SOURCE TO SEA

Effectiveness of measures to reduce nutrient inputs
– importance of point sources (PLC-8)

Baltic Marine Environment Protection Commission

Nutrients

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Introduction

Presently the HELCOM Pollution Load Compilation (PLC) database does not include any kind of data on mitigation measures (e.g. what kind of measures have been conducted, how those measures have affected nutrient inputs, what kind of additional measures have been planned and how those measures are projected to affect inputs). Therefore, in order to get a better understanding of these questions the PLC-6 implementation group in 2016 made a first attempt to gather information from different countries. That compilation revealed that data concerning measures and their effectiveness was not easily available and the estimates of potential reductions were uncertain. In addition, the estimation methods varied widely between the countries.

A further attempt to evaluate the effectiveness of measures (EOM) was made in the HELCOM ACTION project (2018–2020), in which the evaluation would have been done on the basis of selected river basins exemplifying cases where measures have been particularly effective in reducing nutrient loads as well as those where significant efforts have been made to reduce nutrient inputs, but without apparent success. The idea was to ease the work burden of Contracting Parties in gathering all necessary information. Anyhow, it became evident, that even at the river-basin level there was no information on mitigation measures or it was too time-consuming to compile it. Therefore, the original aim of the study had to be redesigned according to the availability of the data. The main emphasis of the redesigned approach was in the estimation of how indirect and direct point source loads have changed during the study period of 2000–2018 on the basis of data extracted from the PLC database. An additional aim was to estimate how reliable and comprehensive this point source data is in regard of nutrient loads.

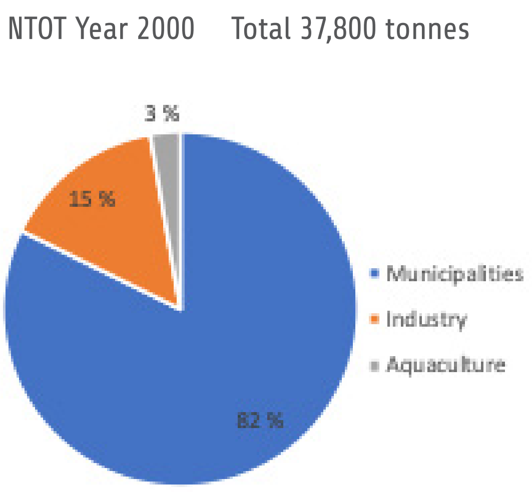
The main purpose of this assessment is to show what kind of data and information linked to EOM the HELCOM Contracting Parties were able to collect during the PLC-8 project.

1. Point source data in the PLC database 2000–2021

1.1. Direct point source loads

Direct point source data was collected from the PLC-database, except for older Russian data that was provided by the Russian PLC implementation group member during the PLC-7 project. Direct point sources were categorized into loads originating from municipalities, industry and aquaculture.

In 2021 the total nitrogen (NTOT) load into the Baltic Sea from direct point sources was 26 800 tonnes and the main origin was municipalities with 87% (Figure 1, right). Since the year 2000 NTOT load from direct point sources has remarkably decreased by 10 800 tonnes (29%). The loads from all three sources decreased, but the biggest proportional decrease was detected in industrial loads, and therefore the relative shares of its input diminished from 15% to 10%.



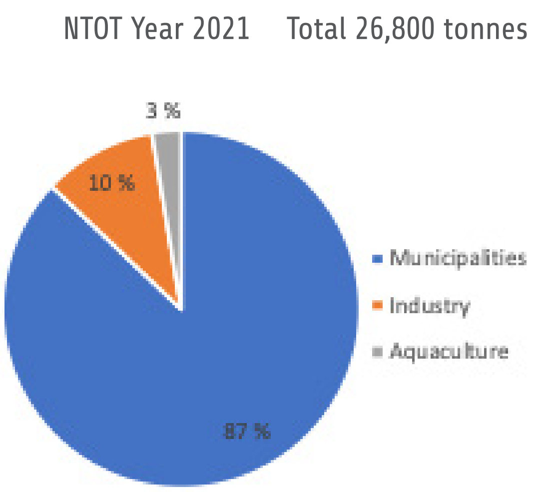
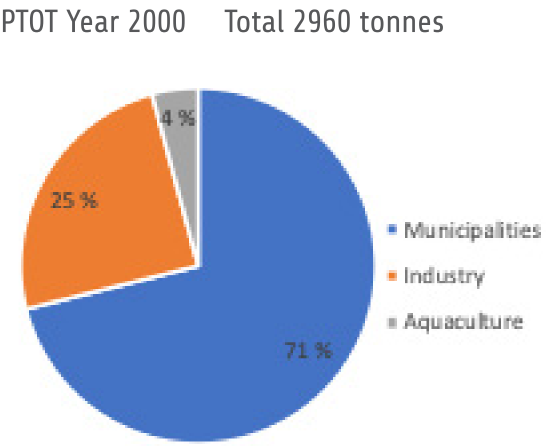


Figure 1. Direct point source NTOT loads by sources in 2000 (left) and 2021 (right).

In 2021 the total phosphorus (PTOT) load into the Baltic Sea from direct point sources was 1153 t and the main origin was municipalities (Figure 2, right). Since the year 2000 the PTOT load has substantially decreased: 1800 tonnes (61%). Especially loads originating from municipal and industrial sources have decreased and therefor the relative share of aquaculture has increased from 4% to 6%.



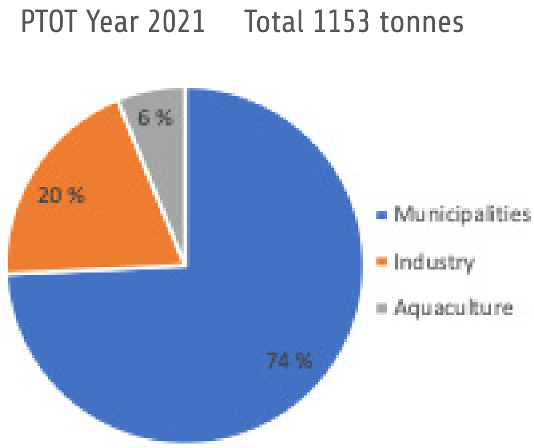


Figure 2. Direct point source PTOT loads by sources total 2960 tonnes (t) in 2000 to the left and 1153 tonnes (t) in 2021 to the right.

1.1.1 Direct municipal loads

In 2021 the municipal wastewater treatment plants discharged nearly 23,500 tonnes (t) of nitrogen (N) directly into the Baltic Sea (Table 1a). Russia had the highest N loads (8790 t) followed by Sweden (7400 t), Finland (2920 t) and Denmark (1960 t). Direct municipal NTOT loads decreased between 2000 and 2021 with 5480 t, which equals to a 19% decrease. N loads were reduced with over 1000 t in four countries: Finland, Germany, Latvia and Sweden. The reductions could be attributed to large investments in wastewater treatment in the biggest cities.

Table 1a. Direct municipal NTOT loads from 2000 to 2021, presented per country.

Country	Parameter	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Change (2000-2021)	Change (2000-2021)
		t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	%
DE	NTOT	2393	1628	807	800	759	730	790	539	663	697	796	686	840	538	618	810	776	870	810	868	875	853	-1539	-64.3
DK	NTOT	1967	1791	2023	1648	1904	1761	1867	2189	1722	2126	1721	1973	1956	1991	1774	1920	1819	1895	1676	2077	1785	1963	-3.88	-0.20
EE	NTOT	978	992	946	971	1119	867	563	826	833	714	704	694	569	502	467	438	480	483	423	463	439	376	-602	-61.6
FI	NTOT	4273	4366	3935	4031	3481	3019	3069	3171	3343	2824	3075	3000	3358	3030	3167	3154	3099	3787	2884	2963	2712	2922	-1351	-31.6
LT	NTOT	285	78.2	74.8	102	269	99.1	85.5	241	246	198	48	215	197	166	157	168	171	205	163	173	149	165	-120	-42.0
LV	NTOT	1551	1613	1539	1914	1561	1656	1786	2437	2477	1292	1155	1179	1086	678	495	551	520	434	410	449	372	437	-1114	-71.9
PL	NTOT	1022	744	768	1184	1028	888	928	1720	919	880	727	874	565	913	827	496	373	939	560	268	580	581	-441	-43.1
RU	NTOT	8038	7942	8490	8668	8529	7566	8653	8653	8016	9549	9375	9989	9614	9562	8940	8924	8690	8191	6663	8078	8394	8793	755	9.39
SE	NTOT	8463	8334	8447	7662	8049	8017	9191	9344	9447	8751	8577	8511	8347	8252	8080	8325	7905	8029	7303	7693	7226	7401	-1061	-12.5
Total	NTOT	28968	27487	27030	26981	26699	24603	26932	29120	27665	27032	26178	27119	26532	25632	24526	24786	23834	24834	20890	23033	22532	23491	-5477	-18.9

In 2021 the municipal wastewater treatment plants discharged 877 tonnes (t) of phosphorus (P) directly into the Baltic Sea (Table 1b). Russia had the highest P load (348 t) followed by Denmark (188 t) and Sweden (172 t). The direct municipal P loads decreased between 2000 and 2021 with 1130 t and in percentage the decrease was larger than the respective N decrease: 56%. The biggest reduction in municipal P loads was detected in Russia (593 t) followed by Latvia (180 t) and Denmark (89 t). The reduction of Russian load was mainly due to enhanced P removal from wastewaters in St. Petersburg. It is noteworthy that in Sweden and Finland the P removal percentage from municipal wastewaters was at a high level already before the year 2000, but both countries have been able to further reduce their PTOT loads.

1.1.2 Direct industrial loads

In 2021 the industrial wastewater treatment plants discharged 2780 tonnes (t) of nitrogen (N) directly into the Baltic Sea (Table 2a). Sweden and Finland together contributed 94% of the N inputs, so the proportion from other countries was minor. The high industrial N inputs in Sweden and Finland originates largely from pulp and paper industry. Direct industrial total nitrogen (NTOT) loads decreased markedly between 2000 and 2021: by 2410 t, which equals a 46% decrease. The biggest reduction in industrial N loads was detected in Sweden (971 t), Estonia (602 t) and Finland (471 t). There were large gaps in the data coverage of several countries (Table 2a).

Table 1b. Direct municipal PTOT loads from 2000 to 2021, presented per country.

Country	Parameter	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Change (2000-2021	Change (2000-2021)
		t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	%
DE	PTOT	36.4	20.9	22.4	20.9	19.8	16.1	20.4	16.3	21.7	18.1	27.0	12.0	17.9	10.8	15.9	25.1	25.6	26.5	26.2	25.1	23.0	22.9	-13.5	-37.2
DK	PTOT	277	254	295	223	238	227	208	267	281	380	247	282	336	310	263	269	222	210	177	240	168	188	-89.3	-32.2
EE	PTOT	90.0	76.1	67.3	62.4	68.0	57.6	50.8	71.1	69.1	55.2	57.5	58.9	52.6	28.8	24.1	23.8	27.3	26.6	22.3	25.2	24.1	22.0	-68.0	-75.6
FI	PTOT	110	88.0	85.1	74.2	85.2	74.8	73.7	64.0	71.5	55.8	64.1	58.8	63.6	57.8	86.5	66.4	52.5	74.5	46.4	51.2	51.6	48.1	-61.6	-56.1
LT	PTOT	38.1	7.52	6.99	8.01	29.7	5.40	10.6	19.1	11.7	10.0	4.18	11.4	11.2	6.27	10.0	6.52	8.68	12.8	8.37	10.9	11.4	10.4	-27.7	-72.6
LV	PTOT	213	239	223	174	189	212	173	180	154	55.4	44.0	33.7	71.3	53.4	58.0	63.9	44.9	41.3	36.0	37.0	34.1	33.9	-180	-84.1
PL	PTOT	75.0	28.8	43.1	49.8	56.7	60.9	71.1	140	90.2	51.6	35.1	46.0	36.9	45.8	45.4	31.8	17.8	47.7	31.5	18.5	27.9	31.2	-43.8	-58.5
RU	PTOT	941	1024	1066	1259	1924	1291	1175	1005	943	742	388	260	249	270	521	613	595	403	164	290	235	348	-593	-63.0
SE	PTOT	228	221	213	177	187	187	247	212	190	150	167	189	171	155	160	158	148	156	174	180	153	172	-55.7	-24.4
Total	PTOT	2009	1959	2022	2049	2798	2132	2029	1974	1832	1517	1034	951	1009	939	1185	1258	1142	998	686	878	728	877	-1132	-56.3

Table 2a. Direct NTOT loads from industry from 2000 to 2021, presented per country.

Country	Parameter	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Change (2000-2021)	Change (2000-2021)
		t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	%
DE	NTOT	22.1						25.0	23.5	21.9	11.3	25.7	6.78	36.3	36.2	31.2	38.1	30.4	35.0	31.4	44.9	30.6	26.3	4.16	18.8
DK	NTOT	439	412	358	266	194	144	148	152	178	113	123	150	121	134	127	109	94.3	104	95.4	106	132	76.5	-363	-82.6
EE	NTOT	626				33.4	85.0	61.2	68.9	88.4	41.5	29.0	42.0	42.0	51.0	7.66	8.16	18.9	24.1	18.8	16.4	22.2	24.1	-602	-96.1
FI	NTOT	1367	1103	1077	1125	1018	877	862	886	835	774	848	903	944	1203	1200	920	1034	1094	1004	1029	810	896	-471	-34.4
LT	NTOT	8.49	13.3	12.7	9.4	3.19	7.88	3.83					5.54	8.59	6.96	9.36	6.84	10.7	13.7	11.6	21.7	9.28	9.6	1.10	13.0
LV	NTOT		20.7	18.2	11.5	10.2	5.6	14.3	20.8	10.0	7.07	8.01	11.2	10.6	11.1	10.4	8.29	3.98	4.67	1.64	3.64	1.90	2.10		
PL	NTOT	15.0	0.47	0.45	0.27	0.28	0.21			3.29							5.53		23.4	19.2	17.3	23.8	24.3	9.28	61.7
RU	NTOT	32.7	29.5	22.3	1.56	0.58	12.7	60.4	16.4	6.98	5.40				8.64	39.2	39.2	36.0	70.8	7.98	126	18.4	15.1	-17.6	-53.9
SE	NTOT	2672	2274	2559	2592	2517	2585	2622	2209	2198	2007	1895	1864	2006	2100	1987	1971	1833	1751	1653	1554	1589	1701	-971	-36.3
Total	NTOT	5183	3853	4048	4006	3776	3718	3796	3377	3342	2960	2929	2982	3169	3551	3412	3106	3061	3120	2843	2919	2637	2775	-2410	-46.5

In 2021 the industrial wastewater treatment plants discharged 226 tonnes (t) of phosphorus (P) directly into the Baltic Sea (Table 2b). Sweden and Finland together contributed 91% of the P inputs, so the proportion of other countries was minor. The high industrial P inputs in Sweden and Finland originates largely from pulp and paper industry. The direct industrial P loads decreased between 2000 and 2021 with 156 t and in percentage the decrease was 41%. The biggest reduction in industrial P loads was detected in Sweden (97 t). There were large gaps in the data coverage of several countries (Table 2b).

1.1.3 Marine aquaculture

Marine aquaculture in the Baltic Sea is concentrated in three countries: Finland, Denmark and Sweden. In 2021 the direct nitrogen (N) input from aquaculture was 709 tonnes (t). Finland's contribution was 50%, Denmark's 44% and Sweden's 5% (Table 3a). Finland managed to reduce N inputs from aquaculture by 53% between 2000 and 2021, whereas the respective N inputs increased in Denmark by 20%. Swedish inputs have substantially decreased since 2019.

Table 2b. Direct PTOT loads from industry from 2000 to 2021, presented per country.

Country	Parameter	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Change (2000-2021	Change (2000-2021)
		t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	%
DE	PTOT	0.86						0.80	0.66	0.54	0.02	0.65	0.28	0.56	1.58	0.83	0.84	0.86	1.48	0.83	1.07	0.59	0.65	-0.20	-23.8
DK	PTOT	25.4	24.2	21.9	13.5	11.6	11.0	10.4	9.7	12.0	5.41	8.99	8.57	9.77	9.67	8.61	8.23	7.17	7.54	7.69	7.34	5.19	5.96	-19.5	-76.6
EE	PTOT	1.36				1.92	8.14	11.9	3.73	9.43	2.58	3.00	3.00	2.00	2.20	0.86	0.81	0.97	1.44	1.89	2.00	1.90	2.20		
FI	PTOT	61.0	54.7	62.2	58.9	58.5	53.9	53.6	66.1	64.1	46.3	48.4	43.8	54.9	56.6	45.3	43.8	39.9	37.2	38.8	38.8	35.0	28.5	-32.5	-53.3
LT	PTOT	0.91	1.02	0.85	0.68	0.18	0.73	0.43					0.41	0.48	0.47	0.45	0.49	0.90	0.83	0.69	1.38	1.02	1.06	0.15	16.8
LV	PTOT		4.28	4.23	3.37	4.13	1.97	3.95	4.75	3.49	2.18	3.14	3.47	3.95	2.88	3.08	1.76	0.66	1.21	0.35	0.91	0.41	0.58		
PL	PTOT	3.59	0.02	0.01	0.05	0.06	0.01			0.31							0.92		2.11	0.98	1.54	1.48	1.35	-2.24	-62.3
RU	PTOT	9.80	8.18	18.4	0.89	1.80	2.32	9.90	10.6	10.1	6.00					9.71	11.0	9.14	9.14		13.6	8.64	5.37	-4.44	-45.3
SE	PTOT	280	250	266	262	280	275	279	254	238	217	219	203	221	227	226	208	218	187	173	159	167	183	-97.3	-34.8
Total	PTOT	383	342	374	339	358	353	370	350	338	280	283	262	292	300	295	276	277	248	224	225	221	228	-156	-41

Table 3a. Direct NTOT loads from aquaculture from 2000 to 2021, presented per country.

