PLC-6

# The seven biggest rivers in the Baltic Sea region

Baltic Marine Environment Protection Commission

Nutrient inputs

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# Input of nutrients by the seven biggest rivers in the Baltic Sea region


**Figure 1.**
The catchment areas of the seven biggest rivers of the Baltic Sea catchment.

## Preface

To tackle the symptoms of eutrophication in the Baltic Sea, the member countries of the Helsinki Commission (HELCOM) have agreed to decrease the input of nutrients to the Baltic Sea. According to the recent HELCOM assessment (HELCOM 2018) the riverine inputs of total nitrogen and total phosphorus contribute about 80% and over 90% to the total input of these nutrients respectively. Therefore the nutrient input reduction targets are unachievable without adequate measures aimed at reducing the loads of the entire Baltic Sea catchment area. The seven biggest rivers (Daugava, Gota, Nemunas, Neva, Oder, Tornio and Vistula) cover 50% of the Baltic Sea catchment area and therefore it is important to evaluate the changes in the nutrient loads of those rivers. This assessment illustrates the total nitrogen and total phosphorus loads, along with trends in the loads, from 1995 to 2014. The assessment is based on the data reported annually to the HELCOM Pollution Load Compilation water database and it is a part of the Pollution Load Compilation 6 project. The statistical methods applied in the data handling procedures (flow-normalisation and trend analyses) were developed especially for the Pollution Load Compilation data (Larsen and Svendsen 2013).

## Summary

The seven biggest rivers cover half of the Baltic Sea catchment area. Nearly 55 million people inhabit their catchment areas, meaning that anthropogenic pressure is high. Anthropogenic pressure is highest in the southern catchments, where population is densest and agricultural activity is intense. Consequently the nutrient loads are high in the south. For example in 2014 the area specific total nitrogen load of the River Oder (in the south) was 339 kg km-2, whereas it was 110 kg km-2 for the River Kemijoki (in the north). The variation in the area specific total phosphorus loads was even larger: for example in 2014 the River Kemijoki (in the north) was 5.1 kg km-2 and the River Vistula (in the south) was 44 kg km-2. Between them the seven rivers exported 220,400 t of total nitrogen and 28,600 t of total phosphorus into the Baltic Sea in 2014, which was nearly one third of the total nitrogen load of the Baltic Sea and half of the total phosphorus load. The Neva River contributes over 40% of the total flow into the Baltic Sea Catchment area, but the River Vistula had the highest total nitrogen and total phosphorus loads in 2014 with 26% and 37% respectively. Both total nitrogen and total phosphorus loads show a statistically significant decrease from 1995 to 2014, with total nitrogen falling by nearly 58,000 t (17%) and total phosphorus falling by 4,100 t (22%), but the trends for individual rivers vary greatly.

## Introduction

Nearly 55 million people live in the catchment of the seven largest rivers entering the Baltic Sea. The human pressure is highest in southern parts of the catchment, where population is densest and agriculture most intensive (Table 1, Figure 2). Around half of the catchment areas of the Nemunas, Vistula and Oder rivers are covered by agricultural areas, whereas forests dominate the catchments of the Göta, Kemi, Neva and Daugava rivers. The proportion of inland lakes is high (>15%) in the Göta and Neva River catchments, which substantially reduces pollution load exported by those rivers.

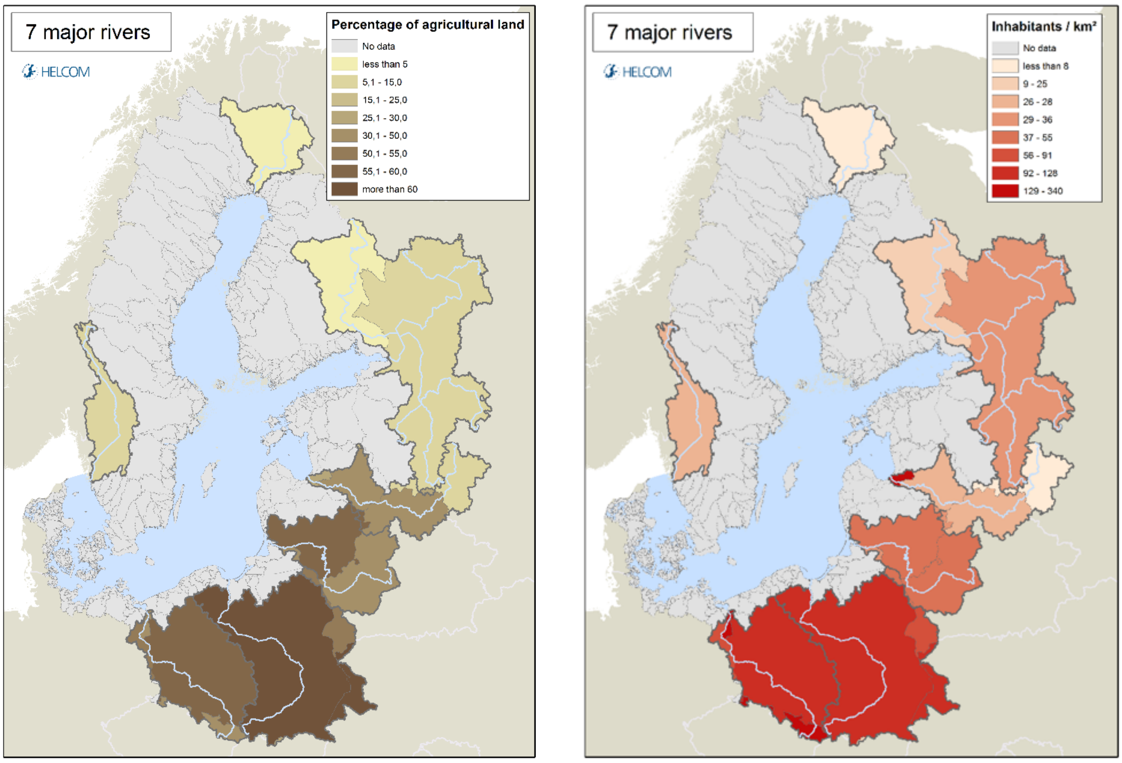



**Figure 2.**
Distribution of agricultural land (2012 for all countries except Russia, where the data is from 2005) and population density in the catchments or sub-catchments of the seven biggest rivers (2012).

*Box 1.*

**Table 1.**
Catchment characteristics of the seven biggest rivers and the entire Baltic Sea.

| River | Area ($km^2$) | Length (km) | Population | Population density (people per $km^2$) | Cultivated area (%) | Urban/ paved area (%) | Forest (%) | Inland waters (%) | Other areas (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Gota** | 50200 | 756 | 1030000 | 21 | 9 | 0.7 | 63 | 18 | 9 |
| **Kemi** | 51100 | 500 | 102000 | 2 | 1 | 0.7 | 75 | 5 | 18 |
| **Dauguva*** | 87900 | 1020 | 2783000 | 32 | 20 | 0.4 | 52 | 2 | 26 |
| **Nemunas*** | 97900 | 937 | 4890000 | 50 | 49 | 0.8 | 30 | 1 | 19 |
| **Oder*** | 118015 | 854 | 14480000 | 123 | 48 | 2.0 | 34 | 1 | 15 |
| **Vistula*** | 183176 | 1047 | 20800000 | 114 | 49 | 1.0 | 31 | 1 | 18 |
| **Neva** | 281600 | 74 | 6108000 | 22 | 12 | 0.1 | 55 | 17 | 16 |
| **Big 7 Total** | 869891 | | 50193000 | 58 | 29 | 0.7 | 46 | 7 | 17 |
| **Whole Baltic Sea** | 1729500 | | 84000000 | 49 | 25 | 3 | 53 | 8 | 10 |

* Data of land use is based on Second Assessment of transboundary rivers, lakes and ground water. UN 2011

# All seven rivers: Loads in 2014 and trends between 1995–2014

The area specific total nitrogen and total phosphorus loads of the seven biggest rivers vary widely, with a general increasing trend from north to south, as population density increases (Figure 3). The highest area specific nutrient loads were detected in the Vistula river basins (Table 2), but some sub-catchments of the Daugava and Nemunas rivers were characterized by equally high values of area specific total nitrogen loads (Figure 3). However, the average specific load from the whole river basins were distinctly lower than in the Vistula. The area specific total phosphorus loads were the highest in the Vistula River basin, and the lowest area specific loads were reported for the relatively pristine Kemi River basin and the upstream sub-catchments of the Neva basin (Figure 3).

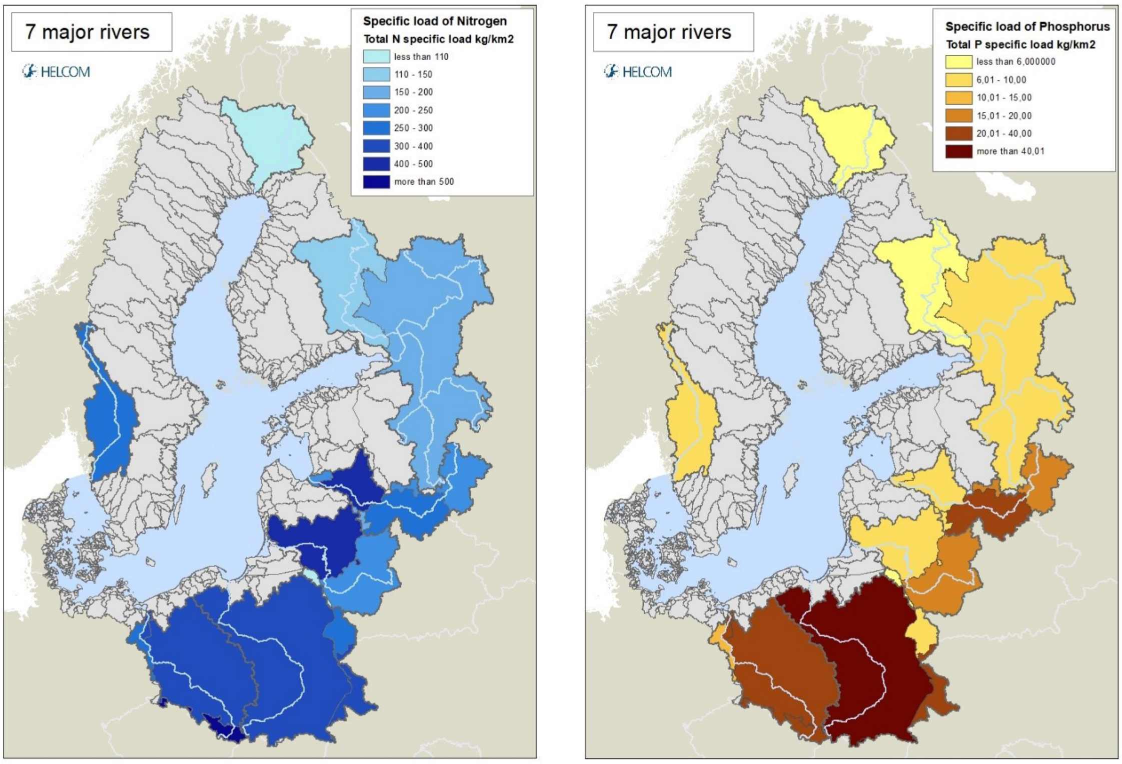



**Figure 3.**
Area specific loads kg km-2 (load/ area) of total nitrogen and total phosphorus from the catchments or sub-catchment of the seven biggest rivers (2014).

Box 2.

