reduction for all sub-basins. All other HELCOM countries and non-HELCOM countries exceeded respective input ceilings for the Baltic Proper. Estonia and Finland exceeded their input ceilings to the Gulf of Finland and Latvia and Russia to the Gulf of Riga. Input from Finland was also slightly above the ceiling for Bothnian Sea. Input ceilings for other sub-basins were either achieved or very close to be achieved. For some of them the input exceeded the ceilings within statistical uncertainty. Reallocation of extra reduction also helped Sweden to achieve the input ceiling for Bothnian Bay and allowed for Lithuania to decrease remaining reduction requirements for the Baltic Proper.

## Internal biogeochemical cycles of nutrients

In addition to the supply of nutrients from land and via atmospheric deposition, there are nutrient sources driven by the internal biogeochemical cycles within the Baltic Sea. A large volume of the nitrogen load (400,000-600,000 t/year) originates from nitrogen fixation by cyanobacteria transforming dinitrogen ($N_2$) of the air to bioavailable ammonia. The magnitude of this N fixation grows with the magnitude of cyanobacteria blooms. Denitrification is a microbially facilitated process where nitrate ($NO_3^-$) is reduced and ultimately produces molecular nitrogen ($N_2$) completing the nitrogen cycle. Denitrification in water column and sediments plays important role in the Baltic Sea nitrogen budget.

Huge resources of phosphorus have been accumulated in the bottom sediments of the Baltic Sea during the past decades. Internal load, caused by release of phosphorus from sediments in anoxic conditions, is a factor contributing to its elevated concentration in the Baltic Sea.

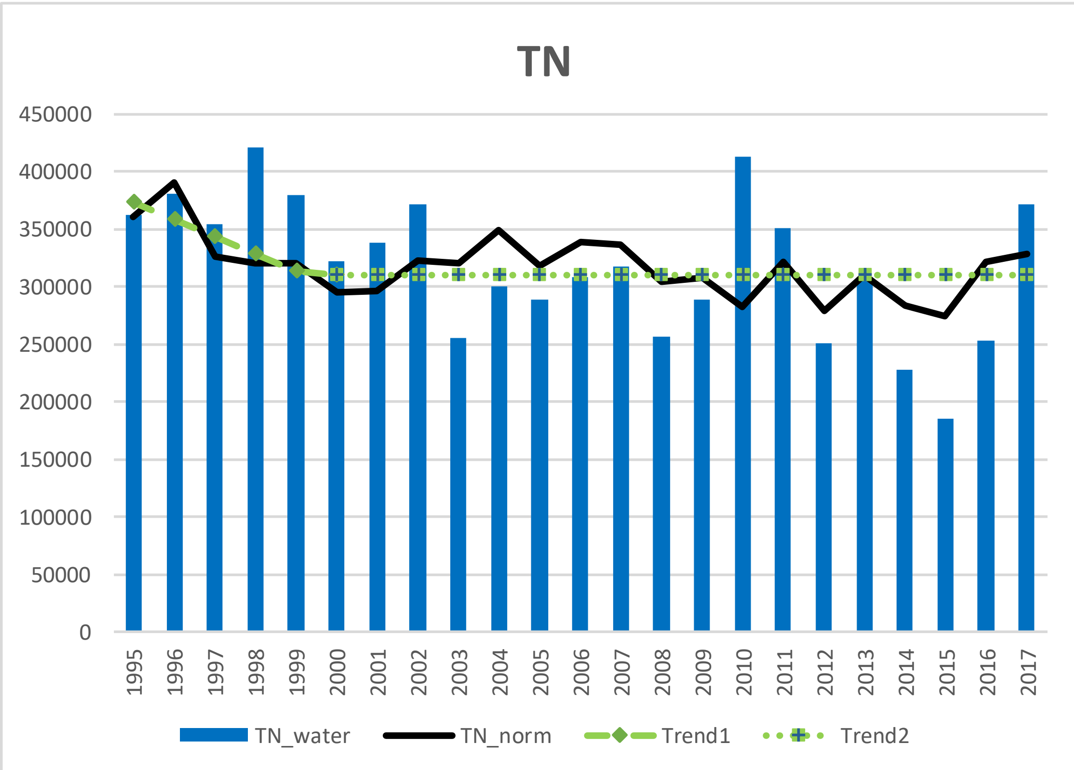
# 4 Input of nutrients by the seven biggest rivers from 1995 to 2017 and apportionment of major sources

The seven biggest rivers of the Baltic Sea (Göta, Kemi, Daugava, Nemunas, Oder, Vistula and Neva) cover 50% of the Baltic Sea catchment area which is inhabited by nearly 55 million people (Figure 6). Therefore, the transport of nutrients by these rivers constitutes an essential part of the overall waterborne inputs to the Baltic Sea and intensive monitoring of water quality in these rivers enables reliable assessment of temporal changes of nutrient runoff from their catchments. In 2017 the seven rivers transported 372,000 t of total nitrogen and 13,500 t of total phosphorus into the Baltic Sea, which was 39% of the net nitrogen and phosphorus input to the Baltic Sea. The River Neva had the highest water flow in 2017 contributing 34% of the total water flow of the seven big rivers, but Vistula had the highest total nitrogen and total phosphorus loads out of these 7 rivers. It contributed 30 and 28 percent of the total load by the 7 big rivers respectively.