Country	Parameter	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Change (2000-2018)	Change (2000-2018)
		t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	%
DK	NTOT	262	248	263	270	240	255	270	285	299	255	266	322	324	338	337	335	322	333	352	306	323	315	52.9	20.2
EE	NTOT							15.3													3.14	3.81	2.80		
FI	NTOT	759	709	507	474	529	503	522	518	498	488	480	437	471	460	466	467	446	470	429	432	409	355	-404	-53.2
LT	NTOT							0.01					0.005												
SE	NTOT							139	139	139	139	139	93		112	90	114	119	99	104	121	34.6	37.3		

In 2021 the direct phosphorus (P) input from aquaculture was 71 tonnes (t). Finland's contribution was 50%, Denmark's 43% and Sweden's 6% (Table 3b). Finland managed to reduce P inputs from aquaculture by 57% between 2000 and 2021, whereas the respective P inputs increased in Denmark by 5%. Swedish inputs have substantially decreased since 2019.

Table 3b. Direct PTOT loads from aquaculture from 2000 to 2021, presented per country.

Country	Parameter	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Change (2000-2018)	Change (2000-2018)
		t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	%
DK	PTOT	28.9	25.0	28.0	28.9	25.8	27.4	29.0	30.5	32.1	27.6	28.2	33.8	35.1	35.4	35.6	35.4	33.9	33.6	38.0	32.0	32.7	30.3	1.48	5.1
EE	PTOT							1.52													0.26	0.15	0.18		
FI	PTOT	93.3	89.5	63.1	59.2	64.9	62.5	64.5	62.9	61.5	60.2	48.9	54.1	56.1	52.8	49.8	47.3	43.7	45.6	42.3	43.2	41.1	36.2	-57.2	-61.3
LT	PTOT							0.002					0.0001												
SE	PTOT							17.8	17.8	17.8	17.8	17.8	11.8		13.9	10.0	11.8	13.1	11.1	10.5	12.5	4.54	4.34		
Total	PTOT	122	115	91.1	88.1	90.7	89.9	113	111	111	106	94.8	100	91.2	102	95.4	94.5	90.8	90.3	90.9	88.0	78.5	71.0	-55.7	-45.6

1.2. Indirect point source loads into inland waters

Indirect point source data was collected from the PLC-database, except for the Russian data, which was received from the Russian PLC implementatiin group member. These indirect point sources are defined as point sources that do not discharge directly to the Baltic Sea, but via relevant pathways and waterways contribute to the total load in the Baltic Sea. Indirect point source loads are reported only for the PLC periodical reporting years. PLC periodical reporting years are: PLC-4 2000, PLC-5 2006, PLC-6 2014 (except for Poland and Germany 2012), PLC-7 2017 and PLC-8 2021. This data was complemented with supplementary data received directly from the HELCOM Contracting Parties.

In 2021 the total nitrogen (NTOT) load into inland waters from point sources was 56 700 tonnes (t) (Figure 3, left) and the respective total phosphorus (PTOT) load was 4040 t (Figure 3, right). The main origin of the inputs were municipalities. Due to gaps in the data coverage it was not possible to estimate changes in loads.

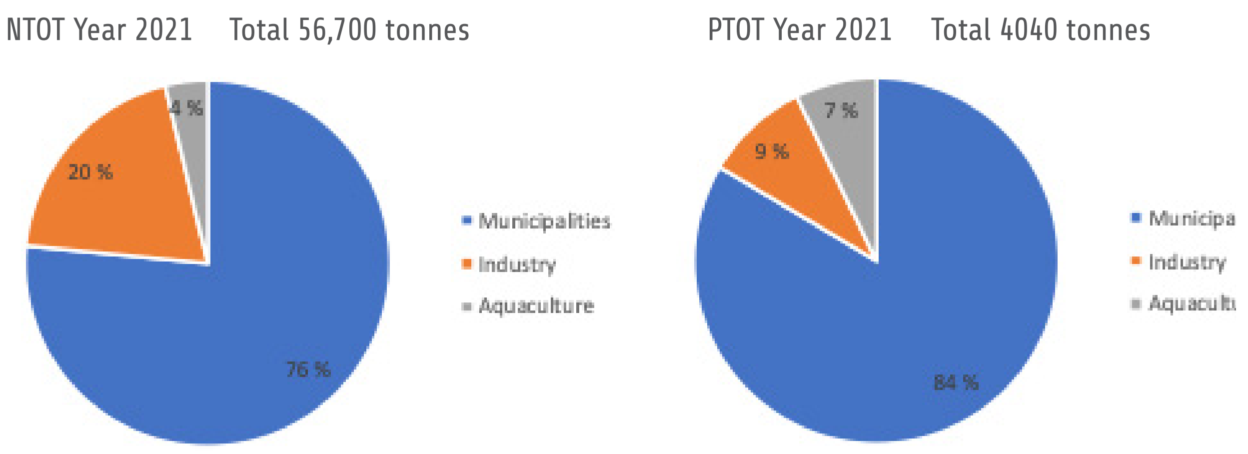


Figure 3. Indirect point source NTOT and PTOT loads into inland waters by sources in 2021.

1.2.1 Indirect municipal point source loads into inland waters

In 2021 the nitrogen (N) inputs from indirect municipal wastewater treatment plants into inland waters were 43 400 tonnes (t) (Table 4a). Poland contributed with 50% of the N inputs followed by Sweden (19%), and Finland (16%). Denmark and Finland managed to reduce their inputs, whereas, according to the reported data N inputs from indirect municipal wastewater treatment plants increased in other countries. Russian N load significantly decreased for PLC-8 compared to the respective load of PLC-7 reporting, which might be due to partly missing data. Totally the municipal N inputs into inland waters increased by 7030 t (20%). Part of the increases might be due to the increased connectivity, i.e. an effort to decrease loads originating from scattered dwellings by increasing the number of people being connected to municipal treatment plants. However, there is high variability in the reported loads between the PLC periodical reporting years for some countries, which might be due to deficiencies in data coverage and indicates that uncertainties are large in the analysis carried out.

In 2021 the phosphorus (P) inputs from indirect municipal wastewater treatment plants into inland waters were 3380 tonnes (t) (Table 4b), of which Poland contributed with 2430 (72%). Russian loads showed the biggest decrease (483 t) and four other countries managed to reduce their P inputs, whereas it increased in four countries. Anyhow, part of the Russian data might be missing. Overall, i.e. at the Baltic Sea scale, the changes indicate a slight decrease. The reported P loads also varied to some extent between the PLC years in some countries, but this variation was minor compared to the respective fluctuation in the reported N inputs.

Table 4a. Indirect municipal NTOT loads into inland waters from 2000 to 2021, presented per country. Note: Part of the Russian data might be missing.

Country	Parameter	PLC-4	PLC-5	PLC-6	PLC-7	PLC-8	Change (2000-2021)	Change (2000-2021)
		t	t	t	t	t	t	%
DE	NTOT	492	262	209	614	853	361	73.5
DK	NTOT	1860	1470	1269	1164	1003	-857	-46.1
EE	NTOT	124	460	210	264	332	208	168
FI	NTOT	7426	7863	7538	7346	6823	-603	-8.1
LT	NTOT	996	1909	1332	1781	1576	580	58.3
LV	NTOT	396	527	515	886	761	365	92.0
PL	NTOT	15654	31788	25145	19579	21689	6035	38.6
RU	NTOT			3546	7840	1938		
SE	NTOT	7503	10450	8823	8834	8444	941	12.5
Total	NTOT	34451	54729	48587	48308	43419	7031	20

Table 4b. Indirect municipal PTOT loads into inland waters from 2000 to 2021, presented per country. Note: Part of the Russian data might be missing.

Country	Parameter	PLC-4	PLC-5	PLC-6	PLC-7	PLC-8	Change (2000-2021)	Change (2000-2021)
		t	t	t	t	t	t	%
DE	PTOT	21.0	15.6	24.0	52.3	108	87.3	417
DK	PTOT	184	124	113	99.7	85.7	-97.9	-53.3
EE	PTOT	26.1	23.9	7.49	9.44	12.4	-13.7	-52.5
FI	PTOT	130	118	74.5	68.6	63.5	-66.5	-51.2
LT	PTOT	75.8	228	112	138	149	73.0	96.3
LV	PTOT	65.4	110	67.8	115	103	37.9	58.0
PL	PTOT	2096	3183	2793	2207	2431	335	16.0
RU	PTOT	785		728	560	302	-483	-61.5
SE	PTOT	122	161	127	111	122	-0.7	-0.57
Total	PTOT	3505	3963	4047	3361	3376	-129	-3.67

1.2.2 Indirect industrial point source loads into inland waters

In 2021 the nitrogen (N) inputs from indirect industrial wastewater treatment plants into inland waters were 11 200 tonnes (t) (Table 5a). Poland, Sweden and Russia contributed together with 84% of the total inputs. Finland, Denmark and Russia were the only countries shown to reduce their indirect industrial N loads, whereas Polish loads remarkably increased. However, there is high variability in the reported loads between the PLC periodical reporting years for some countries, which might be due to deficiencies in data coverage and indicates that uncertainties are large in the analysis carried out.

In 2021 the phosphorus (P) inputs from indirect industrial wastewater treatment plants into inland waters were 373 tonnes (t) (Table 5b). The biggest reduction was observed in the Russian loads, but some other countries were also able to decrease their loading and the total P inputs into inland waters decreased with 45% from 2000 to 2021.

Table 5a. Indirect NTOT loads from industry into inland waters from 2000 to 2021, presented per country.

Country	Parameter	PLC-4	PLC-5	PLC-6	PLC-7	PLC-8	Change (2000-2021)	Change (2000-2021)
		t	t	t	t		t	%
DE	NTOT			231	207	186		
DK	NTOT	231	183	101	23.8	71.0	-160	-69.2
EE	NTOT	22.5	341	168	22.4	37.8	15.3	67.9
FI	NTOT	1472	1278	1303	1168	987	-485	-33.0
LT	NTOT	56.8	132	134	219	219	162	286
LV	NTOT	66.5	135	39.7	186	70.9	4.38	6.60
PL	NTOT	1458	5069	4173	5485	5852	4394	301
RU	NTOT	2282	1366	1761	1634	1371	-911	-40
SE	NTOT	2150	2601	2334	2162	2378	227	10.6
Total	NTOT	7739	11104	10243	11108	11172	3247	42

Table 5b. Indirect PTOT loads from industry into inland waters from 2000 to 2021.

Country	Parameter	PLC-4	PLC-5	PLC-6	PLC-7	PLC-8	Change (2000-2021)	Change (2000-2021)
		t	t	t	t		t	%
DE	PTOT			2.0	7.04	9.37		
DK	PTOT	13.5	4.53	3.23	7.70	2.08	-11.4	-84.5
EE	PTOT	2.15	8.9	3.65	2.15	2.35	0.2	9.3
FI	PTOT	66.2	73.1	44.7	38.7	27.5	-38.7	-58.4
LT	PTOT	9.76	9.24	7.35	8.93	8.37	-1.4	-14.3
LV	PTOT	4.20	21.1	4.08	19.9	8.40	4.2	100
PL	PTOT	80.1	148.2	74.6	131.0	105.5	25.4	31.7
RU	PTOT	390	328	767	399	147	-243	-62.3
SE	PTOT	92.7	74.8	59.5	53.2	62.4	-30.4	-32.8
Total	PTOT	659	668	966	668	373	-295	-44.8

1.2.3 Indirect aquaculture

In 2021 the total nitrogen (NTOT) inputs from inland aquaculture into inland waters were 2130 tonnes (t) (Table 6a). Poland had clearly highest inputs followed by Nordic countries, Sweden, Finland and Denmark. Three countries were able to decrease their loading, but the total inputs from inland aquaculture increased remarkably from 2000 to 2021, which was mainly caused by more comprehensive PLC-8 reporting. Therefore, gaps in earlier reporting hindered a full estimation of changes.

In 2017 the total phosphorus (PTOT) inputs from inland aquaculture into inland waters were 291 tonnes (t) (Table 6b). Poland had clearly the highest inputs followed by the Nordic countries Sweden, Finland and Denmark. Three countries were able to decrease their loading, but due to gaps in earlier reporting a full estimation of changes was not possible.

1.3. Conclusions

The direct point source loads have decreased substantially from 2000 to 2021: nitrogen (N) loads with 29% and phosphorus (P) loads with 61%. Municipalities were the dominant source of nutrient inputs originating from point sources into the Baltic Sea. Even though municipal wastewater treatment has improved substantially during the last decades there is still clear potential to reduce their nutrient loads. However, there are gaps in the data coverage, especially in indirect loads, in the PLC-database, which is reflected in the uncertainty of the results.

Table 6a. Indirect NTOT loads from aquaculture into inland waters from 2000 to 2021.

Country	Parameter	PLC-4	PLC-5	PLC-6	PLC-7	PLC-8	Change (2000-2021)	Change (2000-2021)
		t	t	t	t	t	t	%
DK	NTOT	437	326	221	223	160	-278	-63.4
EE	NTOT					18.4		
FI	NTOT	239	175	142	126	153	-86.0	-35.9
LT	NTOT	28.9	68.7	7.11	4.79	2.60	-26.3	-91.0
LV	NTOT		61.6	0.02	0.68	1.06		
PL	NTOT	141	17.3	250	1294	1454	1313	930
SE	NTOT			363	425	337		
Total	NTOT	847	649	983	2074	2127		

Table 6b. Indirect PTOT loads from aquaculture into inland waters from 2000 to 2021.

Country	Parameter	PLC-4	PLC-5	PLC-6	PLC-7	PLC-8	Change (2000-2021)	Change (2000-2021)
		t	t	t	t	t	t	%
DK	PTOT	33.9	27.0	22.1	20.5	13.4	-20.5	-61
EE	NTOT					1.56		
FI	PTOT	28.3	22.9	13.9	11.6	13.7	-14.6	-52
LT	PTOT	1.89	3.00	0.58	0.57	0.21	-1.7	-89
LV	PTOT		7.86	0.31	0.45	0.56		
PL	PTOT	19.0	2.04	30.3	194.0	219	200	1055
SE	PTOT			60.4	49.1	42.6		
Total	PTOT	83.1	62.7	128	276.2	291		

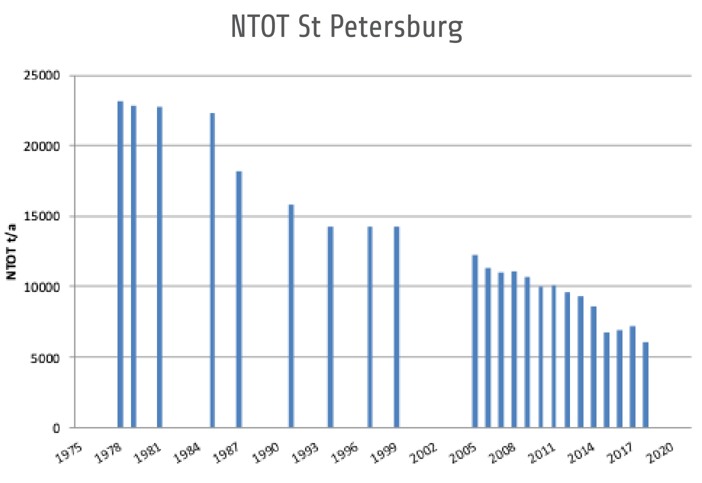
2. Development of inputs of nutrients from nine big municipal wastewater treatment plants

The timeseries of nutrient inputs from point sources were in the PLC database in many cases incomplete making it impossible to reliably estimate the development of nutrient inputs originating from municipal wastewater plants (MWWTP). In order to get temporally more comprehensive overview of the development PLC-8 iplementation group members contacted authorities of the largest MWWTPs in their country to get as long time-series as possible. This study includes time-series of nutrient inputs from the biggest municipal wastewater treatment plant of every HELCOM country: St. Petersburg, Warsaw, Stockholm, Copenhagen, Helsinki, Riga, Vilnius, Tallinn and Rostock. The time-series varied in length: The longest it is for Helsinki (starting from the year 1975) and the shortest for Vilnius (starting from the year 1997). Please note that for St. Petersburg the information is not updated for the PLC-8 project.

2.1. St. Petersburg

Vodokanal St. Petersburg supplies water and wastewater services to a population of 5,3 million people and to tens of thousands of city companies and organizations. Before 1978 St. Petersburg's wastewaters were discharged to the sea almost without any treatment. From then on the wastewater treatment capacity has increased, and phosphorous and nitrogen inputs to the sea have further declined during the past decades as the result of the measures implemented by the Vodokanal.

Nowadays there are altogether 13 wastewater treatment plants of which eight discharge wastewaters directly into the Gulf of Finland. At present, 99% of wastewater is treated in St. Petersburg. The total flow rate of the treatment plants is around 2 100 000 cubic meters (m^3) per day, and most of the treated water is discharged to the Neva Bay. Dramatic reduction of phosphorus inputs after 2005 was related to the enhanced biological treatment and introduction of chemical phosphorus precipitation in wastewater treatment plants (Figure 4). More gradual reduction can be seen in direct nitrogen inputs in the corresponding period. During the last two decades the direct total phosphorus (PTOT) inputs from St. Petersburg WWTPs were reduced by 90% and total nitrogen (NTOT) inputs by 50%. One of the biggest environmental projects focused on closing untreated wastewater discharges directly into the water bodies was the construction of the Northern Collector Tunnel completed in October 2013. After opening of the tunnel untreated wastewaters totaling 334 000 m^3/day were directed to the sewerage system. In 2018, the efficiency of wastewater treatment in St. Petersburg" was more than 98% for suspended solids and biological oxygen demand (BOD), 95% for total phosphorus (PTOT) and 74% for total nitrogen (NTOT).



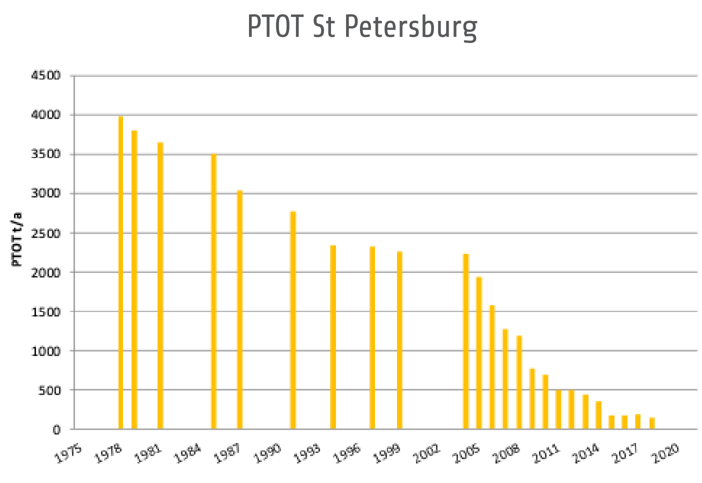


Figure 4. Nitrogen and phosphorus loads from St Petersburg MWWTPs (altogether eight treatment plants) in 1978–2018. Note: The scale of the y-axis differs between the cities.