**Table 2.**
Area specific loads (load/area); concentrations of total nitrogen and total phosphorus in 2014 and average 2010–2014. Concentrations were calculated from annual load and flow values.

| River | Area-specific TN load in kg/km2 | Area-specific TP load in kg/km2 | TN 2014 concentration in mg/l | TN 2010-14 ave. concentration 2014 in mg/l | TP 2014 concentration in mg/l | TP 2010-14 ave. concentration 2014 in mg/l |
|---|---|---|---|---|---|---|
| **Göta** | 298 | 7.2 | 0.626 | 0.647 | 0.018 | 0.018 |
| **Kemi** | 111 | 5.1 | 0.363 | 0.368 | 0.017 | 0.017 |
| **Daugava** | 228 | 9.0 | 1.750 | 1.837 | 0.066 | 0.065 |
| **Nemunas** | 333 | 12 | 2.138 | 2.169 | 0.075 | 0.078 |
| **Oder** | 339 | 22 | 3.087 | 3.438 | 0.177 | 0.171 |
| **Vistula** | 354 | 44 | 2.128 | 2.449 | 0.262 | 0.189 |
| **Neva** | 182 | 9.0 | 0.634 | 0.608 | 0.031 | 0.026 |

Total annual nutrients loads from rivers depend greatly on annual average precipitation in the river basin and consequently river flow. Therefore flow normalized values for total nitrogen and phosphorus loads are used for inter-annual comparison of loads and for analysing long term trends. In 2014 the non-normalized total nitrogen load was 226,000 t and total phosphorus load 15,300 t.

In 2014 the proportion of flow from the seven biggest rivers to the Baltic Sea was 40%, and the respective proportions of total phosphorus load was 42% and total nitrogen load 33% (Fig. 4). The River Neva contributed over 40% of the total flow of the seven big rivers, but the River Vistula had the highest total nitrogen and total phosphorus loads.

Both the total nitrogen and total phosphorus loads showed a statistically significant decrease between 1995 and 2014 (Figs. 5 and 6). The total nitrogen load was reduced by nearly 58,000 t (17%) and the total phosphorus load by 4,100 t (22%).

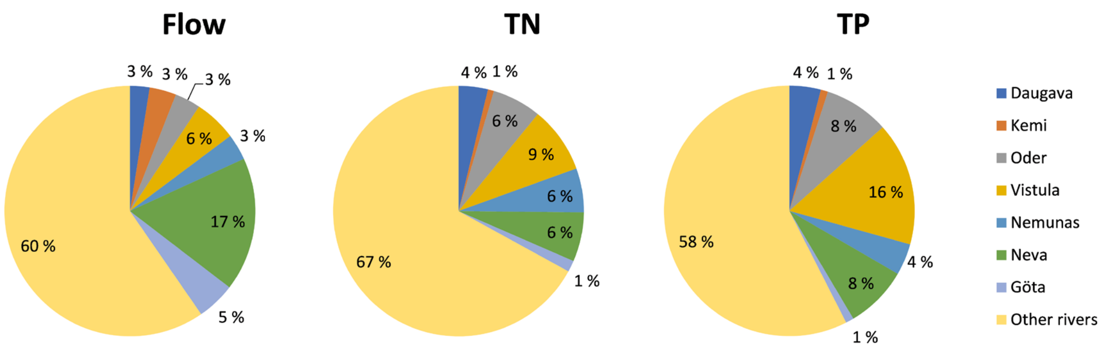



**Figure 4.**
Proportions of the total flow, normalized total nitrogen load and normalized total phosphorus load for the seven biggest rivers of the Baltic Sea catchment area in 2014.

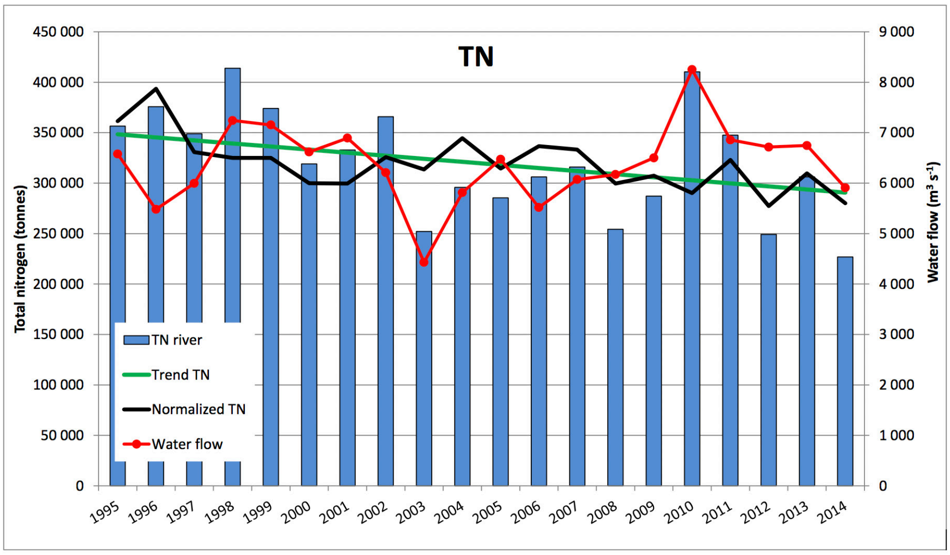



**Figure 5.**
Total nitrogen (blue bars) and flow (red line) of the 7 biggest rivers between 1995 and 2014. The black line is showing flow-normalized nutrient load and the green lines the trend in the flow-normalized load.

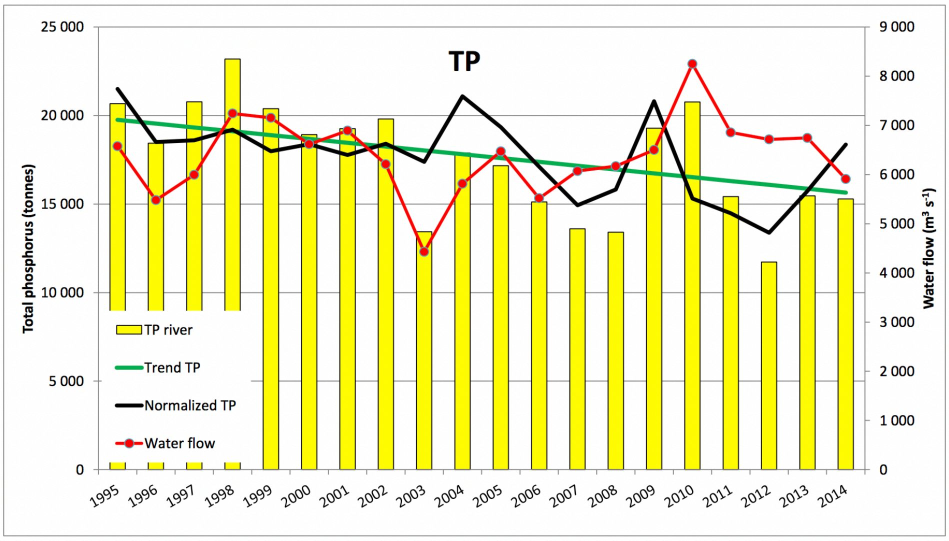



**Figure 6.**
Total phosphorus load (yellow bars) and flow (red line) of the 7 biggest rivers between 1995 and 2014. The black line is showing flow-normalized nutrient load and the green line the trend in the flow-normalized load.

# The Göta River

| | Average (1995-2014) | Year 2014 | 2014 vs. average (%) |
|---|---|---|---|
| Flow ($m^3 s^{-1}$) | 607 | 712 | 117 |
| TN load (t) | 14047 | 14949 | 106 |
| TP load (t) | 403 | 360 | 89 |

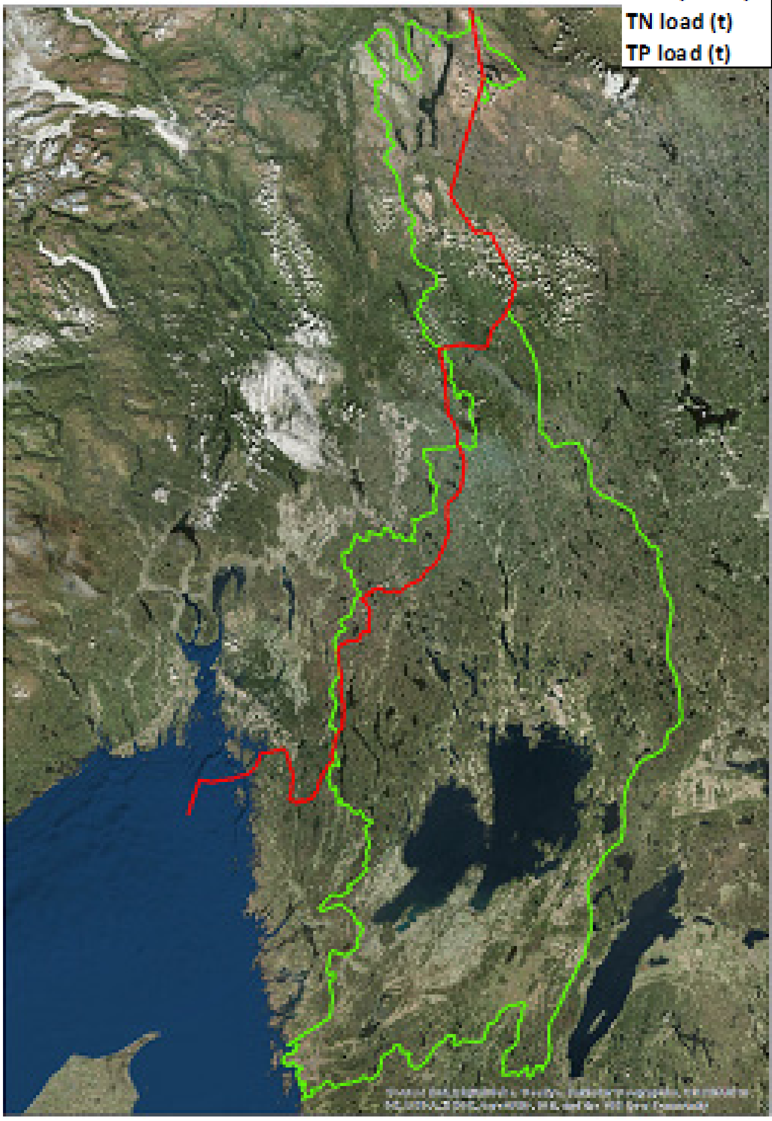


**Figure 7.**
The drainage area (green line) of the Göta River, country borders (red line), average flow, total nitrogen load, total phosphorus load and respective values for the year 2014.

## *Basic information*

The area of the Göta River's drainage basin is 50,200 km2. Most of the catchment belongs to Sweden (85%), and represents about 10% of total Swedish land area. However, the northernmost part of the river system is in Norway (Figure 7). The northern parts are pristine, whereas the human impact is most evident in the southern parts of the catchment. More than 50% of land use is forested areas, especially in the northern part (Sonesten 2004). Arable land is mainly found in the south-eastern part, as well as in the lower reaches of the catchment areas running into Lake Vänern (Figure 6). Also, the areas beyond the outlet of Lake Vänern have a notable amount of arable land. Lake Vänern, the largest lake in Sweden and the third largest in Europe, has an import role in the nutrient transport in the catchment as it efficiently retains nutrients originating from its upstream catchments.

The river divides into two river branches near the estuary leading into the North Sea. At least two thirds of the river volume runs through the northern branch: Nordre älv (Göta älvs vattenvårdsförbund 2015). The southern branch passes through the city of Gothenburg providing more than 700 000 people with drinking water. The Göta River is utilized as a shipping channel and allows for transport of goods both in the upstream and downstream direction. The total fall in height between lake Vänern and the sea is 44 meters. This is used for producing hydropower through a highly regulated water flow in several water power plants, corresponding to a total capacity of approximately 300 MW. The Göta River is a recipient for wastewater from various industries, sewage treatment plants and individual sewers as well as storm water from urban areas and nutrient input from agriculture in the valley. Population density is 28 inhabitants per km2 and Karlstad, Trollhättan and Göteborg are the largest cities in the catchment.

## *Trends in the load: The Göta River*

In 2014 flow was 17% higher than the long term average flow. Even if the annual flow was higher than the long-term flow both total nitrogen load and total phosphorus load were lower in 2014 than the respective long-term average loads. In 2014 the area specific total nitrogen load was 280 kg km-2 and the mean total nitrogen concentration was 666 µg l-1. The respective total phosphorus load was 8.0 kg km-2 and the mean concentration was 16 µg l-1.

Total nitrogen loads have been decreasing between 1995 and 2014, especially since 2006 (Fig. 8). In fact, the total nitrogen load has been decreasing since the mid 1980's. This is a general tendency for nitrogen transport in different parts of the river system as well as for the nitrogen levels in Lake Vänern. The reduced nitrogen levels in the system are due to reduced inputs of nitrogen from point sources (Christensen et al. 2002) including nitrogen removal from waste water treatment plants, and also from diffuse nitrogen sources. Total phosphorus loads do not show any statistically significant changes (Fig. 9).