**Figure 6**. Basins of seven biggest rivers of the Baltic Sea catchment.

Temporal changes of total nitrogen input by the 7 big rivers were characterized by a steady decreasing trend until 2000. Since that year, the load was fluctuating according to changes in flow demonstrating no statistically significant trend (Figure 7a). The total phosphorus load shows statistically significant decrease between 1995 and 2017 (Figure 7b) with a total phosphorus input reduction by 6,000 t (30%). For the first time, the input of some of the rivers was compared with nutrient input ceilings computed for transboundary rivers. These rivers are Daugava, Nemunas, Neva, Oder and Vistula. The assessment revealed that nutrient input ceilings, which indicate the input required to achieve good environmental status of the Baltic Sea in terms of eutrophication, for these five rivers in 2017 were exceeded by 71,000 t for nitrogen and 8600 t for phosphorus.

7A



7B

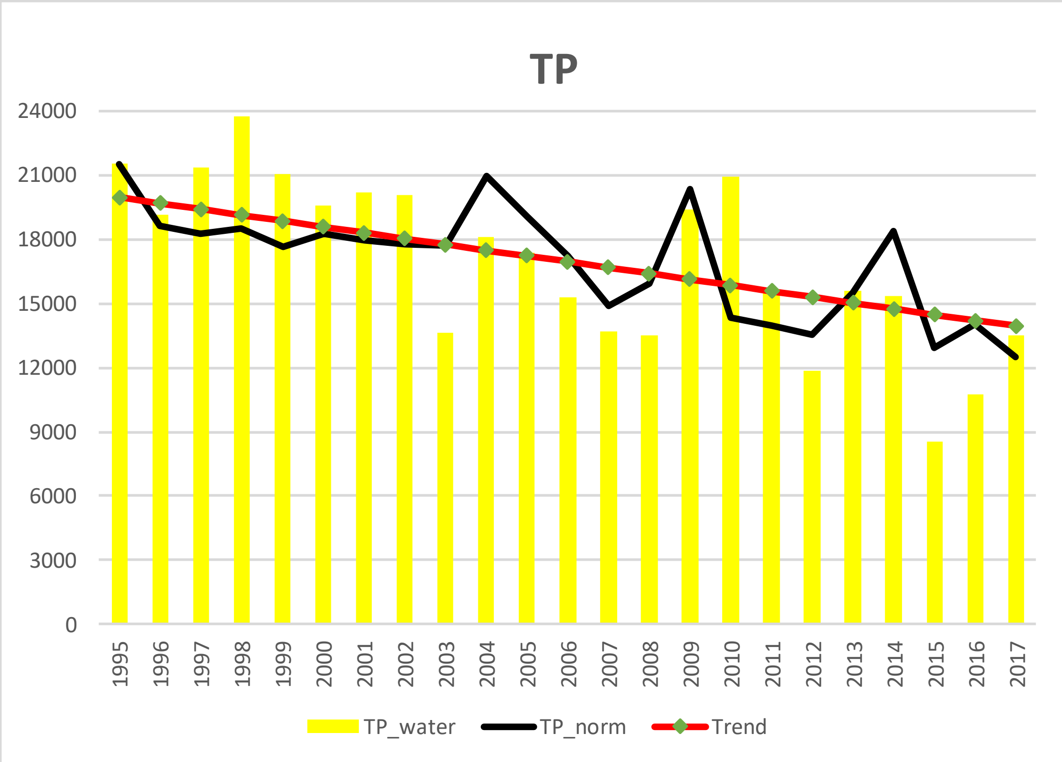


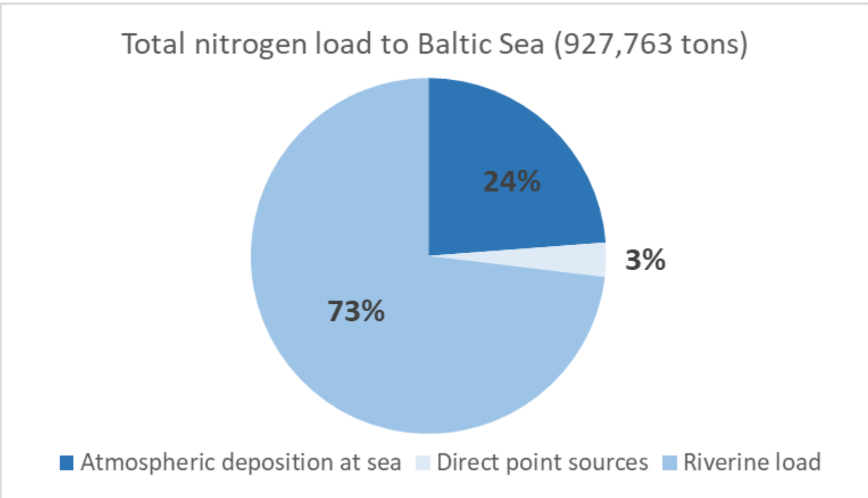

**Figure 7.** Total nitrogen (TN in tonnes, A) and total phosphorus (TP in tonnes, B) load of the 7 biggest rivers in the period 1995 - 2017. Black line shows flow-normalized nutrient load, the green line in A) illustrates the linear trend with a break point in 2000. and the red line in B) illustrates the linear trend.

Evaluation of major sources of nutrients for the seven biggest rivers in the Baltic Sea catchment area revealed three different patterns. The major source of nutrients for rivers Göta, Neva and Kemi is natural background. It constitutes for these rivers around 40, 50 and 80 percent of total input of either nutrient, respectively. Transboundary load is a dominating source of nutrient input for Daugava and Nemunas. Upstream countries contribute 50% nitrogen and 70% phosphorus to the total input by Daugava and 40% nitrogen and 50% phosphorus by Nemunas. Agriculture is the major source of nutrients for Orda (total nitrogen 60% and total phosphorus 40%) and Vistula (total nitrogen 60% and total phosphorus 50%). It’s worth noticing that agriculture significantly contributes to the nutrient input by all seven big rivers.