2.2. Warsaw

Czajka MWWTP in Warsaw receives a biological oxygen demand (BOD) load of more than 1 900 000 population equivalents (PE, 1 PE = 60 g BOD_5/d). The plant was originally designed in the early 1970s and construction began in 1976, but the plant was first completed in 1991. It received wastewater from the right-bank part of Warsaw and from the surrounding smaller right-bank towns. The original MWWTP had classical closed sludge digestion tanks. Between 2008 and 2012 the plant was modernized and extended to receive the wastewaters from the left-bank of Warsaw, including storm waters. At the same time sludge management was completely re-designed and sludge digestion was replaced by sludge incineration.

Before 2008 the average loads from Czajka MWWTP were 1500 tonnes (t) per year of total nitrogen (NTOT) and 130 t of total phosphorus (PTOT) per a year with maximum at 2200 tons of NTOT and 275 t of PTOT during 1996-1998 (Figure 5). Back then, the MWWTP did not meet the EU and HELCOM requirements for urban wastewater treatment, and therefore Warsaw urban area was on the HELCOM Hot Spot list. This was the reason for modernization of the plant, which ended in 2012. After the modernization the nitrogen treatment efficiency increased from 65% to 85% and loads discharged into the Vistula River decreased. The increase of NTOT and PTOT loads after 2012 was caused by the increased amount of wastewater after the modernization. Comparing to period 1995-1998 the NTOT load decreased by a half and PTOT load by 75%. As a result, Warsaw urban area was deleted from the HELCOM Hot Spot list in 2015. After 2012 the NTOT and PTOT loads are relatively constant: 1200 t NTOT and 60 t PTOT annually. In 2021 the NTOT removal was 88% and the respective PTOT removal was 95%.

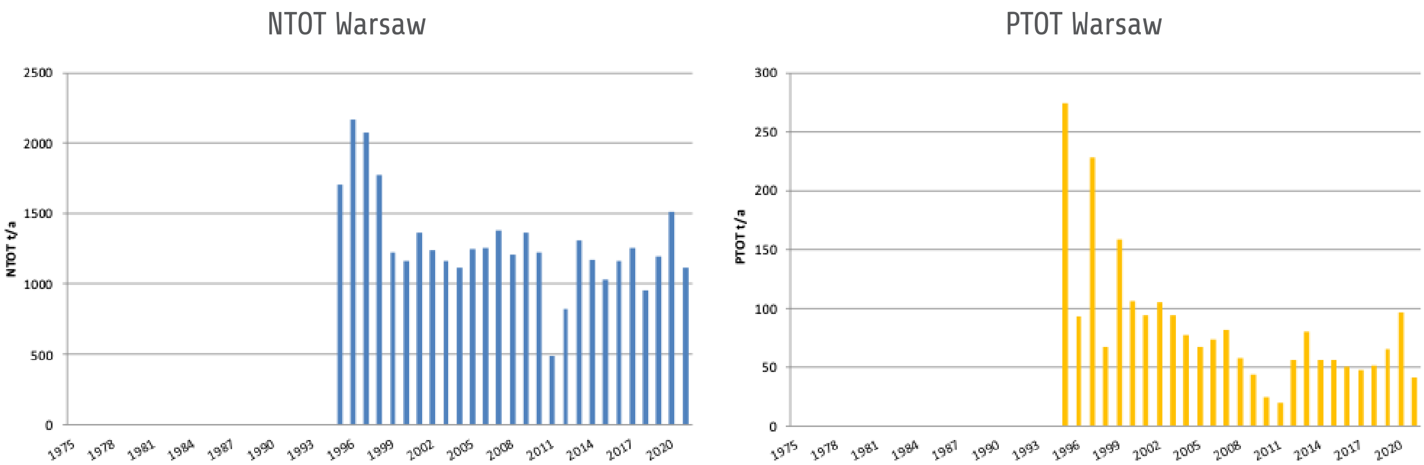


Figure 5. Nitrogen and phosphorus loads from Warsaw Czajka WWTP 1995–2021. Note: The scale of the y-axis differs between the cities.

2.3. Copenhagen

Lynetten, the largest sewage treatment plant in Denmark, treats industrial and municipal wastewater of approximately 750 000 population equivalents (PE) from 535 000 inhabitants, corresponding to 3,2 million liters of wastewater every day. The maximum capacity is 41 500 m^3 per hour. The wastewater originates from the center and parts of the suburbs of the city of Copenhagen, altogether 76 km^2 of urban catchment. Lynetten was founded in 1980 with mechanical separation and removal of organic matter by injection of pure oxygen, and before that there was no real treatment of the wastewater. In 1985, about 100 million m^3 wastewater was treated generating about 25,000 tons sludge.

By 1997, the treatment plant was expanded and inaugurated including biological (e.g. nitrification and denitrification) and chemical treatment of the sludge (e.g. application of iron and aluminum) and sludge incineration with two multiple-hearth furnaces for nitrogen and phosphorus removal. It resulted in markedly reduced nitrogen and phosphorus discharges from the treatment plant by 1997 (Figure 6). In the recent years the focus of operation optimization has ensured higher nutrient removal.

In 2019 about 1.36 billion m^3 untreated diluted wastewater was discharged from Lynetten to the Sound when rainwater amounts exceeded the capacity of the wastewater treatment plant. By 2027, the treatment capacity will be increased reducing discharged annual amounts of untreated diluted wastewater to less than 1 billion m^3 annually. In 2021 the total nitrogen (NTOT) load was 433 tonnes (t) and the respective total phosphorus (PTOT) load was 29 t. In 2021 98% PTOT and 81% of the NTOT was removed from the wastewater.

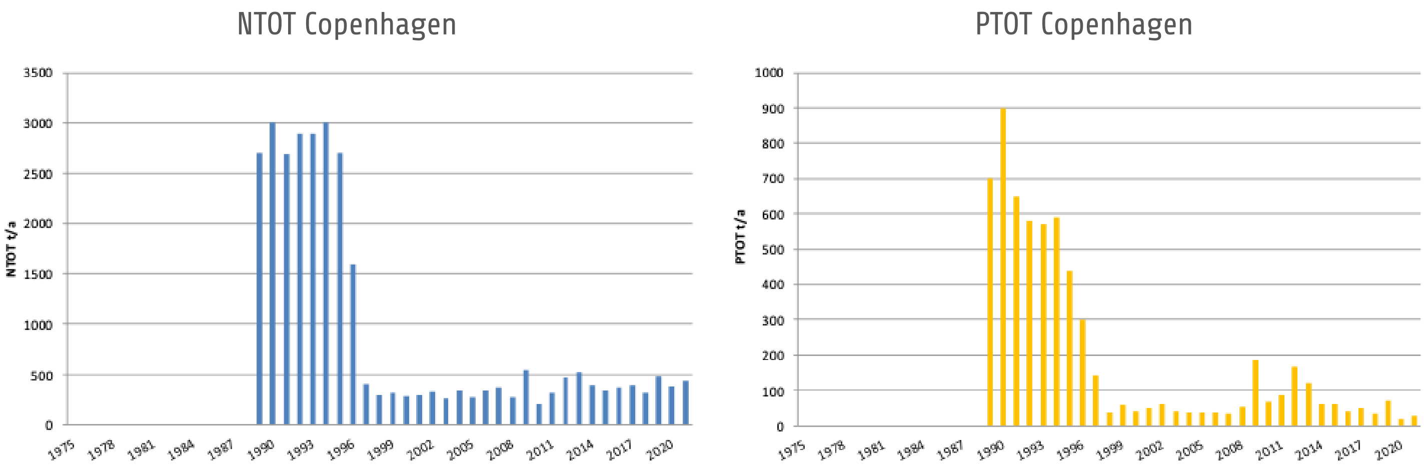


Figure 6. Nitrogen and phosphorus loads from Copenhagen Lynetten WWTP 1989–2021. Note: The scale of the y-axis differs between the cities.

2.4. Helsinki and Espoo

The Viikinmäki wastewater treatment plant in Helsinki is the largest treatment plant in Finland. It processes wastewaters of around 800 000 residents as well as the wastewaters of the region's industry. The plant was taken into use in 1994 and it replaced several small-scale water treatment plants. The total flow rate of the treatment plant is around 270 000 m^3 per day, and an average of 100 million m^3 of wastewater is treated at the plant every year. The treated wastewater is discharged through a tunnel in the bedrock into the sea 8 km away from Helsinki shoreline into a depth of 20 meters.

The Suomenoja wastewater treatment plant processes wastewaters of 310 000 residents in Espoo, Kauniainen and Western Vantaa. Construction of a new plant started in 2016 and like the treatment in Helsinki the plant in Espoo is inside the bedrock. The Blominmäki wastewater treatment plant in Espoo was inaugurated in 2022 and replaced the old Suomenoja treatment plant. It will have a capacity to process wastewaters of up to 400 000 residents. The goal is to remove more than 96% of the total phosphorus (PTOT) and over 90% of the total nitrogen (NTOT) it receives.

In Helsinki and Espoo the improvements in wastewater treatment started in late 1970s, when investments led to more efficient phosphorus removal (Figure 7). The nitrogen removal improved first when the new plant in Helsinki was opened in 1994 and further improvements happened in 2005 when new technologies were taken into use. Since the mid-2000s the inputs have stayed quite stable (on average 1050 t NTOT and 33 t PTOT). In 2021 over 97 percent of PTOT and 91 percent of NTOT was removed from the wastewater.

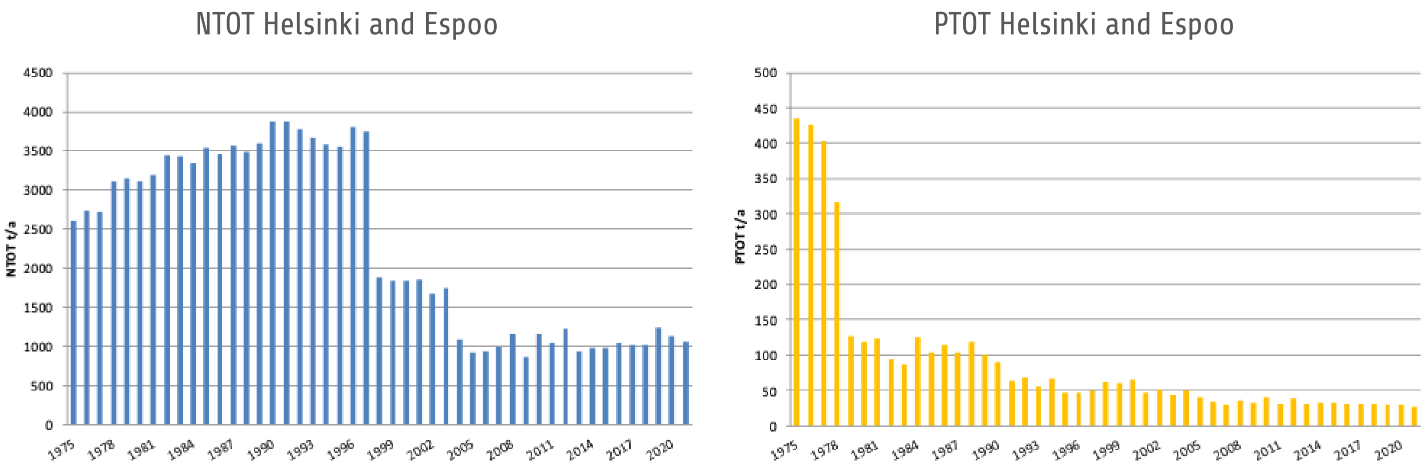
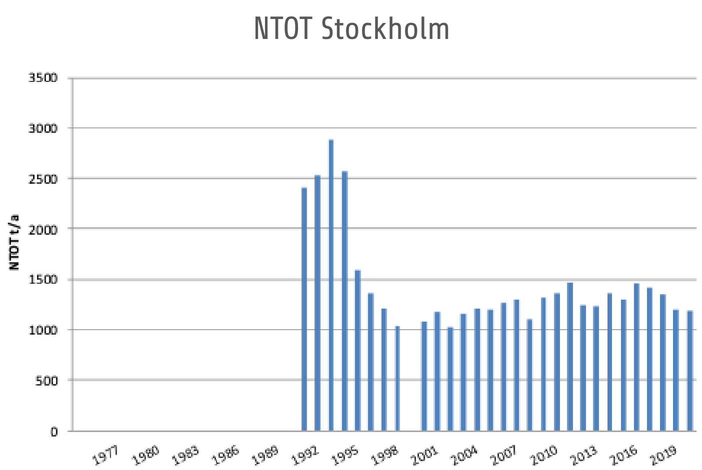


Figure 7. Nitrogen and phosphorus loads from Helsinki and Espoo WWTPs 1975–2021. Note: The scale of the y-axis differs between the cities.

2.5. Stockholm

Bromma and Henriksdal WWTPs, both operated by Stockholm Vatten och Avfall, are two of Swedens largest WWTPs. Bromma WWTP which was taken into operation in 1934 receives wastewater from around 360 000 residents while around 860 000 residents are connected to Henriksdal (in operation since 1941). The two plants treat around 450 000 m^3 of wastewater per day. More than 95% of the phosphorus and 75% of the nitrogen is removed from the wastewater and the organic contaminants are converted into 57 000 m^3/d of biogas, equivalent to 120 GWh annually, that is used to fuel busses for public transport in the city.

Since 1992 the load of nitrogen from Stockholm WWTPs (Bromma and Henriksdal) decreased from approximately 3 000 tonnes to today's level of 1 200 tonnes (Fig. 12). For phosphorus, a corresponding decrease in load is from approximately 140 tonnes in 1975 to 32 tonnes in 2021. An increased load to the WWTPs, some operational problems and the modernisation and expansion of the Henriksdal WWTP explain the small variations in load during the latest years. In 2021 the total nitrogen (NTOT) removal of the two plants was 76-78% and the respective total phosphorus (PTOT) removal was 95-96%.



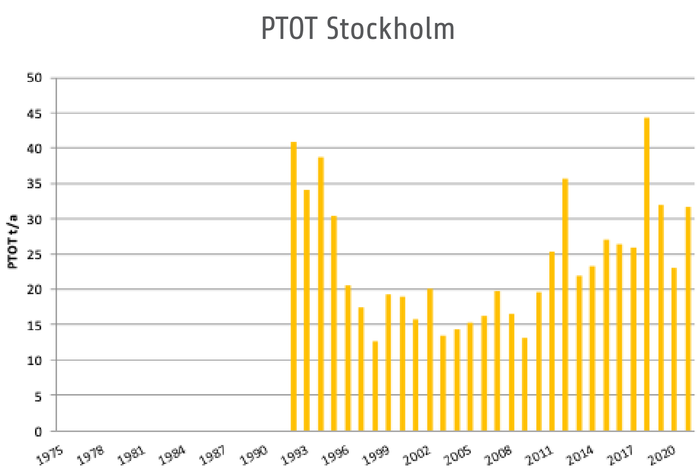


Figure 8. Nitrogen and phosphorus loads from Stockholm WWTPs (Bromma and Henriksdal) 1992–2021. Note: The scale of the y-axis differs between the cities.

2.6. Riga

Daugavgrīva biological wastewater treatment plant in Rīga is the largest treatment plant in Latvia. The first phase of the new biological WWTP in Riga was completed in 1991. At later stages, the sewerage network was considerably extended as well as infrastructure and technologies were improved. Today, about 650 000 inhabitants of Rīga and several nearby municipalities as well as industrial facilities are connected to the Daugavgrīva treatment plant and approximately 27-30% of the total wastewater is generated by industrial facilities. The total flow rate of the treatment plant is around 140 000 m^3 in a day, and an average of 50 million m^3 of wastewater is treated at the plant every year. The treated wastewater is discharged into the Gulf of Rīga at a depth of 15 m and a distance of 2.4 km from the shore.

Since the 1990s large investments have been made to modernize the Riga WWTP in Daugavgrīva. In 2014, major reconstruction works were finished. During these projects, BioDenitroTM technology was introduced, dosing equipment for chemical precipitation of phosphorus were purchased and the control of the wastewater treatment process was improved. Moreover, nowadays the company strictly controls the quality of received industrial wastewater in order to ensure the stability of biological treatment process. The largest industrial enterprises must have their own pre-treatment facilities to remove toxic substances. Improvement in the treatment process has resulted in a significant reduction of nutrient concentrations in wastewater. From 2018 to 2021 the average total nitrogen (NTOT) load was 337 t/y and the respective total phosphorus (PTOT) load was 31 t/y (Figure 9). Since 2013, the efficiency of the Rīga WWTP meets the requirements of HELCOM Recommendation 28E/2, where at least a 70-80% reduction of NTOT load is required. In 2021 the NTOT removal was 89% and the respective PTOT removal was 93%.