There was a better correlation between flow and total nitrogen load than between flow and total phosphorus load (Figure 10), indicating that nitrogen is more easily leached from soils into freshwater during rain events.

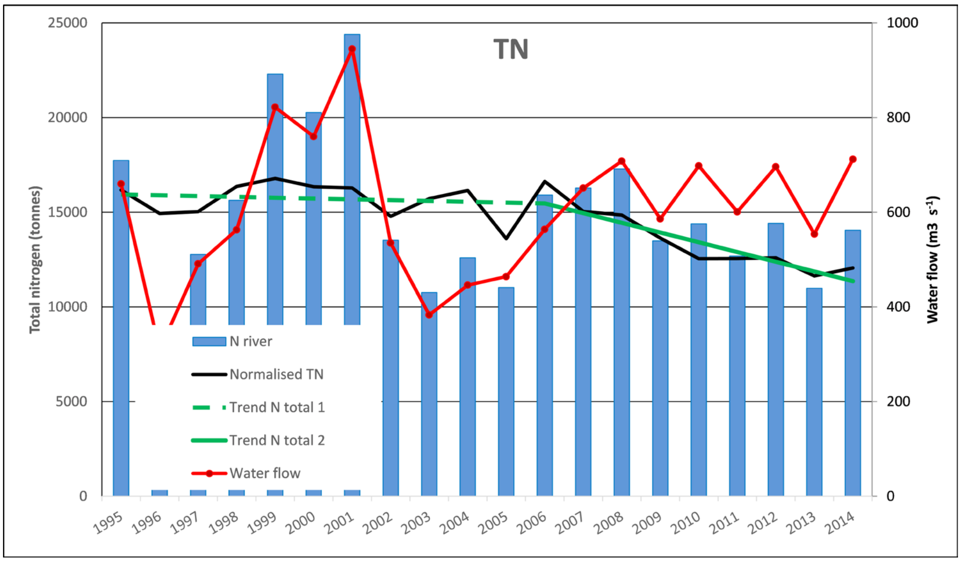



**Figure 8.**
Total nitrogen load (blue bars) and flow (red line) of the Göta River between 1995 and 2014. The black line is showing the flow-normalized total nitrogen load and the dashed green line a not statistically significant trend in the flow-normalized load. The trend analyses took into account also possible break points. A break point in total nitrogen load trend was identified in 2006. This is the starting point of a statistically significant decreasing trend for total nitrogen load (solid green line) in the Göta River.

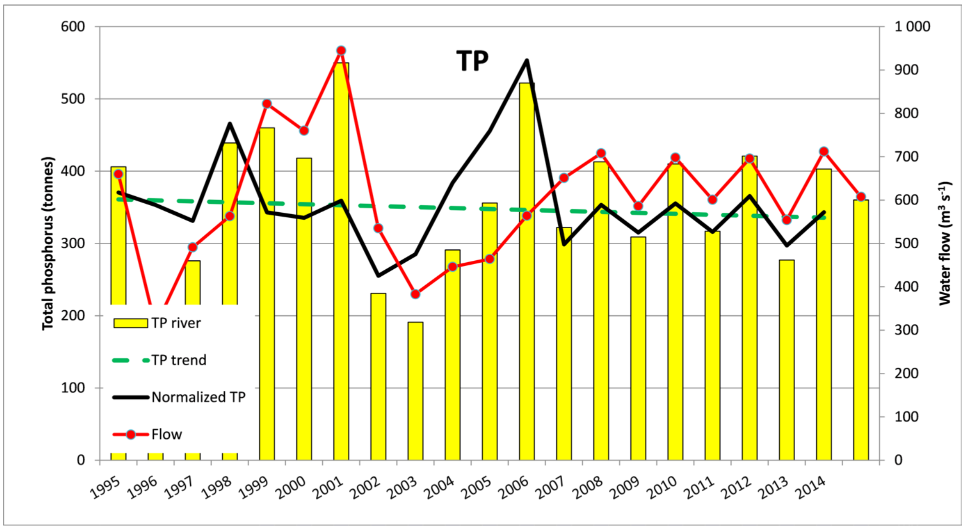



**Figure 9.**
Total phosphorus load (yellow bars) and flow (red line) of the Göta River between 1995 and 2014. The black line shows the flow-normalized total phosphorus load and the dashed green line the statistically insignificant trend in the flow-normalized load.

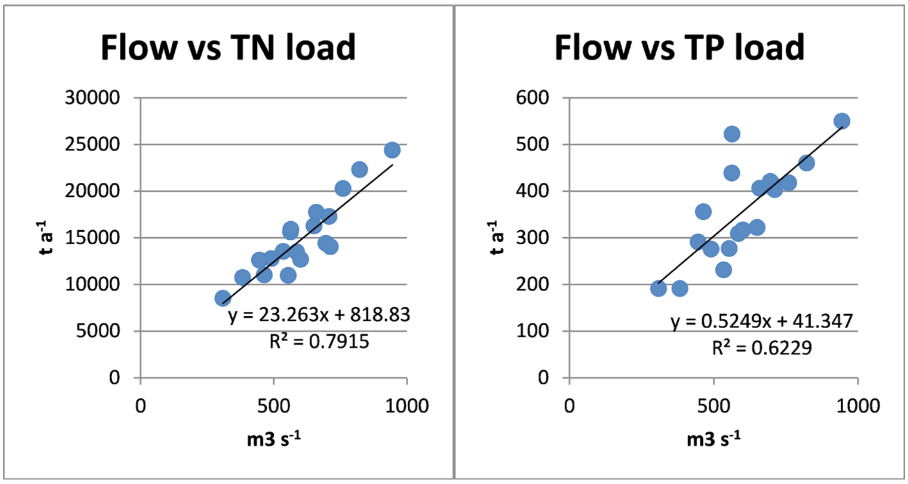
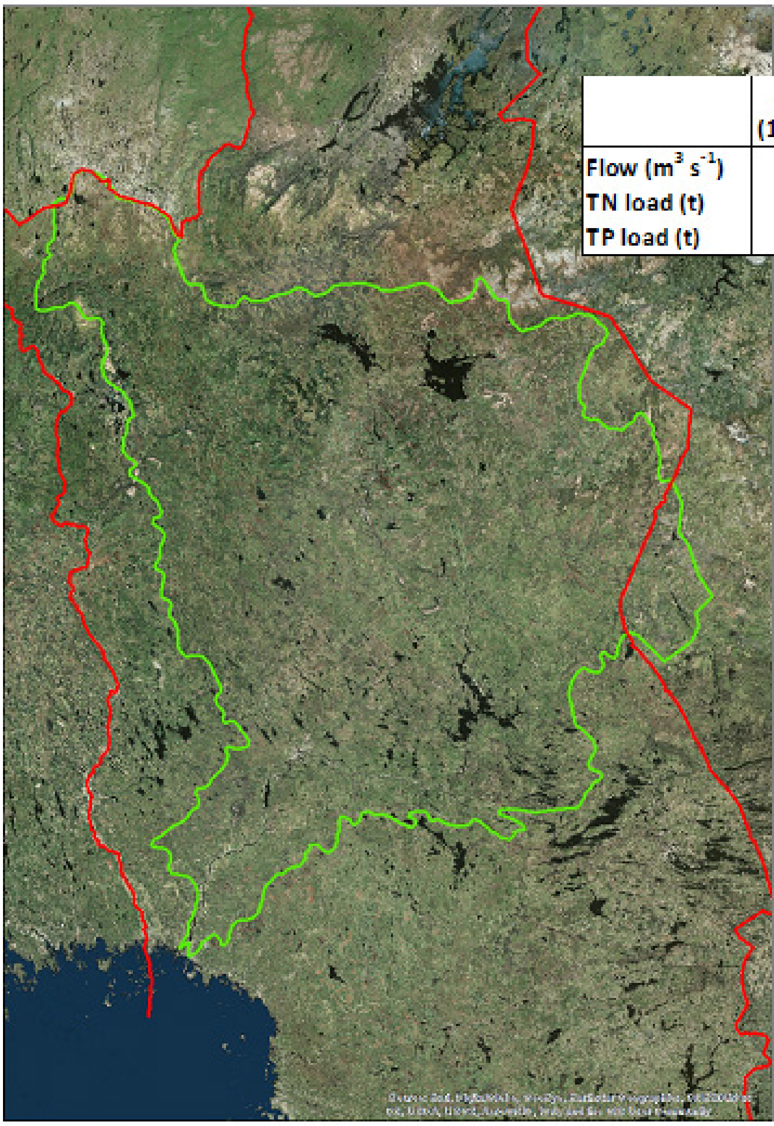



**Figure 10.**
The relationship between flow and total nitrogen and total phosphorus load in the Göta River.

# The Kemi River



| | Average (1995-2014) | Year 2014 | 2014 vs. average (%) |
|---|---|---|---|
| Flow ($m^3 s^{-1}$) | 559 | 495 | 89 |
| TN load (t) | 6492 | 5671 | 87 |
| TP load (t) | 328 | 262 | 80 |

**Figure 11.**
The drainage area (green line) of the Kemi River, country borders (red line) and average river flow, total nitrogen load, total phosphorus load and respective values for the year 2014.

## Basic information

The River Kemi stretches for 550 km, making it the longest river in Finland. It flows into the Bothnian Bay. It drains northern parts of Finland and a small part of its catchment is in Russian territory (Fig. 11). The river has been heavily used for hydroelectric production and the first dam was built in 1946. Today the total number of hydroelectric plants is twenty-one. In addition to dams, two large reservoirs were built in the late 1960s in the northern parts of the catchment for hydroelectric purposes.

Forests cover over half and peatlands one quarter of the catchment area. The northernmost parts of the catchment area are in particularly pristine condition. Human impact, beside hydroelectric production, is mainly due to forestry activities. In addition, there are about 20 peat production areas and three mines. The only other industrial activity contributing to the pollution load was the pulp factory in Kemijärvi, but this closed in 2008. Most of the cultivated areas and the majority of settlements are located in the lower parts of the catchment. Agricultural land areas and urban areas cover together less than 1% of the total catchment area and the population density is only 2 people per km2. The largest city in the area is Rovaniemi with 62,000 inhabitants.

## Trends in the load: The Kemi River

In 2014 flow was 11% lower than the long term average flow and this was reflected in both total nitrogen and total phosphorus loads, which were lower than the respective long-term loads. In 2014 the area specific total nitrogen load was 110 kg km-2 and the mean total nitrogen concentration was 363 µg l-1. The respective total phosphorus load was 5.1 kg km-2 and the concentration was 17 µg l-1.

No statistically significant trends could be detected between 1995 and 2014 (Figure 12 and 13). However, climate change is projected to increase precipitation and runoff especially in the northern parts of the Baltic Sea over the next century (Graham 2004) and there are signs that flow is increasing in northernmost Finland (Räike et al. 2014), which will most likely lead to an increase in nutrient transport to the sea. Approximately half of the annual nutrients in the River Kemi are exported to the sea during spring floods in May to early June. However, the timing of floods is changing and the spring thaw is expected to start earlier in future (Blöschl et al. 2017).

There was a good correlation between flow and loads for both total nitrogen and total phosphorus(Figure 14).