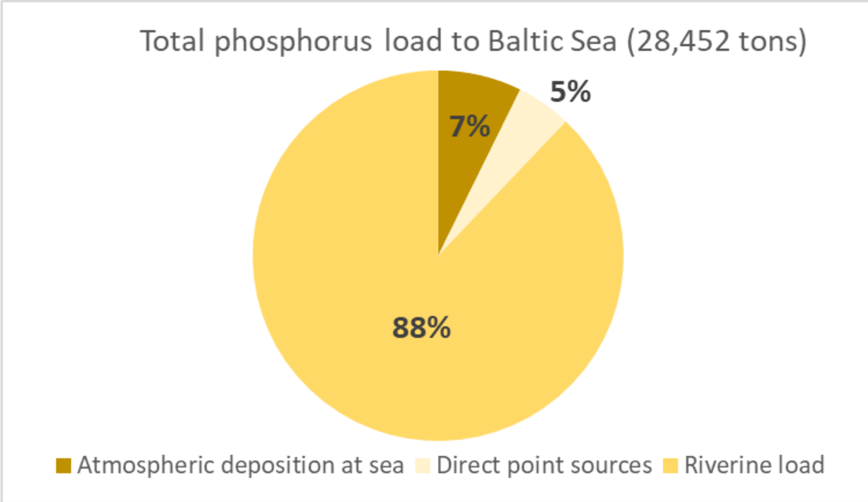
# 5 Pathways of nutrients to the Baltic Sea

Nitrogen and phosphorus reach the Baltic Sea via three major pathways. They can be transported by rivers (riverine input), deposited from air (airborne input) and discharged directly to the Baltic Sea from various industrial and municipal wastewater treatment facilities located on the seacoast as well as from marine fish-farms. Deposition of phosphorus from air is caused mainly by natural factors and for the HELCOM assessment considered as constant.

The riverine input is a dominating pathway for both nutrients in 2017 constituting 73% of total nitrogen and 88% of total phosphorus input to the Baltic Sea (Figure 8A and B). The second most important pathway is airborne input, nearly 24% for total nitrogen and more than 7% for total phosphorus. However, the share of pathways essentially differs between sub-basins. The contribution of airborne deposition for nitrogen varies from less than 7% in the Gulf of Riga up to nearly 48% in the Archipelago Sea, and for phosphorus from less than 3 % to the Gulf of Riga to more than 21% to the Bothnian Sea. The proportion of direct input of nitrogen is less or around 1% to the Gulf of Riga and more than 16% to Baltic Proper and the Sound. The proportion of phosphorus input by direct point sources related to total inputs varies 1-2% in the Gulf of Riga and Baltic Proper up to more than 42% in the Sound. National net inputs demonstrate high variation of proportions of different pathways. For example, for the German territory riverine nitrogen input contributes only 33% to the total input of nitrogen, while it constitutes more than 97% for the Latvian territory, which highlights the high importance of airborne nitrogen inputs from Germany.




A




B

**Figure 8.** Main pathways of A) total nitrogen and B) total phosphorus to the Baltic Sea in 2017.

## Changes in the main pathways of nitrogen and phosphorus input

Total average inputs of both phosphorus and nitrogen for the entire Baltic Sea have reduced over time. However, the input through various pathways strongly depends on weather conditions and corresponding water flows in assessment years. Reduction of nutrient inputs achieved in 2017 since 1995 was not equivalent for different pathways. The highest reduction was achieved for direct point sources. The proportion of direct input was reduced from 5.5 % to 3.1 % for nitrogen and from almost 11 % to almost 5 % for phosphorus. The proportion of airborne input of nitrogen has decreased from about 29% in 1995 to less than 24% in 2017. Since airborne input of phosphorus is considered as constant, its proportional growth results from reduction of direct input. The proportion of riverine input of both nutrients increased from 1995 to 2017. The growth constituted about 10% for nitrogen and 4% for phosphorus. The pattern illustrating the proportion of different pathways in the total nutrient load differs for the different sub-basins and countries. However, the general tendency of the total nitrogen and particularly phosphorus inputs is a decrease of the share of direct point sources experiencing greatest reduction since 1995. This pattern is common for nitrogen inputs to all sub-basins in the southern part of the Baltic Sea (the Baltic Proper, Danish Straits, and Kattegat) as well as to the Gulf of Finland and Gulf of Riga. Particularly, the share of direct phosphorus input to Gulf of Riga was reduced from more than 15% in 1995 to less than 2% in 2017 and to Danish Straits from 38% in 1995 to 18% in 2017. Most countries decreased the share of direct point sources, except Sweden, which demonstrates relatively equal reduction for all pathways. The most probable reason for that is that Sweden together with Denmark, Finland and Germany started reducing nutrient releases from wastewater treatment plants before the observed period. In these countries, measures are now primarily focused on diffuse sources such as agricultural losses and scattered dwellings.