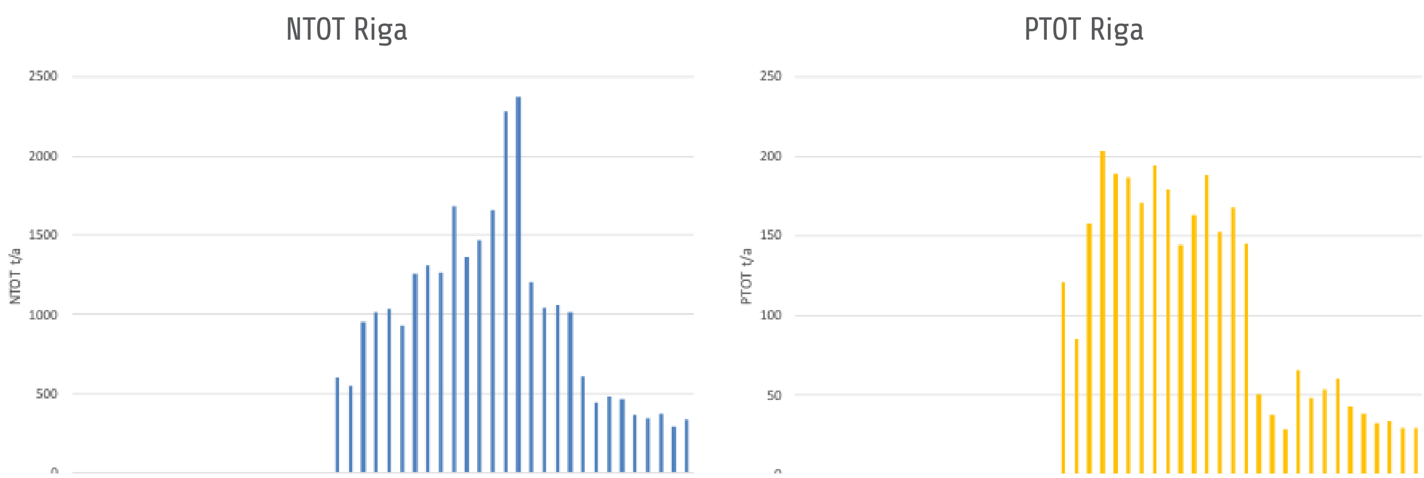


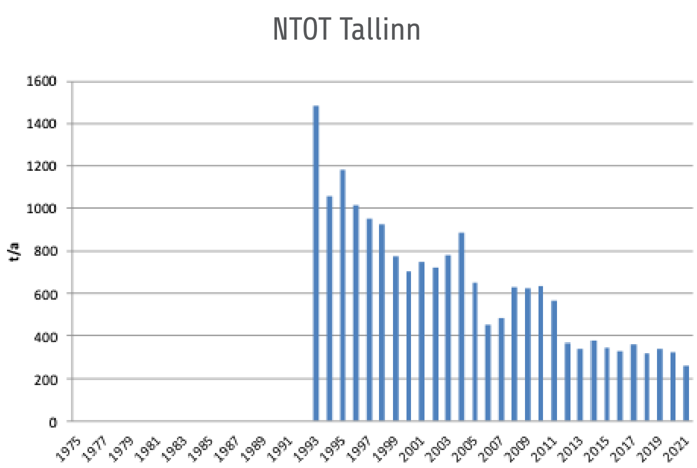
Figure 9. Nitrogen and phosphorus loads from the Daugavgrīva WWTP 1994–2021 in Riga. Note: The scale of the y-axis differs between the cities.

2.7. Tallinn

The Paljassaare wastewater treatment plant in Tallinn is the largest treatment plant in Estonia. It processes wastewaters of around 463 000 residents as well as wastewaters of the region's industry. The plant was taken into use in 1980. The hydraulic capacity of the plant is 350 000 m^3 per day, average flow is 120 000 m^3 per day and an average of 50 million m^3 of wastewater is treated at the plant every year. The treated wastewater is discharged into the sea 3 km away from the Tallinn shoreline.

Over the years, the wastewater treatment plant has made various investments to increase the efficiency of the wastewater treatment process, and the decreased nutrient loads as a result can be seen in Figure 10. The nitrogen and phosphorus loads to the sea have decreased from 1464 t to 258 t and from 137 t to 17 t, respectively, in the years 1993-2021. The biological treatment stage was established as a classical activated sludge process in the wastewater treatment plant during 1993-1997. Between 2004 and 2006, the wastewater treatment plant was further modified and achieved a total nitrogen (NTOT) concentration of 10 mg N/l in the effluent. As part of these modifications, methanol was dosed to the biological treatment process to affect the denitrification. In 2012, the load of nitrogen discharged to the sea reduced by almost 40% due to extensive reconstruction of the first treatment stage (mechanical treatment) and an additional treatment stage, biofilter. The main aim of the biofilter was to reduce load of nitrogen, however, the load of phosphorus discharged to the sea decreased as well. In the end of the year 2015 new coagulant dosing system was launched to help to better control the chemical removal of phosphorus and to achieve a total phosphorus (PTOT) concentration of 0,50 mg P/l in the effluent.

Additional investments in the wastewater treatment are planned in order to further reduce nutrient loads discharged into the Baltic Sea. In 2021 NTOT removal was 88% and the respective PTOT removal was 94%.



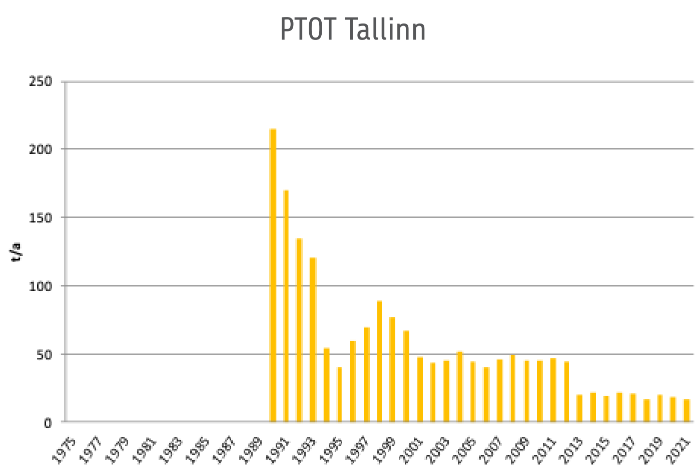
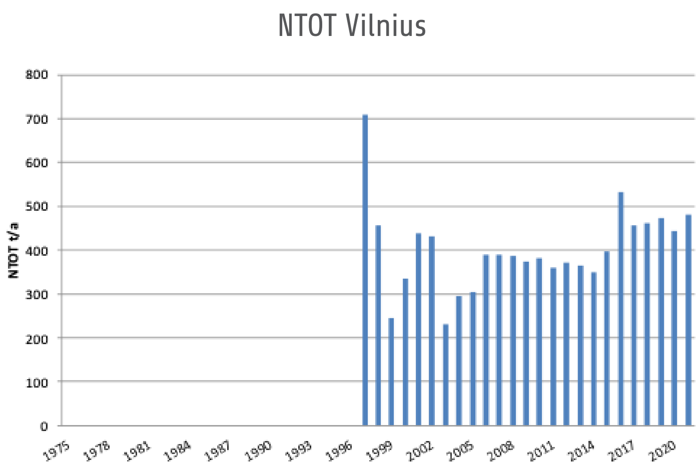


Figure 10. Nitrogen and phosphorus loads from Tallinn WWTP 1993–2021. Note: The scale of the y-axis differs between the cities.

2.8. Vilnius

Vilnius wastewater treatment plant is the largest treatment plant in Lithuania. Situated downstream from the capital on the Neris River, it processes wastewaters from around 500 000 residents and surrounding industries. The plant was built in year 1975 and nowadays treats around 115 000 m³ of sewage a day. In 2021 total the nitrogen (NTOT) and total phosphorus (PTOT) removal rates were around 85% and 92% respectively. The plant has installed mechanical and biological treatment and additional chemical removal of phosphorus and nitrogen. However, a large EU financed project to upgrade its capacity and treatment effectiveness started in 2020 and should be finished in the middle of 2023. Results of it would allow improving many aspects of the treatment plant's operation including increasing its treatment capacity by 30%, tackling stormwater overflows and removing pollutants not properly addressed currently, like microplastics.



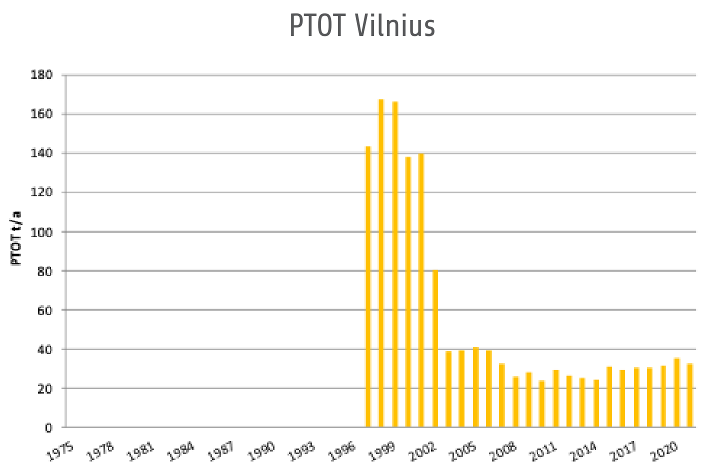


Figure 11. Nitrogen and phosphorus loads from Vilnius WWTP 1997–2021. Note: The scale of the y-axis differs between the cities.

2.9. Rostock

The Rostock-Bramow wastewater treatment plant is the largest in Mecklenburg-Vorpommern. It processes the wastewaters of around 240 000 residents from the city of Rostock and 17 surrounding communities as well as the wastewaters of the region's industry and the seaport. The plant was taken into use in 1996 and upgraded several times afterwards. The total flow rate of the treatment plant is around 44,000 m^3 per day, and an average of 16 million m^3 of wastewater is treated every year. The cleaned water is discharged directly to the estuary of the River Warnow.

In Rostock improvements in wastewater treatment started in mid 1950s, when the first central wastewater treatment plant was built for around 150 000 residents and industry from the city of Rostock. Nitrogen and phosphorus removal both improved when the new plant in Rostock was opened in 1996 and further improvements happened several times after the opening (Figure 12). Since the opening of the central wastewater treatment plant in Rostock-Bramow in the mid-1990s the inputs have stayed quite stable, on average 220 tonnes (t) of total nitrogen (NTOT) and 3 t of total phosphorus (PTOT). In 2021 98% of phosphorus and 81% of nitrogen was removed from the wastewater.

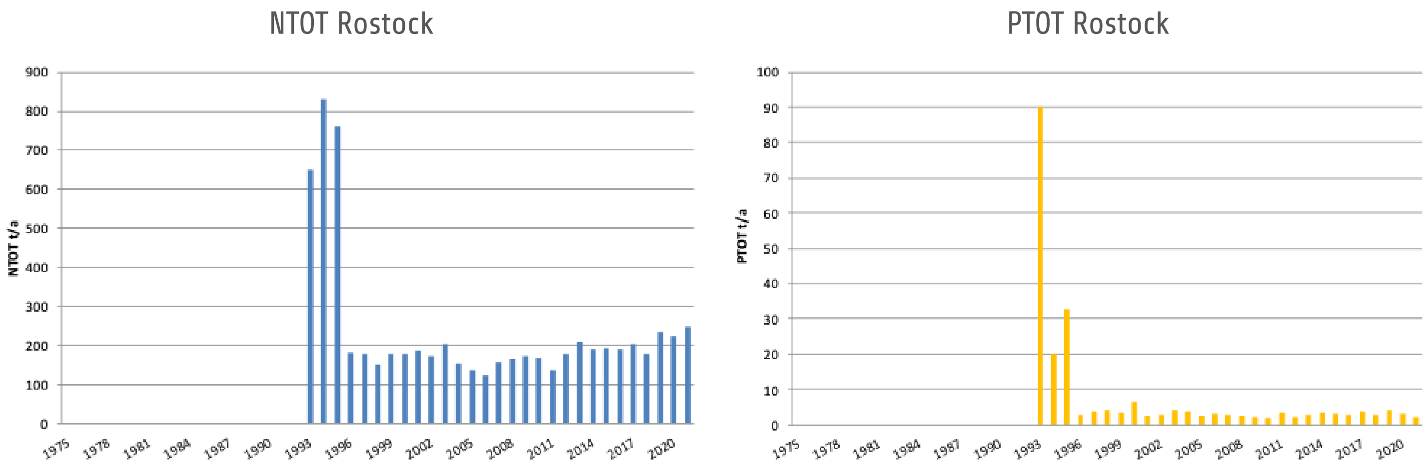


Figure 12. Nitrogen and phosphorus loads from the Rostock-Bramow WWTP 1993–2021. Note: The scale of the y-axis differs between the cities.

3. Municipal wastewater treatment, connectivity and scattered dwellings

Finland and Sweden were the first countries to start more efficient wastewater treatment and in 1990s tertiary treatment was applied nearly in all wastewater treatment plants, followed by Denmark and Germany (Figure 13). A remarkable improvement in wastewater treatment has happened during the last decade in the Baltic countries and Poland. St Petersburg also is a good example of improved wastewater treatment: Before 1978, almost all wastewaters from St Petersburg were discharged untreated into the Gulf of Finland or the River Neva, but nowadays the capacity has increased to 98.5% (Vodokanal, 2015) and the nitrogen load has decreased by 60% and the phosphorus load by 90% (Knuuttila et al. 2017). Anyhow, there are several wastewater treatment plants (WWTPs) that still require upgrading in many countries. Modernization of wastewater treatment plants mostly included tertiary treatment for nitrogen and phosphorus, except for the Bothnian Bay and Bothnian Sea catchments. These areas are considered less sensitive to nitrogen and wastewater treatment plants often have implemented tertiary treatment only for phosphorus. Anyhow, there are several wastewater treatment plants (WWTPs) that still require upgrading in many countries.

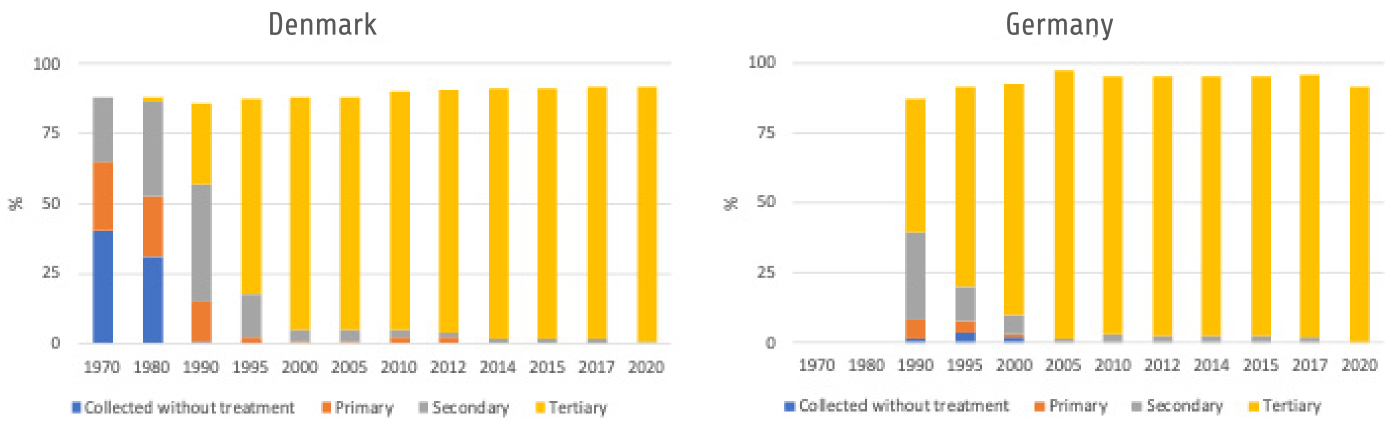


Figure 13. Connectivity and treatment status in municipal wastewater treatment plants of eight HELCOM Contracting Parties from 1970–2020. Note: data for Denmark, Germany and Sweden also include treatment plants outside the Baltic Sea catchment. Source: EEA. Tertiary treatment implies removal of phosphorus and nitrogen, or phosphorus only.

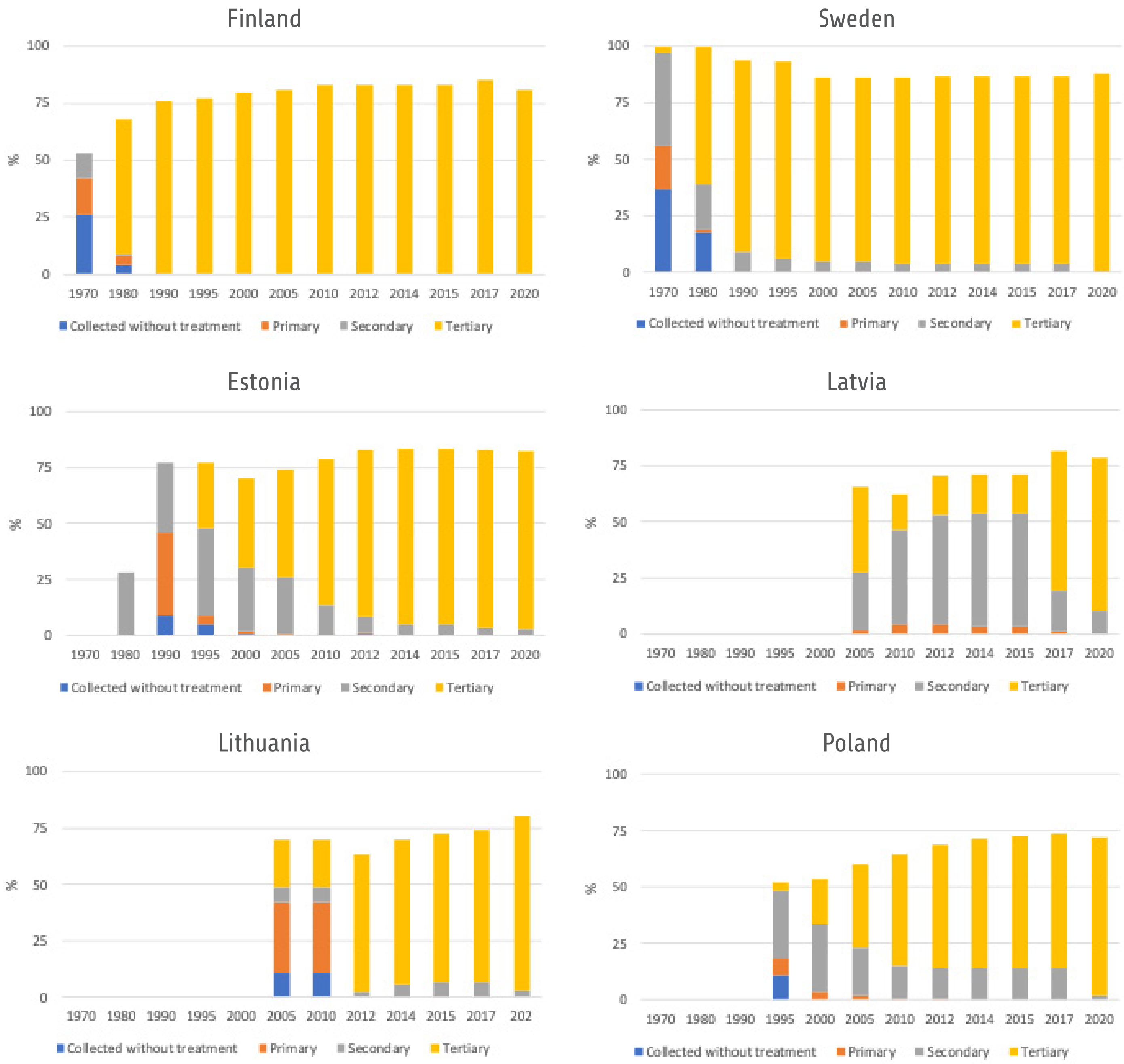


Figure 13. Continued). Connectivity and treatment status in municipal wastewater treatment plants of eight HELCOM Contracting Parties from 1970–2020. Note: data for Denmark, Germany and Sweden also include treatment plants outside the Baltic Sea catchment. Source: EEA. Tertiary treatment implies removal of phosphorus and nitrogen, or phosphorus only.