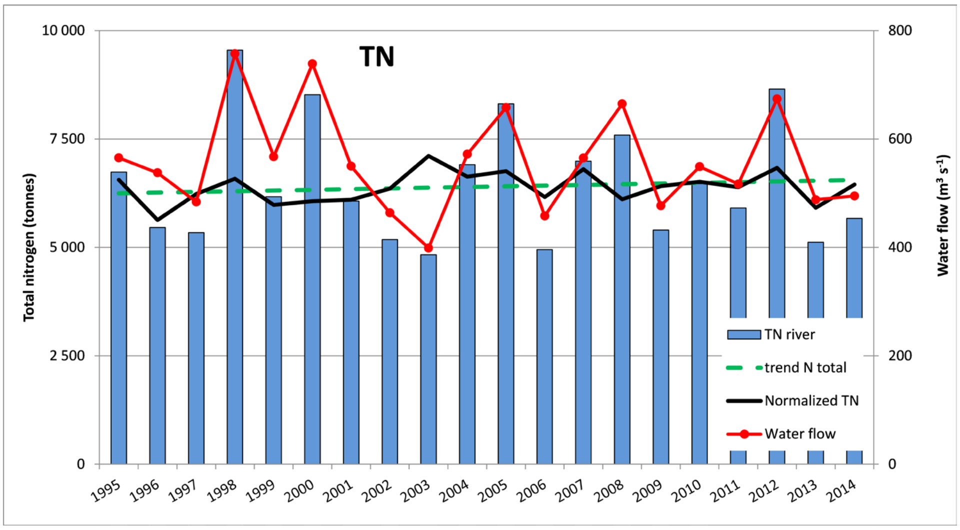



**Figure 12.**
Total nitrogen load (blue bars) and flow (red line) of the Kemi River between 1995 and 2014. The black line is showing the flow-normalized total nitrogen load and the dashed green line the statistically insignificant trend in the flow-normalized load.

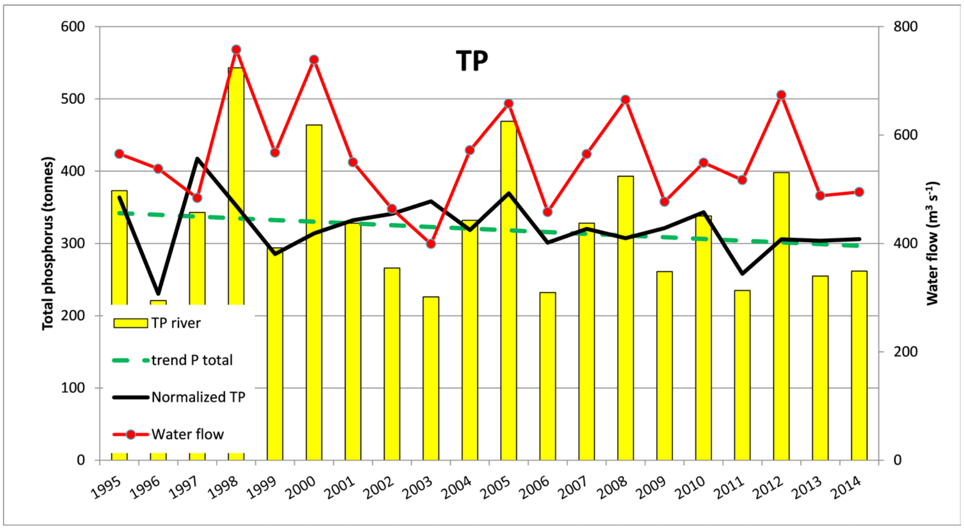



**Figure 13.**
Total phosphorus load (yellow bars) and flow (red line) of the Kemi River between 1995 and 2014. The black line is showing the flow-normalized total phosphorus load and the dashed green line the statistically insignificant trend in the flow-normalized load.

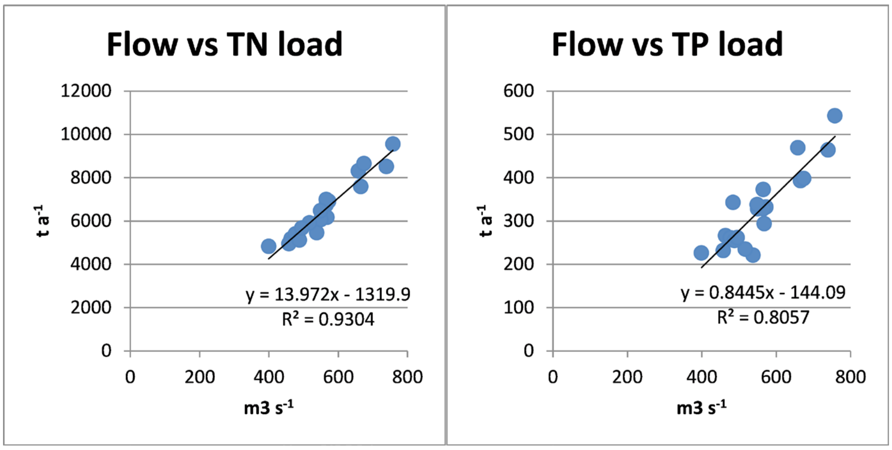
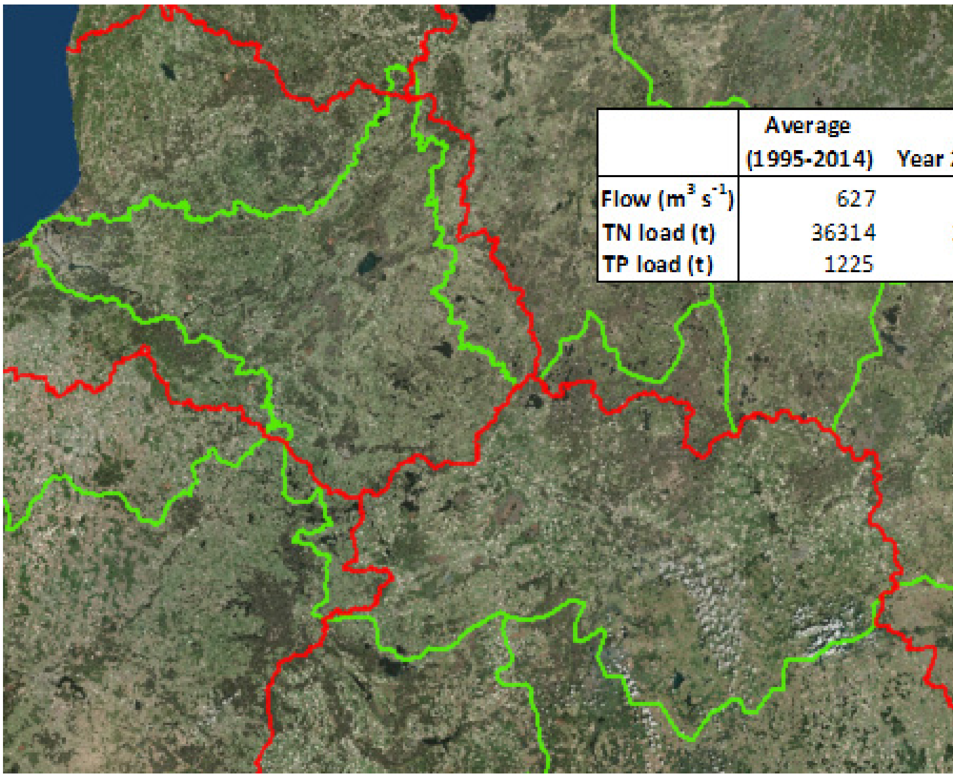



**Figure 14.**
The relationship between flow and total nitrogen and total phosphorus load in the Kemi River.

# The Daugava River



| | Average (1995-2014) | Year 2014 | 2014 vs. average (%) |
|---|---|---|---|
| Flow ($m^3 s^{-1}$) | 627 | 363 | 58 |
| TN load (t) | 36314 | 20044 | 55 |
| TP load (t) | 1225 | 757 | 62 |

**Figure 15.**
The drainage area (green line) of the Daugava River, country borders (red line) and average river flow, total nitrogen load, total phosphorus load and respective values for the year 2014.

## *Basic information*

The area of the Daugava River's drainage basin is 87,900 km2 and it is 1020 km long (Fig. 15). The Daugava River begins in western Russia, in the Valdai Hills, and crosses the territories of Belarus and Latvia where it flows into the Gulf of Riga. Thirty-eight percent of the catchment belongs to Belarus, thirty-one percent to Russia and twenty-eight percent to Latvia. The rest of the Daugava catchment belongs to Lithuania and Estonia.

Forests cover around half of the Daugava catchment, and cultivated areas occupy around 20%. Population density varies greatly, being the highest in the area around Riga. Several large towns in Latvia and Belarus are located on the banks of Daugava River: Riga (700 000 inhabitants), Ogre (27 000 inhabitants), Daugavpils (94 000 inhabitants), Navapolatsk (108 000 inhabitants), Polatsk (82 000 inhabitants) and Vitebsk (366 000 inhabitants). Deterioration of water quality of the Daugava River started during the Soviet era, when large factories and new residential areas were built without the necessary sewage treatment plants. Navapolatsk town is one of the major sources of pollution to the Daugava River due to its oil processing, refinery plants and developed chemical industry. Municipal waste water treatment plants and agricultural activities are also considerable sources of pollution.

The ecosystem of the lower reaches of Daugava is strongly influenced by the dams and reservoirs of three hydroelectric power plants: Plavinas, Kegums and Rīga. Belarus also has a goal to construct a cascade of four hydroelectricity plants on the Daugava River (Polotsk, Vitebsk, Beshenkovichi, and Verkhnedvinsk), with a total capacity of up to 130 MW by 2020. Presently Vitebsk and Polotsk hydropower plants are under construction and currently they operate on a test regime.

## Trends in the load: The Daugava River

In 2014 flow was only 58% of the long term mean flow and nutrient load was 55–62% of the long term mean: 20,000 t total nitrogen and 757 t total phosphorus. In 2014 the area specific total nitrogen load varied from 111 to 476 kg km-2 (Figure 22) and the mean total nitrogen concentration was 1750 µg l-1. The respective total phosphorus load varied from 4.1 to 9.9 kg km-2 and the total phosphorus concentration was 66 µg l-1.

Major reduction in anthropogenic loading in Latvia occurred between 1987 and 1996 when consumption of fertilizers and number of livestock drastically decreased (Stålnacke et al. 2003). Although the total nitrogen load did not show any statistically significant long term trend between 1995 and 2014, changes can be observed in a statistically insignificant linear decreasing trend (Fig. 16). There was a statistically significant increase in total phosphours load between 1995 and 2007 followed by a slightly decreasing trend (Fig. 17). Also changes in analytical methods have hampered the estimation of changes in load, as nutrient load calculation up until 2003-2004 were based on filtered samples, thus underestimating the total loads. This is supported by abrupt changes in DIP/TP (dissolved inorganic phosphorus/total phosphorus) ratio, which occurred at that time (Savchuck et al. 2012).

The correlation between flow and load is weaker than the respective correlation of the Göta and Kemi rivers (Fig. 18). Processes such as input of waste water, nutrient uptake by vegetation or retention in reservoirs can weaken the relationships between flow and nutrient loads. Highest nutrient concentrations in Latvian rivers are observed in spring when nutrients are flushed out from the catchment soils (Klavins et al. 2003). Around 40 % of the annual flow occurs in spring (Apsite et al. 2009), but future projections predict substantial reduction of spring flow and increase of winter flow (Latkovska et al. 2012).

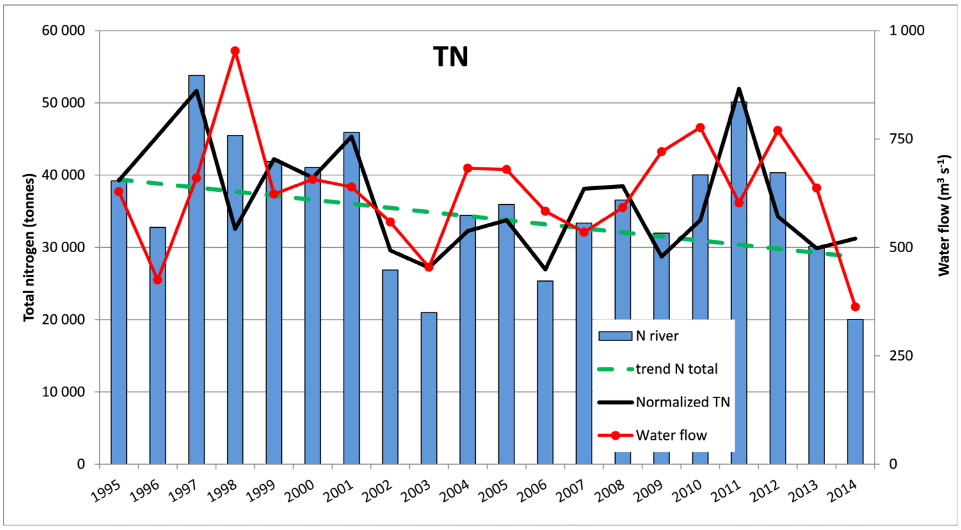



**Figure 16.**
Total nitrogen load (blue bars) and flow (red line) by the Daugava River between 1995 and 2014. The black line is showing the flow-normalized total nitrogen load and the dashed green line the statistically insignificant trend in the flow-normalized load.