## 6 Sources of nutrient loads on the Baltic Sea area

Sources of nitrogen and phosphorus loads on the Baltic Sea can be aggregated in four main groups: natural background load, other diffuse sources (riverine), point sources load (inland and direct) and air deposition (Figure 9A and B; Table 2A and B). Diffuse loads of both nitrogen (49%) and phosphorus (56%) dominate in the entire Baltic Sea. However, the proportion of diffuse load demonstrates large variation between sub-basins: nitrogen - from 20% to Bothnian Sea to more than 83% to Gulf of Riga; phosphorus - from less than 36% to Bothnian Bay to more than 84% to Gulf of Riga. Deposition from air (24%) and natural background (18%) are other main sources of nitrogen load to the Baltic Sea. For phosphorous loads to the Baltic Sea, natural background (20%) and point sources (17%) are other major contributing sources.

Shares of various sources largely vary between sub-basins. For example, the share of natural background for nitrogen load ranges from 7% to Western Baltic to more than 52% to Bothnian Bay and for phosphorus load from 9% to Baltic Proper and Gulf of Riga to more than 52 % to Bothnian Bay. However, it should be acknowledged that methods to estimate natural background losses differ between countries. Airborne nitrogen inputs constitute less than 7% of total nitrogen inputs to Gulf of Riga but nearly 48 % of the corresponding inputs to the Archipelago. The proportion of phosphorus load from point sources constitutes from 5% to Bothnian Bay and Gulf of Riga to nearly 47% to the Sound.

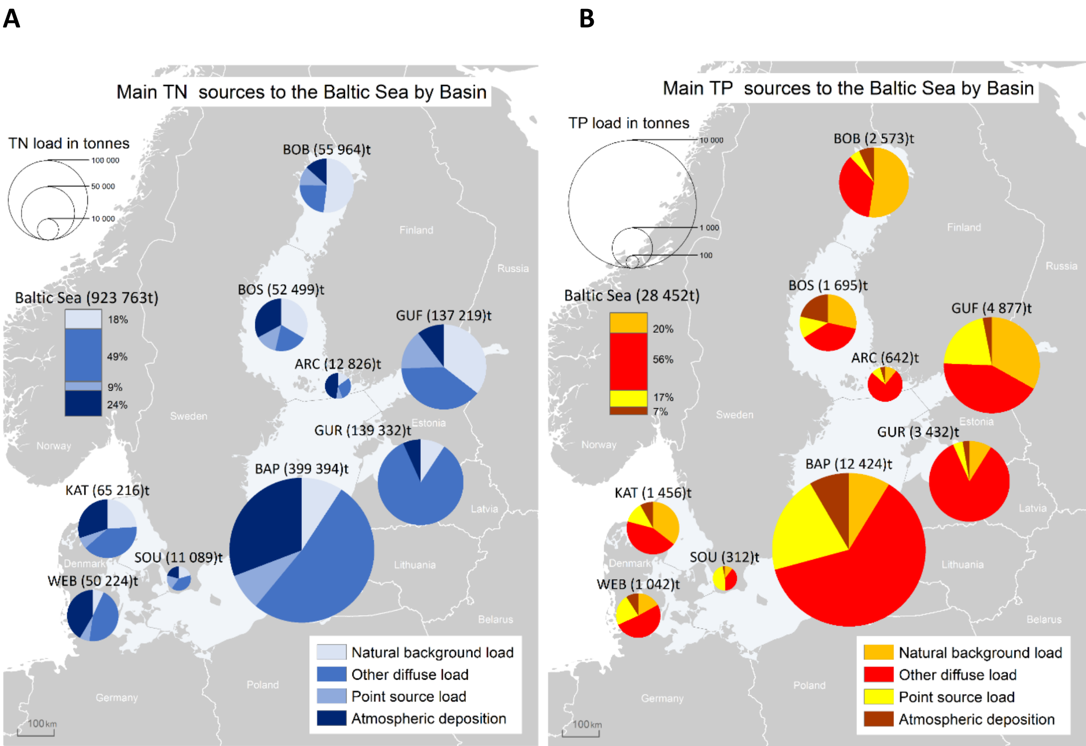



**Figure 9.** Major sources of A) total nitrogen and B) total phosphorus loads to the Baltic Sea sub-basins in 2017.

**Table 2**. Major sources of A) total nitrogen and B) total phosphorus loads to the Baltic Sea sub-basins in 2017.

**A**

| Total Nitrogen | Natural background load (%) | Other diffuse load (%) | Point source load (%) | Atmospheric deposition at sea(%) | Total (tons) |
|---|---|---|---|---|---|
| Bothnian Bay | 52.1 | 23.2 | 11.4 | 13.4 | 55964 |
| Bothnian Sea | 33.4 | 20.2 | 13.5 | 32.9 | 52499 |
| Archipelago | 15.0 | 29.4 | 8.0 | 47.6 | 12826 |
| Baltic Proper | 9.2 | 51.8 | 8.2 | 30.8 | 399394 |
| Gulf of Finland | 35.5 | 38.9 | 15.2 | 10.3 | 137219 |
| Gulf of Riga | 9.2 | 83.3 | 0.9 | 6.7 | 139332 |
| Western Baltic | 6.9 | 45.3 | 6.2 | 41.5 | 50224 |
| The Sound | 20.4 | 39.5 | 19.2 | 20.8 | 11089 |
| Kattegat | 24.0 | 39.6 | 6.3 | 30.1 | 65216 |
| Baltic Sea | 18.2 | 49.4 | 8.5 | 23.8 | 923763 |