There has been a steady increase in the percentage of the population connected to secondary and tertiary wastewater treatment systems (Table 7). In 2021 the connectivity was the highest in Denmark and Germany where it was over 90%. Since 2004 the connectivity to wastewater system has especially increased in Lithuania, Poland and Russia, which has been reflected in a decreased nutrient load from scattered dwellings.

In 2021 in the Baltic Sea catchment area the number of scattered dwellings was nearly 17 million, but over 60% of them were connected to wastewater systems. The number of scattered dwellings not connected to wastewater treatment plants was 7,4 million (Table 8). Over 60% of them were in the Baltic Proper catchment area, mainly in Poland and 22% in the Gulf of Finland catchment. Furthermore, in the Russian Gulf of Finland catchment the number of scattered dwellings not connected to wastewater systems was over one million.

Table 7. Percentage of population connected to urban wastewater collection and treatment systems from 2004 to 2021. Source of the data for the year 2004: PLC-5 Report. Otherwise PLC-8 project.

Country	2004	2014	2017	2021
Denmark	89	85	94	93
Estonia	72	82	83	82
Finland	81	82	83	81
Germany	94	92	93	92
Latvia	70	76	75	77
Lithuania	59	80	82	80
Poland	58	72	71	72
Russia	60	83	89	
Sweden	86	87	87	88

Table 8. Number of scattered dwellings not connected to wastewater treatment plants in 2021. Source: PLC-8 project.

Sea-region	DE	DK	EE	FI	LV	LT	PL	RU*)	SE	BAS
Bothnian Bay				250497					36046	**286543**
Bothnian Sea				225510					121017	**346527**
Archipelago Sea				96349						**96349**
Gulf of Finland			4594	482458	138393			1084640		**1710085**
Gulf of Riga			3801		7669					**11470**
Baltic Proper	33287	7491			24032		4194213	38968	286719	**4584710**
Western Balitc	19029	68869								**87898**
The Sound		5221							12461	**17682**
The Kattegat		54294							189432	**243726**
Per country	**52316**	**135875**	**8395**	**1054814**	**170094**		**4194213**	**1123608**	**645675**	**7384990**

*) Russian data from the year 2017

4. Municipal wastewater treatment plants: Potential for removal of total nitrogen (NTOT) and total phosphorus (PTOT)

HELCOM Recommendation 28E/5 (HELCOM 2007) and the EU Urban Wastewater Treatment Directive set maximum nutrient concentrations for municipal wastewaters discharged into natural waters. The requirement in the HELCOM recommendation is shown in Table 9.

In the Baltic Sea Action Plan 2021 update (HELCOM 2021) the Contracting Parties were requested in action E1 to "Submit an account listing, as detailed as possible, the planned and implemented measures in different sectors and catchments alongside an estimation of their effectiveness to HELCOM by 2023 in order to demonstrate whether national net nutrient input ceilings can be achieved with these measures". Among reported measures many countries have reported reduced emission of nitrogen and phosphorus from municipal wastewater treatment plants (WWTP).

Drafting group for the new hot spots criteria under the WG Source to sea drafted revised criteria for designation and deletion of HELCOM hot spots including WWTPs for implementing action HT24 of the 2021 BSAP.

This chapter includes the assessment results from analyses on potential total nitrogen (NTOT) and total phosphorus (PTOT) reduction in emissions from WWTPs that was conducted as support to the hot spot criteria drafting group and as a follow up on 2021 BSAP action E1. It is an updated version of the HELCOM ACTION project's report where the potential to reduce nutrient discharges from MWWTPs were estimated for the first time (HELCOM 2020). In that study the last year of data was 2017.

Table 9. Removal percentages and concentrations for municipal wastewater treatment plants according to HELCOM Recommendation 28E/5 (HELCOM 2007).

	NTOT %	PTOT %	BOD5 %	NTOT mg/l	PTOT mg/l	BOD5 mg/l
300-2,000 PE	30	70	80	35	2	25
2,001-10,000 PE	30	80	80	-	1	15
10,001-100,000 PE	70-80	90	80	15	0,5	15
>100,000 PE	70-80	90	80	10	0,5	15

Note: If the minimum percentages of the overall load reduction entering all urban wastewater treatment plants in the catchment is at least 75% for NTOT and 90% for PTOT for direct discharges then individual requirements for a plant need not apply. Further, for parts of Finland and Sweden requirements for removal of nitrogen is reduced in accordance to EU Urban Wastewater Treatment Directive.

4.1. Characteristics of municipal wastewater treatment plants

The PLC-8 project is anticipated to produce this report with an evaluation of the effectiveness of measures (EOM). A questionnaire was developed where Contracting Parties among other items were requested reporting information on WWTPs. The following information was requested by plant for the year 2021:

— Name of plant
— Draining to which Baltic Sea sub-basin
— Number of connected person equivalents (PE)
— Total nitrogen (NTOT) removal in %
— Total phosphorus (PTOT) removal in %

All countries reported information on WWTPs except Russia. Many countries have reported WWTPs where either information on connected PE and/or removal percentages of NTOT or PTOT were missing, and these WWTPs were excluded from the assessment. Therefore, the assessment supporting the hot spots criteria drafting group and the results shown in this chapter are based on the analysis of WWTP data from eight countries: Denmark, Estonia, Finland, Germany, Lithuania, Latvia, Poland and Sweden, and the potential from increasing/improving removal of nitrogen and phosphorus is potentially higher than shown in this chapter.

Removal NTOT and PTOT percentages were reported for more than 4100 WWTP plants and number of connected PE for more than 4200 plants (Table 10). The WWTPs reported aggregated have been excluded and are not included in the numbers below.

Table 10. Number of individual reported WWTPs (WWTPs reported aggregated excluded) reported by country for removal of NTOT, PTOT and number of connected PE. To fulfil a complete dataset, removal of both NTOT and PTOT and number of connected PE is needed. * Poland indicated that for 825 WWTPs the removal percentages are estimated roughly. n.i. = no information.

	DE	DK	EE	FI	LT	LV	PL*	RU	SE	Sum
Removal % NTOT	894	367	411	290	53	56	1629	n.i.	419	4119
Removal % PTOT	894	367	411	278	53	56	1629	n.i.	419	4107
Connected PE	889	489	428	314	53	57	1623	n.i	411	4,270
Complete dataset	889	363	409	278	53	55	1621	0	411	4,080

The average removal percentage for NTOT (where each individual WWTP counts equally calculating the average) varies from under 40% for Finland to nearly 85% for Lithuania, but Lithuania has only reported 53 WWTP plants (Table 11). For PTOT the average ranges between 63% in Poland and nearly 93% for Finland and Sweden (Table 12). It should be noted that in northern part of Finland a requirement for NTOT removal is lower due to the cold weather condition. In Sweden, neither the Bothnian Bay nor the Bothnian Sea are designated as nitrogen sensitive (limited) areas according to the UWWTD. Furthermore, for a few plants located in the catchment area of the Baltic Proper, retention processes in lakes and waterways are accounting for the fulfillment of the nitrogen removal obligations in accordance with the UWWTD.

Table 11. Number of WWTPs with different NTOT removal percentages, and minimum, maximum, average and median NTOT removal percentages. n.i. = no information.

NTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE
Number of plants:	894	363	409	278	53	56	1622	0	411
Removal percentages:									
<30%	37	23	33	114	0	0	2	n.i.	140
30%-<50%	74	22	42	80	0	4	17	n.i.	109
50%-<70%	134	18	75	46	4	18	849	n.i.	76
70%-<80%	80	19	61	12	5	7	65	n.i.	47
80%-<85%	58	38	46	9	16	7	90	n.i.	21
85%-<90%	76	67	55	11	14	7	251	n.i.	14
90%-<95%	138	140	53	5	8	11	286	n.i.	3
95%-<97%	53	32	24	1	5	1	50	n.i.	0
97%-<99%	82	3	16	0	1	0	10	n.i.	0
>99%	162	0	4	0	0	0	2	n.i.	1
min. (%)	-10.0	-64.4	0	0	51.7	34	19.3		-114
max. (%)	100	97.5	100	96.6	97.2	97	99.8		100
average (%)	80.2	79.7	72.1	38.8	84.6	74.0	75.6		43.9
median (%)	90.2	89.7	79.4	35.3	86.5	75.0	65.0		39.5

Table 12. Number of WWTPs with different PTOT removal percentages, and minimum, maximum, average and median PTOT removal percentages. n.i. = no information.

PTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE
Number of plants:	894	363	409	277	53	55	1622	0	411
Removal percentages:									
<30%	12931	24	19	4	2	0	5	n.i.	3
30%-<50%	1264	15	19	1	0	6	817	n.i.	0
50%-<70%	1355	13	55	6	1	11	23	n.i.	1
70%-<80%	72	16	32	6	4	5	26	n.i.	5
80%-<85%	26	15	21	10	5	8	47	n.i.	12
85%-<90%	42	39	43	16	9	5	98	n.i.	35
90%-<95%	4854	106	84	66	25	9	238	n.i.	122
95%-<97%	3842	85	66	73	3	3	183	n.i.	120
97%-<99%	7167	47	48	79	4,0	8	173	n.i.	106
>99%	205198	2.0	22.0	16	0.0	0.0	12.0	n.i.	7
min. (%)	-57058	-66.2	0	0	0.0	30	10		-0.7
max. (%)	100	99.2	100	99.9	98.7	99.0	100		100
average (%)	70	83.4	81.6	92.6	85.7	76.1	63.2		93.6
median (%)	77	93.3	91.4	96	90.9	84.0	35.0		95.6

The distribution of plants on NTOT removal percentages show that Finland and Sweden have more than 60 % of WWTPs with less than 50 % removal, which is mainly caused by the mentioned cold climate issues in the northern part of these countries (Table 13). More than 50 % of reported WWTPs in Poland have 50-70 % NTOT removal. For Germany more than 18% of WWTPs have a very high NTOT removal with >99%, where the remaining HELCOM countries have rather few WWTPs with more than >95% NTOT removal.

In Denmark, Finland, Lithuania and Sweden more than 60% of the WWTPs have more than 90% PTOT removal and also more than 80% of the WWTPs have >80 % PTOT removal (Table 14). In Poland more than 50% of the reported WWTPs have less than 50% PTOT removal.

Table 13. Percentages of the reported WWTPs in the individual NTOT removal intervals. The actual numbers are in Table 11. n.i. = no information.

NTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE
Number of plants:	894	363	409	278	53	55	1622	n.i.	411
Removal percentages:									
<30%	4.1	6.3	8.1	41.0	0.0	0.0	0.1	n.i.	34.1
30%-<50%	8.3	6.1	10.3	28.8	0.0	7.3	1.0	n.i.	26.5
50%-<70%	14.35.0	5.0	18.3	16.5	7.5	32.7	52.3	n.i.	18.5
70%-<80%	98.19	5.2	14.9	4.3	9.4	16.42.7	4.0	n.i.	11.4
80%-<85%	6.76.5	10.5	11.2	3.2	30.2	9.112.7	5.5	n.i.	5.1
85%-<90%	8.18.5	18.5	13.4	4.0	26.4	16.412.7	15.5	n.i.	3.4
90%-<95%	14.715.4	38.6	13.0	1.8	15.1	16.4	17.6	n.i.	0.7
95%-<97%	7.05.9	8.8	5.9	0.4	9.4	1.8	3.1	n.i.	0.0
97%-<99%	5.49.2	0.8	3.9	0.0	1.9	0.0	0.6	n.i.	0.0
>99%	22.418.1	0.0	1.0	0.0	0.0	0.0	0.1	n.i.	0.2

Table 14. Percentages of the reported WWTPs in the individual PTOT removal intervals. The actual numbers are in Table 12. n.i. = no information.

PTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE
Number of plants	894	363	409	277	53	55	1,622	n.i.	411
Removal percentages:									
<30%	14.74	6.6	4.6	1.4	3.8	1.80.0	0.3	n.i.	0.7
30%-<50%	14.13.9	4.1	4.6	0.4	0.0	14.510.9	50.4	n.i.	0.0
50%-<70%	15.14	3.6	13.4	2.2	1.9	14.520.0	1.4	n.i.	0.2
70%-<80%	8.1	4.4	7.8	2.2	7.5	10.9.1	1.6	n.i.	1.2
80%-<85%	3.12.9	4.1	5.1	3.6	9.4	14.5	2.9	n.i.	2.9
85%-<90%	4.7	10.7	10.5	5.8	17.0	9.1	6.0	n.i.	8.5
90%-<95%	5.46.0	29.2	20.5	23.8	47.2	16.4	14.7	n.i.	29.7
95%-<97%	4.37	23.4	16.1	26.4	5.7	10.95.5	11.3	n.i.	29.2
97%-<99%	7.95	12.9	11.7	28.5	7.5	7.314.5	10.7	n.i.	25.8
>99%	22.91	0.6	5.4	5.8	0.0	0.0	0.7	n.i.	1.7

Eight countries provided information on the number of connected population equivalents (PE) to the WWTPs. Numbers of PE are aggregated for the removal percentages intervals of NTOT (Table 15) and PTOT (Table 16). The average number of connected PE per plant in a removal percentages interval for NTOT and PTOT are given in Tables 17 and 18, respectively.

Most connected PE are for WWTPs with NTOT removal percentages between 80 and 97% besides for Finland and Sweden (due to low NTOT removal in northern part of Finland and the Swedish implementation of the UWWTD). It indicates that even though there are rather many WWTPs with NTOT removal under 50%, they are rather small (with few connected PE). For PTOT more than 90 % of the PEs are connected to WWTPs with >85 % PTOT removal. In Poland more than 10% of the PE are connected to WWTPs with <70% PTOT removal.

The WWTPs with highest NTOT and PTOT removal (>99%) have a low average number of connected PE according to Tables 17 and 18. Although it should be noted that some few reported removal percentages were suspiciously high (or low) (see Tables 11 and 12) which might explain the result. Overall with higher PTOT removal percentages the average number of connected PE are higher, but this tendency is less evident for the NTOT removal.

Table 15. Total number of connected PE to WWTPs within the NTOT removal percentages interval. n.i.= no information.

Nitrogen	DE	DK	EE	FI	LT	LV	PL	RU	SE
Number of plants	889	363	409	278	53	55	1,622	n.i.	411
Removal percentages:									
<30%	1,485,321	16,235	25,625	483,286	0	0	194,592	n.i.	1,553,159
30%-<50%	1,737,476	19,400	15,455	105,8851	0	6,337	263,611	n.i.	725,013
50%-<70%	182,363	21,9795	59,656	612,282	20,406	69,686	5,182,472	n.i.	1,786,478
70%-<80%	20,409	114,526	539,635	262,025	3,142	131,907	1,177,819	n.i.	3,975,646
80%-<85%	28,170	701,732	193,961	384,501	184,113	92,215	4,726,690	n.i.	2,131,856
85%-<90%	43,693	4,102,887	563,433	818,639	469,425	734,712	1,717,1383	n.i.	619,987
90%-<95%	45,137	4,164,968	686,712	138,038	23,823	20,8452	20,767,104	n.i.	17,894
95%-<97%	77,338	714,413	37,429	1,617	305,217	28,202	3,006,226	n.i.	0
97%-<99%	11,118	83,225	56,323	0	3,628	0	282,210	n.i.	0
>99%	82,699	0	1600	0	0	0	19,100	n.i.	2,800

Table 16. Total number of connected PE to WWTPs within the PTOT removal percentages interval. n.i. = no information.

Phosphorus	DE	DK	EE	FI	LT	LV	PL	RU	SE
Number of plants	889	363	409	278	53	55	1,622	n.i.	411
Removal percentages:									
<30%	3,282,312	7,785	4421	348	12,873	2061	40,447	n.i.	65,382
30%-<50%	125,869	8,349	6849	958	0	13,136	4,662,548	n.i.	0
50%-<70%	55,408	14,613	26,082	2,383	618	34,491	303,820	n.i.	3,215
70%-<80%	42,185	235,368	19,723	3,914	9,063	46,903	405,136	n.i.	28,396
80%-<85%	24,811	205,342	19,049	7,711	22,867	104,277	985,946	n.i.	70,543
85%-<90%	6,109	1,087,264	27,544	19,660	110,460	51,222	2,834,696	n.i.	564,678
90%-<95%	7,144	4,750,263	938,103	321,761	544,954	817,785	14,016,345	n.i.	3,665,879
95%-<97%	71,418	1,880,333	619,645	782,932	270,602	144,917	14,371,424	n.i.	3,793,239
97%-<99%	14,742	1,900,464	370,058	2,381,656	38,317	57,019	14,747,531	n.i.	2,580,128
>99%	83,726	41,400	148,355	237,861	0	0	42,3224	n.i.	41,323

Table 17. Average number of connected PE per WWTPs within the NTOT removal percentages interval. n.i.= no information.

NTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE
Number of plants	889	363	409	278	53	55	1,622	n.i.	411
Removal percentages:									
<30%	40,144	706	777	4239	-	-	97,296	n.i.	11,094
30%-<50%	23,479	882	368	13236	-	1,584	15,507	n.i.	6,651
50%-<70%	1,361	12,211	795	13310	5,102	3,871	6,104	n.i.	23,506
70%-<80%	255	6,028	8,846	21835	628	148,656444	18,120	n.i.	84,588
80%-<85%	486	18,467	4,217	42722	11,507	138,443174	52,519	n.i.	101,517
85%-<90%	575	61,237	10,244	74422	33,530	81,635104,959	68,412	n.i.	44,285
90%-<95%	327	29,750	12,957	27608	2,978	23,16118,950	72,612	n.i.	5,965
95%-<97%	1,459	22,325	1,560	1617	61,043	28,202	60,125	n.i.	-
97%-<99%	136	27,742	3,520	-	3,628	-	28,221	n.i.	-
>99%	510	-	400	-	-	-	9,550	n.i.	2,800

Table 18. Average number of connected PE per WWTPs within the PTOT removal percentages interval. n.i. = no information.

PTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE
Number of plants	889	363	409	278	53	55	1,622	n.i.	411
Removal percentages:									
<30%	25,056	324	233	87	6,437	2,061 -	8,089	n.i.	21,794
30%-<50%	1015	557	360	958	-	1,6422.189	5,707	n.i.	-
50%-<70%	402	1,124	474	397	618	4,3,1136	13,210	n.i.	3,215
70%-<80%	586	14,711	616	652	2,266	79,3817	15,582	n.i.	5,679
80%-<85%	954	13,689	907	771	4,573	13,035	20,978	n.i.	5,879
85%-<90%	145	27879	641	1,229	12,273	10,244	28,925	n.i.	16,134
90%-<95%	132	44,814	11,168	4,875	21,798	90,865	58,892	n.i.	30,048
95%-<97%	1,700	22,122	9,389	10,725	90,201	248,15306	78,532	n.i.	31,610
97%-<99%	220	40,435	7,710	30,148	9,579	148,25579	85,246	n.i.	24,341
>99%	n.i.	20,700	6,743	14,866	n.i.	-	35,269	n.i.	5,903

4.2. Potential for removal of total nitrogen and total phosphorus

Based on the information on connected PE and removal percentages of NTOT and PTOT, four scenarios have been calculated on the potential further removal of NTOT and PTOT for the reported WWTPs:

1. Increasing the present NTOT and PTOT removal percents by one percentage class interval, e.g. from <30% to between 30-<50%, from 30%-<50% to 50%-<70% etc.- see tables 19 and 20.
2. Require that all WWTPs with more than 100 000 connected PE where the present removal percentages are underperforming 5% or more than the requirement (in HELCOM Recommendation. 28E/5 HELCOM, 2007) of at least 70-80% (calculated as 75%) NTOT removal and 90% PTOT removal should fulfil the requirements. The exercise is also done for the remaining reported WWTPs with less than or equal to < 100.000 connected PE underperforming 5% or more – see tables 21 and 22.
3. Require that all WWTPs where the present removal percentages are underperforming 10% or more than the removal requirement of NTOT and PTOT removal in HELCOM Recommendation 28E/5 should fulfil the requirements – see tables 23 and 24.
4. Require that all WWTPs where the present removal percentages are underperforming 20% or more than the removal requirement of NTOT and PTOT removal in HELCOM Recommendation 28E/5 should fulfil the requirements – see tables 25 and 26.

The calculation is made on each of the individual 4080 plants (table 10) and the results aggregated for the indicated PE intervals in tables 19 to 26.

The scenarios consider retention in inland surface waters by calculating the reduction potential with 10%, 30% and 50% retention in inland surface waters, respectively but also includes the potential reduction without retention. As many of the big WWTPs are situated close to the Baltic Sea there is no or low retention (max. 10%) for these, but there are also several WWTPs situated with higher distance to sea and upstream lakes inland where the retention can add up to even 30 to 50%.

4.3. Results of the scenarios

Scenario 1:

Changing one purification class for all reported WWTPs (scenario 1, e.g. from 80%-<85% to 85%-<90%) have a potential of removing more than 22 000 tonnes NTOT and 3 700 tonnes PTOT if no retention is assumed, and it this estimate WWTPs in Russia are not included due to missing information, as this information is reported as aggregated WWTPs and where either information on NTOT and PTOT removal percentages or connected PE are missing. With 10% retention it amounts to more than 23 000 tonnes of NTOT and 3 400 tonnes of PTOT. The scenarios include higher reduction requirements for several WWTPs than in the HELCOM Recommendation 28E/5 (HELCOM, 2007) and at present not realistic, but it indicates a high potential compared with remaining reduction according to the latest MAI assessment (HELCOM 2024) where about 90 000 tonnes of NTOT and 5 300 tonnes of PTOT reduction, respectively remained to fulfil MAI.

Scenario 2:

The drafting group for new hot spot criteria proposed a criterion that big WWTPs (with >100,000 PE connected) underperforming with 5% or more on NTOT and PTOT removal percentages according to HELCOM Recommendation 28E/5 should be fulfilling the criterion for hot spots. The potential of increasing removal of NTOT and PTOT percentages for these big WWTPs in six HELCOM countries to fulfil HELCOM Recommendation 28E/5 is about 3 300 tonnes NTOT and 73 tonnes PTOT, respectively without considering retention in inland surface waters according to tables 21 and 22. The exercise is also performed for the WWTPs with less or equal than 100 000 PE connected and the results are included in tables 212 and 22. The potential for NTOT and PTOT reduction is higher but rather comparable with scenario 3, where underperformance of 10% or more from fulfilling HELCOM Recommendation 28E/% is assessed. For all WWTPs underperforming with 5% or more the potential without considering retention in inland surface waters is approximately 10 500 tonnes of NTOT and 2 500 tonnes of PTOT, respectively.

Scenario 3:

Another scenario was assessed for the drafting group for new hot spot criteria, requesting that all WWTPs underperforming with 10% or more on NTOT and PTOT removal percentages according to HELCOM Recommmendation 28E/5 should be fulfilling the criterion for hot spots. The potential of increasing removal of NTOT and PTOT percentages for these WWTPs in six HELCOM countries to fulfil HELCOM Recommendation 28E/5 is about 10 000 tonnes of NTOT and 2 400 tonnes of PTOT, respectively without considering retention in inland surface waters according to tables 23 and 24.

Scenario 4:

The final scenario is as scenario 3 but with underperforming with 20% or more on NTOT and PTOT removal percentages according to HELCOM Recommendation 28E/5 should be fulfilling the criterion for hot spots. The potential of increasing removal of NTOT and PTOT percentages for these WWTPs in eight HELCOM countries to fulfil HELCOM Recommendation 28E/5 is about 8 400 tonnes of NTOT and 2 300 tonnes of PTOT, respectively without considering retention in inland surface waters according to tables 25 and 26.

Table 19. Potential removal of NTOT (in tonnes) by increasing removal one removal interval (e.g. from 50%–<70% removal to 70%–<80 % removal) and considering different removal percentages of retention in inland surface waters (scenario 1). n.i. = no information.

NTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE	Total	Retention 10%	Retention 30%	Retention 50%
Number of plants	889	363	409	n.i.	53	55	1622	n.i.	411				
Removal percentages changed from to:													
<30 % to 30%-<50%	1301	14	22	423	0	0	170	n.i.	1361	**1,991**	**3,292**	2,963	2,305
30%-<50% to 50%-<70%	1522	17	14	928	0	6	231	n.i.	635	**1,830**	**3,352**	3,017	2,346
50%-<70% to 70%-<80%	120	144	39	402	13	46	3405	n.i.	1174	**5,210**	**5,343**	4,809	3,740
70%-<80% to 80%-<85%	7	38	177	86	1	43	387	n.i.	1306	**2,037**	**2,045**	1,840	1,431
80%-<85% to 85%-<90%	6	154	42	84	40	20	1035	n.i.	467	**1,803**	**1,849**	1,664	1,294
85%-<90% to 90%-<95%	10	899	123	179	103	161	3761	n.i.	136	**5,258**	**5,371**	4,834	3,760
90%-<95% to 95%-<97%	7	638	105	21	4	32	3184	n.i.	3	**3,983**	**3,994**	3,594	2,796
95%-<97% to 97%-<99%	7	63	3	0	27	2	263	n.i.	0	**332**	**365**	329	256
97%-<99% to 99%	0	4	2	0	0	0	12	n.i.	0	**18**	**19**	17	13
Total	**2,980**	**1,970**	**529**	**2,124**	**188**	**310**	**12,448**		**5,081**	**22,463**	**25,630**	**23,067**	**17,941**

Table 20. Potential removal of PTOT (in tonnes) by increasing removal percentages of PTOT one removal interval (e.g. from 80%–<85% removal to 85%–<90 % removal) and considering different removal percentages of retention in inland surface waters (scenario 1). n.i. = no information.

PTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE	Total	Retention 10%	Retention 30%	Retention 50%
Number of plants	889	363	409	278	53	55	1622	n.i.	411				
Removal percentages changed from to:													
<30 % to 30%-<50%	647	2	1	0	3	0	8	n.i.	13	**673**	606	471	337
30%-<50% to 50%-<70%	25	2	1	0	0	3	919	n.i.	0	**950**	855	665	475
50%-<70% to 70%-<80%	36	10	17	2	0	23	200	n.i.	2	**289**	261	203	145
70%-<80% to 80%-<85%	3	17	1	0	1	3	30	n.i.	2	**58**	53	41	29
80%-<85% to 85%-<90%	1	10	1	0	1	5	49	n.i.	3	**71**	64	50	35
85%-<90% to 90%-<95%	0	54	1	1	5	3	140	n.i.	28	**232**	209	162	116
90%-<95% to 95%-<97%	0	164	32	11	19	28	483	n.i.	126	**865**	778	605	432
95%-<97% to 97%-<99%	1	37	12	15	5	3	283	n.i.	75	**432**	389	303	216
97%-<99% to 99%	0	19	4	23	0	1	145	n.i.	25	**218**	196	152	109
Total	**715**	**314**	**71**	**53**	**35**	**68**	**2257**		**275**	**3,788**	**3,409**	**2,652**	**1,894**

Table 21. Potential removal of NTOT (in tonnes) by increasing removal percentages of NTOT for WWTPs underperforming 5% or more according to HELCOM Recommendation 28E/5 to fulfil the Recommendation, considering different removal percentages of retention in inland surface waters (scenario 2). In parenthesis the number before "/" indicates number of WWTPs in the PE interval and after "/" number of WWTPs underperforming >5% or more in the NTOT removal. Total number of underperforming WWTPs are also indicated in the bottom row of the table per country and per removal interval in last right row. n.i. = no information

											Retention	**Retention**	**Retention**
NTOT	**DE**	**DK**	**EE**	**FI**	**LT**	**LV**	**PL**	**RU**	**SE**	**Total**	**10%**	**30%**	**50%**
Number of PE													
Up to 2,000	2.5 (742/21)	8.2 (100/20)	2.8 (352/20)	32.2 (159/73)	0 (30/0)	0 (10/0)	0 (92/0)		28 (64/22)	**74**	66	52	37
2,001-10,000	0 (77/0)	13.0 (124/3)	2.3 ((35/1)	29.6 (65/12)	0 (12/0)	(23/0)	1.6 (88/1)		154 (202/44)	**200**	180	140	100
10,001-100,000	13.8 (65/10)	0 (115/0)	6.4 (16/1)	1,230 (43/29)	57.2 (14/1)	25.5 (21/2)	1,264 (548/79)		4,324 (128/85)	**6,921**	6,229	4,845	3,460
>100,000	0 (5/0)	102 (23/1)	63 (6/1)	1,698 (11/5)	0 (3/0)	0 (1/0)	483 (100/1)	n.i.	962 (17/5)	**3,308**	2,977	2,316	1,654
Total (tonnes)	**16**	**123**	**75**	**2,990**	**57.2**	**25.5**	**1,749**		**5468**	**10,503**	**9,453**	**7,352**	**5,251**
Number of plants	31	24	23	119	1	2	81		156	**437**			

Table 22. Potential removal of PTOT (in tonnes) by increasing removal percentages of PTOT for WWTPs underperforming 5% or more according to HELCOM Recommendation. 28E/5 to fulfil the Recommendation, considering different removal percentages of retention in inland surface waters (scenario 2). In parenthesis the number before "/" indicates number of WWTPs in the PE interval and after "/" number of WWTPs underperforming >5% or more in the PTOT removal. Total number of underperforming WWTPs are also indicated in the bottom row of the table per country and per removal interval in last right row. n. i.= no information.

										Retention	**Retention**	**Retention**	
PTOT	**DE**	**DK**	**EE**	**FI**	**LT**	**LV**	**PL**	**RU**	**SE**	**Total**	**10%**	**30%**	**50%**
Number of PE													
Up to 2,000	19.9 (742/342)	7.5 (100/47)	5.8 (352/76)	0.6 (159/8)	0.0 (30/1)	0.8 ((10/6)	27.8 (92/75)		0.9 (64/1)	**63**	57	44	32
2,001-10,000	8.9 (77/13)	3.1 (124/6)	1.6 (35/2)	0.3 (65/1)	0 (12/0)	13.8 (23/12)	1,795 (881/721)		0.8 (202/2)	**1,824**	1,641	1,276	912
10,001-100,000	10.3 (65/1)	13.9 (115/3)	0 (16/0)	0(43/0)	0 (14/0)	8.9 (21/6)	536 (548/93)		60.5 (128/4)	**630**	567	441	315
>100,000	0 (5/0)	35 (23/1)	0 (6/0)	0 (11/0)	19.4 (3/1)	0 (1/0)	0 (100/0)	n.i.	0 (17/0)	**54**	49	38	27
Total	**39**	**60**	**7**	**1**	**19.4**	**24**	**2,359**		**62**	**2,571**	**2,314**	**1,800**	**1,285**
Number of plants	356	57	78	9	2	24	889		7	1,066			

Table 23. Potential removal of NTOT (in tonnes) by fulfilling removal percentages of NTOT for WWTPs underperforming 10% or more according to HELCOM Recommendation 28E/5 to fulfil the Recommendation, considering different removal percentages of retention in inland surface waters (scenario 3). In parenthesis the number before "/" indicates number of WWTPs in the PE interval and after "/" number of WWTPs underperforming >10% or more in the NTOT removal. Total number of underperforming WWTPs per country are also indicated in the second last bottom row and how many of these being big WWTPs > 100 000 PE in the bottom row of the table. Sum of underperforming WWTPs per removal interval are in last right row. n.i. = no information.

NTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE	Total	Retention 10%	Retention 30%	Retention 50%	Number of plants
Number of PE														
Up to 2,000	2 (742/13)	7.0 (100/16)	2.2 (352/12)	29 (159/58)	0 (30/0)	0 (10/0)	0 (92/0)	n.i.	22.3 (64/9)	**6163**	546	424	301	95108
2,001-10,000	0 (77/0)	13.0 (124/13)	2.3 (34/1)	18.4 (65/6)	0 (12/0)	0 (23/0)	1.6 (881/1)	n.i.	137 (201/35)	**173**	155	121	86	56
10,001-100,000	0 (65/0)	0 (115/0)	6.4 (15/1)	1211 (43/27)	23 (14/1)	20 (21/1)	1,137 (548/67)	n.i.	4,208 (128/78)	**6,582605**	5,9245	4,60824	3,291303	1745
>100,000	0 (5/0)	102 (23/1)	0 (6//0)	1698 (11/5)	0 (3/0)	0 (1/0)	483 (100/1)	n.i.	962 (17/5)	**3,248**	2,923	2,274	1,624	12
Total	**2**	**122**	**11**	**2,656**	**23**	**20**	**1,622**		**5,329**	**10,06489**	**9,05780**	**7,04462**	**5,03244**	**33751**
Number of plants	**130**	30	14	96	1	1	69		127	**33751**				
>100,000		1	0	5	1	0	1		5	**12**				

Table 24. Potential removal of PTOT (in tonnes) by fulfilling removal percentages of PTOT for WWTPs underperforming 10% or more according to HELCOM Recommendation 28E/5 to fulfil the Recommendation, considering different removal percentages of retention in inland surface waters (scenario 3). In parenthesis the number before "/" indicates number of WWTPs in the PE interval and after "/" number of WWTPs underperforming >10% or more in the PTOT removal. Total number of underperforming WWTPs are also indicated in the second last bottom row and how many of these being big WWTPs > 100 000 PE in the bottom row of the table. Sum of underperforming WTWPs per removal interval are in last right row. n.i. = no information.

PTOT	DE	DK	EE	FI	LT	LV	PL	RU	SE	Total	Retention 10%	Retention 30%	Retention 50%	Number of plants
Number of PE														
Up to 2,000	18.4 (742/299)	6.2 (100/47)	15.4 (352/61)	0.6 (159/16)	0 (30/0)	0.8 (10/6)	28 (92/75)	n.i.	0.9 (64/1)	**5270**	4763	3649	2635	206505
2,001-10,000	7,6 (77/9)	2.6 (124/13)	1.6 (34/2)	0 (65/0)	0 (12/0)	13 (23/11)	1,794 (881/717)	n.i.	0.6 (201/1)	**1,8129**	1,6317	1,26874	9106	74453
10,001-100,000	10,3 (65/1)	2.2 (115/1)	0 (15/1)	0 (43/0)	0 (14/0)	1.4 (21/1)	467 (548/64)	n.i.	59.3 (128/3)	**5340**	47786	3718	26570	701
>100,000	0 (5/0)	23.1 (23/1)	0 (6/0)	0 (11/0)	19.4 (3/1)	0 (1/0)	0 (100/0)	n.i.	0 (17/0)	**243**	2138	1630	121	12
Total	**129**	**29**	**17**	**0.6**	**19**	**15**	**2,289**		**61**	**2,4172**	**2,17225**	**1,692731**	**1,20836**	**1,02331**
Number of plants	**309**	62	64	16	1	18	856		5	**1,02331**				
>100,000	0	1	0	0	1	0	0		0	**12**				

Table 25. Potential removal of NTOT (in tonnes) by fulfilling removal percentages of NTOT for WWTPs underperforming 20% or more according to HELCOM Recommendation 28E/5 to fulfil the Recommendation, considering different removal percentages of retention in inland surface waters (scenario 4). In parenthesis the number before "/" indicates number of WWTPs in the PE interval and after "/" number of WWTPs underperforming >20% or more in the NTOT removal. Total number of underperforming WWTPs are also indicated in the second last bottom row and how many of these being big WWTPs > 100,000 PE in the bottom row of the table. Sum of underperforming WWTPs per removal interval are in last right row. n.i. = no information.