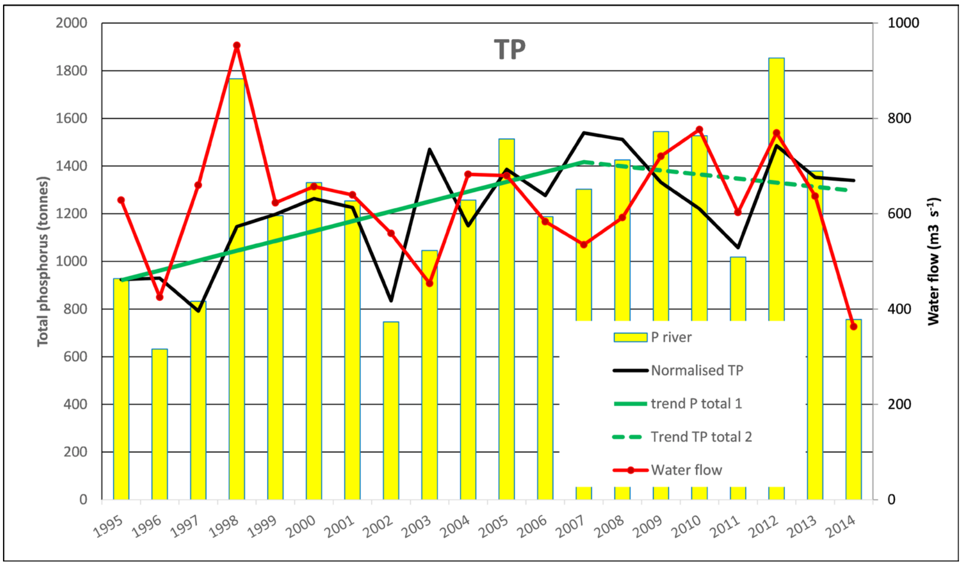



**Figure 17.**
Total phosphorus load (yellow bars) and flow (red line) from the Daugava River between 1995 and 2014. The black line is showing the flow-normalized total phosphorus load and the green line the trend in the flow-normalized load. The trend analyses took into account also possible break points. In 2007 there was a break point in total phosphorus load and a statistically significant increasing trend (solid green line) turned into a statistically insignificant decreasing trend (dashed green line) in the Daugava River.

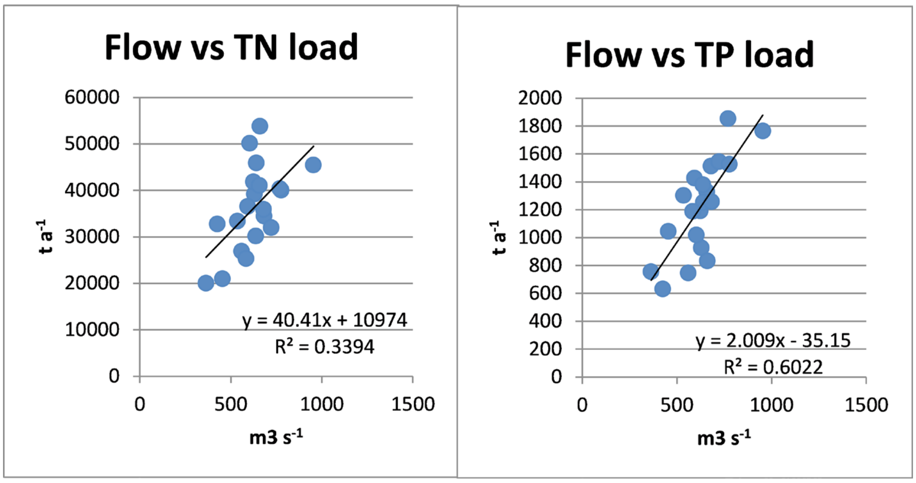
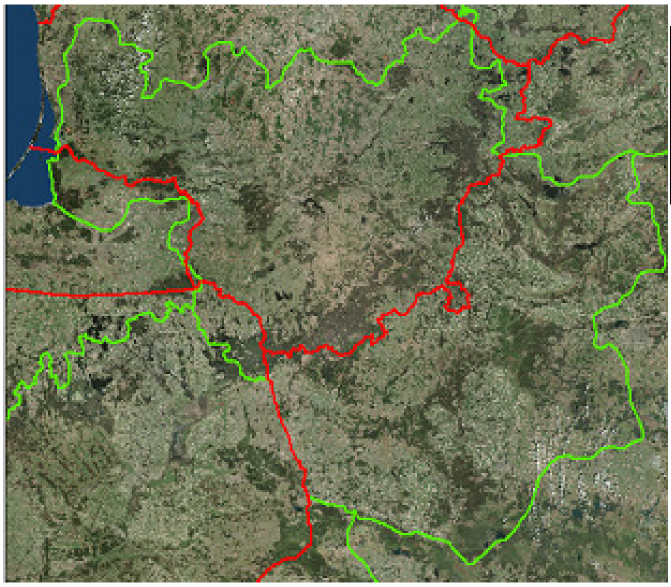



**Figure 18.**
The relationship between flow and total nitrogen and total phosphorus load in the Daugava River.

# The Nemunas River



| | Average (1995-2014) | Year 2014 | 2014 vs. average (%) |
|---|---|---|---|
| Flow ($m^3 s^{-1}$) | 611 | 484 | 79 |
| TN load (t) | 40611 | 32645 | 80 |
| TP load (t) | 1989 | 1150 | 58 |

**Figure 19.**
The drainage area (green line) of the Nemunas River, country borders (red line) and average flow, total nitrogen load, total phosphorus load and respective values for the year 2014.

## *Basic information*

The area of the Nemunas River's drainage basin is 97,900 km2 (Figure 19), which is shared between five countries making it a good example of complicated transboundary issues. The largest, and nearly equal parts, of the catchment belongs to Lithuania (46,700 $km^2$) and Belarus (45,463 $km^2$). The rest is shared between Russia (3,125 $km^2$), Poland (2,515 $km^2$) and Latvia (88 $km^2$). Additional complication arises because the mouth of the river and a significant part of downstream water is shared between two countries: Lithuania and Russia, making it at the same time a transboundary and border river, which is a unique combination in the Baltic Sea drainage basin. Moreover, it all gets even more complex because of theMatrosovka channel, which at 50 km from the river mouth diverts one quarter of all Nemunas river volume into Russian territory.

The total length of the Nemunas River is 937 km. It is the fourth longest river in the Baltic Sea basin. 436 km of it flows in Belarus, 359 km in Lithuania and the remaining 116 km stretch is the border between Lithuania and Russia's Kaliningrad oblast. Land cover in the Nemunas River basin is dominated by agricultural land, which occupy more than half of the basin area in Lithuania. Forest and natural areas make up around one-third, while surface water bodies and urban areas cover 2% of the basin each (Table 1). Total population in the basin is estimated at around 5.4 million people and the biggest city is Vilnius with around 543,000 inhabitants. There is only one major reservoir in the Nemunas River, which was built for hydroelectric power generation in 1960, close to Kaunas (Lithuania). Another hydroelectric power generation station was built close to Grodno city (Belarus) in 2012. However, it was built using run-of-the-river hydroelectricity, meaning that no reservoir was needed.

## *Trends in the load: The Nemunas River*

In 2014 flow was 21% lower than the long term average flow and loads were accordingly lower. In 2104 the total nitrogen load was32,600 t and the total phosphorus load 1150 t. The total phosphorus load in 2014 was only 58% of the long term average. In 2014 the area specific total nitrogen load varied from 108 to 458 kg km-2 and the mean total nitrogen concentration was 2140 µg l-1. The respective total phosphorus load varied from 4.5 to 18.8 kg km-2 and total phosphorus concentration was 75 µg l-1.

Two trends can be observed in the time series of total nitrogen load: up to until 2001 total nitrogen loads were decreasing, while after 2001 the opposite trend emerged (Fig. 20). This happened due to an increase in the intensity of agricultural activities. From 2001 onwards the area under cultivation and fertilizer usage gradually increased.

A statistically significant decrease in total phosphorus load could be detected between 1995 and 2014 (Fig. 21). A distinct change in total phosphorus load happened during 2004-2005, around the time when Lithuania joined the European Union. This was due to large investments in the upgrading and building of new waste water treatment facilities, largely financed by the European Union.

The correlation between flow and total phosphorus load was very weak (Fig. 22), while the correlation between flow and total nitrogen load is more pronounced.

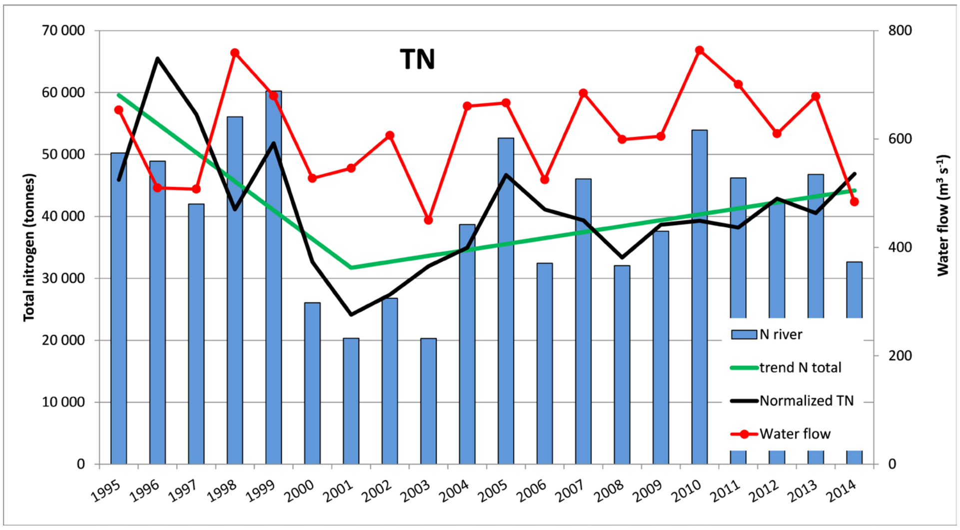



**Figure 20.**
Total nitrogen load (blue bars) and flow (red line) by the Nemunas River between 1995 and 2014. The black line shows the flow-normalized total nitrogen load and the green line the statistically significant trend in the flow-normalized load. The trend analyses took into account possible break points. In 2001 there was a break point in total nitrogen load and the decrease turned into an increase in the Nemunas River.

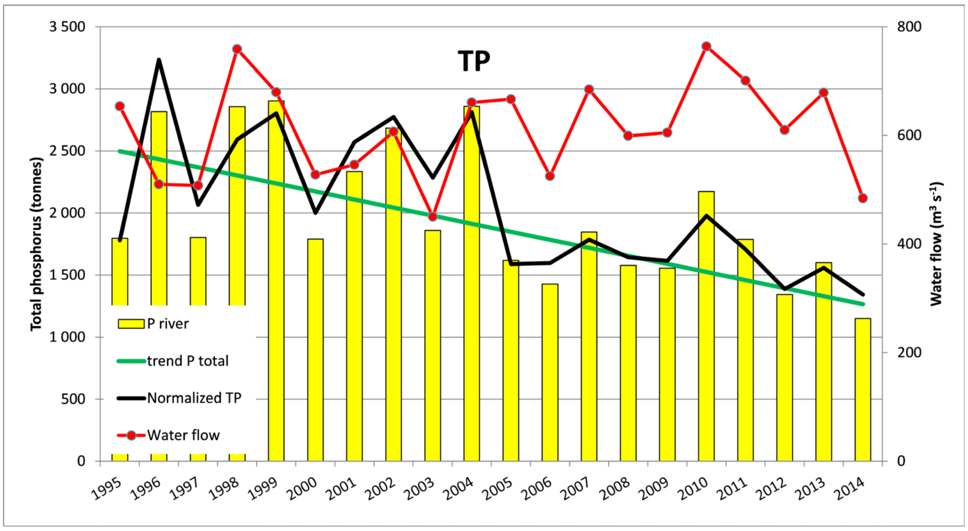



**Figure 21.**
Total phosphorus load (yellow bars) and flow (red line) for the Nemunas River between 1995 and 2014. The black line shows the flow-normalized total phosphorus load and the green line the statistically significant trend in the flow-normalized load.