**B**

| Total Phosphorus | Natural background load (%) | Other diffuse load (%) | Point source load (%) | Atmospheric deposition sea (%) | Total (tons) |
|---|---|---|---|---|---|
| Bothnian Bay | 52.4 | 35.7 | 4.9 | 7.0 | 2573 |
| Bothnian Sea | 28.4 | 37.8 | 12.4 | 21.4 | 1695 |
| Archipelago | 10.8 | 75.6 | 8.8 | 4.8 | 642 |
| Baltic Proper | 8.7 | 62.1 | 20.8 | 8.4 | 12424 |
| Gulf of Finland | 33.1 | 42.5 | 21.3 | 3.1 | 4877 |
| Gulf of Riga | 8.9 | 84.4 | 3.9 | 2.7 | 3432 |
| Western Baltic | 16.9 | 51.3 | 22.6 | 9.1 | 1042 |
| The Sound | 10.4 | 39.6 | 46.8 | 3.2 | 312 |
| Kattegat | 35.5 | 43.6 | 12.8 | 8.1 | 1456 |
| Baltic Sea | 19.8 | 56.3 | 16.6 | 7.3 | 28452 |

The contributions of main sources of nitrogen and phosphorus load largely vary between HELCOM countries. For example, diffuse sources provide 92% of nitrogen and 90% of phosphorus load from Latvian territory; nitrogen air deposition dominates among German sources; natural background constitutes a major share of both nitrogen and phosphorus loads from Sweden. Points sources only play a minor role, constituting primarily few percent of total nutrient load. However, nitrogen load from point sources in Latvia reaches 17% and phosphorus load from point sources in Russia 29%.

## Sources of riverine nutrient loads on the Baltic Sea area

Natural background loads of nitrogen and phosphorus constitute nearly a quarter of the riverine load of nutrients to the Baltic Sea in 2017 (Figures 10 A and B). The largest contribution from natural background is found in the Bothnian Bay (65% for nitrogen, and 59% for phosphorus), and Bothnian Sea (55 % for nitrogen and 41% for phosphorus); the lowest in the Gulf of Riga (10% for nitrogen and 9% for phosphorus). Other anthropogenic diffuse sources such as agriculture (the dominating one), managed forestry, wastewater from scattered dwellings, storm waters, etc. made up about two third of the total riverine nitrogen and phosphorus load to the Baltic Sea in 2017. Different land use character (proportions of agricultural lands, managed forests, scattered dwellings etc) results in large variation of loads. For example, the highest proportion of anthropogenic diffuse load was observed in catchment areas with intensive agriculture and a large number of scattered dwellings such as: Gulf of Riga (90 % nitrogen and 88% phosphorus), Western Baltic (82% nitrogen), Baltic Proper (76% nitrogen), Archipelago (87% phosphorus) and the Sound (73% phosphorus). The proportion of different sources differ even between individual river catchments. For example, the share of phosphorus natural background load in the loads of 73 Danish monitored rivers within the Western Baltic catchment area ranges between 25 to 100%, other diffuse sources between 0 and 75% and inland point sources between 1 to nearly 80 %.

Inland point sources constitute 7% of the total nitrogen load and 13% of the total phosphorus load. High nutrient load from point sources was observed in the Baltic Proper (10% nitrogen, 21% phosphorus), Bothnian Bay (12% nitrogen), Danish Straits and Gulf of Finland (15% and 13% phosphorus, respectively). Unfortunately, reported data does not specify sources of transboundary riverine load which constitutes an essential share of total load to the Gulf of Riga and Baltic Proper. For example, in the Gulf of Riga catchment area transboundary load constitutes nearly 30 % of nitrogen and 44 % of phosphorus.

