MORPHEUS
Model Areas for Removal of Pharmaceutical Substances in the South Baltic

EU STRATEGY FOR THE BALTIC SEA REGION FLAGSHIP

Interreg South Baltic

EUROPEAN UNION

European Regional Development Fund

MORPHEUS

Model Areas for Removal of Pharmaceutical Substances in the South Baltic

Occurrence of PIE in the South Baltic, results from MORPHEUS

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Pharmaceuticals in the environment

(EU strategic approach to pharmaceuticals, 2019)

About 3,000 active pharmaceutical substances are currently authorised on the EU market as a whole, with a wide variability across Member States. The number of new pharmaceuticals reaching consumers per year has nearly doubled in the last decade (between 2005 and 2014), both for human and veterinary products.

On a global scale, the EU takes the second place for pharmaceuticals sales, with about 25 % of the world pharmaceutical sales for human consumption vs. 31% for veterinary consumption.

The EU market has grown substantially over the last 15 years to reach an estimated €220 billion for human pharmaceuticals (x4,5 since 2010)

Pharmaceuticals in the environment
(EU strategic approach to pharmaceuticals, 2019)

Residues of several pharmaceuticals have been found in surface and ground waters, soils and animal tissues across the EU at concentrations depending upon the pharmaceutical and the nature and proximity of sources.

Certain painkillers, antimicrobials, antidepressants, contraceptives and antiparasitics are commonly found. Traces of some pharmaceuticals have also been found in drinking water.

Pharmaceuticals mainly reach the environment through:

- the discharge of effluent from urban waste water (sewage) treatment plants – containing excreted pharmaceuticals
- unused pharmaceuticals thrown away into sinks and toilets. The chemical and/or metabolic stability of some pharmaceuticals means that up to 90% of the active ingredient is excreted (or washed off) in its original form);
- the spreading of animal manure, sewage sludge, discharge of effluent from manufacturing plants

More information is still needed to understand and evaluate certain pharmaceuticals as regards their environmental concentrations and the resulting levels of risk.

Proposed EU actions/strategic approach

1. **Increase awareness and promote prudent use of pharmaceuticals** (development of guidelines on prudent use, environment aspects in medical training programs, advertising, raising awareness, sharing best practices)
2. **Support the development of pharmaceuticals intrinsically less harmful for the environment and promote greener manufacturing** (support the development and procurement of greener/degradable pharmaceuticals, improve efficacy in wastewater treatment, EQS for posing risk, cooperation with third countries, etc.)
3. **Improve environmental risk assessment and its review** (developing guidance on the environmental risk assessment, authorisation for marketing human medicinal with completed ERA, public access to ERA)
4. **Reduce wastage and improve the management of waste** (optimize the package size matching needs environmentally safe disposal - take-back schemes, **monitoring/assessment of existing WWTPs and investigate the feasibility for upgrading selected, use Union programmes to invest in technologies to improve the efficiency of removal of pharmaceuticals**,
5. **Expand environmental monitoring** (select potentially relevant pharmaceuticals-EC Watch List, research on monitoring individual substances and mixtures of substances in fresh and marine waters, soils, sediments, and wildlife, in effluents from potential hotspots, Include antimicrobials and possibly antimicrobial resistance genes)
6. **Fill other knowledge gaps** (research the eco-toxicity and environmental fate those without risk assessment, exposure on humans of low levels of pharmaceuticals via the environment, etc.).

Removal of pharmaceuticals from wastewater is today not required within the EU, only to monitor.

Effects of pharmaceuticals on the environment

(EU strategic approach to pharmaceuticals, 2019)

Pharmaceuticals that persist in the environment and spread through water and soil or accumulate in plants or wildlife, may pose a risk because of their toxicity or similar properties.

Studies have shown direct effects on wildlife from some pharmaceuticals at or even below the low concentrations found in water and soil. For example:

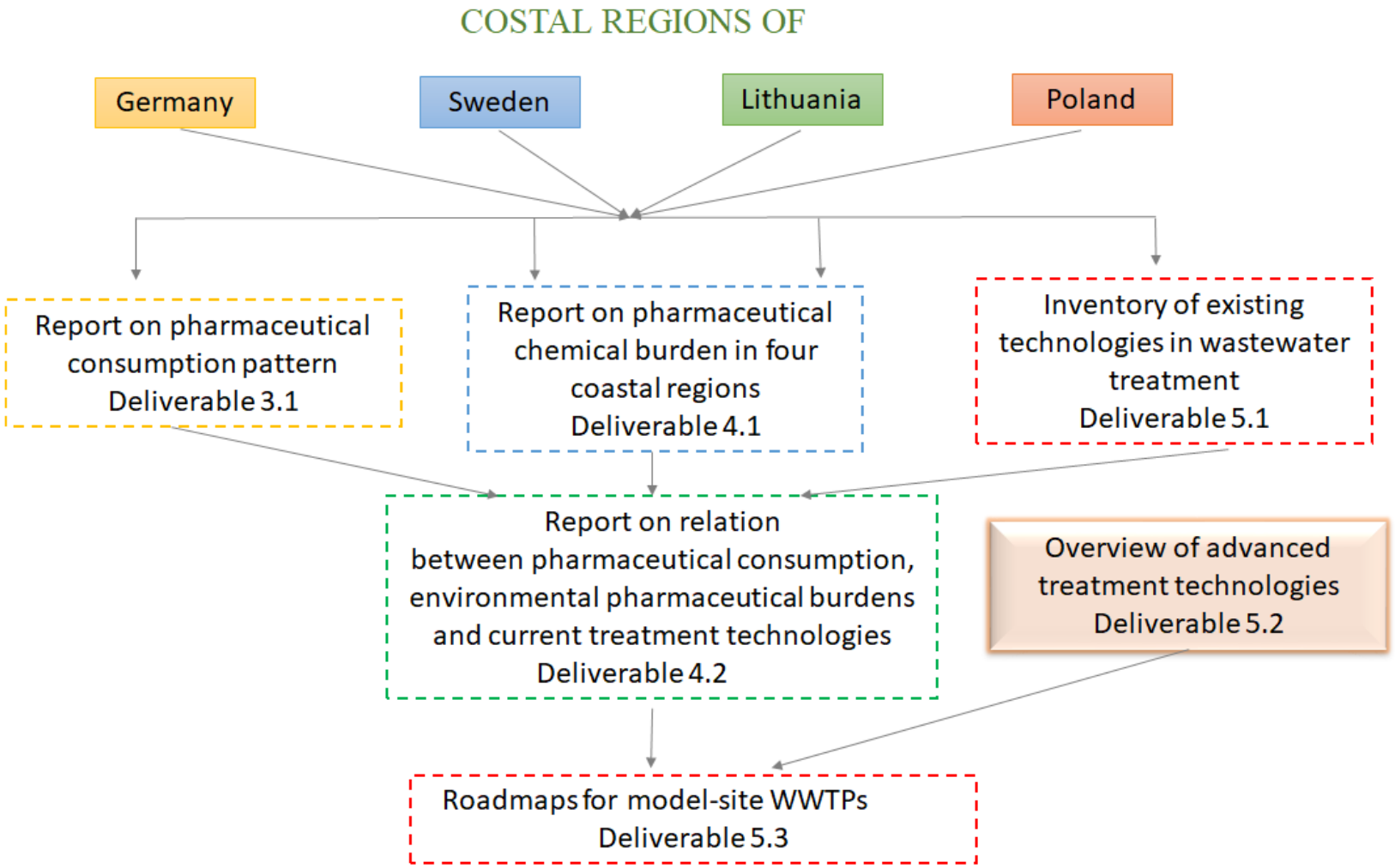
- male fish exposed to such concentrations of the contraceptive pill may become feminised as a result of its effects on the endocrine system, thus affecting the capacity of the population to reproduce.

- In other studies, fish exposed to low concentrations of certain antidepressants have been found to change their behavior in ways that could affect their survival.

- alarm was raised several years ago over the unexpectedly lethal effect of this pharmaceutical on vultures in Asia, which were exposed to it via the carcasses of cattle treated with it.

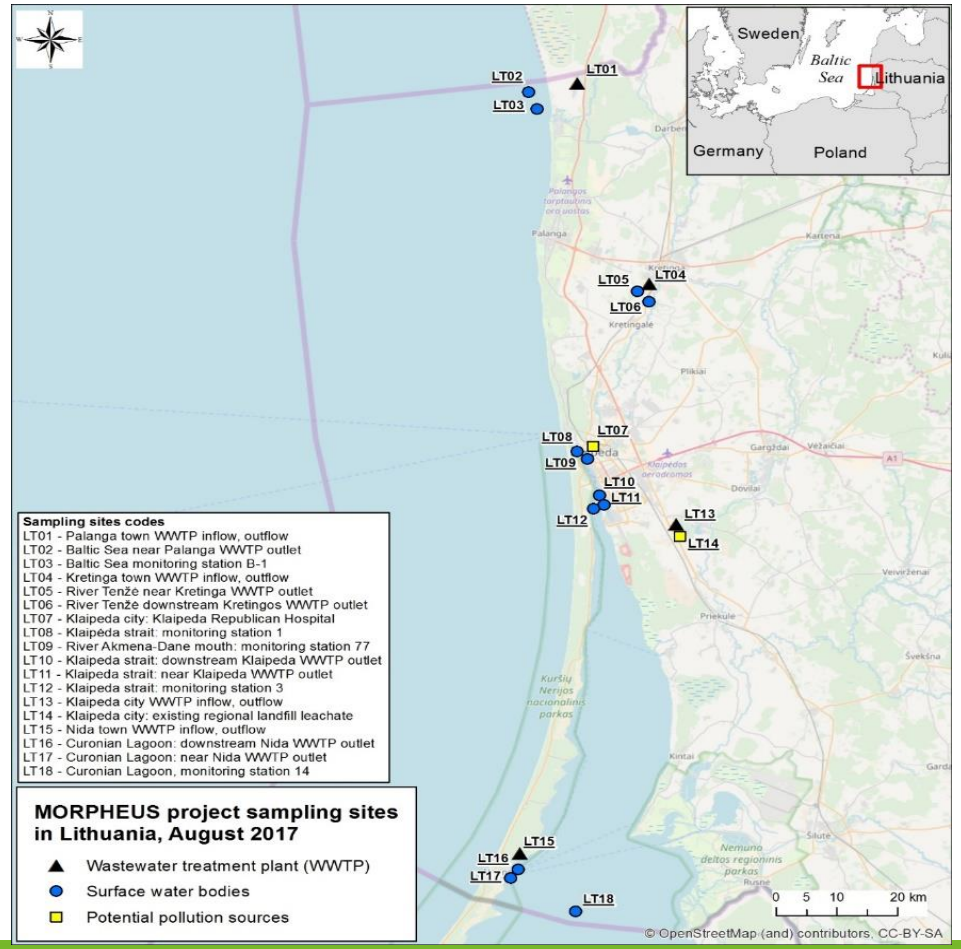
- decline in populations of dung beetles is thought to be at least partly attributable to the use of anti-parasitic pharmaceuticals, including ivermectin in livestock.