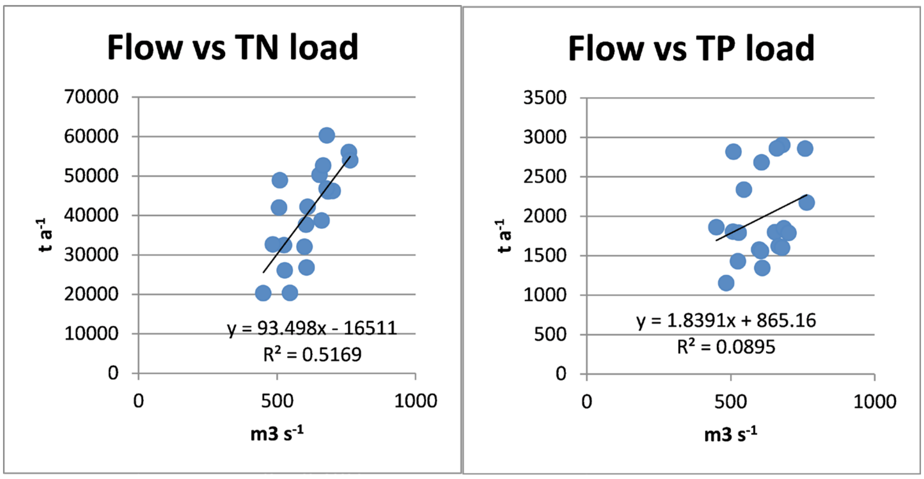
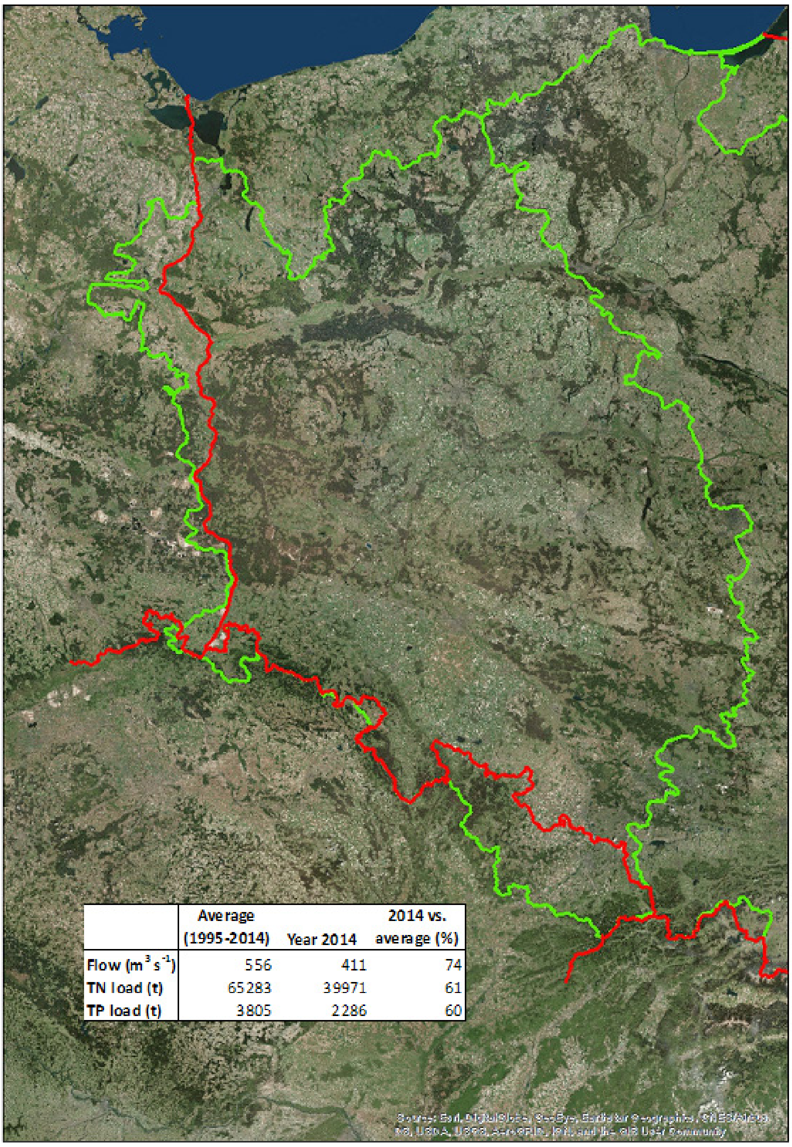



**Figure 22.**
The relationship between flow and total nitrogen and total phosphorus load in the Nemunas River.

# The Oder River



| | Average (1995-2014) | Year 2014 | 2014 vs. average (%) |
|---|---|---|---|
| Flow ($m^3 s^{-1}$) | 556 | 411 | 74 |
| TN load (t) | 65283 | 39971 | 61 |
| TP load (t) | 3805 | 2286 | 60 |

**Figure 23.**
The drainage area (green line) of the Oder River, country borders (red line) and average flow, total nitrogen load, total phosphorus load and the respective values for the year 2014.

## Basic information

The source of the Oder River is in the Czech Republic in the Odrzanskie Mountains at an altitude of 634 m above sea level (Figure 23). The river is 841 km long and the area of river basin is 124,049 km$^2$, of which 107,000 km$^2$ is in Poland (86%), 7,300 km$^2$ in the Czech Republic (6%), and 9,600 km$^2$ within the boundaries of Germany (8%). The Oder flows into the Szczecin Lagoon.

Beside pollution from municipal waste water treatment plants and scattered dwellings a large share of nutrient load originates from cultivated areas, which cover 57% of the Oder's catchment area (Table1). Over 16 million people live in the Oder River catchment and the population density is high. Large cities include Ostrava, Opole, Frankfurt, Poznan, Wroclaw, and Szczecin.

## Trends in the load: The Oder River

In 2014 the flow was 26% lower than the long term average flow and nutrient loads were also at a lower level: The total nitrogen load was 40,000 t and total phosphorus load 2290 t. The area specific total nitrogen load varied in 2014 from 250 to 511 kg km-2 and the mean total nitrogen concentration was 3080 µg l-1. The respective total phosphorus load varied from 14.1 to 30.6 kg km-2 and total phosphorus concentration was 176 µg l-1.

Total nitrogen load decreased between 1995 and 2014 (Fig 24) and total phosphorus load showed a decreasing trend between 1995 and 2011 (Fig 25). To some extent, the changes in nutrient inputs from the Oder to the Baltic may be explained by developments in wastewater management and in agriculture. In Poland the 1990's were a period of stagnation in agriculture and of major investments in wastewater treatment plants, prompted by the adoption in 1991 of regulations requiring nitrogen and phosphorus removal in all wastewater treatment plants. From the early 2000's onwards, and particularly since Poland's accession to the European Union, there has been a pronounced increase in the intensity of agriculture, including a growth in the use of mineral fertilizers, to some degree offset by the implementation of more environment-friendly agricultural practices concerning natural and mineral fertilizer use. The net effect of the changes in wastewater treatment and agriculture was a slow reduction in nutrient inputs to the Baltic. There is little doubt that in the past decade nutrient loads (particularly nitrogen) from large wastewater treatment plants continued to decline. However, the apparent recent surge in phosphorus inputs, if confirmed by future monitoring, could be associated with the fact that in 2006 regulations concerning effluent quality were relaxed, allowing smaller wastewater treatment plants not to remove phosphorus upon expiry of their pre-2006 permits. This rather complex picture is further altered by the irregularity of flows, including the 2010 flood which resulted in a strong spike in actual nitrogen and phosphorus inputs.

Correlation between flow and total nitrogen load is more pronounced than the correlation between flow and total phosphorus load (Fig. 26).

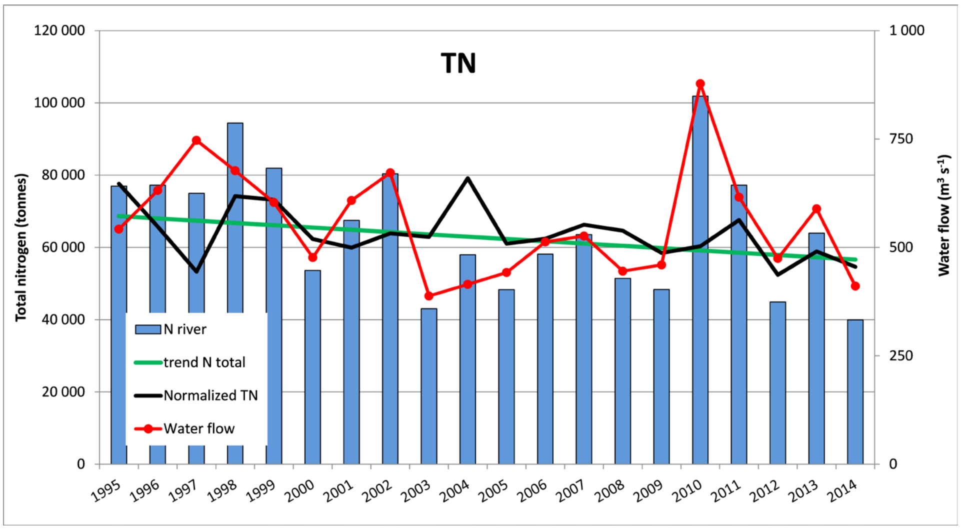



**Figure 24.**
Total nitrogen load (blue bars) and flow (red line) of the Oder River between 1995 and 2014. The black line is showing the flow-normalized total nitrogen load and the green line the statistically significant trend in the flow-normalized load.

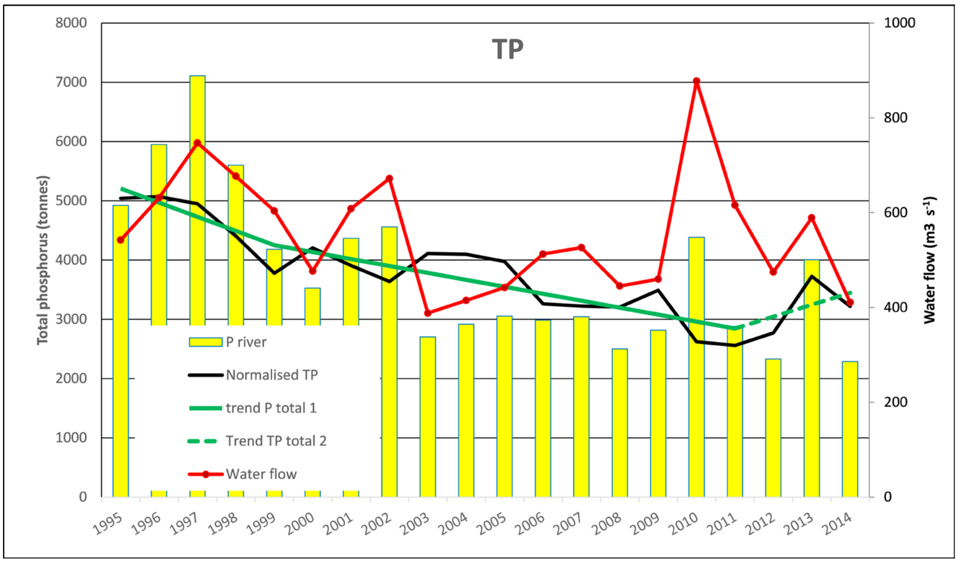



**Figure 25.**
Total phosphorus load (yellow bars) and flow (red line) of the Oder River between 1995 and 2014. The black line shows the flow-normalized total phosphorus load and the green line the trend in the flow-normalized load. The trend analyses took into account also possible break points. In 2011 there was a break point in the total phosphorus load and a statistically insignificant increasing trend (dashed green line) starting in the Oder River.