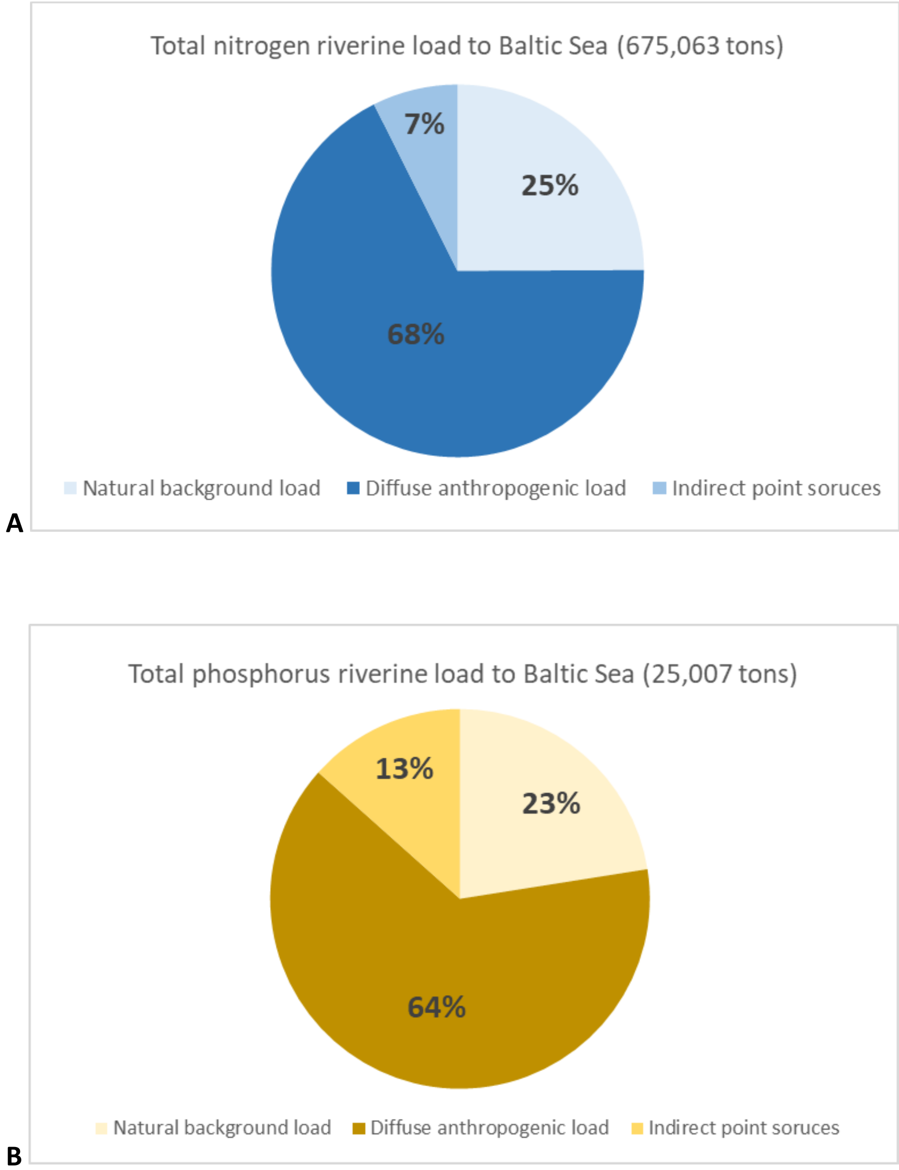



**Figure 10.** Major sources of riverine A) total nitrogen and B) total phosphorus inputs to the Baltic Sea in 2017.

# 7 Inputs of hazardous substances to the Baltic Sea

The monitoring and reporting guidelines for waterborne inputs of hazardous substances to the Baltic Sea (PLC-Water guidelines) are to a large degree focused on metal inputs (Figure 11). Information on atmospheric deposition is annually supplied by EMEP and contains data on priority heavy metals and organic contaminants included in the respective protocols of the Convention on Long-Range Transboundary Air Pollution. In addition, an assessment of a specific HELCOM data call on nonyl- and octylphenols, as well as per- and polyfluoroalkyl substances (PFASs) in rivers and coastal waters is presented in the PLC-7 thematic report on hazardous substances.

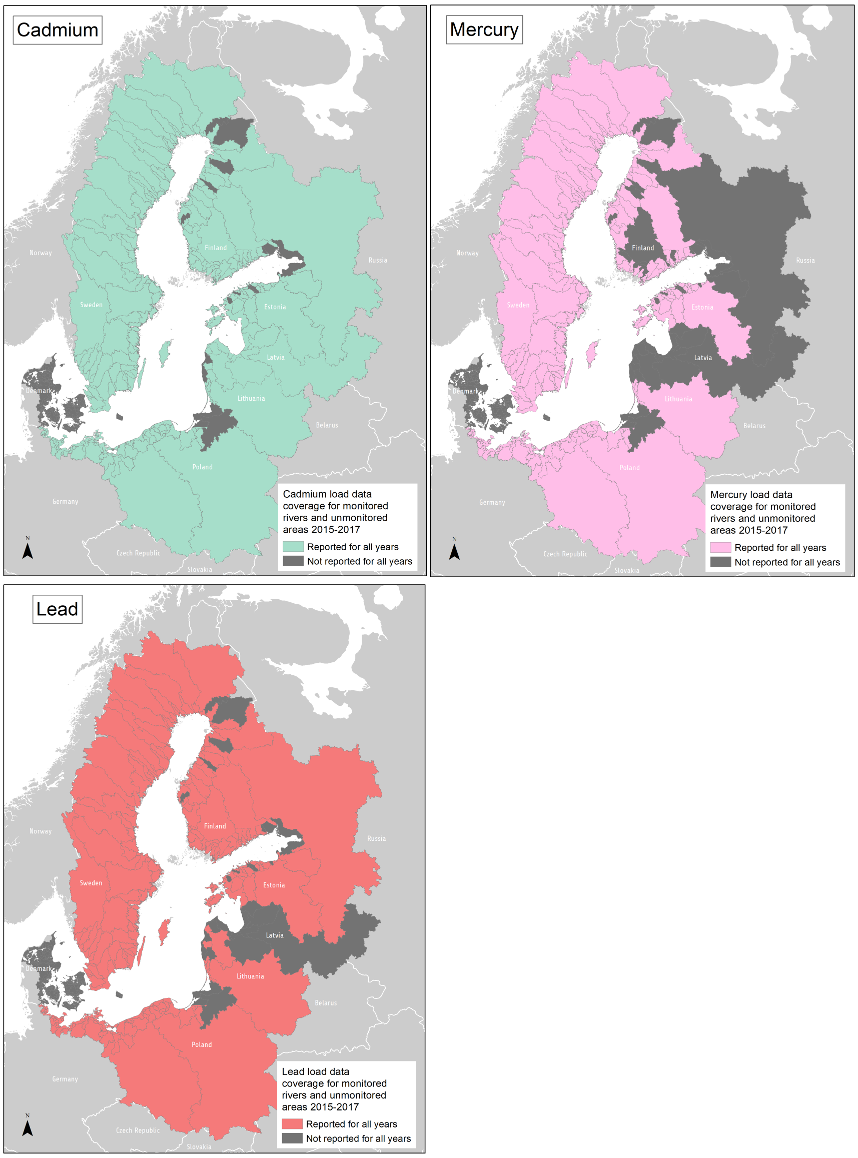



**Figure 11**. The spatial data coverage 2015-2017 of reported riverine inputs of mandatory metals cadmium (Cd), mercury (Hg) and lead (Pb).