NTOT	**DE**	**DK**	**EE**	**FI**	**LT**	**LV**	**PL**	**RU**	**SE**	**Total**	**Retention 10%**	**Retention 30%**	**Retention 50%**	**Number of plants**
Number of PE														
Up to 2,000	**1.4 (742/6)**	3.4 (100/8)	0.1 (352/2)	26 (159/30)	0 (30/0)	0 (10/0)	0 (92/0)	n.i.	18.3 (64/6)	**489**	434	343	254	4652
2,001-10,000	**0 (77/0)**	11.6 (124/2)	0 (34/0)	11 (65/3)	0 (12/0)	0 (23/10)	0 (881/0)	n.i.	77.4 (201/12)	**100**	90	70	50	217
10,001-100,000	**0 (65/0)**	0 (115/0)	2.3 (15/1)	1,010 (43/19)	23 (14/1)	20 (21/1)	487 (548/11)	n.i.	3,943 (128/59)	**5,46083**	4,914	3,822	2,730	912
>100,000	**0 (5/0)**	0 (23/0)	0 (6/0)	1,698 (11/5)	0 (3/0)	0 (1/0)	483 (100/1)	n.i.	651 (17/2)	**2,832**	2,549	1,982	1,416	8
Total	**1**	**15**	**2.4**	**2745**	***23***	**0**	**970**		**4,690**	***8,4640***	***7,59618***	***5,90825***	***4,2320***	***17269***
Number of plants		10	3	57	1	*1*	12		79	172	*17269*			
>100,000	0	0	0	5	*0*	0	1		2	*8*				

Table 26. Potential removal of PTOT (in tonnes) by fulfilling removal percentages of PTOT for WWTPs underperforming 20% or more according to HELCOM Recommendation 28E/5 to fulfil the Recommendation, considering different removal percentages of retention in inland surface waters (scenario 4). In parenthesis the number before "/" indicates number of WWTPs in the PE interval and after "/" number of WWTPs underperforming >20% or more in the PTOT removal. Total number of underperforming WWTPs are also indicated in the second last bottom row and how many of these being big WWTPs > 100,000 PE in the bottom row of the table. Sum of underperforming WWTPs per removal interval are in last right row. n.i. = no information.

PTOT	**DE**	**DK**	**EE**	**FI**	**LT**	**LV**	**PL**	**RU**	**SE**	**Total**	**Retention 20%**	**Retention 30%**	**Retention 50%**	**Number of plants**
Number of PE														
Up to 2,000		6.1 (100/39)	7.9 (352/36)	0.6 (159/16)	0 (30/0)	0.6 (10/6)	28 (92/74)	n.i.	0.9 (64/1)	**4359**	354	428	2230	172415
2,001-10,000	16.2 (742/243)	2.6 (124/3)	1.3 (34/1)	0 (65/0)	0 (12/0)	12 (23/10)	1,787 (881/710)	n.i.	0 (201/0)	**1,8093**	1,442628	1,172266	9014	7249
10,001-100,000	5.7 (77/5)	0 (115/0)	0 (15/1)	0 (43/0)	0 (14/0)	0 (21/0)	419 (548/20)	n.i.	57.4 (128/2)	**4876**	4381	31041	23843	233
>100,000	10.3 (65/10)	0 (23/1)	0 (0/0)	0 (11/0)	0 (3/0)	0 (1/0)	0 (100/0)	n.i.	0 (17/0)	**0**	0	0	0	1
Total	**32**	**8.7**	**9.2**	**0.6**	**0**	**12**	**1,234**		**58**	**2,32355**	**2,119,858**	**1,510648**	**1,16177**	**9201,178**
Number of plants 258		43	38	16	0	16	804		3	**920**	**9201,178**			
>100,000	0	1	0	0	0	0	0		0	1				

4.4. Discussion

Scenario 1 on increasing removal percentages for all reported WWTPs in eight HELCOM countries results in the highest potential reduction as we estimated the consequences of increasing removal of NTOT and PTOT, including for many plants that are already fulfilling the HELCOM Recommendation 28E/5. This scenario is at present not realistic, but with a potential reduction of 25 000 tonnes of NTOT and nearly 3 800 tonnes of PTOT it could be an important contribution to reduce some of the remaining reduction to fulfil MAI according to the latest MAI assessment (HELCOM 2024) of about 90 000 tonnes of NTOT and 5 300 tonnes of PTOT, respectively.

Scenario 2 on estimating potential NTOT and PTOT reduction for all WWTPs underperforming 10% or more provides the next highest reduction potential with about 10 000 tonnes of NTOT and nearly 2 600 tonnes of PTOT (without considering retention in inland surface waters). The potential corresponds to approximately 11 % of remaining NTOT and 45% PTOT, respectively to fulfil MAI (HELCOM, 2024). The potential is even higher as Russia is not included in the reduction potential due to missing data, and not all WWTPs were reported or information on removal percentages or number of connected PE were missing. If the criteria to all WWTPs were strengthened for the ones underperforming e.g. 1 or 2% or more the reduction potential would also increase. The HELCOM ACTION project estimated, that NTOT load into the Baltic Sea would decrease by 10 500 t and the respective PTOT load by 1210 t, if all MWWTPs would follow the HELCOM Recommendation 28E/5 (HELCOM 2020). Thus, according to these new results the potential to reduce nutrient inputs from MWWTPs, especially PTOT inputs, might be even larger than the former estimates, but depending on retention in inland waters.

Scenarios 3 and 4 are assuming WWTPs underperforming 10% or more or 20 % or more, respectively and they provide less potential for NTOT and PTOT reduction than scenarios 1 and 2, but the difference is not very marked.

It should be noticed that for WWTPs in northern Finland and Sweden the cold climate influences the potential for NTOT removal and therefore the reduction potential in the scenarios could be overestimated for these areas.

The biggest reduction potential (97%) are for WWTPs >10,000 PE for NTOT but for WWTPs between 2,000 and 100,000 connected PE for PTOT (95%).

In conclusion, by ensuring that the WWTPs fulfill the HELCOM Recommendation 28E/5 (HELCOM, 2007) and further strengthening the removal requirements particularly for PTOT would contribute substantially to fulfil the MAI defined in the 2021 BSAP.

5. Combined Sewerage overflow (CSO) and Stormwaters

The results of the circulation of a questionnaire regarding CSO and stormwaters amongst the Contracting Parties within HELCOM reflect the complexity of these topics. The quality and quantity of the information provided varies significantly among the countries.

The questionnaire which was at least partially filled in by 7 out of 9 Contracting Parties, shows that there are different national approaches in place when it comes to the monitoring of CSOs and estimating the composition of stormwaters making it hard to estimate the contribution of CSOs to eutrophication. Regarding the potential impact of CSOs on the pollution load in the receiving waterbodies, the ECs evaluation of the Council Directive 91/271/EEC of 21 May 1991 ("UWWTD"), estimated that in a scenario with full compliance with the directive, CSOs can contribute to 50% or more of the remaining impact on waterbodies. In the light of climate change and its attributed changes in precipitation patterns this will likely become even more severe.

According to the information provided there are national regulations for the monitoring of CSOs in place in Germany (at least partly), Finland, Sweden, Poland, Estonia, and Denmark. The monitoring itself is mostly restricted to the number of events and the flow or alternatively the discharge during an event. In addition to that Denmark is monitoring BOD_5, COD, NTOT and PTOT in the case of a CSO happening at the wastewater treatment plant (WWTP) with a capacity higher than 30 PE. Sweden and Estonia are monitoring nutrients (BOD_7/BOD_5, PTOT, NTOT) in the case of CSO at a WWTP with a capacity of more than 2 000 PE, and in Sweden additionally some metals are being monitored in the case of CSOs at a WWTP with a capacity exceeding 10 000 PE. In Latvia only the number of events and the flow is monitored while in Poland only the number of events is monitored.

Nationally there are different regulations and standards in place aiming at ensuring a minimum quality of the discharged CSO water. In Poland for example, maximum allowable values for total suspended solids (TSS) and petroleum are in place while in Estonia the released overflow water must consist of at least ¾ stormwater and only ¼ sewerage and the stormwater has an assumed concentration of 3,6 mg N/l and respectively 0,27 mg P/l. In Denmark the composition of stormwater is modelled for areas which are bigger than 1500 m^2 and connected to a sewer system. Also in Sweden the surface runoff water and its composition in urban areas is estimated using models. According to the questionnaire, Estonia is the only country with national standard values for nutrients in stormwater in place.

It remains to be seen how the update of the UWWTD impacts the situation regarding monitoring of CSOs and assessing their impact on waterbodies in the future but there appears to be potential for improvements.

6. Examples of river catchments with reduced nutrient inputs

6.1. Case study 1: Successful reduction of diffuse nitrogen emissions at catchment scale. Example from the pilot River Odense, Denmark

6.1.1 Introduction

Land-based total nitrogen (NTOT) loads to Danish coastal waters have been markedly reduced since 2000. This has been achieved by general measures reducing discharges from all point sources and N leaching from farmland supplemented with more local and targeted mitigation measures such as restoration of wetlands to increase the catchment-specific N retention. In the catchment of the River Odense, restoration of wetlands has been extensive.

Thus, in the major gauged catchment (485 km^2) eleven wetlands (860 ha) have been restored since 2000. A comparison of data on N concentrations and loss from a gauging station in the River Odense with data from a control catchment (772 km^2), in which a significantly less intensive wetland restoration programme has been undertaken, showed an excess downward trend in N, amounting to 124 t N/a, which can be ascribed to the intensive wetland restoration programme carried out in the River Odense catchment. In total, the N load in the River Odense has been reduced by 377 t N/a (39%) since 2000.

6.1.2 The catchment

The River Odense catchment upstream of the Kratholm monitoring station drains a 485 km^2 area in the central and southern part of the island of Funen, Denmark (Figure 14).

The control catchment, 11 sub-catchments also situated on Funen, drains a total area of 772 km^2. Precipitation, runoff, soil types and land use characteristics of the two catchments are relatively similar, average annual precipitation amounting to 860 mm for both catchments and river runoff to 275 mm and 305 mm, respectively, during the period 2000–2013. Both catchments are mainly underlain by clayey till and meltwater sand, and top soils are dominantly sandy clay soils (48 and 44%) and clayey sandy soils (45 and 49%).

Table 27. Changes in agricultural land use and discharges of NTOT with sewage outlets and implementation of mitigation measures in the River Odense and the control catchment.

	Control catchment		River Odense catchment	
	2000	2013	2000	2013
Catch crops (%)[a]	7.7	13.5	6.4	9.9
Livestock units (LU/ha)[b]	1.1	1.0	1.0	0.9
Buffer strip width (m)	2	10	2	10
Restored wetlands (ha/km^2)	0	0.5	0	1.8
Forested land (%)	15	16	16	18
Agricultural land (%)	73	64	73	64
Sewage outlets, t N/y	75	60	40	40

[a] Data from 2005 and 2013 as percentage of spring crop areas.

[b] Data from 2005 and 2013 (related to total catchment area).

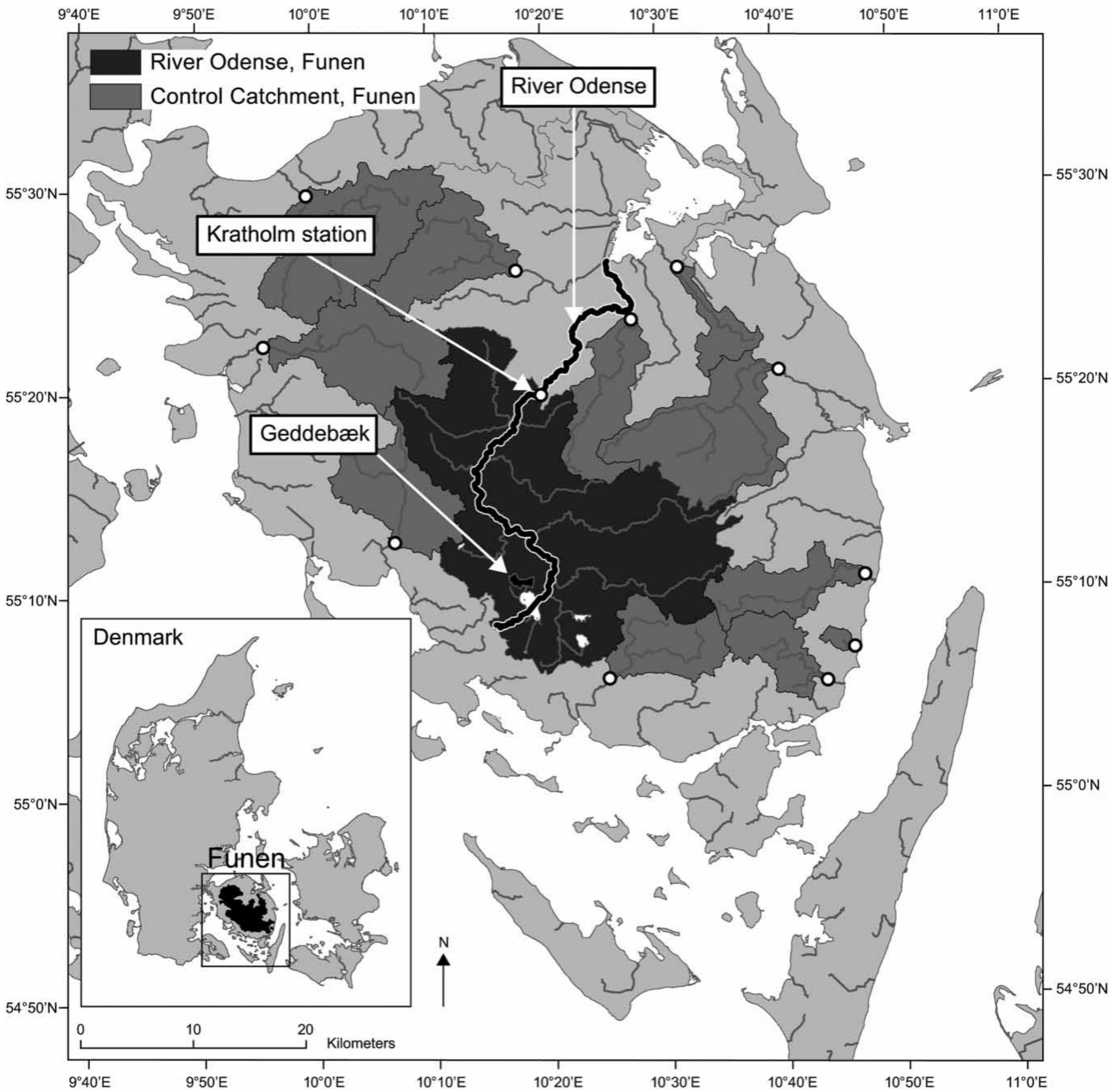


Figure 14. The river Odense Catchment and the Control Catchment with gauging stations.

6.1.3 Trend analysis

A trend analysis of flow-weighted NTOT and nitrate-N concentrations was conducted for the River Odense and control catchment for the period 2000–2013 (Figure 15 and Table 28). Significant ($P< 0.001$) reductions for both parameters and catchments were detected. However, reductions in NTOT and nitrate-N were higher in the River Odense catchment (2.55 and 2.26 mg N/l) than in the control catchment (1.90 and 1.73 mg N/L; $P< 0.001$) (Table 28). These reductions are also reflected in the estimated reductions in NTOT load normalized to mean water discharge in the River Odense and the control catchment (377 t N/a (39%) and 403 t N/a (30%), respectively, during 2000–2013.

The observed trend in the two catchments cannot be explained by a reduction in NTOT emissions from sewage outlets as these were constant in the River Odense catchment and decreased only slightly (15 t N/a) in the control catchments during 2000–2013 (Table 28).

Thus, the observed downward trends in N concentrations and loss can be ascribed to adoption of general mitigation options such as catch crops and the general decline in the proportion of agricultural land due to afforestation, widening of buffer strips, restoration of wetlands, etc. (Table 27). The reduction in NTOT and nitrate-N concentrations and flow-normalised loads were much more pronounced in the River Odense catchment than in the control catchment, despite a larger reduction in both point source emissions and more catch crops in the control catchment (Tables 27 and 28). The larger reduction (trend) of the NTOT and nitrate-N loss found in the River Odense catchment as compared to the control catchment amounted to 124 t N and 104 t N, respectively, during the period 2000–2013. This higher reduction seems to be closely linked with wetland restoration as a significant ($P < 0.0001$) downward trend was detected in the difference in monthly flow-weighted NTOT concentrations observed at the gauging stations in the River Odense and in the control catchment during 2005–2013, the period where most wetland restoration projects took place (Figure 15).

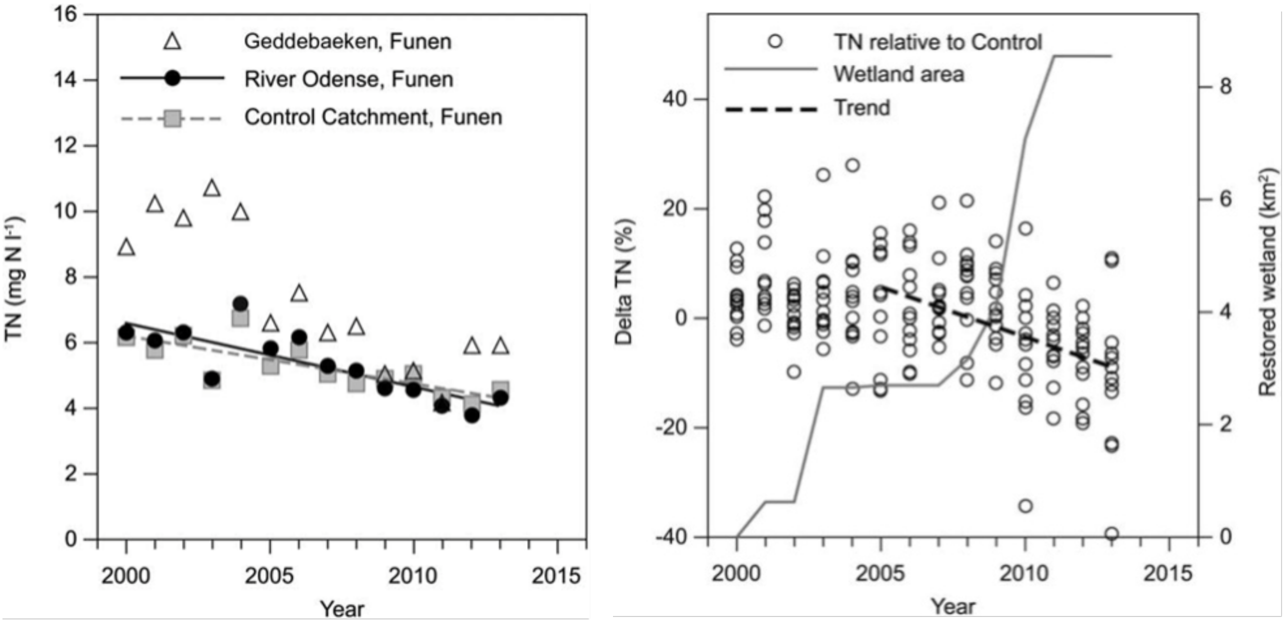


Figure 15. The annual flow-weighted NTOT -concentration in River Odense and control catchments (left) and difference in monthly flow-weighted NTOT concentrations in the River Odense compared to the control catchments and the area of restored wetlands (right).