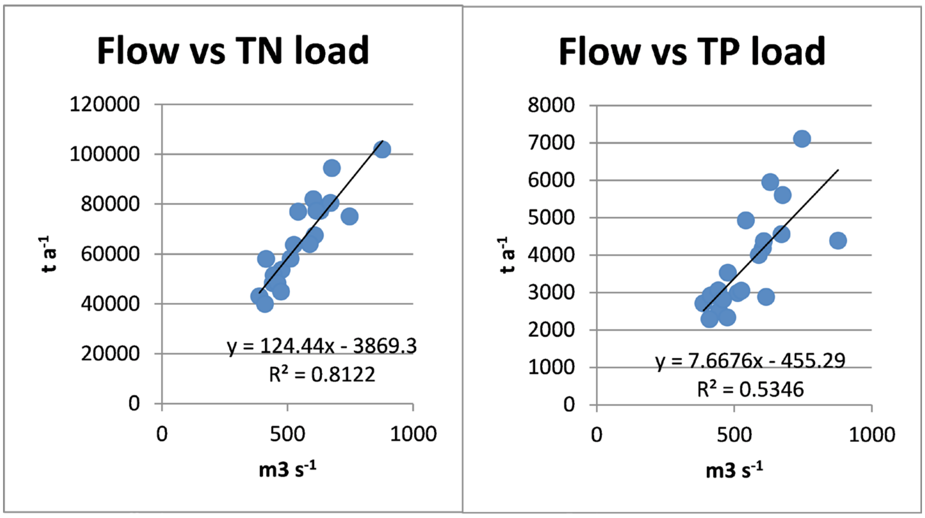
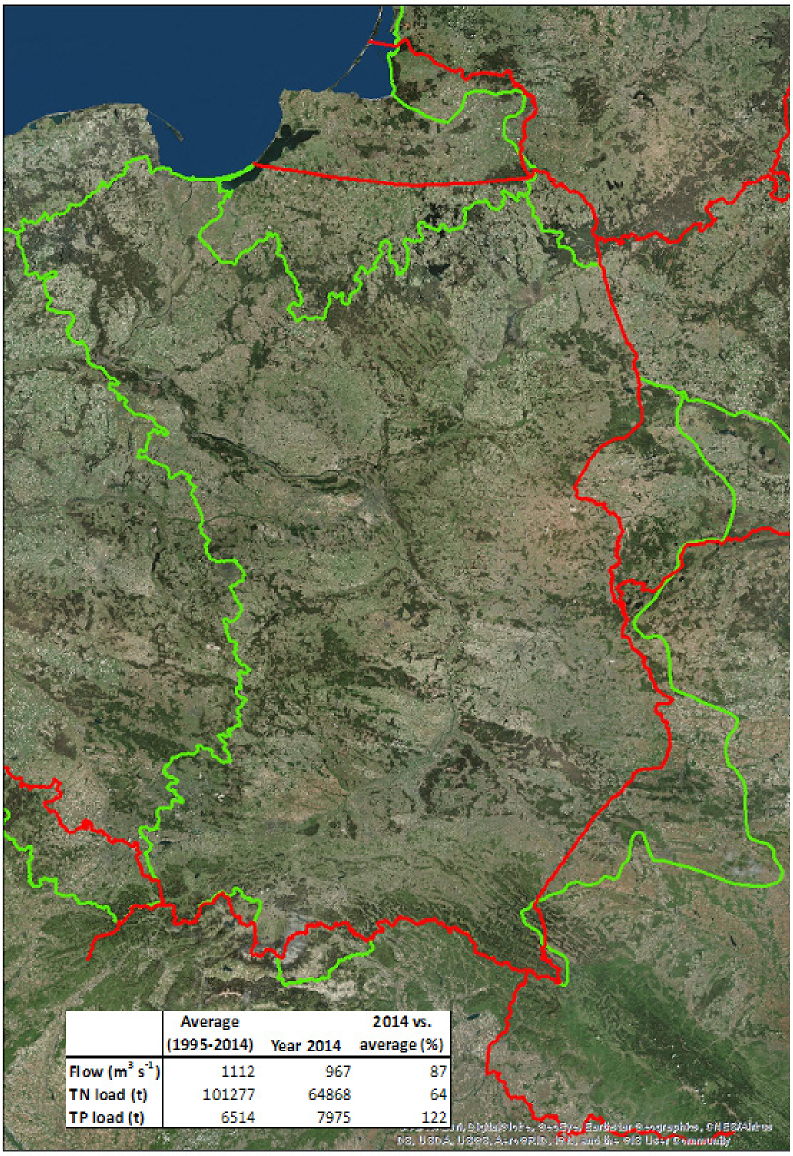



**Figure 26.**
The relationship between flow and total nitrogen and total phosphorus load in the Oder River.

# The Vistula River



| | Average (1995-2014) | Year 2014 | 2014 vs. average (%) |
|---|---|---|---|
| Flow ($m^3 s^{-1}$) | 1112 | 967 | 87 |
| TN load (t) | 101277 | 64868 | 64 |
| TP load (t) | 6514 | 7975 | 122 |

**Figure 27.**
The drainage area (green line) of the Vistula River, country borders (red line) and average flow, total nitrogen load, total phosphorus load and respective values for the year 2014.

## Basic information

The area of the Vistula River's drainage basin is 194,000 km2. The source of the Vistula River is located in the southern part of Poland and the mouth of Vistula River is in the Bay of Gdansk. The largest part of the catchment belongs to Poland (Figure 27). It is densely populated and intensively cultivated, which is reflected in high area specific loads.

The Vistula river's Polish catchment area covers about 183 176 km2 which is approximately 59 % of the total surface area of Poland. 88% of the Vistula river basin is located in Poland, the remaining part is on the territories of Belarus, Ukraine and Slovakia. The river basin of the Vistula covers almost the entire eastern part of the country and it is inhabited by nearly 21 million people, which is more than half of Poland's population. The largest cities are Krakow, Warsaw and Gdansk.

The most important factors responsible for diffuse sources of pollution are agriculture, scattered dwellings and atmospheric deposition. The agricultural land covers about 50% (Fig. 41) and forests about 30% of the total Vistula river basin area (Table 1).

In the Vistula catchment area the major sources of point source pollution are municipal wastewater treatment plants, but pollution also originates from industrial activities including the crude oil processing, organic and inorganic chemistry plants, paper production, textile industry, iron and steel metallurgy, food industry and shipyards. Another anthropogenic pressure originates from water discharge from mine drainage and leachate from landfills that are not properly protected.

## *Trends in the load: The Vistula River*

In 2014 flow was 13% lower than the long term average flow. Total nitrogen and total phosphorus loads responded differently to this slight decrease: total nitrogen load was 36% less and total phosphorus load 22% more than the respective long term average loads. The area specific total nitrogen load varied from 146 to over 5000 kg km-2 and the mean total nitrogen concentration was 2130 µg l-1. The respective total phosphorus load varied from 8.4 to 138 kg km-2 and mean total phosphorus concentration was 262 µg l-1.

There was a sharp decrease in total nitrogen load from 1995 to 1999 and after that the downward trend was modest (Fig. 28). There was no trend in phosphorus load (Figure 29). To a large extent, the changes in nutrient inputs from the Vistula to the Baltic may be explained by developments in wastewater management and in agricultural practices. The 1990's were a period of stagnation in agriculture and of major investments in wastewater treatment plants, prompted by the adoption of regulations requiring nitrogen and phosphorus removal in all wastewater treatment plants in 1991. From the early 2000's onwards, and particularly since Poland's accession to the European Union, there has been a pronounced increase in the intensity of agriculture, including a growth in the use of mineral fertilizers, to some degree offset by the implementation of more environmentally-friendly agricultural practices concerning natural and mineral fertilizer use. The apparent recent surge in phosphorus inputs, if confirmed by future monitoring, could be associated with the fact that in 2006 regulations concerning effluent quality were relaxed, allowing smaller wastewater treatment plants not to remove phosphorus upon expiry of their pre-2006 permits. This rather complex picture is further altered by the irregularity of flows, including the 2010 floods which resulted in a pronounced peak in actual nitrogen and phosphorus inputs.

There was a good correlation between flow and load for both nitrogen and phosphorus (Fig. 30).

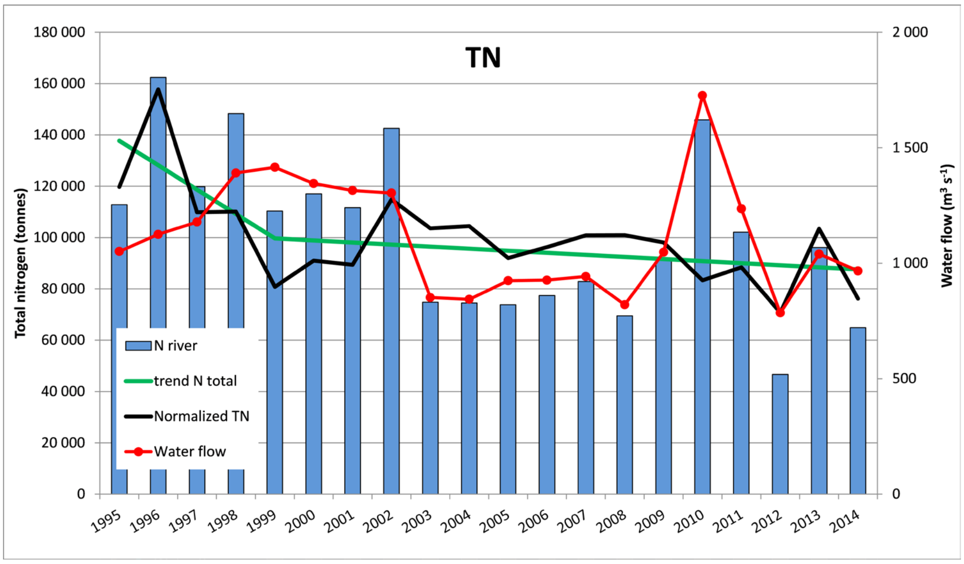



**Figure 28.**
Total nitrogen load (blue bars) and flow (red line) of the Vistula River between 1995 and 2014. The black line shows the flow-normalized total nitrogen load and the green line the statistically significant trend in the flow-normalized load. The trend analyses took into account also possible break points. In 1999 there was a break point in the total nitrogen load in the Vistula River.

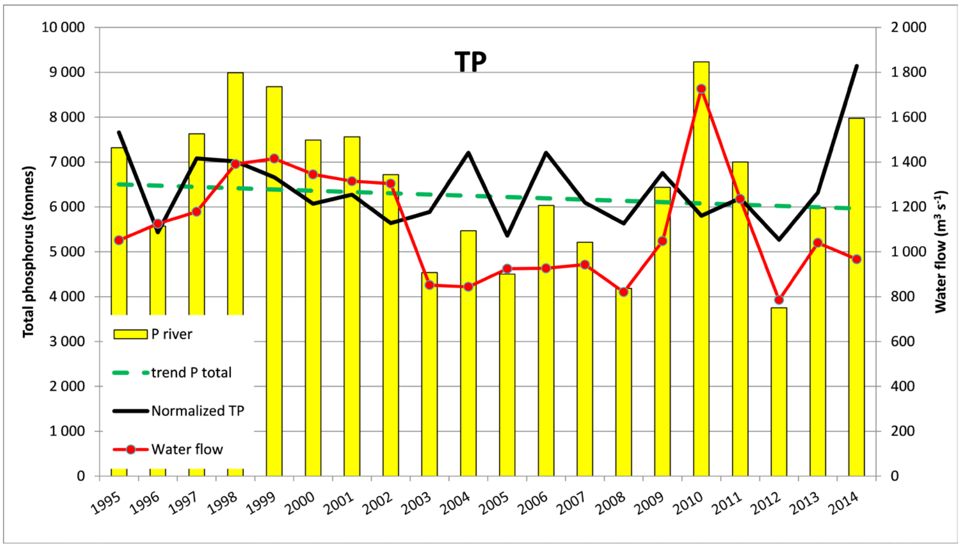



**Figure 29.**
Total phosphorus load (yellow bars) and flow (red line) of the Vistula River between 1995 and 2014. The black line shows the flow-normalized total phosphorus load and the dashed green line the statistically insignificant trend in the flow-normalized load.

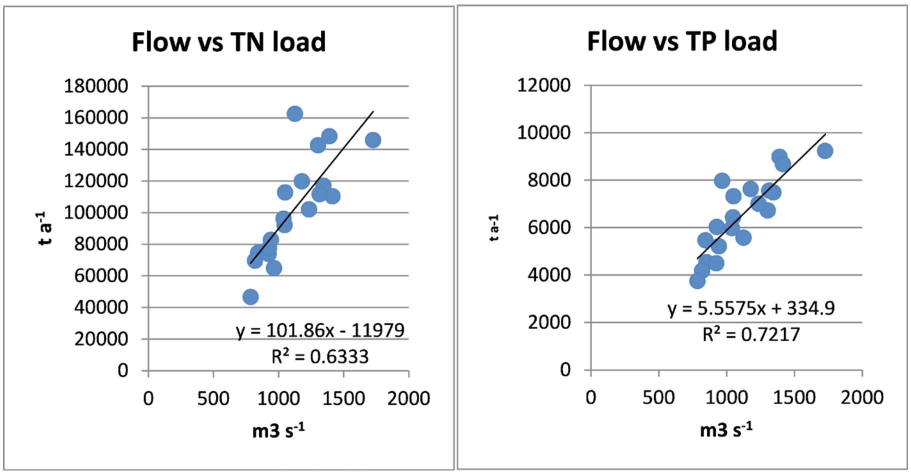
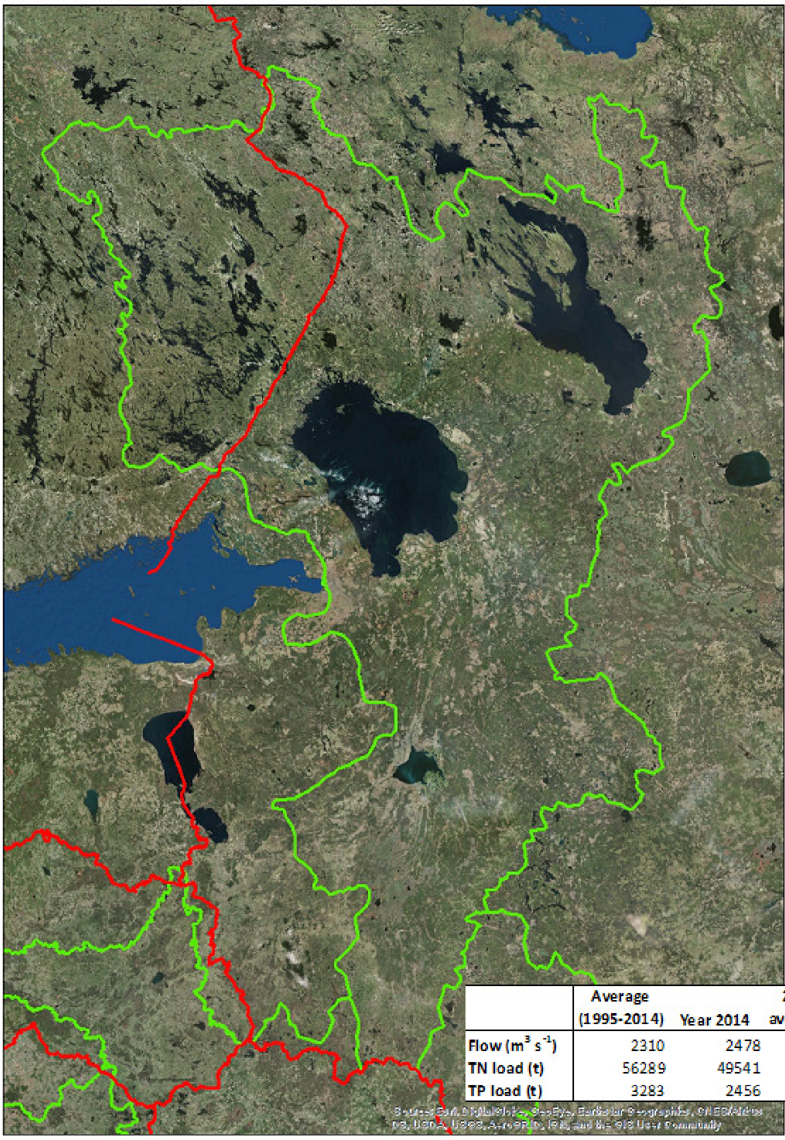



**Figure 30.**
The relationship between flow and total nitrogen and total phosphorus load in the Vistula River

# The Neva River



| | Average (1995-2014) | Year 2014 | 2014 vs. average (%) |
|---|---|---|---|
| Flow ($m^3 s^{-1}$) | 2310 | 2478 | 107 |
| TN load (t) | 56289 | 49541 | 88 |
| TP load (t) | 3283 | 2456 | 75 |

**Figure 31.**
The drainage area (green line) of the Neva River, country borders (red line) and average flow, total nitrogen load, total phosphorus load and respective values for the year 2014.

## Basic information

The Neva River has the largest drainage basin of all Baltic rivers: 281 600 km2. The biggest part of the catchment belongs to Russia, but also a large area is in Finnish territory (Figure 31). The north-eastern parts are in a pristine state, whereas the areas along the riverside are densely populated. Europe's two largest lakes (Ladoga and Onega) are situated in the catchment area and they retain a large share of the nutrient inputs from their upstream catchment. Forests cover 55% of the catchment area, whereas urban and cultivated areas together cover only approximately 12% (Table 1).

## *Trends in the load: The Neva River*

In 2014 flow was 7% higher than the long term average flow, but total nitrogen and total phosphorus loads were at a lower level than the respective average loads. The area specific total nitrogen load varied from 142 to 171 kg km-2 and the mean total nitrogen concentration was 634 µg l-1. The total phosphorus load varied from 2.5 to 8.5 kg km-2 and the mean total phosphorus concentration was 31 µg l-1.

Nitrogen load in the Neva River increased between 1995 and 2004, and subsequently decreased in later years (Fig. 32). Flow-normalized phosphorus load did not show any statistically significant trend, but the non-normalized load has decreased markedly(Fig. 33). The main reason behind the decrease in phosphorus load were improvements in treatment of wastewater originating from point sources. One of the most important achievements was the reconstruction of the main sewer collector in the northern part of St. Petersburg, carried out by Vodokanal between 2008 and 2012), which enabled the closure of sixty-seven direct discharges of untreated waste water to the Neva River. Presently (2014) 99% of wastewater is treated in St. Petersburg and the nitrogen load has decreased by 14,000 t y−1 (60%) and the phosphorus load by 3600 t y−1 (90%) since 1978 (Vodokanal 2015).

The correlation between flow and load was weak (Fig. 34).

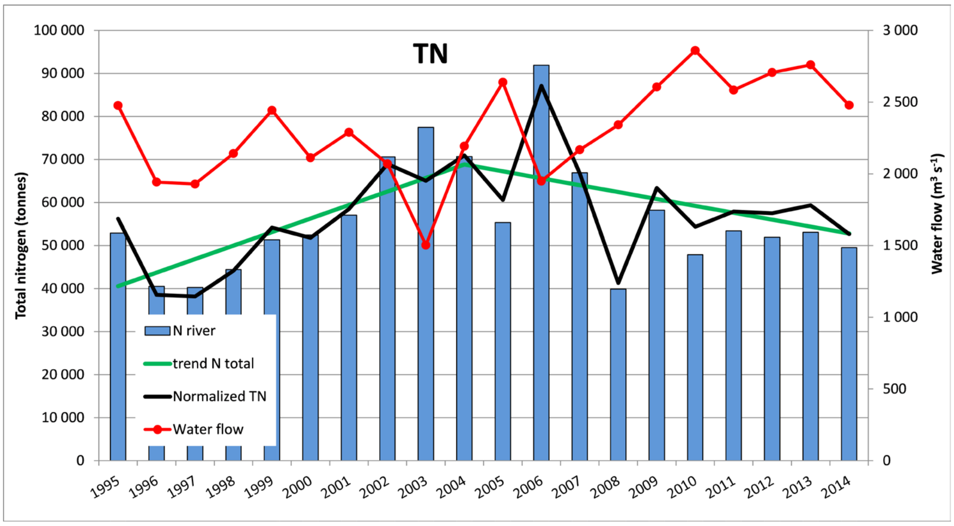



**Figure 32.**
Total nitrogen load (blue bars) and flow (red line) of the Neva River between 1995 and 2014. The black line shows the flow-normalized total nitrogen load and the green line the statistically significant trend in the flow-normalized load. The trend analyses also took into account possible break points. In 2004 there was a break point in total nitrogen load and a decreasing trend in total nitrogen load started in the Neva River.

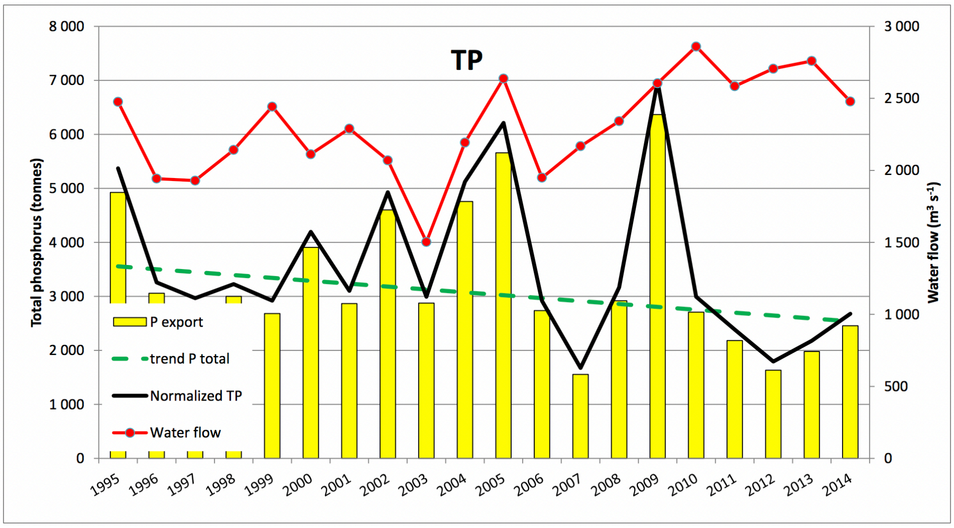



**Figure 33.**
Total phosphorus load (yellow bars) and flow (red line) of the Neva River between 1995 and 2014. The black line is showing the flow-normalized total phosphorus load and the dashed green line the statistically insignificant trend in the flow-normalized load.

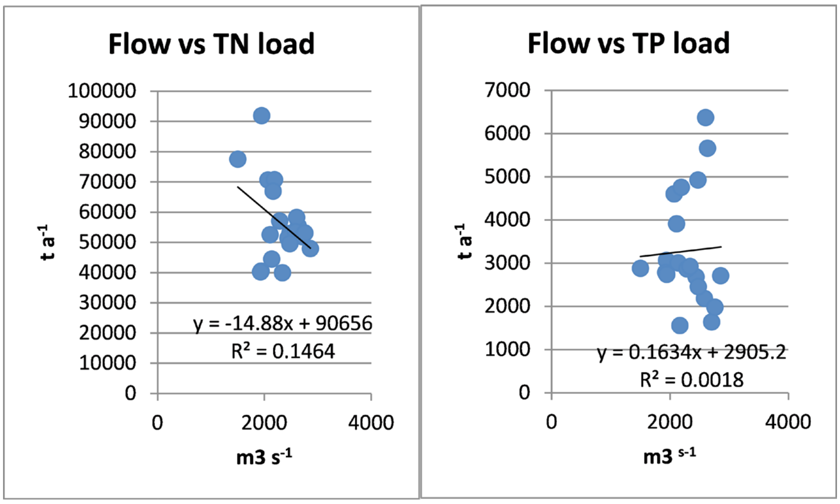



**Figure 34.**
The relationship between flow and total nitrogen and total phosphorus load in the Neva River.

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