## Inputs of Cadmium, Mercury and Lead to the Baltic Sea

There are quite large differences in the estimated total amounts of metals that enter the Baltic Sea every year. The main route of entry is also quite variable between metals. In total, estimated annual average inputs of cadmium (Cd), mercury (Hg), and lead (Pb) to the Baltic Sea in 2016-2018 have been around 24 t, 5 t, and 357 t per year, respectively. Mercury is mainly entering the Baltic Sea via atmospheric deposition (about 60% of the total inputs). For lead and cadmium, the riverine inputs are most important (60%, and 80% respectively). In all cases, the role of direct point sources is rather small. They contribute a few percent of the total inputs (Figure 12).

According to the data reported by EMEP, airborne deposition of cadmium and mercury has been constantly decreasing during the whole observation period 1990-2018. Atmospheric deposition of lead has been effectively decreased by about 2010. Since then and until 2017, the deposition of lead remained constant.

In addition to three heavy metals prioritized in HELCOM Recommendation 31E/1, waterborne inputs of chromium (Cr), copper (Cu), nickel (Ni) and zinc (Zn) were assessed. Annual average inputs of these metals to the Baltic Sea by rivers and point sources in the period 2016-2018 were – Cr 135 t; Cu 593 t; Ni 434 t; Zn 3962 t.

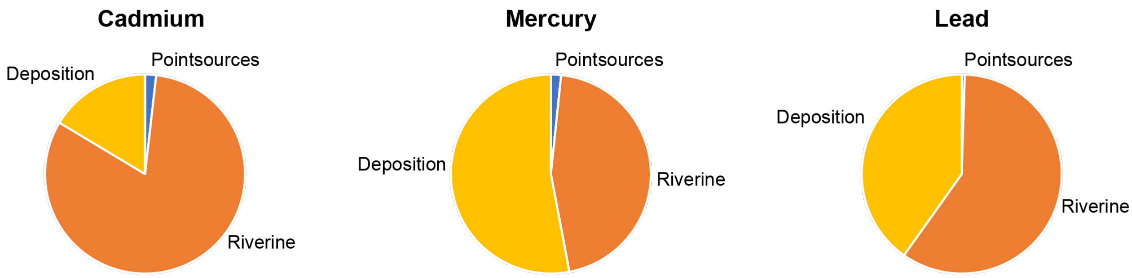



**Figure 12**. The division of inputs of cadmium, mercury and lead from point sources, via rivers, and atmospheric deposition to the Baltic Sea based on average inputs 2015-2017.

## Atmospheric deposition of some selected organic pollutants

The modelled atmospheric deposition of Benzo(a)pyrene, polychlorinated biphenyls (PCBs) and dioxins and furans (PCDD/Fs) shows a continuously decreasing trend for the period 1990-2017 (Figure 13).