Table 28. Results of the linear (Y=a+bX) trend detection for NTOT and nitrate-N in the River Odense and control catchments. The trend for the analysed period 2000–2013 is given per catchment area (P=significance level; SD=standard deviation)

	N	α	β±SD	R^2	P	Trend (mg N L^{-1})	Trend (kg N ha^{-1})
TN							
River Odense	14	6.60	-0.1959±0.0399	0.67	0.0004	-2.55	-7.77
Control Catchment	14	6.21	-0.1460±0.0329	0.62	0.0008	-1.90	-5.22
Nitrate-N							
River Odense	14	5.74	-0.1737±0.0338	0.69	0.0002	-2.26	-6.89
Control catchment	14	5.45	-0.1327±0.0301	0.62	0.0009	-1.73	-4.74

6.1.4 Conclusion

A trend analysis was carried out with emphasis on N, using water quality monitoring results from two paired catchments during the period of 2000–2013. The results showed different reductions in nitrogen load and concentrations. Reductions were higher for the River Odense catchment with restored wetlands of 1.8 ha per km^2 catchment area than for the neighbouring control catchment with restored wetlands of 0.5 ha per km^2 catchment area. Implementation of different mitigation measures for combatting diffuse pollution explains the downward trend in the control catchment and most of the trend in the River Odense catchment, as expected. However, an excess trend for NTOT in the River Odense catchment compared to the control catchment (124 t N/a) was shown to be linked to a wetland restoration programme implemented in the River Odense catchment during the period 2000–2013.

6.2. Case study 2: The Archipelago Sea catchment area

6.2.1 Introduction

The Archipelago Sea (ARC), located in southwestern Finland, is a shallow sea area (mean depth 27 m) characterized by tens of thousands of small islands and skerries (Figure 16). The catchment area of the ARC is 8 950 km^2 (including Åland islands) and nearly 500 000 people (49 inhabitants/km^2) live in the catchment. The western part of the archipelago belongs to the autonomous Åland islands. Agricultural land areas cover 27% of the total catchment area and 71% of the fields are on clayey soils making the river and coastal waters turbid (Ekholm et al. 2024). Beside agriculture MWWTPs and fish farming are important sources of nutrient inputs. As a consequence of high nutrient loads the ARC is facing severe symptoms of eutrophication such as increased cyanobacterial blooms, oxygen depletion and changes in fish stocks. Nutrient loads originating from agriculture in the ARC catchment area is the last HELCOM hot spot left in Finland.

Figure 16. The Archipelago Sea and its catchment (excluding the Åland Islands).

6.2.2 Nutrient inputs

In 2021 the waterborne NTOT load to the ARC (excluding the Åland Islands) was 5 760 t and the respective PTOT load was 366 t. The area specific nutrient loads of the ARC are higher than of any other Finnish sea region: The area specific NTOT load in 2021 was 1263 kg/km^2 and the respective PTOT load 51 kg/km^2 (including deposition and load originating from the Åland Islands). The figures 18-20 show only waterborne inputs, but it is noteworthy that atmospheric deposition (including shipping) had the biggest contribution in 2021 to the NTOT inputs: its share of the total inputs was 44%. Due to prevailing south-westerly winds the biggest part of atmospheric deposition originates in other countries than Finland.

In 2021 agriculture was the dominant source of waterborne nutrients contributing with 79% of the NTOT inputs and 84% of the respective PTOT inputs (Figure 17). Municipalities were the second most important source of NTOT loading (7%), whereas the proportion of storm waters was 6% of both NTOT and PTOT loads.

Waterborne NTOT (Figure 18) and PTOT (Figure 19) inputs into the ARC showed a statistically significant decrease from 1995 to 2021. In both cases the decrease could be attributed to diminished point source loads.

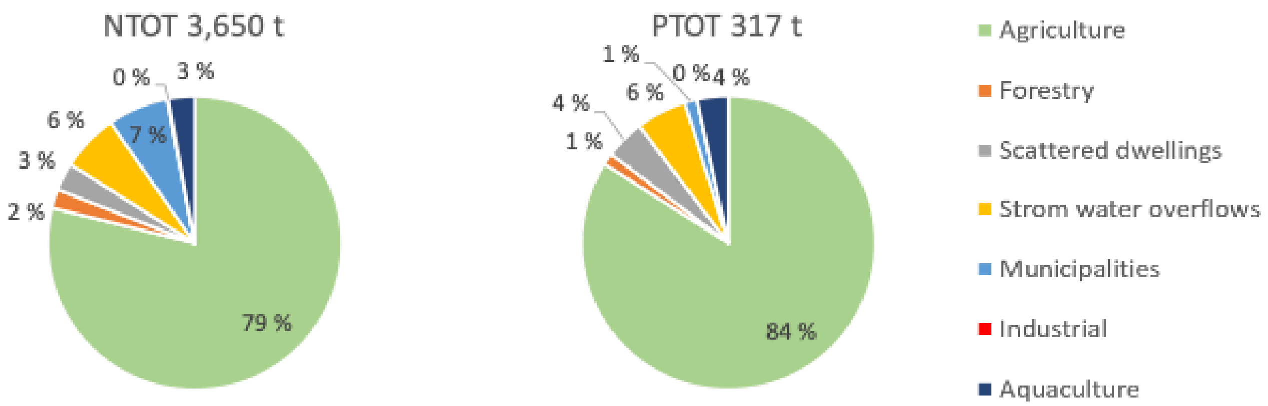


Figure 17. Sources of waterborne anthropogenic NTOT and PTOT inputs into the ARC in 2021 excluding the Åland Islands.

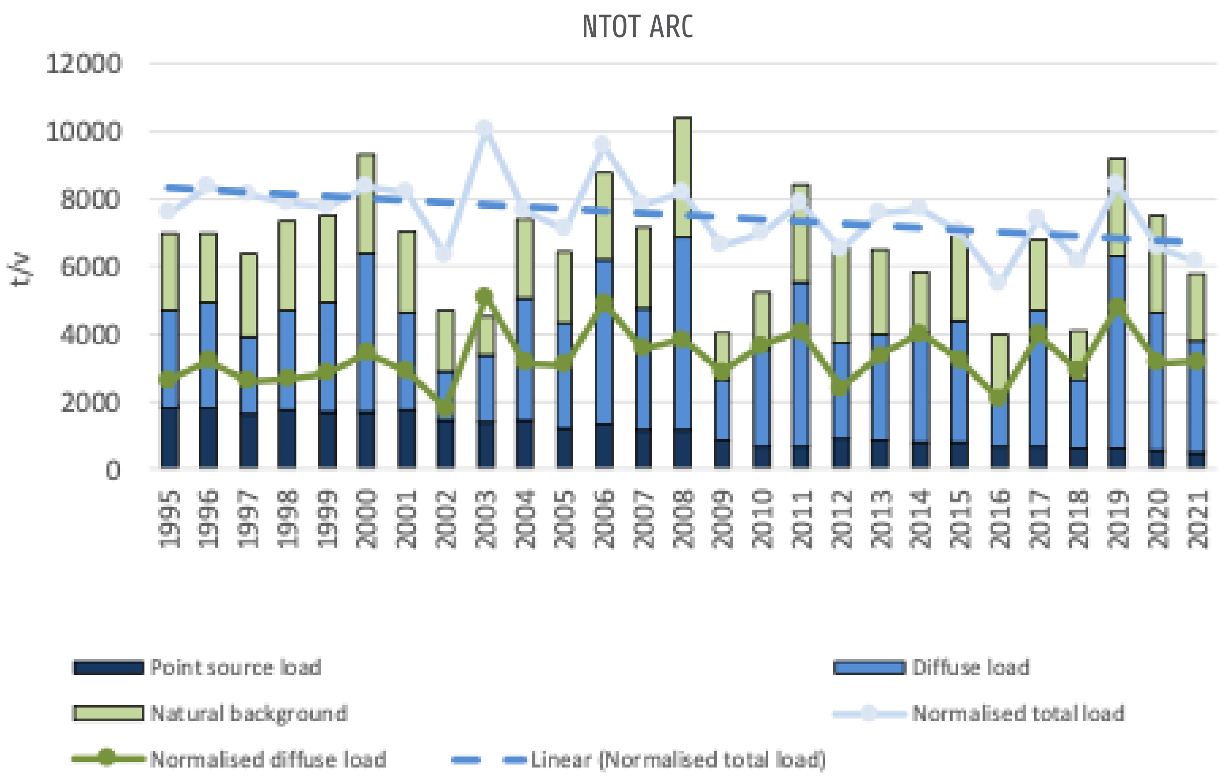


Figure 18. Waterborne NTOT load to the ARC excluding the Åland Islands between 1995 and 2021. The black bar shows point source load, blue bar diffuse load, light green bar natural background, light blue line flow-normalised total load, green line flow-normalised diffuse load and dashed blue line trend of the statistically significant flow-normalised total load.

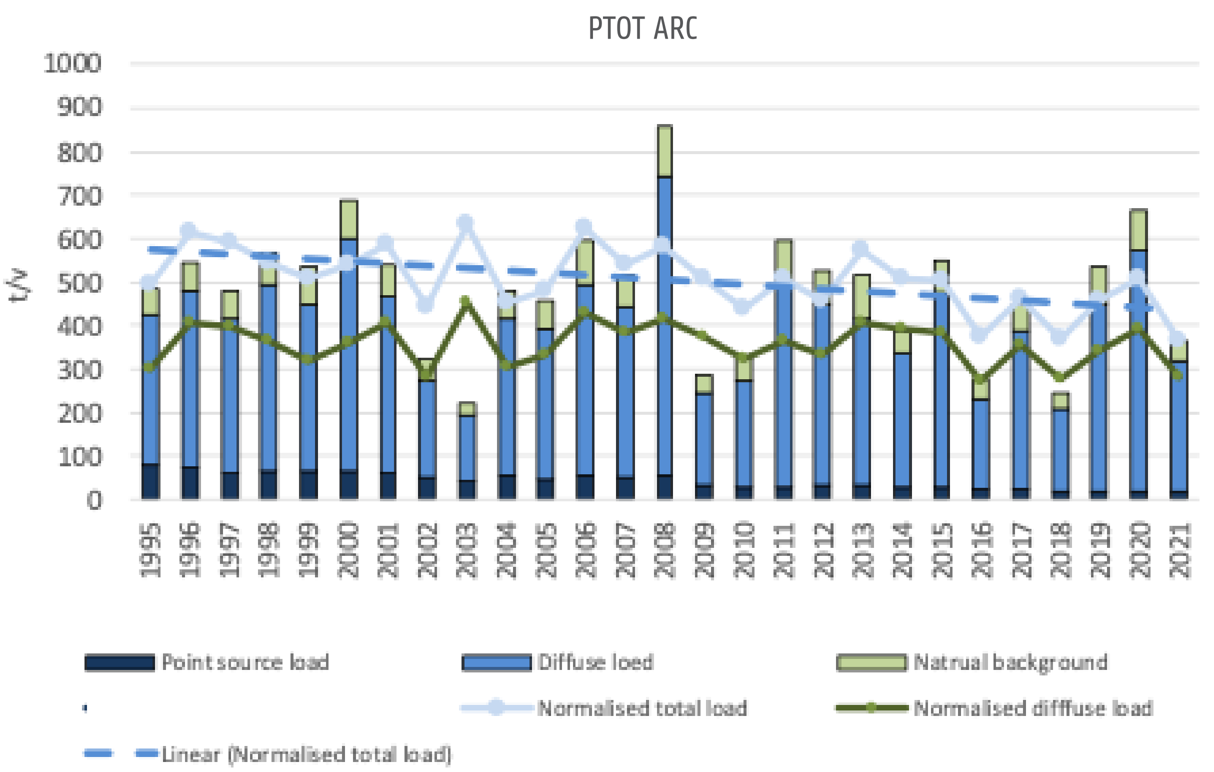


Figure 19. Waterborne PTOT load to the ARC excluding the Åland Islands between 1995 and 2021. The black bar shows point source load, blue bar diffuse load, light green bar natural background, light blue line flow-normalised total load, green line flow-normalised diffuse load and dashed blue line trend of the statistically significant flow-normalised total load.

6.2.3 Mitigation measures

During the last decades many projects have been searching for efficient measures to reduce nutrient inputs into the ARC. The Archipelago Sea Programme (ASP) was launched in 2021 and it aims at reducing loading caused by agriculture in such a way that the ARC can be removed from the list of HELCOM hot spots by 2027 .

The first phase of the ASP created a roadmap for agriculture, which evaluated the extent of ongoing mitigation measures and their effectiveness in reducing nutrient loads. Since most of the waterborne nutrient inputs originate from agriculture many of the mitigation measures are targeted to reduce nutrient loads from cultivated fields. It was estimated that nutrient loading from agriculture can be most efficiently reduced by improving the water economy and soil properties of arable lands, increasing the use of soil amendments, promoting the transfers of manure to nutrient deficit catchments and increasing wintertime plant cover. In addition, from 2022 to 2027 there will be investments in the maintenance of municipal sewage system to decrease leakage and improvements for wastewater treatment of scattered dwellings. If all planned mitigation measures are implemented the present PTOT loading into the ARC would be reduced by 100–150 t (Laurila *et al.* 2022).

6.2.4 Effectiveness of measures

Municipal nutrient loads into the ARC have substantially decreased since 1995, but there is still capacity do decrease NTOT loads (Figure 20). In contrast, nutrient loads from aquaculture have decreased more modestly. Industrial nutrient inputs are of minor importance.

In the ARC catchment the estimation of the effectiveness of mitigation measures in agriculture is mostly done by monitoring of river and stream water quality and by estimating changes in nutrient fluxes. This does not usually enable estimation of the impact of different mitigation measures, since often various measures are conducted simultaneously.

In the ARC catchment the focus has been especially in the usage of gypsum which may offer a rapid cost-effective and socially acceptable measure to tackle PTOT loads (Ekholm et al. 2024 and the references therein). Soil amendment with gypsum was tested in 2016 in the ARC catchment, when 1490 ha clayey fields were treated with phosphogypsum. The results indicated that the treatment immediately decreased riverine phosphorus fluxes. The effect lasted at least 5 years and compared with an upstream control area the fluxes of particulate phosphorus decreased by 15% as a 5-year average (Ekholm et al. 2024).

6.2.5 Conclusion

In 2021 NTOT inputs into the ARC were below the NIC, but despite of different mitigation measures aiming at reducing PTOT loads into the ARC, the inputs were still above the NIC. The PTOT content in soils (legacy phosphorus) are still at a high level and several factors connected to climate/weather (e.g. temperature and precipitation) have counteracted the mitigation measures and thus hampered reaching the nutrient reduction targets (Räike et al. 2020). Furthermore, to achieve good environmental status in the coastal waters of the ARC would require, according to the national coastal model, stricter NICs compared to those in the BSAP (Fleming et al. 2023).

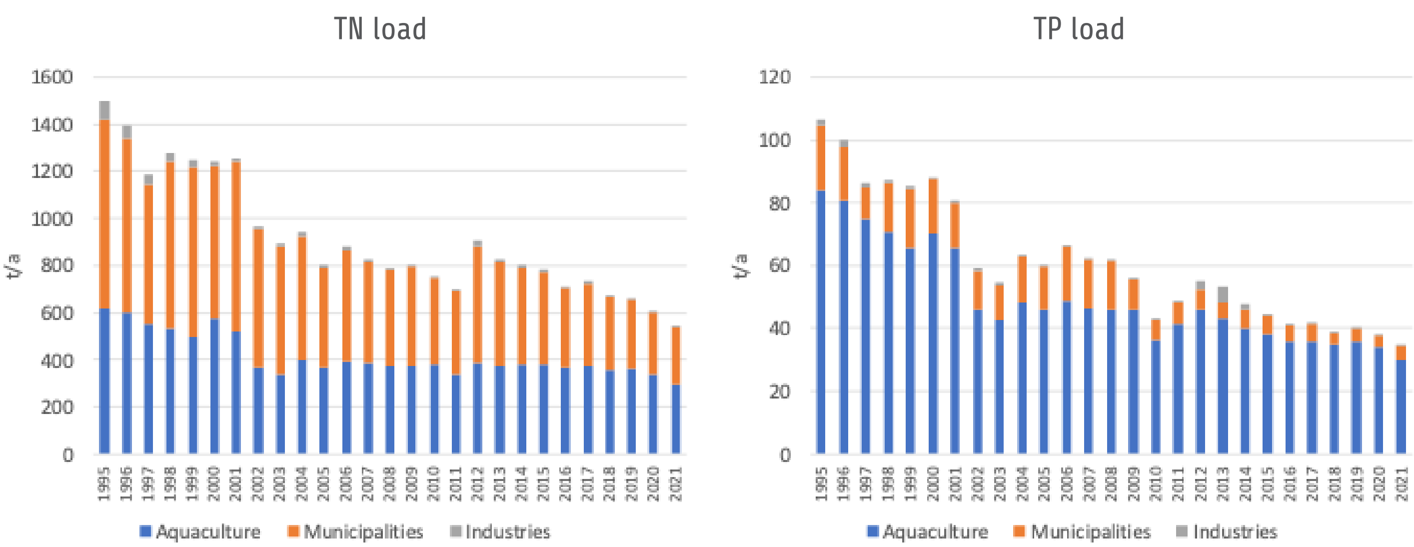


Figure 20. NTOT and PTOT loads (t/a) from point sources into the ARC from 1995 to 2021.

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