Project main outputs

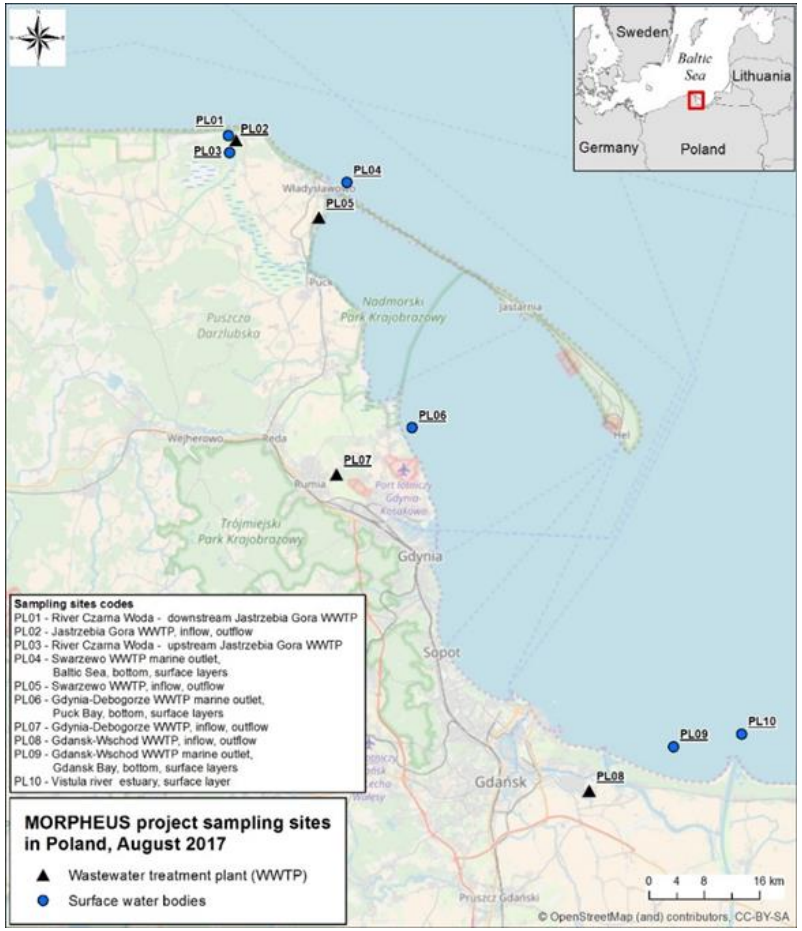


Sampling points at WWTPs and receiving waters
15 selected WWTPs in 15 coastal towns of the South Baltic Sea: 3 in Sweden, 4 in Germany

LT WWTPs Klaipeda, Palanga Kretinga, Nida

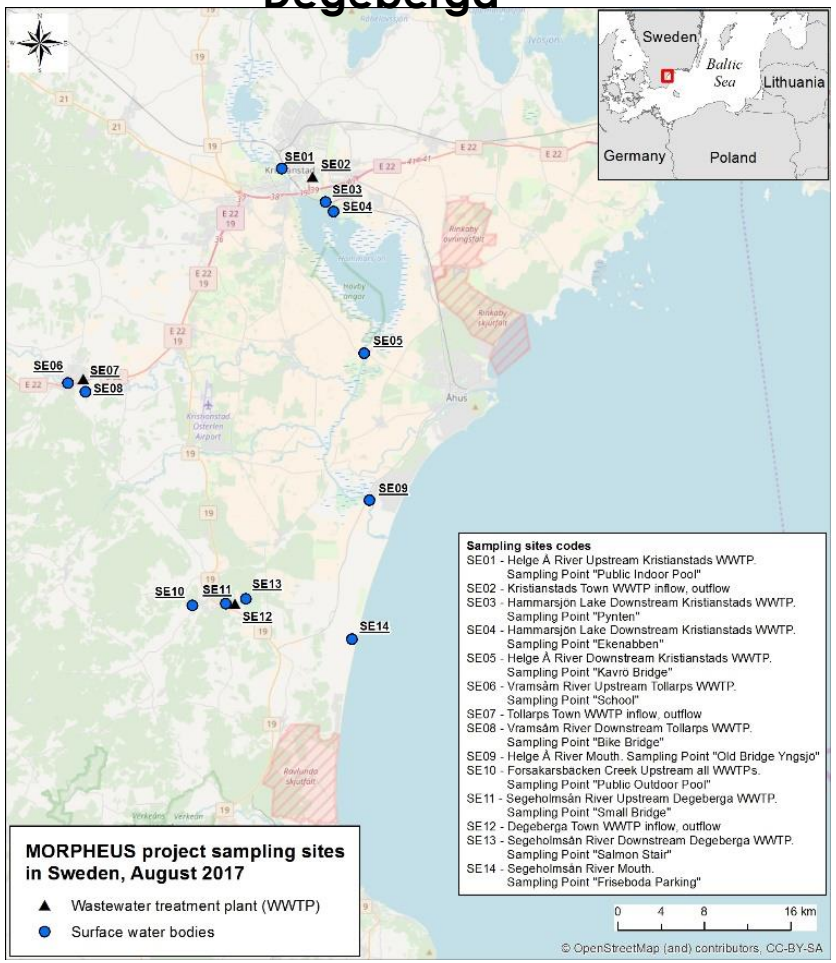


PL WWTPs Gdansk, Gdynia, Swarzewo, Jastrzebia Gora

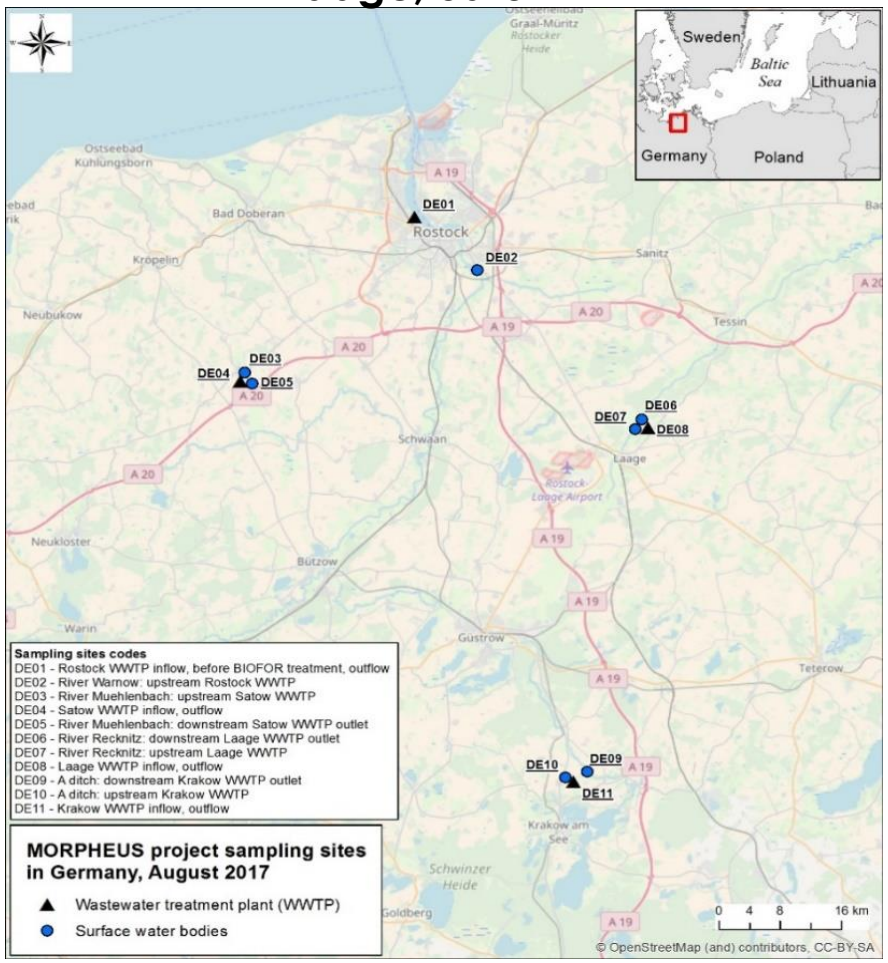


Sampling points at WWTPs and receiving waters
15 selected WWTPs in 15 coastal towns of the South Baltic Sea: 3 in Sweden, 4 in Germany

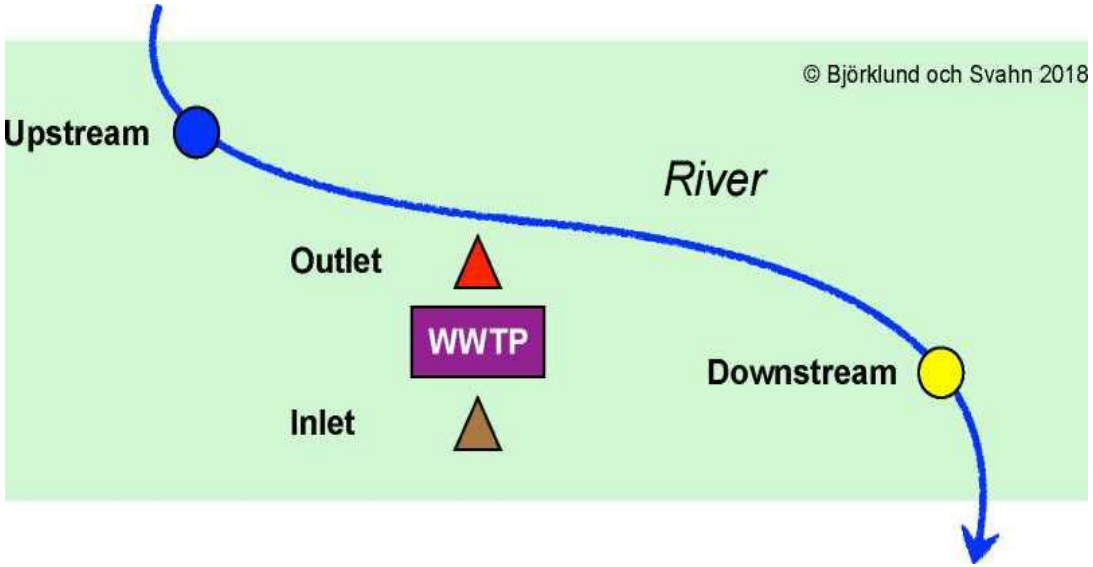
SE WWTPs
Kristianstad, Tollarp
Degeberga



DE WWTPs
Rostock, Krakow
Laage, Satow



Sampling procedures



- To take samples at the WWTPs influent and effluent. Preference should be given to 24 hours mixing samples – proportional to flow or time;
- To take grab/spot samples upstream the WWTPs in the receiving water bodies, i.e. in surface water not impacted by wastewater spot to find out the background concentration;
- To take grab/spot samples downstream of the WWTP outlet (discharge point) at the distance of sewage and receiver water complete mixing point;

In order to compare the data during different seasons, it was decided to take samples in the summer of 2017 and the winter of 2018

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Sampling and analysis

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	WWTP + Receiving water bodies	Season	Upstream/ background concentration	WWTP Inlet	WWTP Outlet	Downstream	
							At WWTP (before BIOFOR-treatment)
DE	4 towns WWTPs, 4 receiving water bodies	Summer + Winter	8	8	8	6	2
	∑ Samples	**32 (16 summer, 16 winter)**					
LT							At 2 potential pollution sources
	4 towns WWTPs, 4 receiving water bodies, two potential pollution sources	Summer + Winter	3	8	8	16	3
	∑ Samples	**38 (22 summer, 16 winter)**					
PL							Vistula River
	4 towns WWTPs, 2 receiving water bodies	Summer + Winter	2	8	8	12	2
	∑ Samples	**32 (16 summer, 16 winter)**					
SE	3 towns WWTPs, 3 receiving water bodies	Summer + Winter	7	6	6	14	
	∑ Samples	**33 (17 summer, 16 winter)**					
Total	**135 samples, 15 pharmaceuticals, 2025 chemical analysis**						

Pharmaceuticals detected in 15 WWTP inlets and outlets. ">" means higher detected concentrations cases in summer or winter seasons.

	DE, 4 WWTPs				LT 4 WWTPs				PL 4 WWTPs				SE 3 WWTPs				∑, DE+LT+PL+SE 15 WWTPs			
	> inlet		> outlet		> inlet		> outlet		> inlet		> outlet		> inlet		> outlet		**> inlet**		**> outlet**	
	summer	winter	summer	winter	summer	winter	summer	winter	summer	winter	summer	winter	summer	winter	summer	winter	**summer**	**winter**	**summer**	**winter**
Atenolol	4	0	0	4	3	1	1	3	2	2	1	3	2	1	0	3	**11**	**4**	**2**	**13**
Azithromycin	2	2	2	2	0	4	0	4	0	4	0	4	0	3	0	3	**2**	**13**	**2**	**13**
Carbamazepine	3	1	4	0	4	0	4	0	2	2	1	3	3	0	3	0	**12**	**3**	**12**	**3**
Ciprofloxacin	1	3	4	0	1	3	4	0	0	4	0	3	0	3	1	2	**2**	**13**	**9**	**5**
Clarithromycin	0	4	0	4	1	3	0	4	1	3	0	4	3	0	2	1	**5**	**10**	**2**	**13**
Diclofenac	1	3	0	4	3	1	3	1	0	4	0	4	2	1	1	2	**6**	**9**	**4**	**11**
Erythromycin	4	0	2	1	4	0	2	2	4	0	4	0	2	1	1	2	**14**	**1**	**9**	**5**
Estrone	2	2	0	2	4	0	1	3	0	4	3	1	1	2	1	2	**7**	**8**	**5**	**8**
Ibuprofen	0	4	0	3	2	2	0	0	0	4	0	0	3	0	1	2	**5**	**10**	**1**	**5**
Metoprolol	2	2	0	4	2	2	0	4	0	4	0	4	3	0	2	1	**7**	**8**	**2**	**13**
Naproxen	3	1	0	4	1	3	1	3	0	4	2	2	1	2	1	2	**5**	**10**	**4**	**11**
Oxazepam	3	0	1	2	2	2	3	1	1	3	0	4	3	0	1	2	**9**	**5**	**5**	**9**
Paracetamol	1	3	1	3	3	1	0	2	1	3	0	4	2	1	0	3	**7**	**8**	**1**	**12**
Propranolol	3	1	0	4	0	4	0	4	0	4	0	4	1	2	0	3	**4**	**11**	**0**	**15**
Sulfamethoxazole	4	0	2	2	4	0	3	1	2	2	0	4	1	2	2	1	**11**	**4**	**7**	**8**
∑	33	26	16	39	34	26	22	32	13	47	11	44	27	18	16	29	**107**	**117**	**65**	**144**
																	224		**209**	
																%	**48**	**52**	**31**	**69**

Average (summer + winter) inlet load in four coastal regions WWTPs

The total average annual inlet chemical **load of 15 pharmaceuticals varied from 11,5 kg in Nida settlement, Lithuania to 18840 kg in Gdansk** WWTP, Poland. Analgesic **Ibuprofen** form the highest load in all WWTPs inlets, reaching almost 50 000 kg or 90 percent of total load. The second highest compound was analgesic **paracetamol**, which contributed 2164 kg or 4 % of the total load. Antibiotics **Azithromycin** ranked third contributing 569 kg (1,1%) to all WWTPs. Other chemicals accounted for less than one percent of the total influent load. The total inlet load is 54.4 tons.

	LT Average Inlet Load, kg/a				DE Average Inlet Load, kg/a				PL Average Inlet Load, kg/a				SE Average Inlet Load, kg/a			Total
WWTPs/connected residents' 2016 m.	Klaipėda 170 000	Palanga 13 000	Kretinga 19 150	Nida 1 714	Rostock 235 645	Laage 4 516	Krakow 3 964	Satow 1 303	Gdansk 571 350	Gdynia 360 000	Swarzewo 35 668	Jastrzębia -Góra 10 000	Kristianstad 52 000	Tollarp 3 000	Degeberga 950	∑, kg/a
Atenolol	1.66	0.39	0.3	0.01	10.21	0.07	0.05	0.04	4.94	3.53	0.3	0.07	9.50	0.33	0.26	22,16
Azithromycin	4.19	0.43	0.55	0	28.32	0.78	1.81	0.39	265.31	247.72	15.35	4.09	1.51	0.00	0.01	568,95
Carbamazepine	6.5	0.75	0.23	0.07	13.91	0.42	0.72	0.07	67.69	37.43	4.06	0.66	5.24	0.08	0.41	133
Ciprofloxacin	4.33	0.3	0.33	0	6.87	0.08	0.18	0.02	56.15	49.1	7.8	1.17	4.21	0.16	0.38	126,87
Clarithromycin	20.19	1.78	3.84	0.05	9.13	1.2	0.76	0	100.04	64.35	10.91	0.76	0.94	0.22	0.01	213,24
Diclofenac	40.99	5.5	6.16	0.81	50.42	1.19	1.03	0.26	104.69	76.24	12.97	1.65	5.20	0.14	0.14	302,19
Erythromycin	1.32	0.1	0.43	0	2.62	0.11	0.06	0	1.76	0.7	0.11	0.02	2.47	0.02	0.00	7,25
Estrone	1.25	0.18	0.15	0.01	1.22	0.01	0.02	0	2.4	1.65	0.19	0.02	0.41	0.01	0.01	7,12
Ibuprofen	2198.41	193.19	386.58	8.21	9683.76	83.96	427.81	82.98	17 127	16 957	2 252.21	387.1	367.22	12.27	18.21	49818,69
Metoprolol	20.71	3.32	2.86	0.16	43.77	0.97	1.58	0.3	37.6	21.98	1.69	0.46	7.33	0.32	0.27	135,99
Naproxen	15.37	2.94	2.48	0.03	12.63	0.05	1.09	0.41	104.23	78.31	6.49	1.36	16.10	0.34	0.28	226,01
Oxazepam	0.84	0.11	0.11	0.01	0.46	0	0.01	0	0.88	0.55	0.05	0.01	2.93	0.21	0.09	3,33
Paracetamol	130.82	24.82	28.69	2.12	198.63	2.18	2.54	0.85	946.66	680.12	109.61	22.67	171.96	11.09	3.36	2164,16
Propranolol	0.17	0.01	0.01	0	1.3	0.02	0.03	0	1.24	0.73	0.09	0.02	0.37	0.01	0.01	3,64
Sulfamethoxazole	13.04	1.26	0.49	0	15.81	0.11	0.18	0.14	20.06	14.7	1.3	0.74	3.28	0.01	0.00	67,84
∑, kg	2459.80	235.08	433.22	11.50	10079.06	91.15	437.87	85.46	18840.65	18234.11	2423.13	420.8	598.68	25.23	23.43	
∑∑, kg	**54 400**															
Ibuprofen, % of total WWTP load	89.4	82.2	89.2	71.4	96.1	92.1	97.7	97.1	90.9	93.0	92.9	92.0	61.3	48.6	77.7	

Average (summer + winter) outlet load in four coastal regions WWTPs

Both, ibuprofen and paracetamol which occur in large amounts in inlets, were almost completely removed during wastewater treatment process, e.g. ibuprofen and paracetamol were detected only in 5 and 10 WWTPs respectively and in small quantities, both with less than 1% of the total effluent load. The top 4 pharmaceuticals present at the highest loads in WWTP effluents were **diclofenac, azithromycin, metoprolol and carbamazepine**. **The highest average load of 178 kg or 30 % of total load was calculated for the anti-inflammatory drug diclofenac**. Azithromycin with 126 kg (21%) takes the second place. Metoprolol and carbamazepine contribute 100 kg (16,8%) and 92 kg (15,4%) to the total effluent load, respectively. The total outlet load is 0,6 tons.

	LT Average Inlet Load, kg/a				DE Average Inlet Load, kg/a				PL Average Inlet Load, kg/a				SE Average Inlet Load, kg/a			∑, kg/a
	Klaipeda	Palanga	Kretinga	Nida	Rostock	Laage	Krakow	Satow	Gdansk	Gdynia	Swarzewo	Jastrzębia-Góra	Kristianstad	Tollarp	Degeberga	
Atenolol	0.37	0.05	0.02	0	1.95	0.01	0.01	0.01	1.54	0.53	0.03	0.02	2.79	0.08	0.00	7,41
Azithromycin	0.96	0.11	0.02	0.01	1.37	0.02	0.13	0	63.3	56.08	2.12	1.4	0.42	0.00	0.00	125,94
Carbamazepine	6.87	1.02	0.24	0.04	16.03	0.29	0.66	0.04	39.57	20.47	2.05	0.82	3.50	0.09	0.35	92,04
Ciprofloxacin	0.04	0.01	0.01	0	1.2	0.02	0.01	0	2.28	2.05	0	0.03	0.32	0.01	0.00	5,98
Clarithromycin	10.58	1.03	0.39	0.04	2.4	0.31	0.32	0	5.61	3.02	0.35	0.05	0.40	0.09	0.00	24,59
Diclofenac	31.66	5.45	4.4	0.36	30.62	0.41	0.64	0.08	57.18	37.35	3.5	1.01	4.74	0.23	0.09	177,72
Erythromycin antibiotics	1.2	0.08	0.07	0	2.24	0.02	0.1	0	2.35	1.14	0.1	0.02	2.21	0.08	0.00	9,61
Estrone	0.02	0.01	0.01	0	0	0	0	0	0.11	0.14	0.003	0.001	0.02	0.00	0.00	0,314
Ibuprofen	0	0	0	0	0	0.01	0.09	0.12	0	0	0	0	4.93	0.46	0.00	5,61
Metoprolol	16.14	2.63	0.86	0.16	21.48	0.15	0.55	0.09	31.96	19	1.14	0.26	5.46	0.33	0.02	100,23
Naproxen	0.65	0.1	0.12	0.01	1.21	0	0.02	0.01	2.87	0.89	0.09	0.03	3.81	0.34	0.00	10,15
Oxazepam	1.01	0.14	0.09	0.01	0.47	0	0.01	0	1.18	0.76	0.06	0.02	3.47	0.25	0.07	7,54
Paracetamol	0	0	0.01	0.01	0.12	0	0	0.01	0.13	0.24	0.04	0.004	0.08	0.04	0.00	0,684
Propranolol	0.16	0.01	0	0	1.27	0.01	0.03	0	1.37	0.75	0.07	0.01	0.24	0.01	0.00	3,93
Sulfamethoxazole	6.93	0.34	0.08	0	4.49	0.02	0.03	0.03	6.71	4.24	0.3	0.13	0.90	0.01	0.00	24,21
∑, kg	76.60	10.97	6.32	0.65	84.85	1.27	2.6	0.39	216.16	146.66	9.85	3.81	33.27	2.03	0.53	
∑∑, kg								**596**								
Diclofenac, % of total WWTP load	41.3	49.7	69.6	55.4	36.1	32.3	23.8	20.5	26.5	25.5	35.5	26.5	14.2	11.3	17.0	

Average (summer + winter) pharmaceuticals removal rate in four coastal regions WWTPs. Removal efficiency = (inlet load – outlet load)/inlet load*100.

	LT Average efficiency of removal, % (summer + winter)				DE Average efficiency of removal, % (summer + winter)				PL Average efficiency of removal, % (summer + winter)				SE Average efficiency of removal, % (summer + winter)			Average in all WWTPs
	Klaipeda	Palanga	Kretinga	Nida	Rostock	Laage	Krakow	Satow	Gdansk	Gdynia	Swarzewo	Jastrzębia-Góra	Kristianstad	Tollarp	Degeberga	
Atenolol	77.7	87.0	92.2	83.8	80.9	85.7	80.0	75.0	68.8	85.0	90.0	71.4	70.7	76.5	100.0	**81,6**
Azithromycin	77.0	74.3	96.5	-79.9	95.2	97.4	92.8	100.0	76.1	77.4	86.2	65.8	72.5	33.3	93.3	**70,5**
Carbamazepine	-5.7	-35.7	-2.0	43.8	-15.2	31.0	8.3	42.9	41.5	45.3	49.5	-24.2	33.3	-13.8	14.8	**14,3**
Ciprofloxacin, antbiotic	99.0	96.9	96.2	65.3	82.5	75.0	94.4	100.0	95.9	95.8	100.0	97.4	92.5	91.9	99.2	**92,1**
Clarithromycin	47.6	41.8	89.8	12.3	73.7	74.2	57.9	0.0	94.4	95.3	96.8	93.4	57.5	58.4	94.1	**65,8**
Diclofenac	22.8	1.1	28.6	55.1	39.3	65.5	37.9	69.2	45.4	51.0	73.0	38.8	8.8	-67.6	37.3	**33,7**
Erythromycin	8.5	20.5	84.3	-75.0	14.5	81.8	-66.7	0.0	-33.5	-62.9	9.1	0.0	10.8	-216.7	14.3	**- 14,1**
Estrone	98.8	94.3	95.3	98.5	100.0	100.0	100.0	0.0	95.4	91.5	98.4	95.0	94.8	88.6	100.0	**90,0**
Ibuprofen analgesic	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	100.0	100.0	100.0	100.0	98.7	96.3	100.0	**99,7**
Metoprolol	22.1	20.6	69.8	-4.5	50.9	84.5	65.2	70.0	15.0	13.6	32.5	43.5	25.5	-2.8	93.8	**40,0**
Naproxen	95.8	96.6	95.3	58.0	90.4	100.0	98.2	97.6	97.2	98.9	98.6	97.8	76.3	0.6	99.5	**86,7**
Oxazepam	-19.5	-30.9	16.4	-47.9	-2.2	0.0	0.0	0.0	-34.1	-38.2	-20.0	-100.0	-18.3	-17.8	26.4	**- 19,1**
Paracetamol analgesic	100.0	100.0	100.0	99.7	99.9	100.0	100.0	98.8	100.0	100.0	100.0	100.0	100.0	99.6	100.0	**99,9**
Propranolol	9.1	53.6	69.5	-150.0	2.3	50.0	0.0	0.0	-10.5	-2.7	22.2	50.0	34.9	0.0	68.3	**13,1**
Sulfamethoxazole	46.9	73.3	83.4	-114.3	71.6	81.8	83.3	78.6	66.6	71.2	76.9	82.4	72.7	-8.3	-100.0	**44,4**
∑	780.1	793.4	1115	144.98	883.8	1126.9	851.3	832	818.2	821.2	1013.2	811.3	830.7	218.2	941	
Average %	52.0	52.9	74.3	9.7	58.9	75.1	56.8	55.5	54.5	54.7	67.5	54.1	55.4	14.5	62.7	**53,2**

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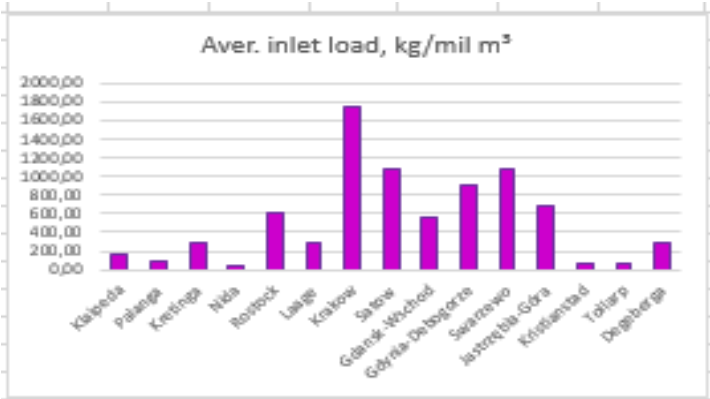
Calculated comparative pharmaceuticals inlet and outlet loads in the four coastal regions WWTPs

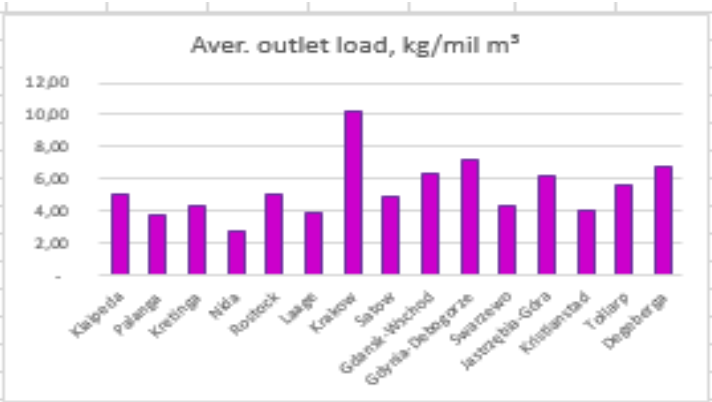
Parameters	LT WWTPs comparative parameters				DE WWTPs comparative parameters				PL WWTPs comparative parameters				SE WWTPs comparative parameters		
	Klaipeda	Palanga	Kretinga	Nida	Rostock	Laage	Krakow	Satow	Gdansk-Wschod	Gdynia-Debogorze	Swarzewo	Jastrzębia-Góra	Kristianstad	Tollarp	Degeberga
Q m³/a	15 100 000	2 879 000	1 471 000	230 000	16 894 000	321 000	253 000	80 000	33 930 000	20 180 000	2 250 000	610 000	8 186 000	361 000	79 000
Q mil. m³/a	15.10	2.88	1.471	0.23	16.894	0.321	0.253	0.08	33.93	20.18	2.25	0.61	8.186	0.361	0.079
Aver. inlet load, kg	2459.8	235.08	433.22	11.5	10079.06	91.15	437.87	85.46	18840.65	18234.11	2423.13	421.8	598.68	25.23	23.43
Aver. outlet load, kg	76.6	10.97	6.32	0.65	84.85	1.27	2.6	0.39	216.16	146.66	9.85	3.81	33.27	2.03	0.53
Aver. inlet load, kg/mil m³	162.90	81.65	294.51	50.00	596.61	283.96	1730.71	1068.25	555.28	903.57	1076.95	691.48	73.13	69.89	296.58
Aver. outlet load, kg/mil m³	5.07	3.81	4.30	2.83	5.02	3.96	10.28	4.88	6.37	7.27	4.38	6.25	4.06	5.62	6.71
Number of connected residents	170 000	13 000	19 150	1 714	235 645	4 516	3 964	1 303	571 350	360 000	35 668	10 000	52 000	3 000	950
Factor of connected 1000 residents	170	13	19.15	1.714	235.645	4.516	3.964	1.303	571.35	360	35.668	10	52	3	0.95
Aver. inlet load kg per 1000 residents	14.47	18.08	22.62	6.71	42.77	20.18	110.46	65.59	32.98	50.65	67.94	42.18	11.51	8.41	24.66
Aver. outlet load kg per 1000 residents	0.45	0.84	0.33	0.38	0.36	0.28	0.66	0.30	0.38	0.41	0.28	0.38	0.64	0.68	0.56
Actual number PE (BOD_7)	210 070	19 945	28 727	3 130	342 483	12 658	6 209	1 303	742 521	476 000	149 000	12 540	118 000	4 790	950
Factor of PE per 1000 PE	210.07	19.945	28.727	3.13	342.483	12.658	6.209	1.303	742.521	476	149	12.54	118	4.79	0.95
Aver. Inlet load kg per 1000 PE	11.71	11.79	15.08	3.67	29.43	7.20	70.52	65.59	25.37	38.31	16.26	33.64	5.07	5.27	24.66
Aver. Outlet load kg per 1000 PE	0.36	0.55	0.22	0.21	0.25	0.10	0.42	0.30	0.29	0.31	0.07	0.30	0.28	0.42	0.56
Number of PE divided by actual number of residents	1,236	1,534	1,500	1,826	1,453	2,803	1,566	1,000	1,300	1,322	4,177	1,254	2,269	1,597	1,000

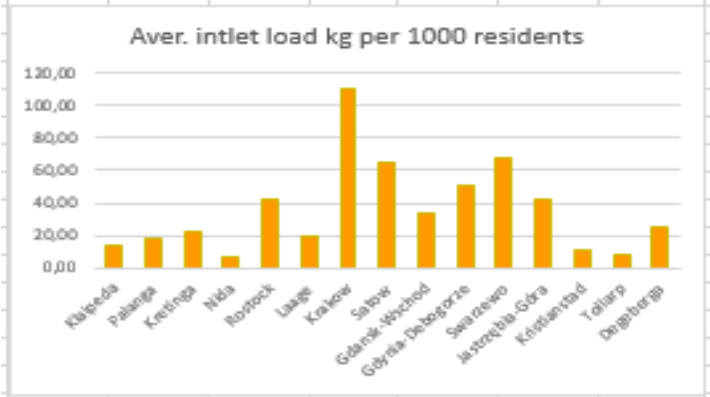
MORPHEUS
Model Areas for Removal of Pharmaceutical Substances in the South Baltic

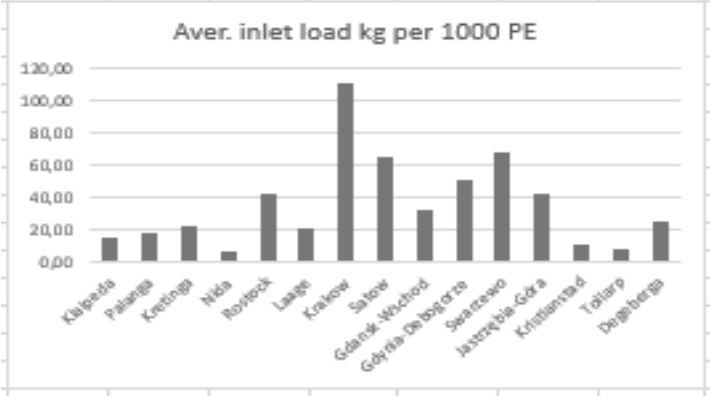
European Regional Development Fund
EUROPEAN UNION

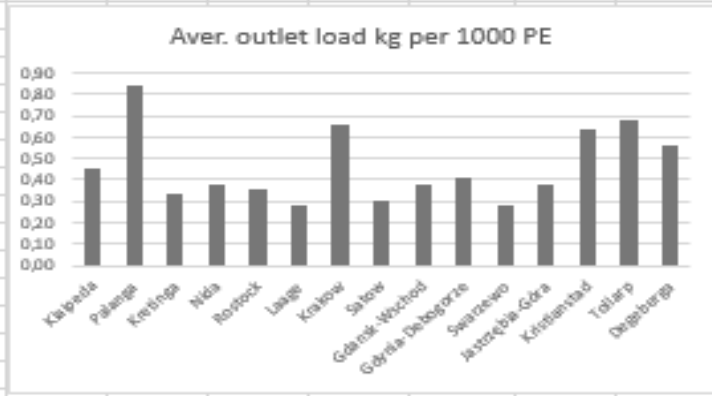
Visualization of calculated comparative pharmaceuticals inlet and outlet loads



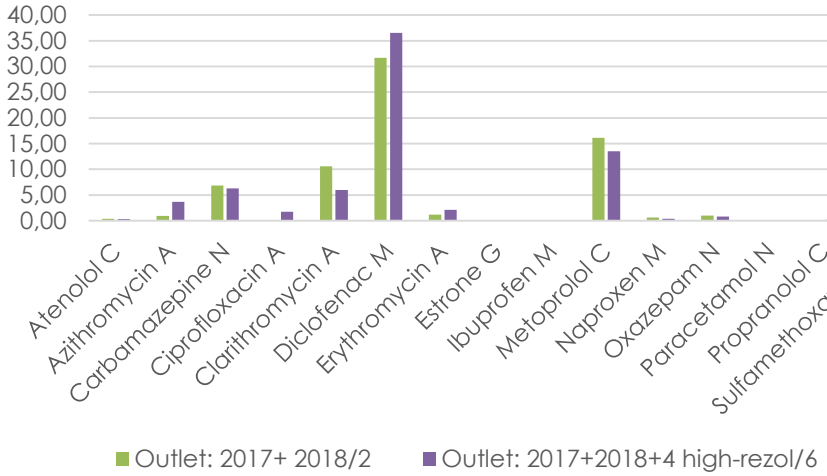


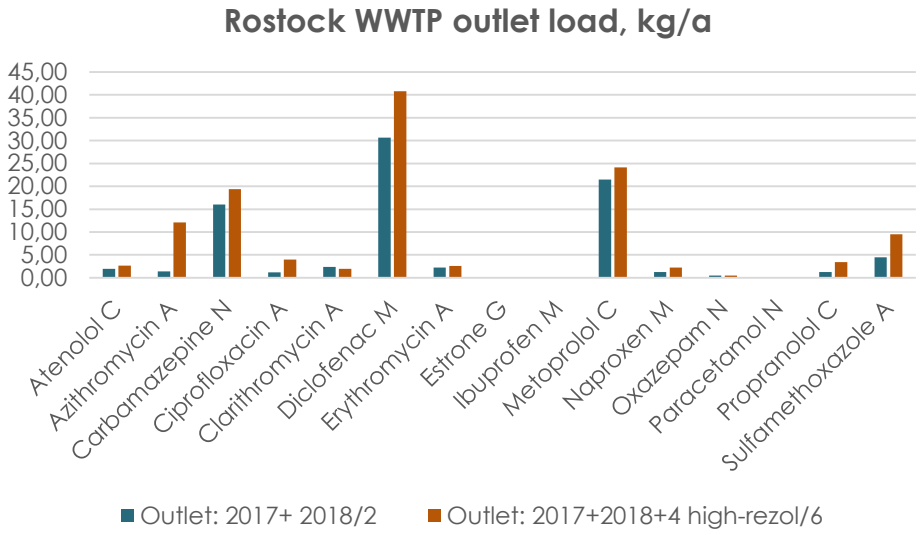


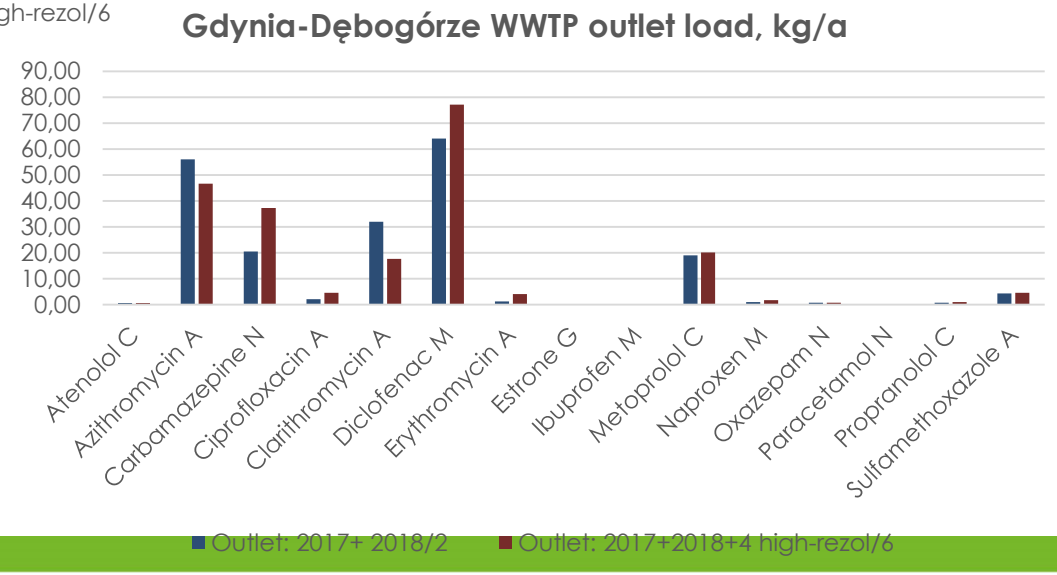




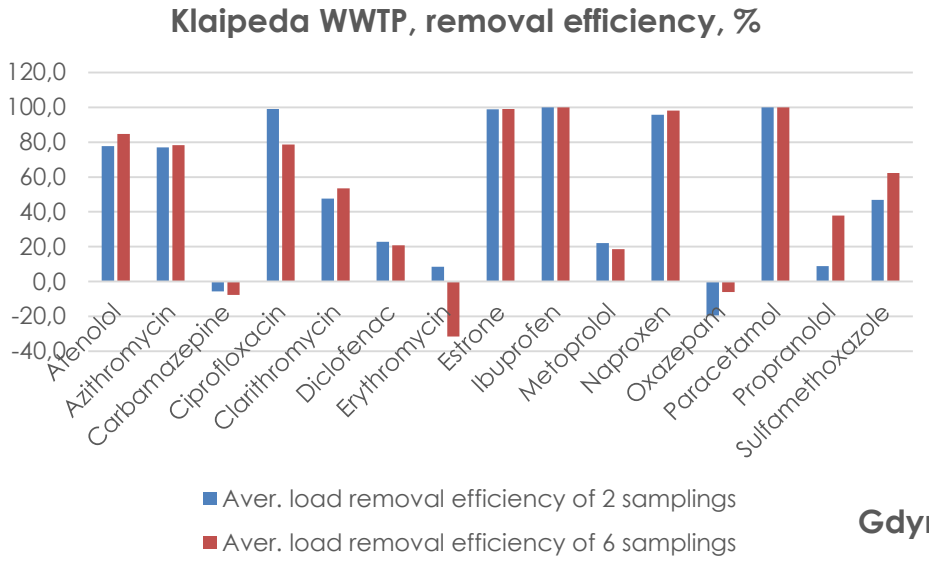
Comparision of outlet loads in three WWTPs estimated by averaging two (summer, winter) and six (2017 summer, 2018 winter + 2019 April 4 high-resolution) loads

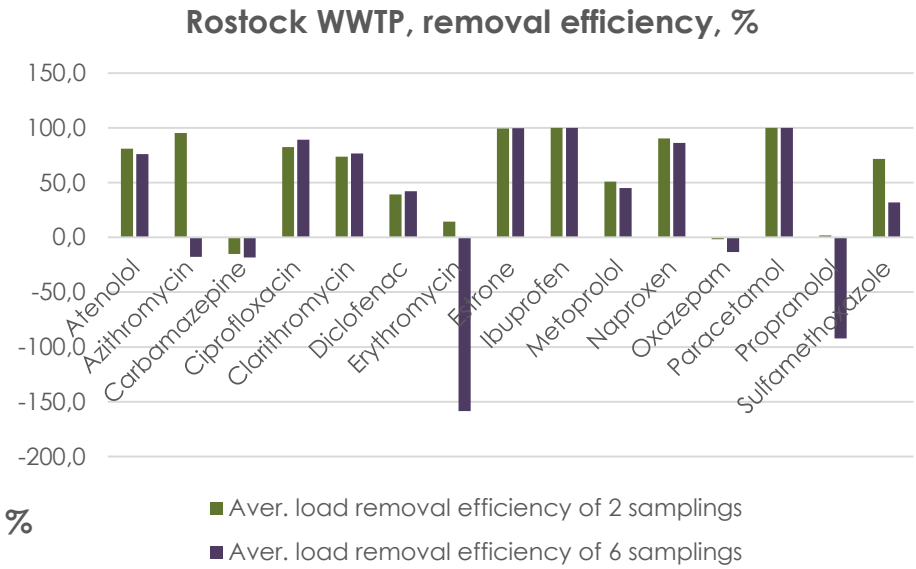


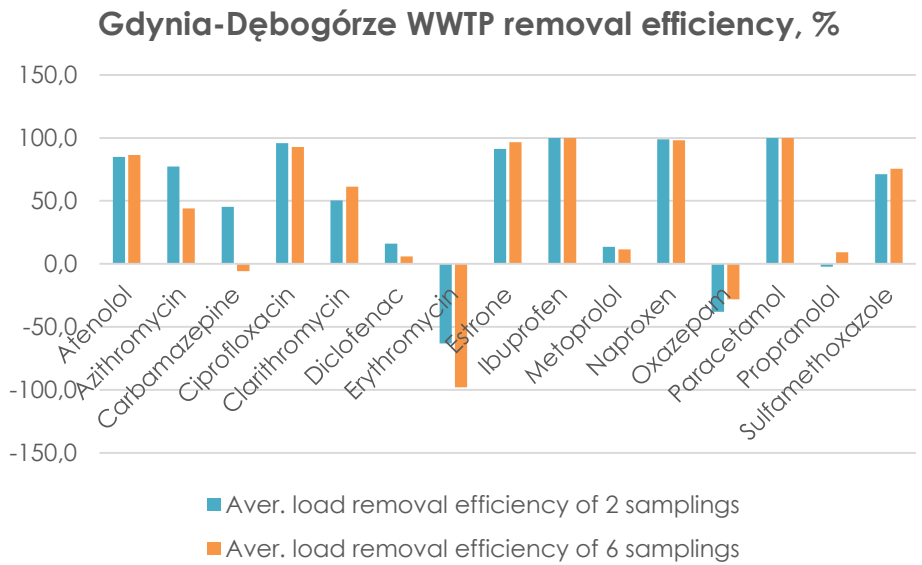




The removal efficiency (%) of pharmaceuticals in three WWTPs estimated by averaging two (summer, winter) and six (summer, winter + 4 days high-resolution sampling) inlet and outlet loads







Status of receiving water bodies

Rivers

In **Germany - 4 rivers, 8 st., 14 samples,**

Warnow river (WWTP Rostock), in

Recknitz river (WWTP Laage), in

Small ditch/stresam (WWTP Krakow) and

in **Mühlenbach stream** (WWTP Satow).

In **Lithuania, 2 rivers, 3 st., 5 samples**

Tenžė river (Kretinga WWTP) and

Akmena-Danė river (only in summer).

In **Poland**, 2 **rivers, 3 st., 6 samples**

Czarna Wda river (WWTP Jastrzębia-Góra) and

Vistula river.

In **Sweden, 3 rivers, 10 st., 20 samples**

Helge Å river (Kristianstad WWTP),

Vramsån river (Tollarp WWTP) and

Segesholmsån river (Degeberga WWTP).

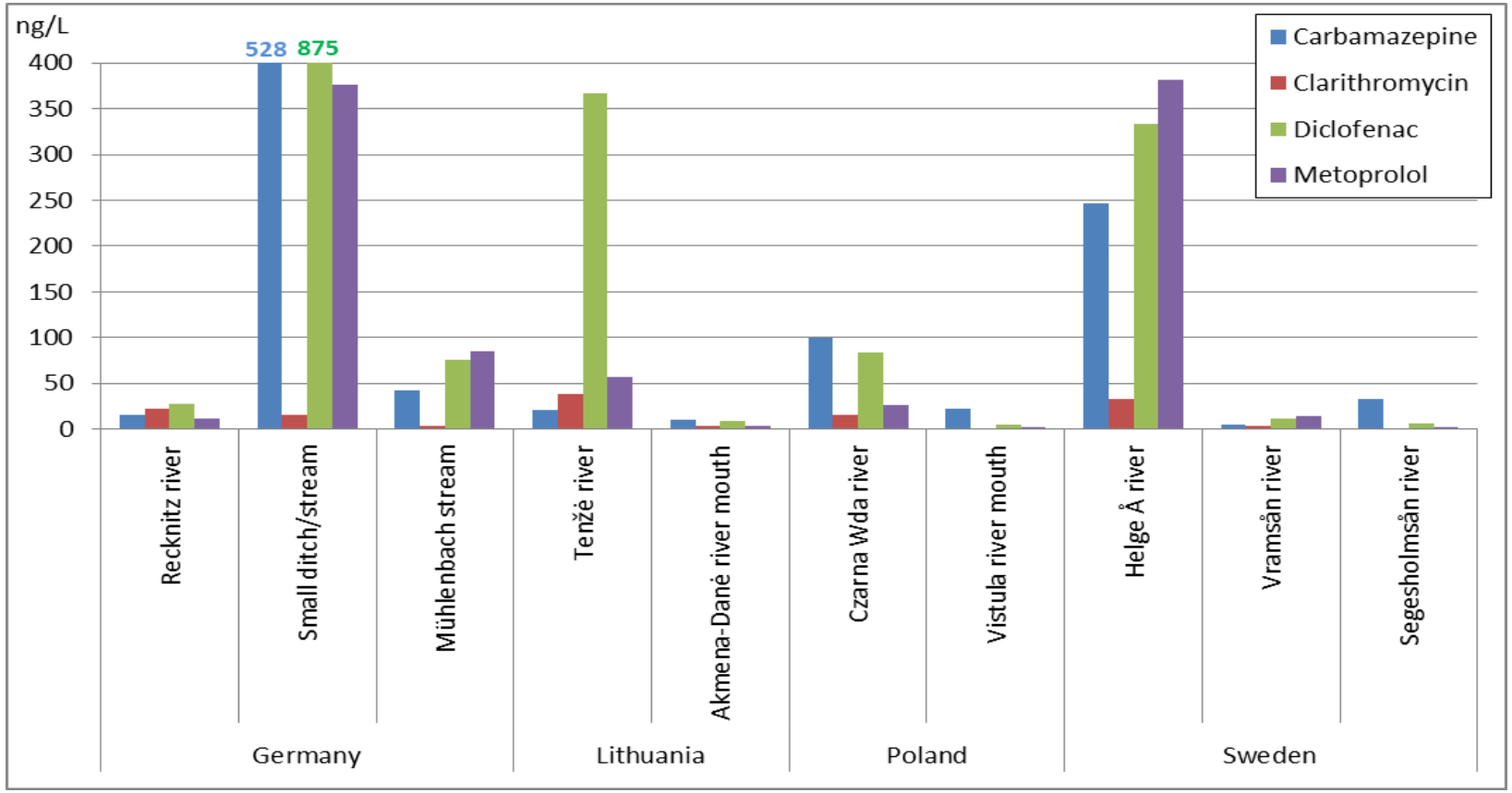
In all waterbodies the **upstream** concentrations were much lower then downstream.

Status of receiving water bodies

Rivers

Small streams/ ditches could be distinguished with high pharmaceutical concentrations **downstream** treated wastewater discharge points

Average concentrations (summer and winter) of Carbamazepine, Clarithromycin, Diclofenac and Metoprolol in rivers, streams or ditches in Germany, Lithuania, Poland and Sweden downstream of the WWTPs

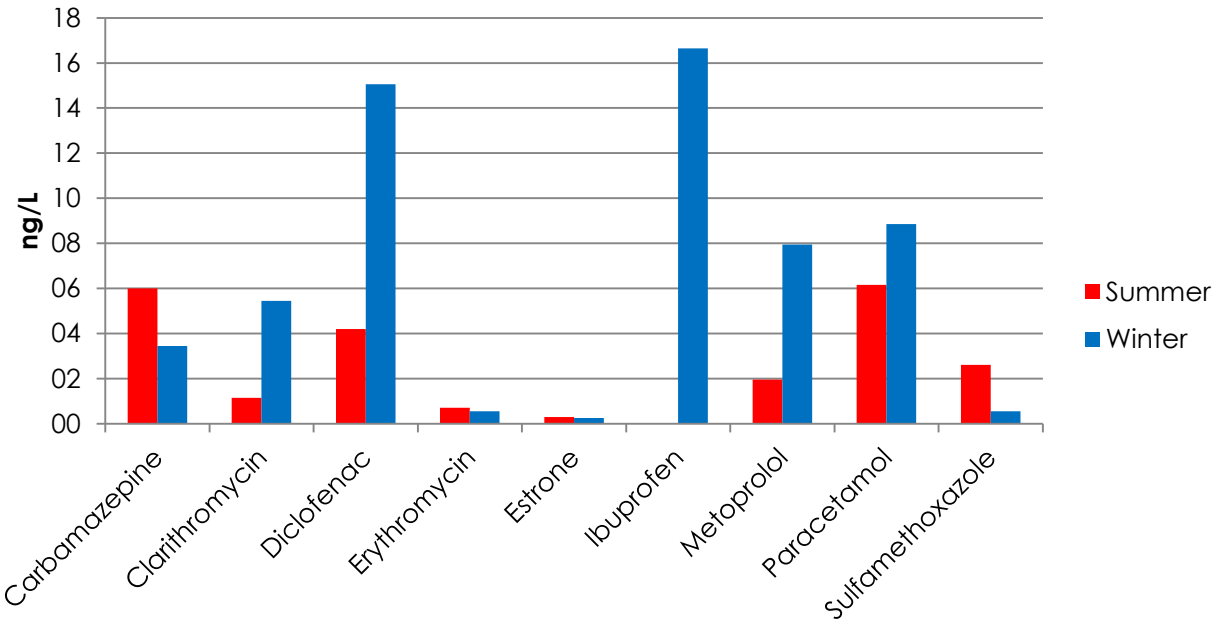


Status of receiving water bodies

Transitional waters

Higher concentrations of pharmaceuticals were detected in **transitional waters** of Lithuania – in the Klaipeda Strait and in the Curonian Lagoon. The same substances as in the marine water of Lithuania were detected in the water of Klaipėda Strait. Additionally, clarithromycin - up to 6.5 ng/L, diclofenac - up to 15.2 ng/L, paracetamol - up to 14 ng/L, ibuprofen - up to 23.1 ng/L and metoprolol - up to 8.8 ng/L were detected in Klaipėda Strait.

Average concentrations of pharmaceuticals in Klaipėda Strait (Lithuania) in summer 2017 and winter 2018



Status of receiving water bodies

Marine waters

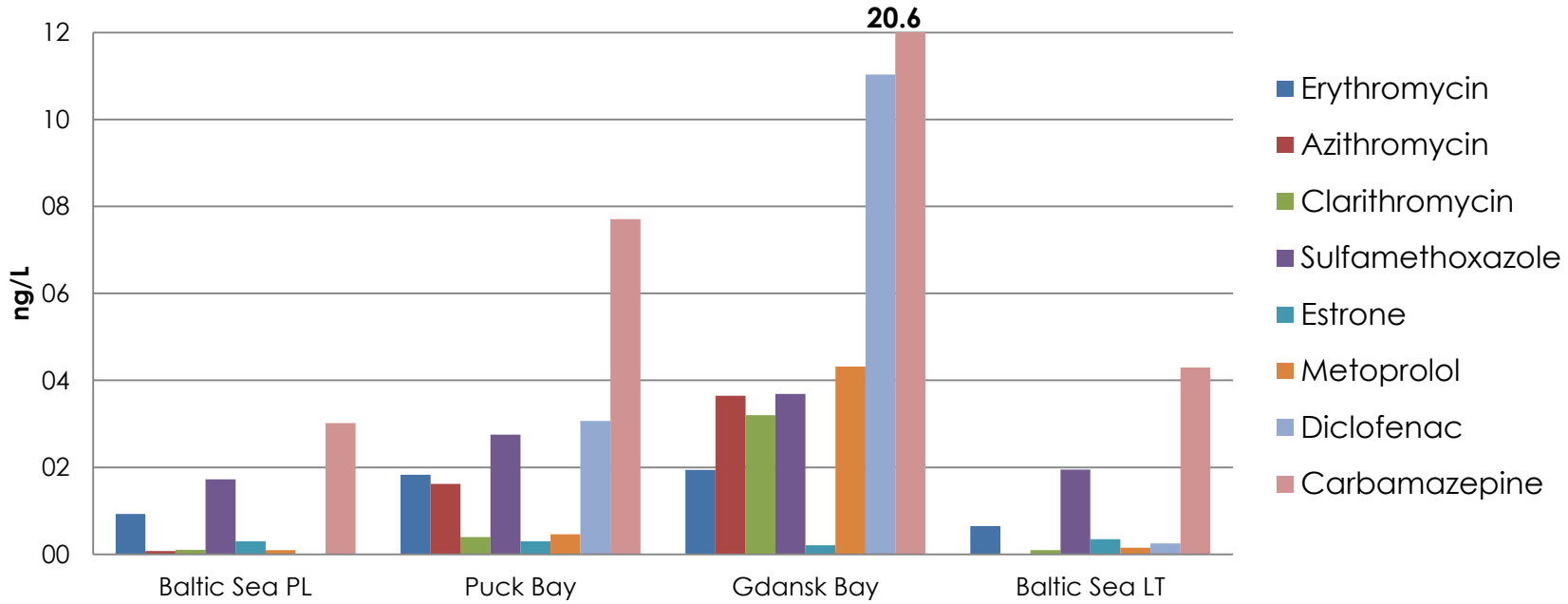
Marine water samples were taken in Poland:

- from the Gdansk Bay near the outlet of Gdansk-Wschod WWTP (surface and bottom water layers),
- from the Puck Bay near the outlet of Gdynia-Debogorze WWTP (surface and bottom water layers) and
- from the Baltic Sea near the outlet of Swarzewo WWTP (surface and bottom water layers)

and In Lithuania:

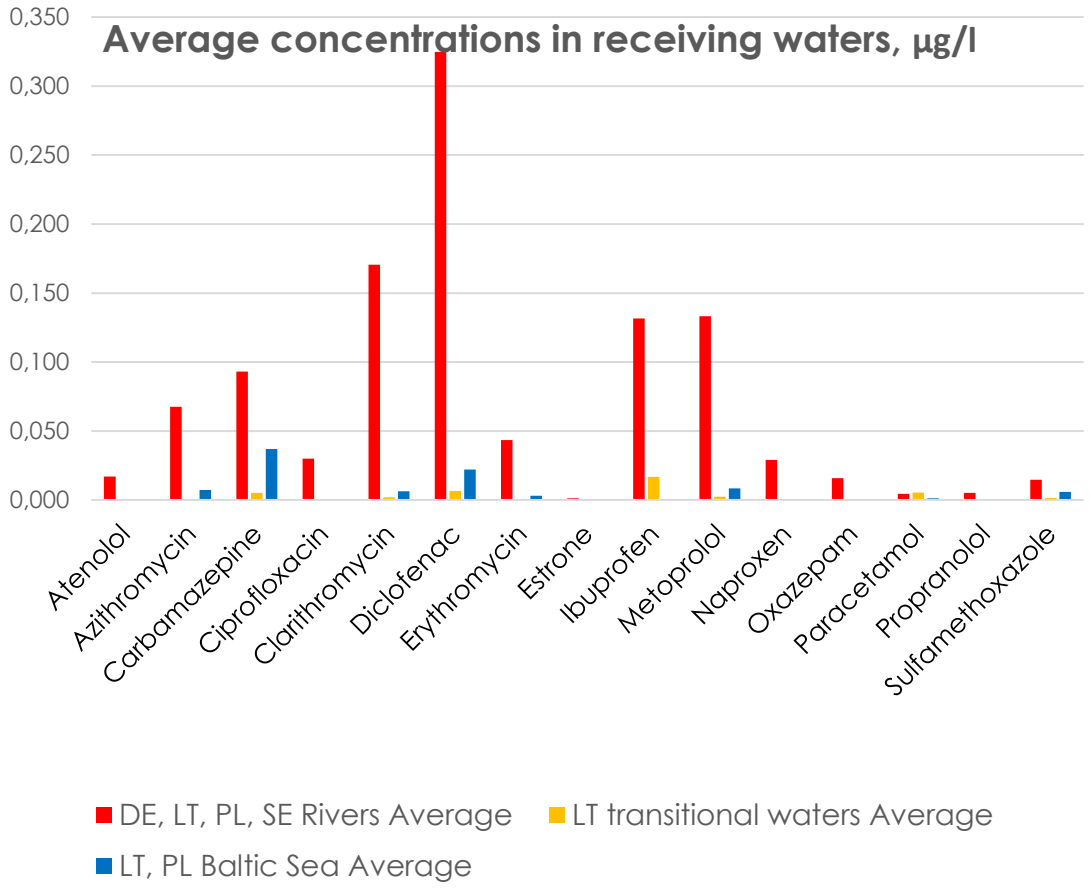
- in the Baltic Sea near the outlet of the Palanga WWTP (bottom water layer) and at monitoring station (B-1) as a background concentration.

Average concentrations of pharmaceuticals in marine samples taken in summer 2017



Status of receiving water bodies

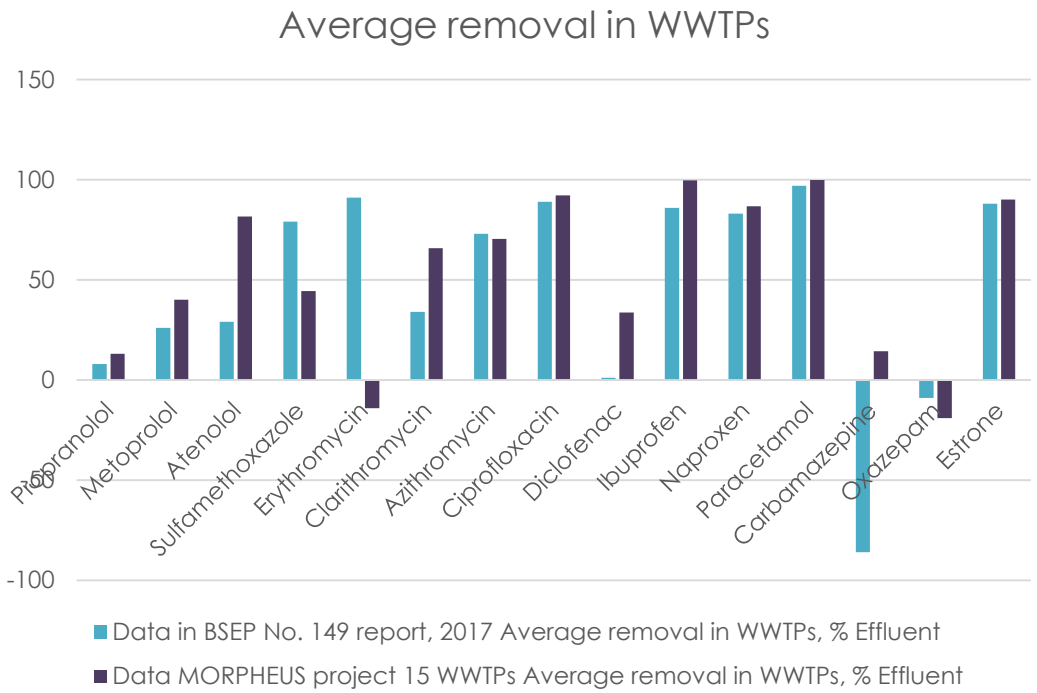
Morpheus project, µg/L							
	Therapeutic group	DE, LT, PL, SE Rivers		LT transitional waters		LT, PL Baltic Sea	
		Average	Maximum	Average	Maximum	Average	Maximum
Atenolol	Cardio beta-blocker	0,017	0,245	0,000	0,000	0,001	0,001
Azithromycin	Antibiotics	0,068	0,354	0,000	0,000	0,007	0,002
Carbamazepine	Anticonvulsant	0,093	2,168	0,005	0,006	0,037	0,005
Ciprofloxacin	Antibiotics	0,030	0,131	0,000	0,000	0,000	0,000
Clarithromycin	Antibiotic	0,170	2,610	0,002	0,007	0,006	0,001
Diclofenac	Analgesic	0,325	2,460	0,007	0,015	0,022	0,002
Erythromycin	Antibiotics	0,044	0,487	0,000	0,001	0,003	0,001
Estrone	Hormone	0,001	0,007	0,000	0,000	0,000	0,000
Ibuprofen	Analgesic	0,131	0,696	0,017	0,023	0,000	0,000
Metoprolol	Cardio beta-blocker	0,133	1,017	0,002	0,009	0,009	0,001
Naproxen	Analgesic	0,029	0,296	0,000	0,000	0,000	0,000
Oxazepam	Nervous system	0,016	0,249	0,000	0,001	0,001	0,000
Paracetamol	Analgesic	0,005	0,012	0,005	0,014	0,001	0,001
Propranolol	Cardio beta-blocker	0,005	0,038	0,000	0,000	0,000	0,000
Sulfamethoxazole	Antibiotics	0,015	0,061	0,002	0,003	0,006	0,002

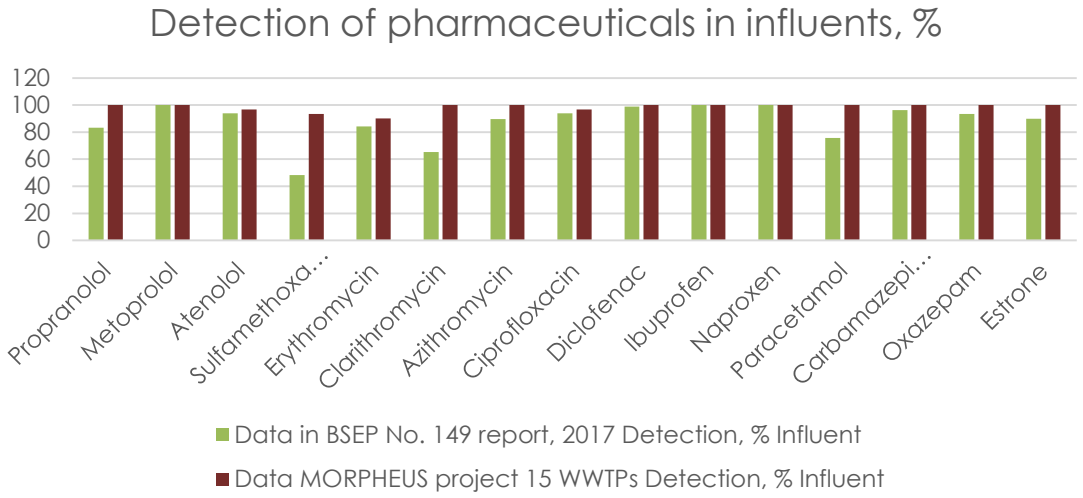


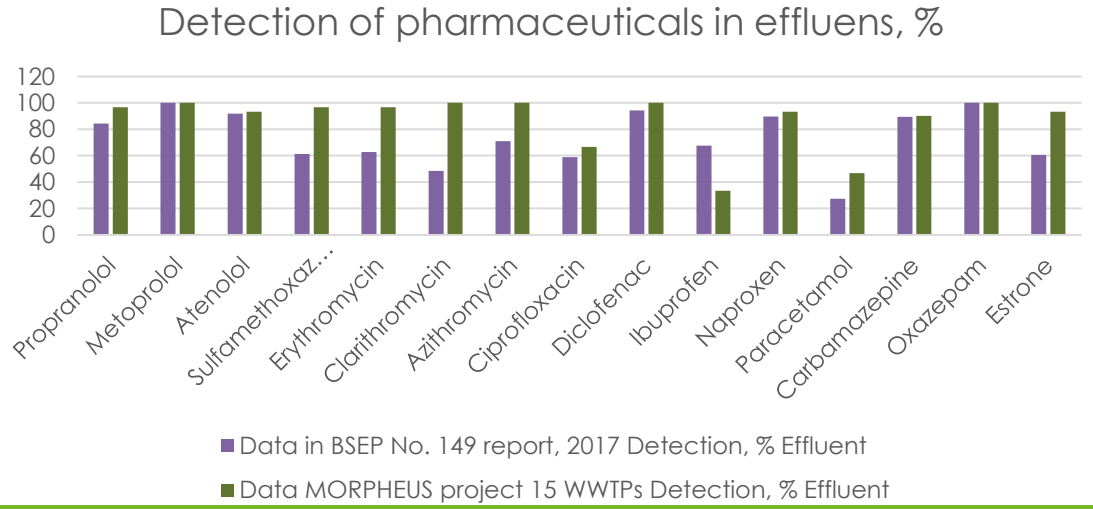
Comparison of pharmaceuticals removal rates provided in the report *Pharmaceuticals in the aquatic environment of the Baltic Sea region* (HELCOM BSEP No. 149, 2017) with the analytical data in 15 WWTPs in SB region

	Data in BSEP No. 149 report, 2017					Average removal in MORPHEUS 15 WWTPs					
	WWTPs Sampled/detected		Detection, %		Average removal in WWTPs, %	WWTPs Sampled/detected		Detection, %		Average removal in WWTPs, %	
	Influent	Effluent	Influent	Effluent		Influent	Effluent	Influent	Effluent		
Propranolol	18/15	38/32	83,3	84,2	8	30/30	30/29	100	96,7	13,1	cardiovascular agent
Metoprolol	50/50	228/228	100	100	26	30/30	30/30	100	100	40	cardiovascular agent
Atenolol	50/47	74/68	94	91,9	29	30/29	30/28	96,7	93,3	81,6	cardiovascular agent
Sulfamethoxazole	118/57	313/192	48,3	61,3	79	30/28	30/29	93,3	96,7	44,4	antimicrobial agent
Erythromycin	69/58	94/59	84,1	62,8	**91**	30/27	30/29	90	96,7	**-14,1**	antibiotics
Clarithromycin	26/17	31/15	65,4	48,4	34	30/30	30/30	100	100	65,8	antibiotics
Azithromycin	58/52	62/44	89,6	71	73	30/30	30/30	100	100	70,5	antibiotics
Ciprofloxacin	84/79	90/53	94	58,9	89	30/29	30/20	96,7	66,7	92,1	antibiotics
Diclofenac	96/95	387/365	98,9	94,3	1	30/30	30/30	100	100	33,7	anti-inflammatory drug
Ibuprofen	193/193	397/268	100	67,5	86	30/30	30-spal	100	33,3	99,7	anti-inflammatory drug
Naproxen	68/68	203/182	100	89,7	83	30/30	30/28	100	93,3	86,7	anti-inflammatory drug
Paracetamol	128/97	201/55	75,8	27,4	97	30/30	30/14	100	46,7	99,9	central nervous system
Carbamazepine	107/103	277/248	96,3	89,5	**-86**	30/30	30/27	100	90	14,3	central nervous system
Oxazepam	31/29	45/45	93,5	100	**-9**	30/30	30/30	100	100	**-19,1**	central nervous system
Estrone	148/133	210/127	89,9	60,5	88	30/30	30/28	100	93,3	90	hormones

Comparison of pharmaceuticals removal and detection rates provided in the report *Pharmaceuticals in the aquatic environment of the Baltic Sea region* (HELCOM BSEP No. 149, 2017) with the analytical data in 15 WWTPs in SB region







Preliminary findings

- **Seasonal variation of concentrations. Number of pharmaceuticals with higher concentrations detected more than twice during the winter season.**
- **Ibuprofen** form the highest load in all WWTPs inlets, reaching almost 50 000 kg or 90 percent of total 54 400 kg load. **Paracetamol** ranked second, contributed 2164 kg or 4 % of the total load. **Azithromycin** - third contributing 569 kg (1,1%) to all WWTPs
- The top 4 pharmaceuticals present at the highest loads in WWTP effluents were **diclofenac** (30% of total load), **azithromycin** (21%), **metoprolol** (17%) and **carbamazepine** (15%).
- the total amount of pharmaceuticals after treatment is reduced by almost 97-99 percent. The average reduction rate for all drugs is about 53%. This can be explained by the large quantities of ibuprofen entering the WWTPS and their complete removal after treatment. Pharmaceuticals **reduced >90 %** during treatment processes are **paracetamol, ibuprofen, ciprofloxacin and estrone**. Between 60-90 %: **naproxen, atenolol, azithromycin, clarithromycin**.
- large differences in the specific loads indicate that there is potential to reduce consumption.
- Introduction of advanced wastewater treatment techniques in major southern Baltic cities would reduce pharmaceutical load significantly.

Preliminary findings

- reduction efficiency of conventional WWTP is different; more investigation to improve conventional systems could be helpful for those plants which will probably not be upgraded.
- number of comparing a smaller measurements (average of two previous samplings) with a larger number (average of six samplings – previous two + four high resolution), the overall trend of outlet load and removal efficiency remains similar. However, the larger number of measurements shows some differences, such as the higher outlet load of diclofenac and lower removal efficiency of Erythromycin.
- The average **inlet loads** per 1000 residents varies which **is a factor 13 different**, which is somewhat lower than for inlet load in kg per one million m^3 of wastewater.
- **Outlet loads** in kg per 1000 residents, shows a variation from 0.28 kg at Laage (Germany) and Swarzewo (Poland) to 0.84 kg at Palanga (Lithuania). This is a **factor 3.00** which is lower than the variation when applying load expressed as kg per one million m^3 of wastewater.
- **Using actual number of residents most likely will give a better comparison between WWTPs.**
- Today local and **regional monitoring** of pharmaceuticals in the environment is **very limited, especially in the eastern Baltic**.