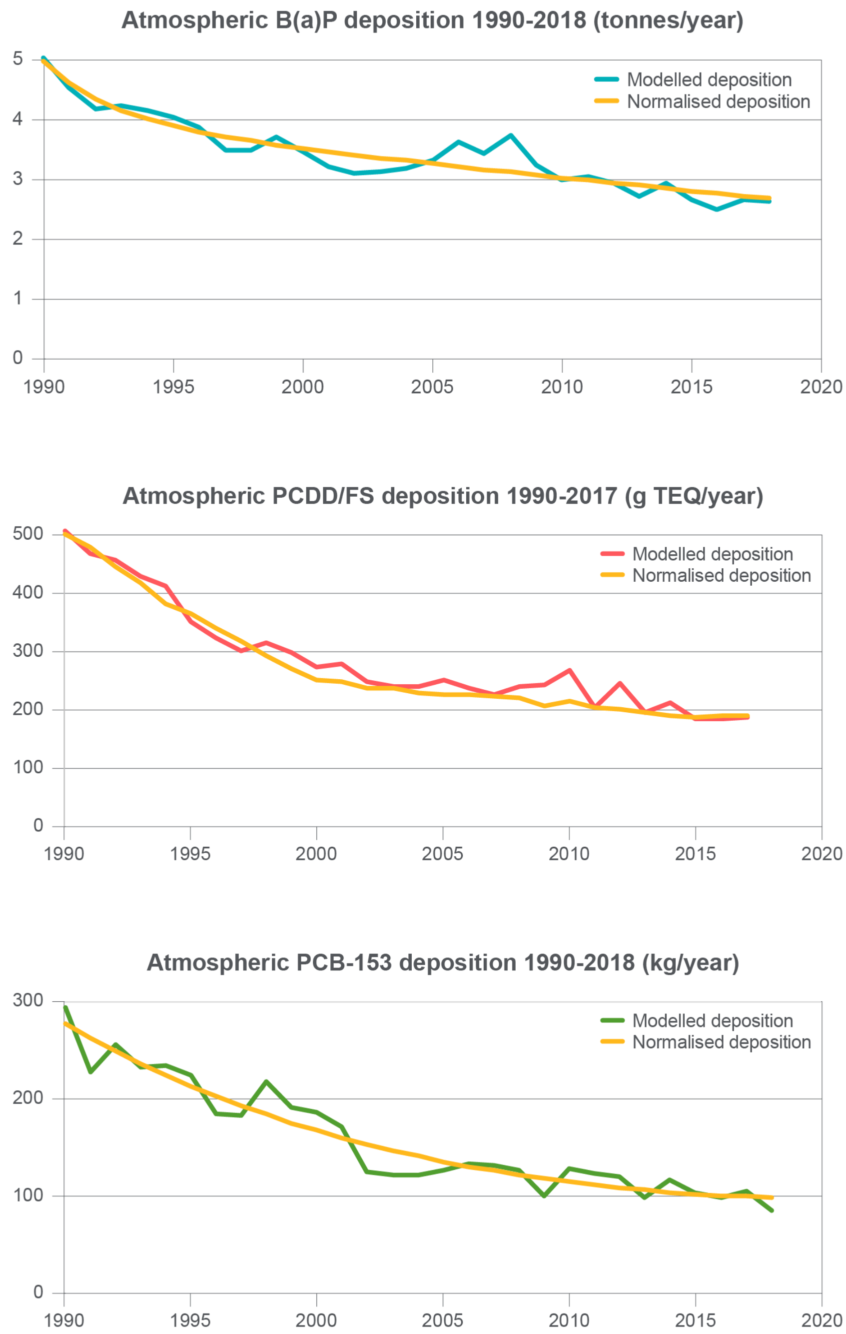



**Figure 13**. Modelled and normalised atmospheric deposition of B(a)P (tonnes per year), PCDD/Fs (g TEQ[1]/year) and PCB-153 deposition (kg per year) on the Baltic Sea 1990-2018.

[1] Toxic Equivalents

## Concentrations of nonyl- and octylphenols, and PFASs in rivers and coastal waters

In the HELCOM enquiry within the PLC-6 project on prioritization of contaminants discharged to the Baltic Sea by rivers, the HELCOM Contracting Parties expressed concern regarding several groups of hazardous substances such as nonyl- and octylphenols, per- and polyfluoroalkyl substances (PFASs), and heavy metals. This resulted in a dedicated data call on observation of these compounds in WWTPs, rivers and coastal zones in the Baltic Sea catchment. Collected data on observations in influents and effluents of wastewater treatment plants (WWTPs) became a part of the HELCOM report on micropollutants in WWTP, whereas the information on concentrations of nonyl- and octylphenols, and PFASs found in rivers and coastal waters are included in this PLC-7 thematic report on hazardous substances.

Nonylphenols and octylphenols are priority substances listed under the Water Framework Directive (WFD). Concentrations of these compounds in river waters vary greatly both temporarily and spatially in the range of three folders from single nanograms to several thousand nanograms per liter. Some observed concentrations exceed the current annual average environmental quality standard (AA-EQS) for inland waters of the Directive on Environmental Quality Standards (300 ng/l) and most measurements demonstrate exceedance of suggested chronic EQS by the Ecotox Centre Eawag-EPFL (43 ng/l).

The per- and polyfluoroalkyl substances (PFAS) constitute a large group of synthetic organic chemicals consisting of more than 3000 substances. Per-fluorinated octyl sulfonate (PFOS) is one of the most well-known PFAS and is a HELCOM Core Indicator, as well as a priority substance under the WFD. It’s also listed for restrictions under the Stockholm Convention. In total 1827 measurements were reported for a number of PFAS in rivers and coastal waters, 712 (39%) of these were above the detection limit or limit of quantification. PFOS and PFOA are the most frequently measured and these substances also exhibited the highest detection frequency (about 60% of samples) in rivers and coastal waters. Their concentrations vary in the range from less than one tenth of nanogram per liter up to more than ten nanogram per liter. The majority of observed concentrations are below the AA-EQS (0.65 ng/l) and chronic EQS (2 ng/l) suggested by Ecotox Centre Eawag-EPFL.

## 8 Effectiveness of measures to reduce input of nutrients

The thematic report on the effectiveness of measures to reduce input of nutrients is one of the key PLC-7 products. The evaluation is intended to evaluate the effects of measures to reduce nutrient inputs implemented and planned for implementation by HELCOM countries. The report is a compilation of the best available information on measures and an evaluation of their effects across the Baltic Sea region. It incorporates also information obtained through the HELCOM ACTION project and presented at workshops. But the main source of data for the thematic report is information reported by the Contracting Parties and thus, the report objectively reflects current state of regional knowledge on the effects of measures to reduce input of nutrients to the Baltic Sea.

The thematic report prominently illustrated the difficulties that Baltic Sea countries face evaluating of the effects of measures to reduce input of nutrients from diffuse sources and especially from agriculture. Since agriculture remains the key contributor to the nutrient load to the Baltic Sea, lack of this information does not allow a holistic assessment of the effect of applied measures but only an evaluation for specific sectors. The most complete information on the achieved and remaining reduction was compiled for the wastewater management sector. The analysis showed that despite the achieved progress there is still reduction potential for municipal wastewater treatment plants estimated at the level of 10% of the 2007 HELCOM Baltic Sea Action Plan (BSAP) targets for both nitrogen and phosphorus. This reduction can be achieved through technological update of large municipal WWTPs in the whole region to meet HELCOM requirements for nutrients removal and increasing the connectivity of the population in scattered dwellings to centralized sewerage systems. The effect of measures applied in the wastewater sector is illustrated by examples of nutrient input reduction achieved after upgrading large municipal WWTPs in Saint-Petersburg, Stockholm, Rostock, Vilnius, Riga, Tallinn, Warsaw, Copenhagen, Helsinki and Espoo.

One of the key outputs of the PLC-7 work on the evaluation of effectiveness of measures are recommendations and proposals on the improvement of related regional data, which lay the basis for the continuation of this task in the PLC-8 project and accomplishment of action E1 of the updated 2021 BSAP by 2023. This action is intended to compile the best available information on measures which are implemented or planned for implementation by HELCOM countries to achieve nutrient input reduction targets set in the BSAP by 2030. The analysis of this information will also serve for the development of river basin management plans and programmes of measures under the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD).